2 Sheets--Sheet 1.

C. BENDER, C. H. LATROBE, & C. S. SMITH.

Bridges.

No. 141,310. Patented July 29, 1873.

Fig. 1

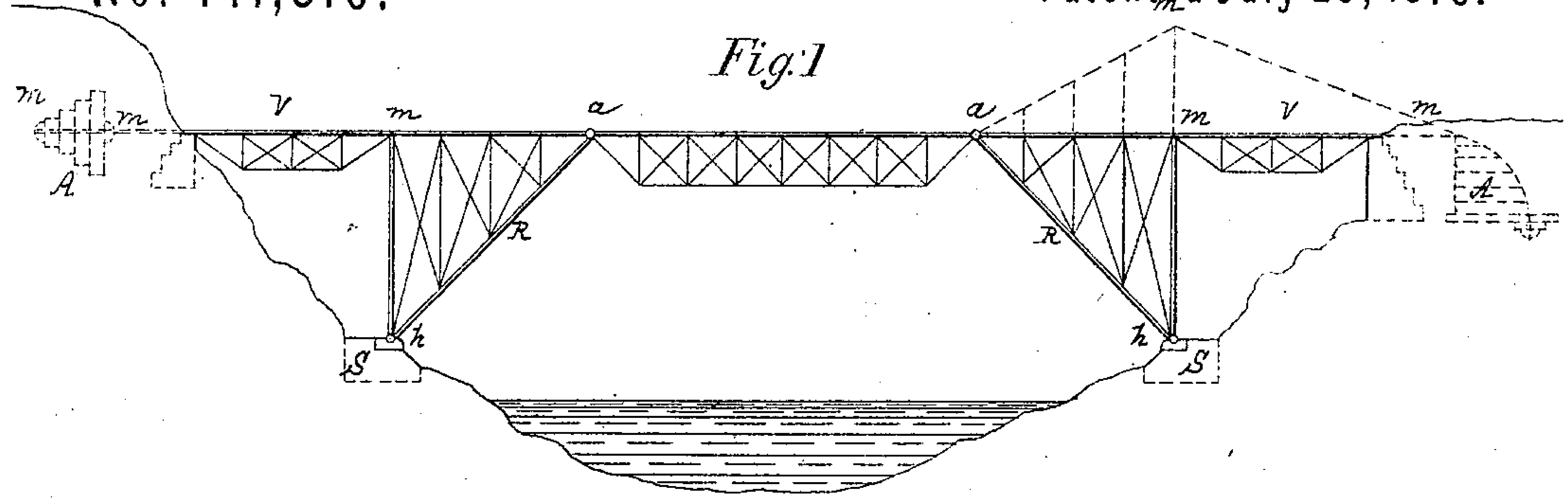


Fig. 2

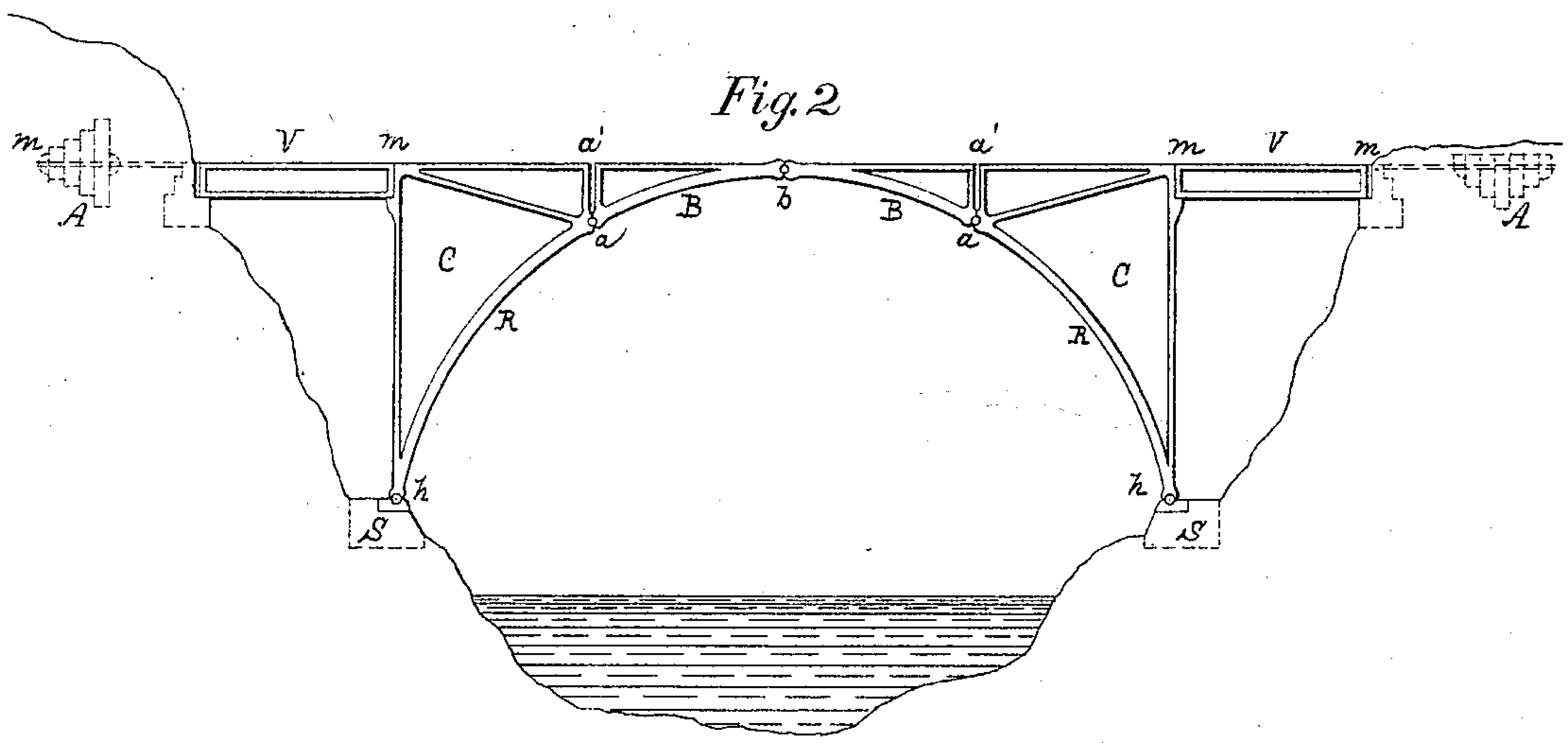
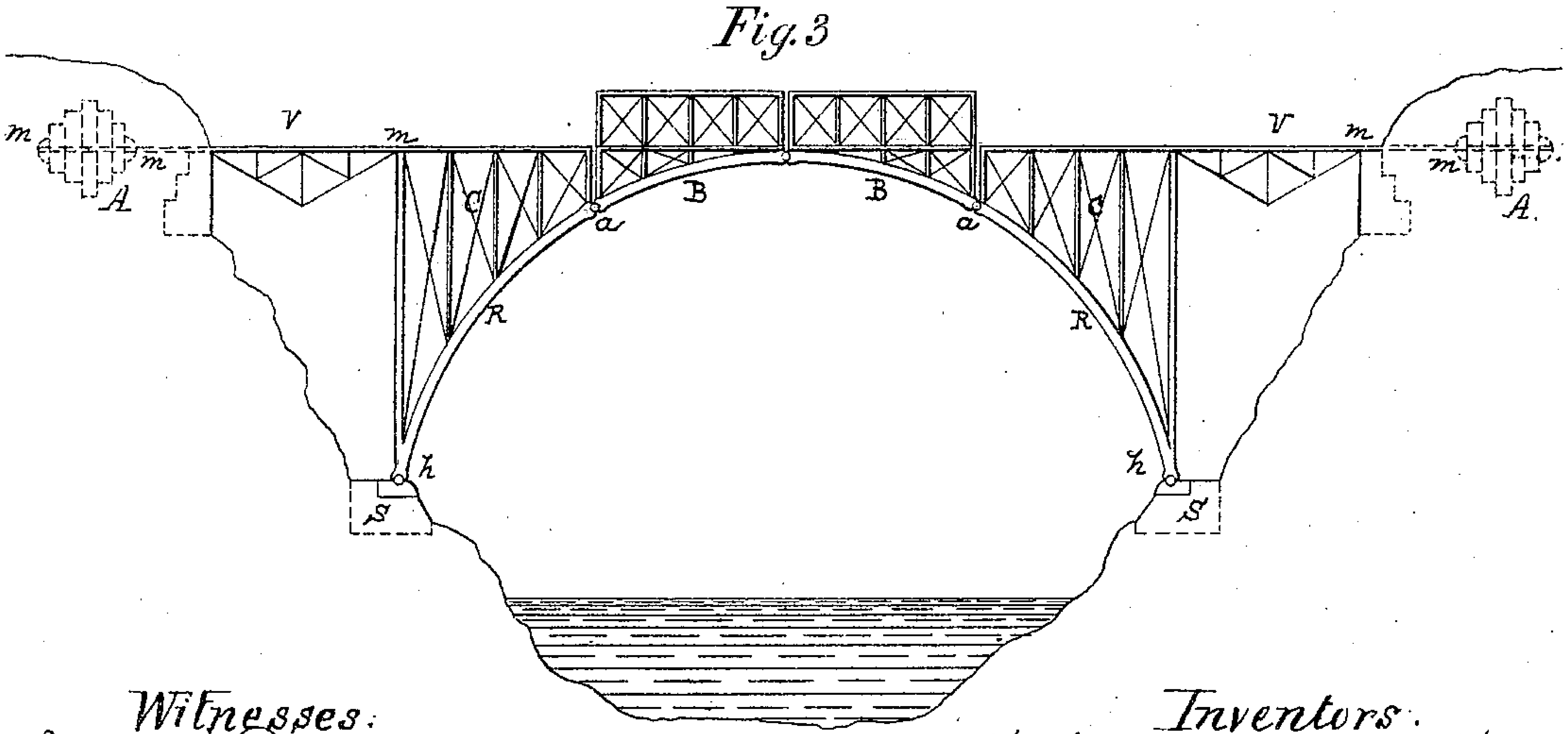


