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A REINFORCED CONCRETE STAND-PIPE.

Some notes on a reinforced concrete stand-pipe recently built at Westerly, R.I., and described in the September Proceedings of the American Society of Civil Engineers, by W. W. Clifford, will be of interest because of some methods of construction used for the first time, and also because of its appearance and water-tightness.

The general shape of this stand-pipe is shown by Fig. 1. The cement seemed to give the concrete a somewhat lighter color than usual, and this was increased by the lime which was added, the result being an almost white concrete. As steel forms were used, its surface was very smooth. The jointing seen in Fig. 2 is due to the fact that the forms were not absolutely water-proof at the joints, and the water running out caused a slight burr at the edge of each panel. The finishing tiles of the dome are dark red and glazed, and, forming a marked contrast with the light concrete, give a distinctly pleasing appearance.

The stand-pipe is founded on hardpan, which at this point is only 5 or 6 ft. below the surface. The inside diameter is 40 ft.; the height, from the floor to the overflow, is 70 ft., and from the ground to the top of the ventilator on the dome, is about 88 ft. The thickness of the wall at the floor is 4 ft., tapers to 14 in. at a height of 5 ft., and is of this thickness up to the water line. The wall, for the first 5 ft. above the ground, has an outside diameter of 44 ft. 4 in., then an ornamental moulding reduces it to 42 ft. 4 in., which is constant to the bottom of the triglyphs, 6 ft. below the water line. Just above this there is a fillet 6 in. deep and projecting 4 in. Above the water line there is a cornice 24 in. deep and projecting 30 in. This is surmounted by a parapet wall 4 ft. high. A Guastavino dome of red tile springs from a seat 2 ft. above the water line. Its diameter is 41 ft. and its rise 13 ft.

A steel ladder, 1 ft. wide, of ½ by 1½-in. flats and ¾-in. rounds, is secured by bronze bolts in cast-iron sockets with 1-in. bronze faces, set into the wall at 16-ft.6 intervals. The rungs are 12-in. from centre to centre, but this spacing is reduced to 6 in. through the opening in the cornice. The ladder was erected in 16-ft. sections, and the bottom is about 16 ft. from the ground. Over the parapet the flats are replaced by 1½ by 2½ by ¾-in. angles.

For construction purposes, a frame tower, large enough for a 1-yd. Ransome auto dump bucket, was placed so that it cleared the outside edge of the cornice by about 1 ft. This tower had 6 by 6-in. uprights, and was thoroughly cross-braced. A No. 2 Smith concrete mixer, run by steam, was set in a pit so that the materials could be conveniently dumped into the hopper from the ground. The mixer emptied directly into the bucket, which was run by a hoisting engine. The same boiler furnished steam for mixing, hoisting, and later, also, for pumping water to the top of the wall for washing it. The concrete for the foundation floor and base was hoisted about 20 ft. and dropped in a chute; one section of this chute carried the concrete from the tower to the centre of tne tank, and from there a movable sc.ion delive.ed it in place.

An inside stage was used for all but the first few feet of the wall. The floor of this stage was framed of two rings

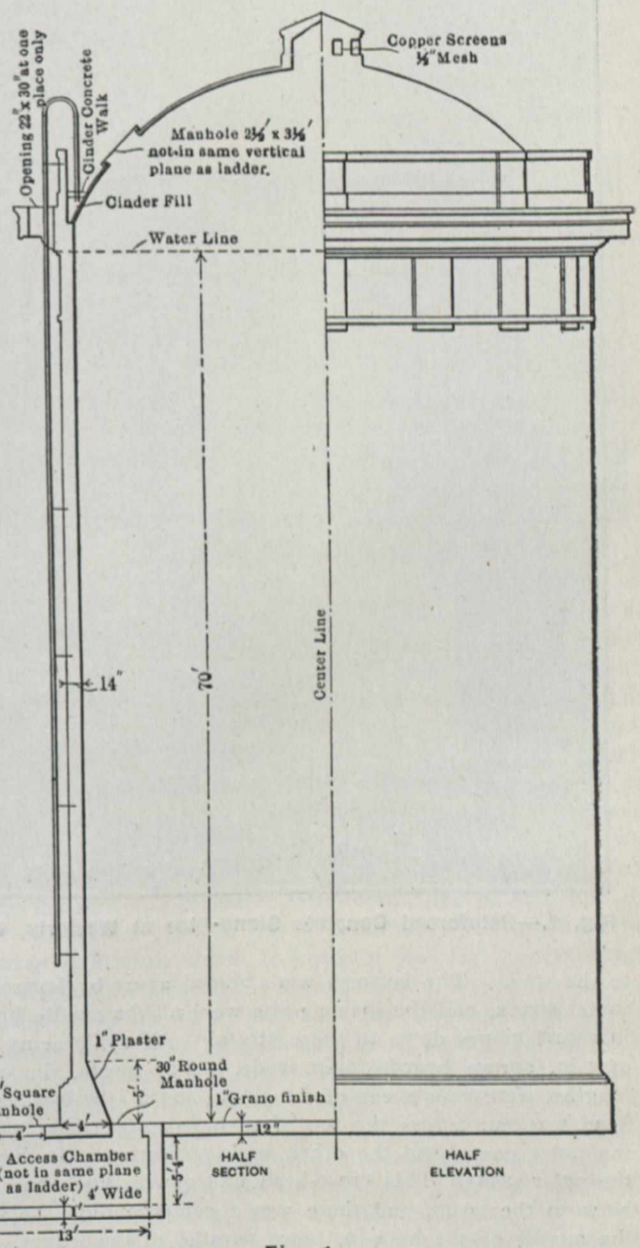


Fig. 1.

of 8-in., 11¾-lb. channels. These rings were 38 and 28 ft. in diameter, respectively, and were in four sections, bolted together with standard splice-plates, the splices being staggered on the two rings. Two braces, each consisting of two 6¾-in., 5-lb. channels, held parallel and 18 in. apart by bolts passing through pipe spacers, were placed diametrically across the inside of the inner ring at right angles to each other. There was a lattice bracing of single 2 by 2 by ¼-in. channels between the curved channels. The upper flanges of the curved channels were bored every 3 ft. to receive the bolts for the nailing strips. Planks, 2 in thick and 6 ft. long, were nailed on the curved channels, making a solid floor of this width which cleared the inside of the wall by 6 in., and was very rigid and satisfactory. A floor of boards, 2 ft. wide, ran across one pair of diametrical channels, and on this was stored wheel-barrows, and other tools when not in use. The uprights for this stage were 4 by 4-in. spruce posts. Ledges, composed of two 1 by 6-in. boards, were nailed on each pair of uprights, and the 8-in. channels rested on these. The outside posts went down vertically to the point where the wall commenced to flare in, and there they also bent toward the centre and rested on the bottom close

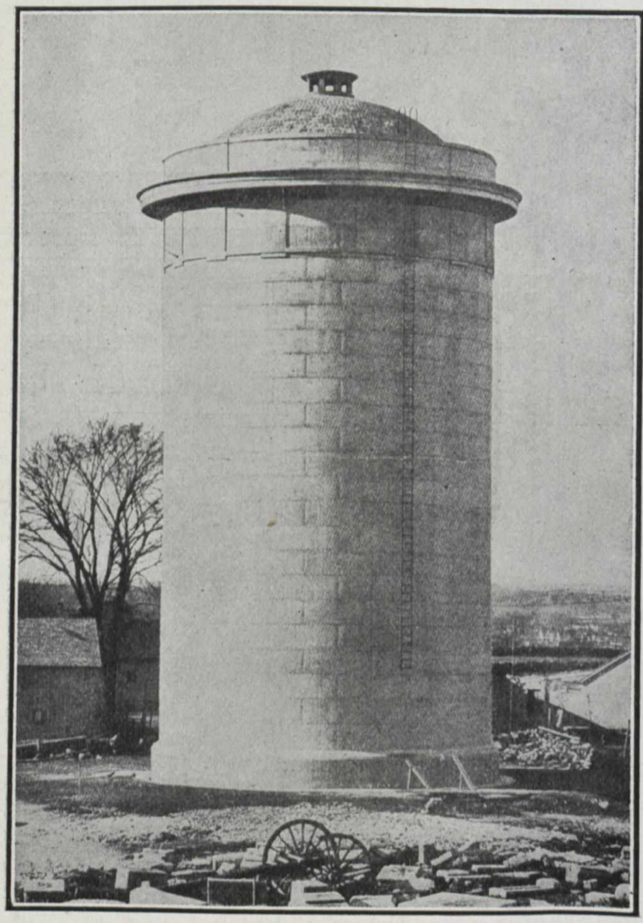


Fig. 2.—Reinforced Concrete Stand-Pipe at Westerly, R.I.

to the wall. The bottoms were braced apart by horizontal, radial struts, and the inside posts were all diagonally braced in radial planes down to these struts. All the bracing was of 1-in. spruce boards, 6 in. wide. The posts, in 16-ft. lengths, were kept ahead of the stage, and a 4 by 6-in. cross-head was put across the top of each pair, the inner end at the inner posts, and the other end projecting 2 ft. beyond the outer posts. This cross-head had a wire hook half way between the posts, and there was a corresponding hook at the middle of a 4 by 4-in. piece parallel to the ledges, and wedged in between the 8-in. channels radially.

When the stage was to be raised, eight 2,000-lb. differential chain falls were hooked into these loops, and, with two men on each, the stage was raised in a few moments, the whole floor moving as a unit. When the proper height was reached, new ledges were put on, and bracing below if necessary, and the stage was ready to use. The concrete, hoisted in a bucket, was dumped into a hopper hung on the face of the construction tower about 3 ft. above the stage; a platform 6 ft. wide was laid down between the stage and the tower, over the top of the wall. The wheel-barrows received their load from a gate in the bottom of the hopper, and were wheeled around and dumped directly into the forms, the stage during the pouring being flush with the top of the form which was being filled.

The forms for the outside of the base were of wood with 2 by 8-in. horizontal ribs and ⅞-in. vertical laggings. These forms, and also the soft pine moulding forms, were made in a local lumber yard. The forms for the inside of the base were made at the site, and were in short chords instead of arcs.

Steel forms were used successfully for all plain wall. They were made in panels about 3 ft. deep, and 8 ft. long. The exact depth was one-twentieth of the distance from the top of the moulding at the base to the under side of the triglyphs. Each panel was of ⅛-in. plate with 1½ by 1½ by ⅛-in. angles riveted on the edge, the back of the angle being toward the edge of the plate. They also had two vertical stiffener angles. The angles on the edge were bored to receive the bolts which held the panels together and kept one set in place on top of the other. The panels were of such a size that they could be handled easily by two men, and two complete sets were used.

Pieces of 2-in. plank cut radially were bolted under the top flange of the twentieth form, and supported wooden forms for the lower ends of the triglyphs and the fillet. Both steel forms were set up on the fillet, with spacers between the panels to spread them to the outside diameter of the triglyphs. Through holes bored in the steel forms nailing strips were bolted, and vertical lagging was nailed to these, to make boxes for the indentions between triglyphs. The pieces of plank which had supported the fillet forms were again bolted under the top flange of the forms, and supported wooden forms for the short section of walls between the top of the triglyphs and the bottom of the cornice.

The plans called for overflow holes, 12 in. wide and 3 in. deep, spaced 45° apart around the circumference, but as these openings provided the only opportunity to support the cornice forms, they were spaced 11¼° apart, and the extra ones were filled up afterward. One day's pouring was ended at the top of these openings, and flat concrete blocks were placed over them and incorporated in the wall, in order to obviate the difficulty of removing forms from such small openings. Pieces of 4 by 4-in., 6 ft. long, were cut down to 3 by 4 in. for 18 in. at one end, and two were put in each overflow hole, making as great an angle as possible with each other. The outer ends of these brackets were braced down to the fillet 6 ft. below. On these 64 brackets the cornice forms were built, partly of lumber sawed in the yard and partly of plaster of Paris on metal lath which was used so that the concrete would not be damaged by the swelling of the wood when wet. The plaster was composed of equal parts of plaster of Paris and Limoid. It was placed and shaped by trowel and template, and smoothed with a 4-in. paint brush and water while still green.

The outside base forms, with boxes built inside to give the proper shape, were used in building the parapet. The inside steel forms were used from the top of the base to the top of the parapet, spreaders being put between the panels above the dome seat. For carrying up the centre, short vertical planks were bolted into four sockets inside the wall. These were set at the same height and equally spaced. To the tops of these planks two wires were fastened so as to stretch diametrically across the tank.

By revolving the planks slightly about the bolts, the wires were adjusted so that their intersection was exactly at the centre. This arrangement was put in every 15 or 20 ft., for the tank was filled as the work progressed.

The centres for the dome were supported by the inside stage, which was left in for that purpose, and later all the long pieces were taken out through a manhole in the dome by a gin pole placed on the cornice. The smaller pieces were taken out through the access chamber.

The main reinforcement was of plain, round, mild-steel bars, 1½ and 1⅜ in. in diameter. These bars were 71 and 69 ft. long, so that two formed a complete ring, allowing 40 diameters for lap. The bars were bent on the ground, by from 4 to 6 men, blocks being set by trial to give the necessary curvature. They were then hammered to set. They were hoisted by two No. 0 Parker derricks, and, in addition, it was found necessary to use one of the swinging stage falls on the middle of the bar. On arriving at the top of the wall, they were taken to their position by hand. These hoops were supported by twelve equally spaced 1½-in. vertical iron pipes, resting on standard 6-in. flanges on the floor. These pipes were in 3-ft. sections, corresponding to the height of a form. The sections were joined by ordinary couplings, and erected as the work progressed. Braces of 2 by 2 by ¼-in. angle iron connected these pipes while the steel was being put on. These were bolted into special castings screwed into the couplings on top of the last erected sections of pipe, and were removed when the steel was in place and another section of pipe was to be erected. Radial ¼-in. holes were bored through these pipes at the proper intervals for the rods, and through these holes were put ¼-in. hooks, in which the rods were placed. The hooks were then hammered flat against the pipe or around the bar. In some cases it was found necessary to use some No. 10 wire, as well as the hooks, to fasten the rods to the pipes. The pipes were filled with grout as the work progressed. The joints were staggered so that about one in twelve came in the same vertical plane. Two Crosby clips, such as are commonly used for guy wire, were also used on each joint.

In the floor the secondary reinforcement is composed of ¼-in. square rods, 6 in. from centre to centre both ways. The rods are 1 in. below the surface, and are bent up 4 ft. into the wall. Around the manhole and the access chamber in the roof, ⅝-in. round and 1¼-in. square rods are used. Just under the dome seat there are ¼-in. square rods, set horizontally, and ⅝-in. round rods, 4 ft. from centre to centre, are bent out into the cornice. Round ⅝-in. rods, 7 ft. long and 2 ft. from centre to centre, run vertically up into the parapet.

The proportions for the concrete were decided after numerous carefully made experiments, for dependence was placed on the density of the concrete to make it impervious. The materials available were crushed granite and several bank sands, all of good quality. Vulcanite cement was used. The granite (gray Westerly) was a satisfactory larger aggregate. The sand chosen was that which contained the least vegetable matter and showed the greatest percentage of strength.

The only water-proofing agent used was Limoid (a patented form of hydrated lime) to the extent of 5% by weight of the cement. Some tests made by the writer seemed to indicate that the addition of lime to cement increased its volume by approximately the volume of the lime added. As the cement was more than enough to fill the voids in the sand, and the mortar to fill the voids in the stone, it is difficult to see wherein lay the advantage of the lime.

The joints were given special care, and the separate day's work seemed to be completely bonded. The top surface of the concrete was thoroughly cleaned each night after it had taken its initial set, and all the laitance was removed, leaving clean sand and stone surfaces exposed. At the beginning of each pouring the surface was covered with grout, and a 1-in. layer of 1:3 mortar was put in before the concrete. The first joint above the floor could not be cleaned before final set, because the floor finish was fresh, and water could not be run over it, so it was found necessary to clean the joint with muriatic acid, and even this was not sufficient for some parts, and they had to be picked.

The floor had a 1-in. granolithic finish, and this was carried up as a plaster coat to the top of the inside bevel. The outside surface was rubbed with carborundum and then painted with a grout wash, except on the base, which, from the ground up to a level 2 in. below the top of the moulding, was picked.

Several porous spots showed dampness on the outside when the tank was first filled. These spots were quite wet in the morning, but the sun dried the most of them in the course of the day. They were treated by forcing grout into them. A cavity was picked in the wall for 7 or 8 in. at the point which seemed to be the source of the leakage, and a ¾-in. nipple, 6 in. long, was bedded in this with 1:2 mortar, the inner end being kept clear by filling stone around it.

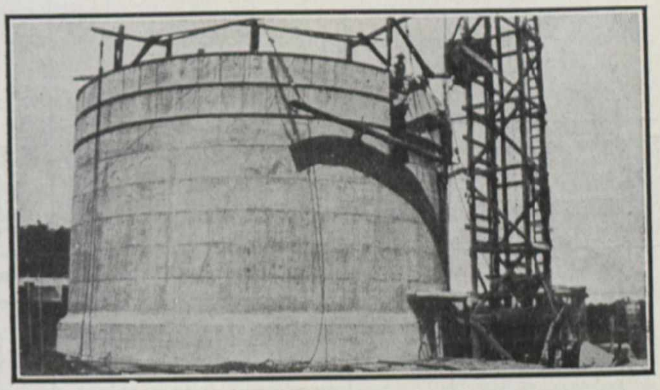


Fig. 3.—Setting Steel Form for Concrete Stand-Pipe.

Grout was then forced in, under a pressure of about 100 lb. per sq. in., furnished by a tank of carbon dioxide gas, such as is used at soda fountains. This eliminated these leaks. Another leak, which appeared along the top of the moulding on the outside, showed as a horizontal crack nearly half way around the circumference, and varying in amount of leakage. As this was too big to repair by grouting, it was decided to water-proof it from the inside. A paraffin treatment was tried on the wall for 8 ft. above the floor. The wall was heated with charcoal furnaces, and hot paraffin was applied; then the wall was reheated, thus forcing the paraffin into the pores. Several coats of this were applied, but they have not proved sufficiently elastic to keep the wall tight under stress.

Apparently this leak is a stress strain, due to the unequal expansion of the 14-in. wall and the thickened base. The original design had been changed by bringing the top of the inside bevel above the outside moulding to prevent this very difficulty, but without entire success. This is the only structural defect which has been brought to light, thus far, and, in the design of concrete tanks under high pressure, is one of the greatest difficulties to overcome. In addition to the differential expansion, there is also the change of stress, from the compression on the bottom to the tension on the wall. If there is no projecting base, the source of the difficulty is simply lowered to the junction of the floor and wall. All the porous spots were on the south side, and most of them were also in the part of the wall nearest to the construction tower, where drippings from the chute fell into the wall forms.

TABLE 1.—COST OF REINFORCED CONCRETE STAND-PIPE AT WESTERLY, R. I.

