No. 804,744. PATENTED NOV. 14, 1905.

G. LINDENTHAL.

BRIDGE.

APPLICATION FILED SEPT. 11, 1903. RENEWED APR. 21, 1905.

5 SHEETS—SHEET 1.

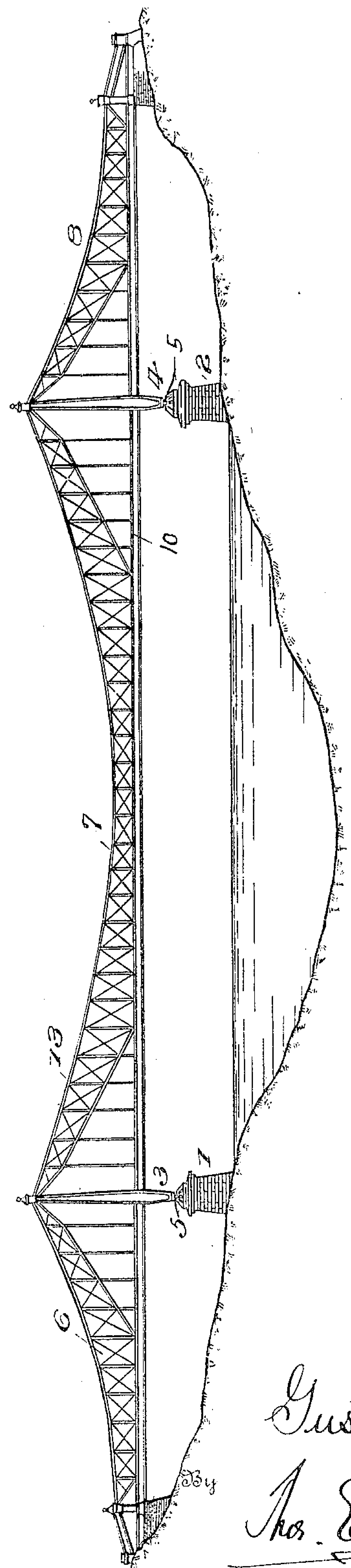

Fig. 1.

Witnesses

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5 SHEETS—SHEET 2.

Fig. 2.

