June 16, 1936. F. LJUNGSTRÖM 2,044,435

TURBINE

Filed Dec. 5, 1933 2 Sheets-Sheet 1

Fig. 3

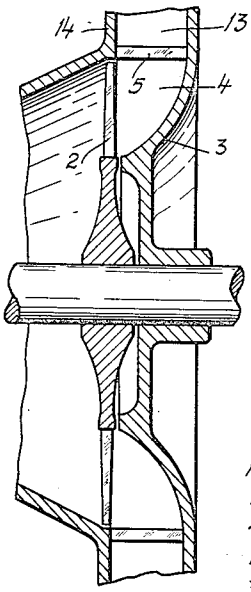


Fig. 2

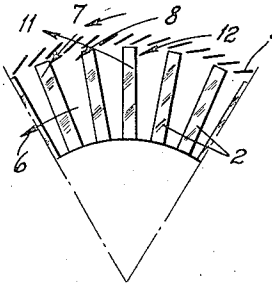


Fig. 7

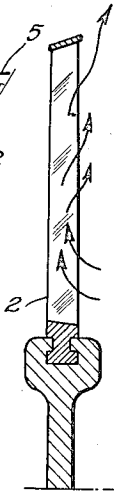


Fig. 1

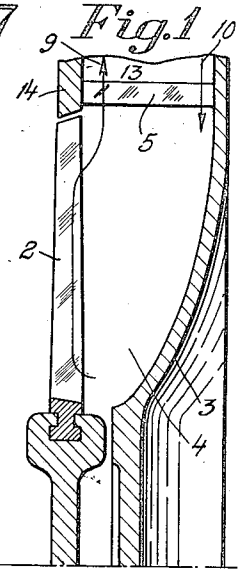


Fig. 4

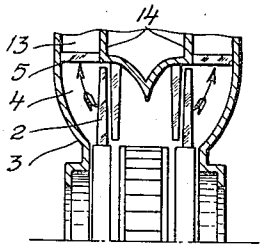


Fig. 5

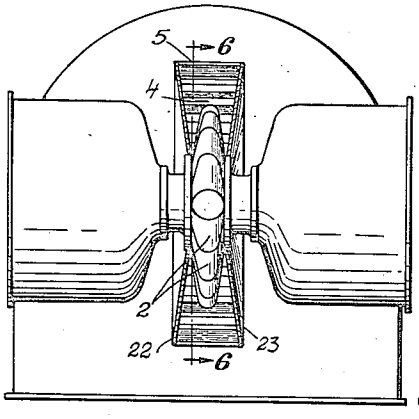
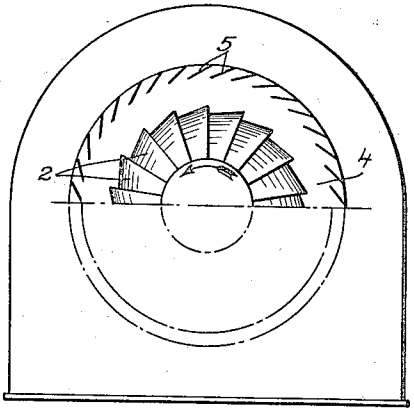


Fig. 6



INVENTOR
Fredrik Ljungstrom
BY
Cameron, Kerkam & Sutton.
ATTORNEYS.

June 16, 1936. F. LJUNGSTRÖM 2,044,435

TURBINE

Filed Dec. 5, 1933 2 Sheets-Sheet 2

Fig. 8

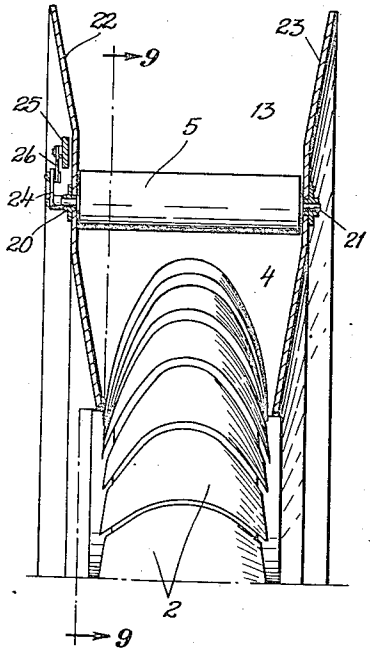


Fig. 9

INVENTOR
Fredrik Ljungstrom
BY
Cameron, Kerkam & Sutton
ATTORNEYS.

