Oct. 20, 1942. R. C. ALLEN 2,299,449

DIAPHRAGM CONSTRUCTION

Filed July 5, 1941 2 Sheets-Sheet 1

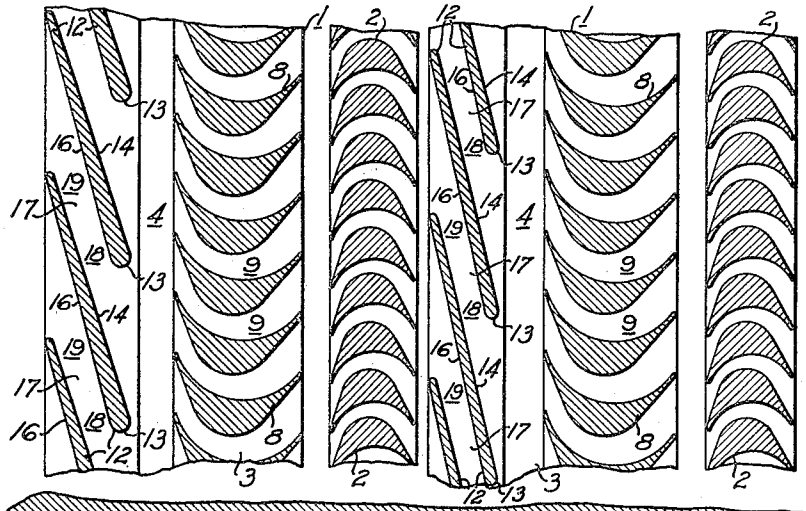


Fig. 2

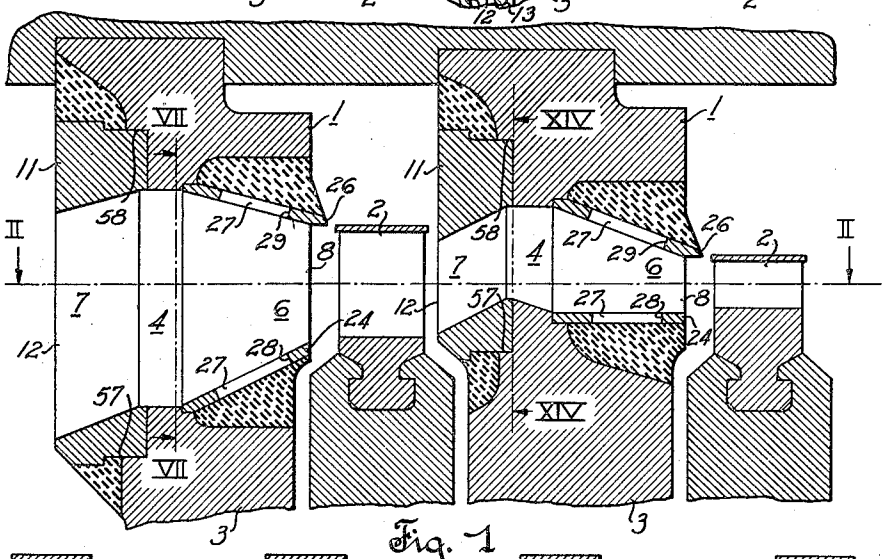


Fig. 1

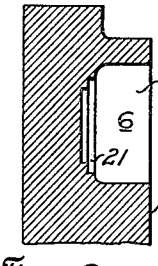


Fig. 3

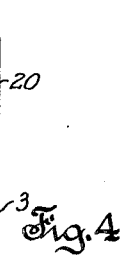


Fig. 4

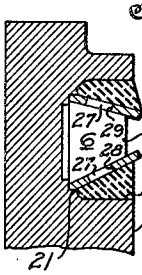


Fig. 5

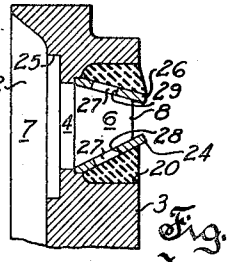


Fig. 6

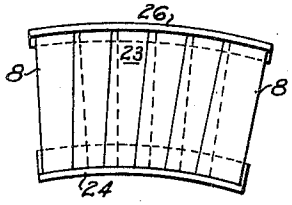


Fig. 7

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DIAPHRAGM CONSTRUCTION

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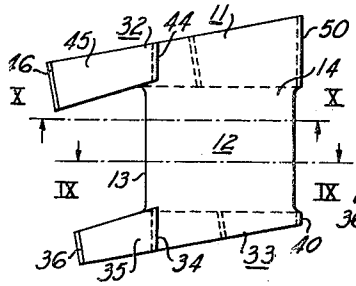


