W. FRENCH & C. W. FREDERICK.

APPARATUS FOR SOLVING SPHERICAL TRIANGLES.

APPLICATION FILED JULY 1, 1909.

943,532. Patented Dec. 14, 1909.

5 SHEETS—SHEET 1.

Fig. 1.

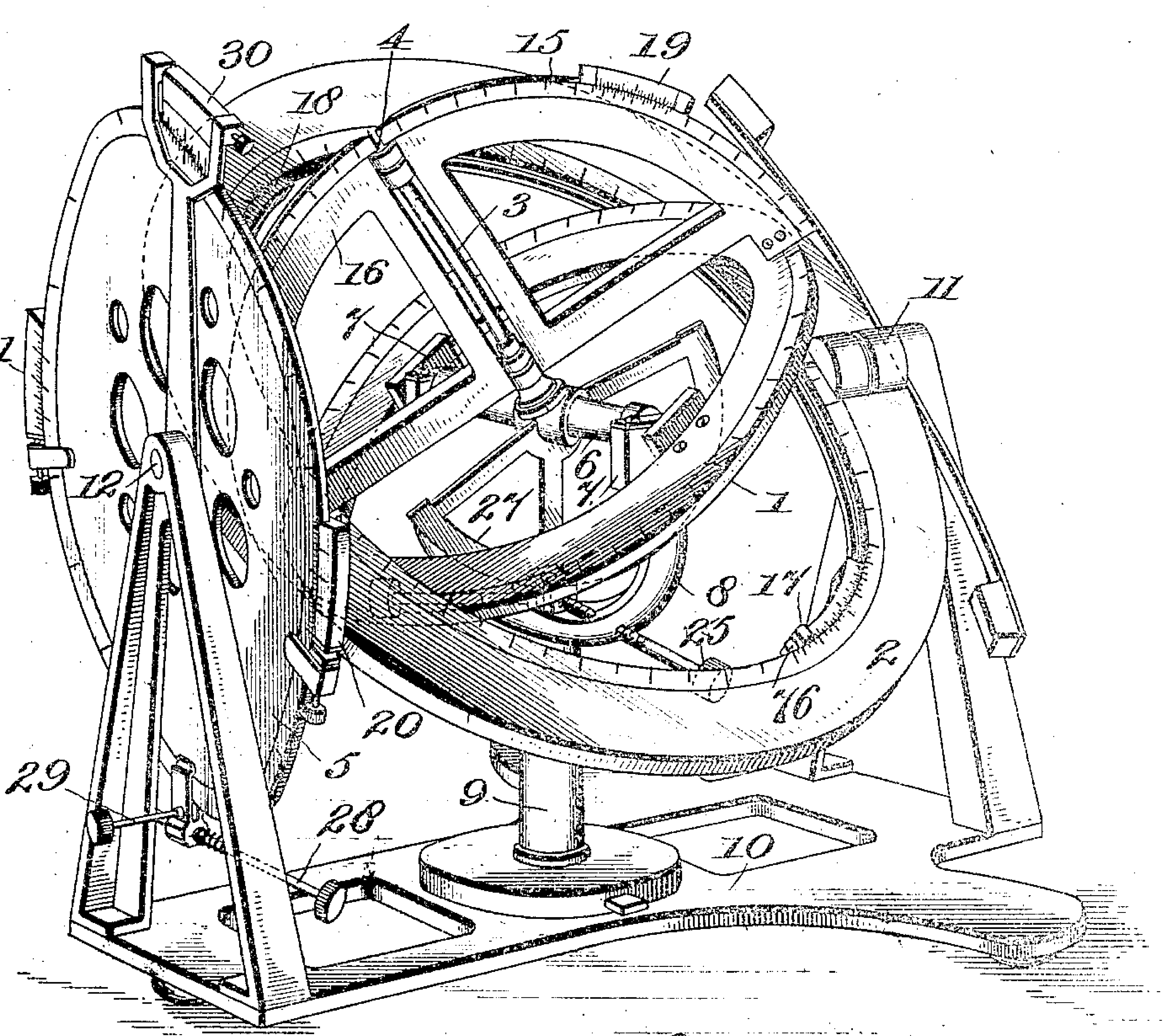
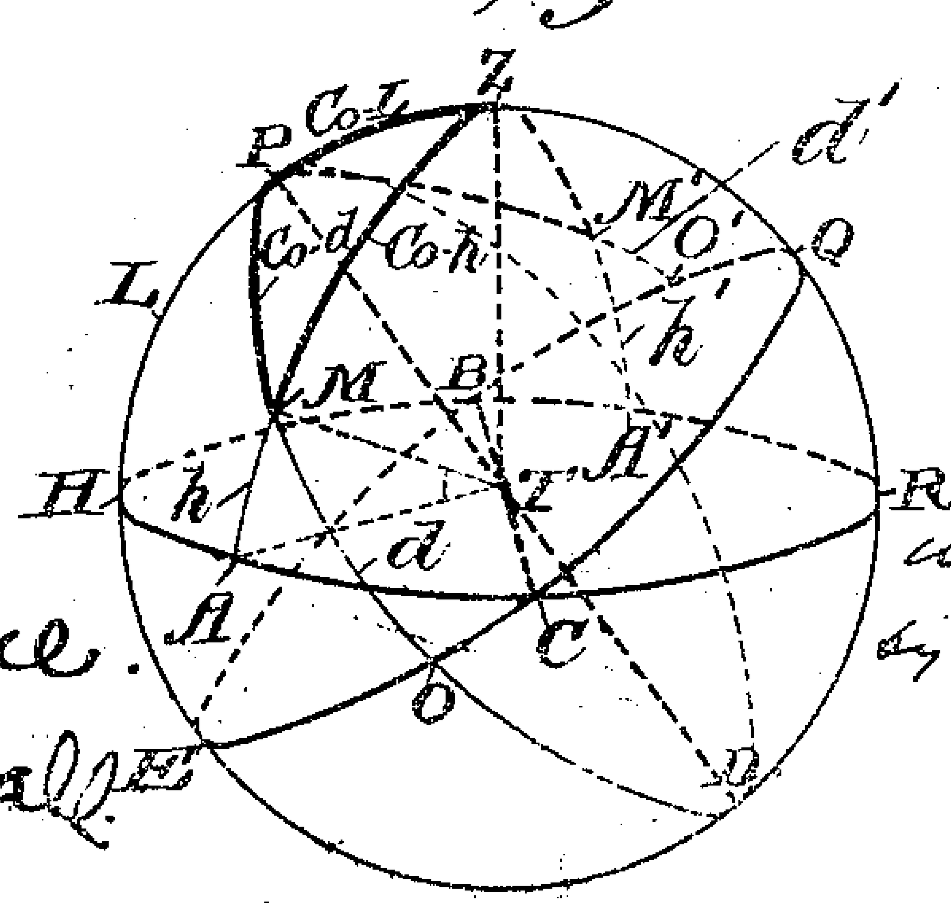


Fig. 2.



Witnesses

Geo. A. Bepue.

W. MacDonald.

Inventors

W. French & C. W. Frederick

by Wilkinson Fisher & Witherspoon

Attorneys

W. FRENCH & C. W. FREDERICK.

APPARATUS FOR SOLVING SPHERICAL TRIANGLES.

APPLICATION FILED JULY 1, 1909.

943,532. Patented Dec. 14, 1909.

5 SHEETS—SHEET 2.

Fig. 3.

