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No. 4 1890-91

PAPERS

READ BEFORE THE

ENGINEERING SOCIETY

OF THE

SCHOOL OF PRACTICAL SCIENCE

TORONTO

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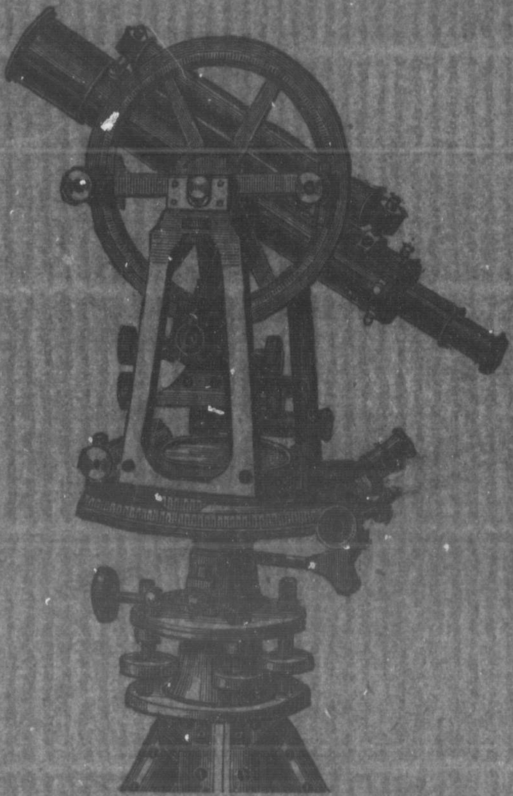
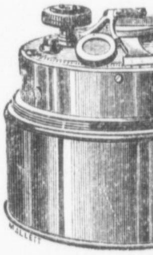
BROUGH & CASWELL,
14 BAY ST.

1891





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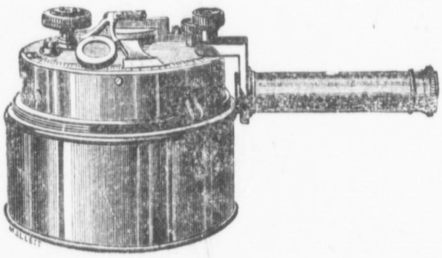

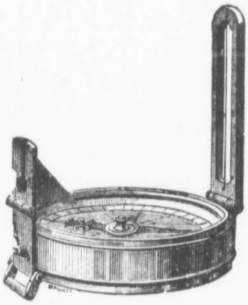

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CONTENTS.

PAGE
President's Address. By J. K. Robinson 7
Underground Waters as Sources of Public Water Supplies in Ontario. By P. H. Bryce, M.A., M.D 15
The Separate System and the Brockville Sewers. By C. J. Marini, F.E. 36
Notes on Railway Location and Construction in the North-West. By T. S. Russell 42
Foundations. By R. McDowall 54
Water Supply. By E. F. Ball 60
The Drainage System in Essex and Kent. By W. Newman 76
Photography. By W. A. Lea 82
Freiberg Smelting Process. By G. R. Mickle, B.A 89
Modern Copper Smelting. By G. D. Corrigan 100

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PREFACE.

THE Engineering Society of the Ontario School of Practical Science, was founded in the spring of 1885, by the students in the department of engineering of that year, assisted by Professor Galbraith.

Its officers are elected yearly, and form the Executive Board of the Society.

Regular meetings of the Society are held every alternate Tuesday during the session of the School, at which papers are read and questions upon engineering matters discussed.

The Society has yearly increased in membership and usefulness.

In order to present to every member in good form for reading and reference, and to hold the interest and sympathy of all graduates in the work of the Society, the best papers are published yearly. This edition contains only those read before the Society during the year 1890.

Most of the papers have been prepared by students of this School, a special exception, however, is the paper by Dr. Bryce.

The Society has during the year received valuable papers and letters from H. E. T. Haultain, J. A. Duff, B.A., E. F. Ball, and other graduates, and hopefully expects that graduates and members of the Society in actual practice will continue to prepare papers, plans, estimates, specifications, or other matter to be read at the meetings of the Society, or filed in the library; and, moreover, will welcome and duly acknowledge similar contributions from those of the profession not directly connected with the Society.

One thousand copies of this edition will be printed for distribution to Engineers and Surveyors, and for exchange with kindred Societies.

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ENGINEERING SOCIETY

OF

The School of Practical Science

TORONTO.

PRESIDENT'S ADDRESS.

GENTLEMEN,—I, with pleasure, greet you all to-day at this, the first regular meeting of our society, for the sessional term of 1890-91.

We have great reason to be thankful to the Giver of all good for this reunion without loss, by death, of any member during our separation.

You have chosen me to act as your president during the ensuing term. I assure you that I regard not lightly the honor you have conferred upon me; and I shall the more esteem my integrity and honor, at all times, for the confidence and good-will the students of the Ontario School of Practical Science reposed in me, and shall always regard with satisfaction and pride my association with the teachers and students of this school. For throughout all the hard work of the past, and consequent contact and address, there has been a friendly feeling of confidence and good-will amongst the teachers and students of this school that I hope may ever continue.

In accepting this position, I feel and know my incompetency to fill it with full credit to my predecessors and fellow-students. Yet I shall be encouraged to good endeavor by your support, and the very willing and able staff of officers that form our general committee.

We who have worked through the last few terms of this school in the over-crowded and unventilated condition of its rooms may and do congratulate one another on the possession of such rooms as we now have, combining, as they do, good light, good ventilation, good heating, convenience, taste, and a spaciousness that will more than accommodate the old students, and the fifty-three new ones that have come among us, and which are divided as follows: Thirty-five in the Civil Engineering Department, thirteen in the Mechanical Engineering, and five in Architecture. Success to them.

We civil engineers may feel proud of our new instruments, models, drawings, and testing machines; the mechanical, of their models, drawings, and machinery, to demonstrate their study by actual contact and practice; the architects, of their models, drawings and photographic collection; and we all of our library, large, comfortable, and convenient.

With these facilities and conveniences, and the staff, with its additions, Messrs. Rosebrugh and Wright, the school becomes more efficient, and confers honor upon these graduates and its past work, and encourages those who are now or will become students of this school.

It is a source of pleasure to see, in apparent appreciation of the efforts of the Government of the country and this school to make it efficient and worthy of esteem and patronage, so many new students for the various branches. On my own behalf and that of this Society, I welcome you to this meeting and Society, and hope that you will all now, as you certainly will sooner or later, become useful and interested members. Very many students make a sad mistake in looking with doubts and suspicions upon the aims and benefits of this Society and their fellow-students generally. They defer becoming members until the Society has proved itself by report, which, obviously, it cannot do, unless many of the first year students attend and become its supporters and champions; and by the time they become convinced of the benefits of attending our meetings, hearing papers on various engineering and architectural subjects read and discussed, and see the advantages of the library, they have lost much time and benefit, and care not to pay the regulation fee of one dollar for the balance of the year. Again, many look upon the Society as a means of extracting another dollar from their pockets without giving any return but loss of time. To such I will say, do not entertain such an idea, or you will regret it and feel heartily ashamed of yourself before the term is over.

Become members at once and cultivate personal acquaintance with your fellow-students outside your own year, and you will find yourself improved, and the wearisome routine of work broken and made cheerful by acquaintance that will quickly develop friendship if you prove true and worthy students of this institution and of the profession that you signify by your presence here you intend to follow.

It is not expected or possible that students of the first year can make themselves as useful in this Society as they can later, after becoming familiar with the work of the school, and the aims and usages of the Society. Yet it is a credit for students of the first year to render their share of assistance, to be willing when requested to give a paper, or work upon a committee, and thus render themselves capable of further usefulness.

And now, before turning my attention from the first year students, there is another phase of disposition that should be guarded against by all those whose sense of the rights and regards of others is obtuse. This disposition is the very reverse of backwardness. It is called "freshness." And although the term grates harshly upon the sensitive, and perhaps I should have said sensible, ear, for which it is not intended, it has no significance with the subject of the malady. I mean that some students make themselves obnoxious and the subjects of ridicule, and in extreme cases, of more convincing disrespect, from their lack of respectful address and consideration of the rights and feelings of their fellows.

However, I hope for the coming term that good-will and pleasantness will alway proceed from those of the first year to their seniors and to one another. And I believe in such cases that the same will be returned. Be real. Be honest, fair and considerate, and remember unto performance the Golden Rule. We have entered upon grand professions. Will the smooth running of our minds in mathematical grooves fit us for such professions? No. We may become well-trained in mathematical reasoning and yet be no credit to ourselves or our profession. What should we be? Men—liberal in thought, education, and sympathy for our fellows, honoring truth and fairness in every act, dealing honorably with all men, as well as being educated and proficient in the requirements of our work.

We have reason to think well of our espoused professions. Take a glimpse at their advancement during the last few years. See that flying steel monster, carrying in his wake a train of handsome coaches, whose speed and comfort compare so strikingly with the stage coach of a few years ago! Observe how swiftly it moves, now skimming over the plain, now rising over lofty hills and deep gorges, and again darting through and beneath them, and connecting by easy transit one ocean with another—even passing with ease and rapidity beneath rivers, and connecting the commercial enterprise and industry of nations.

See even the arrows of the heavens are giving light to our streets and shops. They propel our street-cars. They flash a message beneath the ocean, and around the globe. They carry even our voices to ears miles away, and the wasting energy of nature for the economic purposes of man.

Compare the useful and comfort-producing machinery of to-day with that of fifty years ago. Ride with safety, comfort and convenience in that modern city of steel, the ocean steamship, and look down upon the dugout of the aborigines.

See the graceful, yet sometimes appalling, masses of steel that unite the banks of chasms and rivers deep and wide. Compare the sanitary condition of the houses and towns of to-day with those agone, and the elegance of proportion and design of modern true architecture.

Shall we, who have the rich heritage of the thought and experience of the past, be of less use than our predecessors? We ought not. How many of us aspire to the thoroughness necessary to success in any cause?

What has been said of law, that "There is always room at the top," is also true for engineers and architects.

Perhaps none that graduate from this school will ever rise to the height of his profession, and surprise the world with his skill. But who knows? It is not impossible. One thing is necessary—thoroughness. Therefore let us so apply ourselves to the work of our cause, and to the auxiliary work of our Society, that we may be alike a credit to our profession and the school from which we graduate. For, let us not think that the reputation and work of this school has reached its height, but rather by our individual and united effort second the desire and work of the Council to make this school second to none in America, and the pride of our Canadian profession.

Now, let us turn our attention to a resumé of our Society. As many of you know, it was organized in the spring of 1885, to supply a real need in the student life and study for some place of general gathering to ripen acquaintance and friendship, to exchange ideas and methods, for systematic reading and discussion, to make students more familiar with the work and practice of their profession, by showing the relation of the more or less abstract work of the school with the concrete work of the practising student.

From its start up to the end of the term of 1887-8, the membership was small, but the Society had for its president Prof. Galbraith, who directed and encouraged its members in doing good and permanent work. Constitution and rules were drafted, periodicals and magazines on the subjects of engineering, architecture, and sanitation, were obtained, papers were read and discussed, printed copies of which you may find in our library. At the end of this time Prof. Galbraith considered the Society self-supporting, and advised the election of a student as president. Accordingly Mr. H. E. T. Haultain, who is now chief engineer in a tin mine in Bohemia, and who is an able and pushing young man, was chosen. The Society, by his help, made good progress—a good library was established, the periodicals and magazines were continued and increased, and contributions from graduates were solicited and obtained, which together with good papers prepared by the students were printed in illustrated and interesting form, copies of which were presented to you at the beginning of this term.

During the past year the Society made good progress with Mr. J. A. Duff, B.A., president, and Mr. T. R. Deacon, who is now our vice-president, as secretary-treasurer. Library rules were made, the constitution was amended, and a more commodious room was obtained for the library. The office of secretary-treasurer, which had become heavy, was divided the office of special students' representative was discontinued, and many valuable papers were read during the year, some of which you will find in the pamphlet presented to you. And among the indirect but important doings of last year was the starting of a branch of the Canadian Society of Civil Engineers.

By the burning of the University on the 14th of last February, at the time of our annual conversazione and engineering exhibit, we sustained many losses of papers, models, instruments, and decorations; but we are pleased to say that our Society, in common with the other societies, was able to clear itself, and now stands ready for the performance of good work during the coming year.

And now we face our position. Shall we accept the labor and rewards of the work of our predecessors in form only, and allow the Society, which we received in a healthy, growing state, to dwindle and die amidst the dense foliage of its environment, whilst the many societies that surround it have considered it a live and growing competitor? Shall we be content in doing less than they? They have nurtured this Society in its weakest days, and have implanted it in the soil of this school. Shall we not continue its supporters?

All who have taken an interest in this Society have by it been benefited just in proportion to their interest and work; hence for your own good and that of the Society, we say become active members at once. The Society will be the better of you, and you of the Society.

From the vigorous growth of the branches of this school, there may arise a desire for a separation of this Society into branches; but since one of the main objects of the Society is to broaden the mind of the student, and acquaint him not only with the work and practice of his profession, but also with its bearings upon and relation to other professions to which it is closely connected in practice; and since civil engineering, mechanical engineering and architecture bear such relations, and the mathematics of each are so alike, that papers written on any one line may be readily understood and discussed by the students of the others, it is of mutual benefit that we maintain our present vigorous unity, and the more intimate that unity the better for all.

Our constitution states that "The objects of this Society shall be (*a*) the encouragement of original research in the science of engineering ; (*b*) the preservation of such research ; (*c*) the dissemination of such research among its members ; and (*d*) the cultivation of a spirit of mutual assistance among the members of the Society in the practise of the profession of engineering."

Now, while these may have been the primary objects of the Society, they are not now the sole purpose of this institution.

This Society may, by its educational influence and solicitation of papers, encourage original research by graduates ; but such research by students is, from the present state of the science, our undeveloped minds, and the extent of our studies here, inadvisable. A greater benefit to the undergraduate members is the free, voluntary, and interested thought, practised in preparing a paper, in discussing it, or in reading an engineering or architectural article.

Here among the students original research, so far as the benefit to the science itself is concerned, would be too much like the small boy hunting through a menagerie for a rare animal not known to the owners of the show ; he might find a shylikulie, but Professor Chapman would surprise him by giving its real name, its family relation and history, from away back in the rocky past.

Yet original research, even by the students, is not to be despised, for it strengthens his reasoning and fixes the practice of independent thought, and the result of his efforts firmly within his mind.

What we need here is not so much originality as the seeing of new or old thoughts in new aspects and interesting forms.

We have in our course of study thoughts, reasonings, and facts, assorted, classified, and concise. Their very conciseness has deprived them of their beauty and attractiveness, and cut them down until but the framework or bones remain.

A part of the effective work of this Society is the shaking up of these dry bones into form, that we may see the better their use and relation to one another, and their actual necessity to support the flesh of detailed practice; the muscles of clear and active thought, the steady stride of ability, the full, sleek coat of sound sense from wide knowledge, and the spirit of courage and success, that will win the full measure of the meal of approbation, and of the oat whose kernel is golden.

As the veterinary student, reading by the help of the bones of his subject, is improved and encouraged by the sight of and acquaintance with his living subject ; so we like to see our subject in life-like form, inspecting him from all sides and becoming used to his disposition and habits, that when he carries us proudly out from these walls, we may with confidence ride into the world and compare favorably with our fellows.

The last clause of the objects of our Society, as given in our constitution, I endorse heartily, that is, "The encouragement of mutual assistance among the members."

Everywhere around us, in labor and capital, profession and art, politics and religion, we find organization, circle within circle, as molecules, composed of atoms of mutual affinities, combine to make up the composite whole; so we, if we wish either in student life and pursuits here or in the practise of our professions to occupy a place of security and advantage, and not be dissipated though the interstices as a bye-product of other organizations—we must support each other and uphold our Society union, for in union there is strength.

All matter is capable of receiving and transmitting energy in some form from and to other matter; so we, in like manner, are susceptible of receiving and imparting education from one to another, not only by words and acts, but also through the subtle agent of influence. Now, as success in our profession depends upon the knowledge of our work, let us cultivate and retain the society and educational influence of our fellows, and in no way can we do this better than by organized society work.

On entering the practice of our profession, we will be confronted by the application of our theory to actual practice. Shall we be able to make our way clear, or shall we be confounded? This will depend upon our knowledge of the ways and methods of actual practice. Where and how can we best keep in touch with the practice of our study whilst students here? By the preparation, reading and discussion of papers before the Society, by the reading of live engineering and architectural news, such as our library affords.

On account of your superior opportunities for education and of your profession, you will not only in the discharge of our duties, but as citizens, be called upon to take active parts, and give opinions in matters that will require prompt action, good judgment, and a ready and clear explanation to others that will oppose you on every side. Can you conceive of anything better suited to your development in these lines, and at the same time within the range of pleasant possibilities, whilst students here, than the duties and privileges that our Society involves and affords?

And lastly, look at our library. I shall not dwell upon the advantages of its free use; the books, new and old, that it contains; its models and sketches; its live scientific news, to which are to be added the books now in the University library that relate to our subjects, which will make it more valuable and interesting. The conditions of these additions have not been arranged. This, together with changing rules, will be one of the important things that will come before the General Committee and this Society early this term.

And now, regarding interesting material for these meetings, it is a part of the duty of the General Committee to arrange work for the meetings, and yours to second them in their endeavor. One of these will call upon each of you to render something. If they miss you, volunteer. Will you? None need refuse. We have had in the past, I might say, equally good papers from first, second, and third year students. Very few of us but know something of general interest that others do not, the preparation and giving of which would improve the giver and instruct the others. Our offering need not attempt to exhaust the subject of which it treats. This is not expected. If we even cannot do as well by trying as others, let not that be to our discredit, but his who could but would not.

Our corresponding-secretary, Mr. G. E. Sylvester, has been instructed by your General Committee to correspond with Dr. P. H. Bryce, Secretary of the Provincial Board of Health, who has volunteered a lecture upon a very interesting subject at one of our early meetings. He will also correspond with our graduate members, and invite papers from them for our Society. He has also short letters from each of our two past presidents, that he will read at your convenience.

And now we wish to express loyalty to the charge of our predecessors' work and desires, compatible with the best interests of the Society and the good of the members and students; deference and honor to the merits and opinions of teachers, members and students; fairness in all dealing, and confidence in the judgment and support of our General Committee and yourselves in maintaining the usefulness and reputation of this, our Society, for this year and the years to follow.

J. K. ROBINSON.

UNDERGROUND WATERS AS SOURCES OF PUBLIC WATER SUPPLIES IN ONTARIO.

By Peter H. Bryce, M.A., M.D.,
Secretary Provincial Board of Haalth.

Mr. Chairman and Gentlemen of the Engineering Society,—When we observe the remarkable situation of Old Canada, but notably of Ontario, in its relations to the bodies of fresh water constituting the Great Lakes, and note the configuration of the surface of the country contributing to the supply of these great lakes, we are naturally surprised to see that, at some point or other, the whole of these immense watersheds contribute their drainage to some one or other of these great lakes, as completely as if Ontario were an island and the great lakes the surrounding ocean. Remembering, too, the comparatively small distance north and south that the various watersheds of the great lakes occupy from the points at which their waters are delivered into some particular lake reservoir, we are surprised to see how comparatively short is the course of any individual river, even the longest, the Ottawa. There result from these conditions two remarkable phenomena, without, I think, any parallel on the face of the globe. The first of these is the unusual exposure of the sources of these streams to the effects due to the destruction of their protective forests. Already, as will be noticed, all the protection is gone from the head waters of the rivers of Western Ontario. Follow them along, starting with the Lake Simcoe and Severn supply, and note them till we have reached the Humber and Rouge. Where are the Nottawasaga, the Sydenham, the Maitland, the Saugeen, the Thames, the Irvine and Grand, and the many creeks, as Stoney creek, Twenty-mile creek, etc., flowing into Lake Ontario from the Niagara escarpment? Even in the brief history of fifty years since settlement properly began many of them remain as little more than memories, unless when the sudden floods of some autumnal storm fill them almost as suddenly as does a storm among the rocky scaurs of the mountains of Scotland. But note again the watershed, starting at the Upper Ottawa and follow along the undulating table land, for it is nothing more, of the Laurentides, till where the waters run toward Lake Nipissing and the Georgian Bay, then skirting along the line of the C. P. R. till Port Arthur is reached, and it will be noticed how really short are the courses of the streams flowing into Lake Superior or the Georgian Bay. To many who have been on exploring or surveying parties in these northern wilds, it may appear that whatever may have happened in Western Ontario cannot happen in the case of this rocky district; but we have only to listen to the warnings given by those who have studied the subject, such as Mr. R. Little, of Montreal, and other members of the American Forestry Association, to realize how the same process of destruction is going on at a rate in this region incomparably more rapid than that which went on in Central Ontario. Already we learn from lumbermen that the great pine limits of this area are enormously reduced, while personal observations, made in various portions of the region, too surely indicate that deforesting by vandal acts and fires is rapidly denuding these areas of the natural protection to the sources of the feeders of our great lakes.

The second remarkable phenomenon is, that the natural basins into which these numerous watersheds pour their waters constitute so many basins which, narrowed at their outlets, serve to maintain an equilibrium of waters in proportion to the shallowness of their outlets and to the evaporation which takes place from their surface. The preservation of these waters is remarkable in both these respects. For instance: the outlet of Lake Superior is comparatively a small stream discharging but little more than some of the tributaries of the lake, while the temperature of the lake is relatively so low, and its depth so great, that the relative evaporation from its surface during the short season of summer must be infinitely less proportionately than from shallow, smaller reservoirs, whose surface would be in proportion much greater were the volume of water the same. To illustrate the manner in which the low temperature of these lakes is maintained, it may be mentioned that the greatest depth of Lake Superior is given at 895 feet, and that of Huron 1,000 feet. Now it will be apparent to all that, apart from the consideration of the supply to these lakes or the rain falling on their surfaces, it will be a very important factor in the maintenance of their levels to enquire whether the waters flowing into them have been, or are likely to be, so altered in their annual amounts as to create notable differences in their levels, assuming, as seems to have been proven by calculations made of the rainfall, registered at the Toronto observatory, during a period extending over forty years, that the annual precipitation of moisture does not greatly vary over a series of years. It might, at first sight, appear that the lake levels are not likely to be altered, but a closer enquiry reveals the fact that an actual decrease in lake levels, at some points, at any rate, has taken place. I was recently informed by a close observer that the fall at Kincardine at some seasons of the year is at least four feet. That this should take place at certain seasons of the year seems inevitable, if we consider some of the facts in regard to the decrease in the volume of water observed in the streams of some of the older portions of the Province. Thus at the time I made a study of the rainfall of semi-decades from 1840 to 1845, to 1870 to 1875, I found great variations in the rainfall of the later spring and summer months to have taken place. Thus March has remained the same, while in April I found a decrease of not more than half an inch ; a decrease that increases with each month until September. Thus :—

	April, May, June.	July, Aug., Sept.
1840-44	48.55 inches.	68.101 inches.
1850-54	40.195 "	48.625 "
1860-64	32.742 "	45.617 "
1870-74	34.670 "	35.14 "

Or take May and we have :—

1840-44	15.015 "
1850-54	13.675 "
1860-64	14.055 "
1870-74	8.64 "

When it is remembered that at a lakeside station, as Toronto, influences which create such striking differences are less than at more inland and upland localities, as those of the central plateau and oak ridges, we may affirm that their effects at those points, whence so many of the rivers of the Province take their origin, would be at least as great as at Toronto. Again, while it might be said that, in a region such as the Laurentides of the Muskoka district, the numerous small lakes act as so many reservoirs containing the waters which flow into them from innumerable streams, yet if we consider that such an area denuded of its forests presents unlimited stretches of bare rock where the virgin soil has been destroyed by fire, or wasted away by erosion, we can very well understand that the spring rains and melting snows are yearly more rapidly swept into these basins, and thence into the great lakes, instead of being stored up in the humus and leaf-mould of the hillsides and valleys, thereby producing as yet, of course in less degrees, the same summer losses to the streams which we know have taken place in the streams of Central and Western Ontario.

