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A BRIDGE REMOVAL was successfully accomplished at Chicago last week to make way for a new bridge and for an improvement of the river. The approach to the Grand Central Station (which is owned by the Chicago Terminal Transfer R. R.) was by a double track drawbridge of 285 ft. span, which crossed the Chicago River just below the Taylor St. bridge. In improving the river to secure the capacity necessary for the flow to the Drainage Canal, it was decided to remove the center piers of the two drawbridges at Taylor St. and the C. T. T. R. R., and to replace the swing bridges by two rolling-lift bascule bridges of the Scherzer type. The railway bridge has therefore been moved 53 ft. north from its old site, and established on a temporary pier for use during the improvement of the river and the erection of the new bridge. Upon the guard pier substantial timber "ways" were constructed, and when the bridge was swung open, parallel with the stream, it was jacked up 26 ins. to allow of a cradle or sliding "ways" being built under it. The weight of the bridge was then transferred to the cradle, and two pile-driver engines then hauled the structure along to its new position, the contact surfaces of the "ways" being well lubricated with tallow. The bridge weighs 600 tons, and was loaded with 10 tons of rails distributed over the floor to prevent vibration and racking strains. The bridge crosses the river at such a skew that it was impossible to use scows to move it. The general arrangement resembles that employed in the removal of the Newark bridge of the Pennsylvania R. R., described in our issue of July 27, except that car trucks running on steel rails were used to carry the Newark bridge. The method of handling the Chicago bridge was planned and executed under the direction of Mr. F. E. Paradis, Chief Engineer of the Chicago Terminal Transfer R. R.

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THE INVENTION OF SKELETON CONSTRUCTION in office buildings is being discussed among architects. The Society of Architectural Iron Manufacturers of New York lately placed a tablet on the Tower Building, 50 Broadway, New York, calling it the "earliest example" of what is now termed skeleton construction. Chicago architects object to this statement and claim the honor for Mr. W. L. B. Jenny, of Jenny & Mundie, of that city. They say that the first building of this type was the Home Insurance Building, of Chicago, erected in 1883-'84. Mr. Bradford L. Gilbert, the architect of the Tower Building, denies this claim, and says that the Chicago building was of the "cage construction" type, with the ironwork bearing the weight of the floors alone; while in "skeleton construction" the frame carries the weight of the walls and the floors to the foundation. The site of the Tower Building called out the design, says Mr. Gilbert, as it had a frontage of only 21 ft. 6 ins., and the building laws require a certain thickness of wall proportioned to the height of the building, that, in this case, would have left little room inside the structure. This building was completed in 1888-'89. Previous to 1883 Mr. Geo. B. Post, of New York, had used cast-iron columns to support the walls of the inner court of the Equitable Life Building in New York. Mr. Wm. H. Birkmire, architect and engineer, the author of a work on "Skeleton Construction," published in 1893, supports the Chicago architects, and claims that he worked up the plans for the iron construction of the Tower Building, as engineer of the Jackson Architectural Iron Works, which obtained the contract for erecting this building. This Mr. Gilbert denies

THE THIRD MISSISSIPPI RIVER BRIDGE at St. Louis is being considered by a board of U.S. Engineer officers, including Majors W. L. Marshall and W. H. Bixby, and Capt. Edward Burr, Engineer Corps, U. S. A. The point at issue between the War Department and the bridge company is the length of the river spans. The site, at the foot of Mullanphy St., was fixed some time ago by another board; but it was then recommended that the west span be made 700 ft. long instead of 500 ft. as shown on the plans. The company held that the added 200 ft. "would kill the project," on account of cost; that 550 ft. was the limit of "fixed spans" and that 700 ft. would demand a cantilever structure at an added cost of $165,000. The board is now hearing testimony from those interested. Mr. A. J. Tullock is the Chief Engineer of the East St. Louis and St. Louis Bridge & Construction Co., which has this bridge project in hand. The Merchants' Bridge at St. Louis has spans of 506 ft., and the old Eads Bridge spans are 515 ft.

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THE OLD WOODEN BRIDGE over the Wabash River, at Clinton, Ind., is to be replaced by a modern iron structure. This bridge was 600 ft. long and was built over 50 years ago. The old bridge was destroyed by burning it on Aug. 18.

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THE MOST SERIOUS RAILWAY ACCIDENT of the week was a locomotive boiler explosion on the Mexican Central Ry., at Cardenas, Mex., on Aug. 11, in which seven men were killed and three fatally injured. Four of the former and one of the latter were American engine drivers. The engine was of a special pattern designed for the heavy grades on this road.

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IN AN EXPLOSION at the Llest Colliery, in Glamorganshire, Wales, on Aug. 18, 25 persons were killed and many injured.

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THE COLLAPSE OF A CHICAGO DRAWBRIDGE occurred Aug. 17, but fortunately without causing any loss of life. The Chicago highway drawbridges have long been notorious for their dilapidated and disreputable condition. On Aug. 17, the drawbridges over the Calumet River at 95th St. broke in two when swung open, and both ends fell into the river. The report of the City Bridge Engineer, Mr. Wilmann, to the City Engineer, Mr. Ericson, describes the condition of the wreck as follows:

> The structure is a total wreck, and is beyond repairing. The west truss is broken in the center, both top and bottom chord completely severed. The bottom chord is again broken 30 ft. from the south end of the truss. The east truss, top chord, is severed some 30 or 40 ft. north of the center of the span, and the bottom chord is badly twisted and broken. A number of the pieces forming the lateral bracing for the top chord have fallen on the floor of the bridge. The floor is badly broken and displaced in several places. The channel of the river is not obstructed.

As a result of this accident, the City Engineer has closed the Weed St. bridge and the North Halsted St. bridge to traffic, and has declared seven other bridges dangerous (Clybourne Place, Northwestern Ave., 22d St., Archer Ave., Southwestern Ave., Randolph St. and Polk St.). The Chicago Ave., Division St. and North Ave. bridges are also in bad condition, but can be used for a time. The Commissioner of Public Works will probably have some of these bridges closed, as he is not willing to accept the responsibility for what may be a terrible accident. We have referred to this accident in our editorial columns.

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A "GANG-PLANK DISASTER" somewhat similar to the one at Bar Harbor, which resulted so seriously, occurred some time ago at Minneapolis, Minn., according to a letter sent us by Mr. E. T. Abbott, C. E., of that city. There was to be a bicycle parade at Lake Harriet; and to enable people to cross the bicycle track a temporary bridge was erected with stairways at both ends. This bridge had a span of 30 ft., and was 8 or 10 ft. wide. But, instead of using this bridge for a crossing only, the discovery was made that it was one of the best places from which to view the races, and it was promptly crowded from end to end with spectators, including women and children. The structure collapsed and precipitated the crowd 12 ft. to the ground below. No one was killed, but many were injured, and the bicycle companies who had caused the bridge to be erected had to pay several thousand dollars damages in personal injury suits. After the accident Mr. Abbott was called in to examine the plans, and he found that even with the best material—which was not used—the structure would fail with a load of not over 60 lbs. per sq. ft. of roadway. The bridge cost $125, and could have been made safe by the expenditure of about $30 more. It was a case where the possible crowding should have been foreseen and provided for; and the failure to have the plans first examined by an engineering expert cost the builders—in damages—many times the price of the original structure. It is worthy of note that the contractors who erected the stand freed themselves from legal responsibility by showing that the bridge was only to be used as a bridge to cross the tracks, and not for a "grand stand."

A TEST OF BRAKES for street surface railroad cars has been arranged for by the Board of Railroad Commissioners of the state of New York. Twenty-two permits have been issued for that purpose, and each person or company receiving a permit is allowed to equip with brakes one of the cars of the Metropolitan Street Railway Company, and the tests will be made, three or four on one day, at Lenox Ave. and 146th St., New York city. The first series of tests will take place on Tuesday, Aug. 29, and Wednesday, Aug. 30, between the hours of 9 a. m. and 5 p. m. On these days from five to seven brakes will be tested. Notice of the dates of the tests to follow will be given. The secretary of the board is Mr. John S. Kenyon, Albany, N. Y.

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THE MADRAS ELECTRIC TRAMWAY, says "The Indian and Eastern Engineer," now operates three miles of double track and 4⅓ miles of single track, with 2⅔ miles of new single track to be opened to traffic in a few months. The girder rails weigh 60 lbs. per yard, and are laid on wooden sleepers with concrete filled in between them to the level of the rail. The gage is 1 meter and the overhead trolley system is adopted. In the power-house are four Babcock & Wilcox boilers of 106 HP. each, with two Worthington pumps for feeders. The two 200-HP. horizontal compound non-condensing engines are made by the Burnley Iron Works Co. of England. The plant includes 26 motor cars with a 10-minute service, and 428 employes, of all grades; of the latter 55 are conductors and 63 "drivers." The fare is 6 "pies," or 1½ U. S. cents, for the first mile and 3 pies, or ¾-ct., for each succeeding mile. The plant was furnished by the Electric Construction Co., of Wolverhampton, England.

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THE RAILWAYS OF INDIA aggregated 26,060 miles open and authorized, and 22,491 miles in operation on March 31, 1899. Of the grand total, 14,300 miles had the Indian standard gage of 5 ft. 6 ins., 11,000 miles were of meter gage, and the balance had various special gages. The standard and meter gage lines had 4,315 locomotives, 12,814 passenger cars, 80,708 freight cars, and 97,254 cars of all kinds. About 1,140 of these engines and 6,514 cars were fitted with the automatic vacuum brake, while 600 cars were piped, but not fitted with brakes. The passengers carried during the year 1898 on the two principal gages, numbered 150,374,114, of which about 140,000,000 were fourth-class passengers. The freight carried aggregated 36,121,835 tons. The number of passenger-miles was 5,801,375,000; and the ton-miles numbered 5,727,878,000. There were 308,600 employees, of whom only 4,967 were Europeans, and 6,936 East Indians, while the native employees numbered 296,700. There were 3,114 stations open. The various accidents resulted in the killing of 69 passengers, 197 employees and 553 other persons (including trespassers and suicides), or 819 in all; the persons injured in these three classes were 254, 371 and 174, respectively, or 799 in all. The total coal production in 1898, was 4,568,880 tons.

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THE LA BELLA MILL, WATER & POWER CO., in the Cripple Creek region of Colorado, formally opened its new power plant on Aug. 19. This plant is designed to furnish electric power for running the Florence & Cripple Creek, and the Golden Circle railways, described in Engineering News of Sept. 8, 1898, and also to operate hoists, pumps, compressors, etc., in mines throughout the district. The plant includes six Babcock & Wilcox boilers, with automatic stokers, capable of supplying steam to engines aggregating 3,000 HP. under normal conditions. The engine-room is 110 × 45 ft. and contains an Ingersoll-Sargent air-compressor, run by an Allis-Corliss engine, which has a capacity of 5,000 cu. ft. of free air per minute, or enough to ordinarily operate 50 drills, or 35 drills at this altitude of 10,000 ft. The engines coupled to the electric generators are of the horizontal condensing type, with a normal capacity of 750 HP. each. The generators are General Electric three-phase alternators. As water is valuable, the water is used over and over again by the condensing machinery, and is cooled between each successive use by pumping it to a cooling-tower, 40 ft. above the engine-floor and allowing it to fall by gravity in contact with the air. The La Bella plant is intended to represent the most advanced state of power-house design. The Engineer of the plant was Mr. L. L. Summers, 824 Equitable Building, Denver, Colo.

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THE GREAT FALLS POWER CO., of Washington, D. C., is asking proposals for building a dam across the Potomac, at the Great Falls, and a canal to convey the water to a power house some distance below the dam. This company is controlled by the Washington Traction & Power Co. The proposed dam would be located below the present government dam at this point, but no estimate is published of the power to be developed, and the information as to the engineering features of the work are very vague, as published in the Washington "Star."

TWO UNUSUAL INSTANCES OF RAILWAY TRACK DISPLACED BY OCEAN WAVES.

Two rather unusual instances of how the forces of nature sometimes contribute to vary the monotony of the maintenance of way engineer's work are shown in the accompanying cuts. Both of these occurred during the heavy storms, which many of our readers will remember swept the New England coasts early this year, and in both cases old ocean was the agent which upset the established order of things as it was laid down by the man of transit and level. The latter, however, has this comfort, that while, as will be seen, his structures gave way to superior forces, they preserved their identity, and to a large extent their integrity for future usefulness, and this is not always the case where man and his works attempt to cope with the powers of the sea.

FIG. 1.—VIEW SHOWING SECTION OF RAILWAY TRACK DISPLACED BY OCEAN WAVES; NEW YORK, NEW HAVEN & HARTFORD R. R.

Turning to the illustrations, the engraving from the photograph, Fig. 1, shows a section of track on the Nantucket Branch of the New York, New Haven & Hartford R. R., about one mile south of Pemberton, which is about 20 miles by rail from Boston, Mass. As Pemberton was the meeting place of the American Society of Civil Engineers a few years ago many of our readers will doubtless recall the locality. It will be observed that one track is in its original position, while the other has been lifted and thrown over against the trolley poles, which it indented about 1½-in. Just beyond where the men stand the track was completely torn to pieces for a short distance. The rails weigh about 74 lbs. per yard. The comparatively light shelter for passengers near the middle of the view was only slightly damaged, and that by wind. It will be noticed that only one trolley pole in the view is out of plumb, these poles being set in a block of concrete perhaps 3 ft. in diameter. About one-fourth mile north of this point is the location of the new fort being built to protect the harbor, and about opposite the fort a three-masted schooner, carrying a cargo of 20,000 ft. of timber, was washed up onto the railway company's right of way. The schooner and lumber were only slightly damaged, as far as a casual inspection could determine. On the beach at Pemberton two barges and a four-masted schooner, all full of coal, went to pieces during the same storm.

Fig. 2.—Sketch Showing Displacement of Track by Ocean Waves on the Old Colony R. R.

The line sketch shows a different, and, in some respects, a more curious accident of the same nature as the one just described. In this instance the track was a part of the South Shore Line of the Old Colony R. R., and was located on an embankment crossing a swamp or flat, Fig. 2, only a few feet above low tide. The waves swept the track inland in the direction shown by the arrows, bending over and stripping the cross-arms off the telegraph poles but not breaking the poles themselves. A considerable length of track practically intact was carried some distance away from its original position in this case.

For the information from which this note of the somewhat curious phenomena illustrated has been prepared, we are indebted to Mr. N. K. Higgins, Assistant Engineer, New York, New Haven & Hartford R. R., Boston, Mass.

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THEORY AND CALCULATION OF THE TWO-HINGED ARCH.

By Alex. Rice McKim,[*] M. Am. Soc. C. E.

PART I.—THEORY.

An arch differs from other structures in that vertical loads produce inward horizontal reactions as well as vertical reactions. As there can be no moment at a hinge, the points of application of the reactions are fixed by the two hinges, which are at the supports. With given loads and unknown reactions there are, therefore, four unknown quantities as regards the forces, the two components of the reaction at each hinge. In order to determine these four unknown quantities four equations of condition are necessary. The equilibrium of the arch gives us three equations; namely, the sum of all the horizontal components of the loads and reactions must equal zero, the sum of all the vertical components of the loads and reactions must equal zero, and the sum of the moments of the loads and reactions about any point must equal zero. These three equations are not sufficient to determine the four unknown quantities, and the system is statically undetermined as regards the outer forces. The fourth equation is obtained by considering the elasticity of the material of the structure.

There are three methods in use by which the elasticity of the structure is employed in the calculations. 1st, Maxwell's, which is a graphical method, and considers the elasticity of each piece successively. This method is used by American engineers, and is briefly treated in Prof. Greene's "Graphical Statics." 2d, Weyrauch's, which makes use of the neutral axis and the moment of inertia of the cross-sections. This method was very fully treated by Prof. Mueller-Breslau, and recently in English by Prof. Howe, by Prof. Lanza and by Prof. Jacoby. 3d, Mohr's, as developed by Dr. Winkler, and which method will be followed in this article. The third method is the best for framed structures, and the second for arched ribs.

Consider the structure (Fig. 1) as without loads and without weight, free to move without friction at the right-hand support, and fixed in position at the left-hand support. If a horizontal outward unit force be placed at the right support, there will be an equal outward reaction at the left support and certain stresses in the pieces, which stresses we will designate by h for any piece.

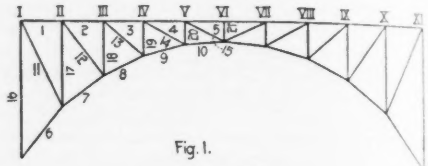

Fig. 1.

Now consider the structure as before, but without the horizontal force. At any joint, as III, place a vertical load P, and call its distance from the left support a, and from the right support b. The vertical reactions for the left and right supports will be, respectively,

$$P \frac{b}{L} \quad \text{and} \quad P \frac{a}{L}, \tag{1}$$

where L is the span or distance between hinges. This force will produce certain stresses in the pieces, which we will designate as V for any piece. The length of the span would, however, be increased somewhat by the action of these stresses. The change in span we will designate by $\triangle$ L. Now place an inward horizontal force H at the right support, just sufficient to diminish the span to its length L before P was applied. The stress in any piece would then be

$$S = V - h\,H. \tag{2}$$

and

$$\frac{d\,S}{d\,H} = -\,h. \tag{3}$$

From the theory of elasticity we have for the external work upon a homogeneous bar of constant cross-section A for a gradually applied load s,

$$= \frac{s^2\,l}{2\,E\,A},$$

and for the system

$$W = \Sigma \frac{s^2\,l}{2\,E\,A}. \tag{4}$$

Also, if W represents the work due to the change of form of a framed structure in equilibrium under the action of forces applied at its joints and expressed as a function of these forces, and if the point of application of one of these forces P moves by the action of the forces a distance p relative to the line of direction of P, then,

$$p = \frac{d\,W}{d\,P}. \tag{5}$$

From equation (5) we have

$$-\triangle\,L = \frac{d\,W}{d\,H};$$

therefore

$$\frac{d\,W}{d\,H} = \Sigma \frac{s\,l}{E\,A} \frac{d\,s}{d\,H},$$

which, with (2) and (3), gives

$$-\triangle\,L = -\,\Sigma \frac{s\,l\,h}{E\,A},$$

or

$$\triangle\,L = \Sigma \frac{V\,l\,h}{E A} - \Sigma \frac{l\,h^2\,H}{E A},$$

which solving for H gives

$$H = \frac{\Sigma \dfrac{V\,l\,H}{E A} - \Sigma \triangle\,L}{\Sigma \dfrac{h^2\,l}{A}}.$$

If the horizontal reaction is resisted by a tie-rod, as is often the case with roof trusses, the relative displacement of the hinges $\triangle$ L is equal to the

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[*] 106 East 23d St., New York city.

strain on the tie-rod. If, however, the supports are fixed, $\triangle$ L will equal zero, and

$$H = \frac{\Sigma \frac{V\,l\,h}{E\,A}}{\Sigma \frac{h^2\,l}{A}}. \qquad (6)$$

Again, assume the system to be without forces or weight, and free to move without friction at one support and fixed in position at the other support.

If all the pieces are subjected to a change in temperature, the length of the span will change. In order to bring the span back to its initial length, a force T would have to be applied at the movable support, an inward force for a rise of temperature, and an outward force for a fall of temperature. These forces would produce opposite stresses, in the two cases. If all the bars changed t degrees, and if e represent the coefficient of expansion, then the change in span would be e t L. Taking the same steps as before we have

$$-e\,t\,L = \frac{d\,W}{d\,T}, \qquad s = \pm\,h\,T, \qquad \frac{d\,s}{d\,T} = \pm\,h.$$

$$W = \Sigma \frac{s^2\,l}{2\,E\,A}, \qquad d\,W = \Sigma \frac{s\,l}{E\,A} \cdot \frac{d\,s}{d\,T}$$

and

$$T = \pm \frac{E\,e\,t\,L}{\Sigma \frac{h^2\,l}{A}}. \qquad (7)$$

Formulas (6) and (7) can be simplified somewhat. Take the left-hand hinge as the origin of rectangular axes, and let the axis of X pass through the right hinge. Let x and y be the coordinates of the Moment Point of any piece, r the perpendicular distance of the Moment Point from the line of direction of its piece, M' the moment of the forces about any Moment Point, and m the moment about the same Moment Point, neglecting the horizontal reactions, or considering the forces as acting on a simple beam. The Moment Point for any piece is the point about which, in the Method of Sections, the moment is taken to determine the stress of the piece, and the section taken is the Moment Section. Then,

$$s = \frac{M'}{r} \quad \text{and} \quad M' = m - H\,y;$$

or,

$$s = \left[\frac{m}{r} - H\,\frac{y}{r}\right].$$

Comparing this with (5) we obtain

$$V = \frac{m}{r} \quad \text{and} \quad h = \frac{y}{r}.$$

Substituting these values in (6) and (7) we obtain,

$$H = \frac{\Sigma\, m \frac{y\,l}{r^2\,A}}{\Sigma \frac{y^2\,l}{r^2\,A}}, \qquad (8)$$

$$T = \frac{E\,e\,t\,L}{\Sigma \frac{y^2\,l}{r^2\,A}}. \qquad (9)$$

If we substitute for m in equation (8) the values of equations (1) for the horizontal reaction, with a load P at distances a from the left support, and b from the right support,

$$H = \frac{P\left\{\frac{b}{L}\,\Sigma \frac{y}{r^2}\,\frac{l}{A}\,x + \frac{a}{L}\,\Sigma \frac{y\,l}{r^2\,A}\,x'\right\}}{\Sigma \frac{y^2\,l}{r^2\,A}} \qquad (10)$$

Where the summation of the first term in the brackets of the numerator is for pieces to the left of the load P, x being the distance of each Moment Point from the left support, and where the summation of the second term is for pieces to the right of the load, x' being the distance of each Moment Point from the right support.

Multiplying the quantity

$$\frac{y\,l}{r^2\,A}$$

for each piece by the unit force, and considering the products as vertical forces, each acting at its respective Moment Point on a simple beam of span L, the moment of these forces about any point, at a distance a from the left support, and at a distance b from the right support, will be equal to

$$M = \frac{b}{L}\,\Sigma \frac{y\,l}{r^2\,A}\,x - \frac{a}{L}\,\Sigma \frac{y\,l}{r^2\,A}\,x' \qquad (11)$$

As this is the equivalent of the quantity in the brackets of the numerator of equation (10), we can, therefore, express the latter as

$$H = P\,\frac{M}{\Sigma \frac{y^2\,l}{r^2\,A}}.$$

If P is equal to the unit force, we have

$$H = \frac{M}{\Sigma \frac{y^2\,l}{r^2\,A}}. \qquad (12)$$

This, however, applies only to such pieces as are on the same side of the load as its Moment Point, which is the case only with the chords. The web members can be taken account of in two ways. The force

$$\frac{y\,l}{r^2\,A}\,1$$

can be put in the summation (11) for the opposite side from the piece, and x taken as L — x. Or the force can be replaced by two equivalent vertical forces at the bays of the joints on each side of the intersection of the Moment Section with the lower chord. For instance, with the Moment Point on the right of the piece, if c represent the horizontal distance between the joints at which the forces are to be placed, and d the distance from the right-hand joint to the Moment Point, then the force for the left-hand joint would be

$$+\frac{d}{c}\,\frac{y\,l}{r^2\,A}\,1. \qquad (13)$$

and for the right-hand joint

$$-\frac{d+c}{c}\,\frac{y\,l}{r^2\,A}\,1. \qquad (14)$$

In order to determine the stress in any piece we take moments about the Moment Point of all the forces acting on one side of the Moment section. And in order to better study the effect on any piece of any loading which we might have, we first take a unit force and place it successively at each joint and determine its effect upon the piece. There are three actions working upon the piece, which have to be determined. The action on the piece of the vertical loads and their vertical reactions, the action of that part of the horizontal reaction produced by the vertical loads, and the action of the horizontal reaction produced by changes of temperature. The first two actions produce opposite effects in the piece, while the third may produce either a tensile or a compressive stress for the same piece, the one for a rise and the other for a fall in temperature. For the stress in the upper chord and verticals we have

$$s = \frac{-m + H\,y \pm T\,y}{r} = \frac{y}{r}\left[H - \frac{m}{y} \pm T\right] \qquad (15)$$

and for the lower chord and diagonals

$$s = \frac{m - H\,y \pm T\,y}{r} = \frac{y}{r}\left[\frac{m}{y} - H \pm T\right]. \qquad (16)$$

PART II.—CALCULATION.

