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No. 54.

TYPES OF MOVABLE BRIDGES.

BY J. S. LANGTHORN, MEM. B. E. C.

PRESENTED APRIL 14TH, 1904.

The movable or draw bridge is built as a compromise between navigation interests and street or railway travel. The passing navigator wants it always open and the crossing traveler wants it always closed. This circle cannot be squared, but approximations have given rise to a class of interesting structures.

From the navigator's point of view, the channels for vessels should be wide enough for vessels to pass easily and should be located, not necessarily in the central portion of the waterway, but far enough from the sides not to be blocked by vessels lying at the adjacent docks. In crowded - waters, like the Chicago River and Gowanus Canal, this condition imposes a central channel. On the Harlem River, where the width is 400 ft., side channels of 100 ft. each, obtained with a swing bridge 300 ft. long, leaving margins of 50 ft. out from the dock lines for vessels to lie undisturbed at their berths, have given satisfactory results. Better results are obtained here with the two 100-ft. channels than would be the case with one 200-ft. channel, as two wide tows that would require extreme care to pass each other in a single wide channel on account of the tide, can each have a channel to themselves with fenders only to collide with. Speed of operation seems to concern only the land travel.

The War Department regulates the widths and locations of channels and the clear head room. Their regulations provide 24 ft. head room above mean high water on the Harlem River and 16½ ft. on the Chicago River.

From the crossing traveler's point of view, there should be the fewest number of openings, each to be made in the shortest possible time, and at the times of day when the street or railway is least congested.

Closing the bridges during so-called commission hours, application of power for operating the bridges and fixing a grade high enough for all but masted vessels to pass under, will give the fullest relief in these directions.

As to the time occupied by an opening, it is not merely the turning or raising time, but the total time for all operations that concerns the delayed passenger, such as for gates, locks, end lifts, etc.

The author's experience is that the speed of opening does not vary much for bridges of the same size, regardless of types, but there is a little advantage in the retractile type in small bridges.

The following letter shows the money value of the time saved by the substitution of a high-level bridge over the Harlem River, New York City:

No. 127 Duane Street,
New York, Nov. 1, 1898.

To the Commissioner of Bridges, New York.
Dear Sir:

I have caused an account of traffic over Third Avenue Bridge to be made for the twenty-four hours beginning at 7 A. M., August 15, 1898.

Number of vehicles, both ways		5 087
" " electric cars, both ways		718
" " bicycles, both ways		2 159
Persons on foot	19 972	
" in vehicles, average 2 in each	10 174	
" on bicycles	2 159	
" in cars	17 311	
		49 616

About five-sixths of this travel is during ten hours.

This is a greater traffic than on any bridge in the United States, excepting the Brooklyn Bridge, which carries many more passengers in cars.

The number of openings per day varies during week days from five to twenty-one. On Sundays from two to five times. The average during sixty-two week days is twelve.

The average time of opening and closing is:

Removing end supports and raising rails and aprons..	17 sec.
Revolving bridge...........	85 "
Closing "	85 "
Replacing end supports, etc.	15 "
	200 sec. = 3 m. 20 sec.
Time of vessels passing.....	1 m. 40 sec. to 2 m.
	5 m. 00 sec. to 5 m. 20 sec.

The average time of detention at present is five minutes. It would not be safe to increase the speed of the bridge, but when some obstacles are removed, vessels can pass in less time than now.

Few persons who have not made figures on this subject have any idea of what a great tax upon the public is caused by drawbridges.

If we assume that the value of ten hours of people is $1.00; of electric cars, $10.00, and of vehicles, $3.00, we shall have the following results:

People	49 616 x .00166	$82.36
Cars	718 x .0166	11.92
Vehicles	5 087 x .005	25.43
Cost per minute..............................		$119.71
And for each opening of five minutes.....		$598.55

The value of the new Third Avenue Bridge (which is 24 ft. in the clear above high water) in saving time, which is money to the public, will be seen from the fact that the old bridge, 8 ft. above high water, which it replaced, had to be opened thirty-seven times each day. The time required in opening and closing that bridge, which was smaller than the new one, was four minutes. At a cost of $119.71 per minute, the cost of each opening was $478.84. The saving to the public of dispensing with twenty-five openings per day, or 7 825 openings per year, exclusive of Sundays, is $3 297 292.24 annually, arrived at as follows:

Annual cost of opening old bridge,	478.84 x 37 x 313 =	$5 545 446.04
" " " " new "	598.55 x 12 x 313 =	2 248 153 80
Annual saving..................................		$3 297 292 24

So that it may certainly be said that the new bridge pays for itself every year.

The foregoing statement shows that in a first-class city bridge it would be very poor economy to have anything but the best machinery, and the best class of operators.

Yours truly,
(Signed) THOMAS F. CLARKE.
Consulting Engineer,
Third Avenue Bridge.

CLASSIFICATION.

Movable bridges may be classified as follows:

1.—Swing bridges, which revolve in a horizontal plane.

2.—Side folding bridges, which fold up in a horizontal plane.

3.—Bascule bridges, which revolve in a vertical plane and include the following:

(*a*) Trunnion bridges, which are revolved on horizontal shafts.

(*b*) Scherzer bridges, which open by rolling backwards and upwards on segmental girders.

(*a*) Miscellaneous types, as the Harway Ave., Page, Schinke, Jack-knife or vertical folding, etc.

4.—Retractile bridges, or sliding draws which open in a horizontal plane and are mounted on wheeled trucks. The telescopic bridge at Queens Ferry, England, is a modification of this type.

5.—Direct-lift bridges, which are simply large elevators.

6.—Pontoon or floating bridges, in which the channel pontoons may be moved for passing vessels. In some cases the pivot end is placed on the shore.

7.—Transporter bridges, in which a car hung from a high level truss travels back and forth between the banks of the waterway.

SWING BRIDGES.

This type is so well known as to hardly require description. The lighter bridges are usually built with a center bearing only, and the heavier bridges are built with the weight distributed from the trusses through distributing girders to a circular drum (see Fig. 4), or with some of the weight on the pivot casting.

Swing bridges with unequal arms, the shorter one counterweighted, are sometimes called "Bobtail" draws. One of these is shown in Fig. 3 and is a railroad bridge in Milwaukee, now under construction for the Chicago, Milwaukee and St. Paul Railroad. An ingenious method of erection, devised to enable both railroad travel and navigation to be carried on as usual during the construction of the new span and the removal of the old one, is described in a recent issue of the *Engineering Record.*

Swing bridges are the cheapest form of movable bridge and are still the most used. The bascule bridges are replacing them, however, in crowded waterways.

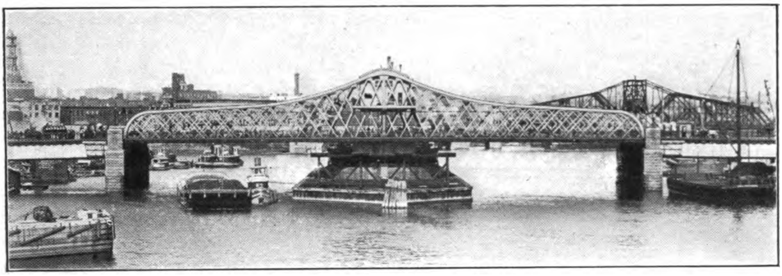
DIMENSIONS OF SOME OF THE LARGEST SWING BRIDGES.

Bridge.	Designer.	Span.	Total weight of draw-span.	
Arthur Kill Bridge, Staten Island	....	496.5 ft.	650 T.	Single R. R. track.
Duluth-Superior	A. P. Boller.	491 ft.	2 000 T.	59 ft. wide, 2 R. R. tracks, 2 trolley tracks, 2 walks.
Alton, Ill	Geo. R. Morison.	450 ft.	1 061 T.	2 R. R. tracks.
Rock Island R. R. for Davenport, R. I. & N. W. RR.	....	442 ft.	700 T.	Single R. R. track.
Macomb's Dam, Harlem River	A. P. Boller.	400 ft.	2 800 T.	Total cost, $1,360,000; 165-ft. channels. 40-ft. roadway, 2 10-ft. walks. Built, 1895.
U. S. Gov't. Rock Island at Davenport	Ralph Modjeski.	366 ft.	....	Double-deck bridge, swung by sprocket chains. Two R. R. tracks on upper deck. 26-ft. roadway. 2 8-ft. walks.
3rd Ave., Harlem River (shown in Fig. 1)	T. C. Clarke.	300 ft.	2 400 T.	104-ft. channels, 86 ft. wide. 3 17-ft. roadways. 2 9-ft. walks. Built, 1898. Total cost, $1,750,000.
Charlestown, Boston (shown in Fig. 2)	John E. Cheney.	240 ft.	1 200 T.	See description.

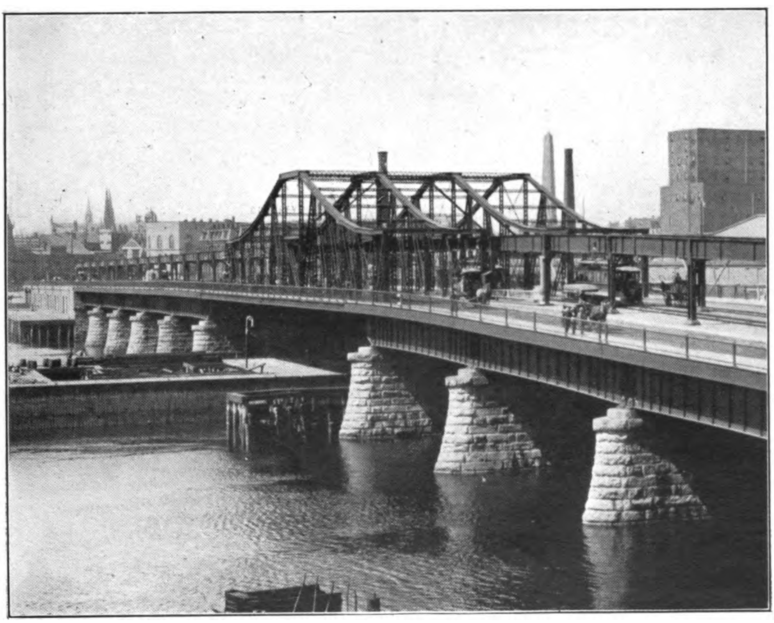
The following swing bridges have double decks: Charlestown, Boston; United States Government bridge at Rock Island; the Delaware, Lackawanna and Western Railroad bridge at Newark over the Passaic River; and the Fraser River bridge in British Columbia which has a 380-ft. span.

CHARLESTOWN SWING BRIDGE, BOSTON.

Including the approaches, this bridge is about 1 900 ft. long. Its width is 100 ft., comprising two sidewalks, each 10 ft. wide, two roadways each 27 ft. 9 ins. wide, and a middle span 22 ft. wide for electric cars. Over the car space are the elevated railroad tracks.



THIRD AVENUE SWING BRIDGE, NEW YORK CITY.
FIG. 1.



CHARLESTOWN SWING BRIDGE, BOSTON, MASS.
FIG. 2.

The swing span is 240 ft. long and weighs 1 200 tons, and the two draw channels are each 50 ft. wide. The under side of the draw is 23 ft. above high water.

The main trusses are four in number, of the pin-connected type, and discontinuous when the draw is in position for travel. Floor beams, sidewalk brackets, and beams and stringers of the elevated railway floor system are built sections, and roadway and sidewalk stringers are rolled beams provided with nailing pieces of hard pine. The sidewalks are covered with 2-in. hard pine plank, and the roadways with 6-in. kyanized spruce, upon which a wearing surface of 2-in. spruce is laid.

The draw is so designed that when swung clear of its end supports its entire dead load is concentrated on the four tower posts of the inside trusses, the outside trusses being hung to them by two transverse trusses. The spaces occupied by the middle panels of these trusses being required for the passage of the elevated trains, it was not practicable to counterbrace them, and therefore unbalanced live loads on the outside trusses are transferred to the turntable by cantilever girders, to which the trusses were connected by adjustable shoes after the draw was swung. The weight of the four tower posts of the inside trusses is carried to eight equidistant points on the turntable drum by a system of heavy plate girders.

The turntable drum is 54 ft. in diameter, with planed steel track, and rests upon seventy steel wheels 27 ins. mean diameter. The lower track is planed steel attached to a bed casting.

The turning mechanism of the draw span consists of two trains of gears driven by electric motors and engaging with a circular rack fastened to the bed casting of the lower track. The motors are operated from a controller in the power room. A strap brake operated by compressed air is connected with the main shaft of each train of gears. The power of these brakes is such that no damage to the turning mechanism can result from their use. The ends of the draw span are provided with hydraulic jacks for bringing them to the proper grade for traffic. The cylinders of these jacks transfer the weights at ends of trusses to movable landings, these blocks being operated by the gateman at each end of the draw span.

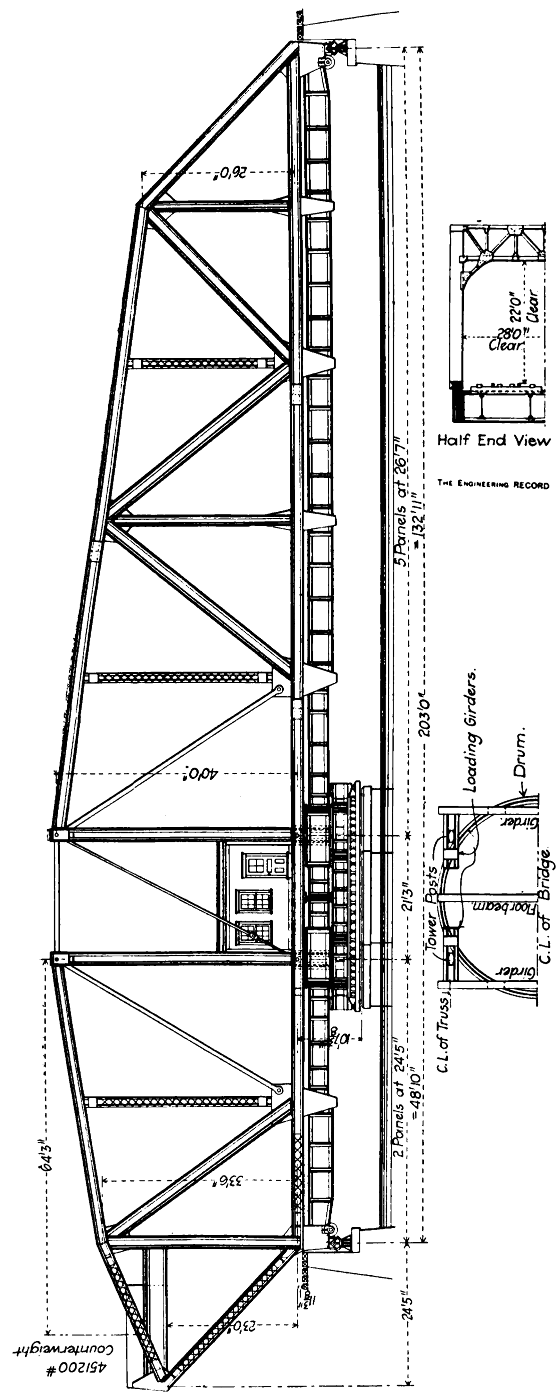
All the operations incident to turning and adjusting the draw span, except the moving of the landing blocks, are controlled from a power room located between four of the distributing girders of the turntable. The hydraulic jacks under the ends of the main trusses are operated by a special mineral oil kept under pressure by compressed air in a set of accumulators consisting of heavy steel tubes. The initial air pressure in the accumulators is obtained from an air compressor of 1 000 pounds per square inch capacity, and the required operating pressure obtained by pumping a proper quantity of oil into them.

An automatic air pump connected with an air tank supplies air for operating the air brakes and an oil ejector. All the machinery in the power room is driven by electric motors, and the room is lighted and heated by electricity. An electric signal system is provided for the general operation of the draw span, and an emergency system, including speaking tubes, affords means of further communication between the operator and the gatemen.

A target is provided to assist the operator in bringing the draw span into the proper position for traffic, this target being electrically illuminated at night.

In operating the draw span, its ends are first lifted clear of the landing blocks and the blocks withdrawn by the gateman. The pressure on the jacks is then relieved, and the ends of the span allowed to settle to their swinging level, the plungers of the jacks being meanwhile lifted clear of the draw landings by counterweighted levers. When the draw span returns to its position over the landings the ends are lifted about ½ in. above the proper grade, and after the landing blocks are inserted, allowed to drop into bearing upon them. In case of air accumulating in the pipes near the jacks, the flow of oil from them is accelerated by the use of an ejector. The time required for the operations just described, and the turning of the draw span through 180°, seldom exceeds 4½ minutes, the additional delay of about 2 minutes to traffic on the bridge being ordinarily due to the time taken by the passage of the vessel.

After an operation of the draw span the air pressure in the accumulators is regained by pumping into them the amount of oil used in the jacks in lifting the ends of the span. Loss of air from the accumulators is replenished from time to time by the air compressor working in combination with the hydraulic pumps.



BOB-TAIL SWING BRIDGE FOR DOUBLE-TRACK STEAM R. R., MILWAUKEE, WIS.
FIG. 3.