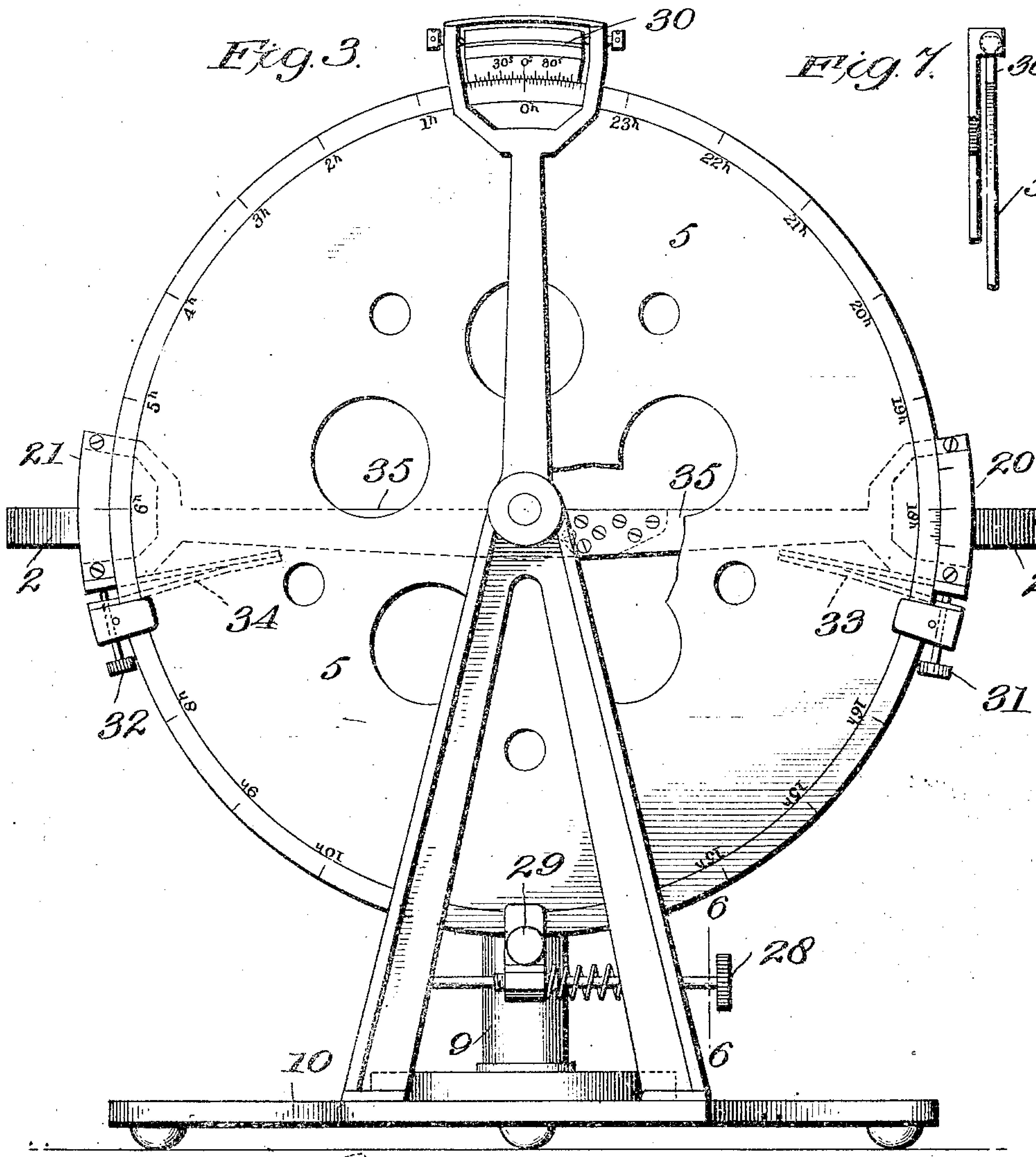


Fig. 7.

Fig. 4.

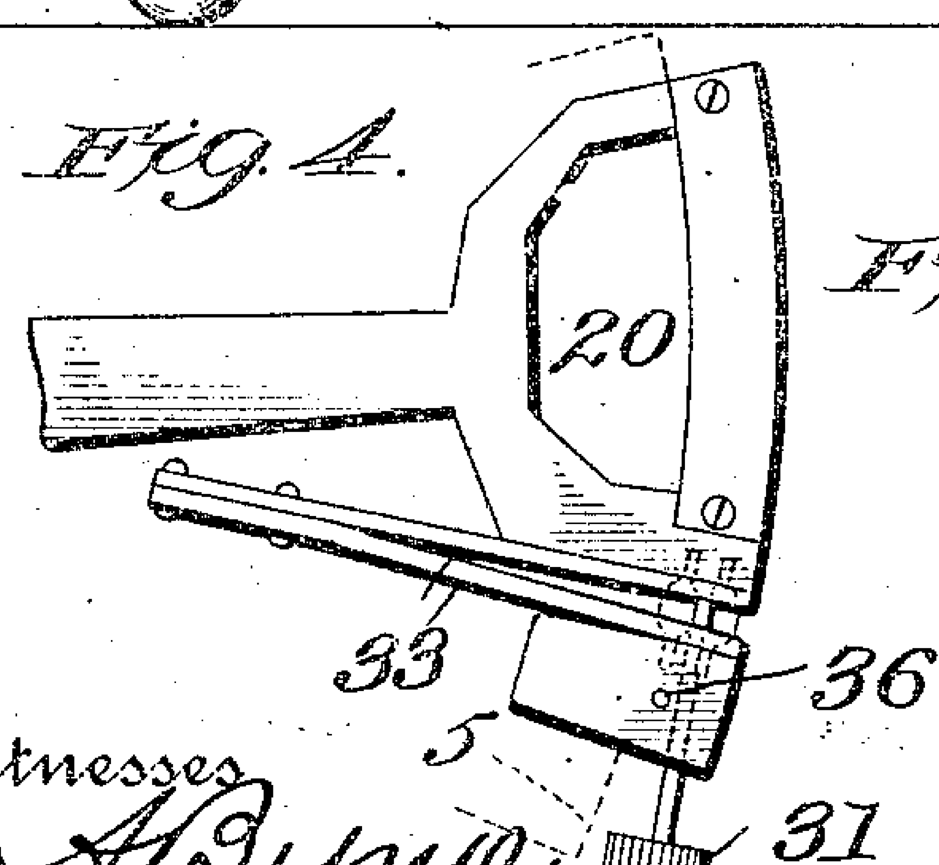


Fig. 5.

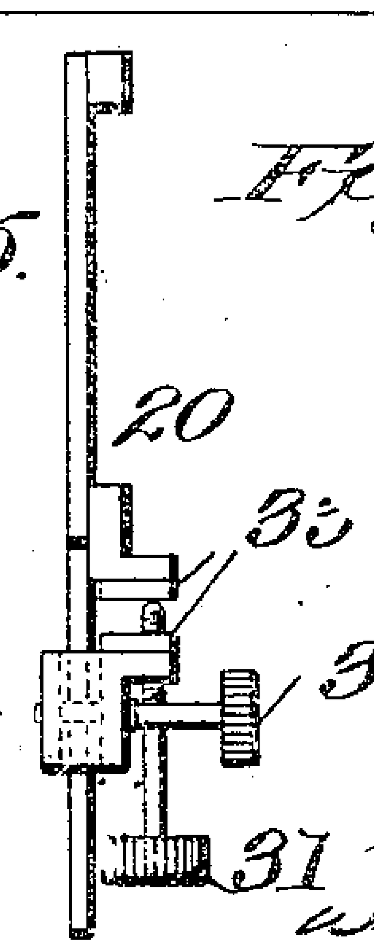
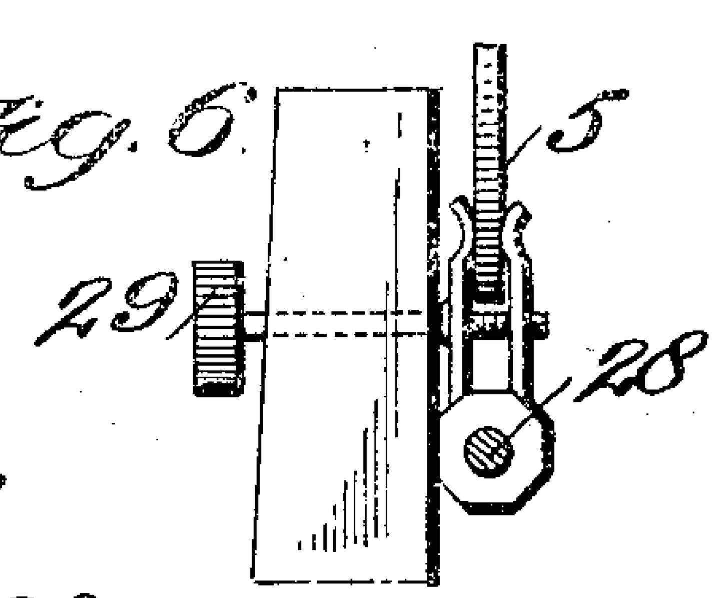


