MOVABLE BRIDGES

BY

OTIS ELLIS HOVEY, B.S., C.E.

Member of the American Society of Civil Engineers, American Society of Mechanical Engineers, American Society for Testing Materials, American Iron and Steel Institute, and Associate Member of the American Railway Engineering Association

Assistant Chief Engineer of American Bridge Company

IN TWO VOLUMES

VOLUME I.—SUPERSTRUCTURE

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and the action positive and certain. As it is difficult to fabricate and erect the two rack frames exactly alike and truly opposite, an equalizer should always be introduced in the gear train, preferably in the first counter shaft from the motor.

This bridge was built in 1904.

Figure 4M shows the general elevation of a small, double-track, through plate girder bridge, on the Central Railroad of New Jersey, across the Elizabeth River, at Elizabeth, N. J. The span is 73 ft. between end bearings and the clear channel is 60 ft. The method of operation is the same as for the larger bridge shown in Fig. 4L. The counterweight is of concrete and extends across the entire width of the structure.

This bridge was built in 1912.

Figure 4N represents a typical, small, double-leaf highway bridge. Center shear locks and rear anchorages and locks are required, to enable the leaves to act as cantilevers for live loads. The breaks in the floor of such a deck structure must be well to the rear of the center of the main pinions, on account of the recession of the leaf in opening. The same movement makes a simple center lock feasible. This lock is a tongue-and-groove device on the ends of the main girders of the leaves, as shown in Fig. 4O. No mechanical parts are needed, for the tongue can be entered by controlling the relative positions of the closing leaves, as indicated at (*a*). As the leaves advance, in closing, the tongues are driven into positive locked position, as shown at (*c*). The rear end of the counterweight frame engages overhanging anchorage girders, carried by columns extending into the masonry to secure ample resistance to the uplift caused by cantilever action of the channel leaves. When live load is also carried by the extensions of the main girders beyond the counterweights, it will also be found that tail locks are needed to take the reactions from the loads on the girder extensions.

Statistics.—The principal dimensions, facilities afforded, and the weights of the structural steelwork and operating machinery of several Scherzer Rolling-lift bridges are given in Table 4B. It will be noted that the percentage of machinery to structural parts is less than in Table 4A, for the simple-lever trunnion type. This is due to the simplicity of the designs and the small rolling friction developed. The proportion varies widely for the different designs and is larger for those with two leaves. The weight of the motors and power plant proper is not included, but only the gear trains from the motors to the point of application to the bridge, including the racks.

9. Rall bascule bridges.—This type was developed and patented by Mr. Theodore Rall, and is controlled by the Strobel Steel Construc-

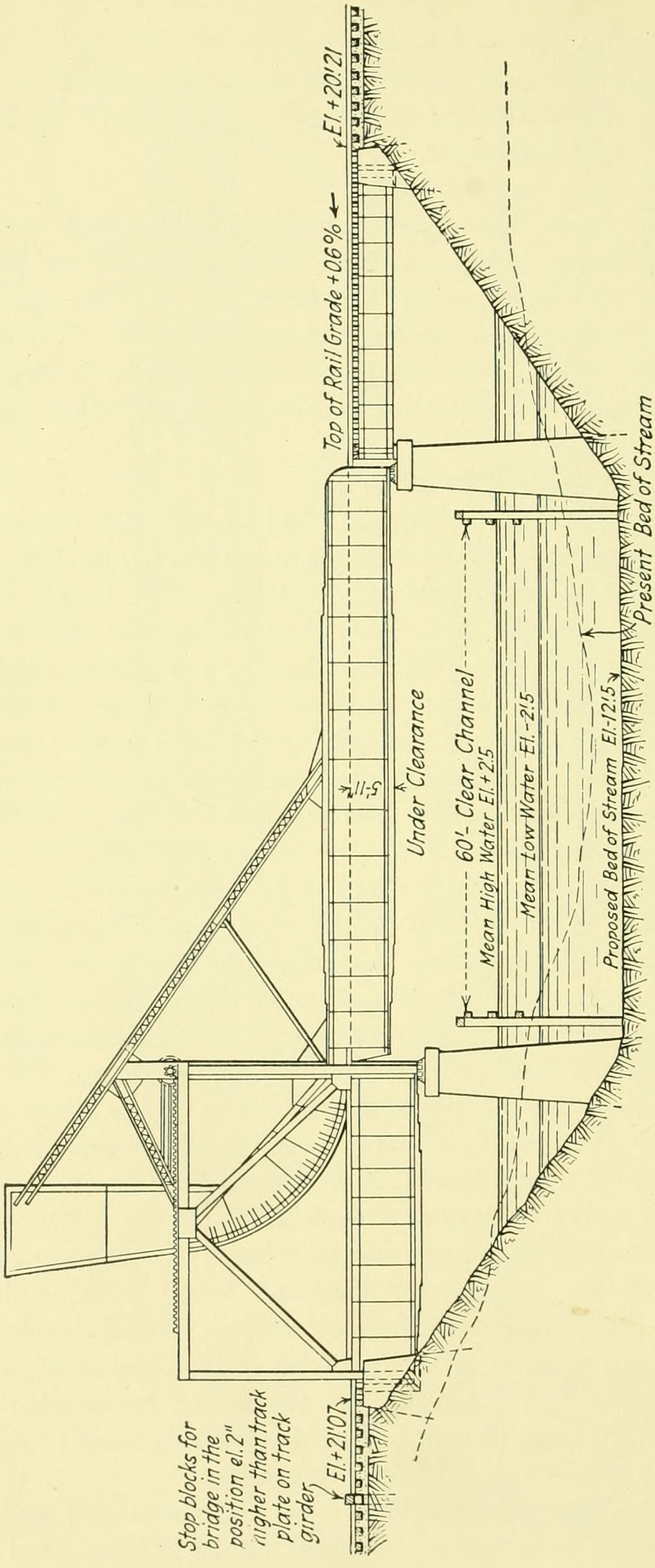

El. +20.21
Top of Rail Grade +0.6 %
Under Clearance
5'-11"
60'- Clear Channel
Mean High Water El. +2.5
Mean Low Water El. -2.5
Proposed Bed of Stream El. -12.5
Present Bed of Stream
El. +21.07
Stop blocks for bridge in the position el. 2" higher than track plate on track girder

Fig. 4M.

