

Sept. 28, 1926.

1,601,402

C. LORENZEN

GAS TURBINE

Filed Feb. 14, 1922

4 Sheets-Sheet 1

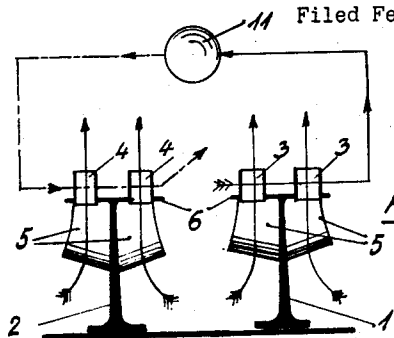


Fig. 1.

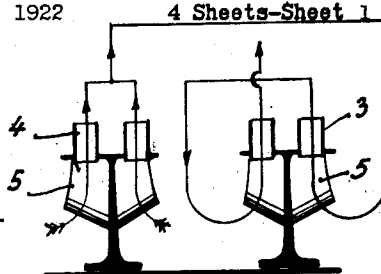


Fig. 3

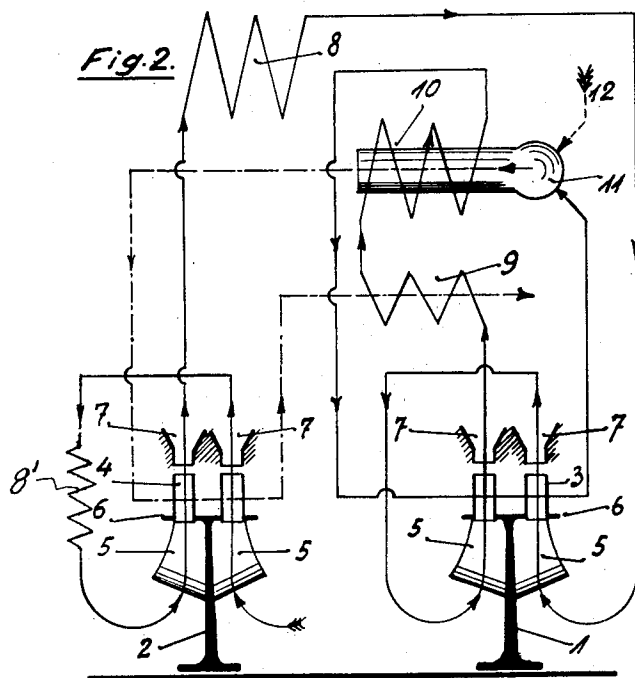


Fig. 2.

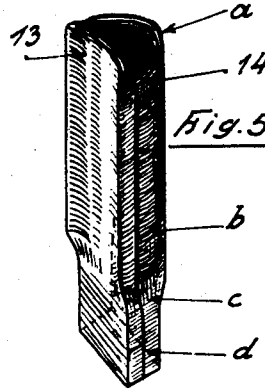
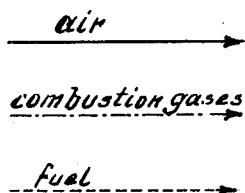


Fig. 5.

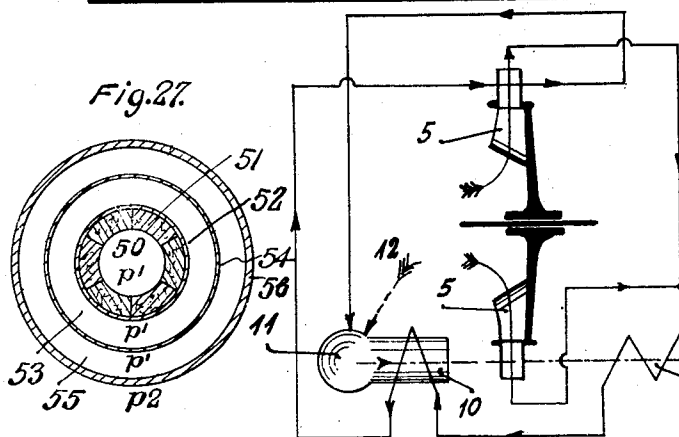


Fig. 27.

Fig. 4.

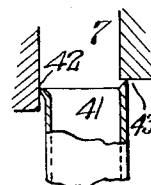


Fig. 26.

Inventor:

CHRISTIAN LORENZEN,

by Spear, Middleton, Macdonald & Hall
Attys.

Sept. 28, 1926.