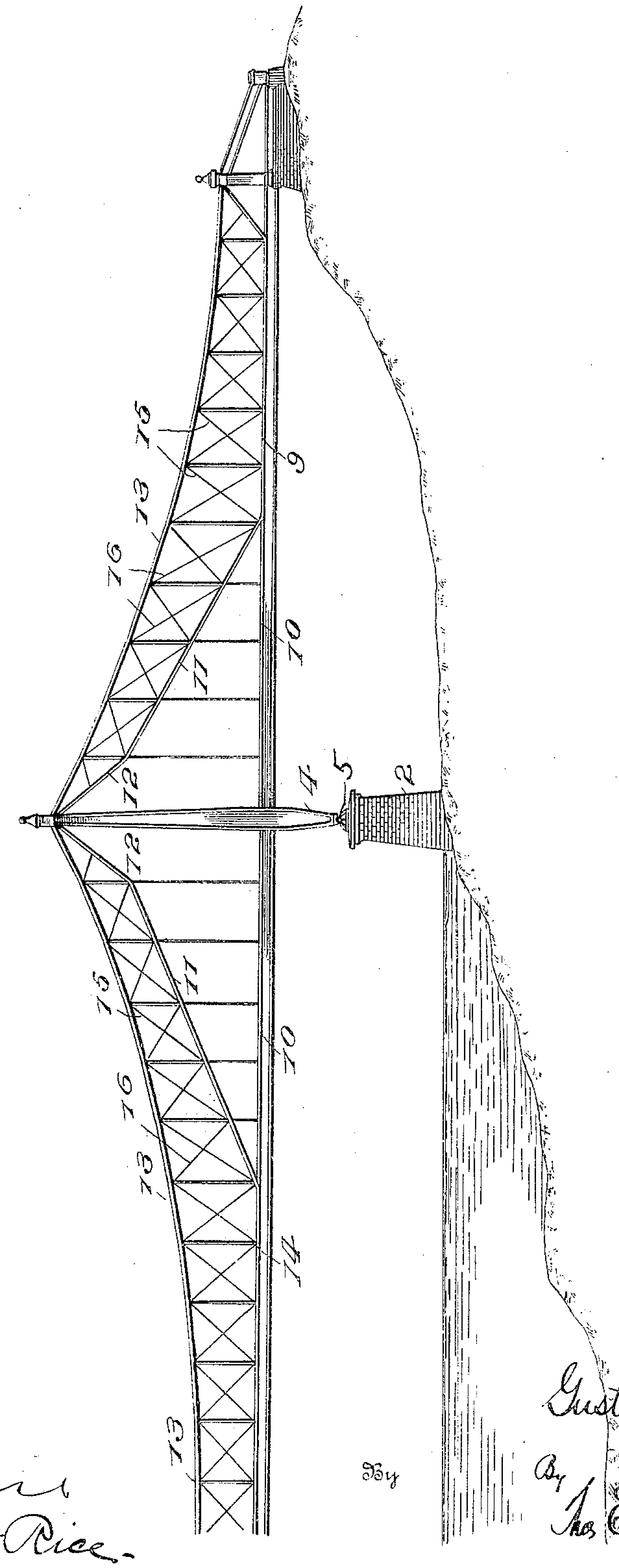

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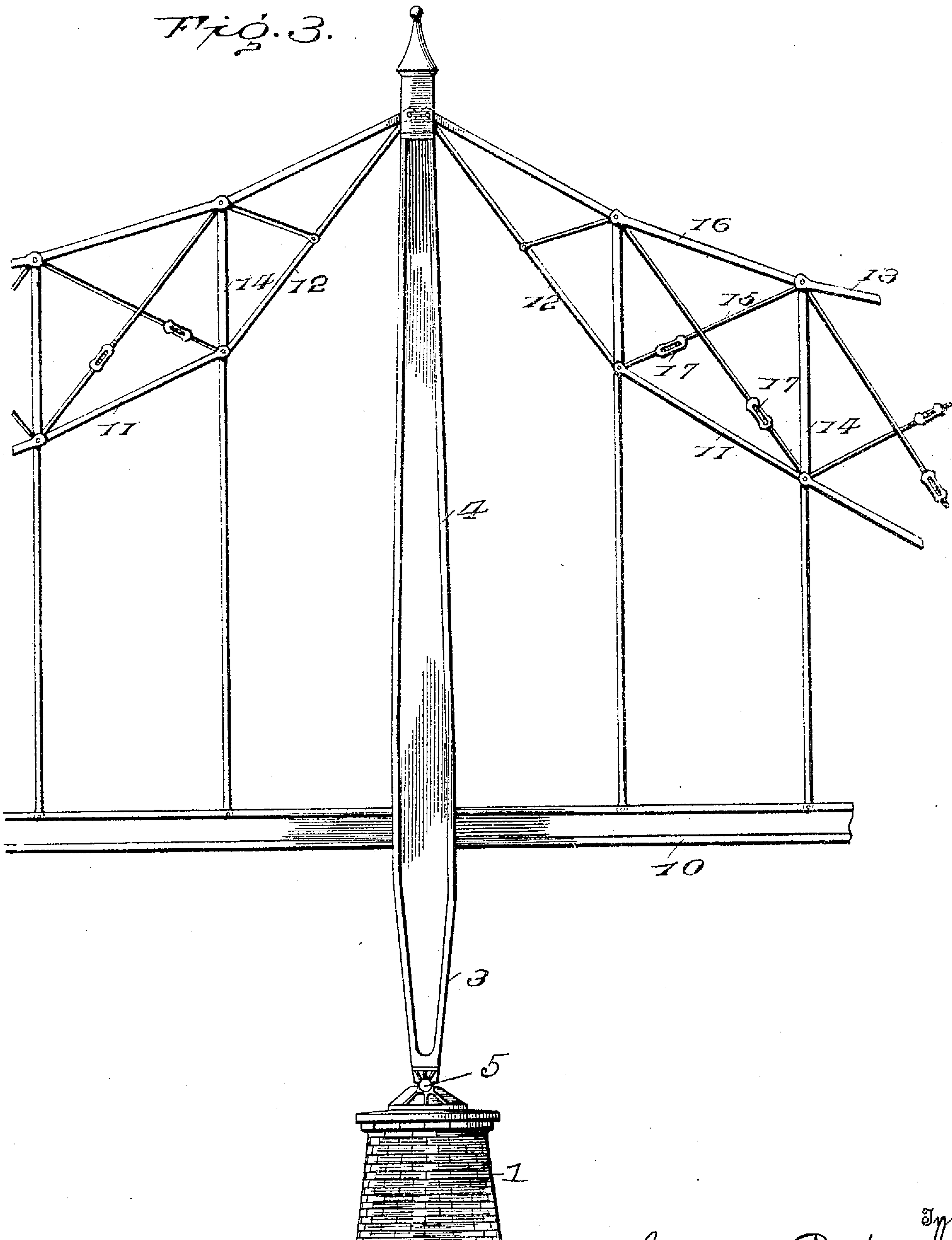
Fig. 3.