I. Conditions.—Suppose we have a truss similar to Fig. 1, of 200-ft. span, divided into 10 panels of 20 ft. each, with the upper chord horizontal and the joints of the lower chord lying in a parabola, hinged at the two supports, an end height of 100 ft., and a center height of 10 ft. The bents are marked with Roman numerals, and the pieces with Arabic. The truss is to sustain a live load of 6,000 lbs. per running foot, besides the dead load, which will be assumed at 40 tons per panel. The allowable stresses in pounds per square inch are: for compression,

$$\frac{9{,}000}{1 + \frac{l^2}{30{,}000\,R^2}}$$

for live load and 16,000 for dead; and for tension, 10,000 for live load and 20,000 for dead load. The temperature stresses are to be added to the dead load stresses, and 80% of the reverse stresses are to be added to the live load stresses in getting the sections. The Modulus of Elasticity will be taken at 2,088,000 tons per square foot, and the Coefficient of Expansion as

$$\frac{1}{150{,}000}$$

of the length per degree of temperature Fahrenheit.

2. Preliminary Calculations.—For each piece calculate the length l, the vertical distance y of its Moment Point above the supports, and the perpendicular distance r of the Moment Point from the line of direction of the piece. For the upper chord pieces the Moment Points would be at the joints of the lower chord; for the lower chord they would be at the joints of the upper chord, and for the diagonals and verticals they would be at the points where the line of direction of the lower

TABLE I.

Piece.	2. l	3. y	4. r	5. $\frac{y}{r}$	6. $\frac{y^2\,l}{r^2}$	7. $\frac{y^2\,l}{r^2}$	8. $-\frac{y\,l}{r^2}$	9. $+\frac{y\,l}{r^2}$
1	20.00	32.40	67.60	0.48	4.60	1.42 II.	...	...
2	20.00	57.60	42.40	1.36	36.91	0.64 III.	...	...
3	20.00	75.60	24.40	3.10	192.00	2.54 IV.	...	...
4	20.00	86.40	13.60	6.32	807.20	9.34 V.	...	...
5	20.00	90.00	10.00	9.00	160.00	18.00 VI.	...	...
6	38.07	100.00	52.54	1.90	137.94	1.38 I.	...	...
7	32.17	100.00	42.03	2.38	182.13	1.82 II.	...	...
8	26.90	100.00	31.52	3.17	270.68	2.70 III.	...	...
9	22.73	100.00	21.47	4.66	493.12	4.93 IV.	...	...
10	20.32	100.00	13.39	7.47	1,314	11.34 V.	...	...
11	70.50	100.00	59.19	1.69	201.23	2.01	6.21 II.	4.20 I.
12	46.88	100.00	48.52	2.06	199.10	2.00	5.34 III.	3.35 II.
13	31.55	100.00	36.44	2.74	237.67	2.38	5.60 IV.	3.22 III.
14	24.18	100.00	25.41	3.93	374.37	3.74	8.46 V.	0.47 IV.
15	22.36	100.00	33.80	2.96	195.83	1.96	7.40 VI.	5.44 V.
16	100.00	100.00	61.73	1.62	.....	....	...	...
17	67,60	100.00	53.65	1.86	234.85	2.35	7.29 II.	0.49 I.
18	42.40	100.00	47.11	2.12	191.04	1.91	5.12 III.	3.21 II.
19	24.40	100.00	45.19	2.21	119.51	1.19	2.81 IV.	1.62 III.
20	13.60	100.00	75.56	1.32	23.82	0.24	5.38 V.	3.00 IV.

TABLE II.

		II.	III.	IV.	V.	VI.	VII.	VIII.	XI.	X.
1	—	0.549	0.488	0.427	0.366	0.305	0.244	0.183	0.122	0.061
2	—	0.280	0.560	0.490	0.420	0.350	0.280	0.210	0.140	0.070
3	—	0.186	0.373	0.560	0.480	0.400	0.320	0.240	0.160	0.080
4	—	0.135	0.270	0.405	0.540	0.450	0.360	0.270	0.180	0.090
5	—	0.111	0.222	0.333	0.444	0.555	0.444	0.333	0.222	0.111
6	+	0.180	0.160	0.140	0.120	0.100	0.080	0.060	0.040	0.020
7	+	0.160	0.320	0.280	0.240	0.200	0.160	0.120	0.080	0.040
8	+	0.140	0.280	0.420	0.360	0.300	0.240	0 180	0.120	0.060
9	+	0.120	0.240	0.360	0.480	0.400	0.320	0.240	0.160	0.080
10	+	0.100	0.200	0.300	0.400	0.500	0.400	0.300	0.200	0.100
11	+	0.555	0.494	0.432	0.370	0.308	0.246	0.184	0.123	0.061
12	+	0.126	0.589	0.515	0.441	0.368	0.294	0.220	0.147	0.73
13	+	0.112	0.224	0.609	0.522	0.435	0.348	0.261	0.174	0.087
14	+	0.095	0.190	0.285	0.630	0.525	0.420	0.315	0.210	0.105
15	+	0.044	0.089	0.133	0.178	0.777	0.622	0.446	0.310	0.155
16	—	0.555	0.494	0.432	0.370	0.308	0.246	0.184	0.123	0.061
17	—	0.662	0.589	0.515	0.441	0.368	0.294	0.220	0.147	0.073
18	—	0.112	0.696	0.609	0.522	0.435	0.348	0.261	0.174	0.087
19	—	0.095	0.190	0.735	0.630	0.525	0.420	0.315	0.210	0.105
20	—	0.044	0.089	0.133	0.930	0.777	0.622	0.466	0.310	0.155

TABLE III.

1 Piece.	2 Dead.	3 Maximum live.	4 Minimum live.	5 Temperature, ±.	6 Reverse.	7 Gr. area, sq. ft.	8 $\frac{y^2\,l}{r^2\,A}$	9 $\frac{y\,l}{r^2\,A}$	10 $-\frac{y\,l}{r^2\,A}$	11 $+\frac{y\,l}{r^2\,A}$
1	— 6.48	+ 14.72	— 24.44	2.71	+ 11.00	0.075	61.3	1.89 II.	.....	.....
2	— 21.30	+ 29.71	— 61.54	7.68	+ 16.085	0.197	187.4	3.25 III.	.....	.....
3	— 48.46	+ 39.60	— 112.29	17.51	+ 8.654	0.304	631.6	8.35 IV.	.....	.....
4	— 74.20	+ 36.21	— 147.51	35.89	.....	0.510	1,582.7	18.32 V.	.....	.....
5	— 132.16	0.00	— 198.18	50.85	.....	0.580	2,793.1	31.03 VI.	.....	.....
6	— 114.81	+ 8.56	— 180.80	10.75	.....	0.578	238.7	2.39 I.	.....	.....
7	— 86.42	+ 9.70	— 139.34	13.44	.....	0.403	452.0	4.52 II.	.....	.....
8	— 39.08	+ 4.30	— 101.63	17.92	.....	0.260	1,041.1	10.41 III.	.....	.....
9	— 1.49	+ 57.29	— 59.54	26.32	+ 82.12	0.258	1,911.3	19.11 IV.	.....	.....
10	+ 27.49	+ 53.79	— 12.55	42.21	— 27.27	0.173	6,555.2	65.55 V.	.....	.....
11	+ 24.67	+ 87.89	— 50.89	9.54	— 35.77	0.217	927.4	.....	28.62 II.	19.35 I.
12	+ 30.16	+ 83.61	— 38.45	11.64	— 20.94	0.182	1,076.2	.....	28.87 III.	18.11 II.
13	+ 39.96	+ 80.53	— 16.35	15.51	.....	0.154	1,543.3	.....	36.35 IV.	20.92 III.
14	+ 57.76	+ 97.03	— 10.39	22.23	.....	0.153	2,446.9	.....	55.28 V.	30.81 IV.
15	+ 42.73	+ 161.93	— 97.84	16.72	— 71.82	0.355	551.6	.....	20.84 VI.	15.32 V.
16	— 43.65	+ 48.79	— 117.51	9.15	+ 14.15	0.413	.....	.....	.....	.....
17	— 64.19	+ 34.78	— 131.07	10.53	.....	0.382	614.8	.....	18.97 II.	12.83 I.
18	— 70.98	+ 15.92	— 122.39	11.99	.....	0.361	529.2	.....	14.20 III.	8.90 II.
19	— 72.32	+ 3.59	— 112.07	12.50	.....	0.340	351.5	.....	8.28 IV.	4.76 III.
20	— 58.92	+ 27.63	— 116.02	7.48	.....	0.328	726.3	.....	16.41 V.	9.14 IV.

chord pieces intersect the upper chord. For each piece obtain the quantities

$$\frac{y}{r},\ \frac{y^2\,l}{r^2}\ \text{and}\ \frac{y\,l}{r^2}.$$

Multiply each of the last by the unit force and consider them as vertical forces acting at their respective Moment Points. As there are forces between the Moment Point and Moment Sections of the web members, their forces are to be replaced by the two equivalent forces,

$$\frac{d}{c}\ \frac{y\,l}{r^2}\ \ (13)\quad\text{and}\quad -\frac{d+e}{c}\ \frac{y\,l}{r^2}\ \ (14),$$

acting at the upper chord joints on either side of the Moment Section, the former at the joint further from the Moment Point, and the latter at the nearer joint. In above equations c is the panel length, and d the horizontal distance of the nearer joint from the Moment Point. These quantities are all given in Table I., and also the joints at which the forces act.

3. Values of $\frac{m}{y}$.—Obtain for each piece for every bay from II. to X. the stress $\frac{m}{y}$, where m is the moment neglecting the horizontal reaction about the Moment Point of the piece with a unit load at the bay in question, and y is the vertical distance of the Moment Point above the supports,

These stresses can best be represented by ordinates of an Influence Curve. In Fig. 2 let A B represent the span, C the Moment Section, and D the Moment Point of any piece distant a from A and b from B. Draw A E and B G perpendicular to A B, and make A E equal to $\frac{a}{y}$ 1 and B G equal to $\frac{b}{y}$ 1. Draw A G and B E, and they will intersect at F, on the ordinate from D. For any bay at the left of the Moment Section C, the stress $\frac{m}{y}$ will be equal to its ordinate from A B to A G, and for any bay at the right of the Moment Section C the stress $\frac{m}{y}$ will be equal to its ordinate from A B to B E. Table II. contains these ordinates from each bay for every piece, the sign placed after the number representing the piece indicates the character of the stresses in the line, + for tensile and — for compressive.

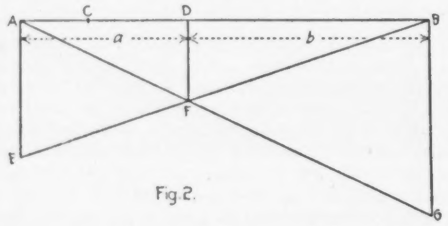

Fig. 2.

4. First Estimate.—Horizontal Reactions.—In this paragraph we will neglect the web members and consider only the sections of the chord members. We will consider the chords as having the same uniform section throughout, which section we will take as that required for the piece of the upper chord whose stress is nearest the average stress of both chords. This piece will contain a point which is at a distance from the supports equal to the square of the span divided by the three-halves power of the difference between the end and middle vertical pieces. For the truss under consideration it would be piece 3.

In formula (10) for a uniform section the area A would cancel out, and for a load P = 1, we would have for the expression of the horizontal reaction for a unit load at a point distant a from the left support and b from the right support,

$$H=\frac{\frac{b}{L}\,\Sigma\,\frac{y\,l}{r^2}\,x-\frac{a}{L}\,\Sigma\,\frac{y\,l}{r^2}\,x'}{\Sigma.\,\frac{y^2\,l}{r^2}}.\qquad(17)$$

where the numerator is the moment of the first 10 quantities taken on both sides in column 7 of Table I., each multiplied by the unit force, and considered as a vertical load acting at its Moment Point, and the denominator is twice the sum of the first 10 quantities of column 6 of Table I. The forces of the numerator are: for bays II and X 1.963 each, for III and IX 3.348 each, for IV and VIII 7.471 each, for V and VII 20.682 each, and for VI 36. The moments for these forces in foot-tons will be: for II and X 1098.28, for III and IX 2019.30, for IV and VIII 2942.36, for V and VII 3716.00, and for VI 4076.00. These moments, divided by 9757.148, or twice the sum of the first ten quantities of column 6 of Table I, will give a horizontal reaction for a unit of load at II or X of 0.105, at III or IX of 0.207, at IV or VIII of 0.302, at V or VII of 0.381, and at VI of 0.418.

5. Chord Stresses.—These are obtained by means of formula (15),

$$s=\frac{y}{r}\left[H-\frac{m}{y}\pm T\right]$$

for the upper chord and formula (16),

$$s=\frac{y}{r}\left[\frac{m}{y}-H\pm T\right]$$

for the lower chord.

The factor $\frac{y}{r}$ for each piece is found in Table I., Column 5; the horizontal reactions for a unit load at any bay is found in the preceding paragraph; the values of $\frac{m}{y}$ for every piece with a unit load at each bay is found in Table II.; and the horizontal reaction T, due to the greatest assumed change in temperature, can be obtained from paragraph 6. As according to the conditions in paragraph 1, we must calculate the dead, live and temperature stresses separately, we will separate the terms in the above expression. We will then have for the dead stress in any piece in the upper chord,

$$40\,\frac{y}{r}\left[H-\frac{m}{y}\right].$$

For the maximum live stress,

$$60\,\frac{y}{r}\ (\text{summation of}\ \left[H-\frac{m}{y}\right]\ \text{for positive values}).$$

For the minimum live stress,

$$60\,\frac{y}{r}\ (\text{summation of}\ \left[H-\frac{m}{y}\right]\ \text{for negative values}).$$

And for the temperature stress,

$$\pm\frac{y}{r}\,T.$$

The terms maximum and minimum are used algebraically. By changing the signs the above apply to the lower chord pieces. Table III gives these results in columns 2, 3, 4, 5, and 6.

Taking the algebraic sum of the first two quantities within the brackets for each bay for the piece 1, gives for a unit load at II the value 0.044, at III 0.085, at IV 0.119, at V 0.137, at VI 0.113, at VII 0.15, at VIII — 0.125, at IX — 0.281, at X — 0.444. Adding the positive and the negative values gives for piece 1, + 0.513 and — 0.850. In the same way we obtain for piece 2, + 0.363 and — 0.755; for piece 3, + 0.213 and — 0.604; for piece 4, + 0.095 and — 0.387; for piece 5, — 0.367; for piece 6, + 0.075 and — 1.583; for piece 7, + 0.068 and — 0.976; for piece 8, + 0.226 and — 0.534; for piece 9, + 0.205 and — 0.213; and for piece 10, + 0.120 and — 0.028.

6. Temperature.—By formula (9) we have

$$T=\pm\frac{E.e.t.L}{\Sigma\,\frac{y^2\,l}{r^2\,A}}=\pm\frac{2{,}088{,}000\times80\times200\times A}{150{,}000\times9{,}757.15}=\pm\,22.82\ A$$

From paragraph 5 we have for the largest compressive stress in piece 3 by formula (15),

$$s=3.1\,[-\,36.7-22.82\ A].$$

This must equal p A where p is the allowable stress, which we will assume to be 720 tons per square foot. Solving for A, we obtain,

$$A=\frac{-\,36.1\times3.1}{720-22.82\times3.1}=0.247\ \text{sq. ft.}$$

Therefore T equals ± 5.65 tons.

7. Final Calculations.—Web Stresses.—Using the same formulas as in paragraph 5, the stresses for the web members contained in Table III. are found.

8. Areas.—Having now obtained approximate values for all the stresses, settle upon the sections for each piece, and determine its area according to the allowable stresses in paragraph 1. The wind stresses should in practice also be obtained and the necessary areas here added. However, as these do not effect the method, we have omitted them. The area of each piece in square feet is given in column 7 of Table III.

9. Correction for Assumptions.—In paragraph 4 we assumed that the chords had a uniform section which cancelled out in formula (10). Now, however, we have approximate areas for all the pieces. Divide the quantities in columns 6, 7, 8 and 9 of Table I. by their areas in column 7 of Table III. We then obtain the quantities in columns 8, 9, 10 and 11 of Table III. Take the summations and insert in formula (10).

$$H=\frac{P\left\{\frac{h}{L}\ \Sigma\,\frac{y\,l}{r^2\,A}\,x+\frac{a}{L}\ \Sigma\,\frac{y\,l}{r^2\,A}\,x'\right\}}{\Sigma\,\frac{y^2\,l}{r^2\,A}}$$

obtaining the horizonntal reactions for a unit load at each bay. Also insert in formula (9),

$$T=\frac{E\,e\,t\,L}{\Sigma\,\frac{y^2\,l}{r^2\,A}},$$

and obtain the horizontal reaction due to the change in temperature, as was done in paragraph 6. With these values obtain the stresses and areas, as was done in paragraphs 5, 7 and 8.

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THE LAUNCH OF A BATTLESHIP.*

By H. R. Champness.†

(With full-page plate.)

The launch to be described was that of Devonport's first modern battleship, H. M. S. "Ocean," the first since the days of wood shipbuilding, the preceding ship having also been named "Ocean," and launched as long ago as 1863. How great the advance was will be understood from the fact that the weight of the present ship as launched was 7,110 tons, the nearest approach to this being a steel cruiser, whose launching displacement was 2,830 tons, sent off the same slip in November, 1890.

It is true that this is not a record weight even for battleships launched from the Imperial Dockyards, and it has been far eclipsed by what was lately done in launching the "Oceanic," when 11,000 tons slid into the water, though the mean pressure per square foot of the cradle was only 2.35 tons as compared with the 2.5 tons of the "Ocean"; but those most closely responsible for ship launching have little desire to create records of this sort, and certainly so far as the chief constructors of the naval dockyards are concerned, the builders of the "Oceanic" are welcome to their pre-eminence.

Building Slips.—An incidental evidence of the growth in dimensions of modern ships is seen in some of the naval yards, where the building slip has been adapted for launching the present ships of great beam and flat floor by cutting away the sides of the slip at the lower end to enable the full section of the ship to clear it. This was avoided at Devonport by increasing the width of the slip throughout sufficiently to provide for all probable increases of beam; the slip was also lengthened at the upper end, and two concrete piers 25 ft. wide were built at the lower end in wake of the launching ways, to carry the ship into deep water when the fore end of the cradle left the groundways.

How well these old slips were piled is clear, since, in spite of the enormous increase of weight borne beyond what could have been dreamed of when they were first prepared, no sign of subsidence of any kind was discernible, though periodical tests for it were made, and the structure was carefully watched.

Building Declivity.—The declivity of the keel in building was ⅝-in. to the ft., about as usual for a ship of this size, and that of the groundways, or foundation on which the cradle carrying the ship slides, was 51-64-in. to the ft. The longitudinal section of this surface was a circular arc, and had a "camber," or round up, of 9 ins. in a length of 300 ft. This prevented the groundways becoming hollow under compression due to the weight of the ship and cradle, and so increasing the difficulty of launching, though there is perhaps no absolute necessity for this in naval yards where the floor of the slip is of granite or other hard stone upon a thick bed of concrete. It is, however, de-

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sirable that the form of the groundways should have some effect in holding the ship just before launching, and this varies with the position decided on for the top of the camber. Dockyard practice in this respect differs, and this point is sometimes at mid-length, and in other cases at two thirds the length of ship from the bow, or even at the after perpendicular. The declivity of $^{51}/_{64}$-in. to the ft., referred to above, is the gradient of the tangent to this curved surface at the top of the camber, and the holding tendency is greatest the farther aft the tangent point is. In the "Ocean," this point was at the aft side of stern post or after perpendicular.

In launching, the fore end of the straight part of the keel approaches the bottom of the ship in each foot of movement approximately by the difference between the launching and building declivities, viz., $^{51}/_{64} - \frac{5}{8}$, or $^{11}/_{64}$-in., and as the distance from the fore end of the keel to the after end of the straight floor of the slip was 348 ft., this drop of the keel was $^{11}/_{64}$-in. × 348, or 5 ft.

This consideration, and the clearance between the keel and the bottom of the slip at this point, generally from 1 to 2 ft., determines the height at which the foremost block shall be laid for building, and taken in connection with the building declivity, enables the blocks to be laid correctly, in view of the launching conditions. It is further necessary that this height of blocks should be sufficient to allow room on top of the groundways for the section of cradle shown in Fig. 15, including the bilgeway, the wedges or "slices," and the solid timber between them and the ship which is known as "stopping up," and had a minimum depth of about 6 ins.

The length of the groundways must be such as to secure that the ship and cradle shall not tip about their after end, and to determine this, certain calculations were necessary, the results of which are shown in Fig. 2.

Calculation of Ship's Launching Weight.—The approximate date of the proposed launch determined the time the ship would be upon the slip, and the local circumstances as to available labor, coupled with building experience, enabled an approximation of the launching weight to be made. The proper progress of the ship fixed the parts which made up this weight, and thus it was possible to calculate in detail the weight of the several parts, and the positions of their centers of gravity. The weight calculation is much simplified when, as is usual, a record is kept of all weights put on board. The total weight, and the position of center of gravity both vertically and horizontally, were thus obtained, and were easily corrected as the actual date of launch approached, and a closer approximation to the launching weight became possible.

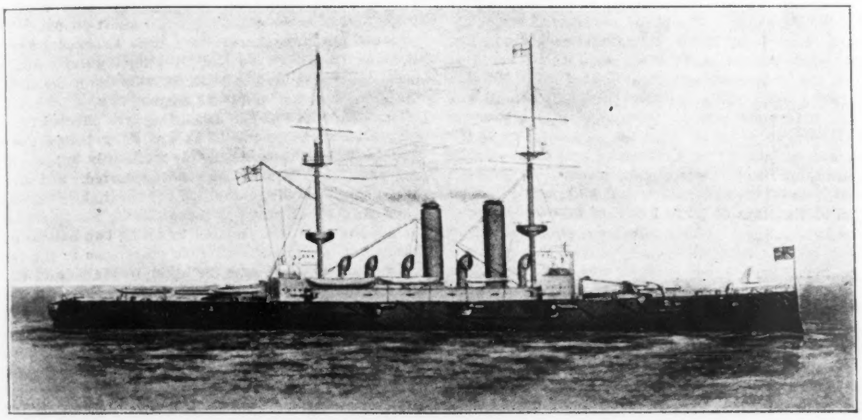

FIG. 1.—VIEW OF BRITISH BATTLESHIP "OCEAN," LAUNCHED AT DEVONPORT DOCKYARD, PLYMOUTH, 1898.