Fig. 3



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their attorney

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2 Sheets--Sheet 2.

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Fig. 4.

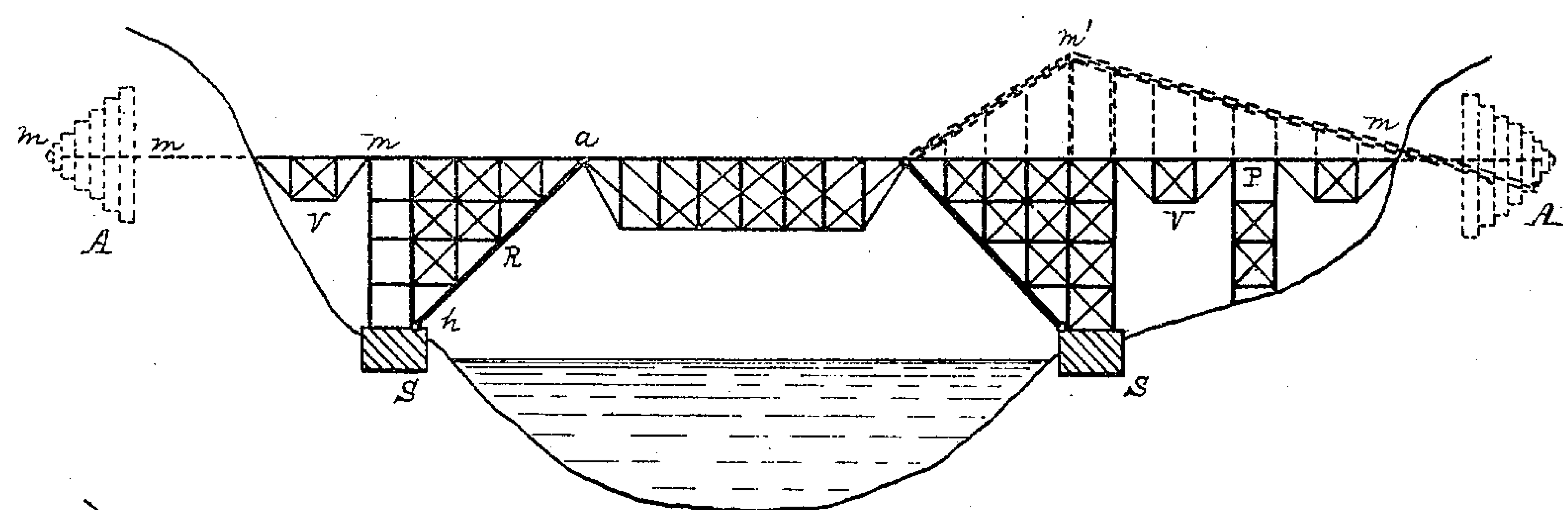


Fig. 5.

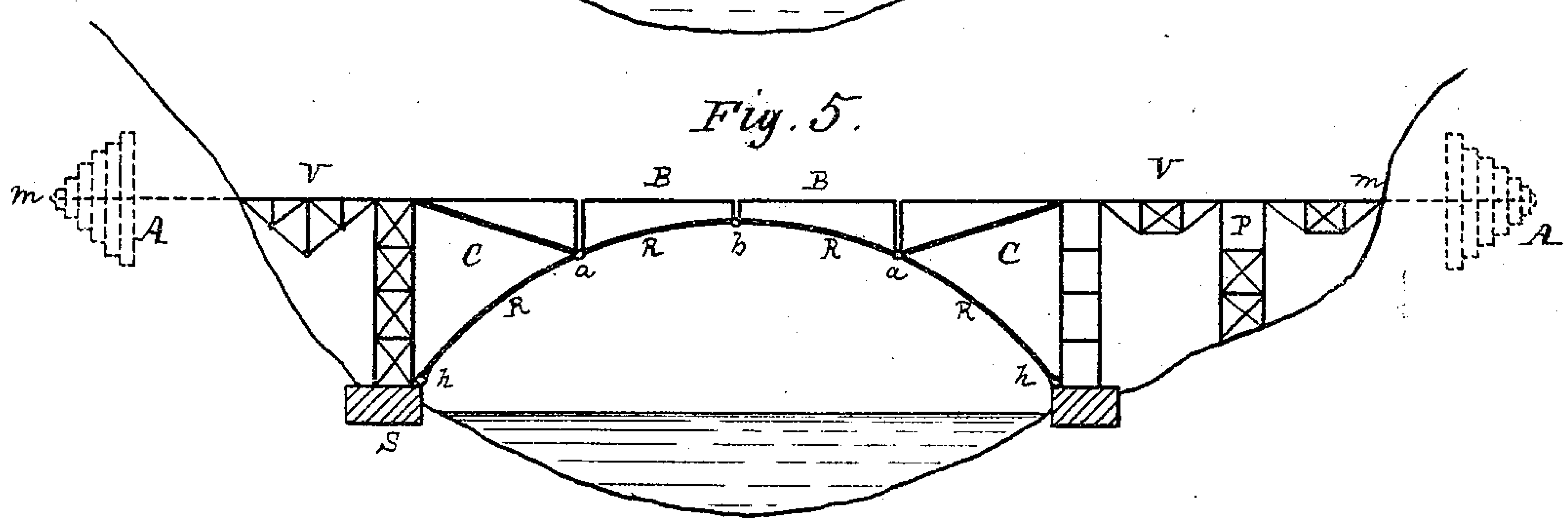
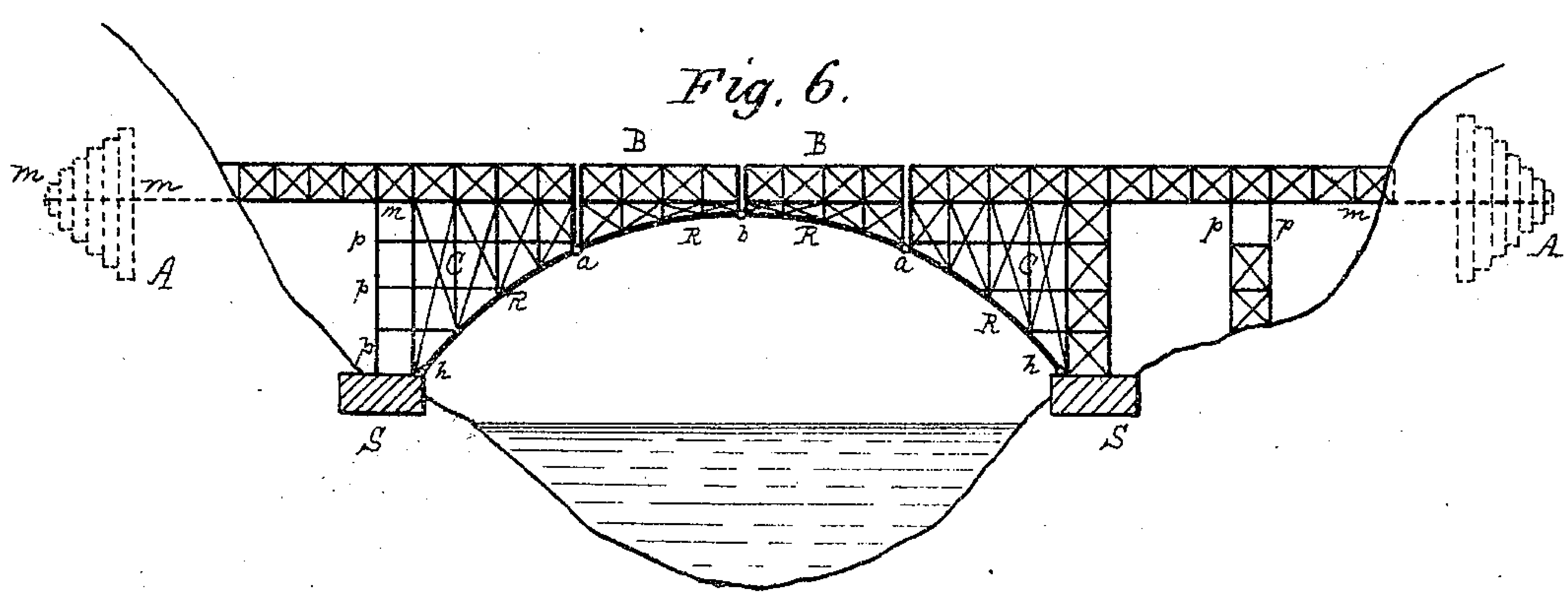