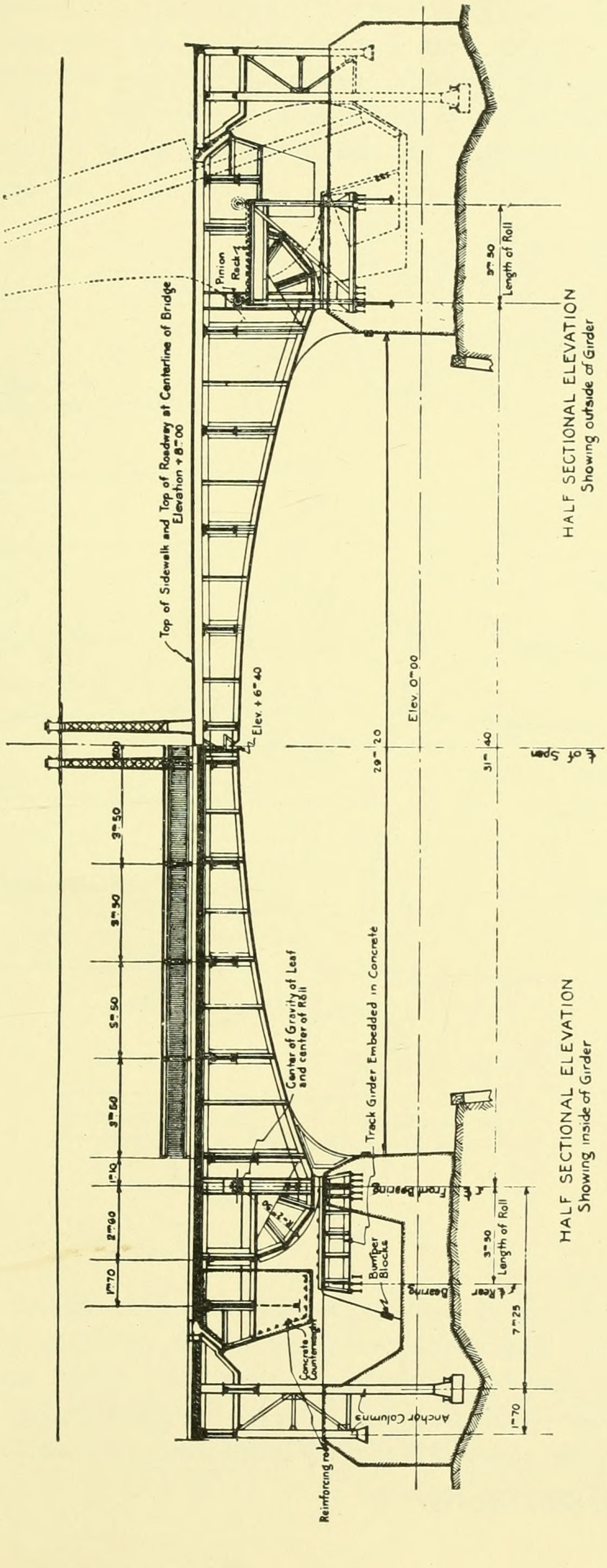

Top of Sidewalk and Top of Roadway at Centerline of Bridge
Elevation + 8.00
Pinion
Rack
Elev. + 6.40
Elev. 0.00
29.20
31.40
℄ of Span
3.30
Length of Roll
HALF SECTIONAL ELEVATION
Showing outside of Girder
3.50
3.50
5.50
3.60
1.10
2.60
1.70
Center of Gravity of Leaf and center of Roll
Track Girder Embedded in Concrete
℄ Front Bearing
℄ Rear Bearing
Bumper Blocks
Concrete Counterweight
Anchor Columns
Reinforcing rods
7.25
1.70
HALF SECTIONAL ELEVATION
Showing inside of Girder

Fig. 4N.

tion Co., of Chicago. The bascule leaf opens by a combined rolling and swinging movement that can best be explained by reference to Fig. 4P, which is a diagram of one end of a double-leaf, electric railway bridge over the Illinois River, at Peoria, Illinois.[11] The span is 142 ft. between centers of end supports. The leaf is carried at its center of gravity

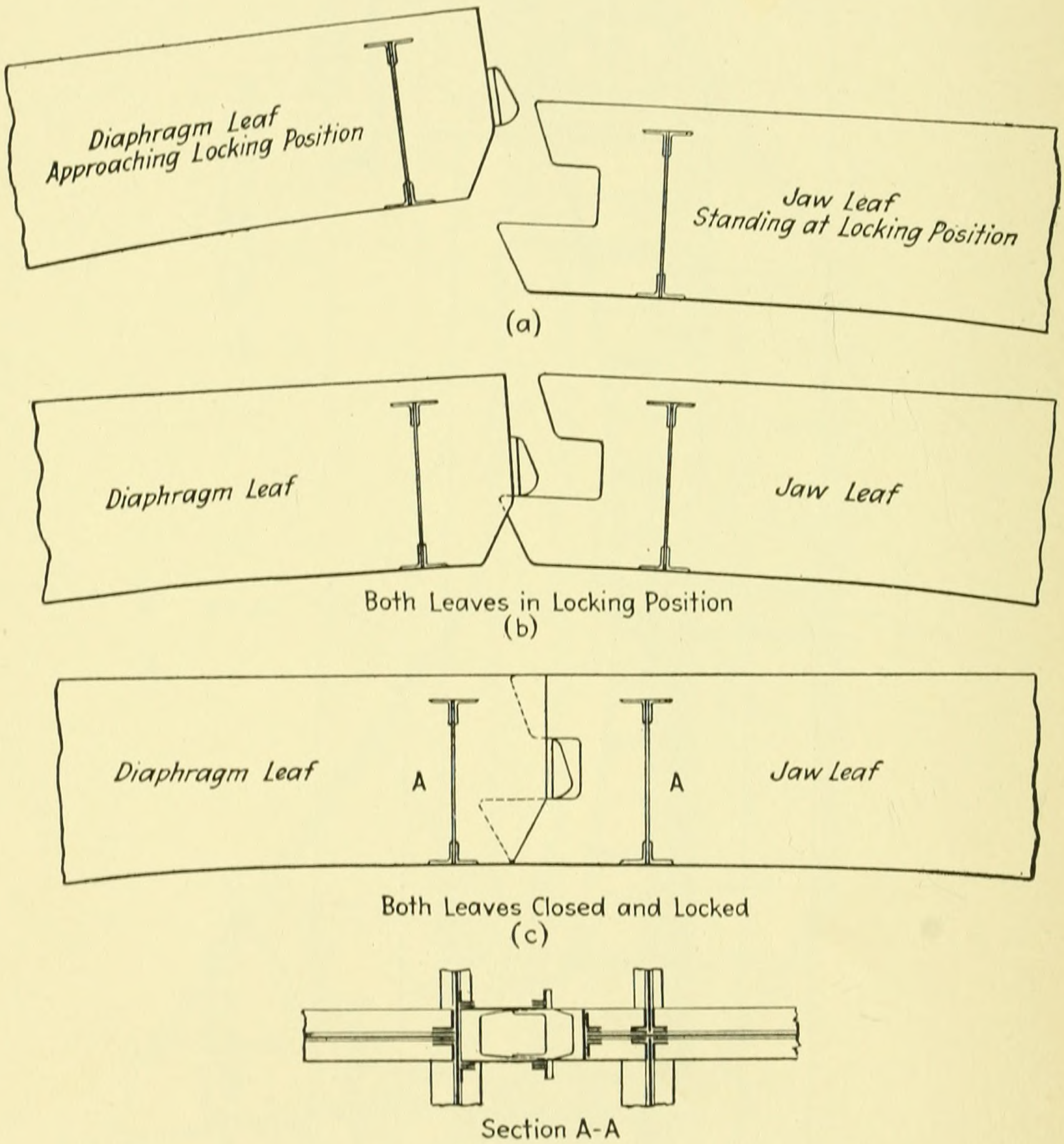


Fig. 4O.

by a shaft A, having at each end a roller B, which rolls on a horizontal track girder C. The counterweighted end of the main girder is connected to the pier by the swinging-strut EF, which turns on pins. When the bridge is closed, pedestal G, on the main girder, seats on pin F, on the pier, and roller B is slightly lifted from its track C. Operating

[11] *Eng. News*, 1907, II, p. 56.