The probable height of tide was given by the tide table, and was drawn upon the profile of the ship as she lay on the blocks, Fig. 2. The displacement was calculated to lines parallel to this at any convenient distance, say 2 ft., which, as the ship was launched as a declivity of 51-64-in. to the ft., corresponded to a travel down the ways of $\frac{2 \times 12 \times 64}{51}$, or about 30 ft., and this is the distance apart of the calculated ordinates giving the curve of buoyancy, Fig. 2. The position of the center of buoyancy was also estimated for the displacement to each waterline. These calculations assumed that the ship did not lift off the groundways as the after part became immersed, and it is also clear that the trim differed widely from the water-borne condition, because the keel was at a declivity of $\frac{5}{8}$-in. to the ft., and in a length of 390 ft. this gave a difference of draft at the fore and after perpendiculars of $\frac{5}{8} \times {}^{390}/_{12}$ ft. = say 20 ft. 4 ins.; while the trim by the stern when the vessel was afloat was only 3 ft., and her fully laden condition is designed for an even keel.

The results of these calculations, and the moments of weight and buoyancy about the after end of the ways and the fore poppet are plotted in Fig. 2, where the abscissæ represent the travel of the ship down the ways. The weight being constant is shown by a straight line parallel to the base. The curve of buoyancy intersects this at a point A after the ship has travelled 337 ft., when she is fully water-borne.

The center of gravity of this ship was over the after end of the ways when she had moved 277 ft., when of course the moment of weight about this point was zero, while there was then a large positive moment of buoyancy, which was maintained and increased relatively to the moment of weight until the ship was fully afloat. There could therefore be no tipping motion while on the ways. Although when the weight of the ship was taken on the cradle, the pressure per square foot on the groundways was not uniform, it only varied with the relatively small variation in the weight of the ship per foot of length as built at time of launching, when generally there is but little concentration of weight due to such fittings as armor, machinery, etc. As buoyancy is gained in launching, a point is reached when the fore end of the cradle is alone in connection with the groundways, and it is there the local stress in launching is greatest. This is shown in Fig. 2, where the moment of weight about the fore puppet being constant is represented by a straight line parallel to the base, and the curve of moment of buoyancy about the same point intersects it at a point B corresponding to a travel of 302 ft., when the stern of the ship commences to lift. The compressive force on the fore poppets at this moment is shown by the difference of ordinates, C D, between the curves of weight and buoyancy, and was equal to 1,320 tons, or 660 tons on each poppet, which had an area of 25 sq. ft., and therefore bore momentarily a stress of 26.4 tons per sq. ft. The mean pressure per square foot of bearing surface of the cradle between the fore and after poppets when in position on the slip differs considerably with different ships, ranging from about 1 to 3 tons, which is very seldom exceeded. In this instance it was 2.5 tons.

While it is not generally necessary with warships to determine whethey they will have stability in the launching condition, because they are designed to be stable however light, yet such a calculation is made, and both the vertical position of the center of gravity and the metacentric height are ascertained. The latter in this case was 12 ft.

The trim of the ship when afloat was also estimated, and showed that she would not be fully water-borne when the cradle left the end of the groundways, but would drop about 4 ft., for which there was ample depth of water.

The details of the structure of groundways and cradle, and the internal shoring of the ship to enable the strains developed in launching to be effectively distributed and safely borne, are worth description.

Groundways.—The groundways were 427 ft. long and 6 ft. 6 ins. wide, and were laid on transverse blocks of oak in wake of each "land tie," or wood foundation of the slip spaced about 5 ft. 9 ins. apart. Between the oak blocks were two of fir equally spaced for about two-thirds the length of the slip, until near the position of the fore poppet already referred to, where the stern of the ship commences to lift. Below this, the blocks were of oak or teak, laid side by side. The upper surface of the blocks was trimmed throughout to the camber, and covered with 5-in. teak plank, secured with ¾-in. bolts 9 ins. long, rag-pointed and punched down below the surface at least ¾-in. to obviate all danger of their protruding under the compression of the ways and obstructing the launch. The butts of these planks were well distributed, and were beveled, as shown in Fig. 8, to facilitate the travel of the cradle over them. The foremost planks in each strake were made as long as possible, dowelled into the blocks, and extended well abaft the fore end of the cradle. Through these planks was bolted the large cleat, A (Fig. 4), which formed a base for the pressure of the hydraulic pumps, provided for pushing the ship off, if necessary. On the outer end of these groundways, a "ribband," A (Figs. 7 and 9), 12 × 10 ins., extending the whole length of the ways, was fitted. It was of fir except the upper 30 ft., which were of best English oak. The general security was 3½-in. wood dowels, about 5 ft. apart for about 300 ft. down, with intermediate bolts 1-in. in diameter, except at the fore end where they were 1⅜ ins. The plank of the groundways on which the ribband rested was also dowelled to the transverse blocks in wake of the land ties below it, as well as bolted like the other plank. The oak ribband, whose fore end took the thrust of the dog-shore, was dowelled to the plank, and bolted alternately through it to each transverse block of the groundways, and had a steel shoe at the fore end whose faying surface against the dog-shore was planed, B, Fig. 7. This ribband was laid so that when the cradle was in position there should be a clearance between the two varying from ½-in. at the upper to 2¼ ins. at the lower end of the ways. This provided against the cradle jamming between the ribbands as the ship went off, and the increased clearance at the lower end gave play for some small amount of swerving on the ways if the tide caught the ship before she was fully afloat. To resist the tendency of any such movement to carry away the ribband, each piece was shored not only at the butt, but also in mid-length, the shore being about 10 ft. apart in wake of the cradle and 20 ft. below. To prevent the shores which are fitted below high water from lifting under the action of the back wash as the ship went off they were bolted to the groundways, and lashed to the land ties of the slip at their outer ends. The three ribband shores at the fore end of the cradle were only 5 ft. apart. The outer ends of all these shores butted against the solid masonry at the sides of the slip.

Cradle.—The general construction and component parts of the cradle will be understood from the accompanying cuts. The fore end of it was about 65 ft. abaft the stem, and the after end at extremity of inner shaft tube, both being in wake of one of the main transverse bulkheads. Resting on the groundways are the bilgeways, solid timber structures of Dantzic fir, 310 ft. long, 5 ft. wide, and 2 ft. thick; the lower surface being faced with 4-in. teak, called the "sliding plank." The fir section of 20 sq. ft. was made up of 4 baulk with plain butts, the several lengths well overlapping and being bolted and dowelled together. The teak sliding plank was fastened with ¾-in. rag-pointed bolts, 8 ins. long, the heads being punched below the surface at least ¾-in., as described for the fastenings of the groundways, and for a similar reason. The ends of the bilgeways were built up by cleats, B C, Figs. 4 and 5, and thus formed stops for the heels of the end poppets. As the fore end of these bilgeways had to bear considerable stress, the cleat was of English oak the full width of the ways and strongly bolted to them, and on its outer side was fitted the dog-cleat of English oak, 1 ft. square in section, fastened not only with dowels, but with 1¼-in. galvanized bolts, passing right through the cleat, the heads bearing on a steel face-plate to the dog-cleat ⅝-in. thick, and the points hove up on a similar plate, as shown on plan and section through CD, Figs. 10 and 11. The after end of this dog-cleat was fitted with a steel shoe, E, similar to that at the fore end of the ribband. The space between these two points was filled by the dog-shore of African oak, 10 ft. long and 1 ft. square in section, having a steel shoe at each end, F G, similar to those it bore against.

It was this shore on each side which, with the few blocks remaining under the keel just before launching, and the friction of the grease on the ways, prevented the ship from being launched. Fig. 7 shows that the shore was cut at the fore end to such an angle that it cleared itself as it fell. A trial of this is always made when the shore is first fitted, and before any strain come upon it, by letting a dummy weight fall upon it. The wedge-shaped steel face H on top of the dog-shore, immediately under the weight, had its upper surface square to the direction of the blow, the full effect of which was thus transmitted to the shore. While the exact resistance to be overcome in knocking away the dog-shore cannot be determined, a rough estimate on the safe side may be made by resolving the weight of the ship parallel to the thrust of the shore, and assuming that the blocks remaining under the ship and the grease upon the ways bear no part in resisting this. We thus get a crushing force on each shore of about 240 tons, and taking the coefficient of steel on steel as 0.3, and allowing that the shore clears itself after about ½-in. of travel, which is really the case, we get

$$\text{Work to be done} = 240 \times 0.3 \times {}^{1}/_{24} = 3 \text{ ft.-tons.}$$

The work due to the fall of half a ton through 17 ft., which was provided for, is 8½ ft.-tons, which, with the other assumptions in favor of the pressure to be overcome, gave sufficient margin for safety.

The remainder of the cradle above the bilgeways consisted of three parts, the stopping up (amidships) and the fore and after poppets. The stopping up, which, like the poppets, was of the full width of the bilgeways, namely 5 ft., consisted of solid Dantzic fir timber carefully fitted to the bottom of the ship and 192 ft. long. The poppets varied from 15 to 25 sq. ft. in sectional area, and were nearly vertical, except the first and last two or three, which stood rather more square to the surface of the bottom in a fore and aft direction. The heels of these poppets were steadied by tenons 9 ins. wide by 1½ ins. deep, which fitted a fore and aft groove, KKK, in the 6-in. poppet board of English elm below them; the spread of these poppets at the heel just above this board, and also at the head, was preserved by chocks, LL, Figs. 7 and 12, but the end poppets, especially those forward, were close fitting from the head well down their length. The various pieces composing them were not only bolted together like the others, but were also dowelled. Each set of poppets was connected together outside the cradle by steel "dagger" plates, TT, Figs. 7, 12 and 16, three aft and two forward, 14 ins. wide and ¾-in. thick, secured to the poppets by Blake's screws, and extending far enough from each end to overlap and be fastened to the stopping up.

Between the upper surface of the bilgeways, and the underside of the stopping up and poppet board, was a space of 4¼ ins., in which the "slices" or beech wedges, 6 ft. 6 ins. long, were inserted when it was desired to "set up" the ship, i.e., to take the weight on the cradle, and off the blocks sufficiently to enable the latter to be rammed out.

To prevent the cradle falling outward at the head, a steel angle, M, Figs. 7 and 12, was riveted to the bottom of the ship, extending from near the fore end to the extreme after end, where it was turned down over the aftermost poppet. The position of the after poppet, and the shape of the bottom there, gave their heads a much better bearing against the ship than was the case forward, and as the after end of the ship was soonest water-borne, and the poppets there were not subject to the great stress of those forward, it was not necessary to do more than support the angle referred to by the bracket plates shown at NN, Fig. 12, which in each case were continued as far as the projecting edge, OOO, of the bottom plate above. At the fore end special strengthening was necessary for reasons already stated, and is shown by Fig. 7, where the plate PPP was of ½-in. steel, with a similar plate QQQ riveted at the back of it, and fitting closely between the projecting edges of the bottom plates above and below it, thus greatly stiffening the structure to resist shearing of the fastenings. Over the heads of the poppets, a ⅝-in. steel plate RRR riveted to a 7 × 3½ × ⅝-in. angle-bar, was fitted and turned down over the fore end of the foremost poppet, the connection being stiffened by 10 brackets, SSS, formed of ½-in. plates and double steel angle bars. All the parts of this plate and angle structure were most carefully fitted to each other and the bottom, the only connection to the latter being by 1-in. steel rivets through the plating between the brackets. The single shearing stress of each rivet is assumed as 20 tons.

This structure might yield in two ways (a) by the shearing of all the rivets in the brackets and angle-bars over the heads of the poppets, or, (b) by shearing all those through the bottom, and also those through the brackets and doubling plate. The pressure on the fore poppet when the stern began to lift has been given as 660 tons, and this may be resolved into a tangential stress of 585 tons, and one of 320 tons normal to the bottom. Assuming this tangential stress distributed by means of the structure over the area surrounding the heads of the foremost three poppets, we should have to shear about 120 rivets in case (a), giving a total shearing stress of 120 × 20 = 2,400 tons, and a factor of safety $= {}^{2400}/_{585} = 4.1$, which is ample. Fracture in case (b) would need a shearing stress of 157 × 20 = 3.340 tons, or a factor of safety $= {}^{3340}/_{585} = 5.7$.

In order that the two parts of the cradle should preserve their relative positions during launching, spread shores, about 12 ins. square and 10 in number, were fitted between them under the keel, and resting in English elm cleats secured to the bilgeways, Figs. 16 and 17. One of these shores was at each end of the ways, one opposite the fore end of the dog-shores, and the remainder divided the intervening length about equally. These acted as struts. Between them at the butts of the stopping up, spread chains were fitted as ties, setting up to 1¾-in. steel eye-bolts through the stopping up, the bolts being hove up on plates covering the butts on the outside of the cradle, Fig. 15. These spread chains were not fitted in wake of the poppets.

No part of the cradle was attached to the bottom of the ship, and as it was fitted below the bilge-keel, and had a certain amount of buoyancy, it might leave the ship as soon as she was afloat and be held under the bilge-keel, unless this were provided against. To keep it clear, T-bars or double angles were fitted as shown by B, Fig. 15, at intervals of about 15 ft., tapped to the bottom of the ship and bilge-keel, and having a wood strut, C, above each in the angle formed by the bilge-keel and bottom of the ship. The close-fitting of the cradle, and the pressure developed in launching, generally make the cradle adhere so firmly that it must be pulled out by tugs, as it is necessary to remove it for the safety of the ship in docking. For this purpose, steel-wire hawsers were separately attached to the fore and after ends of the cradle, and to each piece of the stopping up, the ends of the hawsers being carried inboard on the upper deck till wanted.

Internal Shoring.—While the fullest use was made of the structure of the ship to prevent any alteration of form under the strains borne in launching, by having all possible pillaring complete, and all bulkheads and flats riveted off, it was necessary to provide some internal wood shoring, as shown in Figs. 15 to 18. The spread of the cradle from out to out was 35 ft. 6 ins., Fig. 16, which caused it to bear directly under one of the longitudinals for a great part of its length, Fig. 15. Short shores were also fitted, as shown, between the inner and outer bottoms, above the edges of the cradle, and a covering baulk was laid on top of the inner bottom, from which stout shores reached to the protective deck. The great strength of the framing between the inner and outer bottoms for the engine bearers, and that of the bearers themselves, which were complete, made special shoring at that part unnecessary, but for the remaining length of the cradle, and particularly abreast of the foremost poppets, it was provided, and at the latter place the structure was stiffened from one side of the ship to the other, Fig. 18. The total weight of these shores was about 90 tons.

Lubrication of Sliding Surfaces.—The whole of the work already described was completed a fortnight before the launch, when preparations were made for applying the lubricants to the sliding surfaces. For this purpose the whole of the cradle above the bilgeways was temporarily suspended to the bottom, on the outside of the cradle by strips of ½-in. plate, Figs. 15 and 16, tapped through the bottom of the ship and screwed to the cradle. On the inside, wood struts, D, Figs. 15 and 18, 6 × 6 ins., resting on the bottom of the slip, and screwed below to the groundways and above to the cradle, kept the latter in position against the bottom of the ship. The poppet board was secured to the poppets, both inside and outside the cradle, by plates, VVV, Figs. 7 and 12, screwed to both, and left in position until the ship was afloat, which prevented the board from leaving the poppets and sinking, as being of English elm it might do. The ribband on the outer edge of the groundways was then removed, and 5-in. plank, E, Fig. 18, fixed at intervals from 20 to 30 ft., with its inner end at top level with the top of the groundways, and sloping up and outward. The bilgeways were next hauled by steam winches on to these supports, and the remainder of the cradle was temporarily shored up from the groundways, F, Fig. 18. After a careful inspection of these surfaces, the lubricants were applied first to a short length of the ways, which was coated to the required thickness, and then loaded over a portion of its surface to the mean pressure of 2.5 tons per sq. ft. by ballast, this load being launched, and testing the adhesiveness of the lubricant to the groundways and its adaptability generally for its work. The exact position of the bilgeways have been razed in on the groundways for fitting purposes, wood battens ½-in. thick were nailed to these lines, and the space between them coated with Russian tallow applied hot until a solid coating ⅝-in. thick was obtained. It is sometimes an advantage to mix beeswax with the tallow, in order to assist the cohesiveness of the lubricant and prevent it from cracking and caking. On this a coating of "slum" was placed, made up of Russian tallow and train oil boiled together and well mixed in the proportion of 4 gallons of oil to 1 cwt. of tallow, being one part oil to two of tallow. This was not applied hot. The proportions of oil varies with the temperature of the atmosphere, being less in hot than in cold weather. The surface of the slum was irregularly grooved, after which train oil was poured upon it, and finally soft soap scattered in patches throughout the length of the cradle. The under surface of the bilgeways was coated with Russian tallow similarly applied, but only to a thickness of about ¼-in., on which the slum was placed. The side of the ribband next to the bilgeways was also thickly coated with slum, and the narrow space between them sprinkled with oil. Across the surface of the groundways, 40 grease irons, GG, Fig. 18, to keep the bilgeways clear of the groundways while being hauled back, were then placed in pairs and steadied on the inside of the cradle by workmen, until the bilgeways were hauled again into their proper position, and fayed against the struts previously described as supporting the cradle against the bottom of the ship. The grease irons were withdrawn, the battens removed, and the long beech slices, of which about 1,300 were used, were inserted between the bilgeways and upper part of the cradle, except those below high water, which were not put in until it was necessary to drive them, and so were kept dry. The temporary struts and angle supports to the cradle were next removed, the ribband on the outer edge of the groundways was replaced, fastened and shored, the holes through the bottom of the ship were plugged, and the cleats on the bilgeways replaced and bolted. A large cleat, D, Fig. 5, was also bolted to the groundways at the lower end of the cradle, to prevent any premature sliding movement. Ten steel keys, E, Fig. 15, on each side, varying regularly from ½ to 1¾ ins. in thickness from fore to after end of bilgeways, were then inserted at equal distances between them and the ribband, and maintained them in position. Battens F were nailed over this groove to prevent any substance getting in which might obstruct the launch. The remaining slices were inserted, the dog-shores were placed, and two "triggers," WW, Fig. 7, put beneath each, that with a plain bevelled end preventing the shore from falling, and the other with rounded end serving the same purpose when just before launching the former was removed. Between the slices at intervals were 12 steel angles, YY, Figs. 7 and 12, on each side of the cradle, connected by bolts hove up with nuts, and these helped to keep the sides of the cradle in position and flush with those of the bilgeways.

Setting up the Ship.—Preparations were then made for "setting up" the ship. This operation is generally begun the day before the launch, the after portion only being dealt with at that time, say about one-fourth the length of the cradle. For this purpose the slices were manned both inside and outside the cradle by shipwrights with heavy mauls. The shores at this part were also manned and kept effective as the setting up proceeded by tightening the wedges under them. At a given signal the whole of the men struck together. The strain on the building blocks was tested at intervals by striking the wood wedge blocks, HH, Fig. 18, of each tier until it was clear that they had been relieved sufficiently to enable them to be readily removed. This removal followed immediately upon the conclusion of the setting up and the building shores under the bottom inside the cradle were also taken away, the remaining shores outside the cradle being roped at the head, and the ropes carried inboard in readiness for lowering them on the launching day after completing the setting up. As the blocks were removed, "skeg" shores, EE, Fig. 3, rounded at each end, were placed under the keel at intervals, to assist in supporting the overhanging part of the ship beyond the cradle and the blocks left standing. These shores are generally left in position until the ship is launched, the form of their ends making it easy for her to trip them as she moves. The drying and lubrication of the ways below the cradle was carried out on the morning of the day of the launch as the tide ebbed, and finished as it rose. The completion of the setting up commenced at about the same time and somewhat abaft where it was left the day before, and was continued until near the fore end of the cradle. It is not usual to set up the extreme forward end, but only to tighten up the slices there as necessary to give them a proper bearing. Three or even four slices were allotted to each man in setting up. When this work was finished, the heads of the slices were roped together, as they have some buoyancy and might otherwise float away singly when the ship was launched. The remaining shores between the cradle were removed, and the dog-shores were tightly set by driving a thin steel wedge between them and the fore end of the ribband on the groundways. Additional security was given to foremost and aftermost poppets by driving two long bolts through each into bilgeways F, Fig. 4, and G, Fig. 5, and to somewhat lessen the resistance, a cut water, Plate 5, was fitted against the aftermost poppet. The remaining building shores were then knocked away, commencing from forward and working regularly aft, as the foremost shores tend to push the ship down the slip, while the after ones act as struts against this.

The completion of the setting up was effected in time to enable all these shores to be got away before the rising tide reached the aftermost. It frequently happens that as the remaining keel blocks are removed, and the ship settles down on the cradle, she moves slightly or "draws," and before knocking away these blocks, means are adopted for measuring this movement by fixing two battens parallel to but not in contact with each other, one to the fore end of the sliding ways, and the other to the side of the fixed cleat at the fore end of the groundways, and with their upper edges in the same place. Across the edge a line is transversely drawn, and whatever slight sliding motion takes place is shown by the distance between this line on the fixed and the moving batten, Fig. 6. A corresponding "tell-tale" was also fitted to the stem of the ship upon the launching platform. The difficulty of getting the keel blocks away varies greatly with different tiers, depending partly upon unequal crushing of the blocks during the building, and the extent to which the ship is set up and afterwards settles upon the cradle and blocks. Generally the excessive pressure is only upon a few tiers of blocks, and, as the hour of launching draws near, may be only upon one tier. As a rule, upon the day of launching, the blocks are only removed sufficiently in advance of the tide to permit the work to be done. This remark applies also to the removal of the bilge-cleat at the after end of the bilgeways, and to that of the steel keys and battens on top of the ribband. Should the ship be lively and draw to any extent, some tiers of blocks would be replaced and the ship would be allowed to trip them in launching. If, however, the tell-tales show no sign of movement in the ship, the removal of the blocks would proceed right up to the time of launching, and it might even happen that no blocks would remain under the keel when the dog-shore fell, but this extreme is not usual. Experience must guide in this matter in connection with the circumstances of each case, and ships of the size now described have been launched with as many as 29 tiers of blocks standing, and with as few as one. The removal of the blocks is facilitated by the method of building them; the wedge blocks, H, Fig. 18, generally soon yield to the blows of a ram, but in addition to this, the thin top or "cap" block is usually of some straight-grained but fairly hard wood, such as teak, which has to be split out by steel wedges when the ram fails. The use of gunpowder for this purpose has been known in a private shipbuilding yard.

Hogging and Sagging.—After the ship was set up, means were taken to ascertain how much the elasticity of the structure allowed her to alter form, both longitudinally and thwartships, from the land-borne to the water-borne condition. As great a length as possible on the upper deck was chosen, and three vertically-adjustable sight battens were fixed, one toward each end and one about amidships. The edges of the battens were carefully sighted, so as to be in one plane, and the positions were marked upon the fixed framework carrying the sights.

Similar adjustments were made after launching, and the differences afforded a measure of the droop of the ends of the ship relatively to the middle, or vice versa, known as hogging and sagging respectively. Athwartship observations of this kind are only made in the ships of greatest beam, and seldom show an appreciable movement. In the case of the "Ocean," the "breakage" by hogging in a length of 312 ft., was only $^{5}/_{16}$-in. and in the breadth of 61 ft., nil.

