No. 843,167. PATENTED FEB. 5, 1907.

J. P. NIKONOW.

BRIDGE STRUCTURE.

APPLICATION FILED MAR 24, 1906.

3 SHEETS—SHEET 1.

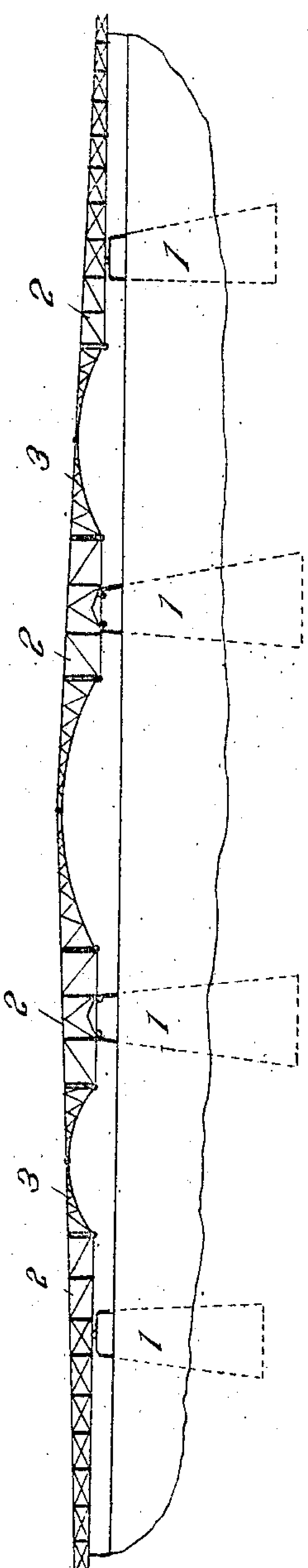

FIG. 1.

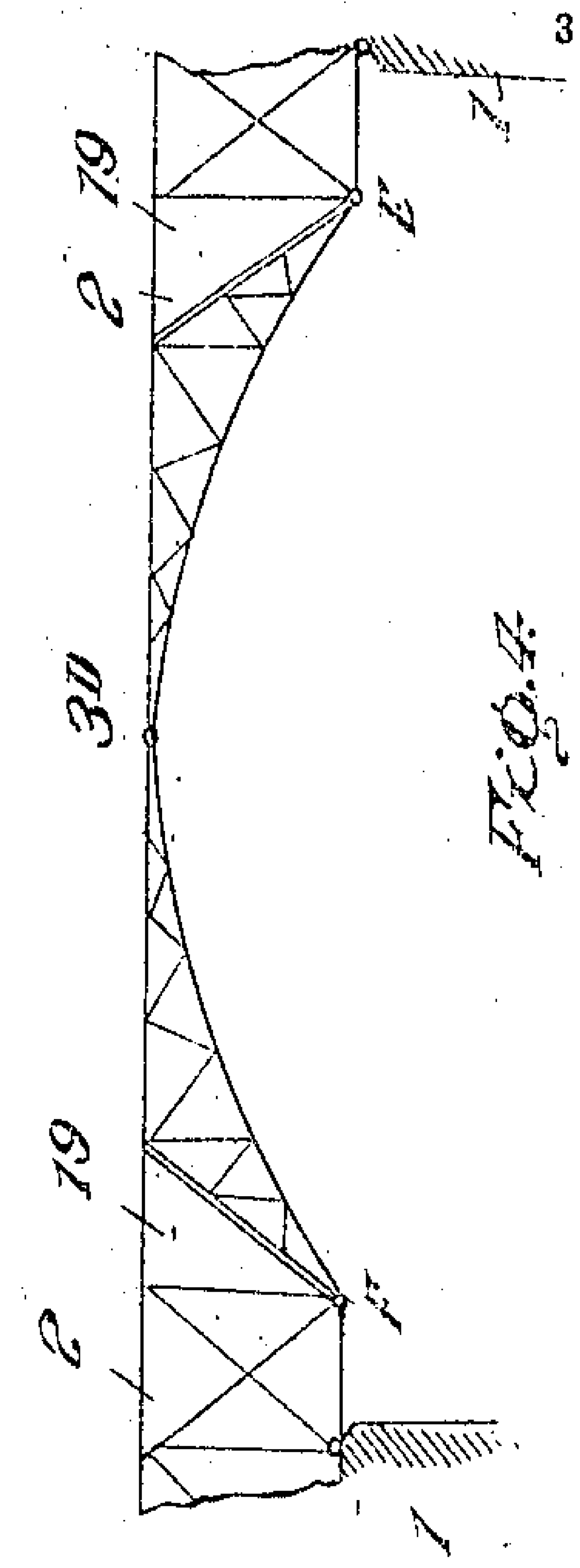

FIG. 4.