Fig. 6.



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UNITED STATES PATENT OFFICE.

CHARLES BENDER, OF NEW YORK, N. Y., CHARLES H. LATROBE, OF BALTIMORE, MD., AND CHARLES S. SMITH, OF ST. LOUIS, MO.

IMPROVEMENT IN IRON BRIDGES.

Specification forming part of Letters Patent No. **141,310**, dated July 29, 1873; application filed July 7, 1873.

To all whom it may concern:

Be it known that we, CHARLES BENDER, of New York city, in the county and State of New York, CHARLES H. LATROBE, of Baltimore city, in the county of Baltimore and State of Maryland, and CHARLES SHALER SMITH, of St. Louis, in the county of St. Louis and State of Missouri, have invented certain Improvements in Bridges; and we do declare that the following is a correct description thereof, and that the accompanying drawing illustrates the said improvements, which relate to the construction of trussed and arched bridges on the cantilever principle; and said improvements consist—

First, in separating the skew-backed abutments of the straight or curved cantilever-ribs from the anchorage, and also hinging the said cantilever at the skew-backed abutment bed-plates, so as to diminish the quantity of masonry and to more properly dispose the same than would be the case if the cantilevers were rigidly fastened to their skew-backed abutments and depended upon the stability of the said abutments to resist the turning movement arising from loading the structure as well as from thermal changes. By referring to Fig. 1 the several points referred to will be seen. S is the skew-backed abutment. A is the anchorage. *m m* or *m′ m* are the lines of anchorage sustaining the cantilevers, as shown; and *h*, the hinges at the skew-backs, around which the cantilevers revolve when their extremities *a* are elevated or depressed by thermal changes or passing loads.

