No. 885,098. PATENTED APR. 21, 1908.

C. P. STEINMETZ.

BUCKET FOR TURBINES.

APPLICATION FILED NOV. 21, 1905.

2 SHEETS—SHEET 1.

Fig. 1. Fig. 2.

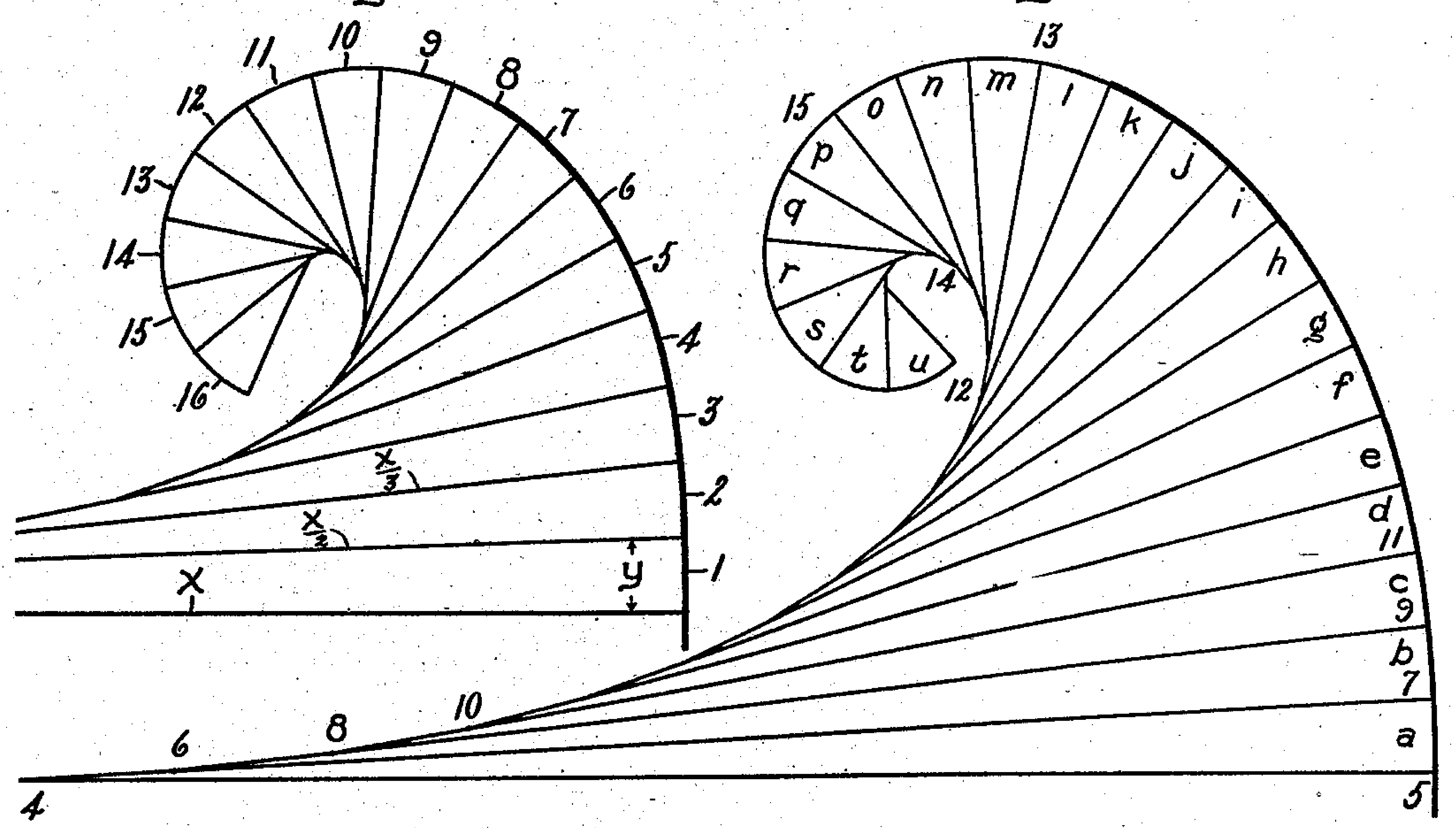
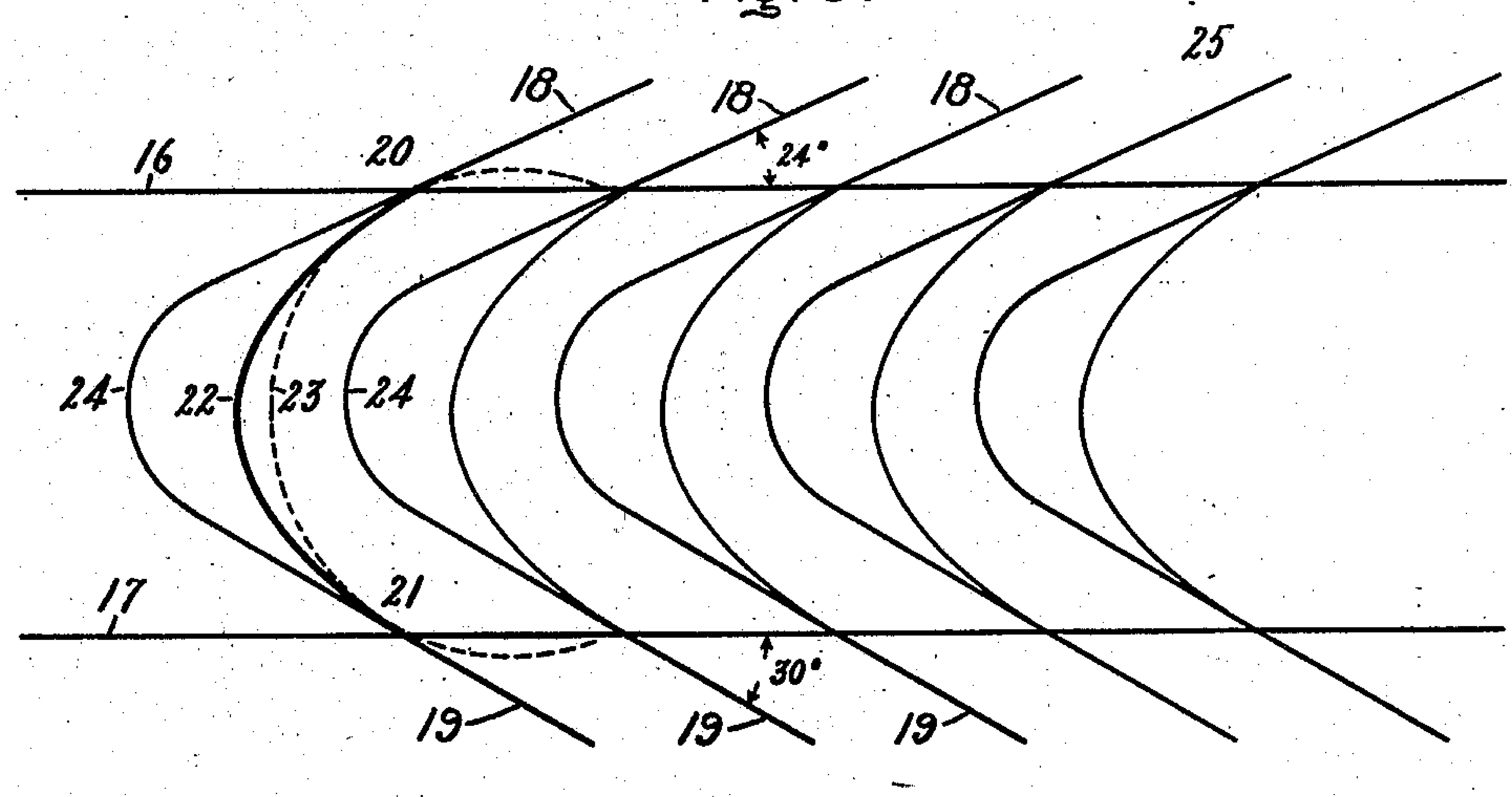