Fig. 8

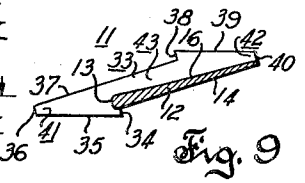


Fig. 9

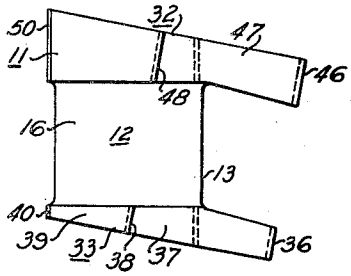


Fig. 11

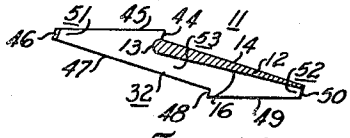


Fig. 10

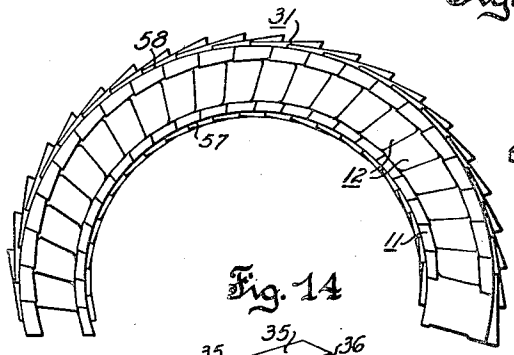


Fig. 14

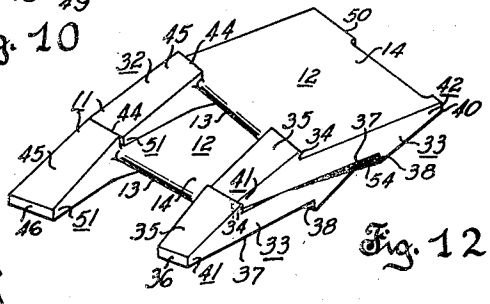


Fig. 12

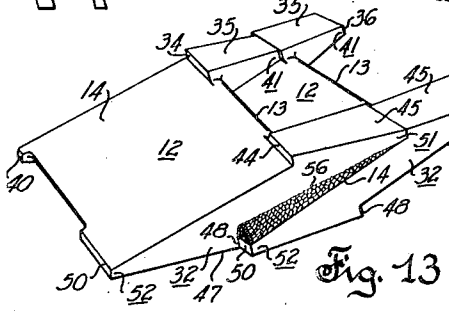


Fig. 13

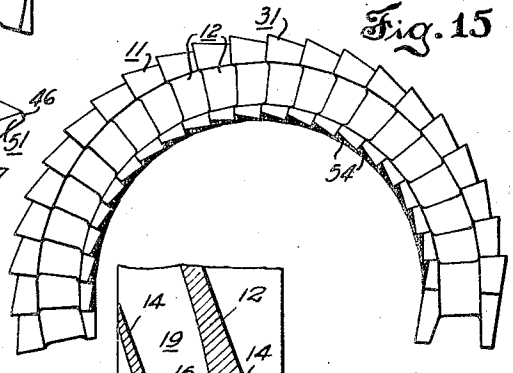


Fig. 15

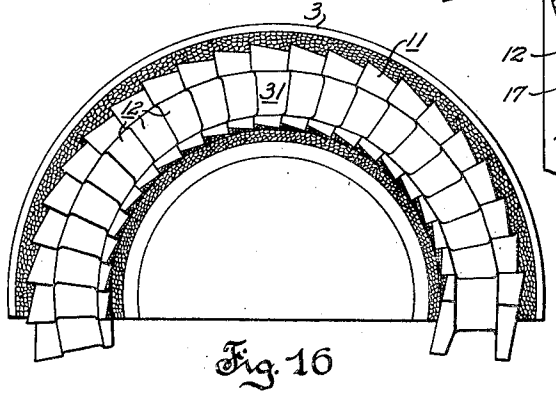


Fig. 16

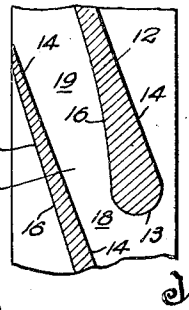


Fig. 17

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UNITED STATES PATENT OFFICE

2,299,449

DIAPHRAGM CONSTRUCTION

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Application July 5, 1941, Serial No. 401,105

11 Claims. (Cl. 253—78)

This invention relates generally to impulse turbines and more particularly to the construction of the diaphragm disposed between the axially spaced rows of moving blades for directing the elastic fluid issuing from one blade row into the next adjacent blade row.

The known diaphragm constructions embody an annular series of circumferentially spaced guide vane or blade elements defining therebetween elastic fluid directing passages, commonly termed "nozzle passages," which are shaped and arranged to receive the fluid issuing from one row of moving blades and to cause the fluid to turn and enter the next row of moving blades. The inlet and outlet angles of the guide vanes are generally nearly equal to the outlet and inlet angles, respectively, of the blades in the associated rows of moving blades and the guide vanes in many turbines are shaped to provide a nozzle passage of nearly uniform cross-sectional area from the inlet to the exit end thereof. However, in most turbines, the cross-sectional area of the diaphragm nozzle passage is decreased from the inlet to the outlet end thereof in order to produce a converging nozzle, while in other turbines the cross-sectional area of the nozzle passage is decreased and then gradually increased to produce a diverging nozzle.

