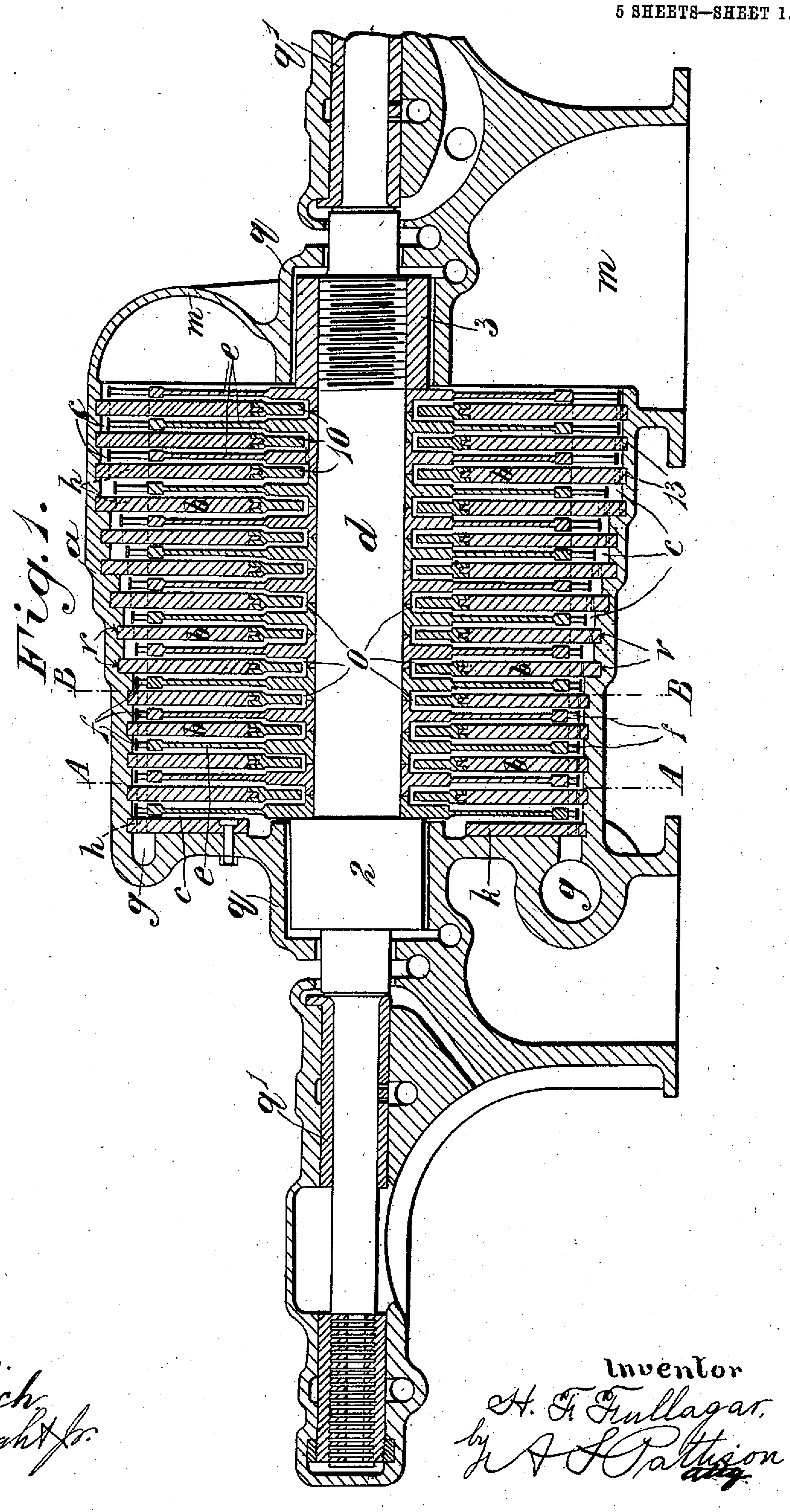
No. 720,415. PATENTED FEB. 10, 1903.

H. F. FULLAGAR.

COMPOUND STEAM TURBINE.

APPLICATION FILED SEPT. 16, 1901.

NO MODEL. 5 SHEETS—SHEET 1.



Witnesses.

Geo. E. Frech

C. R. Wright Jr.

Inventor

H. F. Fullagar,

by H. A. L. Pattison

Atty.

THE NORRIS P. ERS CO., PHOTO-LITHO., WASHINGTON, D. C.

No. 720,415. PATENTED FEB. 10, 1903.

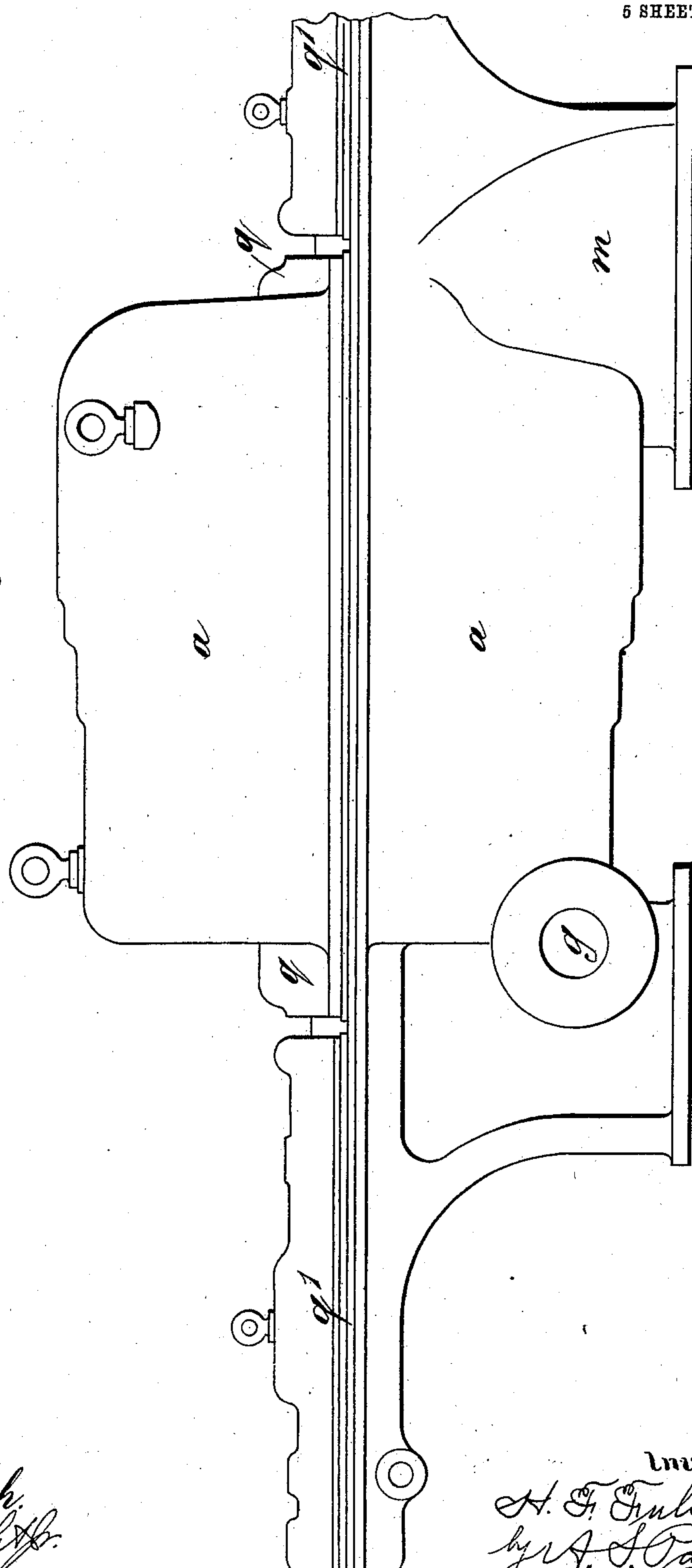
H. F. FULLAGAR.

COMPOUND STEAM TURBINE.

APPLICATION FILED SEPT. 16, 1901.

NO MODEL. 5 SHEETS—SHEET 2.

Fig. 2.



Witnesses
Geo. E. Frech.
C. R. Wright Jr.