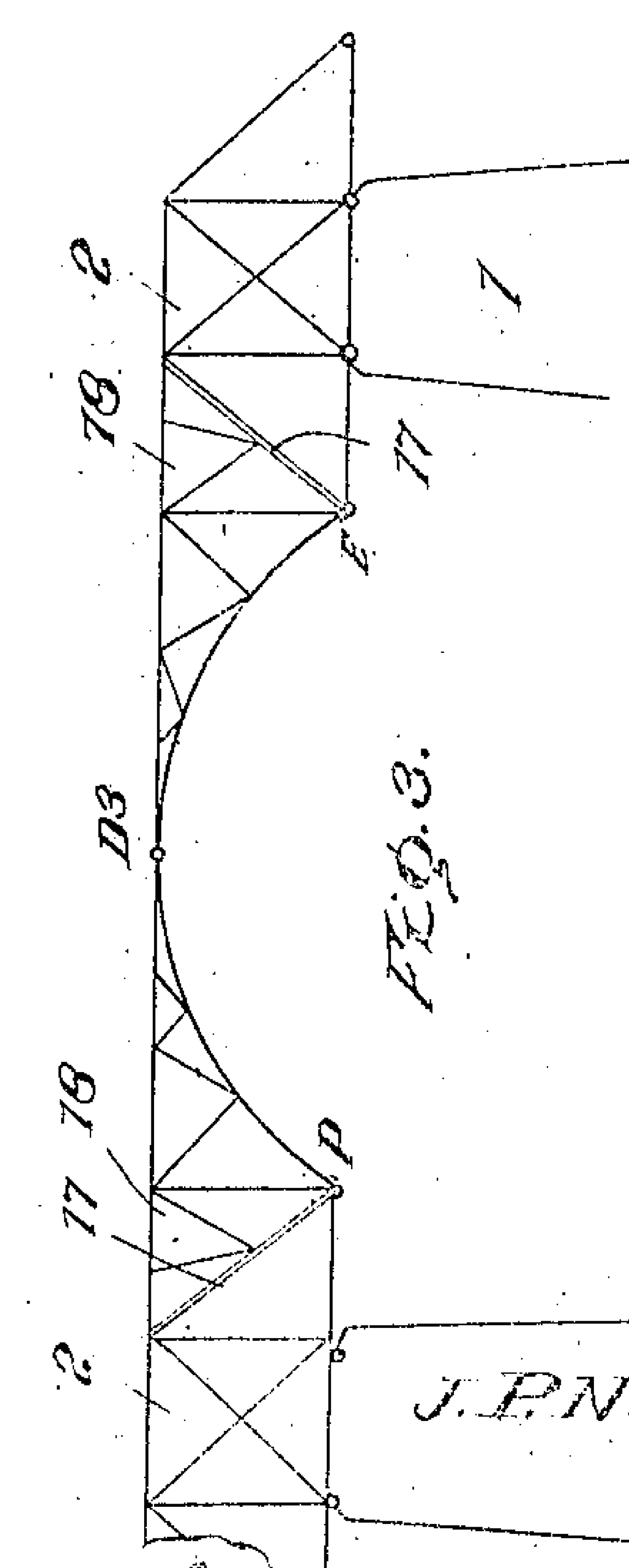

FIG. 3.

Witnesses

[signatures]

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3 SHEETS—SHEET 2.