Fig. 3.



Witnesses:

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2 SHEETS—SHEET 2.

Fig. 4.

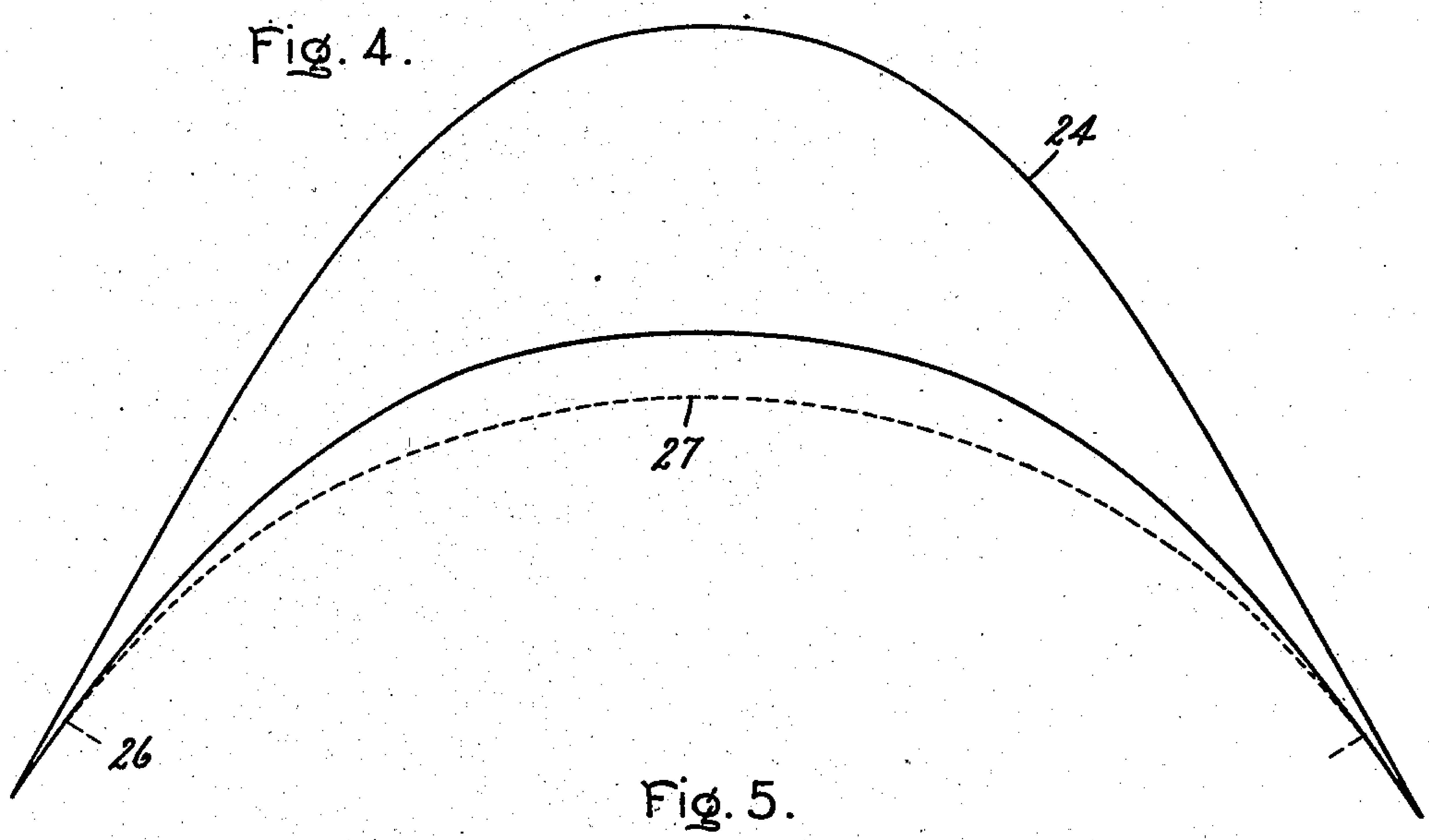
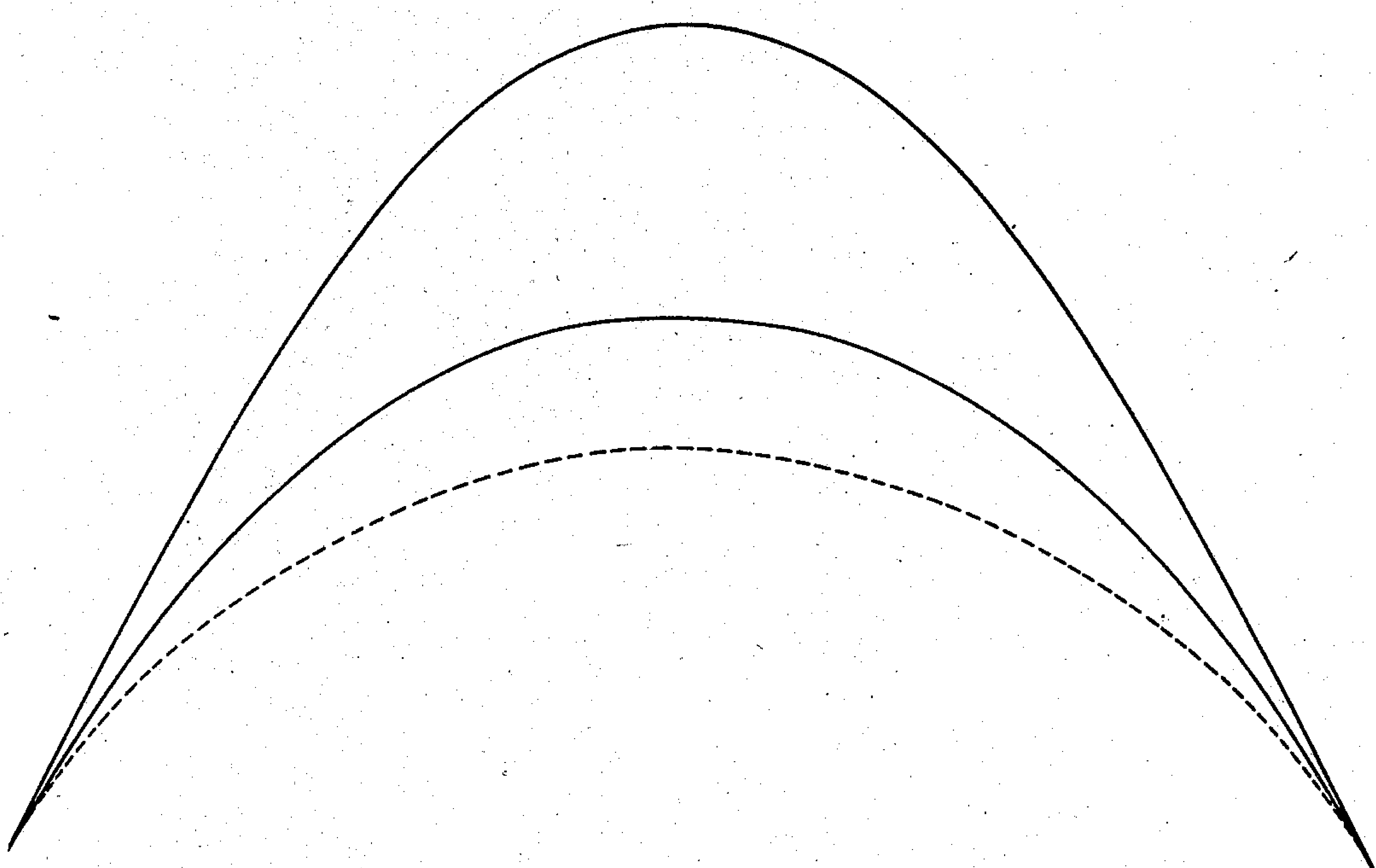


