

May 12, 1942.

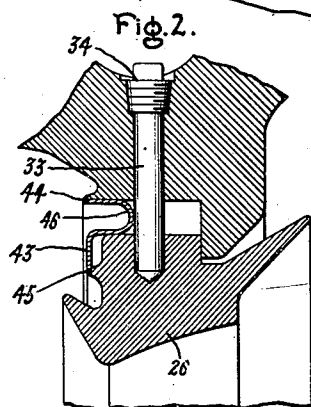
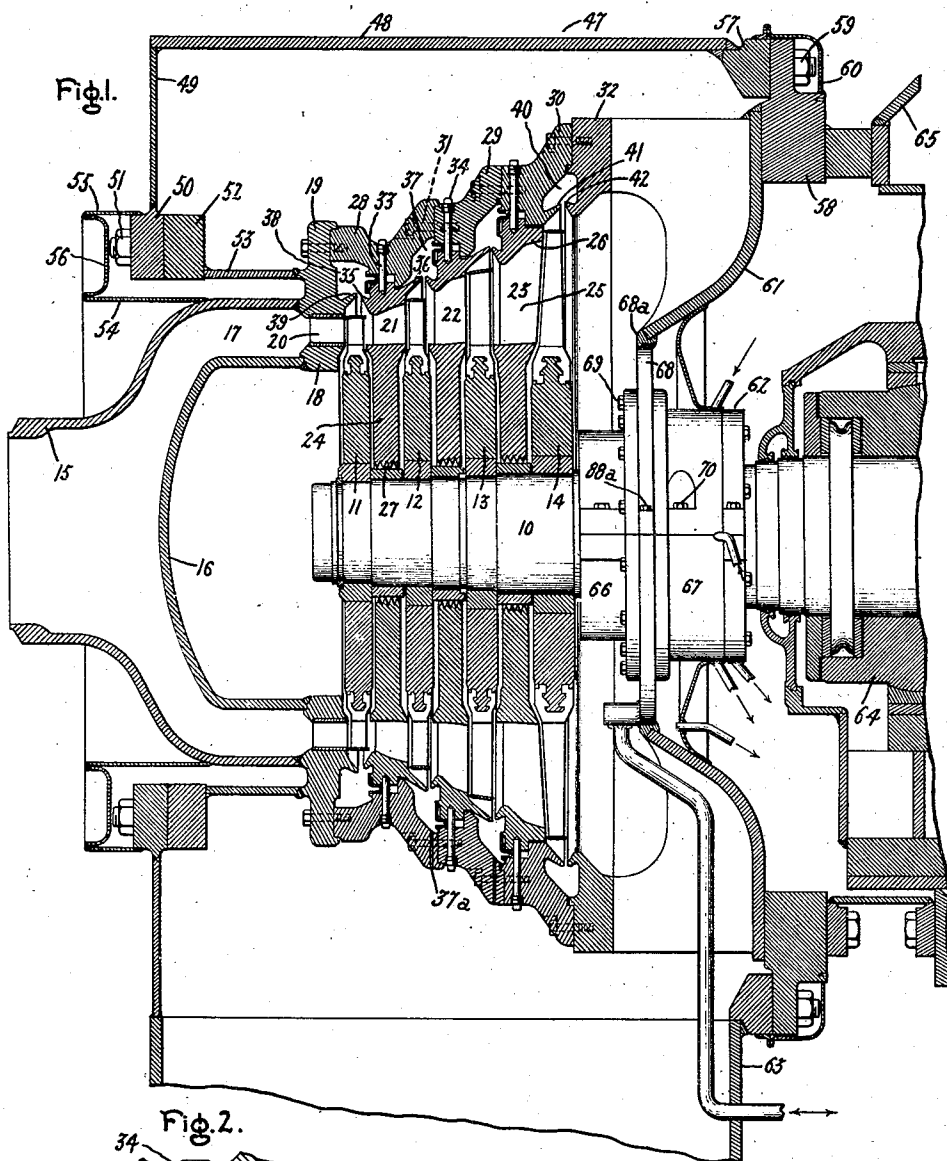
L. A. SHELDON