The steel work of the draw span and two river spans was furnished by the Pennsylvania Steel Company, and Miller & Shaw furnished the draw machinery.

The degree of perfection reached with the turning machinery may be realized by the fact that the maximum power used under ordinary working conditions and with both motors is only 16 h. p. Mr. Wm. Jackson was Chief Engineer and Mr. John E. Cheney was Engineer in charge. The bridge was completed in 1900 at a cost of over $1 000 000.

Double Swing Bridge at Columbus Street, Cleveland, Ohio.

This interesting structure is a double swing highway bridge, operated by electricity and compressed air. The design of the bridge was the outgrowth of somewhat peculiar conditions. The river here has a sharp bend and the old bridge with its center pier was very troublesome to vessels passing this bend. Moreover, the old bridge had very steep approaches, and its abutments blocked access to valuable dock property. The problem was to eradicate the center pier and steep approaches, and to leave a passage to the dock property for the railway owning it. This is probably the only bridge of its kind in America, but smaller double swing bridges were built in England over canals more than fifty years ago.

It is a double swing bridge 279 ft. long over all, consisting of two 139½ ft. swing spans, with their pivot piers located just inside the dock lines and the ends of their long arms meeting over the center of the stream. The two swing spans are identical in design and construction, with the exception of the center locking device, and a description of one span will answer for both.

The trusses were calculated for a live load of 100 lbs. per square foot of roadway and 80 lbs. per square foot of sidewalk, or 3 000 lbs. per linear foot of bridge. In addition to the uniform load, the roadway was figured for a concentrated load of 16 tons on four wheels. Channel sections were used for chords and posts and eyebars for diagonals.

Each span is mounted on a rim-bearing turntable, with a drum 23 ft. in diameter and 3 ft. 3 ins. high. Mounted on the drum are two loading beams supported by spherical bearings on four crossgirders. These loading beams carry the bridge. The load is distributed to eight points on the drum. The grade of the bridge is secured by a difference in the heights of the bearings for the loading beams, thus allowing the drum to turn in a horizontal plane.

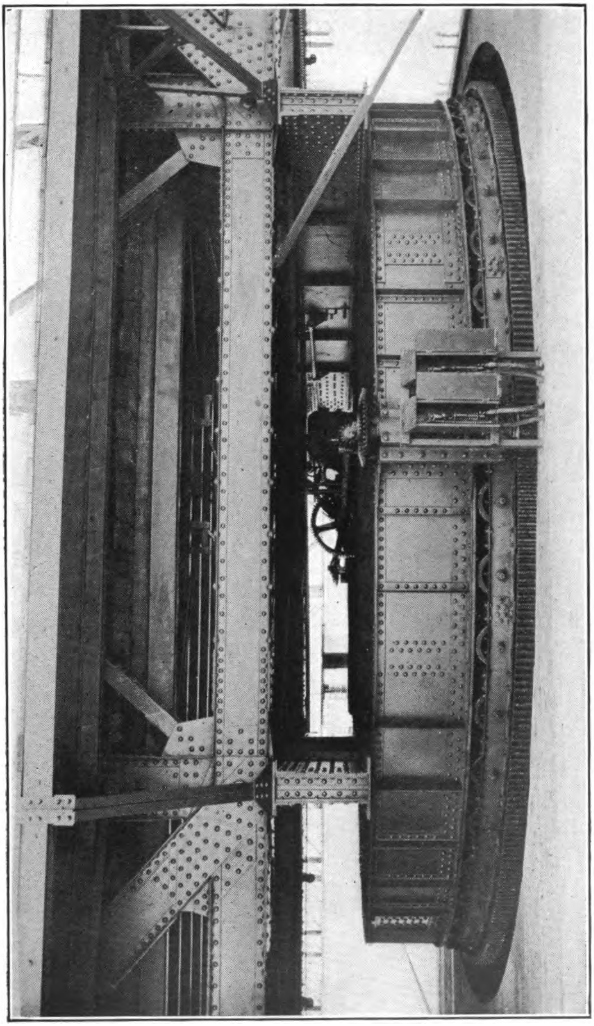
The drum is revolved by means of the usual rack and pinion with electric power. A 25 H.-P. electric motor operates a horizontal shaft. Bevel gears at the ends of this horizontal shaft actuate the vertical shaft and pinion which turns the drum. A 5-H.-P. auxiliary motor is used for operating an air compressor.

The 5 H.-P. motor operates an air compressor pumping into two 25 cu. ft. receivers. This air is used to operate the end-locking machinery and the pneumatic safety gates. The locking devices at the shore ends of the spans are the same for both spans, but the center locking device is not.

The ends of the spans meeting at the center of the bridge are convex, and the circle beams approach to within 4½ ins. of each other at the center line of the roadway. On account of the rapid departure of the curves in the vicinity of the sidewalks the space is bridged by means of an apron 5 ft. 4 ins. in length and extending the full width of the bridge. When this apron is raised, the movements of the spans are unobstructed. It is hung on horizontal bearings and counterweighted to revolve easily. On the outer edges of these segmental counterweights are cast-steel racks, which mesh with two spurs carried at the end of a horizontal shaft. This shaft is operated by the movement of the two steel plungers which pin the ends of the spans together, and the plungers themselves are operated by the pistons of two 11½- x 19½- in. air cylinders. A single movement of the piston serves to withdraw the plungers and lift the apron.

Similar air cylinders are used to operate the locking devices at the shore ends of the spans. The locking and anchoring device consists of a toggle driven slightly past its center by the piston of the air cylinder and fitting into two cup-shaped bearings forming a portion of the anchorage. Hand-power devices are available for operating all parts of the turning and locking mechanism. Safety gates, like railway crossing gates, operated by compressed air, are used.

The substructure consists of masonry piers and abutments on pile and grillage foundations.



ENG. RECORD.

TURN-TABLE OF MERRIMAC RIVER BRIDGE.
FIG. 4.

Weight of superstructure...........	$427\frac{1}{2}$	tons.
Cost of "	$27 000	
" " electrical and air equipment..	5 000	
" " operating house	592	
" " real estate	14 686	
Total cost	$96 743	

Side Folding Bridge.

This type can be used only for railroad bridges and no ties can be used, the rails being carried on the girders, there being a girder for each rail. The girders revolve in a horizontal plane about a pivot at one end of each girder. There are struts hinged at each end which hold the girders parallel to each other, but do not prevent the closing together of the girders as the bridge revolves. The outer ends of the girders are held up by guy rods which are fastened to the top of a tower, the point of attachment being vertically over the axis of rotation of the girder supported, so that the girder will remain in a horizontal plane when it revolves. A rack and pinion working on a prolongation of the girders is usually used for operation.

There are two of these bridges in the city, over Coney Island Creek and crossed by the cars of the Brooklyn Heights Railroad. One of them was recently constructed. Another of these bridges is in Boston and is used by the Boston and Maine Railroad.

Bascule Bridges.

The bascule bridge is the oldest form of movable bridge, having been used in the middle ages to cross the moats surrounding the feudal castles. Up to the completion of the Tower Bridge in London in 1894, and the two Scherzer Bridges in Chicago in 1895, however, the standard draw bridge was the swing bridge. With these three bridges an era of bascule bridge building has come in, manifested principally in Chicago, where the Chicago Drainage Canal project, requiring an unrestricted stream flow in the Chicago River, the narrow river, the increasing size and number of vessels, the enhanced value of the dock room and the demand for the greatest freedom in every artery of travel, place the center pier and swinging arc of the swing bridge out of consideration.

Since 1895 about thirty bascule bridges have been built in Chicago. Four built by the city have been trunnions, the remaining number, with the exception of the Page bridge, have been Scherzer bridges, most of which were built by the Drainage Canal Board. Other cities and railroad companies in conditions similar to the Chicago River have been building bascule bridges until they are no longer a curiosity.

The advantages of the bascule bridge are due to the center channel, free from piers and fenders, lessened interference with the adjacent dock spaces, and for the railroad companies the ability to provide for increasing the number of tracks.

In Amsterdam, Holland, there are twenty-one bascules, twenty of which are light bridges and operated by hand.

More bascule bridges of the Scherzer type have been built in the last ten years than any other. The Scherzer list, including those under construction or adopted, comprises about forty bridges.

TRUNNION BASCULE BRIDGES.

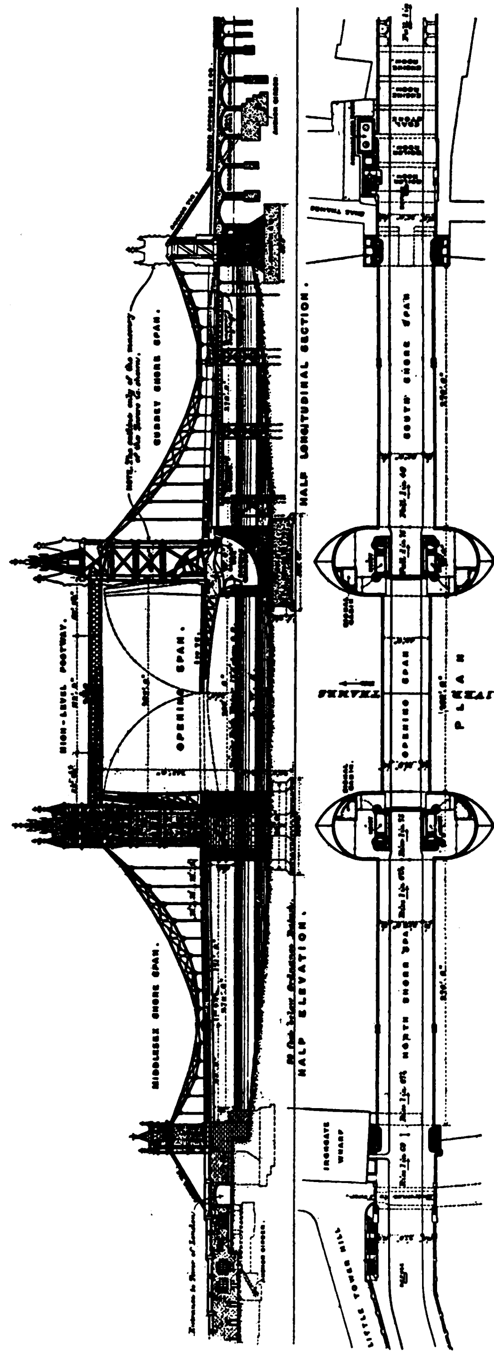
Tower Trunnion Bascule Bridge, London, England.

This is the largest trunnion bascule and the second largest bascule bridge in the world.

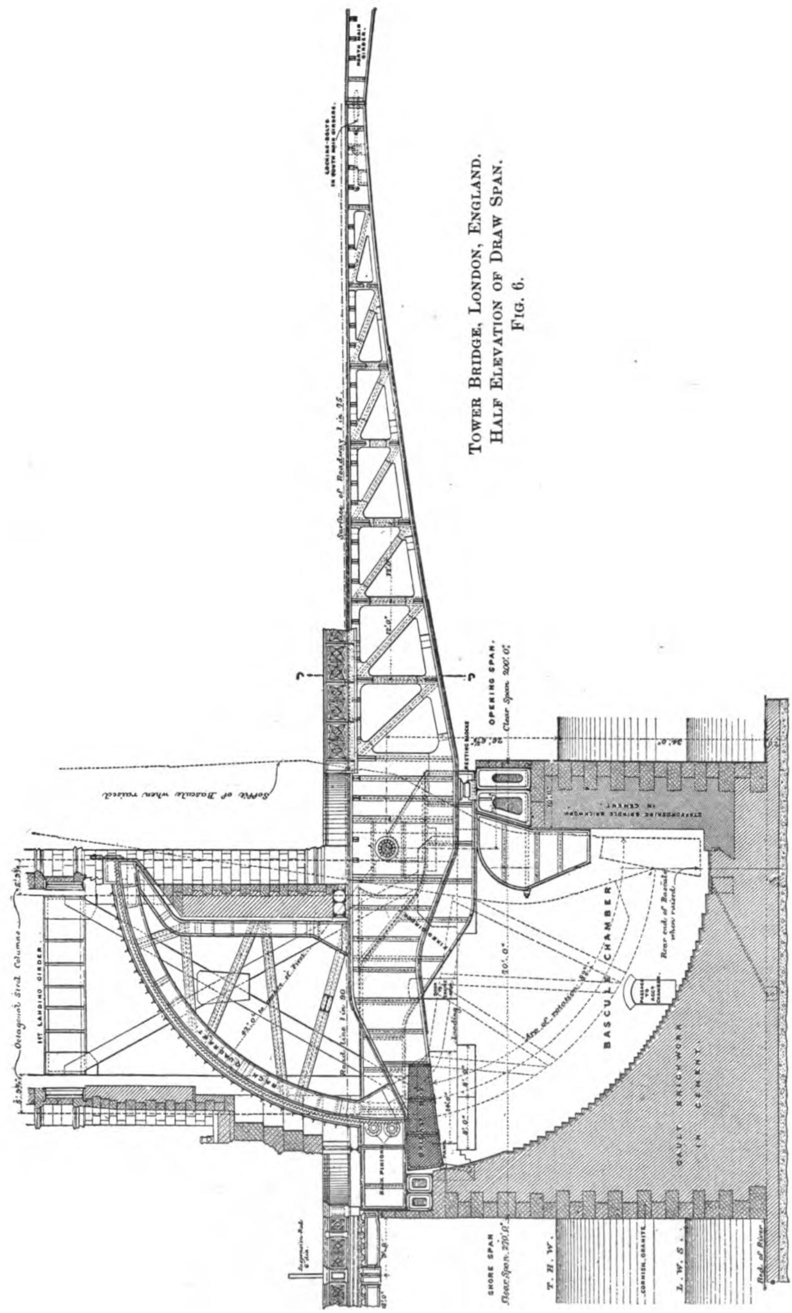
The clear channel is 200 ft. wide and the center to center distance of trunnions is 226 ft. and 6 ins. The tail ends are 62½ ft. long and the extreme width of the bridge is 49 ft., accommodating a 32-ft. roadway and two 8½-ft. walks.

Each leaf of the bridge has four lattice girders which rotate on a solid forged shaft 21 ins. in diameter and 48 ft. in length. This shaft is supported on eight journal boxes, each provided with steel rollers $4\frac{7}{16}$ ins. in diameter and 22½ ins. long, housed in cast-steel sockets.

The journal boxes are carried on eight approach girders, grouped in four pairs, which also support the roadway of the fixed part and span the exceptionally wide and deep counterweight pits. The counterweight itself is composed of 290 tons of lead and 75 tons of



Tower Trunnion Bascule Bridge, London, England.
Fig. 5.



TOWER BRIDGE, LONDON, ENGLAND.
HALF ELEVATION OF DRAW SPAN.
FIG. 6.

cast iron for both leaves, and is carried in a ballast box running transversely across the bridge underneath the approach floor and riveted to the tail ends of the moving leaf trusses. The live load uplift from the bascule when closed is taken by cross-girders between each pair of approach girders. Secondary resting blocks are provided on the front wall of the pit.

The roadway floor of the moving leaf has ⅜-in. buckle plates, upon which is laid transverse creosoted pine, shaped to fit the buckles. Above this comes a layer of longitudinal greenheart planking, both layers of timber being secured to the buckleplates by countersunk bolts. Upon the greenheart planking is placed a wearing surface of 4½-in. creosoted pine blocks, with oak dowels. The blocks are fastened to the planking by 5-in. spikes and the joints are filled with asphalt. The sidewalk paving is similar, except that the blocks are smaller and the longitudinal planking is omitted.

The operating racks are of cast steel, bolted to structural steel quadrants built up on the tail ends of the two outer girders of each leaf. The pitch is 5.9 ins. and the pitch diameter 42 ft. Two pinions, one above the other, mesh with each rack, the pinion shafts extending across the bridge, supported on roller bearings at frequent intervals. The machinery is hydraulic. A 5-in. longitudinal pin in each truss at the outer end of one leaf, adapted to engage with the opposite leaf, constitutes the center lock. Hydraulic buffers and tail locks are provided, all controlled from the operating houses situated in the very elaborate masonry towers flanking the bridge at the ends.

The draw span is shown in Fig. 6, and the great structure of which it is a part in Fig. 5. The high level footway seen in the figures is reached by stairways and elevators in the towers, and was intended to prevent delay from the opened bascule. Since it takes from five to six minutes to cross the opening by the upper passage, while the opening and closing of the bascule consumes scarcely three, the footway is very little used.

The bridge was opened to traffic in June, 1894, and has been in continuous service since, opening and closing from 17 to 20 times daily, or an average of about 7 200 times per annum. The average daily number of vehicles using the bridge is 8 000, and of pedestrians 60 000. The total length is nearly 3 000 ft. and the total weight of steel 12 800 tons.