Reverting now to the special subject we have proposed for discussion, we can understand how important is the bearing of these facts, not only on the question of underground waters as a source of public water supply, but also upon that other of paramount importance, namely, the retention in the soil of such stores of water as are required in the successful prosecution of agriculture. Leaving the latter out of consideration for the present, it may appear to some that so long as our great lakes remain as unlimited reservoirs, there need be no anxiety as to our obtaining abundant supplies of water for public purposes. This might be true if all our cities, towns and villages were situated on the shores of some one of these great lakes ; but unfortunately all are not. But even if they were, their growth and the methods of disposal of their sewage at present in vogue force upon us the disagreeable fact that we have no guarantee that these inexhaustible sources of supply will remain unpolluted to the extent of their yielding supplies of water beyond question in the matter of purity. Already we have presages of evil. On the River St. Clair, we have, growing up on both sides, large towns, both taking water from and pouring sewage into the same stream. On the Detroit river, Windsor is already having cause to doubt the purity of her supply with Detroit and Walkerville polluting the river above ; and only last week the submission of a scheme to the Provincial Board for supplying Niagara-on-the-Lake with public water from the river, revealed the fact that chemical analysis found the water to be second class in the matter of purity, and by no means equal to Lake Ontario water at the bell-buoy outside Toronto island, as shown by analysis several years ago. Very recent analysis has shown Toronto water to be depreciating in quality. Thus :—

	Niagara River at Niagara-on-the-Lake. In parts per million.	Lake Ontario at bell-buoy. In parts per million.
Chlorine	2.00	3.00
Free ammonia	0.04	none
Albumenoid ammonia	0.12	0.02
Oxygen absorbed in 15 min	0.24	0.16
Oxygen absorbed in 4 hrs	0.74	0.508
Total solids	133.00	124.00
Loss on ignition	48.00	

While it might be unfair to charge this pollution of Niagara river water wholly to sewage, yet the fact remains that Buffalo, Tonawanda and Niagara Falls towns, on both sides of the river are polluting the river. Evidently the rapids, the falls and the whirlpool are not all sufficient for purifying purposes. What the fate of Toronto's water supply will be in case the scheme of a trunk sewer discharging off Victoria Park be carried out remains to be seen. When, however, it is remembered that our inland towns, situated on streams of yearly diminishing volume, have shortly, and many have already begun, to exploit local sources for their supply, we must recognize how important becomes this question of underground waters for public purposes. While the problem of obtaining these waters for drinking purposes is not a new one, since up to the present they have been practically the sole source of our supply as taken from wells, yet there can be no doubt that the popular belief that these wells are due to the happy accident of striking some isolated spring prevails very generally. Manifestly, therefore, it is important to those of us who have to deal with these problems of public water supplies to enquire to what extent we may look to these underground waters for a solution of the difficulty of obtaining public water supplies for at least our inland towns. That their volume is enormous may be concluded from our knowledge that where surfaces consist of leaf-mould, humus, or sands and gravels, an amount of water roughly calculated as at least equal to that which flows from the surface into the streams and rivers penetrates the soil, and passing downward is either stored up in subterranean reservoirs or flows gradually along the hidden inclined strata, appearing here and there again, where the strata have been denuded, as springs. Indeed, as regards their amount, we may say that beneath the surface of the gathering grounds, creating these immense reservoirs of our inland lakes, are stored as great quantities of water as those in our lakes, less whatever differences evaporation and the rainfalls directly upon the latter may make. It is, perhaps, difficult for us to at once realize this, but if we consider for a moment the nature of the springs which we see cropping out on many a hillside, we may not be surprised at the statement. A spring appearing as a small stream and flowing at the rate of ten gallons a minute gives a 24-hour flow of 14,400 gallons. How small a stream this means is best realized when we remember that a three-inch tile running full at a dip of one in fifty gives a 24-hour flow of over 90,000 gallons. If we further remember that with an annual rainfall of 30 inches, of which 15 may be said to sink into the soil, the amount of water which an acre would yield will keep a spring yielding the above daily amount flowing for nearly 23 successive days, or for nearly a month's time we can understand what it means to have an upland of miles in extent dipping towards some valley eroded transversely to the strata and consisting of an impervious clay below and a permeable soil of gravel above. It here becomes important that we enquire into the conditions upon which the storage of underground water depends generally, but especially into the conditions which prevail in Ontario. It will be remembered that we have bordering the Province along the east and north the gneissoid Laurentian rocks, and that super-imposed on this, and following each other in regular order, the series of Silurian and Devonian rocks, mostly of compact limestone or calcareous shale, till the River St. Clair is reached. In central Western Ontario these have an elevation of over a thousand feet, and from this height the strata dip more or less regularly in every direction. All evidence goes to show that at the close of the glacial period these rocks were covered with a body of fresh water, and that materials from their disintegrated surfaces were gradually deposited in a more or less quiet inland sea in an order depending upon their character. In the shallower waters the heavier materials of boulders and gravels sank to the bottom or were thrown up on the shores or deposited on shallow beaches, many of which can be seen in the highlands of Wellington, Perth, and Huron counties. Mingling with these deposited drift materials would of course be certain proportions of clay, and indeed these deeper boulder strata, and in these districts highly argillaceous strata in the deeper waters, were deposited in a state of great regularity and in a state of great purity; but even under these beds of clay are to be found in most instances, as throughout Kent, Lambton, and Essex, a thin stratum usually of from one to two inches of fine gravel, with extremely fine grained sand above it. The latter over some parts of the oil region is black in color and forms the reservoir for water and in some places gas. As the waters receded further and these so-called Erie clays came into shallower water, they became overlaid with strata of finer gravels and sand in less regular order, similarly as on the uplands intermixed with clay in varying proportions, thereby giving us the warmer loams of Waterloo, Oxford, Brant, Norfolk, and Elgin, as also in some portions bands of the so-called Saugeen clay. To the west, north-west, north-east, and east of Toronto, running from the Niagara escarpment to the gneissoid rock, again we have, according to the height, these same strata more or less regularly appearing, while they are not wholly absent from the surface of the gneiss, although it is mostly in the smaller lake basins or river valleys that they can be said to be of any extent.

Inasmuch as the rainfall of any region in Ontario may for practical purposes be considered as averaging a given amount, say 30 inches as snow and rain annually, it must become apparent that it will depend upon the nature and condition, as also upon the inclination of the surface strata, what proportion of this rainfall will sink into the soil to become the source of these underground waters that we have been discussing. It will further be apparent that the order of arrangement of pervious and impervious beds, as well as the thickness of strata, must become essential factors in considering the amount and constancy of any underground supply. Thus, to illustrate this we have only to refer to the variation in the prevalent depth at which the water of ordinary wells is obtained in different sections. For instance, in Ontario, in the flat country around Chatham and Windsor, shallow wells of ten to twelve feet are most common, these being supplied only from the soakage from the black humic loams lying on the top of practically impervious clays, and becoming dry when the dry season comes on. Further east, as around London, Woodstock, etc., abundant waters for household purposes are found in sands and gravels lying upon the top of the clay. Similar variations can be pointed out as occurring in closely contiguous districts, and nowhere are they better seen than around Toronto. While, however, these shallow wells may afford in many instances abundant supplies for the purposes for which they are intended, it is apparent that inasmuch as the area of their gathering grounds is very limited, their supplies can easily be exhausted. Let the surface be locally eroded by a water-course and we find, especially in the sands and gravels, springs cropping out, creating local bogs, etc., and presenting exactly the same general conditions as would a spring far down the declivity of a deeply eroded valley, except that in the first case a summer drought would cause it to dry up, while in the latter the flow of water would not be altered by one season's drought. *

The following cuts will serve to illustrate various conditions which occur in the deposition of soils and rock material, and upon which we may expect to find the abundance of water in any locality dependent:—

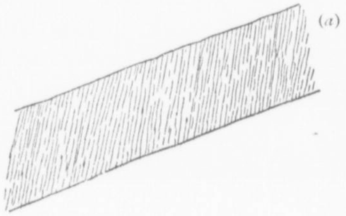

FIG. 1.
Impermeable clay, Erie clays (Logan).

Such soil has great retentiveness, or its hygroscopic character is very high, reaching 75 per cent. of its own volume, or may hold three-fourths of its own volume of water. With impermeable clays forming hillsides, rain will flow rapidly from the surface; but where this clay has a level surface, the land will be wet, whether on high plateau or in river bottom.

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* The celebrated French engineer, Durand Claye, has classified springs into: First, springs from impermeable layers. There is no water-layer, properly speaking, in soils of this character; the place of springs in this case is the surface of the country, and as the surface flow carries away the great part of the rainfall, these springs are always very small. Second, springs from layers entirely permeable. Here the absorbed waters descend in continuous or discontinuous layers towards the deepest valleys. The springs are found in the humid and even peaty plains which carpet the bottoms of these great valleys. We find them at the bottom of bogs, along water-courses, while the less deep valleys, the hillsides and plateaus remain dry all the season. Springs of this class are far apart and have considerable yield. This class of springs exists in the soils of this Province, but not to the same extent as those of France, in the oolitic limestones of Burgundy, the white chalks of Champagne, of Normandy, and in tertiary limestones. It is to this class belong the springs which supply Paris, and these are not always perennial. Third, springs from permeable or moderately permeable layers, upon impermeable beds. Following the plain of contact of permeable and impermeable layers, there is established a water level on the side of the hill as well as in the bottom of valleys. These springs are generally numerous and consequently of a small flow. This class is especially characteristic of the strata which are superimposed upon the rocks of the Province of Ontario. Fourth, artesian springs, or those which flow from an imprisoned water layer between two impermeable stata and flowing forth from a boring or well.

Into it rain will very gradually penetrate. Where impermeable clay has a locally denuded surface (as in Fig. 3 at 1), forming local depressions or basins, vegetable deposits and fresh water plants are largely present, creating waters often unwholesome as public supplies.

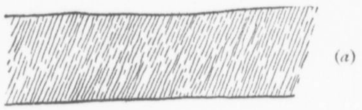


FIG. 2.

In retentive clays, cultivation, deposits of litter and leaf-mould, straw, roots of trees and grasses, and frost, all increase perviousness of surface to rain and air by loosening the soil.

FIG. 3.

FIG. 4.
Leaf mould or virgin soil at top of clay.

Leaf mould, while very pervious to rain, has at the same time great capacity for moisture. A moss has a small capacity for retaining moisture.

The amounts in percentage of volume which various leaf litter or mould can contain, according to Wollny, are:—

Depth of litter.	Oak leaves.	Spruce leaves.
Two inches....	50.11%	38.98%
Eight inches.......	53.09	41.65

Permeable sands and gravels receive and retain a very large proportion of the rain which falls upon them. At the London Asylum sewage farm six inches of water from the open ditches will frequently have disappeared in twenty-four hours. The capacity of such sand for retaining moisture is small in the above locality. Not more than 15 per cent. of the volume remains in the soil, but passes downward until it reaches an impermeable stratum. Such soils, when of sharp sand (pulverized quartz, gneiss, etc.), are the

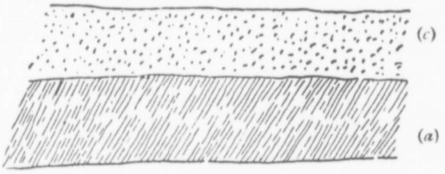


FIG. 5.
Permeable sands and gravels (overlying unpervious clay) as in Waterloo, Oxford, Brant counties and Oak Ridges.

most favorable for purposes of a sewage farm, allowing of the passage of the largest amounts of water, leaving organic matter behind in the upper film of the soil, where it is rapidly destroyed by nitrification.

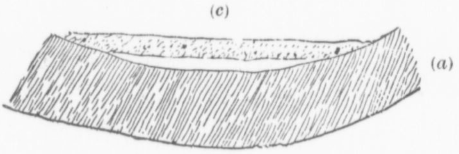


FIG. 6.

Sandlayer in denuded valley on top of clay. It occurs in many places as a common source of many surface wells, and even, when over large areas, of artesian water.

FIG. 7.

Deep sand and gravel strata, finer above, overlying boulder gravels. These soils over extensive areas become the great deep water reservoirs, the sources of large springs, and, with favorable deep strata, of artesian waters of large supply.

In such cases, as in No. 8, the rain falling upon the permeable soil at (*c*) passes along the surface of the impermeable bed (*à*) and will be found at varying depths from the surface at different points.

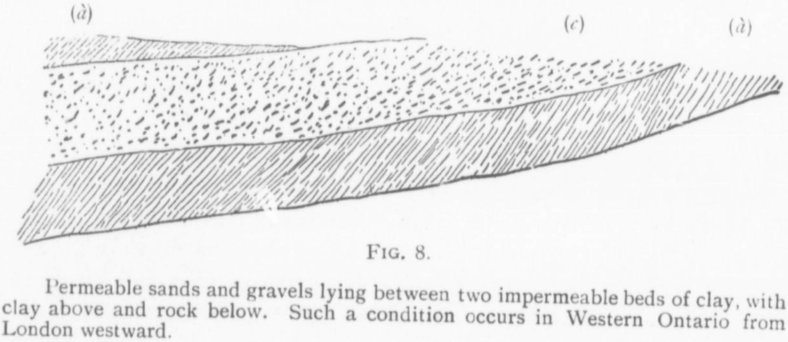


FIG. 8.

Permeable sands and gravels lying between two impermeable beds of clay, with clay above and rock below. Such a condition occurs in Western Ontario from London westward.

As shown in Fig. 9, it will be seen that the permeable strata receive the rainfall and store it as a subterranean lake reservoir, giving an artesian supply in proportion to the extent of the synclinal basin, to the extent of the permeable beds at the surface and to the angle of the dip of the underlying impermeable clay or rock stratum.

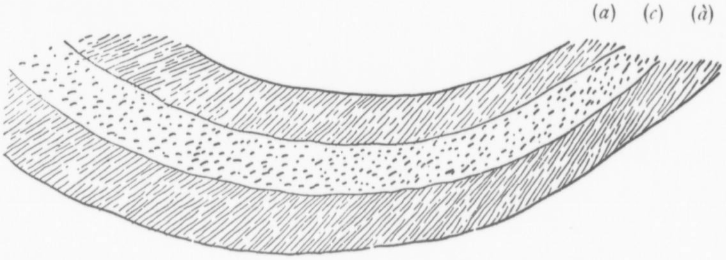


FIG. 9.

Permeable sands and gravels in a basin between impermeable beds. This condition is present in many places in Ontario, notably in the synclinal between London and the River St. Clair at Chatham, Leamington, etc.

In such instances the rainfall may disappear in faults and fissures, or be diverted in various directions according to the varying dip of rock strata. See Fig. 10.

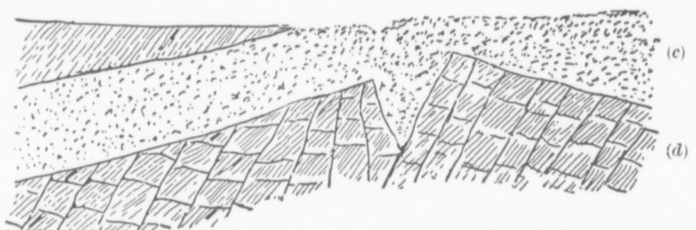


FIG. 10.

Permeable sands and gravels deposited upon underlying rock, folded and forming an anticlinal with a fault and strata at different angles. Such instances occur in the Alleghanies and other mountain ranges, and create local difficulties in obtaining underground supplies.

As springs are nothing more than surface indications of the existence of underground streams, they become interesting as an index of the locality of such underground streams, and of their volume. We have already referred to the depth of these underground streams as being to some extent a measure of their perennial character. Remembering the source of their supply, we naturally expect variations in the amount of the flow of a spring at different seasons of the year. These variations follow a movement consecutive to that of the rain and subterranean streams.

Durand Claye in a table gives the rainfall and flow of the streams forming the River Vanne, which supplies the city of Paris, thus:—

Springs of the Vanne.	1869.	
	Rain.	Flow.
	millimetres.	litres per second.
January	20	1190
February	38	1103
March	65	1232
April	24	1278
May	131	1195
June	55	1150
July	42	1057
August	19	972
September	60	818
October	35	818
November	72	807
December	33	839
	594	1057

In this connection Durand Claye points out by a comparison of the constancy of the source of the river Dhuis, as compared with that of the Vanne, that the deep springs are much less variable in their flow than those from shallow water zones.

Having discussed some of the principal points in the origin of springs and underground water courses, it will be proper for us now to consider them in their application to this Province. Unfortunately we have no literature whatever bearing upon this subject, and any investigations of the subject have hitherto been of a most partial character. The Geological Survey has, I understand, been collecting data with regard to borings in different parts of the province, but as only related to salt, oil, and gas. The most that we know is gathered from towns and villages here and there which have utilised some local source for fire purposes, and in some instances for domestic purposes. Owen Sound obtains an abundant supply from a large spring flowing high up out of the hillside from a fissured limestone stratum of the Niagara formation. Kincardine obtains at a depth of 420 feet (also at a depth of 240 probably) a splendid artesian flow, while on the hillside numerous springs crop out supplied by waters flowing along a hard-pan 15, 20, and 30 feet below the town, the present source of wells.

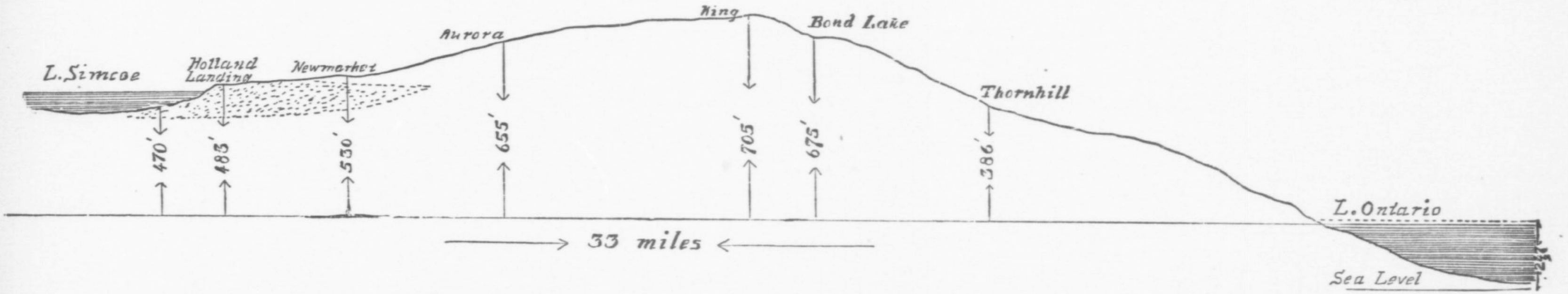
Goderich obtains a daily supply of nearly 2,000,000 gallons from six eight-inch borings down about 240 feet, within a quarter of an acre of ground. Walkerton is obtaining from springs situated on a hillside enough for a supply by gravitation. Various places in Lambton County, as about Forest and in Warwick township, obtain from a sand layer some 75 feet deep artesian water coming to within 20 feet of the surface. In Chatham and vicinity are a number of artesian wells coming to the surface, or nearly so, from a depth of 64 feet. At Kingsville, in Essex, some borings down to the rock have resulted in no water, while others have yielded an abundant supply of sulphurous water. Leamington is being supplied by artesian water from 55 feet deep, while at St. Thomas they have obtained at the court house a fine supply and at other points sulphurous water as artesian supply by borings. Springs out-cropping up the valley of Kettle creek at St. Thomas, flowing from the superficial sands and gravels, are likely to be developed finally for a public supply. Around London, borings to the rock have supplied sulphurous artesian water in some instances, and in others waters of a perfect character. The city of London is obtaining an abundant supply of splendid water from springs which appeared at the surface of the hillside along the bank of the Thames, some three miles below the city, and the supply has been enormously developed by simply running a gallery along the hard-pan for half a mile or so and conducting the water to the small pumping basin. These waters are gathered on the higher grounds which to the south of this point rise to nearly 200 feet, and are formed largely of pervious sands and gravels. No tests that I am aware of have been made of the variations of the flow of these magnificent springs. At St. Marys, and I believe at Woodstock, artesian water is obtained. Springs abound above Berlin, a public water supply being there obtained from them, while Guelph, too, is supplied mainly by springs. At Tilsonburg is found artesian water, while at Dunnville and about Jarvis in Haldimand County artesian water is obtained within a few feet of the surface. Brantford has a magnificent supply, obtained from perforated pipes laid on the hard-pan 13 feet under the sand and gravel of the island in the river. Niagara-on-the-Lake has numerous springs which are now being developed, with a view to a public supply. St. Catharines gets the supply from springs forming Decew's creek, flowing from the Niagara limestone mountain south of the city. About Toronto, no true artesian well water has been, so far as I know, obtained, although Mayor St. Leger has obtained at his residence on Bloor Street, near High Park gates, water rising, in a six inch boring, 189 feet deep, to within 40 feet of the surface. Borings down to the rock under the clay at the Mimico new asylum buildings obtained no water, nor yet when over 1,000 feet of rock had been bored. Curiously enough artesian water is obtained at Newmarket, situated on the north side of the Oak Ridges, while Barrie and Orillia both have artesian water, at depths of 100 to 150 feet. Smith's Falls in the east has water, partly artesian, rising in borings in the rock. Penetang and Markham are developing springs to obtain public supplies, while most curious of all Sundridge, on the Laurentides, some fifty miles south of North Bay, is obtaining abundant supplies of artesian waters at a depth of 100 feet.

Such is, in the briefest possible way, a statement from memory of the underground sources of public or private supply which have been developed in different parts of the province. They clearly point to the extreme importance of the problem which lies before you future engineers in the matter of supplying our inland towns with water. It is by no means improbable that the problem of applying to these underground sources for supplying large cities in Ontario will be discussed in the near future. Brooklyn, N.Y., is now supplied with 30,000,000 gallons a day from pipes driven into a sand stratum within twenty feet of the surface, and so abundant is the supply under the level surface of Long Island, only a few feet above the sea-level, that I personally saw from 125 2-inch pipes coupled together within an area of one-eighth of an acre over four millions being pumped day after day.

I may be pardoned for referring in this connection to the possibility of obtaining for Toronto a public supply from these underground sources. Here we are hampered again by a lack of data from speaking very positively, and yet there is a large amount of information regarding the topographical and surface physical conditions which may serve as a basis for discussion. We usually speak of Lake Ontario as being 247 feet above sea level, while the strata rise towards the north till at King Station a height of over 900 feet is reached, thence descending till Lake Simcoe is reached at 717 feet above sea level. We all remember, too, that running south, some easterly and some westerly, are a number of valleys, as those of the branches of the Don and various other creeks, some dipping toward the valley of the Humber, and others toward the Rouge. From what has been already said regarding the law governing the deposition of the post-glacial deposits, we may expect to find, what at most points is found, that over the rock strata of this region the Erie clays have been deposited with much regularity, over probably, as in the west, a thin layer of sand and gravel, and that over them but less regularly sands and gravels varying in their calcareous and argillaceous character—and therefore in their permeability—have been deposited. Were we to assume for a moment that no variations have taken place in the level of the underlying rock and its superimposed clays, sands, and gravels, it would be an easy thing for us, with a known rainfall, the degree of permeability of the strata, and their inclination to dip southward, to calculate with much precision the probabilities of obtaining a given amount of water at any point. Unfortunately for the calculation, however, deep erosions have taken place in these various deposits, and so have been formed river valleys dependent for their water supplies upon springs of the third class of Durand Claye.

Another class of erosions exists in the shape of depressions, creating small lake basins. From the survey of McAlpine and Tully, we find that the whole of those forming the so-called Bond Lake system have an area of 462 acres and a watershed of 7,600. From calculations made on the basis of this area of 7,600 acres receiving 30 inches of rainfall, half of which soaks into the soil, it would hold a possible supply of water equal to 20,000,000 gallons for 135 successive days. Of course a certain loss by evaporation must be allowed for. The existence of these lakes points to two interesting facts in this connection: first, to the existence of pervious upper beds, and second, to impervious deeper layers which form an impounding reservoir for the water flowing from the supersaturated zone, where the upper pervious meets with the underlying impervious layer of clay. Now the maintenance of a more or less constant supply, in spite of evaporation, of the water in these shallow basins throughout the summer points to the existence of an extended water zone in the surrounding higher lands. Springs along the valleys do the same. At Aurora such supply the village with ample public water, while at Newmarket, as already mentioned, have been developed what seems on first appearances for this locality a remarkable phenomenon, namely, artesian wells. It is further interesting to note that for a considerable space at Holland Landing and to the eastward around the lake basin is a flat bottom land of fine sand. From this there is an abrupt ascent of clay, thence a depression till Newmarket is reached, some fifty feet above the level of the lake. Since I learned of the existence of artesian wells in Newmarket, I have been much disturbed as to how to account for them. They are, so far as I know, the only ones between the two lakes. Recalling, however, the existence of the sand flat surrounding Lake Simcoe at Holland Landing some fifteen feet above the lake, and finding from the levels that Newmarket is only fifty feet higher than Lake Simcoe at the railway station, I venture the following explanation as accounting, in part at any rate, for their existence. (See diagram, page 19.)

The fact of the existence of this sand layer and of the artesian wells makes us curious to learn whether, assuming it to be thus continuous, it appears to the south of the Oak Ridges. As Bond and other lakes lie about, on the height of land, only 26 feet lower than Oak Ridges and 200 feet above Lake Simcoe, it does not seem at all probable that the permeable beds which supply these lakes have anything in common with the aforesaid sand layer. The same level as Lake Simcoe 717 feet to the



Section of country between Lake Simcoe at nearest point, Holland Landing, and Lake Ontario. Heights above the level of Lake Ontario are shown, as also the relative distances between places. Local variations in height are numerous.
Dotted area represents the sand stratum at Holland Landing continuous presumably with that under the superficial clay at Newmarket.

south of the watershed, arrived at along Yonge street, is seven miles south of Bond Lake; and did these underlying strata maintain the same level, it would be near Thornhill that we would expect to find the layer of sand. If in this latter locality there should be found a widely distributed layer of water-bearing sand superimposed upon a bed of clay, and having a head of water extending back as far as the Oak Ridges, there seems no good reason why it should not supply ample water for the purposes of a large city. Remembering that McAlpine and Tully's scheme contemplated using the Bond lakes, Rouge, etc., and recollecting that their summer supply, constantly being reduced by evaporation, is wholly dependent upon these underground sources, apart from an occasional rain, there surely can be no reason why we should not find these same waters in greater quantities in the water-bearing sands and gravels from which they flow, and unpolluted by any surface wash or contamination or by the free vegetable growth which makes these lakes as they now exist such undesirable sources of supply. It will be seen how interesting this local supply becomes when we recognize that in the small area of a few miles we have, illustrated, the various sources of public water supplies. First, we have the various creeks of the water-shed, which uniting create on the east the branches of the Rouge and on the west the branches of the Humber, thus yielding a river supply undesirable because of uncertainty through evaporation during the summer and the certainty of surface pollution. Second, Bond Lake and her sister lakes forming reservoirs of water, made to some extent impure with surface drainage, but further enormously contaminated by deposits of organic matter which have been washed into them during the past and from the abundant vegetable growth always present in such shallow basins. Third, water from springs flowing from the hillside and supplying the village of Aurora with a public water of a perfect character as regards freedom from organic pollution. Fourth, at Newmarket, artesian water flowing clear and cold from a sand stratum over 100 feet beneath the surface. Now, in order to gather that portion of the waters from the first two classes produced from these underground supplies in the same state of purity as those in the last two classes, it is apparent that all that is necessary will be for a perforated tile of sufficient capacity to be laid at a gentle incline in galleries dug down to the hard-pan of clay along which the waters flow on the south side of the height of land and collecting them before they appear as springs at the surface, flowing thence into the lakes or creeks, at a time when they are in a state of absolute purity, due to their long underground filtration, and before they are contaminated by any surface wash. Examples of how this can be done may be seen well illustrated both in London and Brantford, where ample supplies of first-class water have been obtained; but if we wish for higher authorities, because they are farther away, we may cite Toulouse, Florence, Lyons, etc., as examples of the method.

