No. 741,776. PATENTED OCT. 20, 1903.

A. R. DODGE.

MEANS FOR IMPROVING THE EFFICIENCY OF TURBINES.

APPLICATION FILED DEC. 13, 1902.

NO MODEL. 3 SHEETS—SHEET 1.

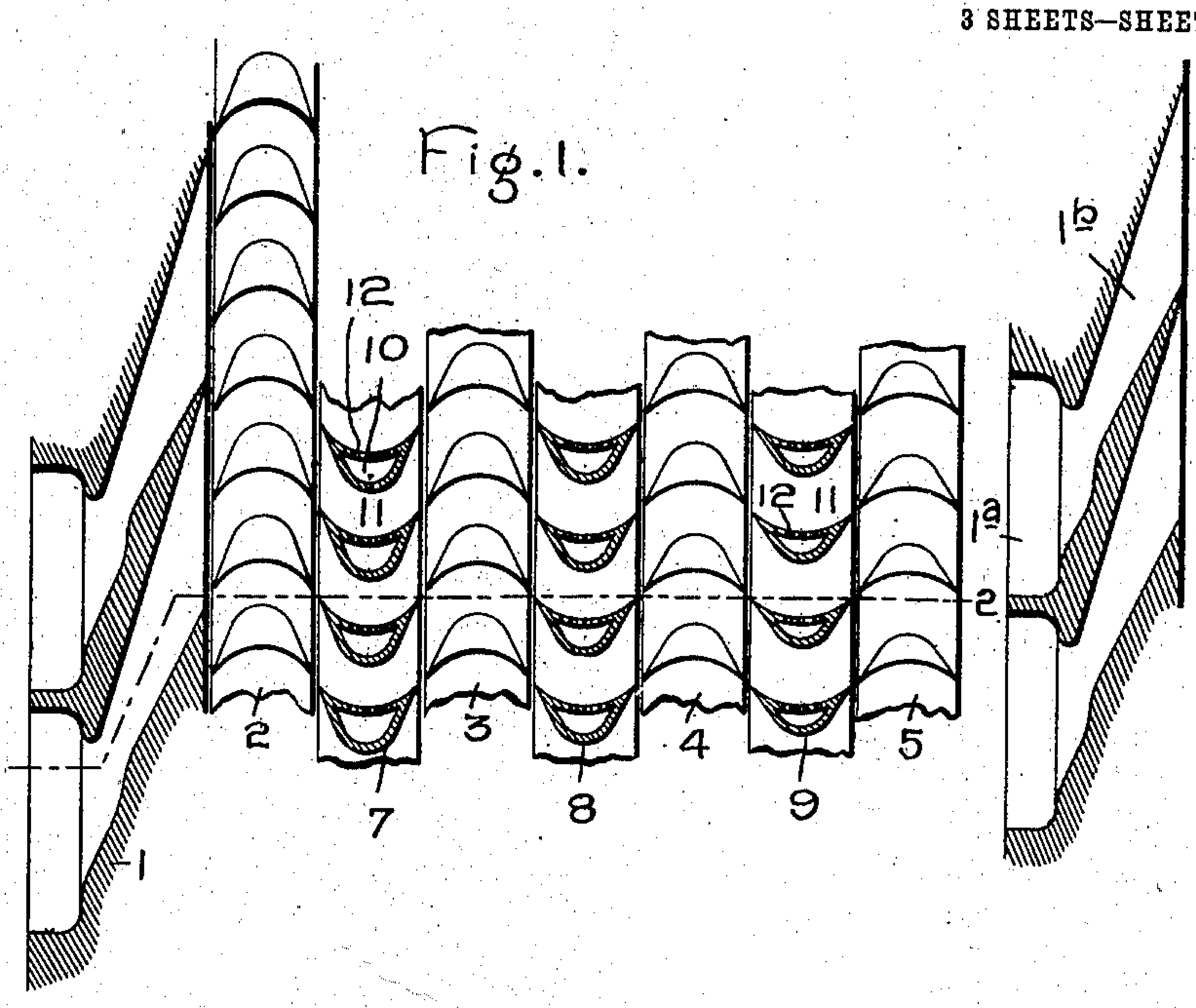
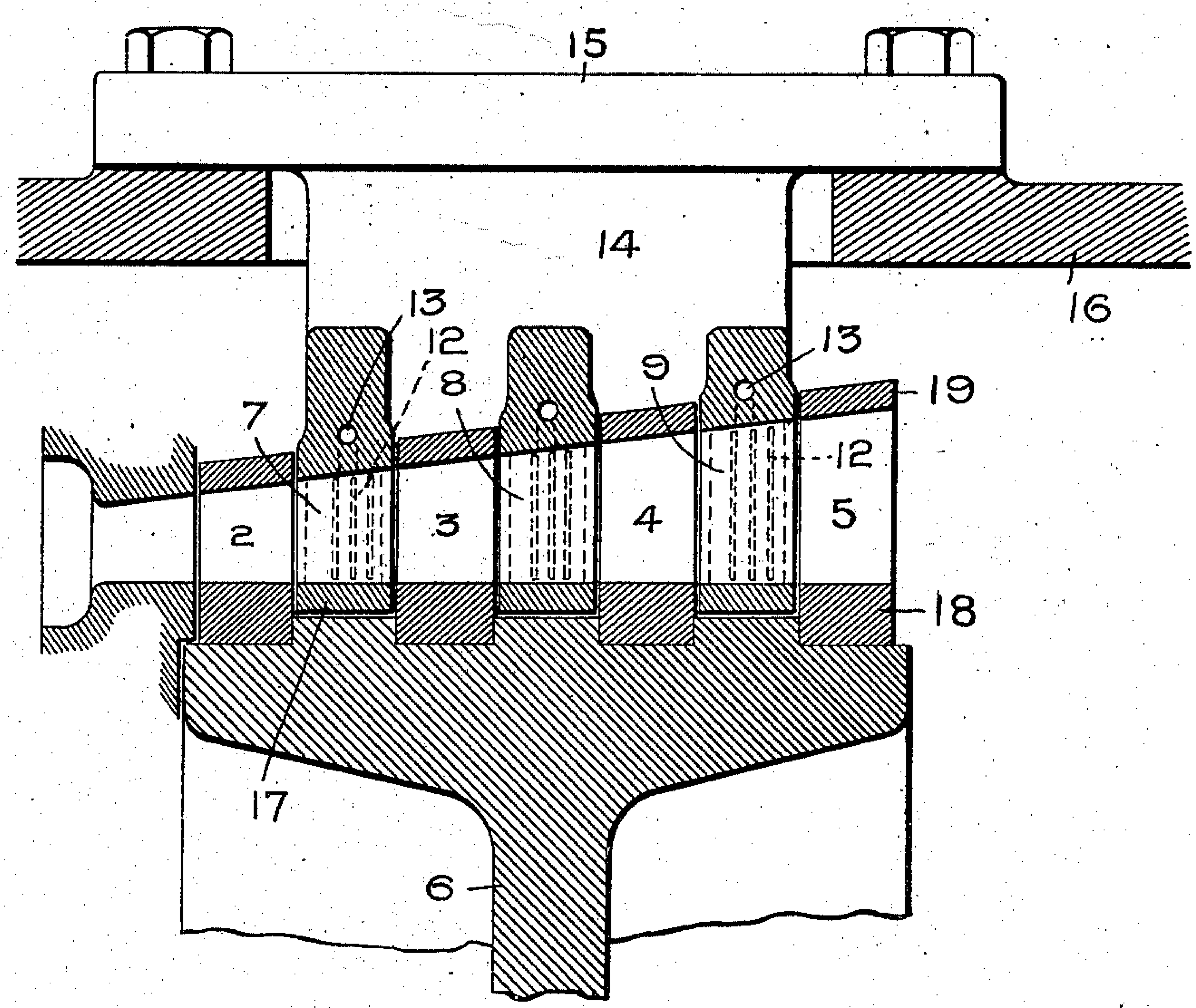


Fig.2.



