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THE GRONWALL STEEL REFINING FURNACE.

T. D. ROBERTSON, M. Met.

In recent years great advances have been made in the electric smelting of steel and several types of furnaces have proved themselves capable of making good steel economically.

One of the latest types to be introduced and one that possesses sevaral distinct advantages over any other is the "Grönwall" furnace.

This furnace, the invention of three Swedish engineers, Messrs. Grönwall, Lindblad, & Stalhare, of Ludvika, is of the arc type as opposed to the induction type; but it is the only arc furnace employing two phase current.

It will be seen from the illustration (Fig. 1) that the furnace has two carbon electrodes, carrying separate phases, passing through the roof. The current arcs from these on to the slag and metal, passing through this, then through the basic lining to the neutral return, which is a carbon block fixed in the bottom of the furnace.

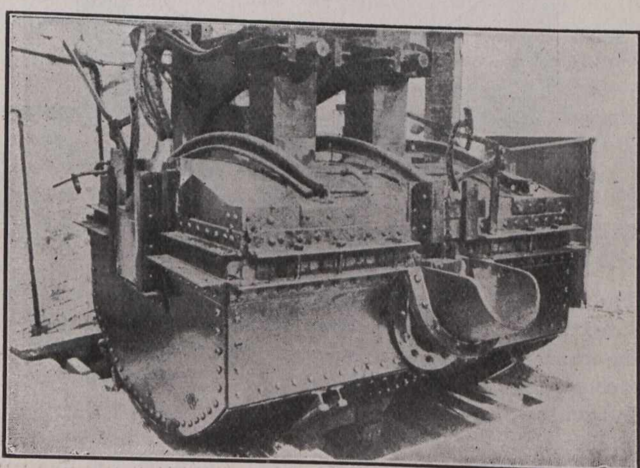

Fig. 1. Exterior View of Furnace.

Furnace Construction.

The iron tank of the furnace is lined with magnesite bricks and inside this lining the hearth of dolomite or magnesite is rammed. (See Figs. 2 and 3.)

The carbon block forming the lower terminal is held in an iron casting bolted to the furnace bottom, and just comes level with the brickwork, so that it does not project into the basic lining. In this way, the bottom of the furnace is not broken by any projections, and after each charge, the bottom can be repaired exactly in the same manner as that of an open hearth furnace.

The roof consists of a channel iron framework holding silica bricks and is detachable, so that when the bricks are worn thin, it can be taken off and replaced by a new one, this operation of changing only requiring about twenty minutes.

There is a working door at each end of the furnace and another one at the tapping spout. At the back of the furnace are the cranes for raising and lowering the electrodes, which can be done either by hand or by automatic regulators. The electrodes are of a new type and are so constructed that they can grip the electrodes at the points where they enter the roof. This reduces the electrical energy losses in the electrodes to a minimum.

The furnace is mounted on curve rails and is tilted by hand-wheel gearing or by hydraulic cylinders. The furnace construction although simple, is cheap, strong and efficient.

Electrical Equipment.

The high tension supply, if three phase, is transformed by means of two single phase transformers with Scott's connections to low tension two phase current at 50 to 70 volts. The voltage can be altered by changing the number of primary windings.

The switch gear consists of one two pole oil switch in circuit with the high tension mains. There is an ammeter on each phase and one on the neutral return. A volt meter with a 3-way switch shows the voltages of each phase and also that between phases.

The current is conveyed to the electrode holders by means of bare flexible cables from the bottom casting to the transformers by similar cables.

Regulation of the current is brought about solely by raising and lowering the electrodes, in this way increasing and decreasing the resistance of the arc gap.

Advantages of the Two Phase Furnace.

Compared with single phase furnaces, the Grönwall furnace has the advantage of allowing the current to be taken direct from the mains of either a two or three phase system without the intervention of motor generators, which compared with static transformers are not only very inefficient but have high initial cost and running expenses.

A marked feature of the two phase arrangement is that when melting cold charges, the furnace runs very smoothly. One of these furnaces is working in Sheffield, Eng., and is supplied with power from the municipal station. The working is so smooth that the authorities permit the furnace to be started on a cold charge during their peak load.

Apart from electrical considerations, it has been found that this system has decided metallurgical advantages.

The passage of the current through the basic lining keeps the bottom of the furnace well heated all over, using to do this very little energy, and without damaging the lining in any way.

Unlike a single or three phase arrangement, the two phase current induces horizontal and vertical movements in the charge, the result of this being that the metal from the bottom of the bath is constantly being brought to the hot surface where it comes into intimate contact with the refining slag thus reducing time and current consumption for refining. In this way, equality of temperature tends to be established all through the charge. In addition, heat is taken away from the very hot region below the electrodes by this movement, so that the reflection of heat from this part on to the roof is much less than with single or three phase surface heating, the result being to prolong the life of the roof.

The roof of an arc furnace is made of silica brick and when this is overheated, pieces of silica drop down into the basic slag, upsetting the equilibrium of the reactions. The longer the roof wears the less silica will pass into the slag per charge, thus producing greater regularity of working.

Electric Steel Making.

The process of steel making in this furnace may be divided into two main branches—melting from cold and refining molten metal.

The local conditions at each plant usually determine whether cold melting is used or not. Concerns having Open Hearth or Bessemer plants will probably use hot metal from these.

Many electric furnaces are working which melt cold scrap and refine it. To compete, using this method, with the best open hearth practice requires current at a fairly cheap rate, the quality of electric steel however being superior.

Steel has been made in Sheffield, England, in one of these Grönwall furnaces from common Bessemer rail scrap. This steel when tested gave results equal to that of Sheffield crucible tool steel selling at $175 per ton.

The current consumption varies considerably with the size of furnace, the larger sizes being more economical.

The Bessemer process at present is on the decline; the regularity of product obtainable from the Open Hearth furnace probably being the cause of this. The electric furnace opens up a new field for existing Bessemer plants. Blown

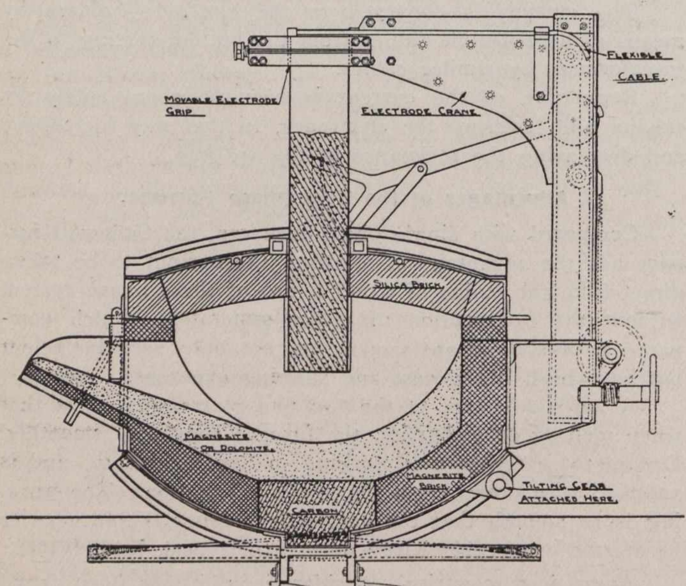

Fig. 2. Cross Section.

metal without any deoxidizing additions is just in the proper condition for purification in the electric furnace.

This refining takes place in two stages, the first, dephosphorizing requires an oxidizing basic slag, so that the

This refining takes place in two stages, the first, dephosphorizing requires an oxidizing basic slag, so that the highly oxidized blown metal lends itself to this treatment. When dephosphorizing is complete the slag is raked or poured off. A new slag is made for desulphurizing and deoxidizing and produces steel of great chemical purity which can be poured into sound ingots without any killing addition of alloys, the recarburization being made in the usual manner.

This method of refining Bessemer metal is the same as that used for refining cold scrap after melting and for Open Hearth hot metal.

Alloy Steels.

The electric furnace is especially adapted for making alloy steels. The temperature can be raised to a degree hotter than any furnaces heated with fuel, so that steels containing refractory alloys can be rendered perfectly fluid for pouring. The reducing conditions which obtain at the end of the refining, prevent oxidation losses of added alloys, for this reason the final composition can be controlled to a nicety.

Steel Castings.

There is a good opening in this line for electric furnaces. The metal from these is particularly dead, giving very sound castings free from blowholes when used in cooperation with good steel moulding.

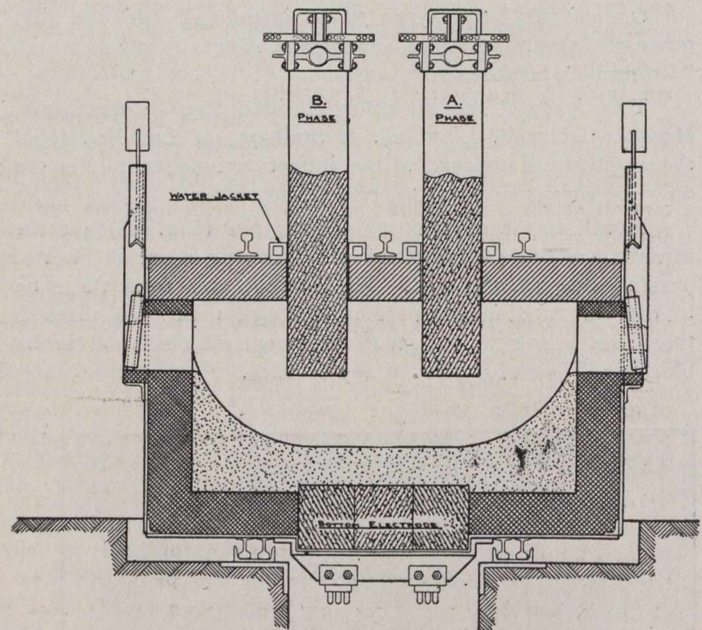

Fig. 3. Longitudinal Section.

The casting temperature of the metal can be so easily regulated that thin light castings requiring very hot metal, can be made as easily as heavier sections needing somewhat cooler steel.

In general, the future for electric furnaces is bright. As specifications are becoming harder to fill by the old processes every year, any apparatus which improves the quality of steel at a very reasonable cost has a good field open for it.

The inventors of the Grönwall furnace have profited by the experience of the pioneers of electric furnace design and have succeeded in combining most of the advantages of existing types at the same time eliminating most of their disadvantages.

DISINFECTING THEATRES.

A committee of French doctors has been instructed to submit to the Paris police regulations for minimizing the danger of the dissemination of infectious diseases at theatrical performances. It is proposed that every theatre shall be disinfected after every performance by means of sawdust steeped in antiseptics. Also that windows and doors shall be kept wide open in the intervals between the performances, that cushioned seats shall be sponged with antiseptics, the cloakroom attendants' undergo regular medical inspection and the air of the house shall be sterilized once a week by means of steam charged with formaldehyde.

THE EDISON-BEACH STORAGE BATTERY CAR *

R. H. Beach.

Probably it is not clear to many electric railway men how a storage battery can perform the very difficult task of supplying the large amount of electrical energy necessary to propel a heavy car, to accelerate it at frequent intervals and cause it to climb grades. Experience with batteries composed of lead compounds immersed in acid-electrolyte has been such as to lead many to think that all secondary batteries are delicate and have a short life, and therefore are to be avoided for use on vehicles. The Edison secondary battery, which is the source of energy in the Edison-Beach storage battery car, is neither delicate nor short-lived. The principle of the Edison storage batterv is that metallic iron tends to combine with oxygen. When oxygen is combined with iron energy is developed either in the form of heat or electric energy. Conversely the oxygen may be removed from iron oxide, but to do this requires the expenditure of energy. The Edison battery consists essentially of plates of iron oxide and plates of nickel oxide immersed in water, to which potash is added. If an electric current is caused to pass through the electrolyte from the iron plate to the nickel plate the oxygen present in the iron oxide passes to and remains with the nickel oxide. When all of the oxygen has been removed from the iron oxide and is taken up by the nickel oxide then the battery is fully charged. In this condition the negative plate is composed of metallic iron, while the positive or nickel plate is composed of oxide of nickel and also a super-oxide of nickel. The finely divided metallic iron has an affinity for the oxygen in the positive plate and it will receive this oxygen if permitted to do so. It cannot receive the oxygen, however, without giving off energy in some form. If an electrical circuit be completed between the two plates an electro-chemical action takes place and the oxygen in the positive plate is transferred to the metallic iron in the negative plate. This process is accompanied by the generation of electricity.

The Edison battery is analogous to but quite different from the older forms of lead batteries. Combinations of iron and nickel oxides and water are not self-destructive. Neither are they destroyed by the transfer of the oxygen back and forth. In a word, the distinctive feature of the Edison secondary battery is its stability. The battery is not liable to injury from use, and it suffers nothing from neglect. It may be charged at a rate as high as ten times the ordinary rate, or it may be discharged on short circuit. The electrolyte may be boiled or frozen without damage to the cell. With ordinary treatment the battery can be relied upon to do its best work, providing it is kept reasonably clean. From experience extending over several years, it is known that the battery will not fall off in capacity during the first six years of its life. It is guaranteed for three years and it is believed that it will last for a much longer time, especially if distilled water is used.

With the older types of storage batteries it has been necessary to allow almost as long for charging the battery as for discharging it under service conditions. The older types of batteries require about eleven hours for a complete charge and in car operation this would mean that the car would be out of service at least half of the time. Because of the fact that the Edison battery is not injured by high rates of charging, a car equipped with this type of battery need be out of service practically none of the time. In Washington, D. C., a car is operated over a line 4 miles long. The running time is sixteen minutes and the layover time at the terminal is three minutes. The battery is charged at five times its normal rate during the three-minute layover and the car then runs to the other terminal, where the operation of charging is repeated. The battery is not charged at any other time and the car runs 204 miles each day. The three-minute layover at each terminal is required for changing the fender and giving the conductor an opportunity to reset the fare register. Advantage is merely taken of this time to charge the battery. Another car, operated in Concord, N. C., makes 99 miles a day and is charged twenty times for ten minutes at each terminal. The total charging time is three hours and twenty minutes during the day.

Mr. Edison has said of this battery that it is the most useful of all of the devices that he has invented. As the field of its application becomes better known it will be the means of supplementing and, to a large extent, supplanting many of the present means of electrical transmission. It makes not only possible but almost certain the removal from the street of all overhead trolley wires, and makes unnecessary and uneconomical the third rail and the conduit.

In designing the cars on which these batteries are used the writer has aimed to reduce the dead weight and to eliminate, as far as possible, friction losses. The average Pullman car weighs 3,000 lb. per seated passenger. The ordinary wooden day coach used by steam railroads weighs about 1,500 lb. per seated passenger. A steel suburban coach weighs 1,100 lb. per seated passenger. An ordinary single-truck trolley car weighs about 800 lb. per seated passenger and an ordinary double-truck car about 1,000 lb. per seated passenger. The average current consumption of a trolley car is approximately 125 watt-hours per ton mile. The Edison-Beach double-truck storage battery car weighs only 600 lb. per seated passenger, while the small single-truck car weighs 380 lb. per passenger. The latest type of long wheel-base, single-truck car weighs 360 lb. per seated passenger. The weight of the battery required on each of these cars is about 60 lb. per seat.

This reduction in weight has been accomplished by making a number of departures from the usual practice in body and truck construction. All of the joints in the truck frame are welded instead of being riveted or bolted. No difficulty has been experienced from broken welds. In longitudinal seat cars an electrically welded latticed steel girder forms a rest for the seat and extends the length of the car body. It is bolted to the side and cross sills and side posts. In an 18-ft car these girders weigh about 300 lb. and they so stiffen the body that a reduction of nearly 3,000 lb. can be made in the weight of the other parts. A very light roof is used because it is not necessary to support a trolley base. The body of an 18-ft. car with 5-ft. platforms and folding doors, but no bulkheads or interior doors, weighs about 3,700 lb. A standard monitor-deck car body of the same length weighs about 6,700 lb. and the light bodies with the steel girders are much stronger than the heavy bodies.

After extensive experiments had been made it was found that there was a considerable saving in friction losses if the wheels were permitted to rotate on the axles instead of having the axles fixed in the wheels and rotate in the journal bearings. Exactly how much saving in current consumption has been effected by this change is not known. A silent chain drive is used between the motors and the wheels. There is some gain in efficiency with this type of drive over the gear drive, but it is difficult to say exactly the amount. When new the gear drive is probably very nearly as efficient as the chain, but as it wears it loses its efficiency, whereas

* Abstract of a paper read at the annual meeting of the Street Railway Association of the State of New York.

the chain does not. The chain drive possesses a great advantage over the gear drive while the car is coasting. On a test run between Athena and North Newark on the Erie Railroad, a distance of about 7 miles, a chain-driven car accelerated from 0 to 35 m.h.p. and maintained that speed on a practically constant grade of from ½ to 1 per cent. without the use of any current. An ordinary journal-bearing car will scarcely move on this grade without the application of power. The average current consumption of the Edison-Beach storage battery car is very low, in no case exceeding 60 watt-hours per ton mile. In a test made at Atlantic City at the time of the American Electric Railway Association Convention in October, 1910, one of these cars made thirty-six trips, aggregating 14.4 miles, with an average of six stops per mile and an average speed of 9 m.p.h. The average number of passengers carried was eighteen and the average consumption of current per ton mile was 54.2 watt-hours.

A double-truck car which was tested on the Greenwood Lake Division of the Erie Railroad between Forest Hill and Sterling Forest ran a total distance of 70.2 miles. The weight of the car, including passengers, was 16.53 tons and the maximum speed was 25 m.p.h., the schedule speed being 18 m.p.h. This line has a number of heavy grades, but the current consumption per ton mile averaged only 49.63 watt-hours. Another test made on the Erie Railroad between West Orange and Forest Hill at the same rate of speed showed a current consumption of 46.1 watt-hours per ton mile.

The Washington, Spa Springs & Gretta Railroad has had an Edison-Beach car in service for a number of months on a line which has grades as steep as 8 per cent. The battery car has averaged about 355 watt-hours per car mile and it has been found that one of these cars consumes only about one-fourth the current required for an ordinary trolley car.

It is of interest to note the long-distance runs which may be made by these cars on a single charge of the battery. The double-truck car previously mentioned has been run on a single charge from West Orange, N.J., via Jersey City to Middleton, N.Y., over the Erie Railroad as the second section of an express train. The same car was run on a single charge from Jersey City to Atlantic City, N. J., over the Central Railroad of New Jersey and the Reading Railroad, a total distance of 135 miles. Sufficient current was left in the battery upon arrival at Atlantic City to run about 40 miles more. This car can attain a speed of 25 m.p.h. on a level with full load and a speed of 16 m.p.h. on a 6 per cent. grade. It is equipped with four motors rated at 15 amp. and 200 volts and an Edison battery weighing 4,800 lb. On the single-truck cars carrying twenty-six passengers two motors rated at 30 amp. and 110 volts are used and the battery weighs 1,800 lb. The lower voltage used in the single-truck cars lessens motor and controller troubles.

As showing what can be done with one of these cars on a small road, the results of operation on the Salisbury & Spencer Railway, Concord, N. C., are of interest. The total cost of this road, which is 1½ miles long, was $20,000 and the net earnings of a single car are at the rate of $7,670, which is equivalent to more than 33 per cent. on the investment. The current for charging the battery of this car is purchased from the Southern Power Company at a price of 1¾ cents per kilowatt hour, measured on the alternating-current busbar. The car is operated by one man, passengers entering and departing by the front door. The following is a record of thirty days' operation:—

Number cash fares	19,733
Number ticket fares	243
Total	19,976
Total car miles	2687.5
Total kw.	5268
Kw. per mile	1.95
Total moneys received	$986.65
Operating expenses:	
Power at $1.75 per kw.	92.19
Conductors and motormen	232.94
Miscellaneous	22.39
Total expenses	$347.52
Net profit	639.13

CARBON BLOCKS FOR BLAST FURNACES.