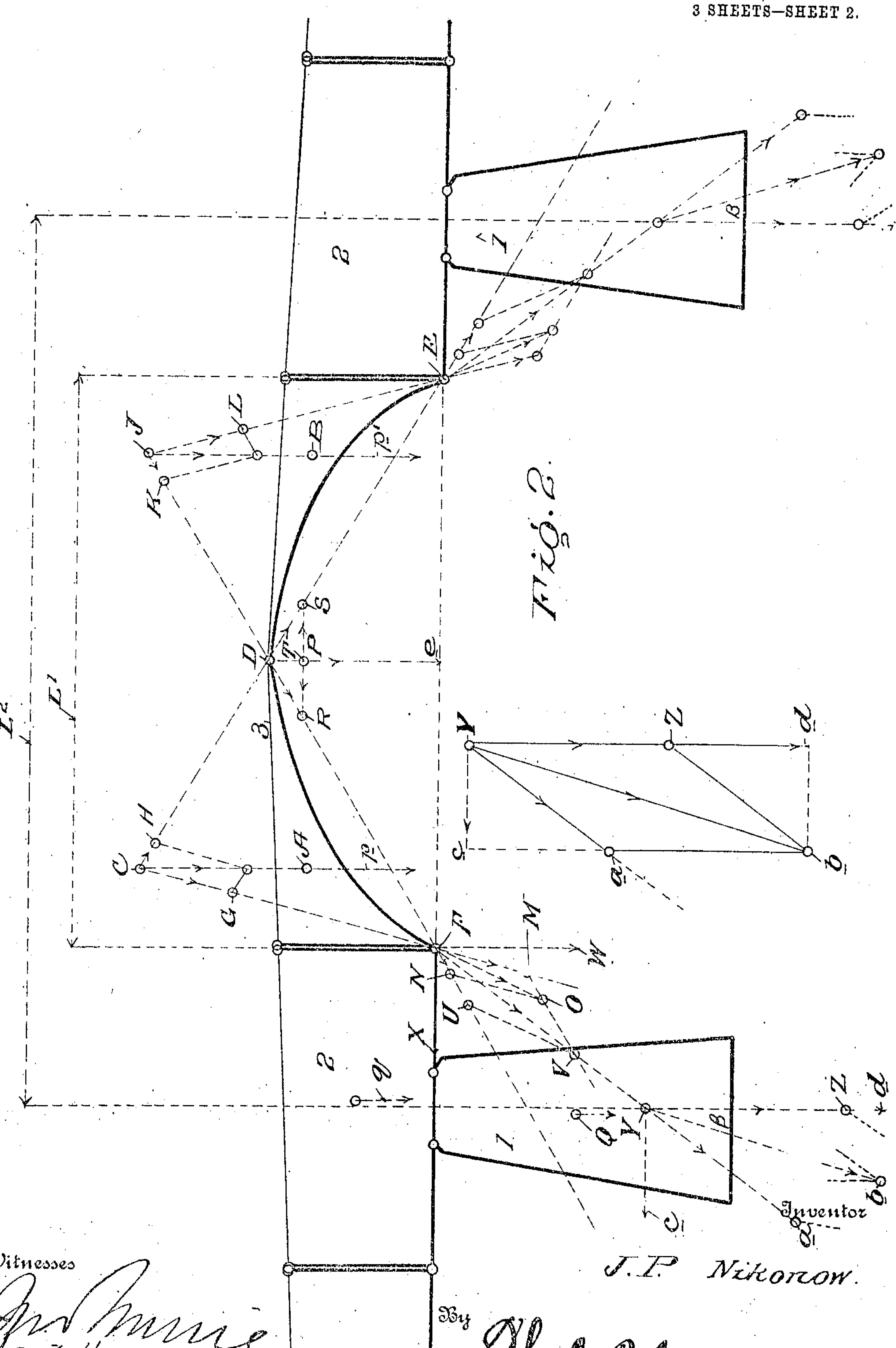

Fig. 2

Witnesses

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3 SHEETS—SHEET 3.

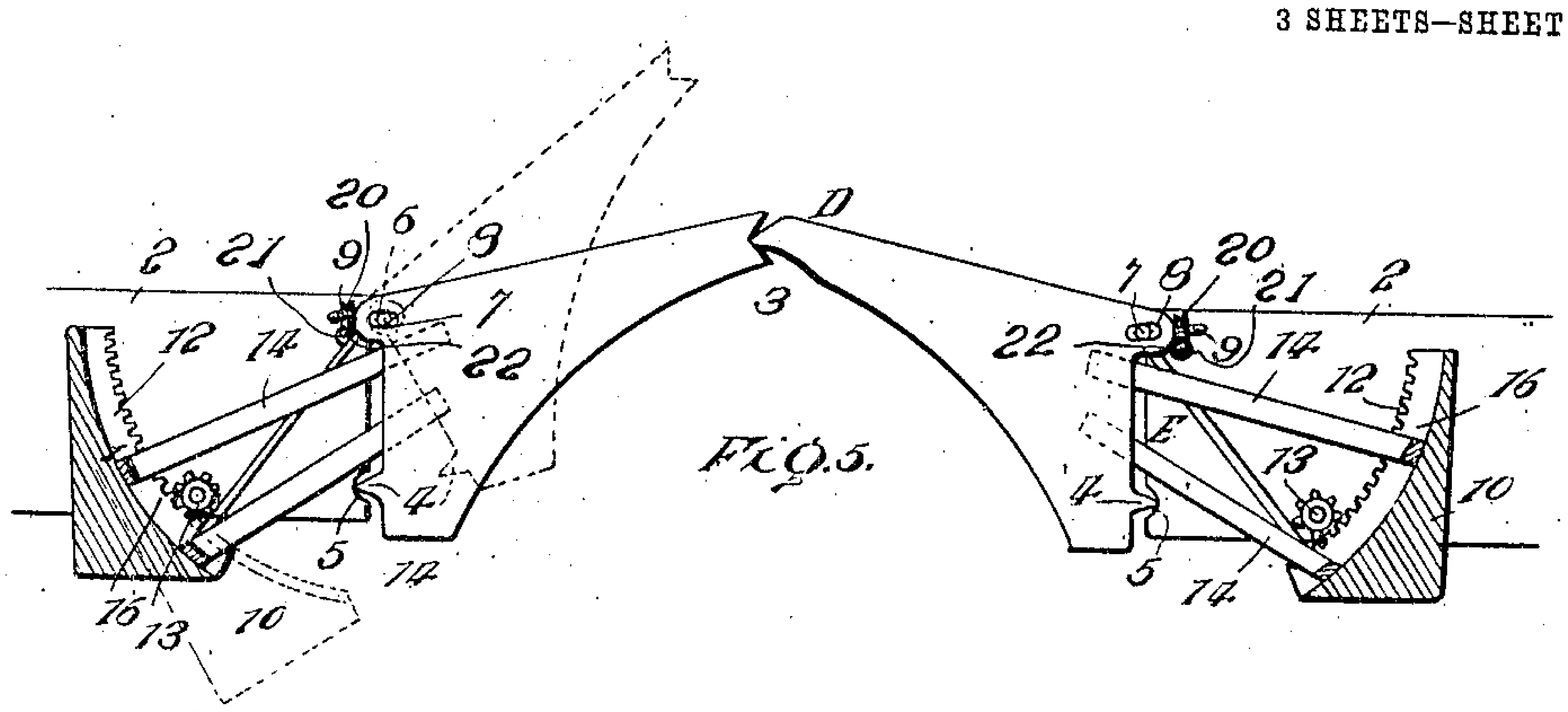


FIG. 5.