Fig. 5.



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UNITED STATES PATENT OFFICE.

CHARLES P. STEINMETZ, OF SCHENECTADY, NEW YORK, ASSIGNOR TO GENERAL ELECTRIC COMPANY, A CORPORATION OF NEW YORK.

BUCKET FOR TURBINES.

No. 885,098. Specification of Letters Patent. Patented April 21, 1908.

Application filed November 21, 1905. Serial No. 288,389.

To all whom it may concern:

Be it known that I, Charles P. Steinmetz, a citizen of the United States, residing at Schenectady, county of Schenectady, and State of New York, have invented certain new and useful Improvements in Buckets for Elastic-Fluid Turbines, of which the following is a specification.

This invention relates to buckets or blades for elastic fluid turbines, and its object is to provide a bucket so shaped that it will vary the centrifugal force of the elastic fluid flowing through it, preferably in such a manner that the increase of centrifugal acceleration and retardation are constant. In the ordinary type of buckets, the elastic fluid enters through a straight or tangential portion and passes thence over a curved portion which is the arc of a circle, from which it departs on a tangent again. In the entering tangent the fluid moves in straight lines so that no centrifugal force is exerted. On entering the circular portion of the bucket the centrifugal force suddenly rises from zero to a finite value which remains constant until the fluid leaves the curved portion for the quitting tangent, when the centrifugal force suddenly becomes zero again. There is thus a sudden shock imparted to the fluid column at each end of the circular portion of the bucket, causing compression on entering the bucket and expansion on quitting it, giving rise to oscillations which result in a loss of energy and cause wasteful eddy currents in the steam.