Fig. 6.



Witnesses

Geo. A. Byrne.

W. May. Duvall.

Inventor.

W. French &

C. W. Frederick, by

Wickersham Fisher &

Wilkinson

Attorneys

W. FRENCH & C. W. FREDERICK.

APPARATUS FOR SOLVING SPHERICAL TRIANGLES.

APPLICATION FILED JULY 1, 1909.

943,532. Patented Dec. 14, 1909.

5 SHEETS—SHEET 3.

Fig. 8.

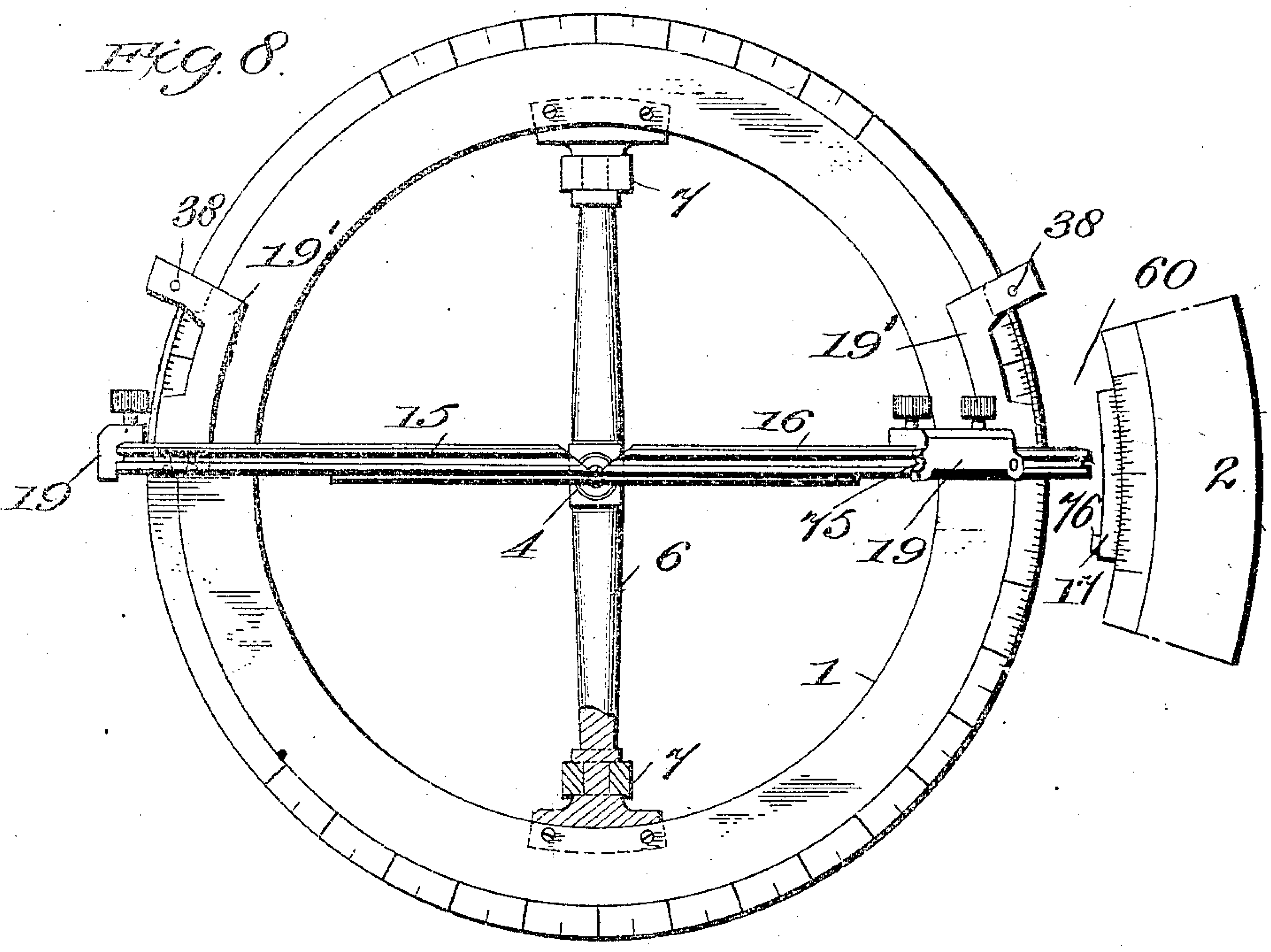
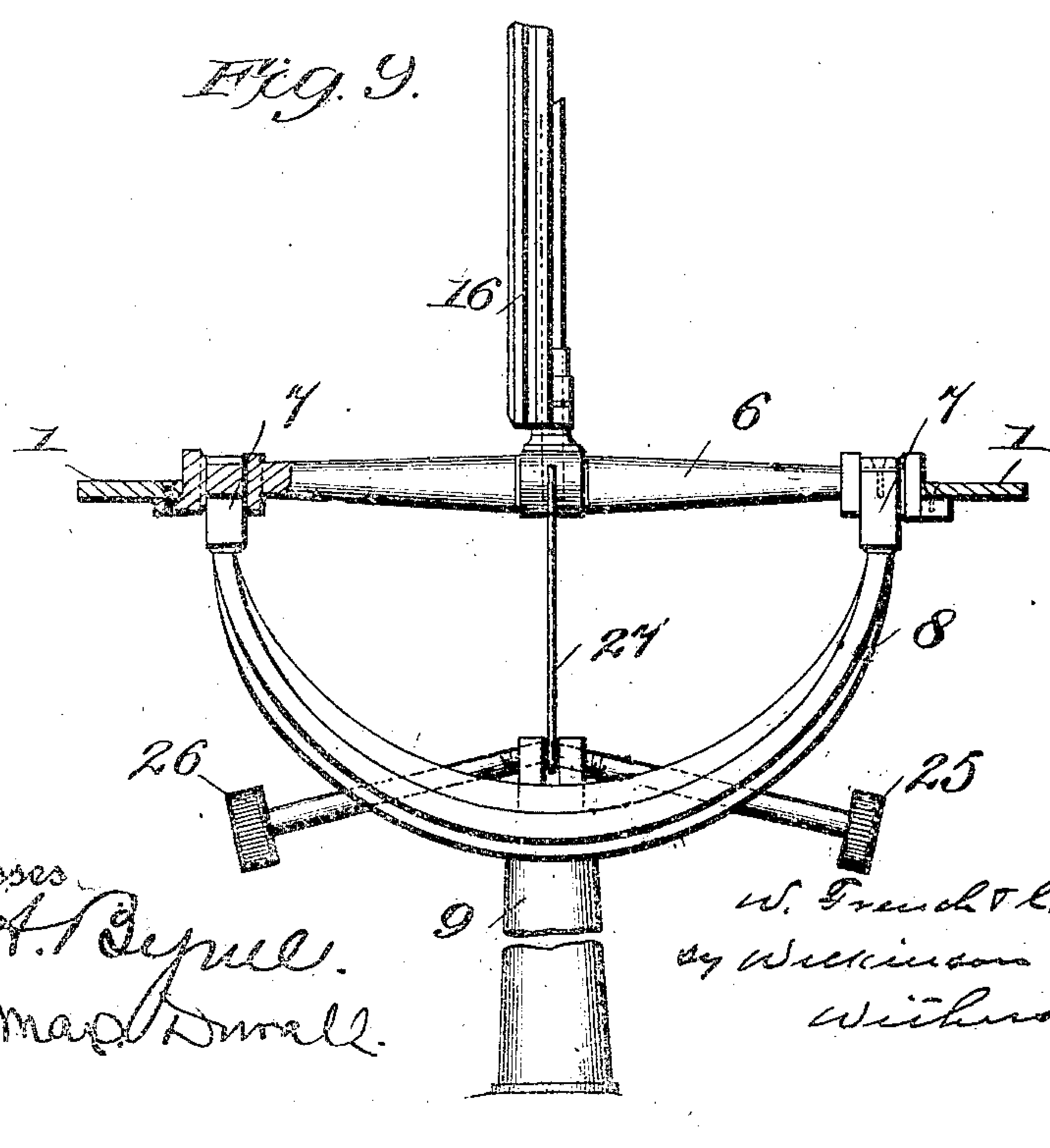