Items.	Quantities.	Cost per Cubic Yard.				Total unit cost.	Total cost.
		Labor.	Plant and stage.	Cement and Limoid.	Aggregate.		
CONCRETE:							
In foundations	337 cu. yd.	$0.90	$1.44	$1.43	$2.09	$5.86	$1 975
" floor	119 " "	1.52	1.44	3.40	1.56	7.92	942
" walls and cornice	423 " "	1.74	2.14	3.34	1.56	8.78	3 714
" parapet	13 " "	1.00	2.14	2.53	1.56	7.23	94
" walk around roof	....	....	....	....	....	....	60
FINISH:		Cost per 100 Sq. Ft.					
		Labor.	Lumber.	Cement and Limoid.	Aggregate.		
Rubbing and wash on walls	20 866 sq. ft.	$1.14	....	$0.03	....	1.17	244
Picking on plinth	573 " "	14.14	....	....	....	14.14	81
Plaster on plinth	132 lin. ft.	0.46	$0.76	0.04	....	1.26	166
Picking angle for plaster	....	....	....	....	....	....	33
Granolithic on floor and plastering angle	1 767 sq. ft.	5.85	....	4.43	$0.15	10.43	184
Granolithic on cornice	400 " "	2.25	....	1.00	0.15	3.40	14
Granolithic on outside walk	343 " "	1.84	....	3.60	0.15	5.59	19
FORMS:		Cost per 100 Sq. Ft.					
		Labor.	Plant and stage.	Material.			
Foundation	450 sq. ft.	$18.29	....	$3.40	....	21.69	98
Plinth	1 249 " "	12.50	....	2.20	....	14.70	184
Walls	16 733 " "	4.40	$3.36	5.46	....	13.22	2 212
Walls, triglyphs	1 208 " "	18.00	3.36	20.24	....	41.60	502
Floor	247 " "	5.08	....	2.20	....	7.28	18
Cornice	1 163 " "	38.32	3.36	13.58	....	55.26	643
Parapet	1 225 " "	13.68	....	8.41	....	22.04	269
					Carried forward	....	$11 452
STEEL REINFORCEMENT:		Cost per Ton.					
		Labor.	Stage.	Material.			
Rods	68 tons	$9.73	$4.50	$39.00	....	53.23	3 619
Crosby clips						....	171
Pipe standards for steel	852 lin. ft. at 20 cents					....	169
Hook spacers	2 200 " " 1¼ "					....	28
OFFICE AND GENERAL:							
Telephone, stationery, traveling, etc.						....	200
Board						....	320
Travel, and superintendence (at beginning of work)						....	56
Watchman, and lights						....	50
Delay (waiting for lost cars of steel)						....	104
Clearing site, and grading						....	120
Setting pipes, manhole cover, and tablet						....	17
Miscellaneous extra work, and pipe-laying						....	196
Material for steel ladder, $90.50; setting and painting ladder, $44.25						....	135
Guastavino tile dome						....	1 200
Trap door in dome						....	9
Water-proofing (test blocks)						....	10
Bond (surety)						....	105
					Total		$17 961

The materials were delivered by a granite company, on a side track about 100 ft. from the site of the work, for 35 cents a ton, the additional costs being for the labor of unloading and carrying the materials to the site of the work. The steel was carried by hand, and the cement in wheelbarrows. The stone and sand were delivered in piles beside the mixer by carts.

The following prices were paid for labor:—

Foreman carpenter	48	cents per hour.
" "	43¾ and 45	" " "
Carpenter's helper	35	" " "
Engineman	35	" " "
Labor foreman	50	" " "
Laborers	22½ and 25	" " "

The following prices were paid for materials:—

Cement	$1.52	per bbl. (less 30 cents for bags returned).
Sand, delivered at site	1.15	" yd.
Stone, " " "	1.07	" "
Limoid	1.00	" bag (100 lb.).
Plaster of Paris	2.00	" bbl.
Steel	38.00	" ton, plus the freight

In Table 1, the cost of the stage is divided between concrete, forms, and steel, in the proportions of ¼, ½, and ¼. In the labor costs for the wall steel, about one-third is charged to bending and two-thirds to placing. In the secondary reinforcement, the cost of bending was a negligible quantity.

The capacity of the stand-pipe is 660,000 gal., and its cost was about 2¾ cents per gal. It was designed and built by the Aberthaw Construction Company, of Boston, Samuel M. Gray, M. Am. Soc. C.E., being Consulting Engineer for the Water-works.

A THEORETICAL FORMULA FOR THE CURVE RESISTANCE TO THE FLOW OF LIQUIDS.*

By Philip J. Markmann, C.E., St. Louis, Mo.

The resistance offered by bends in pipes or curves in open channels to the flow of liquids is a much-mooted subject in hydraulics.

We find empirical formulae for the loss of head due to bends in pipes by Du Buat, Navier, Weisbach and probably others.

These formulae, being empirical ones, probably cover the range of the respective experiments with regard to velocities, kinds, size and curvature of pipes under observation.

One of the contributions within recent years, in the line of experimental data, is the paper of Williams, Hubbell and Fenkell, of Detroit, entitled "Experiments at Detroit, Michigan, on the Effects of Curvature upon the Flow of Water in Pipes," published in the Transactions of the A. S. C. E. of April, 1902, vol. xlvii.

In the introduction to their paper they made this statement: "Having satisfied themselves that there was no data extant that an engineer was warranted in applying to the cases occurring in ordinary practice, notwithstanding the unanimity of opinion expressed in hydraulic treatises, the writers have considered it unnecessary to present any resume of meager data supposed to bear upon the question in hand." etc.

This in itself is a rather remarkable statement of the status of hydraulic knowledge, and becomes rather sensational when supplemented by the authors' conclusions, on the basis of their own experiments, which are:

"The experiments taken as a whole prove beyond question or doubt that the hitherto accepted notions of the laws governing curve resistance are wholly in error.

"Curves of short radius, down to a limit of about 2½ diameters, offer less resistance to the flow of water than do those of longer radius, and hence the theories and practices regarding curve resistance, as set forth in the hydraulic treatises of all nations up to the present time, are absolutely incorrect and the diametric opposite of the true conditions."

Later on, when summing up the discussion and the criticism on their paper, these authors found themselves compelled to modify their above statement, as follows:

"In a given length of pipe, consisting of two tangents joined by a curve of 90 degrees, the loss of head will de-

*A paper before the St. Louis Engineers' Club.

crease as the radius of the curve is decreased, to a limit of about 2½ diameters, and will increase as the radius is increased above that limit, the total length remaining the same."

They insist, however, on the originality of their statement, that "the theories and practices regarding curve resistance, as set forth in the hydraulic treatises of all nations up to the present time, are absolutely incorrect and the diametric opposite of the true conditions," by saying: "An examination of the various treatises on hydraulics, contained in one of the most complete libraries in America, made before this paper was written, failed to show in Italian, Spanish, French, German, English, Canadian or American hydraulic textbook or manual a single statement to indicate that curve resistance ever decreased with the radius, and likewise failed to show one in which it was not either directly stated or clearly intimated that long, easy curves offer less resistance to the flow of water than those of shorter radius."

We readily believe, without this emphatic statement, that such is the fact, because we cannot stultify ourselves by ever accepting Williams, Hupbell and Fenkell's conclusion to the contrary as true. Not one of the numerous contributors to the discussion intimated that the doctrine of Williams, Hubbell and Fenkell was not a new one to them.

Some time later, in 1906 and 1907, "Experiments by Brightmore on Curves in Four-Inch and Three-Inch Pipes" was published in Proc. Inst. C. E., of Great Britain. This investigator is the first one, apparently, who states that the excess loss depends, not only upon the radius, but also on the velocity.

Still later we have "Experiments by Schoder on Curve Resistance in Water Pipes, Six and Eight-Inch Diameters," published in the Transactions, A. S. C. E., 1909, vol. lxii.

We should also mention an earlier paper, "Experiments by John R. Freeman on Curves from Two to Four Feet Radius in Fire Hose," published in the Transactions A. S. C. E., vol. xxi, page 362.

All these tests and empirical formulae refer to the flow in closed pipes. Nothing, apparently, is on record referring to any compensation for flow in curves in open channels.

The title given to this paper is, "A Theoretical Formula for the Curve Resistance to the Flow of Liquids."

The speaker does not know positively that a theoretical formula in some form has not been given somewhere. The sources which have been quoted and two well-known hydraulic treatises, "Church" and "Merriman," do not even allude to any theoretical formula.

The engineers of the sewer department of this city have for some time been aware of the obvious necessity of increasing the fall of the sewers in the curves, so as to compensate for the additional resistance caused by the curvature of the channel.

The records show that at least some of the earlier sewers have been built without any increase in fall around and through such curves. In the opinion of the present management of the sewer department the lack of compensation for the additional curve resistance is to be held accountable, in some cases at least, for the congestion of some sewers during heavy storms and for the consequent claims for damages by flooded cellars and for many resulting relief bills passed in the settlement of such damages.

The slopes of all sewers designed in recent years have been increased through the curves in a more or less arbitrary way. The question of the proper amount of required compensation for the greater resistance to the flow in curves has been given a good deal of special attention. The speaker has been a party in the consultations on the subject, and has subsequently given his special attention to the question.

As the subject came up in this particular form, the investigation which the speaker made, naturally applied to the flow in "open channels." The compensation for the resistance which he found, as the result of his analysis, applies to the analogous case of flow in "closed pipes," as a special case.

The speaker will proceed to present in as brief and comprehensive a form as is compatible with a certain degree of completeness, the development of a theoretical equation for the curve resistance to the flow of liquids in "open channels," and will then show its application to the flow in "closed pipes."

Problem of Open Channel Design.

The problem of the most economical design of a drain requires computation, of the smallest size of conduit which, for a given alignment and for a given total fall, will be just sufficient to furnish the given rate of flow, or, in other words, will have the required capacity.

Rankine speaks of "flow in an open channel" as "flow in a stream," and gives this definition:

"A stream is a moving fluid mass, indefinitely extended in length and limited transversely, and having a continuous longitudinal motion."

Continuing, he demonstrates that "the normal velocities at a given instant at two fixed cross-sections are inversely as the areas of these sections."

When a stream of liquid completely fills the "pipe" or "tube" or "conduit," the area of each cross-section is given by the figure and dimensions of the conduit.

A "channel" partially encloses the stream flowing in it, leaving the upper surface free, and this description applies not only to channels, commonly so called, but to pipes or conduits partially filled. In this case the area of a cross-section of the stream depends not only on the figure and dimensions of the channel, but on the figure and elevation of the free upper surface of the stream. The upper surface is free to conform in elevation to the dynamic conditions governed by the channel.

In a stream not uniform as to velocity and section the loss of dynamic head is the sum of that expended in overcoming resistance and of that expended in producing increased velocity, when the velocity increases, or the difference of those two qualities, when the velocity diminishes.

In a stream uniform as to velocity and section the dynamic head is wholly expended at any point along the line in overcoming resistance.

If we have a straight open stream, varying in its cross-section as to figure and dimensions, while roughness and slope of bed are uniform, the velocity will vary from place to place inversely as the cross-sections.

The velocity of a straight open stream will likewise vary when the slope of the bed is not uniform, while roughness and cross-section of the channel are uniform.

Therefore a straight open stream can only be uniform as to velocity and section when the fall is uniform also.

When we have a bend in the line of the stream flowing in a uniform channel of a uniform fall neither the velocity nor the cross-section of flow can be constant or uniform.

But in a case where a stream follows an alignment composed of tangents and curves, we can, nevertheless, have a uniform stream as to velocity and section if the slope of the bed of the channel varies in a certain way, governed by the changes in alignment in conjunction with the velocity. (The roughness of the bounding surface assumed as uniform throughout.)

Recognizing, as we are compelled to by experience if not by analysis, that the flow through any curved portion of the course meets with greater resistance there than in the straight course, we must come to the conclusion that through the curve more potential energy has to be expended, or in plain words, more (mechanical) work has to be performed in overcoming the resistances than in the straight course, if a uniform velocity is to be maintained throughout.

Therefore, for a curve we have to ascertain the additional potential energy required; we have to provide for a variable potential energy, capable at any point to do the work of overcoming the respective local resistances, while maintaining a constant velocity throughout; and in such a stream of uniform cross-section and uniform velocity the dynamic head is, as stated, wholly expended at any point along the line in overcoming resistance.

The principles and laws of dynamics applied to this problem will furnish the theoretical solution.

The Derivation of the Formula.

Let it now be proposed to build an open channel having a uniform cross-section and its bounding surface being of uniform roughness.

The alignment of the channel is a combination of tangents and curves. A certain quantity per second is to flow through this channel at a uniform velocity; therefore, the cross-section of flow (and with it, its hydraulic radius) is uniform and constant throughout.

And, necessarily under these conditions, the slope of the bed is parallel to the slope of the surface, but both are variable.

Let us further assume that we have, in some way, found a cross-section of channel, which with a certain slope in the tangents, will pass the given quantity per second, in the tangents.

If we consider by itself, the mass of the liquid, which passes a given cross-section in a second, or which is the same, the mass of a prism of the liquid v feet in length (v being the velocity per second), this prism in gliding down an inclined rough bed (of constant slope in the tangents) is moving with the uniform velocity, v, that is, there is no acceleration of motion.

The hydrostatic pressures upon the two ends of the prism balance each other. Let the weight of the prism be resolved into its two components, parallel to the sloping bed and normal to same. The normal component is the normal pressure on the bed; it is balanced by the pressure of the bed upon the prism (action and reaction normal to direction of moment and having no virtual moment). The "slope" component is in the direction of the flow, and it is the "moving" force.

The friction between the moving prism and the bounding surface constitutes, in the straight course, the resistance to the motion; it is equal and opposite to the "slope" component of the weight, because the prism, moving with uniform velocity, must be under the action of balanced force in one second in overcoming the forces.

The work performed by this moving friction of v feet, is the slope component of the weight multiplied by the velocity and is equal to the resistance multiplied by the velocity.

While the velocity of the flow varies in different parts of the cross-section, being a minimum next to the bounding surface and a maximum at a point most distant from the bounding surface of the channel, the mean velocity, v, is the distance through which the slope component of the weight of the whole volume passing a cross-section in a second, moves per second.

Regarding "internal liquid friction," it may suffice to state as certain, that the particles of liquid resist being made to slide over each other, and that there is a lateral communication of motion amongst them; that is, there is a tendency of particles which move side by side to assume the same velocity.

The effects of internal friction may be stated thus: Internal friction causes a friction of a stream against its channel to take effect, not merely in retarding the film of liquid which is immediately in contact with the bounding sides of the channel, but in retarding the whole stream.

Regarding any other hypotheses of "sliding friction," "curves of velocity," flow in "fillets or filaments," etc., the speaker is in full accord with the statements of Mr. Herschel in his discussion of Mr. Charles H. Tutton's paper, "A proposed solution of hydraulic problems," published in the same volume of the Transactions A. S. C. E. with the paper "Detroit Experiments," (April, 1902, Vol. XLVII).

Let us now consider the motion of this same mass through the curve.

The velocity acts in the direction of the tangent, and the mass would continue moving in the tangent but for the constraint on the part of the channel built for it. Let us for simplicity's sake, assume the curve to be a circular curve. The change of motion of a point which moves with uniform velocity in a circular path, is necessarily a uniform deviation. The force which causes this uniform deviation must be a constant deviating force; it acts upon the mass unbalanced, and will impart to it a uniform acceleration.

Centrifugal force is the force with which a revolving body acts on the body that guides it, and is equal and opposite to the deviating force with which the guiding body reacts on the revolving body.

In fact, as every force is an action between two bodies, centrifugal force and deviating force are but two different names for the same force, according as its action on the guiding or on the revolving body is under consideration at the time.

Centripetal force is the proper name for this deviating force, as expressing the opposite direction to centrifugal force.

The author proceeds to demonstrate:—

1. That the acceleration of the centrifugal force is the square of the velocity divided by the radius of the curve on which the motion occurs.

2. That the distance through which an unbalanced constant force, acting in a constantly changing direction, moves in any second is one-half of the acceleration imparted by the force to the mass. In the case of the centripetal force this distance, therefore, is one-half of the square of the velocity divided by the radius of the bend.

An unbalanced constant force continuing to act in the same direction does work which is not constant for successive seconds.

Now we realize that the deviating force which co-operates in the curve with the slope component, which latter alone does the work of moving in the straight line of the course, is not an independent force. Its existence depends on a velocity and this velocity in our case is created by the force of gravity. Therefore, the work done by the deviating force is simply a certain part of the total work performed by the force of gravity.

One part of the work of the force of gravity has been shown to be the work required to overcome the frictional resistance; the other part of the work of the force of gravity is converted into the work of deviating force, which latter is the work required to deviate the motion, hence the sum of the two is the total work which must be performed by the force of gravity. The sum represents the total expenditure of potential energy in the curve in one second.

The slope required to furnish all the energy for overcoming the frictional resistance and for deviating the motion is equal to the slope in the straight course plus the slope compensation for the curve resistance. This additional or curve-compensating slope is the dynamic head required for the curve resistance. It varies as the cube of the velocity, v, and inversely as the square of the radius of the curve, being equal to the cube of the velocity divided by 2g times the square of the radius of the curve.

Upon further reasoning it becomes evident that this curvature head applies generally to the motion of any mass, liquid or solid, gliding or rolling down an inclined path with a uniform velocity, gravity being the moving force.

In railroad engineering, according to a definition by Willard Beahan, in his "Field Practice of Railway Locations," "equating for curvature" is the "making of an allowance for the frictional resistance on curves due to the rubbing of wheel flanges on the rails, and the slipping of the wheels." As a matter of fact, this allowance, ascertained from tests, also includes the resistance of the train weight to having its motion deflected from the straight line. Of the total curve resistance to a train the additional incidental frictional resistance is the predominant part, the curve resistance proper is negligible in this case.

For a train moving at the rate of:

Miles Per Hour	Deg. Curve	Lbs. Per Ton
12	1	.005
22	1	.03
12	5	.125
22	5	.75

while it has become customary to allow 0.5 lbs. per ton for total curve resistance in a 1 degree curve.

In the case of a liquid in motion through a channel the resistance due to curvature is the resistance of the liquid to having its motion deflected from the straight line, and nothing more, as the frictional resistance in the curve is no greater than in the straight channel, if the roughness of the bounding surface is the same in both cases (which we have assumed).

Experiments, as already stated, are accepted as showing that the skin friction is independent of the pressure of the liquid on the conduit. The resistance to the flow under pressure, therefore, is just the same as that to the open flow in a pipe just full. It is, therefore, evident that the dynamic head absorbed in bends in the case of closed pipes (pipes flowing full, under head) is the same curvature head as derived in the above, and when added to that absorbed by skin friction per foot gives the total loss of head in bend per one foot.

The author has computed the accompanying table of values for the compensating slopes for velocities varying from 2½ feet to 30 feet (per second) and for radii varying from 5 feet to 1,000 feet.

These slopes added to the slope in the tangents give the total slope in the curves.

Respectively, heads added to skin friction head give the total head lost in the bend.

Numerical Examples for Curve Compensation.

A 42-inch diameter brick sewer, with a slope S, equals .005 (in the tangents), with Kutter's co-efficient c (n equals .013), in the Chezy formula has a capacity of about 72 sec. cu. ft. and a mean velocity of flow equals about 7½ ft. per sec.