Freeing Dog-Shores.—Each weight of 10 cwt. for freeing the dog-shore was placed in position on the day of the launch at the top of a shoot which allowed a drop of 17 ft. The weights had been suspended for ten days previously by the white manila rope to be severed at the moment of launch, so that the rope had been fully stretched before the weight was finally put in position. This rope was led over a sheave at the top of the shoot to the front of the ship's ram, and lashed across a wood-chock there. The framework of the shoot, consisting of steel angles at the corners and so having open sides, admitted readily of the insertion of a shore to take the strain of the weight off the rope until the last moment.

A tide gage was fixed at the after end of the groundways and the height of water over the groundways was recorded in sight of the launching platform every quarter of an hour during the last hour and a half before launching. The number of the blocks remaining under the keel was similarly recorded as each tier was removed.

It is not often that the blow of the weight fails to free the dog-shore and release the ship, but in case of failure, men are ready to cut away this shore with axes until its weakened section causes it to yield. This operation is dangerous not only to the men, but may be so to the safety of the ship if one shore yields before the other.

To assist the ship to start on the fall of the dog-shore, a hydraulic pump of 150 tons pressure was placed on each side at the fore end of the bilgeways, and one of 80 tons in reserve. There was also one of 500 tons directly beneath the stem, to ease her off the groundways. Special care was taken to test the efficiency of these pumps, both before and on the day of the launch, and also to see that they were not exerting any pressure until the dog-shores had actually fallen.

Watertight Compartments.—As the work of building progressed, all compartments below the calculated launching draft of the ship, and as many more as possible, had been completed and tested for watertightness, and the permanent doors or other means of access were also in place and closed before launching. All Kingston valves, sea-suctions to pumps, inlets and discharges through the bottom were tested and certified to be tightly closed. Two 9-in. Downton's pumps were completely fitted on board to give some power of ridding the ship of water if necessary, and the sluice-valves on bulkheads, and water-courses to the pump suctions were all seen to be clear. Men were launched in the ship to make an inspection of all compartments below water as soon as she was afloat, and report the result.

The Launch.—All being thus in readiness, the tide gage showing sufficient water, and the harbor reported clear, the men removing the blocks were withdrawn, the shores supporting the weights were taken out, the triggers beneath the dog-shores were removed, and the rope holding the weights was severed, knocking away the dog-shore, which together with the weight, was pulled clear of the ways, and the ship was free.

No observation of the launching velocity was made,but as a series of such records for various ships launched on the same groundways with different building declivities and launching weights, would furnish useful information, it may be possible at some future time to supplement the present paper by a discussion of such particulars.

The speed in launching is checked in many private yards by heavy anchors bedded in the ground, and with lengths of cable ranged alongside the groundways, the ultimate tautening of the cable checking the ship. This is suitable and necessary where the ship is launched into a channel of comparatively small extent relatively to her length, and the distance she would travel if free; but the ordinary means of dropping anchor are adopted in the government yards where the channel is ample enough for the ship to go well out and swing up into the tide when the cable is slipped.

If possible the wood cradle is pulled out before berthing the ship, but generally this is done more at leisure on days subsequent to the launch, and before docking.

DOUBLE DECK BRIDGE AT WELLS ST., CHICAGO.

((With full-page plate.)

Work is now in progress in Chicago upon a double-deck bridge carrying Wells St. and the Northwestern Elevated Ry. over the tracks of the Chicago & Northwestern Ry., in front of the Wells St. terminal station of the latter road, just north of the Chicago River. The remodeling of the 220-ft. drawbridge over the river, to transform it into a double-deck structure, was done in 1896, but the new fixed bridge has been postponed until the present time in consequence of the stoppage of work on the construction of the elevated railway. The street was formerly carried over the tracks by a light through-truss pin-connected bridge, of 83-ft. span, built by the Keystone Bridge Co. in 1872, but the new structure will have deep rectangular trusses of much heavier design. The length of span will be 88 ft. 10¼ ins. c. to c. of end pins, and the depth of truss will be 13 ft. 2½ ins. c. to c. of chords. Fig. 1 shows the general arrangement and design of the work. The cost will be paid by the two railway companies in equal proportions.

The new abutments will be of Joliet limestone, backed with heavy rubble, the face courses decreasing gradually from 28 to 16 ins. in height. Under the stone masonry will be a 24-in. bed of Portland cement concrete 13 ft. wide, increased to 48 ins. in depth and 15 ft. in width at the center and ends. The coping course is of Bedford granite 18 ins. deep. The length of the wall under the coping is 54 ft. 6 ins., with sides and face batterings 1 in 12. The thickness of the wall itself is 9 ft. at the base and 6 ft. 1 in. under the coping.

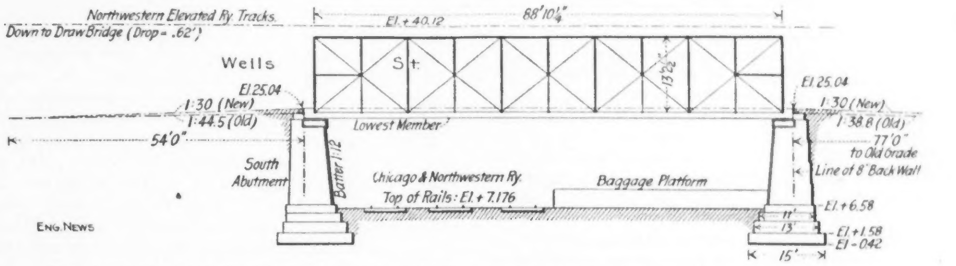

FIG. 1.—DIAGRAM ELEVATION OF DOUBLE-DECK BRIDGE AT WELLS ST., CHICAGO.

The superstructure consists of three trusses, 88 ft. 10¼ ins. c. to c. of end pins, set 24 ft. 3 ins. apart, with floor beams projecting 15 ft. 9 ins. beyond the outer trusses. The total width is thus 80 ft. There are eleven floor beams, 8 ft. 10⅝ ins. apart c. to c., except that the end floor beams are 10 ft. 8⅝ ins. from the next beams. The diagonal bracing below the floor is between alternate panel points, forming five bays or panels between each pair of trusses. The floor beams support roadway stringers, 2 ft. 10 11-16 ins. apart, c. to c.

Fig. 2 shows the construction of the center truss. The end posts are built-up members, having four angle irons and two side web plates, the front and back having lacing bars. The other main posts are double channels, connected by lacing bars and plates. There are also short intermediate posts of similar construction, extending from the top chord to the intersections of the diagonals, whence eyebar hangers are suspended to carry the intermediate floor beams. The top chord is of box section, with web and cover plates and four-flange angles, the lower flange angles being connected by lacing bars and batten plates. The diagonals and bottom chords are built up of eyebars, and the end panel has a horizontal strut at mid-height. In the two end panels, the chord eyebars are connected by horizontal diagonal bracing, secured by bolts passed through gas-pipe spacing sleeves. The outer trusses are of similar design, but somewhat lighter in some of the members. The north or sliding end of the bridge will have a nest of six 3½-in. rollers, 30 ins. long, under each end post.

The top floor consists of a series of rectangular troughs formed by pairs of vertical 12-in., 35-lb. channels, with the flanges inward, these pairs being connected by horizontal 12-in., 25-lb. channels. This floor rests upon the top chords, and angle iron knee braces connect the floor and the truss posts. The lower floor has lines of 10-in., 35-lb. I-beam stringers, whose webs are riveted to angle brackets or knees on the webs of the 15¼-in. plate girder floor beams. These beams have web plates ½ × 15 ins., and four angle irons ¾ × 4 × 4 ins., but beyond the outer trusses the lower chords of the beams are inclined upwards, giving an end depth of 11 ins. The floor beams are suspended from the pins of the lower chord, and from the hangers of the intermediate posts by means of stirrups supporting cast-steel blocks which take a bearing under the top flange angles of the beams. The end floor beams are 15-in., 42-lb. I-beams, set close to the face of the back wall. The one at the north or sliding end of the bridge has stirrups and guides for the stringers, while at the other ends the webs of the beam and stringers are connected by brackets or knees.

The clear headway on the roadways will be 13 ft. 11½ ins. The paving of the roadways between the trusses will be of 7½-in. oak blocks on a flooring of southern pine planks, 3¾ × 12 ins. On each roadway will be an electric railway track laid with the North Chicago Ry. Co.'s standard 7 3-16-in. side-bearing girder rails, laid directly upon the planking, the edges of the paving blocks being beveled to form a flangeway. The center of the track will be 6 ft. 3 ins. from the center of the truss. Outside of each outer truss will be a solid floor of steel channels, 12 × 3¼ ins., forming a series of longitudinal troughs, alternately open and inverted. These are connected by a single line of rivets through the adjacent flanges. Over this floor will be a filling of natural cement concrete, 6 ins. deep above the floor beams, and covered with a granolithic pavement, 2 ins. thick, forming the sidewalk. An ornamental railing will protect the sidewalks. It was originally intended to use inverted segmental troughs with horizontal flanges, but the channels have been adopted instead.

To protect the iron-work from the corrosive effects of gas and smoke from the engines passing under the bridge, there will be a close flooring of ¾-in. plank, nailed to pine stringers 2 × 6 ins. As the clearance between this planking and the tops of the smokestacks of the locomotives is very small, the planking is protected against fire by nailing to it a strip of No. 16 galvanized iron, 30 or 36 ins. wide, over the middle of each track, this iron being heavily painted.

On the upper floor will be the two tracks of the elevated railway, with centers 8 ft. from the center of the middle truss. The rails are spiked to ties 6 × 8 ins., 8 ft. long, which are set in the shallow 12-in. troughs and embedded in a bituminous concrete, which is sloped down to drain into a gutter with downspouts, outside the outer trusses. There are double-guard timbers to each rail, and the third-rail conductor will be on the outer side of each track. The material is mild steel, and all shop rivets are of steel, while field rivets are of wrought iron. The rivets are mainly ⅞-in. diameter, and cavity nuts are used on all the pins.

The assumed loading was as follows: trusses, 100 lbs. live load per sq. ft. of roadway; and 75 lbs. per sq. ft. of sidewalk. Roadway floor beams, 17 tons on 6 ft. of width. Roadway stringers, 5 tons concentrated on the center. Standard trains of the elevated railway were used in the calculations for the upper (railway) floor. The estimated weight of the steel-work is about 390 tons, and the concrete sidewalks, roadway paving, etc., will bring the total weight of the span to about 500 tons.

The plans were prepared in 1896 by Mr. A. G. Riter, City Bridge Engineer, and Mr. J. G. Pihlfeld, under the direction of Mr. L. B. Jackson, who was at that time City Engineer. The work is now being done under the supervision of Mr. John Ericson, City Engineer. The contractors for the substructure and superstructure are Messrs. Shailer & Schniglau, Western Union Building, Chicago. The material for the superstructure will be furnished by the New Jersey Steel & Iron Co., of Trenton, N. J.

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ADVERTISING RATES: 20 cents a line. Want notices, special rates, see page XXII. Changes in standing advertisements must be received by Monday morning; new advertisements, Tuesday morning; transient advertisements by Wednesday morning.

In view of the recent discussion upon the protection of metal structures crossing railway tracks from corrosion by the locomotive gases, in our issue of Aug. 3, it is of interest to notice the construction of the Wells St. viaduct in Chicago, which is shown upon our inset sheet this week. It will be seen that a ¾-in. pine ceiling covers the entire under side of the structure. As we pointed out editorially in our issue of July 20, this protection has been used before, but we are glad to see evidence that increasing attention is being paid to the necessity of some provision of this sort if any reasonable length of life is to be insured for an overhead bridge. We should be glad to receive more information from those who have applied wooden ceilings of this sort as to the method by which they are finished, whether painted or left bare. It would appear that painting might be objectionable on account of the increased readiness with which the wood might take fire, while if the boards were left bare warping might occur. A coating of lime whitewash, made adhesive by the addition of glue, suggests itself to us as perhaps the best covering that could be applied to the wood, and it could be spread from a compressed air nozzle at a trifling cost for labor. We should be glad to learn, however, what experience has shown in this matter, which promises to be of very considerable importance since wooden ceilings are likely to be applied to hundreds of existing bridges which are now rapidly dissolving into rust.

◆

Although the good people of Chicago are much given to boasting of their superiority over other cities in such matters as population and commerce, the disreputable condition of the streets and drawbridges of that city has long been notorious. Last week public attention was forcibly attracted to the condition of the bridges by the collapse of one of these venerable structures when it was swung from its end bearings. It good-naturedly waited until it was swung full open, and then its chords parted and both ends dropped into the pellucid waters of the Chicago River. The bridge tenders were unhurt and were rescued by a boat. This accident has startled the city officials into action, and certain other bridges have been closed to traffic to prevent further accidents which might have far more disastrous results. In consequence of this the communication between the West Side and the other sections of the city will be cut off in many places, and the insurance companies have requested that additional fire engines be stationed in the isolated district, which is considered as a dangerous fire risk. The city has 61 bridges and 37 viaducts, exclusive of railway drawbridges. The estimated cost of necessary repairs and for new bridges to replace those which are beyond repair is $2,000,000; but in consequence of the failure of the City Council to make appropriations there is said to be no money now available for even the most urgent repairs. The Council has been warned again and again by the engineers and other officials of the state of affairs, but has chosen to disregard all warnings and to reject all plans for improvement and for raising the necessary funds. Last year the appropriation for maintenance of bridges and viaducts was only $85,000, with an additional emergency appropriation of $13,500 for urgently needed repairs on eight bridges, which might otherwise have collapsed as the 95th St. bridge did last week. The Commissioner of Public Works, Mr. L. E. McGann, in his report for 1898 made the following remarks on this subject:

> There is no portion of the city's service that is in such need of immediate attention as the bridges and viaducts of the city, and it is to be regretted that appropriations of sufficient amount cannot be secured to make proper and necessary repairs. Many of the structures are old and dilapidated, and have reached that stage of decay where wise expenditure of money cannot be made to repair them, and they should be replaced by new structures.

◆

The description of the launching of a modern battleship which is published in this issue is not only a remarkably well written piece of technical literature, but, so far as we are able to find, it is the only paper in which all the details in connection with the launching of a modern ocean going vessel of the largest size have ever been fully set forth and illustrated. The task of sliding the great steel hull of an ocean steamer of large size from the ground where it is built into the water which is to hereafter support it, and doing it without mishap or bringing excessive pressure upon the hull at any point is a most delicate one. Mr. Champness' paper shows how extensively the engineers in charge of this work make use of computations and measurements to insure the safety and correct action of their apparatus. The old time rule-of-thumb methods worked well enough in their day, but those who used them had no means of altering them to correspond with the growth in size and weight of the vessels to be handled.

◆

In a recent issue the editor of "The Electrician," of London, discusses the unsuitability of the arc light for light-house service, and advocates in its place some form of lamp similar to the Nernst. We think this suggestion could be improved upon. The trouble with the arc light is that the waves emitted are mostly of short-wave lengths, belonging to the violet end of the spectrum, and are soon absorbed in a foggy atmosphere. The Nernst lamp would be open to precisely the same objection, as in it the incandescent material is carried to a very high temperature and the light is nearly pure white. The kind of light that most readily penetrates a foggy atmosphere will be evident to anyone who observes the sun on a foggy morning. The only rays that then reach the eye are the orange and red. As is well known, the light from the ordinary incandescent lamp is rich in these same rays. Therefore we would expect that the incandescent lamp would be particularly well adapted for light-house service in foggy weather, and we are informed that an American company is conducting experiments looking towards the production of incandescent lamps of high candle power for light-house use.

The paper by Prof. Edgar Marburg on the growth of correspondence schools and their place in technical education, which will be found elsewhere in this issue, deserves the serious attention of all who are interested in the advancement of educational work. He discusses in plain terms the faults which the correspondence schools have developed as well as the excellent features of their work, and he gives on the whole, we have reason to believe, a very fair picture. There is one point, however, on which Prof. Marburg only touches, which has impressed us most strongly, and that is the demand for education in a hitherto unknown field which the work of the correspondence schools has uncovered. Here is one school alone with over 80,000 pupils on its rolls, who are paying money which they have themselves earned, by hard labor in nearly every case, and which they have saved by rigid self-denial. For what are they spending it? For pleasure or recreation? No, for a little assistance in the laborious work of study and self-improvement, carried on in many cases after a hard day's work and under the most discouraging conditions.

No doubt the correspondence schools have greatly increased the numbers of their pupils by their vigorous advertising and soliciting. No doubt many have been induced to enter on the courses with no real interest back of it to compel their perseverance; but after making all allowances it must be conceded that there is an enormous demand for help of the sort which the correspondence schools can give, and the founders of these schools are deserving of no small credit for discovering and demonstrating it.

The point which especially appeals to us is the desire which these students evince for education. Let us draw a little contrast. There are in the United States, according to the last report of the Commissioner of Education, about fifty "schools of technology" with about 13,000 students. Most of these schools have been liberally endowed by generous benefactors, and by large gifts from States or cities or the Federal Government. The opportunities afforded to those who attend these institutions are the wonder of the present generation. Capable instructors, elaborate apparatus, everything is done that money can do to make the road to learning a royal one. These schools are doing magnificent work; there is no doubt of it at all; and yet it must be frankly confessed that very few of the students who attend these institutions are really appreciative of the benefactions of which they are the recipients; and a not small proportion in every institution derive very doubtful benefit, if any, from their collegiate training. They are at college because they are sent there—to enjoy athletics and society and other good things of life—and not for grinding over studies.

Now, if we read human nature aright, it was not this sort of people at all that the men and women of wealth and generosity had in mind when they gave their thousands and hundreds of thousands to these colleges to further the cause of education. They had in mind, we are fain to believe, just such sorts of young men as the young mechanics and artisans who patronize the correspondence schools—men who are thirsting for knowledge and who need a helping hand to gain it. In fact in many well-known cases it was because the benefactor had once been a young man himself with his own way to make in the world that he bethought him in his old age of helping other young men to get the education which had been denied him or which he had found it hard to obtain.

◆

As we have said, the technical schools are doing admirable work. The correspondence schools cannot possibly take their place; but we doubt not we speak the mind of every instructor in these schools when we say that it is a great pity that the desire for knowledge and the willingness to undergo self-denial to obtain it cannot be imparted to a considerable percentage of the students who attend our institutions of higher learning—for any reason other than the desire to be taught. So far as raising the standards of admission and increasing the difficulties of the course of study tends to bar out the non-studious element from

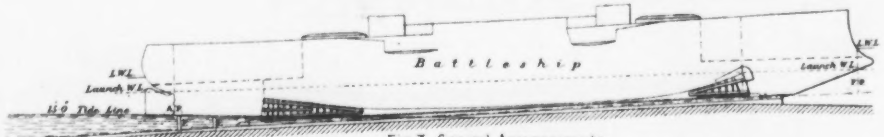


Fig. 3. General Arrangements.

Launching weight 7,110 *tons.* *Area of Sliding way surface* 3,100 *sq. ft.*
Launching draught {14.5 *forward.* / 17.5 *aft.* *Pressure per sq. foot on ditto* 2.5 *tons.*
Camber in Groundways 9 *in* 300 *feet.* *Spread of Bilgeways out to out* 35.6.
Tangent to Groundways at After Part 41/64 *declivity to 1 foot.*

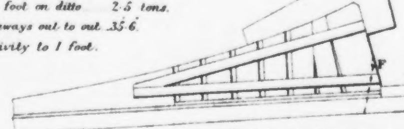


Fig. 4. Fore Part. (See Fig. 7.)

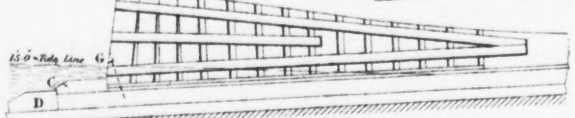


Fig. 5. Aft Part. (See Fig. 12.)

Fig. 6. Fitting for Measuring Draw of Ship.

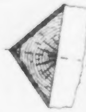


Fig. 13. Section of Cutwater at A-B.

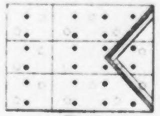


Fig. 14. Plan of Cleat C.

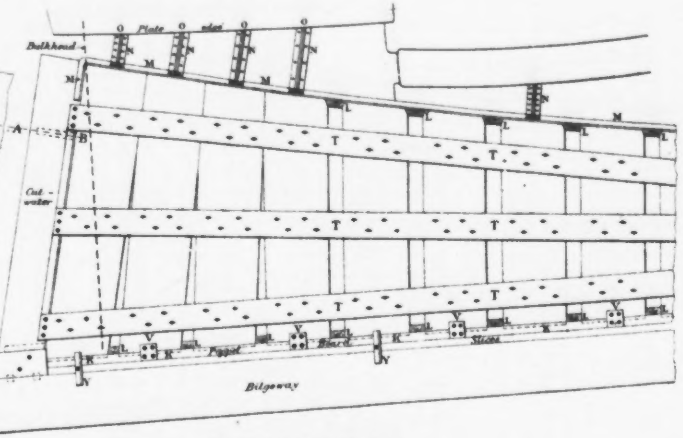


Fig. 12. Details of After Part.

Fig. 8. Butts of Groundway Planking Showing Beveling.

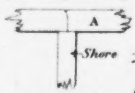
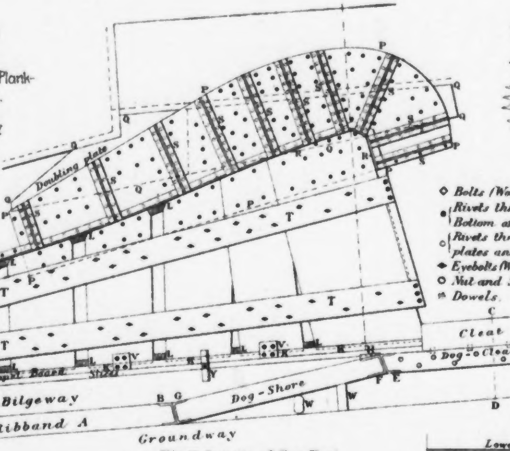


Fig. 9. Butt of Ribband.



◇ *Bolts (Wood screwed.)*
● *Rivets through Bottom of Ship.*
○ *Rivets through plates and bars.*
◆ *Eyebolts (Wood screwed.)*
○ *Nut and Screw bolts.*
✱ *Dowels.*

Fig. 7. Details of Fore Part.

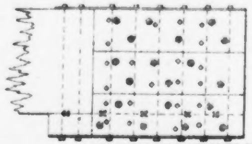


Fig. 10. Plan of Cleat.

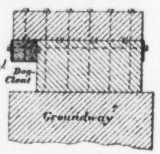


Fig. 11: Section C-D

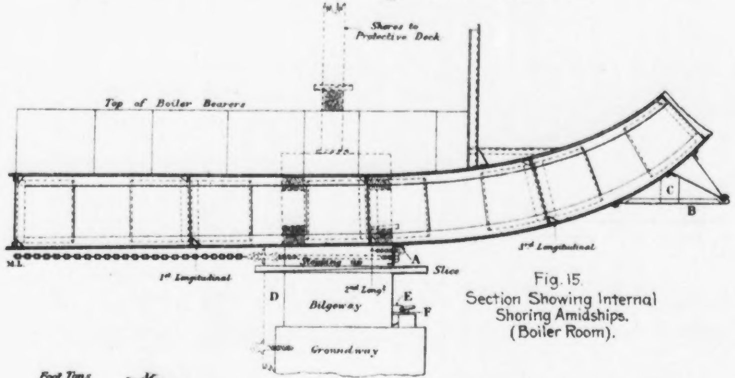


Fig. 15. Section Showing Internal Shoring Amidships. (Boiler Room).