TABLE 4B
Scherzer Rolling-lift Bridges

Name or Location	Design	Number of Leaves	Clear Channel-Feet	Span c. to c., Feet	Roller Track Span, Feet	Tracks, Number or Roadway, Feet	Sidewalks, Number, Width	Weight of Structural Steel, Pounds	Weight of Machinery, Pounds	Machinery to Structural, Per Cent	Total Weight, Pounds	Date Built
Railway Bridges												
Newburg & South Shore Ry., Cuyahoga River, Cleveland, Ohio	Thro. Riv.	1	120	160 skew	38	2	....	1,327,000	106,000	7.99	1,433,000	1904
New York, New Haven & Hartford R.R., Cos Cob, Conn.	D. P. G.	2 parallel	67.5	81	20.17	2 @ 2	....	1,741,000	99,000	5.69	1,840,000	1906
New York, New Haven & Hartford R.R., Naugatuck Jct., Conn.	Thro. Riv.	2 parallel	81	108	34.67	2 @ 2	....	1,839,000	89,000	4.84	1,928,000	1907
New York, New Haven & Hartford R.R., Connecticut River, Lyme, Conn.	Thro. Riv.	1	149.25	158.25	38	2	....	2,060,000	91,000	4.42	2,151,000	1907
New York, New Haven & Hartford R.R., Pelham Bay, N. Y.	Thro. Riv.	3 parallel	66.75	81.58	29.5	3 @ 2	....	1,993,000	61,000	4.57	2,054,000	1908
New York, New Haven & Hartford R.R., Bronx River, N. Y.	Thro. Riv.	3 parallel	66.75	103.25 skew	37.17	3 @ 2	....	3,222,000	108,000	3.55	3,330,000	1908
Chicago Lake Shore & Eastern R.R., East Chicago Canal, Indiana Harbor, Ind.	Thro. Riv.	1	86.5	96	....	2	....	637,000	41,500	6.52	678,500	1908
Buffalo Creek R.R. Co., City Ship Canal, Buffalo, N. Y.	Thro. Riv.	1	....	151	28.5	2	....	1,350,000	42,000	3.12	1,392,000	1909
New York Central & Hudson River R.R., Peekskill, N. Y.	T. P. G.	1	50	67	16	2	....	488,500	16,000	3.28	504,500	1913
River Terminal Ry., Cuyahoga River, Cleveland, Ohio	Thro. Riv.	1	....	148	47.25	1	....	622,500	20,500	3.29	643,000	1914
Maine Central R.R., Wiscasset, Me.	T. P. G.	1	....	83	48.5	1	....	332,500	16,500	4.96	349,000	1916
Maine Central R.R., Thomaston, Me.	D. P. G.	1	....	30.04	....	1	....	76,000	6,500	8.55	82,500	1921
Maine Central R.R., Georges River	T. P. G.	1	39	44.92	30	1	....	120,000	7,500	6.25	127,500	1921
Highway Bridges												
Newtown Creek, Brooklyn, N. Y.	Thro. Riv.	2	150	172 skew	2 @ 80	40	2 @ 8	2,210,000	200,500	9.07	2,410,500	1902
Malden River, Boston, Mass.	D. P. G.	2	50	56	....	28	1 @ 8	226,000	35,000	15.49	261,000	1905
Saugus River, Boston, Mass.	D. P. G.	2	50	56	....	26	1 @ 6	210,000	35,000	16.67	245,000	1905
Kimberley Ave., New Haven, Conn.	D. P. G.	2	....	51	23	44	2 @ 10.58	343,000	51,000	14.87	394,000	1906
Buffalo Creek R.R., Union Canal, Buffalo, N. Y.	Thro. Riv.	1	....	90	....	27	2 @ 6	428,000	41,500	9.70	469,500	1906
Charles River Basin Lock, Boston, Mass.	D. P. G.	2 parallel	....	52	21	2 @ 31.17	2 @ 9.83	457,000	45,000	9.85	502,000	1907
Pelham Bay, New York, N. Y.	Deck Riv.	2	60	80	....	34	2 @ 7.5	401,000	32,000	7.98	433,000	1908
Taunton Great River, Fall River, Mass.	D. P. G.	2	....	113.5	....	44	2 @ 8	878,500	56,500	6.43	935,000	1908
Mill Creek, Bayville, L. I.	D. P. G.	2	79	85	8.5	21	1 @ 5	139,000	30,000	21.58	169,000	1922

strut J is hinged to the main girder and has a bottom rack, engaging pinion H, on the fixed span or the abutment. Rotation of the pinion draws the rack rearward, first causing the roller to contact with its track. The span then turns about the trunnion in the roller and the anchor pin F, causing a combined rotary and retractile movement of the leaf. Point E rotates in the arc of a circle about the center F, and other parts of the span move in various curves.

As in case of a simple rolling-lift bridge, the span length may be a minimum and the angular motion is less than for a simple trunnion bascule. The weight of the entire leaf is carried by the rollers and travels backward across girder C, when opening. This shifts the load upon the piers and foundations in a manner similer to that of a simple rolling-lift span. The weight must also be taken by line contacts between the rollers and their tracks, so that these parts require the best of design, material, and workmanship. The friction of motion is greater than that of a rolling-lift, for the trunnions must turn in the rollers under maximum load and the hinged links will also offer some resistance.