1,601,402

C. LORENZEN

GAS TURBINE

Filed Feb. 14, 1922

4 Sheets-Sheet 2

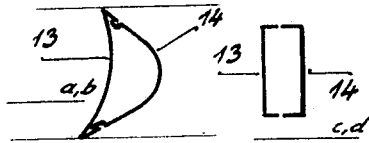


Fig. 6.

Fig. 7.

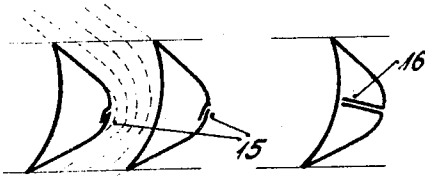


Fig. 8.

Fig. 9.

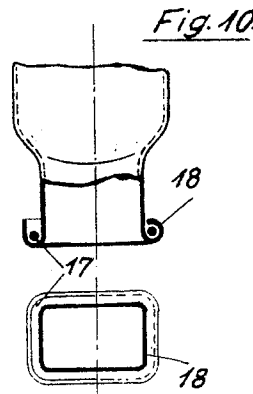


Fig. 10.

Fig. 11.

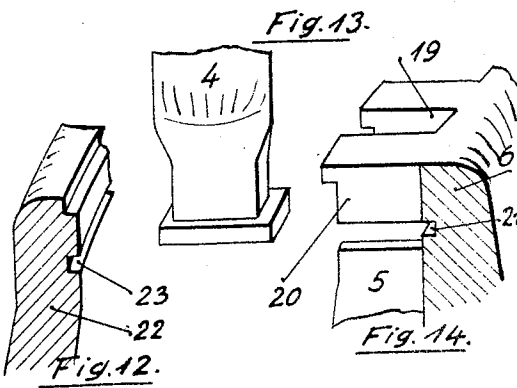


Fig. 12.

Fig. 13.

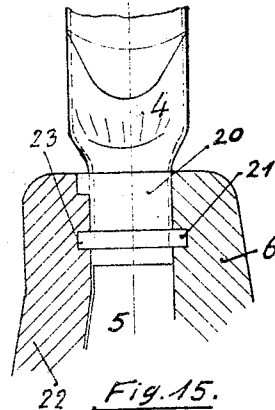


Fig. 14.

Fig. 15.

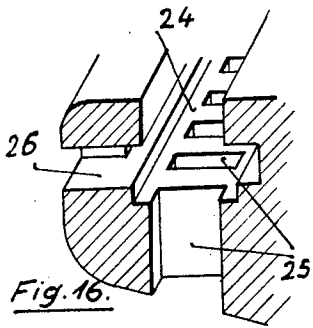


Fig. 16.

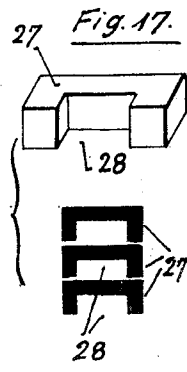


Fig. 17.

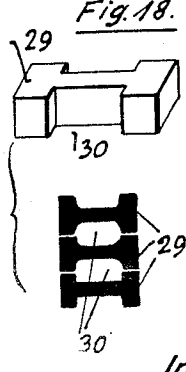


Fig. 18.

Inventor:

CHRISTIAN LORENZEN.

by Spear, Middleton, Donaldson & Hall.
Attys.

Sept. 28, 1926.

1,601,402

C. LORENZEN

GAS TURBINE

Filed Feb. 14, 1922

4 Sheets-Sheet 3

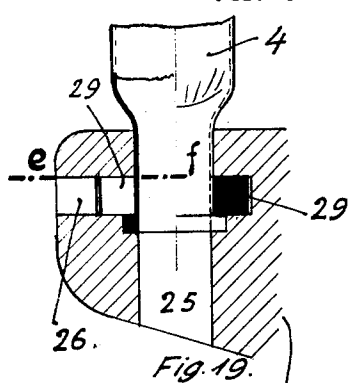


Fig. 19.

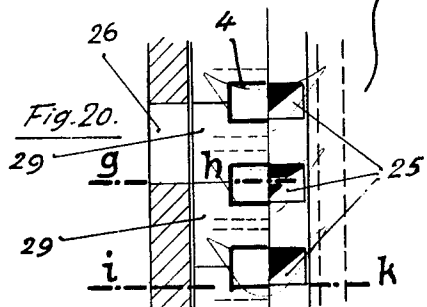


Fig. 20.