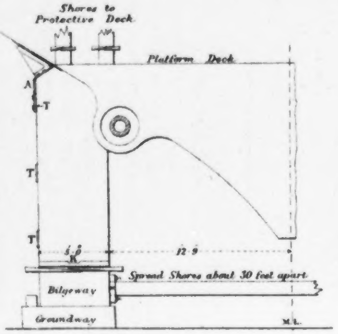


Fig. 16. Sections at Bulkhead.

Fig. 17. End of Spread Shore.

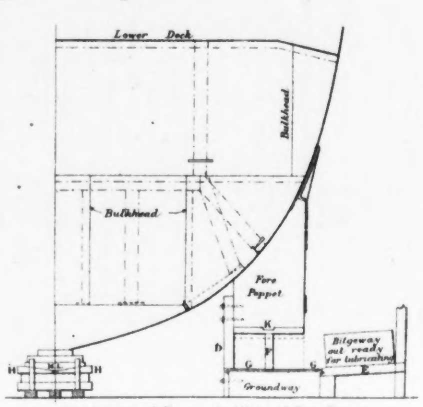
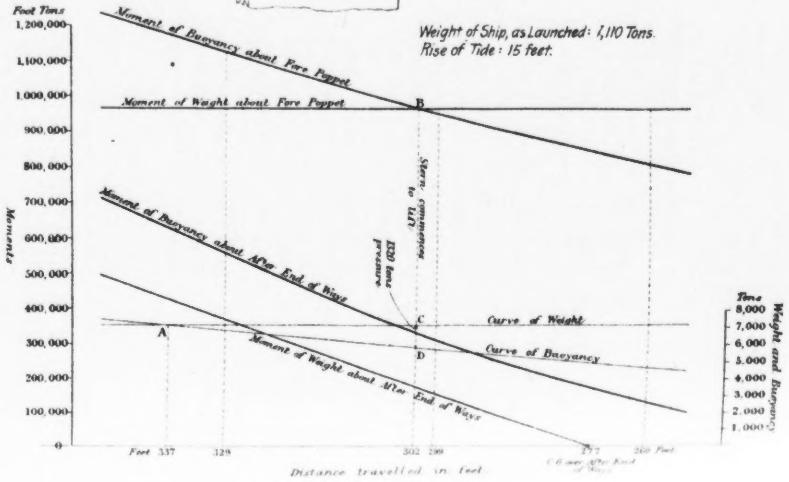


Fig. 18. Internal Shoring in Wake of Fore-Poppet.



Weight of Ship, as Launched: 1,110 Tons.
Rise of Tide: 15 feet.

Fig. 2. Battleship Launching Curves.

THE LAUNCHING OF THE BATTLESHIP "OCEAN," AT DEVONPORT DOCKYARD, ENGLAND.

THE LAUNCHING OF THE BATTLESHIP "OCEAN," AT DEVONPORT DOCKYARD, ENGLAND.

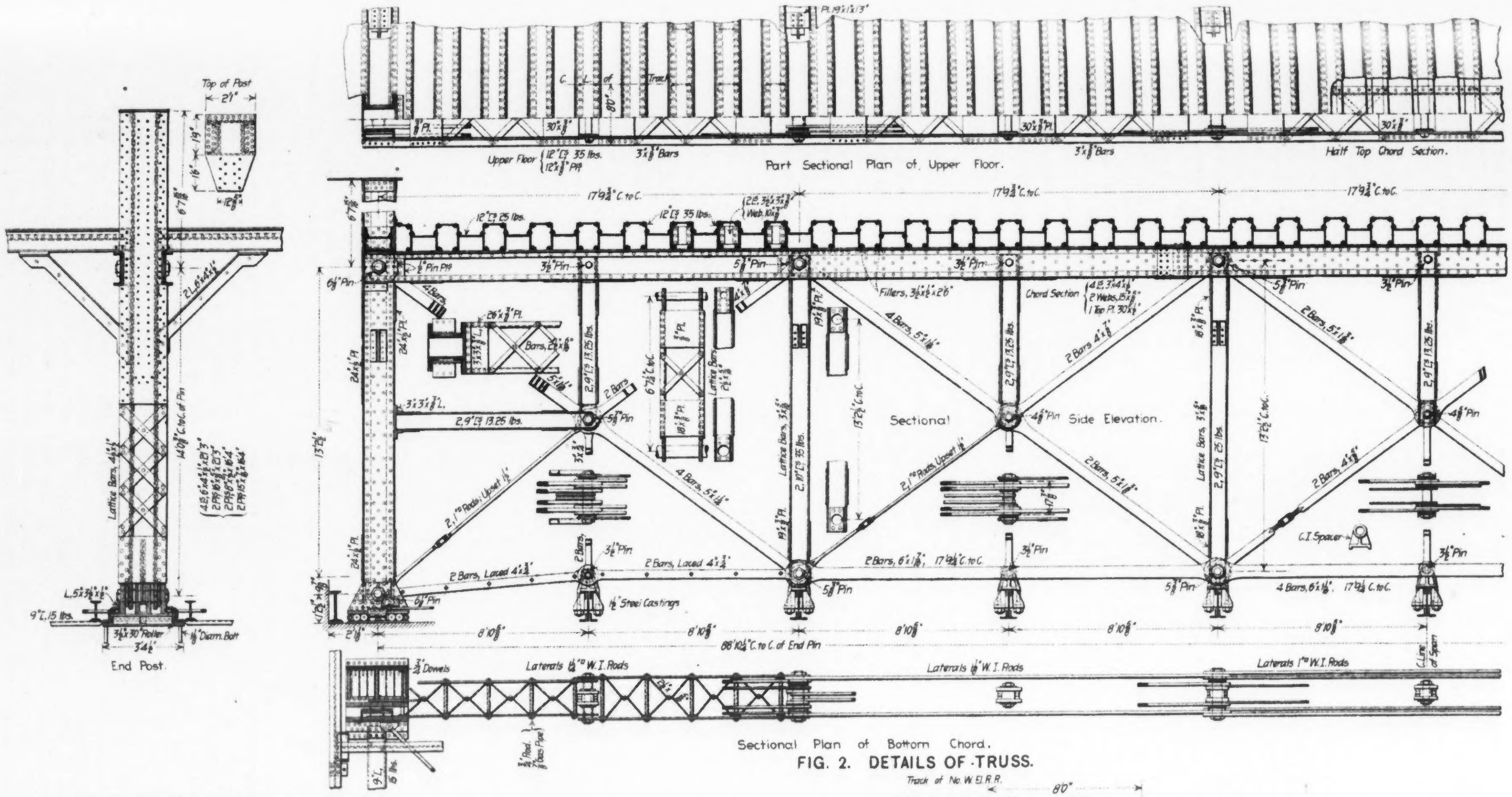


FIG. 2. DETAILS OF TRUSS.

THE WELLS ST. DOUBLE DECK BRIDGE, CHICAGO, ILL.

C. V. Weston, Chief Engineer,
Northwestern Elevated R. R.

John Ericson, City Engineer.

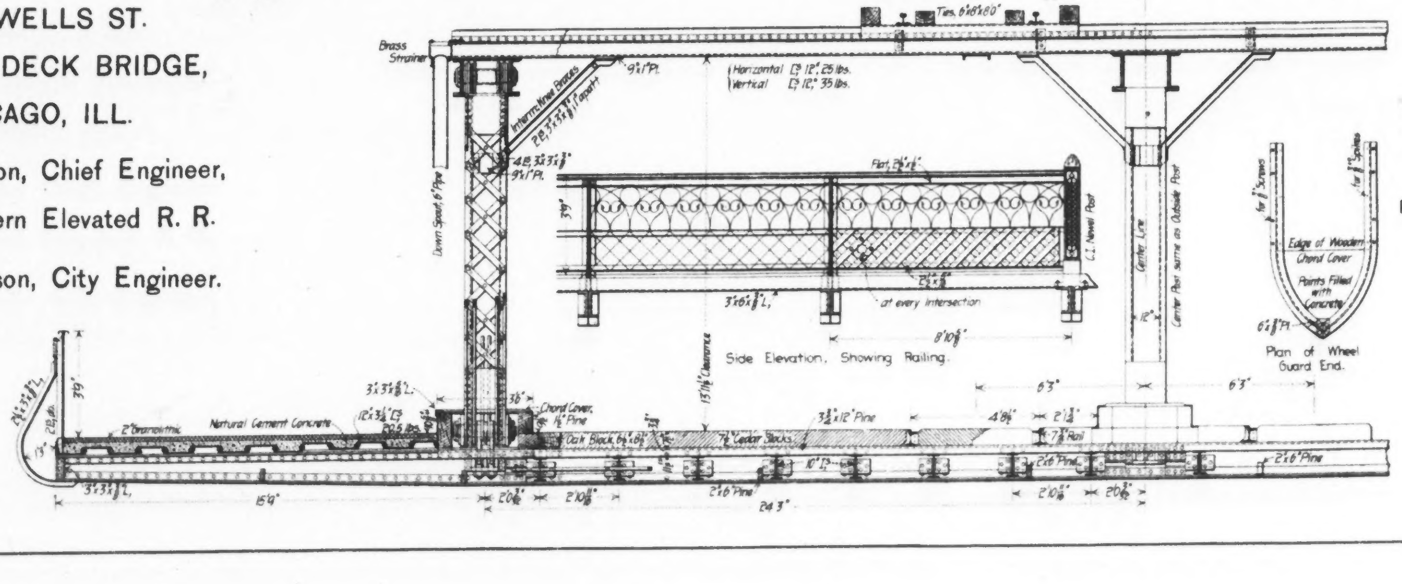


FIG. 3. CROSS SECTION.

CHAS. HART, LITH., 36 VESEY ST., N. Y.

our technical schools, its effect is wholly good. So far as it tends to exclude the youths whose means are limited and to confine the attendance to rich men's sons and students who are mere bookworms and nothing else, its effect is wholly bad.

But it is not our intention now to discuss the technical schools. Our theme is the correspondence schools. They have demonstrated the need. If the need is being poorly supplied in many cases, as Prof. Marburg avers, then better means should be provided. In other words, why is not the instruction of men just as deserving of philanthropic aid as the instruction of youths? Why might not a correspondence school—with the right organization of course—be as legitimate a subject of endowment as a University or a School of Technology? There are not wanting keen critics at the present day who aver that our educational system is far too topheavy. A dozen universities will send their agents soliciting the patronage of the boys who can raise the funds to go to college; but what is being done for the million boys who will occupy places of more or less responsibility in the world, and who cannot spend four to eight years at institutions of higher education? If a hundred thousand of them desire to pursue further studies, and the correspondence schools can give efficient aid, are not they doing a work worthy of high praise?

THE FUTURE WATER SUPPLY OF NEW YORK CITY.

Never in the history of New York have its citizens been more aroused and with more reason over a proposed contract between the city and a private corporation than they have since Aug. 16. On that date only a tie vote prevented the Board of Public Improvements from entering into a $5,000,000-a-year water contract, extending over a period of 40 years. With scarcely a breath of warning, and without the shadow of an engineering report on behalf of either the city or the company, there was suddenly sprung upon the people, and almost railroaded through a brief session of the board, the most audacious contract ever submitted to an American municipality. The total sum involved runs into the hundreds of millions, especially if the accompanying estimates of future water consumption are correct. The yearly charge of $5,000,000 would pay 3 per cent. interest on works costing $166,000,000, or the same interest and a yearly sinking fund charge of 2 per cent. on $100,000,000. The size of the annual tribute demanded from the city by the Ramapo Water Co. and its allied interests can be better appreciated when it is remembered that only four years ago an investigation made for the city of Brooklyn by the late Wm. E. Worthen showed that 100,000,000 gallons of water a day from the Ramapo could be delivered to the Ridgewood reservoir in Brooklyn at a cost of only $16 per 1,000,000 gallons, whereas the price under the proposed contract is $70 per 1,000,000 gallons for 200,000,000 gallons a day, or more, delivered in bulk at some indefinite point on the northerly line of the city, leaving New York to stand the expense of carrying the conduit to and beneath the East River, and thence to the Ridgewood reservoir. While the two propositions may not admit of close comparison, there is an enormous difference between them which can by no means be explained to the satisfaction of the taxpayers of Greater New York.

Another audacious feature of the scheme is the lack of engineering investigation. One would expect a proposition of this magnitude to be accompanied with exhaustive reports from the best hydraulic engineers of the country, both on the part of the company and the city. Nothing of the sort was forthcoming. The only indication that the matter had been given consideration by the engineering staff of the city is a statement that the Commissioner of Water Supply, accompanied by four expert engineers, including the chief engineer of the department, has visited the proposed drainage area. Contrast this with the years of preliminary study, by some of the most eminent engineers of the country, put upon the new Croton Aqueduct, the new Cornell Dam, and the additional water supplies now being developed for Boston and Cincinnati.

A work of this magnitude, entered upon so blindly, absolutely without competition, is simply unprecedented in the history of engineering and municipal public works; and it is made all the more notorious because it is proposed at a time when the most marked feature of municipal administration is the insistence on getting and keeping public water supplies under municipal control. Whatever may be thought of the claims for municipal ownership of lighting, street railway and telephone systems, it is now almost universally admitted, except by those directly interested in private plants, that water-works should be under public ownership. As is shown by "The Manual of American Water-Works" for 1897, not only is it true that only 9 of the 50 largest cities of the United States are dependent upon private companies for their water supply, but in addition four of these nine have recently taken steps to change to public ownership, New Orleans having actually voted to do so, while San Francisco, Denver and Omaha have the matter under consideration. Of the remaining 41 cities, about half were formerly under private ownership. We started the century with 16 private to 1 public works, and early in 1897 had 1,500 private to 1,700 public works. Besides the changes among the 50 largest cities there had been enough others to bring the total changes from private to public ownership up to some 200 by 1897, while since then many have been added to the list, and Oakland, Los Angeles, Burlington, Dubuque and Ottumwa, Ia., together with a host of smaller places, are actively striving to reach the same goal. At present many of our ablest engineers, instead of being engaged in new construction, are spending large portions of their time as expert witnesses in arbitration and condemnation proceedings where works are being taken over by cities, or in legal controversies over the interpretation and enforcement of water contracts.

Returning to the Ramapo scheme, let us first consider some of the other possibilities of increasing the water supply of Greater New York. In our issue of Feb. 13, 1896, we discussed this question at some length, including in a general way Jersey City, Newark and other New Jersey suburbs. We showed that the New Jersey cities and towns must be considered in any adequate study of the subject, and that in the course of half a century it is quite possible that there may be a conflict of interests between New York and Philadelphia. The water supply of Brooklyn was then, as now, the most pressing question in the territory making up the present city of New York. Basing our opinion on the information then in hand, we said then, and we still believe, that as a purely engineering problem the needs of Brooklyn could be met most advantageously for some years to come by a further development of the available supplies on Long Island. At that time Mr. I. M. de Varona, M. Am. Soc. C. E., then Engineer of Water Supply for Brooklyn, estimated that an additional 100,000,000 gallons of water could be secured to the eastward of the existing works at a total cost, including interest, sinking fund, pumping and all other expenses, of $39 per 1,000,000 gallons. There was no question about his estimates being sufficiently liberal, both as regards cost and quantity. Mr. Alfred T. White, then Commissioner of Public Works, thought the estimates too high, and that those made at the same time for the Housatonic and Ramapo, $20 and $16 respectively, were probably too low, in view of certain contingencies that might arise. The Housatonic supply, as will be shown later, should be developed in connection with the Croton supply, and not independently. One weighty consideration in favor of the Long Island extension is that it can be done piecemeal. Mr. de Varona said that the whole work could be done in about four years, or in three sections six or seven years apart. Vigorously pushed, the immediate needs of Brooklyn could be supplied from the first section of this extension before water could be brought from the Ramapo or any other source by either city or company.

The work that should be given precedence, so far as Brooklyn is concerned, is the 66-in. steel pipe line needed to parallel a portion of the old brick aqueduct to make available the supply already developed. A contract for this work was let as long ago as 1896, but though its necessity has been urged repeatedly it has been continuously hung up; first on account of the failure of the Comptroller of the old city of Brooklyn to certify that funds were available for the work, and since consolidation because the present authorities have failed to take the requisite action.*

The failure to provide means to bring to Brooklyn the supply already available may be partly due to the financial straits of that city in recent years and the chaos preceding (and unfortunately following) consolidation; but any one who has followed Brooklyn water-supply matters for the past few years can suggest other and perhaps more potent reasons. For years there has seemed to be a systematic and never-ceasing effort in Brooklyn to belittle the quantity and quality of its water supply, and to render it impracticable, if not impossible, to go further afield on Long Island. Contemporaneous with, or perhaps preceding, the reckless legislation designed to give the Ramapo Water Co. precedence over the city itself in condemnation powers in the drainage areas north of the city, was other legislation prohibiting the development of further public water supplies in Suffolk County, L. I., without first securing the permission of the Supervisors of that county. It was an easy matter to work up a popular sentiment against taking water for Brooklyn from Suffolk County. There have also been lawsuits to prevent Brooklyn from using the driven well system, brought, it is true, in the name of landowners who claimed that the wells had deprived them of their individual supplies, but exploited in such a way as to arouse the suspicion that the suits were only a part of the great scheme of promotion in progress for so many years. After the disclosures that may be expected before the Ramapo scheme fades from public view, and in connection with the establishment of the city's right in the Ramapo or any other drainage area of the State, this special legislation, pretending to be for Suffolk Co. but actually drawn in the interest of the Ramapo Water Co., should be repealed. If the legislature does not do it, perhaps the courts may annul it as contrary to public policy. Meanwhile the pipe line mentioned above may be built, giving considerable relief to Brooklyn, and perhaps it should be enlarged, or duplicated, for use in connection with further water developments on Long Island.

Coming now to the needs of the area comprising the old city, known as the boroughs of Manhattan and the Bronx, it is obvious first of all that there should be developed as much additional water above the capacity of the Croton drainage area as is needed to utilize the full carrying capacity of both the old and new Croton aqueducts, which, with the works now taking water from the Bronx and Bryam rivers, would give Manhattan and the Bronx 400,000,000 gallons a day. This can easily be done by turning the yield of the Housatonic River "into the upper affluents of Croton River," and "at a comparatively small expense."† The importance of this factor in the water-supply problem can be appreciated when it is stated that the average daily consumption of water in New York in 1898 from the Croton, Bronx and Bryam drainage areas was 243,000,000 gallons, leaving a margin of 157,000,000 daily between this and the total capacity of the conduits leading to the city. If more water can be diverted to the Croton drainage area than the aqueducts can bring we venture as an offhand suggestion well worth investigating that they might be supplemented by a steel pipe line, laid down the Croton and Hudson valleys. Numerous such pipe lines, of great size and length, have been constructed since the new aqueduct was built, and they are now accepted as one of the possible great economies of modern hydraulic engineering. Besides cheapness, they have the merit of remarkable facility of construction, scarcely limited except by the output capacity of

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*It is only fair to the Commissioner of Water Supply to say that he has requested authority to award a new contract and has asked for a new bond issue to carry out this work. See p. 16, First Annual Report Department of Water Supply.

†See p. 82, Report Croton Aqueduct Commission, 1887-95, which refers, for details, to the Report of the Department of Public Works for the city of New York for the quarter ending June 30, 1879.

the mammoth steel mills of the country. With two large masonry aqueducts, the larger of which is for most of its length far below the surface, no apprehension for the safety of the supply need be felt if additional conduits are placed at or near the surface.

Another important means of safe-guarding the capacity of the water supply of the whole city is the immediate installation of the most improved modern methods of reducing the enormous waste of water known by all engineers to be going on throughout the city. The report of the Commissioner of Water Supply for 1898 gives the consumption of water in Manhattan and the Bronx as 121 gallons per capita, and in Brooklyn as 88 gallons, estimating the respective populations supplied at 2,000,000 and 1,180,000 gallons, respectively. He believes, or is informed, that the 35,442 meters in Manhattan and the Bronx cover "every place where water is used to any considerable extent for other than domestic purposes," and that "the bulk of the waste must, therefore, be in the dwellings, which are exempt from the use of meters and meter charges," since meter bills are such forcible monitors that it is not reasonable to assume "that any considerable portion of the people" who pay them "persist in wanton or careless waste of water." Brooklyn, with more than half the population of Manhattan and the Bronx, the report states, has only 2,705 meters, against the 35,442 in New York. The Commissioner assumes that the consumption in Brooklyn will mount rapidly when more water and higher pressures are available, and concludes that:

> The necessity for further extension of the meter system seems unavoidable, in whatever light the situation may be considered.

If Brooklyn, without meters, can be kept down to a per capita consumption of 88 gallons, what might be expected with them, and what might be hoped for in New York if the waste prevention were extended as far as possible? We are not speaking of legitimate use, but of useless waste. The consumption is as low as it is in Brooklyn because waste, rather than use, is already partially curtailed. With an extension of meters to cover all large consumers, leaving domestic services alone, the consumption would fall in a surprising manner. Meters can be applied so quickly that the available supply might, by that means, be as good as increased by many millions inside of three months, if half as much determination were shown in that line as has been exhibited in the proposed contract which will tend, if not deliberately designed, to encourage and increase waste at every possible point.

Thus far we have been discussing volume of water, in terms of average daily consumption for yearly periods. As a matter of fire protection, however, the chief claim for the proposed new supply is the increased pressure it would give, the actual quantity used for extinguishing fires being a mere bagatelle compared with the total consumption. By far the quickest and cheapest means of supplementing or improving the fire protection in the portions of the city most needing it is to put in special fire pipe lines, taking water from the East and North Rivers, on a plan similar to that recently installed in Boston, and in service for a number of years at Cleveland and other cities on the great lakes. A year's time would work marvels in improving the fire service of the city in this way, and the plan has been urged repeatedly. With the Ramapo scheme out of the way, something of the sort may be done. Again, the consumption of the potable water supply might be reduced somewhat by using salt water for street sprinkling and sewer flushing, as is done extensively in some English and other foreign cities, and also, we believe, on the Pacific coast. This subject deserves more extended consideration than can be given it in the space remaining at our disposal.

One phase of the water question needing special mention is the quality of the present supply. The Brooklyn supply, as has been hinted already, has been shamefully abused in the interests of water syndicates. Suspicion has also been cast, at times, on the Croton supply, although that has diminished with the expenditure of millions for its sanitary protection. It is recognized by sanitarians that the typhoid mortality of a city is one of the most reliable indices of the character of its water supply. Brooklyn has long been noted for its enviable record in the matter of low typhoid rates, and New York has stood close beside it. In the "Medical Record" for Aug. 12, 1899, Mr. F. S. Crum, Ph. D., of Newark, N. J., presented the "Typhoid Mortality in 24 American Cities, 1889-1898." The cities chosen were among the 50 largest in the country. For the ten-year period Brooklyn made the best showing of the 24 cities, and New York stood third, the mortalities per 100,000 being 19 and 21, respectively, against 82 for Pittsburg and 77 for Denver, the cities making the worst showing, 33 for Boston, one of the best, and 46 for Philadelphia.