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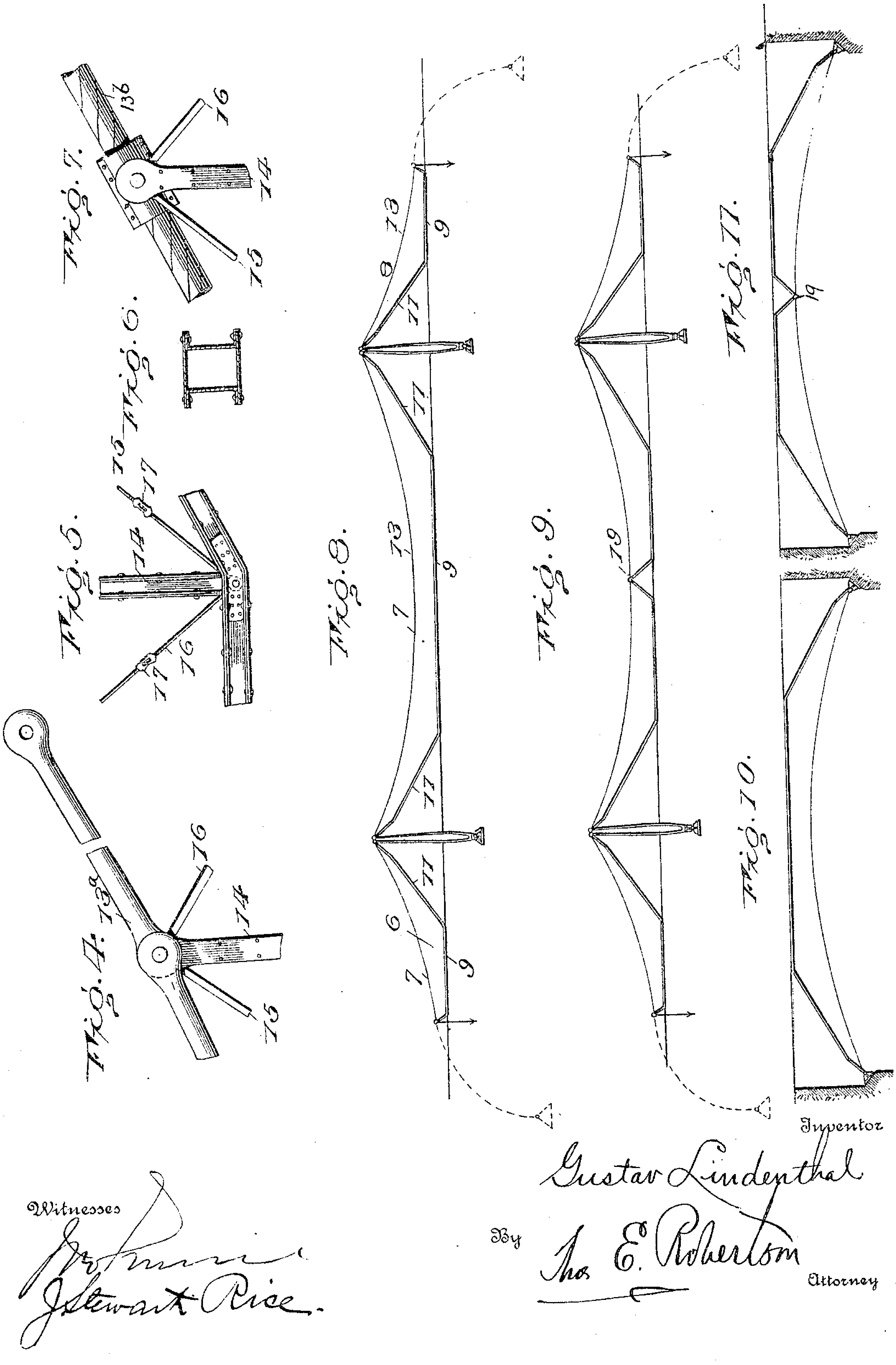