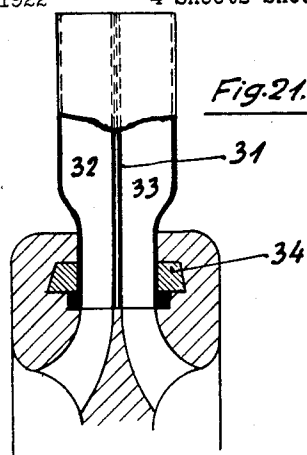


Fig. 21.

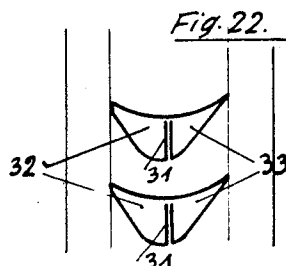


Fig. 22.

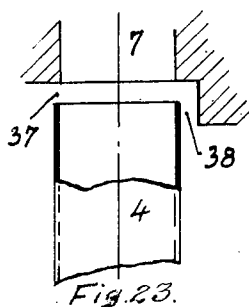


Fig. 23.

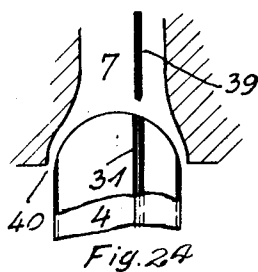


Fig. 24.

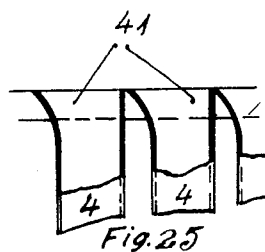


Fig. 25.

Inventor:

CHRISTIAN LORENZEN

by Spear, Middleton, Donaldson & Haas
Attys.

Sept. 28, 1926.

1,601,402

C. LORENZEN

GAS TURBINE

Filed Feb. 14, 1922

4 Sheets-Sheet 4

Fig. 28.

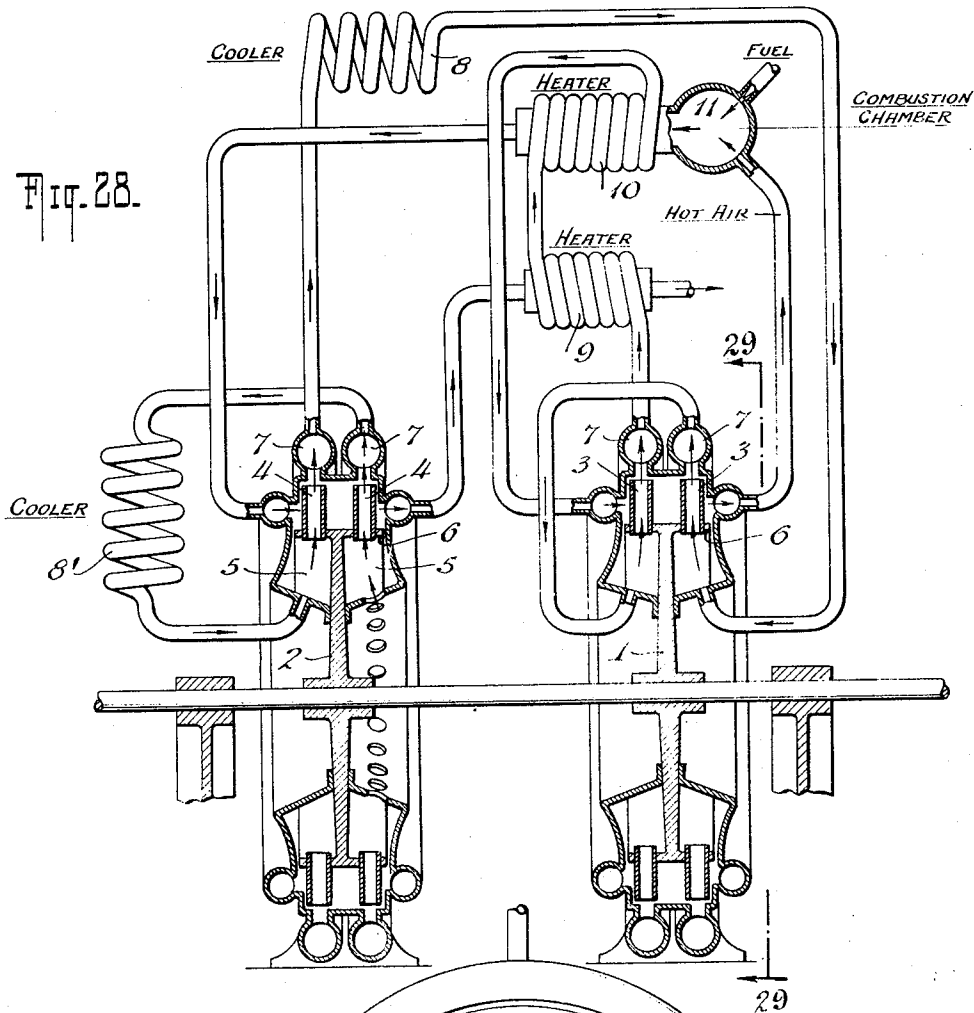
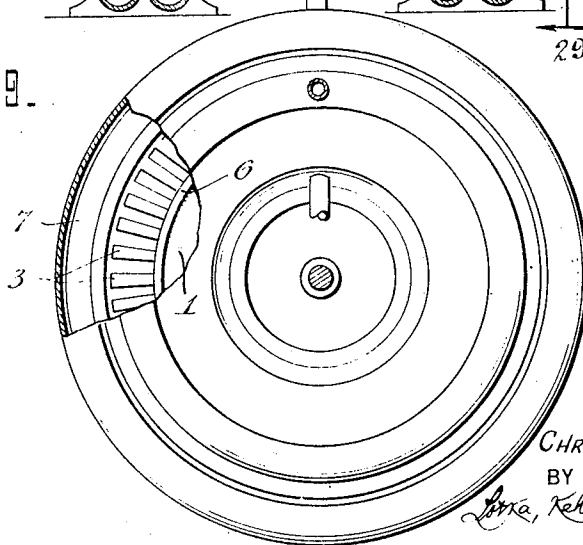