2,282,894

ELASTIC FLUID TURBINE

Filed April 2, 1940

2 Sheets-Sheet 1



Inventor:
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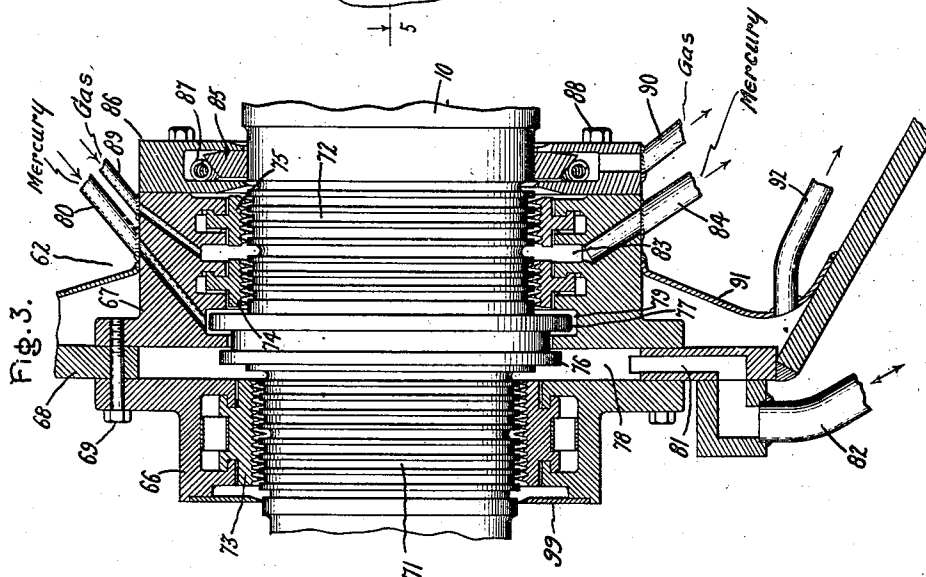
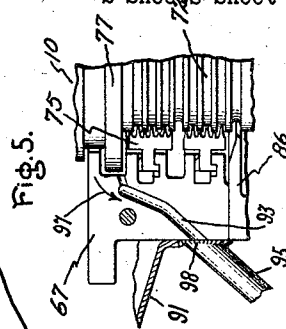
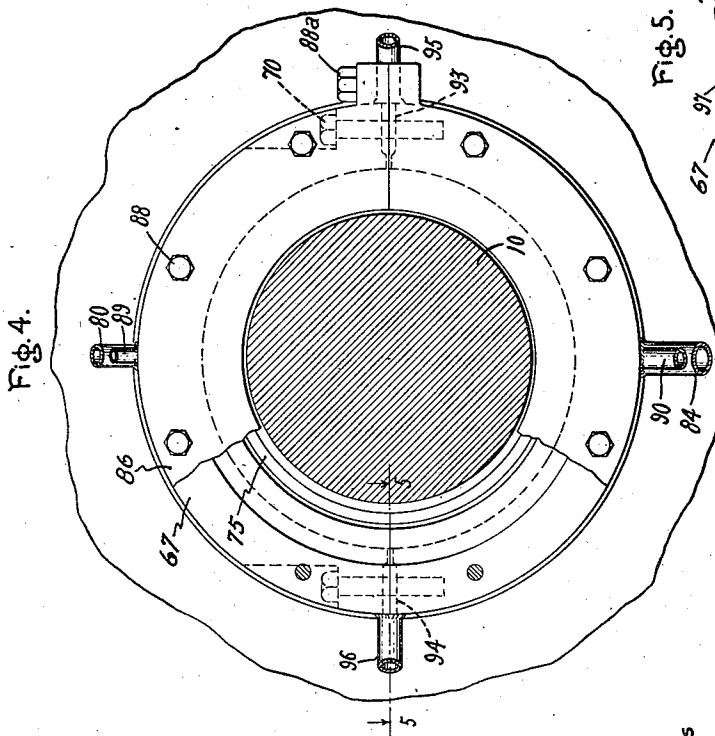
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UNITED STATES PATENT OFFICE

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ELASTIC FLUID TURBINE

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Application April 2, 1940, Serial No. 327,381

4 Claims. (Cl. 253-69)

The present invention relates to elastic fluid turbines and has for its general object the provision of an improved construction and arrangement of elastic fluid turbines. A specific object of my invention is to provide an improved casing or shell construction whereby warpage due to high temperature changes is reduced to a minimum. Another object of my invention is to provide an improved arrangement to reduce leakage of elastic fluid between successive stages of a multi-stage turbine. Still another object of my invention is to provide an improved shaft packing or sealing device to reduce leakage of elastic fluid along the turbine shaft. A further object of my invention is to provide an improved construction and arrangement for centering a turbine diaphragm on a turbine casing.