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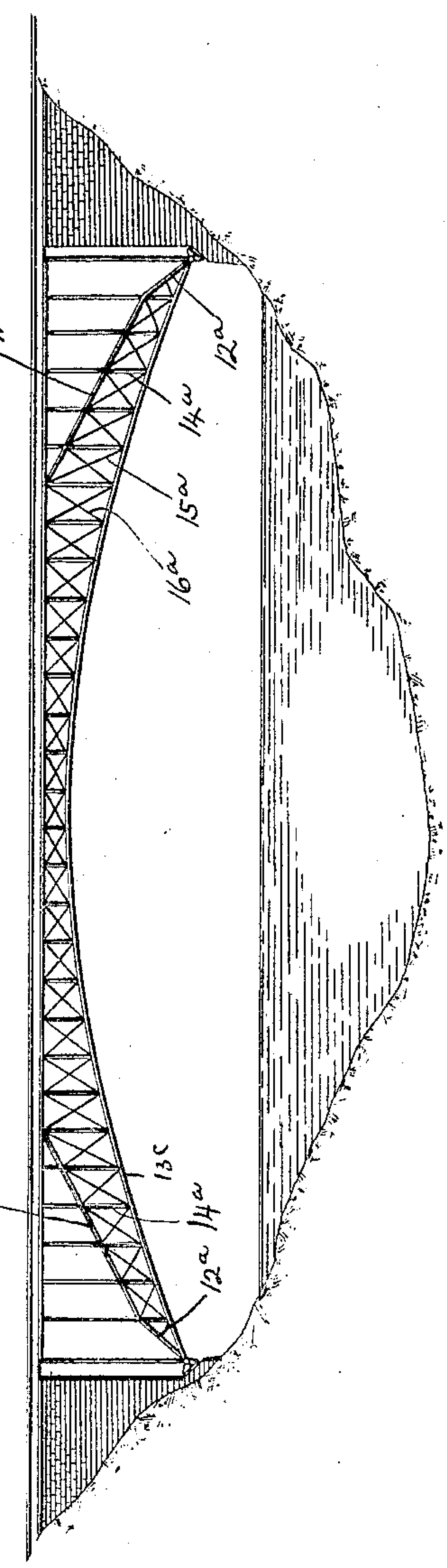
5 SHEETS—SHEET 5.

Fig. 72.



WITNESSES:

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UNITED STATES PATENT OFFICE.

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BRIDGE.

No. 804,744. Specification of Letters Patent. Patented Nov. 14, 1905.

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To all whom it may concern:

Be it known that I, GUSTAV LINDENTHAL, a citizen of the United States of America, and a resident of New York city, in the county and State of New York, have invented certain new and useful Improvements in Bridges, of which the following is a specification.

This invention relates to certain new and useful improvements in arch and suspension bridges, and more particularly to a stiffening-frame used as a part thereof. As is well known, a suspension-bridge is theoretically an inverted-arch bridge, and while in the following description I shall describe my invention in connection with the inverted-arch or suspension bridge I wish it understood that my invention is also applicable to the erect arch and that my statement of invention and claims are broad enough to cover each form. Arches, whether erect or inverted, are liable to deformation resulting from loads passing over them, and they therefore require to be stiffened. The usual method of stiffening a suspended bridge is by a beam or truss suspended from the cable forming the arch. Another method of stiffening is that in which a stiffening-frame is not suspended, but attached directly to the cables forming the arches.

My invention has particular relation to the latter method; and it consists in attaching to the convex side of the arch a polygonal frame or truss which is so formed as to have its greatest depth where the largest flexure moments from moving loads occur, and the invention will now be more particularly described in detail and then definitely set forth by the claims at the end hereof.