It now becomes of interest to enquire into the purity of these supplies. As you are very well aware we have distinctive classes of water, such as those of our great lakes, of our smaller inland lakes, of our rivers of the new districts, of rivers with towns situated on their banks, and of wells shallow, wells artesian, and deep pipe wells for pumping. These show that the various chemical compounds have certain general relations according as the waters have been churned up in the great lake reservoirs, have been flowing out of peat bogs, along clay banks or through limestone districts, whether they have received the surface drainage from cultivated land or from sewers, or from wells receiving a steady soakage from local sources of pollution, as soil contaminated with excreta or barnyard wash. All are aware that the rain water falling, chemically pure, at once dissolves from the surface soil whatever soluble materials are present, and that similarly as they descend into the soil they become loaded with organic impurities in the upper soils. In addition to chemical impurities, they likewise, through these impurities, become culture media through which infinite numbers of bacteria from the soil and air find abundant nutriment. Here again we find not only variations in the class of waters, which, according to their temperature, to the class of pollution and to their exposure to agitation and to the free oxygen of the air, present very different species of bacteria and enormously different numbers in a given volume. With regard to the bacterial life of waters under these numerous different conditions, we cannot be said as yet to have any complete or classified knowledge, but we do know that as the destruction of organic matter is slow or rapid, according to circumstances, so the degree of purity of a water for drinking purposes must depend upon the constancy of a settled condition unfavorable to a pollution from any source and remaining at a temperature inimical to the growth of bacterial life. Remembering it is only through the upper three feet of soil that organic materials with their contained bacterial life usually extend, and that it is therefore in these that the descending waters receive bacterial pollution, it is apparent that in the measure the waters continue to pass downward through permeable strata will they leave behind all suspended matters whether organic or bacterial, which they receive in the upper soils. Manifestly, however, the effect of the destructive influences going on in the soil will depend upon the depth of the organic materials and the porosity of the soil as regards movement of gases and the depth at which the bacteria of the soil are found to be capable of developing. Duclaux has stated that of the agencies which render water sterile in its passage through the soil, the first, the oldest known, and without doubt the most potent, is the capillary action of the soil. Filtration practically retains in the capillary pores the materials in suspension in the water, and with them the germs of microbes. It is a fact clearly demonstrated, he says, on which I shall only insist in order to attempt to indicate slightly what we call capillary filtration.

"It is proper to mention at the outset, that the capillary character of the channels in which circulates the water of rain has only the effect of augmenting the action of the surfaces on the volume of water which laves them, that is to say, of multiplying the chances which a solid particle in suspension in water can have of encountering a portion of wall on which it fixes itself, drawn by a force analogous to that which fixes coloring matter in a tissue placed in a coloring bath. The effect would be the same if the chances of contact were found increased by any other cause. . . . It could happen and sometimes does happen, moreover, that a long repose causes to adhere to the walls of a vase the particles held in suspension in the liquid which it contains. It can happen, and without doubt does happen, that a slow filtration through a great length of spaces non-capillary, and even somewhat large, produces the same result as through capillary spaces shorter and narrower."

Accepting these conditions as being those upon which the purification of ground waters depends, it is apparent that we have them supplied to the full in the case of those waters which create the enormous subterranean reservoirs which, we see, may result from downward movement of water through permeable soils. Further positive proof has recently been given us by the experiments of Carl Fraenkel, of Berlin, on the water of pit and driven wells, in which he shows that pit wells, owing to their receiving surface wash and soakage through their walls, as also owing to their communication with the outer air, are not only not sterile as are these deeper underground streams, but that, in the case of pit wells, in the neighborhood of habitations, these are too frequently found to be enormously contaminated. Thus in an unused well in the court of the Berlin Hygienic Institute, the water first removed was found to contain 10,800 bacteria in twenty drops.

To show the more or less constant differences in the chemical constitution of waters, I give here a number of analyses of Ontario waters from different sources :—

Source of water.	In parts per million.								
	Chlorine.	Free ammonia.	Albumenoid ammonia.	Nitrates.	Oxygen absorbed in 15 min.	Absorbed in 4 hours.	Hardness before boiling.	Total solids.	Loss on ignition.
Lake Ontario at bell buoy	3.0	None.	0.02	0.066	0.188	0.688	94.3	124	
Lake Superior	1.0	0.04	0.06		0.27	0.35		56	
Lake Simcoe at Roach's Point	0.5	0.04	0.12		0.588	1.512	115	156	
Bay of Quinte (Belleville)	Trace.	None.	0.08			2.66		142	60
Bond Lake	0.5	0.04	0.14	0.214	0.696	1.596	55	80	
St. George's Lake	0.5	0.32	0.20	0.049	1.220	2.828	142.1	192	
Ottawa River	5.7	0.07	0.014		0.06			128	
Niagara River	2.0	0.04	0.12		0.24	0.74		133	48
Kettle Creek (St. Thomas)	2.0	0.20	0.08		0.434	1.411		240	84
Artesian well (Leamington)	1.0	0.10	0.04		0.112	0.388	148	300	
" " (Goderich)	13.0	0.12	Trace.		0.21	0.32		540	
" " (Barrie)	7.0	None.	None.		0.306	0.3568	175	284	112
Penetanguishene (Springs)	1.0	0.057	0.057		0.30	0.085	235	205	
Walkerton (Springs)	1.0	None.	0.06	6.20	None.	0.108		318	
Orillia Asylum (Springs)	2.0	0.04	None.	None.	0.346		157	296	
St. George's well near Bond Lake	15.5	None.	None.		0.148	0.400	278	464	

From studying these natural waters it becomes manifest that each has some certain characteristics attaching to it, possessing an advantage in some one or more particulars. Clearly, however, the more important question is that of their sanitary character; in other words, of (1) their freedom as regards bacterial life, (2) their freedom from such organic materials as form a pabulum for these bacteria, and (3) their freedom from exposure to those sources of animal contamination, whether direct or indirect, likely to introduce pathogenic forms of bacteria.

From the various classes of waters as we have seen them, and the characteristics which specially belong to each, it becomes easy for us to form conclusions as to what conditions become necessary to maintain such in a state of purity, or, when necessary, to subject them to such conditions as will alter them into waters of a superior class. To make plain what I mean, I would say that, on the one hand, we must seek to maintain underground waters, as those of springs and artesian wells, in a state of biological sterility. Hence, (1) we must not conduct them along natural channels or artificial ones made of soil of any kind; in other words, their conduits must be of masonry, tile pipe, or of iron, and (2) we must not, if possible, store them at all. But if this be unavoidable it must be as limited as possible, and in stand-pipes where a low temperature is maintained, and where the surface presented to the dust and outer air is as little as possible, or else store them in concrete-lined reservoirs, supplying those conditions found in a stand-pipe. On the other hand, if we are dealing with the waters of rivers and small lakes, it must be our aim to apply such methods as those which make sterile our standard underground waters. As seen these are, (1) a removal of the vegetable matter, both suspended and soluble, found in them. Hence we apply the principle of filtration on some such scale as we find going on in nature, and at the same time, by allowing the action of oxygen to go on in the reduction of soluble organic matters, as albumenoid decomposable materials, into fixed salts, such as those found sometimes in excess in artesian and spring waters. The same agencies must be set in operation even in a more thorough manner where, as in many river waters, the pollution is of animal origin, as sewage. Remembering, as Hofmann tells us, that the rate of movement of underground waters is usually not more than a few millimetres a day, it is hardly necessary for us to enquire whether a few feet of a bed of sand and gravel, of magnetic iron filings or of spongy iron, or of any of the much-lauded artificial filters now advertised for the market, can supply the conditions for removal of impurities by the law of capillarity and adhesion on the one hand, or of oxidation on the other, in any degree similar to those whereby underground waters arrive at that state of biological purity which is our ideal.

It was not without reason that legend and romance attached to the fountains of the sunny climes of classic lands specific virtues. Greece had her Castalian font on Parnassus consecrated to Apollo and the Muses; the Isle of Crete her "many fountained Ida," sacred to Jupiter; Petrarch celebrated the fountain of Vaucluse; while healing virtues have attached to many a St. Ninian's well and St. Margaret's spring. Certain it is that these ancients did not seek in their rivers for those waters of crystal purity which supplied for them the nearest approach to the nectar of their gods; but rather they found them in the springs of those sylvan abodes where, with so much reason, were located the habitations of their somewhat numerous divinities.

THE SEPARATE SYSTEM AND THE BROCKVILLE SEWERS.

By Cesare J. Marani, Fellow in Engineering, S.P.S., Toronto.

Mr. President and Gentlemen,—In addressing the Engineering Society of the School of Practical Science, it would indicate a want of judgment on my part were I to dwell on the necessity of efficient sewerage, and upon the criminality—alas, too often entered into by civic authorities—of overlooking the means which science places at our disposal for decreasing mortality, preventing epidemics of the zymotic tribe, and preserving the health of our fellow-citizens.

In considering the sewage and sewerage questions, the only points where we may hold diversity of opinions are, the system to be adopted and the details of construction.

Before an examination was made into the several sewerage systems proposed for the town of Brockville, it was wisely considered advisable that such a plan should be adopted as would be capable of extension with the growth of the town; so that the part first completed could, in the end, become a portion of an efficient and economical system for the whole town.

I need not give an account of the different systems proposed and upheld by different promoters; suffice it to say that after a great deal of labor, thought, and time, had been expended by consulting experts; after a certain survey and maps of the whole town had been made; after levels and contours had been fixed, and the nature of the excavation on the different streets ascertained, it was decided to adopt the Modified Separate System.

With your permission I will say a few words in explanation of this system.

By the Separate System is meant a system which conveys house-sewage, and of course that water which comes from the flush-tanks, but excludes all rain water, both from the roofs and streets. It also excludes all cellar and soakage or underground water from its main artery. Cistern overflows, steam exhausts, and all that might be classed along with these, are of course excluded from the sewer.

Provision is made for the cellar and soakage waters by a line of ordinary porous agricultural drain tile laid in the same trench, but having no connection with the sewer proper. Advantage is taken of all such old sewers as are found in fairly good condition and which discharge readily into some water course or lake, as the case may be, to remove the storm water from the roofs and streets. Surface gutters are also used for this purpose.

From a careful digest of all that has been written for and against this system, I feel certain that those who have coursed their pens through the lengthiest manuscripts, or hurled their spears with deadliest aim at the Separate System, are just such as, only caring for fresh food to uphold their own conjectures, have not seen fit to discard self-inebriation for a moment in order to make themselves more fully acquainted with its *modus operandi.* From a theoretical as well as a sanitary standpoint, I consider that the Separate System is better adapted to the majority of cases than the Combined ; from a monetary point of view it is far cheaper ; and from a practical side, though it may sometimes be found advisable to allow certain portions of the system to be constructed on the Combined plan, yet it is just certain portions, and these are only on the branches and not on the main trunk of the sewer system.

Some forty years ago the excluding of the surface or storm water from the sewers was a departure advocated by several of the leading sanitary engineers in England, with this result, that several small towns were shortly afterwards sewered in that way.

In the year 1880 the attention of sanitarians and engineers in America was attracted by the sewering of Memphis, Tennessee, by Col. George E. Waring, in accordance with his extreme views. These views had been advocated by him a year before in a paper read before the American Public Health Association at Nashville, but the actual works brought the advantages of the system more prominently before the public. Since the year 1880 a great many of the American towns have been sewered according to this system, modified in the majority of cases, more or less of course, in order to meet the requirements of certain local peculiarities.

Permit me to read you some of the advantages of what is at present known as the Separate System from a paper read before the Brockville Sanitary Convention of last year by Mr. Willis Chipman, B.A.Sc., C.E.

(1) "The quantity of sewage to be dealt with is a comparatively fixed quantity, not varying from 1 to 60 as in the Combined System."

(2) "The quantity being small, sewers can generally be made of salt-glazed sewer pipes, impervious to liquids and gases, under ordinary working pressures, which offer a smoother surface than any brick or cement."

(3) "The sewers are regularly and thoroughly flushed by means of automatic flush tanks with pure water, while in the Combined System the rainfall is supposed to flush the system, but it is done irregularly and imperfectly."

(4) "The sewers have no connection with the cellars of buildings, the cellar and subsoil water being removed by separate conduits from the house sewage pipes."

The writer, after meeting the supposed disadvantages urged by the opponents of the system, goes on to say:

"This system is especially adapted to those towns in which the storm water can be removed by surface gutters or old drains with few long or expensive sub-surface channels."

"Secondly, those in which it is necessary to carry the sewage to any great distance."

"Thirdly, those in which it is now necessary, or will become necessary in the future, to treat the sewage, whether by sub-surface irrigation, broad irrigation, downward intermittent filtration, or by chemical precipitation and clarification."

In this paper it would be impossible to give as full a description of the Brockville sewers as they deserve; I shall therefore try to point out only a few of the main characteristics in the work now almost completed.

Brockville is one of the first, I believe the only place at the present moment, in Canada where the Separate System has been carried out on a reasonably large scale.

The town lies on the north side of the River St. Lawrence, twelve miles above Prescott. It is mainly built on and around a slight hogsback or ridge which runs parallel to the river, and therefore increases the difficulty of sewering the back portion. The spur end of this ridge faces westward, the other end, gradually spreading out, is lost in the highlands further down the river to the east.

The town is therefore divided into two portions, one standing on the slope facing the river, and the other overlooking the country at the back. Around the foot of the spur we find Shepherd's Creek, to the west we find a colony of buildings which form the remainder of the town.

Through want of knowledge, stupidity, or faithlessness on the part of past civil officials, or what not, at all events a charter was granted to a company to build, manage, and control the Brockville water works; and it was such that the company found itself at liberty to run its water mains in any and every conceivable direction, crossing and recrossing streets at any point wherever they might wish to do so.

As this charter contained no clauses properly restricting and regulating the laying of side branches and service pipes, these were therefore thrown underground in every imaginable shape. As an inducement to the company, and to help in defraying expenses, I suppose, that portion of Orchard street right at the water's edge was offered them free as a suitable site for their pumping-station. This being a central spot and giving scope for plans entailing the least expenditure in rock excavation, the company at once entered into a contract with the city fathers and proceeded to construct the works.

The result was that Brockville, after losing the smooth road surfaces, suffering from badly filled trenches, blocking of streets, delays in carrying out the works, and a score of other nuisances that spring out of poor workmanship and worse management, at last possessed the desired waterworks, which, owing to the terrible want of system both in their plan and execution, proved an energetic factor in raising the cost of construction of the sewers that were to follow.

This town, being one of the oldest in the Dominion, suffers from the fact that no matter in what direction you may run a trench on any street (except on those which have rock close to the surface), you cannot proceed many paces before you strike a regular nest of box drains, of all sizes and ages, running at all angles and elevations below the surface, and in all directions conceivable.

Some will be found comparatively new and in use, while others will be old and rotting, not having been used for years, but in most cases full of soakage water. This water bursting out into the trench gives endless trouble. Some of these drains are public, but others again are private, the owners holding special permits and rights which protect their position, and renders their removal, even by the engineer, very troublesome.

Owing to the amount of rock in Brockville, gas pipes were also laid crossing and recrossing the same street from side to side so as to avoid blasting as far as possible. From these among the many local difficulties that presented themselves, we can easily see that to attempt the introduction of a sewerage system in the town of Brockville, comprising both economy and efficiency, was no easy matter.

One of the greatest difficulties arose from the position of the waterworks pumping-house and intake pipe. A trunk sewer, running along Water street, capable of carrying twice the sewage of the whole town, and ending in a costly cast-iron outlet-pipe emptying below the said waterworks and in mid-current, suggested itself as the only remedy. But then, again, how could this trunk sewer be passed under the railway tunnel at the foot of Market Square, so as to catch all the sewage from the back part of the town?

This should bring vividly to view the necessity for careful thought and sound judgment on the part of an engineer before ever a spade is turned or a scratch of the pen made.

The system of sewers adopted in the town of Brockville is the Modified Separate System and is designed to carry off:—

(1) Liquid house wastes.
(2) Excreta.
(3) A limited amount of roof water.
(4) Subsoil and cellar water by special conduits.

The main sewer and laterals consist of vitrified salt-glazed sewer-pipe of Scotch, St. John's, and Hamilton make, and called sewers, designed to carry off the liquid house wastes, excreta, and the above limited amount of roof water.

Alongside of the sewers are laid agricultural drain tiles, one foot to a foot and a half in length, and three to six inches in diameter, and designed to carry off the subsoil and cellar water.

At the top of each of the branch lines leading from the main trunk sewer, we find an automatic flush tank, arranged to discharge 200 gallons of water twice a day.

When this water is discharged into the sewer it flushes all parts, and especially those of least grade, which require it most.

Nearly all those branch lines are nine inches in diameter, but vary from 900 to 3,300 feet in length; the flattest grade being about 0.32 feet per hundred, and the steepest probably 8.00 feet per hundred. All points are gasketed and cemented in the most approved manner, the cement used being the very best Portland, having withstood a tensile stress of over 120 lbs. per square inch after one hour's exposure in the air, and 24 hours submersion in water. It is used mixed with an equal portion of clean sharp sand.

Manholes or sampholes are met with at the intersection of every street, the sewer running straight and at a uniform grade between manholes or between a manhole and samphole or flush tank, as the case may be.

By this method the sewers can be readily inspected and cleaned if necessary. All junctions of mains and laterals are made inside of manholes, a Y or T junction, according to the depth of the trench, being placed opposite each house or vacant lot, and at such a point as to render it of most service.

From each cellar comes a line of from three to four-inch agricultural drain tile, which in the majority of cases runs up to, but does not break into, the trench line running along the side of the salt-glazed sewer, and therefore reducing in a great measure the possibility of vermin emigration.

The main trunk, which collects nearly all the sewage of the town, starts as a 12-inch sewer, swells to a 15-inch before it reaches Mill street, and then to an 18-inch, when it has only .16 of a foot fall per hundred. On Water street it passes as an 18-inch cast-iron water-pipe right under the C. P. R. tunnel without an invert or bend of any kind; beyond it continues as a soft-glazed pipe at the bottom of a trench, in many places nearly 13 feet deep, and at last it reaches the lowest manhole in the system, at the foot of Ford street, where the submerged outlet pipe begins.

This outlet consists of 16-inch cast-iron water piping over 900 feet in length, and running diagonally across and down the river.

The outfall is located in 45 feet of water and right in the current; contamination of the water supply is therefore rendered impossible.

Wherever practicable, the sewers have been laid in the centre of the streets.

On account of the Shepherd's creek to the west, the cluster of buildings beyond had to be drained by a small and separate system from that of the town. Their sewage empties into the river at a point above the water-works intake-pipe it is true, but the distance is great compared with the amount of sewage discharged, and experiments with floats have shown that the current at this point is up stream, this being caused no doubt by the position of the islands and also by the length of the C. P. R. wharf a little lower down.

Plans and records have been kept of the depth and grade of every sewer, the location of all flush tanks, sampholes, manholes, etc., also the position of all gas and water-mains, including all those service pipes, both for gas and water, that were met with in the trenches.

The average cost for five of the 9-inch sewers built on the frontage or local improvement plan, namely, Orchard, Market, Bethune and branches, Ormond and branches, and Pine, has been about $1.55 per lineal foot.

The average cost of the main sewer east of the tunnel has been about $3.88, while the portion to the west only cost $2.80 per lineal foot.

When we consider the uneven character of the soil, those local difficulties peculiar to Brockville alone, the hardness and quantity of the rock to be excavated, the difficulty of securing sufficient material, when most needed, to keep the works going, the fact that the character of the work and its dimensions here in Canada were new, and that therefore manufacturers of porous tile, salt-glazed pipe, bricks, etc., were at first unprepared to provide goods of the standard required and in the quantities called for, we wonder that so effectual a system could have been completed at these figures. It certainly reflects great credit on the chief engineer, Willis Chipman, B.A.Sc., and leads us to suppose, and in fact feel certain, that the majority of our Canadian towns could enjoy a similar system considerably cheaper.

NOTES ON RAILWAY LOCATION AND CONSTRUCTION IN THE NORTH-WEST.

By T. S. Russell.

There are several points in which the construction of railways in Manitoba and the North-West Territories differs from eastern practices. The most noticeable, perhaps, is the quickness with which the surveys and construction is carried on.

It is my intention in this paper to give a few notes on general western work, which I shall put in the form of a short history of the building of an ideal railway. I will at the outset remind those who may be disposed to criticize the manner in which these roads are built that, while eastern railways are generally built to connect towns and cities, between which they have an assured traffic, and have therefore some good prospect of paying expenses at the start, western roads are, as a rule, projected through an unsettled or sparsely settled country, which has first to be peopled by immigration before the required traffic returns can be hoped for. Add to this the fact that, with the exception of earth, all materials of construction are much more expensive than in the east, and it is not surprising that western railway companies try to build their roads as cheaply as possible.

In the month of May, 1888, two young engineers, one of whom I shall call Patterson, the other, the writer of this paper, were kicking their heels in Winnipeg, impatiently waiting for the opening of work on the railroads, ready to take almost any position which might be offered on an engineering party. When a whisper reached their ears that Mr. Smith, the chief engineer of the Sod Town Railway, was in the city, and about to organize a surveying party to locate the line of said railway, they immediately hunted up the gentleman and learned from him that for once rumor spoke truly; and as they were fortunate enough to be the first applicants they were offered work, Mr. Patterson as transit man, the writer as leveller, positions which they both accepted without delay. They were ordered to engage their own picket men and rod men and report on the following day, and to hold themselves in readiness to go west at a day's notice.

Within three days this notice came. Everything had been collected and put on the train—tents, cook's outfit, instruments and party, and after a few hours run on the C.P.R. the first representatives of the Sod Town Railway were deposited at Sod Town Station. The first proceeding was to overhaul the camping outfit and put up the tents, which were five in number. First and foremost, according to the unwritten law which governs all surveys, the cook's tent, which served also as a dining tent, was erected ; then came the chief's tent, which was shared by the engineer in charge, the transit man, and the leveller. The office tent came next, and then two more, in which the other members of the party slept.

Having superintended the erection of the camp, Mr. Smith went off to the town to make arrangements for a permanent office there. The transit man and the leveller started off on an exploring expedition, mounted on two gay and festive bronchos from the nearest livery stable, and hunted up a few section lines and explored the first three or four miles of country through which the new railway was to pass. At six o'clock the party reassembled in camp around the dinner table to test the merits of the cook, whose office is by no means the least important on a survey, and to make each other's acquaintance.

Besides Mr. Smith and the two instrument men already referred to, the party consisted of one rod man, two picket men, two chain men and one man to carry and drive in stakes, two teamsters, and the cook. Axe men were not necessary, as the prairie was quite destitute of any vegetation longer than sage bush, except near the banks of streams and rivers, where a few scattered poplars were found. As night came on the various members of the party betook themselves to their tents ; the chief, with the transit man and the leveller, held a consultation in the office tent, and laid down on the map a line to be run on the following day. This done, they went to their sleeping tent and turned in, but it was not an easy thing to go to sleep on the first night in camp, so that the first hour or two was spent in relating experiences on former surveys, and in listening to the choruses which came from the other tents.

Next morning's train from the east brought two more officials of the new railway, Mr. Hustler, who was to take charge of the location, and Mr. Quill, a draughtsman, who was to remain in Sod Town in charge of the office. The chief engineer had decided to remain in the town also, or at least to make this place his headquarters.

The regular work of the party began by running in a curve from the main line of the C.P.R., and then off on a long tangent. First went the front picket man with the two chain men and a man to carry stakes These were marked in the usual manner and lined in by the transit man. Hubs were put in about a half mile apart, and the line was projected by means of back pickets, a man being left behind to hold a picket on each hub over which the transit was last set up. The leveller and a rod man always kept behind the transit man.

The height above sea level was obtained from the C.P.R. and a bench mark established near the beginning of the survey. As there were no trees or stones on which to establish bench marks along the line, a bench was taken on each hub left by the transit man, the elevation being marked on the hub stake and entered in the level book. As the country was fairly level and without obstruction, the work went ahead very quickly.

On our first day we ran a mile and a half of line, on the second four miles, on the third five miles, and at the end of two weeks we were able to average seven or eight miles per day, except when we had to back up to try new lines, or change our course and run on curves. We moved camp about twice in three days. The cook and one teamster with an extra man attended to this work, the other teamster drove the party to and from work, carrying stakes, lunch, and such things as the party required during the day. Mr. Hustler, armed with a pocket-compass, hand-level, and map of the country, went ahead, either on horseback or driving in a buckboard.

The manner in which the land in the North-West is surveyed makes the running of railway locations and trail lines an easier matter than in the east; but as this system of survey has been so often referred to I shall not describe it here. In railway surveys the problem usually is to get the shortest possible route between a certain number of fixed points. When two of these points are known with reference to the system of land survey, the calculation of the course of the straight line connecting them and its length is a very simple matter.

The intersection of each land line with the line of railway should be taken by the transit man, and the distance to the nearest post measured and recorded in the transit book. In the evening he should plot this line, showing intersections with all land lines and the topographical features of the country on each side of it. The leveller should also plot his day's levels on profile paper every evening, and try grade lines, so as to form some idea of the probable cost of earth work. He must also note in his level book, and on his profile, all places where culverts and bridges will be necessary, although the fixing of grades and distribution of culverts is finally attended to by the engineer in charge.

The country through which the first sixty miles of our Sod Town Railway ran was fairly well settled for Manitoba. At first nearly every section had one, two, or sometimes four houses on it. As we moved farther away from the C.P.R. the number of settlements grew less; still for the first sixty miles we were never out of sight of houses. Sometimes, early in the morning, we could see houses all around us—hundreds of them apparently—looking, in the distance, like towns and villages. On account of a mirage which often occurs on the prairie, buildings twelve or fifteen miles away could be seen very clearly, and appeared to be only a mile or two distant, but as soon as the sun rose this illusion vanished. Perhaps such scenes are, as one of our party remarked, prophetic visions of what will be seen in reality in the course of a few years, when the country is better opened up and more thickly settled.

We ran through numerous grain fields, past cattle and horse ranches. One evening we met half a dozen travellers, who had camped for the night on the trail; their horses were turned loose to graze. One of the party was cooking supper at an open fire, another was making beds under the wagons, for they seemed to think a tent was an unnecessary luxury. They were farmers, they told us, and were bringing in their wheat to the nearest mill on the C. P. R. They had already come fifty miles, and had forty more to go before reaching their destination—Sod Town. Ninety miles to haul wheat and farm produce to the nearest market, and ninety more to return to their farms! Truly, railways are badly needed in the North-West.

