

April 8, 1952

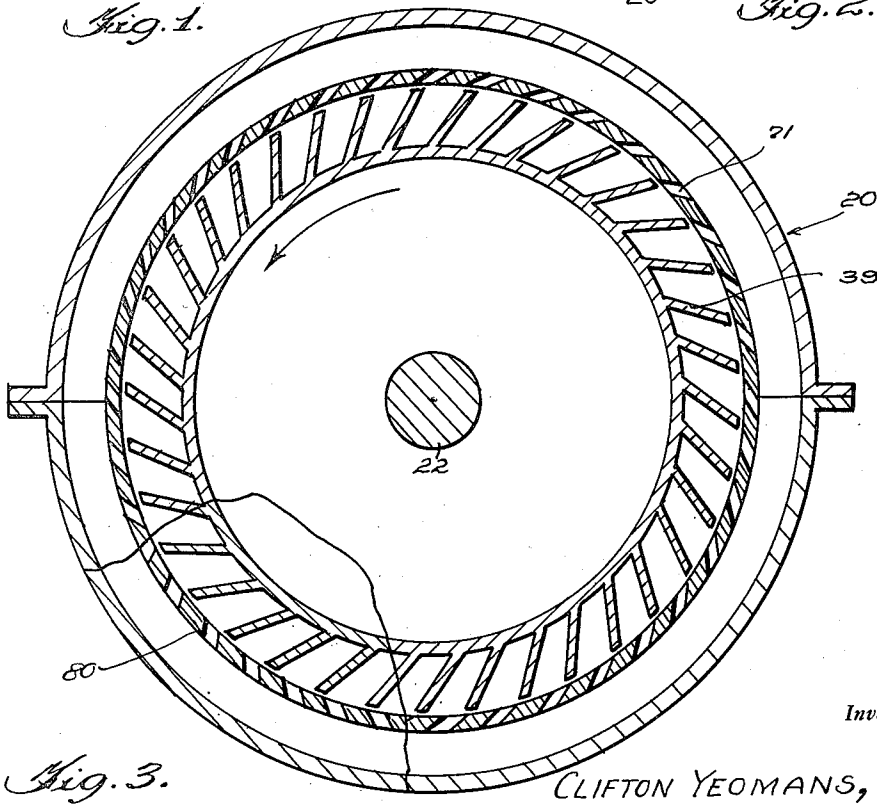
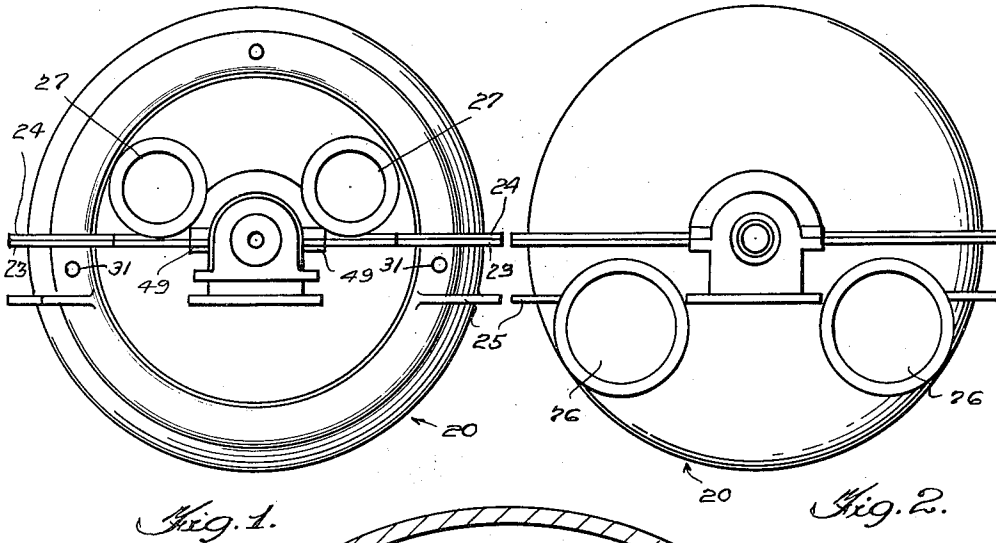
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2,592,227