For a consideration of further objects and of what I believe to be novel and my invention, attention is directed to the following description and the claims appended thereto in connection with the accompanying drawings.

In the drawings Fig. 1 illustrates a sectional view of a turbine embodying my invention; Fig. 2 is an enlarged detail view of a diaphragm centering and supporting arrangement in Fig. 1; Figs. 3 and 4 are enlarged detail views of a packing arrangement of Fig. 1; and Fig. 5 is a view along line 5-5 of Fig. 4.

The turbine arrangement shown in the drawings is especially suited for operation with high temperature mercury vapor although it is not necessarily limited thereto. The arrangement comprises a rotor having a shaft 10 with a plurality of successive bucket wheels 11, 12, 13 and 14 securely fastened thereto; bucket wheels 11 and 14 form part of the first and last turbine stages respectively. Elastic fluid is supplied to the first stage bucket wheel 11 by means including a conduit 15 centrally arranged with the turbine shaft and having a flared end portion surrounding a cap 16 to form therewith an annular channel 17. Concentrically spaced rings 18 and 19 are secured to the end portions of the cap 16 and the conduit 15 and in turn act as a support for a nozzle structure 20. This nozzle structure in the present instance extends over 360 annular degrees and thus constitutes a full admission arrangement for the first stage bucket wheel 11. Elastic fluid discharged from the first stage wheel 11 during operation is conducted to the second stage wheel 12 by means of a diaphragm 21. Similarly, fluid discharged from the bucket wheels 12 and 13 is conducted to the succeeding bucket wheels by means of nozzle diaphragms 22 and

23 respectively. Each nozzle diaphragm comprises a disk 24, a row of circumferentially spaced radial blades 25 with inner ends secured to the disk and outer ends secured to a support on an outer ring 26. Blades 25 define the nozzle passages. The inner portions of the stationary disks 24 are sealed to the shaft by suitable means such as by labyrinth packings 27 to reduce leakage of elastic fluid from higher to lower stages along the shaft. The diaphragms 21, 22, 23 may be split along a plane through the center of the shaft 10 to facilitate assembling and dismantling.

The turbine casing, according to my invention, is composed of a plurality of rings 28, 29 and 30, one ring for each diaphragm 21, 22 and 23 respectively. The rings 28, 29 and 30 are secured together by means of rings of circumferentially spaced horizontal bolts 31. The first ring 28 is secured by bolts to the aforementioned inlet ring 19 and the ring 30 is secured to an outlet ring 32 by horizontal bolts. The various rings of the casing have adjacent shouldered or recessed portions engaging and centering each other and assuring the maintenance of centered relationship during operation. The provision of a casing made of separate rings reduces the heat transfer from the inlet portion of the casing toward its outlet portion and thereby reduces warping as compared with an integrally formed casing.

The diaphragms are supported and centered on the casing. To this end each of the casing rings 28, 29 and 30 and the corresponding outer diaphragm rings 26 are connected by a plurality (at least 3) of circumferentially substantially uniformly spaced radial pins 33 slidably projecting into radial openings in the outer diaphragm rings 26 and the corresponding casing rings and prevented from outward movement by means of plugs 34 screwed into the openings of the rings 28, 29 and 30. During assembly the pins are inserted from the outside through the radial openings in the rings 28 to 30. The plugs 34 are preferably integral with the pins 33 to facilitate removal of the latter. These radial pins support the diaphragms and maintain concentric relation between them and the shaft. During operation the radial pin support permits relative expansion between the diaphragms and the casings without causing the setting up of excessive stresses and at the same time maintains concentric relation.

At least some of the outer diaphragm rings 26 have annular, conically-shaped projections 35 and 36 on opposite sides thereof. The projections 35 and 36 of adjacent rings are closely spaced

and together with the outer casing or casing rings form moisture or liquid collecting grooves or chambers 37. During operation some of the elastic fluid condenses during its passage through the turbine and this condensate is forced outward and collected in the annular grooves or chambers 37 and drained therefrom through openings 37a in the lower parts of the casing. In certain instances the elastic fluid as it leaves the first stage already contains several percent by weight of moisture and it becomes desirable to provide such moisture-collecting grooves also with regard to the first stage. In the present instance a moisture-collecting chamber 38 for receiving moisture from the fluid discharged from the first stage bucket wheel 11 is formed by the projection 35 of the ring 26 of the diaphragm 21 and a projection 39 of the inlet ring 19. A last stage moisture-collecting groove or chamber 40 is formed by projections 41 and 42 of the casing ring 30 and the end ring 32 respectively to receive liquid particles contained in the fluid discharged from the last stage bucket wheel 14.