It is now well established, however, that the best nozzle passage efficiency for either stationary or moving blades is obtained (1) with a converging passage of relatively short length when the velocity of the fluid is less than the critical velocity; i. e., the velocity of sound, and (2) with a converging diverging passage when the velocity of the fluid exceeds the critical velocity; that the critical velocity varies from about 1200–1800 feet per second as the temperature increases from about 80° F. to the highest temperature permissible for continuous operation; that the efficiency of the Curtis guide vane construction, such for example, as that shown by the U. S. patent to Curtis No. 541,822, is much less than that obtained with ordinary stationary blades having a maximum radius of curvature consistent with the inlet and outlet angles employed (see, for example, the type of blade shown by the U. S. patent to Egli, No. 2,197,521); and that the efficiency of impulse turbines employing the ordinary types of stationary blades is relatively low unless several stages are employed.

It is also well established that in order to obtain the best possible efficiency the T over r ratio of the fluid passages formed by either stationary or moving blades (where T equals the width of the passage and r the radius of curvature of the concave face) must conform with the velocity of the fluid entering the blades; that in general the channel or passage efficiency improves with low values of T over r; that the edge loss, which increases as a function of the fluid velocity in the channel, reduces the increase in efficiency obtained by employing low values of T over r; that the T over r ratio can be reduced with wide blades although no appreciable gain in efficiency is obtained with a ratio of less than 0.32; that for entering velocities of less than 1000 feet per second the best results are obtained by employing larger values of T over r, the practical range of values being from about 0.36 to 0.60; and that for entering velocities of more than 1600 feet per second the best results are obtained by using a value of T over r equal to 0.34.