Our survey line crossed two or three streams and small rivers, but we had no difficulty in finding good crossings. The largest, which rejoices in the name of Whiskey creek, gave us a little trouble. It runs through a valley about a mile wide and 150 feet below prairie level. One aggravating feature about this river, a feature that was noticed in the case of many streams, was that the prairie rose, approaching the river, until the edge of the valley was reached, and then dropped down 150 feet at a jump, as if the valley had been scooped out and the excavated material spread on each side to make it as difficult as possible to get a line down into the valley with easy grades. But by running along the side of the valley for about three miles, we managed to get down with a maximum grade of .7 feet per 100. Our maximum grade leaving the valley was one foot in 100. Since on this railway the bulk of the traffic is expected to be easterly, we tried to keep our grades going east below .7 feet per 100 as a maximum.

This location was, from its nature, very slow and hard work, and we camped in this valley for a month before we succeeded in finally locating six miles of road. The creek itself was a very insignificant affair to be the proprietor of such a large valley. It was barely 200 feet wide, and nearly dry where our line crossed it.

We now struck straight west, and soon left the boundary of Manitoba behind us. We left all traces of civilization behind us also; very seldom did we see any person outside our own party. Occasionally a few Indians would honor us with a visit, or a red-coated mounted policeman would call at our camp if it happened to be on the route of his patrol.

When we had run about 200 miles of line we were recalled to Sod Town. The company, it seems, had decided to build about sixty miles during the present season, and we were wanted to look after the construction. We therefore turned our faces eastward, and in ten days reached the point from which we had started our line some two months before.

During the progress of our survey we had from time to time sent in to Mr. Smith, at Sod Town, copies of our transit and level notes. We now found that Mr. Quill had been at work on these notes, and had prepared plans and profiles from them. All the plans of locations, structures, and profiles, showing grades, had been prepared for the first sixty miles which the company intended building. A right-of-way agent had been engaged to purchase the necessary land for right of way. The contracts for the earth work had been signed and the contractors were already on the ground prepared to go to work. There were two firms of contractors between whom the work was divided, thirty miles to each firm. Mr. Smith decided to divide the engineering and supervision of work in the same way, placing Mr. Patterson in charge of the first thirty miles, and myself in charge of the second thirty, as assistant engineers. We both were ordered to report to Mr. Hustler, who was the division engineer, and who took charge of all matters connected with the construction.

As the contractors concentrated their forces as much as possible, the work of looking after thirty miles was not so difficult as might at first appear. The contractors began at the beginning of their contracts and worked straight ahead, finishing up as they went along, and thus they did not as a rule work on more than five miles at once.

Before leaving Sod Town to take charge of our sections, Mr. Quill furnished us with working profiles, showing the grades adopted, the various culverts, bridges and crossings to be put in along the line, and with stationery sufficient for our field offices. We each took three tents, one to be used as an office tent. We also took with us a horse and buckboard, a rod man, a tape man, and an axe man. We took no cooks, but made arrangements for boarding either with the contractors or with farmers.

On reaching my section I began at once to cross-section and lay out the work in the usual manner practised, so far as I know, on all railroads. As most of you are probably familiar with this operation, and as it has several times been described in papers read before the Society, I shall not refer to it except to say that while on eastern roads the engineer pays particular attention to the cross-sectioning of cuttings, and is less particular in cross-sectioning fills, the reverse of this rule is observed on prairie roads. The reason for this is that in the east it is customary to measure and pay for the earth actually excavated in the cuttings and ditches, or borrow pits, and to pay no attention to the theoretical bank quantities, except, perhaps, as a check. While this method is undoubtedly the most accurate, as the shrinkage of the earth in embankments makes the theoretical bank quantities less than the true quantity excavated, yet on prairie roads, where the work is done very rapidly and cuttings are avoided as much as possible, the measurement of ditches would entail a vast amount of work in a very short time, and necessitate the employment of a great many engineers. Then, as these ditches are often irregular in cross-section, it would be a difficult matter to measure them accurately, besides the prices paid for earth on the prairie are so much lower than in the east, and the quantities per mile, as a rule, so much lighter, that the difference in the amounts which would be paid to the contractor by the two systems of measurement is not very great.

I found it a good plan in cross-sectioning to run straight ahead as in ordinary levelling, taking sights along the centre line and to the right and left when necessary, without marking any stakes or putting out any slope-stakes, except where there was a change from a fill to a cut, or *vice versa*, in which places I put in the necessary grade hubs and grade stakes, marking the exact points at which these changes took place before proceeding further. After having run on in this manner until about three or four o'clock in the afternoon, I would then put my level away and drive slowly back along the line. I would hold the reins in one hand and my cross-section book in the other and call out the cut or fill at each station, and the distances out for the slope-stakes; the men who walked along the line would mark the proper cut or fill on each centre-stake and put in the slope-stakes.

A supply of stakes was always kept on the back of the buckboard. By working in this way I could save a good deal of time, and could on fairly level ground lay out three or four miles per day.

In cross-sectioning we laid out the dump fourteen feet wide, and the cuttings twenty-two feet wide. In cuttings of less than four feet we made the side slopes two to one, three to one, or four to one, according to our judgment in each case, the idea being to make a gentle slope and thus lessen to some extent the danger of snow blockades in winter.

As soon as the ground was cross-sectioned, the contractors went over it and drove down at each centre-stake a stout poplar stake, making its height above ground correspond to the fill marked on the centre-stake. They also drove down shorter poplar stakes to mark where the slopes of the dump would come, as our slope-stakes were usually very light and perishable affairs. They then brought on their graders and scrapers, and the various apparatus used by them for the purpose, and proceeded to throw up the dump and haul out the cuttings as quickly as possible.

The New Era graders were used by the contractors of whose work I was in charge. I shall not attempt a very lengthy description of them, as they are fearfully and wonderfully made. The remark which is reported to have been made by a farmer of the old school on seeing a self-binder for the first time would apply to these "infernal machines," as some engineers call them, that "It would be no sin to fall down and worship them, as they resemble nothing in the heavens above, or the earth beneath, or the waters under the earth." The principal parts of a grader are a plow which can be raised or lowered by means of chains running over pulleys, and an elevator, which is simply a rubber belt about thirty inches wide working over two revolving pulleys. The plow turns up the sod and throws it on the belt of the elevator, which revolves so as to carry the sod up along an inclined plane and drop it at a distance of sixteen or eighteen feet from the ditch. The grader is drawn by six teams, four in front and two behind. Three men can work it, one to drive the front teams, one to drive the two rear teams, and the other to raise or lower the plow. The raising or lowering of the plow regulates the amount of earth moved. Four feet is the greatest height of dump that can be built with this machine, but it is used by many contractors for the bottom of all fills, the fill, when it exceeds four feet in height, being finished with scrapers. Under favorable circumstances, a grader will throw up about 1,000 cubic yards per day.

These grading machines make a very pretty ditch but a very loose and unsatisfactory dump. The sods and earth are dropped from the end of the elevator, and as no weight or pressure is applied to solidify them, the dump built with the grader only is very soft, often so soft that a man walking on it will sink six inches in the earth, and it keeps settling as time goes on under the influence of rain.

To remedy this evil some railway companies make the contractor put up all dumps, finished with the grader only, two-tenths of a foot extra for every foot the dump is in height; thus they would have to make a dump intended to be three feet high 3.6 feet high. Other companies do not allow any work to be finished with the grader, but oblige the contractors to put on the last twelve inches on dumps with horses and scrapers. The tramping of the horses thus solidifies the whole. I have yet to meet the first engineer who has a good word to say for these grading machines—that is, for the ordinary purposes of railroad building. Their work is very unsatisfactory, and as a consequence they are a source of frequent disputes between the contractors and the engineer. When the contractor is bound by agreement to use his graders only for the foundations of dumps he has to be watched constantly or he will exceed his limit, for work can be done much cheaper by the grader than in any other way. The use of grading machines has reduced the price paid for earth in Manitoba as low as seven cents per yard.

On the profile given to me by Mr. Quill, the location and size of each proposed culvert and trestle was marked. The contract for earth work did not include bridging, so I was only concerned about the size of the opening to be left, and about leaving such openings in the best places. In this work I had to follow my own judgment to a large extent, changing either the size or location of structures when there appeared to be a necessity for it. The chief engineer often locates these structures from an inspection of the profile and a single drive over the line, and it is only natural, therefore, that the assistant engineer, who goes over the section every day or two, should be able to suggest improvements, which he is usually allowed to make, first obtaining, in important cases, the advice and consent of the division engineer. To the assistant is left also the location of farm and road crossings. Road crossings are of course put in where the railway line crosses the regular road allowance; farm crossings, at such places as may be agreed upon by the assistant engineer and the owner of the land, one crossing being allowed for each quarter section of land. When these points are finally settled, a list is made out of all crossings, culverts, cattle-guards, and structures of all kinds, with the numbers of the stations where they are to be put in, and copies of this list are sent to the contractor and to the chief engineer. The location of these structures is also indicated by stakes, which should be put in at the time of cross-sectioning, or as soon as possible after. The contractors are required to excavate a foundation for box culverts below prairie level, such work being paid for at the usual rate.

During the progress of construction, we were kept busy giving the contractors grades in cuttings, and on high dumps, when they were not able to put in stakes high enough to reach to the top of the dump. When any part of the work was finished, I ran centres and grades over it, to determine whether or not it was properly built on the original centres and up to the required grade. If found wanting in any respect, the contractors were notified to go over it and make it right. They generally did this very reluctantly and with a great deal of grumbling in some cases, but a few occurrences like this made them more careful in future.

At the end of each month an estimate of the amount of earth handled during the month had to be sent in to the head office, and on the completion of the work a final estimate of the total quantity of earth handled, including all crossings, and in some cases culvert excavation and ditches, the material from which was wasted by orders. The prices paid for earth were eight cents per cubic yard for all earth hauled less than 200 feet, and twelve cents for all hauled more than 200 feet and less than 600 feet, and for earth hauled over 600 feet one cent per additional 100 feet of haul. It was necessary, therefore, to state in the estimate how far each quantity of earth had been hauled. Earth was not hauled more than 200 feet, except in the case of cuttings, where the earth had to be hauled each way from the centre of the cutting to the adjacent fills, and in the case of very heavy fills where sufficient earth could not be obtained within 200 feet of the dump. In the former case I calculated the amount of the over-haul by plotting the quantities in the cutting and the adjacent fills to a scale; the horizontal distances were indicated by the numbers of the stations representing distances, along the line; the vertical ordinates represented cubic yards. The number of cubic yards plotted opposite each station is the total number from the beginning of the cut up to that point, and these points are joined so as to make a curve of quantities. This curve of quantities is drawn for the cut in two parts, one commencing at zero, at the beginning of the cut, the other commencing at zero, at the end of the cut, the curves intersecting near the middle or at the exact centre of gravity. A similar curve of quantities is plotted for the fills adjacent to the cut. By finding with a scale or pair of dividers the two points, one on the curve of the cut, the other on the curve of the fill, which are 200 feet apart on a horizontal line, we obtain from the ordinate of these points the total quantity in that end of the cut hauled less than 200 feet. By the same method we find the points on these curves between which the horizontal distance is 600 feet. The ordinate of these points give us the quantity hauled from 0 up to 600 feet; subtracting our first ordinate from the second gives us the quantity hauled more than 200 feet and less than 600 feet, or our over-haul for which twelve cents per yard was to be paid. Similarly, we can find the amount of the over-haul for each additional 100 feet. When the length of haul reached 1000 feet our instructions were to allow the contractor to waste the earth in the cutting, as it was cheaper to pay them eight cents per yard for wasting, and eight cents more for borrowing earth for the fill, than to pay over sixteen cents for over-haul.

The calculation of the quantities for the estimate gave us a lot of work. Mr. Patterson and I calculated our quantities on sheets of foolscap during the evenings and on wet days, and then exchanged level books and estimate sheets, so that each checked the other's work.

It is wise to do this work early in the month, and not leave it all to the last moment and then have to work night and day to get the estimates off in time. I used two methods for calculating these quantities; the first was for cases where the ground was level, or nearly so, and the readings at the slope-stakes the same as at the centre, in which case I used Trout wine's tables of quantities for a fourteen-foot bank, and calculated from them. The second method was for cases where the ground was sloping and it was necessary to consider the heights at the slope-stakes, or other points in the cross-section, in which case I calculated the area of each cross-section in feet, averaging the areas and multiplying by the distance between them, then converting the result into cubic yards. The first is a method of averaging heights, the second of averaging areas. These calculations were, of course, made from the figures in the cross-section book. The quantities in the cuttings were calculated by a method similar to the second here given.

An objection may be urged against these methods, in that they are not mathematically correct, but in no case can one be sure of mathematical accuracy when calculating earth work quantities. The first method, in which the centre heights are averaged, makes the quantity too small; the second, in which the areas are averaged, makes the quantity too large. The prismoidal formula would come nearer the truth, but life is too short and time too precious to admit of its being used. Some engineers are fortunate enough to possess tables calculated by the prismoidal formula, and extended so as to give the cubic contents of prismoids with very large and very small end areas, and these are very useful and accurate.

The following figures will give an idea of the cost of earth work per mile on prairie railroads. Quantities of earth on 16.68 miles of railroad —rolling prairie :—

139,067 cubic yards hauled	200 feet, @ 8 cents	$11,125 36
10,781 " " "	200 to 600 feet, @ 12 cents	1,293 72
7,147 " " "	over 600 feet, @ 26 cents	1,858 22
Total		$14,277 30
Average cost per mile		$855 95

This is for earth work *only*. Another average of the cost of earth work on twenty-three miles of road makes the cost, at the same prices above quoted, $667.89. In this case the prairie was more level.

After the completion of the earth work the bridging engaged our attention. In this paper it will be possible only to outline the work done on bridges. With the exception of our wooden truss bridge over Whiskey creek, the structures were of four kinds: 1. Timber box-culverts; 2. Timber open culverts of fifteen feet span; 3. Pile trestles; 4. Framed trestles.

All structures were of wood. The box culverts were very simple affairs, built of cedar, the average opening being two and a half feet vertical by three feet horizontal.

The fifteen feet open culverts were used in places where the bank was less than five feet high. They consisted of two bents of six piles each, backed by a wall of 10″ x 10″ cedar, which acted as a retaining wall to keep the earth of the dump from falling into the opening. The piles in each bent were driven as follows: Two inside piles five feet apart, or 2′ 6″ from the centre of the track; then two eleven feet apart, each 5′ 6″ from the centre of the track; then two outside piles were driven one-third of the way down the slope of the bank to assist in supporting the timber wall. On top of the four centre piles a cap 4′ x 12″ x 12″ was placed, and on this the stringers were fastened; finally, on the stringers the ties and guard rails were arranged in the usual manner.

The ties, stringers and cap were fastened with ¾″ drift bolts, and the guard rail 8″ by 8″ was let down on the ties 2″. The guard rails and ties were then bolted together through every fourth tie by ¾″ bolts. In all cases the span for these culverts was fifteen feet.

The pile trestles were built with bents, fifteen feet apart, four piles in each bent, the two inside ones being five feet apart, one under each rail; the two outside ones were eleven feet apart.

The piles were braced diagonally by bolting to them 3″ plank. The arrangement of the caps, stringers, ties and guard rails was the same as for the fifteen feet open culverts, except that three stringers 5″ x 14″ and 7″ x 14″ were used in alternate spans under each rail. The spans built in this way were forty-five feet, sixty feet, seventy-five feet, and so on, the distance bridged being always a multiple of fifteen feet.

In these trestles no retaining walls were put in, the earth being allowed to slope under the trestle. All trestles over twelve feet in height were framed. These frames consisted of a 12″ x 12″ sill and cap, the latter fourteen feet long, two vertical 12″ x 12″ posts five feet apart, and two bottom posts 2″ x 12″, eleven feet apart at their tops, built with a bottom of one-quarter horizontal to one vertical. These frames were braced diagonally, and also fastened to each other horizontally. They rested on piles which were cut off close to the ground. The arrangement of stringers, ties and guard rails was similar to that already described.

The work on these bridges was done by a different firm of contractors from those who did the earth work. In order to save expense in hauling timber, they waited until the track-laying started before beginning work on the bridges and then finished them up just ahead of the track.

Mr. Patterson, who took charge of the bridging, laid out the culverts and trestles, putting in stakes for each pile separately and giving heights with the level for cutting off the piles. He had also to inspect all the timber used in construction and see that no bad material was used, and that the structures were built in accordance with the general plans sent to him by Mr. Smith.

I took charge of the track-laying, but as this part of the work was referred to in a former paper I shall say nothing about it here. After the track-laying came the erection of tanks and buildings. Mr. Hustler took charge of this branch of the work, and Mr. Patterson and I, finding that the Sod Town Railway Company did not require our valuable services any longer, decided to come down and visit our friends in the east.

FOUNDATIONS.

BY R. McDOWALL, GRAD. S. P. S.

One of the commonest expressions in literature in regard to man is, "Build on a sure foundation." And to insure a structure against destruction, one of the chief requisites *is* a "sure" foundation.

The subject of this short treatise is to give a general description of how foundations are obtained.

Foundations must not be considered bad even if they do settle below their original level, but the whole surface must sink uniformly without any tilt.

We will divide our subject as follows:—

(1) Rock foundation,
(2) Dry soil foundation.
(3) Under water foundation.
(4) The coffer-dam.
(5) The caisson.
(6) Interesting details.

(1) *Rock.* Of course rock forms the best foundation, but in some instances it is unreliable. If it be shaky or shallow in depth, all shakes must be removed, and all hollows, cracks, etc., must be filled with concrete. If the bed of rock has a dip, it will have to be "stepped" in order to prevent sliding. To test the nature and depth of the strata, several holes should be drilled from three to four feet deep. Rock must be removed generally by blasting.

(2) *Dry Soils.* In good dry soils the foundation must be sunk to such a depth as to be entirely out of reach of atmospheric influences; also the depth should be proportionate to the weight of structure to be built upon it, or the soil will squeeze up about the structure and the foundation will settle. In compact gravel the pressure per square foot of foundation surface should not exceed two or three tons, and in clay, one or two tons. All kinds of tremors help settlement. Equality of pressure is a great point to be gained.

(3) *Foundations under Water.* The great difficulty in placing foundations under water is that of getting rid of the water while excavation and building is being done below water-line. The same kind of soils is found below as above water, but wet soils stand a less pressure than dry. But in water, foundations have to be sunk a great deal deeper than on dry land,

in order to prevent "scouring" or washing out of the soil from beneath the structure, especially in a rapid current. In shallow water, from two to three feet, a bank of clay around excavation is sufficient to keep out the water. In greater depths, as from three to twenty feet, coffer-dams will be required. A coffer-dam consists of two rows of sheet-piling driven about a rectangular space, in which space the excavation is to be commenced. In the space, which is about five feet, between the two rows of piles puddle is placed in order to make it water-tight. Puddle is the name given to whatever material is used, sometimes gravel, sometimes clay, and sometimes a mixture of each with pea straw. Blue clay, from my experience, makes the best puddle. Of course the material close at hand should be used, as it would be very expensive to haul any specified puddle from a distance. The slime on the river bottom should be removed from between the rows of piles before the puddle is placed, so as to allow it to combine with the hard soil at the bottom of the water-basin. If there is a leak in a coffer-dam it generally is at the line where the puddle meets the bed of the river, etc. This slime can be removed from under water by use of a clam dredge. The timber used for sheet-piling is cedar, from twenty-four feet to thirty-six feet long, eight inches thick, and of various widths. It is tongued and grooved in order to more effectually keep out silt. A walling of hardwood (elm is good) surrounds each row of piles, and is bolted to them. The two rows of piles are also connected by iron rods at their top to prevent spreading.

The water inside the coffer-dam is pumped out, and if any leaks should appear they are at once stopped. The centrifugal pump is the best kind for pumping muddy, silty water; one having a 6-inch discharge pipe will throw from 300 to 400 gallons per hour. In any ordinary coffer-dam a single pump should be sufficient to keep it dry and not be working half the time.

The material inside of the coffer-dam is generally excavated by hand, placed in buckets and hoisted by a steam derrick. These buckets dump themselves by being tripped by a line. If at required depth a good bed of gravel or rock is met with, the surface is levelled and the masonry is commenced. But should the bottom be of a soft nature, as quicksand, etc., piles will have to be driven.

Bearing piles are generally from twenty-five to thirty-six feet in length, and from eight to twenty inches in diameter. All kinds of woods are used, but the best are cedar and spruce. They are driven in rows in the foundation spaced about three or four feet apart. The piles are driven by a pile-driver. It consists of two well-braced "leads" made of timber and spaced sixteen inches apart. Between these leads a hammer works freely up and down. The hammer is drawn up by a rope attached to it and passing over a pulley at the top, thence to a pulley at the bottom, and from there to the drum of a hoisting engine. In hoisting with a steam engine the rope is continuously attached to both hammer and drum, and in this way an engineer can strike his pile light or heavy blows by the use of his friction lever. A pile inspector can be thus led astray when he sees a pile stand a full drop blow without budging, while all the time the engineer is striking light blows. Iron rings should be placed about the heads of the piles to prevent them from splitting.

The formula for finding the bearing load of piles is the following:—

$$L = \frac{H^{\frac{1}{3}} \times .023W}{S \times 1} \begin{cases} L = \text{load in tons.} \\ H = \text{fall in weight.} \\ W = \text{weight of hammer in pounds.} \\ S = \text{last sinking in inches.} \end{cases}$$

Example.—Suppose a pile fourteen inches in diameter and thirty feet long is struck by a hammer weighing 2,000 ℔s., and falling twenty-seven feet; find its sustaining power and the friction per square inch on its sides, the last sinking being two inches:—

$$L = \frac{27^{\frac{1}{3}} \times .023 \times 2000}{2+1} = 46 \text{ tons} = 92000 \text{ ℔s.}$$

$$\text{Area in sq. inches} = 14 \times \tfrac{22}{7} \times 30 \times 12 = 15840 \text{ sq. inches.}$$

$$92000 \div 15840 = 6 \text{ ℔s. per sq. inch.}$$

The driving of a number of piles in a foundation throws up a considerable quantity of material. All the piles are now cut off at the same level, and the earth is excavated from about them to the depth of two or three feet. Timber caps twelve by twelve inches are bolted to the top of the piles. Rag-bolts twenty-four inches long and three-quarters of an inch square are used. Then the whole of the spaces between piles and caps is filled in with concrete well tamped down. Upon these caps a longitudinal flooring of twelve by twelve inch timber is bolted. This flooring should be laid so as to break joint. Sometimes a row of sheet piling is driven about the floor to help its sustaining power.

The use of the concrete is to have a solid brace between the heads of the individual piles. On this flooring the masonry is constructed.

If the water exceeds twenty-five feet in depth caissons will have to be substituted for coffer-dams. Caissons are of two kinds—floating and pneumatic. Floating caissons are made up of large timbers in the form of a huge box large enough to build the pile or structure inside. It is floated into its position for sinking and the masonry is started. As the masonry progresses the caisson sinks and more timbers are added to its sides. The foundation for its bottom to rest upon is prepared by divers, but in all cases where these are used there must be but very little excavation under water, and the foundation must be of hard gravel or rock. In some cases iron bottoms are put into caissons and the timber riders are detachable. Caissons of this kind have been sunk in 150 feet of water. The pressure is so great at these depths that the water is squeezed through the pores of the wood and a pump is required to keep the caisson dry. As the centre of gravity rises with each course of masonry, there is sometimes great danger of the caisson tipping over. Pontoons moored and attached to the caisson will aid in overcoming this tendency to tilt. In a bridge recently built by R. G. Reid, in Cape Breton, the pressure of the water burst in the side of a 100-foot caisson and it sunk, or rather filled, as the sides of the caisson were still above the water. Divers were sent down, who filled up the breach with masonry, concrete, and cement, and it was pumped out, when it rose again. Where considerable excavation is required below a great depth of water pneumatic caissons are required.

A pneumatic caisson is only the enlargement of the idea of the diving bell. The caisson is only an inverted box, open at the bottom; the outside edges are shod and cased with iron, if it be built of wood, so as to give a cutting edge. The roof and sides are made of timber or iron thoroughly bolted and braced, and capable of sustaining the load of the structure. The chamber in the bottom is high enough to allow laborers to work comfortably in it. It is built on land and floated to where the foundation is to be sunk. Air is supplied to the chamber by powerful air-compressing pumps. The air pressure increases as the caisson descends, and must always equal the pressure of water at depth of the cutting edge, so as to prevent water entering the air chamber. The descent to the chamber is made through a wrought iron tube built in the masonry. It has at a suitable point an air-lock large enough to pass several men through at a time. This lock is provided with valves, to prevent the compressed air escaping when anything enters. A person enters the air-lock from the outside atmosphere at a pressure of fifteen pounds per inch; he closes the outside door and then opens the inside one and allows the pressure of the lower chamber into the air-lock, which may be increased to thirty pounds per square inch. Besides this, entrance pipes for conveying the excavated material up are also built in the masonry. A force of men loosens the soil and it is then forced up to the outside atmosphere through these pipes by air pressure. Rocks and boulders have to be taken up through the air-lock. The masonry is continually being built, so as to give the required weight to the cutting edge. When bed rock or a good permanent strata is reached, it is levelled for the final location of the caisson. The inside of the chamber is then filled with concrete. When the caisson is descending great care must be taken to keep it from tilting; if a boulder is met by the cutting edge it must at once be removed, lest the other edges lower and upset the whole thing. It is extremely dangerous work to be laboring in the chamber. The late Louisville disaster, in which fourteen men were drowned, shows how careful they must be. The men got in a panic, fought to get through the air-lock, allowed the compressed air to escape, and the water rose and drowned them. The air pressure at depths to which caissons have been sunk is very great; at 110 feet below water it would be fifty pounds per square inch. Men cannot work at greater depths than 100 feet; it affects a man in the following ways: Increased respiration, increased pulse, extreme pain in the lungs, and sometimes paralysis. At depths exceeding 100 feet dredges have to be used. Caissons have been sunk in Australia to a depth of 175 feet. Great trouble was experienced before the invention of the electric light in lighting the lower chamber, the pressure of the air causing the lamps to smoke terribly.