FIG. 6.

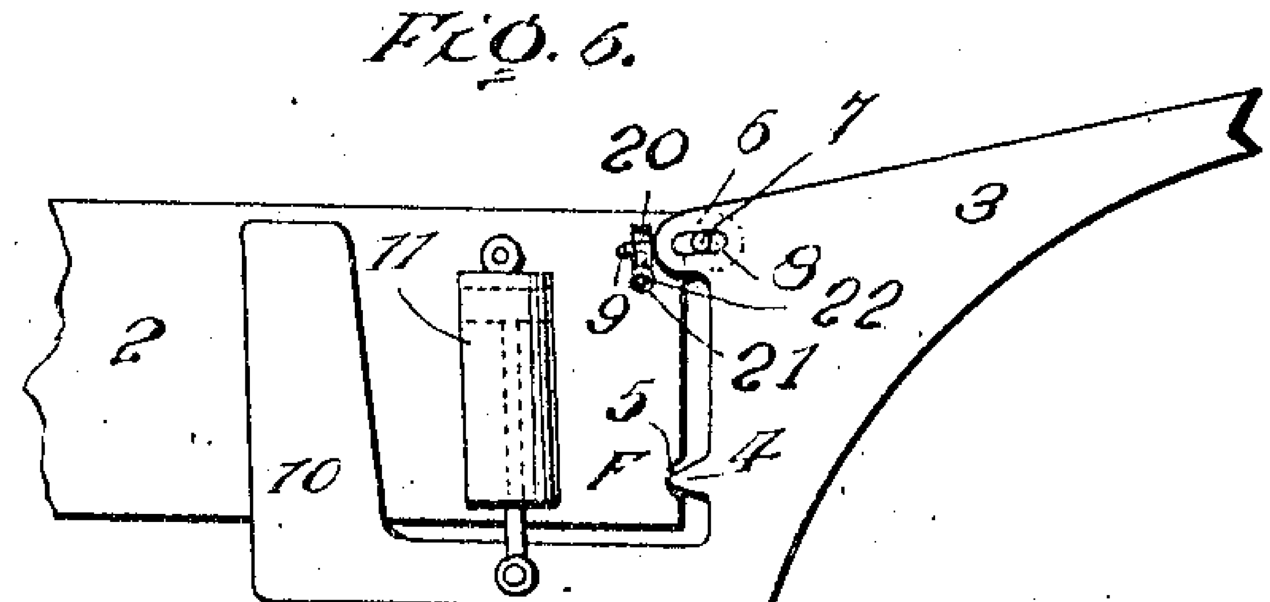


FIG. 7.