Patented June 16, 1936 2,044,435

UNITED STATES PATENT OFFICE

2,044,435

TURBINE

Fredrik Ljungström, Lidingo III, Sweden, assignor to Aktiebolaget Spontan, Stockholm, Sweden, a corporation of Sweden

Application December 5, 1933, Serial No. 701,030
In Sweden December 17, 1932

9 Claims. (Cl. 253—16.5)

One of the difficulties met with in the design of the blade systems for large gas or steam turbines consists in the tendency, particularly of the longer turbine blades, to oscillate. These oscillations may under unfavourable conditions become so large that the blades fail due to breakage caused by the fatigue of the material. Such blade oscillations may be caused either by an incomplete balance of the rotating parts of the turbine or by irregularities in the gas or steam flow which may cause blade vibrations or flutter similarly as in the case of a flag fluttering in the wind, or similarly to the oscillations of a leaf spring at the tone openings of an accordion thereby causing a certain tone.

Correspondingly one finds that the oscillations of turbine blades which are caused by a stream of gas or steam always automatically assume the natural frequency of oscillation of the blade. The gas flow may cause the amplitudes of the oscillations to increase to such magnitude that the blades fail, or until such a limit is reached that the damping action of the gas or steam stream automatically limits the amplitude of the oscillations. Hence it is of importance that the impulses causing the oscillations, that is to say the irregularities in the gas or steam flow through the turbine blades, be reduced to a minimum, so that the damping effect which in turn is caused by the oscillations is capable of reducing these oscillations to a minimum or to eliminate the same entirely. During normal operation of a steam turbine it is generally possible through proper design of the blade system to obtain a uniform steam flow through the various rows of blades, so that the turbine blades only to a minor degree are exposed to undesirable impulses. Quite different conditions are met with when the steam supply to the turbine is interrupted or if the vacuum in the turbine outlet is destroyed, that is to say if air is permitted to enter the turbine casing causing the pressure in the turbine outlet to rise quickly. Hereby the density of the medium surrounding the turbine blades is increased considerably and at the same time the last blade rows of the turbine, hereafter termed the exhaust blades, will work more or less like a centrifugal compressor taking steam or gas from the centre of the turbine and throwing it to the outside of the turbine casing thereby causing a continuous circulation within said casing. Due to the very high peripheral velocities at the exhaust blades of steam turbines, large amounts of energy are in this manner transmitted to the rotating mass of gas in the turbine casing. For example, it has been observed that a steam turbine of 50,000 kw., at normal number of revolutions and with the steam supply shut off, consumed an amount of energy of 5,000 kw., which had to be supplied by the electric generators. It is evident that such large amounts of energy consumed by a mass of gas or steam circulating within the turbine casing in between the turbine blades cause disturbances which as a result of the elasticity of the gas readily may lead to periodic oscillations of the system. Particularly the turbine blades may be set in violent oscillations by such a mass of gas circulating within the turbine.

The object of my invention is to decrease or to eliminate entirely those blade oscillations which are caused under those circumstances where the steam or gas tends to retard the turbine, i. e., when particularly the exhaust blades act as a compressor pump and transmit energy to the steam contrary to the conditions existing under normal operation where the steam gives off its energy to the blades. The inventive idea consists primarily in that the turbine outlet is so designed that the steam or gas is prevented from being pumped in a closed circuit within the turbine casing. According to the invention the annular space provided adjacent to the outmost row of blades, providing a body of rotation defined interiorly and laterally by said exhaust blades and the adjoining portions of the walls of the turbine outlet, respectively, is defined exteriorly by a plurality of guide members, for instance, blades or plates, inclined in the flow direction of the exhausted gas or steam, so as to counteract the pumping tendency of the exhaust blades during idle running or abnormal flow conditions and to facilitate formation of a rotating gas or steam ring within said annular space in the same direction of rotation as said exhaust blades. Hereby the relative velocity between steam and blades is reduced to a minimum and the blades rotate in a surrounding ring of gas or steam so that the blades are effectively protected from undesirable disturbances.

The invention will in the following be more fully described with reference to the accompanying drawings, Figs. 1–9 showing various embodiments thereof, whereby further objects and features of the same will be described.

Fig. 1 is a diagrammatic longitudinal section through a steam turbine showing the principle of the invention.

Fig. 2 is a fragmentary sectional view of the same turbine.

Fig. 3 shows a turbine wheel having a design of the turbine outlet which is characteristic of the present invention.

Fig. 4 illustrates the application of the invention to a Ljungström turbine provided with a double axial exhaust blade system.

Fig. 5 shows the adaptation of the invention to a Ljungström turbine provided with arched blades.

Fig. 6 represents a sectional view through the same turbine seen in axial direction.

Fig. 7 shows the exhaust blades in a standard axial turbine, with arrows indicating the steam flow at these blades in such cases where the turbine is rotating without steam or gas admission, that is to say when the blades are transmitting energy to the steam or gas causing a turbulent circulation within the turbine casing.