There are many other methods of sinking foundations.

In India the natives sink cylindrical brick tubes. The soil is taken out by the natives diving with baskets and filling them under water. As the soil at the bottom is taken out the brick tubes sink. The bricks are fastened together with cement and straw ropes. Foundations have been sunk to the depth of seventeen feet in this manner at a cost of only thirty-two cents per lineal foot. Large cylindrical tubes have been sunk in the same manner as a caisson, and then filled with concrete. The foundations for the Tay bridge were sunk in this manner. The largest caissons ever built were those under the Brooklyn bridge; they are 102 x 168 feet, with a chamber nine feet six inches high. The Brooklyn pier is sunk forty-five feet below high water, and the New York pier seventy-eight feet. They were built of timber and went to rock. The pneumatic caissons under the piers of the Forth bridge are built of iron and are circular; they are capable of sustaining a pressure of six tons per square foot. They were provided with separate distinct chambers, so as to be loaded with concrete in different places so as to regulate the sinking; notwithstanding one of them upset and caused endless trouble. The caissons under the Eiffel tower are capable of sustaining four tons per square foot. This pressure is mostly due to the wind's effect on such an enormous height.

Hollow iron piles have also been used instead of wooden ones. A novel way of sinking piles is by a jet of water forced from a steam-pump. This jet plays through a small nozzle at the toe of the pile and keeps the sand in a mobile state. The weight of the pile then sinks itself. In quicksand this is a faster process than by driving with a hammer. Off Cape Henlopen, in the United States, piles were driven with the water jet that could not be driven by the hammer at all. Screw piles have also been used with a large platform attachment to help their bearing surface. Hollow iron piles may be sunk to an enormous depth, allowing the hammer to fall inside of them, striking their solid iron feet. This device is to prevent the pile bending, as would be the case by striking its top. As the pile is driven new lengths are screwed on at the top. Concrete is largely used is foundations. It is composed of broken stone, cement, and gravel, or sand, in proportions of two, one, and three. The cement should be a quick-setting one, as building is commenced immediately in deep foundations, owing to the danger of bursting in and the cost of pumping, etc. Concrete should be well mixed.

WATER SUPPLY.

By Edward F. Ball, Grad. S. P. S.

Mr. President and Gentlemen,—This branch of engineering is yearly growing in importance. Towns which a few years ago relied upon wells and cisterns to furnish water for domestic and mechanical uses are now taking or have already taken the necessary steps to secure a plentiful supply of wholesome water, at such pressure as will enable powerful streams to be thrown over the highest buildings directly from the hydrants without the use of portable fire engines.

The preliminary steps towards securing the necessary appropriations for constructing a system of water-works are usually prolonged and tedious. After much talk and discussion, an engineer is usually appointed to make surveys and examinations and report upon the most desirable system to be adopted, giving estimates of costs, etc. A by-law to raise the necessary amount is then submitted to the ratepayers, and is sometimes defeated once, twice, or even three times, before it is finally carried. In case the town is unable to construct the works, a company may be induced to build and operate them, the town paying an annual rental for the use of hydrants, usually from \$50 to \$60 per hydrant per annum.

Should the works prove unremunerative the company are the losers; but if they should prove a paying investment and the town should wish to acquire the works, the statutes provide that they can do so by paying the appraised value of the works, which value cannot exceed the actual cost of the works more than ten per cent.

There is a general feeling that towns should own and operate their own works, but in the case of small towns it may be advisable to rent from a company.

If the engineer employed by the town to devise a system of waterworks, be a man of large and extensive practice, he will probably advocate a very complete and extensive system, which may be beyond the financial ability of the town to construct. If, on the other hand, the engineer be of limited practice, he may advocate a cheap system, in order that his plans may be carried out.

In the first case the system will, in all probability, be a very safe and economical one to operate, but the interest on the capital expended in its construction may more than counterbalance this. In the second case, although the item of interest will be low, the expenditure in fuel or attendance or both will probably pay interest on the additional cost of a considerably better plant. It will thus be seen that the town should give careful consideration to the operating expenses as well as to the first cost.

While it is a comparatively simple matter to devise a thorough system of works provided abundant means are at the disposal of the engineer, it is not such an easy matter to say just where the line should be drawn between a complete system and one which will barely supply the needs of the town.

The item of first cost is very apt to be the principal consideration of the ratepayers, and cheap systems are too often the result. In such a case it would be far better for the town to rent from a company, for the company would construct works which could be economically operated, and as a rule this means a more reliable system.

SOURCES OF SUPPLY.

The sources of supply are usually streams, lakes, springs, or sometimes artesian or driven wells. Whatever the source, samples should be carefully collected and submitted to a chemist for analysis. This analysis should state the hardness of the water (both permanent and temporary), as well as the impurities dangerous to health. The hardness of the water is an important consideration in manufacturing towns where large quantities will be used for generating steam.

About two quarts of water from each proposed source should be collected for analysis, and the best vessels for this purpose are the Winchester two quart bottles, with glass stoppers, found in drug stores. Bottles which have contained sulphuric acid are to be preferred, as any trace of sulphuric acid left in the bottle would probably appear in the analysis as a sulphate of some metal, and traces of sulphates do not indicate contaminated water. Chlorine and nitrogen point strongly to contamination from animal or vegetable matters, and for this reason bottles which have contained these substances in any form, as hydrochloric acid, ammonia, etc., should not be used. When no others were obtainable the writer has succeeded by repeated washings and tests by litmus paper in removing the contents of ammonia bottles so that no traces were detected in the analysis. The bottles and stoppers should be repeatedly rinsed with clear water, and finally with the water to be analysed, then carefully filled, sealed, and labelled. If the water be collected from a stream or lake, the sample should be taken below the surface in order to avoid any floating particles.

Samples may also be taken from wells in the town, in order to compare the proposed supply with that in present use. In collecting samples from a pump the handle should not be raised high, as the plunger may thereby be made to travel in an unused part of the barrel, thereby stirring up sediment. Two or three pailfuls should be pumped and thrown away before the sample is collected. In sealing the bottle a piece of cloth should be placed over the stopper, turned down and tied around the neck. The seal should be placed on the knot of the string.

If the proposed source of supply be a stream, the nature of its source and of the land through which it flows must be ascertained, in order to discover any possible source of contamination or the likelihood of any future pollution.

If the stream be a small one, gaugings will have to be made.

In a large stream or river the water near the edges may be polluted by drainage, etc., and it then becomes necessary to locate the intake some distance from the shore, as at Buffalo, and the system devised by Mr. Monro for the town of Niagara Falls, Ont.

In large lakes the water may become turbid after wind storms. This turbidity extends a long distance from shore, and cannot be avoided by extending the intake into the lake. In such cases settling or filtering basins are necessary.

If sewers discharge into the same body of water that the supply is taken from, the intake must be so located as to prevent the sewage from being carried into it by eddies or currents.

The point at which diluted sewage becomes harmless has never been satisfactorily determined.

Dr. Letheby, formerly medical health officer for London, says: "I have arrived at a very decided conclusion that sewage, when it is mixed with twenty times its volume of running water and has flowed a distance of ten or twelve miles, is absolutely destroyed, the agents of destruction being infusorial animals, aquatic plants and fish, and chemical oxidation."

Dr. R. A. Smith, in his testimony before the Royal Commission of Water Supply of London, says: "No one has conclusively shown that it is safe to trust to dilution, storage, agitation, filtration, or periods of time, for the complete removal from water of disease-producing elements, whatever these may be. Chemistry and microscopy cannot and do not claim to prove the absence of these elements in any specimen of drinking water."

Dr. Lyon Playfair, of London, remarks: "The effect of organic matter in the water depends very much upon the character of that organic matter. If it be a mere vegetable matter, such as comes from a peaty district, even if the water originally is of a pale sherry color on being exposed to the air in reservoirs, or in canals leading from one reservoir to another, the vegetable matter gets acted upon by the air and becomes insoluble and is chiefly deposited, and what remains has no influence on health. But where the organic matter comes from drainage it is a most formidable ingredient in water, and is the one of all others that ought to be looked upon with apprehension when it is from the refuse of animal matter, the drainage of large towns, the drainage of any animals, and especially of human beings."

Small lakes or ponds are often polluted by decomposing vegetable matter. Such matter will decompose very slowly if immersed in ten feet of water, so that if all the vegetable growth be removed for a depth of ten feet no danger need be apprehended.

Lakes and ponds subject to vegetable growths should have their edges deepened and protected by a retaining wall.

Dr. P. H. Bryce, Secretary of the Provincial Board of Health, gives the following rules indicating the purity of water:—

"(1) Water must be clear and entirely free from suspended matter.

"(2) It should be colorless or bluish if looked at through a depth of two or three feet; green waters are not generally hurtful; yellowish or brownish are to be looked upon with suspicion, unless the color is known to depend upon peat or iron.

"(3) Water should be sparkling and bright, showing that it is well charged with air and carbonic acid.

"(4) It should have the pleasant sparkling taste of good water, but no brackish or any other unpleasant or peculiar taste.

"(5) There should be no smell other than the peculiar, indescribable smell which fresh spring water yields.

"(6) It ought to be soft to the touch and dissolve soap easily (that is, not have too much carbonate of lime in it).

"Though it would not be safe to say that any water having these characteristics is absolutely good, yet no water without them can be considered free from objections."

Perhaps the best test for organic impurities, in inexpert hands, is to put one or two drops, or enough to give a pink color, of a solution of permanganate of potash in an ounce vial of the suspected water. The solution should be of the strength of eight grains of permanganate to an ounce of pure water—distilled water, or filtered rain water caught in the open, or the water-works water will do nearly as well if more convenient than the other. If the water be unfit for drinking the color will be discharged or bleached in about twelve hours, and usually the impurity may be seen precipitated at the bottom of the vial. The test is more satisfactory if a similar bottle of pure water be treated the same as the suspected sample and placed alongside it for comparison. *The Pharmaceutical Journal* quotes Heische's simple sugar test for water as follows: "If half a pint of the water be placed in a clean, colorless, glass-stoppered bottle, a few grains of the best white lump-sugar added, and the bottle freely exposed to the daylight in the window of a warm room, the liquid should not become turbid even after exposure for a week or ten days. If the water becomes turbid, it is open to grave suspicion of sewage contamination, but if it remains clear it is almost certainly safe."

If the source of supply be a pond or small lake the water often becomes lowered, leaving a margin exposed to the air. Upon this margin a luxuriant plant growth springs up, decays quickly, and produces foul vegetable muck. This may be remedied by deepening the margin of the lake as before described.

Usually the lowering of the waters will cause the water from the drainage-bed of the lake to percolate more rapidly towards it, so that unless the lake be very small the supply will probably remain sufficient.

In some localities large springs discharging from thirty to eighty gallons per minute are found. Where a sufficient number of these can be collected they will afford a good supply. The impurities of spring water are chiefly mineral in character and not injurious to health.

Driven wells consist of wrought-iron pipes from one and a quarter to three inches in diameter. They are driven into the ground in sufficient numbers and to such depths as to yield the required supply. They are then connected to one common suction main, which should be provided with a sand chamber of ample size and proper construction to arrest the flow of sand and admit of cleaning when required.

The Hyde Park, Mass., Water Co. derive their supply in this manner from sixty-four wells of two inches diameter, varying in depth from twenty to thirty-eight feet, and from this system a supply of 1,000,000 gallons per day can be pumped. The town of Auburn, N.Y., is supplied with water from Owasco lake by a suction pipe twenty-four inches in diameter and 9,830 feet long. This suction pipe follows the contour of the ground, as it would have cost about $50,000 more to lay it to a grade, and to make provision for removing the air which collects in the highest parts of the pipes, a wrought-iron pipe was laid connecting these points with an air-pump, which keeps the pipe free from air and causes the pipe-line to work as an immense siphon.

SYSTEMS OF SUPPLY.

It is not only necessary that water be delivered in the mains of a town under sufficient pressure to force it to the upper stories of houses; it should have a pressure sufficient to throw streams over the highest buildings directly from the hydrant. The advantages to be derived from such a supply of pure water are manifold:—

(1) The death rate in many places is lessened.

(2) The best-known system of fire protection is secured.

(3) Insurance rates are reduced.

(4) Extra inducement is offered to manufacturers, who are generally wary about investing capital where insurance rates are high, and where the whole outlay may be swept out of existence by a single disastrous fire.

(5) Facilities are provided for street and lawn sprinkling.

Towns are supplied by one of the following systems, which are given in order of merit:—

(1) Gravitation.

(2) Gravitation and pumping, (*a*) by water power, (*b*) by steam power.

(3) Direct pressure, (*a*) by water power, (*b*) by steam power.

THE GRAVITATION SYSTEM.

The gravitation system consists of damming a stream at some high elevation and allowing the water to flow into the town by its own weight. Lakes may sometimes be utilized in this way. Such a system is manifestly a reliable and economical one to operate, and considerable expense is justifiable in securing such a system. When the additional main, etc., required for a gravity supply necessitates such an expenditure that the interest on the cost greatly exceeds the probable annual running expenses of a pumping system, it may be more judicious to adopt a pumping system. For a town of 3,000 or 4,000 the supply main would cost about $2 per foot. Four miles would cost about $42,000, besides the dam and the land necessary for the reservoir, or a total, say, of $45,000. The interest on this at 5% amounts to $2,250 yearly. The cost of pumping-engines, house, and reservoir or stand-pipe for the same town would be about $16,000, the interest on which at 5% would amount to $800 per year. To this add $2,000 for operating expenses, and the total cost of operating a steam pumping plant will be about $2,800 per year.

It will thus be seen that the gravitation system, although costing $29,000 more than the pumping system, would effect a saving in operating expenses of $550 per year. These figures are only given in a general way, and are not intended to be applied to any particular town.

PUMPING AND GRAVITATION.

In this system the water is taken from a low level and pumped either by steam or water power to a high level, from which it flows to the consumer by gravity. The contrivance for holding the water at a high level may be a masonry or earthwork reservoir embanked or excavated, or it may be a metallic stand-pipe. In some cases wooden tanks are employed. With a carefully constructed reservoir holding five or six days' supply, and good duplicate water-power pumping machinery and duplicate forcing mains this system, is very little inferior to a gravity supply.

DIRECT PRESSURE.

This is the cheapest system to construct, and consists in simply pumping the water into the mains, the pressure being maintained by the pumps which must be kept in constant operation day and night. This necessitates the employment of two engineers, one for night and one for day duty, besides a great waste in fuel where steam power is used.

Sudden jars and shocks are inseparable from any system of direct pumping, and these greatly increase the liability to accident to the pipes and machinery. In direct pumping by steam some time is required to get up a sufficient pressure to meet a sudden increase in the consumption of water, as in the case of a fire, and this delay may cost the town more money than the total value of the water-works.

Water power can respond more readily to a sudden demand than a steam boiler can, and is much to be preferred for a direct pressure system. Whenever such a system is adopted, every precaution should be taken to enable the supply to be continued in case of accident to any part of the machinery. To effect this the boilers and engines, and also the suction and forcing mains, should be duplicated, so that either set may be operated independently of the other. The greatest strain comes on the whole system when a conflagration is raging, and at such a time any interruption of the supply would prove most disastrous. Although the question of safety and reliability has usually a secondary consideration with aldermen and ratepayers, the item of expense is a very important one. Perhaps the most forcible comparison may be made in the following way :—

Annual cost of operating a direct pressure system for an average consumption of 150,000 gallons per day :—

Coal, 300 tons, at $3.75	$1,125 00
Attendance, two engineers	800 00
Salary of superintendent	600 00
Repairs and incidentals	300 00
Total	$2,825 00

With a stand-pipe or reservoir holding from one to six days' supply, sufficient water could be pumped every morning to last all day and night. The fires could then be banked, the machinery examined and cleaned, and only one engineer would be necessary.

Annual cost of operating a pumping and gravity system for an average consumption of 150,000 gallons per day :—

Interest on stand-pipe or reservoir	$500 00
Coal, 225 tons, at $3.75	844 00
Attendance, one engineer	400 00
Salary of superintendent	600 00
Repairs and incidentals	300 00
Total	$2,644 00

Of course such estimates are very indefinite, and will vary considerably with the price of coal, the pressure at which the water is maintained, and the skill of the fireman, but no doubt can remain as to the economy of an elevated reservoir or stand-pipe holding at least a day's supply.

As before stated, direct pumping by water power is less objectionable, and when electric lights are operated in connection with a direct pressure steam plant, the annual expenses of operation may be less than if an item of $400 or $500 interest on the cost of a small stand-pipe were incurred. If, however, a reservoir or large stand-pipe were constructed, so that the pumping could all be done during the hours the electric lights were operated, a saving would be effected.

It may here be mentioned that the object of this paper is simply to give such information as will enable the reader to report intelligently upon the most desirable system for a small town. No attempt will be made to describe details of construction, as such information can be found in "Fanning's Water Supply Engineering, "Some details of Water-Works Construction," by W. R. Billings, and the descriptive catalogues of various manufacturers of pumping machinery, as The Holly Mfg. Co., Lockport, N. Y.; Henry R. Worthington, New York, N. Y.; The Blake Mfg. Co., Boston, Mass.; The Volker & Felthousen Mfg. Co., Buffalo, N. Y.

AMOUNT OF WATER CONSUMPTION.

In New England towns and cities the average daily consumption and waste of water is approximately as follows :—

Places of	10,000 population,	35 to 45	gallons* per head of population.
"	20,000 "	40 to 50	" " " "
"	30,000 "	45 to 60	" " " "
"	50,000 "	55 to 75	" " " "
"	75,000 and upwards,	60 to 100	" " " "

In small towns and villages the amount of water daily consumed may not exceed ten gallons per head per day, while in large cities it may be as

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* All gallons referred to in this paper are the U. S. standard of 231 cubic inches, unless otherwise mentioned.

much as 175 gallons. This difference is due to the fact that in villages only a small number of the inhabitants will be consumers, the majority retaining their wells and cisterns; while in large cities nearly all are consumers, and in addition large quantities are used for street sprinkling and various mechanical purposes.

The daily consumption varies with each month of the year, and with each hour of the day. If unity be taken as representing the average daily consumption throughout the year, the lowest daily consumption may be represented by 0.89 for the months of January, February, and March, and the highest by 1.14 for July, August, and September. The maximum rate of consumption will probably occur about 10 o'clock a.m., and will probably be 1.75 of the average daily supply.

In designing mains and pumps provision must be made, not only to provide for the *average daily* flow, but for the *maximum* rate, which is about double the average rate.

FLOW OF STREAMS AND RAINFALL.

If the contemplated source of supply be a small stream whose average daily flow is insufficient, a large storage reservoir, holding three months' supply, may be necessary. If the land drained by the stream is hard and impervious, the rain which falls upon it will flow over its surface to the nearest water-course, which, becoming swollen and turbid, will rapidly convey the water away, and the water-course will be left nearly dry. If, on the other hand, the soil be porous, the rain water will be quickly absorbed and will percolate slowly through it to the stream, which will not be so much swollen and discolored, and which will flow comparatively evenly all the year.

It is the office of the storage reservoir to impound the storm waters (which would otherwise escape) and to store them for use in the dry season.

The mean annual rainfall may be taken at forty inches, but during dry years it will be only 80% of this, or thirty-two inches. The available flow of the stream will be about 50% of the rainfall on the land drained by it, or sixteen inches.

The evaporation and percolation from the reservoir may be taken at 5% of the mean rainfall, or two inches, leaving fourteen inches available for consumption. As it is not always permissible to consume the whole flow of a stream, only half this quantity, or seven inches of rainfall, should be relied on.

A safe general estimate of the maximum continuous supply of water to be obtained from forty inches of annual rainfall upon one square mile of watershed, provided the storage equals at least 15% of the rainfall, gives seven cubic feet per head per day to from 13,000 to 15,000 persons dependent upon the amount of available storage of winter and flood flows; or say 750,000 gallons of water daily.

FIRE STREAMS.

As before stated, the pressure at the hydrants should be sufficient to throw water over the highest buildings, through, say, 250 feet of hose. Assuming the height of the tallest buildings to be seventy feet, an effective pressure of thirty-five pounds per square inch at the nozzle will be required. This will throw a one-inch stream, discharging 154 gallons per minute, to a height of seventy-one feet, and will require a pressure of fifty-four pounds at the hydrants to overcome the friction of 250 feet of two and a half inch rubber hose. The friction in the mains (including bends, valves, etc.) should not exceed ten pounds for moderate distances, so that the static pressure at the hydrant should be about sixty-four pounds per square inch. The head required to give that pressure is 147 feet—say, 150 feet.

To find the static pressure in pounds per square inch, multiply the "head" of the water in feet by the constant 0.434, and to find the head in feet divide the pressure in pounds per square inch by 0.434. The directions for fire pressure given in Fanning's Water Supply Engineering are as follows: "For a really valuable fire service, the *effective* head pressure remaining upon the pipes, *with full draught*, should be in commercial and manufacturing sections of a town not less than 150 feet, and in suburban sections not less than 100 feet."

A consulting engineer to a town council should be very familiar with the subject of fire streams, as questions like the following are likely to be asked:—

"What pressure (or head) will be required to throw a one-inch stream —— feet high through —— feet of hose?"

"What difference would be made by the addition of —— feet of hose?"

It is beyond the scope of this paper to introduce tables of fire streams, but the following rough rules will be useful to remember:—

1. With one-inch nozzles, the loss of pressure due to friction in each 100 feet length of two and a half inch rubber hose may be taken at nine pounds per square inch for an effective pressure of forty pounds at the nozzle. It varies from six pounds for an effective nozzle pressure of twenty-five pounds to eleven pounds for an effective nozzle pressure of fifty pounds.

2. Between effective pressures of twenty-five and forty pounds at the

nozzle, the vertical distance in feet reached by the jet will be about double the number of pounds pressure.

Example.—An effective pressure of fifty pounds at the hydrant will give an effective pressure through 200 feet of two and a half inch hose of $50-(2\times 8)=34$ lbs. at the nozzle, and will throw a stream to a height of about $2\times 34=68$ feet.

DISTRIBUTING RESERVOIRS AND STAND-PIPES.

After the source of supply has been determined, the next step is to select a site for a reservoir. As before stated, this should be at an elevation of 150 feet above the business part of the town, unless the reservoir is a considerable distance away, when the elevation should be greater. If no higher elevation can be obtained, and the deficiency may be remedied by increasing the size of the supply main. The best material for a reservoir is a mixture of clay, sand, and gravel, in the following proportions:—

Coarse gravel	100	parts by volume.
Fine gravel	35	" " "
Sand	15	" " "
Clay	20	" " "
Total	170	

When thoroughly compacted this will make about 125 parts.

Gravel and sand alone will not make water-tight work, and clay by itself is apt to slip.

When a reservoir is impracticable a metallic tank or stand-pipe, built up of plate iron or steel like a steam boiler, becomes desirable. The following quotation is from Fanning:—

"Many municipalities are situated in slightly undulating districts, where elevated, embanked, or masonry reservoirs of capacity to hold a supply of water equal to five or six days' draught of the town are unattainable. In such places the metallic stand-pipe or water-tower, located on some moderate elevation, or raised on a trestle or masonry tower, becomes a valuable adjunct to the water system, and especially so to the systems of the smaller town and villages, where its capacity ought always to equal a full day's consumption of water.

"The tank stand-pipe has great value in connection with steam pumping-plants unconnected with a large elevated reservoir when compared with direct pressure alone. The ready-filled elevated tank may save a delay in increased volume and pressure of water, that saves also one-half the town from destruction by fire."

Stand-pipes act as cushions to the pumps, and greatly decrease the liability to accident through sudden shocks. In towns and small cities they may also serve as reservoirs, enabling the daily pumping to be done in twelve hours or less.

The reservoir or stand-pipe may be located in three different positions in regard to the pumps.

In the first case, the reservoir is between the pumps and the town, and all water is first delivered into the reservoir, from which it flows to the consumers. In such an arrangement a connection should be made between the forcing-main and the supply-main, so that when the water in the reservoir is drawn off for cleaning or repairs the supply may still be maintained directly by the pumps.

In the second case, which is manifestly not the most desirable arrangement, the pumps are between the reservoir and the town.

In the third case, the town lies between the pumps and the reservoir, and thus has a "head" at both ends. Should the reservoir or stand-pipe be of insufficient elevation to afford the necessary fire pressure, an arrangement should be provided whereby it could be disconnected from the mains, and any desired pressure maintained directly from the pumps.

Following is a list of some of the largest stand-pipes:—

Location.	Diameter. feet.	Height. feet.
Wichita, Kansas	2½	150
Danville, Illinois	3½	200
Louisville, Kentucky	4	170
Erie, Pennsylvania	5	233
Burlington, Kansas	8	120
Marion, Kansas	10	140
Great Bend, Kansas	12	150
Crawfordsville, Indiana	15	175
Gravesend, New York	16	250
Lansing, Michigan	18	152
Pensacola, Florida	20	194
Paducah, Kentucky	22	175
Sandusky, Ohio	25	229
Houston, Texas	30	150
Marysville, California	40	80

Tall stand-pipes must be securely bolted to their foundations in order to prevent being overturned by the wind when empty. The calculations for determining weight of foundation and strength of fastenings will not be given here, as they are matters to be considered when the final plans are prepared.

Very tall and narrow stand-pipes are enclosed in masonry towers.

PUMPING MACHINERY.

A separate paper might easily be devoted to this interesting subject, but although the temptation is strong to discuss the relative merits of direct acting and rotative engines and various forms of steam and water valves, only such descriptions will be given as will convey a general idea of the subject.

Direct Acting Engines.—This is the style of the Worthington, Blake, and numerous other makes. In principle it is very simple, the piston-rod of the steam cylinder acting directly upon the plunger of the pumps. This style of engine is comparatively cheap in first cost, and for small cities, where the daily pumping would be done in a few hours, is the most desirable. When the pumps have to be operated constantly day and night a more economical engine becomes desirable, and this style of engine is fitted with a crank and fly wheel, and is supplied with one of the well-known forms of steam valves, as the Corliss or Holly.