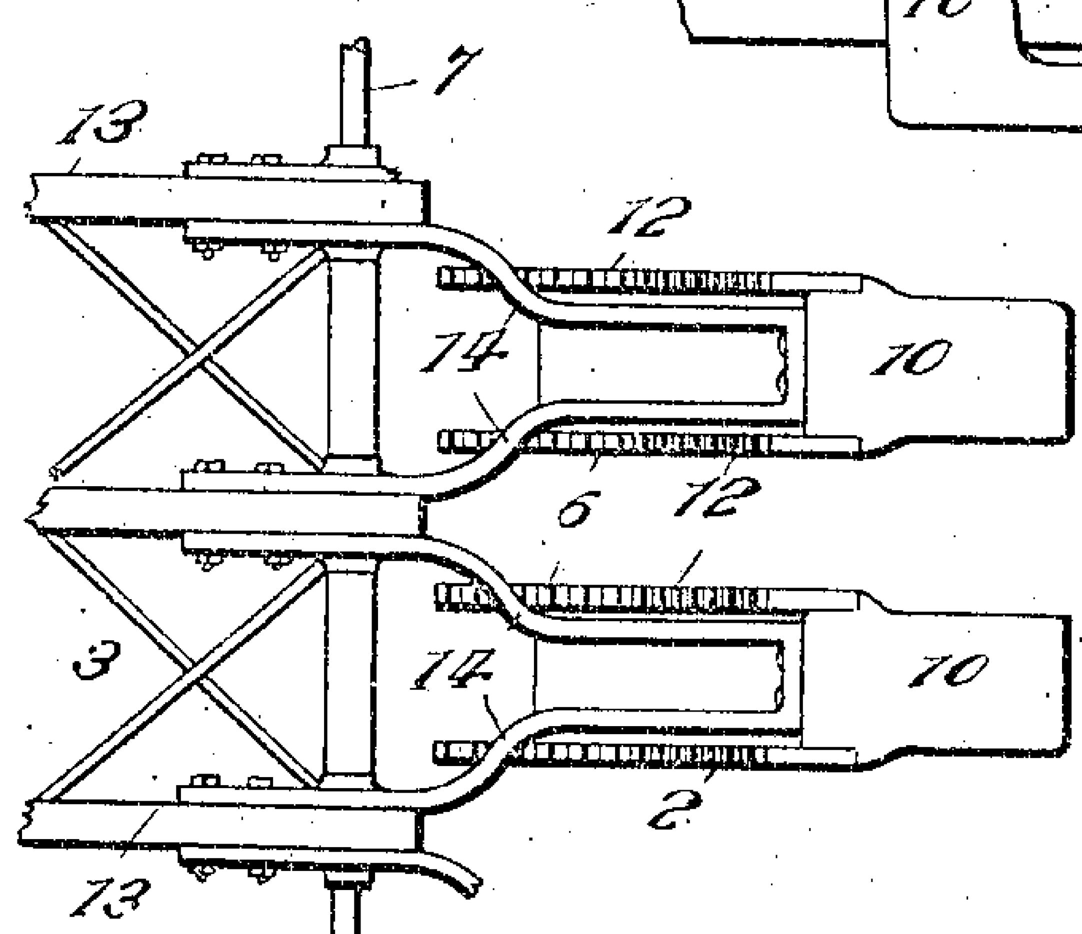


FIG. 8.

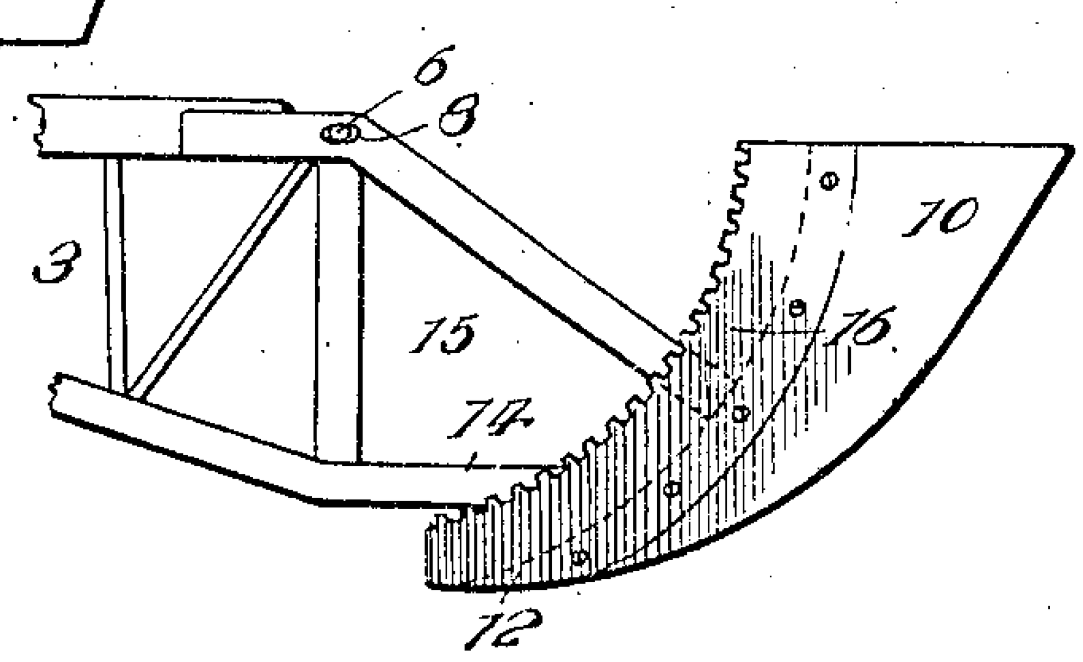
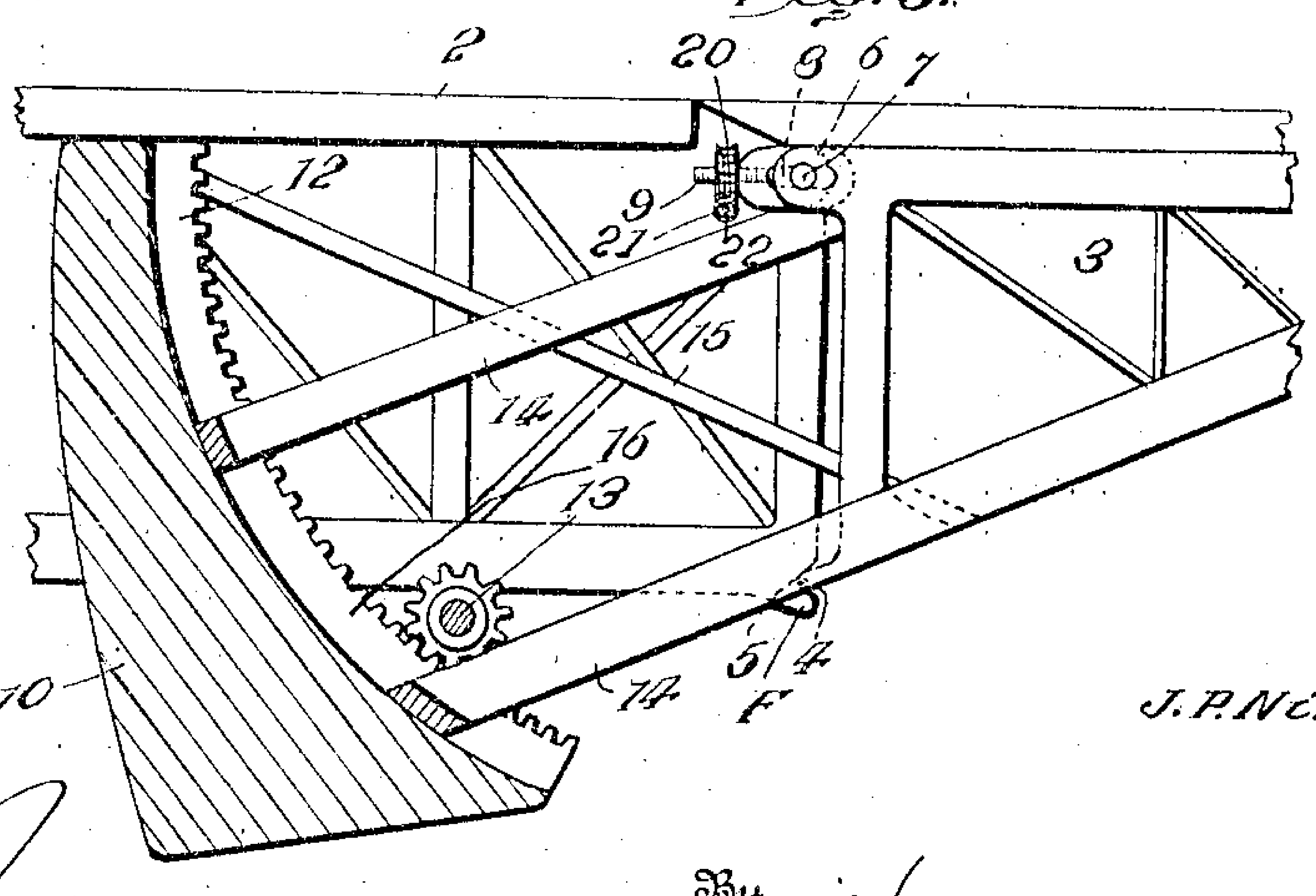