Witnesses:
Marcus L. Byng.
Alex F. Macdonald.

Inventor:
Austin R. Dodge,
by Albert G. Davis
Att'y.

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NO MODEL. 3 SHEETS—SHEET 2.

Fig. 3.

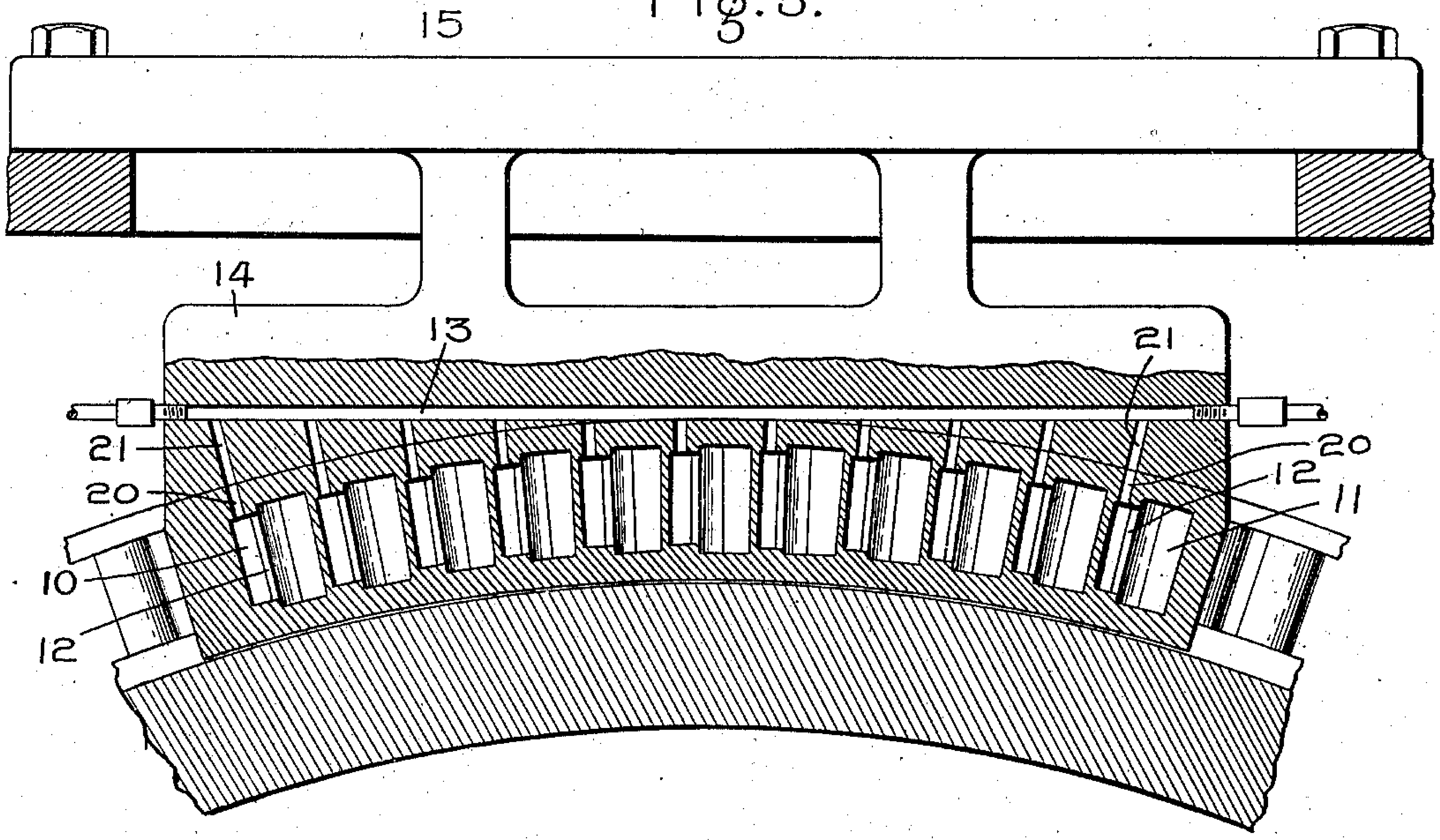


Fig. 4.