COMBINED RADIAL AND AXIAL FLOW MULTISTAGE TURBINE

Filed Oct. 24, 1944

6 Sheets-Sheet 1



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6 Sheets-Sheet 2

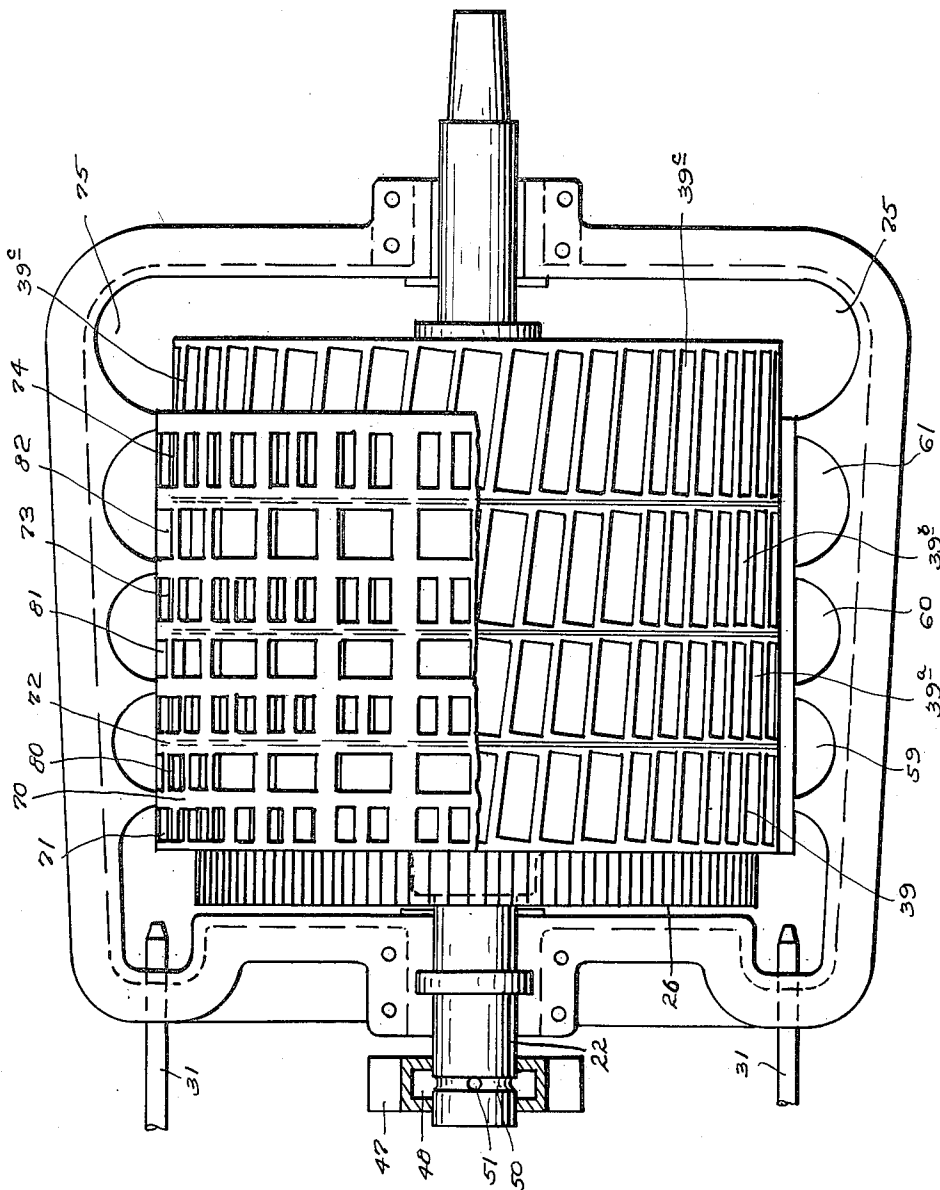


Fig. 4.