By my invention I provide for an increase of the centrifugal force from zero or a finite small value at the beginning of the curved portion of the bucket to a given maximum at the middle of said curved portion, and a decrease of centrifugal force from the middle of the bucket to the beginning of the quitting tangent, where it falls to zero or a finite small value again. I prefer to provide for a regular and gradual increase and decrease of the centrifugal force. But this is not absolutely essential, as the variation may be at first rapid and then more gradual, or vice versa. In the following description, however, I shall assume that the variation is to be uniform and regular.

The formula for centrifugal force $(F = \frac{MV^2}{R})$ shows that the force varies inversely as the radius, if the mass and velocity remain constant. In the stream of steam flowing through a turbine bucket the mass and the velocity do not alter appreciably. If, therefore, the curve of the bucket is such that the radius of curvature shortens from infinity or a small finite value to a given minimum and then lengthens to infinity or a small finite value again, the centrifugal force of the steam will increase and decrease accordingly. The ratio of variation may be different; for instance, the successive radii may all vary by a constant quantity, or each may differ from the preceding one by a constant fraction thereof.

The result of constructing a bucket on these lines is that the steam leaves it in a jet of constant velocity moving in a uniform direction, which renders it of maximum efficiency when directed against the buckets of another wheel. This result is not possible if shocks are imparted to the steam by the sudden application and withdrawal of centrifugal force in its passage through the bucket, whereby it leaves the bucket in a scattered jet, varying in velocity and in direction. The invention is, therefore, of especial value in turbines which extract the velocity energy from the steam in several successive wheels.

In the accompanying drawing, Figure 1 is a diagram of a curve composed of a plurality of arcs of equal length described by radii which form a harmonic progression of a given initial radius; Fig. 2 is another diagram in which each radius is seven-eighths of the preceding one; Fig. 3 shows the outline of several turbine buckets conforming to these curves; and Figs. 4 and 5 are slightly modified forms of buckets having somewhat thicker edges.

It will be noticed at a glance that the curves are spirals. In Fig. 1, the radius X is laid off at some given length, and with this the arc 1 is described, of a given length y. The next arc 2 is described with a radius $\frac{x}{2}$; the arc 3 with a radius $\frac{x}{3}$, and so on, the lengths of all the arcs being the same, and the successive radii being a harmonic progression;—that is, the reciprocals of an arithmetical progression varying by one, the initial radius being unity. The spiral is made up of the arcs 1, 2, 3, etc., and by using a long radius to start with and making the arcs short, the curve will be fairly smooth.

The mathematical equation of the curve in rectangular coördinates, is rather complicated and need not be set forth here.

The curve shown in Fig. 2 is laid out as follows: First, draw a straight line 4—5 and with this as a radius describe the arc *a*. The point 6 on the line 4—7 is distant from the point 4 one-eighth of the length of the line 4—5 or 4—7. With the line 6—7 as a radius, the arc *b* is described, of the same length as the arc *a*. The distance 8—9 is seven-eighths of the line 6—7 or 6—9, the distance 10—11 is seven-eighths of the line 8—9 or 8—11, and so on. Each of the arcs *c*, *d*, *e*, etc., is equal to *a*. The curved spiral line is made up of the arcs *a*, *b*, *c*, etc. A body of given mass moving along either of these curves at uniform speed will be subjected to a regularly increasing centrifugal force which at any given point is proportional to the length of the radius at that point. For instance, if the radius 12—13 is one and three-fourths times the radius 14—15 (which it is very nearly) then the centrifugal force of the body as it moves through the arc *p* is one and three-fourths times that which it had along the arc *m*.

Fig. 3 shows the utilization of a spiral curve in laying out a turbine bucket. In the drawing, that portion of the curve shown in heavy black has been selected; but it is evident that the length of the portion taken will depend upon the width of the bucket, which in the drawing is represented by the space between the parallel lines 16—17. The lines 18 indicate the walls of the nozzle 25 and also the direction of the steam flowing from the nozzles, and make angles of 24° with the line 16. The quitting angle, that is, that between the line 17 and the lines 19, is 30°. The sides of the bucket coincide with the lines 18—19 at the points 20—21. From the point 20 to the point 22, on the center line of the bucket, the curve is of decreasing radius, while from the point 22 to the point 21 it is just the reverse, the two curves being duplicates.