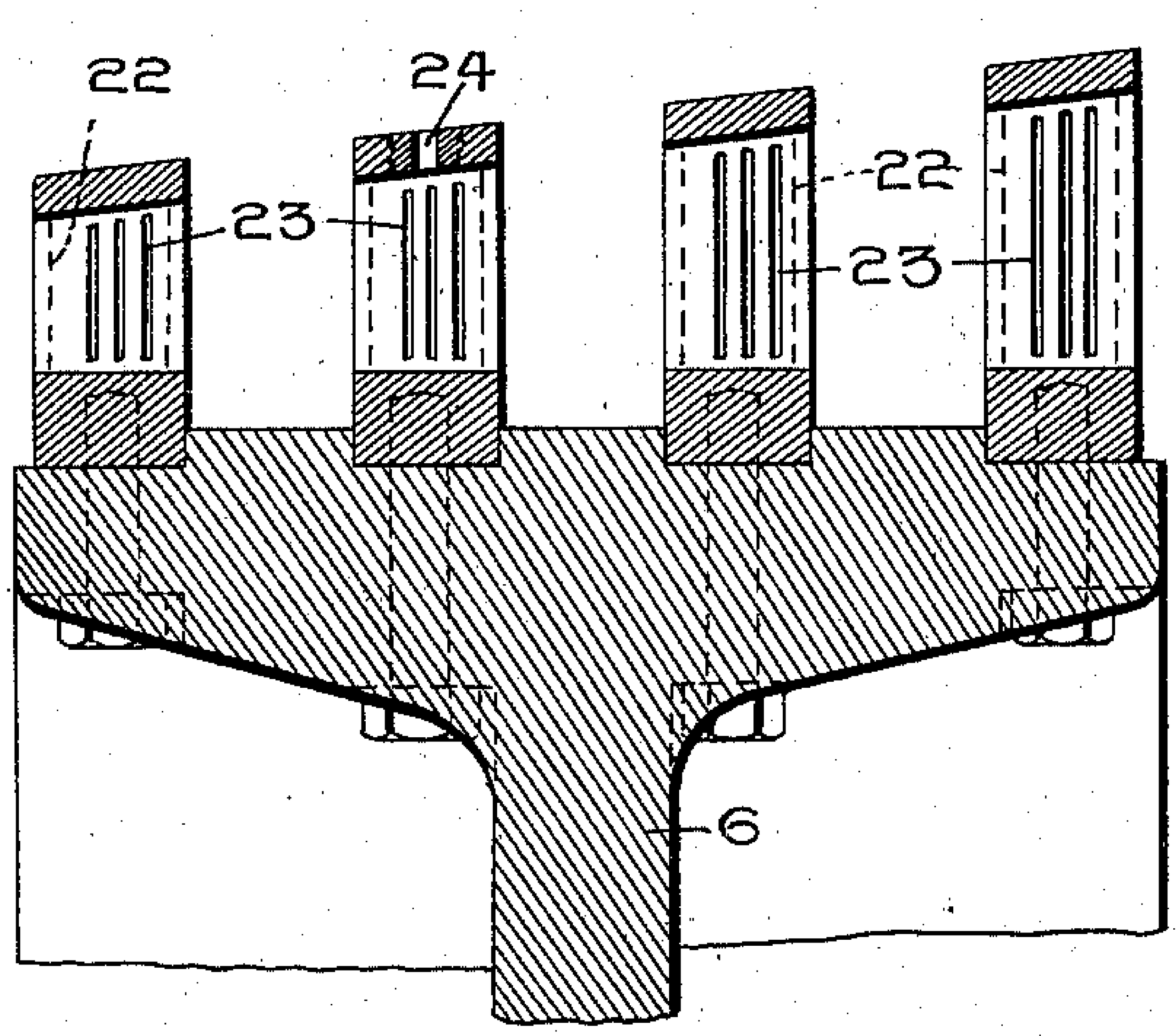
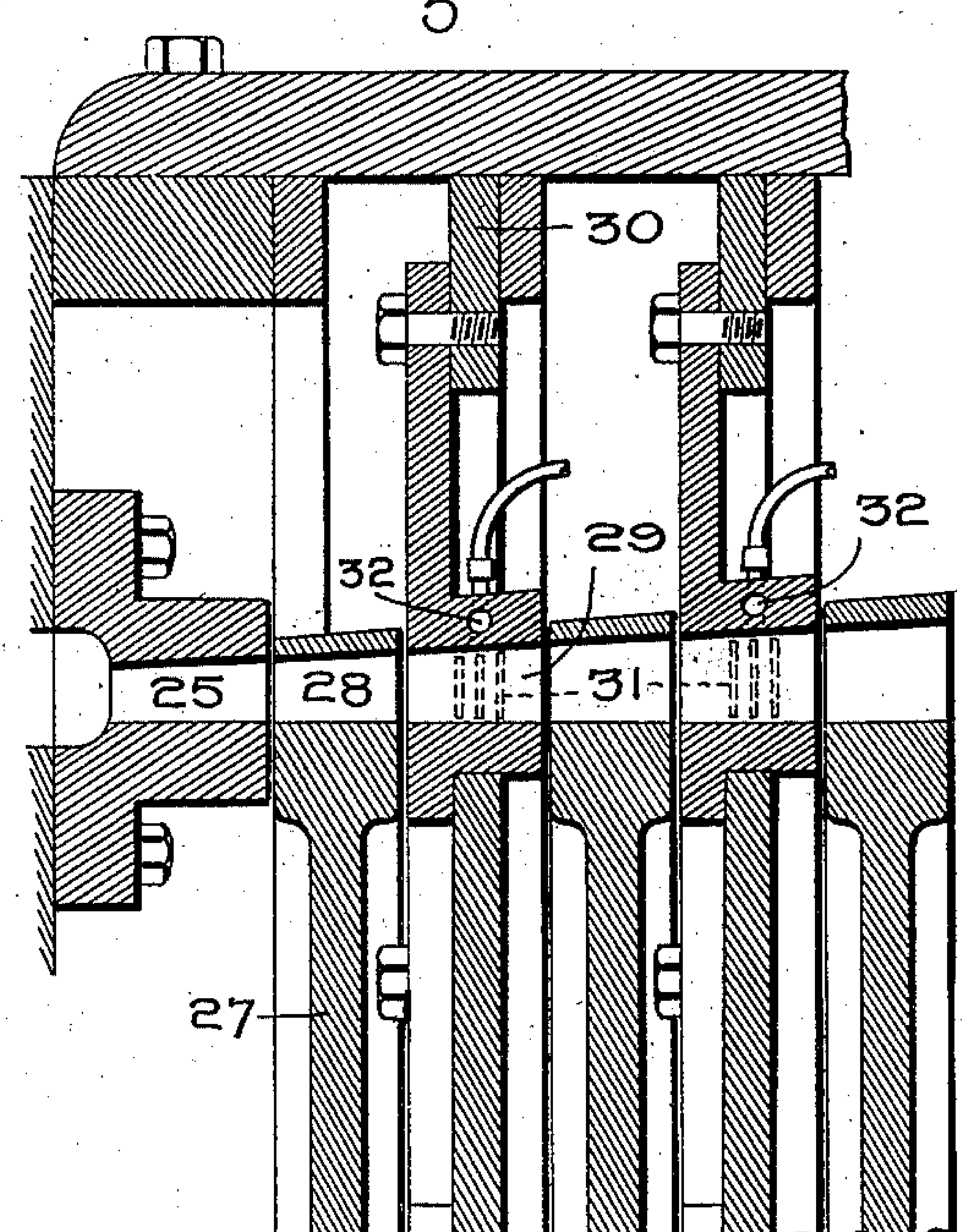


Fig. 5.



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NO MODEL. 3 SHEETS—SHEET 3.

Fig. 6.