All engines (except those reserved for fire purposes) should be compound, and if the daily pumping requires eight to twelve hours, a condenser should be added, otherwise it will hardly pay. Pumping-engines should always be duplex double-acting—never single, as these are certain to produce unpleasant jars and fluctuations in the pressure.

Special engines are required for direct pumping. They should be rotative, and must be fitted with an automatic regulator for maintaining the water at constant pressure. The most approved form of this type of engine is made by the Holly Manufacturing Company, of Lockport, N.Y., a good sample of which can be seen at the High Level Pumping Station at Buffalo, N.Y.

Capacity.—The capacity of an engine is stated by the number of gallons of water it can pump in twenty-four hours. The usual capacities range from 250,000 to 20,000,000 gallons.

Duty.—By the duty of an engine is meant its economy. This is usually expressed by stating the number of foot-pounds of work it will do for every 100 ℔s. of coal consumed under the boilers. With direct-acting compound engines of the Worthington type running but four or five hours per day, the duty will probably be from 20,000,000 to 30,000,000 foot-pounds of work for every 100 ℔s. of coal consumed. With large direct-acting engines, running day and night, the duty will probably be between 40,000,000 and 60,000,000, possibly reaching 70,000,000. With the most improved rotative engines a duty of 100,000,000 to 120,000,000 may be expected, with a possibility of 133,000,000.

Splendid samples of the latter class may be seen in the 15,000,000 gallon and 20,000,000 gallon Holly engines at the Low Level Pumping Station, Buffalo, N. Y., the former of which has developed a duty of 123,000,000.

WATER POWER.

The horse-power required to pump 1,000,000 imperial gallons or 10,000,000 ℔s. of water per day to a height of 200 feet may be found as follows :—

10,000,000 ℔s. per day = 6811 ℔s. per minute.

6811 × 200 = 1,362,200 ft. ℔s. per minute = 41 h.p.

Suppose a stream flows 30,000,000 imperial gallons or 300,000,000 ℔s. of water per day. In order that this stream should develop the required 41 h.p., the water would have to fall through a distance of $\frac{10,000,000 \times 200}{300,000,000} = \frac{20}{3} = 6.67$ feet. A good turbine will utilise about 75% of the power of the water falling on it, so that the fall necessary to develop the required power would be at least nine feet. In other words, the stream would require to be dammed up ten or eleven feet above its present level.

Pumping machinery should always be duplicated, in order that ample time may be afforded for repairs without interfering with the supply.

In a small town the provision to be made for fire streams requires a larger engine than would be necessary for the daily supply, unless there were a large reservoir at a good elevation. For a town of 5,000 inhabitants the engines, if operating in connection with a stand-pipe, should be proportioned in the following way: If the town be thrifty and growing, provision should be made for an increase of, say, 50% of population, or 7,500. The probable *average* daily rate of consumption would be 300,000 gallons, but the *maximum rate* of consumption will be nearly double this, or at the rate of 600,000 gallons per day. Four one-inch fire streams, discharging 155 gallons per minute, would require 620 gallons per minute, or at the rate 892,800 gallons per day. Adopting the sizes usually made, the engine for the domestic supply would be a three-quarter million gallon one—compound, and if preferred, condensing, although the condenser would hardly pay, as the daily pumping would be confined to a few hours. The engine reserved for fire purposes should have a capacity equal to the maximum domestic rate plus the maximum fire rate of consumption, or 1,500,000 gallons per day, but for a town of 5,000 inhabitants a 1,000,000 gallon high pressure engine would answer every purpose.

If a direct pressure system were contemplated for the same town, each engine should be capable of pumping both the domestic and fire supply, or 1,500,000 gallons per day.

If instead of a stand-pipe a high reservoir, holding from two to six days' supply, could be constructed, two 500,000 gallon compound engines would be sufficient.

MAINS.

In designing mains such sizes should be adopted as will prevent undue friction.

The following table will give the maximum velocities which should be permitted :—

Diameter in inches.	4	6	8	10	12	14	16	18	24	30	36
Velocity in feet per second . . .	2.5	2.8	3	3.3	3.5	3.9	4.2	4.5	5.3	6.2	7

The supply-main should be proportioned to carry the fire supply and the maximum domestic consumption simultaneously.

In the case of the town just referred to with a maximum rate of consumption of 1,500,000 gallons per day, a twelve-inch pipe should be adopted.

Dead-ends should be avoided as much as possible, as the water in them stagnates and requires to be frequently blown off.

The smallest size of main permissible in an efficient town supply is four inches, and if six-inch mains can be substituted so much the better.

HYDRANTS.

Hydrants should be "double nozzle," and should be placed at street corners, not more than 500 feet apart.

Water companies, when negotiating with a town for a rental system, will frequently make an offer to provide a certain number of hydrants not more than —— feet apart. If the interests of the town are not looked after, the company will crowd the hydrants as close together as possible, thereby lessening the length of main.

The consulting engineer for the town should also specify that the hydrants shall not be *less* than —— feet apart.

While referring to rental systems operated by companies, it may be well to caution engineers against attempts at sharp practice on the part of the companies ;—for example, the agreement may state that the engine-house shall be large enough to hold the engines, boilers, condensers, etc. Perhaps in no other part is the condenser mentioned, and when the engineer employed by the town calls attention to the fact that no condenser has been furnished, he will be informed that the company never intended to furnish one !

GATES.

Gates or valves should be so situated that the water can be shut off from any street or part of a street without stopping the supply of a considerable district.

They should be uniformly located, as at the intersection of the pipe with the side-line of the street, so that should any accident occur in winter, when the ground is covered with snow, no delay may ensue through explorations to find the necessary gate to shut off the water.

SETTLING AND FILTERING BASINS.

In localities where the supply of water becomes turbid at certain seasons of the year, settling or filtering basins, or both, should be constructed. If the water becomes very turbid, it should be allowed to deposit the greater portion of its suspended matter in a settling basin, and then be passed through a filter. Several forms of filter are in use, the simplest being a tank or well with porous bottom sunk in the soil at the margin of a stream or lake. Similar in principle is a tunnel running parallel with the shore and below the level of the water.

The form of filter most readily adaptable to various situations has a longitudinal collecting main of sewer pipe, to which are connected lateral branches of perforated tile, the whole covered by a bed which may be made up as follows: Coarse gravel about twenty-four inches, fine gravel twelve inches, coarse sand twelve inches, fine sand twenty-four inches; on this may stand six feet of water, the whole surrounded by masonry.

The water enters the basin above the level of the sand, percolates downwards through it, and is collected by the perforated laterals and brought to the collecting main.

Instead of constructing one large filter, two or more small ones should be provided, in order that one may be operated while the other is being cleaned. The following sizes are recommended for various capacities:—

For	one-quarter	million	gallons	per	day,	two	beds	of	2,250	square feet	each.
"	one-half	"	"	"	"	three	"		3,000	"	"
"	one	"	"	"	"	three	"		6,000	"	"
"	two	"	"	"	"	three	"		12,000	"	"

Where there is no distributing reservoir, a low level reservoir to hold a supply of filtered water is advisable. This reservoir may be of sufficient capacity to hold enough water for an emergency, as an ordinary fire occurring at the time of maximum rate of consumption, or it may contain one or more days' supply. If of limited capacity, direct communication should be established between the pumps and source of supply, so that there may be no diminution of the supply owing to the resistance offered by the filter beds.

THE DRAINAGE SYSTEM IN ESSEX AND KENT.

By Wm. Newman.

In treating this subject the writer will not attempt to go into details, for they will vary with the circumstances surrounding each particular case.

This district is bounded by the River Thames and Lake St. Clair on the north, Detroit river on the west, and Lake Erie on the south.

The rock base of the district is the corniferous formation, which lies almost horizontally. The rock is covered to a depth of about 100 feet with clay, overlaid, here and there, by deposits of drift sands and gravels. Wherever these gravel ridges occur they form watersheds, from which the streams flow to the surrounding bodies of water. In many places the surface of the land is about on a level with the high-water mark of the adjoining lakes, and, as would be expected wherever this is the case, large marshy districts occur, forming a nearly horizontal plane, in some cases many miles in extent. From the borders of these marshes the land gradually rises at an inclination of about two feet per mile, seldom or never exceeding four feet per mile. As is evident, this fall is not sufficient to allow the water to run off quickly, impeded as it is by obstructions of various kinds, such as living and decaying vegetable matter, fallen trees, etc. If left to nature unaided, the water caused by the melting of winter's snow and ice, increased by the heavy rains, would remain on the land till summer's sunshine evaporated it. Here it must remain, covered with its putrescent green scum, to breed mosquitoes and malaria, unless man interposes his skill to assist nature to remove it.

The passing of the Ontario Drainage Act was a boon to the southwestern part of Ontario, for from the passing of this Act the development of the agricultural industries of these countries dates. The Act empowers municipal councils to borrow money, on the credit of the municipality, for the purpose of constructing or repairing drains within that municipality, and charging the same against the lands benefited by the drain; also to engage an engineer to make surveys, plans, etc., for the drains. When any person or persons wish to have a drain constructed or repaired, they circulate a petition throughout the neighborhood, and, if possible, secure the signatures of the majority of those interested, praying the municipal council to consider the matter. An engineer is usually appointed to examine the locality and report to the council; if his report is favorable to the scheme, he is asked to make surveys, plans, estimates, etc., apportioning the expense to be borne by the lands benefited and the municipality for the improvement to roads. If the council then adopt the scheme, they instruct their clerk to prepare a by-law to give it effect, and this by-law is published for at least four successive weeks, in one of the local papers, before its final passing. If any party interested thinks he is over-assessed, or that some should be assessed that are not, he must give notice of the same in writing to the clerk of the municipality. Then, in due time, a court of revision, consisting of the council of the municipality together with the clerk and engineer, sit on the case and consider the grievances complained of.

If the drain passes into another township, or another municipality is in any way affected by it, the engineer is required to make out as many plans, etc., as there are municipalities interested. The clerk will serve these upon the proper officials in the several municipalities. Here is where the fun begins, for almost invariably these outside municipalities think they have been over-assessed, and will fight the matter out, either in the courts or by arbitration. So the lawyers get their fingers in the pie, and many municipalities are now paying thousands of dollars more than they would be paying if they had adopted the engineer's report at first. It generally ends in the engineer's assessment being carried out; but people will have their "say" even though they pay dearly for it.

In making the survey the route the engineer is to follow is usually stipulated in the petition sent in to the council. If it is a new drain, running though the woods where there are no traces to be followed, he usually goes over the ground with a compass or transit and chain, setting two lines of stakes, one where the centre of the proposed drain is to be, the other at a distance to one side, depending upon the width he thinks the drain will have to be, but far enough from the centre of it to be safe from disturbance while the drain is being dug, so that the contractor can get his depths from them. The side stakes are placed two or three chains apart, and numbered from "o" up. After setting the stakes, the engineer then takes levels along the line of side stakes, paying particular attention to any sudden rise or fall in the surface. At every few stations he establishes bench-marks along the entire line.

If the drain follows the course of an old ditch the transit is dispensed with, the level and chain only being used. The side stakes are set on that side of the drain where they are least likely to be disturbed during construction. Then the engineer takes the elevation of all the stakes, together with the elevation of the bottom of the drain opposite each stake, and with a tape or rod measures the top and bottom width of the old drain. Then, from the inhabitants he learns, as nearly as he can, the direction of every little watercourse in the neighborhood. After gaining all the information he can in the field, he returns to his office, and from his notes makes out his plans, profiles, estimates, etc. The profile is usually started first, and upon it the grade line is struck in pencil, then an estimate of the cost is made out, and also of the number of acres of land benefited by the drain, together with the respective benefits to each lot. If the engineer finds the cost of the work will be more than the parties interested will submit to, he must reduce the size of the drain; this is generally done by raising the grade line. When at last the grade line has been struck and the depth of the drain at each station determined, the bottom width is settled on from similar ditches which have a proportionate area to drain, but if the engineer should not be aware of any such drain, he can easily determine the width the bottom will need to be by knowing the area to be drained, and allowing $\frac{1}{10}$ inch as the maximum rainfall that will reach the drain in one hour, then applying the formula:

$$\mathrm{D} = \mathrm{c.a}\sqrt{\mathrm{rs}} = \mathrm{c.bh}\sqrt{\mathrm{rs}} \text{ or } \mathrm{b} = \frac{\mathrm{D}}{\mathrm{c.h}\sqrt{\mathrm{rs}}}$$

where h is depth and b the mean width of the drain at the shallowest place, D the discharge in cubic feet per second, r the hydraulic radius, s slope of grade line, a the area of cross-section of drain, and c a numerical coefficient, which varies with the degree of roughness of the bed and other circumstances. As most drains have side slopes of 1 vertical to 1 horizontal, it is easy to calculate, from the above, the width of the bottom. The bottom width will generally be started less at the head, and will be increased where there are laterals flowing into it, until the outlet is reached.

The depth of the drain will depend on circumstances, but in no case should it be less than three feet, to allow the adjoining lands to be underdrained into it.

When the engineer comes to make out the assessment against each particular landholder, the trouble waxes greater, The assessments are small at the outlet and gradually increase towards the head, but the difference between that at the outlet and that at the head seldom exceeds 50 per cent., yet it puzzles some to see why they should be assessed for the construction of a drain sometimes several miles away from them, when, as they claim, their lands remain dry without the drain; but they forget that the water from their lands is continually pouring down and overflowing the low-lying lands near the outlet, unless some provision is made to prevent it.

The county of Essex and the western part of Kent forms a peninsula about twenty miles wide, with Lake St. Clair on the north and Lake Erie on the south. Nearly all this district is covered with a level clay soil, except a gravel ridge varying from one to five miles in width, skirting Lake Erie, then running north-west until it loses itself in the western part of the country. With few exceptions the water runs north from this ridge to Lake St. Clair, or south to Lake Erie. In the northern watershed there are several creeks or "swales," which can scarcely be discerned by the passing traveller, unless it be during the spring or fall freshets. Large drains have been cut through these "swales," some of them twelve to fifteen miles long and three to eight feet deep, and varying from ten to thirty feet in width at the bottom, which, with a side slope of one to one, gives a surface width of sixteen to forty feet. These large drains have smaller ones flowing into them, and often these laterals have still smaller ones flowing into them, the whole forming a regular network of drains nearly as perfect as nature herself could provide; but, ah! the cost!

The great failing in many of these systems of drains is that the main drain is not of sufficient capacity to carry away the water as fast as it is brought down to them during freshets. They overflow their banks, giving rise to a great number of needless lawsuits for damages. These drains enter Lake St. Clair through the level marshes along its border: of course their velocity is much reduced, and they frequently overflow, doing considerable damage to the crops on the low lands; but to get over this difficulty the earth taken from the drain in its construction is made into dykes or levées to keep the water in the channel until it reaches the lake.

The writer was engaged during a part of the summer of 1889 making plans and specifications for the dredging of one of these drains in the township of Tilbury West. The plan was simple but effective. The length of the channel to be dredged was about three miles, through which two dredge channels were to be cut, each three feet deep and thirty feet wide, one on each side of the old creek channel. The excavated earth was to be thrown up in the form of levées or dykes, one on each bank of the channel. These levées were eight feet wide on top, with a clear space of six feet between the outer edge of the channel and the inner edge of the levée. Where any lateral drain entered large sewer pipes were to be put through under the dyke, and at the inner end of these is placed an automatically acting valve, to prevent the water in the main channel from flowing through upon the adjoining lands, as it would otherwise do during freshets. The estimated cost of the work was about $20,000, but as there were the usual lawsuits the work has not been carried out yet.

To avoid being taxed for one of these large drainage systems, the township of Romney, county of Kent, has resorted to a somewhat novel system for draining a large portion of its lands. The township lies along Lake Erie, and one looking at the map might suppose there would be no difficulty in draining it to that lake, but such is not the case, for along the southern border of the township there is a high gravel ridge from which the water runs naturally over parts of three townships for a distance of twenty miles to Lake St. Clair. Romney was being taxed for outlets across these townships, and to avoid this forever they took the advice of J. C. McNabb, C.E., to cut a tunnel under the gravel ridge to Lake Erie. The distance across the ridge at the point selected is about 7,000 feet. The south end of the tunnel was started on a level with the high-water mark of Lake Erie, and carried back on an inclination of .066 to 100 for 1,300 feet, where a depth of eighteen feet was reached, and here the tunnel proper begins, the first 1,300 feet being an open ditch seven feet wide at the bottom, and varying from ten to eighteen feet in depth. The tunnel is 1,500 feet long, four feet inside diameter, and built of two courses of hard burnt brick laid in cement mortar, and is thirty-eight feet below the crest of the hill. The method of constructing it was simple. They sank shafts about 200 feet apart and tunnelled each way from these. They were very successful in most of them, but in one or two cases they struck quicksand, which caused considerable trouble and delay, but this was finally overcome and the brickwork was completed in the spring of 1890. On the north end a ditch similar to that on the south was constructed. In excavating these approach ditches wheel-scrapers were used, the earth being broken on the south end and kept on an incline, up which the dirt was hauled.

What strikes the engineer most forcibly is the very small carrying capacity of this tunnel when we consider the extent of country that is to be drained into it, namely, about 10,000 acres; now allowing one-tenth of an inch as the maximum rainfall which will reach it in one hour will give about 3,500,000 cubic feet per hour, while the utmost capacity of the tunnel is about 250,000 cubic feet per hour, thus showing that it is altogether too small for the amount of water it is intended to carry.

Another problem now agitating the minds of engineers and land-owners in this section of country is the reclaiming of marshy lands lying along the edges of the lakes and rivers. Frequently the level of this land is not more than a foot above high-water mark. Between the marsh and the lake there is usually a narrow ridge of beach gravel which is broken through in places, so that the lake water can beat in during storms. This ridge prevents the water from getting back readily. The great fertility of the soil and the salubrious climate have induced men of capital to invest in schemes for draining these supposed wastes. Dredges are put in to cut wide, deep channels around the tract to be reclaimed, and the excavated earth is formed into dykes between the channel and the lake. Then large ditches are cut here and there through the whole tract. All the ditches are led to one central drain, at which the pumping machinery is placed, to be used when needed. The cost of making the drains and putting in the pumps varies from six to ten dollars per acre, depending on the area of the tract drained and the kind of pumping machinery used. The cost of keeping it pumped out is fifty to seventy-five per cent. an acre per annum. Several kind of pumps are used. On Pelee Island, where several thousand acres have been treated in this way, they have a wheel with fans on it fitting closely into a sluice, in which it is caused to revolve. The fans lift the water up after the fashion of the old-time water-wheel, but in the reverse order. It is said to work satisfactorily. Where there are only a few hundred acres to be drained, a large endless chain pump is used on an inclined plane like the elevators in a flour mill.

The large ditches are not really needed to carry off the water, but the excavated earth is used to build up dykes to prevent the water of the undrained lands and the lake from overflowing the drained part. The main purpose of the large ditches is to act as reservoirs during sudden freshets, and thus reduce the size of the pumping machinery; for if some such precautions were not taken, the water during a heavy rain could not be pumped out unless we had very heavy pumping works, which is impracticable on account of the expense.

Several thousand acres of land on Pelee Island are now the homes of happy farmers, where a few years ago the muskrat and wild duck were indeed monarchs of all they surveyed. The engineering skill of man has triumphed and bent the elements of nature to his will and purpose, has brought health, wealth, and prosperity to this as well as to almost every other part of the world. Now, instead of producing the green-scummed bog-juice, they produce the rich and clustering grapes from which are made the famous Pelee Island wines.

PHOTOGRAPHY.

By W. A. Lea.

Mr. President and Gentlemen,—The Art of Photography covers so wide a field, from being the means of discovery of stars beyond the reach of any other method of search, through all art and industry down even to enabling the small boy to destroy his clothes and produce stained and spotted caricatures of his friends and relations. So the engineer can scarcely be expected not to add this valuable process to his methods of working, and its use will bring to his attention the widest subdivision of photography, in which there is every variety that can make it pleasant and interesting. In fact, at times this variety becomes somewhat oppressive. This subdivision would include all out-door work, such as topography, buildings, and constructions of all kinds. And there might be included also that branch used in physical research, the main idea of which is to make the noble art into an unbiassed automatic record. But here, as the conditions of light and subject are generally constant or manageable, a few trials will settle any difficulty. But where these are beyond control, and moreover beyond any method of estimation, and of such variety as to occasion the remark that no man has ever taken two similar photographs alike the process is not so easily mastered. And it may be safely assumed that nearly every one connected with this subdivision has several times been on the verge of giving up in despair.

THE APPLICATION OF PHOTOGRAPHY.

It is used now very extensively by engineers and contractors to convey to their employers accurate information in regard to their work. Negatives of the site are taken before anything is done, and also at regular intervals during construction. On the back of the print might be put, besides the date (which should be scratched on the negative), the number of men employed, state of weather, and any other useful information. These pictures would be most valuable for future reference, and on comparing them the amount of work that a given number of men can do in a given time can be estimated. The photographs are also unquestionable evidence in case of any dispute. Also any part of a work that it was thought desirable to have a note of for personal use could be photographed and the information written on the back. In time this would make a valuable series of notes. And one of the greatest advantages is, that when making a report of progress a photograph would convey more and better information than volumes of written matter. Another application would be to record any mechanical device or arrangement; as in overcoming some unforeseen difficulty, or in moving any heavy body. There would be no time for a sketch and a photograph could be taken of the most active scene of work, and there would be complete notes and a description of all the tackle, packing, jacks, or whatever the appliances were.

In selecting sites for various constructions, or in representing the nature of the ground to be operated upon, a few photographs would be of great assistance, especially where those holding the decision were not able to visit the site. And so on; the applications are well-nigh endless. In fact, the engineering department of military science almost depends upon this art, and it is to it that we owe the introduction of its use in surveying. And this is really its most important application. The early attempts in this direction were hampered by crude processes and instruments, but in 1858 Colonel Laussedat, of the French Engineers, brought out a careful summary of the principles upon which successful effort must be based, and since then the idea has been worked at until it is now a method giving accurate results, valuable as an auxiliary to ordinary methods for general work, and with its special applications. For example, to determine compass variations, on a starlight night the camera is pointed approximately in the direction true north, and levelled laterally. After an exposure of several hours the arcs described by circumpolar stars and points in the landscape beneath are clearly shown on the negative, the centre of arcs is found, and the radius perpendicular to the horizon is the true meridian.

THE PRACTICAL WORK.

The subject naturally divides itself into two main parts, the work done in the field and that done in the dark-room. And in the first part we may consider the apparatus, then its arrangement, and afterwards the exposure.

In considering the apparatus, we might as well follow the natural order and begin with the lens. As our object is to obtain as exact a representation as possible, we shall not have to consider those qualifications sought for in pictorial art. But still we should like to have a fair depth of focus, and as good marginal definition as we can. And as we cannot have any distortion, a doublet lens of the type generally called rectilinear, with a focus of about twelve or thirteen inches, would probably be the most suitable. A lens of the wide angle type is useful for a building in a confined situation, or if from the same spot a larger extent of country is required than given by the other. A wide angle lens used on a plate smaller than it is intended to cover gives more accurate pictures for this subject than one of narrower angle on the same sized plate. In the case of near objects, however, where there is some distance between different planes in the picture, the appearance to us is likely to be what we call exaggerated perspective. The lens is the most particular part of the outfit. No amount of care and good work can make up for the want of definition and brilliancy in the picture given by a poor lens. But now the quality of optical workmanship is about at a standard, so there is plenty of choice.

Modern cameras are very different to what they were even ten years ago. Many new and important improvements have been introduced, and the weight has continually decreased without loss of rigidity, so that one is reminded of the contrast between Puffing Billy and a modern fast passenger locomotive. Many of these improvements are not of much value to those who desire to produce a picture fairly right with regard to tone and composition, etc., but they are important as methods of adjustment for obtaining accuracy. In architectural subjects, and wherever consistent perspective is required, there must be some means of levelling the camera. There are several ways of doing this. The simplest is by looking at the horizon along the tailboard of the camera, front and sideways, and adjusting the base correspondingly by means of the legs. But this is open to the objection that we may not always be able to see enough of the horizon, if any, except perhaps in the North-west. Another plan is to hand a small plumb-bob at the side of the camera. When the camera is level sideways it hangs plumb with its side, and a small scale will show its inclination backwards or forwards. But we would naturally dislike to have loose strings hanging about our apparatus, not to mention the probability of their being soon broken or lost. Besides no method can compare with the use of a spirit-level for speed and accuracy. A small level can be carried in the pocket or camera case, and laid on the tailboard to adjust it. But here we have the risk of leaving it behind or dropping and breaking it, and a greater objection, when the camera is horizontal in one direction it is liable to be thrown out in levelling it in the other direction.

An improvement on this is to use a small circular level which can be placed on any flat part of the base, and by watching the position of the bubble with reference to the centre of the level, the base can soon be made horizontal. The loose circular level is open to the same risk of loss or breakage as the straight, and has a further disadvantage, being usually a brass case with a glass top. The rapid alterations of temperature between the pocket and the open air, or the occasional rays of a hot sun and the camera, case make it difficult to keep the joint tight so there is in most bases a tendency to leakage and the destruction of the level.

Another and perhaps the best method is to have two small straight levels let into the tailboard flush and at right angles to each other, or a small circular level may be used.

Another important feature of a camera is the back, that part of it that carries the focussing screen and the slides for exposure. This should be reversible, to use the length or breadth of the plate as required, and have a vertical and horizontal swing. The vertical swing is the vital point of the back, for it is an essential supposition of perspective that the picture plane be vertical, and this plane contains the sensitive plate. So this is a point which cannot be neglected if the parallelism of vertical lines is to be preserved. In most cameras there is some means of adjusting the upright pieces back and front at right angles to the base, and so when the base is made horizontal the plate is vertical. But it is sometimes necessary to tilt the camera to include the view wished for, and then the distortion of convergence is plainly seen. This can be corrected by utilizing the swing-back to once more render the screen vertical. And what has been said with regard to the use of the spirit-level will also apply here.

It may be stated that in copying a photograph that has been distorted by convergence, the swing-back can be used to produce an equal and opposite error, and so give a result with perpendicular lines.