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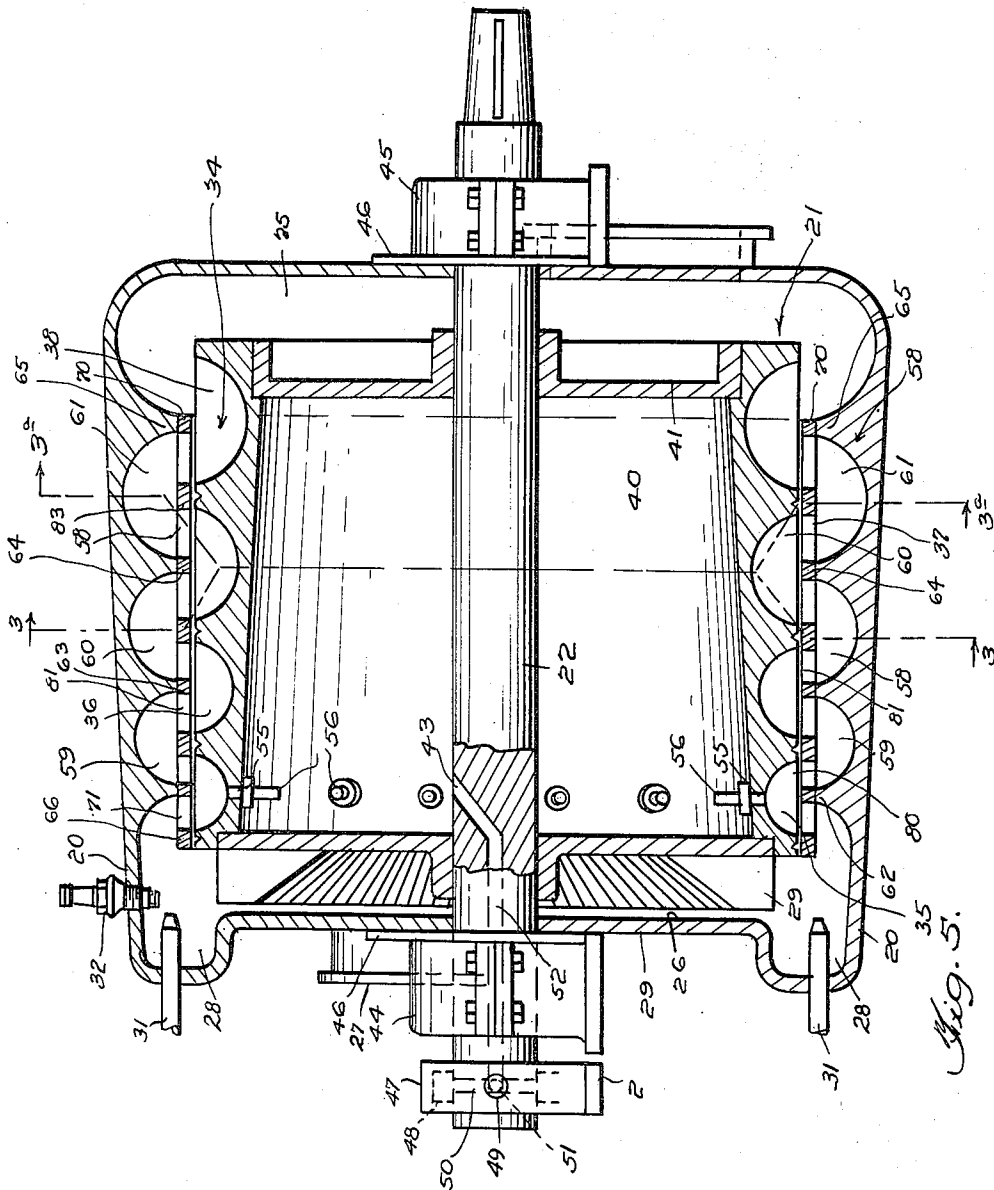
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6 Sheets-Sheet 3



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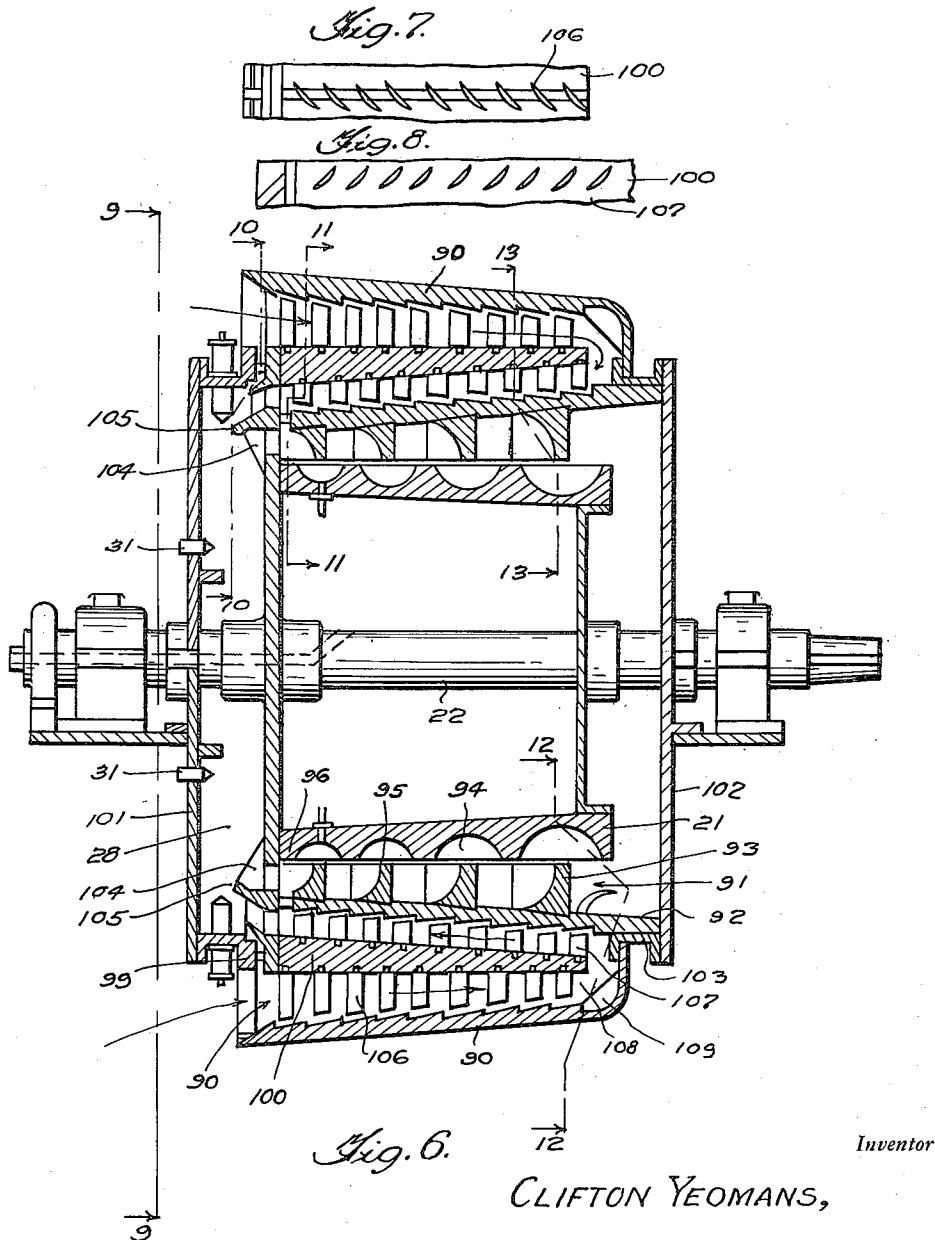
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COMBINED RADIAL AND AXIAL FLOW MULTISTAGE TURBINE