In the accompanying drawings, which I wish it distinctly understood represent what I now consider the preferable, but not necessary, embodiment of my invention, Figure 1 is a side elevation of a suspension-bridge having my stiffening-frames shown thereon. Fig. 2 is a similar elevation of one end of the bridge on a larger scale, but with a portion of the flooring broken away in order to illustrate the lower or horizontal member of the stiffening-frame, which may be behind or built within the floor. Fig. 3 is a similar view of one of the towers, showing the stiffening-frames connected therewith, this figure being on a still larger scale. Fig. 4 is a detail of the connection when eyebars are used to form the arch. Fig. 5 is a detail showing the construction at the point where the horizontal member or chord meets the vertical stiffening member and the slanting member or chord leading to the tower. Fig. 6 is a sectional detail showing the box form of construction, of which certain members or chords of the frame are built. Fig. 7 is a detail showing the construction similar to that of Fig. 4 when a cable is employed. Fig. 8 is a diagrammatic view of the stiffening-frames. Fig. 9 is a similar view of a modified form where there are two central frames pivoted near the center. Figs. 10 and 11 are similar views of the stiffening-frames used on an erect arch. Fig. 12 is a view of an erect arch in which the roadway coincides with the middle half of the stiffening-frame along the horizontal part thereof.

Referring now to the details of the drawings by numerals, 1 and 2 designate the usual masonry piers, on which are supported the towers 3 and 4, which are preferably constructed in column form with narrow bases or pin-bearings 5 5 to permit a slight swaying motion at the tops in order to accommodate themselves to any variations in the length of the cables due to temperature effects and to moving loads.

Inasmuch as the main feature of my invention is the stiffening frame or frames, the parts so far described may be made in any preferred form, and it will also be understood that, as illustrated, the floor, cable, or eyebars or chain-links forming the arch, the suspenders, the anchors, &c., are merely shown in conventional form and may be varied as the taste and skill of the designer and builder may dictate.

The stiffening-frame, which I have just stated is the most important feature of my present application, comprises a polygonal frame or truss which is attached to the convex side of the arch, and these frames, designated as 6, 7, and 8 in Fig. 1, are of such form that one chord for about half its length (see 9 in Fig. 2) runs parallel to or coincides with the line of the roadway 10, while other parts 11 and 12 run in a line nearer to the arch 13 and converge with the latter at the ends where connection is made with the tower, as seen in Fig. 3. The form of the frame thus resembles a sickle with a polygonal back.

The arch 13 may be formed of a chain of eyebars, as 13^a, (shown in Fig. 4,) or a cable 13^b, as in Fig. 7, and the lower members or chords, as well as the members 9, 11, and 12, are preferably of the built-up box form of construction shown in detail in Fig. 6, and the said arch and the other members 9, 11, and 12 are connected by vertical bracing or web members 14, which are also of similar construction. The truss which is thus formed has its greatest depth at one-quarter length from each end of the center arch or at the point where the largest flexure moments from moving loads occur. In a bridge like that illustrated where the end spans are of half the length of the main span the same frame or truss arrangement will give the largest depth between chords at the middle of said end spans.

In Figs. 8 to 11 I have illustrated my frames in diagrammatic form, the first two figures showing the three frames 6, 7, and 8 used in an inverted-arch or suspension bridge and the latter figures showing a single frame used in an erect arch.

In Fig. 12 I have shown the erect arch in conventional form. It will of course be understood that the stiffening construction is just the reverse of what is shown in the central or main portion 7. Its parts 11^a, 12^a, 13^c, 14^a, 15^a, and 16^a correspond to the parts 11, 12, 13, 14, 15, and 16 of the suspended arch shown in Figs. 1, 2, and 3. As before stated, one chord is in each case formed by the arch itself, and in the former the arch will of course be in tension and in the latter in compression. The depth of the truss can always be so arranged that no reversion of stress need occur in the arch from moving load, but the polygonal chord is exposed to an alternation of compressive and tensional stresses from passing loads. From dead-load alone this chord is free from stress at a middle temperature. The normal and usual case is that the entire dead-load is carried by the arch, whether erect or inverted. The stiffening-frame comes into action only from moving loads or temperature changes in resisting changes of form.

The vertical web members 14 of the stiffening-frames, which have been heretofore mentioned as being of box-like construction, are assisted by the double diagonals 15 and 16. (Shown in most of the figures and in Figs. 3 and 5 as being adjustable by means of turnbuckles 17.) The said vertical web members may serve to support directly the floor construction. In that case the diagonals in each panel do not carry any part of the weight or so-called "dead-load" of the bridge.

It is preferable to leave the diagonals loose and without strain until the entire bridge is erected and completed, so that the arches and vertical members shall bear all the dead load in their respective capacities.