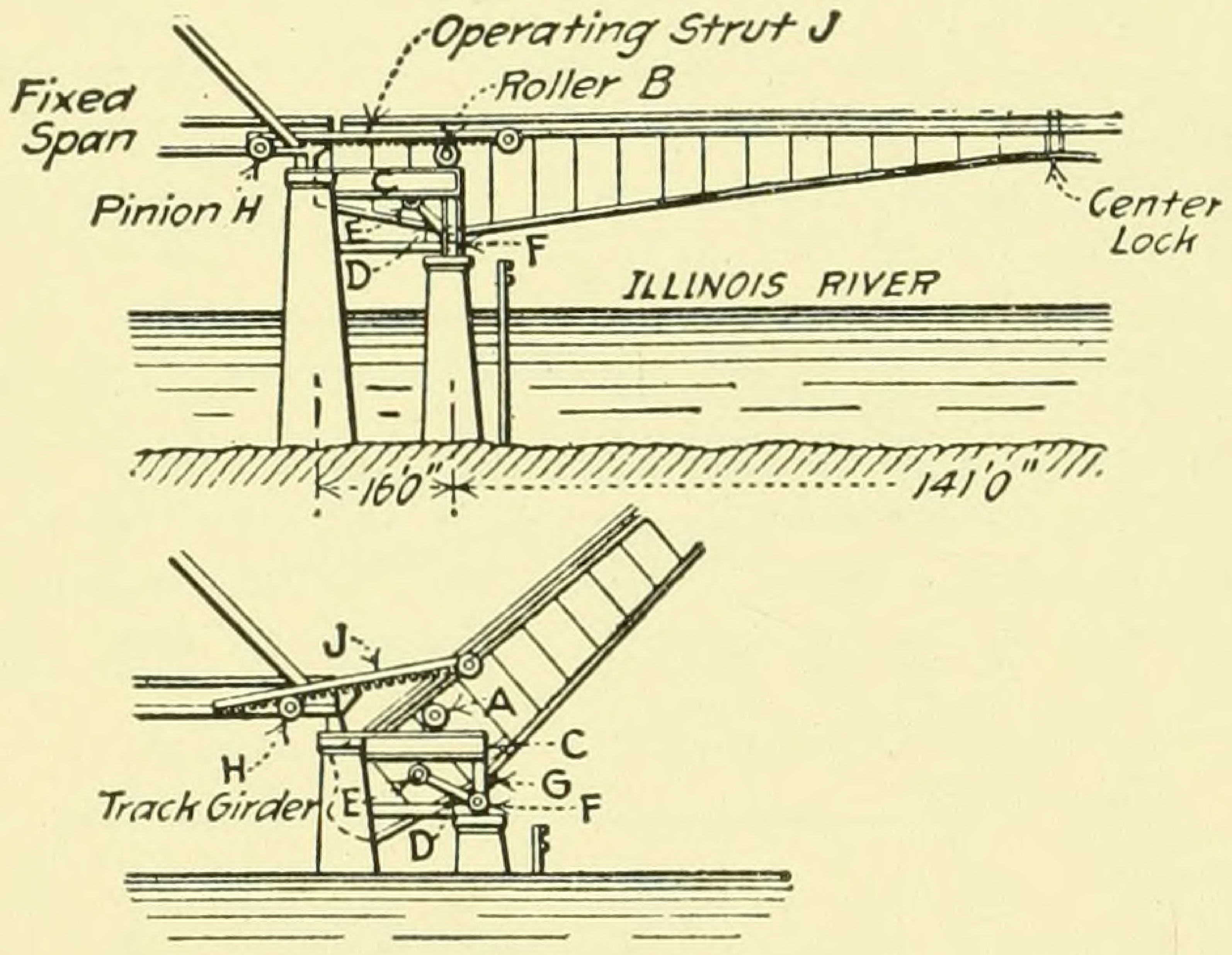


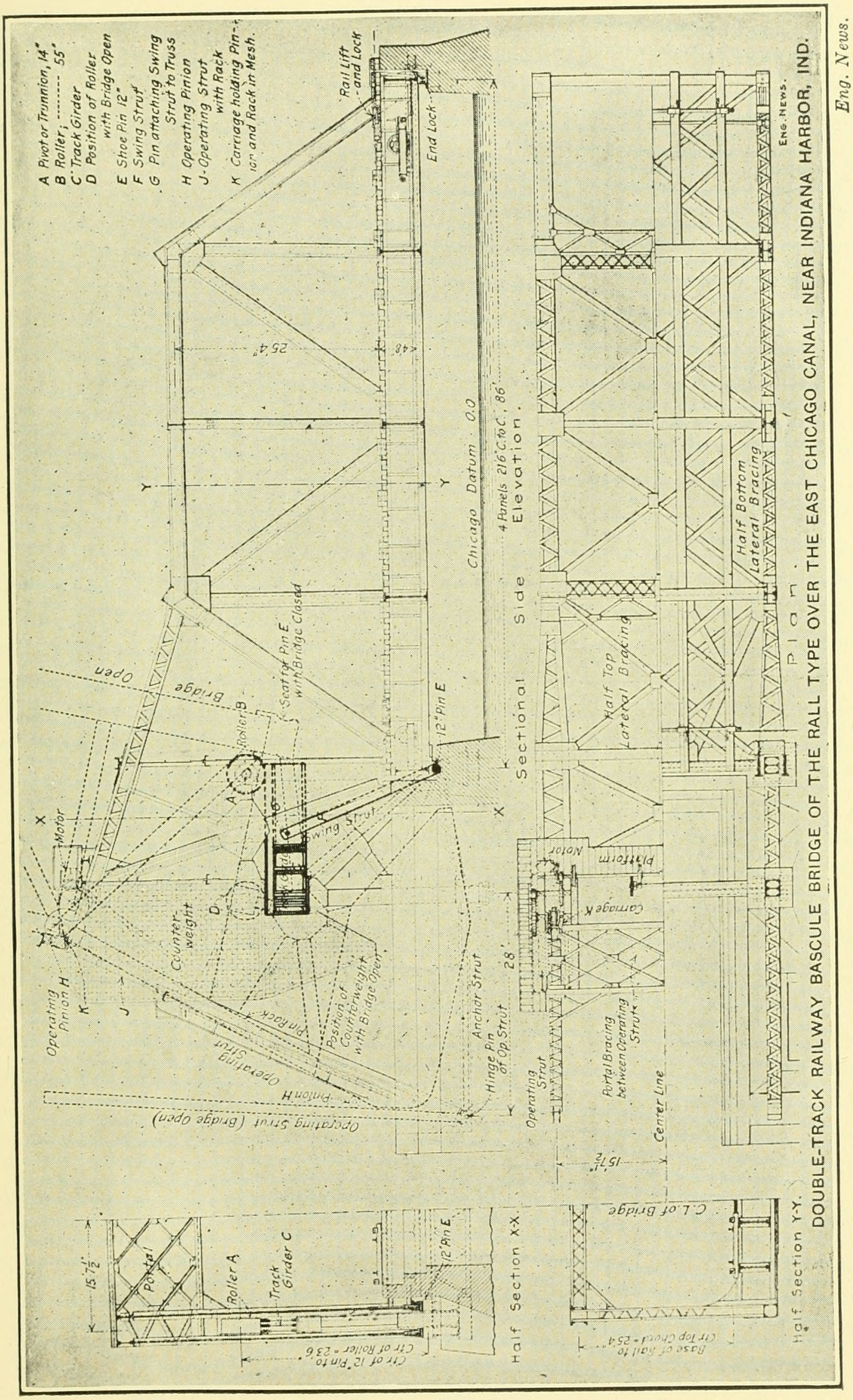
Fig. 4P. *Eng. News.*

One excellent feature of the design is that the rollers can be removed, for repairs or replacement, when the bridge is in its closed position, for they are then relieved of all load. Further, the rollers are of such size that they can be cast solid, and take load directly, while the rolling-lift quadrants are usually so large that they must be built up from structural plates and shapes, with a joint between the girders and the curved tracks attached to their circumference.

This bridge was finished in April, 1907

East Chicago Canal Bridges.—Figure 4Q shows the general design of four double-track, railway, Rall bascule bridges over the East Chicago Canal, near Indiana Harbor, Ind.[12] Two of these were built for the Lake Shore and Michigan Southern Railway, and one each for the Pittsburgh, Fort Wayne and Chicago Railway and the Baltimore and Ohio Railroad. The span length is 86 ft. between centers of end bearings. When the bridge is closed, all live load is delivered

[12] *Eng. News*, 1909, I, p. 295.



Eng. News.

Fig. 4Q.

directly to the piers. Ordinary pier pedestals are used at the free end of the span. At the trunnion end a pedestal is attached to the bottom chord, under the end panel point, which seats on pin E, in a pedestal built and anchored into the masonry. The small deck bridge, in Fig. 4P, had longitudinal operating racks. In the through design in Fig. 4Q, the racks are articulated to the abutment masonry and extend in a diagonally upward direction, in the plane of the trusses, to the top of the counterweight frames, where the main pinions engage the racks. The motor and reduction gearing are mounted on the rear end of the counterweight frames. The main pinion is held in mesh with the rack by a frame, with rollers which travel along the operating strut. When the bridge is open, the strut is nearly vertical. When the span is closed, the free end is secured by a thrust lock, interlocked with the signals. Rail locks are provided at each end of the leaf.

Each bridge is operated by two 35-h.p., 220-volt, direct-current electric motors. The actual power required to move the bridge, under ordinary wind conditions, is about 25 h.p. Thus, one of the motors may be held in reserve. The rail locks at each end of the bridge and the end locks are operated by two ½-h.p., direct-current motors. Each main motor has a solenoid brake and there is an hydraulic emergency brake on the driving shaft, actuated by a hand pump in the operator's house. The several motors are electrically interlocked with each other and with the signals, so that all operations must be performed in proper sequence.

These bridges were proportioned in accordance with the specifications of the Pennsylvania Lines, for a live load of about E60 engines, followed by 5000 lbs. per linear foot of track. The weight of structural material and machinery is about 326 tons for each bridge and the total rolling load is 555 tons. The trunnions within the rollers were proportioned for 1600 lbs. per square inch of bearing, and the rollers for $400 \times D \times L$, at the surface of contact with the track. The rollers are 55 in. in diameter, with 25-in. faces, and are of cast iron, with rims and hubs 3 in. thick and with 2-in. webs. Steel tires, 1½ in. thick, were shrunk around the cast-iron cores. Later practice has been to use cast steel for the rollers, and in some cases special alloy steel has been provided.