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COMBINED RADIAL AND AXIAL FLOW MULTISTAGE TURBINE

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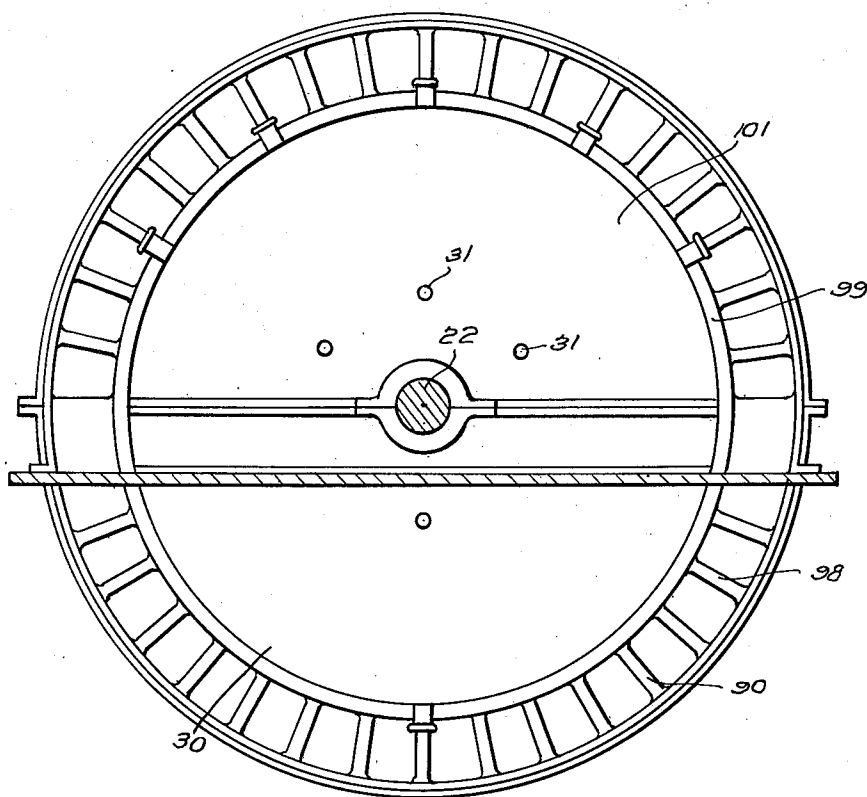


Fig. 9.

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Fig. 10.

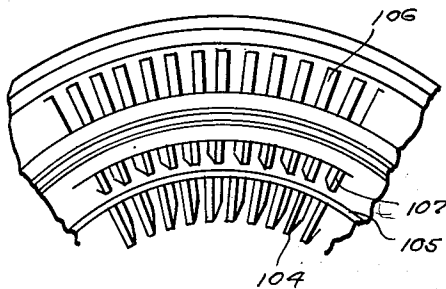


Fig. 11.