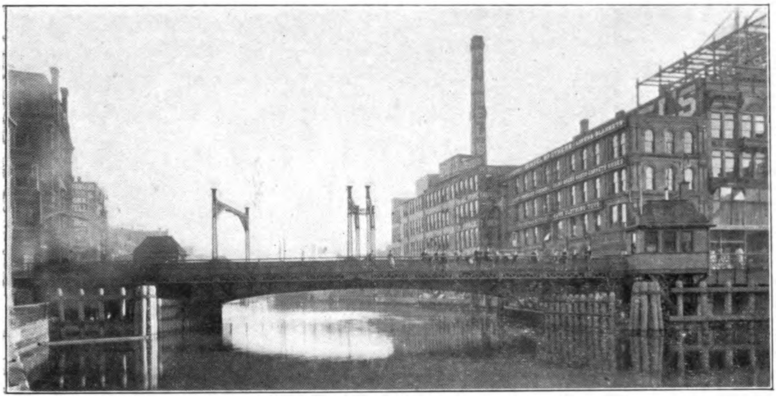
Cost of substructure....................	$656 000
" " steel	1 685 000
" " masonry	745 000
" " machinery, engines, etc..........	426 000
" " miscellaneous	636 000
Total cost	$4 150 000

The weight of the bascule proper, including paving, counterweight, etc., is 2 140 tons. The engineers on the work were J. Wolfe Barry, President, Institute C. E., H. M. Brunel and G. E. W. Crutwell.

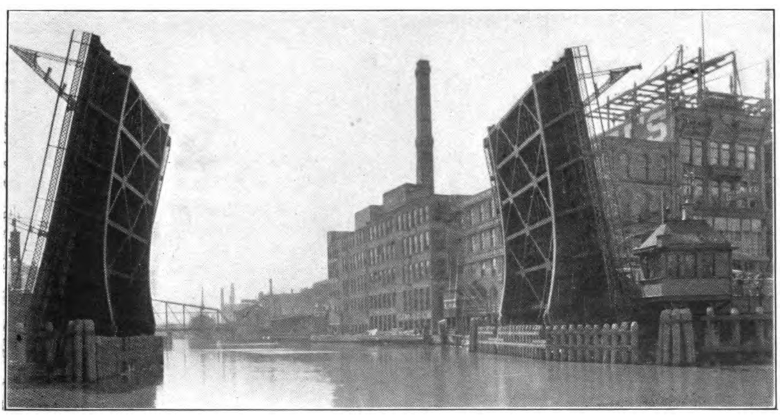
Grand Avenue Trunnion Bascule Bridge, Milwaukee.

The Grand Avenue Highway Bridge at Milwaukee carries a large traffic at a low level across the Milwaukee River, on which navigation must be maintained for tugs and vessels. The banks of the river are curved at this point and are about 200 ft. apart between the docks which line them. The bridge connects Grand Avenue on one side of the river with Wisconsin Avenue on the opposite side; these streets make small angles with the river and with each other and their center lines are more than 50 ft. apart in the center of the river so that the structure is skewed in every direction. The old bridge was a swing span 180 ft. long from out to out. It was supported on a center pier about 40 ft. wide and 220 ft. long in the direction of the river; this left a minimum space of less than 60 ft. between each abutment and the center pier and compelled all boats to pass through a long and crooked channel. For the new bridge it was determined to provide a wider, shorter, straight channel and dispense with the center pier, and this was done by the adoption of a bascule with two leaves mounted on trunnions and operated by rack and pinion gears.

The new structure has a total width of 64 ft. and a length of 180 ft. and consists of two stationary and two movable parts. The movable parts are about 69 ft. long over all and revolve on horizontal axes about 21 ft. from the shore ends. They have floor platforms



CLOSED.
FIG. 7.



OPEN.
GRAND AVE. TRUNNION BASCULE BRIDGE, MILWAUKEE, WIS.
FIG. 8.

about 60 ft. long, meeting in the center line of the bridge and carry a 36-ft. roadway and two sidewalks about 12 ft. wide in the clear. When open the bridge affords a clear center channel opening which for 65 ft. opposite the abutments has a minimum width of 95 ft. in the line of the axis, 70 ft. in the direction of the river, these widths being rapidly increased both sides of the abutments.

The fixed approach spans from the old abutments to the new piers have two lines of deck lattice girders and the channel spans have two lines of half through revolving cantilever plate girders. There are four 16- x 32- ft. piers, each of which supports one approach girder and one cantilever girder, or one-fourth of all the superstructure which is not carried by the abutments. Heavy vertical steel columns are built into the piers and extend above their tops to carry the pivots which support the cantilever girders and around which the shore ends revolve into slots in the masonry when the bridge is open. The bridge requires no clearance for operation beyond either side or either end, all the operating machinery is located under the bridge floor and when the bridge is open no part of it projects above the clear channel space between fenders.

The four piers are symmetrically arranged about the center lines of the bridge and are duplicates, except that two of them have one corner beveled for clearance to navigation. The rectangular piers are supported on 106 and the other piers on 102 piles each, and are built of concrete laid inside a sheet pile permanent cofferdam. Under the pivots the piles are driven in staggered rows 21 ins. apart, elsewhere they are 3 ft. apart on centers. They are not less than 45 ft. long 9 ins. in diameter at the tip and 14 ins. at the butt. The outer rows were cut off at about high-water mark and supported a 12- x 12- in. guide frame in which Wakefield sheet piles, 9 ins. thick and 30 ft. long, were driven to form a cofferdam with the upper edges braced by 8- x 12- in. white oak horizontal waling pieces and tie rods. The cofferdams were braced inside, pumped out and the piles cut off 20 ft. below water level. The earth was excavated 2 ft. below the pile tops and 1:3:5 Portland cement concrete made with 2-in. broken stone was rammed in to a general level of 1½ ft. below water line, wells being left in all the piers for the tail ends of the girders.

The front fenders each have two rows of white oak piles about

2 ft. apart with the piles 30 ins. apart in the rows. They are cut off 7 ft. above water level and are faced on the insides to receive, above water line, two lines of 12- x 12- in. white oak waling pieces bolted between them, 4 ft. apart on centers, with a 1¼-in. bolt through each transverse pair of piles. Between the piles in the front row 12- x 12- in. blocks are bolted to the waling piece to make a continuous outside vertical surface to which a 6- x ½- in. iron band is attached with countersunk bolts, from end to end of the fender. The ends of the fenders terminate with groups of ten white oak piles fastened together with three turns of a 1-in. chain.

In each pier the concrete was reinforced by eight horizontal lines of 2½- x 2½- x ¼- in. angles bedded in it about 2 ft. apart vertically, each being bent to a U-shape and extending continuously around the river end and two sides of the pier. There is also a line of 1-in. horizontal anchor bolts from 3 to 5 ft. apart which are screwed up on the waling piece at the top of the cofferdam, extend 6 ft. into the concrete and are turned down at right angles at the inner ends.

About 4 ft. above the pile tops five 12-in. transverse I-beams are bedded in the concrete and extend across the pier to form a footing for the pivot columns. The pivot columns are 24 ft. long and are made with four 12-in. channels and two 45-in. flange cover plates. They are seated with extended base plates on the top flanges of the grillage beams, and have the lower ends of each pair connected by a horizontal oak beam in the bottom of the girder well. At the shore end of each pier there are two 24-ft. anchor posts, each consisting of a 15-in. channel slightly inclined from the vertical and having riveted across the lower end of the web a transverse piece which takes bearing on a distributing girder under a grillage of 12-in. I-beams bedded in the concrete in a plane at right angles to the anchor post and about 2 ft. from the pile tops on the center line of the anchor post.

The superstructure consists of the two bascule leaves and their two approach deck spans. Each bascule leaf consists essentially of a platform about 64 ft. wide and 61 ft. long which is pivoted on a horizontal transverse axis very near the shore end. It has two main double-cantilever girders 38 ft. apart on centers, which project beyond the platform at the shore end to carry the counterweights. The girders are 79 ft. 1¾ in. long and 15½ ft. in maximum depth, with horizontal top flanges and curved bottom flanges. They are pivoted on pins 21 ins. in diameter that pierce their solid webs 58 ft. 4 ins. from the extremity of the long arms and about 6 ft. below the top flanges. The long arms of opposite girders in the same longitudinal plane meet and when the bridge is closed are locked together over the center of the channel. The short arms revolve downwards into the pier-pits when the bascules are open and when it is closed react against offset seats on the upper sides of the short arms.

The two main girders in each bascule are connected by floor-beams 8½ ft. apart, and by X-brace lateral struts 50 ins. deep which have top and bottom flanges made with single 5 x 3-in. angles latticed together with 2- x 2½- in. web angles. The top and bottom angles of the struts engage the top and bottom flanges of the floor-beams and virtually form top and bottom lateral systems under the roadway. Cantilever brackets about 13 ft. long are riveted to the outsides of the girders to carry the sidewalks and are connected by a system of 4- x 4- in. zigzag angles in the planes of their top flanges. The roadway stringers are 9-in. longitudinal I beams about 3 ft. apart. The sidewalk joists are 4-in. transverse channels 2½ ft. apart. The roadway floor has a lower course of 4- x 8- in. diagonal yellow pine planks, secured to each stringer with hook spikes, and an upper course of 3- x 8- in. transverse white oak planks. The sidewalks are of 2- x 6- in. transverse white pine planks.

The main girders are made with ⅜-in. web plates, and 8- x 8- in. flange angles, 18-in. flange cover plates and 3- x 3- in. vertical web stiffener angles. At the pivot the web is reinforced to a thickness of about 5½ ins. for the bearings, and the lower flange is curved around it to a radius of about 9 ft. On this segment and on a continuation of it formed by an angle bent to the same radius and riveted to the side of the web plate, there is bolted a rack by which the girder is revolved with a pinion. At the shore end of the girder, beyond the pivot, 20-in. horizontal plates about 14 ft. long are riveted to the upper sides of the bottom flange angles and project beyond them to form a support or case for the counterweight castings. The plate is stiffened by transverse diaphragms or gusset plates riveted across them and to the vertical web stiffeners so as to form, with the bottom plates, pockets to receive the cast-iron counterweight sections. These are made in various sizes, all about 20 ins. thick, 1½ to 4 ft. wide and from 2 to 6 ft. high, fitted between the vertical and horizontal web stiffening angles and secured by horizontal bolts through the girder web.

Between the piers at each end of the bridge there is a 50-H. P. electric motor with a transverse horizontal driving shaft which has at each end a pinion engaging a gear wheel keyed to the inside end of a short parallel shaft that passes through the lower part of the pivot column and has a pinion keyed to its outside end engaging the segmental rack on the main bascule girder. By this direct mechanism the bascules can be opened or closed separately or simultaneously in 45 seconds. A two-man hand gear is also provided to operate the driving pinion and swing the leaves if necessary. When closed the bascule leaves are locked together by bolts engaging the adjacent ends of the long arms at mid-span. The bolts do not transmit any stress and the bascules act under both dead and live loads as independent cantilevers, anchored at the shore ends.

The bascule girders are made right and left and the extremities of their long arms are made male and female with reference to the connection details. The female end of the right hand girder has double end vertical web stiffener angles spaced 2¼ ins. apart in the clear. The offset vertical web stiffener angle is reinforced with angles and plates so as to form a rigid side for a vertical slot in the end of the girder. The end of the adjacent male girder is similar with lighter end vertical angles between which is riveted a tongue casting with a front projection which, when both bascules are closed engages the slot in the female girder. It has a horizontal slot across the middle which corresponds with a square horizontal hole through the web and end angles of the female girder. A square horizontal bar can be passed through the hole in the female girder and the slot in the tongue of the male girder and lock both girders together. The bearings for the tongue and latch are fitted with a slight clearance and are ground smooth. Each of the two latch bolts is about 8 ins. long and 4 ins. square at the shoulder, tapering slightly to the points. The shoulder is attached to the end of a horizontal square guide bar sliding in slots through the stringer webs. It is riveted between top and bottom plates which connect it to the operating bar parallel to it and 6 ins. away. One end of it is pin-connected to toggle bars in a horizontal plane which are operated by the short arm of a lever, the long arm of which is moved back and forth by a longitudinal horizontal gas pipe worked by a lever in the operating house. There is also a simple heel latch at the shore end of each leaf. It is merely a wooden strut hinged at the bottom and arranged to have its top jammed tight against bottom chord of the girder when closed. Each leaf has also at the heel two rods running up to dashpots on the adjoining fixed approach span.

From the abutments to the pivots the floor platform is carried over the piers and the river on deck girders. Those which connect the anchor and pivot columns are lattice girders with special ends, having the upper sides of the river ends notched for clearance with the bascules. The I-beam stringers support a roadway floor $\frac{5}{16}$-in. buckle plates, convex side up, which are covered by asphalt pavement on a concrete base. The stationary sidewalks have [illegible]/8-in. buckle plates, concave side up, covered with 2 ins. of 1:2:5 Portland cement concrete finished with 1 in. of 1:1 Portland cement and fine crushed granite. The sidewalks have steel curbs and substantial hand rails 3 ft. 9 ins. high which weigh 30 lbs. per lineal foot. At each end of the bridge there is, on an extension of the stationary sidewalk, on opposite sides of the street, an 8- x 15- ft. wooden operating house.

The bridge is figured for live loads produced by uniform loading and by two electric cars, one on each pair of 7-in. girder rails, and moving in opposite directions. Each typical car is 43 ft. long and 8½ ft. wide, weighs 55 000 lbs., and is carried on two trucks 17¾ ft. apart with 6-ft. wheel bases. The roadway outside the tracks and the sidewalks is assumed to be loaded to 100 lbs. per square foot. Wind pressure is assumed to be a moving load of 400 lbs. per lineal foot applied at floor level. A wind pressure of 25 lbs. of exposed surface is assumed when the bridge is opened and the machinery is proportioned to operate it in any position under such pressure. The counterweights are calculated to be proportioned and arranged to balance exactly the revolving leaves in any position and enable them to remain stationary without the use of the brakes.

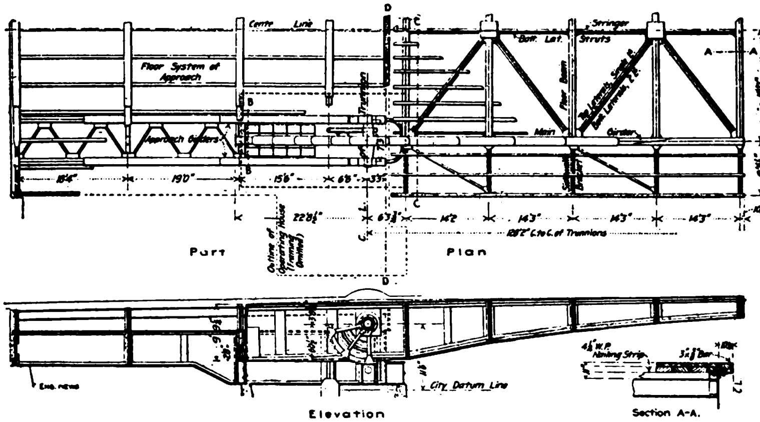
All principal members are made of medium steel with a tensile strength of 60 000 to 68 000 lbs. per square inch. The allowed stresses in pounds per square inch are: For tension, lateral and sway bracing, 18 000; I beams, 13 000; girder flanges, 13 000. Shop rivets are proportioned for 15 000 lbs. bearing and 7 500 lbs. shearing stresses and field rivets for 12 000 and 6 000 lbs. respectively. The bed plates are laid in Portland cement and are proportioned for a pressure of 35 000 lbs. per square foot on the masonry.

The bridge was designed and constructed under the general direction of the Commissioners of Public Works of Milwaukee, by the Wisconsin Bridge and Iron Company of that city. Mr. Charles J. Poetsch, City Engineer, and Mr. B. W. Perrigo, Assistant City Engineer, were in general charge for the city.

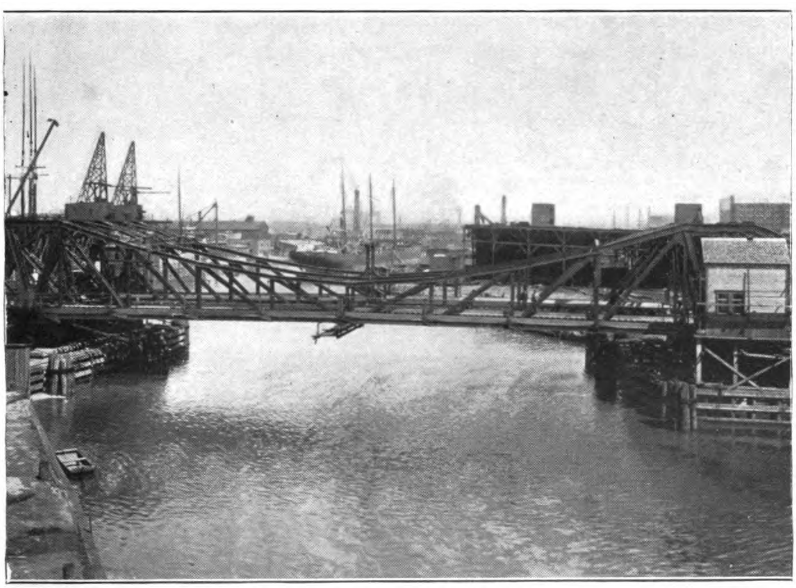
Broadway Trunnion Bascule Bridge at Milwaukee, Wis.