Fig. 9.



Witnesses

Geo. A. Bepue.

W. MacDowell.

Inventors

W. French & C. W. Frederick,

by Wilkinson Fisher & Witherspoon

Attorneys

W. FRENCH & C. W. FREDERICK.

APPARATUS FOR SOLVING SPHERICAL TRIANGLES.

APPLICATION FILED JULY 1, 1909.

943,532.

Patented Dec. 14, 1909.

5 SHEETS—SHEET 4.

Fig. 10.

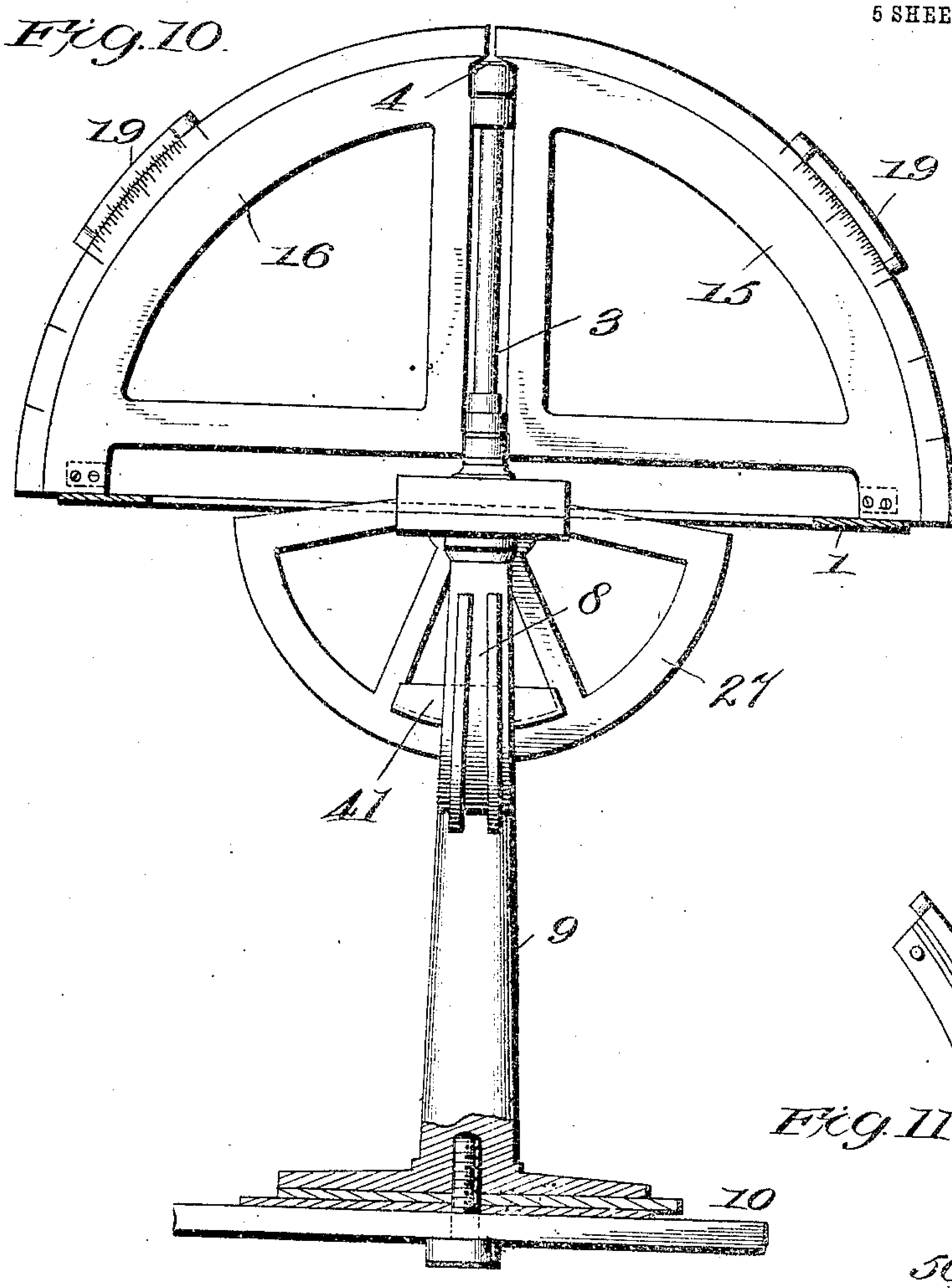


Fig. 11.

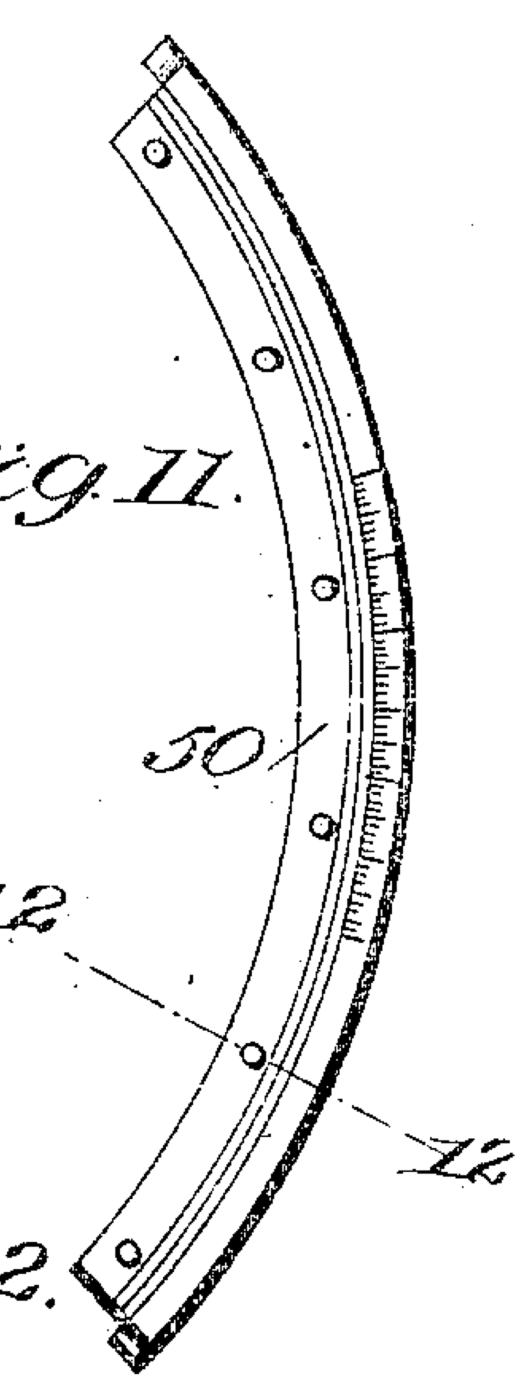


Fig. 12.

