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E. A. KRAFT

COMPOUND ELASTIC FLUID TURBINE

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Fig. 1

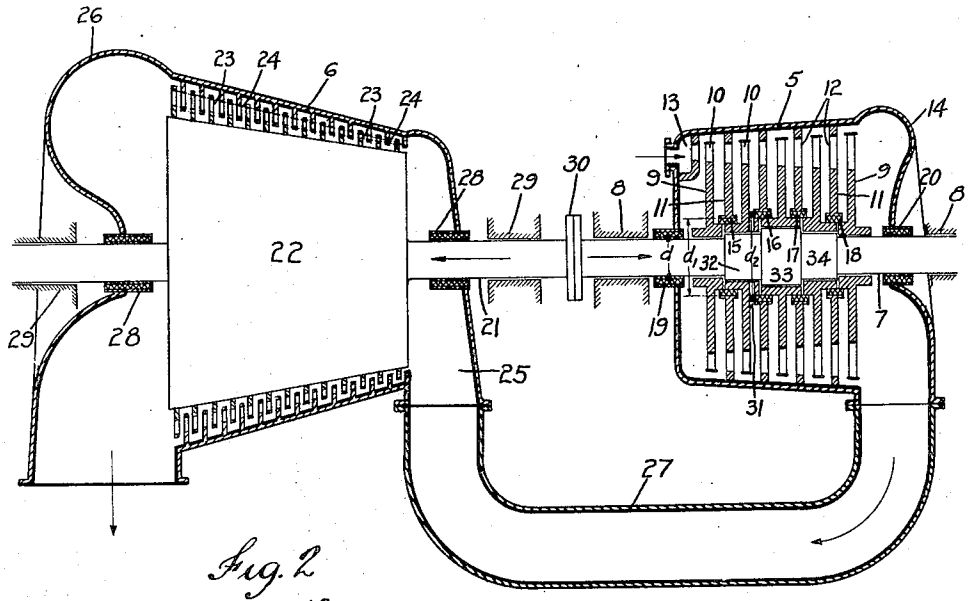
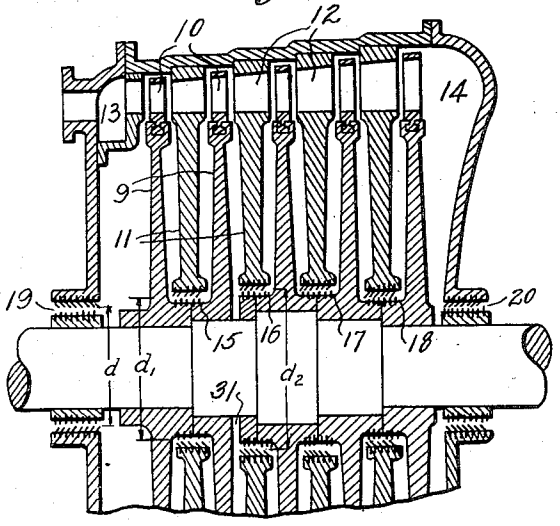


Fig. 2



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COMPOUND ELASTIC-FLUID TURBINE.

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The present invention relates to elastic fluid turbines, and more particularly it relates to compound turbines comprising two or more turbine units mounted on a common shaft, one or more of said units being of the reaction type.

In certain compound turbines which are being used more extensively at present, the arrangement comprises an impulse or bladed-disk turbine as a high pressure unit mounted on a common shaft with a low pressure unit of the reaction or bladed drum type, the low pressure unit being connected with the high pressure unit to receive the exhaust motive fluid therefrom.

Because of the relatively high axial thrust set up by the reaction turbine unit, which the impulse turbine unit, from the nature of its operation, is not designed to meet with a compensating counter thrust of the desired magnitude, auxiliary means for compensating the thrust of the reaction unit in such compound turbines have been required heretofore. Chief among such auxiliary means have been the well-known balancing piston arrangement and the divided flow reaction unit.