The mention of Philadelphia suggests that New York take warning from the unfortunate experiences which the Quaker City has had with private water schemes, "water snakes" they are now called. For more than a dozen years the city has been drinking a grossly polluted water supply, and seeking for a better one, but it has made no progress because the officials have insisted on dealing with private companies having something to unload on the city, but they have never quite dared to put through any of these schemes conceived for the good of corporations and city officials instead of the public. The nearest approach to a contract of this sort was headed off and killed by charges of wholesale bribery, which, while not proven, were universally credited.

In conclusion, the moral of the whole tale is that when a city finds itself in need of an additional water supply, it should engage competent and honest expert advice to determine, (1) what its needs really are; (2) what, if anything, can be done to increase or improve the present supply; and (3) the best of the various additional sources available. In no event should contracts for a supply from private sources be considered which do not provide for early acquisition of the works by the city; and the cases will be few and far between where the city cannot carry out the work itself with greater economy and more advantageously than it can turn it over to a private company.

As regards the Ramapo scheme, we are glad to be able to state that as we close this article news comes that an injunction against the execution of the contract has been issued. This, we trust, will enable Comptroller Coler and his colleagues, who so resolutely insisted on postponement of action at the meeting on August 16, to let in such a flood of light upon this outrageous scheme as to cause it to disappear permanently from public view.

The broad question of a water supply commensurate with the needs of Greater New York, may then be taken up by the city with the thoroughness that the importance of the question involves.

Meanwhile, some of the relief measures suggested above might be carried out as far and as fast as the real need for additional water supply makes them necessary. These measures, in the order of their timeliness and importance, would seem to be: (1) Extend waste prevention measures, especially in Brooklyn, where both the necessity and the opportunity most invites them. (2) Build the pipe line needed to bring to the pumps the full measure of supply already developed on Long Island. (3) Prepare to develop the Long Island supply as indicated in the de Verona report of 1895, unless further investigation proves some other course more practicable. (4) Supplement the Croton by the Housatonic or some other drainage area at least to the extent necessary to utilize the full capacity of the two existing aqueducts. (5) And perhaps this ought to come earlier, develop a supplementary river supply for fire protection in the districts where the fire risks are greatest. Simultaneous with all this work, investigations should be made for a greatly enlarged future supply, including a consideration of a variety of sources, opportunity being afforded meanwhile to watch the effect of the application of every possible and reasonable measure to prevent waste.

LETTERS TO THE EDITOR.

An Old Wooden Truss Bridge.

Sir: Enclosed are two views, which I took on Aug. 7th, of the old covered bridge at Narrowsburg, N. Y., which place is 122 miles from New York on the Erie R. R. The Delaware River at this point flows through a narrow, rocky channel, the bridge span being 262 ft. over all, and the flooring about 40 ft. above present water level.

BRIDGE OVER THE DELAWARE RIVER AT NARROWSBURG, N. Y., SPAN, 262 FT.

Both above and below this point the river widens out to a quarter mile width, and the lower pool is said to be over 50 ft. depth, while under the bridge there is now ten or twelve ft. depth, though for forty miles above or below this spot one can hardly find a place deep enough to swim in.

Evidently this bridge cannot last much longer. A wind storm some two months ago tore away nearly half of the roof, and while the rest of the bridge seems to be in fairly good condition, it has stood over forty years, a well-built specimen of a type of truss well known to your older readers, but which is seldom seen now, and will soon disappear.

Yours respectfully,

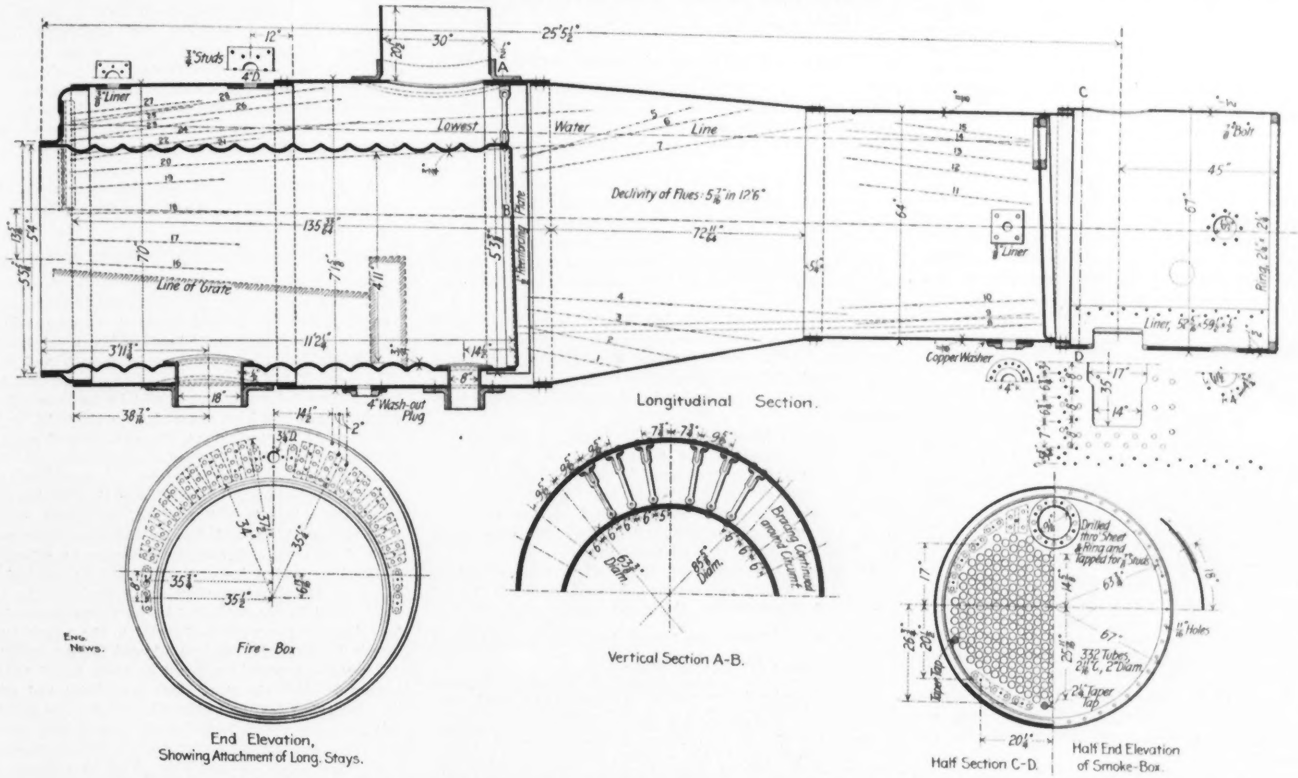
J. K. Noyes.

13 Ferry St., Binghamton, N. Y., Aug. 16, 1899.

(We reproduce herewith one of the photographs of this interesting old structure, which is notable as among the longest spans that were ever attempted with this type of bridge. We may add that when this type of bridge is well protected from the weather, its life should be much longer than 40 years. Well seasoned timber trusses, protected from moisture, will remain safe, we are inclined to think, quite as long as some of the iron structures which are taking their place, when the corrosion of the latter is taken into account.—Ed.)

A LOCOMOTIVE BOILER WITH CORRUGATED FURNACE.

There is now running in freight service on the Central Division of the New York Central & Hudson River R. R. a locomotive with a corrugated furnace which constitutes an important departure from the ordinary type of construction. We give herewith sectional views which will make the construction clear. Previous experiments in corrugated furnaces for locomotives in this country have been made with a double-furnace arrangement, connected in front to a common combustion chamber. In the present case a single corrugated furnace is used with the very large diameter of 5 ft. 3⅜ ins. The furnace has the Morison stiffening rings, and was made at the Continental Iron Works of Brooklyn, N. Y. It is the largest corrugated furnace which these works have ever made, and we do not know of any larger one having been rolled anywhere, either here or abroad. The furnace is rolled from ¾-in. steel, and was tested under an external pressure of 500 lbs. per sq. in. before being put in place in the boiler. The steam pressure it is to withstand is 180 lbs.



Longitudinal Section.

End Elevation, Showing Attachment of Long. Stays.

Vertical Section A-B.

Half Section C-D. | Half End Elevation of Smoke-Box.

CORRUGATED FURNACE BOILER FOR TEN-WHEEL LOCOMOTIVE, NEW YORK CENTRAL & HUDSON RIVER R. R.
A. M. Waitt, Superintendent of Motive Power; Cornelius Vanderbilt, Jr., Jun. M. Am. Soc. M. E., Designer.

As seen by the drawings, the furnace is carried at its front end by a row of slingstays, and the pressure tending to force it to the rear is resisted both by the tubes and by stays attached to an annular re-enforcing plate and at their front end to the waist of the boiler.

The very large diameter of the outer shell of the boiler at the firebox (7 ft. inside) made it necessary to raise the boiler at the rear end and pitch it toward the front to clear the flanges of the rear driving wheels. The plates for this ring are 13-16 in. thick.

The grate is inclined toward the front with a drop of 8 ins. in its length. Its area is 34 sq. ft., and it is shorter and wider and has a little more area than the standard grates used with engines of this type on the New York Central. The grate is carried by bearers which rest in front on the bridge wall and at the rear on the frame by which the mouth of the furnace is closed. This frame is lined on the inner side with firebrick, has in its upper half two firing doors and in its lower part openings through which the fireman can reach the ashes and haul them to the dump hole. This latter, as seen in the cut, is 18 ins. in diameter and opens into a deep ashpan not shown in the drawing. The air supply for the grates passes up this hole, being taken into the ashpan through adjustable dampers, as in ordinary practice. The 8-in. opening into the combustion chamber is for the purpose of cleaning out ashes, and is closed when the engine is running. Rocking grate bars with interlocking fingers are used, and we are informed that the firing arrangements as a whole have been very satisfactory.

The tube heating surface is 1,920 sq. ft., and the furnace heating surface is approximately 90 sq. ft. above the grates. We are informed that the locomotive has proved a very free steamer and is pulling as heavy trains as other engines of its class without difficulty.

The engine is a ten-wheeler with 20 × 28-in. cylinders and 61-in. drivers. The total weight on the driving wheels is 113,300 lbs. Notwithstanding the very heavy metal in the furnace, the total weight of the boiler is considerably less than that of the regular boilers on other engines of this class.

The engine was designed in the office of Mr. A. M. Waitt, Superintendent of Motive Power of the New York Central & Hudson River R. R., by Mr. Cornelius Vanderbilt, Jr., Jun. M. Am. Soc. M. E., who has been an assistant in that department since his graduation from the Sheffield Scientific School of Yale University.

We need hardly say that the principal advantage aimed at in the design is dispensing with the manifold troubles due to the staybolts and side sheets in the locomotive firebox of ordinary construction. If it is found that the corrugated furnace can replace the present standard construction without creating other difficulties of a serious nature, it will appeal strongly to those railway officials who are responsible for the maintenance of locomotives.

◆

THE NAVY PERSONNEL BILL, approved March 2, 1899, terminated the existence of the Steam Engineer Corps of the U. S. Navy, by transferring the former engineers to the line and making all line officers subject to engineering duty. To carry this law into effect, the Navy Department has issued an important general order indicating the duties and responsibilities of the officers concerned. The order gives a list of officers who are qualified to perform engineer duty alone and only on shore; the next list is to perform engineer duty alone, at sea or on shore, until they have qualified for the general duties of the line by passing an examination; unless they so qualify, on obtaining the rank of Commander they will perform engineer duty only on shore. Certain former engineer officers will perform line duty only, but must qualify for such duty after March 3, 1901. The former engineer officers who do not qualify do not succeed to command or the duties of a line officer, either afloat or ashore. It is the intention of the Navy Department, as far as practicable, to detail officers for the duties of the class to which they belong; and commanding officers will not alter these details except in case of emergency. It is also the intention to relieve commissioned officers, as much as possible, from further duty in charge of engineroom watches, and to have this duty performed by warrant machinists, who will act as assistants to the acting engineer officers of the ship in all that relates to the care of the machinery, boilers and appurtenances, and to perform such duty as may be assigned them. The senior engineer officer on board will designate to the warrant machinists their routine duties, and the latter will stand regular engineroom watches, in not more than four watches of four hours each, when the main engines are running, and not more than six hours at any time. These warrant officers may, with the approval of the Captain, be excused from watch, from "pipe-down" to "all hands," when the fires are not lighted under the main boilers for steaming purposes; and when the number of warrant machinists on duty is reduced below four, chief machinists or competent machinists of lower grade may be assigned to engineroom watch duty. These warrant officers, of all grades, will have an especial mess, and steps are being taken to provide suitable additional quarters for warrant officers.

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SHIP BUILDING ON THE DELAWARE is reported upon by the Philadelphia "Press," which paper estimates that 100,000 tons is under contract at the yards of Cramp, Neafie, Roach and Harlan & Hollingsworth. This list covers 40 separate vessels, of which eight are United States ships of war and two are Russian warships, a battleship and a cruiser. The Cramps alone are said to have $20,000,000 in work on hand, including three battleships and one cruiser.

◆

THE LATEST NORTH RIVER TUNNEL PROJECT is being engineered by the Manhattan & Jersey City Railroad Co., incorporated at Albany, on June 16, with $10,000 capital. This company is now asking the Board of Aldermen for a franchise to use several streets in the city. The directors are not well-known men, but Tracy, Boardman & Platt figure as counsel for the company. One of the directors is Mr. Ernest C. Moore, Jun. Am. Soc. C. E., and he is credited with stating that it is the purpose of the company to build two circular tunnels under the North River, each 10 ft. diameter inside, and made of steel with concrete lining. The estimated cost of the tunnels is only $1,000,000, with $4,000,000 more for terminals, etc. The route laid down for one tunnel commences at Liberty and Washington Sts., to Dey St., and under the latter to the North River and Jersey City; the second tunnel would branch from the first to Cortlandt St., and under this street to West St. and to and across the river. The New Jersey charter and Federal consent are yet to be secured.

◆

THE DEVELOPMENT OF SHIPBUILDING, in the last half century, from the "Great Eastern" to the "Oceanic," the new White Star liner expected in this port in September, is illustrated by "Bradstreets" in the following table:

Name of Ship.	Date.	Length, ft. in.	Beam, ft. in.	Depth, ft. in.	Displacement.*
Great Eastern	1858	680	83	57.5	27,000
Britannic	1874	455	45	36	8.500
Arizona	1879	450	45.2	37.6	....
Servia	1881	515	52	40.6	9,900
Alaska	1881	500	50	39.8	....
City of Rome	1881	542.6	52	38.9	11,230
Oregon	1883	500	54	40	....
Paris	1888	527.6	53	41.10	13,000
Teutonic	1890	565	57.6	42.2	12,000
Campania	1893	600	65	42.6	....
Kaiser Wilhelm	1897	625	66	43	20,000
Oceanic	1899	704	68	49	28,500

*Tons.

The "Oceanic" cost about $5,000,000, and she will have accommodations for 410 first-class, 300 second-class, 1,000 third-class passengers, and 390 in the crew, or 2,100 persons in all. The above list, unfortunately, omits the engine power, in which the greatest advance has been made since 1858; for example, the "Great Eastern" engines developed only 2,600 HP., as contrasted with the 30,000 HP. of the "Kaiser Wilhelm."

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A 5-IN. BROWN SEGMENTAL TUBE WIRE-WOUND gun, the first completed out of 25 contracted for with the U. S. government, was tested on Aug. 9 at Birdsboro, Pa. The contract calls for a muzzle velocity of not less than 2,600 ft. per second; with 300 rounds fired in the test with 55-lb. projectiles, and smokeless powder that will develop a chamber pressure not exceeding 40,000 lbs. per sq. in.; but the last five shots must have a sufficient charge to develop a pressure of from 45,000 to 50,000 lbs. The 300 rounds were successfully fired and the five high-pressure shots developed pressures of 46,000 to 49,000 lbs. The same company is under contract to make 25 6-in. guns of the same type.

◆

LAND VALUES IN THE CITY OF LONDON are high. A piece of ground at Nos. 90, 91 and 92 Fleet St., covering an area of 2,200 sq. ft., was lately let on a building lease for a ground rent of $8,500 per year, or about $3.87 per sq. ft. This represents an annual rental value of $168,577.20 per acre; but large as it is New York land values are still greater. In 1893, a lot 22½×64½ ft., at the corner of Broadway and Pine St.,New York, was sold outright for $400,000, or $286 per sq. ft. An acre of this land would cost $12,458,160. Within the same week another lot at Nassau and Pine Sts., 37×80 ft., sold for nearly $700,000, or at the rate of about $251 per sq.ft. In 1894 the American Surety Co., of New York, paid nearly $1,500,000 for a piece of land 85 ft. square, or at the rate of about $8,000,000 per acre. The Fleet St. lot in London, at 3½%, would represent a little over $100 per sq. ft., or $4,256,000 per acre.

◆

SPRUCE PULP FOR NEWS PAPER, and the extent to which it is consumed, is set forth in tabular form in the Boston "Transcript." From this table it appears that one cord of spruce wood, or 615 ft. B. M., will make one-half ton of sulphite pulp, or one ton of ground wood pulp. Newspaper stock is made up of 20% sulphite pulp and 80% of ground wood pulp. The best spruce lands, virgin growth, possess a "stand" of about 7,000 ft. B. M. to the acre; and 22 acres will therefore contain 154,000 ft. B. M. of timber. An average gang of loggers will cut this in eight days, and any large pulp-mill will convert this amount of timber in one day into about 250 tons of the class of paper pulp used in newspaper stock. This pulp will make about an equal weight of paper ready for the press, and this paper will be used up by a single large city newspaper in about two days.

◆

THE ROYAL INSTITUTION OF GREAT BRITAIN celebrated its centenary in June last. The institution was founded by Count Rumford in 1799, the purpose of the founder being the diffusion of knowledge and the facilitation of the general introduction of useful mechanical inventions and improvements of all kinds; courses of philosophical lectures were to be also held, treating of "the application of science to the common purposes of life." The first resident lecturer-in-chief was Dr. Thomas Garnett, who was succeeded in 1802 by Humphrey Davy. Under Davy the institution took on new life and became the home of scientific research; and his successors, Michael Faraday, Tyndall and the present incumbent, Professor Dewar, still further carried out this idea. But its founder was an American by birth, Benjamin Thompson, born in Woburn, Mass., in 1753. Thompson adhered to the King during the American Revolution; went to England, and in 1784 he entered the service of Bavaria and became Minster of War and a Count. He was devoted to science throughout his life, and made many experiments relating to the origin of heat, heat currents, fuel economy, etc.

◆

PUBLIC ROADS IN IRELAND are under the supervision of County Surveyors, who are selected after a rigid civil service examination. The total extent of roads under their supervision in 1895 was 53,064 miles, and the average cost of maintenance per mile was £12 9s. ($60). Labor costs, however, only 1s. 6d. to 2s. 6d (36 cts. to 60 cts.) per day. The total cost of supervision by the Surveyors and their assistants is only about 4¼% of the expenditure. The fund for the road repairs is raised by taxation and amounts to about 2% on the valuation. The average maintenance cost of the main roads is considerably higher, being set at £42 ($204) per mile. We take the above figures from a recent Institution of Civil Engineers' paper.

THE RELATION BETWEEN THE STRUCTURE OF STEEL AND ITS THERMAL AND MECHANICAL TREATMENT.[*]

By Albert Sauveur,[†] M. Am. Inst. M. E.

I. Changes of Structure Brought About by Heat Treatment.

The changes of structure, with their resulting changes of physical properties, brought about in carbon steel by heat treatment, may, I believe, be summarized in the following propositions:

I. When a piece of steel, hardened or unhardened, is heated to the temperature W,[‡] all previous crystallization, however coarse or however distorted by cold work, is obliterated and replaced by the finest structure which the metal is capable of assuming,[§] the structure of burnt steel, which cannot be effaced by such treatment, being the only exception.

II. When a piece of steel, hardened or unhardened, after being heated to the temperature W, is allowed to cool slowly, it retains the fine amorphous-like structure which it had acquired at that temperature. It possesses then the finest structure which unhardened steel is capable of assuming.

III. When a piece of steel, hardened or unhardened, after being heated to the temperature W, is suddenly cooled from that temperature, by quenching it in cold water for instance, it is fully hardened,[‖] and retains the fine amorphous-like structure acquired at that temperature. The metal possesses then the finest structure which hardened steel is capable of assuming.

IV. When a piece of steel, hardened or unhardened, is heated to a temperature above W and allowed to cool slowly and undisturbedly, the metal, whose crystallization had been obliterated by its passage through W, crystallizes again, the crystals or grains increasing in size until the temperature V is reached, below which there is no further growth. (See Appendix I.)

Corollary to III. and IV.—When a piece of steel, after being heated to a temperature above W, is allowed to cool to W and then quenched, it will be fully hardened, but its structure will be coarser than if it had been quenched from W without having been previously heated above that temperature. (See Appendix I.)

V. The higher the temperature above W from which the steel is allowed to cool undisturbedly, the larger the grains.

VI. The slower the cooling from a temperature above W, the larger the grains.

Corollary to V. and VI.—Pieces of steel finished at a temperature above W will have a coarser grain in those parts which have been finished hottest, and where subsequent cooling has been more gradual, i. e. the central portions, or portions further away from the cooling surfaces.

VII. When a piece of steel, hardened or unhardened, is heated to a temperature above W and suddenly cooled, it is fully hardened, but its structure will be coarser than when quenched after having been heated to W. (See Appendix I.)

VIII. When a piece of unhardened steel is heated to a temperature below W and quenched or slowly cooled from that temperature, no change takes place in its structure. (See Appendix II.)

IX. When a piece of hardened steel is heated to a temperature below W, some of its hardening carbon is changed spontaneously into cement carbon, and the metal is thereby softened. The tendency of the hardening carbon to pass into the cement condition increases with the temperature, and is the greatest at the temperature V. This transformation, however, is not accompanied by any change in the dimensions of the grains. (See Appendix III.)

These propositions are for the most part illustrated graphically in Fig. 1, in which I have adopted Brinell's mode of representation.

II. Changes of Structure Brought About by Work.

We must at the outset consider two kinds of work: hot work and cold work. By hot work I mean work performed above the critical range, i. e. above W; by cold work is meant work performed below the critical range, i. e. below V. The work done between V and W will be cold work if the temperature of the metal has just been raised from below V, and it will be hot work if its temperature has just been lowered from above W.

The effect of work upon the structure of steel may be summarized in the following propositions:

I. While steel is being worked it does not crystallize (provided, of course, the working of the metal is sufficiently vigorous to affect all parts of the mass).

II. Hot work as such has no influence upon the structure of the metal. Indirectly, however, by retarding crystallization until a lower temperature is reached, it may influence its structure most decidedly; but the same results could be accomplished by heat treatment alone, i. e. by reheating the unworked metal to the temperature from which the worked piece was allowed to cool undisturbedly.

Remark.—A certain amount of work is, of course, necessary to expel the slag, close blow-holes and other similar irregularities, and otherwise render the piece sound; but once this accomplished, further work will not improve the structure, except indirectly as stated above.

III. Cold work distorts the grains or crystals of steel, flattening them and elongating them in the direction of the forging or rolling.

IV. The lower the temperature the more pronounced the effect of cold working.

Remark.—The structural distortion caused by cold working, with its accompanying alterations of the physical properties of the metal, may be removed by heating the metal to W (see Proposition I.)