In order to reduce leakage of elastic fluid through the joints formed between the outer diaphragm rings 26 and the outer casing, means are provided for sealing the outer diaphragm rings 26 to the outer casing. In the present instance each of the outer diaphragm rings 26 is sealed to the corresponding casing ring 28, 29 and 30 by means of an annular sealing strip 43 which has an outer edge secured to the casing or casing ring by a weld 44 and an inner edge secured to the corresponding outer diaphragm ring 26 by a weld 45. An intermediate portion 46 of the strip 43 is U-shaped in cross section and located between adjacent cylindrical surfaces of the outer ring 26 and the corresponding casing ring. The intermediate U-shaped portion 46 renders the sealing ring flexible and permits relative expansion between the diaphragm and the casing.

The casing composed of the rings 19, 28, 29, 30 and 32 constitutes an inner casing or shell and is surrounded by an outer casing or shell 47. The outer casing 47 is fabricated and comprises a substantially, cylindrically-shaped outer wall of sheet metal 48 extending axially beyond the inlet ring 19 and secured at its left-hand end to a disk 49. An inner portion of the disk 49 is fused to a heavy ring 50 which is secured by bolts 51 to another heavy ring 52. The ring 52 is welded to a cylindrical extension 53 of the inlet ring 19. In order to prevent leakage of mercury vapor along the bolts 51 these bolts are sealed by means of concentrically spaced cylinders 54 and 55 fused to the conduit 15 and the ring 50 respectively and having outer edges fused to a sealing strip 56.

The right-hand end of the outer wall 48 is secured to a comparatively heavy ring 57 which is fastened to another heavy ring 58 by bolts 59. The bolts 59 are sealed to the casing by a sealing strip 60. The ring 58 carries an end wall 61 which has an outer portion fused to the ring 58 and an inner portion fused to a packing casing 62. The packing casing 62 forms part of a packing more fully described hereinafter. A lower portion of the outer casing is open and connected to an exhaust conduit 63 for conducting exhaust fluid to a condenser, not shown. During operation elastic fluid discharged from the last stage bucket wheel flows through the space formed between the inner and outer shell into the exhaust conduit 63.

As stated before, the outer shell 47 is extended

axially with regard to the inner casing or shell. With such extension particularly due to the inner casing extension 53 the transmission of distortions and expansion from the inner casing to the outer casing is reduced and in addition the smooth outer surface of the outer casing gives the entire arrangement a pleasing appearance. Moreover, what is more important is the function of the outer casing to reduce temperature drop across and warpage of the inner casing. The pressure maintained in the space between the inner and outer casing is the exhaust pressure of the turbine and the temperature in said space is that of the exhaust fluid. Thus, for example, in case of a mercury turbine operated with an inlet temperature of 1000° and an exhaust temperature of 450° the temperature of the fluid between the inner and outer casing will be about 450°. This means that the maximum temperature drop across the inner casing, more specifically across the inlet ring 19, will be of the order of about 550° which is about one-half of the temperature drop across both casings. Thus, with the provision of a double shell arrangement the temperature drop may be divided up so that the temperature drop across the inner casing is approximately equal to the temperature drop across the outer casing with the space between the casings subject to the exhaust fluid from the last turbine stage. This is particularly important in the case of mercury vapor operated turbines because of the high temperature at which mercury vapor is exhausted in such turbines. The reduced temperature drop across the inner casing and the provision of an inner casing made of a plurality of rings bolted together reduces considerably warpage of the inner casing and permits the latter to be made of relatively light weight.

The shaft 10 carrying the turbine bucket wheels is supported on a suitable bearing 64 which may form part of an electric generator driven by the turbine and having a casing 65 suitably brazed on the outer turbine shell or casing. Thus, the bucket wheels in the present instance are secured to an overhung shaft portion 10 supported on the low pressure end by the bearing 64. The elimination of a bearing for supporting the shaft near the high pressure end of a turbine permits the elimination of a special packing or sealing for the high pressure turbine end which is especially advantageous in the case of mercury vapor turbines.