Inventor
H. F. Fullagar
by A. S. Pattison
atty

No. 720,415.

PATENTED FEB. 10, 1903.

H. F. FULLAGAR.

COMPOUND STEAM TURBINE.

APPLICATION FILED SEPT. 16, 1901.

NO MODEL.

5 SHEETS—SHEET 3.

Fig. 3.

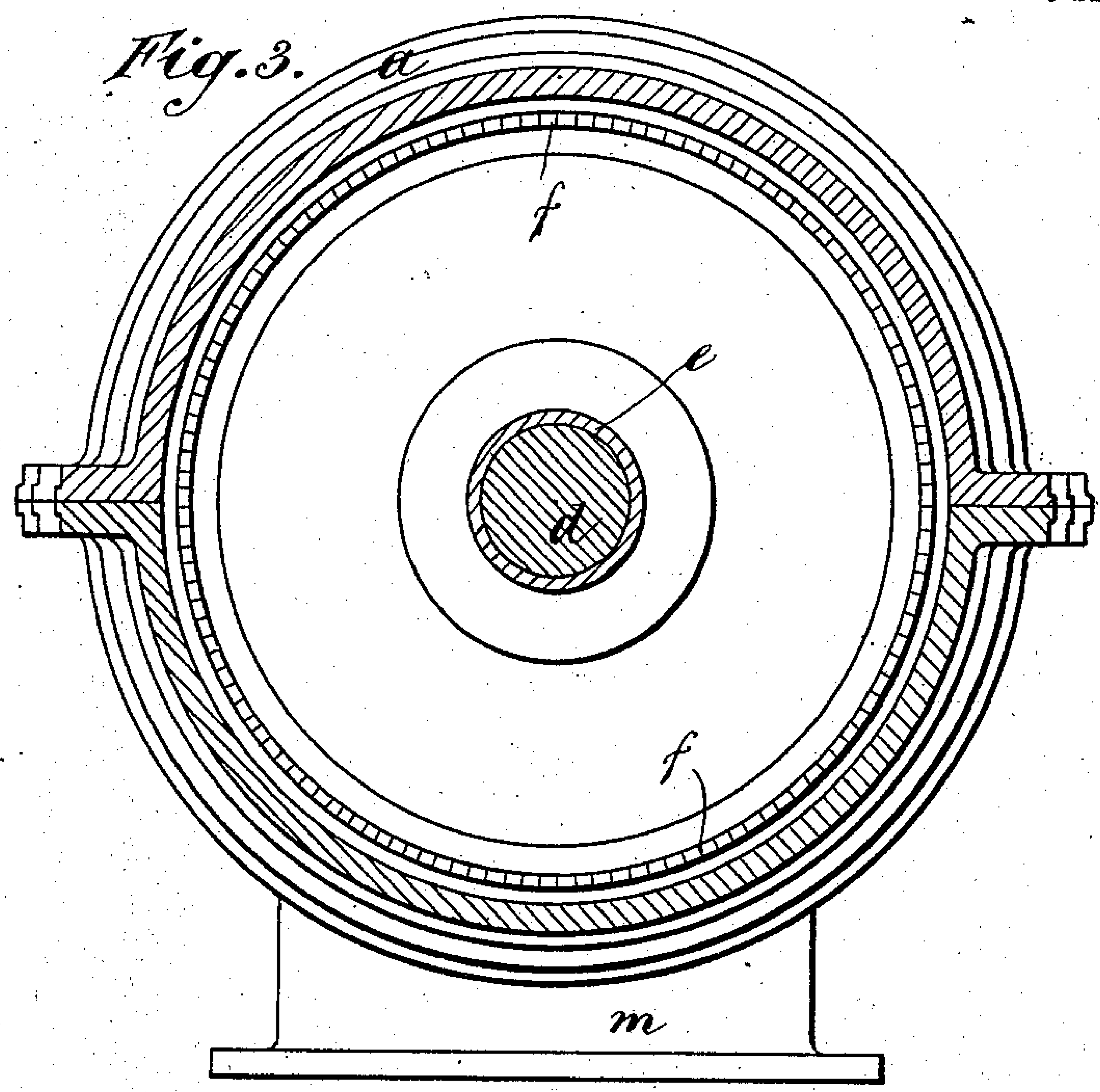
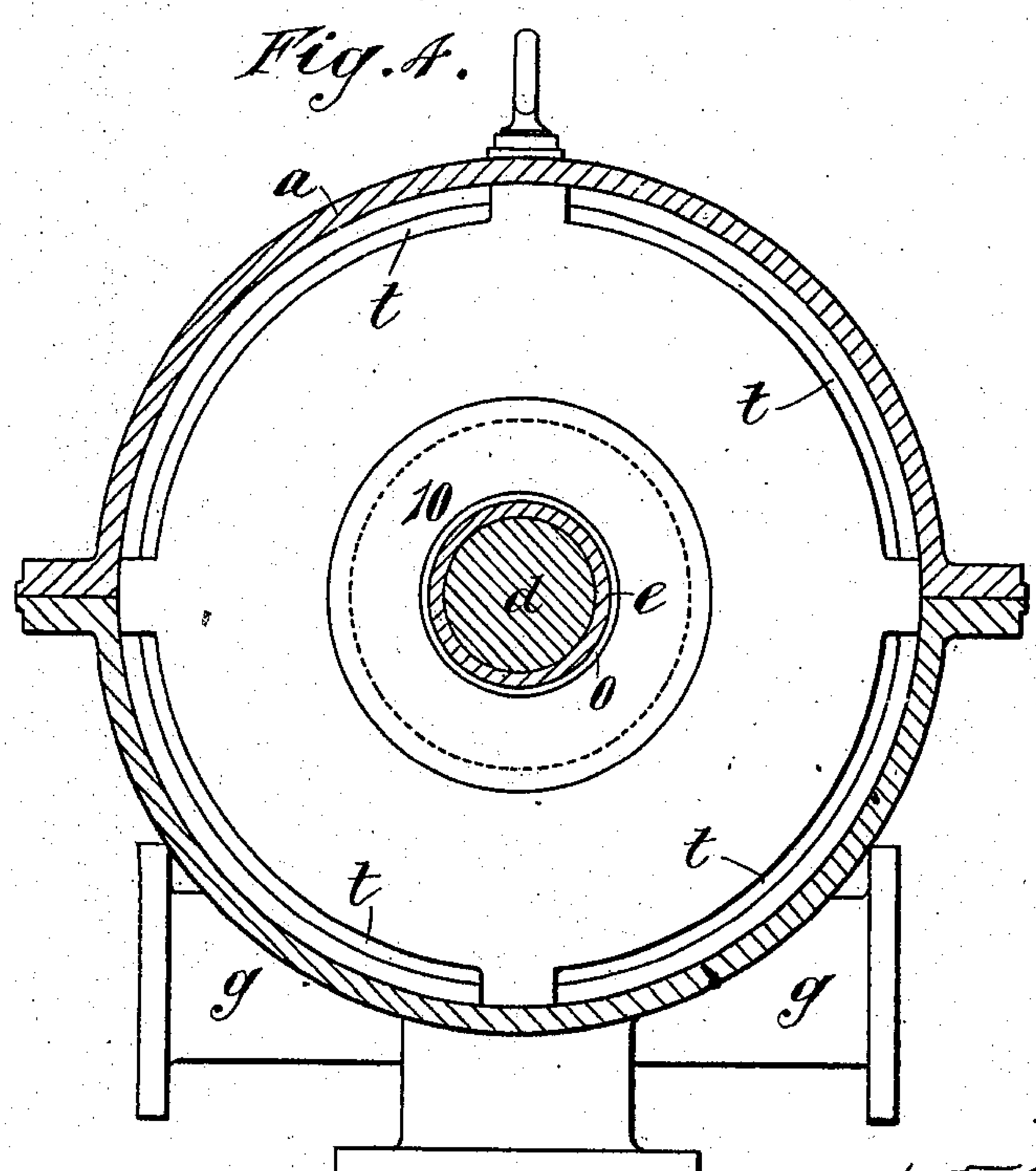


Fig. 4.



Witnesses.
Geo. E. Frech,
C. R. Wright Jr.