Amongst the exhibits at a conversazione of the Cleveland Institute of Engineers were some Erkrath carbon blocks for lining the hearth, well and bosh of blast furnaces. These were exhibited by Messrs. Jarvis Bros., Limited, of Middlesbrough, and from the recently published "Transactions" of the Institute we take the following additional particulars: Molten iron at a high temperature holds carbon in solution, which deposits out when the metal is lowered in temperature (by contact with the cooled walls of the well) and forms a skin or layer of carbon, which ultimately protects the bricks from the action of the molten metal and slag. Over 100 of the most modern Continental blast furnaces have been lined with carbon blocks during the past eight years. The cost of carbon blocks per ton is practically twice that of firebrick, but the specific gravity being 1.25 compared with 1.9 for firebrick, the proportionate cost of a lining is not so great. This is not, however, a true basis for comparison, the cost per ton of iron produced being the only figure of importance. If a furnace produces as much iron in a fourth of the time as a similar furnace lasting four times as long, the cost of lining per ton of iron would be the same, but as the cost of lining forms a small part only of the total cost per ton, the other standing charges remaining approximately the same, the increased production reduces the total cost per ton. Of course, where an ironmaster is satisfied with a weekly output of a few hundred tons per furnace, firebrick will probably continue to answer the purpose. Apart from the question of being able to withstand hard driving successfully the advantages of the carbon block lining amongst others are claimed to be:—(a) The saving of the metal forming the "old horse," which will frequently pay the whole cost of lining the hearth and well. (b) The saving owing to less variation in the quality of the iron purchased due to the form of the furnace being maintained, it being probable that the quality going off is frequently due to the taper of the bosh becoming hollowed out by the action of slag and iron, so that fine material finding its way down the side of the furnace lodges there and accumulates, afterwards coming away with a rush into the well and spoiling the cast. (c) The saving due to the avoidance of "breaks away" from the well of the furnace. (d) The saving in time, labor and material when the furnace has to be re-lined, as a new shaft lining only will usually be required, the carbon bottom and well being permanent.

It is a question, however, whether these carbon blocks will not in some way affect the carbon reactions of the furnace, due to the great reducing activity of the element carbon.

GRADUATES COURSE IN HIGHWAY ENGINEERING AT COLUMBIA UNIVERSITY.*

Arthur H. Blanchard, M. Am. Soc. C. E.
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The status of highway engineering in the United States was ably presented before this Society at the New York meeting in 1909 by the Hon. Logan Waller Page, Director of the United States Office of Public Roads. As stated by Mr. Page, many years will elapse before the supply of thoroughly trained highway engineers will exceed the demand. The conditions existing in 1909 have not been materially improved during the past two years.

The technical graduate who is attracted to highway engineering has several more or less well defined fields open to him: namely, the highway departments of municipalities and towns; those of state, counties and parks; the engineering organizations of contractors; and the engineering and sales departments of companies dealing in materials and machinery used in highway work. In city and town work, matters relative to the construction and maintenance of streets and pavements compose the bulk of the work assigned to the highway departments together with more or less road engineering problems. With state, county and park departments, the construction and maintenance of all types of road surfaces and bituminous pavements constitutes 90 per cent. of the work of such organizations, while certain problems in street pavements and highway bridges have to be dealt with occasionally. The prevailing idea, however, that the two fields just mentioned are easily separable and that the preparation for one should not be the preparation for the other is essentially wrong. Since the lines of demarcation between the above fields are rapidly becoming obliterated the successful highway engineer of to-day, whether engaged by the city or state, must have a comprehensive knowledge of all branches of highway engineering and allied subjects. Otherwise it is obvious that it will be impossible to follow that important principle of economics of highway engineering, the adaptation of methods and materials to local conditions.

In contemplation of these opportunities, the essential pre-requisites of a successful career as a highway engineer must be given due consideration in order that the future prospects offered by this field of engineering may be thoroughly understood.

The ideal foundation consist, first, of four years training in a course to civil engineering; second, practical experience in both field and office in connection with the construction and maintenance of roads and pavements on a system of highways; and, third, the acquisition of knowledge along certain lines of particular value to the highway engineer.

In explanation of the last pre-requisite it might be stated that to be well informed, the highway engineer must acquire considerable knowledge relative to the economics of highway engineering, materials of highway engineering, management engineering, highway laws, and systems of administration, mechanical appliances used in highway engineering, highway bridges and culverts, road and street surveying, drafting and designing, methods used in a road material laboratory, advanced dynamic and structural geology, lithology, petrology and petrography, processes of industrial chemistry, methods of testing bituminous materials and the interpretation of results, and finally advanced highway engineering covering the most recent practice throughout the world in the construction and maintenance of all kinds of roads and pavements.

The fulfilment of pre-requisites numbers one and two is easily accomplished except that the graduate of one or two years standing may with difficulty retain his position during the months from December to March inclusive, especially if he is connected with a state or county department or the organization of a contractor. In these fields of highway engineering the immense amount of work to be completed during the construction season in the north requires the maximum engineering force obtainable both in the field and in the office, while during the four months mentioned above, the natural confinement of a large percentage of the work to the office necessitates reducing the engineering staff. The prospect of being without work for four months of the year has prevented many high grade technical graduates from entering the field of highway engineering. In certain cases it has been possible by co-operation between state highway departments and colleges giving courses in civil engineering to mitigate the evils of this situation. As a concrete example may be cited the writer's experience while he was Deputy Engineer of the State Board of Public Roads of Rhode Island. Many of the best civil engineering students at Brown University were employed throughout the college year part time and during vacations all the time, year in and year out, with the natural result that upon graduation some became members of the permanent force. At all times, however, the office force consisted of trained men of a number commensurate with the work of a given season. It should be said that in many cases this plan will not work out satisfactorily for the field or inspection force, due primarily to the fact that while the construction season extends from April to November inclusive in certain sections of the country, the long vacations cover only June to September inclusive, hence the impracticability of utilizing undergraduates, resident at the University, in the months of April, May, October and November in the above field positions.

The third pre-requisite mentioned might, of course, be covered by collateral reading, but it is self-evident that only a very limited idea of certain of the subjects mentioned can be acquired in this way. Especially is this statement applicable to over 50 per cent. of the subjects which, it is apparent, must be illustrated and exemplified by laboratory equipment and well stocked museums or developed through the medium of research library work. The United States Office of Public Roads, through the medium of its corps of civil engineering students, offers a method by which a limited number of men may receive training in the construction of roads and instruction in various subjects related to highway engineering. However, as Mr. Page stated in 1909, "this plan will provide but a small percentage of the engineers that will be required."

The problem before the educational institutions of this country is that of determining by what method the subjects outlined above can be offered upon a practical basis. The writer does not favour a four years undergraduate course in highway engineering, not only because of the varied and potent reasons which have been presented to this Society on various occasions with reference to specialized undergraduate courses, but also because undergraduate students are not sufficiently mature to acquire the benefits which should be derived from a combination of practical experience and specialized knowledge.

* Presented before the Society for the Promotion of Engineering Education, Pittsburg, Pa., June 27, 1911.

The most practicable plan is to arrange a definite course of instruction as a unified graduate course based on the assumption that the technical graduates enrolled for the Master's Degree will hold undergraduate degrees in civil engineering. If the graduate instruction is to be given in the period from about December 1st to about April 1st it will be possible for practicing highway engineers, especially first, second, and third year graduates, to use the winter period advantageously in acquiring advanced knowledge under favorable circumstances.

It is gratifying to the highway engineering profession and that portion of the public interested in the development of good roads and streets throughout the United States that Columbia University should have decided to establish graduate courses in highway engineering based upon a most comprehensive plan and the principles enunciated above.

The new graduate courses to be offered at Columbia next year will cover the field of subjects referred to previously in this paper, and will in amount be sufficient to satisfy the requirements for the Master's Degree. As the period of attendance will be from December to March inclusive, two periods of residence will be required to fulfill the requirements for the Degree.

The tentative arrangement of the graduate courses to be offered at Columbia University will be as follows:—

First Year.

Process of Industrial Chemistry.
Dynamical and Structural Geology.
Advanced Highway Engineering.
Materials of Highway Engineering.
Seminary in Current Highway Engineering Literature.
Lectures by Highway Engineers, Chemists and Other Experts.
Mechanical Appliances Used in Highway Engineering.
Highway Bridges and Culverts.
Road Surveying, Drafting and Designing.

Second Year.

Industrial Chemical Laboratory.
Lithology, Petrology and Petrography.
Advanced Highway Engineering.
Highway Laws and Systems of Administration.
Seminary in Current Highway Engineering Literature.
Lectures by Highway Engineers, Chemists and Other Experts.
Road Material Laboratory.
Management Engineering.
Street Surveying, Drafting and Designing.

As the special staff of instructors has been appointed and as the various laboratories required will be completely equipped in the near future all the advanced courses in highway engineering and allied subjects as outlined in the above schedule will be open to properly qualified persons next December.

It is of interest to note that this plan has the enthusiastic support of many of the foremost highway officials and engineers in the United States. All emphasize the feasibility of granting four months leave of absence to practically all the young civil engineers who wish to take graduate courses in highway engineering. It is the hope of those interested in the higher education of highway engineers in the United States that it will be possible in the near future to lay the foundation for the establishment of a corps of highway engineers comparable to that admirable body of trained men who have graduated from l'Ecole Nationale des Ponts et Chaussées of France.

FLUE SHEET CINDER FORMATION IN LOCOMOTIVES.*

Robert Job.

Flue sheet cinder is the technical name for a growth which forms, as the name implies, on the flue sheets of locomotive boilers, gradually covering the ends of the flues, unless laboriously removed by the fireman, and ultimately choking the draught. Under some conditions this formation never occurs, and an engine may run year in and year out without difficulty due to this source, but with certain changes the same locomotive may suddenly find a normal rate of steaming out of the question. The composition of these clinkers varies decidedly, and the following analyses of some taken from engines using different types of fuel, will give a general idea of the range which may be found:

	No. 1 Anthracite Coal. Per Cent.	No. 2 Bituminous Coal. Per Cent.
Silica	52.15	28.54
Alumina	34.51	12.30
Total Iron (figured as Fe_2O_3)	10.29	52.00
Total Sulphur (figured as SO_3)	0.81	4.30
Lime (CaO)	2.68	2.75
Magnesia (MgO)	0.27	0.40
	100.71	100.39

in these analyses the total iron has been figured for convenience to the sesquioxide, although a part existed in the ferrous state. Clinker No. 1 was of greenish color, while the other was of a deep red due to the higher proportion of iron and to its more complete oxidation. It is interesting to note that in most cases relatively little sulphur was presented in these clinkers, or "sulphur lumps," as they are often called, and the proportion of alkalis was usually low. The cinders were generally of a characteristic structure and examination under the microscope showed that they were built up of small dark-colored particles which had fused together, resulting in a dense though somewhat porous form. Under service conditions it may be almost impossible to remove these cinders from the flue sheet owing to the more or less plastic state caused by the high temperature of the firebox. When cool they are, however, rather brittle and break with a vitreous fracture.

It was evident that the quality of the coal was of great importance, and a large number of analyses were made of a representative sample of the coal used and of the cinder found on the same run when the formation occurred. On making a comparison it was found, in general, that the composition of the coal-ash corresponded with that of the cinder, but the percentage of iron in the cinder was always higher than in the ash from which the latter was composed. Moreover, the fact was generally developed that when the proportion of iron in the coal-ash was low, say, below about 1 per cent., or when the color of the ash was white or gray, no formation of cinder, or only a slight one, appeared upon the flue sheets, regardless of the proportion of ash present in the coal. In fact, no formation was observed with coal of this character even when the proportion of ash in the coal averaged over 25 per cent. Under these latter conditions the flues themselves became more or less choked with the light powdery white ash "sulphur dust," as the deposit is

* Abstract of a paper read before the American Society For Testing Materials at Atlantic City, June 27 to July 1, 1911.

formed, but it did not adhere to the flue sheet and no clinkering occurred. Analysis showed that the percentage of iron in these flue ashes was lower than that originally present in the coal-ash. In other words, the particles containing iron, being heavier, tended to remain behind and not to be drawn into the flues. It also developed that as the percentage of iron in the coal-ash increased, the tendency toward and the extent of the flue sheet cinder formation increased, beginning often when about 2 per cent. of iron was present in the ash. When the ash contained 2.5 per cent. of iron the clinker formation on the flue sheet was more marked, and it generally became excessive when the ash contained 5 per cent. of iron.

Throughout this paper the proportions of iron have been figured, unless otherwise stated, in terms of metallic iron (Fe) for convenience of comparison. In the course of the investigation it was thought that the excess of iron found in the cinder might be derived in some manner from the firebox itself, owing, perhaps, to the action of fumes or of moisture upon the steel, but investigation showed that under the ordinary condition of service pitting or corrosion of the sheets within the firebox or combustion chamber did not occur, thus proving that the iron in the clinkers was present originally in the coal and was concentrated in the clinker.

From the results of the study, it appeared that the formation of the flue sheet cinders was due principally to the presence of iron in the coal-ash in proportions exceeding about 2½ per cent. Also the actual building up of the cinder was readily understood when we considered that upon shaking the grates, or even by the jolting of the engine, fine particles of ash were loosened and were then easily drawn over to the flues by even a gentle draught. The high temperature of the firebox and combustion chamber brought these fine particles to a partially fused, pasty condition when they contained a fair proportion of iron, and on coming in contact with the flue sheet they adhered to it and were ready to hold the particles next drawn against them, thus gradually building up the clinker.

It was found in service that the clinker grew from the bottom of the flue sheet upward, this being due to the fact that the particles of oxide of iron which were relatively the more fusible, were also of course the heavier and were thus first drawn against and adhered to the lower part of the flue sheet. The cinder accumulated there until the lower flues were partly closed; the draught was then diverted upward and pasty particles of iron were carried higher and higher until the flues were more or less completely closed and combustion was seriously affected.

In the course of the investigation it was found that flue sheet cinders may not in some cases be produced even when the proportion of iron in the ash runs relatively high, the difference being due to the proportion of ash in the coal. When less than 10 or 12 per cent. of ash is present with the proportion of iron indicated above, the flue sheet cinders may be expected to form, but if with the same content of iron, the proportion of ash in the coal averages about 15 per cent., or more, the complaint is apt to be that the coal "has no heat," the reason being that so much clinker forms upon the grate that the draught is interfered with and this, in turn, prevents the particles of iron from being drawn and forced against the flue sheet to the same extent that would occur with a better draught. Also, owing to the lower temperature in the firebox under these conditions, the particles are not apt to be in a partly fused condition and they consequently merely collect in the flues but do not adhere to them.

Choking of the draught through the grates is especially liable to occur when the proportion of ash in the coal is very low, say, less than 5 per cent., with a high proportion of iron, as, for instance, 7 per cent., or more, and we know of cases under these conditions in which the clinker upon the grates was so fluid that it "ran like molasses," as the men said, sticking to the grate and effectively cutting off the draught. It has also been noted that flue sheet cinder formation is greater in simple than in compound engines, this being due to the fact that a large number of ash particles are drawn against the flue sheet under the stronger draught of the simple engine. Also the formation is much more rapid with wet coal than with dry, this condition being readily accounted for by the dissociation of the moisture in contact with the incandescent coals into oxygen and hydrogen gases which, in connection with the draught in the firebox, produce intense heat and fuse into cinder particles, ash which contains a relatively smaller proportion of iron than that which causes clinkering with dry fuel. Owing to this condition flue sheet clinker formation is apt to be more prevalent in the winter months than in the drier season.

From the general statement which has been made it will be clear that the formation of flue sheet cinders is an index of the fusibility of particles of the ash, and it might be thought that whatever would tend to decrease the melting point of the ash likewise might be expected to increase this type of cinder growth. The evidence obtained seems to indicate, however, that this does not necessarily follow, and the decided increase of iron which was found in the flue sheet cinders shows that this element has a large influence in promoting the formation. We have found as a matter of practice that flue sheet cinders can be avoided under ordinary conditions of service, by use of white ash coal, or coal in which the proportion of iron is less than 1.5 per cent. when figured as Fe.

The discussion was a brief experience meeting, in which it developed that, in some cases, the cinder formation had begun at the top of the tube sheet instead of at the bottom, a condition explained on the basis of the draught being greatest through the upper rows of tubes. It was also suggested that the condition of the ends of the tubes might also be a cause of an increase of cinder formation. For example, if the beading were to be burned off so as to leave a rough end projecting into the firebox, these rough places would afford a most efficient means of catching the particles of plastic cinder as they passed. The relationship between tube leakage and cinder formation was also touched upon, with the expressed and uncontradicted opinion that leakage was a cause of cinder formation rather than the reverse. For it had been found that, in some instances, tube leakage had stopped after the flue sheet cinder had been formed and been knocked off.

COLLAPSE OF VESUVIUS CONE.

The collapse of the big cone on the main crater of Vesuvius gives the volcano an uglier appearance than ever. Over 1,000 feet of its former majestic summit was blown off by the terrific Easter eruption in 1906, and now another 200 feet has been shorn off its height on the Naples side, and the mass which has tumbled into the crater has left a huge rent 350 yards long and close upon 100 yards wide, leaving the upper station of the funicular railway recently opened by Messrs. Cool, standing on the very verge of the abyss. Any fresh landslide must inevitably engulf the station. It will be realized, therefore, how narrow was the escape of the thirty tourists who were about to ascend to the crater when the collapse occurred. The adjacent towns of Resina and Portici have been smothered with dense smoke and showers of ashes.

THE INTERPRETATION OF WATER ANALYSES.*

In former years, when waters were judged merely from their chemical constituents, many serious misinterpretations of their sanitary quality were made. Waters of great bacterial purity were condemned because the free ammonia or nitrites were above certain standards and waters practically free from organic matters were given a clean bill of health, when they may have contained the germs of specific disease.

With our present knowledge of the subject, we examine carefully into all phases of the determinations and weigh each according to its merits. Water analysis has become year by year, more complicated and extended and now requires specialists to properly carry out the determinations necessary, but also, year by year, more light has been shed upon the true requirements for water from sanitary and from aesthetic standpoints.

In the days when to add a little silver nitrate to a water and note the amount and nature of the precipitate produced, was the means of examination, the matter was a simple one, but in the light of our present knowledge, it was entirely worthless. Now the analysis requires a specially equipped laboratory and a highly trained analyst to accomplish the result, and he must change and improve his methods, from year to year, to keep up with the constantly growing knowledge in relation to the very numerous diseases which may be transmitted by impure water supply.

Also in former years epidemics of intestinal diseases were almost invariably attributed to water supply. We now know that while they may come from water, they are as often, or perhaps more often, the result of the improper disposal of sewage and garbage, particularly in towns where there are still in use open privy vaults, exposed to flies, vermin, rats or mice, or where excreta is allowed to accumulate in open lots. A proper realization of these facts leads the sanitarian to less often attribute epidemics of intestinal diseases to water supply, particularly those occurring in the summer and fall, unless the proof is more positive than that which has often been taken.

There are four main divisions in the examination of water, namely: physical, chemical, microscopical and bacterial.

Physical Examination.—The physical examination includes the temperature, turbidity, color and odor. The temperature at the time of collection may give an indication as to the source of an underground water, whether shallow or deep, or in the case of a surface water, it may have a bearing on the number and kind of microscopic growths occurring or likely to occur in the water. It is, of course, important to keep down the temperature of water used for drinking purposes.

The turbidity is a measure of suspended matter. The figures represent the relative cloudiness of the water. This suspended matter, or turbidity, may be mineral, vegetable or animal in its nature and the chemical and biological results determine this point.

The color of the water may be affected by the turbidity so that strictly speaking, the water should be filtered before the color is taken, or the color may be stated filtered and unfiltered. The true color represents matter dissolved in the water and is usually lead or vegetable extract containing iron.

The odor of a water may be due to dissolved vegetable or animal matter, or may be due to microscopic plants or animals.

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* Paper by D. D. Jackson, read before American Water [illegible] ssociation.

Chemical Examination. — The chemical examination shows the products of living matter which are or have been in the water, such as the various forms of nitrogen present. It also shows the varieties of dissolved mineral matter which the water has taken up in passing over or through the soil.

The products of living matter which are still living or only partially oxidized, when extracted by the water, are represented by what is called nitrogen as albuminoid ammonia.

This nitrogen may come from microscopic plants or animals, from bacteria or from extracts of large plants or animals. Such extracts as come from the leaves or roots of trees and grass may dissolve in the water but be as harmless as is the colored organic matter in a cup of tea. Or it may come from animal contamination direct or from manured fields in which case it may be very harmful.

The nitrogen as free ammonia, nitrites or nitrates, represents what was originally albuminoid ammonia, which has been to a greater or lesser degree oxidized, the nitrates being the highest degree of oxidation and therefore showing contamination which has passed and become ineffective. Considerable amounts of nitrogen as free ammonia and nitrates d not necessarily show present contamination but may show merely a lack of proper oxidation or also the reduction of what has previously been nitrate. This sometimes occurs in deep wells where the oxygen content is low, or it may occur in the presence of a large amount of microscopic growth in the water. The sanitary quality of such waters should be judged chiefly from their bacterial contents.

The only other feature of the chemical analysis having a bearing on the sanitary quality of a water is the chlorine which may be found to be above the normal amount present in the region from which the water comes. If near the sea, the chlorine is high as it blows in as salt spray from the ocean and is precipitated in the rainfall of the region. On the Atlantic coast as far west as Ohio, lines of equal chlorine may be mapped out which are practically parallel to the coast line. The amount of common salt or chlorine in the water above the normal for the region is the amount which comes from the animal drainage and represents present or past contamination. Whether the contamination is past and therefore not effective may be shown from the rest of the analysis particularly from the bacterial results.