III. Conclusions.

From the above considerations, we may draw the following conclusions of industrial interest:

Finished Pieces of Unhardened Steel.—Since it seems to have been conclusively shown that the smaller the grains of the metal, the more ductile and tough it will be, it is evident that we should endeavor to impart such a structure to all finished pieces, and as the finest possible structure results from heating to W, we naturally infer that every finished piece of unhardened steel, in order to be in the best possible condition, should, as a last treatment, be heated to W.

While, for numerous reasons, such treatment cannot always be applied, being, indeed, in many instances, altogether impracticable, nevertheless manufacturers should endeavor to approach this desideratum as much as is consistent with other conditions and requirements of production. Forged or rolled pieces should be finished as near the temperature V as possible, since finishing them at a temperature much above V leads to the development of a coarse structure during subsequent undisturbed cooling, while if they be finished below V they will suffer from the effects of cold work.

The problem, however, is further greatly complicated

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[*] A paper read before the Iron & Steel Institute of Great Britain.

[†] 446 Tremont St., Boston, Mass.

[‡] In these propositions the letter V indicates the temperature at which hardening carbon is changed to cement carbon during the slow cooling of steel, a change which is accompanied by a retardation in the rate of cooling, indicating an evolution of heat, sometimes so considerable as to produce an actual rise of the sensible temperature, a recalescence, of the cooling metal. In other words V represents the temperature of the critcal point commonly known as the point of recalescence. The temperature V varies somewhat with the carbon content, being lowest in the most highly carburetted compounds. In medium hard and in hard steel it is generally situated between 625° and 700°C., and covers a range of some 20° to 30°. In very soft steel the transformation occurs at a higher temperature. In steel containing very little carbon it is, of course, hardly detectable, and is not found in carbonless iron.

The letter W indicates the temperature at which takes place the opposite phase of the same phenomenon, i. e. the passage of cement carbon into hardening carbon during the heating of steel, which transformation is accompanied by a retardation in the rate of heating, indicative of an absorption of heat. The temperature W is generally some 30° higher than V, and often covers a range of some 25°.

The symbols V and W, first proposed by Brinell, have been selected here in preference to Ar_1 and Ac_1, now more generally used, merely on account of their greater simplicity.

[§] It has been stated by Coffin that in the case of soft steel (containing 0.20% carbon) a single heating to W breaks up only partially a pre-existing coarse crystallization, a second reheating to that temperature being necessary to obliterate it altogether. This point should be further investigated.

Some steel castings also are said to require more than one heating to W to assume the finest possible structure.

[‖] It is evidently meant here, and in all similar references, that after heating to the above temperature, the steel under consideration will acquire all, or practically all, the hardening power which that particular steel is capable of assuming, no further increase of hardness resulting from quenching at a higher temperature. Its absolute degree of hardness will, of course, depend upon its carbon content, rate of cooling, and the presence of other impurities; in the case of the softest steels, the increase of hardness may be quite, if not altogether, inappreciable. Very low carbon steels, moreover, do not seem to acquire, in its entirety, during W, whatever hardening power they possess, it being necessary for that purpose to heat the metal to a higher temperature, i. e. pass the upper retardations.

by the fact that thick pieces cannot be finished at a temperature uniform throughout, the differences of temperature between the central portions and the outside increasing rapidly with the cross section of the piece. If it be finished at a temperature above V, the whole mass will begin to crystallize during subsequent cooling, but the interior, being hotter and cooling more slowly, will have a larger grain than the outside portion; the resulting structure will be far from uniform, and the physical properties of the finished piece in its various parts will also necessarily lack uniformity, as may be ascertained by testing specimens cut from different regions. If the outside or thinnest parts have reached V when the piece leaves the forge or the finishing rolls, the central portions may be considerably above that temperature, and may assume a coarse crystalline structure; while if the working be continued until the interior of the piece has reached the temperature V, the thinnest portions may be much below that temperature and suffer from the effects of cold working.[*]

Uniformity of structure (and therefore of physical properties) in all parts of a worked piece of steel, together with freedom and distortion caused by cold work, can only be secured by reheating throughout to the temperature W; and while such treatment, as already stated, is impracticable in many cases, besides necessitating the use of pyrometers, it remains true that with a clear understanding of the effect of heat treatment and of work upon the structure of the metal, each manufacturer has it in his power to improve the quality of its product.

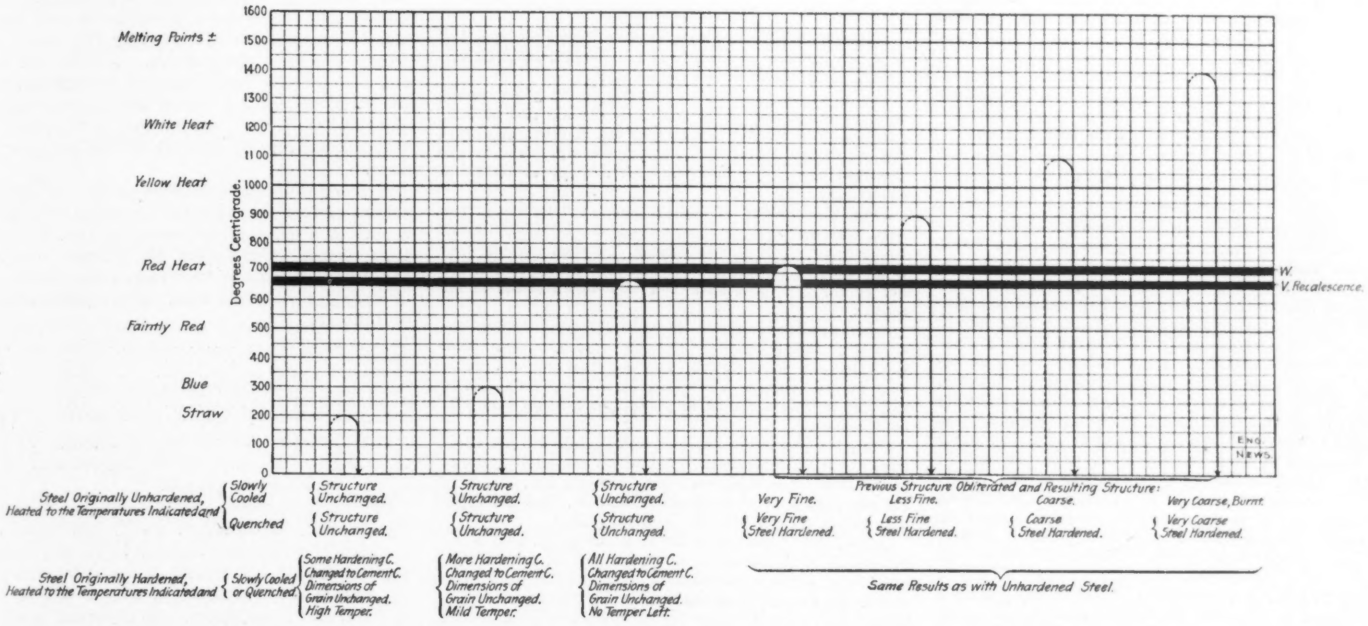

FIG. 1.—CHANGES OF MICROSTRUCTURE BROUGHT ABOUT IN STEEL BY HEAT TREATMENT.

In the manufacture of costly pieces of steel, when large outputs, necessitating the highest possible speed of production, is not the all-important and all-absorbing factor —in the production of armor-plates, for instance, and of expensive forgings—the metal may be treated on these scientific lines, and the highest efficiency secured.

Annealing.—There seems to be considerable difference of opinion with regard to the meaning of the term "annealing," and still more concerning the proper temperature to which the metal should be heated, and the conditions which should prevail during the operation. To the mind of some steel-workers, annealing conveys the idea of a mere heating to a temperature sometimes considerably below, and sometimes considerably above, W. For others it implies a prolonged heating at a temperature varying from barely red to a very bright red or even yellow heat. Some workers cool their steel very slowly in the annealing furnace; some more rapidly in the air; others still quench the metal after reheating to a dull red heat. Finally, the metal is heated in boxes or pipes with or without packing material, or it is heated in the open furnace without any protection.

In short, it is seen that any reheating, followed or not by slow cooling, whose aim is to soften the metal and increase its ductility, might quite properly be called annealing, for I see no sharp line of demarcation between tempering and annealing. Just where the softening and toughening operation should cease to be called tempering to assume the name of "annealing," can only be decided arbitrarily. Tempering should be considered as a species of annealing.

It is not the writer's desire to formulate any dogmatic rules which should be followed in carrying out this most important operation, but merely to inquire into the changes of physical properties which we desire to bring about in the annealing of steel, believing that such inquiry, together with our knowledge of the effect of heat treatment upon the structure of steel, should naturally lead us to the adoption of the most desirable treatment.

The changes in the physical condition of the metal which we desire to bring about by annealing are several in number, and of course depend upon the treatment to which the metal has been previously subjected. I believe that they may be summed up as follows:

I. Softening of the metal (decrease of its mineralogical hardness), by obliterating the increase of hardness conferred by previous hardening or by cold working.

II. Increase of ductility, by obliterating the brittleness caused by previous hardening or cold working, and also by cooling stresses (which always occur during the cooling of large castings or forgings from a high temperature).

III. Obliteration of coarse crystallization caused by a previous undisturbed cooling from a temperature higher than W, and of structural distortion produced by cold working, imparting to the metal the finest possible structure which it is capable of assuming.

In short, in annealing steel our purpose is to render the metal as soft, tough, and ductile as possible, and to do so by decreasing the elastic limit and tensile strength only of such, so to speak, abnormal increments, as were acquired through hardening and cold working.

From our previous considerations it is evident that to accomplish this in the most effective manner the metal should be reheated throughout to W, and slowly cooled from that temperature, maintaining it a sufficient length of time at the temperature V to assure a complete change of the hardening carbon into cement carbon. By heating the metal to W all previous coarse crystallization or distortion is obliterated and replaced by the finest possible structure. In cooling slowly through the V range, its hardening carbon passes back into cement carbon, but as the complete transformation requires time, it is desirable to keep the metal for some time at that temperature. After such treatment the steel will undoubtedly be in its softest and most ductile condition.

The writer is well aware that the above conclusions are somewhat at variance with those of Brinell, who advises heating to V in annealing steel. As already stated, the writer finds that reheating to V for a sufficient length of time will cause all the hardening carbon that may be present in the steel to be changed into cement carbon; it may possibly also remove all cooling stresses, so that such treatment undoubtedly greatly increases the softness and ductility of the metal. It does not, however, impart to it as fine a micro-grain as it is capable of assuming, and consequently the metal, after being reheated to V, does not possess all the ductility that could be its own.[*]

Hardening and Tempering.—It is almost superfluous to state here, that in order to harden steel, and at the same time preserve the best structural arrangement, the metal should be heated to W and then quenched, without allowing the temperature to rise above W. This rule is quite universally followed, and although smiths seldom use pyrometers, some of them become such experts in judging the temperature of the metal by the color, that it is probable that the majority of their pieces are, at the instant of quenching, very near W indeed, or at the refining temperature, as they properly call it.

The temperature of tempering is also very universally regulated by the color of the metal, and generally with great skill and accuracy.

The use of pyrometers in connection with the hardening and tempering of steel should nevertheless be commended, as it removes all uncertainty, secures uniformity of treatment, and may be the means of avoiding the destruction in the quenching bath of many costly pieces.

It is customary, the writer believes, to quench the metal (merely for convenience?) after it has been heated to the proper temperature for tempering, instead of allowing it to cool slowly from that temperature. It is, however, probable that, if it be left to cool slowly, its softness will increase, since the change of hardening carbon into cement carbon, which is arrested by the sudden cooling, will continue a while longer, at any rate, if the steel be slowly cooled.

Appendix.

The fact that all crystallization previously existing in the metal is obliterated during the change occurring at W has been repeatedly demonstrated, and, so far as I know, is not contested by any metallurgist. It is also admitted by all, I think, that steel crystallizes while cooling from a temperature above W. There is, however, a widespread belief that the metal does not retain, until the cooling begins, the fine amorphous-like structure acquired at W, but on the contrary begins to crystallize immediately after the temperature W is passed, and continues to do so while its temperature is rising. This view is held by such eminent metallurgists as J. A. Brinell and H. M. Howe; while D. Tschernoff, on the other hand, took the stand, long ago, that steel does not crystallize while its temperature is rising.

The statement that steel does crystallize while its temperature is rising is certainly opposed to the very nature of crystallization, and on that account we should naturally feel reluctant to accept it without more conclusive evidence. Steel above the critical range has often been likened, and on very good grounds, to a solution—a solid solution, of course. The crystallization of a solid solution, as well as of a liquid solution, consists in the crystallization or segregation of its structural components taking place at certain temperatures and in a certain order. Can the constituents of a liquid solution crystallize—in other words, can a solution solidify when its temperature is rising? The supposition is evidently absurd. Can the structural components of a solid solution segregate, then, on a rising temperature? Does not the same laws apply in both cases? Is not a falling temperature a necessary condition to the formation of crystals? During undisturbed cooling cohesive attraction, the force to which crystals owe their formation, acts powerfully, causing them to grow,

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[*] A familiar instance of such heterogeneousness of structure is found in steel rails whose structure frequently reveals the fact that the web and extremities of the flange have suffered from cold work, while the center of the head exhibits a well-developed crystalline structure, indicative of undisturbed cooling from a temperature above W.

[*] If the steel has just previously been heated to W, then, of course, reheating to V (for the purpose of removing hardening carbon) will be sufficient to render the metal as soft and ductile as possible.

while during heating cohesive attraction is opposed more and more by the rising temperature. Is there a single instance of a solution, or for that matter of any substance, crystallizing while its temperature is rising?

The contention that steel does crystallize above W, while its temperature is rising, is based upon the fact that when a piece of steel is quenched at a temperature above W its structure will be the coarser the higher the quenching temperature—from which it is inferred that its grains must have grown during the heating previous to quenching. It should be remembered, however, that it takes an appreciable time for a piece of steel, especially for its central portions, to cool to V. If the piece be large, the length of time required will be very considerable indeed, and may be such that its centre will not be hardened at all. Has not the growth of the resulting grains taken place during the cooling of the mass, however rapid, rather than during its heating, seeing that the cooling is far from being sudden and increases in length very rapidly with the cross-section of the quenched piece? I find that the larger the cross-section of the piece, the larger will be its grains (because the slower the cooling?), while if the latter had formed during heating there should be, it would seem, little difference in structure between a large and a small sample, unless indeed it be argued, as it reasonably might, that the larger grain of the larger piece is due to the slower heating of that piece.

It has not, however, by any means been shown that if the cooling from a high temperature could be sufficiently sudden the structure would not be as free from coarse crystallization as if it had been quenched upon reaching W.

Although I am inclined to share Professor Tschernoff's view, I frankly admit that no conclusive evidences have been presented on either side, and it is to be hoped that this question will soon be definitely elucidated.

If it should be shown beyond doubt that steel does indeed crystallize on a rising temperature, the phenomenon could not, I think, properly be called crystallization—granulation would probably be a more correct term.

I hope to be able shortly to present some further experimental evidence bearing upon this point.

Appendix II.

In Proposition VIII. it is stated that when a piece of unhardened steel is heated to a temperature below W its structure remains unchanged. Mr. Stead, however, has shown, in a recent and very important paper,* that when a piece of iron or of very soft steel is subjected to a prolonged heating at a temperature between 600° and 750° C. (therefore below W) its structure becomes coarsely crystalline. Here we apparently meet, therefore, with an exception to our proposition. It should be noted, however, that it is only the softest brands of steel whose structure is thus altered at a temperature below W. Mr. Stead has repeatedly failed to produce a change of structure under such condition in steel containing over 0.20 per cent. of carbon. Indeed, in the experiments which he describes, I find no instance of a coarse crystallization having been produced below W in steel containing over 0.11 per cent. of carbon. The exception is therefore apparently confined to a very narrow range of the carbon steel series. It should also be remembered that a prolonged heating is required in order to produce this growth of the grains; a mere heating to a temperature below W leaves the structure of this nearly carbonless iron unaltered.

The metal which Mr. Stead finds to crystallize below W is practically a mass of ferrite, and he has thus demonstrated that when ferrite is heated for a long time at a temperature between 600° and 750° C., it develops a coarse crystallization, or perhaps more properly, granulation. There is no apparent reason to suppose that ferrite will not always crystallize in this way, when subjected to such treatment, whatever the carbon content of the steel. The amount of ferrite present in steel, however, rapidly diminishes with increase of carbon. Steel containing over 0.80 per cent. of carbon does not contain any ferrite, and should therefore remain, as it does, unaffected when submitted to the above treatment. Steel containing less than 0.80 per cent. of carbon is made up of grains of pearlyte surrounded by membranes of ferrite. The coarse crystallization of these membranes of ferrite, supposing that it does occur below W, does not alter the dimensions of the grains of the metal, and has probably little, if any, influence upon its physical properties. Iron and very low carbon steel, on the contrary, are made up of grains of ferrite, and a coarse crystallization, or a change of structure of this constituent, means corresponding changes in the structure of the metal itself. This appears to be the explanation of the notable difference, shown by Mr. Stead, between the behavior of carbonless or slightly carburetted iron and more highly carburetted steel, when subjected to the thermal treatment described above.

Finally, it should also be noted that the alteration of the structure of ferrite requires time, while the obliteration of the structure assumed by pearlyte appears to be dependent only upon the proper degree of heat (W), and takes place simultaneously with the passage of its carbon from the cement to the hardening state.

Appendix III.

In his most valuable chart showing the changes of fractures brought about by heat treatment in steel containing 0.75 per cent. of carbon, Mr. Brinell states that if a piece of steel which has been hardened above W, and which has, therefore, a coarse structure, be reheated to V, and maintained at that temperature for a sufficient length of time, all its hardening carbon will be changed into cement carbon, and its structure will be as fine as if the piece had been reheated to W.

The microscopical examination of a limited number of samples of steel subjected to the above treatment appears to oppose the second portion of Mr. Brinell's proposition, for while the writer finds that a prolonged reheating at V causes practically the whole of the carbon to pass back into the cement state, the size of the grains of the metal seems to remain unaltered. The carbon change appears to take place in situ, within each individual grain, without affecting its dimensions. It is the writer's intention to examine a larger number of specimens containing various amounts of carbon and reheated to V, for different lengths of time, and he hopes that his remarks will induce others to investigate the question.

Mr. Brinell, the writer thinks, based his propositions upon the appearance of the fracture, not of the microstructure, and, judged by its fracture, the annealed metal may appear to have a smaller grain, because the fracture of the grains of pearlyte, as produced by this tempering process, may be finer and more silky than that of the martensite grains resulting from quenching at a temperature above W, although the micro-grains would in both cases have the same dimensions.

Correspondence.

Professor Henry M. Howe, of New York city, who had read Mr. A. Sauveur's paper in manuscript, sent the following contribution to the discussion:

The question, "Can the coarsening of the grain, structure, or crystallization of iron occur during rise of temperature (i. e. during heating), or can it occur only during fall of temperature (i. e. during cooling)?" can be approached either by reasoning from analogy or by direct observation.

From the analogy of certain aqueous solutions it has been reasoned that this coarsening cannot occur during heating, but only during cooling. Without saying that this reasoning is untenable, I will merely say that it has not so far been presented in a way which seems to me cogent.

From aqueous solutions in general crystallization occurs only during cooling, because crystallization from them implies solidification, and solidification can occur only during cooling. Reasoning by analogy from this to the case of iron must be very cautious for two very evident reasons.

First, hot iron is not an aqueous, not even a liquid solution, but a solid solution. That which prevents crystallization in aqueous solutions during heating, viz., that they are not solid and hence cannot crystallize, does not apply here at all, for the hot iron is already solid.

Second, the coarsening of the structure of hot iron is not the setting in or beginning of crystallization, not the passage from a non-crystalline to a crystalline state, but merely the passage from one state of crystallization to another. We refine the structure by heating to E; it is then fine crystalline. If on further heating, say to V, 1,400° C., its structure coarsens, that does not imply that crystallization sets in during rise of temperature, or that iron has passed from a non-crystalline to a crystalline state, but that its crystallization has simply changed. Now the premise that crystallization cannot (as in an aqueous solution) begin, set in, orignate, during rise of temperature, does not imply that if (as in hot iron) it already exists, it cannot change during rise of temperature.

I frame this objection to the reasoning from analogy, with the wish to show wherein this reasoning seems to lack cogency, so as to offer an opportunity to supply this lack.

Turning now to direct observation, I heated a bar of steel very rapidly to a bright white heat. I am confident that during this heating the temperature was at all times rising. I quenched it in cold water very quickly; I found the grain excessively coarse. You tell me that this coarsening of grain did not occur during my rise of temperature, but during the two or three seconds which elapsed between the instant when my bar left the furnace and the instant when it had become too cold to change farther. My answer to this is twofold.

First, if your contention is true, certainly the inside of the bar, which must have cooled much more slowly than the outside, ought to be correspondingly coarser than the outside. In the experiments which I have made, I did not with the eye find this difference. But further trials of this are needed.

Second, assuming that my observations were sufficient, the only escape from the inference that the coarsening occurred during rise of temperature would be, that it occurs so extremely fast during fall of temperature as to complete itself even in the very rapid cooling of the outside of the bar. To say this, however, deprives your contention of industrial importance. For if the coarsening during fall of temperature is so extremely rapid that it can complete itself and reach the great coarseness corresponding to a bright whiteness in the very brief time occupied by the cooling of the outside of a bar ¼-inch thick, the effect is the same for all industrial purposes as if the coarsening had occurred during the rise of temperature.

The following experiment further indicated that coarsening occurs during rise of temperature. A bar was nicked across its middle, was heated to bright whiteness, was struck violently on one-half of the nick, and was immediately quenched. When now broken at the nick, the part not struck was very coarsely crystalline, but the part struck was finely crystalline. This at least strongly suggests that the coarsening had occurred during heating; that the blow had broken up the coarse grain on one side of the bar, and that this coarse grain had not had time to re-form during the cooling. This certainly goes to show that the growth during cooling is not so extraordinarily rapid, and hence to show that the coarsening of my first bar, simply heated white hot and immediately quenched, could not have had time to occur during that brief cooling, and hence must have occurred during heating. The experiment, however, is not conclusive, but I have started others which I hope will be. I should have delayed writing on this subject had not Mr. Sauveur's remarks offered an opportunity which it seemed best to accept.

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*"Journal of the Iron and Steel Institute," 1898, I. and II.; "The Metallographist," October, 1898, and April, 1899.

THE DUTY OF THE INDIANAPOLIS PUMPING ENGINE.

In our issue of Sept. 29, 1898, we published a report of a test by Prof. W. F. M. Goss, M. Am. Soc. M. E., of Purdue University, upon a 20,000,000-gallon triple-expansion pumping engine, built for the Indianapolis Water Co., by the Snow Steam Pump Works, of Buffalo, N. Y. This test showed the remarkably high duty of 167,800,000 ft.-lbs. per 1,000 lbs. of dry steam used in the engine, or 150,100,000 ft.-lbs. per million heat units. The steam consumption was 11.26 lbs. per I. HP. per hour.

A pamphlet has just been issued in which the report of this test is given in detail, and also the report of a second test made on Dec. 3, 1898, for the purpose of checking the results obtained in the first test. This second test gave results closely agreeing with the first. A comparison is given as follows:

Date of test	July 8.	Dec. 3.
Indicated HP.	715.5	782.9
Steam per I. HP. per hr., lbs.	11.26	11.38
B. T. U. per I. HP. per minute	209.7	209.9
Friction, % of I. HP.	4.6	6.2
Duty, per million B. T. U.	150.1	147.5

The difference in friction is thought to be due to a slight difference in the adjustment of some of the stuffing-box glands.