Inventor
H. F. Fullagar
by A. S. Pattison
atty

THE NORRIS PETERS CO., PHOTO-LITHO., WASHINGTON, D. C.

No. 720,415. PATENTED FEB. 10, 1903.

H. F. FULLAGAR.

COMPOUND STEAM TURBINE.

APPLICATION FILED SEPT. 16, 1901.

NO MODEL. 5 SHEETS—SHEET 4.

Fig. 5.

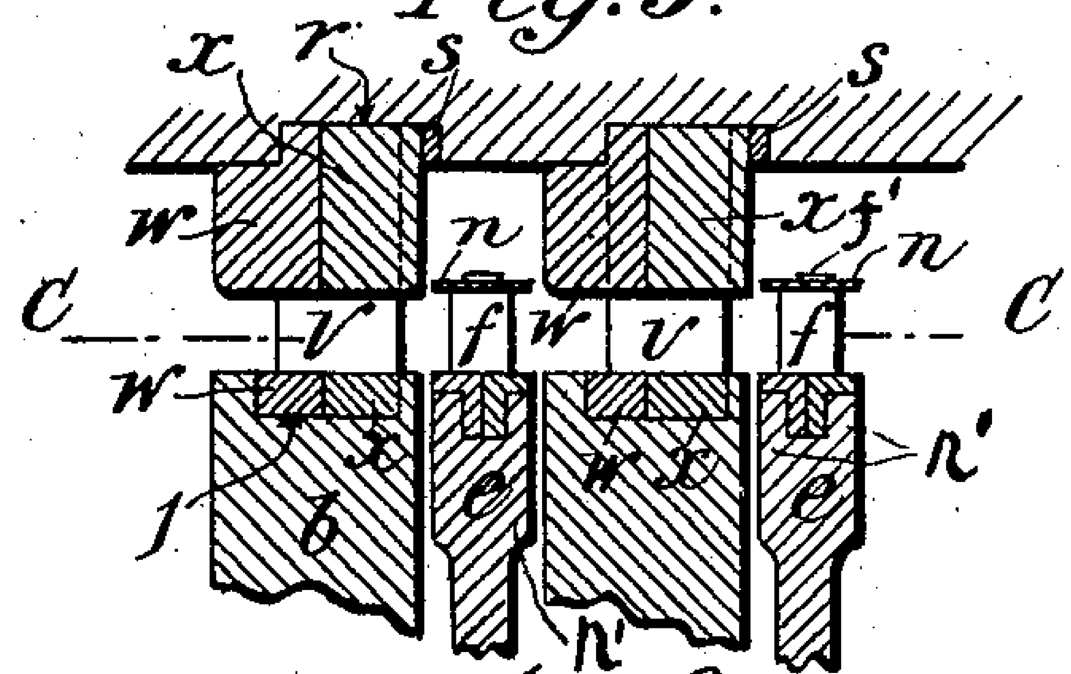


Fig. 6.

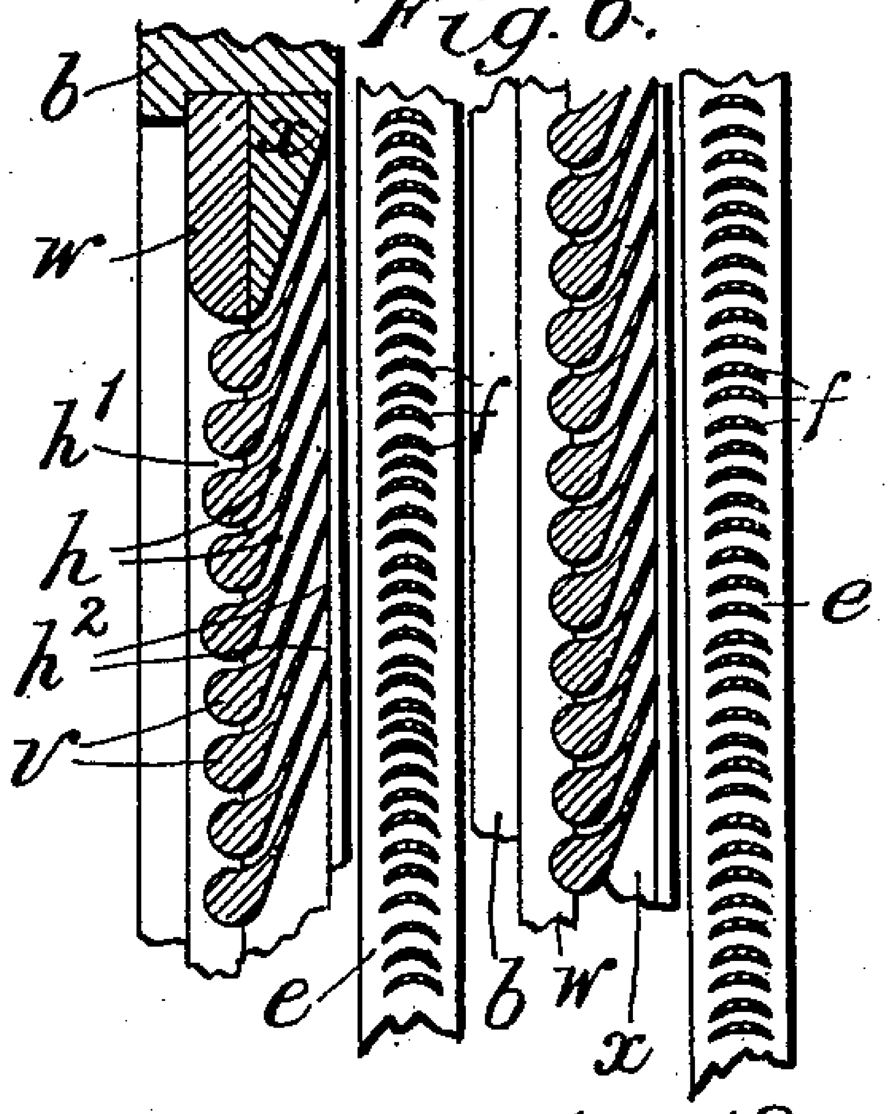


Fig. 11.

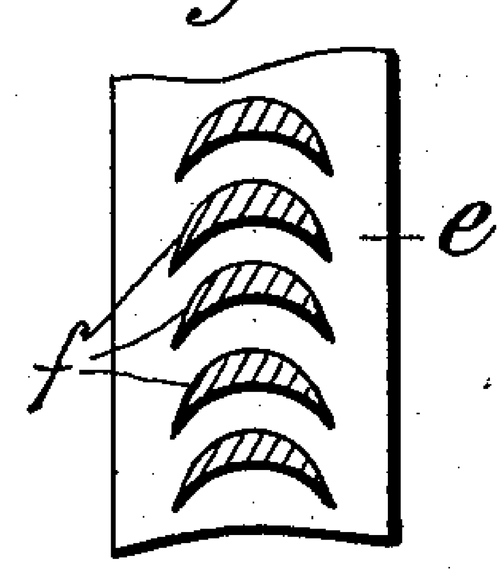
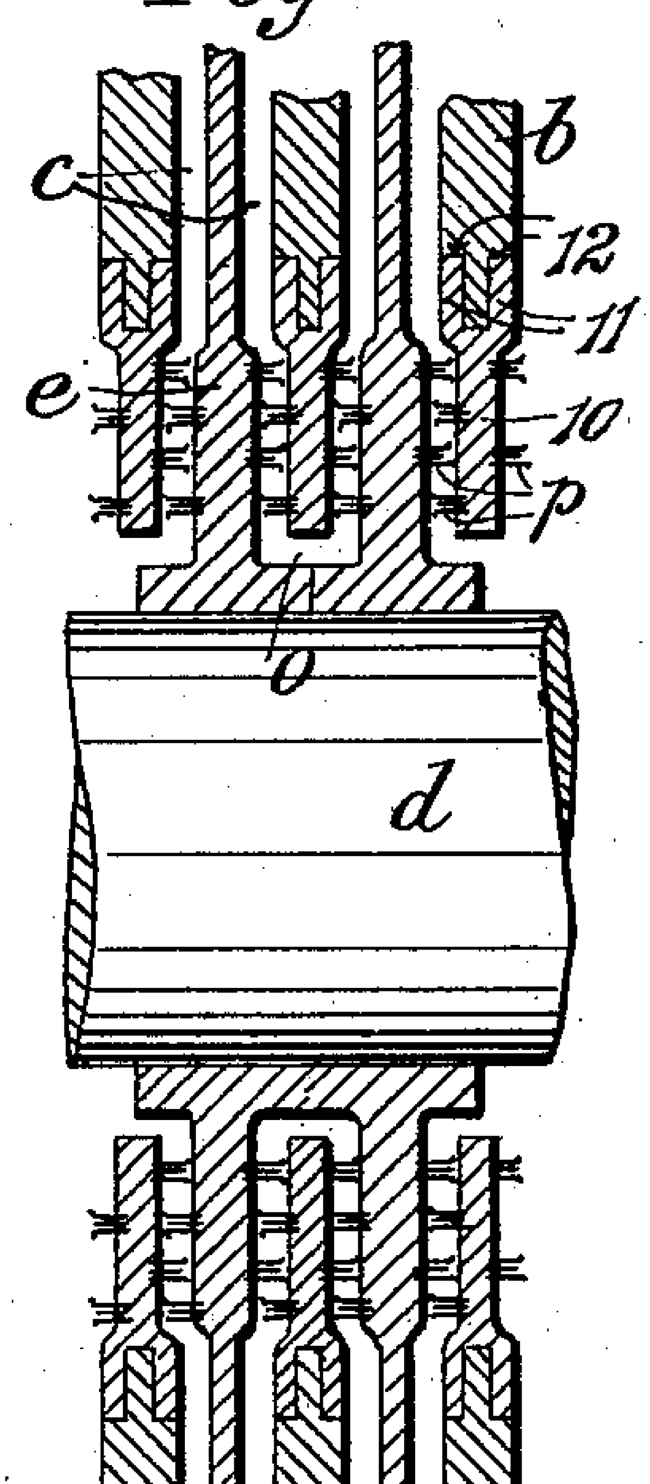