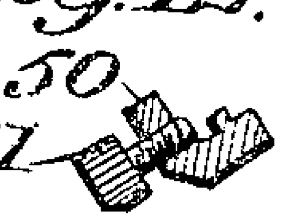


Fig. 13.

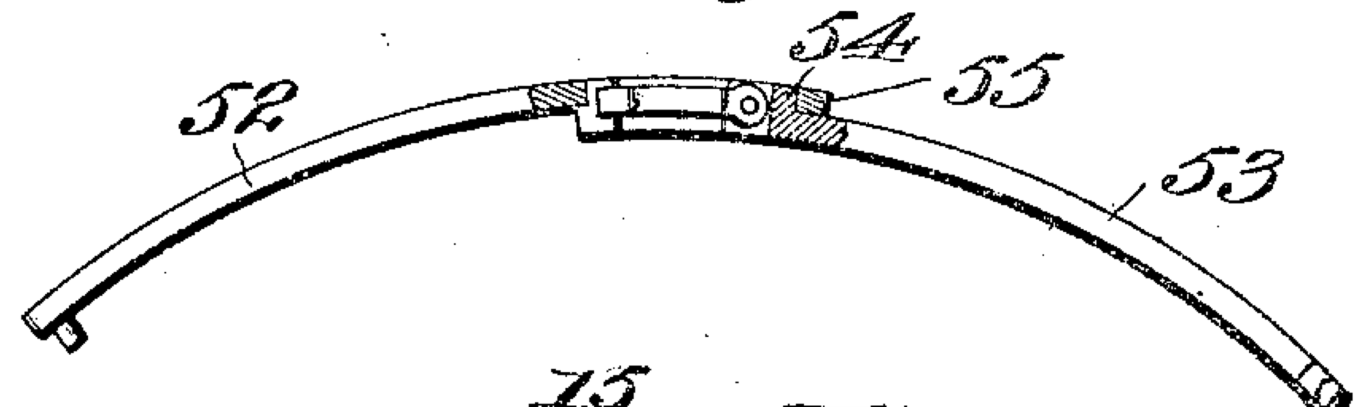


Fig. 14

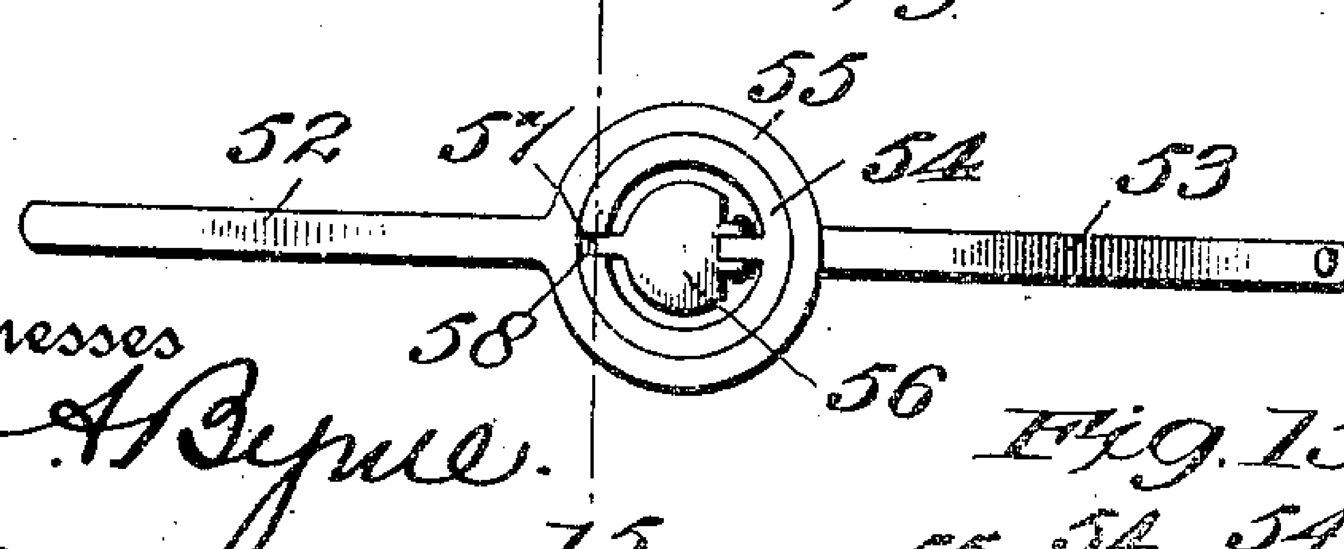


Fig. 15.

Witnesses

Geo. A. Byrne.

W. Max. Duvall.

Inventors

W. French & C. W. Frederick

by Wilkinson Fisher & Witherspoon

Attorneys

W. FRENCH & C. W. FREDERICK.

APPARATUS FOR SOLVING SPHERICAL TRIANGLES.

APPLICATION FILED JULY 1, 1909.

943,532. Patented Dec. 14, 1909.

5 SHEETS—SHEET 5.

Fig. 16.