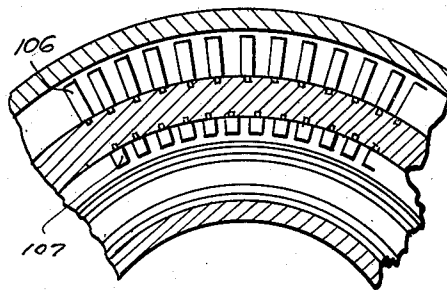


Fig. 13.

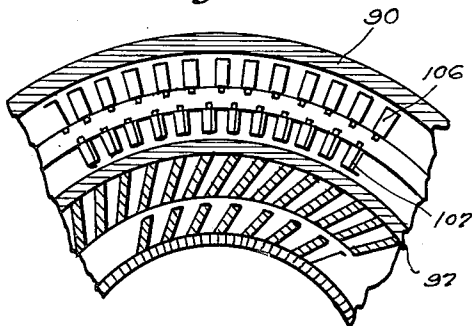
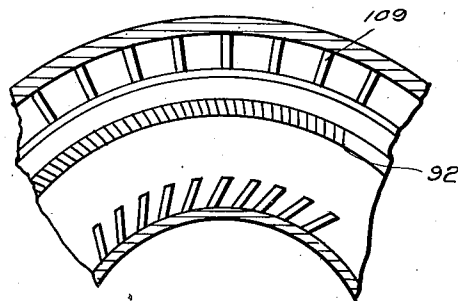


Fig. 12.



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UNITED STATES PATENT OFFICE

2,592,227

COMBINED RADIAL AND AXIAL FLOW
MULTISTAGE TURBINE

Clifton Yeomans, Washington, D. C.

Application October 24, 1944, Serial No. 560,124

5 Claims. (Cl. 60—39.54)

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This invention relates to turbines and although it has specific reference to turbines operated by a gaseous fluid or by a gaseous fluid mixed with steam; it also has reference to turbines driven solely by steam.

The primary object of the invention consists in a turbine in which the thermal and pressure energy of the driving fluid is converted into mechanical power within a minimum of space and with a minimum of weight of the parts necessary to produce the desired conversion.

Another object of the invention consists in providing a turbine which may be operated either as an internal combustion engine, utilizing the gases due to the explosion of a mixture of a fuel and air or may be operated with a mixture of steam and combustion gases or may be operated by steam alone acting as a driving fluid.

A further object of the invention consists in an action and reaction turbine in which the energy of the driving fluid is transformed into mechanical power by a tangential and axial flow of the fluid.

A further object of the invention consists in an action and reaction turbine in which the energy of the driving fluid is transformed into mechanical power by a tangential and axial flow of the fluid.

A further object of the invention consists in providing a turbine of the internal combustion type supplying itself with the air for combustion and being simultaneously equipped for the production of steam within the power unit.

A further object of the invention consists in utilizing the space surrounding the axis of the rotor for the purpose of generating steam.

A still further object of the invention consists in providing a combined turbine and compressor unit, occupying a minimum of space and producing the compression of air necessary for combustion before it enters the combustion chamber.

A number of other objects and advantages will be apparent to those skilled in the art or will be specially referred to in the following detailed specification describing several modifications of the invention. This description by referring to the drawings showing these modifications has to describe specific examples of constructions but it is to be understood that the invention consists in the arrangement, construction and combination of parts in general as outlined in the annexed claims and that the specific examples are described by way of illustrating the best mode of carrying the invention into effect, but are not in any way limitative and that other specific

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details or constructions or arrangements may be substituted for those shown, without departing from the essence of the invention.

The invention is illustrated in the accompanying drawings in which

Figure 1 is an end view of a turbine taken at the fuel admission side;

Figure 2 is an end view of a turbine showing the exhaust side;

Figure 3 is a cross section through the turbine along line 3—3 in Figure 5, part of this section being broken away, this part showing another cross section along line 3a—3a of Figure 5. The cross section along line 3—3 runs through the admission side, the cross section along line 3a—3a through the exhaust side of one stage of the rotor;

Figure 4 is a plan view of the turbine with the upper casing removed showing the lower casing, the jet opening cylinder, partly broken away, and the rotor with its blades;

Figure 5 is an elevational longitudinal section through the turbine according to the invention;

Figure 6 is an elevational longitudinal section through a modification of the invention in which the turbine is combined with an air compressor, and in which the jets acting in the rotor in the various stages are produced by means of a number of rings, equal to the number of stages, each ring being provided with guiding blades;

Figures 7 and 8 are views of small strips of the compressor rotor with the casing removed showing the blades of the compressor;

Figure 9 is an end view of the same modification, partly in section along the line 9—9 of Figure 6;

Figures 10, 11, and 12 are parts of sectional views, showing cross sections through the compressor and rotor along the lines 10—10; 11—11; 12—12; of Figure 6, respectively.