Fig. 12.



Witnesses

Geo. E. Frech

C. R. Wright Jr.

Inventor

H. F. Fullagar

by A. S. Pattison atty.

THE NORRIS PETERS CO., PHOTO-LITHO., WASHINGTON, D. C.

No. 720,415. PATENTED FEB. 10, 1903.

H. F. FULLAGAR.

COMPOUND STEAM TURBINE.

APPLICATION FILED SEPT. 16, 1901.

NO MODEL. 5 SHEETS—SHEET 5.

Fig. 7.

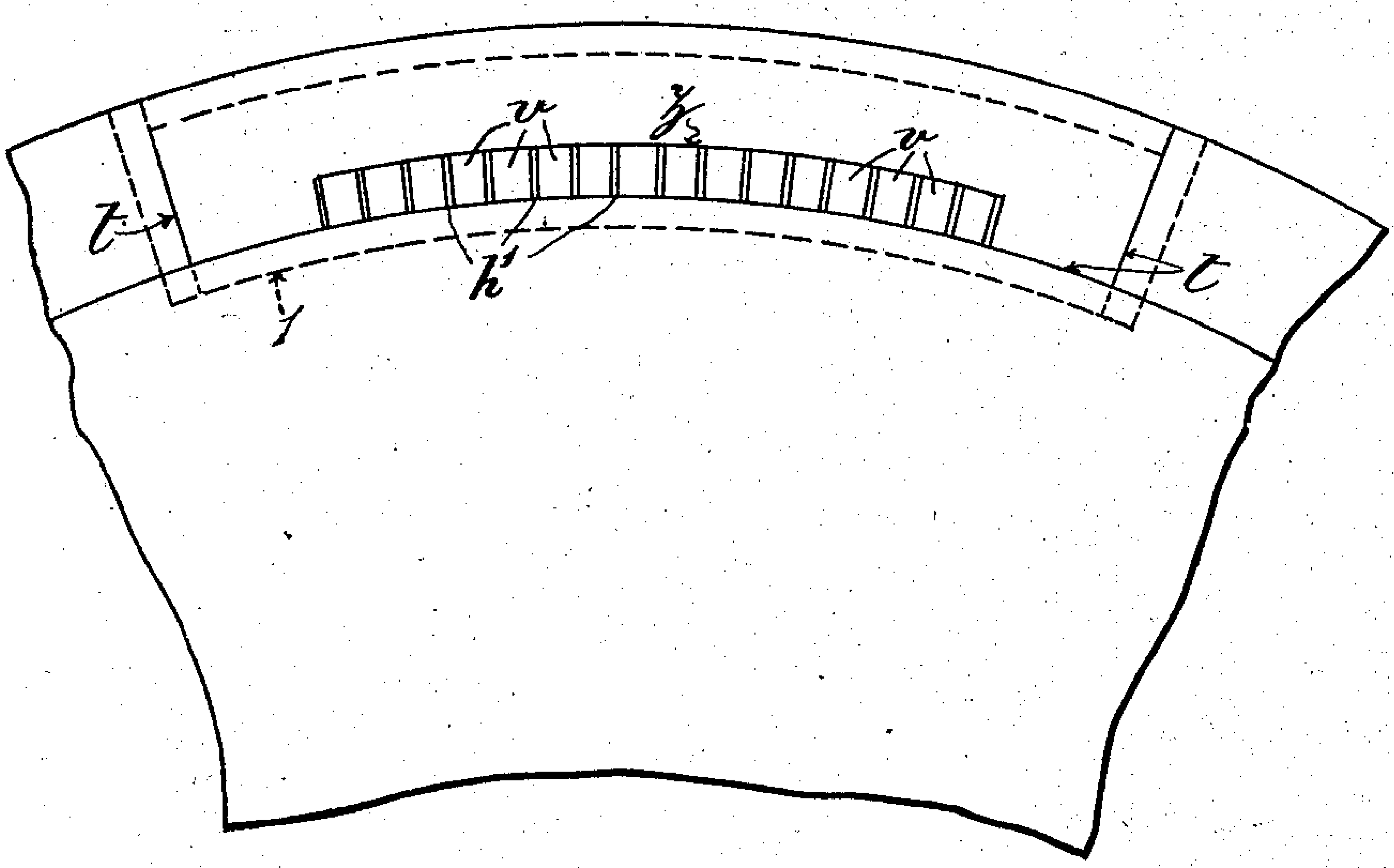


Fig. 8.

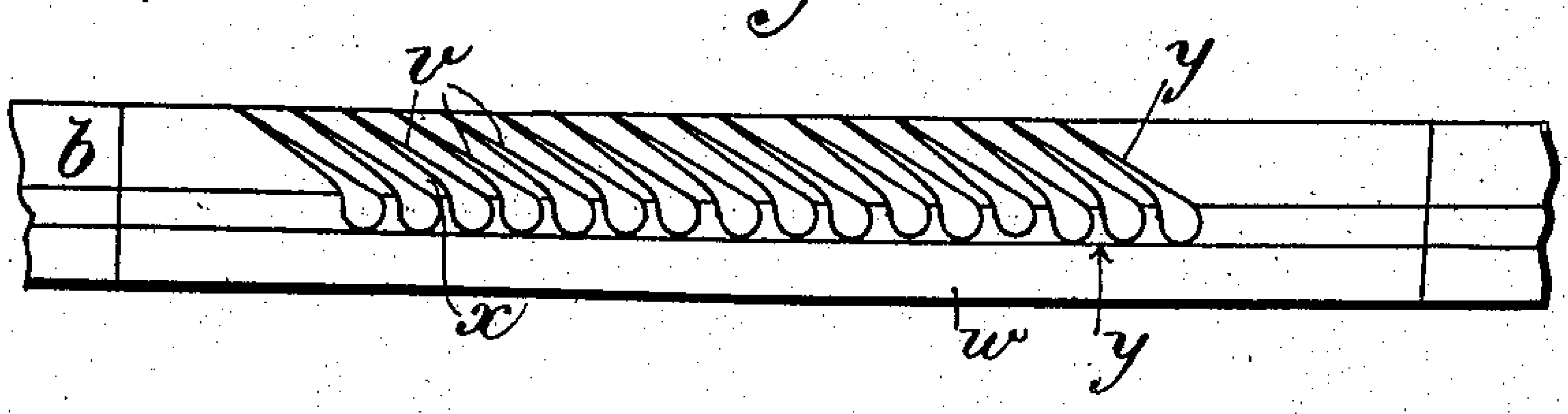


Fig. 9.