Most backs have also a horizontal swing. This would be used when it is necessary to bring into focus an object close to one side of the view.

On the front there is usually a rising front by which the lens can be raised in order to include more of the upper part of the view. This will save for a short space the tilting of the camera.

The tripod should be as light as is consistent with rigidity, and as portable as possible. If it is too light, it is liable to vibrate on a windy day; and although this vibration will not be noticeable there will result, a fine indistinctness in the negative, which will be rather irritating to the operator. Also the joints should be of such a nature as not to move during an exposure, whether suddenly, or slowly and imperceptibly.

The three legs are generally connected at the top by a small triangle, into the centre of which a thumbscrew fastens the camera.

More usually now they are sprung into catches on a small turn-table, so that the camera is free to revolve. The ideal connection is some simple form of double-joint, or a ball and socket-joint, thus rendering unnecessary the clumsiness of dragging the legs about in order to adjust the camera. Many devices have been proposed, some tried, but as yet none have come into use.

The ground glasses in cameras are not usually as fine in surface as is desirable; so it will be well to get an old plate and make one. The following method with emery is about the simplest and quickest. The finest flour of emery usually contains grease, so it should first be washed in water made alkaline with ammonia, or washing soda, before separating from the finest particles by decantation. With this product, and a grinder (a flat piece of lead, two or three inches in diameter, filed to a smooth, true surface), a very fine veil can soon be made on the glass, and no more should be formed than is necessary to see the image.

On this very exact focussing can be done without the use of a magnifier. If plates of more than one size are used, it is a good plan to set off smaller sizes on the screen, so that the amount of view included may be shown.

Perpendicular and horizontal lines traced on the screen and passing through the centre are useful as guides to arrangement of the view.

In order to see this image a covering of some sort is necessary to exclude light, so we have the much-ridiculed focussing-cloth. It is inconvenient and undignified at the best of times, and on a windy day the operator becomes an object of pity to all who have the luck to see him in his struggles.

So that there are many devices for controlling this part of the apparatus. It was proposed to do away with the use of ground glass, and estimate the view by various contrivances, termed view meters, the focus being marked on the camera. But it has still remained necessary to see what was on the screen, if good results were to follow, so the cloth remains yet. However, tapes can be attached to one end to fasten it to the camera, or, better still, a sort of sleeve can be constructed with elastic at each end, one end enclosing the camera, the other the head.

Another plan is a pyramidal construction on something the same principle as the bellows, free to move in any direction, with the base at the screen and an eye-hole at the apex. This can be readily made by a series of square frames of thin wire, diminishing in size, enclosed in a tapering sleeve of black cloth, to fit. These are, perhaps, not so convenient for examining the screen as the plain cloth, but with regard to the comfort and temper of the operator they are an improvement on the older plan of putting his hat on the ground and fighting with a couple of yards of flapping black cloth.

The most usual carrier and backing of the sensitive film has been, and is, glass. And this is now made so free from spots and flaws that its weight is about the only drawback to its use, in these days the plates being, undoubtedly, the heaviest part of the outfit.

So, for some time back, attempts were made to find a substitute. The first practically used was paper of a very even texture, in cut sheets or in rolls, unwound and exposed in a holder devised for the purpose. But no paper could be made that would not reveal its texture in the resulting print, and, in spite of oiling, printing was rather slow, and the best substitute yet made use of, a film of celluloid, has more faults of its own than has the substance it was introduced to supersede.

The most valuable and extensively-used process now outside of the ordinary glass plate is that of Eastman's stripping film in conjunction with a roll-holder. A thin layer of soluble gelatine is interposed between the sensitive insoluble film and the paper support, so that after development this film, now containing the negative image, could be transferred to any support chosen, usually a sheet of transparent gelatine. The manipulations are not difficult if care be exercised, and the resulting negative is clear, transparent, flexible, of only one-fiftieth the weight of glass, and free from the risk of breakage. It is reversible, and easily touched up, though these are not so important, except for photo-mechanical processes. The most valuable point about the roll film is that, as now arranged, forty-eight consecutive exposures can be given with the one holder, so that all the delightful process of changing plates in the corner of a damp cellar or of a tent by the confusing light of a little smoky ruby lamp, with all the attendant risks of fog, dust, and mixing up of plates, is avoided. But still there is opportunity for exercising care in the use of the roll-holder. A mistake is easily made in the winding, and in order to avoid giving a double exposure, or winding up a portion unexposed, it is usual to form a fixed habit with regard to the winding, either immediately before or after the photograph is taken. It is a good thing also, as often as is convenient, to draw out the slide and mark each end of the exposed part with a pencil as a check in cutting up. This, of course, is done in complete darkness.

Where only a few pictures are required at a time, the roll would give place to the single plate, as there is waste of material and inconvenience in cutting off exposures. The most common form of carrier is the ordinary double-back, as it is called, containing two plates back to back. There are also various appliances for carrying and exposing a dozen or more plates, but these have not been much used since the introduction of the roll system. The backs, or slides, are also made of thin metal, to economise bulk, and a single carrier in the form of a paper envelope is used; but this would have the disadvantages of being too easily affected by moisture and of affording no protection to the plate.

We might close this part of the subject with the mention of a few details.

In some cameras, when racking back for a short focus lens, the front moves instead of the back, so that the tailboard is liable to project in front and cut off some part of the picture; it is as well to look out for this when choosing a camera.

There are devices in front of cameras, generally something like a turntable, to change one lens for another, and in these cases the lenses remain attached to the front when the camera is folded together; but it will be found safer and better in every way to have flange adapters if the lenses do not fit the same flange, and a small lined box into which they fit.

In order to use only the rays passing through the lens in the neighborhood of its centre, the smallest diaphragm consistent with exposure should be used; and a simple drop-shutter is necessary, as even with the smallest stop the exposure is often quicker than can conveniently be given by hand.

FREIBERG SMELTING PROCESS.

By G. R. Mickle, B.A., Grad. S.P.S.

To the smelter the Freiberg Smelting Works offer a rich field for study, owing to the complicated nature of the ores which are smelted there and the consequently numerous processes which must be employed in order to separate the various metals. The following ores, which are brought from the mines in Saxony, and also from foreign countries, principally Sweden, Chili, Peru, Bolivia, Australia, etc., come under our consideration :

(1) Ores with 30 per cent. and more of galena.

(2) Ores with less than 30 per cent. of galena.

(3) Quartz, or spar ores, with 0.03 per cent. ag. containing pyrites, sulphur under 10 per cent.

(4) Pyritical ores with more than 0.4 per cent. ag.

(5) Sulphur ores with 25 per cent. and more of sulphur.

Copper ores only in very small quantities.

Arsenic ores with over 10 per cent. arsenic.

Zinc ores with over 30 per cent. zinc.

The galena from the mines here contains, as impurities, iron pyrites, arsenic pyrites, zincblende, copper pyrites, antimony, bismuth tin, cobalt, nickel.

The ores are weighed in quantities of 200 lbs.; the accuracy of the weighing varies from 10 lbs. with ores containing 0.01 to 0.5 per cent. silver to $\frac{1}{50}$ lb. with ores containing 50 per cent. and more of silver. From every 200 lbs. an assay is taken for the smelting and mining office, and also one for reference in case of dispute ; from this assay quantity the percentage of moisture is first determined, and from tables the dry weight is read off and noted.

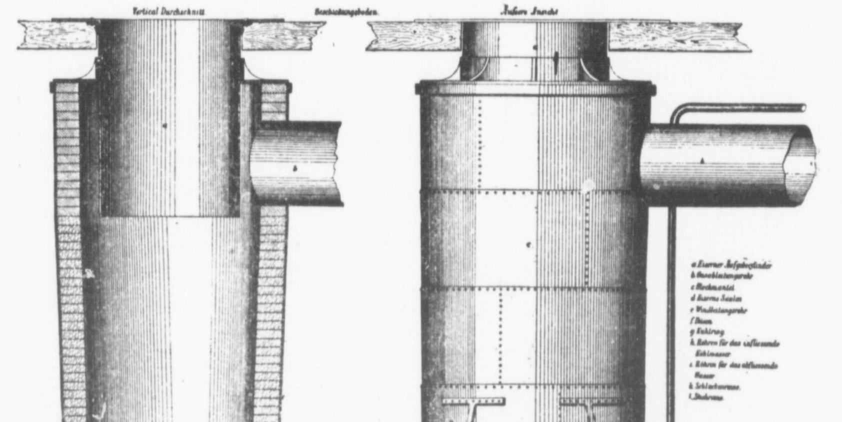
On looking at the tables of the processes the members of the Society will probably feel alarmed, but in order to simplify matters only the lead process, including the winning of gold and silver, also bismuth, will be considered in this paper.

The ores which are delivered in powdered form are roasted, in order to partially remove the sulphur and arsenic, till they contain from five to seven per cent. sulphur, and to bring the ores into a suitable shape for the blast-furnace, that is, into lumps. This roasting takes place in furnaces, the construction of which is seen from the plan. The construction of this furnace allows an economical use of fuel, in that the ores gradually approach the source of heat.

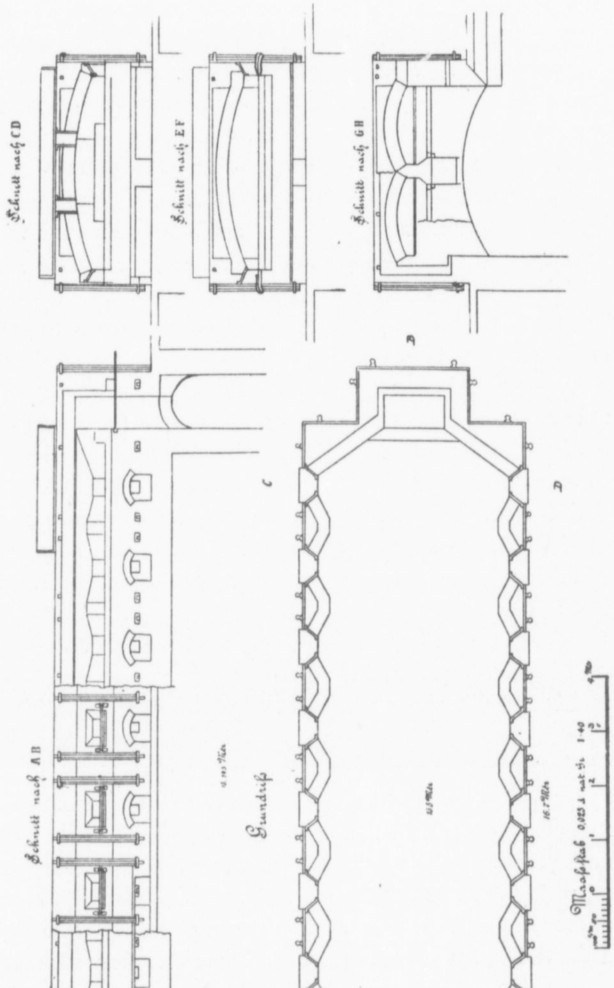
ORES.	PROCESS.	RESULT.
1. Schlach sulphur ores	In Gerstenhof's furnace	Roasted pyrites, flue dust, sulphur dioxide.
2. Lump sulphur ores	Roasted in kilns	Roasted pyrites, flue dust, sulphur dioxide.
3. Sulphur arsenic ores	Smelted for red glass, and residue roasted in kilns	Raw red glass, roasted pyrites, sulphur dioxide.
4. Raw red glass from 3	Melted with sulphur	Red arsenic glass.
5. Arsenic ores, poor in sulphur	Roasted in reverberatory furnace	Residue, raw arsenious anhydride.
6. Raw arsenious anhydride from 4	Sublimated	Arsenic meal, white glass.
7. Zinc ores	Roasted in kilns	Roasted zincblende, sulphur dioxide.
8. Zincblende from 7	Ground and roasted	Zinc, zinc dust, residue.
9. Lead ores, roasted pyrites, residue from 5	Roasted in furnaces	Roasted ore, flue dust.
10. Roasted ore from 9, residue from 8	Smelted in blast furnaces with slag from some work-factory, residues, etc.	Unrefined lead, speises, lead matte, slag, flue dust.
11. Unrefined lead from 8	Liquated	Copper residue, liquated lead.
12. Liquated lead from 11	Refined	Different scums, refined lead.
13. Refined lead from 12	1st. Pattinson's process 2nd. Parke's process 3rd. Cupelled 4th. Further cupelled	Lead, litharge, litharge and residue, impure litharge, separation silver.
14. Litharge and residue from 13	Worked in the wet way	Bismuth.
15. Impure litharge from 13	Returned to 10	

15. Impure litharge from 13	Returned to 10	
16. Separation silver from 13	Separated	Gold, silver, copper sulphate.
17. Scums from 12	Smelted	Hard lead.
18. Speises from 10	1st. Smelted 2nd. Roasted in furnaces 3rd. Roasted again	Speises.
19. Lead matt from 10	Roasted in kilns	Roast matt, sulphur dioxide.
20. Roast matt from 19	1st. Roasted in heaps 2nd. Smelted in blast furnaces, with slag from 10	Unrefined lead, copper matt, slag.
21. Unrefined lead from 20	See 11 to 16	
22. Copper matt from 20	1st. Roasted in kilns, or heaps, or both 2nd. Treated in reverberatory furnace	Concentrated copper matt.
23. Concentrated copper matt from 22	1st. Stamped and roasted in reverberatory furnaces 2nd. Dissolved in sulphuric acid 3rd. Copper sulphate from 16 added.	Lead and silver residue, copper vitriol.
24. Lead and silver residue from 23	See 10 to 23	
25. Slag from 10	Used in 10 and 20, and then thrown away	
26. Flue dust from 10	Used in 5	
27. Sulphur dioxide	1st. Head chamber process 2nd. Purification and concentration	Sulphuric acid.

The course of work is as follows: On each hearth there are always charges of 3,000 lbs. each. The last charge next to the fire bridge, which is in a semi-molten state of such consistency that one can draw it out with a hoe-shaped instrument, is drawn out every two to six hours, according to the ore; the next charge is then transported on into the space left vacant, and so on the whole length of the hearth. This transporting requires a certain amount of dexterity, and is somewhat tedious, as the whole amount of ore has to be moved by means of an instrument about twelve feet long resem-



Achtförmiger Pilz'scher Hochofen
bei der Königlich Muldner Hütte.



Röstofen

der Königl. Halsbrückner Hütten

bling a spade with a flat blade, which is thrust through the openings seen in the side of the furnace. Eight men are necessary to work the furnace, four on each side. The gases of combustion and smoke, after passing over the whole length of the hearth, escape through an underground canal into a series of chambers of sheet-iron, where they cool off and deposit the flue dust. This flue dust, which consists principally of arsenious acid with 10 to 25 per cent. lead and 0.01 to 0.02 per cent. silver, is cleared out from time to time, and used to manufacture arsenic meal and white arsenic glass. From the condensing chambers the smoke escapes finally into a high stock.

The roasted product from this furnace is allowed to cool, and then broken into lumps about the size of the fist, and taken to the blast-furnace. It is at present a mixture of metallic oxides, more or less undecomposed ore and sulphates, together with earthy components and lead silicate. The object of the blast-furnace is to bring the difficult reducible metals, such as iron and zinc, and also the earthy components, into the slag, to reduce lead oxide to metallic lead, to separate out and reduce lead silicate by means of ferrous oxide, to collect the undecomposed sulphates in a matt, which takes up the copper. So at the end of the process it should stand so:

(1) LEAD, with *silver*, *gold* (traces of copper, tin, arsenic, antimony, bismuth, iron, cobalt, nickel).

(2) MATT, with nearly all the copper, also small quantities of gold and silver.

(3) SLAG, with iron, zinc, and earthy components.

The construction of the blast-furnace can be seen from the plan. The work of charging is carried on at the mouth of the furnace, and the charge is always placed at the sides and the coke in the middle; otherwise the charge, owing to its greater specific gravity in comparison with the coke, would move downwards too quickly; the friction at the sides tends to counteract the difference in specific gravity; when, however, the charge is difficultly fusible, coke is also put at the sides.

The horizontal section becomes greater towards the top, the diameter at the bottom being 1.4 metres, and at the top 2.0 metres. The small dimensions of the hearth allow a concentration of heat, the injurious effect of which, on the walls of the furnace, is counteracted by a cooling ring, in which water circulates, and the widening of the furnace towards the top diminishes the velocity of the escaping gases, and thereby the formation of flue dust, and also prevents the deposit of amorphous or crystalline formations on the upper part of the furnace through sublimation, as the charge on its downward way rubs them off. The temperature in front of the blast is 1300° C, and the effective heat is 40 to 45 per cent., a much more favorable result than in the roasting furnace, which only gives an effective heat of 10 per cent.

The quantity that passes through the furnace is 6,000 to 7,000 tons in twenty-four hours; ore and slag are in equal proportions; the relation of coke to charge is about one to ten.

There are two tap holes for the slag, which are tapped alternately; the slag is thus kept running continuously; the plugging is effected with clay. The tap opening for the unrefined lead and matt is at the bottom of the sump, and is tapped about every four hours, or as soon as the matt begins to come out the slag opening.

The mass is run off into a receiver, and settles itself according to its specific gravity, the unrefined lead of course underneath, and the matt on top. The matt hardens first, and while the crust is forming the workmen suspend a stout iron hook in the matt, and when the matt is sufficiently solid it is raised by means of a crane, and the unrefined lead which has remained molten is cast into pigs. The matt is melted several times more with the slag, till it is rich in copper, and then it is used in the manufacture of copper vitriol. The slag is put through the furnace several times more, till it contains only 0.015 per cent. silver and 2 per cent. lead, and then it is thrown away; small quantities are used as building stone.

When the blast furnace is in normal working order, one must be able to see the glowing coke through the openings for the wind blast, and the slag should flow off rapidly without spurting.

When the working order is bad the slag flows thickly, on account of too low a temperature, or it runs too quickly and spurts, and the matt flows off with the slag. The working order can be bad from various reasons; for instance, when too little coke is used; this can be recognized from the dullness seen on looking through the tuyers; as a remedy they shut off the wind on one side and put in more coke at the mouth, then open again and shut off the wind on the other side: or the working order can be bad when bears are formed in the furnace, that is, deposits consisting chiefly of iron, but which take up gold and silver in considerable quantities, and interrupt the course of the furnace; the iron should go into the slag, but when the temperature is too high, or the reducing action too strong, the iron is reduced; as a remedy litharge smelting is resorted to, or slag rich in copper is added to the charge.

The furnaces remain continuously in blast for about two years or more without repair. During the influenza epidemic one furnace, which had been running more than two years, was allowed to cool off owing to scarcity of workmen; it was still found to be in good condition.

A newly-built furnace is first heated with wood, then coke, followed by light charges of ore; after about four hours the slag begins to flow, and the normal running order ensues.

The unrefined lead from the blast-furnace contains silver, gold, copper, arsenic, antimony, zinc, tin, bismuth, iron, cobalt, nickel.

In order to get rid of the copper, also traces of cobalt, nickel and iron, it is taken to the liquation hearth, that is, a slightly inclined hearth with sump in front. The lead, in the form of pigs, is placed on the hearth and heated at low temperature; lead being more easily fusible than a mixture of copper and lead, flows down into the sump, where it can be tapped and run off into moulds; the whole amount of copper, together with iron, nickel and cobalt, and also a portion of the lead, remains unmelted on the hearth. This process lasts three hours, and 7,000 lbs. are worked at one time.

The products of the liquation hearth are lead, with .07 per cent. of copper; the residues, copper 85 to 95 per cent., with silver .0.3 to .04 per cent., nickel and cobalt.

REFINING.

The lead is next refined in a reverberatory furnace in order to get rid of tin, arsenic, and antimony, and the process consists in allowing a current of air to play on the surface of molten lead; the impurities rise to the top, and are skimmed off continuously by means of a piece of wood speared on the end of a long iron instrument, and the workman gently rakes the surface.

Twenty-one tons are brought in in one course of refining. As soon as all is in a molten state the blast is brought to play on the surface, and the impurities form a scum on the top; the first impurity that appears is the tin scum: it is an infusible, powdery substance; then comes a yellowish scum of arsenic; then greenish-black antimony scum; finally a litharge-like scum, which gradually passes over into pure litharge, and the lead assumes brilliant rainbow-colors.

The refining lasts from seven to ten days. When it is finished the lead is run off through a gutter into moulds. The inside of the furnace, which is made of clay, must be repaired after every process, as the clay is eaten away where the surface of the lead was. The tin scum and the litharge like scum are used in the manufacture of hard lead, that is, a lead containing antimony and tin; the other scums are smelted over again in the blast furnace.

The refined lead, when it is not sufficiently rich for cupellation, is given over to the Pattinson and Parkes' processes for the purpose of enriching in silver. By the means of Pattinson's process we obtain a rich lead which has from 1.5 to 2.0 per cent. silver, and a poor lead with only about 0.1 per cent. silver, which then undergoes the Parkes' process.

The Pattinson process is founded on the fact that when lead containing silver is melted and allowed to cool the crystals which are formed are poorer in silver than the liquor. For this purpose a battery of nine iron kettles are employed.

Every kettle has a firing for itself, and every two or three a chimney. The crystals are taken out by means of an enormous spoon with perforated bottom, and always go towards one side while the liquor goes towards the other. The percentage of silver in each kettle is daily determined by means of assays. When fresh lead is added, it must go into the kettle which has a corresponding percentage of silver. Two-thirds of the contents of the kettle are removed as crystals into the next kettle.

The work of dipping out the crystals is performed by two men, a third attends to the firing. The operation of dipping is long and exhausting; in this respect it compares unfavorably with the Parkes' process.

As already stated, Pattinson's process gives two products, a rich and a poor lead. We will first follow the poor lead. It contains 0.08 per cent. silver, and comes to the Parkes' process, which consists in extracting the silver by means of zinc, zinc having a greater affinity for silver than for lead. There are three cast-iron kettles, two large ones and a small one in the middle. About twenty tons of lead are brought into the two large kettles; then they are heated to the melting point of zinc, and sheet zinc is put in and stirred round, the zinc takes up the silver and rises to the top as scum; it is then allowed to stand till a crust is formed at the sides, the scum is skimmed off and placed in the small kettle in the middle, which is also heated; here a scum is again formed, which is removed and distilled; the lead comes back again into the large kettles. This process is repeated till the percentage of silver in the lead is only 0.001. When the percentage is originally 0.1, three applications of zinc of 350 pounds at a time are sufficient. The zinc scum from the second and third application, as it is not fully saturated with silver, can be used again, together with fresh zinc. The lead from the two large kettles, which is now free from silver but has acquired a small quantity of zinc, is run by means of a siphon into a refining furnace of the same construction as the ones previously used; the zinc rises to the top and is skimmed off. When litharge begins to come the process is finished, and the lead, which is at last almost perfectly pure, is run off into pigs and sold.

The distillation of rich scum takes place in a graphite crucible, with a receiver at the side to catch the zinc dust. The products are rich lead for cupellation, zinc, zinc dust, and residues containing zinc.

CUPELLATION.

The rich lead from Pattinson's process, containing about 1.5 per cent., is cupelled. That is an operation that consists in blowing on the surface of melted lead; the lead is thereby oxidized and forms litharge, and the silver remains behind. The furnace, which is of oval shape, with fire at the side, has in front an opening through which the lead oxide or litharge flows. At the back are two tuyeres so inclined to one another that their streams of wind intersect in the centre of the furnace. The whole furnace is covered with a massive lid, which can be moved backwards and forwards. The inside of both lid and furnace is lined with fire-brick. The method of proceeding is as follows: Ten tons of rich lead are put into the furnace, the lid is put on and it is gently fired at first; when the lead is all melted the firing is increased. After about sixteen hours a scum rises to the top; then the blast is turned on through the two tuyeres, and the litharge begins to flow through a narrow channel made by the workman in the wall of litharge that is formed all round the furnace, only a small space in the middle remaining open; the litharge is run off into receivers, put through a fanning mill, and then is sold. This oxidizing process is continued till the percentage of silver is between seventy to eighty per cent., and lasts about 200 hours. Of importance in this process is the temperature. When the temperature is too low the lead becomes too thick, and when the temperature is too high there is a loss of silver; one should be able to see the middle of the lead bath; towards the end of the process, however, the temperature is made very high and the blast is increased. When the cupellation is finished, the rich lead is dipped out into moulds and the residue is cooled off with water and broken out.

This rich lead, containing about eighty per cent. silver, is put in another exactly similar furnace of smaller dimensions, and the process is repeated; a litharge containing bismuth rises to the top and is skimmed off. When the process is finished, the surface of the silver has a peculiar greenish shimmer and there is no litharge to be seen; an assay of the silver is taken in a spoon; it should be white without yellow spots and should also swell out on cooling. The silver is dipped out into a tank containing water in order to get it into a convenient form for the separation from gold. The bismuth in the litharge, which amounts to about six per cent., is extracted in the wet way.

SEPARATION OF SILVER AND GOLD, ALSO PLATINUM.

The amount of silver separated from gold in Freiberg yearly amounts to about 100,000 kg.; in value, according to the present price of silver, about $3,300,000. It is therefore an important operation.

The separation is effected by means of concentrated sulphuric acid (of the strength 66° Beaumé). About 1,000 ℔s. of granulated silver are put into a cast-iron kettle, then about twice the amount of sulphuric acid is added, and it is gently heated at first on account of the vigorous evolution of sulphurous acid. The silver is dissolved, while the gold remains behind; the kettle is stirred from time to time with an iron rod.

When the hissing noise is no longer heard the silver is all dissolved; it is allowed to cool off and stand about ten hours, in order that the fine particles of gold may settle to the bottom; the solution is then somewhat diluted to precipitate any lead that may be present, and put into wooden tanks lined on the inside with lead, and into which steam is conducted. The silver is precipitated by means of sheet copper (for 100 parts silver thirty-two parts copper) till it no longer gives a precipitate with salt; it is then allowed to clear, and finally the silver is taken out, pressed in a hydraulic press, and fused in a graphite crucible in lots of 1,200 ℔s at a time.