In order to obtain good efficiency, a convergent-divergent nozzle passage must permit expansion to take place in a substantially straight line which necessitates a passage construction providing a straight diverging portion disposed in substantial coaxial alinement with respect to the converging portion thereof, and in addition, the stream of entering fluid must be directed toward the converging nozzle portion in substantial coaxial relation. It has heretofore been considered constructionally impractical to machine or otherwise form an integral diaphragm structure providing fluid passages including a turning portion having a proper T over r ratio and convergent and divergent nozzle portions properly correlated with respect to each other and with respect to the turning portion. There are no known turbine diaphragm constructions in which a high temperature elastic fluid is efficiently turned and efficiently expanded to exceed the critical velocity thereby permitting the necessary reduction in fluid pressure to be effected in a high pressure condensing turbine with only a few stages; i. e., with less than five stages, while maintaining an acceptable efficiency.

Consequently, it has heretofore been impossible to construct commercially satisfactory, small, light weight, impulse turbines and it is therefore an object of this invention to provide an improved diaphragm construction for elastic fluid turbines which will render the manufacture of small, light weight impulse turbines commercially practical.

Another object of this invention is to provide an improved diaphragm construction for elastic fluid turbines in which the fluid passages include

a turning portion having a proper T over *r* ratio and converging diverging nozzle portions properly correlated with respect to each other and with respect to the turning portion.

Still anoother object of this invention is to provide an improved method of constructing elastic fluid turbine diaphragms to define fluid passages including a turning portion having a proper T over *r* ratio and converging and diverging nozzle portions properly correlated with respect to each other and with respect to the turning portion.

The invention accordingly consists of the various methods of construction and of the various features of construction, combinations of elements, and arrangements of parts as fully set forth in the appended claims and in the detailed description, in which:

Fig. 1 is a vertical section of a portion of a turbine embodying the invention;

Fig. 2 is a developed view of the blading taken on line II—II of Fig. 1;

Figs. 3–6 illustrate the diaphragm in various stages of construction;

Fig. 7 is a side view of a turning blade segment as seen from line VII—VII of Fig. 1;

Fig. 8 is a view of one side of a nozzle ring forming element;

Fig. 9 is a sectional view taken on line IX—IX of Fig. 8;

Fig. 10 is a sectional view taken on line X—X of Fig. 8;

Fig. 11 is a view of the opposite side of the nozzle ring forming element shown in Fig. 8;

Fig. 12 is a perspective view of two nozzle elements assembled in ring forming relation and showing the manner in which their bottom parts are welded together;

Fig. 13 is a perspective view of two nozzle elements assembled in ring forming relation showing the manner in which their top parts are welded together.

Fig. 14 is a side view of a semicircular nozzle ring forming segment as seen from line XIV—XIV of Fig. 1;

Fig. 15 is a view of the opposite side of the semicircular nozzle ring forming segment shown in Fig. 14;

Fig. 16 is a view looking at the nozzle sides of a semicircular diaphragm member embodying the nozzle ring forming segment shown in Fig. 15; and

Fig. 17 is a partial sectional view exaggerating the convergent divergent portions of a nozzle passage.

Referring to the drawings and particularly Figs. 1 and 2, it is seen that the stationary diaphragm 1, which is disposed between the rows of moving blades 2, comprises a disk member 3 provided with a circumferentially extending passage 4 including an inlet portion 6 and an outlet portion 7. The inlet portion 6 has disposed therein a series of circumferentially spaced elements 8 shaped and arranged to define fluid turning passages 9 having a T over *r* ratio (where T equals the width of the passage 9 and *r* the radius of curvature of the concave face of the element 9) equal to or less than 0.6. The outlet portion 7 has disposed therein a series of nozzle passage forming elements 11 disposed in axially spaced relation with respect to the adjacent edges of the fluid turning elements 8. The nozzle elements 11 each include a passage forming part 12 having a rounded inlet edge 13, a plane side surface 14 and a slightly concave side surface 16 which converges relative to the side surface 14 from the inlet to the outlet edges of the part 12. The parts 12 are circumferentially spaced apart to form therebetween nozzle passages 17 each having a converging inlet portion 18 and a diverging outlet portion 19 disposed in coaxial relation as is best seen in Fig. 2. The converging and diverging passage portions 18 and 19, respectively, are formed by the rounded inlet edge 13 and the concave side surface 16 on one part coacting with the plane side surface 14 on the next adjacent part. It should also be noted in this connection that the converging diverging passage portions 18 and 19 have their common axis extending in the direction the working fluid flows in issuing from the adjacent or discharge end portions of the turning passages 9.