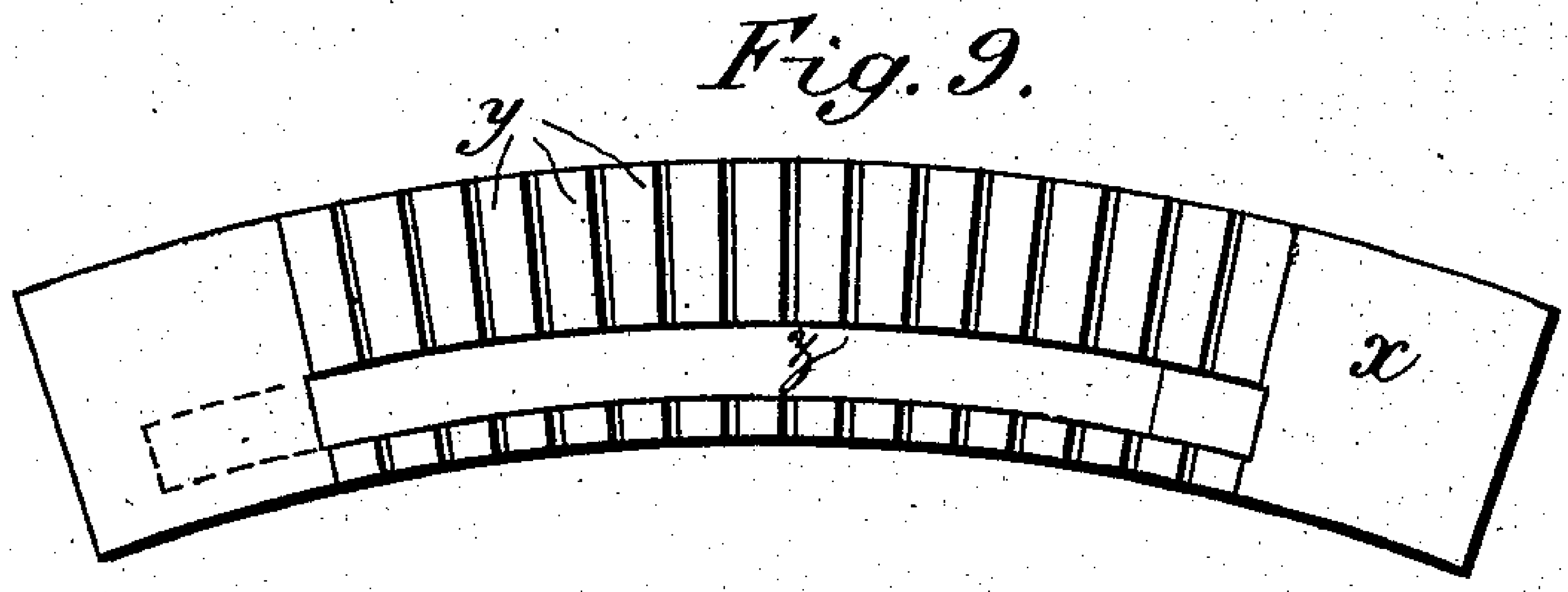
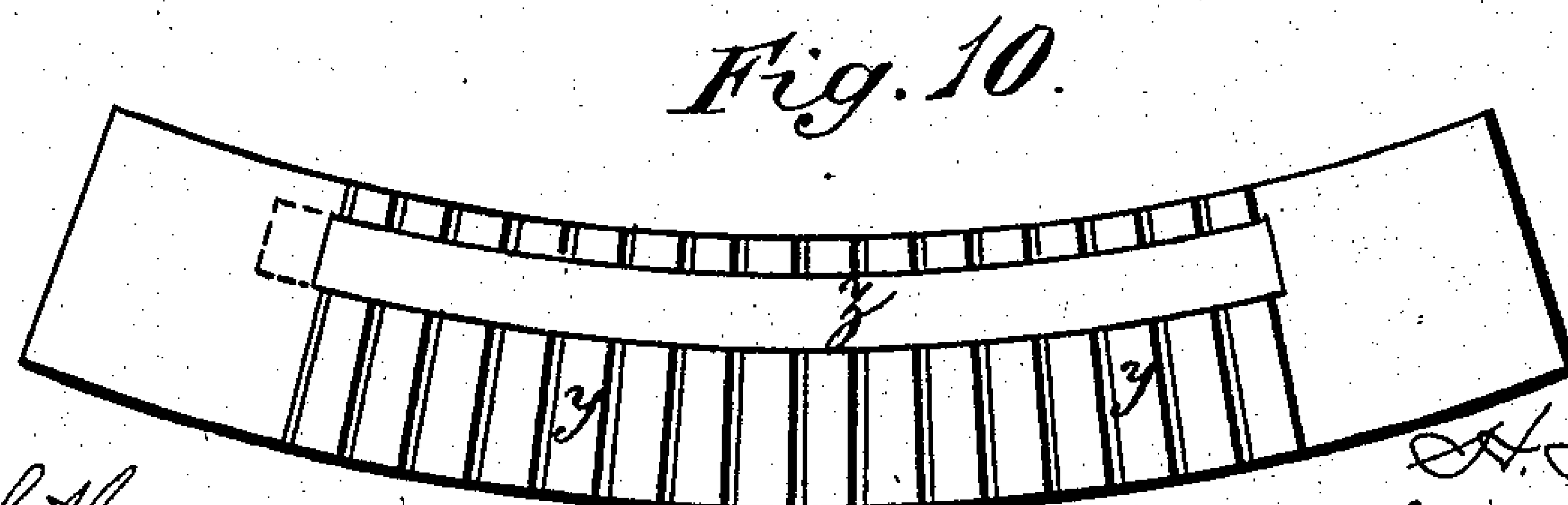


Fig. 10.



Witnesses
Geo. E. Drech.
C. A. Wright Jr.

Inventor
H. F. Fullagar
by A. S. Pattison
atty

United States Patent Office.

HUGH FRANCIS FULLAGAR, OF NEWCASTLE-UPON-TYNE, ENGLAND.

COMPOUND STEAM-TURBINE.

SPECIFICATION forming part of Letters Patent No. 720,415, dated February 10, 1903.

Application filed September 16, 1901. Serial No. 75,649. (No model.)

To all whom it may concern:

Be it known that I, HUGH FRANCIS FULLAGAR, a subject of the King of Great Britain and Ireland, residing at Newcastle-upon-Tyne, in the county of Northumberland, England, have invented Improvements in Compound Steam-Turbines, of which the following is a specification.

This invention has reference to fluid-pressure turbines of the compound type wherein the energy of the motive fluid (hereinafter referred to as "steam") is utilized to produce motion by causing the steam to impinge successively upon rings of vanes, blades, or paddles (hereinafter called "blades") which form a number of simple turbines that are usually fixed to a common shaft or spindle. In such motors it is necessary for economy to prevent the passage of steam from one turbine to another except by the proper openings between the blades, and as, owing to the high velocity of the parts, steam-tight packing is impracticable or undesirable, very fine clearances are used between the rotating and stationary parts to prevent or retard the passage of the steam. The total leakage through any such clearance due to a given difference of pressure increases with the diameter around which such clearance is situated, and, moreover, it is found in practice that the friction caused by the presence of water in such clearance between the fixed and rotating parts is very large and increases very rapidly with the linear velocity of the parts. It is therefore of the utmost importance in any given turbine to keep the diameter around which such clearances are situated and the number of such clearances as small as possible. When the successive simple turbines are situated around a number of drums, the diameter of the annular clearance-spaces (of any simple turbine) is necessarily as large as the drum at that part, and, moreover, to prevent end pressure, which would result from the action of steam on the end of such drums, a rotating balance-piston or a reversely-arranged turbine is required to be coupled to the spindle carrying the drums, and around such there are a number of additional annular clearance-spaces, also of large diameter.