500 ft.	.000026	.005	.005026
200 ft.	.000164	.005	.005164
150 ft.	.00029	.005	.00529
100 ft.	.000656	.005	.005656
50 ft.	.0026	.005	.0076
25 ft.	.0104	.005	.0154
15 ft.	.029	.005	.034

A 10-ft. diameter brick sewer with a slope s = .0025 (in the tangent) with Kutter's coefficient c (n = .013) in the Chezy formula has a capacity of about 780 sec. cu. ft., and a mean velocity of flow equal to about 10 feet per sec.

500 ft.	.000062	.0025	.002562
200 ft.	.00039	.0025	.00289
100 ft.	.00155	.0025	.00405
50 ft.	.00620	.0025	.00870

The loss of head for the entire curve is the above curve-compensating slope multiplied by the length of the curve, or, in the form of an equation,

$$H_2 = \frac{lc\,v^3}{2gr^2}$$

Since the radius of the curve appears in the value of l, this equation says that the curvature-head for the entire length of the curve is inversely as the radius of the curve i.e. (if we double the radius of length of the curve), we reduce the curvature-head for the entire length of the new curve to one-half of the curvature-head of the previous curve (of one-half the length), and if we treble the radius of the curve we reduce the curvature-head to one-third of the original curvature-head.

This fact should be remembered in considering the experimental work and the conclusions of Williams, Hubbell, and Fenkell, the Detroit engineers.

Curvature Head In Feet, For One Foot Length of Curve.

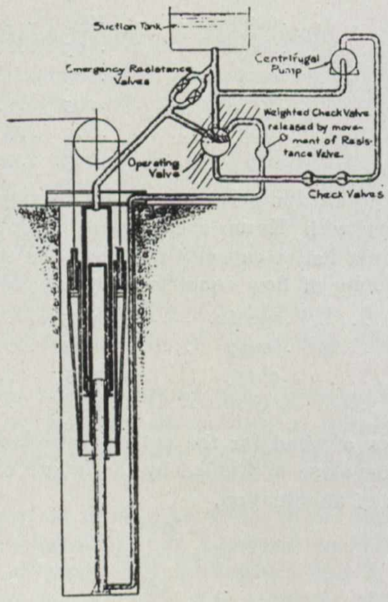
For radii from 5 feet to 1,000 feet, and velocities from 2½ feet to 30 feet per second.

Radius in ft.	Velocities In Feet Per Second. 2.5	5	7.5	10	15	20	25	30
5	.009705	.077640	.262040	.621100	2.101000	4.969000	9.705000	16.770000
15	.001068	.008627	.029116	.069011	.233444	.552111	1.068333	1.964444
25	.000380	.003040	.010400	.024800	.083950	.199008	.388672	.671632
50	.000097	.000777	.002600	.006200	.020988	.049600	.097168	.167408
75	.000043	.000340	.001166	.002750	.009328	.022112	.043186	.074626
100	.000024	.000194	.000656	.001555	.005247	.012438	.024292	.041977
150	.000011	.000086	.000290	.000690	.002332	.005528	.010796	.018656
200	.000006	.000049	.000164	.000390	.001312	.003109	.006068	.010494
300	.000003	.000022	.000070	.000170	.000583	.001382	.002699	.004664
500	.000001	.000007	.000026	.000062	.000210	.000496	.000972	.001679
1000	.000000	.000002	.000006	.000015	.000053	.000124	.000242	.000420

The above quantities, added to s (the slope in the tangent), gives the total slope in the curve, or added to h (loss of head in straight pipe), gives total (net) loss of head in bend.

FENDER CHAINS.

Proposals have been requested for materials for chain fenders for all the locks of the Panama Canal, and bids will be opened at the Washington office on November 14. Included in the proposed contract are castings for hawse-pipe, cylinders and detail parts, certain structural materials, operating valves, piping and fittings from cylinders to pump and tank, and mechanism for starting and stopping the pump. Parts not included are the main pumps and motors and all electrical machinery and wiring, chains, suction tanks, resistance valves, stairways and gratings, drainage pumps, their motors, piping, etc., also riveted steel anchorages attached to hawse-pipe castings, of which a description appears in the Canal Record.

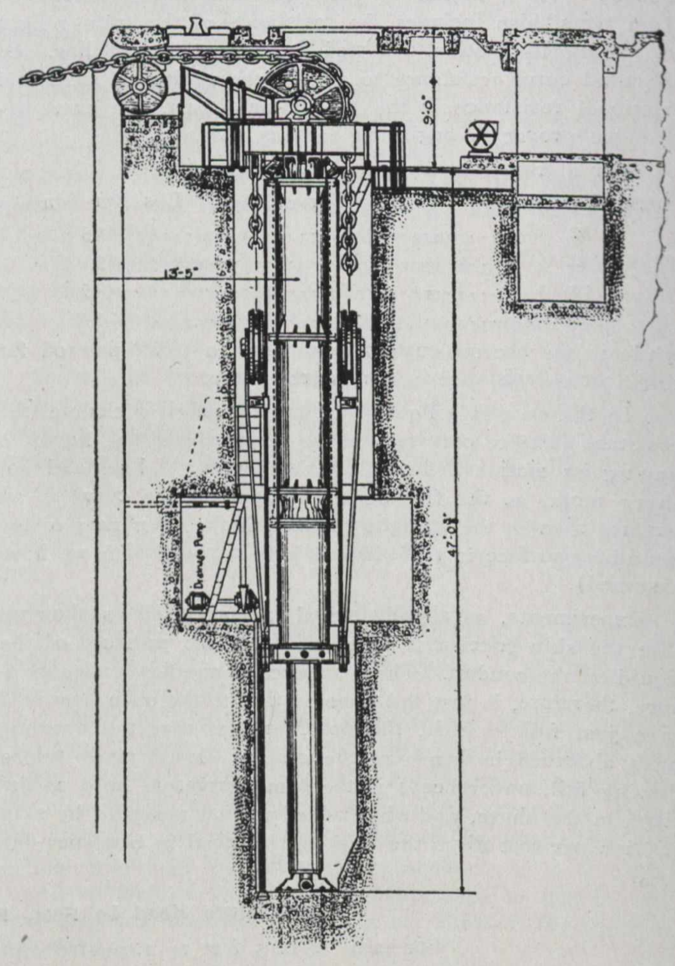


Sketch Showing General Layout of Fender Chain Operating Machinery.

The function of the fender chains is to prevent the lock gates (used as a bulkhead or dam across axis of locks to form a higher level of water, which may have no corresponding amount of water against them on the down-stream side), from being rammed by a ship that may approach too near the gates under its own steam or by escaping from the towing locomotives. They will therefore be placed on the upstream side of the following gates: Gatun—Upper guard gates, intermediate and safety gates of the first or upper locks. Pedro Miguel—Upper guard, intermediate and safety gates. Miraflores Locks—Upper guard, intermediate and safety gates of the upper locks. At the lower end of each flight of locks are guard gates, mitering in an opposite direction from the lock gates, whose function is to keep water from the chamber between these gates and the lower operating gates, in case it is desired to pump water from this chamber for the purpose of repairing or painting the lower lock gates. In front of these guard gates chain fenders will also be stretched. In all 24 fender chains and 48 machines will be required.

In operation the chain will be stretched across the lock chamber from the top of the opposing walls, and when it is desired to allow a ship to pass, the chain will be lowered into a groove made for the purpose in the lock floor. It will be raised again after the ship passes. The raising and lowering will be accomplished from both sides by mechanism mounted in pits or chambers in the lock walls, as shown in sketches, herewith. This mechanism as designed consists of a hydraulically operated system of cylinders, and a train of sheaves by which one foot of movement by the cylinder accomplishes four feet by the chain.

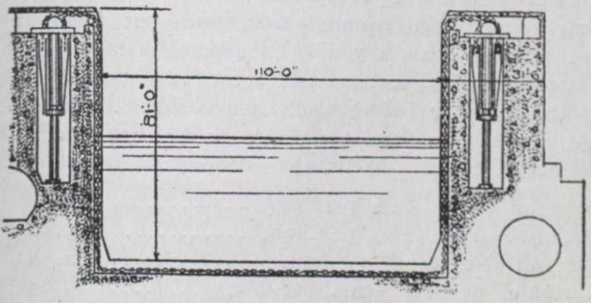
The system of cylinders consists of one fixed cylinder 40 inches in diameter, one cylinder 38 inches in diameter moving within this, and a fixed plunger 25 inches in diameter upon which the smaller cylinder moves. The cylinder is actuated by water forced into the large cylinder for downward motion or raising the chain, and into the small cylinder for upward motion or lowering the chain. This change of flow is produced by varying the position of the operating valve by means of a solenoid operated by remote control. A large open tank provides storage for the water displaced in the outer cylinder as the moving cylinder rises, and also makes up for the waste due to leakage and evaporation. The stroke of the cylinder is 21 feet 6 inches, and each complete movement therefore raises or lowers the chain 86 feet for each machine, or 192 for both. The operating pressure is 60 pounds per square inch.



Water is forced into the cylinders by a centrifugal pump, situated in the pit; which is started automatically by a quick acting electric switch, operated by a system of rods and levers, actuated by a stop fastened to the guide yoke, attached to the moving cylinder. This mechanism also prevents any considerable movement of the cylinder through leakage, insuring the continued maintenance of the chain in its upper or lower positions.

The smaller cylinder carries two sheaves by means of eyebars attached to a crosshead at its lower end. Two similar sheaves at right angles to the lower ones are carried in stationary bearings supported on riveted girders spanning the pit. The chain passes through a hawse-pipe casting in the lock wall, which is secured to heavy riveted anchorages embedded in the concrete. A riveted strut connects the horizontal girders with the hawse-pipe casting, so that the entire outward pull of the chain is transferred to the anchorages.

The chain is supported on an idler fastened to the hawsepipe casting, then makes a quarter turn around one of the fixed sheaves, passes down and makes a half turn around one of the lower movable sheaves, rises up again, making a half turn around the second stationary sheave and going down on the other side of the machine. It then makes a half turn around the second movable sheave and, passing up, has its end fastened to one of the girders at the top of the pit.



Cross Section of Locks, Showing Fender Chain in Position for Passing of Ships, and Situation of Cylinder Pits.

If a ship should run into the fender, exerting a pressure of more than 750 pounds to the square inch, the chain will be paid out gradually by an automatic release until the vessel comes to a stop. For instance, a ten thousand ton ship, running at four knots an hour, striking the fender, would travel 72 feet 6 inches after striking the chain before coming to a stop. The resistance to the paying out of the chain is provided for by two resistance valves arranged in parallel. These valves are so designed as to remain closed until the pressure back of them rises to 750 pounds per square inch, when they open automatically maintaining a constant pressure, and hence stress, on the chain.

PUMPING WATER FOR MUNICIPALITIES AND FOR IRRIGATION BY ELECTRICITY.

One of the largest potential customers for electric power in this country is our cities. Practically every city owns and operates its own water system, and in the operation of this system large amounts of power are used. Up to the present time very little has been accomplished by our central station companies in securing this business. Each year, however, sees a greater amount of this pumping being done with electric power, and the indications are that this business will grow very rapidly during the next few years.

Of course the chief field for the possible use of electric power is in connection with the main city pumping stations for the supply of water for drinking, as well as other domestic purposes. This load offers a great many attractive features from the central station man's point of view.

In a general way there are two kinds of waterworks systems in use in this country—one a direct system, where no reservoir capacity is provided, the rate of pumping water varying directly as the demand for water; and the reservoir system, where a reservoir is provided, so that water may be supplied after the pumps are shut down. Of the two systems, the most attractive and the easiest to get on a profitable basis is, of course, the reservoir system. With such a system the pumping can be very largely done at such times as best suits the load conditions of the central station, and so can be made practically "off-peak" business. For such business the central station can offer very low rates, and still make a profit.

* Abstract of a paper read by B. H. Gardner before the Seventeenth Annual Convention of the Ohio Electric Light Association, held at Cedar Point, Ohio, July 25-28, 1911.

In a direct system, of course, the reservoir feature is lacking, and for this reason this pumping business does not offer so great an attraction for the central station. It must be remembered, however, that the greatest demands for water are during the months from April to October, when the demand for electric current is least; and the demands for water are least from October to April, when the demands for electric current are greatest. There is thus a diversity factor offered, even in direct systems, which is most attractive. Practically all new systems being installed have the reservoir feature, so that there is an opportunity for the central stations of the country to secure most of this business, as "off-peak" business. For the direct systems that are already installed, probably the best method of securing this business is by advocating a combined station, the old steam equipment to operate during peak months, etc., and motor driven pumps to carry the summer peaks. This arrangement should give a central station a diversity factor that would be most acceptable.

In many of our cities the suburbs are built upon hills that are often considerably above the city proper. In many such cities the water pressure which is proper for the main portion of the city is entirely too low for such suburbs, so that the pressure of the water furnished this suburb has to be boosted. Sometimes special high-pressure mains are provided for such suburbs, but a simpler way is by installing motor-driven boosting stations in this suburb. This is business that the central station should have little difficulty in securing, and at the same time it is business that either has very high load factor or else can be kept off the peak, sometimes combining these two features.

Near some of our larger cities there are many small cities, villages, etc., that have small independent waterworks systems, and these can often be obtained as customers, and as very profitable ones, for the sale of electric power.

There are many other uses for electric power by municipalities not mentioned as yet, and if the central station representative keeps in close touch with the city officials he will often find uses for electric power in connection with garbage disposal, high-pressure systems for fire purposes, stations used for pumping in case of high water, and other uses that may be more or less local in character.

All of this business with the municipalities has an importance and a value apart from the profit that is realized on the sale of the current. The more such business that the central station can obtain on terms that are profitable to itself, and at the same time satisfactory to the city officials, the greater the prestige of the central station will be, and the less the talk of municipal ownership of the electric light plant.

Irrigation.

All of us are more or less familiar with what is being done in the matter of irrigation in the far West, but probably few of us realize what an irrigation business will do for a central station.

Probably most of us in the East consider that irrigation is a good thing for the far West, where there is practically no rainfall, but that it is not practical in this section of the country. There are those who question most seriously these views, and hold that our own farmers will soon use irrigation for the same reason that they now use fertilizers, because the increased production of the land will much more than pay for the cost of the irrigation.

Dr. Bailey, of Cornell University, one of our foremost agriculturists, said in a recent speech:

Now and then a fore-handed farmer in the humid region, growing high-class crops, installs an irrigation plant to carry him through the dry spells. As our agriculture becomes more developed we shall greatly extend this practice. We shall find that even in humid countries we cannot afford to lose the rainfall from hills in floods, and we shall hold at least some of it against the time of drought, as well as for cities and for power. We have not yet learned how to irrigate in humid regions, for the practice of draining is equally involved, but we certainly shall apply water as well as manures to supplement the usual agricultural practices.

When irrigation does come into its own, our power load should be greatly increased. The ease and economy with which electricity can be transmitted over wide areas and used to drive motors make electric pumping preferable to the gravity system of irrigation in many ways. The pumps can be in comparatively small units, each supporting a local area. The distributing ditches are small, thus leaving maximum area for crops, and the water supply to each area is always under perfect control. There is minimum danger of broken ditches and flooded crops such as sometimes occur with large ditches.

In regard to pumping water for irrigation, the maximum practical cost of such pumping depends on the value of the crop, and the cost of transportation to market. The height to which water can be pumped occasionally also depends on the same factors.

Tests made by the United States Government indicate that where the water does not have to be lifted more than 25 feet and where the price for current is 3 cents per kilowatt-hour, the cost of irrigation will not be more than $3 per acre-foot or a cost of $6 for 2 acre-feet, 2 acre-feet being about the quantity of water needed per year.

When we take into consideration the enormous loss that the farmers each year suffer on account of the droughts, this seems a rather cheap way of overcoming it.

To those of our companies who are so situated that water may be easily obtained, it seems that irrigation offers an excellent opportunity to improve the central station's load factor and raise their income.

It is reported that a large electric company in a state near Ohio is buying up large tracts of waste lands, with a view to irrigating and improving these lands, and after they have been brought up to a high state of efficiency to divide the lands into small farms, and sell these farms, and at the same time get a contract for electric power for continuing the irrigation of these farms. It is possible that some of our own central stations might find some such endeavor profitable.

ELECTRIC POWER FROM WIND.

There has never been a time when the forces of nature were subjected to such searching scrutiny to determine their availability for the development of mechanical power as they receive at present.

Among other things it is believed that the wind can be utilized to a far greater extent than in the past, especially for electric lighting. With this object in view the average state of the wind has been investigated in England. It is found that for approximately half the time the mean wind velocity is ten miles an hour, and for about one-third of the time fifteen miles.

COSTS ON A CONCRETE ROAD.

The following costs have been abstracted from an article in "Concrete," describing the concrete roads being built in Wayne County, Michigan.

The concrete is a 1:1½:3 mixture of Aetna cement, screened and washed sand and pebbles, which costs, aside from hauling, $1.12 for cement, 95 cents a ton for sand and 95 cents to $1.10 a ton for pebbles. The concrete is laid 7 inches deep and 15 feet wide. On the day mentioned 450 linear feet, or 750 square yards, were put down at a labor cost of 11½ cents a yard. Every care is taken to get a good mix. The ingredients are turned dry three revolutions of the machine before the water is added. The men employed in this gang and the wages paid to get this labor cost figure for the day are listed as follows:—

1 foreman at 50 cents per hour	$ 5.00
1 engineer at 35 cents per hour	3.50
1 fireman at 25 cents per hour	2.50
1 sprinkler at 22½ cents per hour	2.25
2 men covering concrete at 22½ cents per hour	4.50
4 tampers at 25 cents per hour	10.00
2 floaters at 25 cents per hour	5.00
2 bucket men at 25 cents per hour (pushing the clamshell bucket of concrete out on the boom from the mixer)	5.00
1 water man at 25 cents per hour (has charge of mixing and emptying mixer to bucket)	2.50
1 cement dumper at 25 cents per hour (opens sacks and puts cement into charging hopper)	2.50
4 men preparing grade at 22½ cents per hour setting rails, etc.	9.00
2 carrying cement at 22½ cents per hour (they also help with unloading and piling bags of cement)	4.50
4 gravel wheelers at 22½ cents per hour	9.00
4 gravel shovelers at 22½ cents per hour	9.00
2 sand wheelers at 22½ cents per hour	4.50
2 sand shovelers at 22½ cents per hour	4.50
1 water boy at 12½ cents per hour	1.25
1 man preparing steel joints at 22½ cents per hour	2.25
36 men for 10 hours	$86.75

Cost of Road.

On an ordinary working day with normal conditions 400′ of 15′ road usually are laid by such a gang of men. The figure has been as high as 500′ in 10 hours. The average of one such gang for 100 working days in the summer just past was 310′ a day. In these 100 days working time was lost in moving from one job to another, the gang having worked in the time mentioned on five different roads. Occasional rains and breakdowns resulted in short working days at other times. These conditions pulled down the average, which might otherwise be 400 linear feet or 750 square yards a day. The labor cost of concreting per square yard given as 16 cents is based upon 310 linear feet a day at a labor cost equal to that of a full 400′ day.