The dotted semi-circle 23 inside the curve of the bucket shows the line of the ordinary bucket. It is apparent that the spiral bucket has a somewhat longer curve, but the slight increase in surface friction will be more than offset by the elimination of shock and eddies.

The back wall 24 of the steam passage may be of any suitable configuration; preferably a curve parallel with the front of the passage, as shown. The height of the bucket may be such as the size of the wheel requires, and it may or may not provide for an expansion of the steam, as preferred. With these matters my invention has nothing to do, being directed solely to the curve of the working surface of the bucket, as hereinbefore set forth.

The back wall of the bucket is a straight line up to the point opposite the beginning of the front wall. The front wall, as before stated, starts with zero curvature, and the curvature gradually increases to a maximum at the center line of the bucket, and then decreases again to zero at the exit. The low curvature at the ends of the buckets results in an extremely thin knife edge, and where this is impracticable for mechanical or other reasons I employ the arrangements shown in Fig. 4. In this figure the bucket curve starts not at zero curvature but at a given small radius as at 26, which decreases toward the center line of the bucket. The dotted line 27 indicates the circular or standard bucket. It will be noticed that with this arrangement the edges of the buckets may be thickened to the desired degree. This bucket shape gives a less sharp edge but it impresses a certain small centrifugal acceleration to the fluid at the point of entrance, which, however, is very small compared to the standard bucket and may be disregarded.

In Fig. 5 is shown a bucket with the front wall shaped to give the correct acceleration from zero to the given maximum at the entrance and a decreasing acceleration from maximum to zero at the exit with the back wall thickened toward the edges to give the necessary thickness of stock for mechanical reasons.

In the drawings the arcs of successive radii are shown of equal length since this is the preferred arrangement but it is within the scope of my invention to make them of different lengths. The point of maximum curvature as shown in the drawings coincides with the center line of the bucket structure but for different conditions I may locate it on either side thereof.

I have shown what I consider to be the best methods of forming the bucket surfaces but they are to be understood as being only illustrative, since the buckets may be formed in a variety of ways so long as the generic feature of the invention is preserved.

The buckets shown are intended primarily for steam turbines but it is obvious that they may be used with material advantage in turbines using other kinds of elastic fluid.

The nozzles or other fluid discharging devices may be of any suitable form or construction and expanding or nonexpanding in character.

What I claim as new, and desire to secure by Letters Patent of the United States, is,—

1. An elastic fluid turbine bucket having a curved surface developed by radii which vary in a harmonic progression.

2. An elastic fluid turbine bucket having a curved surface developed by a radius which

shortens up to the middle point of the bucket and then lengthens.

3. A U-shaped elastic fluid turbine bucket having a surface composed of two spiral curves.

4. An elastic fluid turbine bucket having a surface composed of two spiral curves, one the reverse of the other.

5. An elastic fluid turbine bucket having means for gradually varying the centrifugal force of the steam flowing through it to obviate shock.

6. An elastic fluid turbine bucket having means for first gradually increasing and then gradually decreasing the centrifugal force of the steam flowing through it to obviate shock.

7. An elastic fluid turbine bucket having means for first uniformly increasing and then uniformly decreasing the centrifugal force of the steam flowing through it.

8. An elastic fluid turbine bucket having two straight end portions at an angle with each other, and an intermediate curved portion which is tangent to the straight portions at each end and is described by decreasing radii from said ends to its middle point.

9. An elastic fluid turbine bucket having two straight end portions at an angle with each other, and an intermediate curved portion which is tangent to the straight portions at each end and is described by constantly decreasing radii from said ends to its middle point.

10. An elastic fluid turbine bucket having two straight end portions at an angle with each other, and an intermediate curved portion which is tangent to the straight portions at each end and is described from said ends to its middle point by radii which decrease in a harmonic progression.

11. In an elastic fluid bucket, the combination of a device which discharges motive fluid at a suitable velocity and angle with a row of buckets situated in front of the device and receiving the fluid therefrom, each of the said buckets being provided with a wall which gradually increases the centrifugal force and compression of the fluid entering from an initial to a maximum value, and gradually decreases the centrifugal force and compression of the discharging fluid from the maximum to a predetermined value.

In witness whereof, I have hereunto set my hand this 20th day of November, 1905.

CHARLES P. STEINMETZ.

Witnesses:
BENJAMIN B. HULL,
HELEN ORFORD.