The total solids obtained by evaporating the water shows the total amount of mineral, vegetable and animal matter present. The loss on ignition is the vegetable and animal matter but may also represent some water and combined carbonic acid in mineral combination and the difference between the total solids and the loss on ignition represents the fixed solids or purely mineral matter.

Included in this purely mineral matter is the common salt before mentioned, the hardness, the alkalinity and the iron. The remainder, usually undetermined, is more often chiefly silica, but may have various mineral constituents.

The hardness or soap destroying power of the water is made up of lime and magnesium carbonates, sulphates, chlorides and nitrates, that is, the various lime and magnesium salts dissolved from the soil. The alkalinity consists of the carbonates alone.

The iron or manganese are determined to see that they do not occur in amounts sufficient to precipitate and cause an objectionable turbidity or the staining of clothes. Usually the iron is unobjectionable in amounts below 0.5 parts per million, while somewhat lower amounts of manganese may cause precipitation in the water.

Microscopical Examination. — Microscopical examination shows the number and kind of microscopic plants and animals in the water. These have a bearing only on the tastes and odors which they may develop. The animals or their eggs which may cause intestinal diseases are not at the present date distinguishable from other forms. In fecal matter many forms of disease, including cilliated and flagellated infusoria and various types of worms may be determined, but no work of this nature has as yet been developed in water analysis.

Certain of the common organisms produce strong tastes and odors in the water, due to the development of essential oils, while many other organisms even when occurring in large numbers do not cause more than a turbidity in the water. The microscopical plant growths may also increase the wash water where filters are used. They are all eliminated by proper treatment with copper sulphate, but some require larger doses than others to complete their removal.

Bacterial Examination.—The bacterial examination is all important in the sanitary analysis of water. The number of bacteria per cubic centimeter gives evidence of the quality of the water but the species of bacteria present is of most importance.

The intestinal bacteria are determined by a solution of oxgall peptone and lactose and the fermentation of this solution shows their presence; the dilution used giving an idea of their numbers. A low number may be admissible in surface waters, but B. coli should not often occur in as small an amount as one cubic centimeter. In ground waters no B. coli should occur.

The enormous numbers of B. coli which ordinarily occur in the fecal discharge of man and other warm blooded animals render the test for B. coli in water one of great delicacy. The bacterium is in itself entirely harmless but its occurrence shows the possibility of the presence of any one of the many forms of intestinal diseases, the germs of which would of necessity be accompanied by large numbers of B. coli. If the B. coli are numerous, the water is of suspicious character and tests may be made for the various species of specific disease bacteria such as the typhoid bacillus, the cholera spirillum, the dysentery bacillus or the series of spore forming bacteria which produce intestinal disturbances such as the B. welchii, N. sporogenes, B. edematis, etc., all of which may be isolated by a broth made from beef liver.

The animal infections and the spore forming bacteria are not affected by hypochlorite treatment in the dilutions ordinarily applied and are only removed by long storage or filtration.

These spore forming bacteria have been isolated by the author from several infected water supplies as well as from infected feces. They are particularly virulent among small children and much more stress will be placed upon them in the future than has been in the past.

From what has been said, it is evident that the bacterial examination of water is of decided importance and while the physical, chemical and microscopical examinations tell much about the condition of the water, the bacterial examination gives the strongest evidence as to its sanitary quality.

GAS-ELECTRIC MOTOR CARS.*

W. B. Potter, Chief Engineer Railway and Traction Department, General Electric Company.

The electric car meets certain transportation conditions where steam operation would be both unsatisfactory and uneconomical, and there are other conditions which, in the present state of the art, are undoubtedly better met by the steam locomotive. There are intermediate conditions where self-propelled cars are less expensive to operate than steam trains and where the investment for such cars would be considerably less than for complete electrification. In this latter class are many branch lines of steam roads and projected developments of new roads which might not at first justify electrical equipment. Recognizing this situation, efforts have been made to drive such a car with a self-contained boiler and engine, but without great success, as the performance is limited by restrictions imposed on the boiler capacity.

The development of the gasoline engine and its application to this class of work have resulted in marked success. The gasoline engine as a prime mover is essentially different from a steam engine in that it has no variable effective pressure in the cylinders such as may be secured by the variable cut-off of a steam engine. To secure the tractive force required for starting and to meet the changing requirements of speed and grade, it is necessary that some form of variable gear reduction be introduced between the engine and the driving wheels. To utilize the power of the gas engine to the best advantage it is essential to have a wide range of gearing. To a limited extent this can be secured by mechanical drives, with different sets of gears, as commonly used in automobiles. But the mechanical drive cannot, within practical limits, be provided with the desirable manner of gear changes, and it also subjects the engines and driving mechanism to a severe strain by reason of the mechanical shock resulting from the use of a clutch.

The electric drive may seem a refinement, but its advantage will be appreciated when it is recognized that the engine may be driven at its most advantageous speed, independent of the speed of the car, and that the tractive force, without changing the speed of the engine, may be varied from what is required to accelerate the car to that required to drive it at 60 m.p.h. This change in tractive force and speed is accomplished smoothly, and without shock to the mechanism throughout the entire range. As an illustration, the electric drive makes it possible to develop a tractive force of 10,000 lb. at m.p.h. and, without manipulating anything other than the electric controller, to propel the car at 60 m.p.h.

The gas-electric equipment referred to consists of an eight-cylinder, 8-in. x 10-in. gasoline engine, driving an electric generator. The forward truck underneath the engine is equipped with two 600-volt standard railway motors. The weight on the driving wheels effective for traction is about two-thirds the total weight of the car. The movement of the car is controlled by varying the voltage of the generator, combined with series-parallel connection of the motors. The engine control is provided with a combination air valve and gas throttle by which the engine is started on compressed air, and as soon as it begins running on gasoline the air is shut off. With this arrangement, the engine need be run only when propelling the car. Three or four seconds only elapse between the time at which the air for starting is admitted to the engine and the movement of the car, so no perceptible delay is occasioned by stopping the main engine at the station.

The car is lighted by a small two-cylinder gasoline engine which drives a lighting machine. The small engine is also fitted with an air compressor cylinder to charge the air tanks for starting the main engine on its first run. The latter is provided with an air compressor, which maintains a pressure when the car is once in operation.

A demonstration car of this type has been operating for the past two years, carrying passengers on railroads in different parts of the country, and at the present time there are seven cars in regular service. A grade of gasoline satisfactory for the operation of these cars can be purchased for from 6 cents to 7 cents per gallon. The gasoline tanks will

* Abstract of a paper read at the annual meeting of the Street Railway Association of the State of New York.

hold 150 gal., sufficient for at least 200 miles on one filling. The gasoline consumption, per car mile, for cars weighing from 40 tons to 50 tons will vary from 0.5 gal. to 0.7 gal., according to the service conditions. On this basis for fuel, an estimated cost of operation per car mile, based on experience, is as follows:—

Gasoline	$0.05
Supplies	.01
Maintenance (car body and trucks)	.01
Maintenance (engine and electrical equipment)	.03
Engineer, conductor and cleaning	.07*
	$0.17

The car bodies are similar in respect to the engine compartment, the remainder of the interior and the entrances being modified to meet different requirements.

It is preferable that the cars be operated as independent units rather than to haul trailers, but as they are fitted with automatic air brakes, as well as straight-air, and with M. C. B. couplers, they can be used for trailer work, though at reduced speed.

The seats are nearly 4 ft. long, and, not having arms, it is possible for three people comfortably to occupy one seat. The aisle is narrower than in steam practice, though wider than in many trolley cars. The largest cars at present under construction are 70 ft. long and 10 ft. 5 in. wide over all.

The width, inside measurement, is 9 ft. 6 in. This car, with a 6-ft. baggage compartment and allowing three passengers per seat, will seat ninety-eight passengers, and it is practically a complete train within itself. Such a car would have a maximum speed of about 50 m.p.h. on level track, and a scheduled speed of 25 m.p.h. with stops 2½ miles apart.

There are undoubtedly many lines now operated by steam, which under existing conditions are unprofitable, on account of both high operating expense and small receipts, but on which the traffic would be very much increased by a more frequent service and a pleasanter mode of travel.

The self-propelled gas-electric car seems to fulfil these requirements at less cost than by steam and so accomplishes the double purpose of a better and cheaper mode of transportation.

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* This item, in particular, will vary with the mileage and wages paid.

The Electric Smelting of Iron.—According to a statement attributed to the Aktiebolaget Elektrometall, of Ludvika, the cost of producing electric pig-iron at Swedish hydroelectric works, where the annual cost per kilowatt ranges from £1 18s. 8d. to £2 15s. 2d., is from 5s. 6d. to 11s. per ton cheaper than pig-iron made in the blast furnace. At the end of this year there will be four electric furnaces of the Elektrometall type in operation in three different places in Sweden of a total capacity of 12,500 h.p., and an output of 35,000 tons of pig-iron per annum. Several undertakings have also been formed in Norway for the electrical production of iron and steel, and a resuscitation of this industry is expected in that country. The Hardanger Elektriske Staalverk is erecting two furnaces, each of 2,900 h.p., and a steel furnace of 800 h.p.; and similar and large installations are being established by the Tinfors Jernoers Aktieselskab, the Stavanger Staalverk and the Arendals Fosse Company. The production of electric steel is also said to have good prospects in store. If the pig-iron made first in the electric furnace is placed in a gas-heated mixer, and then refined in the electric steel furnace, the product is declared not to be inferior to the best open-hearth steel.

PREVENTION OF HORIZONTAL CRACKS IN CONCRETE STANDPIPES.

The regular appearance of a horizontal crack in the lower part of concrete standpipes has been the cause for the statement that to date only one absolutely watertight reinforced concrete structure of this kind has been built. In a recent paper presented before the Boston Society of Civil Engineers, Leonard C. Wason, president of the Aberthaw Construction Company, of Boston, gave a thorough discussion of this problem and suggested methods that would materially diminish the leakage.

In the course of his remarks he stated that from his experience with the Attleboro, Mass., standpipe, and with that at Westerly, R. I., later, he believed that the addition of considerable vertical reinforcement in the lower 8 or 10 ft. of the standpipe wall, the ends of which are turned out and bonded well into the floor, would assist very materially, and perhaps entirely obviate the formation of a horizontal crack in the lower 10 ft. of a standpipe.

It is obvious that under water pressure the walls, owing to the deformation of the steel, must increase in circumference, and the entire tank increases in diameter in proportion. At the bottom of the standpipe, however, owing to the rigid connection of the wall with the floor, this increase in diameter cannot take place. This rigidity extends a short distance upward to the point where compression on floor changes to tension in wall. At the finish of a day's work, near bottom of tank at or quite close to the plane of weakness above indicated, there may be a direct movement outward of the wall above relatively to that below the joint under pressure. When the pressure is relieved the elasticity of the hoops would tend to draw the wall back to its original position.

It is apparent then, that unless precautions are taken, either by the use of very low stresses in the hoops, or by the addition of vertical steel bars, there may be a distinct movement back and forth on some joint in the standpipe. That this movement is present is further indicated by the fact that when a standpipe has been kept full of water for some time, the leakage through these joints almost entirely disappears, but on emptying the standpipe and re-filling it the little dams formed have apparently been broken down, as the leakage again occurs as vigorously as at first.

In the Westerly, R. I., standpipe they endeavored to take care of this by increasing the amount of steel. At the lowest foot the stress was 6,000 lb. for each foot in height until they reached a maximum stress of about 12,500 lb. per sq. in. No vertical steel, however, was used, and on filling the standpipe they found with the maximum head of water that a small line of dampness occurred in a horizontal joint about 3½ ft. above the floor of the tank. This damp place was nearly 30 ft. long.

The construction of this standpipe was described in detail in Concrete Engineering of September, 1910. The bottom slab was 44 ft. in diameter, 12 in. thick, reinforced with a matting of ¼ in. rods spaced 6 ins. on centers, running both ways, 2 ins. below the top of the concrete. The walls are 4 ft. thick at the slab, with a batter of 2 ft. 5 ins. on the inside, and a step-in of 10 ins. at the water table, the ultimate wall thickness of 14 ins. being reached at a point 5 ft. above the top of the floor slab, and remaining at this thickness for the entire height.

The wall reinforcing consisted of 12 vertical 1½ in. pipe columns, made in 3 sections, connected by ordinary, pipe couplings spaced equi distant and extending from the bottom of the floor slab to the cornice. These pipe columns have drilled in them ¼-in. holes, spaced the proper distance apart for attaching the horizontal reinforcing rods. These rods consist of 50 1½ in. bars in the first 10 ft. from the base, 30 1¼ in. bars in the second 10 ft., then 25 1½ in. bars, 34 1⅛ in., 25 1⅛ in., 15 1½ in., and 10 1⅛ in., in each succeeding 10 ft.

The wall reinforcement is very heavy, and seems to have succeeded in preventing leakage.

STATE OF TENNESSEE STATE GEOLOGICAL SURVEY.

Geo. H. Ashley, State Geologist.

Press Bulletin No. 18—Tennessee's Resources Told in Pictures.

In this day and age when people write in short hand they more and more want to read in pictures, unless the matter is one in which they have already become interested. Taking this view of the case, the State Geological Survey has supplemented the bulletins it has been issuing, which are intended primarily to have information when information is wanted or requested, by a little bulletin describing very briefly the resources of the State, but telling the story largely through photographs. This is intended to interest the man who is now not interested, but who may become interested, and through that interest may ultimately move to Tennessee or invest in Tennessee. Nor is this report intended for the people outside of the State. Very few Tennesseans realize the advantages, the wealth, the development or the future possibilities of their own State. If they did, there would be more boosting for Tennessee, there would be less moving to Oklahoma, there would be less need for the "back home" movement, there would be fewer Tennessee capitalists looking to Texas or New York or other places for investment.

The new bulletin is quite comprehensive in its scope, describing not only the various mineral resources, but also the soils, the forests, the topography, climate, transportation facilities, etc., even citing the State's wealth, its debt, tax rate, etc. It not only says that Tennessee is a pleasant place to live, but it shows by selected pictures from the several sections of the State that it is. It not only says the cities are progressive and busy, but it shows by pictures, buildings, homes, parks, business sections, wharves, etc. that the cities are busy, up-to-date and attractive. Attractive pictures of good roads and other country scenes show some of the phases of country life. The forest resources are illustrated by cuts taken from the flank of the Great Smokies to the bottom of the Mississippi. Tennessee happens to have a number of industrial plants that are the largest of their kind south of the Ohio River. Several of these are pictured in illustrating those industries. Pictures are also given of chert, limestone and marble quarries, of coal, iron and other mines, and iron foundries, copper smelters, etc.

On the whole one can hardly look through the bulletin, even though he does not have time to read it, without gaining the general idea that Tennessee is a pleasant land, beautiful in its physiographic aspect, a good place to live, rich in many kinds of resources, and that those resources are being developed on a more or less large scale. In addition to showing what already exists here, or is being done, the bulletin especially calls attention to opportunities for further expansion or for further development, either in agricultural development or in exploiting the State's wealth of minerals. It states that many of the mineral resources have hardly yet been scratched, and only awaiting capital to become the source of much profit. It calls attention to the fact that the opening of the Panama Canal is going to prove a gate-way to the west coast of both North and South America and to all of the Orient and that in the new tide of commerce, which will take advantage of that gate, the South, from its geographic position, has a great advantage over its more northern neighbors. As Tennessee is probably the richest State of the South, both in its mineral and non-mineral resources, Tennessee ought to see a phenomenal growth during the next ten years. But it is first going to be necessary that the people of Tennessee, as well as those outside, realize the opportunities awaiting investment and labor, and take advantage of those opportunities.

While the Geological Survey work will consist primarily in obtaining accurate information about the various resources of the State, and then in supplying that information to those who may request it, it believes that it is also part of its work to call attention to those resources in a way that would interest both people and capital, whether they are now interested or not.

The bulletin has been attractively printed on calendered paper and reflects credit upon the printer, Brandon Printing Company, of Nashville. It can be obtained by applying to the State Geologist, Capitol Annex, Nashville, or upon request accompanied by two cents in postage from those outside of Nashville.

TEMPERATURE.

The mean temperature of June was above the average from the Rocky Mountains to Lake Superior, also over the greater part of Quebec and the Maritime Provinces. In Western Ontario the average was exceeded in a few localities, while in others it was slightly below. In Eastern Ontario and over British Columbia negative departures of 1 to 4 degrees were recorded. The chief positive departures were recorded in the Western Provinces, and ranged from 3 to 5 degrees.

General Notes.

The table shows for fifteen stations, included in the report of the Meteorological Office, Toronto, the total precipitation of these stations for June, 1911:—

	Depth in inches.	Departure from the average of twenty years.
Calgary, Alta.	2.60	— 0.67
Edmonton, Alta.	3.80	+ 0.39
Swift Current, Sask.	2.70	— 0.35
Winnipeg, Man.	2.30	— 1.14
Port Stanley, Ont.	1.80	— 0.91
Toronto, Ont.	1.52	— 1.27
Parry Sound, Ont.	0.70	— 2.26
Ottawa, Ont.	3.10	— 0.65
Kingston, Ont.	3.50	+ 0.30
Montreal, Que.	4.40	+ 0.38
Quebec, Que.	3.80	— 0.50
Chatham, N.B.	5.40	+ 2.37
Halifax, N.S.	2.90	— 1.00
Victoria, B.C.	0.70	— 0.26
Kamloops, B.C.	0.20	— 1.08

South Australia is well endowed with minerals, but, beyond the output of a large quantity of copper, little has been done to exploit the underground wealth. In the mineral-bearing country of the north-western portion of the state, at Tarcoola, mining operations have been conducted for some time with satisfactory results.

A COLUMN FAILURE.

The disastrous collapse of a gas-holder, which occurred in Hamburg in December, 1909, has created considerable stir among German engineers. The accident killed thirteen people at once and injured forty-seven, some so severely that seven more died. A judicial inquiry was opened, and the contractors were proceeded against; but the Public Prosecutor finally withdrew his charge on the strength of the expert evidence. The several experts agreed that the cause of the accident was not an explosion, nor any other special elementary phenomenon. They unanimously ascribed the collapse to insufficient strength of the structure. They did not hold the contractors responsible, however, because the contractors had merely done what was fairly common practice —i.e., applied Euler's column formula without restrictions. It would appear that the rules drawn up by the German authorities do not sufficiently specify the conditions under which Euler's formula may be applied; the experts were hence inclined to exonerate the contractors, and the proceedings were abandoned. Though the case does not convey any particular lesson to British engineers, it offers some instructive features.

The gas-holder in question had a capacity of 200,000 cub. m. (about 7,000,000 cub. ft.), and it was erected at the Grasbrook gas works of Hamburg. The local conditions made it desirable that the coal-trucks should be able to pass underneath the gas-holder, which was therefore based on an iron structure, consisting of a central column and radial girders, resting upon concrete. The work was entrusted to an experienced firm. By October, 1909, the gas-holder was ready to receive an experimental air-charge, and in the last days of November gas was being supplied from the holder. The quality of the gas has not been questioned. The accident happened on the afternoon of December 7, when the gas-holder had been working satisfactorily for more than a week. The gas-holder was rising at the moment, engaging with the second section, it is believed. The understructure gave way, the escaping gas caught fire, and the gas-holder, after being twice lifted several yards, crushed down, destroying the whole structure.

The experts were well-known men. Director-General Koerting and Director Schimming, gas engineers, of Berlin, and Dr.-Ing. Krohn, of Danzig, were called by the prosecution, the latter to explain the iron structure. The contractors cited Professors Müller-Breslau and Boost, of Charlottenburg. A report of the whole case has recently been published by the Deputation for Illumination of the State of Hamburg. The opinion which we outlined above was, in particular, that of Professor Krohn. Professor Müller-Breslau expressed himself to the following effect:—"It must not be concealed that the exclusive use, favored by most engineers, of Euler's column formula, in conjunction with the practice of regarding as one member two members connected at intervals by cross-plates—a method which is not forbidden by the existing official regulations—may lead to systems of construction in which there is no sufficient guarantee against excessive stresses under exceptional loads."

The ruptured member in question was 11.1 ft. long, c. to c. of end connections, and was designed to carry a maximum compression of 118,000 lbs. The city's expert estimated that at the time of collapse it may have borne a load of 133,000 lbs., taking account of all unfavorable circumstances.