Besides the omission of the cost of hauling materials, grading and so on, still other items of labor cost are omitted because they do not come within the scope of the concrete gang. The building of the gravel shoulders follows at least three weeks behind the laying of the concrete because a 10-ton steam roller is used in this work. Nothing is charged up in the above data for water supply except the wages of the man doing the sprinkling of the road, which continues for eight days (specifications call for seven days, but sprinkling actually continues for eight days for good measure.) The water supply cost varies with the proximity of water to the work. Hauling water in sprinkler wagons was found altogether too expensive and in some cases is entirely out of the question, so gasoline motors and pumps are used in as many relays as may be necessary. On a recent work out Grand River Avenue water was pumped six miles from the River Rouge. One pump conveyed it two miles to a vat which was hauled to place; a second pump, to an old well two miles farther and a third to the work, another two miles. The 2-inch pipe is laid along the road the entire length of the work very early in the operations and taps are placed about every 400 feet. One man is stationed at each engine and this man is paid 25 cents an hour. Gasoline costs about 7 cents an hour for each engine, with miscellaneous lubrications and repair expense to bring the cost to about $1 a day for each engine. So that each water pumping relay costs about $3.25 a day.

The cost items in one entire stretch of road built by the commissioners are as follows:—

Gratiot road, 1910 and 1911, 3.236 miles long and 16 feet wide, with 4 feet gravel shoulders, the concrete being 7 inches thick.

Roadway Proper.

Teams	$ 6,557.03
Other labor	12,996.83
Cobblestone	93.84
Pebbles	6 714.57
Sand	2,481.65
Bank run sand and gravel	177.44
Cement	9,890.16
Coal	330.24
Expansion joints	528.85
Lumber and engineer's stakes	190.42
Express, messenger and auto	41.28
* Water supply (repairs to old well)	133.33
Blue prints, advertising and photographs	29.60
Lubrication, waste, etc.	137.11
Board of men in camp	439.24
Hardware and repairs	121.50
Yard and siding	51.88
Liability insurance	107.62
Miscellaneous	112.43
Total	$41,135.02

Drainage.

Open ditch	$ 4[illegible]3.75
Tile drains	1,380.84
Culverts	436.64
Total	$ 2,311.23

The cost of the roadway proper was $1.35 per square yard, and the cost of drainage proportioned over yardage, $0.0758 per square yard, making the total cost of the road approximately $1.426 per square yard. Concrete yardage only is figured. Cost of gravel shoulders, etc., is proportioned over concrete yardage and added to its cost.

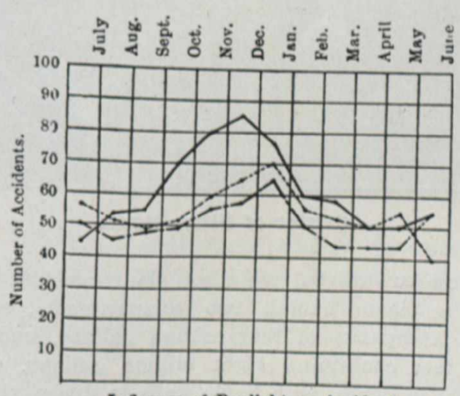
Economy in Handling.

Teams were used for hauling on this work rather than road engines. Team hauling costs $5 per day. Road engine hauling costs $9.50 per day, of which $3.50 is for the engineer, $2.50 for the fireman and $3.50 a day for coal and oil. The team hauls approximately two tons to a load. The road engine hauls three wagons holding a total of about 20 tons and under ordinary conditions makes the same number of trips as the team. The hauling cost per ton by steam is thus about one-fifth that by teams. There are items of repairs, depreciation and interest on investments in connection with engine hauling and these figures are not available for each road job. Such items are lumped at the end of the year (interest on investment and depreciation being charged up at 15 per cent. of original cost) and the sum spread over all the roads built in the year proportionately with the cost of each. The road engine works at not quite so great an advantage over horses in short hauls because the team is able to turn around and get under way again more readily than the engine. On the Gratiot road job, on which more than $6,500 was spent for teams out of a total road cost of about $41,000, the haul was longer than is the general rule but at that time the commissioners did not have the steam hauling equipment available for work. On a repetition of the work the engines might be expected to save 75 per cent. of the hauling cost, or about 15 cents a square yard of concrete.

* Labor cost of water supply is included in labor item.

ILLUMINATION AND INDUSTRIAL ACCIDENTS.

The accompanying diagram, which we reproduce from an article in the Journal of Industrial Safety for April, is of interest as showing the influence of daylight on the number of accidents which take place in factories and workshops.



Influence of Daylight on Accidents.

The chart shows the number of reported fatal accidents per month for three successive years which took place in about 700 factories out of a total of 80,000 reported upon. It will be seen at once that during the months of November, December, and January, when daylight is diminished and artificial illumination has to be resorted to for some hours each day, the number of accidents is greatly increased, this increase being quite noticeable in each of the three years.

As is pointed out in the article from which the above diagram is taken, it is probably not the intensity of the artificial lighting which is at fault—it is comparatively easy to get sufficient light; but the better placing and shading of the lamps to get more perfect diffusion must, it is suggested, be the aim for the future, so that daylight conditions may be more faithfully reproduced, and the "peak" in the accident curve may be removed.

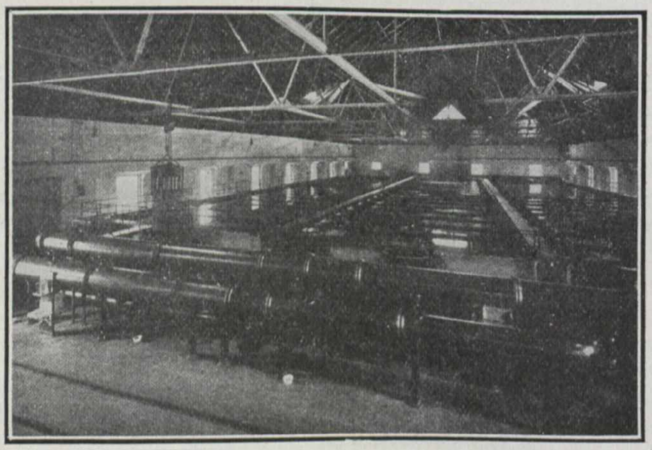
A RECENT WATER-FILTER.

The Louisville Water Company, Louisville, Kentucky, have recently issued a booklet dealing with their method of water purification, from which we extract the following:—

The water supply for Louisville is taken from the Ohio River through a steel-lined conduit to Station No. 1, and two submerged iron pipes, each 36 inches in diameter, to Station No. 2, the outer ends of which are protected by a timber crib built about one hundred feet from the southerly shore line.

The water is forced by pumps to Crescent Hill reservoir through four cast-iron pump mains, two 30 inches and two 36 inches in diameter and about two miles long. The level of the water in the reservoir when full is 175 feet above low water in the river, but the frictional resistance to the flow of the water through the long mains raises the pressure against the pumps to a dynamic head equivalent to about 190 feet.

From the reservoir, where the muddy water has an average of three days' sedimentation, it flows into the new coagulating basin, directly across the road, where the coagulant in the form of aluminum sulphate solution is introduced, and the partially clarified water is then conducted to the sand filter beds.



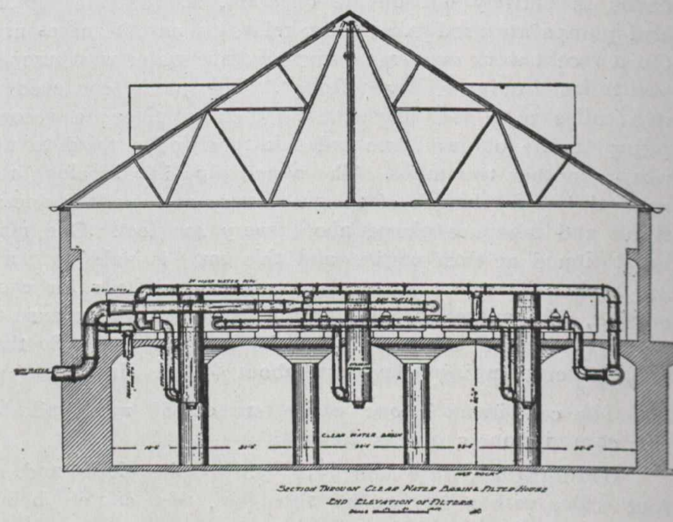
Interior of Filter House.

As now constructed the filter plant consists, first, of a coagulating basin having two compartments, one 80 x 340 feet with a capacity of four million gallons, and the other 160×340 feet containing eight million gallons, each about twenty feet in depth, with baffle walls to divert the direction of the flow of water; second, a solution tank in duplicate, each section holding 140,000 gallons, where the aluminum sulphate solution is mixed and stored, and from which it is conveyed to the coagulating basin; and third, the filter proper, consisting of six filter beds, each 30×72 feet, giving a total area of 12,960 square feet, and a filtering capacity of thirty-six million gallons per day.

The aluminum sulphate is dissolved in the solution tank in the form of a 2 per cent. solution (2 per cent.). It is mixed with the turbid water flowing from the reservoir, the quantity of alum varying with the degree of turbidity from one half grain to upwards of two grains per gallon of water treated. After receiving the sulphate solution the water flows through the winding passage formed by the baffle walls in the coagulating basin, allowing the coagulant to perform its part of the clarifying and purifying process.

At the end of its passage through the coagulating basin the water is drawn off from near the surface, flowing by gravity through a 48-inch main to the filter where the final process of filtration takes place.

The filter is a large steel tank containing a bed of sand and gravel 34 inches in depth, with a strainer system at the bottom. The stratified gravel is placed around the strainers, and held in place by means of a woven wire screen, and above this is the bed of sand.

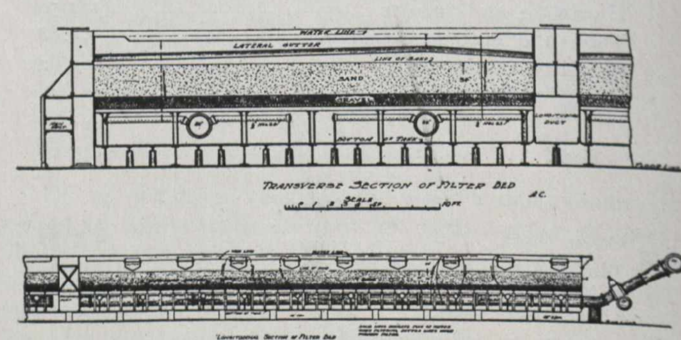


Section Through Clear Water Reservoir and Filter House.

On an average only a fraction of one per cent. (1%) of the bacteria contained in the river water find their way through the filters, and these are mostly saprophytic organisms, the less resistant pathogenic or sewage organisms, being entirely removed.

The level of water in the filters is automatically maintained at a depth of about 18 inches above the sand level, and its rate of flow through the sand bed is regulated by means of a submerged orifice which at all times controls the quantity of discharge, maintaining it at a uniform rate of approximately 4,500 gallons per minute for each bed.

The turbidity of the Ohio River water, which is sometimes as high as 5,000* parts per million, has been uniformly reduced to zero, and the bacteria reduced 99 per cent.



Sections Through Filter.

The present rate of consumption averages over twenty-two million gallons per day, equivalent to one hundred gallons per day for each inhabitant of the city, taking as a basis for population the recent figures submitted by the Government Census Bureau, and while city water is not furnished to all the inhabitants of Louisville, owing to the prevailing use of cisterns and wells in many sections, there is a relatively large population outside of the city that is being supplied, and this suburban consumption should tend to offset in part the number of city residents not so supplied.

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TORONTO'S NEW TUBES.

Tenders for the construction of three miles of reinforced concrete subway for the city of Toronto have been called for, and, from the press comments which are appearing from time to time, it would appear when the by-law is submitted to the people that this money would be voted. When the plans were first made, public opinion appeared to be against the construction of these subways, but indications are that this opinion is changing. It looks now like a possibility of the by-law being favorably received by the citizens of Toronto. This change in public opinion has been due largely to the consistent hammering of the daily newspapers. The subject was one which gave them an opportunity to hit at the common enemy, the Toronto Street Railway Company.

Toronto at the present time has a great deal of construction work going on, costing the city many millions of dollars. They are building some sixteen miles of street car lines, and this, no doubt, is a necessary item. However, this matter of subway construction is a different proposition altogether. The subway would take some four or five years to construct, and would cost in the neighborhood of $5,000,000. In ten years the Toronto Street Railway franchise ends, and the city will no doubt then take over the surface lines and operate them. If the subway is built, it will only be in operation five years in competition with the Toronto Street Railway, and will at the end of that time compete with the city's own lines. During this ten years, however, interest charges must be paid on this $5,000,000, with little prospect of any return.

It would be well for the city to proceed very cautiously on this question, for it would appear that there are other remedies available to reduce the congestion on the street car lines before proceeding as a last resort to subway construction. The new civic lines, when they are all in operation, will materially assist, and it would be better to spend more money on these lines in preference to loading the city with additional debt for subway construction.

CANADIAN ENGINEERS.

Every few days there appear statements in the press that certain contracts have been awarded to American firms, or that American experts have been chosen to report on engineering problems in Canada.

In a news item from Vancouver, B.C., this week we see that the Canadian Northern Railway has awarded to Messrs. Waddell & Harrington, Civil Engineers of Kansas City, a contract for designing and superintending the construction of ten steel bridges along the route between Cisco and Kamloops. Their total cost will amount to about $1,100,000. Messrs. Waddell & Harrington are now carrying out in Canada contracts approximating $5,000,000.

In our issue of October 19th we made comment on certain Grand Trunk Pacific contracts which had been let to American firms, and we stated then that, as the Grand Trunk Pacific is a heavily subsidized Government road, that the people of Canada have a right to ask that, in so far as it is possible to handle work here, this expenditure should be distributed in the Dominion.

The Canadian Northern Railway Company are in a similar position to the G.T.P. They have been heavily subsidized by the Government with heavy land grants and guarantee of their bond issues, and in common justice should endeavor to further Canadian enterprise. In fact, as a mere matter of business, it should be their policy to foster the industries and professions here.

These companies are not in a similar position to private corporations, as they are operating for the public good under public franchise. The interests backing the Canadian Northern have been spoon-fed, both by the Provincial and Dominion Governments, for many years, but they seem to have forgotten this fact.

In the particular instance to which we make reference, we might say that there are quite as competent engineers in Canada as Messrs. Waddell & Harrington —men who are as capable of designing and superintending the construction of these bridges; and, considering the obligation under which the Canadian Northern labors with respect to the Government, one would have thought that Canadian engineers would have secured this work.

There are many instances of this same lack of loyalty, for so it may be termed. Ottawa, Montreal, Toronto, and many of our other cities, when they desire outside engineering advice, call in Americans. At the present time, in the city of Toronto there are three American consulting engineers superintending work and preparing reports for the city, work which could be better handled by local engineers, who understand local conditions.

These are the facts; but what is the remedy? It would appear that the cause rests with the engineering profession. The profession, as a whole, take too little interest in work outside their own narrow walk. A general apathy exists, and until this is shaken off we can expect little change in the present conditions, for, unless the engineers as a body force a change, there is little chance of this condition of affairs being remedied.

THE CANADIAN SOCIETY OF SANITARY ENGINEERS.

Last week we stated that the Plumbers' and Steamfitters' Union had made application to the Provincial Government for incorporation under the name of "The Canadian Society of Sanitary Engineers."

The engineering profession took strong issue to allowing this to be granted, and a committee representing the Canadian Society of Civil Engineers, composed of Mr. C. H. Rust, Mr. J. Galbraith, Mr. H. E. T. Haultain, and Mr. E. A. James, met the Hon. M. Hanna on Tuesday, October 24th, to discuss the matter and present reasons why this should not be allowed. At this meeting the whole matter was discussed, the committee stating that in their opinion it would be very detrimental to the profession of engineering if this charter was granted.

However, little consideration was paid to their claims, with the exception that the name of the Society will be slightly changed. The Plumbers' and Steamfitters' Union will now be known as the Society of Domestic Sanitary and Heating Engineers. To our mind there is little difference between this and the Canadian Society of Sanitary Engineers, the title they originally asked for. The committee did their utmost, but it is very much to be regretted that their efforts resulted so miserably.

The plumbers and steamfitters under their new designation of Sanitary Engineers will have an added dignity in the eyes of the public, while as a natural result, the term Engineer will lose its present significance.

We must express our sincere regret that the Hon. Mr. Hanna allowed this charter to be granted under such a name. It is a serious blow at the prestige and dignity of the engineering profession in Canada and we would have thought that a man of Mr. Hanna's breadth of view would have appreciated better the results which will flow from the granting of this charter.

A CORRECTION.

In our issue of October 5th we published a re-print from the "Engineering Supplement of the London Times" of an article on "Welded Steel Pipe." Our attention has been drawn to one paragraph in this article which is false and misleading. This is the statement that "No fully equipped concern exists in the United Kingdom for the purpose of manufacturing this class of pipe." The firm of Thomas Pigott & Company, Birmingham, England, informs us that it is fully equipped for producing this class of work, and that there are at least three other large firms in Britain capable of doing likewise.

We are sorry, indeed, that this statement should have been reproduced in the columns of the Canadian Engineer, for it is statements such as this which injure British manufacturers.

FACULTY OF APPLIED SCIENCE EXCURSION TO NIAGARA FALLS.

It has become customary for the fourth year Engineering students of the University of Toronto to take an annual excursion to Niagara Falls to inspect the works of the different power companies operating there. The annual excursion occurred this year on Wednesday, October 25, when the students and representative members of the Faculty, to the number of one hundred and thirty, left Toronto at 7.30 a.m. by special G.T.R. train, arriving in Niagara Falls at 10 a.m.

Street cars were waiting there to take them at once to the intake works of the Ontario Power Company at the Dufferin Islands, thence to the powerhouse and distributing station. After lunch the works of the Canadian Niagara Power Company were inspected, and the powerhouse of the Toronto Power Company.

Altogether a most enjoyable and profitable day was spent. The arrangements for the excursion were in the hands of Professor R. W. Angus, to whose unflagging interest and consistent efforts much of the success of the trip may be credited. Mr. W. J. Wright, the student representative, should also be mentioned in connection with a comment on this trip.

SEASON OF LECTURES.

The following list of lectures are to be given before the Province of Quebec Association of Architects:

Tuesday, November 21—"Modern Methods in Foundation Work," Alexander Alaire, M.E.

Tuesday, December 19—"Ventilation of Public Buildings," Dr. T. A. Starkey, of McGill University, professor of hygiene.

Tuesday, January 16—"Improvements to Traffic Routes in Montreal," F. G. Todd.

Tuesday, February 20—"Mouldings," Prof. P. E. Nobbs, A.R.I.B.A.

Tuesday, March 19—"French Apartment Houses," Prof. Jules Poivert, of Polytechnic School.

Tuesday, April 16—"Colonial Architecture," Prof. T. W. Ludlow, of McGill University.

DR. HOUSTON'S FIFTH ANNUAL REPORT ON THE WATER SUPPLY TO THE CITY OF LONDON.

By Joseph Roce, F.I.C.