The pamphlet claims this engine to rank as the highest duty engine ever built; but while it undoubtedly broke the record, it is now eclipsed, apparently, by the record of the Nordberg pumping engine, at Wilkinsburg, Pa., a test of which, by Prof. R. C. Carpenter, was reported in our issue of May 4, 1899. This engine developed a duty of 162,948,824 ft.-lbs. per million B. T. U. in the steam delivered to it. It is a quadruple-expansion engine, working with 50 lbs. higher steam pressure than the Indianapolis machine and pumping against a head over three times as great, all of which circumstances are favorable to a higher economy.

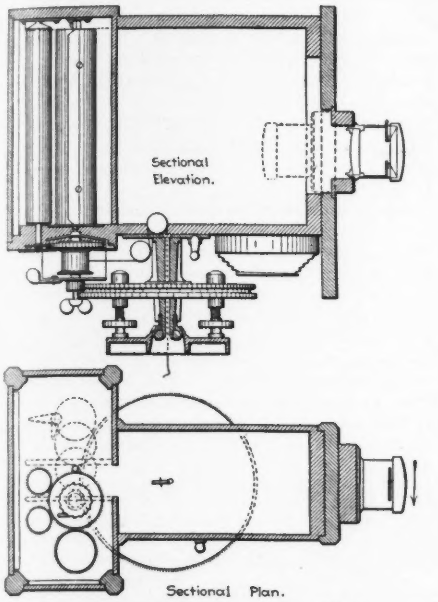
Copies of the pamphlet can be obtained from the Snow Steam Pump Co., of Buffalo, N. Y., on request.

A REVOLVING CAMERA FOR SURVEYING PURPOSES.

In using photographs for extended or panoramic views, as required for surveying purposes, considerable trouble and liability to error arises from the necessity of joining prints from different plates, made by different exposures, and there is considerable inconvenience attending the use of the tangent scale. To overcome these difficulties, as well as that due to the movement of the film, a revolving camera has been devised by Mr. G. W. Pearsons, M. Am. Soc. C. E., of Kansas City, Mo.

The instrument, which is shown diagrammatically in the accompanying cut, is mounted upon a tripod and revolves like a transit. The exposure is made during its revolution, which is controlled by clockwork, and occupies from 1½ to 2 minutes for a complete revolution. It will be seen that the lens and film both move, and as their movement is uniform, all horizontal angles are given without tangential measurement. The degrees are also photographed on the sky line of the film, so that any shrinkage of the film in developing does not affect the accuracy of the measurements. The sky line also makes a place of reference for the vertical tangential measurements.

The roll of film is placed in a compartment at the back of the camera box, and the strip passes across the narrow opening, through which light is admitted from the lens, to a winding roller on the opposite side of the compartment. By means of the gearing, the film is given a motion parallel to that of the lens, but in the opposite direction. The winding roller is held to its spindle by friction, and the movement of the film is governed by a pair of friction rollers, which make its motion uniform. A small wheel marked with notches corresponding to the degrees passed over, photographs the degrees on the film, as already noted, and as the exposure lasts only about 1° no effect of parallax is shown on the print.



Revolving Camera for Survey Work.
G. W. Pearsons, M. Am. Soc. C. E., Inventor.

The instrument is about 12 ins. high, 12 ins. long and 8 ins. inside, weighing about 12 lbs., and is intended to be used on the tripod of a transit. It uses any width of film up to 6½ ins., and any length of picture can be taken, from an arc of 1° to a full circle. The gearing is driven by means of a small weight attached to the cord, which passes round a drum on the roller spindle and down through the pivot of the instrument.

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THE CORRESPONDENCE SCHOOL IN TECHNICAL EDUCATION.[*]

By Edgar Marburg,[†] M. Am. Soc. C. E.

At the last annual meeting of this Society, the retiring President, in a thoughtful, far-seeing address[‡], brought us face to face with certain serious gaps in our educational system. It was shown that, except for insignificant beginnings, here and there, no provision had been made for the specific training of our youth for industrial and commercial pursuits. Our own shortcomings were revealed the more strikingly on the background of Germany's achievements. That nation's phenomenal strides, during the past quarter century, towards a commanding position in manufactures and in commerce was attributed primarily to its elaborate system of monotechnic and commercial schools, of which, as has been said, no counterpart is to be found in this country.

With us the opinion is yet too widely prevalent that such elementary liberal education as may be had in the grammar, or at most the high school, is all-sufficient for young men destined for the trades and industries or for commercial life—that the special training peculiar to each particular vocation can be best acquired in actual service. The soundness of this proposition, within limits, is of course conceded. School processes, however, carefully perfected, will never cease to have their limitations. Their highest function, after all, is to endow the individual, as well as may be, with the potentialities of after-development. To look for an output of accomplished financiers, business men, artisans or industrial foremen, straight from the schools, were as preposterous in its way as to expect similar results from our professional departments. On the other hand, barring the great field of common, unskilled labor, there is scarcely a human calling so lowly but that its horizon might be broadened, its inherent dignity developed, its usefulness to society augmented, and the individual interests of its followers immeasurably promoted, if our present loose and narrow courses of apprenticeship were to yield to a well-ordered system of specialized instruction, in which the scientific and practical elements are suitably blended.

That such a change must come about in the United States, as it has in Germany, probably few thoughtful men, at all familiar with the situation, will seriously question. It would betoken small faith in the progressive spirit of our nation to hold otherwise. But while Germany's achievements serve as inspiring object-lessons, the social conditions in this country are so essentially different, that the problem presents itself to us in an entirely new phase. Its final solution must be of a kind not only best adapted to our own peculiar needs, but in best consonance with our school-systems, our political and industrial institutions, and the general traditions of our people.

A tremendous amount of agitation will be needed for the successful inauguration of so great a movement. It is to be hoped that the suggestion made last year that this Society should assume the initiative in this matter will not prove to have fallen on barren ground. In the educational campaign which will have to be directed against our trade and commercial organizations, and our legislative bodies, the first concern will be to impress upon them the reality of the need we set ourselves to advocate. To most men of average information the statement that we are falling far short of Germany in preparedness for assuming a leading hand in the world's industrial affairs will come as a revelation and much scepticism will have to be silenced by argument. Overweening faith in the resourcefulness of this country and in the genius of its people is characteristic of Americanism. But self-confidence, however admirable a trait in nations as in individuals, carries with it the constant danger of merging into self-sufficiency, than which there can be no greater bar to sustained advancement.

While America has time and again triumphed against signal odds, through expedients improvised to suit the means and the occasion, it were a fatal delusion to assume that forces can be created over night to cope successfully with the gigantic industrial movement to which Germany has lent its best thought and energies for the past three or four decades. Patient, painstaking effort in the furtherance of a carefully conceived, broad and enlightened policy can alone accomplish for our nation what has been attained by like measures for another.

In the meantime there has arisen among us, in the correspondence schools, an educational movement whose remarkable headway must be attributed in no small measure to the existence of those very gaps in our regular system to which reference has been made. Sprung from seemingly insignificant beginnings, some ten years since, its growth, notably during the past two or three years, has been little less than phenomenal. It is a significant fact that the correspondence schools have found their largest following among our technical workers, especially those of our shops and factories. Thus a single institution devoted principally to engineering and the mechanic arts claims a total enrolment of upwards of eighty thousand students, a number four times greater than that of only two years ago. Whatever the merit of the system, these figures bear striking evidence that our craftsmen are keenly alive to the defects in their education and are grasping eagerly at such opportunities as present themselves. In most cases there exists only the single other alternative of self-instruction. Night-schools in which technical courses are offered, are to be found only in a few of our most populous cities. Besides, their disadvantages are such that they have not come into much favor.

An inquiry as to the probable efficiency of the correspondence system becomes thus a matter of considerable interest. Is the scheme to be regarded simply as a passing fad, or does it contain the elements of real merit and permanency? Are these schools attracting their immense patronage under false pretenses, or are they engaged in a worthy and successful effort to give their students generous returns on their investment? And, finally, does the general plan give promise of such possibilities that, in its higher development, it may be expected to yield even a fair approach to what has been realized abroad by German methods?

Before attempting to suggest an answer to these and similar questions, more especially with reference to the technical correspondence schools, certain considerations relating to such institutions in general deserve to be briefly noticed.

Among our regular seats of learning, but two, namely the University of Chicago and the Illinois Wesleyan University, have entered the fields of correspondence teaching. The other institutions engaged in this work were organized and are conducted primarily, if not solely, as money-making enterprises. Their general policy is determined largely by this circumstance. It also serves to render an accurate and searching investigation difficult, if not impossible. The competition for students is already very keen. Statistics of the kind freely published by our regular schools are either withheld on grounds of business expediency, or, where furnished, cannot always be accepted with confidence. From their own circulars, it appears that the various schools view each other with the utmost distrust, and open charges of a serious character are not infrequently passed. Their advertising methods in general are not calculated to inspire confidence, or to command respect. Ingenuity is fairly exhausted in the attractive wording of their circulars. Clap-trap schemes of the most transparent nature are resorted to with a view of attracting students. Thus one school quotes its own advertisements as opinions of the press. A postal card addressed to another with the simple request for a catalogue elicited the usual pseudo-personal, typewritten circular containing the lines: "We judge, from an intimation discernable in your letter, that you have a will as well as a gift for success." The schools vie with each other in their offers of special inducements for immediate enrolment. Their disinterested anxiety to enlist patrons before the date of an impending advance in tuition fees is quite remarkable. Testimonials and photographs of graduates are prominently paraded. On the other hand a complete list of students or graduates is not permitted to appear.

In an endeavor at an impartial inquiry, one has constantly to remind himself that these matters have no direst bearing on the subject proper, namely the intrinsic value of the instruction itself. However, tactics of the kind described tend inevitably to give rise to prejudice and distrust. Nor does it serve to lessen one's scepticism to be informed, that even such subjects as music and art can be successfully taught by correspondence. There remains, in fact, scarcely an important field of learning that these schools have not confidently invaded.

That the correspondence scheme throws the doors wide open to charlatanism cannot be denied, nor can it be questioned that the opportunities it offers for illegitimate practices have been freely exploited. Some of these irresponsible concerns have already closed their doors, to the possible gain of their patrons. Others have sprung up in their place whose existence will doubtless prove no less ephemeral. That the general interests of the cause suffer in proportion goes without saying. As with commercial enterprises in general, probably only a few of the fittest are destined to survive. It would seem, however, that the time has come when the financial responsibility of these schools should be made the subject of official inquiry, as in the case of other institutions organized for the receipt of moneys upon the promise of future returns. Without some reasonable guarantee of good faith in the discharge of prospective obligations, the use of the mails should be interdicted.

Referring now to the technical schools in particular, the writer has, by visits and otherwise, made as critical an investigation of their methods as circumstances permitted. Generally speaking, their scheme of operation is essentially the same. Instruction papers, especially prepared for the purpose, take the place of the usual text-books. These are issued of a size convenient for the pocket. The student is pledged not to allow others to share in their use. The papers on any given subject are furnished collectively in book-form at the beginning or end of the course. Each instruction paper is accompanied by an examination paper containing the questions which the student is required to answer. These answers are promptly and carefully corrected. The writer has seen ample evidence that at the better schools this important feature receives close, painstaking attention. A final examination is usually prescribed at the end of the course. The award is commonly in the form of a certificate of study or of proficiency. A single institution confers the regular degrees. To the latter practice reference will be made hereafter.

The tuition fees are moderate, in fact, lower than the average cost of text-books in the regular technical schools. The charges on the installment plan are relatively much higher. The other expenses are for a drawing outfit, paper and postage in one direction. A paid-up scholarship is non-forfeitable. Its holder may consume as much or as little time as he elects for the completion of his course. The unused portion of the scholarship is transferable at the option of the owner. In short, the financial policy in general is quite liberal to the student.

The only educational requisites are a knowledge of reading and writing. The courses in pure mathematics begin with arithmetic and end with trigonometry. The instruction papers on technical subjects are usually prepared by graduate engineers, sometimes men of considerable ability and practical experience, but not always connected with the schools. Such men also exercise a general supervision of the correspondence in their respective specialties. The ordinary routine of correcting papers and of letter-writing is entrusted to lower-salaried assist-

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[*] A paper read at the annual meeting of the Society for the Promotion of Engineering Education.

[†] Professor of Civil Engineering, University of Pennsylvania, Philadelphia, Pa.

[‡] Prof. J. B. Johnson on "A Higher Industrial and Commercial Education," Eng. News, Aug. 18, 1899.

ants, often young women especially trained for these duties. Such correspondence is reviewed by some one in higher authority, and, if necessary, revised before forwarding. Communications are written, as a rule, by hand, rather than by mechanical means. This practice, while entailing a considerably greater outlay, seems to appeal to a certain student-element, as more distinctly personal and serves to allay suspicion that the methods are in any way stereotyped. In the better schools, the administrative details in general are thoroughly systematized and all operations conducted with business-like regularity and dispatch.

That the net influence of these schools is for good does not seem to admit of a reasonable doubt. They are extending a helpful hand to large numbers of aspiring people who have not the remotest prospect of gaining better advantages through the regular channels. They hold out opportunities of greater promise than can be looked for from average efforts at self-instruction.

Such adverse criticisms as suggest themselves are applicable in part to certain practices of the schools and in part to defects inherent in the correspondence system. The distinction is, however, not always easily drawn.

Since the schools are operated primarily for revenue, it is directly to their interest to appeal to the largest numbers. The curriculum is, therefore, designed to include the most elementary subjects. These may be omitted by students who pass the preliminary examinations. However, the statistics of one of the leading schools indicate that less than ten per cent. of the applicants can meet the requirements in arithmetic. Thus there is the necessity on the one hand of beginning with the most elementary studies and on the other of not wearying the student with an excessive amount of preparatory work before entering upon the technical courses proper. The compromise appears in narrow, short-cut courses. It carries with it also the omission of analytic geometry and the calculus. The effect of all this on the more advanced courses is easily conjectured. The more difficult features of a subject are suppressed or treated in a superficial manner. Important formulas that cannot be passed unnoticed are sometimes presented without a hint as to their derivation or their practical limitations.

Through the courtesy of certain schools the writer has had the opportunity of examining complete files of their instruction papers. In point of general make-up, that is paper, typography, illustrating and indexing they are superior to many modern text-books. The excellence of the illustrations is an especially praiseworthy feature. In fact, it may be said that they are of a profusion and elaborateness not always in keeping with the context. Upon closer scrutiny one's impressions are apt to be less favorable than after the first cursory examination. However, on the whole, the texts are written with much care and discrimination. It is readily seen that the author's task is by no means an easy one. The texts must be concise and at the same time veritable models of clearness. The mathematical work must be reduced to the simplest form, inadequate, though it may be, for the purpose in view. General forms of treatment must yield to the presentation of simple, special cases. As a partial offset to these deficiencies, and presumably with an eye to the demands of their peculiar constituency, there is an evident effort to give the studies as practical a trend as possible. In certain subjects a good deal of valuable information is given of a kind not ordinarily found in text-books. In point of thoroughness and general excellence, the courses on the whole are, however, in no wise comparable with those offered in the regular technical schools. It is, of course, only reasonable to assume that since the field is comparatively new, the methods are as yet somewhat tentative. Nevertheless, for reasons previously suggested, there appears to be little prospect of any substantial gain in thoroughness without raising the matriculation requirements to a standard that would usually prove prohibitive. Perhaps the solution will eventually be found in graded courses. In fact some beginnings in that direction are already discernable.

In the meantime, it may be fairly charged that the schools are far too pretentious in their claims. Without attempting to particularize, the evidence in this respect is unmistakable. Engineering instruction of a truly professional standard is not carried on by any of these institutions. Be it said, however, to the credit of the technical schools that there is but one of their number which presumes to confer the regular degrees. This school claims to have received its authority by law. Its home is in the District of Columbia. It has the arrogant assurance to proclaim that the holder of its degree "will be equipped with all the theoretical knowledge that is required for the same degree in any college in the country." The courses prescribed for the degree of C. E., are Surveying, Mapping, Railway and Structural Engineering, and so-called Higher Mathematics. What is meant by the latter term can only be vaguely inferred from the published statement that "in this course the more complicated and difficult questions of the subject are taken up"; and again "the instruction of the regular courses prepares the student to understand these more abstruse matters." Inconsistently enough, the prescribed courses in engineering require no knowledge of mathematics beyond trigonometry. Further comment appears superfluous.

Another practice of certain schools which seems deserving of strong censure is that of furnishing complete keys to those who profess to find the work too difficult. At least one school issues these keys indiscriminately to all, and claims that "if employed judiciously they can be made to save both time and labor, without injury to the student." Beyond some words of caution against their use, in other than cases of assumed necessity, the matter is left purely to the discretion of the student. One school which supplies such aids makes the naive claim, quoted verbatim, that "every student who has enrolled with us has successfully graduated from our schools." Let it be presumed that the term "student" is here meant in the somewhat exclusive sense of "one devoted to study."

It should, in fairness, be observed that as a rule these institutions do not claim to stand on an equal plane with the regular schools. On the contrary, in some instances they go so far as to advise persons who have the time and means, to obtain a college education. This is followed, however, by the most unqualified and extravagant assertions in proof of the superiority of the correspondence system and particular stress is laid on the claim that in their courses nothing of any real practical value is omitted, but that all so-called useless matter is eliminated. The effect of this is especially harmful in so far as it serves to imbue prospective students with the notion that the day is passed for making great efforts and sacrifices with a view to gaining a thorough and well-rounded education by the older methods. This tendency of diverting students from the regular technical schools, is perhaps more than neutralized by the stimulus given to technical education generally among the many who would not have been reached by other means.

In general the schools place much dependence on the ofttimes glowing testimonials of those who have come under their instruction. Without discrediting the authenticity of such evidence it may be properly insisted that it is entitled to little weight. It comes as the testimony of individuals just emerging from darkness into half-light. Their horizon is too narrow for accurate orientation.

In an attempt at gaging the probable influence of these schools, the criterion of numbers is no less misleading. Where thousands enroll, but few graduate. To complete the more extensive courses, elementary though they are, requires a degree of perseverance and self-denial in the utilization of spare moments that few can muster. It is to be remembered that the students, as a rule, are employed at regular vocations. Through seductive advertising literature and the personal solicitation of agents many are persuaded to enlist without any adequate conception of the sacrifices afterwards involved. According to statistics kindly furnished by one of the leading schools, of a thousand persons who entered upon a certain course four years ago, on the average, thirty per cent. have not yet finished arithmetic, another forty, that is a total of seventy per cent., have completed no subject beyond arithmetic, and only one-half of one per cent., or five persons have graduated.

To sum the matter up, it is believed that any attempt at giving by the correspondence methods, a really thorough education to persons who at the same time follow their daily occupations must end in failure. Narrow and shallow courses, of the kind described, may be regarded as the inevitable issue. It should, however, again be emphasized that in the absence of better means, and in so far as these schools are honestly conducted, they hold out opportunities to the many, and rewards to the few, well worth the effort of attainment. And, in conclusion, their highest destiny will have been achieved if by their coming they shall but quicken the birth of a system of popular education—industrial and commercial—worthy, in every sense, of this great nation.

SOFT MUD EXCAVATING AT KEYHAM DOCKYARD, PLYMOUTH, ENGLAND.

In a late paper submitted to the Institution of Mechanical Engineers of England, Mr. Whately Eliot describes the mechanical appliances employed in the construction of the Keyham dockyard extension works at Plymouth. These works cover 113 acres, of which 78 acres are below high-tide mark, with a tidal rise of 15½ ft. The material to be excavated was made ground, mud and rock; but it is in the removal of the soft mud alone that apparatus of especial novelty was employed, and an abstract is made of this portion of the paper.

This mud was of two qualities; the hard mud, upon which rubble had been tipped in former years, was consequently compressed until it had assumed the nature of stiff clay; it was under the made ground referred to, and it was excavated by hand labor or by steam excavators. The soft mud was that which had remained uncovered and exposed to the tidal action. There was a large quantity of this latter class of material; it was at first removed by the mud-scoops here illustrated.

The scoops were hauled over the site of the dock by engines placed on each side of the site. The outside engines were 40 HP. each, and were fixed at the end of an elevated stage from which the mud was discharged into barges and carried out to sea. The inside engines were 20 HP., and they were fixed upon travellers which could be moved back and forth so as to direct the travel of the scoop as desired. The scoop was hauled directly over the mud and filled itself, the depth of the entrance of the cutting edge into the mud being regulated by the arrangement of the hauling chains. These chains were attached to the front and back of the scoop; those at A could be shortened by winding about the bar B, to which they were attached, and this shortening of the back chains tilted the scoop forward and caused the cutting-edge, C, to assume the position shown in Fig. 1.

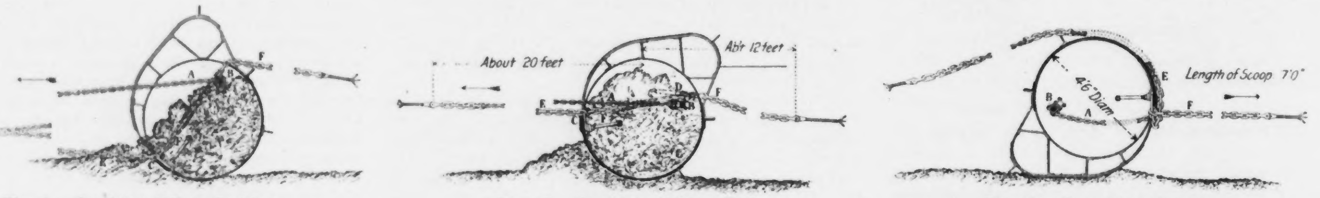

Fig. 1.—Position When Cutting.

Fig. 2.—Position When Full.

Fig. 3.—Returning Empty.

EXCAVATING BUCKET FOR SOFT MUD, USED AT KEYHAM DOCKYARD WORKS.

When the scoop was filled a catch, D, holding the rod, B, was knocked out; the back-chain at once lengthened, and the cutting-edge, C, was lifted by the hauling chain, E, as shown in Fig. 2. In the latter position the scoop was hauled over the mud surface, up an incline and along the high-level stage to the shoot leading to the barge. The hauling chain, F, was so arranged that as soon as it commenced to haul the scoop back again it turned it completely over and discharged its contents through a hole in the staging into the barge shoot, in the position shown in Fig. 3. The empty scoop was now drawn back in the same position, down the incline and over the mud to the point of attack again. The action of the forward chain, E, then set the cutting-edge at the proper angle, and the scoop again filled.

The average distance travelled by the mud scoops is not stated, but from the plan shown the distance would seem to be about 1,200 ft. One complete trip was made in from 5 to 10 minutes, the load varying from 2 to 3 cu. yds. in very wet mud and 5 cu. yds. when the mud was dry. The wear on the hauling ropes was very great, and it was found difficult to control the work of the scoops. They answered their purpose, however, in preparing the way for wagons, which latter could not be used on the soft mud during the wet winter months. Wagons, later, almost entirely replaced the scoops; and these wagons were filled partly by hand and partly by steam excavators. The latter were only employed after the site was sufficiently open to permit the establishment of the necessary roads to take away the excavated material.