Figure 13 is another sectional view showing a cross section through the compressor and rotor along line 13—13 of Figure 6, which illustrates in detail the ring construction and shows the blades arranged on the rings.

As seen in Figures 1 through 5, the improved turbine comprises a casing 20, enclosing a rotor 21 mounted on a shaft 22.

The casing 20, as shown in Figures 1 and 2 consists of two parts joined by flanges 23, 24. It is supported by a supporting flange 25 which rests on the structure carrying the installation.

The interior of the turbine may be divided into sections or chambers. Near the front or entrance end is the air chamber 26, to which air is admitted

through the openings 27 (Figure 1) when the turbine is operated as an internal combustion engine with or without admixture of steam to the gases produced by explosion. This air is blown into the combustion chamber 28 by means of ventilator blades 29 arranged at the front end of the rotor 21 on the wall 30 which closes the said front end.

Into the combustion chamber 28 pipes 31 (Figures 1 and 5) are projecting through which the liquid fuel, such as gasoline, alcohol, or heavy fuel oils, is admitted. This chamber also carries a number of spark plugs 32, which are operated at predetermined intervals by an igniting device (not shown), and are mainly used in the starting phase, when the interior of the combustion chamber still has a low temperature.

The second section 34 is the expansion or rotor chamber, which houses the rotor 21. The latter consists of a body which is cylindrical at the outside and conical at the inside; the periphery is provided with a number of channels or grooves of semi-toroidal form 35, 36, 37, 38 with gradually enlarged cross sections within which the blades are arranged. The blades 39 are appropriately spaced within these channels and are inclined with respect to the axis of the cylindrical surface and of the turbine as clearly seen in Figure 4. This inclination may also be defined as an inclination of the edge of the blade, located in or near the cylindrical circumference, towards an element or a generatrix of the cylindrical surface, passing through one point of said edge. By virtue of this inclination an action of the gas (or steam) jet on the rotor is exercised as the impact of the jet on the blades produces forces having a component acting in a plane perpendicular to the axis of the turbine and thereby produces rotation around said axis.

This inclination of the blades 39, 39a, 39b, 39c as seen when comparing Figure 3 with Figure 5 is such that the blades are not only inclined at an angle to the axis of the rotor as above defined but are also inclined with respect to the periphery of the rotor, so that they are tangents to an ideal cylinder (or cone) around the axis in addition to being inclined with respect to the latter. As the blades are inclined in two directions it will be easily understood that in addition to the action exercised by the jet and producing a rotary movement by virtue of a component acting in a plane perpendicular to the axis, the change of direction of the fluid streaming along the blades within the toroidal channel or groove of the rotor will also produce a component in the plane, so that the rotor is driven both by action due to the jet and by reaction due to change of direction.

As already described the rotor is provided with a plurality of semi-toroidal channels or grooves 35, 36, 37, 38 carrying blades 39 and each channel represents a stage of expansion. The channels or grooves 35, 36, 37, 38 are, therefore, of unequal width and depth, which are increasing towards the exit or exhaust end.

The rotor 21 is keyed to the shaft 22 and surrounds a central hollow space or chamber 40, which is closed on the ends by walls 30 and 41, which at the same time serve to support the rotor 21 on the shaft 22. This central space is tightly sealed (by means not shown) and forms the steam generating chamber of the turbine in those cases in which steam is to be admitted to the expanding combustion gases.

The generation of steam is obtained by admit-

ting water to said chamber which, as will be clear, is brought to a very high temperature.

Water is admitted through a channel 43 in shaft 22 on which the rotor 21 is mounted. This shaft is journaled in bearings 44, 45 connected with the casing 20 by means of connecting shields 46. The said bearings are supported on the structure supporting the entire installation.

For introducing the water a separate water admission collar 47 is provided. It surrounds the shaft 22 like a bearing and is provided with a cavity 48 to which water under pressure is admitted by means of pipes 49. The shaft 22 is provided with a groove 50 into which several radial channels 51 open which all communicate with a central channel 52. The latter again communicates with the outwardly inclined channel 43.

The water is forced into the chamber 40 and is converted into steam under pressure on account of the high temperature of the rotor. The steam penetrates into the grooves 35 by means of the openings 55 into which short pipe sections 56 are inserted. These pipe sections are of such lengths that they prevent the admission of water which may have collected on the bottom of the rotor especially during the starting stage.