Fig. 29.



INVENTOR

CHRISTIAN LORENZEN

BY

Wm. Kellenbuck & Farley
ATTORNEYS

UNITED STATES PATENT OFFICE.

CHRISTIAN LORENZEN, OF BERLIN-NEUKOLLN, GERMANY.

GAS TURBINE.

Application filed February 14, 1922, Serial No. 536,562, and in Germany January 15, 1921.

The present invention relates to improvements in gas turbines, and consists of the details hereinafter more fully described.

The attempts to construct an efficient and economically working gas turbine have hitherto proved unsuccessful on account of the high temperature and considerable mechanical strains to which the material of such a gas turbine is exposed. It has indeed been attempted to reduce the combustion temperatures by internal cooling, for example by the injection of water or the supply of air in excess of the amount required to support combustion. Other inventors again have attempted to overcome the difficulty by a generous water-cooling of the hot walls. Such loss of energy, however, always occurs so that such attempts in this direction, up to the present, have met with no success.

The present invention deals with a new working method for gas turbines which avoids these difficulties and which, therefore, assures an economical working, hitherto unknown, with all kinds of fuels. As is more clearly explained below, the turbine is operated according to the constant pressure principle. The construction and working method of the turbine are such that the important working parts exposed to high temperatures are effectively cooled, but that the amount of heat conducted off may be practically all employed again for the further working process.

Fig. 1 shows diagrammatically the turbine with its most important detail and in its working method.

Fig. 2 shows diagrammatically the construction of the turbine with the principal apparatus belonging thereto.

Fig. 3 shows diagrammatically a three stage compressor.

Fig. 4 shows diagrammatically a one stage compressor.

Figs. 5, 6 and 7 are details of one form of blade.

Figs. 8 and 9 are details of modified blades.

Figs. 10 and 11 show details of a root and associated blade.

Figs. 12 to 15 show one method of securing the blades to a blade rim.

Figs. 16 to 20 show a modified method of securing the blades to a blade rim.

Figs. 21 and 22 show details of a double blade.

Figs. 23 to 26 illustrate several forms of head construction of the blades.

Fig. 27 illustrates a construction of the combustion chamber used for high temperature.

Fig. 28 is a view similar to Fig. 2, but showing the structural features with greater detail; and Fig. 29 is a cross-section on line 29—29 of Fig. 28, with parts broken away.