A turbine diaphragm embodying fluid turning and nozzle passages arranged as described in the preceding paragraph is preferably constructed by forming in the outer portion of one face of a diaphragm disk member 3, a circumferential groove 20 having a reduced portion 21 as indicated in Fig. 3, inserting and welding in said groove as indicated in Fig. 4, a series of circumferentially spaced fluid turning elements 8 (the turning elements are positioned and retained prior to welding by the reduced portion 21), forming in the outer portion of the opposite face of said disk member a circumferential groove 22 having a reduced portion 25 as is indicated in Fig. 5 which merges and forms with the groove 20 a passage extending through the disk member 3, inserting and welding in the groove 22, a series of nozzle forming elements 11 as indicated in Fig. 6 (the elements are positioned and retained prior to welding by the reduced portion 25), and then if necessary, machining the diaphragm disk member to remove any excess weld metal and to obtain the final dimensions desired. After the diaphragm disk member has been completed in the manner just described, it is preferably heat treated or annealed to eliminate stresses which may have been set up by the welding and machining operations and to obtain the desired physical properties.

The fluid turning elements 8 prior to their insertion in the groove 20 as previously described are preferably preassembled in segmental groups 23 of the type shown in Fig. 7. This can be readily accomplished by anyone skilled in the art simply by placing the elements 8 in a suitable jig (not shown) which is designed to hold the elements in their proper cooperative relationship and then weld, rivet or otherwise secure the inner and outer ends of the elements 8 to the segmental strips 24 and 26, respectively. The assembly of the segmental groups 23 can be facilitated by providing the ends of the elements 8 with tenons 27 and by forming openings 28 and 29 in the strips 24 and 26 which are arranged to receive the tenons 27 and thereby correctly position the strips 24 and 26 on the ends of the elements 8 as is best indicated in Figs. 1, 4, 5 and 6.

The nozzle forming elements 11 prior to their insertion in the groove 22 as previously described are preferably preassembled in a semicircular segmental group 31 as is best indicated in Figs. 14 and 15. Each element 11 includes thickened top and bottom portions 32 and 33, respectively, which are preferably formed integral with the nozzle passage forming part 12 as is best shown in Figs. 8–13, inclusive. The thickened bottom portions 33 present as best shown in Figs. 9 and 11, a plurality of plane side surfaces of which one