This bridge, designed by Mr. John Geist, of Milwaukee, and now under construction, presents in design and construction several novel features. It is a deck bridge with the roadway 14 ft. above water level; it is 240 ft. long between end abutments, and has one 36-ft. roadway and two 10-ft. sidewalks. The central movable portion of the bridge consists of two equal leaves hinged at the outer ends. The span of 128 ft. 2 ins. center to center of trunnions affords a clear waterway of 100 ft. between fenders. The two side spans at approaches, which are always stationary, are so designed that they serve to balance not only the whole dead weight of the swinging leaves, but also any live load which may come on these.

The approach girders are arranged in pairs and rest with one end on the abutments, while their other ends are supported by steel main columns inside the river piers in such a manner that they form 6½ ft. long cantilevers, to which the trunnions of the moving portions are fixed. The main bascule girders are single web girders, whose extensions back of the trunnions carry the necessary counterweights. They swing centrally between the pairs of approach girders (and also between the two main columns) into pockets in the river piers. These piers are of concrete supported by piles. Each pair of approach girders is rigidly connected together at their overhanging ends by a curved strut 4 ft. deep built of angles and plates. At each panel point back of the trunnions the two approach girders, which are spaced 7 ft. 3 ins. apart on centers, are connected by transverse diaphragms or girders having central plates on top, on which the transverse floor beams carry the stringers and approach



BROADWAY TRUNNION BASCULE BRIDGE, MILWAUKEE, WIS.
FIG. 9.



DIVISION STREET TRUNNION BASCULE BRIDGE, CHICAGO, ILL. ENG. RECORD.
FIG. 10.

floor rest. By this arrangement the whole dead weight of the approach is equally transferred to the approach girders. These diaphragms are of plate-girder construction, except the one next to the trunnion. This frame is open-webbed, so that the tail ends of the bascule girders can catch under its upper flange, abutting against an oak bumping block bolted thereto. Should any live load come on the leaves, the dead weight of the approach spans will counterbalance it.

In order to give the necessary weight to the approach spans, heavy concrete arches with expanded metal reinforcement were used instead of the common buckleplate construction. The roadway of the approaches is paved with Trinidad asphalt and the sidewalks have a granolithic finish. The roadway of the movable portion is covered with a lower layer of 4-in. surfaced yellow pine planks laid diagonally with 1-in. openings and with an upper layer of 3-in. white oak planks laid close and at right angles to bridge. The sidewalk floor is of 2-in. surfaced white pine planks laid with ¼-in. openings at right angles to bridge. The planks are well spiked to nailing strips bolted to the longitudinal stringers, which in turn are supported by floor beams and cantilevers riveted to the main girders.

Where the trunnion shafts pass through the webs of the main girders, the latter are reinforced with steel plates and steel castings. The trunnion shafts, which are forged steel, are 25 ins. in diameter at the center and have 16- x 16- in. journals, which rest in phosphor bronze bushings in cast-steel bearings. The bearing pressure is about 800 lbs. per square inch. Lubrication is effected through four channels radiating from a central hole in the end of the trunnion, to which oil is fed from an oil cup fixed to the shaft.

The counterweight, about 125 tons for each girder, is of cast-iron blocks in four layers, two layers on each side of girder web. The two inner layers are directly bolted to the girder webs with two 1¼-in. horizontal bolts to each block. Each of the blocks of the outer layers is recessed to fit a projection on the inner block and is fastened to the latter by two 1¼-in. vertical pins with head on top, these pins being simply dropped in place. By this arrangement the difficulty of using very large, long bolts was overcome.

Each trunnion shaft carries an operating sector, placed next to the roadway, the sector consisting of an angle and plate framework with cast-steel hub and rack. This sector is fastened to the girder web with 1-in. turned bolts. The racks of the two sectors for each leaf engage pinions of trains of gear wheels (one train for each sector) placed underneath the floor of approach spans on steel machinery girders and anchored to concrete piers. The two trains of gears are connected by a transverse shaft driven by a 500-volt General Electric motor of 500 H.-P. running at 110 r. p. m. With this machinery each leaf, weighing 400 tons, can be raised or lowered in about 20 seconds without jar. The transverse motor shaft is also coupled by miter gear wheels (which can be thrown in or out of gear by a lever) to a vertical shaft connecting it with gear-work for hand power, so that each leaf can be operated by two men with a 10-ft. lever in 15 to 20 minutes.

The break in the roadway and sidewalk floor at the junction of the stationary and movable portions of the bridge is about 3 ft. in front of the trunnions. In operating the bridge the floor of the lifting leaf rises and moves towards the approach and thus forms a strong continuous barrier. When it is considered that this bridge is opened sometimes as often as 150 times a day, this feature must be appreciated as a valuable guard against accidents. It also prevents water, dirt and snow from being deposited on the machinery below, as is the case when the break in the floor is back of the trunnions; this makes it easier to keep the bridge clean and in good order.

The centre lock consists of one 6- x 1¾- in. steel bar for each girder of one leaf, set transverse to the bridge, and engaging slots at the ends of the girders of the other leaf. The locks are actuated from the operating house by a system of levers and shafts. The joint in the locking gear between the portion fixed to the approach and that fixed to the bascule leaf is made in a transverse throw rod located in front of the trunnion; the "movable" part of this rod has a head adapted to lift out of a socket in the "fixed" part.

The operating houses are built on steel girders projecting from the approach spans. From here the hand brakes are operated, as well as the electric power and light equipment, which is very complete. Steel stairways with gas-pipe railings lead to the machinery platforms below, which are also surrounded by railings and so located that every part of the machinery is easily accessible for oiling and inspection. The pits are also completely surrounded by steel work, except in the rear, and therefore accidents are guarded against without additional expense.

The principal feature of this design is the freedom from unequal loadings and absence of uplift on the river pier foundations. The main columns placed in the center of the piers rest on steel grillage and transmit their loads uniformly over the piling, about 10 tons per pile. In other bascule bridges are anchor columns placed as near the rear end of the pier as possible, is generally used to take the uplift caused by loads on the leaves; the main bearings of the bridge are placed at the front end of the pier and as far away from this anchor column as possible. The front piles of the pier are then subjected to a very high concentrated pressure aggravated by the uplift at rear end, from which results a very unequal and variable loading, with consequent unequal settlement and cross-strains on the masonry. The effect of this is to bring the ends of the two leaves closer together than intended.

The Broadway bridge was designed for a uniform live load of 100 lbs. per square foot of floor surface, and in addition a double-track electric railway with cars concentrating 57 000 lbs. on two four-wheel trucks. Each main girder of the leaves was calculated as a cantilever for the maximum loads without considering any transference of load from leaf to leaf through the locks. The material used for the structural work was medium steel. The working stresses correspond practically to those of Cooper's latest specifications for highway bridges. Mr. Chas. J. Poetsch, City Engineer of Milwaukee, prepared the general specifications governing the construction of the bridge. Mr. Adolph F. Bues, of Milwaukee, was the contractor for the structure, which cost $125 375. The steel work was manufactured by the Modern Steel Structural Company, of Waukesha, Wis., and the erection of the bridge was in charge of Mr. John Ramsey.

Division Street Trunnion Bascule Bridge, Chicago.

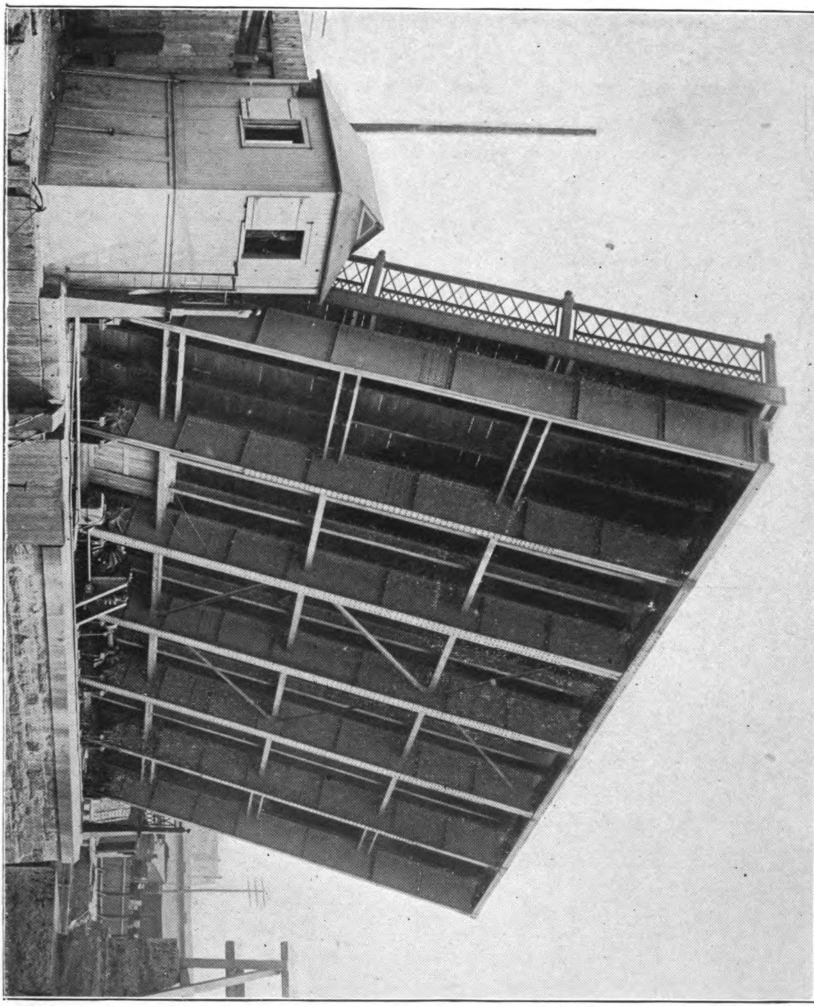
A double-leaf, bascule highway bridge of 160-ft. 8 ins. clear opening is now being built across the Chicago River at Division Street, Chicago (completed June 8, 1904). The concrete superstructure was carried down to an elevation of 23 ft. below water level, and is supported on piles driven to solid rock and cut off 21 ft. below water level. The concrete was built inside a mud cofferdam, and was carried to about 8½ ft. above water level.

The two leaves each have three riveted-through trusses 21 ft. apart on centers, with 9-ft. cantilever sidewalk on both sides of the bridge, extending the platform to a total width of 60 ft. The counterbalanced leaves revolve through arcs of nearly 77°, and have 16½ ft. clearance above the water when closed. They are each hinged on a long transverse horizontal cast-steel shaft under the floor, 6 ft. back of the center line of the river pier. The projecting ends of the shafts form trunnions 16 ins. in diameter and 26½ ins. long, which are supported over the tail pits on longitudinal box-girders spanning from the abutments to the piers, and just clearing the outsides of the outer trusses. The hinge-shafts are 172 ft. 8 ins. apart on centers, and their arrangement and support constitutes the principal feature of interest in the structure.

The operating racks have a length of about 35 ft. on the pitch line, are attached to the tail ends of the trusses, and with them revolve down into the tail pits in the abutment masonry when the bridge is opened. Each leaf is counterweighted by about 250 tons of old rails and concrete, carried in a transverse box attached to the extremities of the trusses below the floor.

There are independent houses on each side of the river, each with a switchboard and controller, by which the two leaves are separately opened and closed.

Each leaf is operated by two 37-H.-P., General Electric, type 58, motors, located below the approach roadway, and geared to a horizontal transverse shaft on top of the abutment wall. Each shaft has three pinions engaging the racks on the tails of the bascule trusses and is provided with band-brake wheels commanded by a vertical hand lever in the bridge house. The racks have special open teeth, designed to allow dirt and refuse to drop through and prevent obstructing accumulations of ice and snow. A current of about 50 amperes is required to overcome inertia and friction, and start the revolution of the bascule leaf from the horizontal position. The motors are operated by a 500-volt current obtained from the mains of the Chicago Union Terminal Traction Company, which controls the trolley line across the bridge.



ENG. RECORD.

185TH STREET TRUNNION BASCULE BRIDGE, NEW YORK CITY.
FIG. 11.

The leaves are brought gently to rest at both open and closed positions by pneumatic buffers. These cylinders are anchored to the piers and each contains a cross-head piston connected by a pair of eye-bars to a pin, which is picked up by a hooked lug on the back of the truss as the leaf nears the end of its movement, and the piston is thus forced into the cylinder. Another lug near the hook returns the pin and cross-head to their normal positions upon the movement of the leaf in the opposite direction, any vacuum in the cylinder being relieved by a check valve. Each truss has two cylinders arranged to govern the closing and opening movements, respectively. These are alike, except that the head ends of the closing cylinders are connected by piping to relief valves in the bridge house, whereby the operator can control the compression in them, and finally allow their pistons to bear against the heads, locking the leaf against further motion downward. This amounts to a positive lock, since the center of gravity of the closed leaf is on the river side of the pivot and the movable part of the roadway does not extend back of the pivot. This latter feature also results in the dumping of the dirt from the leaf, as the bridge is opened, upon the approach roadway, whence it is more easily removed than from the tail pits.

When the bridge is closed, the adjacent ends of the bascule trusses are locked together by three horizontal bolts at the center of the span. Each bolt is proportioned to transmit a half panel load of live load from one leaf to the other, and all of them are simultaneously operated by a transverse crank-shaft. This shaft is geared to a 3-H.-P. motor and locks and unlocks all the bolts by one complete revolution. The positions of the bolts are shown by an electric indicator in the bridge houses.

The bridge contains about 700 tons of structural steel and 100 tons of machinery, and cost about $94 000 for the substructure, and $160 000 for the superstructure. Work on the substructure was commenced on May 1st, 1902, and finished August 27th, 1903. Work on the superstructure was commenced August 25th, 1903. The bridge was designed and constructed under the supervision of the city engineer's office, Mr. John Ericson, Chief Engineer, and Mr. Thomas G. Philfeldt, Bridge Engineer.

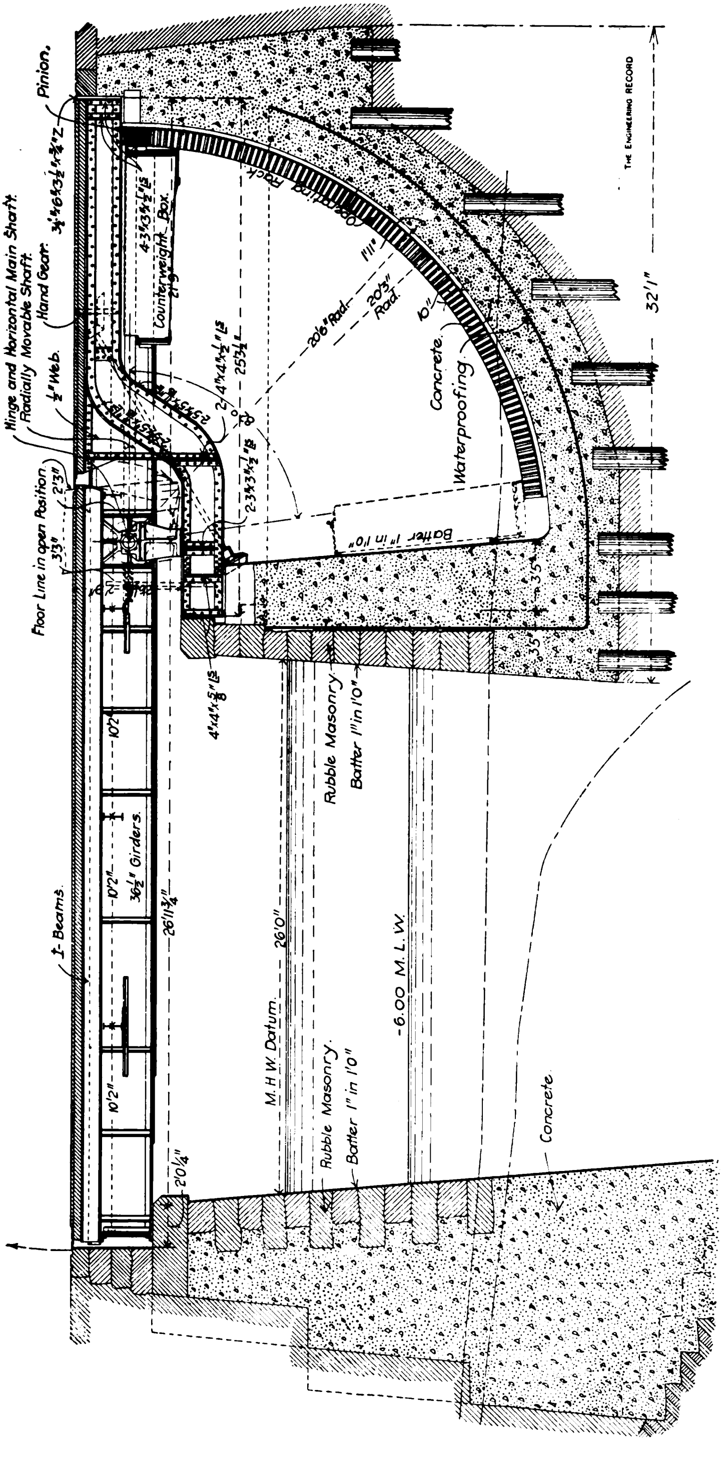
135TH STREET TRUNNION BASCULE BRIDGE, NEW YORK CITY.