According to Fig. 1 the turbine is operated in general by air and combustion gases, and consists therefore of the rotor 1 for the air stage and the rotor 2 for the gas stage, both rotors being indicated as mounted rigidly on the same shaft. The air serves in the first place for cooling the rotor disc and the hollow turbine blades 3 and 4. In the method described below the cooling air, in order that it may afterwards be employed as operating air in the air stage, is compressed in the compression vanes 5 and by the hollow blades 3 and 4. By cooling additional parts the compressed air takes up further amounts of energy in the form of heat, and is conducted to the air turbine rotor 1 as operating air. The air leaving the rotor 1 retains a certain compression and acts as combustion air for the ensuing combustion in the chamber 11. The combustion gases finally strike against the rotor 2.

The most important features of the invention consist in the novel compression of the air, of the cooling effect, and in the use of the hollow blades.

While practically all previously known gas turbines require a special air compressor in a special casing the compression in the present invention occurs in the turbine rotors 1, 2 (Fig. 1 or 2) which for this purpose possess vanes 5 on the one side or, as shown in the drawings, on both sides. The air if necessary is partly pre-compressed in some manner admitted in the vicinity of the

hub and forced radially outwards through the blade rim 6 and the hollow blades 4. The rotors, in similar manner as in the case of the well-known rotary pump compressor, are inclosed by a permanent guiding arrangement called a diffuser 7 which converts the flow of energy of the air into pressure energy, if required, with the aid of guide blades. The pressure air is conducted from the diffuser to the place of its further employment.

If, as shown in Figs. 1 and 2, but which is not absolutely necessary, two impeller discs are used and the compressing vanes are mounted on both sides of the discs, the air can be compressed in from one to four consecutive stages, (Figs. 1, 2 and 3), and brought to a final pressure which may be selected within wide limits. According to Fig. 2 the four halves of the compressor vanes are connected in series and a four stage compression with relatively high final pressure thereby attained. Fig. 3 shows a three stage and Fig. 4 a single stage compression, the latter with, for example, a single disc and only one sided compressor vanes 5.

The most important advantages of the compression cycle above described are the following:—Compact, symmetrical construction, efficient utilization of fuel and, where the compressor vanes are positioned on both faces of the discs, a complete pressure compensation and also a decrease in losses due to friction and other resistance.

In addition to the novel compression cycle the method of cooling the turbine blades forms an important feature of the invention. It is known, for instance, from steam boiler construction that high temperatures may be employed if only the walls are continually and effectively cooled. The cool fresh air or the re-cooled pressure air is drawn in in a continual stream and led right along the walls of the rotor. Above all, however, the turbine blades 3 and 4, exposed to the hot gas or air stream, are constantly cooled internally with the result that the wall temperature remains considerably below the temperature of the impinging gas so that the metal of the blades is not injured by becoming overheated. It has been found that there is no danger of the blades becoming fouled with an accumulation of heated material, since the force of the stream of gas or air is sufficient to remove such accumulation as quickly as it is formed. The inner walls of the blades are not fouled because they only come in contact with pure air which can leave no dirt particles behind if filtered before the entrance to the cycle. The hollow blades, as explained below, may be produced from a very thin sheet material so that an intensive cooling of the walls is attained.

Now that the most important features of

the invention have been emphasized the operation of the machine in connection with Fig. 2 may be more clearly explained. Fig. 2 shows the construction in general form. The simplifications which may be made in case of need are also indicated.

The cool fresh air is, for example, drawn up through the right hand compressor vane-work of the gas stage 2, passes through the right hand side hollow blade row 4, through the diffuser 7, and if desired through a cooling device of any suitable construction indicated at 8'. In similar manner it is then drawn through the left hand side compressor half. In the intermediate cooler 8 the twice compressed cooling air, warmed in the meantime, can be re-cooled, to be warmed anew in the air stage 1 and compressed in two further stages. As the drawing shows, solid line the compressed air, which may now be designated as driving air, withdraws from the discharge gases (dotted line) in the preheater 9 practically the whole amount of heat. It is thereupon carried round the jacket 10 of the combustion chamber 11. The combustion gases are thereby cooled down to a certain extent. The amount of heat withdrawn, however, as in the case of the amount of heat already taken up, in the pre-heater 9, is led into the ensuing air stage 1 for working purposes. For this purpose the driving air is directed in any approved manner on to the moving blades through nozzles (not shown). The expansion nevertheless in the air stage is not entirely the result of atmospheric pressure, but due to the exact proportioning of the gas nozzles through which the air later has to pass an exactly ascertainable pressure remains. The discharge air under pressure is now directed as air for supporting combustion into the combustion chamber 11. As the air has been preheated to a substantial extent a relatively high combustion temperature is given by the combustion with the solid, liquid or gaseous fuel injected at 12. By properly proportioning the amount of fuel and air the temperature of the gases leaving the combustion chamber may be maintained at a predetermined level, which may be selected within a wide range. Within the combustion chamber the same pressure is always present (constant pressure principle) that is, apart from losses, the pressure of the air flowing off from the air stage. The same pressure will also be present later at the gas nozzles. The combustion gases, as already explained above, will be cooled to a certain temperature by the driving air conducted round the jacket 10 and are led to the gas stage 2 in which, with gain of work, the complete expansion follows down to atmospheric pressure. The exhaust gases still contain a certain amount of heat which, as already described, is withdrawn