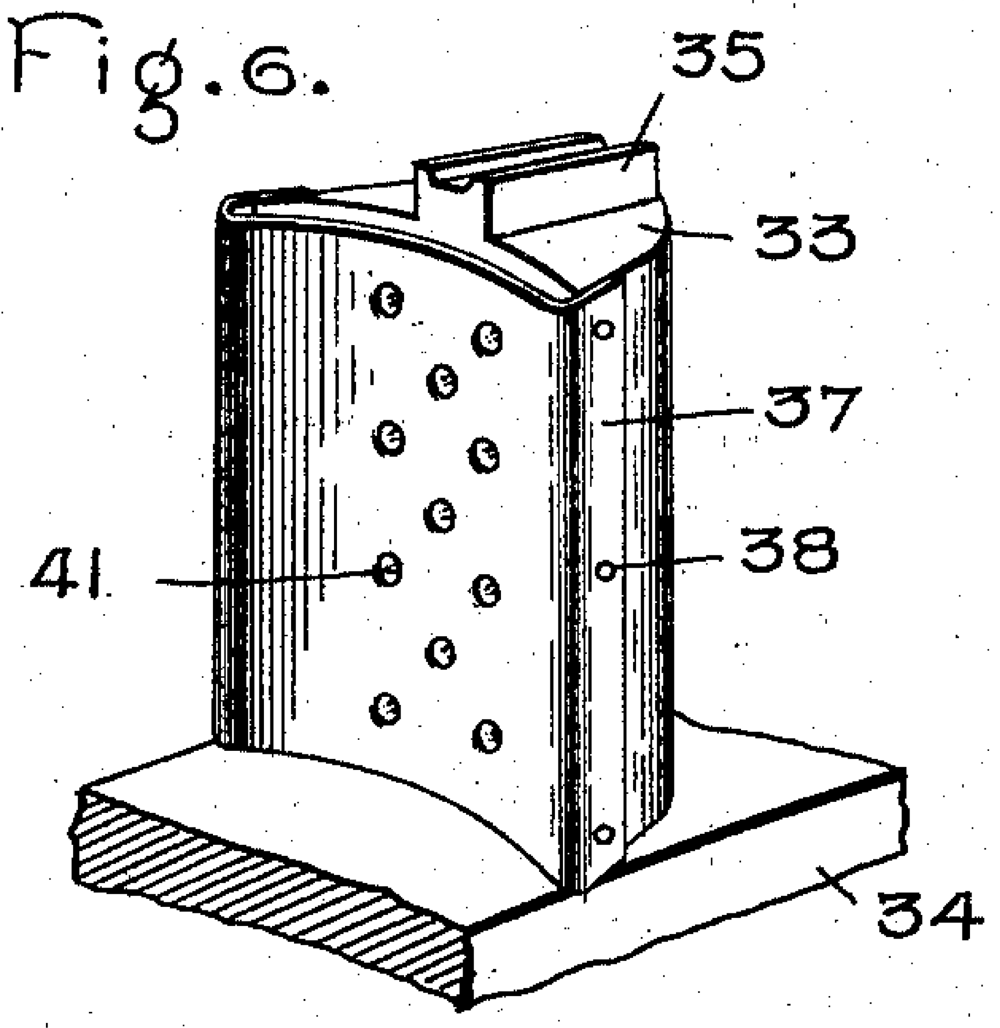


Fig. 7.

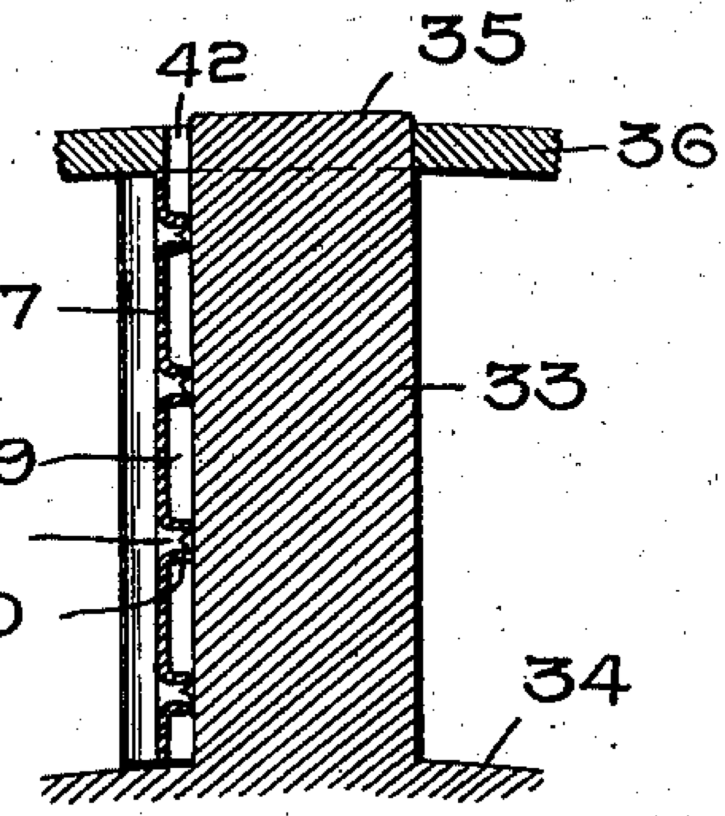


Fig. 8.

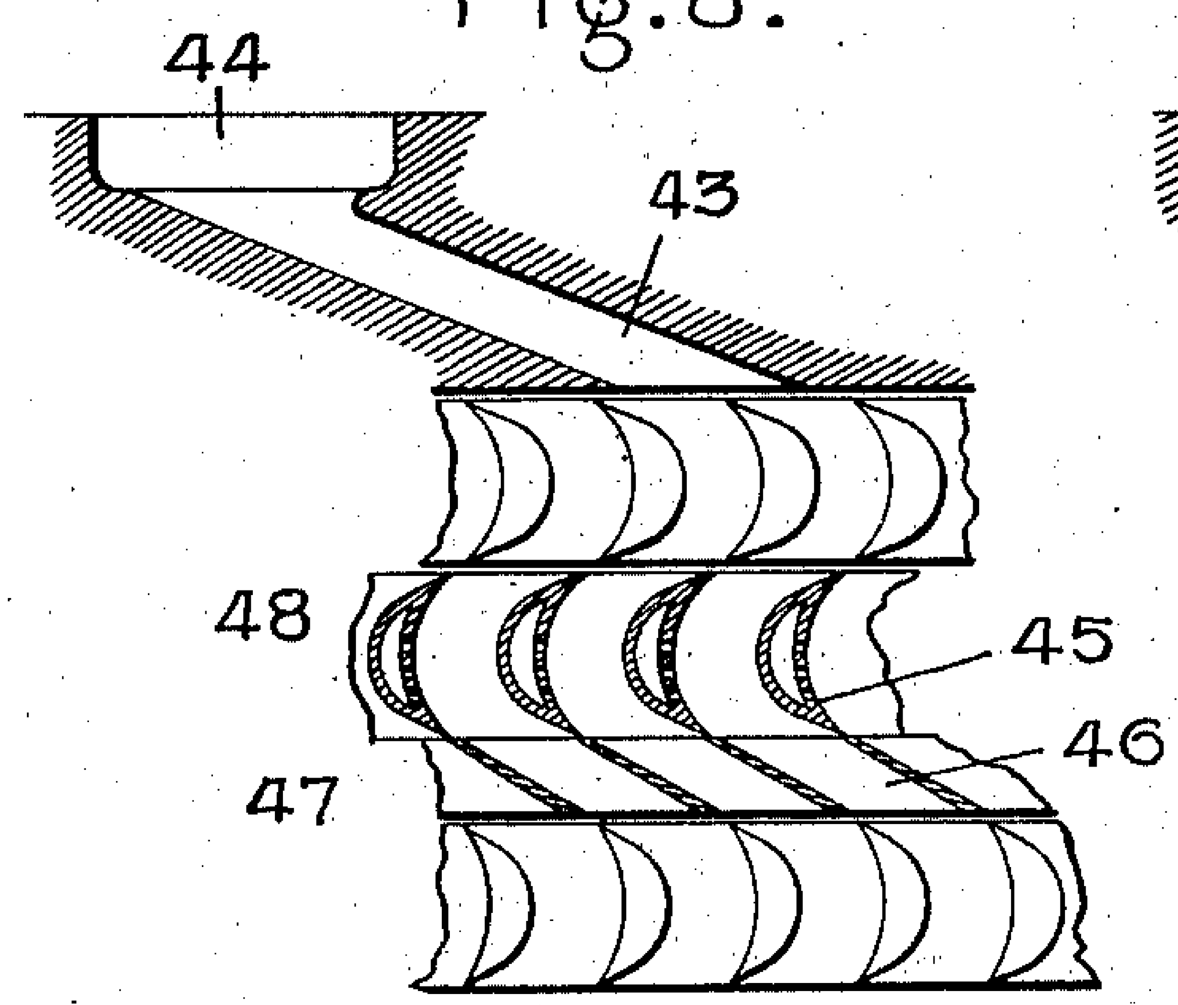


Fig. 9.