The packing for sealing the wall 61, that is, the low pressure end of the outer shell 47 to the shaft 10, as shown in Figs. 3 to 5, comprises the packing casing 62 which has a left-hand portion 66 and a right-hand portion 67 secured to opposite sides of a ring 68 by means of a plurality of bolts 69; the portion 66 is located inside the exhaust space of the turbine. The outer edge of the ring 68 is secured to the end wall 61 by a weld 68a. The casing as a whole is split along a horizontal plane through the center of rotation to form two halves joined together by means of a plurality of bolts 70. The shaft portion within the packing casing has two grooved sections, an inner section 71 adjacent the exhaust end of the turbine and within the packing casing portion 66 and an outer grooved portion 72 facing away from the exhaust end and within the casing portion 67. The grooved portion 71 is in cooperative relation with a toothed packing ring 73 suitably supported on the packing casing portion 66 and having teeth in cooperative relation

with the grooved shaft portion 71. The outer grooved portion 72 is in cooperative relation with the teeth of two packing rings 74 and 75 supported on the packing casing portion 67. The shaft portion between the grooved section 71, 72 forms two impellers 76 and 77. The impeller 76 projects into a chamber 78 formed between the spaced casing portions 66 and 67 and the impeller 77 projects into a groove 79 of the packing casing. In a preferred embodiment the impeller 77 and the groove 79 have hardened surfaces which may be formed by hardened metal inserts or covers. The groove 79 is connected through a channel in the packing casing to a conduit 80 for receiving mercury liquid during operation. The liquid thus supplied to the groove 79 forms a liquid seal between the groove and the impeller 77. Part of the liquid continuously supplied during operation to the groove 79 is discharged therefrom towards the impeller 76 which acts as a guide and throws the liquid outward in the chamber 78. The liquid is discharged from said chamber through a channel 81 in the ring 88 and a conduit 82 connected to the channel. Part of the liquid contained in the groove 79 flows along the labyrinth packing 74 towards a groove 83 formed by the casing portion 67 between the labyrinth packing rings 74, 75. The groove 83 is connected to a discharge conduit 84. The outer end of the packing arrangement is further sealed by means of a packing ring such as a carbon ring 85 biased towards an end plate 86 and towards the shaft 10 by means of a helical spring 87. The end ring 86 is secured to the casing portion 67 by a plurality of bolts 88. The end ring 86 is made up of two halves joined and secured together by bolts 88a.

During starting of the turbine a considerable amount of mercury is needed to produce a liquid seal between the shaft and the packing casing. For this reason a great amount of liquid is forced into the chamber 78 through the conduit or pipe 82 to fill the space 78 between the inner and outer grooved shaft portions 71 and 72. As soon as the shaft has reached approximately half speed the mercury liquid is supplied through the conduit 80 to the groove 79 to form a rotary liquid seal whereupon the supply through the conduit 82 is disconnected and said conduit becomes a discharge or drain conduit.

With the provision of the outer grooved shaft section 72 and the labyrinth packing rings 74, 75 small particles of mercury leaking along the shaft are prevented from leaking into the atmosphere. In a preferred embodiment non-oxidizing gas, such as nitrogen, is admitted into the space 83 between the outer labyrinth rings through a pipe 89 at a pressure slightly below that of the atmosphere. This gas is discharged from the space between the packing ring 75 and the carbon ring 85 through a pipe 90. The supply of gas maintains the pressure between the outer labyrinth and the carbon ring to slightly below atmosphere, thus permitting always a slight inflow or leakage of air from the atmosphere into the space 83 to prevent any leakage of mercury into the atmosphere. Leakage of fluid along the adjacent surfaces of the casing portion 66 and the ring 88 flows into the exhaust space of the turbine. Leakage of fluid along the adjacent surfaces of the ring 88 and the casing portion 67 is prevented from flowing into the atmosphere by the provision of a sealing strip 91 secured between the end wall 61 and the casing portion 67. Leakage of fluid into the space

formed by the sealing strip 91 and the adjacent elements is drained through a pipe 92.