So much discussion has recently taken place regarding the water supply of the City of Toronto that the report of Dr. Houston, Director of Water Examination to the Metropolitan Water Board, for the year ending the 31st of March, 1911, is of more than passing interest, dealing as it does with the purification of a water supply that is admittedly heavily polluted with sewage.

The report consists of the usual statistics regarding rainfall, etc., together with tables showing the chemical and bacteriological condition of the water during the various steps of purification.

The water supply of the City of London is chiefly obtained from the rivers Thames and Lee, supplemented by the New River and the Kentish deep wells.

Probably the best method of gauging the pollution of water supply by sewage, is by the estimation of the amount of typical Colon Bacilli present, and the following table gives the results of the application of that test to the various supplies:—

Judged by the ordinary bacteriological standards 80% of these samples would be considered excellent and only 4.6% open to suspicion. This is remarkable when it is remembered that 80% of the raw water is derived from sewage polluted rivers.

Dr. Houston's conclusions are so aptly put and some are so pertinent with regard to the Toronto supply that the chief ones might, with advantage, be given.

He points out that "Within recent years a marked improvement has taken place in the methods of purifying sewage so as to render the resulting effluents non-putrescible and chemically unobjectionable. Apart from sterilization, however, no known process has yet been found that turns out a safe effluent bacteriologically, and the great majority even of chemically satisfactory effluents are swarming with excremental bacteria." In this connection it should be remembered that although it is possible to minimize the pollution of the Great Lakes it is practically impossible to entirely prevent it, so that although legislation may run on the common sense lines of protecting the general interests of the community at large, it must be left to the individual authorities, who use these waters for waterworks purposes, to employ such superadded processes as the particular necessities of their own case demand.

Percentage of Samples.

	100cc	+100cc —10cc	+10cc —1cc	+1cc —0.1cc	+0.1cc —0.01cc	+0.01 —0.001	+0.001
Raw Thames, Hampton	0.4	2.8	11.7	35.6	38.5	10.5	0.4
Raw Lee, Ponders End	0.8	1.6	8.5	40.1	35.6	11.3	2.0
Raw New River, Hornsey	2.0	10.1	41.7	35.2	10.1	0.8	...
All Kent Wells	93.3	5.3	0.8	0.5	....	....	...

It is very evident from these figures that the main sources of supply are heavily contaminated with excremental organisms, and in their raw state, are quite unfit for drinking and domestic purposes. The raw waters are passed into large storage reservoirs of several weeks' capacity, and finally filtered through slow sand filters of the type now being installed in Toronto. Great stress is laid upon the importance of adequate storage of the water previous to filtration, as it has been shown by Houston and others that under such conditions, pathogenic organisms such as typhoid and cholera vibrio rapidly become devitalized and are finally exterminated. These organisms die out more rapidly in polluted water than in pure water and this is possibly caused by the obtaining conditions being more suitable to the growth of the hardier organisms present; the final result being a survival of the fittest. The quantity of bacillus coli present is also reduced in this process. Houston says, "If all the pre-filtration waters (stored waters) were imagined to be mixed in their respective proportions, the quality of the mixed water antecedent to filtration would be such that on the average one-third would contain no typical B. coli in 10 c.ccms of water." In other words, although 87% of the samples of water taken previous to storage showed typical B. coli in 1 c.ccm, only 66% of the pre-filtration samples showed the presence of this organism in 10 c. ccms. The stored water is filtered through sand at the rate of about two million gallons (Imp.) per acre per day, and is finally passed to the distribution reservoirs.

The water, as delivered, gave the following figures for the bacillus coli test:—

Percentage of Samples.

— 100cc	80.0%
+ 100cc — 10cc	15.3%
+ 10cc — 1cc	4.3%
+ 1cc — 0.1cc	0.3%

Dr. Houston finally states that "As a counsel of perfection I am still bound to advocate the choice of an initially pure source of water supply; but my own results and experiments do seem to indicate clearly that the evil effects of an impure source can be largely, if not entirely, annulled by adequate storage and efficient filtration."

In the case of Toronto, under normal conditions, adequate storage is obtained by means of the lake and ample purification will probably be secured by sand filtration so that supplementary processes of purification will only occasionally be required.

CASTING CONCRETE WALLS.

A new method of building with reinforced concrete has been developed in which the walls were erected by screw jacks, of which a series was set on the foundation wall and on piles inside the building site. These jacks consist of a supporting carriage, a pivoted walking beam, and a telescopic screw driven by a worm and worm gear. A platform is laid on the jacks and the door and window frames are set in the proper relative positions, after which the concrete is poured. The reinforcement is easily placed, because the wall resembles a large drafting board and the bars can be very readily laid out. The entire wall is poured at once, and this can be done in a single day even though the wall be 200 feet long and three stories high. The wall is allowed to set for 48 hours, when a small gasoline engine or an electric motor is connected with the driving shaft and the wall is raised to its permanent vertical position. When all the walls are in place the corners are poured where the reinforcements from either wall project and interlock. The floor and roof structures are put in place in the same way as in any other building. No forms are required except the wooden platform which is used repeatedly.

Metallurgical Comment

T. R. LOUDON, B.A.Sc.

Correspondence and Discussion Invited

MODERN ALLOYS OF ALUMINUM.*

Fred. C. A. H. Lantsberry, M.SC.

Aluminum is a silvery-white metal, which melts at 657 degrees C., and is a good conductor of heat and electricity, its conductivity being about 60 per cent. of that of pure electrolytic copper. Undoubtedly its most interesting property is its extreme lightness, its specific gravity ranging from 2.6 to 2.7 according to its physical condition. Its mechanical strength is, however, very low, but it holds a very high place among the ductile metals.

In the form of sand castings its tensile strength is only about 5 tons per square inch, in the form of rolled sheets about 9 tons per square inch, while by hard drawing into wire its strength can be raised to 15 tons. In the latter condition it has a yield point of 13 tons per square inch and an elongation of about 25 per cent. It can, however, be rolled into very thin sheets and drawn into very fine wire.

Copper-Aluminum Alloys.—The high ultimate strengths of these alloys were known to Dr. Percy, who is credited with their discovery.

The result of adding aluminum to copper is to cause an immediate increase, not only in the strength, but also in the ductility of the copper. The ductility attains a maximum at 7.35 per cent. aluminum; beyond this the tenacity increases, and the ductility falls, but above 11 per cent. aluminum the ductility becomes so small that the alloys cease to be of any commercial value.

Experiments on heat treating the alloys show that up to 7.35 per cent. aluminum they are indifferent to annealing or quenching from 800 degrees C. Above 7.35 per cent. aluminum, the alloys are stiffened by heat treatment at 800 degrees C.

During the discussion of the results, objection was made to the representative character of the results on the grounds of the small dimensions of the castings, and in a later research ("Production of Castings to withstand High Pressures." Proc. Inst. Mech. Eng., 1911), on the suitability of these alloys for castings to withstand internal pressure, Messrs. Carpenter and Edwards have taken mechanical tests of cylindrical castings 9 inches long by 3 inches diameter. The results obtained were quite good, though somewhat lower than the original ones, a 10 per cent. alloy having a tensile strength of 26.23 tons per square inch with an elongation of 13 per cent.

The effect of mechanical work on the alloys, hot rolling from 3 inches to 13/16-inch diameter, is to increase the tenacities and ductilities of the alloys, especially those containing more than 7.5 per cent. aluminum.

Alloys containing below 7.5 per cent. aluminum are not amenable to cold working, but the higher alloys draw well and show a vast improvement in their mechanical properties. The 9.90 per cent. alloy drawn from 15/16-inch to 13/16-inch diameter, shows a yield point of 40.4 tons, an ultimate stress of 43.94 tons, with an elongation of 13 per cent. Tests made by the author in conjunction with Dr. Rosenhain indicated that these alloys showed no deterioration in properties or "aging," even after standing several years.

In the description of the above tests it will have been noticed that the alloys appear to divide themselves into two groups (1) containing below 7.35 per cent. aluminum and (2) containing 7.35 to 11 per cent. aluminum.

This is explained by reference to the micro-structures shown in Figs. 1 and 2. Up to 7.35 per cent. aluminum the alloys consist of a single phase, the α solid solution, which is soft and ductile. Above 7.35 per cent. aluminum a second dark etching phase makes its appearance. This is the β solid solution which is hard and brittle.

It is this phase which contributes to the hardness of the alloys; so much so, in fact, that an alloy containing 15 per cent. aluminum, and hence a large proportion of the β constituent, has a Brinell hardness number of 539, a figure quite comparable with that of a hardened tool steel.

In torsion, the properties of the alloys are very interesting, the 7.35 per cent. alloy possessing the maximum torsional strength of 31.51 tons per square inch with a total twist of 1,374 degrees. The appearance of the β constituent causes an immediate reduction in the total twist, the 9.9 per cent. alloy showing a torsional strength of 31.3 tons per square inch, with a total twist of 234 degrees. Under alternating stress tests the alloys showed almost marvelous results. Prof. Arnold reported that the 7.35 per cent. aluminum alloy showed a record resistance.

A remarkable similarity in properties exists between the 9.9 per cent. alloy and a mild Swedish steel containing about 0.35 per cent. carbon, not only in mechanical properties, but also in microstructure. Both materials show a duplex structure under the microscope which becomes acicular when quenched from high temperatures. The resemblance to the martensitic structure of quenched steel is remarkable.

Fig. 1.—α Solid Solution.

Fig. 2.—α and β.

The aluminum bronzes show a remarkable superiority, however, in their resistance to corrosion over mild steel and such alloys as Muntz metal and Naval brass. This has been shown conclusively by experiments both in the laboratory and the open sea, ranging over a period of several years. In this connection it is interesting to note that while Muntz metal corrodes at practically a constant rate, the aluminum bronzes show a considerable falling off in the rate of corrosion after a few months' time.

In a recent research Messrs. Carpenter and Edwards have shown that if sound castings of these alloys are obtained they are eminently suitable for the production of castings to withstand hydraulic and steam pressures.

One of the chief difficulties encountered in dealing with these alloys lies in the formation of a dross or skin of alumina which appears to be almost elastic, and defies all efforts to remove it. The alumina is produced partly by the reduction of copper oxide, and partly by atmospheric oxidation. It was considered, therefore, that this difficulty could at all

*From a paper read before the Birmingham branch of the British Foundrymen's Association.

events be partly removed by reducing the copper oxide before adding the aluminum.

The addition of manganese results in a considerable improvement of the alloys in all forms. By cold-drawing, the alloy containing 10 per cent. Al. and 2 per cent. Mn. can be hardened up to a yield point of 41 tons, an ultimate stress of 52.1 tons, with an elongation of 10 per cent. In this condition it is quite hard enough to cut stone. This alloy should be eminently suitable for bronze gear wheels and for making cutting tools for explosives.

The effect of the addition of manganese is also shown in the shock-resistance of the alloys.

Unfortunately, however, these alloys possess a very low modulus of elasticity, which tells against them in their use in the construction of machinery, more especially in the rapidly moving parts. The modulus of elasticity ranges about 14×10 pounds per square inch, which is only about half the figure given by steel. Herein lies the explanation of the remarkable behavior of the aluminum bronzes under dynamic stresses.

In the preparation of the alloys it was found that thermit-manganese and ferro-manganese could be used directly, but considerable advantages are derived from starting from a cupro-manganese alloy. This is done by melting copper under a borax slag saturated with oxide of manganese and afterwards adding the requisite quantity of manganese or ferro-manganese. The alloy is cast into small ingots, and for fine weighing and making up, part of the alloy is granulated by pouring into water. In this way considerable refinement is effected, e.g., starting from an 80 per cent. ferro-manganese, the resulting alloy had the composition: Copper, 66.14 per cent.; manganese, 31.68 per cent.; silicon, 0.014 per cent.; iron, 1.86 per cent.; nickel, 0.36 per cent., and carbon, 0.053 per cent.

Alloys prepared from this cupro ferro-manganese contain about 0.31 per cent. iron, which is not present in the alloys of thermit origin. The result appears to be a slight all-round improvement in the alloys. Little need be said about the preparation of the actual alloys except that it is necessary to add the whole of the cupro-manganese before adding the aluminum, and that the casting is best made in surface-dried green-sand molds at as low a temperature as possible. As in the case of the aluminum alloys, the use of very large gates is necessary in order to insure soundness of the castings.

Aluminum is almost an essential constituent of manganese bronzes, in which its function is that of a deoxidizer. An analysis of Parsons manganese bronze made some years ago by the author, showed: Copper, 56.72 per cent.; lead, trace; aluminum, 1.78 per cent.; iron, 2.20 per cent.; manganese, 0.52 per cent.; zinc, 37.68 per cent.

Aluminum Brasses.—Aluminum is often used as a partial substitute for zinc in brasses, it having the effect of increasing the hardness and tenacity, and reducing the ductility of brass.

Dr. Guillet says that 1 part of aluminum can act as a substitute for 3½ parts zinc. Alloys containing over 4 per cent. aluminum are difficult to cast sound and work, but below this percentage the alloys give excellent castings suitable for pumps, valves, pinions and propellers. Further, the alloys forge and draw well.

Light Alloys of Aluminum.—The aluminum-rich alloys are coming into great prominence for aeroplane work.

It has already been pointed out that aluminum itself is mechanically weak, but practically the whole of the elements in the periodic table have been added to aluminum with the object of increasing its strength.

In his book, "Introduction to the Study of Metallurgy," Sir Wm. Robert Austen says that the addition of 2 per cent. titanium to aluminum produces remarkable results.

Aluminum-Copper Alloys.—Carpenter and Edwards showed that the limit of useful alloys is obtained at a content of 8 per cent. copper, and that very little advantage is derived from adding more than 4 per cent. of copper.

By cold drawing the 3.76 per cent. copper alloy its yield point was raised to 18.5 tons, its ultimate stress to 18.5 tons, with an elongation of 7.5 per cent. Subsequent experiments on rolled sheets showed that the improvement in mechanical properties, due to cold working, was entirely removed by annealing at 500 degrees C. The effect of remelting these alloys is very slight; if anything, a slight improvement in the ductility is obtained.

It is interesting to note that the deterioration observed in the heavy alloys does not extend to the light ones. Experiments made on the effect of casting temperature showed that an alloy which, when cast at 650 degrees C., had a yield point of 5 to 6 tons per square inch, an ultimate strength of 9.68 tons per square inch, with an elongation of 8.5 per cent., only showed a yield point of 4.5 tons, an ultimate strength of 4.89 tons, and an elongation of 3 per cent. when cast at 707 degrees C. This clearly shows the influence of casting temperature on the results obtained with these alloys. In fact, there seems to be no class of alloys in which the effect of overheating is felt so keenly as it is in the alloys of aluminum.

Aluminum-Zinc Alloys.—Such alloys are undoubtedly those which lend themselves best for casting purposes, and are largely used in castings for instruments, such as electrical meters and so forth. The alloys used in motor-car construction are essentially zinc alloys, containing from 1 to 4 per cent. copper.

It appears that zinc rapidly increases the tenacity of aluminum, until at a content of about 20 per cent. zinc the tenacity reaches 17.5 tons, after which the tenacity slowly increases to a maximum of about 17.8 tons, at a content of 50 per cent. zinc, and then falls down to that of pure zinc.

The tenacity of 17.5 tons per square inch for a 20 per cent. zinc alloy is somewhat higher than is obtained in actual practice, 15 tons per square inch, with an elongation of 5 per cent. on 2 inches, being a more average figure. In the light of our present knowledge the 20 per cent. alloy is probably the most useful one of the zinc-aluminum series.

Dr. Guillet divides these aluminum alloys into two classes: (1) those containing about 15 per cent. zinc which cast well and are amenable to working, being very malleable and (2) those containing about 30 per cent. zinc, which give very fine castings, but are not amenable to such operations as forging and drawing.

Macadamite is a ternary alloy, containing 24 per cent. zinc, 4 per cent. copper and 72 per cent. aluminum, for which great strength is claimed.

Aluminum-Magnesium Alloys.—Magnesium appears to be an ideal element to add to aluminum, primarily because of its lightness, its specific gravity being only about 1.7, and secondly because of its power as a deoxidizer being greater than that of aluminum itself. The alloys were first discovered by Wohler in 1866, later by Parkinson in 1867, but the first to investigate them at all thoroughly was Dr. Mach, who called the metal magnalium. The alloys examined contained from 10 to 30 per cent. of magnesium, and the harder ones are capable of taking a very high polish, rivalling that of pure silver. Further, the alloys show a high resistance to atmospheric influences and retain their polish for a long time. Consequently they find application in the manufacture of scientific instruments.

Between 15 per cent. magnesium and 15 per cent. aluminium, the alloys are too brittle for constructional work, for which purposes magnesium is usually used in conjunction with other metals.

In the form of castings the second alloy has a tensile strength of 14 to 21 tons per square inch. Both alloys work well, and in drawing require to be frequently annealed, followed by rapid cooling. Tin is said to reduce the shrinkage, enabling sharp castings to be obtained.

Aluminum-Nickel Alloys.—Nickel behaves like copper, but the high nickel alloys possess, like the manganese alloys, the faculty of falling to powder in the atmosphere. Alloys containing above 5 per cent. nickel are brittle, but a 2 per cent. alloy casts and rolls well, giving sheet with a strength of 12 tons per square inch and an elongation of 20 per cent. The Pittsburg Reduction Co., however, claims that in the construction of the "Defender" an aluminum-nickel alloy having a tensile strength of 30,000 to 45,000 pounds per square inch, and an elongation of 10 per cent. was used. The alloys rapidly corrode in water.

Tungsten appears to be a useful element to add to aluminum, especially for alloys which have to be rolled into sheet, etc., and a most interesting alloy of this nature is wolframium which appears to have the composition: Copper, 0.357 per cent.; tin 0.015 per cent.; antimony, 1.442 per cent.; wolfram, 0.038 per cent.; aluminum, 98.040 per cent.

In the hard drawn condition the alloy has a tensile strength of 23 tons, with an elongation of about 10 per cent. On annealing the tenacity falls to 16 tons with an elongation of 15 per cent.

Duralumin was originally discovered in Germany and has lately been very much boomed in this country by Messrs. Vickers, Sons and Maxim. The alloy is not specially suitable for castings, but it finds its main uses in the form of wire and sheets. It is claimed that the material can be obtained in strengths varying from 26 to 40 tons per square inch with elongations varying from 3 to 21 per cent. and Brinell hardness numbers of from 100 to 174, according to the degree and manner of working. The alloy is capable of taking a very high polish and resists atmospheric corrosion very well. The author has made several analyses of the material and its mean composition appears to be: Copper, 3.58 per cent.; silicon, 0.53 per cent; iron, 0.63 per cent.; manganese, 0.43 per cent.; aluminum, 94.87 per cent.

THE COMMERCIAL UTILITY OF ELECTROLYTIC IRON.*

James Aston.

Although engineers are supposedly familiar with iron, since it is our most prominent construction material, our knowledge of its properties and uses are of a comparatively impure or alloyed substance, and very little information has been available regarding the properties of iron of high purity. In fact, until rather recently pure iron was considered a rarity and, although the world's production has been forty to fifty million tons per year, a decade ago the available iron of a purity of 99.9 per cent. was most fittingly estimated in grams.