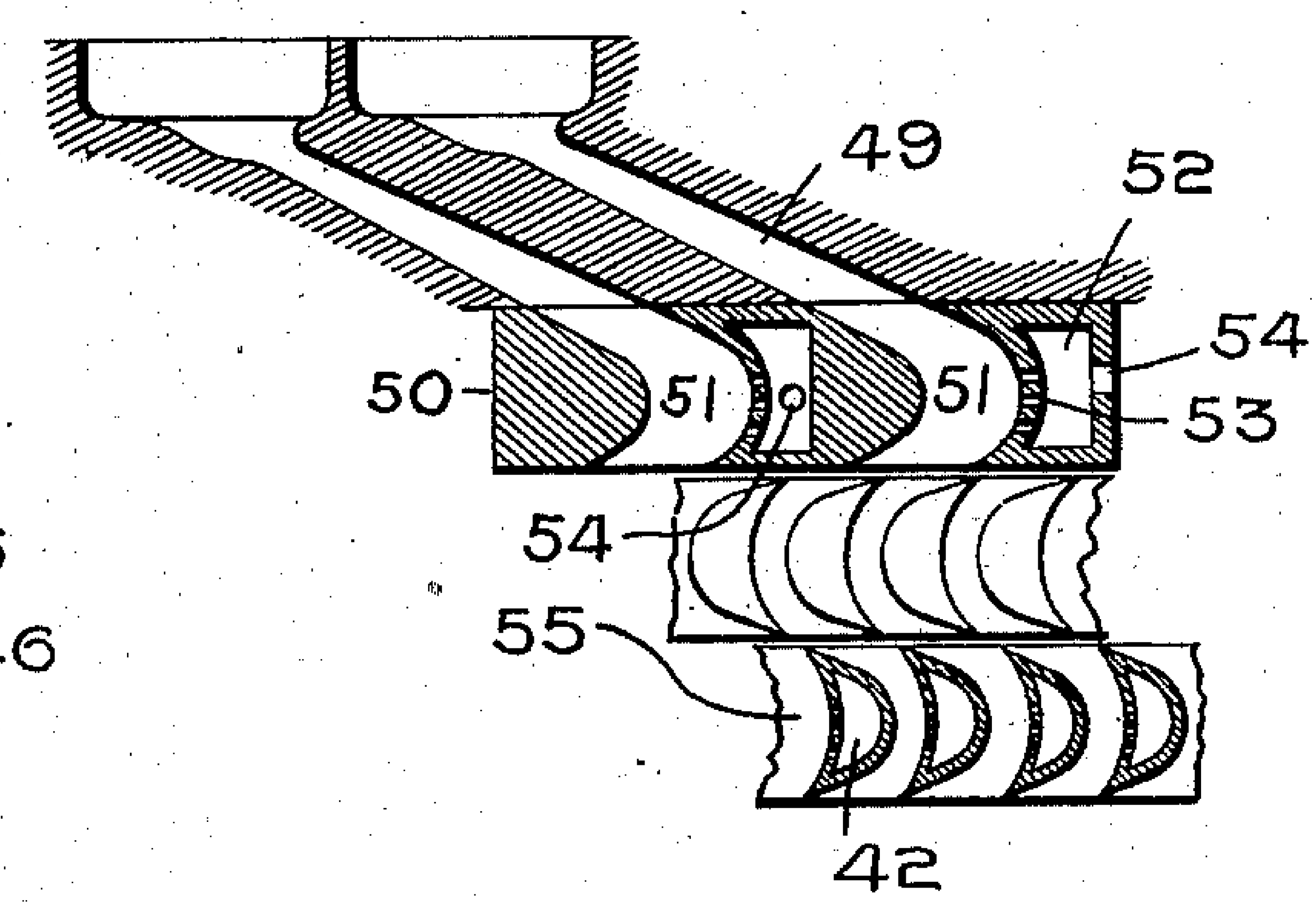


Fig. 10.

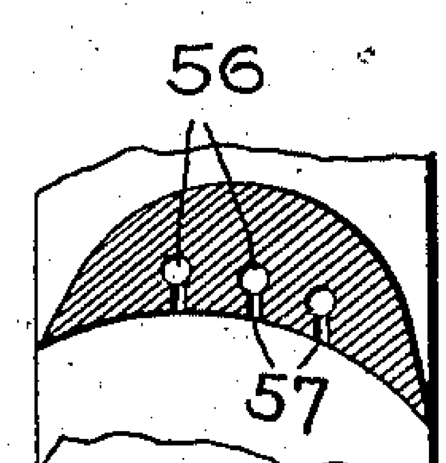
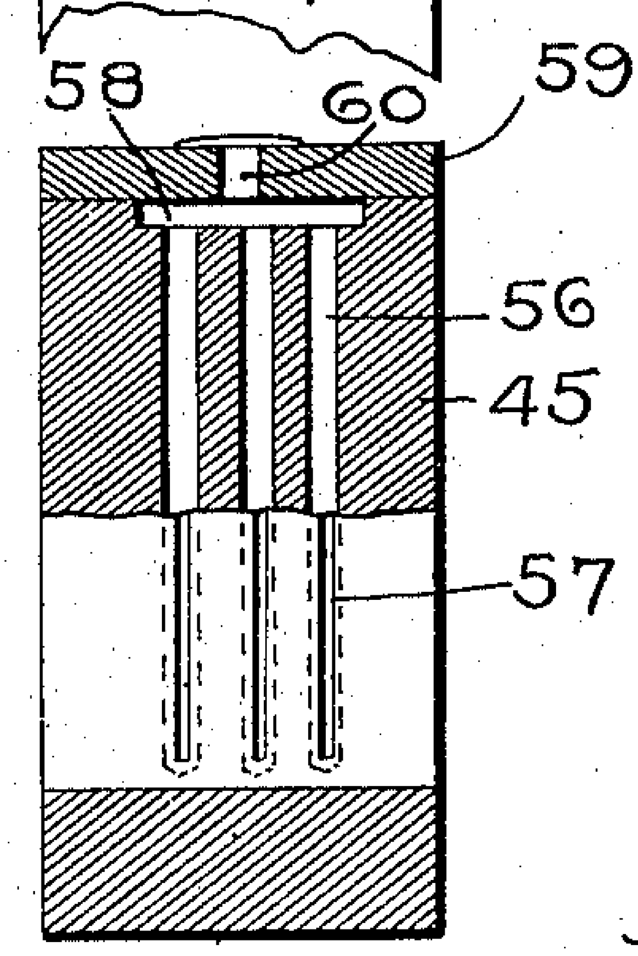


Fig. 11.



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Alex F. Macdonald

Inventor:
Austin R. Dodge,
by Albert G. Davis
Att'y.

No. 741,776. Patented October 20, 1903.

UNITED STATES PATENT OFFICE.

AUSTIN R. DODGE, OF SCHENECTADY, NEW YORK, ASSIGNOR TO GENERAL ELECTRIC COMPANY, A CORPORATION OF NEW YORK.

MEANS FOR IMPROVING THE EFFICIENCY OF TURBINES.

SPECIFICATION forming part of Letters Patent No. 741,776, dated October 20, 1903.

Application filed December 13, 1902. Serial No. 135,069. (No model.)

To all whom it may concern:

Be it known that I, AUSTIN R. DODGE, a citizen of the United States, residing at Schenectady, in the county of Schenectady, State of New York, have invented certain new and useful Improvements in Means for Improving the Efficiency of Elastic-Fluid Turbines, of which the following is a specification.