In axial-flow turbines of the type referred to, wherein the successive rings of blades forming the simple turbines are fixed to a common drum or cylinder, it is necessary in order to allow for the required expansion of the steam often one hundred fold or more and at the same time to maintain the velocity of the steam reasonably uniform to increase the steam-opening through the successive rings of blades from the inlet to the exhaust. The area of steam-opening through the last ring of blades being fixed by the necessity of allowing the steam to escape at a velocity not greatly exceeding the velocity of the blades, the opening through the preceding rings of blades can be diminished by reducing the diameter of the rings of blades in steps toward the inlet end or by reducing the radial length of the blades in the same sequence. Usually a combination of these two methods is adopted, the diameter of that part of the spindle holding the first row of blades being, for example, commonly about half that of the part holding the last row of blades, and a blade in the first row being from about one-fifth to one-tenth of the radial length of those in the last row. As, however, the momentum absorbed from the steam by the rings of blades decreases very rapidly with a decrease in the linear velocity, the reduction of diameter necessitates the use of a very large number of rings of blades, as many as eighty pairs of fixed and rotary rings of blades being commonly employed in a compound turbine. Decreasing the radial length of the blades, on the other hand, increases the proportion which the leakage area around the rings of blades bears to the passage-way through them and necessitates the use of annular clearance-spaces of correspondingly large diameter on the rotating balance-piston or the reversely-arranged turbine used to balance end thrust. Consequently compound turbines as heretofore usually constructed require the use of a very large number of rings of blades of comparatively small diameter and necessitate that the clearance-spaces toward the inlet end of the turbine shall be reduced to the smallest possible limit, which renders such turbines costly and delicate.

Now this invention has reference to a compound steam-turbine designed to obviate the above-mentioned disadvantages and which can be made in a more compact, convenient, and economical manner and run at a slower speed than the compound steam-turbines at present in use. For this purpose the invention consists in various novel features of construction and combinations and arrangements of parts, all as hereinafter described, and more particularly pointed out in the claims.

In the accompanying illustrative drawings, Figure 1 is a central longitudinal section, and Fig. 2 a side elevation, showing a steam-turbine constructed according to this invention. Figs. 3 and 4 are cross-sections on the lines A A and B B, respectively, of Fig. 1. Fig. 5 shows in longitudinal section the outer and adjacent portions of two sets of stationary and movable blades and their carriers. Fig. 6 is a sectional plan taken on the line C C of Fig. 5, the section being taken in a circular direction. Figs. 7 and 8 show, respectively in side elevation and plan, part of one of the fixed carriers with a segmental set of stationary guide-blades. Figs. 9 and 10 show the inner surfaces of two grooved strips which when placed with their grooved surfaces together form a compound segmental-shaped holding device for a set of stationary guide-blades. Fig. 11 is a plan of a few of the rotary blades, drawn to a larger scale than Figs. 5 and 6. Fig. 12 shows, to a larger scale than Fig. 1, part of the central portion of the turbine with baffling devices between stationary and rotary parts thereof.

The casing *a* of a compound steam-turbine according to this invention is provided with a number of transversely-arranged walls or partitions *b*, (hereinafter called "walls,") that divide its interior into a number of flat or short transversely-arranged chambers *c*, through which the turbine-spindle *d* extends clear of the said walls and in each of which is a disk-like wheel *e*, that is fixed to the spindle and provided with a ring of blades *f* around its circumference, which is made large in comparison with that of the spindle *d*, upon which it is mounted. The steam entering the turbine through one of the branch passages *g* is conducted to a number of carefully-formed apertures or passages *h*, formed in the rear end wall *k* of the first chamber *c*, near to the outer periphery thereof and opposite to the ring of blades *f* on the outer periphery of the first wheel *e*. The steam after passing through these passages *h* and impinging upon the first ring of blades *f* reaches the second chamber *c* through similar passages *h*, that are formed in the intervening transverse wall *b*, near the outer periphery thereof, and directs such steam against the ring of blades *f* on the second wheel *e*, and so on to the last wheel *e*, whence the steam passes to the exhaust *m*. The total area of the groups of passages *h* in each of the transverse walls *b* of the successive chambers *c* is made to increase from the inlet end in such proportion that the velocities of the issuing streams of steam are approximately constant throughout the length of the turbine. The blades *f* of each wheel are made of crescent shape in section and are so arranged as to form a practically parallel passage-way between each adjacent pair of blades, (see Fig. 11,) so that the steam will experience practically no drop in pressure on its passage through each of such rings of blades. The blades are also symmetrically arranged with reference to the sides of the wheels, as shown. The outer diameter of each ring of blades *f* is such as to leave between such ring of blades and the casing *a* an annular clearance-space *a'* of ample depth in a radial direction. A wide annular inner baffler *n'* may also advantageously be provided at the inner end of each ring of blades *f*, so that the effective portions of each ring of blades that come opposite each set of steam-passages *h* in the fixed walls *b* will be confined between concentrically-arranged annular baffling devices *n* and *n'*, that are wider in an axial direction than either the blades *f* or the wheel *e* carrying them, so that the edges of such baffling devices can be arranged to rotate in any desired proximity to the walls *b* on either side, while ample clearance both radially and axially is allowed to the blades *f* and the wheel *e*, so as to prevent any possibility of these parts coming in contact with the said walls or the casing *a*. Each of the outer baffling devices *n* may conveniently consist of a ring or hoop of some suitable non-corrosive sheet metal or alloy—for example, brass—secured to the outer ends of the blades *f* by forming the latter with projecting portions *f'*, Fig. 5, that are passed through holes in the ring or hoop *n* and then riveted over the latter. Each of the inner baffling devices *n'* may be formed by laterally-arranged annular flanges or enlargements at the outer peripheral portion of the corresponding disk-like wheel *e*. Such annular flanges are, however, preferably made much thinner than shown, so as, in effect, to become thin wearing-strips, or, as is preferred, each of such baffling devices *n'* may be formed, like each outer baffling device *n*, of a ring or hoop of sheet material secured to the inner end portions of the said blades *f*, close to the outer periphery of the wheel *e*. By the use of such outer and inner baffling devices steam will be prevented to a large extent from spreading laterally, and by making them wider than the blades *f* and disks or plates *e* considerable clearance can be allowed between such parts and the walls *b*, and by making them thin should they accidentally come in contact with either wall at any time the abutting parts will readily be worn away to a small extent without causing any inconvenience. Secured around and to the outer ends of each set of the blades is a ring or hoop *n* to prevent steam passing out radially between the blades and to minimize fan-like action—that is to say, any action of the rotating blades to throw in an outward direction steam passing between them. The entrance *h'* to the passages

h in the stationary transverse walls b, Fig. 6, face the direction in which the steam leaves the preceding ring of blades f, and the passage-ways are curved to again turn the steam into a tangential direction toward the next ring of blades f. The cross-sectional area of each passage h is made smallest at a point more or less about half-way through the corresponding wall b, and from this point to the outlet h^2 it increases in the desired ratio of the expansion to be given to the steam, so that the steam issues in an approximately parallel stream and strikes the next rotary ring of blades f with substantially the full velocity due to the drop in pressure from that obtaining in the preceding turbine-chamber c or in the steam-supply pipe or passage g. By the construction described the steam has little or no tendency to spread or pass over the ring or hoop n, secured around the ends of each ring of blades f, so that ample clearance can be provided all around the wheel e and its ring of blades f and the ring or hoop n thereon both radially and axially. The steam, moreover, will communicate little or no end thrust to the spindle d, because the fluid-pressure on the two sides of each wheel e is approximately equal. The drop in pressure is therefore with the construction described caused to take place only while the steam is passing through each wall b from one chamber c to the next chamber, the pressure throughout each chamber being approximately uniform. There is therefore a tendency to leakage between each disk e and the adjacent wall b by reason of the central opening o in the latter, through which the spindle d passes.

A baffling device p is therefore placed between the inner end of each wall b and the spindle d or, as shown in Fig. 12, between the inner portion of each wall b and one or both sides of the central portion of each wheel e, so as to prevent or retard the escape of steam from one chamber c to another through the clearance-space o between the inner end of each stationary wall and the spindle. In this position, owing to the comparatively small diameter of the parts, it is possible to employ a more complete and efficient baffling device than it is possible to use around the outer circumference of a ring of blades, so that the diameter of the spindle being small the leakage of steam can be reduced to almost any desired extent.