Broadway Bridge, Portland, Oregon.[13]—This is the largest Rall bascule yet built. It is a double-leaf, city-street structure, 278 ft. between end bearings and 70 ft. wide. There is one 46.5-ft. roadway and two 9-ft. sidewalks. The clear distance between the tops of the open leaves is 250 ft. The draw is the middle of three river spans,

[13] *Eng. News*, 1913, II, p. 704.

each of the two flanking fixed spans being 297.213 ft. long. The roller-track girders, their supports, the swinging-struts, and the machinery are supported in the first long panel of the adjoining fixed spans. The closed leaves act as cantilevers. The horizontal end bottom reaction is taken by the bottom chord of the fixed span. The tension at the top is delivered to the top chord by a long link, which is slotted and moves on a pin at the upper hip panel point. The counterweight frames are inside of the bascule trusses and the counterweights move between the end posts of the anchor spans.

Each leaf has two operating struts, each placed 12 ft. from the longitudinal center of the span. They are attached by pins to the moving leaf and extend back over the end of the fixed span. Racks on their bottom faces mesh with the main driving pinions. The operating struts are 91 ft. long and weigh 21 tons each. They are stiffened by top vertical diaphragm-girders, and are held in mesh by a frame at the pinion, with guide rollers running on the flanges of the struts. The slotted tension anchors are 52 ft. long with a travel of 35 ft. They are anchored to the bascule leaves by 13-in. pins and move on $10\frac{1}{2}$-in. pins in extensions of the top chords of the anchor spans. Adjustment is provided, so that when the leaves are closed the slots come to exact bearing on the pins and all of the live load is taken. Hydraulic buffers, within the anchor slots, assist in bringing the closing bridge to bearing without shock. The swing-struts are articulated to the counterweight frame at one end and to the track girder at the other. They are 23 ft. long and swing through an arc of 105°.

The rollers on which the leaves move are the most unusual features in the bridge. Figure 4R shows one of them, with its track and the adjacent steelwork. They are of nickel-chrome steel, 100 in. in diameter with 40-in. faces. The track is of the same material and is 20 in. deep to distribute properly the great concentrated load to the webs of the the supporting box girders. The nickel-chrome steel was specified to have an elastic limit of 52,000 lbs. per square inch, an ultimate tensile strength of 102,000 lbs. per square inch, an elongation of not less than 15 per cent, and a reduction of area at the fracture of not less than 17 per cent.

The load on each roller is about 2,000,000 lbs. The load per linear inch of roller is 50,000 lbs. Thus the load may be expressed by the formula,

$$P = 500 \times D \times L,$$

in which D is the diameter of the roller and L its length, both in inches.

The bridge was designed for a load of 2000 lbs. per linear foot on each street-car track, and for 100 lbs. per square foot on the balance of the roadways and the sidewalks, making a total load of 7600 lbs. per linear

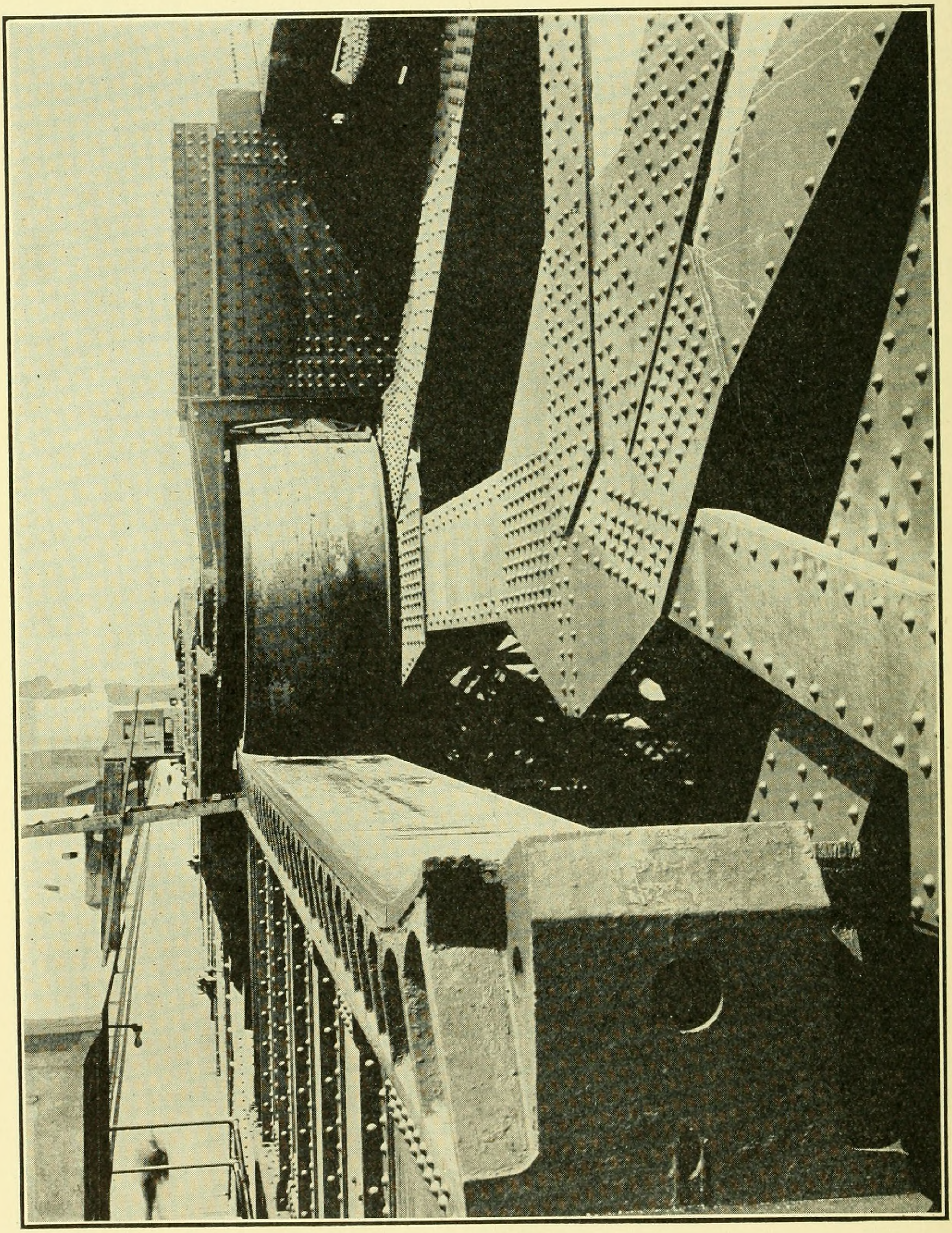


FIG. 4R.

foot of bridge. A special feature of this bridge is that the specifications required the trusses of the bascule span to be in line with the trusses of the approach spans. This necessitated special recesses in the counterweight boxes and their supports to enable them to pass between the trusses of the approach spans, and rendered the design of the bracing rather difficult.

The bascule span was designed by the Strobel Steel Construction Co., of Chicago, subject to the approval of Mr. Ralph Modjeski, of Chicago, who was chief engineer in charge of the design and construction of the entire bridge, for the city of Portland, Oregon.

The bridge was opened for traffic in April, 1913.

The estimated weight of the steelwork is given below.