The next section of the turbine is the reaction chamber 58 which comprises the part of the casing surrounding the rotor 21. This section is adjacent to the combustion chamber 28 and comprises a number of semi-toroidal grooves or channels 59, 60, 61 whose size increases gradually in the same way in which the grooves in the rotor are increasing. Between these grooves there are ledges 62, 63, 64, 65, and these ledges serve to support the jet-opening and discharge-opening-cylinder 70 which is provided along its periphery with jet or admission openings 71, 72, 73, 74 for every expansion stage and rotor channel 35, 36, 37, 38. Similarly, this cylinder is provided with discharge or exhaust openings 80, 81, 82 through which the gases mixed with steam are discharged in every stage. The toroidal channels 59, 60, 61, 62 are not provided with blades and admission is simply regulated by the jet- and discharge-opening cylinder.

It will be clear from Figures 4 and 5 that the gases from the combustion chamber 28 will pass through openings 71, pass channel 35 of the rotor, entering between blades 39, pass through discharge openings 80 of cylinder 70, reenter openings 72 of cylinder 70, pass between the blades of rotor channel 36 and continue to pass through the channels of the casing which reverse the direction and through the channels of the rotor until they reach the exhaust chamber 75. From there they are carried away through the exhaust openings 76 (Figure 2) to an exhaust pipe (not shown).

It will be noted from Figure 3 that the openings 71 are not radially directed but are inclined, preferably at an angle which is larger than the angle at which the blades are inclined in this projection in order to reduce resistance during transition from the stationary to the moving part. Similarly, the discharge openings 80 are inclined at an angle less than the angle of the blades, this reduction resulting mostly in an apparent inclination in the other direction to reduce resistance during the passage from the moving to the stationary part.

The operation of the turbine is possible with steam alone, or with expansion gases mixed with steam. The latter is added to the gases for

cooling the rotor and for reducing the temperature at which the parts operate in order to reduce the corrosion of the parts of the turbine.

When operating with steam, the latter is admitted under appropriate pressure through the openings 27 and the blades or vanes 29 may be omitted. No steam is then admitted into the interior of the turbine rotor.

Figures 6 to 13 show another modification of the turbine which is designed for explosive gases which have to be mixed with air.

In this modification the shaft 22 and the rotor 21 are substantially identical with the corresponding parts of the modification as above described. They need not be described in detail. The casing, however, is of a different construction.

As seen in Figure 6, the casing is provided with an outer section 90 housing an air compressor and with an inner section 91 housing the rotor. The inner section 91 in this modification is conical and has a smooth inner surface. The channels of the reaction section of the casing are formed by separate rings 93, 94, 95, 96 which are fixedly mounted within said conical surface and may be held firmly by appropriate means such as screws (not shown) and by caulking after having been fitted properly. The said rings 93, 94, 95, 96 may be provided with blades 97, as clearly seen in Figure 13, subdividing the gas stream and producing the desired jet effect. The cylindrical sleeve inserted between the casing and the rotor, such as shown in the modification illustrated in Figure 4, can therefore be dispensed with. The rings may be relatively short with an arcuate inner surface covering an arc of only 90°.

On the outside the conical part 91 of the casing presents a stepped appearance. It forms the inner surface of a multi-stage rotary compressor which provides the combustion chamber 28 with compressed air.

The said multi-stage compressor is enclosed in a casing 90 of conical shape which may be stepped on the inside. This outer casing 90 is fixed to the turbine casing by means of a large number of radial ribs or spokes 98 (Figure 9) holding a ring 99 which is V-shaped and surrounds the combustion chamber 28; said ring is closed by the front wall 101.

The rear part of the outer casing 90 is joined to the inner casing 92 and to the rear wall 102 of the casing by a ring 103.

In the space between the two members 90 and 91 the rotor of the compressor is inserted which comprises a conical blade carrier 100 fixed to the front wall 30 of the rotor 21 by a number of ribs 104 between which the gases may enter from the combustion chamber into the rotor. The ribs 104 carry a ring 105 which forms a projecting dish-like collar guiding the compressed air which is discharged by the compressor into the combustion chamber.

The blade carrier 100 carries two series of blades 106 and 107 one at the inside and one at the outside. The outer set 106 diminishes in size from the front end to the rear end of the casing in accordance with the increasing pressure while the second set 107 decreases in size from the rear side to the front side. A plan view of a strip of the blade carrier 100 with blades 106 arranged at the outside of the carrier is shown in Figure 7, while a similar strip showing the blades on the inside is shown in Figure 8. The blades have any well-known

shape and are arranged in rows around the blade carrier 100.

The air is drawn in between the ribs 99 and is driven by blades 106 towards the rear end of the casing being more and more compressed during this flow. When the air reaches the chamber 108 on the rear of the casing, which may be provided with radial ribs 109, its direction of flow is reversed (as shown by the arrow) and it is now driven by blades 107 towards the front end, being compressed on the way. It finally is discharged over the collar 105 into the combustion chamber; it has acquired a high pressure during the process and it may therefore be used in connection with heavy fuel oils which are injected through pipes 31.