FIG. 9.



Inventor
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Witnesses
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UNITED STATES PATENT OFFICE.

JOHN P. NIKONOW, OF PITTSBURG, PENNSYLVANIA.

BRIDGE STRUCTURE.

No. 843,167. Specification of Letters Patent. Patented Feb. 5, 1907.

Application filed March 24, 1906. Serial No. 307,850.

To all whom it may concern:

Be it known that I, JOHN P. NIKONOW, a subject of the Czar of Russia, residing at Pittsburg, in the county of Allegheny and State of Pennsylvania, have invented certain new and useful Improvements in Bridge Structures, of which the following is a specification.

This invention relates to improvements in the construction of bridges, and more particularly those of the cantaliver type.

The object of the invention is to provide a construction which with a given load will enable the piers to be placed farther apart than usual or where the piers are fixed a comparatively light superstructure to be employed.

To this end the invention comprises a bridge structure in which the principles of the cantaliver and arch are combined, so that the horizontal and vertical components of the reactions of the arch have opposite moments about the bases of the piers and tend to counteract each other.

The structure also has the advantage of enabling the piers to be built with a comparatively small base, since the accepted condition of safety that the resultant of all the forces acting shall pass through the middle third of the base of the pier can be very readily satisfied.

For a full description of the invention and the merits thereof, and also to acquire a knowledge of the details of construction of the means for effecting the result, reference is to be had to the following description and accompanying drawings, in which—

Figure 1 is a diagrammatic view of a bridge constructed in accordance with the invention. Fig. 2 is a similar view of one span of the bridge, showing the position of the reactions as determined by the graphical method. Fig. 3 is a diagrammatic view of one span, showing a modification in which the end post of the cantaliver is inclined inwardly and the arch provided with an overhanging end portion. Fig. 4 is a similar view of a modification in which the end post of the cantaliver is inclined outwardly. Fig. 5 shows the sections of the arch designed so as to be lifted. Fig. 6 shows a portion of the arch and a hydraulic cylinder lifting the same. Fig. 7 is a plan view of an end portion of one of the arch-sections. Fig. 8 is a side elevation of a portion of one of the arches, and Fig. 9 is an enlarged sectional view showing the method of attaching the counterweight to the arch-sections.

Corresponding and like parts are referred to in the following description and indicated in all the views of the drawings by the same reference characters.