The undissolved gold which was left in the iron kettle is, however, by no means pure enough. It is treated with boiling water, which dissolves out any sulphate of silver and copper which are present, then again boiled with sulphuric acid and washed out. This operation is repeated several times, but beyond a certain point the silver is not dissolved. In order to further remove the silver, it is gently heated several times with acid sulphate of soda, and the sulphate of silver which is formed is dissolved out with water. The gold, however, still contains a small quantity of platinum, which makes it hard and unsuitable for many purposes. In order to remove the platinum the gold is heated with saltpeter; platinum, together with a minute portion of the gold, go into the slag and can be extracted. The gold is finally fused with borax in a graphite crucible, and is at last a mercantile product, containing in 1,000 parts 997.5 parts gold.

MODERN COPPER SMELTING.

By G. D. Corrigan, Grad. S. P. S.

Mr. President and Gentlemen,—It is not the intention of this paper to go into details of smelting, but only to outline some of the more striking points; and since we are not at present concerned with the mining of the ore, we may begin our subject by taking up the process of smelting as begun at the top of the shaft. Here we have an inclined track on which is carried the ore, varying in size from one to one hundred pounds. Next it is broken either by spalling or passing through a crusher, and the proper size to which it must be broken depends much upon the character of the ore. If it be free from rock matter, the largest size, upon breaking, should be that which will pass through a three-inch ring; while if the ore be silicious, it will be necessary to break it still smaller. Among metallurgists it is as yet an unsettled question as to whether hand-spalling or machine-breaking is the better, considered financially. The relative merits of the two may be put thus: "In hand-spalling there is by far a smaller quantity of fines, while the machine will crush the ore at a smaller cost. Now this last consideration may appear to be the ruling one, but in machine-crushing the proportion of fines become large, from fifteen to twenty per cent., and becomes an increasing source of trouble as to its disposal, as will be seen further on. And it will often appear that hand-spalling, though at first more expensive, is in the end advantageous. The crusher used is much the same as that used for stone-crushing, but requires to be run much faster, especially if the ore is damp. A crusher with a jaw opening of fifteen by nine inches, making 230 revolutions per minute, will, with sufficient power, give a capacity almost unlimited. Where the crusher is used the car which contains the ore drawn from the mine is raised by an automatic engine, so that when it reaches a point directly over the crusher the bottom drops, the ore falls into the crusher, and the car at once descends the shaft again. After the ore is crushed it drops into a revolving barrel-screen made of punched boiler-plate, about eight feet long and thirty inches in diameter, placed below the crusher, and is made to revolve eighteen to twenty-five per minute, and has a slope of about one inch to one foot. By means of this the ore is separated into three sizes, the upper five feet of the screen having holes of one inch in diameter punched in it, and the lower three feet holes about two inches. All that comes through the first part is called fines, that through the lower part raggings, while the remainder comes out at the end. Hand-cars stand on tracks below this screen so as to catch the ore which is there culled. The relative percentage of each class separated in this manner is in about the proportion of twenty, twenty-five, and fifty-five. The building in which the operation takes place is elevated about fifteen feet, so that trams are built from it on which the hand-cars are run out to a line of railroad which carries the ore to a system of roast-beds. The ore is dumped from these hand-cars into shoots, which are so placed that the dump-cars are run under them as to catch the ore and prevent all trouble and expense in loading. From here the ore is drawn on an ordinary railroad to the roast-beds, which are generally at some distance from the shaft (about a mile), so as to protect the men from the dangerous and obnoxious gases.

The next part of the operation is roasting or calcination, which signifies the exposure of the ores of metals containing sulphur, arsenic, and other metalloids, to comparatively moderate temperature with the purpose of effecting changes required for their subsequent treatment. There are three different methods of roasting the ore, viz. :—

(1) Heap roasting.
(2) Stall roasting.
(3) Kiln roasting.

Each system has its merits and advocates; but as the writer's experience only refers to the first, the others will not be treated of.

Heap roasting is the most primitive of all, and when properly arranged grounds are chosen and good superintendence is given, it is by all means the cheapest method of calcination of raw ores. In laying out a roasting ground two important features to be considered are, first, the direction of the prevailing winds of the locality, and, second, the elevation, slope, and drainage of the ground. The first precaution is necessary in order to protect the works from the immense clouds of sulphur fumes, so that they shall not be distributed among the workmen. This is a matter of much importance, not only to the workmen but to the surrounding country, if it be an agricultural one, since the sulphurous acid is very injurious to vegetation. The grounds should be protected from inundation, and should be well drained; where a side-hill can be chosen, it often saves much expense.

A long line of trestle-work is built up for running the loaded ore cars to the beds, and by gaining this elevation and using dump cars very little handling is necessary; then, by having a lower track, the roasted ore may be reloaded on the cars beneath without much trouble. The area for roasting-beds depends much upon the capacity of the smelter. The piles are generally forty feet long, twenty-four feet wide, and six feet high, containing 240 tons each, and to furnish 100 tons per day thirty-five heaps will be necessary, requiring an area of 75,000 square feet of roasting ground. The heaps are formed in a single line along beneath the trestlework.

To prepare the ground it is necessary to remove all stumps, stones etc., and also the top soil, while the space the latter occupied is replaced by broken stone, slag, and tailings from the smelter. The ground should by this means be raised several inches above its surroundings; then over the surface is spread a layer of clay loam, which should be successively damped and rolled several times until it becomes as hard as an ordinary macadam road.

Coming now to the roasting process, the height of the pile will depend much upon the character of the ore; the higher the heap the more fiercely will it burn and the longer it will take to roast; consequently where the ore is rich in sulphur the heaps should be low. The best height for ordinary ore is about five to six feet, under which circumstance it will burn seventy days, the time being diminished or increased ten days for every six inches less or greater than the above height. The area of the pile will have very little influence on the time. The heaps should be thoroughly covered and watched, and combustion kept at the lowest point compatible with safety, the object being to prevent the formation of matte, since the more of this substance that is present, the smaller must be the furnace charge. As stated before, the area of the pile is about 24x40. This is marked out by corner-posts of stone. The surface is then covered to a depth of six inches with fine ore, which prevents the baking and adhering to the ground of the coarser ore, and shows after roasting the boundary between the worthless and valuable material. The fuel is next laid on. Since most sulphide ores will not stand the heat generated by dry hardwood, it frequently happens that a cheaper variety will do; in fact, any old rubbish, as rotten pine, old logs, etc., if dry, answer perhaps the same purpose. The outside border of wood should be of better quality. The usual practice is to lay a course of good cordwood around the outside to a depth of sixteen to eighteen inches, closely packed together; the inside is then filled in to the same depth of poorer wood, closely arranged and packed so as to show a tolerably close and even top, and to prevent ore dropping through. About three chimneys or draught chambers are necessary in a bed of such a size, and they are placed at equal intervals along the centre line. They may be made by nailing four old boards together about six inches wide. Two of the opposite sides should go down to the ground, while the top should be a couple of feet above the ore pile. Three cordwood sticks will serve the same purpose when bound together with wire.

The ore is drawn by an engine and dump-cars up the tram and dumped, then wheeled in iron barrows and put on the pile, the first few barrows being put about the draught chimneys. The main part of the pile is formed of the coarse ore. The heap is formed into a neat pyramid with sharp corners and sides sloping at from 40° to 45°, or as steep as the ore will lie without rolling down, care being taken that the pile does not extend over the outside of the border, which must be kept clear to regulate the draught. The ragging or second grade is next put on, forming a comparatively thick covering. The fines are seldom placed on the pile until after it has been fired. The amount of wood required to burn 240 tons properly will, of course, vary according to the efficient heating-power of the wood, as also upon the amounts of sulphur and bisulphide in the ore, but a fair average is twelve cords, or one cord of wood to twenty tons of ore. Bunches of cotton-waste saturated with kerosene are inserted into the pile here and there on the leeward side of the piles, and a match applied; for a few hours after lighting the pile may be left to itself, in fact it is hardly safe to work around it, since dense fumes of smoke, saturated with pyroligneous acid and the various gaseous compounds of sulphur and arsenic, are almost unbearable and often dangerous. After a few hours the flame will have spread pretty well through the pile, and then is the time it requires attention, since draughts will occur at different points and will soon show themselves by a falling in. It is now the proper moment to put on the fines; but if no signs of uneven burning show, the fines are spread all over the pile. Once well kindled nothing will put the fire out except a dense torrent of water, so all that it is required to do is to keep control of the fire. If matters go all right dense clouds of opaque yellow smoke, smelling strongly of sulphur dioxide, arise from each chimney. The entire surface will be found damp and sticky, while at the vents in the pile will be noticed deposits of mineral sulphur, and often pools of molten sulphur will form. It may be mentioned here that this process at one time formed one of the principal sources of supply of sulphur. To one who has never before come in close proximity with thirty or forty of these roasting piles, the experience might perhaps be very suggestive of other climes, and the sensation can hardly be likened to anything in the natural world. However, like many other things, one gets used to it. The heaps will require constant attention for about twenty days, so as to keep the draught even, as stated before, by covering any spot with fines when it shows too great a draught. After this period the pile needs very little or no attention. The corners and outside and part of the top will not become desulphurized and is used for covering the next pile to be burned; but herein lies the trouble, since it together with the fines from the crusher are an ever-increasing quantity, and give considerable trouble in their disposal. To overcome this it is sometimes necessary to build a kiln in which to roast this surplus.

A constant source of loss from heap-roasting is the amount of copper dissolved by rains and drainage from the grounds, and where precaution is not made against flooding this loss becomes serious. To lessen this sometimes the roasting ground is constructed so that it can be drained to a lower level, where large vats containing old scrap-iron are made to receive the copper in solution, which upon coming in contact with the iron collects upon it in the metallic form. The one great precaution in all roasting is to prevent the formation of matte, which is a lower sulphide than the original ore or artificially-formed sulphide. When once the roast-heap has become tolerably cool it is torn down, loaded on the cars by barrows, and transferred to the smelter, all of the ore which has not been thoroughly roasted being, of course, stripped off and kept for the next roasting. The average cost of roasting is estimated at eighty to eighty-five cents a ton.

SMELTING.

By this is meant the fusion of the copper-bearing material with some one or more fluxes, when the copper, from its greater specific gravity, separates from the slag and is recovered. In the case of oxidized ores, it is obtained in the metallic condition somewhat adulterated with sulphur, iron, nickel, or whatever other metal may be present, but requiring only a single operation to bring it into the proper form for commerce. But when it occurs in combination with sulphur or arsenic, accompanied by an excess of foreign sulphides, the result of the first fusion is merely a concentrated ore freed from the earthy gangue and resulting from a combination of the copper with a sufficient quantity of sulphur to form a sub-sulphide ($Cu._2 S$), to which is added as much more sulphide of iron ($Fe. S$) as corresponds to the remaining sulphur. If tin, lead, or silver be present, they combine with sulphur for the most part and enter the alloy. The ultimate production being called matte, we consequently see that the grade of the matte will depend upon the amount of sulphur in the ore. There are two distinct methods of copper smelting, (1) smelting in Blast Furnaces, (2) smelting in Reverberating Furnaces. In this country and the United States the blast furnace has been generally adopted, the result being that it has been so improved and changed that the American system is far in advance of the European methods, being radically different from them. Such a revolution has taken place that whereas ten years ago the ordinary run of a furnace for twenty-four hours was forty tons, it now runs over 100 tons. I shall not here attempt to describe the Reverberating System, although the most of the copper manufactured still has at some stage to pass through such a furnace.

The great difference between the two methods is that a reverberating furnace will not smelt sulphides well, for the ore must be reduced to an oxide. The Blast System, however, will smelt any ore, and where the amount of sulphur is small it is not roasted at all, but at once turned into the furnace with its quota of flux and coke. The roasted ore is easily loaded on the cars, by which it is conveyed to the smelter, and here another tram is built, so that the ore is dumped into the second story of the building. The one end is divided into three spaces or large stalls, one for ore, one for coke, and one for fluxes.

THE FLUXES.

If the ore contains much silica, little else will be required to form a flux; a small addition of clay being required. But since ores seldom carry enough fluxing, something must be added. Some of the fluxes used are silicious oxide ore, clay, slate, silica of alumina, pebbles, crushed quartz, sand, rock, etc., but by far the most important is lime. In some cases, where large furnaces are used, limestone is used, but generally the quicklime is preferred. The percentage of flux depends altogether upon the nature of the ore. The fuel used is either charcoal or coke. The three substances are mixed in an exact proportion, and in beginning work many trials are required to get the right proportion. The charging door is on the second floor, and each barrowful is weighed on a scale before dumping. A man is placed at this scale to note all weights and direct the proper proportions. The amount of coke used at Sudbury is 12½ per cent. All ore is weighed before going into the smelter, and then the matte is weighed and a sample of every day's work assayed, so that an exact account is kept and any loss of copper in the slag is at once detected. In speaking of blast furnaces we may omit a description of the small brick furnaces of that kind, but to trace the evolutions from such to the present plan is interesting, and at the same time would give perhaps one of the best lessons in smelting that could be obtained. It is not well settled to whom belongs the credit of having first adopted the principle of water-cooling to copper blast furnaces, but it was soon hailed as the greatest advance in the treatment of that metal that had been made for many years. By its employment the burning out and consequent freezing up of the furnace from the half-fused mass of molted fire-brick have become things of the past.

For a diagram showing some of the main features of the blast furnace, see Fig. 1.

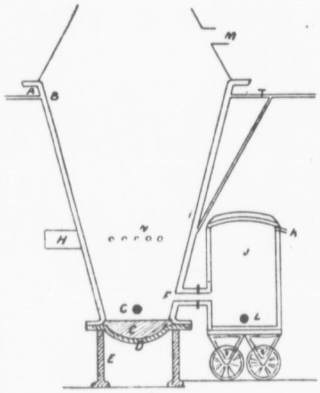


Fig. 1

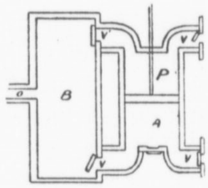


Fig 2

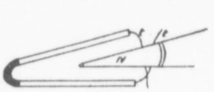


Fig 3

Here A represen the water-jacket made of the boiler-plate, the top is flanged two inches; B, the furnace proper, also of the same material, is flanged four inches, thus giving a water space of two inches; the flanges being riveted, and also having holes for bolting on the smoke stack. The bottom of the furnace, D, is a disk of cast-iron plate 2″ thick fastened to the bottom flange, to which are also attached the legs E. The hole F is the outlet of both slag and matte, and is 9″ high and 7″ wide, made by riveting the furnace and shell together at that point. The tap-hole G in the shaft is used only in blowing out the furnace; C is fire-clay rammed into the bottom on the supporting plate. H represents the wind-box; I the entrance of cooling water. J is the movable fore-hearth containing the crucible and placed on wheels, with fire-brick top and bottom and water space on the sides. K is the slag spout, and L the tap-hole for matte. M is the charging door where the fuel, ore, and flux is thrown in. The molten material flows directly from the shaft through the opening F into the crucible in J. The point between the two is readily made or severed, for it consists of two water-jacketed faces of iron, which are placed in contact by moving the fore-hearth against the opening. The two surfaces are smeared with fire-clay, which together with the molten matte immediately close up any small space between the faces. N represents the tuyeres carrying the blast to the furnace. There are from three to five on each side. The height of the furnace is ten to twelve feet, the width at top 4′ 6″ and 3′ 6″ at bottom. The water-jacket was formerly made about four inches wide, but of late has been much reduced. The cold water is introduced near the middle or lower part of the jacket, and on account of its weight sinks to the bottom, where becoming warm it rises to the top and passes out. In a thirty-six inch furnace the water necessary (when used over and over again) amounts to only 3,000 gallons a day. Frequently this water is used for the engine running the fans. The tuyere pipes, by which the blast is conducted to the furnace, are from two to four inches in diameter. They pass through the water-jacket and extend eight to ten inches into the furnace at about 6″ to 8″ from the bottom. Sometimes they are water-jacketed but more frequently are just cast-iron nozzles. To prevent the blast from reaching the outside crucible, it is arranged to have the slag-lip about 12″ to 18″ above the outlet from the furnace; thus when the molten metal runs from the furnace to the crucible, the level is soon raised above the opening and will continue to rise until the slag-lip is reached, the matte and slag standing at the same level in both crucible and furnace, and thus the blast is effectually cut off from the crucible. This state may be maintained provided the crucible is not, when tapped, emptied of all its contents; if such should occur a blast of cinders, slag and matte at once appears at the tap-hole. The blast supplied is from a Baker blower, No. 4½, which at 115 revolutions per minute will supply ten ounces per square inch of blast. This may appear a small blast, but when it is understood that the heat obtained is only to fuse the ore, not to reduce it, it will readily be seen that a stronger blast is not necessary.

Two different systems of blowers have been used:

I. Those producing a positive blast, and which, if obstructed, must result in the bursting of some part of the apparatus or the stopping of the blower.

II. Centrifugal fan-blowers which, even if obstructed, continue revolving. They consume much less power, the air being simply beaten by the vanes but not passing out of the pipe.

One advantage of the first kind lies in the fact that sometimes the matte becomes cooled on the tuyere pipes, forming what are called noses, which will continue to grow until the opening is closed, unless a strong blast be produced to keep it open.

Figure 2 shows the principle of the first kind of blower.

Here A is a large cast-iron cylinder accurately turned on the inside, in which the piston P works up and down, and made air-tight at the piston opening. The cylinder is closed at both ends by carefully-fitted iron plates. The cover is provided with two lateral openings V and V′, one of which V communicates with the outside air and is furnished with a valve opening inwards; the other V′, on the contrary, opens outwards and communicates with another chamber, B, also of cast-iron. The lower end of the cylinder is constructed exactly like the top.

To understand the action of this machine, let us suppose the piston has been raised to the full extent and has begun to be again forced down. If the valves V and V′ of the upper chamber are closed, the air contained in the upper portion will gradually become more and more rarified, and the difference of density of the air inside and out will cause the valve V′ to apply itself firmly against the metallic bearing before which it is hung. The valve V, on the contrary, which opens inwards, will be lifted and air will pour into the chamber from the outside. The motion which causes the air above the piston to dilate will evidently at the same time compress that which is beneath, causing the valve V to close, the valve V′ to open, and forcing the contained air to the chamber B, from whence it escapes through the aperture O to the pipes connecting with the tuyeres. In this way the upper portion of the cylinder draws the air from without during the descent of the piston and forces that which is beneath into the pipes with which it connects, and when the piston is raised these operations are reversed in the upper and lower chambers. Thus there will be an almost continuous blast supplied to the tuyeres; the only time when any irregularity will be shown is when the piston is at the end of the stroke; but to prevent the check thereby caused, the pipe leading from the chamber B is made to connect with a large closed reservoir, where the variations referred to is lost through the elasticity of the air itself. The cylinder is about six feet in diameter and nine feet long, while the piston makes about thirteen strokes a minute, furnishing about 12,000 cubic feet of air per minute to be discharged through the tuyere area.

Fig. 3 is a diagram of a water-jacketed tuyere showing a vertical section through it. It consists of a conical tube of cast-iron, in which an annular space is preserved in the metal composing the sides. Through this opening a current of cold water is made to circulate by means of two tubes t and t′, one of which t supplies the cold water, while the other t′ carries off that which has become hot. In this is placed the nozzle N, made either of thin copper or sheet-iron, and connected with a leather hose or otherwise with the pipes leading from the the blower. The pipes are set pointing slightly downwards, so as to prevent one tuyere blowing into another.

Now to follow the ore through the process, starting from the weighing and mixing. The ore, flux, and fuel are cast into the furnace from iron barrows, which are wheeled up alongside of the charging door and dumped. As the mass settles down it becomes heated up, and then the mixed fuel, at the tuyeres, creates a powerful heat, by which the ore and flux is melted, and the slag being taken up by the flux, the whole sinks to the bottom and runs out into the crucible, where the matte and slag separate, the slag floating and the molten metal sinking to the bottom. When the level reaches the slag-lip, which is always open, the slag flows out and into a slag buggy placed to catch it. After a time the metal will begin to show itself at this opening, and is indicated by a greater fluidity and much spluttering. Then a slag-buggy is wheeled up to the side of the crucible, which is then tapped. The hole, which is stopped with fire-clay, is opened by driving a pointed iron rod into it, which breaks the clay. The rod for this purpose is of ⅜″ iron and 10″ to 12″ long, and upon tapping there will be a sudden spurt of matte to the distance of four or five feet. When sufficient has been drawn off, the opening is stopped with a ball of fire clay made on the point of another rod of the same length and pressed firmly into the tap-hole. The tapping is done at regular intervals, the object being never to let the matte overflow at the slag-lip; care also being taken never to lower the level of the crucible so much that the slag will flow out at the tap-hole. The floor of the smelting house is covered with iron plates, so as to prevent burning when the matte or slag falls upon it. The slag is wheeled out and dumped and from its bulk soon increases to a considerable size, so that much care is required to so arrange the dump that as little labor will be required as possible in its disposal. The matte, after running into the matte-buggy, is wheeled out and allowed to cool, when it is dumped and afterwards broken by sledge, ready to be loaded on the cars for transportation. The slag-buggies are merely large pots about 18″ in diameter and two feet deep, which are hung on two wheels, to which is attached a handle for drawing. The pots are larger at the mouth than at the bottom and are made of cast-iron ½″ thick.

The capacity of a blast-furnace is dependent on many varying causes and is to a considerable extent independent of shape or size, though its tuyere area is, of course, the most important function in determining the amount to be smelted. Next to the fusibility of the charge, the pressure and volume of the blast have the principal influence in this determination, provided the fuel is the same and of sufficient density to stand the pressure of the blast. Both ore and fuel are spread in layers over the whole area of the furnace, which procedure is quite different from the old plan.

Large and high furnaces naturally require heavier charges, and it is still an unsettled point as to whether deep or thin layers of fuel and ore serve the best purpose, while some claim that they should be to a certain extent mixed. A proper charge for a 36″ furnace is 500 to 800, while a 42″ will take 1,200.

In Canada we have not as yet carried our copper smelting any farther than the production of rich mattes, but these are all shipped either to New Jersey or Swansea, to be there refined. This refining is done chiefly by the reverberatory furnace. Underlying the whole process is the fact that copper has a greater affinity for sulphur than for oxygen, while the other metals generally present in the matte have a stronger affinity for oxygen than for sulphur, and thus we can understand how it is that metallic copper is never obtained at the first or second treatment, since the sulphur is used as a means of concentrating the copper, while at the same time the impurities are to be got rid of. The matte is broken up and placed in the reverberatory furnace together with silicious fluxes. The iron and other impurities in the form of sulphides become reduced to sulphates, then to oxides, and are carried off into fluxes. This process is repeated several times until an almost pure sub-sulphide of copper is obtained, which will also contain any metallic copper which has been reduced in any of the processes. This last form is called white metal, which is next smelted with a small amount of coke or coal and thoroughly roasted to an oxide, which is afterwards roasted with a fresh supply of coal, when the carbon combines with the oxygen and sets free the metallic copper in the form called blister copper. This is treated by hammering and rolling to bring it into a marketable form.

It has been the object of this paper to treat only of the reduction of the ores to the form of mattes, so that this last sketch is only given to show in a very few words the treatment after it leaves our Canadian smelters. With the activity shown during the last ten years, together with the prospects of the future, it is to be hoped that our vast mineral resources will justify the putting up of smelters for the perfect treatment of copper ores in our own country. Our one great drawback is, of course, the lack of coal, but if the mining companies can succeed in getting the duty on that article removed, doubtless we will soon have a perfect smelting process, and then we have every reason for believing that Canada will become the chief source of the supply of copper for the world.

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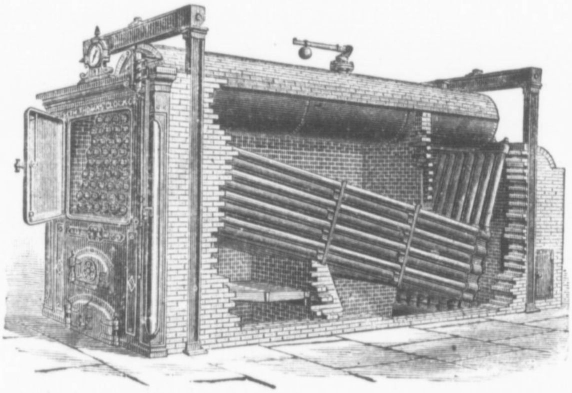

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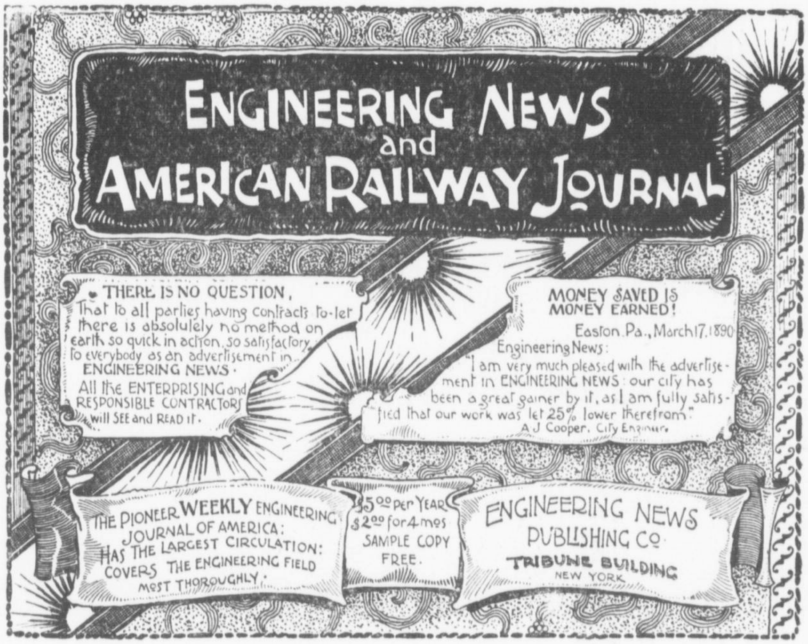

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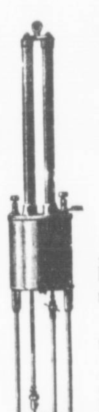

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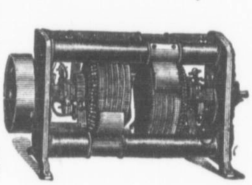

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