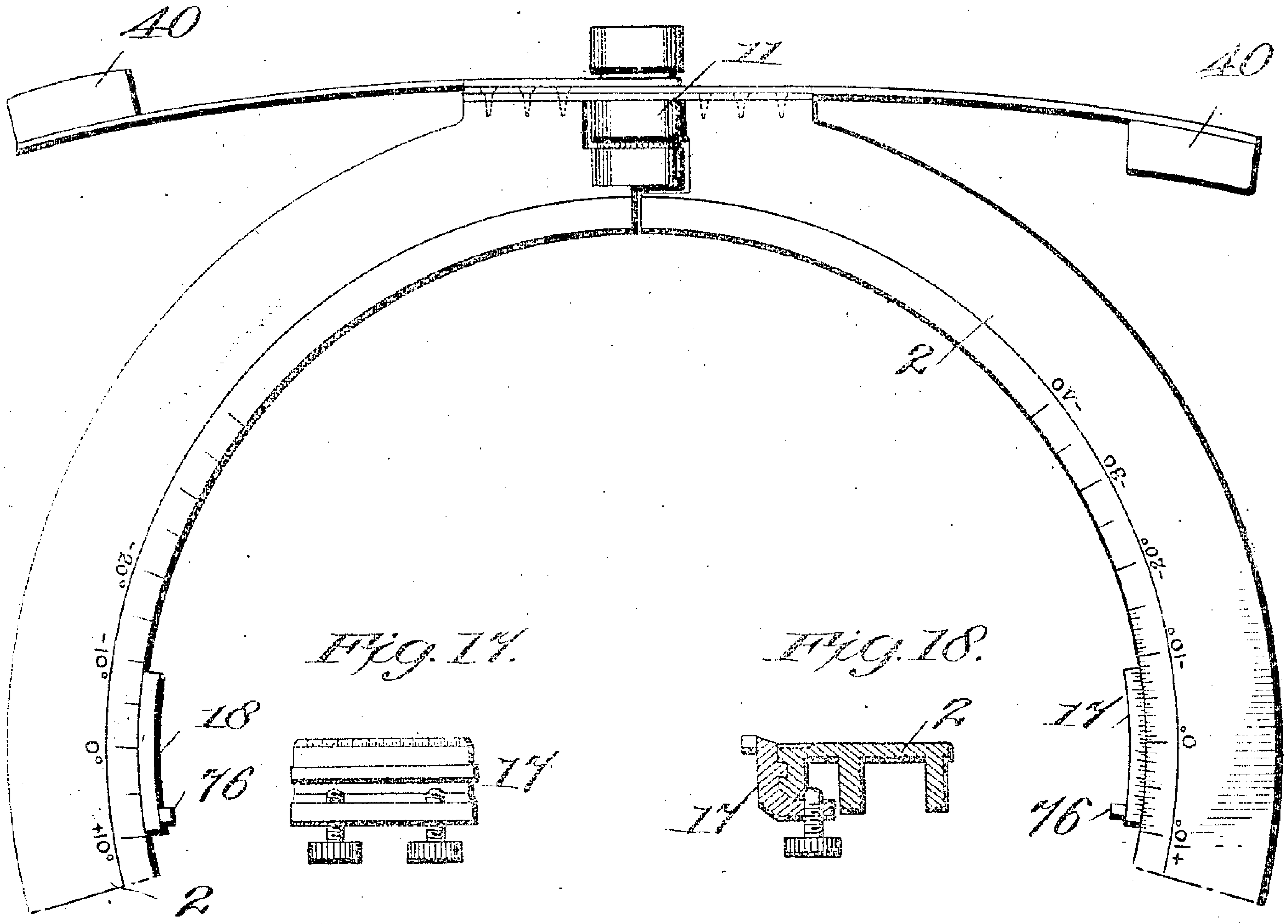


Fig. 17.

Fig. 18.

Fig. 19.

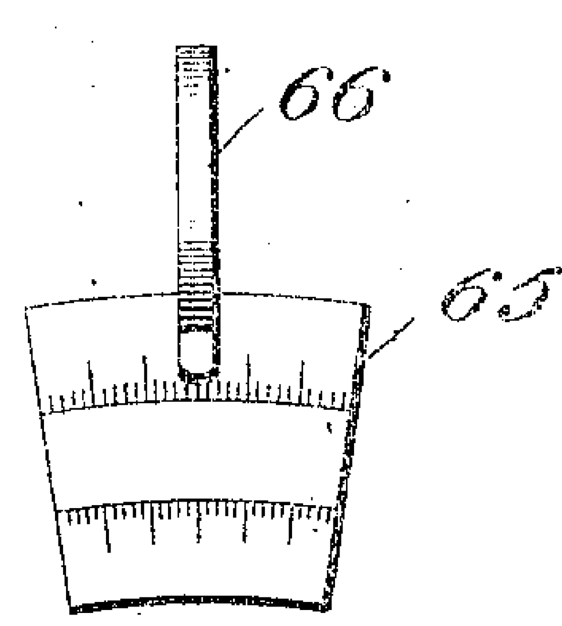
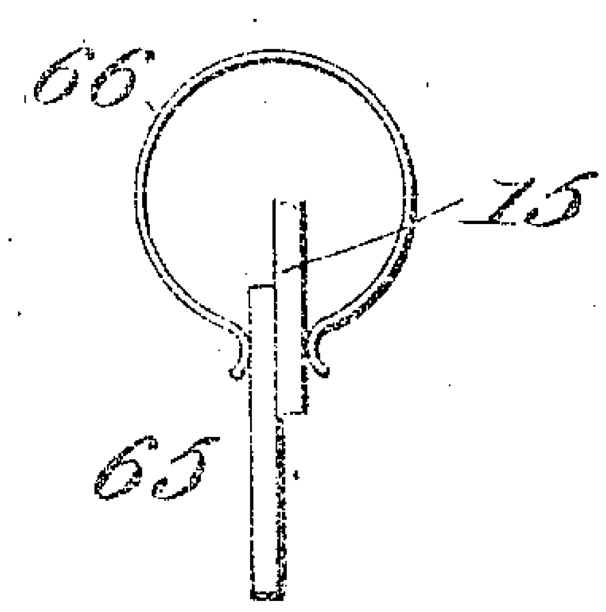


Fig. 20.



Witnesses
Geo. A. Depue.
W. Mary Duvall

Inventors
W. French & C. W. Frederick
By: Wilkinson Fisher & Witherspoon
Attorneys

UNITED STATES PATENT OFFICE.

WILLARD FRENCH AND CHARLES W. FREDERICK, OF WASHINGTON, DISTRICT OF COLUMBIA, ASSIGNORS, BY DIRECT AND MESNE ASSIGNMENTS, TO JOHN D. SPRECKELS, OF SAN FRANCISCO, CALIFORNIA.

APPARATUS FOR SOLVING SPHERICAL TRIANGLES.

943,532. Specification of Letters Patent. Patented Dec. 14, 1909.

Application filed July 1, 1909. Serial No. 505,432.

To all whom it may concern:

Be it known that we, WILLARD FRENCH and CHARLES WARNOCK FREDERICK, citizens of the United States, residing at Washington, in the District of Columbia, have invented certain new and useful Improvements in Apparatus for Solving Spherical Triangles; and we do hereby declare the following to be a full, clear, and exact description of the invention, such as will enable others skilled in the art to which it appertains to make and use the same.

This invention relates to an apparatus for solving directly and simultaneously the two, and sometimes the three, spherical triangles involved in finding a ship's position from two star sights, or from two sun sights, as well as all other problems involving spherical triangles.

It has for its object to improve the device disclosed in Patent No. 703,139, dated June 24, 1902, to R. T. Lawless.

To these ends the invention consists in the novel details of construction and combinations of parts more fully hereinafter disclosed and particularly pointed out in the claims.

Referring to the accompanying drawings forming a part of this specification in which like letters and numerals refer to like parts in all the views:—Figure 1 is a perspective view of the complete instrument; Fig. 2, a diagrammatic view of the celestial sphere serving to explain the operation of the instrument; Fig. 3 an end elevational view of the instrument; Fig. 4 a detail view of one of the verniers used on the right ascension circle; Fig. 5, an end view of the parts shown in Fig. 4; Fig. 6 is a detail sectional view on the line 6—6 of Fig. 3; Fig. 7 is a detail side elevation of the upper vernier shown in Fig. 3; Fig. 8 is a plan view of the horizon and altitude circles; Fig. 9, a sectional elevational view of said circles; Fig. 10, a view partly in section of said circles, but showing the altitude circle in side elevation; Fig. 11, a detail of a vernier adapted for use in connection with said altitude circle; Fig. 12, a section on the line 12—12 of Fig. 11; Figs. 13 and 14, elevational and plan views, respectively, of a measuring device described more fully hereinafter; Fig. 15, a sectional view on the line 15—15 of Fig. 14; Fig. 16, is a plan view of a portion of the declination circle; Figs. 17 and 18 details of a marking vernier to be used in connection with said circle; and Figs. 19 and 20, details of a reading vernier used in connection with the altitude and declination circles.