In other respects, the turbine will operate like the modification shown in Figures 1 to 5.

It will be seen from the above that the turbine according to the invention is an action-reaction turbine combining the advantages of the tangential flow turbine with those of the axial flow turbine. It will also be seen that the turbine may have any size; it may merely have the size of a motor driving a tool or the like, a feature which is of great advantage. The construction is moreover such that a minimum of distortion under the high temperatures will occur. The jet effect produced in each stage allows a certain amount of clearance and a certain amount of distortion may even take place without binding between the moving and the stationary parts.

It will moreover be noted that all the parts used may be easily machined with great precision.

The examples described show a definite direction of rotation, which may be reversed, as well known, by reversing the position of the blades and jet openings with respect to the shaft.

I claim:

1. A multistage turbine for operation with elastic fluids passing through the turbine in a combined axial and radial flow, comprising a rotor with a cylindrical outer surface, provided with a series of juxtaposed radially extending circumferential grooves of substantially semi-circular cross section of increasing width and depth in the direction of axial flow, blades arranged within said grooves inclined tangentially and axially, so that a line proceeding along the blade towards the axis of the cylindrical surface is inclined with respect to a radial plane passing through said axis and a line running along the blade in an axial direction is inclined with respect to the elements of the cylinder, a stator with a cylindrical inner surface provided with a series of juxtaposed radially extending circumferential grooves of substantially semi-circular cross section, of a width and depth increasing in the direction of flow, acting as flow direction reversing chambers, the grooves in the rotor and stator being staggered and a flow dividing cylinder, arranged between the cylindrical surfaces of the rotor and the stator, provided with inlet and outlet openings, the former subdividing the circumferential continuous radial flow of the fluid emerging from the flow reversing circumferential grooves of the stator into a number of separate jets.

2. A multistage turbine for operation with elastic fluids passing through the turbine in a combined axial and radial flow, comprising a rotor with a cylindrical outer surface, provided with a series of juxtaposed radially extending circumferential grooves of substantially semi-

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circular cross section of increasing width and depth in the direction of axial flow, blades arranged within said grooves inclined tangentially and axially, so that a line proceeding along the blade towards the axis of the cylindrical surface is inclined with respect to a radial plane passing through said axis and a line running along the blade in an axial direction is inclined with respect to the elements of the cylinder, a stator with a cylindrical inner surface provided with a series of juxtaposed radially extending circumferential grooves of substantially semi-circular cross section, of a width and depth increasing in the direction of flow, acting as flow direction reversing chambers, the grooves in the rotor and stator being staggered and a flow dividing cylinder arranged between the cylindrical surfaces of the stator and the rotor, provided with inlet and outlet openings of an increased axial width, arranged so as to coincide with stator and rotor grooves respectively, the width of each opening not exceeding one-half of the axial width of the stator and rotor groove covered by the said opening.

3. A multistage turbine for operation with elastic fluids passing through the turbine in a combined axial and radial flow, comprising a rotor with a cylindrical outer surface, provided with a series of juxtaposed radially extending circumferential grooves of substantially semi-circular cross section of increasing width and depth in the direction of axial flow, blades arranged within said grooves inclined tangentially and axially, so that a line proceeding along the blade towards the axis of the cylindrical surface is inclined with respect to a radial plane passing through said axis and a line running along the blade in an axial direction is inclined with respect to the elements of the cylinder, a stator with a cylindrical inner surface provided with a series of juxtaposed radially extending circumferential grooves of substantially semi-circular cross section, of a width and depth increasing in the direction of flow, acting as flow direction reversing chambers, the grooves in the rotor and stator being staggered and a flow dividing cylindrical member interposed between the cylindrical surfaces of the stator and rotor, said member being subdivided into separate axially spaced cir-

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cumferential zones of increasing axial width, a continuous series of ports being provided in said member along said zones, and said member being arranged between the stator and the rotor so that the zones coincide with the overlapping portions of the staggered circumferential grooves in the stator and the rotor, adjacent zones being provided with inlet and outlet openings respectively, the number of the former being equal to the number of blades in the adjacent circumferential rotor groove, so as to subdivide the fluid emerging from a flow reversing stator groove into a number of jets equal to the number of blades in the rotor groove.

4. A multistage turbine for operation with elastic fluids as claimed in claim 1 wherein the inlet openings are provided with radially inclined walls which are also inclined at an angle to the adjacent portion of the blade.

5. The combination of claim 1 including means for generating and introducing steam into the first stage of the turbine.

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