A small bascule bridge over Mott Haven Canal (a small private waterway), at One Hundred and Thirty-fifth Street, Bronx Borough, has a clear span of 26 ft. and a width of 66 ft. over all, and carries a 42-ft. roadway and two 11½-ft. sidewalks. It is ingeniously arranged with a long and a short arm operated by a simple rack mechanism contained in the pit, which receives the counterweighted shore arm, and contains all the machinery, so that the bridge presents the external appearance of an ordinary plate girder span and has no tower nor other members projecting above the roadway deck.

The floor is supported by seven symmetrically-arranged longitudinal plate girders, one of them on the center line, which have tranverse I beams web-connected to them, carrying light longitudinal beams across their top flanges to receive the double thickness of floor planks, which just clear the top flanges of the side girders and are crowned a few inches above the center girder. At the movable end all the girders are seated on flat bed plates on the abutment masonry; at the opposite end they are hinged so as to revolve upwards through an angle of 82° from the horizontal. The outside four girders terminate at their hinges, but the center three girders extend 19 ft. beyond them to support the counterweight platform. They project under the fixed approach floor and revolve down into the pit under it when the bridge is opened. The hinges consist of 7-in. horizontal pins through the lower parts of the ribbed castings bolted to both sides of each web between pairs of vertical web-stiffener angles, and are supported at their ends in pairs of cast pedestals.

The pedestals for the four outer girders and the outside pedestals for the two adjacent girders are seated on the abutment masonry. Both pedestals for the center girder and the two inside pedestals for the two adjacent girders are seated on the top flanges of the curved drop girders, which support the fixed roadway platform over the counterweight pit, as shown in the longitudinal section. This arrangement permits the bascule hinge to be offset clear of the abutment wall and allows the ends of the long girders to revolve clear of the masonry.

The bridge is operated with a combination of horizontal and inclined shafts and miter gears. A very short vertical shaft nearly



135th Street Trunnion Bascule Bridge, New York City.

Fig. 12.

in the center of the pit terminates in a capston head at floor level, where it is operated by detachable hand levers at an angle of about 45° with the horizontal. The lower end of the shaft is connected by a miter gear with a longitudinal shaft inclined downwards which has a miter gear on its lower end operating a vertical shaft seated on the ends of two drop girders. The upper end of this shaft carries a worm gearing into a transverse horizontal shaft in the axis of the bascule hinge. This shaft is 15 ft. long and passes through a hole bored through the hinge pin of the center girder. Close to the bearings of the outer girders of this set the shaft has miter gears driving two longitudinal shafts about 15 ft. apart, which are horizontal when the bridge is closed and extend to the rack quadrant bolted to the pit masonry. Each shaft has a pinion engaging the rack teeth, and as it is radial to the rack when it is operated, it follows the latter and, traveling down on it, revolves the counterweight bascule leaf upwards, or *vice versa*.

The sectional counterweight consists of about 65½ tons of cast iron, the machinery weighs 29 tons, and the structural steel weighs 66½ tons.

The bridge can be opened in 20 seconds by an 18-H.-P. street-car motor, seated on the abutment masonry and geared to the main vertical shaft. It is proportioned for the heaviest street roller and city traffic, and was built at a cost of about $30 000.

Mr. G. R. Ferguson designed the bridge, and Mr. J. G. Theban was engineer in charge of the construction. The contractor was Mr. Augustus Smith and the bridge was completed in 1902, and has been working smoothly since then.

The openings for 1903 were 1 456, and in this year 2 140 vessels passed the bridge.

The bottom of the canal is about 3 ft. below mean low water, and the tide gates under the north end of the bridge are opened only near high water time, when the bridge is opened and the vessels enter and leave this portion of the canal.

SCHERZER BASCULE BRIDGES.

Van Buren Street Scherzer Bascule Bridge, Chicago, Ill.

The first two Scherzer bridges were built across the river in Chicago, near Van Buren Street, in 1894. One was the Van

Buren Street Bridge and the other the Metropolitan Elevated Railroad Bridge. The old bridge at this site was a swing bridge which divided the river into two narrow channels, neither of which was in direct line with the channel above or below the bridge. A new swing bridge, even if of longer span, would not have materially improved these channels, or have allowed the Metropolitan West Side Elevated Railway to cross the river where it was desired to carry the line across, at a point near this bridge. A lift bridge moving in a vertical plane would permit the Metropolitan Elevated Road to cross as desired, and would have no center pier to obstruct the channel and interfere with navigation. A special construction was therefore designed, which consists of two bascule leaves, which are nearly horizontal and unite above mid-channel, when the bridge is closed, and is sustaining vehicular traffic, and which when open to permit the passage of boats occupy approximately parallel and vertical positions directly above their respective abutments. Each half rolls up and down with a cycloidal motion of segmental bearing girders at the shore end engaging a rack on the surface of the abutment.

The west approach is longer than the east, the abutment and pier on the west being separated by 40 ft., while on the east they are combined in one piece of masonry. This space between the abutment and pier is bridged over with plate-girders, and forms a room for the machinery on the west side. On the east side of the river space for the machinery was provided by building a room in the abutment. In each room are placed the motors, air pumps, air reservoirs, and other machinery necessary to operate one-half of the bridge, and each half is operated independently of the other.

The foundation for each part of the substructure is formed of piling, driven about 3 ft. centers. The piles used were about 50 ft. long, driven nearly to the water, and sawed off 17 ft. below the water line. In building the masonry for the west abutment, the west pier, and the pier portion of the east abutment, open caissons were used. The bottom of the caissons consisted of four courses of 12- x 12- in. pine, and the side walls a single course of the same. Each caisson was built at the dock and filled with concrete until it sunk almost to the level of the piling. It was then floated into position, and the concrete continued up to within 2 ft. of the water line. The pier was then faced up with Bedford masonry to the coping, the concrete backing for each course being put in before the following course of masonry was added. The coping was of large blocks of Bedford stone.

Each main truss has rigidly attached to it a segmental girder and a tail girder, the latter being secured and counterweighted at its shore end so as to form a cantilever arm, maintaining the bascule leaf in a horizontal position while the former serves as a rolling fulcrum for moving the bridge. An operating strut has one end pin-connected to the truss and the other end is provided with a rack engaging a large pinion-wheel.

In raising the bridge the power from the operating strut is carried from the center truss to the two outside trusses by heavy vertical bracing. Within the tail girders and between them, beneath the roadway floor, are placed the weights for counterbalancing the bridge. These weights are sufficient to prevent the bridge from coming to a horizontal position when freely lowered by the brakes. The bridge when so lowered comes to rest a little above the horizontal; the current is then applied and the motors force the bridge down to a level.

There are two 50-H.-P. electric motors on each side of the river, hung on the same shaft, and wired to operate in unison or separately. On each end of the motor shaft is an automatic brake wheel. The brakes on these wheels are operated by compressed air, the air compressors being operated by an eccentric on the end of the motor shaft. If at any time during the motion of the bridge the current is cut off, these brakes are automatically applied. In addition to these brakes there is an emergency brake on the center of the first shaft, back of the motor shaft, which may be set any time by opening an air valve leading from the air reservoir to this brake cylinder. This brake is intended to be used only in case of an accident.

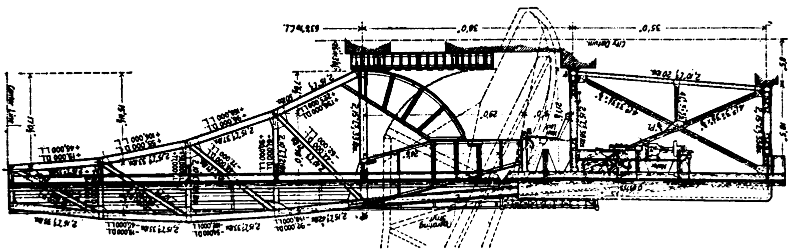
The bridge gates on the right-hand roadway at each end of the bridge and the signals at the center of the span are also operated by compressed air. The air for use on both sides of the river is compressed on the west side; that to be used on the east side being piped across beneath the river and stored in a reservoir. The gear wheels are all of cast steel, excepting the spokes and hub of the rack wheel, which are of cast iron, as are also the journal boxes. On top of the center girder on each approach is located the operator's house. To each of these houses run all electric cables and all air pipes for controlling one-half of the bridge, the operator having here before him all the apparatus for the complete control of one-half of the bridge.

The bridge was designed and patented by Mr. William Scherzer, who died before the drawings for it were entirely completed, and though his design was carefully and ably carried out, if he had lived to finish the work he had so well begun still more improvements would probably have been added to the bridge. Work was begun on this bridge early in 1894, and it was opened for traffic February 4th, 1895. The substructure was built by the Fitz-Simons & Connell Company, of Chicago. The east pier and abutment, which came between two seven-story buildings, and the excavation for which was considerably below the foundations of these buildings, was especially difficult of construction. This work was all done very successfully and with credit to the contractors. The contract for the superstructure was originally let to A. Gottlieb & Company, but Mr. Gottlieb's death very soon afterward made it necessary to relet this work, and it was given to Mr. Charles L. Strobel, of Chicago. Mr. Strobel had the work manufactured by the Elmira Bridge Company, of Elmira, N. Y., who sublet the machinery to Scaife Foundry and Machine Company, of Pittsburg. The electric equipment, including the brakes, air compressors, gates, signals, etc., was furnished by G. P. Nichols & Brother, of Chicago. The bridge was constructed under the supervision of Mr. Samuel G. Artingstall, City Engineer, Warren R. Roberts, City Bridge Engineer, having direct charge of the work. The total cost of the bridge, including the approaches, the electric equipment, and cables to the power-house, was $169 700.

North Halsted Street Scherzer Bascule Bridge, Chicago, Ill.

The third bridge of the Scherzer type, but of much longer span, was built in 1897 across the Chicago River at North Halsted Street.

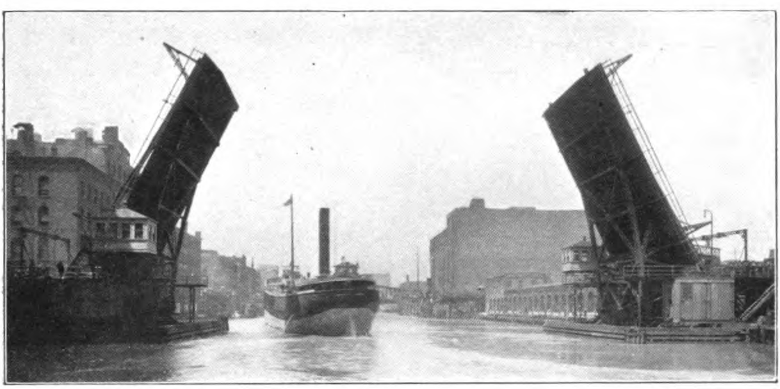
Superstructure and Foundations.—The general dimensions of the bridge, exclusive of the 50-ft. approach span on the south side, are: Length of movable portion, 176 ft., divided into two equal



HALF ELEVATION. ENG. RECORD.

NORTH HALSTEAD ST. SCHERZER BASCULE BRIDGE, CHICAGO, ILL.

FIG. 13.



STATE ST. SCHERZER BASCULE BRIDGE, CHICAGO, ILL.

FIG. 14.

parts of 88 ft. each; length of anchor span on the south side, 48 ft. 6 ins., and on the north side, 52 ft. 6 ins., making the total length of the bridge 277 ft. The width of the roadway is 32 ft., the width of each sidewalk is 6 ft. and the width over all is 50 ft. The clear opening between the protection piles is 109 ft; between the faces of the masonry, 121 ft., and between the centers of the bearings, 127 ft. The bridge was designed to carry a uniformly distributed live load of 100 lbs. per sq. ft., or a motor car weighing 18 tons loaded, followed by trailers weighing 15 tons loaded, each having a wheel base of 8 ft. and a length of 32 ft. over all. This gives about 4 400 lbs. per lin. ft.

The segmental girder has bolted to its curved flange a sole plate 26 ins. wide x 2½ ins. thick, with 6- x 12- in. holes spaced 2 ft. apart center to center. The track upon which this rolls has corresponding lugs which act as a guide to hold the movable part of the bridge in position while it is in motion. The tracks consist of steel castings 26 ins. wide and 2½ ins. thick, bolted to heavy box girders which span an opening of 10 ft. between the piers.

The substructure supporting the movable part and the columns of the anchor span consists of three separate piers on each side of the river, that portion of the piers below datum being made of Portland cement concrete and that part above datum of Bedford limestone. The piers rest upon a pile and timber foundation, the piles being cut off at 17 ft. below city datum, which is about the average stage of water. The piles were driven about 30 ft. into a rather stiff blue clay. Excavation was made to a depth of 2 ft. below the point of cut-off of the piles. Upon the piles 12- x 12- in. oak timbers were placed and secured by drift bolts. Between the heads of the piles and timbers were placed concrete, then two more courses of timber upon which the concrete pier rested. The foundations were put in "dry" by the construction of a coffer dam consisting of piles, timber and clay. Columns are anchored to the masonry by two rods, each 2⅜ ins. square, running from a pin near the top of the column to a point near the timber grillage, where they are attached to a system of I-beams.

Operating Machinery and Electrical Equipment.—The bridge is operated by a 50-H.-P. electric motor with an armature speed of 600 rev. per min. on each side of the river. The reduction from the armature of the motor to the main driving wheel, which engages in the rack of the operating strut is 550 to 1. By the use of worm gearing the machinery was very much simplified, not only a large amount of gearing being dispensed with, but also the necessary supports to carry the same, all machinery being suspended from the main girders and floor beams of the anchor span.

On the motor shaft, which runs longitudinally with the bridge, is placed a beveled gear for hand power, which connects with a vertical shaft running up to the floor level and also the brake wheel and worm. The latter engages in the worm wheel which is placed on a cross shaft. On each end of this shaft and in line with the center of the girders of the anchor span is a pinion which meshes into the main driving wheel and this in turn engages in the rack of the operating strut, which is connected by pin to the movable part of the bridge. The bearings of the motor shaft are babbited, but all the other bearings are phosphor-bronze made of 88 parts copper and 12 parts of phosphorized tin, the latter containing 5% of phosphorus.

The worm is of the Hindley type as made by the Albro-Clem Elevator Company, of Philadelphia, Pa., the threads being cut on lines radial to the center of the worm wheel. In the use of the worm it was found there was little or no necessity for a brake as the machinery holds the bridge in any position in which it may be placed. The worm wheel is a steel casting and the worm is of phosphor-bronze, the center diameter being 16 ins. and the end diameter 18 ins., the threads being cut to 3-in. pitch. The maximum thrust on the worm is about 22 000 lbs., and is taken up by the steel castings, which are bolted to the lower flanges of the girders which support the worm wheel. In these castings, which also act as bearings for the worm shaft, is a phosphor-bronze bushing, between this and the ends of the worm are three loose collars, the one next to the worm being cast iron, the one next to the thrust block being forged steel, and the one between these being made of phosphor-bronze in two pieces for easy removal in case of wear. All bearing surfaces have proper radial grooves for the purpose of oiling.

The current is furnished by the street railway company, which has an electric line crossing the bridge. To open the bridge an average of about 40 h. p. is required on each side of the river, and about the same is required for closing. The maximum required is about 55 h. p., which occurs for a few seconds only at or near the end of the operation of opening or closing. The time required for opening and closing is from 40 to 50 seconds each way. The center locks, heel locks, safety gates and brakes are worked by compressed air, there being placed in the operator's house on each side of the river an air compressor operated by an electric motor. These are so arranged as to be automatic, the current being cut out at 60 lbs. pressure in the receiver. The receivers on each side of the river are connected by a 1-in. lead pipe passing beneath the river, and each compressor is of sufficient capacity to operate the locks, signals, etc., on both sides of the river.

The only necessity for gates in a bridge of this type is to stop the traffic when the bridge is ready to be opened. Each gate is operated independent of the other, so that those of the roadway on the right can be closed first, thus gaining time by stopping the traffic approaching the bridge and allowing that on the other roadway to pass off, while the signals are being given and the center locks drawn.

The work on the substructure was commenced January 22d, 1896, and the bridge was opened to traffic January 20th, 1897. Wilson & Jackson, of Chicago, Ill., were the contractors for the substructure; the King Bridge Company of Cleveland O., for the superstructure, and the Vulcan Iron Works, of Chicago, Ill., for the machinery and electrical equipment. The plans for the superstructure were prepared by Mr. W. M. Hughes, M. Am. Soc. C. E., of Chicago, acting as Consulting Engineer for the city, subject to the approval of Mr. L. B. Jackson, City Engineer. Mr. Hughes also had general supervision of the work during construction. The cost of the work in round numbers was:

Substructure	$34 500
Superstructure	55 400
Machinery (including operating struts)	13 560
Electrical equipment	5 400
Engineering, inspection, temporary foot bridge and other incidental expenses	14 740
Total	$123 600

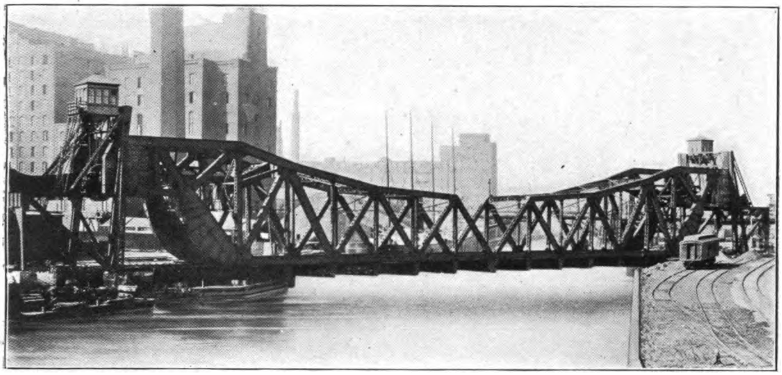
chord channel-webs. The total weight of the superstructure is about 755 tons, including machinery, and excluding 800 tons of cast-iron counterweights, and is counterbalanced so as to be at rest in all positions.