Referring first to Fig. 2, for the purpose of explaining the fundamental principles of this device, E Q represents the celestial equator running around the concave surface of the heavens; H R the horizon; P the north pole; Z the zenith; T the earth located at the center of the celestial sphere; and M any heavenly body, for example, the sun. As is well known to astronomers and navigators, the declination d of a heavenly body M is its distance from the celestial equator E Q measured on a meridian or declination circle P M O, and its altitude h is its distance above the horizon H R measured on a vertical or altitude circle Z M A. It is also well known that the distance P H measured on the circle Z P H passing through the pole and zenith, and which is the altitude L of the celestial pole, is equal to the latitude of the place at which the observation is taken. Since the arcs P O, Z A and Z H are each equal to 90°, it is evident that the arc P M is equal to 90°—d or to *Co*—d; that the arc Z M is equal to *Co*—h; and that the arc P Z is equal to *Co*—L. In other words, since the altitude h, which is the angle M T A, may be obtained by observation; and since the declination d may be obtained from a *Nautical Almanac*, if the latitude of the place is known, the three sides *Co*—d, *Co*—h, and *Co*—L of the spherical triangle Z P M may be also known; and therefore the other parts of the triangle may be ascertained by calculation. The angle M Z P, for example, being thus obtained, and if the body M is the sun, the local time is had; and from this the longitude of the place of observation is gotten by comparing it with the Greenwich time as given by a chronometer, all as is well known to navigators. But it is equally well known that these and other calculations necessary in navigating a ship take time, that they require a certain amount of astronomical knowledge in order to be made with accuracy under all conditions; and that they are often very laborious. In order to overcome these difficulties I provide an instrument having circles corresponding to the celestial equator, to the horizon, to the meridians or declination circles, and to the vertical or altitude circles of the heavens; and on these circles I provide markers which are adapted to set off or indicate the various data constituting the coördinates of a body such as altitudes, declinations, latitudes, etc., that may enter into the calculations. Said circles in the instrument are also so pivoted relatively to each other that the marked positions of a heavenly body or two intersecting circles can be made to coincide, and thereupon said circles are caused to reproduce accurately the celestial triangles to be solved. When said triangles are thus accurately reproduced, it is evident that their various parts may be read off at once without any calculations, all as will now be explained.

Referring more particularly to Fig. 1 of the drawings, 1 represents a graduated circle corresponding to the horizon or azimuth circle H R; 2 represents a meridian or declination circle corresponding to the meridian P M O; 3 an axis perpendicular to the plane of the circle 1 and the end 4 of which therefore corresponds to the zenith Z. While 5 is a circle perpendicular to the circle 2 and therefore corresponding to the equator or right ascension circle E Q. For convenience of construction, the circle 5, instead of intersecting the azimuth and declination circles, as does the equator in Fig. 2, is placed to one side of said circles, as indicated in Fig. 1. If said circle 5 is imagined, however, as shifted toward the right in said figure, until its center coincides with the center of said circles 1 and 2, but always lying in a plane perpendicular to said circle 2, the relative positions of all the circles mentioned will be the same as in Fig. 2. The azimuth circle 1, is carried by an axis 6 pivoted in the wyes 7, carried by a yoke 8, supported on the standard 9, rising from the base 10. This axis may be pictured as corresponding to the line B C in Fig. 2, and it permits the horizon or azimuth circle to swing through very large arcs. In the same way the meridian or declination circle 2 is pivoted at 11 and 12 on an axis perpendicular to the axis 6, and corresponding to the straight line joining P D in Fig. 2. The two axes just mentioned are so disposed in the instrument that they intersect at the common center of the circles which corresponds to the position of the earth or to the point T in Fig. 2. A little consideration will show that the point 12 on the instrument corresponds to the north pole of the heavens, the point 11 to the south pole, and the pivots 7 to the east and west points in the horizon. These four points, it will be observed, are fixed in relation to the base 10. Pivotally mounted on the axis 3, and movable around the same, are two quadrants 15 and 16 constituting a semicircle, as shown, and corresponding to the vertical or altitude circle Z M h in Fig. 2. The axis 3 therefore corresponds to the line Z T in Fig. 2, and it also passes through the common center of the circles and at right angles to the axis 6. The declination circle 2 is provided with suitable markers 17 and 18 of the vernier type; the vertical circle 15, 16 is provided with like markers 19, and the right ascension circle 5 is provided with movable verniers 20 and 21 rigid with the declination circle 2.

It is evident from an inspection of Fig. 2, that if the declination circle P M O could be swung around the axis P D, and if the altitude circle Z M A could be swung around the axis Z T, while the azimuth circle could be swung around the axis B C, that any triangle corresponding to any given set of coördinates whatever could be formed. That is to say, with the freedom of movement stated, these three particular circles could be so disposed as to cause the point of intersection of the altitude and declination circles to be located in any point in the heavens whatever, and when said intersection is so located said circles would, also, give by inspection all the other parts of the astronomical triangle. Furthermore, Fig. 2 shows that the inclination of the declination circle P M O to the altitude circle Z M A is measured by the arc P Z or *Co*—L. Therefore, it is obvious if we observe the sun, for example, and find its altitude h to be 30° 24′ 31″, we may get its true declination from the *Nautical Almanac* and mark it off by the appropriate vernier 17 or 18 on the declination circle. We may likewise mark off said observed altitude on the altitude circle 15, 16, by the appropriate vernier 19; and we may incline the point 4 of the axis 3 so that its distance from the polar point on the declination circle is equal to the difference between 90° and the latitude, or to *Co*—L. Finally, we may then without disturbing this last relation move the circles 1 and 2 about their respective axes until each of the marking verniers show said circles to intersect at the point corresponding to the coördinates given. After having performed these operations it is evident that the triangle Z P M in Fig. 2 will be reproduced on the instrument, and that its hour angle Z P M may be read off on the right ascension circle 5, since it is measured by the arc O Q. From this we may get at once the local time and the longitude of the place by comparing with a chronometer, all in the manner well known, and without the usual calculations.

In carrying out the above operations, however, if accuracy is to be attained it is essential that the instrument be provided with certain refinements now to be described, and which are not found in Patent No. 703,139 above. Also, if two star sights, or two sun sights, are to be solved simultaneously, it is necessary to divide the declination circle, as well as the altitude circle, into two parts hinged together, as will appear below, which features are likewise not found in said patent.

In the first place, it is desirable that the circle 15, 16, be capable of a slow motion and be provided with a clamp to fix it in any position to which it may be adjusted. To these ends there is provided the screws 25 and 26 appropriately threaded and beveled at their ends, which take against the sector shaped piece 27 rigid with the axis 6. When these screws are unclamped the altitude circle can be freely moved by hand to the approximate position, after which by setting up on one or both screws a very fine micrometer adjustment may be attained, while at the same time clamping the circle. Again, the adjusting screw 28 and clamping screw 29 serve to slowly move and to accurately fix the circle 5 in any desired position. This circle is provided with a vernier 30, as shown, and is preferably graduated on one face with hours of right ascension, and on the other with degrees of longitude.

The circle 2 is provided with the rigidly fixed arms 35 carrying the verniers 20 and 21, playing over the circle 5, and these verniers are provided with the adjusting screws 31 and 32, taking against suitable springs 33 and 34 respectively. Suitable clamping screws as 36 are also provided for the verniers, as best shown in Fig. 5.

The altitude circle 15, 16 is not only provided with the slidable verniers 19, as shown, but also with the verniers 19′ which are fixed to said circle and traverse the azimuth circle 1. Clamping screws are also provided for said verniers 19′, the upper ends of which appear at 38.

To counterbalance the circle 2, weights 40 are provided, and to counterbalance the circle 1, the sector 27 is provided with a weight 41, Fig. 10. The plane of the face of circle 15, 16, passes accurately through the center of its hinges, as illustrated, and the plane of the face of circle 1 passes accurately through the axis of its pivot 6.