For the first few wheels e the rings of blades f are preferably made of the same radial length, as shown, the number of the steam-passages h in the walls b of the chambers c successively increasing until they form a continuous or nearly-continuous annular series of openings, after which to allow for the further expansion of the steam the radial length of the passages h in the remaining walls b and the radial length of the blades f on the remaining wheels e are gradually increased.

With the construction described, the leakage being practically independent of the diameter of the wheels and there being no very small clearance-spaces between parts of large diameter to cause friction through the presence of water and danger from risk of contact of fixed and rotating parts, the diameter of the several simple turbine-wheels e can be made as large as convenient, and as the rotary rings of blades f have a high linear velocity very few simple turbine-wheels e are required, from one-half to one-tenth of the number used in axial-flow compound turbines as at present constructed being sufficient for a given pressure of steam when the shaft is revolving with a given angular velocity. For an eight-hundred-horse-power motor there may, for example, be only about fourteen wheels e of a diameter of about two feet four inches, (about seventy centimeters,) the radial length of the rings of blades f—say for the first five rings—being equal and, say, of about half an inch (= 1.27 centimeters) and the radial length of the remainder gradually increasing toward the exhaust. The spindle d, being short, is well suited for steady running, and any axial clearances in the baffling devices p, hereinbefore described, or in the glands q at the ends of the casing will not be subject to much alteration by expansion or bending of the spindle, and as there are no small clearance-spaces in a radial direction wear of the spindle-bearings q' will not affect the working of the turbine, so that the constant risk of serious damage that is liable to take place with compound turbines of the ordinary type is entirely avoided. Furthermore, the various parts of the compound turbine are well adapted to be made and finished separately on an interchangeable system. Also failure of the blades f on one of the turbine-wheels e is not liable to cause damage to those of the remaining turbine-wheels, and should such failure occur it can readily be made good by the substitution of spare parts—an important consideration with marine turbines. The number of such spare parts necessary to be stocked is also small.

In carrying out my invention the casing a is preferably made in two halves with a horizontal joint in the plane of the axis of the spindle. Annular grooves r are formed in the inner surface of the casing to hold the stationary transverse walls b, each of which is also made in halves in the form of half disks or rings, and when provided near its outer periphery with correctly-formed steam-passages h to form the steam-jets are placed in the annular grooves r of the casing and suitably secured therein, as by calking the sides of the grooves r or by calking a strip s, Fig. 5, of brass or other soft metal into each groove alongside the corresponding disk or ring. To form the steam-passages h, two or more equidistant segmental notches t may conveniently be cut in the outer periphery of each wall b, the arcs covered by these segmental notches increasing in area successively from the inlet end to about the middle of the length of the turbine, where the central and remaining disks are nearly surrounded by segmental notches. In each segmental notch *t* is fixed a segment, preferably of some non-corrosive metal or alloy, such as brass, with the steam-passages *h* carefully formed in them. Each of these segments may consist of several thicknesses of metal with the openings in each milled to the proper shape, or each segment may be built up of blades *v*, carefully shaped to give the required form to the passages *h* between them and held at their inner and outer ends in a compound holding device or devices, as shown, for example, in Figs. 5 to 9, inclusive, where a single compound holding device is used, consisting of two segmental strips *w x* of brass or other metal fitting side by side, the adjacent sides of the two strips being formed with notches *y* to receive the blades *v*, which are embedded for part of their width in each strip and are firmly held between the two, oppositely-arranged segmental slots *z* of the desired length and radial depth being formed through the two strips for the passage of steam to and from the passages *h* between the blades *v*. The inner peripheral portion of this compound holding device *w x* is held in a groove 1 milled in the base of the segmental notch *t* in the wall or disk *b*, and the outer peripheral portion of the said holding device is made of sufficient width to fit the annular groove *r* in the casing *a*, which holds the said wall or disk *b* and which may be secured in place by calking in the same manner as the said wall or disk. The inner and outer peripheral portions of the pair of strips *w x* may be disconnected from each other, so as to form two separate compound holding devices; but the construction shown is preferred.

The rotary disk-like wheels *e* may conveniently be all made of the same diameter, as shown, for the sake of cheapness and interchangeability and may be of steel plate turned to shape to insure balance, the several wheels being threaded on a spindle *d*, provided with a longitudinal feather or key and secured in place between a collar 2 and a nut 3 on the spindle. The rings of blades *f* may be attached to the outer periphery of the disk-like wheels *e* in any suitable manner.

For preventing or retarding the flow of steam from chamber to chamber *c* through the central openings *o* in the transverse walls *b*, through which the spindle *d* extends, several baffling devices may, as shown in Fig. 12, be arranged between the inner central stationary portions of each wall *b* and the adjacent parts of the rotating wheels *e*, such baffling devices comprising thin concentrically-arranged rings *p*, each of which may be composed of a single thickness of material, or, as shown, of several thicknesses bent or folded to present successive baffling edges with interposed spaces to the steam tending to flow past them. These baffling-rings may be attached to one or to both sides of the walls *b* or to one or both sides of the opposing wheels *e*, or, as shown in Fig. 12, to both the walls *b* and the wheels *e*. It is preferred, however, to fix the baffling devices *p* to one side only—say the left-hand side—of each wheel *e* and to the opposite or right-hand side of the adjacent fixed walls *b*, so that the distance between the free edges of all the baffling devices *p* and the surface of the wall or disk toward which they extend can be simultaneously adjusted by endwise movement of the spindle *d*. By the construction and arrangement of baffling device described leakage of steam through the holes *o* can be reduced in a very effective manner without any direct contact between fixed and movable parts of the turbine, while at the same time providing ample radial clearance between the said parts. Should the edge of a baffling-ring *p* accidentally touch the opposite face, being comparatively thin it will readily wear itself clear without causing undue friction, heating, or strain to other parts of the turbine. The central portion of each wall *b*, where such a baffling device is situated, may conveniently be made in the form of a ring or bush 10, with one or more flanges 11 fitting one or more recesses 12, turned in the adjacent part of the outer portion of the wall *b*. This construction will facilitate making a steam-tight joint at this part and cheapen manufacture.

For drawing off water from the bottom of the chambers *c* to the exhaust-passage *m*, and thereby obviating any friction which such water may cause by contact with the rings of blades *f*, holes 13 of small diameter are formed in the lower part of the transverse walls *b*, or each of the chambers *c* may, as indicated in dotted lines in Fig. 1, be provided with a suitably-controlled drain-pipe 14.

The glands or packings *q* for the ends of the spindle *d* are made in halves, as usual, and of any suitable construction.

Turbines constructed as described are equally applicable for use with any elastic fluid. As will be understood, they are lubricated by causing lubricant to continuously flow under pressure through the spindle-bearings and thrust block or blocks when used, as heretofore usual.

It will be evident that various changes can be made in the details of construction of my apparatus without departing from the spirit and scope of the invention so long as the relative arrangement of parts shown in the drawings or the mode of operation described in the specification is preserved.

What I claim is—

1. A compound fluid-pressure turbine comprising a casing having an inlet at one end and an outlet at the opposite end, transversely-arranged walls fixed in said casing and each provided near its outer periphery with a number of passages extending therethrough from one side thereof to the opposite side, a rotary spindle extending longitudinally through said

casing and walls, ample radial clearance being left between said spindle and walls, wheels fixed to said spindle and arranged to rotate in the chambers formed between said walls, rings of blades arranged on the outer periphery of said wheels in proximity to the passages in said walls, and annular baffling devices fixed to the outer ends of said blades, said baffling devices being of greater width than said blades and arranged to leave ample radial clearance between them and the interior of said casing.

2. A compound fluid-pressure turbine comprising a casing having an inlet at one end and an outlet at the opposite end, transversely-arranged walls fixed in said casing and each provided near its outer periphery with a number of passages extending therethrough from one side thereof to the opposite side, the total area of the groups of passages in the successive plates gradually increasing from the inlet toward the outlet as set forth, a rotary spindle extending longitudinally through said casing and walls, but out of contact with the latter, wheels fixed to said spindle and arranged to rotate in the chambers formed between said walls, rings of blades arranged on the outer periphery of said wheels in proximity to the passages in said walls, and annular baffling devices attached to and of greater width than said blades.