The rolling mechanism will be operated by two General Electric 50-H.-P. railway-type motors, with a General Electric series parallel controller, and an electric solenoid brake, a foot brake, and a pneumatic cylinder and piston at the end of the span acting as an air buffer. The front latch is made with an automatic catch operating in 5 sec. A 12-lever mechanical interlocking plant, supplied by the Union Switch and Signal Company, controls the approaches to the bridge and the front latch, and interlocks with the electric motors. The operating mechanism is on the movable part of the bridge, while the operator's house is on the shore. The pinion at the center of the rolling segment engages with the rack, which is fixed and supported alongside of the track girder. This arrangement, which is an improvement on the moving rack, tends to shorten the total length of bridge required and simplifies the machinery and operation, and is used here for the first time on a Scherzer bridge. Electric bells and electric lights indicate in the house all operations and positions of the bridge. If in raising the bridge it passes beyond the danger point, the electric current is cut out, the brakes are set and the bridge stopped automatically.

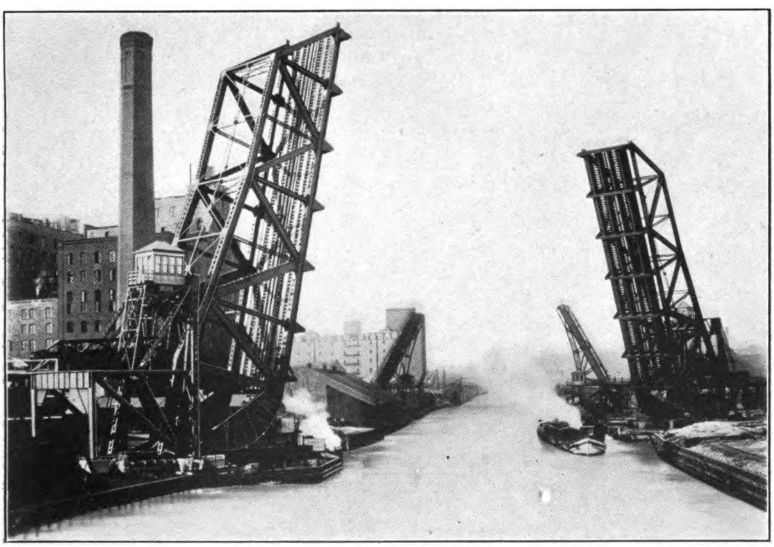
The bridge has a clear waterway of 120 ft. at right angles to the channel between the faces of the main piers, and is located over a channel, which it crosses at an angle of 62°, where the navigation requires it to be opened very frequently. It was erected with the trusses in an approximately vertical position, but without the necessity of maintaining train service on the line of the bridge. The bridge was built at the Toledo plant of the American Bridge Company from the plans of the Scherzer Bridge Company. It is designed for a loading on each track of two 177½-ton locomotives, followed by uniform train load of 5 000 lbs. per lineal foot, with a safety factor of 5.

Scherzer Bascule Railroad Bridge Over Newark Bay.

The double-track main line of the Central Railroad of New Jersey enters Jersey City over a pile and timber trestle, 1½ miles



CLOSED.
FIG. 15.



OPEN.
SCHERZER BASCULE BRIDGE, CHICAGO TERMINAL TRANSFER R. R., CHICAGO, ILL.
(TAYLOR ST. BRIDGE SHOWN IN BACKGROUND.)
FIG. 16.

with solenoid brake attachment suspended from the floor joists in the tail of the leaf and moving with the bridge. The main pinion shafts are brought through the rocker girders at the center of the rolling segment, their pinions engaging fixed horizontal racks, supported on girders outside of the rockers. Control of the operation may be had from each side, or from one side only, by means of a submarine connection to the motor on the opposite leaf. Contacts placed on the rack girder are employed to inform the operator by means of signal lights and gongs of the position of each leaf and tail lock during the operation. The first notch of the controller releases the tail locks and solenoid brakes, and on the second notch the current goes to the motors. An automatic device on the controller handle prevents the operator proceeding to the second notch until the locks are open.

Each rocker was shop riveted complete and erected in the full open position. *G2* was first erected and guyed in place. Floor beams *Ub, U* and *U2* were bolted to *G2* and the free ends blocked up in position, each a few inches higher than clearance for next beams below. G_1 was then swung into position and successively engaged with the floor beams and bolted up; the last beam *Ub* to be thus connected was a few inches higher than final position and permitted lowering the partially assembled leaf over the teeth of track plates. *U3* is web-connected to the ends of the rockers and was readily swung into place. The brackets were then erected, followed by the laterals and stringers. All machinery was erected and temporary electrical installation made before the leaves were lowered.

All masonry is of concrete with 18-in. limestone copings. The rest piers have outside dimensions of 53 x 19 ft., and are founded on piles at 18.5 ft. below mean high water. The abutments, low face walls forming the tail pits and the foundations of the operators' houses are built on timber platforms supported on piles cut off at mean low water.

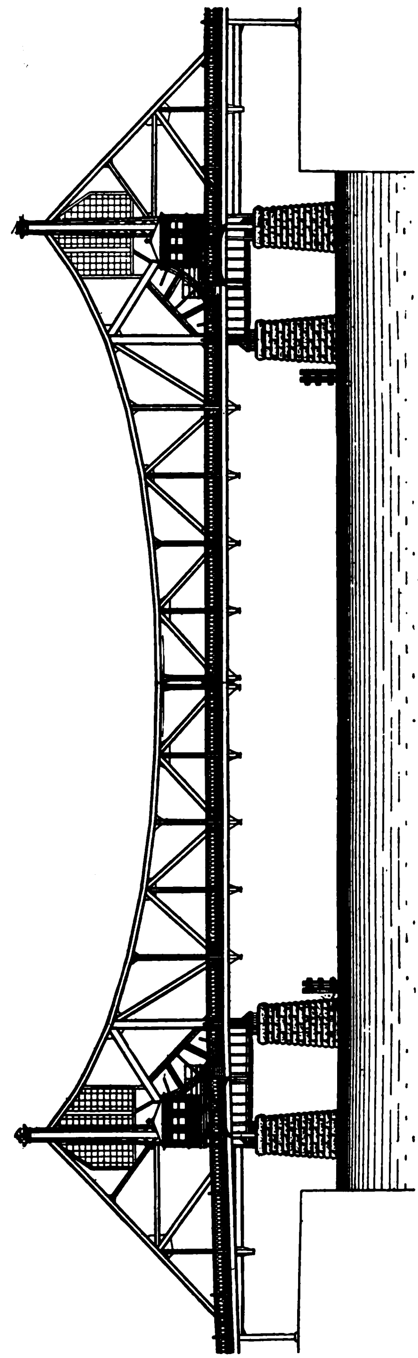
The steel superstructure was fabricated at the Penn Bridge Company's shop at Beaver Falls, Pa., and erected by the R. H. Hood Company, general contractors for the bridge. Each moving leaf weighs 175 tons. The Wilson & Baillie Manufacturing Company were the sub-contractors for the concrete work, which amounts to about 6 400 cu. yds. The principal quantities are: Steel, 260 tons; cast-iron counterweight, 116 tons; and machinery, 18 tons. The electrical equipment cost $3 000. The total estimated cost is $175 000, which includes raising the grade of Hamilton Avenue 10 ft. at the bridge. The work of removing the old bridge began on April 9th, 1904, and the bridge is expected to be completed early in 1905. The work has been done under the direction of Mr. O. F. Nichols, Chief Engineer of the Department of Bridges. The author has been in charge of the work, and Mr. F. W. Perry, Resident Engineer. The plans for the superstructure and machinery were made by the Scherzer Rolling Lift Bridge Company. An elevation of one leaf and a part plan are shown in Fig. 19.

Ninth, Third and Union Street Scherzer Bascule Bridges, Brooklyn, N. Y.

The bridges at Ninth, Third and Union Streets, over the Gowanus Canal, Brooklyn, are of the two-leaf Scherzer deck type, 56 ft. between bearings, and all three are now under construction. These bridges are exactly alike, the same shop plans being used for all three, and provide a 50-ft. channel, 8-ft. head room, one 35-ft. roadway and two 6-ft. 2-in. sidewalks. The leaves are supported on two rocker girders, 33-ft. 7-in. centers, the extreme width of superstructure being 48 ft. 4 in. The sidewalks are carried on brackets, web and flange connected to the rockers. In rear of floor beam *Ub* cast-iron counterweight is disposed to counterbalance the dead load of the channel arm. All live loads on the channel arm are transmitted through the ends of floor beam *Ub* to the bumpers, which are stirrup-connected to the approach floor beam. The approach girder is web-connected to the approach floor beam and engages anchors at each end.

The operating mechanism is standard on all of the Gowanus Canal bascule bridges and, excepting the main shafts and racks, is interchangeable. The racks on these bridges are fastened to the approach girder at the level of the pitch lines.

The moving leaves were erected as follows: First the rocker girders were set on the tracks and then floor beam *Ub* was put in place and the stringers carrying the counterweights put in, then by springing apart the outer ends of the rocker girders, the floor beams *U1, U2* and *U3* were dropped in place and bolted up.



MARINE REVIEW.

VERNON AVE. SCHERZER BASCULE BRIDGE, NEW YORK CITY.
FIG. 21.

The estimated quantities for one bridge are steel, 180 tons; cast-iron counterweight, 230 tons; and machinery, 15 tons. One contract was let for the three bridges and the contractors were the same as for the Hamilton Avenue Bridge. Mr. C. I. Crocker was Resident Engineer on the work.

Vernon Avenue Scherzer Bascule Bridge Over Newtown Creek, L. I.

The bridge over Newtown Creek, connecting Manhattan Avenue, Brooklyn, and Vernon Avenue, Long Island City, now under construction, is of the double-leaf type, each leaf consisting of two through-riveted cantilever trusses. The distance center to center of bearing of the leaves is 172 ft., and with the plate girder approaches the total length of the draw span proper is 332 ft. It has a clear roadway of 40 ft. with two sidewalks each 8 ft. in width.

The minimum clearance over the roadway is 15 ft. and the lowest point of the lift span when closed is 24 ft. above mean high water. A clear channel 150 ft. wide is provided for navigation.

The river traffic is very heavy at this point, more than 8 600 boats having passed the bridge in a single month. By placing the superstructure so high above the water a large proportion of the boats are allowed to pass without requiring the bridge to be opened. This brings the roadway on a level with the long approach viaduct at the north end which carries Vernon Avenue over the tracks of the Long Island Railroad.

The bridge is operated by electric power, two 40-H.-P. motors being provided for each leaf. The machinery for each leaf is on a stationary platform and is connected to the rolling part by two operating struts which move horizontally.

The weight of the superstructure, exclusive of 625 tons of cast-iron counterweight, is 1 050 tons. Mr. Edward A. Byrne is Engineer-in-charge of the work for the Department of Bridges.

MISCELLANEOUS TYPES OF BASCULE BRIDGES.

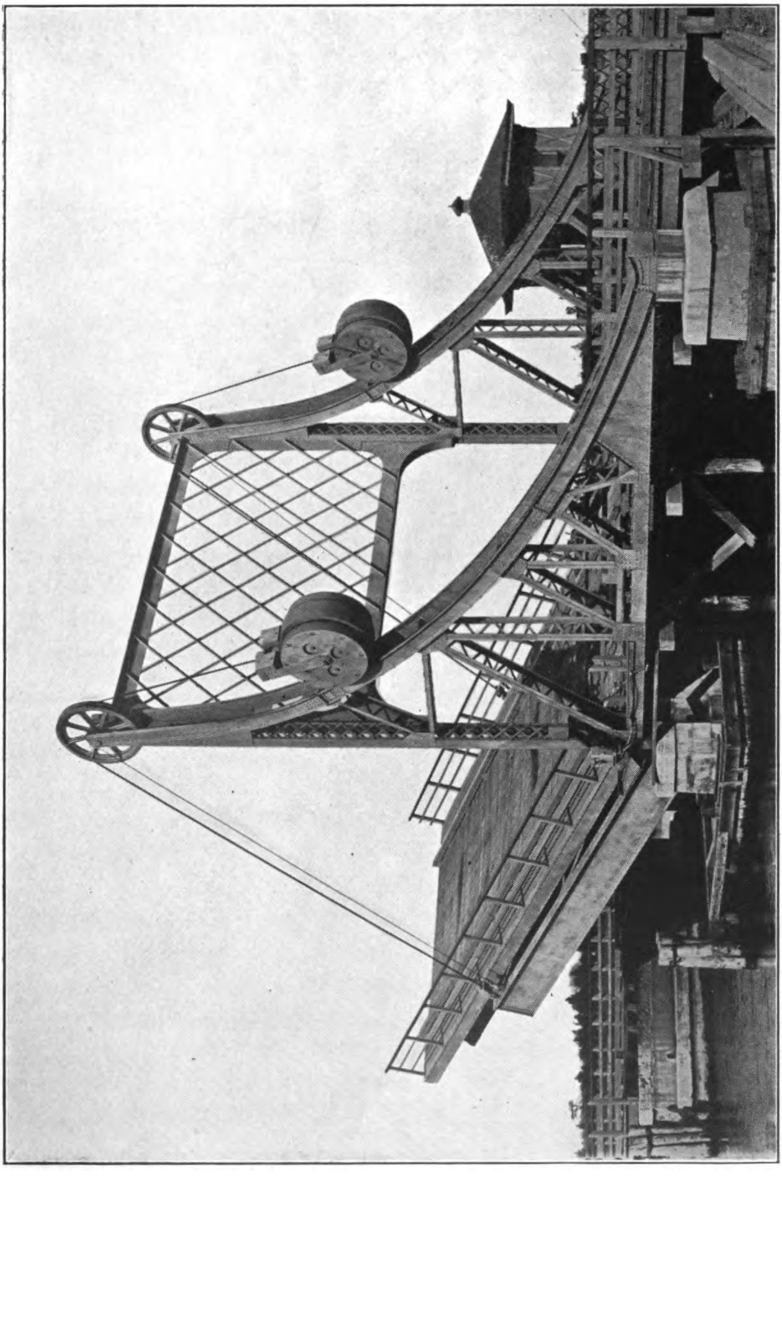
Harway Avenue Bascule Bridge, Brooklyn, N. Y.

Harway Avenue is carried across Coney Island Creek by a bascule bridge having a clear span of about 50 ft. and a width of 31 ft. 4 ins. between hand rails. It is built throughout of medium steel and is proportioned for live and dead loads of 1 400 and 550 lbs., respectively, per linear foot. There are three main longitudinal plate girders 10 ft. apart on centers. Each of them is 42 ins. deep with flanges having two 6- x 4- in. full-length angles and one 13- x $\frac{7}{16}$ - in. cover plat 32½ ft. long. They are connected by four transverse panels of sway bracing which consist of top and bottom horizontal angles and zigzag diagonals. There are *also* pairs of lateral diagonal angles in each of the three main panels. The floor beams are 12- x 4- in. timbers about 33 ft. long bolted to angle lugs 2 ft. apart on the top flanges of the outside girders.

They are covered with a longitudinal and transverse thickness of 2-in. yellow pine plank and carry the 20-ft. roadway between the main girders and the 5-ft. 4-in. sidewalks on their cantilever ends.

At one end the bridge is hinged to the lower ends of a pair of vertical tower columns about 35 ft. high. The tower columns are made with pairs of 12-in. channels and are seated in masonry pockets 5 ft. 4 ins. below grade. They are connected by a latticed girder about 20 ft. deep, which has a clearance of 19½ ft. above the roadway and is made with T-shaped top, bottom and end flanges, which are composed of an 18-in. web plate with pairs of 6- x 3- in. horizontal bulb angles and 3½- x ½- in. vertical flange angles. The diagonal members are single 3½- x 3½- in. angles. The concave track girders for the counterweights are made with pairs of 15-in. channels bent to a curve plotted to correspond with the varying moments of the draw span in different positions. The horizontal members connecting the feet of the track and the columns are pairs of 12-in. channels, and the principal connecting members are each made with four 4- x 3- in. angles.