The use of a balancing piston arrangement involves an auxiliary device with additional packings of complicated design on which the successful operation of the device depends, and because of its recognized disadvantages, such as lack of reliability, it has been superseded by the divided flow reaction turbine unit in which the motive fluid flows in opposite directions in separate parts thereof, the axial thrust of one part serving to compensate or neutralize the axial thrust of the other. The further division of a turbine already comprising separate high and low pressure units, such as the modern compound turbine above mentioned, leads to complications in design, greater size and increased manufacturing costs.

It is the object of this invention to provide a simple and improved arrangement in a compound elastic fluid turbine comprising an impulse unit, which will operate to automatically compensate or neutralize the axial thrust of the reaction unit without dividing the reaction unit, and without the use of complicated or auxiliary devices, whereby the above-mentioned disadvantages accruing to thrust compensating arrangements used heretofore are obviated.

In carrying out the object of the invention in one of its aspects, an impulse turbine is mounted on the same shaft with a reaction turbine which serves as a low pressure unit receiving motive fluid from the exhaust of the impulse turbine, the flow of motive fluid in the two turbines being in opposite directions. Such an arrangement is illustrated in the accompanying drawing, to which, the description thereof and the appended claims attention is now directed for a further consideration of what is believed to be novel and the invention.

In the drawing, Fig. 1 is a sectional side view of an impulse and reaction turbine unit embodying the invention, and Fig. 2 is a sectional side view of a portion of the impulse turbine of Fig. 1, on an enlarged scale.

Referring to the drawing, 5 and 6 are the high and low pressure units respectively of an axial flow compound turbine. The high pressure unit 5 is a multistage impulse or action turbine of the usual bladed-disk or wheel type comprising a shaft 7 mounted on suitable bearings 8, a series of spaced bucket wheels 9 carried by the shaft and provided with annular bucket rings 10, and stationary diaphragms 11 provided with suitable annular nozzle rings 12, interposed between the wheels to segregate the latter into successive stages between a high pressure inlet chamber 13 and a low pressure exhaust hood 14. Suitable annular interstage packings 15, 16, 17 and 18, carried jointly by the diaphragms and the wheel hubs serve to maintain a pressure difference between the adjacent stages in the usual manner, while similar high and low pressure end packings 19 and 20 respectively are provided for the shaft at the turbine ends.

The low pressure unit 6 is a multistage reaction turbine of the usual bladed drum type comprising a shaft 21 on which is mounted a rotor or drum 22 of comparatively large diameter. The drum carries a series of blade rings 23 between which are interposed suitable stationary reaction nozzles or guides 24 forming with the bucket

rings a series of reaction stages between an inlet chamber 25 at one end and an exhaust hood 26 at the other end.

The two units are arranged to be traversed by motive fluid in opposite directions and so that the flow in the high pressure or impulse unit is in a direction opposing the axial thrust of the low pressure or reaction unit. In carrying out this arrangement in the present example, the turbines are placed with their inlet ends adjacent each other and are connected for compound operation by a conduit 27. The low pressure unit then receives exhaust elastic fluid from the high pressure unit.

Shaft 21 of the low pressure turbine is provided with end packages 28 similar to those provided for shaft 7 in the high pressure unit and is axially aligned with said shaft in suitable bearings indicated at 29. The shafts are joined at their adjacent ends by a shaft coupling 30 to form a common shaft for the turbine.

With this arrangement the axial thrust on the shaft 21, which is set up in the low pressure reaction unit by the pressure in the inlet chamber 25 acting on the large end surface of the drum 22 and by the reaction thrust in the stages, is transmitted to shaft 7 of the high pressure unit. This thrust is represented by the arrow on shaft 21, and since the motive fluid flow in the two units is in opposite directions the slight axial thrust of the high pressure impulse unit tends to compensate this thrust with a counter thrust in the opposite direction. This counter thrust in impulse or disk type turbines, such as the high pressure unit shown, is relatively low, as hereinbefore mentioned, and therefore cannot be utilized to fully balance the thrust of the low pressure reaction unit.