is a continuation of the plane surface 14 of the part 12. The remaining side surfaces, which are designated by numerals 34–40, inclusive, coact with each other and with the surface 14 and form oppositely facing wedge shaped end portions 41 and 42 which are connected by an intermediate portion 43 defined by the surface 16 and the surface 37, the latter being spaced from the surface 16 and extending parallel to the surface 14 as is best seen in Fig. 9. Surface 34 is parallel to surface 40 and surface 35 is parallel to surface 39. Referring to Fig. 10, it is seen that the thickened top portion 32 also presents a plurality of plane side surfaces one of which is a continuation of the plane surface 14 of the part 12. The remaining side surfaces, which are designated by numerals 44–50, inclusive, correspond in number and arrangement to the plane side surfaces 34–40, inclusive, of the thickened bottom part 33 as is obvious from a comparison of Figs. 9 and 10. Consequently, it is seen that the plane side surfaces 44–50, inclusive, of the thickened top portion 32 also coact with each other and with the plane surface 14 and form oppositely facing wedge-shaped end portions 51 and 52 which are connected by an intermediate portion 53 defined by the surface 14 and the surface 47; the latter being spaced from the surface 16 and extending parallel to the surface 14 as is best seen in Fig. 10. In this connection, it should be particularly noted that the plane surfaces 44–50, inclusive, of the thickened top part 32 are parallel to the corresponding plane surfaces 34–40, inclusive, respectively, of the thickened bottom part 33, that the opposed surfaces on the wedge portions 51 and 41, i. e., the underside surface of the member 51 and the upper side surface of the member 41, are nearly parallel, that the intermediate portions 53 and 43 present opposed and substantially parallel surfaces as is best indicated in Figs. 8 and 11, and that the upper side of the top part 32 is parallel to the underside of the bottom part 33 and is oblique with respect to the opposed surfaces presented by the intermediate portions 53 and 43 as is clearly indicated in Figs. 8 and 11.

The nozzle forming elements 11 when shaped in the manner just described can be angularly disposed in abutting superposed ring segment forming relation and thereafter secured in this relation by depositing weld metal along portions 54 and 56 as is clearly indicated in Figs. 12 and 13. The portion 54 is defined by the exposed portions of the surfaces 37 and 38 of one element and the proximate portion of the surface 16 on the abutting underlying element. The portion 56 is formed in a similar manner by the exposed portion of the surface 14 on the underlying element and the proximate portion of the underside of the top part 33 on the said one element. The elements 11 can be readily assembled and securely held in proper cooperative relationship prior to performing the welding operations by any suitable means such as a jig or clamps (not shown). The construction of a suitable jig or clamps for this purpose is within the province of anyone skilled in the art and a further description in this connection is deemed unnecessary for a complete understanding of the invention. Preferably a sufficient number of the elements 11 are assembled in the manner just described to form a nozzle ring segment somewhat greater than 180° as is clearly indicated in Figs. 14 and 15. The nozzle ring segment 31 is then turned in a lathe or otherwise shaped to provide inner and outer concentric shoulder portions 57 and 58 (see Fig. 14) adapted to fit snugly within the reduced portion 25 of the groove 22 (see Fig. 5) and thereby correctly position and retain the nozzle ring segment 31 in its proper cooperative relationship in the disk member 3 as is best indicated in Figs. 1 and 6. The nozzle ring segment 31 is then integrally united with the disk member 3 by filling the space provided between said segment and the inner opposed surface of the groove 22 with a suitable weld metal as is clearly indicated in Figs. 1, 6 and 15. The diaphragm disk member 3 is preferably made in two segments each of which is somewhat greater than 180° as is clearly indicated by Fig. 15 which shows one of said segments and after each segment has been completed to the extent indicated by Fig. 15, it is then finish machined to remove any excess weld metal and to form a 180° segment having the requisite or desired dimensions. Obviously, a complete diaphragm can then be readily formed by assembling two 180° segments in a turbine and in this connection, it should be understood that the diaphragm segments can be secured in the turbine stator in any desired manner and that the construction shown in part by Fig. 1 is to be considered as merely illustrative of a conventional structure.

A diaphragm constructed in the manner just described presents a unitary structure embodying the improved features of construction heretofore unobtainable in the type of structure under consideration. The diaphragm ring segments are preferably constructed by assembling and welding a series of nozzle elements in the manner just described, but it should be understood that the nozzle ring segment could be formed in a different manner, such as by casting, if it is so desired. Moreover, it should also be understood that it is not desired to limit the invention to the exact details and methods of construction herein shown and described as various modifications within the scope of the appended claims may occur to persons skilled in the art.