It is well known that in the elastic-fluid turbines there is considerable moisture in the motive fluid and that the amount of moisture depends upon the character of the turbine, and more especially upon the degree of expansion employed. By tests I have determined that the moisture in the motive fluid of the first stage of a two-stage turbine of the jet type working between absolute terminal pressure of one hundred and sixty-five and one pound, wherein the pressure of the fluid is largely converted into *vis viva* before being delievered to the wheel, commonly amounts to thirteen per cent. of the total weight of the fluid. The vapor is discharged from the last wheel or row of buckets on a wheel with considerable velocity, in some instances having a velocity of a thousand feet per second. The vapor loses its velocity by impact between the molecules in striking the shell or casing that surrounds the wheel or in striking some part within the shell, and on so doing its energy is transformed into heat. This transformation of the energy from one form to another causes a certain amount of the water due to expansion and condensation to be reconverted into vapor. This reconversion, however, can only take place at the expense of a considerable amount of thermal energy, which means a loss in efficiency. From actual tests it appears that with a turbine of the construction specified for every one hundred pounds of vapor delivered to it there are thirteen pounds of water at the end of the first stage. It also appears that in passing into the second stage eleven pounds of this water are reconverted into vapor, thus leaving two pounds to mingle with the steam. The steam in the second stage also has a certain percentage of moisture, due to its expansion, which is in addition to that already mentioned. The reconversion of water at this or any other point in the turbine calls for a considerable expenditure of thermal energy, and a large portion of the energy thus expended appears as latent heat in the second stage which performs no useful work.

The amount of moisture in an elastic-fluid turbine is less where a non-expanding nozzle is used than an expanding nozzle; but in either case there is a substantial loss whenever there is a reëvaporation of the moisture.

The advantages of using superheated steam or other vapor in elastic-fluid turbines to increase the efficiency are well known. It is a comparatively simple matter to supply superheated vapor to the first stage; but to supply it to a subsequent stage or stages presents quite a different proposition. As before stated, the sudden checking or retarding of the stream of motive fluid under high velocity creates a large amount of energy in the form of heat. Where there is a considerable percentage of moisture in the steam, this energy is expended in reëvaporation; but where the steam is dry, or practically so, the energy can be expended in superheating. I make use of this condition of affairs in practicing my invention and provide a separator which abstracts the moisture from the vapor while it is performing useful work, after which the energy represented by the discharged vapor can be utilized for the purpose of superheating. By carefully separating the moisture from the steam at an intermediate point or points and superheating the steam the efficiency of the machine can be increased a number of per cent.

Efforts have been made in connection with reciprocating engines and with a fair degree of success to separate the moisture from the steam before delivering it to the cylinder; but in so far as I am aware the separator has always been placed in a conduit at some point where the steam is doing no useful work. These separators are more or less objectionable on account of their bulk and also on account of the additional piping, all of which add to the cost of installation. Broadly speaking, these separators are based on the idea of suddenly changing the direction of the steam-jet during the time that it is not performing any useful work, thereby causing the water, which is heavier than the vapor, to be discharged into a receptacle specially provided. The separators are composed in certain instances of stationary parts and in other instances of moving parts or a combination of stationary and moving parts. These have been placed between the boiler and the engine in some cases and between the high and low pressure cylinders in other cases.

The present invention has for its object to improve the efficiency of an elastic-fluid turbine by providing a means for separating the moisture from the motive fluid during the time that it is actually engaged in performing useful work.

In so far as I am aware I am the first to abstract moisture from steam or other elastic fluid during the time that it is acting on a piston or other moving body in a manner to perform useful work, and my claims are to be construed as generic in this respect.

In carrying out my invention as applied to elastic-fluid turbines means are provided at one or more points along the working passage which receive the stream of motive fluid, change its direction, and discharge it against an adjacent vane or bucket. The same means may also act as a separator and as a receptacle for the moisture which is separated from the main body of the vapor, the separation taking place on account of the sudden change in direction of the fluid stream.

In using the term "working passage" reference is made to the passage through which the motive fluid passes in going from one part of the turbine to another. In using the term in its broadest sense it refers to the passage in a nozzle or to that between adjacent buckets and in a more limited sense it refers to both nozzle and bucket passages.

The separation of moisture from the vapor as it passes through the working passage may be accomplished in several different ways. I may provide the intermediate buckets, which may be stationary or movable, as desired, with water-receiving chambers and restricted openings leading thereto, or the wheel-buckets can be similarly constructed. I may also arrange one or more of the nozzles with moisture-separating means. Either of the means above specified can be used singly or in combination, as occasion demands.

I have described a means which is applicable to small-sized machines, where the volume of fluid to be handled is relatively small—that is to say, where the fluid passes through the machine as a single stream. Where the power of the machine is high, I find it desirable to subdivide the total volume of fluid into a number of streams, which while they may form, in effect, a single stream can be treated, in so far as the separation of moisture is concerned, as a number of relatively small streams, each of which is acted upon by one or more separators as it flows through the working passages.

In the accompanying drawings, which represent an embodiment of my invention, Figure 1 is a partially-developed view of an elastic-fluid turbine. Fig. 2 is a longitudinal section taken on line 2 2 of Fig. 1. Fig. 3 is a cross-section of an intermediate and bucket-wheel. Fig. 4 is a partial longitudinal section of a bucket-wheel on a slightly-modified plan. Fig. 5 is a horizontal section of a single-wheel-per-stage turbine. Fig. 6 is a perspective view of a modified form of bucket. Fig. 7 is a sectional view of the bucket shown in Fig. 6. Fig. 8 is a partial view of an elastic-fluid turbine, showing means attached to the intermediate for abstracting moisture from the motive fluid. Fig. 9 is a partial view of a turbine, showing a means applied to the nozzle for abstracting moisture from the motive fluid. Figs. 10 and 11 are sectional details illustrating a modified form of bucket construction.

Referring more particularly to Figs. 1 and 2, I have shown my invention in connection with a prime mover. In the present instance it takes the form of an elastic-fluid turbine. It comprises a nozzle 1, which is adapted to deliver elastic fluid under considerable velocity to the rows of moving buckets 2, 3, 4, and 5. These moving buckets are mounted upon the wheel 6, and consequently move together, and, in effect, form a piston which is acted upon by the motive fluid in successive operations. Situated between the rows of moving buckets are intermediate buckets 7 8 9. These buckets may or may not be stationary, as desired. Each bucket is provided with a chamber 10, that communicates with the working passage 11 between the buckets by small openings 12. These openings may with advantage take the form of slits, as is more clearly shown in Fig. 2. The passage between the stationary buckets forms a part of what I term the "working passage," the said working passage comprising the nozzle and the various passages between the wheel and intermediate buckets. The intermediate buckets, in addition to changing the direction of the stream of motive fluid and discharging it against the adjacent wheel-buckets, act as a separator for abstracting moisture from the motive fluid as it passes through the working passage. This feature of my invention is based on the general principle that moisture can be separated from steam or other elastic fluid by giving to said elastic fluid a sudden change in direction, which causes the heavy particles, such as water, to be projected into a different path from that taken by the lighter particles, which form the vapor. The fluid in the turbine has a velocity depending upon the character of the expansion of the working passage. For example, it may be assumed that in the present instance the expanding nozzle 1 discharges steam against the first row of wheel-buckets 2 with a velocity of two thousand two hundred feet per second, and as the motive fluid passes through the working passage formed by the stationary and moving buckets its velocity is fractionally abstracted—that is to say, at the first row of buckets it loses a certain amount of its velocity, at the second row of wheel-buckets it loses a certain amount more, and so on. As the steam or other elastic fluid is discharged from the wheel-buckets against the intermediate buckets the particles of water will strike the concave surface of one bucket and the particles forming the vapor will be in contact with the convex surface of the adjacent bucket. The water which is collected in the chambers 10 is carried off by the conduit 13, which is in communication with one or more of said chambers. When the pressure of the steam in the working passage is above that of the atmosphere, the water will be blown out; if it is below, the water can be removed in any one of the well-known ways.