APPROXIMATE ESTIMATED WEIGHT OF STEELWORK

One Bascule Span, 250 Ft. Clear Opening

Structural Steel	Pounds	Pounds	Per Cent of Steelwork
Movable part:			
Floor system	590,000		
Overhead bracing	160,000		
Main trusses, river arms	700,000		
Main trusses, tail arms	460,000		
Cross girders over wheels	120,000		
Counterweight boxes	160,000		
Live load anchor struts; Structural part of operating struts; Controlling struts	190,000		
		2,380,000	
Stationary part:			
Track girders; Supporting columns; Bracing		400,000	
Stairs, machinery supports, floor, bolts, spikes, and other miscellaneous parts		70,000	
		2,850,000	
Mechanical parts:			
Cast steel wheels	110,000		
Cast steel tracks	106,000		
Forged hollow trunnions	20,000		
Forged solid trunnions	10,000		
Bronze bushings	4,000		
		250,000	8.77
Operating machinery		150,000	5.26
Total steelwork		3,250,000	14.03

10. Strauss bascule bridges.—The first Strauss bascule bridge was completed in 1905. It was patented by Mr. Joseph B. Strauss, and this and his later patents are controlled and advocated by the Strauss

BRIDGE ENGINEERING

BY

J. A. L. WADDELL

C.E. (Rens. Poly. Inst.); B. A.Sc., Ma.E., D.Sc. (McGill Univ.); D.E. (Univ. of Neb.); LL.D. (Univ. of Mo.); Kogakuhakushi (Doctor of Eng., Imp. Univ. of Japan)

Correspondant de l'Institut de France dans l'Académie des Sciences; Correspondiente de la Real Academia de Ciencias y Artes de Barcelona; Corresponsal de la Sociedad de Ingenieros del Perú; Knight Commander of the Japanese Order of the Rising Sun; Ordre de Bienfaisance de la Grande Duchesse Olga de Russie, Première Classe; Second Class Order of the Sacred Treasure of Japan; Second Class Order of the Sacred Grain of China; Cavaliere del Ordine della Corona d'Italia; Consulting Engineer New York City; Member of the American Society of Civil Engineers; of the American Institute of Consulting Engineers; of the Franklin Institute; of La Société des Ingénieurs Civils, Paris; of the Engineering Institute of Canada; of the Western Society of Engineers; of the Society for the Promotion of Engineering Education; of the American Association for the Advancement of Science; of the American Society for Testing Materials; of the International Society for Testing Materials; of the American Railway Engineering Association; of the China Society of America; of La Société de Géographie de France; of the National Conservation Association; of the National Economic League; of the Liberal League; of the Authors' Club, London; and Honorary Member of the Chinese Institute of Engineers; of the Association of Chinese and American Engineers; of the Chinese Railway Association; of the Asociacion Nacional de Ingenieros Industriales de Espagña; of the Kogaku Kyokai (Engineering Society of Japan); of the Engineers' Club of Kansas City; of the Société Internationale d'Études de Correspondance et d'Échanges Concordia, Paris; of the Phi Beta Kappa Society; of the Sigma Xi Society; and of the Tau Beta Pi Society

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tributed over greater area, thereby reducing the unit bearing stress; and at the same time the frictional resistance to rotation is decreased.

Much ingenuity has been exercised in devising various mechanisms and operating machinery in the attempt to overcome the several unsatisfactory features of the original bascules. This has led to different sub-types or varieties. To the rolling lift class belong the Scherzer and the Rall varieties. To the trunnion class belong the Strauss, Brown, Page, Chicago City, and Waddell & Harrington varieties; and to the roller bearing class belong the Montgomery Waddell and the Cowing varieties.

In the Scherzer bascule (see Fig. 30*a*), the leaf, L, rotates on the quadrant Q, which rolls along the horizontal track girders, T. The centre of gravity, G, of the leaf is at the centre of this quadrant and, therefore, moves in a horizontal line as the bridge opens. A counterweight, W, is attached to the short arm projecting shoreward, so that the leaf is main-

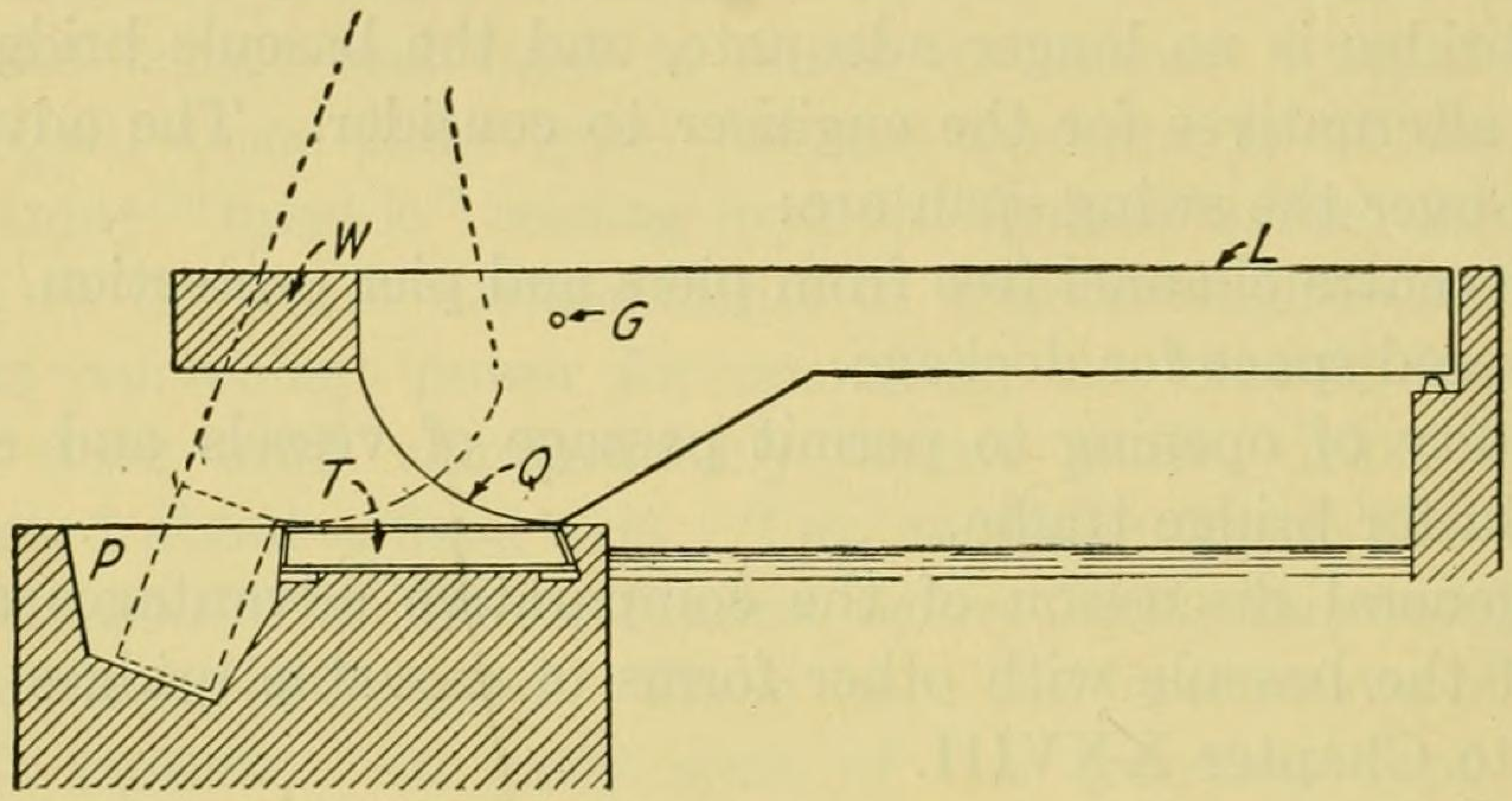

FIG. 30*a*. Scherzer Bascule.

tained in balance at all positions; and, consequently, the operating machinery has only to overcome inertia and the friction of the moving parts. A pit, P, is provided in the main pier so that the counterweight can sink into it as the leaf opens and rolls backward. This pier is of large size, as it carries the track girders; and it requires a good, solid foundation, since the shifting of the point of application of the load disturbs the base pressures. Two other smaller piers are required for a single leaf structure— a rest pier at the front end and a shore pier or abutment at the rear end to carry the approach span. In the case of a double leaf bascule a second main pier will be required and also an abutment. A locking device at the centre of the span connecting the two leaves when the bridge is closed renders unnecessary a rest pier. The span is operated by a pinion working in a rack pivoted to the upper part of the quadrant. Fig. 30*b* shows one of the Scherzer rolling lift bridges.