It is claimed and desired to secure by Letters Patent:

1. An elastic fluid turbine diaphragm adapted to receive the fluid issuing from one row of moving blades and to cause the fluid to turn and enter the next row of moving blades at a velocity exceeding the critical velocity comprising a disk member having therein a circumferentially extending fluid conducting passage including an inlet portion having disposed therein a series of circumferentially spaced fluid turning elements, an outlet portion having disposed therein a series of circumferentially spaced nozzle elements, and said nozzle elements forming therebetween nozzle passages each including coaxial convergent divergent portions having their common axis extending in the direction fluid flows in issuing from the adjacent ends of the passages formed between said turning elements.

2. An elastic fluid turbine diaphragm adapted to receive the fluid issuing from one row of moving blades and to cause the fluid to turn and enter the next row of moving blades at a velocity exceeding the critical velocity comprising a disk member provided with a circumferentially extending fluid conducting passage including an inlet portion having disposed therein a series of circumferentially spaced fluid turning elements, an outlet portion having disposed therein a series of circumferentially spaced nozzle elements disposed in axially spaced relation with

respect to the adjacent ends of the fluid turning elements, and said nozzle elements forming therebetween nozzle passages each including coaxial convergent divergent passages having their common axis extending in the direction fluid flows in issuing from the adjacent ends of the passages formed between said turning elements.

3. An elastic fluid turbine diaphragm adapted to receive the fluid issuing from one row of moving blades and to cause the fluid to turn and enter the next row of moving blades at a velocity exceeding the critical velocity comprising a disk member provided with a circumferentially extending fluid conducting passage including an inlet portion having disposed therein a series of circumferentially spaced fluid turning elements shaped and arranged to define fluid turning passages having a T over r ratio equal to or less than 0.6, an outlet portion having disposed therein a series of circumferentially spaced nozzle elements, and said nozzle elements forming therebetween nozzle passages each including convergent divergent portions having a common axis extending in the direction fluid flows in issuing from the adjacent ends of the passages formed between said turning elements.

4. An elastic fluid turbine diaphragm adapted to receive the fluid issuing from one row of moving blades and to cause the fluid to turn and enter the next row of moving blades at a velocity exceeding the critical velocity comprising a disk member having therein a circumferentially extending fluid conducting passage including an inlet portion having disposed therein a series of circumferentially spaced fluid turning elements shaped and arranged to define fluid turning passages having a T over r ratio equal to or less than 0.6, an outlet portion having disposed therein a series of circumferentially spaced nozzle elements, said nozzle elements forming therebetween nozzle passages each including coaxial convergent divergent portions having their common axis extending in the direction fluid flows in issuing from the adjacent ends of the passages formed between said turning elements, and said diverging passages being dimensioned to expand the fluid passing therethrough to a velocity exceeding the critical velocity.

5. An elastic fluid turbine diaphragm adapted to receive the fluid issuing from one row of moving blades and to cause the fluid to turn and enter the next row of moving blades at a velocity exceeding the critical velocity comprising a disk member having therein a circumferentially extending fluid conducting passage including an inlet portion having disposed therein a series of circumferentially spaced fluid turning elements shaped and arranged to define fluid turning passages having a T over r ratio equal to or less than 0.6, an outlet portion having disposed therein a series of circumferentially spaced nozzle elements which are axially spaced from said turning elements, said nozzle elements forming therebetween nozzle passages each including coaxial convergent divergent portions having their common axis extending in the direction fluid flows in issuing from the adjacent ends of the passages formed between said turning elements, and said diverging passages being dimensioned to expand the fluid passing therethrough to a velocity exceeding the critical velocity.