3. A compound fluid-pressure turbine comprising a casing having an inlet for motive fluid at one end and an exhaust-outlet at the opposite end, transversely-arranged walls fixed in said casing between its ends and each provided near its outer periphery with groups of steam-passages extending from one side thereof to the other, a spindle extending through said casing and walls but out of contact with the latter, wheels fixed to said spindle and arranged to rotate in the transverse chambers between said walls, rings of blades fixed to the outer periphery of said wheels and between the groups of passages through said walls, and inner and outer annular baffling devices at the inner and outer ends of each ring of blades, said baffling devices being made of greater width than said blades and arranged near to the walls of said chambers.

4. A compound fluid-pressure turbine comprising a casing having an inlet at one end and an outlet at the opposite end, transversely-arranged walls fixed in said casing and each provided near its outer periphery with a number of passages extending therethrough from one side thereof to the opposite side, the cross-sectional area of each passage increasing from one point thereof to the exit in the same ratio as the expansion to be given to the steam in passing from one chamber to the next, a rotary spindle extending longitudinally through said casing and walls but with ample radial clearance between it and said walls, wheels fixed to said spindle and arranged to rotate in the chambers formed between said walls, rings of blades fixed to the outer periphery of said wheels so as to rotate between the passages in adjacent walls, and annular baffling devices attached to the outer ends of said rings of blades and arranged to leave deep radial annular spaces between them and the interior of said casing, substantially as described for the purpose specified.

5. In a compound fluid-pressure turbine, the combination of a casing having an inlet and outlet for motive fluid, transversely-arranged walls fixed in said casing and each formed near its outer periphery with groups of steam-passages each of which is made to increase in cross-sectional area from one point to the outlet thereof in such a ratio that the working fluid will expand fully to the increased volume, corresponding to the required diminished pressure, before leaving said passage, a rotary spindle extending through said casing and through openings in said walls but out of contact with the latter, wheels fixed on said spindle and mounted to rotate in the chambers formed between said walls, rings of blades fixed to the outer peripheries of said wheels located between the groups of passages, in said walls, and arranged so that practically parallel passage-ways are formed between the adjacent blades, and baffling devices arranged between the fixed and movable parts but out of rubbing contact therewith and adapted to retard passage of motive fluid from one chamber to the next through the central opening in the intervening wall, substantially as described for the purpose specified.

6. In a compound fluid-pressure turbine, the combination with a casing having an inlet and outlet for motive fluid and a rotary spindle extending through said casing, of transversely-arranged walls fixed in said casing and formed near their outer peripheries with openings extending therethrough, separately-formed guide-blades removably fixed in said openings, and arranged to form steam-passages by and between them, wheels fixed to said spindle and arranged to rotate between said walls, and rings of blades fixed to the outer peripheries of said wheels and arranged to revolve past said guide-blades.

7. In a compound fluid-pressure turbine, the combination with a casing having an inlet and outlet for motive fluid and a rotary spindle extending through said casing, of transversely-arranged walls fixed in said casing and each formed near its outer periphery with segmental-shaped notches, and provided with segmental holding devices each carrying a group of fixed guide-blades having passages between them, wheels fixed to said spindle and arranged to rotate between said walls, and rings of blades fixed to the outer periphery of said wheels so as to revolve past the passages between said fixed blades.

8. In a compound fluid-pressure turbine, the combination with the turbine casing and spindle, of transverse walls fixed in said cas-

ing and each formed with openings near the outer periphery thereof, groups of guide-blades removably fixed in said openings, wheels fixed to said spindle and arranged to revolve between said walls, movable rings of blades fixed to the outer periphery of said wheels, the guide-blades in each group thereof being shaped and arranged to form between them passages the inlets of which face the direction in which the steam leaves the preceding ring of rotary blades and the remaining portions of which are inclined to the side of the next ring of rotary blades, and annular baffling devices attached to the inner and outer ends of said movable blades and made of greater width than said blades and arranged so as to leave the effective radial depth of the movable blades equal to about the radial depth of said guide-blades.

9. A compound fluid-pressure turbine comprising a casing having an inlet and an outlet at the respective ends thereof, transversely-arranged walls fixed in said casing and each provided near its outer periphery with a number of curved guide-passages for extending therethrough from one side to the other, a rotary spindle extending longitudinally through said casing and walls but out of contact with the latter, a number of wheels of the same diameter fixed to said spindle and arranged to rotate between said walls, rings of blades fixed to the outer peripheries of said wheels, said passages and blades being made of different radial lengths at different parts of the turbine, concentric annular baffling devices at the inner and outer ends of said rings of blades, and baffling devices fixed between the rotary and fixed parts and adapted to retard passage of motive fluid from one chamber to the next through the intervening wall.

10. A compound fluid-pressure turbine comprising a casing, having an inlet and an outlet for motive fluid, transversely-arranged walls fixed in said casing and provided near their outer peripheries with passages extending therethrough from one side to the other, a spindle extending through said casing and walls but out of contact with the latter, turbine-wheels fixed to said spindle and arranged to rotate in the chambers between said walls, and baffling devices arranged between the rotary and fixed parts, substantially as described.

11. A compound fluid-pressure turbine comprising a casing having an inlet and an outlet for motive fluid, transversely-arranged walls fixed in said casing and provided near their outer peripheries with passages extending therethrough from one side to the other, a spindle extending through said casing and walls but out of contact with the latter, turbine-wheels fixed to said spindle and arranged to rotate in the chambers between said walls, and baffling devices arranged between the central portions of said walls and wheels and near said spindle, substantially as described.

12. A compound fluid-pressure turbine comprising a casing having an inlet and an outlet for motive fluid, transversely-arranged walls fixed in said casing and provided near their outer peripheries with passages extending therethrough from one side to the other, a spindle extending through said casing and walls but out of contact with the latter, turbine-wheels fixed to said spindle and arranged to rotate in the chambers between said walls, and baffling devices arranged between the central portions of said walls and wheels and consisting of concentrically-arranged rings fixed to one of said parts.

13. A compound fluid-pressure turbine comprising a casing having an inlet and an outlet for motive fluid, transversely-arranged walls fixed in said casing and provided near their outer peripheries with passages extending therethrough from one side to the other, a spindle extending through said casing and walls but out of contact with the latter, turbine-wheels fixed to said spindle and arranged to rotate in the chambers between said walls, and baffling devices arranged between the central portions of said walls and wheels, and consisting of concentrically-arranged rings fixed to the opposing surfaces of both of said parts, substantially as described.

14. In a compound fluid-pressure turbine, stationary walls fixed transversely to and within the casing of the turbine and each formed near its outer periphery with segmental-shaped notches, segmental-shaped compound holding devices fixed in said notches and each composed of two parallel strips having segmental-shaped holes therethrough and notches on their adjacent faces, and a group of blades spaced apart and held between the notched surfaces of each compound holding device, substantially as described.

15. In a compound fluid-pressure turbine, stationary walls fixed transversely to and within the casing of the turbine and each formed near its outer periphery with segmental-shaped notches, segmental-shaped compound holding devices fixed in said notches and each composed of two parallel strips having segmental-shaped holes therethrough and notches on their adjacent faces, and a group of radial guide-blades held by and between the two parts of said holding device and shaped and arranged substantially as described and shown for the purpose set forth.

16. A compound steam-turbine comprising a casing having a steam-inlet passage at one end and an exhaust-passage at the other end, a plurality of transverse walls fixed in said casing and formed with groups of steam-exit passages near their outer peripheries, the cross-sectional areas of the groups of passages in the successive walls gradually increasing from the inlet end of the turbine to the out-

let end thereof, a rotary spindle extending centrally through said casing and walls, but out of contact with the latter, a plurality of wheels of uniform diameter fixed to said spindle and arranged to rotate between said walls, and rings of blades fixed to the outer peripheries of said wheels and having practically parallel passage-ways between the adjacent blades, the steam-passages in said walls and the rings of blades being arranged opposite one another and made of different radial lengths at different parts of the length of the turbine, substantially as described.

Signed at Newcastle-upon-Tyne this 27th day of August, 1901.

HUGH FRANCIS FULLAGAR.

Witnesses:
W. SPELMAN BURTON,
PERCY CORDER.