It has been found, however, that an impulse turbine unit in connection with a reaction turbine unit may be arranged to fully compensate or neutralize the axial thrust of the latter by the proper selection of the interstage packing diameters to provide enlarged areas exposed to the thrust of the motive fluid in the successive stages. This arrangement is carried out in connection with the high pressure unit of the present example by making the high pressure end packing with a certain relatively small or normal diameter d and increasing the diameters of the successive interstage packings 15, 16, 17 and 18 in a series of graded steps d_1, d_2, toward the low pressure or exhaust end of the turbine, that is, in the direction of the motive fluid flow.

The interstage packings may be of any suitable construction, such as the usual labyrinth packings which comprise an annular externally-grooved ring carried by the shaft or rotor, and a similar stationary internally-grooved ring carried by the diaphragm within which the first ring rotates with a slight clearance. Thus any pressure exerted on the rotor area between the shaft and the packing will tend to move the rotor in the direction of said pressure.

In the present example, the pressure acting on the area provided by the high pressure side of packing 16, which area is represented by d_2, sets up a right-hand axial thrust on the shaft which overbalances a left-hand axial thrust on the shaft set up by the pressure acting on the area provided by the low pressure side of packing 15, which area is represented by d_1, while the pressure acting on the area provided by the high pressure side of packing 15, which area is also represented by d_1, sets up a right-hand thrust on the shaft which overbalances a left-hand thrust set up by the pressure acting on the area provided by the inner end of packing 19, which area is represented by d. By this arrangement, it will be seen that the combined overbalance of the different stages in the right-hand direction may be made to equal and balance the left-hand thrust set up by the reaction unit 6.

In order to cut down leakage losses between stages which are increased with an increase in the packing diameters, the lower pressure packings 17 and 18 are given the same diameters as packings 16 and 15 respectively. Also the low pressure end packing 20 is of the same diameter as the high pressure end packing 19 for this reason, although it should be understood that its effective area may be increased to assist in the compensation of the axial thrust, like those of the interstage packings by increasing its diameter within limits determined by the permissible leakage losses. An increase or decrease in the lower pressure stage packing diameters is not as effective in changing the axial thrust as is a corresponding change in the higher pressure stage packing diameters because of the much lower pressure drop per stage in the low pressure stages. For this reason in certain cases, like that of the present example, the increasing packing diameters may not be carried back progressively increasing to the low pressure end of the turbine, but may, for the reason above given be reduced in the direction of the low pressure end of the turbine as shown, without affecting the axial thrust beyond limits which may be compensated for by the use of proper high pressure packing diameters and corresponding pressure areas. The effective pressure area, as provided by the large diameter interstage packings, may be increased by providing an annular pressure groove adjacent one or more of the packings on the higher pressure side thereof, as indicated at 31.

The arrangement is such that the pressure

to the right (as viewed in the drawing) in each thrust compensating stage, acting on the enlarged pressure area provided by its right-hand packing, sets up an axial thrust to the right thereon which is transmitted to the shaft and which overbalances an axial thrust to the left also transmitted to the shaft and set up by said pressure acting on the smaller pressure area provided by the left-hand packing of said stage. The desired pressure areas are obtained by increasing the diameters of the interstage packings in as many of the diaphragms as is necessary to provide the desired counter pressure or axial thrust to compensate or neutralize the axial thrust of the low pressure reaction unit. This counter pressure is indicated by the arrow on shaft 7. In any case, the diameter of the high pressure end packing will be maintained at a minimum value because it is subjected to a high pressure and consequently higher leakage losses than other packings of the same diameter and because its location with respect to the pressure exerted on it is such that it tends to move in the direction of the axial thrust of the low pressure reaction unit, and in opposition to the compensating thrust provided by the arrangement in the remainder of the packings. The use of a small diameter, high pressure packing also permits the use of correspondingly smaller diameter packings throughout, thereby reducing packing leakage areas while maintaining the compensating thrust arrangement.

In providing the interstage packings of gradually increasing diameter, the shaft is preferably provided with corresponding stepped or shouldered sections 32, 33 and 34 on which the bucket wheels are mounted. This permits the use of bucket wheels with short webs, and considerably stiffens the shaft and rotor structure. It will be noted that the axial thrust compensating arrangement provided in accordance with the invention is relatively simple in construction as compared with devices used heretofore for the same purpose. This materially reduces the cost of manufacture, and renders it more reliable in operation since there are no complicated parts to get out of order.