Owing to the rapidity with which the steam travels through the working passage, it is difficult to abstract all of the moisture in one operation, and in order to do this I make all of the intermediate buckets of the character previously described—that is to say, each bucket has a chamber with one or more perforations, which connect the working passage with the chamber.

From the foregoing it will be seen that the energy is fractionally abstracted from the motive fluid by the wheel and also that the moisture is fractionally abstracted from the motive fluid during such times as it is actually engaged in performing useful work.

The moving and stationary buckets are so arranged that they do not abstract all of the velocity due to the first nozzle from the motive fluid, and as the fluid stream is discharged from the last wheel or row of buckets, as the case may be, it is retarded by the bowl 1^a of the second-stage nozzle. This retardation of the fluid stream changes its energy from that of motion into heat, and the heat thus produced is employed in superheating the steam prior to its entrance into the second stage or to an intermediate stage where more than two are provided. The superheated steam passes from the bowl into the second-stage nozzle 1^b, where it attains the proper velocity prior to being delivered to the second-stage wheel. The buckets of the second stage resemble those in the first; but by preference the area of the working passage is somewhat greater to compensate for the increased volume and reduced pressure. Where only two stages are employed I may or may not use water-collection chambers in the intermediates or in the wheel-buckets; but where more than two stages are provided they will be found to be useful. As a general proposition it may be stated that the separators are useful wherever there is any considerable amount of moisture due to condensation and expansion, except in the case of the last stage, which is connected to a condenser.

With turbines of low power it is satisfactory to deliver the motive fluid to the wheel by a single nozzle or passage; but for higher powers it is desirable to subdivide the volume of fluid into two or more streams before delivering it to the wheel. These streams are closely associated and, in fact, constitute a single stream in so far as their action on the wheel is concerned, yet this subdivision enables the turbine to be more readily governed and at the same time facilitates the abstraction of moisture from the fluid, since by this subdivision a greater surface is exposed to the action of the separators, which is an important consideration.

In the drawings I have shown two sections of a nozzle, it being understood that the figures are only partial views of a machine; but any number of sectional nozzles or passages can be employed to meet given conditions.

Referring to Fig. 2, the intermediate buckets are mounted on a suitable support 14, which is provided with a flange 15, that is bolted or otherwise secured to the casing or shell 16, which surrounds the working parts of the turbine. Each row of intermediate buckets is provided with a cover 17, which is situated between the detachable segmental pieces 18, that carry the wheel-buckets. Each row of wheel-buckets is provided with a cover 19, which may be made in sections or in a single piece, as desired. These covers are situated between the supports for the intermediate buckets, with the exception of the two outer ones, which are beyond the sides of the support.

Referring to Fig. 3, I have shown the intermediate buckets in longitudinal section. For convenience of manufacture I have shown the intermediates as being cast integral with each other; but, if desired, they can be made separately and secured to their support in any desired manner. The support 14, which is secured to the wheel-casing, is provided with a surface that is curved concentrically with the driving-shaft, and engaging with this surface is a corresponding surface formed on the detachable intermediates. Each intermediate bucket is provided with a chamber 10, that communicates by a passage 20 with a corresponding passage 21, formed in the support 14. The passages 21 communicate with the passage or conduit 13, and the latter is connected by pipes to the outside of the wheel-casing. Each chamber communicates with the working passage by one or more slots or openings 12.

Referring to Fig. 4, the wheel-buckets are shown as being provided with chambers 22, (shown in dotted lines,) which are in communication with the working passage by the slots 23. When the motive fluid is discharged against the curved faces of these buckets, the water due to condensation and expansion passes through the slots into the chamber, from which it is discharged through the peripheral opening 24 by the centrifugal action of the wheel. The buckets can be made of castings, or they can be built up, as desired, the essential feature being to provide each bucket with means for separating the moisture from the steam and discharging it into a suitable receptacle. As shown, the buckets are mounted on segmental pieces, which are secured to the wheel 6 by bolts that extend through the flange.

Referring to Fig. 5, I have shown my invention in connection with a single-wheel-per-stage turbine, wherein 25 represents a nozzle that may be of the expanding or non-expanding type, as desired. Situated in front of the nozzle is a wheel 27, having working passages 28 formed near its periphery. The form of this passage is similar to that described in connection with the previous figures. The fluid from this wheel is delivered to an intermediate 29, that is detachably secured to a diaphragm 30, formed in the wheel-case. In addition to acting as a means for receiving fluid and changing its direction the intermediate also acts as a nozzle in that it gives to the motive fluid a certain predetermined amount of expansion. Each intermediate is also provided with a water-receiving chamber, which chamber connects with the working passage by slots 31. In the present figure the slots are on the opposite side of the bucket from the observer. Hence they are shown in dotted lines. The chambers of the several intermediate buckets are connected to the passage 32, and the latter is connected to a pipe by means of which water is carried to the outside of the wheel-casing.

Referring to Figs. 6 and 7, I have shown a further modification of my invention wherein the separator is formed as a separate part and is applied to the buckets, which may revolve or not, as desired. 33 represents a bucket which is formed integral with its support 34, and the upper end thereof is provided with a tenon 35, by means of which the cover 36 can be secured in place. Covering the front or working face of the bucket is a thin sheet-metal plate 37, which may or may not be detachable, as is desired. In the present instance it is secured to the bucket by small rivets 38. Between the plate and the main body of the bucket is a collection-chamber 39, which corresponds in all respects to the chamber 10 formed in the intermediates and the chambers 22 in the wheel-buckets. The plate is perforated at a number of points 40, and in punching these plates the bur 41 acts as a means for holding the plate away from the front face of the bucket. A construction of this kind is desirable because the faces of the buckets that are cut from solid stock do not have to be so finely finished and, again, in case of wear the plates can readily be renewed. The chamber 39 registers with the opening 42 in the bucket-cover, and owing to the centrifugal action of the wheel the water due to expansion and condensation is thrown outwardly away from the working passage, where it is collected by any suitable means.

Referring to Fig. 8, I have shown a further modification of my invention wherein a nozzle 43 of the non-expanding type is provided having the usual bowl 44. A nozzle of this character imparts a greater or less velocity to the steam, depending upon the difference in pressure between the bowl and the shell or between adjacent shells. Manifestly when a non-expanding nozzle is used the moisture in the vapor due to the expansion is less than where an expanding nozzle is used; but there is still considerable moisture which it is desirable to remove from the motive fluid. In connection with this type of nozzle I may abstract the moisture fractionally by means of separators formed in the intermediates or by separators formed in the wheel-buckets. I have shown, however, a slight modification wherein a series of buckets 45 are provided which act as separators for abstracting moisture from the steam, but do not act to deliver it to the bucket-wheels, this being taken care of by a series of passages or nozzles 46. These nozzles may be of the expanding or non-expanding type, as is desired. In constructions of this kind the passages 46 may be formed in a diaphragm 47, and the support 48, carrying the buckets 45, secured thereto, or the support 48 may carry the piece 47.