This strut consisted of two 6.3-in. channels (German standard channels No. 16) back to back, 1-in. apart. The combined sectional area of both channels was 7.4 sq. ins. They were not latticed, but merely tie-plated at intervals of 40 ins., by plates 6 x 5/16-in. by 5½ ins. long; these plates were attached by four 13/16-in. rivets. If the column section be assumed to be integral, its least radius of gyration is 1.44 ins.; the least radius of a single channel is 0.74-in.

It may be noted that the mean load per square inch of section at the time of failure was just 18,000 lbs. per sq. in., according to the expert's assumption, or 15,900 lbs. per sq. in. according to the designer's assumptions. In connection herewith, the length conditions must be remembered: For the length between tie-plates (38 ins. clear), l/r for one channel was 51. For the whole length of the strut, considering the section as integral, the value of l/r was 93. Any partial fixity due to the end connection would reduce the latter ratio, but as the tie-plated aggregation is very much less rigid than a truly integral section the equivalent l/r was doubtless much greater.

The designer, it appears, proportioned by Euler's formula, as follows: Taking the full length as free, but considering the section as integral, the buckling load is found from this formula as 260,000 lbs., or about 35,000 lbs. per sq. in. But the designer figured on end constraint, and used in the formula only seven-tenths of the actual c. to c. length; by this change, the buckling load from the formula is multiplied by $(10/7)_2$ or is practically doubled, giving an apparent total capacity of 520,000 lbs.; i.e., a strength of 70,000 lbs. per sq. in. A factor-of-safety of 4 was sought for, and the above ridiculous result was interpreted as showing that this factor was obtained.

It is well understood that a compression test has not the same general value as a tension test. Two similarly conducted tension tests may be relied upon to give very fairly similar results with similar specimens. This does not hold with compression tests, which may be vitiated by a slight deviation of the member from straightness. When such a deviation exists, or has developed, it is no longer the crippling strength which comes into question. That may have been the case at Hamburg. But there are other considerations. Euler's formula presumes stresses well below the limit of proportionality. The contractors had made their design for a fourfold factor of safety. That would have been ample, but the report proves plainly that nothing of the kind was realized. In the first instance the contractors had in their calculations taken 0.7 of the length of the members as equivalent to the free length, considering the ends of the members as fixed. This procedure is criticized by the experts; but it was not the most important point. Euler's formula should not have been applied at all in this case. Most German engineers of standing agree with Tetmajer that Euler's formula is applicable only so long as the quotient of the length of the member divided by the smallest radius of inertia exceeds the value 105. In the case of the member the failure of which seems to have started the collapse, this quotient was only 93. Further—and this is the point emphasized by Professor Müller-Breslau—the member was not a single unit, but it consisted of two members, which, instead of being properly braced and triangulated, were imperfectly stiffened by flat plates riveted at intervals. The results of this reprehensible practice were clearly discernible, for the plates were found to have given way along the rivet lines, and some of the rivets had been shorn off. If the stiffening had been perfect, the real factor of safety would, it is calculated, have been about 1.25. That was low enough, but there was really no safety at all under the actual circumstances. The deplorable accident must hence be regarded as due to want of foresight.

The Canadian Engineer

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CONTENTS OF THIS ISSUE.

EDUCATION AND TRAINING OF ENGINEERS.

At a recent conference convened by the Institution of Civil Engineers (England) on the Education and Training of Engineers, many papers were read and a large number of opinions given in the discussion bearing on the subject of the convention. The consensus of opinion seemed to be that there was only one place in which to learn the actual engineering practice, and that was out in practical life. This, of course, is a well-accepted principle; but there is always more or less variance of opinion as to how much of the practical can be taught in the college, and to what extent the student should specialize.

The following extract from a paper read by Professor A. Barr, M. Inst. C.E., brings out a point of view that is too often lost sight of in the present day rush and hurry:—

"The end to be kept in view in a college course is the education of the student, and the result is to be measured not by the amount of detailed knowledge he has gained, but by the extent to which his mind has been developed, and by the insight he has gained into the principles underlying successful practice. If I may state my own view, it is that little specialization should be attempted, if for no other reason than that the young engineer, if he has the elements of success in him, cannot foresee the trend his career will take. The best college course is the one that is most educational, and this will be the course that gives the student the broadest outlook upon his profession. It need deal little with the details of specialized practice; these can best be learned in the workshop, the field or the drawing office.

Other things being equal, a man who has had a practical training is better able to benefit by a course of study in engineering science; and on the other hand. a man who has had a sound training in science is in a better position to take full advantage of his apprenticeship or pupilage. But he cannot have it both ways. In favor of taking the college course first, and pupilage or apprenticeship after graduation, it may be urged, with good reason, that by securing continuity in the pupil's education, the danger of his losing the habit of systematic study, and his grip of what he has already learned at school, is avoided. Further, he will enter on his practical training with his mind disciplined and developed by his study of science, and experience comes most quickly, and with most lasting effect, to one who can place each item, as it presents itself, in its proper place in a connected system of knowledge based upon general laws, the workings of which he has learned to recognize."

ELECTRIC FURNACE PROGRESS.

It is but a short time since results of tests on the electro thermic reduction of Canadian iron ores were published. Since then and now, a period of five years or so, such rapid progress has been made in electro-metallurgy that, whereas the results referred to were perhaps satisfactory in a theoretical way, but hardly indicative of any near commercial possibility, yet present-day indications are such that in certain localities, notably Sweden, the electric furnace for reducing iron ores has been brought to the position of an actual commercial possibility.

This is a subject that is of vital interest to Canada, with its large possibilities in water power, and consequent cheap electric energy. There are in Canada large undeveloped areas of iron ore, undeveloped because of their nature, which renders the ore unsuitable for ordinary blast furnace practice. If these ore beds are to be touched at all, it must be by means of electro-thermic methods. Then, of course, there is always the question, as far as Canada is concerned, of the lack of suitable coal for coking purposes near enough to the ore beds to make the smelting of our iron ore a reasonable business proposition. Looked at from every possible angle, the electric smelting proposition takes on definite possibilities in certain fields, but it must always be remembered that just as the horse was said to be doomed when the automobile was perfected, so with the iron and steel industry, there is no immediate question of the decrease of the present day methods as some optimists would have one believe.

In this issue there are several articles dealing with this branch of the steel industry, and while such information is necessarily of more importance to the metallurgist, yet the subject is one that should at least be in the minds of all engineers in Canada to a certain extent. The articles referred to are not of such a technical nature as to be tiresome to the general reader.

The Grönwall steel furnace, described in one of the above-referred-to articles, is one which is the outcome of the work of a small group of men in Sweden, which country has been very successful in its electric furnace propositions. This furnace is typical in its construction of a few of the present day successful electric steel furnaces, although, of course, it has distinctive features, which are very clearly brought out in the description. The information given with reference to this furnace is from actual experience, Mr. Robertson having spent considerable time in Sweden with the firm of inventors. The point that this is first-hand information cannot be too greatly emphasized, as there is a great deal of matter published which is more or less conjecture on the part of the writers.

A PROFESSIONAL CODE AND SCHEDULE OF FEES.

In our last issue there appeared a report of the American Institute of Consulting Engineers on a Professional Code and Schedule of Fees for Consulting Engineers. This article came in too late for editorial comment in that issue, but the subject is of too much importance to pass without some reference.

It has always been one of the prime objects of technical societies to keep before the members of the engineering profession the importance of certain features relative to conduct in professional matters. The question of a schedule of fees, however, has been always a more or less sidetracked issue, so that in consequence the American Institute of Consulting Engineers is to be congratulated in having formulated a general guide for determining fees for professional services.

Although there is bound to be more or less variance in opinion on such a question as that of a proper schedule of fees, yet the guide referred to is drawn up in such a manner as to be sufficiently elastic to meet any unforeseen contingencies that might arise. Coming from the source that it does, even if not generally accepted, this schedule is of great value if looked upon as only an expression of opinion.

EDITORIAL COMMENT.

The Wagner Electric Manufacturing Company, of Saint Louis, announces the formation of the Wagner Electric Manufacturing Company, Limited, of Canada, under a Dominion charter, with a capital stock of $50,000, fully paid. The Canadian corporation becomes the exclusive Canadian licensee under patents owned and controlled by the Saint Louis company, which has granted exclusive manufacturing and sales rights for the full output of the Saint Louis company. Mr. Alfred Collyer, who for many years, as representative of Wagner interests in Canada, is largely responsible for the volume of Wagner business here, has been appointed manager of sales of the new company. Various of the alternating current apparatus in which the Wagner Company specialize, including the new unity power factor and adjustable speed motors, have been patented in Canada, and the new Canadian Wagner Company will proceed to manufacture and popularize these in Canada along the same lines as the Saint Louis Company does in the United States. It is expected that manufacture will begin within the current year. The officers of the new company besides Mr. Collyer are: S. M. Dodd, president; W. A. Layman, vice-president and general manager; W. S. Thomas, treasurer. The previous headquarters of the Wagner Electric Manufacturing Company in the Bell Telephone Building, Montreal, becomes the headquarters of the new company.

* * * *

Are you interested in electricity? If you are, you will find at the Canadian National Exhibition every device of which the great white power has been made the servant of man. The Hydro-Electric will have a special display, and independent concerns are clamoring for space to show the public the value of their inventions. It is the electric age. Between fifteen and twenty thousand electric lights are what the Hydro-Electric people are using to make the Canadian National Exhibition Park a blaze of light during the coming Exhibition.

* * * *

At a recent meeting of the Irish Roads Congress the following was pointed out with reference to good roads maintenance: The three guiding principles of the greatest importance: (1) The best materials are generally the cheapest, and it pays to carry them considerable distances; (2) the vital necessity in the economical administration of roads is skilled and faithful supervision, and it is a most wasteful policy to underpay the supervising officers and to give them districts of excessive size; and (3) careful detailed accounts should be kept of all road costs. These principles are by no means new, but sometimes they require repetition.

Editor, Canadian Engineer:—

Sir,—We notice on page 810 of your issue of June 8th that the Simplex Valve and Meter Company are credited as being the originators of a device for adding hypochlorite or other solution to water flowing under pressure. This apparatus was patented by us in 1909, and is in use by us, and has been illustrated and made public We thought you ought to be made aware of this, and should be glad if you would make this public in your next issue.

Yours faithfully

For THE CANDY FILTER CO., LTD.

F. Pullen Candy.

THE EXAMINATION OF DRINKING WATER.

The science of bacteriology, though a member of the younger and more recent sciences, nevertheless is a vast subject, and it will be possible to confine this article to a few remarks regarding bacteria in general with the method of their determination in water.

A glance at Fig. 3 will show the microscopic appearance of the three great classes in the bacteriological field: (a) Globular forms, called cocci. (b) Straight rod forms, called bacilli. (c) Curved or spiral rods, known as Spirilla. These micro-organisms have an average diameter 0.001 mm., written IU. The cell is composed of a membraneous cell-wall and cell contents. A centre, or nucleus, of the mass is not found.

To cultivate bacteria from water there will be required: Shallow glass dishes (petri dishes), bent tubes, one end sealed (fermentation tubes), pipette graduated in .1 c.c., a means of sterilization,* cotton wool, test tubes, culture media, an incubator, sulphuric acid. To this might be added (though not essential) a microscope with an abbe condenser with iris diaphragm and an oil immersion objective.

The culture media will consist of nutrient gelatine, dextrose bouillon peptone solution.

To make nutrient gelatine, take one-half pound lean beef and run through a good mincer, or chop fine by other means. Cover with about 18 ounces of distilled water and allow

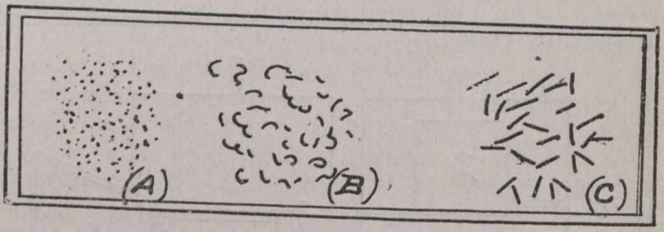


Fig. 3.

to soak, covered, for 12 hours. Strain the liquid thus obtained through cloth, and, after making up to one litre, add 120 grammes gelatine and 10 grammes peptone. Heat in an oatmeal boiler or water bath until gelatine dissolves, and add the white of an egg, previously shaken with its own bulk of distilled water. Cover the mixture and keep the water in the bath boiling for a half hour. Filter by means of a hot water funnel, or through a filter previously heated. If the latter method is chosen, a much smaller bulk of media will be secured. The clear liquid must now be neutralized with sodium carbonate (saturated solution). It should be distinctly blue to litmus paper, but an excess of alkalinity must be avoided. When neutralized pour the media into test tubes, close with cotton plugs, and sterilize for fifteen minutes on three successive days in the sterilizer. This and all media should be stored in a cool, dark, damp box. Three grammes of Liebig's beef extract may be used in place of the half pound of beef.

For a bacteria count, the nutrient gelatine possesses many advantages over agar-agar, and is to be preferred in growing colonies from the individual bacteria present in a water undergoing examination.

In making a media for the fermentation tubes (dextrose bouillon should be employed), Liebig's beef extract, 3 grammes, is placed in 1 litre distilled water. Add 10 grammes peptone and 10 grammes dextrose. Heat in the oatmeal boiler or water bath, adding the white of an egg should the mixture not be clear. Bring to boil, omitting stirring, and, if necessary, filter while hot. If preferred, lactose may be substituted for dextrose with equal results. The water to be examined should be embedded in the culture media with all possible speed after collecting, as the bacteria increase in astounding manner when standing or being transported in glass jars. It is usual to surround the container with ice, but no reliable information may be obtained from a count in the petri dishes after the water has been encased for eighteen or twenty hours. The greater number of bacteriologists prefer gelatine over agar-agar as a media in counting colonies, but an advantage may be cited for agar which gelatine does not possess. Agar-agar (which is made in a similar manner to nutrient gelatine, employing 12 grammes of agar to replace the 120 grammes gelatine) has a much higher melting point than nutrient gelatine, and may often be used to advantage in inoculating with the water immediately upon collection.

When the sample is obtained, .1 c.c. is measured into the sterile petri dish by means of a sterile pipette, and the gelatine poured over it by first placing the tube in hot water. The cover is placed on the dish, and, after cooling to solidify the media, the dish is maintained in a cold, damp, dark

Fig. 4.

incubator for 48 hours at a temperature of 20° C. Each bacterium, finding itself embedded in a condition congenial to existence and surrounded by plenty, proceeds to found a colony of sufficient size to be easily seen by the unaided eye in from two to four days, as shown in Fig. 4.

Of course, all bacteria present in the sample will found colonies, and from a glance at the dish it would be difficult to make a statement regarding the presence or absence of bacteria of the colon group. To determine the presence of this group 1 c.c. of the sample is placed in the dextrose media contained in a fermentation tube, as shown at Fig. 5.

The bacteria of the colon group are among that class known as acid-formers and gas-producers, and the water is placed in the dextrose media to allow a collection of the

*The Arnold steam sterilizer is to be recommended for this purpose. A good one may be obtained for $2 from dealers in physicians' supplies.

gases to be obtained. The tube and media, after being inoculated and plugged with cotton, is placed in the incubator for three days at a temperature of 38° C. or thereabouts.

If B. coli is present in considerable quantities the upper end of the tube will be about half full of gas in this time. This gas, if formed by the presence of B. coli, will be readily analysed, quantitatively, consisting generally of CO_2 and H in the ratio of 1:2. To determine the composition of this gas a mark is made with a crayon or pen and India ink, showing the portion of the tube where the liquid ends. A few drops of a 10 per cent. solution caustic potash (KOH) placed in the tube and tilted several times (closing the open end with the thumb) will absorb the CO_2, the liquid rising. The hydrogen, after being transferred to the end held by the thumb, may be fired over a small spirit lamp or burner.

B. Coli has the property of forming indol (C_8H_7N). It is formed by the breaking up of peptone by the action of putrefactive bacteria.

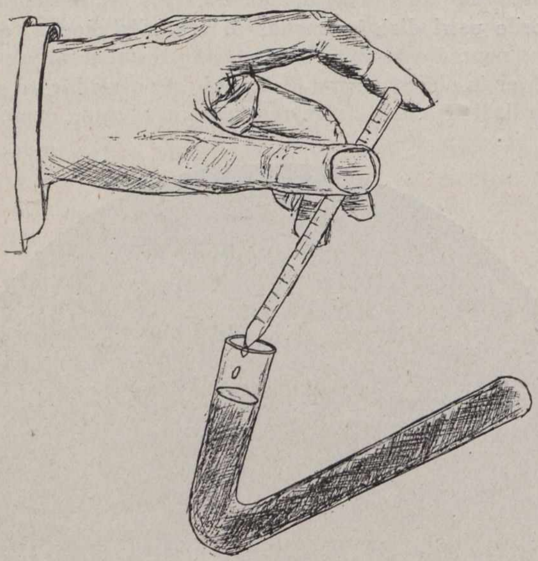


Fig. 5.

To test for the presence of indol, place 20 c.c. of the water with 50 c.c. of a sterile solution of peptone (10 grammes peptone, 1 litre water) in a test tube and transfer to the incubator for four days at 38° to 40° C. At this temperature common water bacteria will succumb, but bacteria of the colon group will be encouraged.

Place 2 CO strong sulphuric acid and 2 c.c. of sodium nitrate solution (0.75 gramme to the litre) in a clean flask. Dilute with 50 c.c. of distilled water and add the solution from the test tube in the incubator. A red coloration forming within a few minutes shows the presence of indol, which is more evidence of the presence of B. Coli.

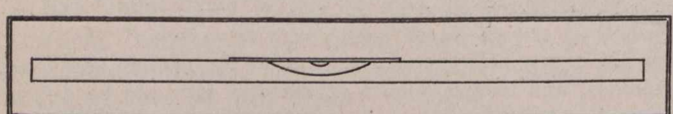


Fig. 6.

B. Coli has slight power of motility, and this feature may be seen by examining in a hanging drop culture. To make this, a glass slide will be required with a cavity in the centre and an extremely thin cover glass. A drop of sterile nutrient gelatine is inoculated with a sterile needle from the tube used in the indol test. After smearing the edge of the cover glass with vaseline the slide is placed over the drop and then turned right side uppermost, as shown in Fig. 6. This is placed in the incubator for a day or two, and then examined with a high power microscope. This motility is best seen by having only a portion of the bacilli present in the field.

In summing up a determination for the presence of B. Coli, should the following conditions exist the presence of bacteria of this order is to be presumed:—

1. Gas in fermentation tube.
2. Gas, about 30 per cent. CO_2 (not exceeding 50 per cent.).
3. Gas, nearly all formed during first twenty-four hours.
4. Hanging drop shows motility.
5. Indol formed from peptone solution.

The operator or experimenter must be duly cautious in making bacteriological investigations to have everything he uses sterile. The dishes and tubes may be sterilized by exposure to a strong, dry heat for a few minutes. In cleansing dishes and tubes the best disinfectant to use is mercuric chloride ($HgCl_2$). Care must be taken to remove all traces, as this chemical, even in minute quantities, will stop organic growth.

If the experimenter wishes to expend the money for a first-class incubator, he will have the means at hand to obtain first-class cultures, but a good incubator with a

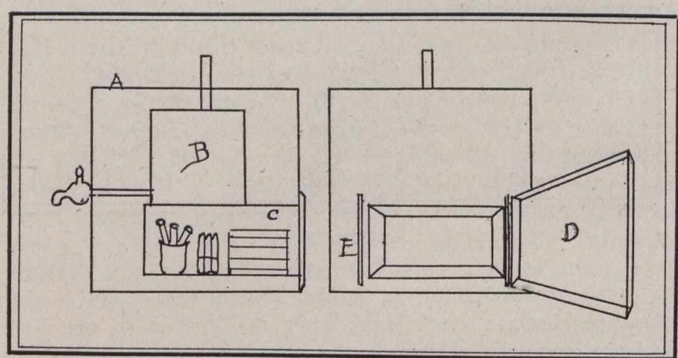


Fig. 7.

reliable thermostat comes to a considerable sum. Some surprising results may be obtained by constructing an incubator as shown in Fig. 7. A is an outer casing, 14 x 14 x 14 in. B is a watertight compartment, 6 x 6 in., soldered to C, which may be any convenient size, if allowance is made for an air space all around excepting the front, which is covered by a door (D), bevelled outward to allow a darkened glass to be slid in the tracks (E) from above. A tube leads into B from the top, and a tapped tube permits the water to be drawn off. The space not occupied by the various compartments is filled with dry sawdust. To operate this incubator, boiling water is poured through and allowed to remain in the can for twelve hours. This, of course, imparts its heat to the surrounding sawdust, which will maintain a constant temperature for hours. To cool the incubator open the door. An experimental incubator constructed as described above by the writer will maintain a temperature for twenty-four hours with a drop of only one or one and a half degrees centigrade. A few trials will suffice to teach the experimenter or investigator the time allowance for the water supply.