Fig. 8 is a fragmentary radial and Fig. 9 is a fragmentary lateral section of an embodiment of this invention employing means to control the position of the guide blades, Fig. 9 including vector diagrams indicating the relative directions and velocities of fluid flow both during normal operation and when the turbine is being driven electrically at normal speed with the fluid supply shut off.

In Fig. 1, reference character **2** designates an exhaust blade in a steam turbine which extends over a relatively large distance in a radial direction and **3** an adjoining wall of the turbine casing which is formed in the shape of a body of rotation, so that an annular space or chamber **4** is obtained between the blades **2** and the walls **3**, said chamber being so formed that the cross-sectional areas obtained by the intersection of planes through the axis of rotation with the said annular chamber are of uniform size. Towards the outside the said chamber of rotation is surrounded by a number of blades or guides **5** (Figs. 1 and 2) which preferably may be adjustable and which divide the turbine outlet, forming in known manner a diffusor, into an inner exhaust chamber **4** and an outer exhaust space **13**. Seen in an axial direction (Fig. 2), the blades or guides **5** are set at such an angle towards the circumference that steam tending to flow from the outside towards the inside is forced to rotate in the direction of rotation of the turbine. Arrow **6** of Fig. 2 indicates the direction of rotation of the turbine and arrows **7** and **8** indicate the direction in which steam passing from the outside towards the interior is flowing between the blades **5**.

From the above it is evident that any steam or gas flow through the guide ring **5** directed from the outside towards the inside assists in causing the mass of steam or gas within the annular chamber **4** to rotate in the direction of rotation of the turbine. Assuming a flow according to arrow **9** (Fig. 1) through blade ring **2** and assuming further that no steam or gas is admitted to the turbine, it is evident that the flow indicated by arrow **9** must be accompanied by an equally large return flow within the annular chamber **4** as indicated by arrow **10**. The outwardly directed flow **9** which is caused by the rotation of the blades **2** has imparted to it by these blades a direction of flow having the same direction of rotation as that of the blades. The flow tendency **9** is in Fig. 2 indicated by arrow **11**. From this figure it may clearly be seen that viewed in the direction of the arrow **11** said blades **5**, by reason of their direction and relationship, constitute a substantially continuous guide ring and outward flow is effectively prevented by the guide blades **5** which would cause the steam or gas to completely change its direction of rotation before the steam or gas could pass between the blades **5** towards the outside. As a result only a very small quantity of steam or gas may pass between these blades to the outside. Consequently, the return flow through the guide blade ring is equally small and such returning quantities of steam or gas are forced to flow in the direction of arrow **12** (Fig. 2), that is to say to rotate in the direction of rotation of the turbine. In this way a steam or gas ring is formed in the annular chamber **4**, rotating together with the blade in one and the same direction, which ring is practically not affected by the conditions existing at the outside of the guide blade ring **5**. Since only a very small amount of energy is required for maintaining the rotation of the annular steam or gas ring in chamber **4** and since further the return flow from the outside of guide ring **5** is practically eliminated, the turbine blades are protected from all undesirable disturbances which may cause oscillations.

That the guide blades **5** are thus both inclined in the direction of normal flow of the fluid exhausted from the turbine blades and also so disposed, without any change in position, as to counteract the pumping tendency of the rotating blades when the turbine is driven electrically is clearly illustrated by the vector diagrams of Fig. 9. Referring now to that figure, it will be seen that during normal operation—that is, with steam being supplied to blades **2** in the usual manner—the exhaust steam will leave the top of the blades with a relatively high velocity represented in both magnitude and relative direction by the vector w_1. The circumferential velocity of the rotating blades is represented by the vector u. By combining the relative velocity of the exhausting steam w_1 with the circumferential velocity of the blades u the absolute velocity of the steam is obtained, the vector c_1 representing said velocity in both magnitude and direction. As is clear from Fig. 9, guide blades **5** are so positioned and inclined as to in no way restrict this flow of the exhaust steam.

As soon as the steam supplied to the turbine is shut off, however, and the turbine is driven electrically at the same speed, conditions of flow within the turbine casing will change considerably. If no guide blades are provided in the exhaust space of the turbine, the exhaust blades will work like a centrifugal compressor drawing steam or gas from the exhaust space at the inner side edges of the blades and throwing it outwardly from the tops thereof with a relative velocity indicated by the vector w_2. Since the circumferential velocity of the rotating blades u has the same magnitude and direction as during normal operation, the combination thereof with the relative velocity w_2 gives a resulting absolute velocity of the steam flow corresponding to the vector c_2, which it will be noted is almost radial in direction. The amount of steam thus thrown outwardly or pumped by the exhaust blades is continuously supplied to the blade ring at the inner side edges thereof, as through the constricted spaces indicated in Fig. 8 between walls **22** and **23** and the sides of blades **2**. Such a pumping action would give rise to turbulent currents of steam of the type referred to above and would

cause considerable ventilation losses which it is the object of the present invention to reduce.