The arrangement also includes means to reduce leakage of fluid, particularly air from the atmosphere into the turbine, along the joint formed between the lower and upper halves of the casing portion 67. To this end the joining surfaces of the lower and upper halves of these casing portions are provided with grooves 93 and 94 extending from the outer surface of the casing portion 67 towards the annular groove 79. The grooves 93 and 94 in the present instance are formed in both the lower and upper halves of the casing portion 67. The outer ends of the grooves communicate with pipes 95 and 96 respectively through which a continuous stream of mercury liquid is conducted to the grooves 93 and 94 respectively during operation. With this arrangement mercury, particularly mercury vapor, leaking along a joint formed between the lower and upper halves of the casing portion 67 in the direction of the arrow 97 indicated in Fig. 5 is collected or condensed in the grooves 93, 94 and thereby prevented from reaching the outer end of the casing portion 67 and air from the atmosphere is prevented from leaking into the sealing arrangement. The pipes 95 and 96 are connected to the grooves 93 and 94 respectively by means of welds 98 which extend along the entire end portions of the joined casing portions 67 (Fig. 5). A sealing ring 99 is secured to the left-hand end portion of the packing casing and has an inner edge in close proximity to the shaft to prevent mercury liquid particles from being thrown from the packing towards the last stage bucket wheel.

Thus, a packing according to my invention includes a casing forming three axially spaced annular grooves or chambers, a first groove 78, a second groove 79, and a third groove 83. The second or intermediate groove 79 accommodates an impeller 77 on the shaft. Sealing liquid supplied to the groove 79 during operation forms an annular liquid seal between the impeller 77 and the surface of the groove 79. The first groove or chamber 78 accommodates an impeller or deflector 76 to throw outward mercury liquid discharged from the groove 79 during operation, such liquid being drained from the groove or chamber 78 through a discharge conduit 82. The conduit 82 being substantially wider than the conduit 80 acts as a supply conduit for mercury liquid during the starting operation.

The third groove 83 located near the outer or atmospheric end of the packing and between the two outer labyrinth packing rings 74, 75 acts as a chamber for receiving an inert gas during operation from a supply pipe 89. Such gas, as pointed out above, is preferably supplied at a pressure slightly below that of the atmosphere whereby a small amount of air may be drawn into the packing casing along the carbon packing ring 85 and the discharge of mercury liquid from the packing casing to the atmosphere is substantially entirely prevented.

The packing casing is made of two halves joined together along a horizontal plane through the axis of the shaft and the joint surfaces have sealing grooves for receiving mercury liquid during operation to prevent the leakage of vapor from the packing along the casing joint.

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

1. Elastic fluid turbine comprising an inner casing composed of a plurality of rings bolted

together, an outer casing enclosing the inner casing, a plurality of diaphragms each having an outer ring, a plurality of circumferentially spaced radial pins secured to inner casing rings and slidably projecting into radial openings of the outer diaphragm rings for centering and supporting the diaphragms and permitting relative radial expansion between the diaphragms and the inner casing, the inner casing and the outer diaphragm rings forming annular grooves for receiving moisture from fluid passing through the turbine, and sealing strips connected between corresponding outer diaphragm rings and inner casing rings to prevent fluid from bypassing a diaphragm along the inner surface of the casing.

2. Elastic fluid turbine comprising a casing forming a plurality of shoulders, diaphragms disposed within the casing and each seated against one of the shoulders, each diaphragm having an outer cylindrical surface concentrically spaced from a corresponding cylindrical surface of the casing to form an annular space therewith, and means sealing each diaphragm to the casing, said means comprising an annular strip substantially U-shaped in cross-section and disposed in said space with the legs of the U engaging said cylindrical surfaces and an outer edge fused to the casing and an inner edge fused to the diaphragm.

3. Elastic fluid multi-stage-turbine comprising a casing having a plurality of rings of successively increasing diameter, separate bolting means for securing adjacent rings together, a plurality of diaphragms disposed within the casing, each diaphragm having an outer ring associated with and supported on a casing ring, the outer diaphragm rings having annular conically-shaped projections forming together with the casing annular grooves for receiving moisture from elastic fluid passing through the turbine, the last stage casing rings having inner projections defining a groove for receiving moisture discharged from the last turbine stage, and sealing means for sealing each diaphragm to a casing ring.

4. Elastic fluid turbine comprising a casing with a plurality of axially spaced shoulders, a plurality of diaphragms disposed in the casing and each having a face engaging a shoulder and an outer surface defining an annular groove with the adjacent surface of the casing, and separate sealing means between each diaphragm and the casing, each sealing means comprising an annular strip U-shaped in cross-section located in the groove and having inner and outer edges fused to a diaphragm ring and the casing respectively.

LUCIAN A. SHELDON.