Always place a dish of cold water in the incubator chamber when cultivating bacteriological growths.

MILD STEEL FROM IRON ORE.

In a paper entitled "Notes on the Direct Reduction of Iron Ore in the Electric Furnace," published in the Revue de Métallurgie, Mr. G. Arnou, of Paris, states that the French company, La Néo-Métallurgie, has for several years made a study of this direct process, and has patented a method which it is believed will solve the problem. The tests made do not resolve themselves into purely laboratory experiments, but refer to over 15 tons of metal manufactured in a Chaplet-Néo-Métallurgie electric furnace. This is an arc furnace in which the current enters by one or more current collectors projecting from the furnace, with connection above the level of the bath. The elements for the formation of a suitable slag are first put into the furnace, then there is added to these the mixture of iron ore and coke in given proportions, and of the required amount for producing the metal for a charge. Reduction first takes place, the metal melts on nearing the arc, filters through the slag and collects on the hearth. The apparatus works as it were as a small blast-furnace, and has two distinct zones, one for reduction, and one for smelting or for fining, the latter zone being at a very high temperature. When the metal is completely melted down, the bath is purely and simply an iron bath of the usual class, which can be dealt with on the well-known methods. By suitably regulating the charge it is practically possible to obtain iron containing only very low proportions of foreign elements, the corresponding content of oxide of iron in the slag being also low. The latter in normal running has always been found to be below 8 per cent.; frequently, with the aid of reducing additions, a white slag has very rapidly been arrived at, corresponding to complete efficiency. The charges have hitherto been made up in different ways. Briquettes made of pulverized mixtures of hematite and charcoal, carefully dried, were first used. These, however, being costly to prepare, the hematite alone was briquetted, the charge consisting of dried briquettes of hematite plus charcoal, then of a mixture of charcoal and hematite dust shovelled in the furnace. The results obtained were the same both as regards the composition of the final product and working. The output, however, varied, as shown by the following figures which apply to equal working conditions:—

Using briquettes made of hematite and charcoal	35 kg. (77 lb. p. hr.)
Using hematite briquettes and charcoal in pieces	32 kg. (70.5 lb. p. hr.)
Using hematite and charcoal dust	31 kg. (68.5 lb. p. hr.)

Iron Ore.

	Fe_2O_3.	Fe_3O_4.	CO_3Fe.	SiO_2.	CaO.	Al_2O_3.	S.	P.	Mn.
Hematite	93.82	.....	.....	3.57	0.33	0.78	0.023	0.052	Traces
Magnetite	.....	95.84	.....	0.60	0.20	0.60	0.40	0.03	0.10
Sparry ore	.....	.....	80.80	8.96	1.0	0.75	0.04	0.02	2.98

Fuel.

	Fixed Carbon	Volatile Matter	Ash	Sulphur
Paraffin distillation residues	92.55	6.25	0.90	0.125
Charcoal	88.02	10.54	1.35	.....
Anthracite	83.20	.....	5.35	1.32

The consumption of charcoal per ton of iron also differed—it amounts to 300 kg. (661 lb.) in the first instance, to 330 kg. (728 lb.) in the second, and to 360 kg. (792 lb.) in the third. The further experiments showed that smaller differences occurred when using other fuels—for example, anthracite and coke. The above affords a proof that it is possible to work pulverulent ore in the electric furnace without first briquetting it. The material used was of the composition given in the table above.

The experiments showed that any class of ore used could easily be reduced by any of the fuels. With charcoal the current pressure had a tendency to remain higher than when either of the two other classes of fuel was used; but since the working of the furnace is intermittent, and no high incandescent columns are resorted to, as in the blast-furnace, the pressure differences have no importance, and the electric requirements can easily be regulated at will by varying the height of the electrode. Anthracite gave the best results from the point of view of thermal efficiency. For an equal power spent in smelting crushed hematite in the furnace the output was 31 kg. (68.5 lb.) per hour using charcoal, and 38 kg. (83.7 lb.) using anthracite, the fuel consumption per ton of iron being 360 kg. (792 lb.) in the former case, and 271 kg. (597 lb.) in the latter. With anthracite the mixture is more thorough, and the mass more compact, hence the descent of the charges and the ascent of the gases are both delayed, leading to a more complete reduction previous to melting, and a better utilization of the heat in the gases, this favoring the reaction $2\ CO = CO_2 + C$, there resulting an addition of heat and energy.

Magnetite and charcoal gave a better output than hematite and charcoal, the reduction of magnetite briquettes having yielded 41 kg. (90.5 lb.) per hour; using anthracite, there was not much difference in the yield of either. Sparry ore is easily reduced, but requires a greater expenditure of power, owing to its comparatively low percentage of iron and its greater percentage of gangue.

Regularity in the output forms an important factor, and the paper gave the following seven analyses to show that this point was fully met, the product thus directly obtained being malleable iron:—

Iron Obtained.

C. per cent.	Mn. per cent.	Si. per cent.	S. per cent.	P
0.08	0.10	0.02	0.02	Traces
0.09	0.09	0.04	0.02	Traces
0.11	0.46	0.06	0.02	Traces*
0.09	0.15	0.08	0.02	Traces
0.10	0.12	0.07	0.02	Traces
0.13	0.10	0.03	0.02	Traces
0.10	0.14	0.19	0.012	Traces

These results were arrived at without any refining addition and without acting upon the slag (which would have permitted the lowering of the sulphur contents).

The experiments were made using both direct and alternating current; the form of current did not lead to any marked difference either in the quality or in the quantity of the output. The reversing of the current when using direct current led to no effect, this showing that no electrolytic action whatever intervened in the process.

The furnace was one of 120 kilowatts, and the experiments showed that in such a furnace the current consumption to produce 1 ton of mild steel would amount to

3150 kilowatt-hours using magnetite and charcoal.
3050 " using magnetite and anthracite.
3430 " using hematite and charcoal.
3100 " using hematite and anthracite.
4000 " using sparry ore and anthracite.

The current consumption, when using larger furnaces, of 200 kilowatts, for example, would be much less, and would probably not reach 2,500 kilowatt-hours as against the 3,430 for refining hematite, using charcoal.

* Heavy additions of ferro-manganese for comparison.

The cost of repairs to and maintenance of the furnace is practically negligible. We have given above the proportion of fuel required in the reduction of hematite. Magnetite required only 310 kg. (685 lb.) of charcoal, or 260 kg. (573 lb.) of anthracite. The consumption of electrodes varies, as is well known, with the working of the furnace and the nature of the slag. In normal working for the production of mild steel, it lies between 25 kg. and 35 kg. (55 lb. and 78 lb.) per ton.

The author then gave the following examples:—That of a plant, containing a 200-kilowatt furnace, situated close to a mine yielding magnetite ore containing 66 to 68 per cent. of iron, costing 15 francs (12s.) in a country where waterfalls are available, where the kilowatt-hour would cost 6 centimes (0.23 farthing), and where charcoal only would be available, this costing 60 francs (£2 8s.) per ton. These conditions would give approximately for the cost of producing one ton of iron:—

	Francs.	£	s.	d.
1,600 kg. (3,525 lb.) of iron ore...	24.0	0	19	3
310 kg. (685 lb.) of charcoal	18.60	0	14	11
2,600 kilowatt-hours	15.60	0	12	5
Lime and additions	1.0	0	0	10
Maintenance of the furnace	2.50	0	2	0
Electrodes	15.0	0	12	0
Labor	10.0	0	8	0
Sundry expenses	5.0	0	4	0
Total	91.70 =	3	13	5

In the case of a locality where pure anthracite is available, at the price of 25 francs (£1) per ton, and which could easily be supplied with rich ore (hematite, Krivoi-Rog, for example) costing also 25 francs per ton, the cost of one ton of iron, in places where the current could be produced cheaply by using blast-furnace gas or producer-gas derived from cheap fuel, would work out approximately as follows:—

If larger furnaces than the 200-kilowatt one considered in the above examples were used, several of the items of expenditure would be much lower. Further, the electric furnace is most easily adapted to the production of cast iron for the manufacture of castings; the figures for current consumption, above stated, apply to the production of steel; they would be much lower for the production of cast iron. The process makes it possible to obtain direct from the ore, and by charging suitable oxides in the furnace before the commencement of a heat, or by additions during a heat, all the various grades of cast iron required for any special purpose.

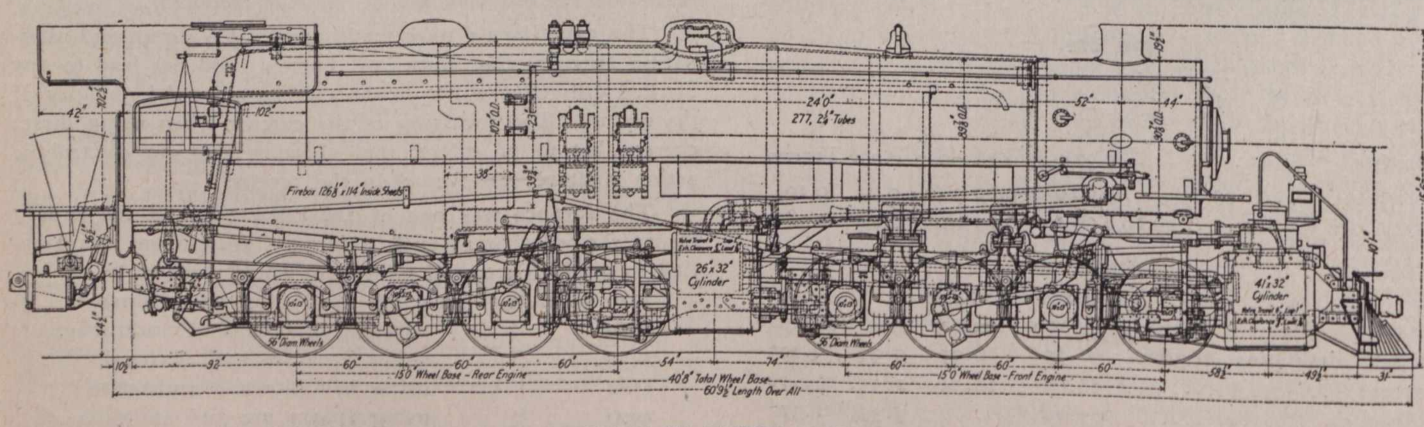
Working Cost of the Process.

	0.6 Centimes (0.23 Farthing) per Kilowatt-Hour.				2 Centimes (0.768 Farthing) per Kilowatt-Hour.				3.5 Centimes (1.34 Farthings) per Kilowatt-Hour.			
	Fr.	£	s.	d.	Fr.	£	s.	d.	Fr.	£	s.	d.
1,600 kilogs. (3,525 lb.) of iron ore............	40	=1	12	0	40	=1	12	0	40	=1	12	0
270 kilogs. (595 lb.) anthracite	8.10	=0	5	9	8.10	=0	5	9	8.10	=0	5	9
2,600 kilowatt-hours	15.60	=0	12	6	52	=2	1	8	91	=3	12	10
Lime and additions	1	=0	0	10	1	=0	0	10	1	=0	0	10
Maintenance of the furnace	2.50	=0	2	0	2.50	=0	2	0	2.50	=0	2	0
Electrodes	15	=0	12	0	15	=0	12	0	15	=0	12	0
Labor	10	=0	8	0	10	=0	8	0	10	=0	8	0
Sundry expenses	5	=0	4	0	5	=0	4	0	5	=0	4	0
Total	97.20	=3	17	1	133.60	=5	6	3	172.60	=6	17	5

A POWERFUL LOCOMOTIVE.

In 1904 the American Locomotive Company, New York, completed an order received from the Baltimore and Ohio Railroad for an articulated compound locomotive. Its introduction occasioned some comment from competitive roads.

Twenty-nine railroads on the American continent are now using an aggregate of over 400 locomotives from the design shown in the accompanying cut. Railroads purchasing freight locomotives in 1910 weighing 100 tons and over from the American Locomotive Company ordered 18 per cent. articulated.



SIDE ELEVATION AND CROSS SECTIONS OF 230-TON ARTICULATED COMPOUND LOCOMOTIVE

Seven years of service have placed it beyond the experimental class. The above-mentioned railway have recently purchased ten engines of similar construction, the specifications, however, calling for an increased solidity and tensity of 40 per cent.

The original locomotive has been operated in pushing service on the Connellsville Division between Rockwood and Sand Patch, 16 miles. The track is exceedingly crooked, having seven curves of seven degrees. The maximum grade is 1 per cent. In the Rockwood yard the curves are even worse than on the road. With one consolidation at the head, the articulated locomotive handles a train of 2,200 tons on the above grade at a speed of 18 miles an hour. It does the work of two consolidation locomotives in pushing service at a saving in the cost of maintenance alone of 38 per cent., as shown by the following figures from records:—

From January 6th, 1905, to December 31st, 1910, the total cost of repairs to the articulated locomotive, including running and classified repairs, per actual mile run was 11.07 cents; the corresponding aggregate figure for the two locomotives which it replaced was 18.2 cents per the same unit. This is based on the average for thirteen consolidation engines in identically the same service as the articulated locomotive for a period of two years.

This locomotive is in operation 24 hours a day, running forward up the hill and backing down, and is never turned.

With the track conditions previously mentioned, an exceptionally good opportunity has been afforded to determine whether there was any tendency toward excessive flange wear due to the wheel arrangement. Careful comparison between the articulated and consolidation locomotives in the same service shows that the former makes about four times as much mileage as the latter between tire turnings necessitated by flange wear. The articulated engine made 47,234 miles for the first set of tires, while the consolidation locomotives make an average of only 10,000 to 12,000 miles.

In the matter of wear in the valve motion, it has shown a marked advantage as compared with the consolidation locomotives. In 4,454 miles the lost motion in the valve gear of the articulated engine was 3-64 in. as compared with ½ in. for the consolidation locomotives for an equal length of time and measured in the same way.

On a recent occasion this locomotive, with a consolidation locomotive rated at 475 tons, handled a train of 2,032 tons on the 2.01 per cent. six-mile grade from Newburg to Kingwood tunnel. The articulated locomotive pushed 1,557 tons.

The locomotive was stopped by a flag on the worst part of the grade for five minutes, after which it easily started the train when thrown into simple working. The six miles were made in a total time of 47 minutes, including the five minutes' stop, making the actual running time 42 minutes. The length over all is 93 ft. 3⅜ in.

TESTS OF LIGNITE.

The results of the investigations into the briquetting of lignite have just been published by the Bureau of Mines in Bulletin No. 14. Charles L. Wright, who conducted the tests and who is author of the bulletin declares that enough testing has been done to indicate that some American lignites equal German lignites in fuel value and can probably be made into briquets on a commercial scale without the use of binding materials.

"Three samples of lignites," says the author, "one from Texas, one from North Dakota, and one from California, were made into satisfactory briquets without the addition of a binder. It was proved that some lignites after having slacked by exposure can be made into briquets without the use of binding material, notwithstanding a general opinion that this could not be done. Cohesion and weathering tests demonstrated that good briquets endure handling and resist weathering much better than the lignite from which they are made.

"The tests described apparently show that the cost of briquetting run-of-mine lignites with a German plant, which was used, would be from $1.35 to $1.75 per ton, according to the location of the plant. The cost per ton of briquets, loaded on cars, from a briquet plant at the mine would be, in Texas, $2.51; in North Dakota, $3.53; and in California, $5.24. It must be borne in mind that these figures are only approximate and are subject to wide changes because of local conditions. They apply to briquetting run-of-mine lignite to improve its heat value and weather resisting properties rather than to briquetting slack or waste coal. Since the tests have shown that at least some lignites slacked by exposure to the weather can be made into excellent briquets, it may be possible to utilize lignite slack as well as bituminous slack and anthracite screenings for briquetting, the two latter materials having been made into briquets on a commercial scale both in this country and abroad.

"Of four samples of raw lignite, three samples contained about 40 per cent. moisture and had a fuel value of 6,079 to 6,241 B.t.u., while a Texas lignite, with a moisture content of 33 per cent. had a fuel value of 6,840 B.t.u. The percentage of moisture removed in the process of briquetting ranged from 24 to 32 per cent. and the heat value of the briquet was 36.5 to 54 per cent. higher than that of the raw lignites.

"Excessive moisture in fuel not only causes a waste of useful heating during combustion, because the moisture is vaporized and the vapor superheated, but also is a source of expense to the consumer, who pays freight charges on useless water. For both these reasons lignite briquets have the advantage over raw lignite. In the case of one of the North Dakota lignites the removal of 32 per cent. of moisture during briquetting permits a decided lessening of the cost of supplying a consumer with a given number of heat units. The advantage of the briquets in this respect is of especial importance when transportation to a distant market is involved. If the briquets possess no other advantage over raw lignite than their higher heat value, they would be worth 50 per cent. more than the raw fuel."

This bulletin can be obtained by those interested by writing to the Director of the Bureau of Mines, Washington, D.C.

POLES USED IN CANADA IN 1910.

Report of the Forestry Branch of the Department of the Interior.

The Forestry Branch of the Department of the Interior has compiled statistics dealing with the poles purchased in Canada during 1910. The total number of poles purchased was 782,841, or an increase of 118 per cent. over 1909. The total value of these poles at point of purchase was $1,043,874, and the average price of poles was $1.33 or less by 6 cents than the price per pole in 1909. Steam Railroad, Telephone and Telegraph Companies used 95 per cent. of these poles, the remaining 5 per cent. being used by Electric Roads, Power and Light Companies; 97 per cent. of the total consumption were cedar poles, which for their cost give better service than any other wood. At present none of these poles are treated or preserved by any method, in which respect we are far behind the United States. The United States using in 1909, 3,738,740 poles at an average cost of $1.89, or at 50 cents more per pole than in Canada, found that it paid them to use preservative methods. During the last three years the treatment of poles has advanced rapidly, so that in 1909, 15 per cent. of the total number were treated by creosote or other methods. This is an increase of 67 per cent. over the number treated in 1908. At present the United States have 87 timber treating plants, while Canada has none. It is to be hoped that this great inequality will soon be done away with, and that pole users in Canada may take up this cheap and rational method of securing greater service from the poles used and thus lessening the drain on the forest.

DESTRUCTION OF CEMENT MORTARS AND CONCRETE THROUGH EXPANSION AND CONTRACTION.*

Alfred H. White.

The change in volume of concrete due to temperature change has been determined with considerable accuracy to be for unit length 0.0000055 or 0.00055 per cent. per degree Fahrenheit. There are, however, other changes due to the chemical processes of setting and hardening which are barely mentioned in even the more important treatises and other variations due to the wetting and drying of the concrete whose varying existence is practically unknown. It is with these two latter classes of changes that this paper will deal.

Review of Literature.

The literature of the subject is brief.

Quantitative measurements of the change of volume of cements while hardening commence with the classic experiments of Bauschinger who in 1879 reported on the change in volume of eight different cements made into small cubes of neat cement and 1:3 and 1:5 mortar. One set of cubes was kept in water and one in air and the changes in length of one side observed for 16 weeks. The most important study of the subject was made by Schumann, who, in 1881 and 1889, reported to the German Association of Portland Cement Manufacturers the result of expansion measurements made on blocks not only of neat cement and cement mortar but also on blocks of building stone. Gary in 1899 reported from the Royal Mechanical Experiment Station at Gross Lichterfelde the results of the tests on ten Portland cements carried out jointly by the Experiment Station and a committee of the Association of German Portland cement manufacturers. The tests included measurements of expansion bars of neat cement and of 1:3 mortar placed in water. No tests were made of bars in air. The average results of the expansion tests at the experiment station are given in Table 1.

A few results of Tomëi were quoted by Gary before the International Engineering Congress in 1893.

Campbell and White in 1906 presented a study of 56 expansion bars of neat cement which had been under observation for five years. A number of these were pathological specimens of unsound cement containing free lime and magnesia, but their experiments showed as much as 0.19 per cent. expansion with sound neat cements kept in water for five years and a shrinkage as high as 0.39 per cent. with bars of sound neat cement kept in air. A reliable and inexpensive micrometer and a satisfactory method of inserting the glass plates in the expansion bars were described in this paper. These improvements obviate the difficulties found by some of the earlier German investigators in getting concordant results. Table 1 presents the condensed data of the investigators mentioned.