The numerals 1 designate the piers, which are of the usual construction, 2 the cantaliver structures resting upon the piers, and 3 the arches connecting the cantalivers, said arches preferably being of the three-hinged type, as shown. In their specific construction both the cantaliver and the arch may comprise beams having solid webs and flanges or may be given a truss construction with upper and lower chords connected by suitably-designed web members. The arch 3 and the cantalivers 2 are so disposed with regard to each other that the horizontal and vertical components of the arch reactions have opposite moments about the bases of the piers and tend to counteract each other. This has obvious advantages over the true arch construction where the vertical component of the reaction has no moment about the base of the abutment and the entire horizontal thrust has to be resisted by either reinforcing or enlarging the abutment. This feature can best be shown by determining the reactions which would occur when the arch is loaded and observing the effect of the reactions upon the structure. For the present purpose this result can best be accomplished by the graphical method. The dead load or weight of the arch-sections will first be considered, and for the purpose of determining the reactions the dead-loads can be considered as acting upon the centers of gravity of the two halves of the arch.

In Fig. 2 the force p, acting at A, represents the weight of the left-hand section of the arch, and the force p', acting at B, represents the weight of the right-hand section of the arch. Considering these forces separately the components of the reactions due to these forces can be determined These are determined by the usual method of solving the three-hinged arch. In considering the force p the line of action thereof is extended upwardly to C, where it meets the line DE, passing through the center hinge D and the right hinge E. The line CF is then drawn through the left hinge F, and this line gives the line of action of the component of the left reaction, due to the force p. This solution is based upon the principle that three non-parallel forces must be concurrent in order to be in equilibrium and the fact that the line of action of the component of the right reaction, due to the force p, must pass through the two hinges DE. By laying off the force p from the point C and completing the parallelogram of forces the magnitude of the components can be determined. In the present instance the force transmitted to the left reaction is represented in magnitude and direction by the line CG, and the component transmitted to the right reaction by the line CH. In a similar manner the force p' can be considered by extending the line of action thereof upwardly to J, where it intersects the line FD, and then drawing the line JE. The parallelogram of forces can then be drawn in the same manner as for the force p, the line JK representing the magnitude and direction of the component transmitted to the left reaction, while the line JL gives the similar properties of the force tsansmitted to the right reaction. By setting off the distance FM equal to CG and FN equal to JK and completing the parallelogram of forces the left reaction FO may be determined for the dead-load. In a similar manner the right reaction may also be determined. In considering the live or moving load P it may be stated that the horizontal thrust of the arch will be greater when the live load is concentrated at the crown D and that this position will therefore be the most trying upon the present structure. Considering the force P as acting at D the magnitude and direction of the components may be determined by drawing the horizontal line RS through the point T, the latter point being so taken that the line DT represents the magnitude of one-half the force P. The arch reactions due to the combined dead and live loads can now be found by laying off the line FU equal to line DR and completing the parallelogram of forces. The line FV then represents both the magnitude and direction of the left reaction of the arch, due to the dead load and the most trying condition of live load, and this reaction may be resolved into its vertical component FW and its horizontal component FX. The horizontal component represents the thrust of the arch and has a negative moment about the base of the pier, which tends to overturn the same. However, it will be apparent that the vertical component FW has a positive moment about the base of the pier which tends to counteract the negative moment of the thrust of the arch. As before mentioned, this construction has obvious advantages over the pure arch, where the vertical component passes through the pier and has no moment. With this construction it will be apparent that the resultant moment tending to overturn the pier will be comparatively small and that the pier may accordingly have a lighter construction than would otherwise be the case. The fact that the critical position of the force P is when acting at the hinge D may be readily proven by moving the force to either side of the point D and observing the effect upon the reactions.

By studying the diagram it will be apparent that any movement of the force P will increase the vertical component of the reactions and decrease the horizontal component, and since the vertical component tends to overcome the moment of the thrust of the arch it will be apparent that the critical condition will exist when the vertical component has the smallest value.

In order to determine the resultant of the combined weight of the pier 1 and cantaliver 2 and the arch reaction FV, the line FV is prolonged to the point Y, where it intersects the vertical line passing through the center of gravity of the force Q, representing the weight of the pier, and the force q, representing the weight of the cantaliver structure. The distance YZ is then set off equal to $Q+q$, and Ya equal to FV. The resultant Yb of all the forces acting can then be found in the usual way, and this resultant may be considered as having the horizontal component Yc and the vertical component Yd. Since the weight of the pier 1 and cantaliver 2 can have no horizontal component, it will be apparent that the horizontal component Yc is exactly equal to the thrust FX of the arch. Owing to this fact, the resultant Yb forms a comparatively small angle β with the vertical, and the condition that the resultant of all the forces shall pass through the middle third of the pier can be easily fulfilled.