Secondly, they further consist, when in combination with the triple-hinged arch, in making the lines of anchorage rigid and capable of resisting a compressive as well as a tensile strain, this compression strain on the lines of anchorage being the result, in the triple-hinged arch, of certain partial loads tending to throw backward the cantilevers by revolving them on the skew-back hinges. This will be seen in Fig. 2, when, if the arch be loaded between the points *a′*, there will result from the peculiar character of the triple-hinged arch a backward movement of the cantilevers, which is met by the rigid character of the lines of anchorage.

Thirdly, they also consist in sustaining or combining the said lines of iron or steel anchorage upon or with a permanent viaduct approach between the backs of the cantilevers and the fixed terminal points of said lines of anchorage, in such a manner as to prevent undulations and injurious vibration in any direction, and to enable said lines of anchorage to resist the compressive as well as the tensile strain arising from the triple-hinged arch, as stated above, and also to enable said lines of anchorage, when deemed advisable, to resist the transverse loading of the floor-way of the said viaduct approach by the addition of a small amount of metal. This may be seen by referring to Figs. 1, 2, and 3.

Fourthly, they consist in building arched bridges with three (3) hinges intermediate between the skew-backs, the skew-backs being also hinged or not, as may be deemed advisable, combined with rigid lines of anchorage, or their equivalents, in such a manner that the three hinged points can be considered as being fixed; and, with reference to uniformly-distributed loads, the same action will take place as if vertical forces were applied in said points, preventing their upward and downward movements.

The triple-hinged cantilever-arch is illustrated in Fig. 2, where it will be seen that the arch is divided into four separate stiff parts, only connected by their hinges at the points *a b a*.

Fig. 3 shows the same arched bridge stiffened with spandrel bracing, which performs the office of the anchor-struts *a m* of Fig. 2.

The abutment masonry or other foundation S is provided to only take up the pressure caused by the ribs R, for which purpose any of the best known arrangements used for arch-bridges may be chosen. Further back from S the anchorage A is arranged, which has the sole office of holding the end points of the anchors *m m* in place against tensile and compressive forces, the latter being developed in case the triple-hinged arch is used. The reasons for the adoption of this arrangement are these: Truss or arch bridges combined with the principle of the cantilever will only be used for very large spans over wide navigable rivers or over deep ravines, and the height from S to *m* will therefore be very considerable, so, if the overthrowing moment caused by the weight of the bridge were neutralized by one mass of stone-work at S, there would be involved a very great loss of time and money. This last is the method patented in England in the year 1864, (see English Patent 3,069 of 1864 and 633 of 1865,) while the cantilever-bridges proposed previous to those dates were intended to be arranged with truss-extensions toward A, which were then anchored down vertically. In the arrangement described at present no moment of flexure is thrown on the abutment S, nor is the anchor *m m* or *m′ m* combined with another cantilever or truss anchored down vertically; but the anchorage, as invented and proposed now, is reduced to a minimum of material and cost by using long iron or steel anchors *m m* or *m′ m*, whose end points are made immovable by a mass of masonry or rock sufficient in weight to give the necessary safety against the tensile or compressive forces acting on them, principally in a horizontal direction. The anchors *m m* or *m′ m* are carried by the permanent viaduct V so as to prevent stretching when the bridge is loaded, or to prevent sagging when the bridge is unloaded, and so as to remove all objectionable deflection and the vibrations and oscillations so injurious to suspension-bridges.

Where an arch is to be used the anchors will have to stand compression as well as tension, in which case they, by the permanent viaduct, receive the needed lateral and vertical stiffness. They may also, by a small addition of sectional area, be made to serve as chords for the viaduct.