To obtain this high purity product a natural method of attack was to refine an impure stock electrolytically. This process was employed to a considerable extent in the facing of electrotypes with iron, not because of a resulting high purity, but rather because it afforded a means of giving a thin, accurate, and hard face to an easily formed, softer material. The advantage lay largely in the hardness of the deposit which seems to be due to the occlusion of hydrogen liberated on the cathode together with the iron itself.

Attempts were made to use higher current densities and to obtain thicker deposits, and thus extend the scope of the process to the probable field of commercial production of iron of high purity; but these attempts were generally unsuccessful, the use of high current densities resulting in rough deposits long before they had become of practicable thickness; or if smooth, thick deposits were obtained with high current densities, it was only for short periods of time and at the expense of a costly electrolyte.

To make the electrolytic refining of iron a commercial possibility, high current densities must give smooth, thick deposits in a cheap electrolyte which will allow of long continued operation of the tanks without undue depletion. The entire operation may best be compared with the electrolytic refining of copper as a standard.

In the spring of 1904, Professor C. F. Burgess and Mr. Carl Hambuechen presented a paper before the American Electrochemical Society, giving the results of an extended investigation on the electrolytic refining of iron. Their research had solved the problem to the point of possible commercial development, and good deposits of three-fourths of of an inch in thickness were obtained at a cost which could be brought to one cent per pound or less, thus placing it on a comparable basis with that of refining copper.

As at present conducted, a solution of ferrous ammonium sulphate is used as the electrolyte and bars of Swedish iron about 1 in. by 3 in. by 10 in. (or most recently, of American Ingot Iron ½ in. by 3½ in. by 10 in.) form the anodes; three bars suspended vertically from each anode, the surface of each, therefore, being approximately 90 to 100 square inches per side. Double anodes are employed, and the deposit is formed upon both sides of a single cathode sheet (10 in. by 12 in.) suspended between the anodes. The cathode starting sheets are of iron, lead, or aluminum. In the research work, since special purity of product was desired, a double refining was resorted to, and the iron was first deposited on a lead sheet in the first set of refining tanks, and this in turn used as the anode for the second refining, with an aluminum sheet as cathode. In this case, less care need be exercised in obtaining smooth deposits in the initial refining, and heavy cathode sheets about an inch or more in thickness are the result; while the cathodes in the second refining are removed when the iron deposit reaches a thickness of ¼ to ⅜ inch per side, or a total of ½ to ¾ inches. The deposited iron may be readily removed by stripping, and on account of its brittleness due to the occluded hydrogen, may be easily broken into small pieces if desired. The current density is about 8 to 10 amperes per square foot of cathode surface, at an electromotive force of about one volt per tank; the current efficiency of deposition is close to unity. The tanks give continuous service, with periodical attention in changing anodes and cathodes, cleaning out slimes, and an occasional replenishing of the electrolyte.

The possibility of obtaining considerable quantities of iron of high purity, free from the customary elements accompanying iron made by the usual smelting operations, opened up a field for investigation of great magnitude, and this was naturally given first consideration in the plans for the utilization of the material available. To gain an adequate idea of the possible scope of such a research, the approximate composition of the various commercial irons and steels are given in the following table, together with a typical analysis of the electrolytic product.

*Abstracted from The Wisconsin Engineer.

	Swedish Iron.	O. H. Soft Steel.	Rail Steel.	Cast Iron.	Dbl. Refined Electrolytic Iron.
Carbon	0.10	0.15	0.60	3.75	0.00
Silica	0.10	0.15	0.20	2.00	0.002
Sulphur	0.01	0.05	0.05	0.01	0.003
Phosphorus ..	0.02	0.06	0.10	0.50	0.003
Manganese ...	0.10	0.75	0.80	0.50	0.02

In the above table are listed the impurities usually found in commercial steels, in such quantities as are desired for the particular service required of the steel, or as a necessary accompaniment of the process of manufacture. Carbon belongs in the first class and may thus be considered as a useful element; of the remainder, sulphur and phosphorus are decidedly injurious and their elimination is sought as far as may be practicable; while silicon and manganese are necessary additions because of their indirect influence on certain harmful constituents. The generally listed analyses make no mention of the gases occluded in the steels, particularly nitrogen and oxygen. Yet the vital influences of these elements have recently been recognized and they may be considered as the cause of the marked differences, hitherto unexplained, in Bessemer and open hearth steels of seemingly identical composition.

Of the enormous number of tests of the physical quality of steels, practically all have been made up of materials whose properties may have been influenced by the above mentioned impurities. In the newer field of alloy steels, it is especially true that the effect of the additional element, such as nickel, manganese, silicon, chromium, tungsten, molybdenum, vanadium, etc., is very markedly influenced by slight amounts of impurities, carbon in particular. It may truthfully be said, therefore, that an investigation starting with essentially pure iron as a basis, might branch out into any channel, no matter how thoroughly it has apparently been covered before, without in reality repeating the previous work.

A most promising field was the study of the alloy steels. As may be readily seen, with the vast field opened up, one person could do but little more than scratch the surface, especially in view of the numerous difficulties arising, when the work was first begun, to keep the alloy during melting free from contamination from the furnace gases and from the impurities of the crucible. The electric furnace and magnesia crucible were found to be the best solution of the problem.

It is not the purpose of this article to enumerate the various alloys made up or the nature of the tests; its object is rather to discuss the probable usefulness of the development of the electrolytic refining of iron from the general results of the investigation. It is sufficient to say that most of the earlier work consisted in the preparation of alloys and in testing them for various properties. The scope of the work may be summed up as follows:—(1) the influences of the alloying elements in varying proportions, in the absence of carbon and particularly the sulphur, phosphorus, and manganese accompanying ordinary materials—(2) the testing of alloys which may not have been feasible previously, because of the detrimental effect of the general impurities, particularly carbon, on the nature of the alloy formed—(3) the correlation of the several properties observed, with the hope that it might aid in interpreting the inner make-up of the materials.

In general, electrolytic iron can hardly be expected to take a conspicuous place in steel for ordinary purposes, since the properties would have to be very greatly superior to those of the less pure metals of otherwise identical composition to warrant its use, as the cost of the refining operation is necessarily high. As far as structural materials are concerned, the carbon is a beneficial agent, permitting one to vary the strength, ductility and elasticity of the alloy according to the nature of the service required; the great advantage of the electrolytic iron comes in enabling a closer regulation of the properties to be made because of the absence of the other detrimental impurities, particularly sulphur, phosphorus and oxides.

Conspicuous results may be cited in the copper steels where in the absence of carbon, copper is seen to be a beneficial agent, and not the extremely deleterious one indicated by tests upon steels of the usual holding of carbon. Again, in those materials used for their magnetic properties, small amounts of impurities, especially carbon, are injurious, and alloys made with electrolytic iron as a base material showed a higher permeability than those of corresponding additions to commercial iron.

There are many special fields of usefulness, however, where the primary cost of the material is a secondary consideration if the resultant properties are of sufficient merit.

Pure iron is a factor in the commercial world only indirectly because of the elimination of the customary impurities, as sulphur and phosphorus; manganese, and carbon in particular, can hardly be classed as such. The great measure of its utility will rest in the elimination of the variables incident to the use of customary stock as a basis for a high grade, uniform product.

EXPERIMENTS ON THE USE OF PYRITIC RESIDUES.*

In Italy experiments have been carried out by Carcano for the production of pig iron from pyrites residues. Purifying, enrichment, and agglomeration are necessary to prepare pyrites residues for treatment in the blast-furnace. The material often carries more than 4 per cent.

The residues treated by Carcano in the electric furnace contained:

Silica	From 7.9	to 12.25	per cent.
Iron	From 47.0	to 60.3	per cent.
Alumina	From 6.9	to 18.80	per cent.
Sulphur	From 2.01	to 4.25	per cent.

The residues were charged in their powdery condition. It was endeavored to work with the most basic slag possible, with a certain percentage of manganese, so as to ensure a sufficiently strong desulphurizing effect. Generally, manganese is found to be a satisfactory desulphurizer. In the experiments raw material containing up to 4.25 per cent. sulphur yielded a pig iron running between 0.015 and 0.058 per cent. sulphur in the presence of from 2.17 to 2.54 per cent. manganese. Various types of electric furnace of different powers were used. The furnace tried by Carcano in 1908, which gave the most favorable results, was of a capacity varying from 200 to 300 horse-power. It was a closed furnace with neutral hearth supplied with single-phase or three-phase current with automatic charging, and with recovery of the carbon monoxide evolved during the reactions. That gas was used to prevent deoxidation of the pyrites residues. The energy consumption per ton of pig produced averaged 2,100 kilowatt hours in a furnace of 180 kilowatts and using residues containing 50 to 55 per cent. of iron in the form of ferrous oxide. The lower ends of the vertical electrodes rested on the slag, so that the furnace worked as a surface resist-

*Abstracted from a paper on The Application of Electricity in the Metallurgical Industry of Italy, by R. Catani.

ance furnace and the slag was of very high temperature, much above that of the bath. By this means it was possible to obtain highly fluid slags sufficiently basic in character.

Too much data is lacking to make it possible to present a practical estimate on the future economic aspect of the process.

NEWS ITEMS.

A new copper alloy which has the hardness of steel and has great tensile strength has been invented by a French metallurgist. Eleven pounds chromium are melted for one hour with eleven pounds aluminum, and then 242 pounds copper are added. The entire charge is kept at fusing temperature during one-half hour. Then 55 pounds nickel are added and the mixture is heated another hour, upon which 44 pounds zinc are added.

The proportions of copper and chromium can be varied according to the use to which alloy is to be put, but the order in which the metals are brought to melting temperature, as also the addition of aluminum, must not be changed. The breaking load with this alloy is said to be 40 tons per square centimetre.—La Fonderie Moderne.

The Canadian Venezuelan Ore Co. has recently acquired an area of about 6,000 square miles of Hematite ore beds at the mouth of the Orinoco River, this site being situated about 2,000 miles from Philadelphia. It seems that this Canadian company beat out a German syndicate in acquiring this ore bed. The shipping facilities are said to be good, and it is expected that the second year's operations will be in the neighborhood of 1,000,000 tons. The following is a furnished sample analysis:—Fe, 57.5; Mn, 0.49; S, 0.062; P, 0.078; TiO_2, 0.078; SiO_2, 12.4; CaO, 0.22. Among those prominently connected with this development are Sir Max Aitken, F. P. Jones, and H. S. Holt.

THE STRENGTH OF SHEET PILING.

In an appendix to the report of the Committee on Wooden Bridges and Trestles of the American Railway Engineering and Maintenance of Way Association, the strength of sheet piling is discussed.

The magnitude of the stresses in sheet piling, due to bending, depends upon the kind of material retained by it. Sheet piling is generally held in place by a wale at the top, one at or near the bottom of the excavated trench or area, and sometimes by one or more at intermediate points.

In deriving the following formulas all weights are expressed in pounds per cubic foot, all distances in feet, and all bending moments in pound-feet. A vertical strip of piling 1 ft. wide is considered for the sake of convenience.

1. Pressure Due to Water. Let the upper wale be assumed at the water surface and the lower wale at the bottom of the excavation, or at a distance D below the surface of the water, both wales being properly braced. By the methods of mechanics the greatest bending moment occurs at a distance 0.577 D below the surface, if the piling be treated as a simple beam. This point is farther from the middle of the unsupported length than in any other case where one or more additional wales are employed. The eccentricity may, however, be regarded as offset by the partial continuity of the lower end which penetrates the soil, and thus the greatest bending moment may conveniently be taken at the middle of the unsupported depth. The value of the greatest bending moment is $3.91\ D^3$, the weight of a cubic foot of water being taken as 62.5 pounds. If an additional wale be located at a height C above the bottom one, the greatest bending moment between them is $3.91\ (2\ C^2D - C^3)$. In case both the top and intermediate wales be omitted the bending moment at the bottom is $10.42\ D^3$. If the fluid material retained by the sheet piling is heavier than water the pressures and bending moments are proportionately increased.

2. Pressure Due to Dry Sand. According to Coulomb's theory the horizontal pressure expressed in pounds per square foot for material which assumes a slope of 1.5 to 1 is $W\ H\ \tan^2 (45° - \frac{1}{2}\ R)$, in which W is the weight per cubic foot of the material, H the depth at which the pressure occurs, and R the angle of repose expressed in degrees. This indicates that the pressure varies directly with the depth as in hydrostatic pressure, but that the unit weight of the material is $W \tan^2 (45° - \frac{1}{2}\ R)$ instead of W. In the material under consideration it is observed that the trench may be excavated a foot or more below the bottom of sheeting without causing any flow, and hence it may be assumed that the pressure is zero at the bottom as well as at the top.

It has also been observed that the center of pressure against sheet piling is not at one-third of the depth from the bottom, but more nearly two-thirds of the depth (see Earth Pressure and Bracing, by J. C. Meem, in Trans. Am. Soc. C.E., Vol. 60, and the accompanying extended discussion). It seems, therefore, that the angle of repose for any given material is not constant but varies in some manner, although not directly as the depth. In conformity with these facts R may be taken equal to $90° (H/D)^{0.6}$. The exponent 0.6 is based on the result of observations.

For material having an angle of repose of 33° 40', which corresponds to a slope of 1.5 to 1, Coulomb's formula gives a horizontal pressure equal to $0.12\ W D^2$, and the overturning moment about the base of $0.04\ W D^3$, which is claimed by Sir Benjamin Baker to be double the true value. From the results of Trautwine's experiments on overturning moment, due to dry sand, it is computed to be $0.019\ W D^3$. By plotting the horizontal pressures derived from the values $W\ H\ \tan^2 [45° - 45° (H/D)^{0.6}]$ for different depths, the total pressure for dry sand is found to be $0.029\ W D^2$, and the centre of pressure is approximately two-thirds of the depth of the excavation from the base, making the overturning moment $0.019\ W D^3$, as before.

For sheet piling resisting the pressure of dry sand when held in position by wales at the top and bottom of the excavation, the greatest bending moment occurs at a distance 0.43 D from the top and equals $0.0045\ W D^3$. When an intermediate wale is placed at a height C above that at the bottom, the bending moment becomes $0.0045\ W C^2 D$.

3. Pressure Due to Wet Slipping Material. There remains to be considered the wet slipping material which exerts a much greater pressure than dry sand but a smaller pressure than water. Such material produces a considerable pressure at the bottom of the excavation. To meet this condition it may be assumed that the depth at which the horizontal pressure becomes zero is 2 D instead of D. When this change is made in the previous value for horizontal pressure the results agree closely with those of observation. The total pressure above the bottom of the excavation is $0.08\ W D^2$ and the center of pressure is at ½ D. The overturning moment about the base is then $0.04\ W D^3$.

The greatest bending moment on sheet piling supported at the top and bottom only and retaining wet slipping material is $0.013\ W D^3$ and occurs at half depth. When an intermediate support is placed at a distance C above the bottom the bending movement is $0.013\ W C^2 D$.

STRESSES IN TUBES.*

By Prof. Reid T. Stewart, Pittsburg, Pa.

While engaged in planning a series of collapsing tests on commercial lap-welded steel tubing, the principal results of which are recorded in the Transactions of the Society, the writer made a theoretical investigation of the stresses in the wall of a tube exposed to external fluid pressure. It was thought that the results of this theoretical investigation would aid in conducting the experiments on a more scientific basis and also serve to simplify the working up of results. The writer was led to believe that an annulus near the middle of a long tube exposed to external fluid pressure is subjected to the same kind of stress that exists in a column whose

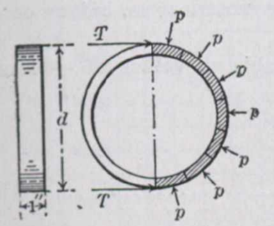

Fig. 1—Annulus of Unit Length at the Middle of a Long Circular Tube.

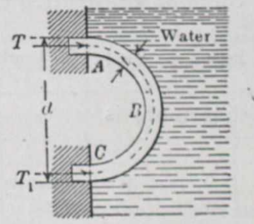

Fig. 2—Half Annulus with Fixed Ends.

ends are fixed in direction when loaded axially. The following is a brief synopsis of this investigation, together with a comparison of the results obtained by the use of these new column formulae with the results of actual tests of columns and struts having ends fixed in direction.

2. **Apparent Theoretical Stresses in the Wall of a Tube Exposed to External Fluid Pressure.**—Fig. 1 represents an annulus, 1 in. long, located near the middle of a long tube that is perfectly circular in cross section. Let p represent the external fluid pressure in lb. per sq. in. and T the resulting tangential stress in the wall due to this fluid pressure Now if δa represents, in angular measure, an increment of the circumference of this annulus, then an increment of the area exposed to the external fluid pressure will be ½ d δa. The normal pressure on this increment of area will be ½ p d δa, and the component of this pressure parallel to the line of action of the tangential stress T will be ½ p d sina δa. Therefore the tangential stress

$$T = \frac{1}{2} \int_{\pi}^{0} \frac{1}{2} p\, d \sin a\, \delta a = \frac{1}{2} pd \ldots\ldots\ldots\ldots [1]$$

Since the tube is assumed to be perfectly circular in cross section and of uniform thickness, this formula shows: (a) that the circumferential stress in all parts of any annulus of a tube exposed to an external fluid pressure is constant; and (b) that this constant circumferential stress per in. length of tube equals the fluid pressure in lb. per sq. in. multiplied by one-half the outside diameter in ins.

3. **Apparent Stresses in a Tube Annulus Compared with those in a Column or Strut.**—Fig. 2 shows one-half of a tube annulus with the ends fixed in direction, the outside surface of the half annulus being exposed to a fluid pressure. Evidently the laws above deduced for the complete annulus apply without modification to the half annulus when its ends are fixed in direction, at the same time being free either to recede or to approach each other. All portions of this half annulus, then, are subjected to the compressive stress T (Formula 1) which acts circumferentially in the direction ABC. Opposing this, of course, is the equal circumferential stress T_1, acting in the direction CBA. By straightening the half annulus (Fig. 2) so as to bring A, B and C into the same straight line, the column or strut shown in Fig. 3 will result. It is evident that the forces T and T_1 are each rotated by this action through 90 deg. This shows that the theoretical stresses in a tubular half anulus are identical with those of the column having ends fixed in direction, when the length of the column equals the mean semicircumference of the annulus, the two, of course, having the same cross section.

4. It will become evident from a comparison of Figs. 4 and 5 that we should take for the length of a column having fixed ends, the half circumference of an annulus located near the middle of a long tube exposed to an external fluid pressure. Fig. 4 shows the ideal collapse section for all the long tubes tested. It will be observed that the tangents to the annulus at both the highest and lowest points before collapse, as shown by the dotted lines, are precisely parallel to the tangents at the same points after collapse. In other words, these portions of the annulus while undergoing deformation remain fixed in direction. Comparing this with Fig. 5, which shows the most probable manner of buckling of a long column having fixed ends, it will be seen that the two are identical as regards apparent stresses for the conditions above stated, namely, when the annulus is perfectly circular and of uniform cross section, the length of the column with fixed ends being equal to the mean half circumference of the annulus.