If, however, the turbine is provided with guide blades 5 according to the present invention, any outward flow of the steam from the exhaust blades is prevented by the overlapping arrangement of blades 5 which, as shown, present a substantially continuous surface approximately normal to vector c_2, the result being that the relative velocity of steam with respect to the rotating blades becomes zero. With a relative steam velocity $w_3=0$, and the same circumferential velocity u of the exhaust blades as before, it is clear that the absolute velocity c_3 with which a steam particle adjacent the top of an exhaust blade is carried forward will be $c_3=u$; in other words, said particle has the same velocity and direction of rotation as the rotating blade ring. Should the steam particle, however, leave the top of the exhaust blade, it would go on its way in a tangential direction, as indicated by c_3, until it engages one of guide blades 5 when, as is obvious from the drawings it would be deflected or directed into the steam ring rotating between the exhaust and guide blades with the same angular velocity as the exhaust blade ring.

From the preceding description and particularly from Figs. 3–6 it is also evident that the blades 5 simultaneously serve as stays between the outlet walls 3, 14 and 22, 23, respectively.

The previously mentioned arrangement for adjusting the guide members 5 may naturally be designed in different ways. Figs. 8 and 9 show an axial and lateral view of an embodiment of such controlling device. This design is similar to that used for the adjustment of the guide blades in water turbines. The annular steam or gas space or chamber 4 is again formed by the exhaust blades 2, the diffusor shields 22, 23 and the guide blades 5. The guide blades 5 are supported pivotally by means of pintles 20, 21 in the diffusor shields 22, 23. Pintles 20 are rigidly connected with levers 24 which in turn are movably connected with pivot arms 26 which by means of pintles are supported movably on the adjustment ring 25. The adjustment of ring 25 in the circumferential direction is determined by the position of the controller arm 28 which by means of link arm 27 is interconnected with ring 25. In this way each position of the guide blades 5 corresponds to a definite position of arm 28. Since it is desirable that blades 5 offer the least possible resistance to the gas or steam leaving the turbine during normal operation, the position of the blades 5 may be so adjusted by means of controller arm 28 that the direction of the blades 5 always co-incides with the direction of the steam or gas flow. In the previously mentioned cases where the steam or gas is tending to retard the turbine, the blades 5 may preferably be so adjusted that their inner sides form a comparatively smooth surface surrounding the annular chamber 4, thus facilitating the formation of a rotating steam or gas ring.

What I claim is:

1. In a gas or steam turbine, in combination with a last row of rotatable turbine exhaust blades of the type extending radially through a substantial distance, a plurality of relatively stationary guide members adjacent to said exhaust blades and having their inner ends inclined in the direction of normal flow of the exhaust fluid when the turbine is driven normally by the fluid, said guide members being so related that during idling or abnormal flow conditions when said blades tend to pump the fluid they constitute a substantially continuous guide ring for obstructing the flow of said fluid from the interior to the exterior of said guide members.

2. A gas or steam turbine according to claim 1 in which said guide members are formed by blades mounted adjacent the periphery of said exhaust blades.

3. A turbine according to claim 1 in which said guide members divide the turbine outlet into an inner annular space in which a rotating ring of fluid may form an outer exhaust space.

4. A turbine according to claim 1 in which said exhaust blades are so inclined that fluid flowing therethrough from the exterior thereof is directed thereby in the direction of rotation of the fluid moving with the exhaust blades.

5. A turbine according to claim 1 in which said guide members operate as stays between the walls of the turbine outlet.

6. A turbine according to claim 1 in which said guide members are adjustable.

7. A turbine according to claim 1 in which said guide members are pivoted in the walls of the turbine outlet, and means cooperating with said pivoted guide members for adjusting the angle thereof to the radius of said annular space.

8. A turbine according to claim 1 in which said guide members form a diffusor and divide the turbine outlet into an inner annular space in which a rotating ring of fluid may form and an outer exhaust space.

9. In a gas or steam turbine, in combination with a last row of rotatable turbine exhaust blades of the type extending radially through a substantial distance, a plurality of relatively stationary guide members adjacent to said exhaust blades and having their inner ends inclined in the direction of normal flow of the exhaust fluid when the turbine is driven normally by the fluid, said guide members being so related that during idling or abnormal flow conditions when said blades tend to pump the fluid they constitute a substantially continuous and substantially cylindrical guide ring for obstructing the flow of said fluid from the interior to the exterior of said guide members.

FREDRIK LJUNGSTRÖM.