The main girders are intersected by two transverse girders of the same depth and about 35 ft. long, which are web-connected to them and diagonally braced so as to form the framework of a solid platform. One of them is riveted across the hinge end and the other about two-thirds of the way to the opposite end. The second girder is cut to clear the webs of the longitudinal girders, and is thus made in four sections. Both girders project about 7½ ft. beyond each outside longitudinal girder and have their extremities connected by fascia plate girders 42 ins. deep with single 4- x 3- x ⅜-in. flange angles. At the tower ends these girders project about



HARWAY AVE. BASCULE BRIDGE, BROOKLYN, N. Y.
FIG. 22.

3½ ft. beyond the transverse girder and have ¾-in. web reinforcement plates riveted to them, which project above and beyond their beveled ends to form offset hinge plates on which the bridge is pivoted to horizontal 5-in. pins. The ends of these girders enter the open faces of the columns and the hinge pins engage the column webs.

Gusset plates ¾ ins. thick are riveted to the revolving ends of the fascia girders and each projects above the top flange to receive a 1½-in. and a 4-in. pin. The former engages the end of the ¾-in. steel hoisting rope and the latter engages the 1¾-in. counterweight rope, both of which pass over sheaves at the top of the tower. The counterweight rope is secured to a yoke pivoted to the axle of a cast-iron roller weighing about 45 000 lbs. The hoisting rope is led down the rear face of the column to a drum driven by a 5-H.-P. General Electric motor. The counterweight rollers were found a little too light and additional weight has been added to their yokes. They balance the bridge to within about 6 tons in all positions, so that the bascule leaf always has a positive tendency to close.

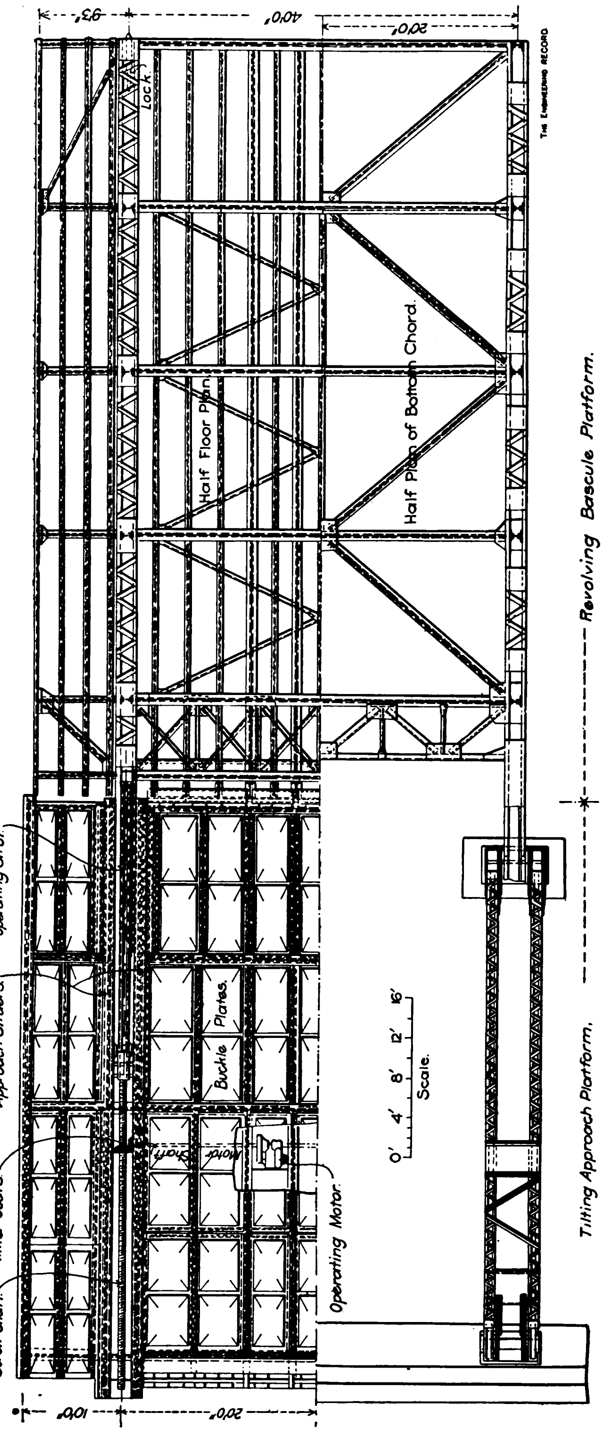
The bridge can be raised by the motors in about 40 seconds. It also has hand gear, with which it can be lifted by three men in about 5 minutes. When closed both ends of the main longitudinal girders rest on flat bearing plates on the masonry abutments. The bridge was completed in 1898 at a cost of about $25 000. It was built by the Department of City Works, Division of Construction and Repairs, Brooklyn, N. Y. The design was made by Mr. Joseph Mayer; Mr. E. S. White was the engineer in charge, and the author was Resident Engineer of construction. Messrs. Dean and Westbrook were the general contractors and the superstructure was built by the Canton Bridge Company.

The first bridge of this type was built at Michigan Avenue, Buffalo, and is described in the *Engineering Record* of August 21st, 1897; two were built by the Erie Railroad, and one in Chicago by Mr. Geo. R. Morison which is described in the *Railroad Gazette* of June 2d, 1899.

Page Bascule Bridge at Ashland Avenue, Chicago.

The bridge has two main bascule leaves, each with two main trusses, which are essentially cantilevers revolving vertically on their end lower chord pins, and when in position to receive street traffic abut at mid-channel with the leaves from the opposite shore. They are anchored in all positions by cantilevers extended from the shore ends of the trusses. The counterweights are formed by the approach spans, which are pivoted on the abutments and are supported at the river ends by rollers engaging curved tracks in the anchor arms of the cantilever trusses. These tracks are so designed that as the bascule revolves the point of application of the counterweight is constant relative to the center of gravity and the fulcrum is such that the bascule is always mantained in equilibrium. The operating power is therefore only required to overcome friction and inertia, and if it be withdrawn or the machinery breaks, the bridge will remain fixed.

The open position of one of the bascule leaves and approach spans is shown by broken lines in Fig. 24. The bascule trusses are of ordinary riveted construction, resembling semi-arch spans, although they are in reality cantilevers, except when keyed together at mid-span, when they become virtually three-hinged arches. They are of ordinary riveted construction with stiff members throughout, and are only peculiar on account of the curved track and connections with the approach spans and operating mechanism. The approach spans are of special construction with two double-plate girders pivoted on the abutments and have bent lower chords. They are made very heavy and under the floor have boxes filled with concrete to increase the counterweights. The pivots are connected with the end lower chord pins of the bascule trusses by inclined struts, which transmit the arch thrust to the abutments. Horizontal pins, at the river ends of the girders, carry large cast-iron rollers between their webs, which engage the curved tracks in the anchor arms of the bascule trusses and transmit to them the counterbalancing loads. The bridge carries a 36-ft. roadway, two street-car tracks and two 8-ft. sidewalks. The clear waterway is 140 ft. wide, and there are two side channels under the approaches, each 42 ft. wide. The bascules and sidewalks have a plank pavement, and the approach spans have vitrified brick on concrete foundations, the latter being deepened to afford the necessary amount of counterweight. Each half of the bridge is independently operated



The Page Bascule Bridge, Ashland Avenue, Chicago, Ill.
Fig. 23.

by two 50-H.-P. direct-current 500-volt motors suspended under the approach span. Both motors of each pier are geared to a transverse shaft, the ends of which have beveled gears engaging intermediate shafts, which extend diagonally upwards between the webs of the double approach girders. Above the abutments they terminate in beveled gears which drive horizontal longitudinal shafts between the top chords of the approach girders. These shafts, 7½ ins. in diameter and 30 ft. long, are threaded from end to end with double square threads. They engage nuts or thrust boxes traveling in parallel guides on the girders. These nuts are pivoted to the shore ends of horizontal operating struts, which are pivoted at the river ends to the top chords of the bascule trusses. The operation of the screw thus revolves the bascule truss around its end lower chord pin, and as it rises the river end of the approach span travels downward on the curved track. When the bridge is closed the opposite river ends of the adjacent bascule trusses are locked together by horizontal steel pins operated by pneumatic cylinders. The approach span was first assembled in its inclined lower position and afterwards the bascule trusses were erected by a stiff-leg derrick having a steel boom 90 ft. long.

The traffic gates, center and back locks and signals are operated by compressed air. The bascule leaves can be stopped at any position while being raised or lowered by merely shutting off the power. The screws act as brakes and keep the bridge continually locked. All of the machinery is controlled from two cabins, one at each end of the bridge. The north cabin contains the two motor controllers and was designed to operate both sides of the bridge from this point with one operator. Either side can, however, be raised or lowered independently of the other. The bridge was opened to traffic October 24th, 1902, and has been operated successfully. The principal advantages claimed for this type of bridge are that it has a low truss with nothing projecting above the hand rails; that no portions of the structure are ever revolved below the water line; that the masonry is reduced to a minimum, the by-pass is increased to a maximum, and that cheap concrete is substituted for high-priced cast-iron in the counterweights. No other bridge of this type has been erected, however.

Messrs. Page & Schnable were the designers of the bridge. Mr.

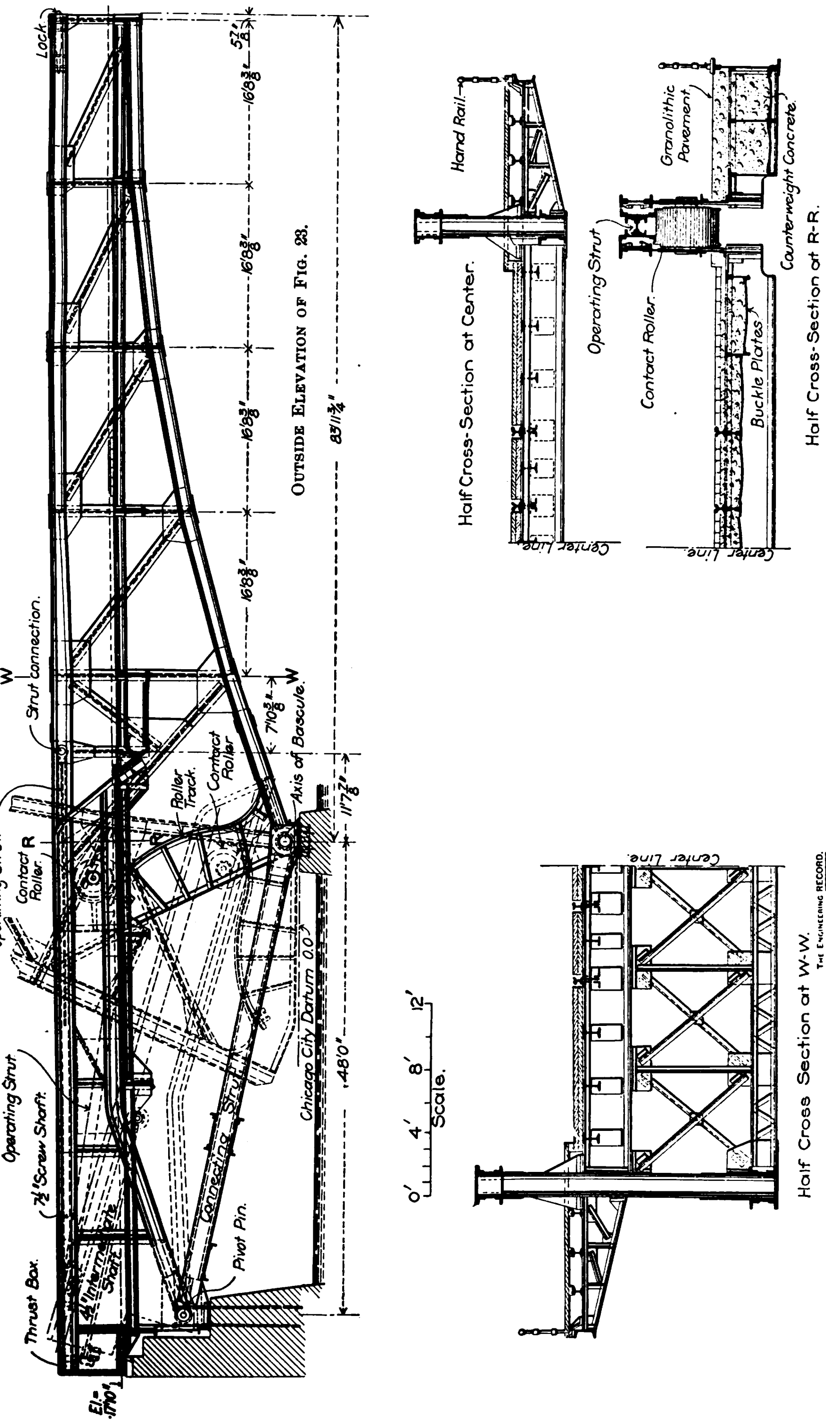
W. M. Hughes was the Consulting Engineer, the Chicago Bridge and Iron Company was the contractor for the superstructure, and the bridge was built under the direction and supervision of Mr. Isham Randolph, Chief Engineer of the Sanitary District of Chicago, and Mr. J. E. Grady, Assistant Engineer.

SCHINKE BASCULE BRIDGE AT HURON STREET, MILWAUKEE, WIS.

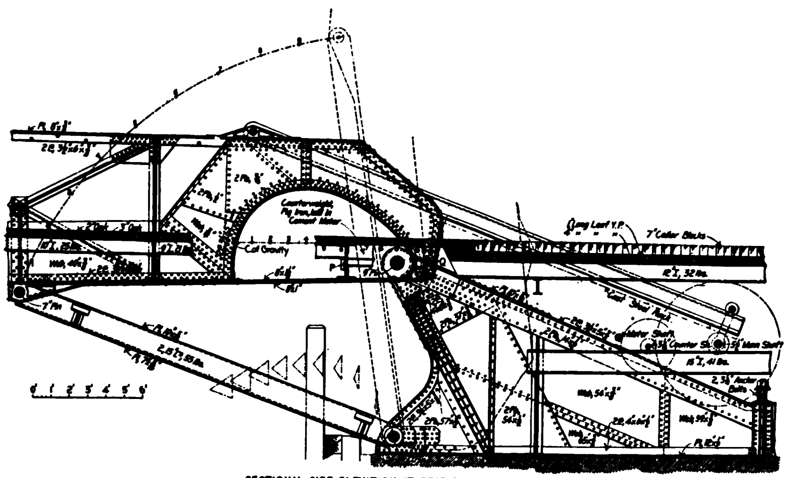
The substructure consists of two abutment walls, about 80 ft. long, and four piers 10 ft. by 25 ft. in plan. All of the masonry rests on piles, the solid strata to which the piles are driven being about 57 ft. below datum. Piles under the abutment walls are cut off 5 ft. below datum to receive the grillage; the bottom of the masonry is 3½ ft. below datum. The abutment walls are held in place against the earth pressure by anchor rods, bearing on anchor piles driven about 24 ft. back of the abutment.

The four piers consist of Portland cement concrete blocks, 10 to 25 ft. in plan and 10 ft. high, resting on a timber grillage, for which the piles were cut off 15 ft. below datum. The concrete is surrounded by Wakefield sheet piling 8 ins. thick. Considerable trouble was experienced in getting this sheeting tight for the work in the interior, the water being 17 to 18 ft. deep in the channel and the sheeting apparently too light for the water pressure. The top of the piers is 1 ft. above datum, and their upper part is formed by three courses of Menomonee limestone, 3 ft. 6 ins. thick altogether. The sheeting is held in place by an oak wale-streak, 6 by 12 ins. in section, well secured at the corners. The work is protected at the corners by four heavy clumps, consisting of ten piles each, and by three rows of fender piles in front, with intermediate timbers, the front row of piles reaching as high as 8 ft. above datum to guard the ironwork of the bridge against overhanging parts of boats. The contract for the substructure was let to the lowest bidder, Wm. Forrestal, at a price of $24 300, and was completed to receive the iron work on the west side by the end of September, 1896, and on the east side a month later.

The superstructure consists of two stationary approach spans, 87 ft. and 42 ft. long, respectively, and two equal parts of a lift-span each 46 ft. long. The clear width of roadway is 34 ft., the clear width of sidewalks on the stationary parts is 9 ft., on the



The Page Bascule Bridge, Ashland Avenue, Chicago, Ill.
Fig. 24.



SECTIONAL SIDE ELEVATION AT REAR END OF MOVING GIRDER.

Fig. 25.

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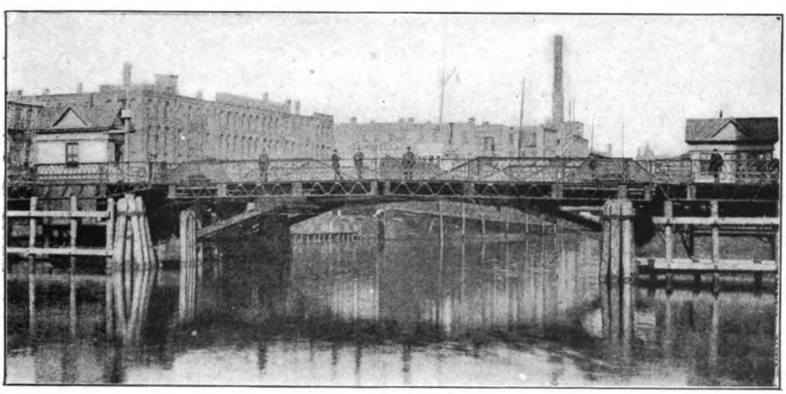


Huron Street Schinke Bascule Bridge, Milwaukee, Wis.
Fig. 26.

movable parts 7 ft. The grade of the roadway is slightly ascending towards the middle, where it is 13.5 ft. above datum. The roadway has a crown of 3 ins. There is a platform projecting beyond the sidewalk on the northwest corner of the east approach and one diagonally opposite on the west approach to carry the bridge houses and also to form the stands for the men operating the bridge.