6. An elastic fluid turbine diaphragm adapted to receive the fluid issuing from one row of moving blades and to cause the fluid to turn and enter the next row of moving blades at a velocity exceeding the critical velocity comprising a disk member having therein a circumferentially extending fluid conducting passage including an inlet portion having disposed therein a number of circumferentially spaced fluid turning elements shaped and arranged to define fluid turning passages having a T over r ratio equal to or less than 0.6, an outlet portion having disposed therein a lesser number of circumferentially spaced nozzle elements which are axially spaced from said turning elements, said nozzle elements forming therebetween nozzle passages each including coaxial convergent divergent portions having their common axis extending in the direction fluid flows in issuing from the adjacent ends of the passages formed between said turning elements, and said diverging passages being dimensioned to expand the fluid passing therethrough to a velocity exceeding the critical velocity.

7. A high pressure impulse turbine comprising a stationary diaphragm disposed between spaced rows of moving blades, said diaphragm having formed therein a plurality of fluid turning passages adapted to receive and turn the fluid issuing from one row of moving blades and a lesser number of nozzle passages adapted to receive the fluid issuing from said turning passages and expand and direct the expanded fluid into the next row of moving blades, said turning passages being formed by a series of circumferentially spaced elements shaped and arranged to define therebetween fluid turning passages having a T over r ratio equal to or less than 0.6, said nozzle passages being formed by a series of circumferentially spaced nozzle parts which is axially spaced from said series of turning elements, and said nozzle parts being shaped and spaced to define therebetween nozzle passages each including coaxial convergent divergent nozzle portions having their common axis extending in the direction fluid flows in issuing from the adjacent ends of the fluid turning passages.

8. A high pressure impulse turbine comprising a stationary diaphragm disposed between spaced rows of moving blades, said diaphragm having formed therein a plurality of fluid turning passages adapted to receive and turn the fluid issuing from one row of moving blades and a lesser number of nozzle passages adapted to receive the fluid issuing from said turning passages and expand and direct the expanded fluid into the next row of moving blades, said turning passages being formed by a series of circumferentially spaced elements shaped and arranged to define therebetween fluid turning passages having a T over r ratio equal to or less than 0.6, said nozzle passages being formed by a series of circumferentially spaced nozzle parts which is axially spaced from said series of turning elements, said nozzle parts being shaped and spaced to define therebetween nozzle passages each including coaxial convergent divergent nozzle portions having their common axis extending in the direction fluid flows in issuing from the adjacent ends of the fluid turning passages, and said diverging passages being dimensioned to expand the fluid passing therethrough to a velocity exceeding the critical velocity.

9. A built-up ring forming segment for elastic fluid turbine diaphragms comprising a plurality of similar elements each having a relatively thin nozzle forming part terminating in thickened

top and bottom portions each presenting oppositely facing wedge shaped ends defined by plane top, bottom and side surfaces, said thin part having a plane side surface forming a continuation of a plane side surface on said top and on said bottom portions, said wedge shaped ends being adapted to coact and angularly position said elements in abutting superposed ring segment forming relation, and weld metal uniting proximate portions of the plane surfaces on the top and bottom parts of abutting elements.

10. A built-up ring forming segment for elastic fluid turbine diaphragms comprising a plurality of similar elements each having a relatively thin nozzle forming part terminating in thickened top and bottom portions each presenting oppositely facing wedge shaped ends defined by plane top, bottom and side surfaces, said thin part having a plane side surface forming a continuation of a plane side surface on said top and on said bottom portions, said wedge shaped ends being adapted to coact and angularly position said elements in abutting superposed ring segment forming relation, said plane surfaces on said top and bottom portions of abutting elements coacting and defining triangular recesses, and weld metal deposited in said recesses.

11. An element for use in constructing built-up ring forming segments for elastic fluid turbine diaphragms comprising a relatively thin nozzle forming part terminating in thickened top and bottom portions each presenting oppositely facing wedge shaped ends defined by plane top, bottom and side surfaces, said thickened portions each having a like number of similarly arranged side surfaces with the side surfaces on one portion disposed in alined parallel relation with respect to the corresponding surfaces on the other portion, and said thin part having a thickened inlet edge and a plane side surface forming a continuation of a pair of corresponding side surfaces on said top and bottom portions.

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