The horizontal thrust of the arch is the most trying force which the structure has to resist, and it may be shown that this thrust depends upon the loading and dimensions of the arch. For present purposes the dead-load will be ignored and the thrust due to the live load considered alone. In the triangle DRT the line RT represents the thrust of the arch, or the horizontal component of the reaction due to the live load P. This triangle is similar to the triangle DFe, and the following ratio may be deduced.

$$\frac{TR}{TD} \text{ equals } \frac{Fe}{DE}$$

or

$$\frac{RT}{\frac{P}{2}} \text{ is equal to } \frac{\frac{L'}{2}}{h}$$

This latter ratio is obtained by substituting one-half P for DT, $\frac{L'}{2}$ for Fe, where L' equals the span of the arch and h the rise of the arch. From the latter ratio we can obtain the following equation:

$$\text{RT equals } \frac{PL'}{4h}$$

where RT represents the thrust of the arch due to the force P. With a given force P the value of the ratio $\frac{PL'}{4h}$ will depend entirely upon the variable quantity $\frac{L'}{h}$. In the practical construction of bridges the value of the ratio $\frac{L'}{h}$ must not exceed 20 when the horizontal component of the force would be equal to five times the force, as can be seen by substituting values in the equation. In the present construction L′, or the span of the arch, represents only a fraction of the distance between the adjacent piers or the total span of the bridge, which may be designated by L^2. Therefore, since the ratio $\frac{L'}{h}$ is used for the entire span L^2 the value of the ratio is diminished. This can be readily seen from the following equation, in which the quantity h is constant:

$$\frac{L'}{h} < \frac{L^2}{h}$$

In other words, for the same rise of arch I am enabled to employ a greater total span than with the pure-arch construction. This feature has a very great advantage in actual construction, since it enables the piers to be spaced farther apart, or with fixed piers the superstructure may be constructed of lighter steel.

A modification is shown in Fig. 5, in which the two halves of the three-hinged arch are so constructed as to be readily lifted in order to give a free channel. With this construction the hinge D at the crown of the arch is formed by giving one of the arch members a tongue, which rests loosely within a depression upon the opposite arch member. The hinge-joints F and E are formed in a somewhat similar manner by sharp projections 4, which bear against the bases of recesses 5 in the cantaliver structure. The upper portion of the ends of the arch-sections is hinged or pivotally connected at 6 to the upper portion of the cantaliver structure. The pivot connection 6 is made very loose or so as to have a sufficient play when the arch is in normal position to not interfere with the action of the three hinges. For this purpose the shaft 7, upon which the arches are hinged, is preferably provided with means whereby its position can be shifted when it is desired to lift the arch. In the present instance the arch portions are formed with slots 8, through which the shafts 7 are passed, and the latter members are so mounted so to be drawn to one end of the slots 8 by means of the threaded stems 9 and coöperating nuts 20 when lifting the arch.

In order to provide for the simultaneous operation of the nuts 20 on each section of the arch, the said nuts may be formed with worm-gearing, which engages with the worms 21 upon the shafts 22.

With the lift construction the arch-sections are each provided with a counterweight 10 and means whereby the counterweights can be forced downwardly in order to lift the arch. For the latter purpose hydraulic cylinders may be employed, as shown at 11, or the counterweights 10 may be provided with segmental racks 12, which coöperate with pinions 13, the latter being operated by any suitable source of power.

In Fig. 7 a plan view is given, which shows a method of connecting the counterweights 10 to the various beams 13 which compose the arch. In connecting the beams 13 and counterweights 10 it will be observed that a pair of approximately U-shaped members 14 are employed, which have their arms joined to the beams, while their heads are connected to the counterweights. A diagonal brace 15 may also be employed to insure a rigid construction. On each side of the U-shaped members 14 the counterweights 10 are provided with the inwardly-projecting flanges 16, which have the racks 12 formed thereon.

Another modification is shown in Fig. 3, in which the end posts of the cantaliver construction 2 are inclined inwardly at 17 and the arch-sections are provided with the overhanging portions 18. With this construction the horizontal component of the reaction due to dead-load is somewhat diminished. At 19 in Fig. 4 the end posts of the cantaliver construction 2 are inclined in the opposite direction, and this has the result of increasing the weight of the cantaliver and correspondingly increasing the vertical component of the resultant of all the forces acting, and when this vertical component is increased it will be apparent that the angle β which the total reaction bears to the vertical will be decreased.

From the foregoing explanation it will be apparent that the principal advantages of the present construction reside in the fact that the cost of building a bridge of a given length and designed to resist given loads will be greatly diminished, owing to the fact that the piers can be given a lighter construction or spaced farther apart, or that where the piers are fixed a lighter superstructure can be employed.

Having thus described the invention, what is claimed as new is—

1. In a bridge, the combination of piers, cantalivers resting upon the piers, and three-hinge arches connecting the cantalivers, the sections of the arches being so formed as to be lifted when desired and for this purpose

being loosely connected to the cantalivers so as not to interfere with the action of the three hinges.

2. In a bridge, the combination of piers, cantalivers resting upon the piers, three-hinge arches connecting the cantalivers, the sections of the arches being connected to the cantalivers by a loose joint which enables them to be lifted when desired and does not interfere with the actions of the three hinges, and means for tightening the joint.

In testimony whereof I affix my signature in presence of two witnesses, March 22, 1906.

JOHN P. NIKONOW. [L. S.]

Witnesses:
BIRNEY HINES,
IDA W. REINECKE.