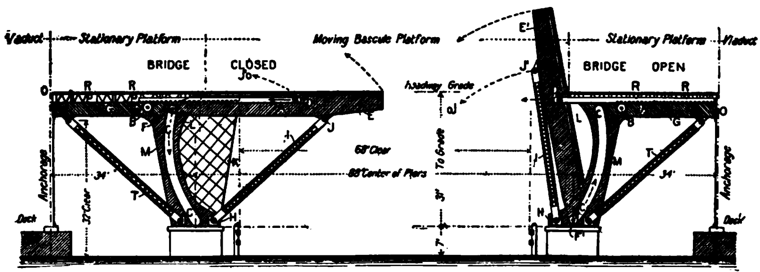
The roadway of the stationary parts is formed by 7-in. cedar blocks resting on two layers of long leaf yellow pine planking, 1 in. and 4 ins. thick. The roadway of the movable parts consists of two layers of white oak planking, 2 ins. and 3 ins. thick. The sidewalk planking is 2-in. white pine. The uniformly distributed live load was assumed at 100 lbs. per square foot of roadway, and 80 lbs. per square foot of sidewalk; the concentrated live load consisted of two street cars weighing 18 tons each and moving side by side on tracks 8 ft. apart, center to center.

The stationary parts, spanning the space between the abutment walls and piers, were designed as plate girder deck-spans. The lift-span may be briefly described as follows: A triangular supporting girder, anchored at its rear end into the masonry, carries a pair of rollers on its top and forward end, which support the rear end of the main girder. The forward support of the main girder is formed by a swinging strut pin-connected to it at the upper end and to the base of the triangular girder at the lower end. The main girder is double for the rear and middle panel. Each of the two parts for the rear panel is provided with a curved track, which runs on the supporting rollers, when the bridge is swung. The whole movable part is counterweighted so as to bring the center of gravity to a certain point, and the curved track is laid out so that this point moves in a horizontal line when the bridge is swung. The rule for constructing the curved tracks may also be expressed thus: A perpendicular line through the center of gravity, the center line of the swinging strut, and a line rectangular to the tangent of the curve intersect in one point for any position of the movable part. In consequence of this rule, the weight of the movable part and the two end reactions (compression in swinging strut and pressure on rollers) are in equilibrium for any position of the movable part. It will be observed that the maximum strains in the swinging strut and on the rollers occur in the closed position, and that the strains diminish going upward to a certain point; at this point the lower end of the main girder finds a support on the pin-casting and in consequence the center of gravity, instead of following the above rule, describes the arc of a circle, and the movable part is supported only by the swinging strut and held in place by the operating machinery. This was done to relieve the rollers for inspection, oiling, etc.

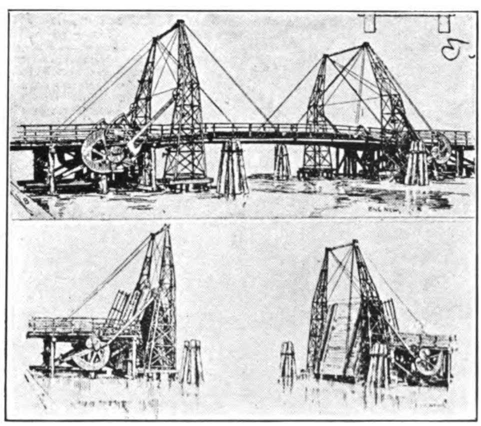
The so-called inside main girder was constructed as a plate girder for the rear panel carrying the track, and as a truss for the remaining two panels. The outside main girder, being only two panels long, was constructed entirely as a plate girder, its rear panel is a counter part to the inside main girder, the second panel is of such depth as to be covered by the sidewalk planking.

In regard to the floor system, special mention is to be made of the fact that there are two end floor beams for the rear end, one attached to the inside main girder and one attached by stiff hangers to the outside main girder. This construction was resorted to for the purpose of getting as nearly as possible equal loads on the two main girders, the counterweight being about equally distributed on the two. The amount of counterweight required for one movable part is a little over 100 000 lbs., the total weight of one movable part is about 255 000 lbs., including the counterweight.

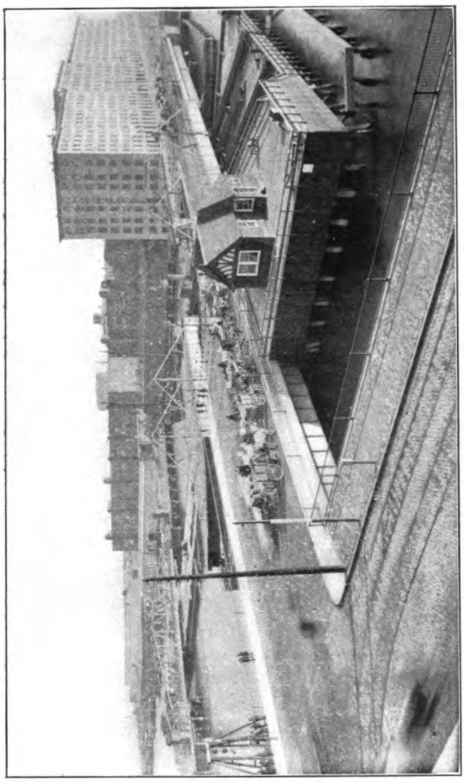
The operating machinery comprises two inclined working struts which are provided with steel racks, into which two pinions engage, mounted on the ends of the main shaft, which is 5½ ins. in diameter. The main shaft carries a cast-iron gear wheel 87 ins. in diameter, which is operated by a 9-in. pinion mounted on the 3¼-in. countershaft, which is driven by the gear of a 25-H.-P. Gibbs electric motor. The sheave for a band brake is also mounted on this shaft. A separate set of gearing for the purpose of operating the bridge by man power is provided and consists of a pinion engaging into the main gear wheel and turning a 3-in. shaft, which by a clutch can be connected to a set of gears operated by hand lever in the usual manner from the deck of the approach spans. The movable part is sufficiently locked by the machinery with the brake set on. As an additional safeguard and for the purpose of locking when for some reason the brake is off, a locking arrangement, thrown in and out by the operator, is provided for.



16TH STREET SCHINKE BASCULE BRIDGE, MILWAUKEE, WIS.
FIG. 27.



CANAL STREET FOLDING LIFT OR JACK-KNIFE BRIDGE,
CHICAGO, ILL.
FIG. 28.



Summer Street Retractile Bridge, Boston, Mass.
Fig. 29.

The structure was erected without false-works. The stationary parts were first put up from shore by a boom derrick, which was afterwards shifted to the forward end of the approach spans. The lift-spans, with floor beams, stringers, etc., were erected in an upright position, as the channel had to be kept open all the time. After nearly all the iron work of the lift-spans, part of the counterweight and all parts of the machinery were in place, the bridge was lowered into its closed position, to receive the flooring and to be finished up otherwise, while always ready to be swung for a passing boat. The heaviest girder to be lifted by a boom derrick was 13 200 lbs.

No other bridge of this kind has been built.

The contract for the entire superstructure was taken by the Milwaukee Bridge and Iron Works (the J. G. Wagner Company, proprietors), at the price of $23 800.

Sixteenth Street Schinke Bridge, Milwaukee.

This bridge has a 68-ft. clear channel, is 88 ft. center to center of piers, 156 ft. long over all, and 54 ft. wide. Its cost, complete, was $42 000.

The moving leaf at the shore end has a roller traveling on a vertical track girder. The other end cantilevers on a pin-connected strut, the motion being such that as the roller moves down, the strut moves up. Under a live load, the bridge is latched and the thrust on the pin-connected strut is met by a strut from the pivot pier to the abutments. No other bridge has been built of this type.

Folding Lift or Jack-Knife Bridges.

Three of these bridges were built in Chicago and one in Milwaukee. The largest of these was the old Canal Street Bridge, shown in Fig. 28, which was 89 ft. center to center of piers. All these Chicago bridges have been removed, but the Milwaukee bridge, which is at Holton Street, is still in use.

In this type the moving leaf is in two parts, hinged near the shore end, the parts being supported by cables passing over towers and connecting with the inner half of the leaves and the counterweights. When the draw is opened the two parts are lifted up and folded together in a manner similar to the closing of an open book.

The counterweight effect is varied by a rope passing over a large cam.

One of the Chicago bridges, the Weed Street Bridge, 17 ft. wide with a 60-ft. channel and on timber foundations, cost about $16 000. One man could operate the bridge by hand power. As in the Canal Street Bridge, there were two moving leaves, one on each shore.

Retractile Bridges.

This type of bridge is mounted on wheels and is rolled back from the draw channel by cables or by rack and pinion. The movement is usually at an angle to the channel.

There are two of these bridges in Brooklyn, one at Washington Avenue over Wallabout Canal, and one at Carroll Street over Gowanus Canal; there is also one at Westchester Avenue over the Bronx River, in the Borough of the Bronx, and a small one at Princess Bay, Staten Island. The type originated in Boston, where there are a number of them, and they are sometimes called a "Boston" draw.

The type is limited to comparatively narrow channels and by the value of the space which they occupy when open. It is a thoroughly reliable bridge and low in first cost and maintenance, and gives the desired center channel.

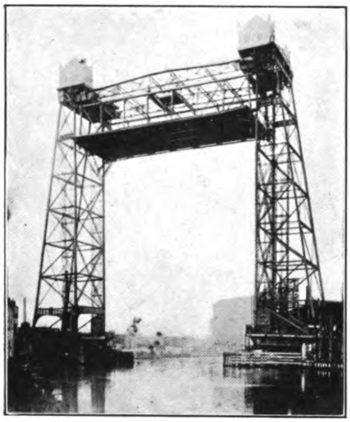
Summer Street Retractile Bridge, Boston.

This bridge carries Summer Street over Fort Point Channel. It is composed of two equal leaves, both retreating to the same side of the channel. Each leaf has a 30-ft. roadway and a 10-ft. walk. The weight of each half is 156 tons, including 6 tons of counterweight. The bridge is mounted on ball bearings and each leaf is handled by a G. E. 58 motor by means of cables wound on a drum.

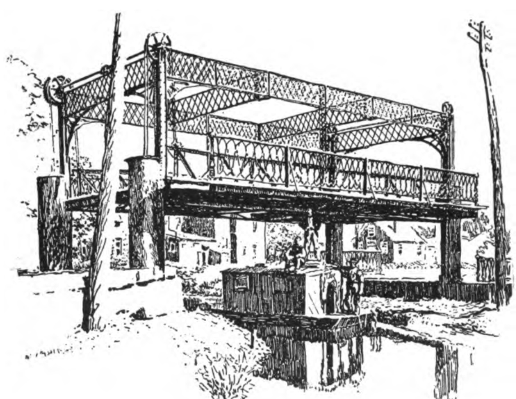
The bridge works very smoothly, rolling for 20 to 30 ft. after the power is shut off.

Telescope Retractile Bridge at Queens Ferry, England.

This bridge gives a clear channel of 120 ft. The draw span is in halves, meeting at the center of the channel. There are two fixed approach spans of 140 ft. each at each end, into which the



WADDELL LIFT BRIDGE, SOUTH HALSTEAD STREET.
FIG. 30.



VERTICAL LIFT BRIDGE OVER A CANAL.
FIG. 31.

draw spans are telescoped. Each half of the draw span is 100 ft. long and projects 60 ft. from the fixed spans and constitute cantilevers of that length. Each is extended 40 ft. within the fixed spans and counterbalanced.

The floor of the draw span is collapsible, being lowered 23 ins. to clear the floor of the fixed spans by an arrangement of levers before being withdrawn into the approach spans. The movement is made by traveling wheels. The railings also fold up. The weight of the movable half span is 90 tons. The motive power is hydraulic and the bridge was opened in 1897, and is known as the Victoria Bridge. The appropriation was $65 000 and the limited amount gave occasion for this ingenious design.

Waddell Lift Bridge at South Halstead Street, Chicago.

The direct lifting bridge at South Halstead Street, Chicago, has a movable span of 130 ft., center to center of bearings, and provides 110 ft. clear opening between pier protections and 155 ft. clear headroom when fully raised. It has 290 tons of counterweight and a total moving weight of 600 tons. The bridge has a total width of 57 ft., a 36-ft. roadway and two 7-ft. sidewalks. It was designed for a live load of 4 500 lbs. per lineal foot. The bridge has two 70-H.-P. motors and is operated by means of nearly three miles of wire rope. The total cost of the bridge was $237 000.

This is the only large bridge in which the movable bridge span is lifted or raised by means of towers, ropes, pulleys and movable counterweights to a height sufficient to allow the passage of masted vessels beneath the bridge when open. The author timed an opening of this bridge and 4 m. 45 sec. was taken to open and 1 m. 20 sec. to lower.

These bridges are sometimes used over small canals when the lift is only enough to clear canal boats. A small cut of one of these is shown in Fig. 31.

Another bridge of this type was erected in Australia over the Murray River at Swan Hill. The span is 58 ft.; the roadway is 14 ft. The weight of the lift-span is 34 tons and it is operated by one man by hand power. It was built in 1896 and cost $44 500.

Pontoon Foot Bridge at State Street, Chicago.

The removal of the old swing bridge over the Chicago River at State Street, to make room for the new Scherzer bascule bridge at this site, has seriously interfered with traffic on this busy thoroughfare, and it was decided to erect a temporary foot bridge for the convenience of the people and to prevent congestion of traffic at the other bridges. Several plans were proposed, but eventually the design of a pontoon bridge was selected.

The bridge consists of two parallel chord timber trusses, 117 ft. long over end panels, 12 ft. deep, center to center of chords, and spaced 11 ft. apart, center to center of trusses. The trusses have 9-ft. panels and are connected by top and bottom lateral bracing. The clear width is 10 ft. and the floor consists of a single layer of 2-in. plank, laid longitudinally, and carried by floor joists 2 x 10 ins. spaced 2 ft. center to center. The bridge is designed for a live load of 80 lbs. per square foot. One end of the bridge rests upon a pile pivot pier, while the other end is carried by a timber pontoon. It is operated by a 15-H.-P. motor placed on the pontoon and driving a crab, around the drum of which is wound a chain whose ends are anchored at opposite sides of the river. When the bridge is open for traffic it gives a waterway of 60 ft., and a headway of 16 ft., which is sufficient for tugs and barges. When swung open for navigation it gives a clear waterway of 100 ft.

The pivoted end of the bridge has a pair of oak bolsters, 12 x 12 ins., extending under the bottom chords; to the middle of these is attached the upper center plate, while their ends carry two conical wheels 12 ins. in diameter and 6 ins. wide on the face. By having these wheels in transverse line with the center pin, the free end of the bridge can rise and fall with the stage of the water without causing any distortion in the relations of the rolling gear or any vertical racking strains in the trusses. The wheels run on 8-in. track plates spiked to the top timbers of the pier, and to those timbers is also bolted the lower center casting for the 4-in. center pin or pivot. An iron ring $\frac{3}{4}$ x 3 ins. encircles this casting, and to it are attached diagonal rods leading to the trusses, by which (as well as by timber braces between the trusses and bolster) the trusses are kept in proper relation to the pivot. The pontoon is 38 x 20 ft. on top, and 20 x 20 ft. on the bottom; it is 7 ft. deep, but drawing only about 24 ins. of water when loaded. It consists essentially of three 38-ft. trusses, the middle one of heavy construction (carrying the greater part of the load) and the side trusses somewhat lighter. Across the top, bottom and sides of the trusses are 6-in. timbers, to which are spiked the sheathing of 2- x 10- in. pine plank. Two trestle bents upon the pontoon carry transverse caps, upon which rests the bottom chords of the bridge trusses. The electric motor and winding drum are mounted in a cabin on the deck of the pontoon. The bridge can be opened or closed in about 45 seconds.

Transporter or Ferry Bridge.

This type consists of a car suspended above the surface of the water to any height desired, by means of cables fastened to trucks running on tracks placed on a truss supported by towers at the banks of the water to be crossed. The supporting trusses are placed high enough to clear the masts of vessels. The inventor of this type is M. Ferdinand Arnodin, who designed a bridge of this kind which was erected over the Seine at Rouen, France. The span is 435 ft. and the height 152 ft. Several other examples of this type have been built in France.

A bridge of this type is proposed at Duluth, Minn., and has been described in the *Engineering News* of March 20th, 1902, and one is under construction now in England over the Mersey River at Runcorn. The fixed suspension structure is 1 000 ft. long and 82 ft. in the clear above high water. The movable car has a 24- x 55- ft. platform, with a capacity for four wagons and 300 passengers. It is expected that the car can make about ten trips per hour.