in the pre-heater 9 and given off to the driving air. If the air thus cooled is withdrawn an increase of efficiency occurs similarly to the case of the condensing arrangement of a steam engine.

By the method described an extensive cooling on the one hand of exactly the most essential parts of the turbine is attained; on the other hand, apart from negligible radiation losses, only relatively small quantities of heat are lost with the cooling water in the intermediate cooler 8 and with the discharge gases in the pre-heater 9. In this way the turbine will run with a favorable working load, and attains a degree of efficiency comparable to that of other types of heat engines.

It is possible to simplify the turbine shown in Figure 2 by eliminating the air driven rotor and passing the air directly from jacket 10 to the combustion chamber 11. This arrangement results in the turbine being driven entirely by the combustion gases and is simpler but somewhat less efficient than the turbine shown in Figure 2.

It is also possible, as shown in Figure 4, to combine the air stage and the gas stage rotors in a single disc, whereby a constructional simplification is likewise attained without, however, the efficiency being reduced as compared with the construction with the two rotor discs. In employing several compression stages the consecutive stages are preferably so arranged that the lateral pressures upon the turbine disc compensate one another. If the turbine with a single rim is chosen the impact with air and gas is so arranged that it works opposedly to the one-sided pressure of the compression stages and eliminates or practically eliminates same. A further simplification can be made in so far as the pressure in the combustion chamber and other parts open to excessive temperature can be lessened, if the air is not compressed in four stages, but according to Fig. 3 or Fig. 4 in three stages or one respectively.

It is quite natural that a machine working upon a new principle must contain a large number of new constructional details especially where, as in the case of gas turbines, excessive strains are placed upon the materials.

In the following several, preferable forms of embodiment, already tested, are described.

Of the greatest importance is the construction of a suitable blade which, according to the above, must be constructed as a hollow blade. Figs. 5/7 show a blade composed of two halves 13 and 14. For this purpose the parts of thin durable sheet metal are preferably united by folding, welding or the like. The cross section of the hollow blade may possess different shape or also different size at the individual points of the blade accord-

ing to the purpose desired. For example, the blade shown in Figure 5 has, between the points designated *a* and *b*, the usual cross-section, as shown in Figure 6, but is formed at its base into a rectangular cross-section, as shown in Fig. 7. In Figs. 8 and 9 two further blade forms are shown which are produced from a single piece of sheet metal. According to Fig. 8 the longitudinal edges 15 of the sheet joints lie protected in the dead angle of the blade channel; according to Fig. 9 the edges 16 are absolutely withdrawn from the effect of the gas stream.

To obtain lighter blades, to reduce the centrifugal strains upon the blade rim, and furthermore to give the hollow of the blade as large a through passage as possible, very thin sheet metal of a few tenths of a millimetre may be employed. If the centre of gravity of the blade protruding freely from the rotor is arranged in radial alignment with the centre of gravity of the area or surface at which the blade is attached or secured, the bending strains caused by centrifugal force will be absolutely eliminated from the blade. But the stresses due to the impact of the gas upon the blades, and those due to inertia of the blade when the angular speed of the rotor changes, are too small to have a detrimental effect on the blades.

In addition to the construction of the blade the efficient and reliable fixing of the same requires careful attention, for the blades must be able to resist the centrifugal force which may amount to several thousand times the actual weight. On the other hand the free entrance of air through the blade rim, which forms the socket for the blade, and through the hollow root of the blade must not be hindered. It has proved to be very suitable by extensive experiment to roll over the underneath edge of the blade, to enclose a wire ring. As is shown in Figs. 10 and 11 the root has preferably a right angular cross section. 17 shows the embedded wire ring, 18 shows the root ready for insertion.