The foregoing tests were all made on small bars without metal reinforcement. So far as the author has been able to discover, only two investigators have ever attempted to study the most important subject of volume changes in reinforced concrete. Considère in 1899 reported the behaviour of small bars of neat cement and of mortar made with 600 Kg. cement to each cubic meter of sand. The prisms were 60 x 25 x 600 mm. Half of them were reinforced each with a round steel bar 10.2 mm. in diameter. The measurements extended over a period of 63 days and at the close of the period showed the following changes reported as mm. per 100 mm:

	In water.	In air.
Neat cement not reinforced	+0.079	—0.132
Neat cement reinforced	+0.022	—0.025
Mortar not reinforced	+0.028	—0.050
Mortar reinforced	+0.006	—0.010

Emerson in 1904 studied the change in length of the reinforcement. Bars of neat cement and of concrete of various proportions were made 8 x 8 ins. x 3 ft., each for carrying a steel rod ½-in. square and 3 ft. 6 ins. long. The progressive changes in the length of the rods were measured for 3 months and the resulting stresses in the steel calculated from Hook's law. The final measurements on bars kept constantly in water showed a tension stress on the steel amounting to about 8,000 lbs. per sq. in. when bedded in neat cement and decreasing to a little over 1,000 lbs. in 1:3:6 concrete. On bars kept constantly in air the steel was shown to be under a compression stress which was usually greater than the tension stress developed in bars kept under water. When bars taken from water were placed in air the stresses in the steel changed from tension to compression as the bars dried. No direct measurements were made on the volume changes in the concrete.

TABLE I.—CHANGE IN VOLUME IN NEAT CEMENT AND CEMENT MORTAR.

Expansion after lying continuously in water:—

	Neat Cement	1:3 Sand.	1:5 Sand.	Duration.
Bauschinger Av. of 8				
Schumann Av. of 7	+0.046%	+0.009%	+0.001%	16 weeks
	+0.150	+0.028	.....	1 year
	.....	+0.029	.....	2 years
Tomëi Av. of 8	.....	+0.027	.....	5 years
Considère	+0.025	+0.027	.....	90 days
Gary Av. of 10	+0.079	+0.028	.....	63 days
	+0.063	+0.008	.....	1 month
	+0.078	+0.013	.....	3 months
	+0.094	+0.012	.....	1 year
Campbell and White	+0.092	+0.020	.....	2 years
Contraction after lying continuously in air:	+0.190	.....	.....	5 years
Bauschinger Av. of 8..	—0.214%	—0.132%	—0.124	16 weeks
Schumann Av. of 4	.....	—0.042	.....	1 week in water then 3 weeks in air.
Tomëi Av. of 8	—0.204	—0.094	.....	90 days
Considère	—0.132	—0.050	.....	63 days
Campbell and White	—0.390	.....	.....	5 years

* Paper read before Annual Meeting of the American Society for Testing Materials.

TABLE II.—CHANGES IN VOLUME OF BRICK AND STONE WHEN ALTERNATELY WET AND DRIED, ACCORDING TO SCHUMANN.

	2 weeks in water.	2 weeks in air.
Brick, light burned red........	+0.016%	—0.015%
Brick, hard burned white......	+0.010	—0.009
Brick, hard burned white......	+0.019	—0.010
Brick, very hard burned black	+0.006	—0.008
Sandstone, red fine grained...	+0.006	—0.018
Sandstone, red coarse	+0.016	—0.023
Sandstone, green fine grained	+0.050	—0.050
Sandstone, red fine grained...	+0.050	—0.050
Sandstone, red very fine grained	+0.206	—0.178
Limestone, white	+0.004	—0.008
Limestone, Lothringer Lias ..	+0.007	—0.008
Limestone, Challe	+0.011	—0.009
Limestone, dense containing clay	+0.026	—0.026
Granite	+0.006	—0.015
Basalt, a	+0.041	—0.050
Basalt, b	+0.026	—0.027
Basalt, c	+0.048	—0.050
Basalt, d	+0.023	—0.057

Only one experiment seems to have been made on a really large scale. Binnie constructed a block of 1:4 granite

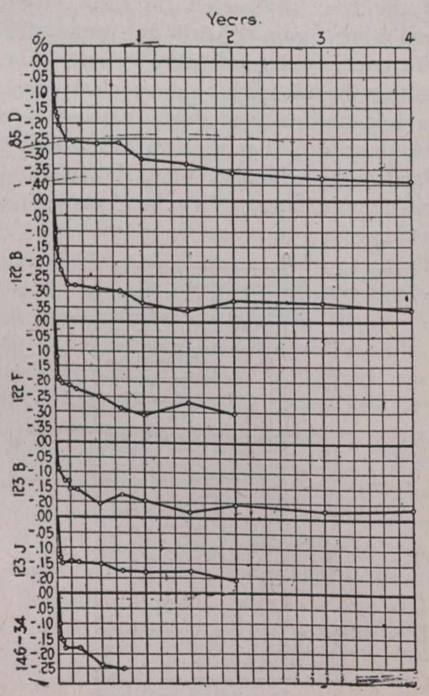


Fig. 1. Linear Contraction of Bars of Neat Cement Kept in Air for Four Years, Expressed in Per Cent.

concrete 100 ft. in length and 1 ft. square built on rollers so as to be free to expand. He dismisses the subject of effect of moisture with the unsatisfactory statement that in wet weather the expansion due to moisture was often as much as that due to summer heat.

The experiments of the investigators cited above agree in showing that in neat cements hardening under water expand at a decreasing rate for several years, that neat cements hardening in the air contract in a similar manner and that cement-sand mortars change in the same direction as the neat cements but to a lesser extent.

The effect of alternately wetting and drying concretes is given quantitatively from the experiments of Emerson. Quantitative measurements are entirely lacking. It is worthy of comment that although several investigators have reported on the behaviour of bars in water for periods of several years, none have reported on the behaviour of bars kept in air for a period of more than four months, with the single exception of Campbell and White, who studied one commercial cement during four years.

This curious laxness in the studies of the properties of Portland cement which, next to steel, is the world's most important building material, arises probably from two causes. In the early days of the Portland cement industry the material was used almost entirely for structures such as foundations where it was kept constantly damp. It justified itself under these conditions and the assurances with which it was used in damp places transferred itself unthinkingly to conditions where cement is less stable. The other reason for the oversight is probably to be found in the fact that few engineers who use cement have had the chemical training which would enable them to study the complex phenomena involved in these changes.

The following paragraphs show especially the effect of alternately wetting and drying bars of neat cement and sand mortar. There are also included the behaviour of various bars of cement kept continuously in water and in air. These are included not only because more data on the subject is desirable but because the Portland cement now being used is a different material from that tested by the European investigators, who undoubtedly worked with cements made in the old vertical kilns. The modern American cement made in rotary kilns differs from the older not only in method of manufacture but also in chemical composition and is worthy of separate study.

University of Michigan Tests.

Experimental Method.—The method of making and measuring the expansion bars was that of Campbell and White. The dimensions of the bars are approximately 4 x 1 x 1 in. and they contain bevelled glass plates cast in the end to ensure a smooth surface for the micrometric measurements. The Portland cements used were all commercial samples which passed successfully the standard tests for soundness. Standard methods were used in proportioning the water and in mixing. The initial measurement was made after the bad had stood in the water 24 hours in the damp box.

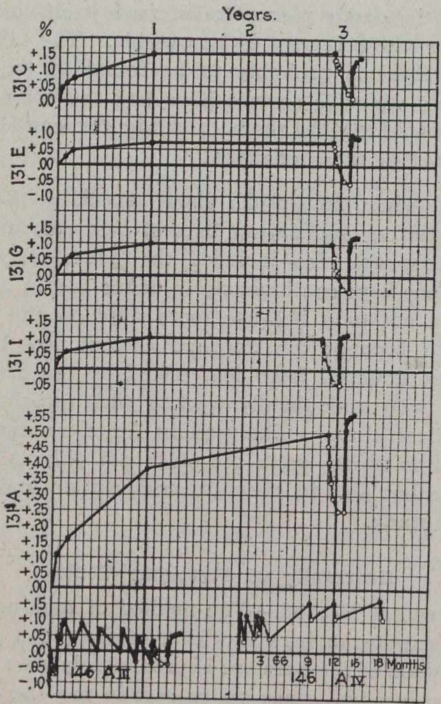
Campbell's perfected micrometer is described and illustrated in the paper referred to. It is possible to make three successive readings with it with a maximum error of about 0.005 mm. Since the bars, after the thickness of the glass plates embedded in the end is deducted, are almost exactly 100 mm. long, each 0.001 mm. equals 0.001 per cent. In making measurements three successive readings are taken and the mean recorded. The bars and micrometer are kept continuously in a room surrounded on all sides by other rooms in a building whose temperature in winter is controlled by automatic thermostats. During the cold weather the temperature of the room will not vary more than two or three degrees from 70° F. In summer the temperature may rise to 80° F. Since the difference in the coefficients of expansion of the cast iron yoke of the micrometer and of concrete is only 0.0000005 temperature variation in the room introduces merely a negligible error.

Contraction of Neat Cement in Air.

The curves of Fig. 1 show the linear shrinkage of bars of neat cement kept constantly in air. Four different brands of commercial cement all passing standard specifications for constancy of volume are represented. The volume of these bars varies with the humidity of the air but on the whole the shrinkage of all the bars is reasonably uniform and averages:—

7 day (Av. of 6)	—0.109%
28 day (Av. of 6)	—0.190
6 months (Av. of 6)	—0.236
1 year (Av. of 5)	—0.270
2 years (Av. of 5)	—0.289
1 year (Av. of 3)	—0.322

It is evident that one-third of the shrinkage comes in the first week, more than half of it in the first month and almost all of it in the first year. A shrinkage of 0.322 per cent. amounts to nearly 4 ins. on 100 ft. and indicates



Closed circles indicate measurements of bars taken from water.

Open circles indicate measurements of bars lying in air.

Fig. 2. Linear Expansion and Contraction of Bars of Neat Cement When Alternately Wet and Dry, Expressed in Per Cent.

clearly why it is not possible to use neat cement for inferior floors and wall finishes. The change in volume of cement and sand mortars will be treated later.

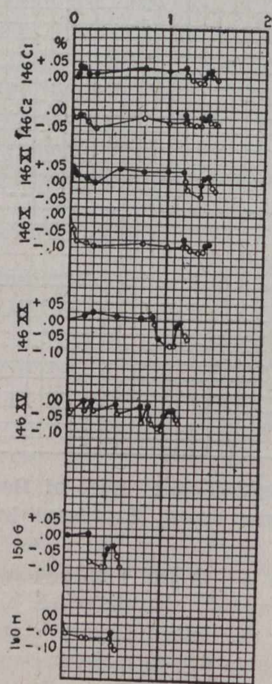
It is often held that the use of fresh cement is responsible for cracks in finished work. It is therefore of particular interest to note that freshness cannot be held responsible for the changes shown here. Bar 85 D was made from cement which had been stored in our laboratory for six months before use. Bar 122 B was made from an inspector's sample of commercial cement when it was received at the laboratory and 122 F was made after it had stood in an open bottle in the laboratory for two years and five months. Bar 123 B was made from a commercial cement the day after it had been ground at the mill and 123 J after it had been aged two years and six months. In neither case can any effect of ageing be noticed. The shrinkage at the end of two years is practically identical in the aged and fresh cement.

Changes in Volume of Bars of Neat Cement in Water and Alternately Wet and Dry.

The first four curves in Plate II show the changes in four bars of neat Portland cement when kept under water at approximately constant temperature for almost three years, then allowed to dry in air for two months at the same temperature and then put back in water again. The mills represented are: 131 C, one of the largest Lehigh Valley mills; 131 E, a small Michigan mill of good reputation working wet process with marl and clay; 131 G, one of the large mills using slag and limestone; 131 I, another Michigan mill using wet process. The fifth curve of Fig. 2 (131 A) shows the changes in a bar of natural rock cement from one of the leading mills of the country. The last curve (146 A3 and A4) show the variations in two bars of cement from still a different Michigan mill.

The behaviour of the first four Portlands kept constantly in water for three years is quite in accord with the results obtained by European investigators. The linear expansion at the end of the first year amounts to from 0.07 per cent. to 0.15 per cent. and the expansion after the first year is very slight. The high expansion of the natural rock cement, 0.49 per cent. after three years in water is worthy of note as being quadruple that of the average of the Portlands.

Attention is especially directed to the contraction in these bars after they were removed from the water and allowed to dry in the air at room temperature. The change in volume was slow and had not entirely ceased after 65 days when the last test was terminated. The values were, however, remarkably concordant, the large contraction of the four Portlands being 0.15 per cent. and the smallest 0.13 per cent. The bars not only shrunk to their initial volume but three of the four contracted further. When the bars thus air-dried were again placed in water the expansion was rapid. In one day they recovered 90 per cent. of all the length which they had lost in 65 days air-drying and in the course of the next month they slowly expanded further until three of the four were longer than they had ever been. The exception, Bar 131 C, changes very slowly and it appears from the curve that it had not reached equilibrium either on drying or wetting.



Closed circles indicate measurements of bars taken from water.

Open circles indicate measurements of bars lying in air.

Fig. 3. Linear Expansion and Contraction of Bars of 1.3 Cement Mortar When Alternately Wet and Dry, Expressed in Per Cent.

From the standpoint of structural stability it is rather disquieting to learn that these cements which had remained in water without any measurable change in volume from their first to their third year shrank 1.7 ins. in 100 ft., when they were dried in air and in 24 hours when again brought in contact with water expanded 1.5 ins. and within a month had expanded 1.8 ins. calculated on an initial 100-ft. measurement. The question of the ultimate limit to these changes is discussed later.

The natural rock cement 131 A changed similarly but in a more marked degree. Its linear contraction on drying for 60 days amounted to 0.24 per cent. and its expansion after subsequent immersion for 24 hours in water to 0.25 per cent. The total expansion after 30 days in water was 0.30 per cent.

A more complete illustration of the magnitude and regularity of the changes in volume as the cement passes from the wet to the dry state is shown by the last curves of Fig. 2, Bars 146 A3 and A4. These bars have during their 18 months' existence been systematically alternated in water and air. The points make a fairly regular sawtooth curve which would probably have been more regular had a longer time been allowed for equilibrium in the early portion of the test. The last change of 146 A3, which was the most carefully watched, shows a variation from —0.038 to +0.058, a total change of 0.096 per cent. as it passed from the wet to the dry state for the seventh time. The behaviour of these companion bars 146 A3 and A4 is treated more fully in the discussion of the behaviour of sidewalks.

Change in Volume of 1:3 Sand Mortars as Alternately Wet and Dry.

Fig. 3 shows the changes in the length of eight bars of Portland cement mortar mixed in the proportion of one part by weight of cement to three standard Ottawa sand. The curves are quite like those of the neat cement but the changes are on a smaller scale. The bars kept continuously in water expand within the first few weeks as much as 0.05 per cent. but decrease after that and usually expand again later to a figure that is no greater than 0.05 per cent. Bars kept continously in air show greater volume changes than those kept in water, the contraction after three months averaging about 0.08 per cent. and running as high as 0.10 per cent. When the bars change from the dry to the wet state and vice versa the change in length is about 0.06 per cent.

One of the best known commercial waterproofing compounds, used in accordance with the manufacturer's directions, was incorporated with the four middle bars of Fig. 3 (146 X, XI, XV, XX) in the hope that the value of such compounds might be demonstrated. There is no evidence of favorable effect, the change between the wet and dry states being fully as large and apparently as prompt as in the bars not waterproofed.

Variations in Volume of Compound Bars.

In order to get a direct comparison between bars of neat cement and those made with sand under identical conditions, compound bars were made by casting a bar of neat cement integrally on a fresh formed bar of the same dimensions made by taking one of cement to three of sand. Four of these bars were made from the same lot of cement at approximately the same time. Their variations in volume are reported graphically in Fig. 4, the initial measurement of each being plotted as zero.

Compound bar 146 VII was kept continuously in water for 14 months. Both portions expanded but at unequal rates so that at the end of this period the neat bar was 0.03 per cent. longer than the one containing sand. On drying in air both shrank, but the mortar bar contracted the more rapidly so that at the end of a week the neat bar was 0.072 per cent. longer than the other. As the mortar bar reached equilibrium the neat bar caught up with it and even passed it so that at the end of two months it was the shorter by 0.012 per cent. On placing in water both shut up rapidly, the sand 0.050 per cent. in 24 hours and the neat 0.086 per cent. The neat bar kept growing until as was the case with the four neat cements previously noted, it overtopped any previous record and at the end of a month was 0.075 per cent. longer than its companion, whereas after 14 months previous immersion in water it had only been 0.038 per cent. the longer.

Compound bars 146 II and 146 VI were made to test the effect of fineness of sand. The mortar bar of 146 II was made with Standard Ottawa sand while 146 VI contained river sand from which everything coarser than 40 mesh had been sifted. Both bars were kept in air for over a year and then immersed in water. No marked effect of the difference in sand can be noted. The contraction of the bar with the fine sand is rather less than that with the standard sand but the difference is not definite enough to be certain. The neat cement portions of the bars behaved alike and similarly to the others noted, contracting over 0.20 per cent. in one year. At the end of the year the neat cement bar 146 II was 0.147 per cent. shorter than its companion mortar bar and the neat bar 146 VI was 0.150 per cent. shorter than its companion. On placing in water there was the usual sharp expansion followed by a contraction as the bars were again dried in air and another expansion as they were placed in water, and so on.

Compound bar 146 I was changed every week during its first few weeks and shows the usual sharp alterations with no sign of decrease in intensity with age.

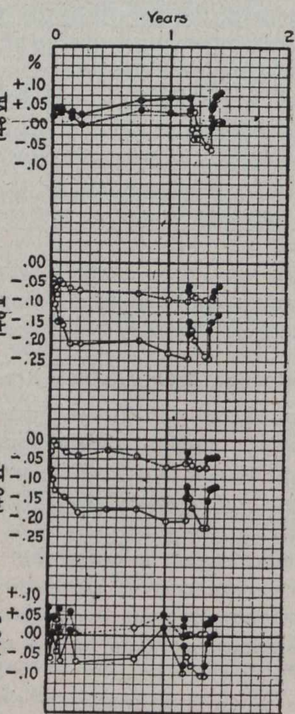
Illustration from Actual Practice.

It may be urged that the foregoing tests were all made in small bars manufactured in the laboratory and that such large values might not be obtained in actual practice. To meet this objection and also to make the case stronger the results shown in Fig. 5 are introduced. The scale in this plate is purposely changed in order that the steady nature of the changes in volume may be shown by the daily measurements. The ordinates remain the same but the abscissas are magnified 30 times, each horizontal unit representing a day.

Bar 156 A is made from a part of the cement sidewalk on the north side of the campus of the University of Michigan. It was laid in 1890 from imported German cement by the University workmen who were paid by the day and under no temptation to slight the work or skimp cement. Most of the slabs of this walk are now warped slightly so that shallow puddles of water stand in them after a rain and even after 20 years the expansion is still occasionally causing adjacent blocks to heave and form an inverted V. The top layer is split from the bottom in many places and it was from one of these pieces of the top coat that bar 156 A was sawed. An examination of its lower surface shows that the split was not due to faulty bonding, for the break has occurred not at the exact junction of the top coat and base, but just below the upper surface of the base. The top coat carries with it a thin layer of the base. This bar became dampened in the sawing process and was therefore put into water and allowed to become saturated and fully expanded before the measurement recorded as the initial was made. It will be noted that it then contracted slowly for 14 days in the air, the total shrinkage being 0.05 per cent. and that on putting it into water it expanded to practically its initial volume in four days. When removed from water it contracted again as before.

Another instance to which attention is called is bar 156 E cut from a piece of cement stucco which came loose from a brick porch after only two years service. The stucco when mixed, has a good ring and is hard. The brand of cement used and the proportions are unknown but it is certainly a rich mixture, probably as high as 1:1. The stucco in coming off did not split off from the brick but in almost all instances carried a thin skin of the brick adhering to it showing that the fault did not lie in failure to bond the two materials together. The behaviour of a bar sawed from this stucco is shown in the curves 156 E. It was sawed to shape without moistening and when placed in water for 24 hours it expanded 0.07 per cent. and reached 0.08 per cent. after four days in water. On drying in air it slowly returned to its original volume. It is not to be wondered at that a stucco which expands practically 1 in. on 100 ft. whenever it gets thoroughly wet, should fail.

Another instance of change of volume in material which has been in use many years is afforded by the study of a section of cement sidewalk which was taken up in good condition after 20 years' service. From this was sawed one



Full lines denote neat cement.
Dotted lines denote 1:3 mortar.
Closed circles indicate measurements of bars taken from water.
Open circles indicate measurements of bars lying in air.