In Fig. 11 is illustrated a large marker 50, extending over a quadrant, which may be placed on the altitude circle for measuring negative altitudes, or altitudes below the horizon. This marker is also useful in clamping the quadrants 15 and 16 together when tracing a great circle course. It is provided with a suitable set screw 51, as shown.

In Fig. 13 is shown a device for measuring arcs, which we term a spherical compass, and it consists of a pair of legs 52 and 53, the leg 53 provided with a hollow rim 54, over which fits the circular pivot 55 of the leg 52, and in which pivots the wedge 56 having the tapered end 57 fitting in the slit 58 of the rim 54. It is evident when the wedge is raised that the leg 52 may readily turn around its pivot, but when the wedge is down the parts will be clamped against turning.

In order that the circle 1 and its markers may freely move inside the circle 2, a considerable space 60, Fig. 8, is left between the two circles; and in order that the points of intersection of the declination and altitude circles may be accurately read, there is provided the glass vernier scale 65, Figs. 19 and 20, which is adapted to lie flat against the altitude circle and to extend over the scale of the declination circle, or vice versa. A clamp 66 is provided in order to hold the parts together.

In operation the clamps being free, the following movements will be possible among the parts. The altitude circle may swing freely in azimuth, its vertical axis 3 may swing freely north and south in the meridian, and the declination circle may move freely in an east and west direction. Therefore, it is evident after the coördinates of a heavenly body have been marked, as above described, on the appropriate circles that the proper marking verniers may be brought together at the intersections of the appropriate circles and the desired spherical triangle reproduced, as above stated. But, since two markers cannot occupy the same space at the same time, the actual point sought cannot be had by a direct reading. Therefore, the scale of each marker is so arranged that when two markers touch, it will either indicate the desired point of intersection, or else such point will be indicated after a known correction has been applied. To facilitate the operation the markers may be provided with inter-engaging grooves 75 and pins 76, as best shown in Figs. 8 and 16, but any other suitable contacting points may be provided, if desired.

Since the spherical problems that can be solved by this instrument are endless, they will not be treated in detail, but it might be observed that a ship's position may be readily obtained with its aid by two star sights, in the following manner:—The altitudes h and h' of the stars M and M′, Fig. 2, are observed in the usual way, while their declinations d and d' and their right ascensions are obtained from a *Nautical Almanac.* These right ascensions also give the longitudes of the stars for the times of observation in the manner well known. The altitudes h and h' are laid off on the two quadrants 15 and 16 of the altitude circle by the markers 19; the declinations are laid off on the declination circle by the markers 17 and 18; and the longitudes of the stars are laid off on the circle 5 by the verniers 20 and 21.

The coördinates of the two bodies of course will not be the same, and therefore if the altitude and declination circles are to aid in reproducing the two spherical triangles shown in Fig. 2, it will be necessary for the arcs Z M, Z M′, P O and P O′, Fig. 2, to be capable of occupying different planes. To accomplish this, the declination circle 2 of the instrument is made in two parts hinged at 11 and 12, only the hinge 11 being shown. This enables the vernier 21 to move independently of the vernier 20 on the circle 5, and therefore to indicate right ascensions or longitudes independently of vernier 20. In the same way the quadrants 15 and 16 may freely move around the axis 3 and indicate independent altitudes. Owing to this construction, it is evident that the instrument may readily, in the manner above described, simultaneously reproduce the two triangles P Z M and P Z M′ in Fig. 2. When these triangles are reproduced the longitude of the ship will appear on vernier 30 which marks the meridian, and the latitude will be represented by the point 4 of the pin 3.

So far as we are aware no instrument has been heretofore proposed which will solve simultaneously two spherical triangles and thereby find a ship's position from two star sights, the latitude not being known. Furthermore, this instrument is capable of finding a ship's position from two sun sights involving the solution simultaneously of three triangles, the latitude not being known and the ship having moved in the interval between the sights. To do this we proceed in the way above described, obtaining the declinations and longitudes of the sun for the times of observation from the *Nautical Almanac*, and setting them off on the instrument as in the case of said star sights. Also, we set off the last mentioned altitude h as above. But in the case of the first measured altitude h', we use the spherical compass, Fig. 13, so setting the extremities of its legs that they will subtend an arc equal to $Co—h'$. Further, we set one of the vanes as 15 upon the reverse course of the ship and place one of the markers 19 on the same vane at a distance from point 4, equal to the distance the ship has moved between the observations, as indicated by the log. This marker will then represent the position of the first zenith Z′ with reference to the second zenith Z. Now engage one extremity of the spherical compass with the marker representing the first zenith Z′, and bring the other extremity in contact with the marker representing the sun's first position M′. Also, move the vane 16 which carries the marker representing the first measured altitude, so it will come into contact with the marker representing the sun's last position M. When this is done the ship's longitude at the time of the last sight will appear under the vernier 30, and the latitude will be represented by the inclination of the axis 3.

It is evident that those skilled in the art may vary the details of construction and the arrangement of parts without departing from the spirit of the invention, it is therefore not desired to limit the invention to the construction shown, except as may be required by the claims.

What is claimed is:—

1. In an apparatus for solving spherical triangles, the combination of an altitude circle in two parts hinged together and adapted to swing on an axis; an azimuth circle provided with an axis at right angles to the axis of said altitude circle; a declination circle provided with an axis perpendicular to said last mentioned axis; a right ascension circle; and suitable marking verniers on said circles, substantially as described.

2. In an apparatus for solving spherical triangles, the combination of an altitude circle; an azimuth circle; a declination circle formed in two parts hinged together and capable of independent movement; said circles provided with axes at right angles to each other on which they swing; a right ascension circle; and a vernier rigid with each part of the declination circle adapted to play over said right ascension circle, substantially as described.

3. In an apparatus for solving spherical triangles, the combination of an altitude circle in two parts hinged together; an azimuth circle; a declination circle in two parts also hinged together; said circles provided with axes at right angles to each other on which they swing; a right ascension circle; a marking vernier on each part of the altitude circle; a marking vernier on each part of the declination circle; verniers 20 and 21 also on said declination circle adapted to independently play over the right ascension circle; and means for imparting a slow motion to said last named verniers, substantially as described.

4. In an apparatus for solving spherical triangles, the combination of an altitude circle in two parts hinged together; an azimuth circle; a declination circle in two parts also hinged together; said circles provided with axes at right angles to each other on which they swing; a right ascension circle; a slidable marking vernier on each part of the altitude circle; a slidable marking vernier on each part of the declination circle; verniers 20 and 21 also on said declination circle adapted to independently play over the right ascension circle; means for imparting a slow motion to said last named verniers; and means to impart a slow motion to said right ascension circle, substantially as described.

5. In an instrument for solving spherical

triangles, the combination of an altitude circle comprising two quadrants hinged together; sliding marking verniers on said circle; an azimuth circle; verniers 19′ rigid with said altitude circle and playing over said azimuth circle; said circles provided with axes at right angles to each other on which they swing; a sector 27 rigid with said azimuth circle; and means for imparting a slow motion to said sector, substantially as described.

6. In an instrument for solving spherical triangles, the combination of an altitude circle comprising two quadrants hinged together; sliding marking verniers, provided with grooves 75, on said circle; an azimuth circle; verniers 19′ rigid with said altitude circle and playing over said azimuth circle; a sector 27 rigid with said azimuth circle; means for imparting a slow motion to said sector; a declination circle; said circles provided with axes at right angles to each other on which they swing; and marking verniers 17, 18, on said declination circle provided with pins 76, substantially as described.

In testimony whereof, we affix our signatures, in presence of two witnesses.

WILLARD FRENCH.
CHARLES W. FREDERICK.

Witnesses:
K. L. Byrne,
A. W. Neale, Jr.