5. As the tube annulus departs from the circular form, while failing under fluid collapsing pressure, new stresses arise which have no counterpart in the equivalent column. An investigation has shown that these stresses are slight for small departures from roundness, so that for commercial tubing exposed to external fluid pressure the stresses are substantially the same as those in an equivalent column as illustrated above.

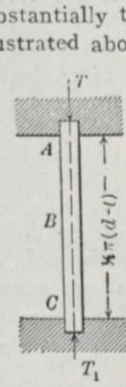

Fig. 3.

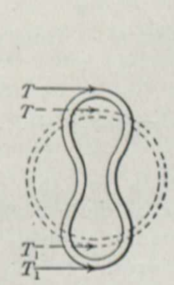

Fig. 4.

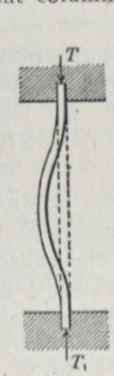

Fig. 5.

Fig. 3.—Strut Representing Half Annulus Straightened.
Fig. 4.—Ideal Collapse Section for Long Tubes.
Fig. 5.—Most Probable Manner of Column Failure.

6. **The Author's Formula [B] for the Collapsing Pressures of Steel Tubes Reduced to an Equivalent Column Formula.**—In order that he might be able to test the accuracy of the above theoretical deductions, the author has transformed his formula [B] for the collapsing pressures of lap-welded bessemer steel tubes so that it may be used for calculating the crippling strength of columns or struts with fixed ends. This transformation was effected as follows:

7. Referring to Figs. 2 and 3, which represent respectively a half annulus of the tube and its equivalent column or strut, it is evident that the length of the equivalent column will be

$$l = \frac{\pi}{2}(d - t) \text{ or, } \frac{d}{t} = \frac{2l}{\pi t} + 1 \ldots\ldots\ldots\ldots [2]$$

* From the January Journal of the American Society of Mechanical Engineers.

where d and t represent respectively the outside diameter and the thickness of the wall of the tube in in. and π the ratio of the circumference to the diameter of a circle. Since $t = 3.464\ r$, where r equals the radius of gyration of cross section of the annulus and of its equivalent columns,

$$\frac{d}{t} = \frac{2l}{3.464\ \pi r} + 1 = 0.1838 \frac{l}{r} + 1 \ldots\ldots\ldots [3]$$

$$p = \frac{2T}{d} = \frac{2tS}{d} \ldots\ldots\ldots [4]$$

where p represents the external fluid pressure in lb. per sq. in., T the total circumferential stress in the wall of the annulus 1 in. long, and S the total circumferential stress per sq. in. of cross section, both being expressed in lb. Also, t and d as before, represent respectively the thickness of the wall and the outside diameter of the tube, in in. Formula [B], using the same notation as before, is

$$p = 86,670 \frac{t}{d} - 1386 \ldots\ldots\ldots [B]$$

By equating the second members of equations [4] and [B] we get

$$\frac{2tS}{d} = 86,670 \frac{t}{d} - 1386$$

from which

$$S = 43,335 - 693 \frac{d}{t} \ldots\ldots\ldots [5]$$

By substituting the value of $\frac{d}{t}$ from equation [3] we get

$$S = 42,640 - 127.4 \frac{l}{r} \ldots\ldots\ldots [K]$$

8. This is a formula for the crippling strength of a column with fixed ends, as derived directly from formula [B] for the collapsing pressures of long tubes that are exposed to external fluid pressures. In this formula, S represents the axial load on the column in lb. per sq. in. of cross section, while $\frac{l}{r}$ represents the slenderness ratio, or the length of column divided by the least radius of gyration of cross section, both being expressed in the same lineal unit.

9. Since formula [B] is applicable to values of thickness divided by outside diameter $\left(\frac{t}{d}\right)$ greater than 0.023, formula [K] should be applicable to values of length of columns divided by least radius of gyration, $\frac{l}{r}$, less than

$$\frac{\frac{\pi}{2}(d-t)}{\frac{t}{3.464}} = 1.732\ \pi \left(\frac{d}{t} - 1\right) = 1.732\ \pi \left(\frac{1}{0.023} - 1\right) = 230$$

Note that formula [G] is tangent to formula [B] at $\frac{t}{d} = 0.024$, which gives a slenderness ratio $\left(\frac{l}{r}\right)$ at point of tangency of 221, which latter should therefore be the true limiting value of r for formula [K] when used in connection with formula [L] as given below.

10. The Author's Formula [G] for the Collapsing Pressures of Steel Tubes Reduced to an Equivalent Column Formula.—In a manner similar to the above derivation of formula [K] the author's formula [G] has been transformed into an equivalent formula for the crippling strength of long columns or struts. Using the same notation as before collapse formula [G] which is applicable to values of $\frac{t}{d}$ less than 0.024 is

$$p = 50,210,000 \left(\frac{t}{d}\right)^3 \ldots\ldots\ldots [G]$$

and its equivalent column formula, derived in a similar manner, is

$$S = 25,105,000 \left(\frac{1}{0.1838 \frac{l}{r} + 1}\right)^2 \ldots\ldots\ldots [6]$$

which is applicable to values of $\frac{l}{r}$ greater than 221, as stated above. This somewhat complex formula is represented with sufficient accuracy for all practical purposes by the following simple formula:

$$S = \frac{708,000,000}{\left(\frac{l}{r}\right)^2} \ldots\ldots\ldots [L]$$

where S as before, represents the axial load on the column in lb. per sq. in. of cross section, and $\frac{l}{r}$ the length divided by least radius of gyration of the column, both being expressed in the same lineal unit. This formula applies only to columns having both ends fixed in direction and for values of $\frac{l}{r}$ greater than 221.

11. **Verification of the Author's Column Formulae [K] and [L] by Comparison with Results of Tests on Columns.**—In order to show that the new column formulae given in this paper are applicable to commercial shapes and annular sections when used as columns with ends fixed in direction, Figs. 6 and 7 were prepared. The only tests on commercial struts and columns with fixed ends known to the writer are those made by James Christie on wrought-iron struts,* and those made at the Watertown Arsenal † in 1909.

12. The average physical properties of the iron in the struts tested by Mr. Christie were

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* Trans. Am. Soc. C.E., 1884, p. 117.

† Proceedings, American Society for Testing Materials, 1909, p. 413.

Tensile strength, lb. per sq. in.	49,000
Elastic limit, lb. per sq. in.	32,000
Elongation in 8 in., per cent.	18

while those of the steel constituting the lap-welded tubes tested by the writer and at the Watertown Arsenal were

Tensile strength, lb. per sq. in.	58,000
Yield point, lb. per sq. in.	37,000
Elongation in 8 in., per cent.	22

13. These data show that the material of the angles and tubes tested by Mr. Christie as compared with those of the tubes tested by the writer and at the Watertown Arsenal had average physical properties less by 15 per cent. in tensile

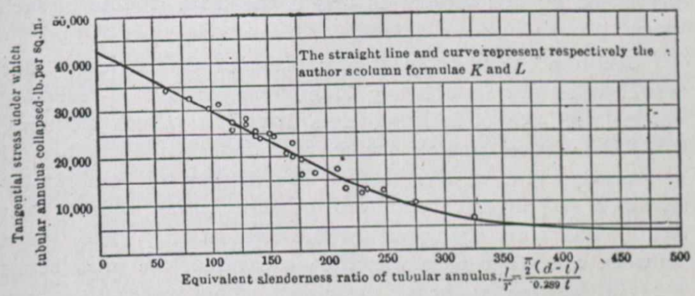

FIG. 6 PLOTTED RESULTS OF THE AUTHOR'S EXPERIMENTS ON COLLAPSING PRESSURES OF LAP-WELDED STEEL TUBES

strength, 13 per cent. in elastic limit, and probably less than 10 per cent. in modulus of elasticity, or rigidity factor. It should be remembered while comparing the results of these experiments, that these differences in the physical properties of the materials, which it will be noticed are comparatively small, will be more or less offset for two reasons: (a) the tubular annulus at the point of failure varies somewhat more from being truly circular than does the strut from being truly straight; and (b) there is a small bending moment on the wall of the tubular annulus directly due to the action of the external fluid pressure on an annulus that is slightly out of round, for which there is no counterpart in the equivalent column.

14. Fig. 6 represents the plotted values of the results of the writer's experiments on the collapsing pressures of lap-welded steel tubes. These results are plotted to a horizontal

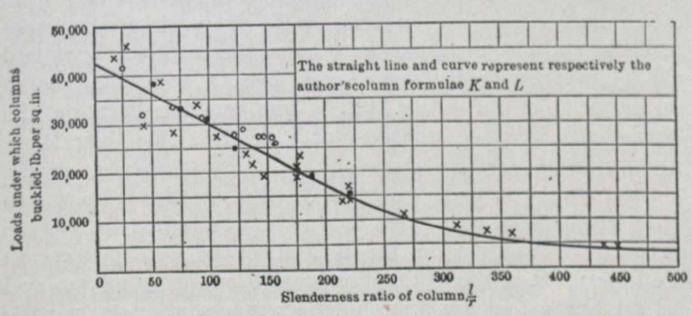

FIG. 7 PLOTTED RESULTS OF VARIOUS COLUMN EXPERIMENTS

(x) indicates plotted results of Christie's experiments on wrought-iron angles ranging from 4 in. × 4 in. × ½ in. to 1 in. × 1 in. × ⅛ in., with fixed ends.
(•) indicates plotted results of Christie's experiments on lap-welded wrought-iron tubes used as columns with fixed (flanged) ends.
(o) indicates plotted results of Watertown Arsenal experiments on lap-welded steel tubes, 5 in. outside diameter, used as columns with fixed ends.

scale representing the equivalent slenderness ratio of the semi-tubular annulus considered as being under the same conditions of stress as a column with ends fixed in direction (Figs. 2, 3 and 4). Since the mean semicircumference of the tube annulus equals $\frac{\pi}{2}(d-t)$ and the radius of gyration of the section equals 0.289t, this slenderness ratio will be

$$\frac{l}{r} = \frac{\frac{\pi}{2}(d-t)}{0.289t}.$$

The vertical scale represents the apparent tangential stress T (Fig. 2), under which the tubular annulus actually failed.

15. Fig. 6 represents the plotted values of the group averages of Series 2 of the author's experiments on the collapsing pressures of lap-welded steel tubes, 3 to 12¾ in. outside diameter. The straight portion of the line represents the writer's column formula [K] plotted to the same scales, while the curved portion similarly represents column formula [L].

16. Fig. 7 represents the plotted values of all results of tests on commercial struts and columns with ends fixed in direction known to the writer. It should be noted here that practically all tests of commercial columns and struts have been conducted under the condition of flat, pin, or round ends.

ENGINE AND MACHINERY FOUNDATIONS.*

By A. E. Dixon.

The first and most important purpose for which foundations are employed is to insure that any settlement which occurs will be uniform; the second is to provide an anchorage. The last purpose may be accomplished in combination with the first, but an anchorage is only necessary where the energy developed in the machine is not absorbed or utilized in a direct-driven machine, as in the case where the power is taken off by or delivered to the machine by belts or ropes. Anchorage is also required by reciprocating machines which are improperly balanced or in which the direction of motion is reversed abruptly, the mass of the foundation serving to absorb and dampen vibration. There are some classes of machines which can be safely set without either foundations or holding-down bolts, as rotary converters and turbo-generators or similar combinations mounted upon rigid bed-plates. The only requirement in these cases is that the supporting structure shall have sufficient rigidity and be capable of meeting the concentrated loadings imposed.

Rock bottom is most desirable where piers supporting heavy machinery are to be put in, but it may introduce complications in getting rid of vibration. Rock has a tendancy to transmit shocks or vibrations to all surrounding structures resting upon the same bed, and where there is any chance of vibration a bed of dry sand from 6 to 12 inches thick must be placed between the rock and the foundation. This sand bed can be made within a pocket excavated in the rock or, where a flat bed exists without natural retaining walls, by building a pocket of concrete to hold the sand in place. Mineral wool and felt cushions have been utilized under light foundations, but they do not possess the lasting qualities of sand.

There are many different grades of rock and the natural bed of the stone may be at any angle between the horizontal and the vertical. The most favorable conditions are those in which the rock has a horizontal bed and does not disintegrate upon exposure to atmospheric influences. Some rock is called "rotten" because it deteriorates and softens upon exposure, while in other cases beds of rock are found which upon their first exposure are soft enough to excavate with a pick and shovel but harden rapidly and must be blasted after exposure. Many other outcrops require blasting, while in

* From Power.

still other cases the natural cleavage permits its removal with wedges; in some of the softer rocks this method of breaking up into derrick or one-man or two-man sizes is less expensive than block-holing and using powder.

The safe loading upon rock beds depends entirely upon its nature, and ranges from 5 to 200 tons per square foot. In cities having building codes the safe-load limitations of the natural soils found within their limits are specified. Where there is no building code the safe loadings can be governed by the values given in Baker's "Masonry Construction." This table has been widely copied and may be found in many handbooks.

Sand or gravel, particularly when dry and well drained, is next to rock in desirability, and in some respects is the best substratum. It is easy to excavate, and if free from clay and loam the excavated material can be utilized in making mortar or concrete, thus reducing the expense of masonry construction. Other soils have to be removed and used for grading low places or back filling, and the disposal of the surplus soil may considerably increase the expense of excavating.

Mud, soft alluvial soil, quicksand, etc., often make foundation work difficult, particularly where heavy concentrated loads are to be carried. Piling or raft foundations then become necessary. Where the water level is permanent, wooden piles cut off below this level will endure as long as the structure above them.

There are two methods of capping a wood-pile foundation. One is to excavate between the piles for a depth of 2 feet or a trifle more; then fill in around the piles to a depth of a foot with clean sand and upon this a bed of concrete is laid. The depth of this concrete over the heads of the piles will depend upon conditions and the load. An interesting example of concrete mat over piles is found in the foundations of the Long Island City power plant of the Pennsylvania Railroad. The mat is 6 feet 6 inches thick at all points except under the four stacks, where it is 2 feet thicker. The site of this foundation is inclosed within sheet piling. In this case the thickness of the mat was partly dictated by the tidal conditions of the East River, on which the plant is located. The floor of the power-house basement had to be above high water while the piles had to be cut off below low water. Sheet piling is necessary in building foundations of this kind in order to prevent the earth about the excavation from caving in, and to prevent damage to adjacent structures. It also serves to limit the quantity of water flowing into the excavation and reduces the expense of keeping the pit dry. Where the surrounding soil is subaqueous, cofferdams constructed of sheet piling or cribwork are required.

The earliest method of capping a pile foundation consisted of laying heavy squared timbers on top of the piles to which they were secured by drift bolts. On top of these and at right angles to them another layer of squared timbers was laid. These two layers were usually of 12 x 12-inch material. The interstices between the timbers were then filled with sand, gravel or concrete and a flooring of 6 x 6-inch timbers was laid over the area. These timbers were solidly drift-bolted together and upon the surface thus prepared was laid the stone of concrete masonry for the foundation. This method was very expensive as the piles had to be cut off low enough to keep all of the timber work below the water line.

There are a number of formulas for determining the bearing power of piles. Most of these depend upon the distance the pile sinks under the last few blows of the pile-driver drop. These are very poor ways of determining how much the pile will sustain, though they are widely used by engineers who should know better. The writer has seen a pile sink 3 feet and more under one blow of the hammer and then come up nearly the same distance as soon as the hammer was lifted off its head. Holding this pile down with a heavy weight for a short time resulted in its becoming so firmly fixed in position that repeated blows with the hammer could not drive the pile down ¼-inch; when the endeavor was made to pull the pile the heaviest tackle available could not stir it. The use of formulas based upon the distance the pile sinks under one blow has often resulted in driving the piles down into themselves until they split and lost strength.

Quicksand, when it reaches a considerable depth, can be overcome by driving piles down to the firm underlying stratum. Thin layers can be removed by placing sheet piling around the area to be excavated; inflow will also be prevented by this means, as this is the main trouble in such cases.

Medium beds occasionally present themselves. The writer once put in a heavy foundation for a twin-reversing engine with 55 x 60-inch cylinders driving a 34-inch blooming mill, the entire area of which was underlaid by a bed of quicksand about 12 feet thick. The method adopted in this instance was to drive two rows of sheet piling about 3 feet apart, inclosing the area for the foundation. The space between the sheet piles was then excavated, the piles being held in position by heavy bracing. This excavation was carried down 2 feet into the firm layer of hard pan underlying the quicksand and then filled with concrete, this forming a concrete cofferdam around the foundation area. The space inclosed was then excavated to the required depth, which left 10 feet of quicksand below the foundation. This sand was so fluid that a man could not stand in it unless supported by a plank. The surface of the quicksand was then covered with two layers of tar paper at right angles to each other and a thin layer of concrete was deposited on the tar paper; then a 2-foot layer of concrete was deposited to form the foundation footing. This method of doing the work saved nearly 1,000 cubic yards of concrete, and the foundation proved all that could be desired. No appreciable settlement had occurred when the elevations were checked up by a bench mark after the machinery had been operated several years.

The holding-down bolts in these foundations were from 1 to 3 inches in diameter and from 4 feet 5 inches to 16 feet in length, 241 bolts being required for the engine, mill, tables and shear. Templets, made from drawings, were made in sections to locate these bolts and all holes were laid out by measurements from centre lines, a hole being bored in the templet for every bolt. The templets locating the heavy bolts were so supported on a scaffold that their lower surfaces were slightly above the elevation of the top of the foundation. A transit was used to line up the templet and after it had been accurately located it was nailed fast to the supporting scaffold. In the meantime the bolt pockets in the lower part of the foundation were brought up to the level for the foundation washers. These washers were set in position and located by plumbing down from the templet.

Sheet-steel galvanized-iron tubes 5 inches in diameter were provided for the 3-inch bolts and 4-inch pipes for the 2-inch bolts. The blocks turned to fit these pipes had been nailed to the under surface of the templet for holding the tops of these pipes in place. These tubes were then placed in position and their lower ends were built in with brick laid on top of the foundation washers. In setting these tubes care was used to get them centrally located with reference to the bolt holes in the washers and templet. After the tubes had been set the location of the templet was carefully checked.

The smaller and lighter bolts were located by hanging them in the templets, which were so built and supported that this could be done. Old 3-inch boiler tubes were rescued from the scrap pile, cut into 2-foot lengths and used to provide adjustment space at the top of the bolts. Newspapers were employed to center the bolts in the tubes and to prevent the concrete from rising in them.

This foundation was brought up and finished about 1¼ inches below the bottom of the bedplates. After the bedplates had been placed, lined up and levelled, the bolts were sufficiently set up to hold them in position, care being taken to avoid springing. The tubes around the bolts were then filled with fine dry sand to within a short distance of the top of the foundation. A dam was next built around each bedplate and the space below it with the tops of the tubes was filled with grout. Steel wedges made from 2 x ½-inch flat iron drawn down to a point under a steam hammer were used to raise the bedplate, the finished wedge being about 6 inches long. After the grout had set, the steel wedges were knocked out and the holes left were filled with pointing mortar. An ample supply of these steel wedges and 3 x 1-inch steel blocks for use as fillers below the wedges is a great convenience, especially when lining up heavy machinery. Hardwood, maple or oak wedges can be used with light machinery, but they are useless in working with machines having bedplates weighing from 40 to 50 tons.