Fig. 4. Linear Expansion and Contraction of Compound Bars of Neat Cement and 1:3 Sand Mortar When Alternately Wet and Dried, Expressed in Per Cent.

bar approximately 1 x 2 x 4 ins. consisting of the top coat 1 x ¾ x 4 ins. on a section of the bottom portion 1 x 1¼ x 4 ins. This bar (156 B) is therefore similar in many ways to the compound bars of neat cement and 1:3 mixture before referred to. This bar showed the usual expansion of both layers in water and the contraction in air which was expected. When placed in water the bottom layer expanded practically its whole amount (0.033 per cent.) in 15 mins. while the richer top layer, expanded in the same time only 0.010 per cent. At the end of 24 hours the top portion had expanded 0.028 per cent., and after three days had become practically constant with almost the identical expansion 0.035 per cent. which the bottom showed. This is interesting partly because of the evidence of alternate bending stress in the concrete due to the more rapid expansion of the lower layer and partly because of the ultimate agreement in expansion of the top and bottom portion. Note that this cement sidewalk was in good condition after 20 years' service. It is possible that its satisfactory condition is due to this agreement in coefficient of the expansion of the two layers.

Another bar was sawed from the same piece of this sidewalk immediately adjacent to the first one but instead of being left as a compound bar it was again sawed at the line of demarcation between the top and bottom coats, so that the top portion (Bar 156 C) was separated from the bottom (Bar 156 D). These two bars were then alternately wet and dried as the others had been to determine whether in the compound bar the change in volume of one portion had been influenced by the other. This has apparently not been the case in this bar for as shown by the curve the two portions C and D expand and contract to about the same extent and at the same rate as in the compound bar B.

Summary of Experimental Data.

In the foregoing pages there has been presented data on the sadly neglected subject of expansion and contraction of hydraulic cements as they age in water and in air and as they are alternately wet and dry. It should be emphasized, however, that the number of experiments is entirely inadequate to make it proper to quote them as average results. They are to be regarded merely as illustrations of how some acceptable commercial cements have behaved. It is, however, permissible to summarize the extremes to show the range of fluctuation.

Neat cement bars hardening under water.
- After 1 year, expansion 0.07 to 0.15 per cent.; 1 year to 4 years, almost no change.
- On drying after three years in water contraction 0.13—0.15 per cent.
- On wetting again expansion of 0.13—0.17 per cent.

Neat cement bars hardening in air.
- Contraction after 3 months............ 0.14—0.28%
- Contraction after 1 year ....0.18—0.34%
- Slight increase to 4 years.

1 cement: 3 sand bars.
- hardening under water—expansion 0.01—0.05 per cent., the greatest changes being in the first few weeks.
- hardening in air—contraction—0.06—0.09 per cent., most of the contraction being in the first three months.
- on wetting and drying, expansion 0.04—0.09 per cent. on wetting, and contraction within same limits on drying.

Compound bars made of one layer of neat cement on a layer of 1:3 sand expand and contract together but at different rates and to different degrees. The differential expansion varies from 0.00—0.15 per cent.

The one natural rock cement tested showed twice as much variation in volume as Portland.

These variations in volume with change of moisture contents do not disappear with lapse of years for changes of 0.05 and 0.06 per cent. have been observed in bars cut from sidewalks which have been laid down 20 years.

Changes in Monolithic Cement and Concrete.

These changes noted above may seem small but when converted into other figures their real seriousness becomes apparent. The following hypothetical illustrations are presented to show the magnitude of the possible stresses.

Imagine a wall of neat Portland cement 100 ft. long anchored at each end to absolutely immovable supports. Let it be kept under water for three years. At the end of that time it would, had it been free, have expanded 0.1 per cent. or 1.2 ins. Since it is supposedly not free to expand the compression will be 0.1 per cent. and the compression stress on an assumed basis of a 5,000,000 lbs. modulus of elasticity will be 5,000 lbs. per sq. in. Perhaps the cement could withstand this pressure.

Imagine now that this cement wall becomes dry. It should contract 1.7 ins., but since it is not free there will be developed a tensile stress of 7,500 lbs. per sq. in., which is several times more than it can stand. The wall would have to crack.

Suppose this neat cement wall had been originally allowed to harden in the open air. After two years it would if free have contracted 0.25 per cent., but since it is anchored at the ends there will be (assuming the same modulus) a tensile stress of 12,000 lbs. per sq. in. Is it not evident why neat cement is not used in practice?

If the above wall had been built of concrete with the same volume changes as the 1:3 sand bars and as the old sidewalks whose measurements are given above, its change in length between the wet and dry states would probably have amounted to 0.05 per cent. which with a modulus of elasticity of 2,500,000 lbs. per sq. in. corresponds to a stress of 1,250 lbs. per sq. in. The concrete could withstand this in compression but not in tension. Not even our best steel will stand indefinitely repeated alternate bending stresses which stress it nearly to its elastic limit. Why should we wonder then if a rich cement mixture should ultimately crack when exposed to the stress resulting from a volume change of 0.05 per cent. every time it is exposed to rain or sunshine.

There is no experimental evidence which shows the changes in volume of leaner concrete. It is evident that the properties of the sand and rock become of increasing importance as their percentage increases. The tests by Schumann on volume changes in building stones, quoted at the commencement of this paper, show small values for limestone but variable values for sandstones, the upper figures being almost as high as those quoted for neat cement. Whatever the values might be for crushed stone as used in concrete it is hardly conceivable that gravels and sands which have withstood the action of the weather for centuries without disintegration can change their volume much when wet and dried. It seems probable that in gravel concrete the volume changes decrease as the cement decreases until a certain lower limit is reached where the change in volume is purely a capillary phenomenon.

If this line of reasoning is correct those concrete structures should be most stable when exposed to the weather where there is just sufficient cement to give strength but not enough to cause excessive volume changes. Practical experience apparently confirms this view.

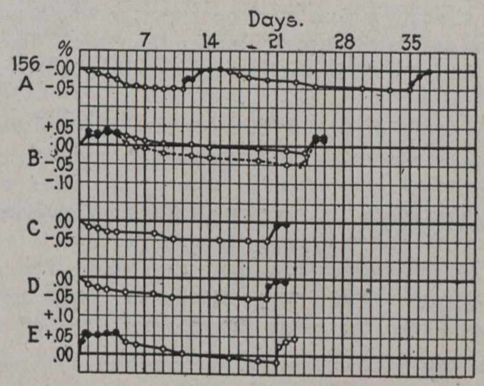
Stucco.

There are many instances where stucco has remained perfect even when exposed to the weather for half a century. There are probably more instances, especially in recent years, where stucco has failed miserably in five years. The excellence of old stucco is sometimes laid to the natural rock cement with which most of it was made. It is not safe to deny this on the evidence of a single experiment, yet attention may be drawn again to the one natural rock cement which has been tested in our laboratory, whose volume changes were in every way much greater than those of Portland.

Is it not more probable that the old stucco has survived because of its lower proportion of cement? When it was simply a question of providing a rough brick or stone wall, entirely durable in itself, with a smooth surface, and when in addition hydraulic cement was expensive, it was natural to use a mortar containing just enough cement to adhere to the wall. With the introduction of metal lath as the support for stucco, and the necessity of protecting the metal from corrosion, coincident with the drop in price of Portland cement came the use of richer stuccos.

The step was apparently an unfortunate one for a volume change of an inch in 100 ft. as shown by the stucco 156 E as it changes from the wet to the dry state cannot but cause cracks. They may be only hair cracks for with a crack every 12 ins., each crack need only be 0.01-in. wide to take up the whole change in volume. The elastic metal lath will probably yield without mechanical injury but the protection against corrosion which the stucco is supposed to afford disappears with the first hair crack and unless the lath has been better protected by galvanizing or painting than most sorts are by the manufacturers, its days are numbered. It would have been better to have used a leaner stucco and kept it free from cracks.

A stucco rich in cement may also split off in time from brick where a lean stucco would have remained good. The change in volume of brick when wet and dry is according to Schumann less than 0.02 per cent. If the change in the stucco is 0.08 per cent. there is opportunity for a stress cor-



Closed circles indicate measurements of bars taken from water.

Open circles indicate measurements of bars lying in air.

Fig. 5. Linear Expansion and Contraction of Bars Cut from Stucco and Sidewalks When Alternately Wet and Dried, Expressed in Per Cent.

responding to a volume change of 0.06 per cent. which might be 1,500 lbs. per sq. in. The fact that the stucco has not split off in one year or two years does not mean that it may not split off in five or ten.

Interior Floors.

The question of reinforced concrete is discussed in a later paragraph. Here only the changes in the concrete itself will be considered. The usual practice will be assumed in which there is a base of rather lean concrete covered with a wearing coat of mortar sometimes as rich as 1:1.

The first case assumed will be that of a cellar floor where the base is tamped down and the top coat at once put on, giving the best conditions for bonding. The whole mass gradually dries out and shrinks, but the top coat because of its high content of cement shrinks more so that the conditions will be somewhat those represented by curves 142 II and VI of Fig. 4. The top coat will tend to split from the base but since a cellar is always relatively damp there will probably be little trouble.

The situation is not so favorable when a top coat is to be laid on an upper floor of a concrete building. The main portion of the floor has been poured for possibly three months and has already completed most of its shrinkage. Its surface is also probably dirty so that the freshly poured mortar will not readily unite with it. Both of these circumstances are unfavorable. The fact that the main portion of the floor has already dried out and shrunk causes an even greater differential shrinkage of the top coat. The advice is usually given to wet the floor thoroughly before pouring the top coat. It would be better to keep it wet for 24 hours beforehand in order to give it an opportunity to expand to somewhere near its initial volume.

It is not surprising if under these circumstances the top splits off the base, shrinkage cracks appear, and the individual slabs curl up somewhat at the edges in the effort to relieve the shrinkage strains. In case electric conduits, etc., are bedded in the top coat their course will be indicated by shrinkage cracks following the lines of weakness which they cause. Since these floors remain continually dry, conditions will become constant after a few months, and there will be little further change.

Sidewalks and Pavements.

The chief factor which influences the behavior of sidewalks and pavements is the weather. The influence of temperature is well known and will not be dwelt on. A sidewalk usually consists of a base of rather lean concrete covered with a wearing coat of cement mortar which may be as rich as 1:1 and is not usually poorer than 1:2. The walk is cut into blocks and is sometimes provided with expansion joints.

As the walk dries out the top coat shrinks more than the bottom, as shown in the experimental study of compound bars. The effects can often be seen in sidewalks where the contraction has dished the centre slab so that shallow puddles of water stand in them after a rain. As the walk is wet by the rain the top expands more than the base. The alternate bending stresses thus developed all too often show themselves after a few years when the top coat splits off the base.

The necessity of expansion joints is now well recognized, although they are put in principally to take care of expansion due to change of temperature. The experiments presented in this paper on both neat and sand briquettes indicate that the expansion of cements kept wet ceases at the end of the year, and that the total expansion does not amount to over 0.1 per cent. This would require a ¼-in. expansion joint every 20 ft. In addition there must be the joints to care for the expansion due to summer heat, which for a rise of 100° F. is 0.05 per cent. about half what may be expected from moisture. To take care of the volume changes from both these causes a ¼-in expansion joint every 10 ft. should be adequate although it does not include much margin of safety. In hot weather after a long rain these joints would be almost closed. In dry or colder weather they would be open.

According to the experimental figures any evils due to expansion should make themselves evident during the first two years, but practice does not always bear out this assumption. Reference was made at the commencement of this article to the cement walk laid around the campus of the University of Michigan 20 years ago, which is still showing expansion and giving mute evidence of the pressure generated by occasionally thrusting up two adjacent slabs in an inverted V. This is not a phenomenon due to summer heat for it occurs usually in the spring. What is the cause which is still making this walk expand after 20 years?

An explanation may be suggested although it is not possible to prove it completely. It is well known that the glass of thermometers expands when heated and contracts when cooled, but not to its original length except after a long lapse of time. Thermometers which are used frequently at high temperatures keep growing longer. If they are laid away for a long period of time they shorten again and may even become shorter than when first calibrated. Metals behave similarly, so that it is not possible to utilize their expansion for making pyrometers which will not need frequent recalibration. The warping of the grate bars of fire boxes due to expansion is another illustration. It would be natural to expect by analogy that concrete would tend to a permanent expansion when it is kept wet longer and oftener than it is dry, and that it would tend to become shorter under the opposite conditions. The experiments of this paper in general confirm this theory. Of the five bars of neat cement of Fig. 2 which had been kept under water for three years and were then dried out and reimmersed, all but one were longer after the reimmersion than they had been, and the one exception is apparently susceptible of explanation.

A more striking illustration is afforded by the two neat bars 146 A III and A IV which are shown at the bottom of Fig. 2. These bars were made on the same day from identical materials, but after the initial measurement A III was left in the air and A IV placed in water. They were then alternated between air and water, at first at the end of each week and afterwards at longer intervals. There is, however, a definite difference in the treatment of the two for with A III each cycle has consisted of a period in air of two or three months followed by an immersion in water of usually a week. It has therefore been dry most of its life and its mean length since the end of the first month has been steadily diminishing as the curve clearly shows. The companion bar A IV was subjected to the opposite treatment in that its long periods were in water and its short periods in air. Its mean length and also its length when wet has been steadily increasing for the 18 months of its existence although the rate of increase since the ninth month has been slow. At its last measurement it was slightly longer than another bar of the same cement which has been kept constantly in water but it will require a longer time to decide whether the increase is material.

This theory of the continued expansion of cement walks in a rather damp climate such as that of Michigan is the only one which seems adequately to explain the compression ridges still occasionally developing in the 20-year-old walk on the campus of the University of Michigan which has been referred to before. If the theory is correct it would indicate that there would be more trouble with cement sidewalks and pavements in wet countries than in those which are reasonably dry, and that there is need of much wider expansion joints in damp climates.

Reinforced Concrete.

It is evident from the data presented here that concrete undergoes a notable shrinkage as it drys. If a concrete beam is formed rigidly fixed at both ends, as is practically the case in skeleton concrete construction, it is evident that on hardening it must be under an initial tensile stress due to contraction. Conditions will not be changed by the presence of steel reinforcement provided the ends are absolutely rigid. If, however, the ends of the beam yield at all and the concrete adheres to the steel the strains will be adjusted between the two. The steel will be in compression and the concrete in tension but to a lesser extent. In the review of the literature at the commencement of this paper attention was directed to the experimental work of Considère and to the experiments of Emerson, who found that even with mixtures as lean as those used in practice, compression stresses of 2,500 lbs. per sq. in. might be developed in the steel through the volume changes in the concrete of bars only 3 ft.

long and not anchored at either end. The paucity of information on this subject should be emphasized. There is every probability that there are important stresses in all reinforced concrete work due to volume changes in the concrete which the designers have had no knowledge. These stresses may have been to blame for some of the collapses which have occurred in reinforced work and the small number of such collapses may be more a tribute to the value of the factor of safety than to scientific knowledge.

It is encouraging to note, however, that in buildings, where the beams remain dry, most of the contraction will have taken place at the end of the first three months and that from that point on the volume changes will be slight. Concrete floor beams are treacherous during the first few weeks not only because the concrete itself is new and weak but because of the tensile stresses developed.

There is danger that a rather slight load on a green beam may cause cracking if not total failure for it is entirely possible that the whole of the concrete is in tension and its tensile strength at that stage is very small. Several weeks should be allowed to elapse even in warm weather before the forms are taken off and the supports removed. Fortunately these tensile stresses seem to practically reach their maximum in three months, while the concrete gains in strength for a much longer period so that if a concrete building is successfully completed there does not seem to be a probability of future failure due to changes within the concrete.

Causes of Change of Volume.

There is no experimental work to account for these volume changes. Their progressive nature as the cement hardens in water or air makes it evident that they are connected with the chemical processes of hardening. Since the hardening of cement is recognized as being essentially a process of colloid formation and change, it may seem not unreasonable to hold that the changes are connected with the volume of the colloid water. The nature of the volume changes as cement changes from the dry to the wet state is in harmony with this view. It is probable that the volume changes are also due in part to purely capillary phenomena, for sandstone and other building stones expand when wet and contract when dry. The amount of the expansion and contraction of concrete decreases as less cement is used so that it appears that the changes are more a function of the cement than of the mineral aggregate.

The subject has not been sufficiently studied to show how far such factors in the manufacture of cement as chemical composition, temperature of burning, fineness of grinding and rate of setting influence the result; nor how far conditions surrounding its use, such as amount of water, temperature of air, etc., affect it. Until the influence of these factors has been determined it will not be possible to make intelligent progress towards lessening the volume changes and increasing the reliability of structures containing Portland cement. The subject is of such importance as to merit most thorough investigation from both the chemical and mechanical side on a larger scale than has yet been attempted.

Conclusions.

Concrete hardening in a moist place and remaining constantly moist throughout its life expands slightly but the compression stress developed in the concrete is probably not large enough to be injurious.

Concrete hardening in air and remaining continually dry contracts. The contraction is roughly twice as much as the expansion of concrete continually damp. This greater stress is harmful not only on account of its magnitude but because it puts the concrete in tension where it is weakest. It introduces an error of unknown magnitude into the calculations for all reinforced beams. It is responsible for the cracks in the top coat of interior cement floors. Fortunately most of the bad effects become evident within three months.

Cement sidewalks, pavements and stuccos exposed to the weather contract when they are dry and expand when they are wet. The richer the mixture is in cement, the greater is the volume change so that there is a differential expansion between the top coat and base of sidewalks which is often sufficient to split the two apart. So also rich stucco may be split from brick. In damp climates irregular expansion occurs apparently for as long as 20 years. Its harmful effects may not appear for many years. Large expansion joints are necessary in sidewalks and pavements.

Rich stuccos will inevitably crack through expansion and contraction and may be ruined. The few experiments made indicate that integral waterproofing compounds do not prevent or lessen the change in volume. The only safety seems to lie in the use of lean mixtures whose volume change is slight. A stucco coat is inadequate as a protection for metal lath. If it is rich enough to keep water out it will crack. If it is lean enough to avoid the cracks water will go through it freely. In a dry climate the tendency is for sidewalks and stuccos to shrink more than they expand. Under these circumstances they will be much more durable and because of the slower corrosion stucco may be permissible as a protection for wire lath.

ORDERS OF THE RAILWAY COMMISSIONERS OF CANADA.

Copies of these orders may be secured from The Canadian Engineer for small fee.

14050-51—June 21—Approving agreements between Bell Telephone Co. and La Compagnie de Telephone de St. Ours, Ltd., P.Q., and Howich Telephone Co. for interchange of business.

14052—June 23—Authorizing South Ontario Pacific Railway to take lands of G.T.R., Twp. of Flamboro, County Wentworth, Ontario.

14053—June 21—Authorizing G.T.P. Branch Lines Co. to open for carriage of traffic (freight) its Yorkton Branch from Melville, Sask., to Canora, Sask.

14054—June 21—Approving G.T.P. Branch Lines Co., Biggar-Calgary Branch, from a point in S.E. ¼ Sec. 1, Twp. 36, R. 15, to south line of Sec. 31, Twp. 34, R. 17, west 3rd Meridian, mileage 0 to 19.97, District of Saskatoon, Saskatchewan.

14055-56—June 26—Approving Kootenay & Alberta Ry. Co.'s standard plan of overhead bridges and bridges over Mill Creek and Lang's Coulee, Province of Alberta.

14057—June 23—Approving C.N. Alberta Railway Co. location through Twp. 53, R. 10-13, west 5th Meridian, Alberta, mileage 82.03 to 101.79.

14058—June 24—Authorizing C.N.R. to cross seven highways in R. M. Antler, No. 61, Saskatchewan.

14059—June 23—Approving location of C.N. Alberta Ry. through Twps. 53 and 52, Ranges 14-18, west 5th Meridian, Alberta; mileage 101.79 to 133.23, Alberta.

14060—June 23—Authorizing C.N. Alberta Ry. to cross with its St. Albert Westerly Line public road.

14061—June 23—Approving location of C.N. Alberta Railway through Twps. 53-52, Ranges 18-23, west 5th Meridian, Alberta; mileage 133.23 to 166.01, Alberta.

14062—June 24—14063—June 21—Authorizing C.N.R. Railway to cross 29 highways in Province of Saskatchewan.

14064—June 21—Authorizing Toronto Eastern Ry. Co. to cross 3 highways in Twp. of Whitby, Ontario.

14065—June 23—Approving Local Freight & Passenger Tariffs, C.R.C. No. 16 and No. 3, of Eastern B.C. Ry. Co., pending judgment in the inquiry into B.C. rates generally.

14066—June 24—Authorizing T.H. & B. Ry. to install block signals between Hamilton & Vinemount, Ontario.

14067—June 19—Authorizing Manitoulin & North Shore Railway Co. to construct spur to premises of Spanish River Pulp and Paper Co.'s Mills, Ltd., at Espanola, Ontario.