The Rall type, shown in skeleton form in Fig. 30*c*, rotates about the centre of gravity, G, of the leaf where a pivot or trunnion is provided, which rests in a roller, R, carried by a horizontal track girder, T. When the leaf is closed the main girder or truss bears on the pin A, which is fixed to the pier; and the roller, R, is slightly raised off the track girder, so that the load on the bridge is carried directly by pin A to the pier. The swing strut, S, is connected at one end to the movable girder by pin B, and at the other end to pin A. When the leaf rises, it first revolves

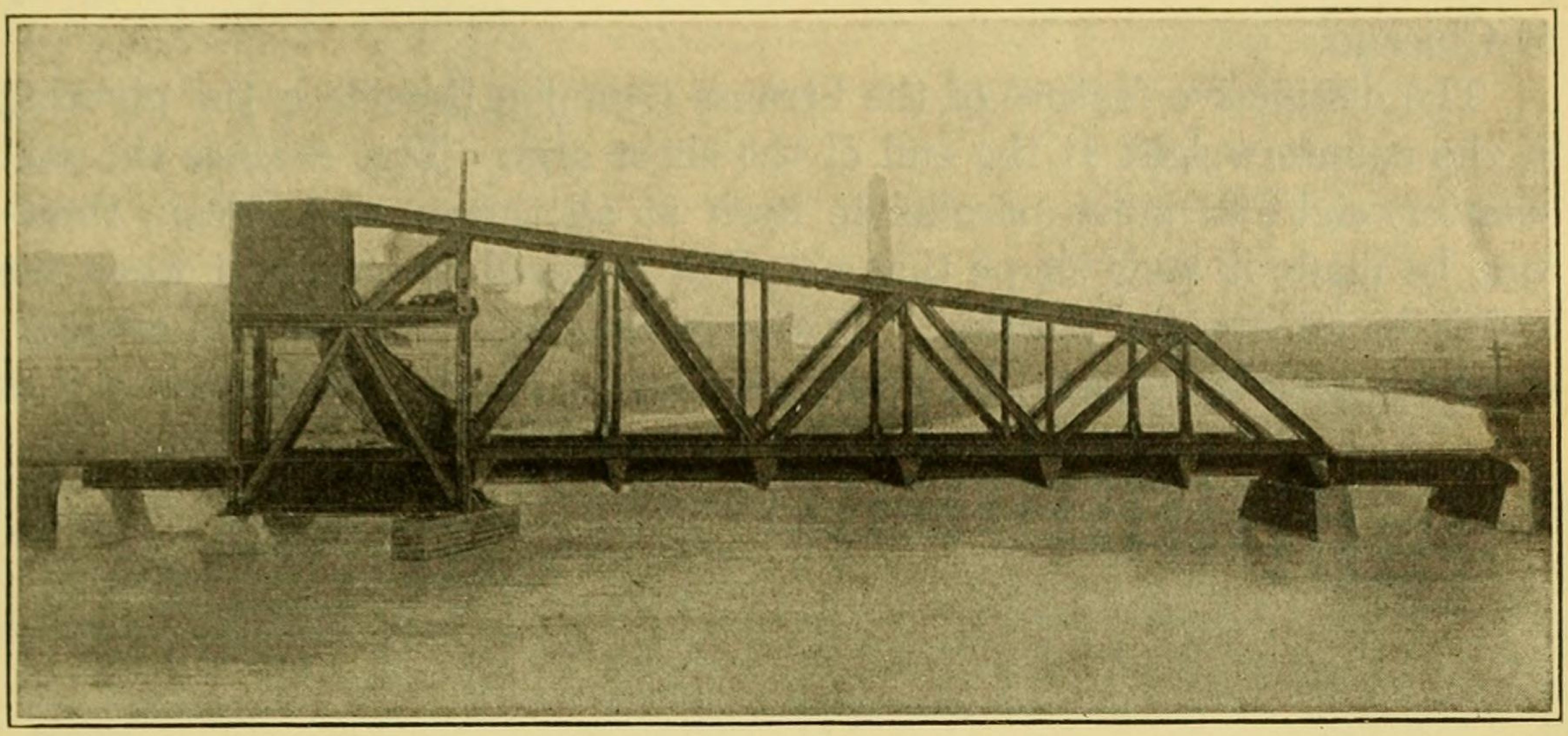

FIG. 30*b*. Scherzer Bascule Bridge.

around pin A, until the roller is in full bearing with the track girder; then as the operation is continued, the roller moves horizontally on the track girder, while pin B of the main girder describes an arc with A as the centre. The leaf is operated by the main pinion, P, engaging a rack fixed to the strut, E, which is pivoted to the girder at C. When the leaf is closed the