While the invention has been described in connection with a turbine having separate high and low pressure units of the impulse and reaction type respectively, it should be understood that it may be applied to any axial flow turbine having a unit or section requiring compensation of its axial thrust and another unit or section which normally provides little or no axial thrust and which is provided with interstage packings capable of being increased in diameter.

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

1. In an elastic fluid turbine, the combination of a reaction unit and an impulse unit mounted on a common shaft, said units being traversed by motive fluid in opposite directions, means forming a series of pressure stages in the impulse unit, and packings between the stages for the shaft, said packings being of increasing diameters in a series of graded steps in the direction of motive fluid flow.

2. In an elastic fluid turbine, the combination of a multistage impulse turbine unit, a reaction turbine unit, a common shaft on which said units are mounted, means for directing motive fluid through said units in opposite directions, and interstage packings in the multistage impulse unit of increasing diameter one with respect to the other in the direction of flow of elastic fluid therein.

3. In an elastic fluid turbine, the combination of a multistage impulse turbine unit, a reaction turbine unit, a common shaft on which said units are mounted, means for directing motive fluid through said units in opposite directions, end packings for the impulse turbine unit, and interstage packings for the impulse unit of larger diameter than the end packings.

4. In an elastic fluid turbine, the combination of a multistage impulse turbine unit, a reaction turbine unit, a common shaft on which said units are mounted, means for directing motive fluid through said units in opposite directions, end packings for the impulse turbine unit, and interstage packings for the impulse unit of larger diameter than the end packings, certain of said interstage packings being of increasing diameter one with respect to the other.

5. In an elastic fluid turbine, the combination of a reaction unit and an impulse unit mounted on a common shaft, said units being traversed by motive fluid in opposite directions, said impulse unit having a high pressure and a low pressure end and a series of stages between said ends, a rotor, end packings for the rotor, and interstage packings for the rotor of increasing diameter toward the low pressure end one with respect to the other.

6. In an elastic fluid turbine, the combination of a reaction unit and an impulse unit mounted on a common shaft, said units being traversed by motive fluid in opposite directions, said impulse unit having a high pressure and a low pressure end and a series of stages between said ends, a rotor, high and low pressure end packings for the rotor, and interstage packings for the rotor of increasing diameter toward the low pressure end one with respect to the other, said interstage packings being of larger diameter than the high pressure end packing for the rotor.

7. The combination with an elastic fluid

turbine having a rotor to which is imparted an axial thrust when in operation, of a multistage axial flow elastic fluid turbine having a rotor joined with said first-named rotor to receive the axial thrust therefrom, means for directing elastic fluid through said multistage turbine in a direction opposite to that of said axial thrust, annular interstage pressure packings in said multistage turbine for the rotor thereof, end pressure packings for said rotor, the interstage packings being of greater diameter than the end packings and of differing diameters one with respect to the other.

8. The combination with an elastic fluid turbine having a rotor to which is imparted an axial thrust when in operation, of a second elastic fluid turbine having a rotor axially aligned and joined with the rotor of the first-named turbine whereby said axial thrust is transmitted to the rotor of the second turbine, and means in the second turbine for compensating said axial thrust, comprising a plurality of pressure stages arranged in series relation along the rotor, which stages receive motive fluid in a direction opposite to the axial thrust, and interstage packings for the rotor of increasing diameter one with respect to the other in the direction of the motive fluid flow.

9. The combination with a reaction elastic fluid turbine, of a multistage impulse elastic fluid turbine mounted on a common shaft therewith, said turbines being traversed by elastic fluid in opposite directions, and said impulse turbine comprising a stepped shaft providing sections of differing diameters along its length, bucket wheels mounted on said stepped sections, rotating annular packing members carried by the bucket wheels concentrically with the stepped shaft sections, diaphragms between the bucket wheels providing separate pressure stages and stationary annular packing members carried by the diaphragms and operatively located with respect to the first-named packing members to form therewith interstage packings.

In witness whereof, I have hereunto set my hand this 26th day of May, 1925.

ERNEST A. KRAFT.