In order to secure the most perfect freedom for expansion or contraction of the long lines of anchorage and of the bridge the upper line of posts P of the viaduct is arranged as standing pendulums rocking on their bases, which is provided for by leaving out or keeping slack the longitudinal vertical diagonals between their heads and feet. (See Figs. 4, 5, and 6, Sheet 2, of accompanying drawings.) In the case of a stone viaduct rollers are to be placed under the anchor-line at intervals to afford them freedom of expansion and contraction.

The arch differs from other arches in having three hinges intermediate between the skew-backs, thus dividing the whole span into four distinct and rigid parts, C B B C. Each part is to be treated as part of an ordinary arch, which is provided with some stiffening construction for the distribution of the load or a part thereof over its ribs.

The detailed mode of giving this stiffness can be any of the three known general methods, which are the stiffened ribs, braced spandrel, a separate stiffening-truss, or any combination thereof. The choice will depend on the available depth for such trussing, on taste, or local conditions.

The hinges are constructed with pins or pivots, or in any other suitable manner, by which a turning around the center line of the rib is made possible, and by which the tangential pressure of the ribs, the vertical forces of the parts, and the lateral forces caused by the wind can be safely withstood, while substantially there is no other connection between the adjoining parts.

The arch when fully and uniformly loaded, or when unloaded, will take up all loads, which are transformed into tangential pressures in the center line of each rib, while no strain is in the stiffening construction or in the anchorage.

When the arch is of circular form there will exist small strain in those parts, which, however, if desired, could entirely be done away with by a nearly parabolic form.

When a live load rests on the central span of the arch-bridge, while the parts C C are free from load, there will be a tendency to throw the cantilevers backward, which results in pressure to the anchors, so that these, for such an emergency, have to be treated as struts, and the anchorage A must act as an abutment. On the contrary, when one of the parts C is loaded it will act as a single cantilever, the anchors *m m* will be under tension, and the anchorage A will act like that of a suspension-bridge. These strains will be confined to the loaded part C, and no other section of the span will be sensibly affected.

The advantage coming from this method of dividing the total span of the arch into four rigid parts, by hinges, instead of two parts, as in the ordinary spandrel-braced arch, is that the moments of flexure in each part are reduced as the squares of the length of said parts, while the sheering forces are at least reduced in single ratio of said lengths. Again, the anchorage is only brought into play by the live load, and even then only when the span is partially covered with live load. When entirely covered from end to end by live load there are no strains on the anchorage, the ribs being in equilibrium and sustaining the entire stress. Again, the hinges give the ribs a most perfect capacity for self-adjustment under thermal changes, preventing all cross strain arising from the same, and obviating that necessity for absolutely perfect workmanship, which it obtains in the case of continuous self-braced arched ribs. Again, the facility of erection is very great on account of the anchorage, each anchorage requiring but a small addition of metal to enable it to act as a back-stay during the erection of one entire half of the whole span, making underneath scaffolding unnecessary.

In Fig. 2 the struts are represented as entirely independent of the stiffening construction, while in Fig. 3 the office of those members is performed by the spandrel-bracing.

In Figs. 1, 2, 3 but one span is shown, but there is no difficulty in applying the same system to a number of spans by building the piers strong enough to resist the overturning moments in the cantilevers, which must be anchored firmly to them.

The points claimed in onr invention, and what we wish to secure by Letters Patent, are—

1. A cantilever-bridge, in which the abutments of the ribs are separated from the anchorage of the back ties or struts, and in which the cantilevers are hinged at their abutments, as herein set forth.

2. The combination of a cantilever trussed or arched bridge with a viaduct, by which the back-ties are supported or stiffened, as herein set forth.

3. An arched bridge, constructed with three hinges intermediate between the skew-backs, combined with a rigid anchorage capable of resisting compression as well as tension, or combined with piers of such weight and stability as will obviate the necessity of any other anchorage.

In testimony whereof we have signed our names to this specification before two subscribing witnesses.

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CHARLES H. LATROBE.
C. SHALER SMITH.

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