In Fig. 9 I have shown a further modification of my invention wherein a separator is applied to the nozzle 49, which may or may not be of the expanding type, as desired. In this case, however, as in those previously mentioned, the abstraction of the moisture from the motive fluid takes place while the latter is flowing through the working passage, it being understood, of course, that the work done by the steam commences when it enters the nozzle. Bolted or otherwise secured to the discharge end of the nozzle is a piece 50, containing one or more segmental working passages 51 and a chamber 52, which communicates with the working passage by means of small slits or openings 53. Water from the chamber is carried away by means of the passage 54.

Where the separation is accomplished by stationary means, the pressure of the fluid stream is sufficient to blow the water out of the chamber; but the openings 53 should be small enough to prevent any appreciable leakage of the motive fluid. Two nozzles are shown in the present instance, but more can be employed, if desired. The intermediates 55 are shown as being arranged to act as separators; but it is evident that I may use the wheel-buckets for this purpose.

Referring to Figs. 10 and 11, I have shown a means whereby existing buckets can be arranged to operate in accordance with my invention. This is accomplished by drilling holes 56 in the bucket near the front face and connecting said holes with the front face by means of narrow slots 57. The upper end of each bucket is provided with a small chamber 58, into which the openings 56 deliver their contents. The openings 56 and the chamber 58 have the same functions and operate in the same manner as the chambers and passages previously referred to. The buckets are provided with covers 59, and formed in the covers and registering with the chambers 58 are openings 60, through which the water can be projected under the centrifugal action of the wheel.

My invention is shown in connection with turbines designed to work with or without condensers, and I desire to be understood as including such uses in the appended claims.

In accordance with the provisions of the patent statutes I have described the principle of operation of my invention, together with the apparatus which I now consider to represent the best embodiment thereof; but I desire to have it understood that the apparatus shown is only illustrative and that the invention can be carried out by other means.

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

1. In an elastic-fluid motor, the combination of a working passage for the motive fluid with means acting on the fluid in said passage while it is performing work for abstracting the moisture therefrom.

2. In an elastic-fluid motor, the combination of a revolving wheel driven by the fluid with a means acting on the fluid stream while it is performing work for abstracting moisture therefrom.

3. In combination, a prime mover operated by elastic fluid under pressure, with means acting on said fluid two or more times in succession during the interval that it is performing useful work for abstracting the moisture therefrom.

4. In a prime mover operated by elastic fluid under pressure, the combination of a piston which is acted upon two or more times in succession by the motive fluid, with means acting on the fluid when it is performing useful work for abstracting the moisture therefrom.

5. In an elastic-fluid motor, the combination of a working passage for the motive fluid, with means acting on the fluid in said passage two or more times in succession for abstracting the moisture therefrom.

6. In an elastic-fluid turbine, the combination of a working passage composed of moving and stationary parts, with a means for changing the direction of the fluid stream and also separating the moisture therefrom.

7. In an elastic-fluid turbine, the combination of a working passage composed of moving and stationary parts, means for abstracting moisture from the fluid as it passes through said passage, and means for collecting the moisture thus abstracted.

8. In an elastic-fluid turbine, the combination of a working passage which is subdivided into a number of smaller passages with separate means acting on the fluid as it passes through each of the smaller passages for abstracting the moisture therefrom.

9. In an elastic-fluid turbine, the combination of a working passage comprising moving and stationary parts, with means carried by the stationary parts for changing the direction of the fluid stream and abstracting the moisture therefrom.

10. In an elastic-fluid turbine, the combination of a working passage comprising moving and stationary buckets, means acting in conjunction with the stationary buckets for changing the direction of the fluid stream and also for abstracting moisture therefrom, and a conduit for drawing off water from said means.

11. In a prime mover, the combination of a piston that is acted upon by the motive fluid two or more times in succession, means for receiving the fluid after it has once acted on the piston and discharging it against the piston a second time, and means acting on the fluid stream as it passes through the prime mover for abstracting the moisture therefrom.

12. In an elastic-fluid turbine, the combination of a bucket-wheel, a passage for discharging fluid against the wheel, and chambered receptacles which assist in conveying the fluid and abstracting the moisture from the fluid.

13. In an elastic-fluid turbine, the combination of a wheel, a passage for discharging fluid against the wheel, and buckets each having an external face that directs the motive fluid in its passage through the turbine and a chamber for collecting moisture from the vapor.

14. In an elastic-fluid turbine, the combination of a wheel, a nozzle for discharging fluid against the wheel, buckets for directing the passage of motive fluid and abstracting moisture therefrom, and means for collecting the moisture from the buckets.

15. In an elastic-fluid turbine, the combination of a means for converting a certain portion of the pressure of the motive fluid into velocity, means for abstracting the velocity fractionally, and means for separating the moisture from the vapor during the period that the velocity is being abstracted.

16. In an elastic-fluid turbine, the combination of an expanding nozzle, two sets of buckets situated in front of the nozzle and coöperating to fractionally abstract the velocity from the motive fluid, and a means acting on the fluid while it is performing useful work for abstracting the moisture from the elastic fluid.

17. An elastic-fluid turbine having chambered buckets between which the working passages are formed, each of said buckets being provided with openings in its wall which connect the working passages with the chambers in the buckets.

18. As an article of manufacture, a bucket for an elastic-fluid turbine, comprising a curved wall for receiving motive fluid and changing its direction, which wall is perforated, and a chamber which is in communication with said perforations.

19. In an elastic-fluid turbine, the combination of a fluid-discharging passage, rows of rotary buckets situated in front of said passage, chambered stationary buckets situated between the rows of rotary buckets which act as separators, and means for collecting the moisture from the chambers of the stationary buckets.

20. In combination, a means for dividing a body of elastic fluid into two or more streams, with means simultaneously acting on the several streams for separating the moisture from the vapor.

21. In combination, a means for dividing a body of elastic fluid into two or more separate streams, means for changing the direction of flow of the several streams, and means acting on each of the streams for collecting the moisture from the fluid.

22. In combination, a fluid-carrying passage, with means acting on the fluid body two or more times as it flows through the passage, for fractionally abstracting the moisture therefrom.

23. In combination, a means for dividing a body of elastic fluid into two or more streams, with means acting on each of the streams two or more times in succession, for fractionally abstracting the moisture therefrom.

24. In an elastic-fluid motor, the combination of a fluid-discharging nozzle, a piston which is acted upon by the fluid, means for abstracting moisture from the fluid stream, means for converting the velocity of the fluid stream into thermal energy for superheating the fluid, and a second piston which is acted upon by the superheated vapor.

25. In an elastic-fluid turbine, the combination of an opening for discharging fluid under high velocity, wheel-buckets situated in front of the opening for abstracting a part only of the velocity of the fluid stream, a means for abstracting moisture from the fluid, a means for converting the residual velocity of the vapor stream into heat after it has left the buckets, a second fluid-carrying passage, and a bucket-wheel situated in front of the passage.

In witness whereof I have hereunto set my hand this 12th day of December, 1902.

AUSTIN R. DODGE.

Witnesses:

EDWARD WILLIAMS, Jr.,

ALEX. F. MACDONALD.