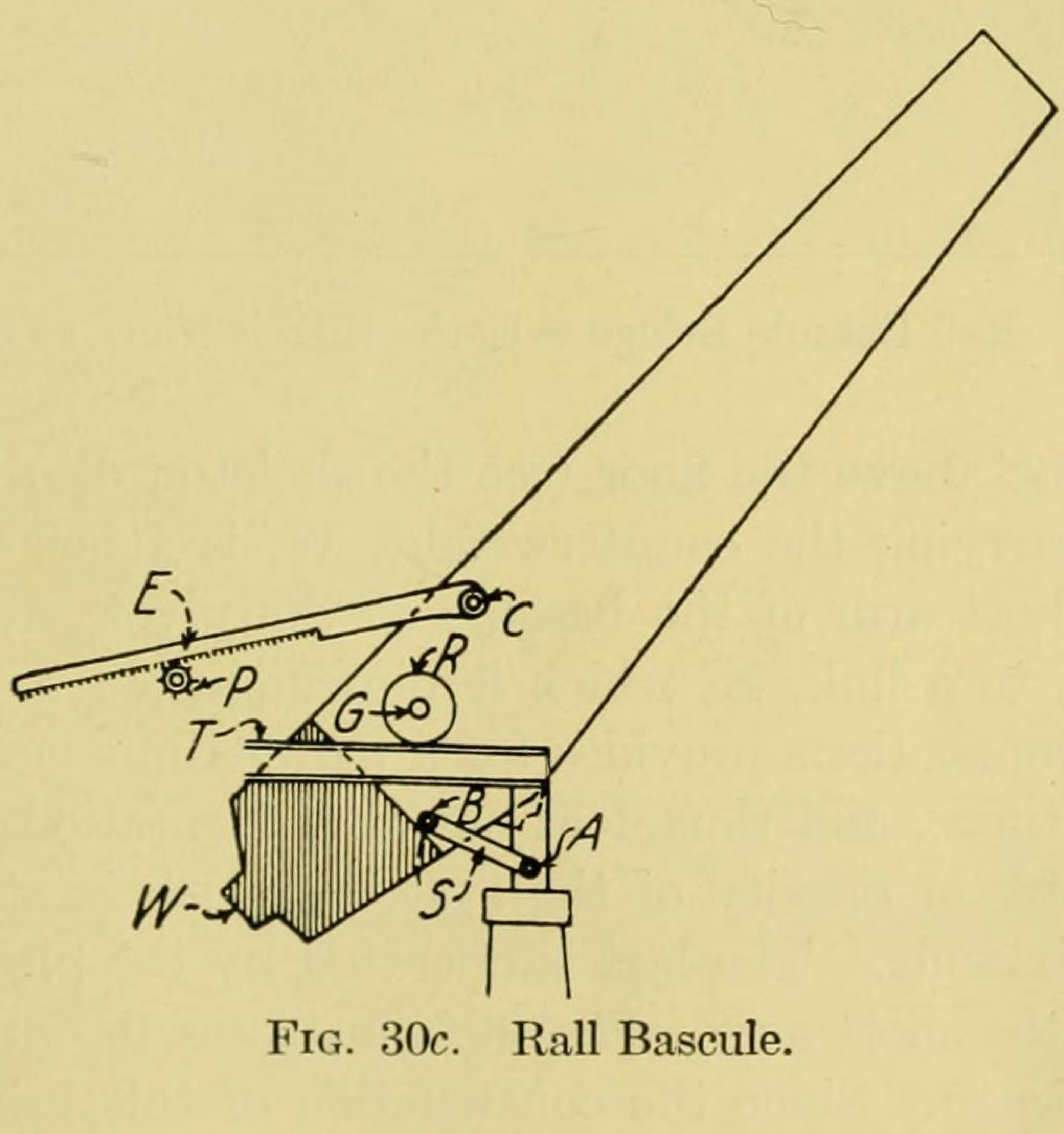

FIG. 30*c*. Rall Bascule.

pivoted roller, R, is free and can be removed and replaced without difficulty. The centre of rotation is so far above the pier that no pit is required to receive the tail or the counterweight, W. The horizontal motion of the pivot is sufficient to allow the tail to clear the masonry when the span is raised. This retreating motion of the leaf permits of using the minimum span length to obtain a given clear waterway. However, the shifting of the centre of gravity disturbs the foundation pressures. Fig. 30*d* shows the Rall bascule erected at Peoria, Ill. The Rall bascule patents are now controlled by the Strobel Steel Construction Company of Chicago.

The distinctive feature of the Strauss trunnion bascule is the pivoting of the counterweight at the end of the short arm. This enables the said counterweight to move parallel to itself at all times; and it can, therefore, be made in such shape that no pit is required to receive it when the leaf is in an upright position. In one variety of this type the counterweight is placed beneath the approach floor. In the other variety it is

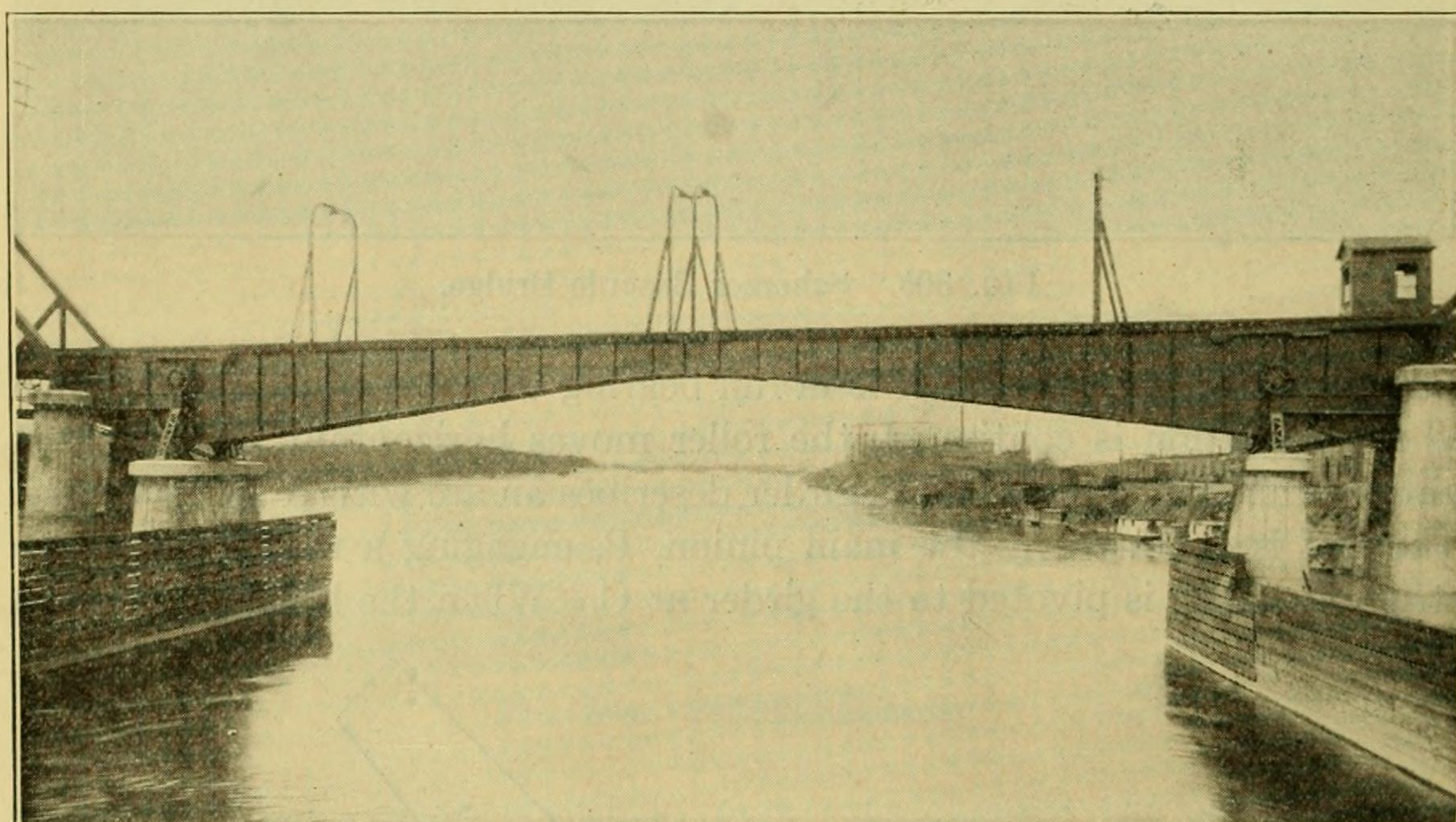

FIG. 30*d*. Rall Bascule Bridge over the Illinois River at Peoria, Ill.

located in a frame above the floor (see the skeleton diagram in Fig. 30*e*). The frame, F, carrying the counterweight, W, is attached by means of a strut to the short arm of the bascule at the pivot, A, and at the top by the pivot, B, to a link, K, which is pin-connected to the tower at C. This system of connections provides for a parallel movement of the counterweight at all times, and thus does not alter the ratio of lever arms nor displace the centre of gravity of the system, which is at the main trunnion, G, of the bascule. The leaf is operated by the pinion, P, engaging the rack, R, on the short arm. Fig. 30*f* illustrates the Strauss bascule at Polk Street, Chicago. Since the construction of this bridge, the Strauss Bascule Bridge Company has developed a modification known as the "heel trunnion" bascule, which is shown in skeleton form in Fig. 30*g*. This modified type has a fixed pivot point, E, at the end pin of the bottom chord of the truss. The counterweight trunnion, T, is also a