In a suspension-bridge the cabl or eyebars under these conditions will assume of itself the equilibrium form, which is termed a "catenary curve." When the cable is in that condition, then the diagonals are without strain.

Should settlement of foundation take place, which would disturb the original conditions of equilibrium in the cable, then such diagonals can be readjusted, and in that way the suspension-bridge can be freed from such stresses as may result from a settlement of foundations.

Another advantage of my system of stiffening is the small depth of the truss at the center of the middle span. The depth at this point can be made much less than elsewhere. This is of great importance as regards temperature stresses. As the arch expands or contracts from changes in temperature the center of the span will either drop or rise. In doing so it will produce bending of the stiffening-frame attached to it. These bending stresses are approximately in inverse proportion to the depth of the stiffening-frame at the center of the bridge. With my form of stiffening-girder this object is attained and combined with the largest degree of stiffness at the points most required, as stated above—namely, at the middle of the end spans and at the quarters of the middle span.

If desired, the arch may be provided with a hinge 19 at the center, as shown in the modifications, Figs. 9 and 11—that is, the other chord may be made discontinuous at the center. This arrangement has the advantage that the calculation of the strength of the bridge is then statically determinate. This advantage is balanced by the weakness of such a bridge against the lateral force of wind-pressure.

The foregoing description when read in connection with my drawings will give such a clear idea of my invention that it is believed to be unnecessary to give any further detailed statement of the operation of the stiffening frame or truss, and it will of course be understood that my invention as illustrated is the form which now seems to be its preferable embodiment and that slight changes and modifications may therefore be made without departing from the scope of my invention as set forth in the appended claims.

What I claim as new is—

1. In an arch-bridge, a stiffening-frame attached to the convex side of the arch; said frame forming a truss or girder, one member of which is the arch itself and another member of which has its greatest depth at the point or points where the largest flexure moments from moving loads occur, substantially as described.

2. In an arch-bridge, a stiffening-frame attached to the convex side of the arch and having vertical stiffening members and diagonals; said frame forming a truss or girder, one member of which is the arch itself and another member of which has its greatest

depth at the point or points where the largest flexure moments from moving loads occur, substantially as described.

3. In an arch-bridge, the combination of swinging towers, a cable firmly attached near the top of said towers and forming the arch, and a stiffening-frame attached to the convex side of the arch; said frame forming a truss or girder, one member of which is the arch itself and another member of which has its greatest depth at the point or points where the largest flexure moments from moving loads occur, substantially as described.

4. In an arch-bridge, the combination of swinging towers, a cable firmly attached near the top of said towers and forming the arch, and a stiffening-frame attached to the convex side of the arch and having vertical stiffening members and diagonals; said frame forming a truss or girder, one member of which is the arch itself and another member of which has its greatest depth at the point or points where the largest flexure moments from moving loads occur, substantially as described.

5. In an arch-bridge, a stiffening-frame attached to the convex side of the arch and having vertical stiffening members and adjustable diagonals; said frame forming a truss or girder, one member of which is the arch itself and another member of which has its greatest depth at the point or points where the largest flexure moments from moving loads occur, substantially as described.

6. In an arch-bridge, a stiffening-frame attached to the convex side of the arch, said frame forming a truss or girder, one member of which is the arch itself and another member of which is given such a form as to have the greatest depth at each quarter of the middle span, substantially as described.

7. In an arch-bridge, a stiffening-frame attached to the convex side of the arch, said frame forming a truss or girder, one member of which is the arch itself, and another member of which is given such a form as to have the greatest depth at the middle of each end span and at each quarter of the middle span, substantially as described.

8. In an arch-bridge, a stiffening-frame attached to the convex side of the arch and having vertical stiffening members and adjustable diagonals; said frame forming a truss or girder, one member of which is the arch itself and another member of which has its greatest depth at the middle of each of the end spans and at each quarter of the middle span; substantially as described.

9. In an arch-bridge, the combination of swinging towers, a cable firmly attached near the top of said towers and forming the arch; a stiffening-frame attached to the convex side of the arch; said frame forming a truss or girder and having a hinge in its center; one member of said frame being the arch itself and another member having its greatest depth at the point or points where the largest flexure moments from moving loads occur, substantially as described.

Signed by me at New York city this 3d day of September, 1903.

GUSTAV LINDENTHAL.

Witnesses:
M. B. SANFORD,
W. HOWARD.