14068—June 23—Authorizing G.T.P. Branch Lines Co. to open for carriage of traffic (freight) portion of its Tofield-Calgary Branch from Tofield to Red Deer Crossing, Alta.

14069—June 23—14070—June 24—14071—June 21—Authorizing G.T.P. Branch Lines Co. to cross certain highways in Province of Saskatchewan and cross and divert eight highways on its Regina-Boundary Branch, and three highways on its Calgary Branch.

14072—June 23—Authorizing C.P.R. to construct industrial spur for the Canadian Gate Company, Guelph, Ont.

14073-74-75—June 23—Authorizing C.P.R. to use and operate bridges Nos. 0.3, 34.0, 37.9, 3.4, and 66.6, 68.0, on its St. Guillaume, Drummondville & Megantic S. Divisions.

14076-77—June 23—Authorizing C.P.R. (Kootenay Central Ry.) to cross with its main line highway at mileage 23.42 in town of Fort Steele, B.C., and approving portion of location of main line from a point in Lot 8.46, at mileage 62.54, thence in northerly direction to a point in Shuswap Indian Reserve, north of townsite of Athalmar, B.C.

14078—June 7—Rescinding Order 13813, June 1st, 1911, re tunnel under C.P.R. at St. Lawrence Boulevard, Montreal, and extending time for completion until 15th September, 1911.

14079—June 7—Approving plan "B" for subway at Brock Ave., Toronto, cost to be assessed as follows:—$5,000, from "Railway Grade Crossing Fund," 20 per cent. of remainder to be paid by city, 32 per cent. by C.P.R., and 48 per cent. by G.T.R.

14080—June 23—Approving Standard Freight Tariff, C.R.C., No. 796, of New Westminster Southern Railway, pending judgment in inquiry into B.C. rates generally.

14081—May 30—Authorizing C.P.R. to construct subway at Jane St., Twp. of York, according to amended plan and rescinding Order 12622, of December 12th, 1910, $5,000 from Railway Grade Crossing Fund.

14082—June 27—Authorizing C.P.R. to construct industrial spur for Brandon Pressed Brick & Tile Co., Twp. of Trafalgar, County of Halton, Ontario.

14083—June 9—Authorizing town of Shawinigan Falls, P.Q., to construct subway under C.N.Q. Ry. on Station Avenue, $5,000 from "Railway Grade Crossing Fund."

14084—June 23—Approving highway diversion of G.T.P. Ry. between Secs 4 and 5, Twp. 25, N. R. 10, west 2nd Meridian, Saskatchewan.

14085—June 24—Authorizing C.P.R. (B.C.S. Ry. Co.) to construct spur for East Kootenay Lumber Co., E. K. District, B.C.

14086—June 26—Authorizing C.P.R. to construct spur for Lethbridge-Weyburn Realty Co., Alberta.

14087-88—June 26—Authorizing C.P.R. to cross with its Regina-Saskatoon & North Saskatchewan Branch, 46 highways, and with its Kininvie Branch 34 highways, Provinces of Saskatchewan and Alberta.

14089—June 24—Approving location and detail plans of G.T.P. station at West Winnipeg, Parish Lots 17-22, Headingly, Man.

14090—June 24—14091—June 26—Authorizing C.N.R. to open for carriage of traffic its line from Hallboro to Beulah, 75 miles. And authorizing crossing of 50 highways on this Hallboro Branch.

14092—June 26—Authorizing C.N.R. Alberta Railway to cross 85 highways in Province of Alberta.

14093—June 28—Approving plans for terrace or covering over track of C.P.R. and Hull Electric Railway adjacent to Chateau Laurier Hotel, Ottawa.

14094—June 15—Authorizing C.N.R. to construct spur to premises of Arctic Ice Co., Mun. of St. Vital, Manitoba.

14095-96—June 27—Authorizing C.N.R. to cross two public roads on its Rossburn Branch, Province of Saskatchewan.

14097—June 20—Authorizing Niagara, St. C. & Toronto Ry. to construct spur to Electric City Athletic Association, Ltd., Niagara Falls, Ont.

14098—June 27—Authorizing C.P.R. to construct spur to premises of St. Lawrence Flour Mills Co., Montreal, P.Q.

14099—June 15—Authorizing C.P.R. to construct third track across Keewatin Street, Winnipeg, Man.

14100—June 21—Authorizing G.T.P. Branch Lines Co. to construct overhead crossing on its Calgary Branch.

14101—June 15—Directing C.N.R. to provide ballast for raising grade of yard and to provide third spur for John Arbuthnot Lumber Co., Winnipeg, Man. Application, F. F. Brock, C. R. Muttleberry, and D. D. Adams, Coal Co., Limited.

14102—June 27—Directing C.P.R. to construct subway under its tracks for John Hextall, Calgary, Alberta, at a point in Sec. 34, Twp. 24, R. 2, west 5th Meridian.

14103—June 15—Authorizing city of St. Boniface, Man., to construct at its own expense Plessis St., across C.P.R. Emerson Branch.

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QUEBEC BRANCH—
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TORONTO BRANCH—
96 King Street West, Toronto. Chairman, H. E. T. Haultain; Secretary, A. C. D. Blanchard,, City Hall, Toronto. Meets last Thursday of the month at Engineers' Club.

MANITOBA BRANCH—
Secretary, E. Brydone Jack. Meets first and third Fridays of each month, October to April, in University of Manitoba, Winnipeg.

VANCOUVER BRANCH—
Chairman, Geo. H. Webster; Secretary, H. K. Dutcher, 40-41 Flack Block, Vancouver. Meets in Engineering Department, University

OTTAWA BRANCH—
Chairman, A. A. Dion, Ottawa; Secretary, H. Victor Brayley, N. T. Ry., Cory Bldg.

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CONSTRUCTION NEWS SECTION

Readers will confer a great favor by sending in news items from time to time. We are particularly eager to get notes regarding engineering work in hand and projected, contracts awarded, changes in staffs, etc. Printed forms for the purpose will be furnished upon application.

TENDERS PENDING.

In Addition to Those in this Issue.

Further information may be had from the issues of The Canadian Engineer referred to.

Place of Work.	Tenders Close.	Issue of.	Page
Burnaby, B.C., valves	July 24.	June 22.	68
Burnaby, B.C., steel pipes	July 24.	June 15.	66
Burnaby, B.C. special casting	July 24.	July 6.	72
Dresden, Ont., waterworks	July 26.	July 13.	68
Halifax, N.S., schoolhouse	July 21.	July 13.	62
Kindersley, Ont., schoolhouse	July 25.	July 13.	54
Moose Jaw, Sask., electrical equipment	July 24.	June 29.	908
Nanaimo, B.C., street paving	July 21.	July 6.	72
Ottawa, Ont., Hudson Bay Railway	Aug. 1.	June 8.	64
Ottawa, Ont., pier and sheds, Halifax	July 20.	June 15.	68
Ottawa, Ont., harbor works, Courtney Bay	Aug. 10.	June 22.	68
Ottawa, Ont., stations	Aug. 3.	July 13.	68
Ottawa, Ont., breakwater, Brooklyn, N.S.	July 26.	July 13.	62
Ottawa, Ont., post office, Kingston	July 31.	July 13.	62
Ottawa, Ont., public building, Chilliwack, B.C.	July 24.	July 13.	62
Penticton, B.C., generators	Aug. 10.	July 6.	68
Regina, Sask., sidewalk	July 28.	July 13.	68
Regina, Sask., pavement	July 28.	July 13.	68
Regina, Sask., building for Leader Publishing Co.	July 26.	July 13.	54
Tavistock, Ont., pumping equipment	July 20.	July 6.	72
Yorkton, Sask., water-main and sewer-main	July 24.	July 6.	72
Toronto, Ont., bridge work	July 31.	July 13.	66
Toronto, Ont., groynes	July 24.	July 13.	66
Toronto, Ont., cribs	July 24.	July 13.	68
Westmount, Que., fire station	July 27.	July 13.	68
Victoria, B.C., work on Parliament buildings	Aug. 15.	July 13.	54

TENDERS.

Ottawa, Ont.—The Public Works Department will receive tenders up to 4 p.m., on Monday, July 31st, 1911, for the construction of a public building at Humboldt, Sask. Plans, specifications and form of contract can be seen and forms of tender obtained at the office of Mr. J. E. Cyr., Supt. of Public Buildings for Manitoba; Post Office Building, Winnipeg, Man.; at the Post Office, Humboldt, Sask.; and at the office of R. C. Desrochers, Secretary, Dept. of Public Works, Ottawa.

Ottawa, Ont.—Sealed tenders will be received until July 24th, 1911, for the construction of a tobacco curing barn, Experimental Farm, Ottawa. Plans, specifications and form of contract can be seen and forms of tender obtained at the office of R. C. Desrochers, Secretary, Dept. of Public Works, Ottawa.

Ottawa, Ont.—Tenders will be received until July 24th, 1911, for the erection of a wireless telegraph station at Midland, Ont. Plans, specification and form of contract can be seen at the office of the Supt. of Wireless Telegraphs, Dept. of Naval Service, Ottawa; the office of the agent of the Dept. of Marine and Fisheries, Parry Sound, Ont.; or at the office of the Postmaster at Midland, Ont. G. J. Desbarats, Deputy Minister, Dept. of Naval Service, Ottawa.

Ottawa, Ont.—Tenders will be received until August 4th, 1911, for lockgates and valve gates, Holland River Division, Trent Canal. Plans, specification and form of contract can be seen at the office of the Chief Engineer of the Dept. of Railways and Canals, Ottawa, and at the office of the Superintending Engineer of the Trent Canal, Peterborough, Ont., at which places form of tender may be obtained. L. K. Jones, Dept. of Railways and Canals, Ottawa.

Ottawa, Ont.—Tenders will be received until July 29th, 1911, for the erection of a wireless telegraph station at Tobermory, Ont. Plans, specifications and form of contract can be seen at the office of the Supt. of Wireless Telegraphs, Dept. of Naval Service, Ottawa; the office of the agent of the Dept. of Marine and Fisheries, Parry Sound, Ont.; or at the office of the Superintending Engineer of Sault Ste. Marie Canal, Sault Ste. Marie, Ont., or at the Post Office at Tobermory, Ont. G. J. Desbarats, Deputy Minister, Dept. of Naval Service, Ottawa.

Ottawa, Ont.—The time for receiving tenders for pier sheds has been extended from Thursday, the 20th of July, 1911, to Monday, the 31st of July, 1911. L. K. Jones, Secretary, Dept. of Railways and Canals, Ottawa. (Adv. in the Can. Eng.)

Ottawa, Ont.—Tenders will be received until July 25th, 1911, for dredging required at Amherst, N.S. Plans and specifications can be had on application to R. C. Desrochers, Secretary, Dept. of Public Works, Ottawa.

Ottawa, Ont.—Tenders will be received until August 1st, 1911, for the construction of asphalt pavements on Church street from Dalhousie to Cumberland, and on O'Connor street from Pretoria to Clemow avenues. Specifications can be obtained from Newton J. Ker, City Engineer, Ottawa.

Ottawa, Ont.—Tenders will be received until August 8th, 1911, for the construction of a public building at Tilbury, Ont. Plans, specifications, and form of contract can be seen and forms of tender obtained at the office of Mr. H. J. Lamb, Dist. Engineer, London, Ont.; at the Post Office at Tilbury, Ont.; and at the office of R. C. Desrochers, Secretary, Dept. of Public Works, Ottawa.

Ottawa, Ont.—Tenders will be received until August 1st, 1911, for the construction of a freight shed on the quay wall at Halifax, N.S. L. K. Jones, Secretary, Dept. of Railways and Canals, Ottawa. (Adv. in the Can. Eng.)

Ottawa, Ont.—Tenders will be received until August 1st, 1911, for the supply and delivery of one spur gear for the waterworks. Specifications may be obtained at the office of Newton J. Ker, City Engineer, Ottawa.

Toronto, Ont.—Tenders will be received until August 4th, 1911, for the construction of Low Level Interceptor and for main drainage works. G. R. Geary (Mayor), Chairman Board of Control, City Hall, Toronto. (Adv. in the Can. Eng.)

Toronto, Ont.—Tenders will be received until July 31st, 1911, for the construction of a reinforced concrete arch bridge over the Don River. Frank Barber, Township Engineer. (Adv. in the Can. Eng.)

Toronto, Ont.—Tenders will be received until July 29th, 1911, for the supplying of machinery with material, labor and construction of macadam roadway. E. A. James, Engineer to Board, Room 6, 57 Adelaide St. East, Toronto. (Adv. in the Can. Eng.)

St. Catharines, Ont.—Tenders will be received until July 31st, 1911, for the trades work in connection with the erection of an assembly hall and gymnasium for the St. Catharines' Collegiate Institute. Plans and specifications to be seen with the architect. T. H. Wiley, St. Paul St., St. Catharines, Ont.

Thorold, Ont.—Tenders will be received until July 20th, 1911, for labor and material required for the construction of macadam roadways, comprising 5,800 lineal feet of 16-foot roadway. Plans and specifications may be seen at the office of the engineer, J. C. Gardner, Logan Building, Queen St., Niagara Falls, Ont., or at the office of D. J. C. Munro, Town Clerk, Thorold.

Winnipeg, Man.—Messrs. Woodman & Carey are inviting tenders for the erection of a large office building for the Dominion Express Company, of this city.

Kirkfield P.O., Man.—Tenders will be received until July 31st, 1911, for the construction of sewers and waterworks on Deer Lodge sub-division, being part of D.G.S. Lots 20 and 21, St. James. Specification and form of tender may be obtained at the office of the St. James' Realty Co., Bank of Nova Scotia Building, corner Portage avenue and Garry street. Frank Ness, Sec.-Treas., Municipality of Assiniboia, Kirkfield P.O., Man.; Col. H. K. Ruttan, Consulting Engineer, Office of Sec.-Treas.

Arcola, Sask.—Tenders will be received until August 1st, 1911, for the erection and completion of an addition to the school building at Arcola, Sask. Plans may be obtained at the offices of Storey & Van Egmond, Architects, Regina and Saskatoon, and at the office of James R. Donaldson, Secretary, School Dist., Arcola, Sask.

Regina, Sask.—Tenders will be received until August 1st, 1911, for the construction of Egg Lake Drain. Plans and specifications to be had on application to F. J. Robinson, Deputy Minister, Dept. of Public Works, Regina, Sask.

Victoria, B.C.—Tenders will be received until July 27th, 1911, for the erection and completion of a four-room schoolhouse, timber-framed, with concrete basement, at Lynn Valley in the Richmond Electoral District. Plans, specifications, contract and forms of tender may be seen at the offices of Mrs. E. J. Campbell, Secretary to the School Board, North Vancouver; the Government Agent, New Westminster; and office of J. E. Griffith, Public Works Engineer, Dept. of Public Works, Victoria, B.C.

CONTRACTS AWARDED.

The D. P. Battery Co., Ltd., Bakewell, Derbyshire, England, inform us that they have just secured the contract for a 500-volt central station battery for Barnstaple, also a battery for the Newark Corporation Water Works, England.

Yamaska, Que.—The Foundation Company, Limited, Bank of Ottawa Building, Montreal, have recently been awarded a contract by the Quebec, Montreal & Southern Railway Co., for the reconstruction of a bridge pier at Yamaska, Que.

Montreal, Que.—The British Electric Plant Company, being the lowest tenderers, have received the contract for the pumping machinery in connection with the filtration plant, their price being $40,000. Mr. F. H. McGuigan, of Toronto, will construct the cement basins at a cost of $673,000. The entire cost of the system is estimated at $1,673,000.

Montreal, Que.—Tenders for the new filtration plant were awarded by the Board of Control. Of the four firms tendering, the lowest price—$673,000—comes from the Toronto firm of F. H. McGuigan & Company. His firm was awarded the contract.

Ottawa, Ont.—Contracts totalling half a million dollars for new equipment for the I.C.R., have been awarded by the Department of Railways. A contract for five locomotives has been let to the Canadian Locomotive Company, of Kingston, for $114,000. The Canada Car Company will build 230 steel-framed cars, 20 steel platform cars, 25 dump cars, one refrigerator car, and 20 baggage cars, the contract price being $334,790. One hundred platform cars, two stock and two postal cars will be built by the Nova Scotia Car Company for $112,000. It is understood that the Dominion Steel Company has put in the lowest tender for a large supply of 80-pound steel rails required by the I.C.R.; the steel rail purchases this season will total $600,000.

Toronto, Ont.—Contracts for the work on the main drainage pumping station on Eastern avenue, have been awarded as follows:—Lathing and plastering, to M. Hutchinson, price $1,337; roofing, to George Sinclair, price $293; carpentering, to M. Hutchinson, price $1,208; masonry, to Wm. Forbes & Sons, price $25,990; painting and glazing, to H. W. Johnston, price $278; plumbing, to the Fred Armstrong Co., Ltd., price $630.

Toronto, Ont.—The Godson Contracting Company have received contracts for the construction of low level interceptor and storm overflow sewers, their bids being the lowest on all sections.

Toronto, Ont.—Weston Road Bridge.—Contractors: The Canada Foundry Co., at $8,740.

Toronto, Ont.—Concrete work on Weston Road bridge. —Contractor: C. E. Lewis, Toronto, at $2,600.

Toronto, Ont.—A contract has been signed with Messrs. Foley Bros., St. Paul, Minn., and the Northern Construction Co., of Winnipeg, Man., for the railway work between Sellwood Junction and Port Arthur. Their contract includes all the work, except superstructure, for steel bridges and buildings on the Sudbury-Port Arthur Division of the Canadian Northern Ontario Railway. Roughly calculating, the line will cost about $50,000 per mile for the entire distance of 551 miles.

Toronto, Ont.—The Board of Control have decided to divide the contract for a supply of 6,000 feet of 2½-inch hose amongst four firms. The Rubber Manufacturing Co. gets half the order at $1.10 per foot, and the Goodyear Rubber Co., the Dunlop Rubber Co., and the Canadian Rubber Co. will each supply 1,000 feet.

Toronto, Ont.—The Board of Control have awarded Messrs. Miller, Cumming & Robertson, the contract for laying the city's new intake pipe. They have offered to do the work for $259,900.

St. Catharines, Ont.—The following contracts have been awarded in connection with the waterworks system: Tunnel, W. H. Weller, St. Catharines, $43,845; pipe laying, the D. West Construction Co., Milwaukee, $18,917.

Welland, Ont.—Messrs. D. Dick & Son have received the contract for the new pumphouse, in connection with the Welland Waterworks System. It will be of cement construction, and will cost in the neighborhood of $10,000.

Fort William, Ont.—A contract for a $30,000 brick business block to be erected on Victoria Avenue, has been awarded to Mr. M. H. Braden.

Winnipeg, Man.—The awarding of contracts for sewer works are as follows:—Trunk sewer on Archibald, Messier and Dufresne streets, Van Hornbeck Co., at $63,403.60. The same firm was awarded the contract for the Mission street sewer for $26,731.53; Montcalm street sewer, Hern & Knox, at $1,953.00; Felix Cottonier secured the remainder of the contracts for St. Mary's road, Crescent street, Lansdowne avenue and Dufferin street, respectively, at the following figures: $2,184.20, $1,445.60, $3,252.50, and $1,297.85.

Winnipeg, Man.—Contracts for 20,000 pounds of lead pipe have been awarded to Jas. Robertson Co., Ltd.

Winnipeg, Man.—President G. T. Somers, of the Sterling Bank, let to Carter-Hallis-Aldinger Company, Ltd., the contract for the erection of a nine-storey bank and office building on the corner of Portage avenue and Smith street. Messrs. James Chisholm & Son are the architects.

Saskatoon, Sask.—Tenders for Knox church manse have been opened by Thompson, Daniel & Colthurst, architects, and the contract let to Mr. S. Baker for $9,295.

Cranbrook, B.C.—Public building.—Contractors: McCallum & Co., of Cranbrook, B.C., at $43,833.

Cranbrook, B.C.—Sewer System.—Contractors: The Galt Engineering Works, at $100,000.

North Vancouver, B.C.—The city council have disposed of a number of tenders and the following tenders accepted were:—Esplanade grading from St. George avenue to St. David avenue, Higgins & Fisher, $9,160; First street, Lonsdale avenue to Forbes and Chesterfield and Semish avenues, First to Second streets, H. V. Tucker, $22,010; Second street, 300 yards east to St. David's avenue, H. V. Tucker, $10,975; Third street sanitary sewers, St. Andrew's to St. David's avenue, E. C. Blake, $10,605.

Vancouver, B.C.—The Kettle Valley Lines have awarded to Messrs. L. M. Rice & Co., of Vancouver, a contract for the construction of 40 miles of the main line from Bull Creek to the summit near the headwaters of the west fork of Kettle River.