Direct-connected sets, such as steam turbines and generators, motor-generator sets, rotary converters or well-balanced reciprocating engines with generators can be mounted on structural foundations. Care, however, is necessary in the case of reciprocating units to insure that their cyclical period of vibration does not coincide with that of the supporting structure or is not a harmonic of it. When these cyclical periods harmonize the entire structure will be thrown into vibration. Should this occur the first remedy to be tried is slight alterations in the speed of the machine. A bucket of water should be set on the floor close to the machine and the vibration ripples on the water will show the effect of the changes in the speed. When it is impossible to cure the trouble in this manner, additions can be made to the weight of the machine by filling in the hollow portions of the bedplate with cement concrete. If enough weight cannot be thus added, a platform can be suspended under the machine in the floor below and a foundation built on it. The rods or bolts carrying this dead weight should be threaded to permit their load being clamped up solidly against the ceiling below the machine.

When properly constructed, a reinforced-concrete structure furnishes a favorable foundation. It is rigid and heavy and thoroughly tied together. Structural steel framing with concrete floor slabs makes the next best arrangement, particularly if care is taken to tie the steel frame with portal and "X" bracing. Tile or tile and concrete floors are not as good as heavy slab construction. The design of this type of foundation should not be lightly undertaken, as it is not a case where "most anything will do" and an improper design will result in trouble, perhaps a serious disaster.

Structural reinforced concrete, sometimes called steel concrete, is not the rough agglomeration it is sometimes imagined to be. Every piece of steel has its reason for being in the position assigned and no liberties can be taken without endangering the structure. Once there was a country millwright who read in the daily papers about reinforced concretes and saw some wonderful pictures of reinforced-concrete dams. It fell to his lot to build a small dam for the local authorities and it was decided to use reinforced concrete. So this millwright bought all the old horseshoes and scrap from the local blacksmith and mixed the mess with sand, cement and gravel and placed it in the forms. The life of this dam was very brief; in fact, it collapsed as soon as the forms were taken partly down, but, fortunately, before any amount of water had accumulated. Steel scrap mixed in the concrete does not act as reinforcing, and it is not wise to attempt a reinforced-concrete structure without competent advice.

AUTOMATIC CENTRIFUGAL FRICTION CLUTCHES.

Many schemes have been devised to reduce heavy starting currents in electric motors. Ingenuity has been expended and elaborate motors and switch-gear designed to meet this difficulty, but the result has been obtained at the expense of simplicity and reliability.

The subject of this article has been evolved to meet a difficulty often met in practice, i.e., to start and accelerate a load or mass requiring a large starting torque, without using special switch-gear, and with a minimum of starting current. The device is particularly valuable where the machines are frequently started and stopped, such as capstans, hydro-extractors, the travelling motions of cranes, air compressors, hydraulic pumps, etc., etc.

The function of the clutch is to enable the motor to start up unloaded, the load being gradually applied as the motor accelerates, this rate can be pre-determined when designing the clutch and is entirely independent of the operator. The switch-gear can be of the simplest form; in many cases the motor can be switched direct on the mains without any starting resistance (or its equivalent) whatever. No-volt and overload release devices are not required, the clutch gives all requisite protection to the motor.

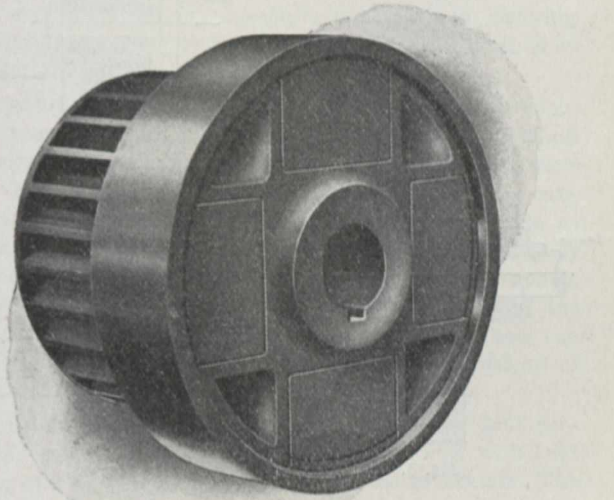

Fig. 1.

The clutch is eminently suitable for use with alternating current motors of the squirrel-cage rotor type. As is well known, this is the simplest and cheapest type of motor, the only wearing parts being the bearings. Up to now, however, its poor starting torque, especially in the single-phase type, has prevented its use in many cases. This disadvantage is at once overcome by using a centrifugal clutch, and complicated switch-gear, with its troublesome coils, resistances, etc., is unnecessary. Belt-shifting arrangements are also done away with, and slipping and wear of belts avoided.

Referring to the illustrations, the clutch consists of a central armed boss keyed to the motor or driving shaft, carrying friction shoes or slippers in suitable slides. These shoes are free to move outwards by centrifugal force as the motor accelerates, and engage with the internal rim of the clutch-pulley which transmits the power to the machine.

The slippers gradually accelerate the outer portion of the clutch, and the machine, which it drives to full speed; they then drive without any slip but can be designed to commence slipping at any desired overload, thus acting as an automatic overload device. Sudden shocks or variations in load are not transmitted to the motor, but are taken by the clutch which acts as a flexible coupling. The action is entirely automatic, and the only wearing parts are the faces of the slippers which can be renewed for a trifling sum. They last a long time under the worst conditions, and their renewal can be easily and speedily accomplished.

If desired the shoes can be fitted with springs, as shown in Fig. 3, to enable the motor to attain a certain pre-determined speed before the slippers engage. This arrangement is of special importance for use with single-phase motors, or where two or more motors of any type are driving the same shaft or machine. The motors can be run singly or together as required, and considerable economy is effected by this

The Standard Clutch Pulley, illustrated in Fig. 2, can be fitted with springs if desired. In this form it makes an ideal means.

driving pulley for single-phase and similar motors having low starting torque.

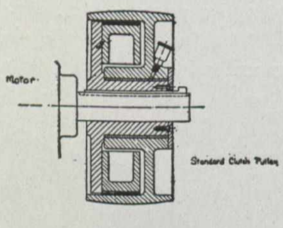

Fig. 2.

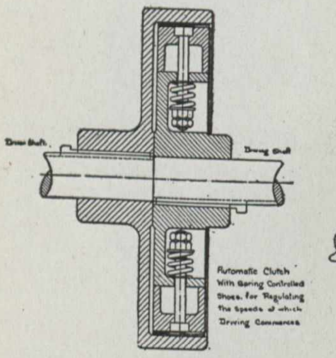

Fig. 3.

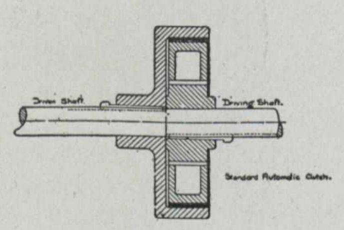

Fig. 4.

The electric capstan is an excellent example of the utility of the clutch, and among other advantages may be enumerated: gradual starting without excessive current, the rate of starting is entirely automatic and independent of the operator, starting current cannot exceed a certain set value, motor cannot be dangerously overloaded.

An entire absence of complicated switch-gear, with its attendant coils, resistances, etc., to give trouble, the switch-gear being of the simplest possible type, i.e., an ironclad quick make and brake main switch operated by a pedal protruding through the capstan lid.

The outer rim of the clutch pulley is utilized for an electric brake, which is applied instantaneously when the switch pedal is released, and the capstan head is brought to a standstill independent of the motor, thus ensuring sensitive control with safety.

The armed boss carrying the slippers is keyed to the motor shaft. Suitable slides are arranged at the bottom of the capstan box to enable the motor to be moved back and the clutch disengaged when required.

This clutch, known as the "Broadbent Automatic Centrifugal Clutch," is the result of considerable experiment on the part of Thos. Broadbent & Sons, of Huddersfield, England, who, when designing their electric hydro-extractors or centrifugals, some ten years ago, were confronted with the problems referred to in the beginning of this article, i.e., how to start and accelerate a load requiring a large starting torque without using special switch-gear, and with a minimum starting current. The clutch is made in sizes from ½ h.p. to 1,500 h.p., and is noteworthy for simplicity of construction, fewness of parts, and adaptability.

EFFICIENT BOILER OPERATION.*

All boiler fittings and accessories in the boiler-house should be maintained in a clean and good condition. Great care should be exercised to see that the safety valves are ample in size and always in good working order. They should be tried at least once every day to see that they act freely and are not overloaded. When the safety valve is blowing off the same pressure should be recorded by the pressure-gauge; if not, one is wrong and the pressure-gauge should be immediately checked with a correct one. With no steam in the boiler the pressure-gauge should register zero.

Carelessness in regard to the water-gauge is the source of many accidents. Besides the annoyance of burst gauge glasses, a faulty water-gauge may place the attendant under continual danger from scalds and flying glass and may be the direct cause of a disastrous explosion. The water-gauge must be kept clean, blown-out frequently, and its passages kept clean. Before starting a fire under a boiler which has stood unused for some time the water-gauge should be tested as to its cleanliness and freedom of the water and steam passages. Water-gauge cocks are so constructed that when necessary a piece of wire may be inserted right through the water-way.

For greater safety there should be two methods of feeding a boiler. The feed pump or injector should be of ample size, and should receive regular and strict attention. The check valves and self-acting feed valves should be frequently examined and cleaned. In case of low water the fire-box doors should be opened, the damper shut down, and the fire immediately covered with ashes (wet if possible), or with any earth that may be convenient. If nothing else is at hand then the fire should be smothered with fresh coal. The feed-water must not be turned on, neither must the engine be started or stopped or the safety valve lifted until the fire is drawn and the boiler has cooled down. The fire should be drawn as soon as it is possible to do so without increasing the heat.

Should foaming occur within the boiler it may be stopped by reducing the outflow of steam; should this fail then the draft and the fires should be kept checked. The fires must be attended to regularly; the coal applied evenly, a little at a time, and not kept too thick. The grate should be evenly covered, no air holes allowed in the fire, and the fire well spread to obtain best results. The dead plate should be kept free from fuel, and the fires should not be cleaned too often.

The heating surfaces of the boiler (outside and in) must be kept clean or there will be a serious waste of fuel. The frequency of the cleaning of the boiler will depend upon the nature of the feed-water and the fuel used. Scale has a serious effect, and in all cases it must be treated as a dangerous enemy. It is difficult to obtain a feed-water which does not contain some proportion of dangerous compounds, either in suspension or in solution; and these not only tend to lower the efficiency of the boiler but form a source of considerable danger. The scale formed within the boiler pre-

* Abstracted from Science and Art of Mining.

vents the heat of the flames and gases being imparted to the water with the result that the boiler plates may become red hot. With feed-water containing salts which are easily soluble scale may be prevented to some extent by frequently blowing off.

Carbonates in the water may be partially removed by boiling, but the more effective method is to treat the feed-water with caustic soda. Sulphates form the most troublesome compounds, and the only really satisfactory method of dealing with such is to pass the feed-water through a water softening plant; though the incrustations may be softened and the removal rendered easier by the addition of carbonate of soda. Accumulated scale should be carefully removed, and any scale chipped off should not be allowed to remain in the boiler.

After a boiler has been cleaned and the brickwork rebuilt, all openings for the admission of air, except through the fire, must be carefully stopped, as this is often a cause of waste.

If a boiler is not required for some time it should be emptied and thoroughly dried; if this is impracticable, it should be filled with water to which has been added a quantity of common soda. Care should be taken if the water is salt or acid in nature that no galvanic action takes place where copper or brass fittings are attached to the boiler. It may be easily prevented by placing metallic zinc or a little lime in the boiler. Particular attention should be observed that the exterior of the boiler is not attacked with.

Should the boiler remain idle in frosty weather the water should be withdrawn and the boiler thoroughly dried. The siphon of the pressure-gauge and the connections of the water-gauge should be drained and examined to make sure that their passages are clear. After the fire has been started under the boiler the steam pressure should not be raised too quickly or the joints and plates will become strained and leakages occur. When the boiler is under pressure the loss of heat by radiation is considerable, and great economy is effected by having the boiler and its connecting steam pipes covered with non-conducting material. The non-conductivity of any material depends largely upon its cellular structure, air—a bad conductor of heat—being confined within the cells of the material. The materials generally used in the manufacture of non-conducting covers are asbestos, magnesia and slag wool. Any substances used to prevent the escape of heat of the steam should be at least one inch thick. Thus, a brief summary of the essentials of a boiler are as follows:

(1) Greatest care and management with regard to firing.

(2) Prevention of overheating of plates due to low water.

(3) Prevention of incrustation, internal and external corrosion.

(4) Good material and construction.

(5) To guard against working a boiler beyond its strength.

Apart from what has been said above, the best measure is to insure the boiler with a reliable insurance firm. The firm will thoroughly inspect the boiler periodicially and report upon its condition and efficiency, calling attention to any defect or source of danger. A responsible man who thoroughly understands his duties should be placed in charge of the boiler and its firing. A good fireman keeps the water-level uniform and maintains a regular feed; keeps the fire in a uniform condition, and avoids sudden and excessive variation of temperatures; suits the air supply to the requirements of the fire; aims at uniform generation of steam to avoid waste by over-pressure, and delay by insufficient pressure.

THE MINERAL PAINT INDUSTRY.

By Dr. F. Mollwo Perkin.*

The production of white lead has been much studied, and several ingenious methods have been suggested. Bleeker Tibbits places lead electrodes in a bath consisting of sodium nitrate and ammonium carbonate or sodium nitrate and ammonium nitrate. Carbon dioxide is blown through the bath, causing the formation of lead carbonate. Ferranti and Noad used lead anodes in a bath of ammonium acetate. Ammonium bicarbonate is fixed with the lead acetate thus formed to produce white lead. Browne and Chaplain electrolyze a solution of 10° Beaumé sodium nitrate in a divided cell. The anodes are of lead and the cathodes of copper. Lead nitrate and caustic soda are formed, and the two solutions are mixed to produce lead hydroxide and sodium nitrate. The lead hydroxide is filtered off and the sodium nitrate returned to the electrolyzer. The hydroxide is then stirred up with a solution of sodium carbonate to produce white lead and sodium hydroxide.

All the processes mentioned above, with the exception of that of Luckow's, require the use of diaphragms, and these are difficult to obtain. Further, secondary reactions take place at the electrodes, white basic lead compounds form at the anode, and these, of course, lessen the yield. Much care and experimenting is, therefore, necessary in carrying out successfully an electrolytic white lead process, if it is to be commercially successful.

Zinc white can be prepared in a somewhat similar manner. A warm solution of sodium sulphate or other alkali salt, the corresponding zinc salt of which is soluble, is electrolyzed. Zinc plates are used as electrodes, and the zinc sulphate formed is precipitated by the sodium hydroxide as zinc hydroxide. Tibbits produced colored white lead by using another metal—as copper—along with the zinc anode. The depth of the color depends on the relative area of the lead-copper anodes. By a similar method chrome yellow can be prepared, using sodium or potassium chromate instead of sodium carbonate.

Browne and Chaplain made lead chromate by first producing lead nitrate or acetate in a diaphragm cell with lead electrodes, and an electrolyte of alkali nitrate or acetate. The caustic alkali produced gradually overflows, and can be continuously collected. In another vessel a solution of chrome alum is treated with caustic alkali. The precipitate is filtered and washed, and then dissolved in excess of caustic alkali. This solution is then electrolyzed, after being mixed with sodium chloride in the anode compartment of a cell, and thus converted into chromate. At the end of the operation the lead solution and the chromate solution are mixed. Potassium or sodium chromate can be produced by electrolyzing in a solution of potassium or sodium hydroxide with anodes of high grade ferro chrome.

To obtain metallic hydroxides a metal anode and carbon cathode is used. In such a case partial disintegration invariably takes place, and particles of the metal fall to the bottom of the electrolyzing cell, thus contaminating the electrolyte; the anode should be wrapped in a piece of cloth or parchment. It is an advantage to keep the solution well agitated by causing the anode or cathode to rotate by blowing air rapidly through the solution.

Metallic sulphides can be obtained in a manner analogous to that in which metallic hydroxides are prepared. Copper

* From abstract of paper read before the Paint and Varnish Institute, in the Electrician.

sulphide is made the cathode in a solution of an alkaline chloride, nitrate or sulphate, and the metal the sulphide of which it is desired to prepare the anode. Copper sulphide is practically the only sulphide that can be used as a cathode, for, unlike most of the others, it is a good conductor. When it is employed in the form of a powder it is packed round a rod of copper and enclosed in a stout linen bag. It should then be electrolyzed for a short time with an insoluble anode, that the outer portions of the cell may become saturated with the alkaline sulphide.

Vermilion can be prepared electrolytically by using circular copper plates in a wooden vessel. Mercury covers the plates to the depth of about 1-cm. The plates are connected to the positive pole of a dynamo, the cathode being a copper plate which has been electrolytically coated with iron. The bath is filled with a solution of 8 per cent. ammonium nitrate and 8 per cent. of sodium nitrate. An iron pipe bored with holes is employed to deliver a constant stream of sulphuretted hydrogen during the electrolysis.

When a highly concentrated solution of ammonium or potassium thiocyanate, rendered slightly acid by the addition of dilute sulphuric acid, is electrolyzed with an insoluble anode, a yellow precipitate known as canamie is produced. The exact formula of this substance is not known, but it is soluble in alkali carbonates and can be used for dyeing silk and wool.

COMING MEETINGS.

CANADIAN SOCIETY OF CIVIL ENGINEERS.—Nov. 9. Monthly Meeting, 413 Dorchester Street West, Montreal. C. H. McLeod, Secretary.

THE AMERICAN ROAD BUILDERS' ASSOCIATION (150 Nassau Street. New York). Nov. 14-17. Annual Convention, Rochester, N.Y.

CANADIAN INDEPENDENT TELEPHONE ASSOCIATION.—Nov. 15. Sixth Annual Convention, Toronto. F. Dagger, Secretary, 21 Richmond Street West, Toronto.

THE CANADIAN PUBLIC HEALTH ASSOCIATION.—Nov. 21-23, Montreal. F. C. Douglas, M.D., D.P.H., Secretary, 51 Park Avenue, Montreal.

AMERICAN ASSOCIATION FOR HIGHWAY IMPROVEMENT.—Nov. 20-24. First Annual Convention, Richmond, Va. Logan Waller Page, President, United States Office of Public Roads, Washington, D.C.

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TORONTO BRANCH—
96 King Street West, Toronto. Chairman, H. E. T. Haultain, Acting Secretary; E. A. James, 57 Adelaide Street East, Toronto. Meets last Thursday of the month at Engineers' Club.

MANITOBA BRANCH—
Secretary E. Brydone Jack. Meets every 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, 319 Pender Street West, Vancouver. Meets in Engineering Department, University.

OTTAWA BRANCH—
Chairman, S. J. Chapleau, Ottawa; Secretary, H. Victor Brayley, N. T. Ry., Cory Bldg.

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