According to Fig. 13 the fixing edge consists of a right angular ring which surrounds the foot of the blade and is fixed by welding or soldering.

The blades which are provided with the root as described can be fixed in different manners in the blade rim. Figs. 12/15 and Figs. 16/20 respectively show different forms of embodiment. According to Figs. 12/15 the blades are inserted laterally in the rotor disc without distance pieces and secured axially by a lateral cover piece. According to Fig. 14 the wheel disc 2 of the gas stage, for example, is provided on the rim 6 with lateral incisions 19, between which are the collars 20. The vanes 4 which are provided with the right angular foot such as described with reference to Figs. 10

and 11 fit exactly into the incisions 19 and lie with the rolled over narrow edge in the ring groove 21. Both broad rolled over edges find a secure backing on the underneath side of the collars 20. Finally the annular cover piece 22, formed in a ring shape, which contains the ring groove 23 for the reception of the fourth rolled over right angular side, is fixed by lateral fixing screws on the blade rim 6 and prevents a bending of the collars 20. At those points at which the fixing screws are placed the vanes may be omitted and the material between the collars 20 may remain in their stead.

For greater centrifugal strains the fixing device disclosed in Figs. 16/20 is more suitable. The blades are set individually in the groove from without and held by laterally inserted distance pieces. Fig. 16 discloses the previously worked-out T-shaped groove 24 which, for instance, is situated in the blade rim 6 of the air step disc 1. The slot 25 assures the radial passage of pressure air to the hollow of the blade. The blade constructed exactly as described above with Fig. 14 is now inserted from outwardly into the groove and turned so far that the root passes freely through the narrowed neck of the blade groove. At one or more points on the circumference of the rotor lateral openings 26 are provided which serve for the insertion of the distance pieces 29 between the individual blades. The distance pieces, of which Figs. 17 and 18 show two forms of embodiment, have the double purpose of keeping the blades at a certain distance apart, and to provide a strong backing on all four right angular sides for the blade root (Fig. 10). The blades, therefore, do not rest against the blade rim but against the distance pieces which, for this purpose, are formed U-shaped or H-shaped, according to Figs. 17 and 18 respectively. Between the blades, that is, at 28 or 30 respectively, the hollow blade is positioned. Fig. 19 shows a section through the groove fitted with blades. The numbers inserted agree exactly with the numbers in the previous figures. The left hand half of the groove shows the section led through the hollow blade, the right hand half the section in front of the blade. Fig. 20 is the corresponding plan view, on the left hand side as section through *e-f*, on the right hand side as plan view of the groove after omission of the distance pieces and blades.

The general form of the blades may be the same as in customary steam turbine construction, as for example is already represented in Fig. 6, i. e., the cross section has the sickle-shaped form of constant pressure profile. In some cases, an excess pressure profile might be employed. The working method of the gas turbine may however

require perfectly new forms. If, for example, as is shown in Figs. 1-4, the rotor is provided on both sides with compression vanes 5, and the pressure air must be further conducted through hollow vanes 4, the rotor must likewise possess two blade rows. In general, however, in the interest of convenient construction of the blading of the turbine, a single row of blades is required. If in this case the rotor, provided with two rows of blades, is to retain the efficiency of the single row of blades the construction according to Figs. 21/24 may be used.

Figs. 21 and 22 show a so-called double blade which is divided internally into the two equal or different sized chambers 32 and 33 by the intermediate wall 31. Both chambers allow the free passage of air to the diffuser as shown in Fig. 2. The construction of the double blade was dealt with in the part of the specification referring to Fig. 9, the fixing of same may be accomplished by distance pieces 34 in the manner according to Fig. 19. Considered from the point of view of the turbine, as shown in Fig. 22, a rotor with one row of blades is dealt with. A reversing device between both halves 32 and 33 need not be considered.

The hollow blade may be formed differently at the head according to the purpose in question. In Figs. 23 to 26 several forms of embodiment are given. As before, 4 represents the blade of the turbine, 7 the diffuser enclosing the rotating portion of the compressor. In Fig. 23 the blade 4 is cut off straight. It may extend according to 37 as far as the diffuser 7, or protrude according to 38 slightly into the diffuser if a passing over of the driving means out of the blade channel into the diffuser 7 or vice versa is to be guarded against. Fig. 24 gives a blade section 40 according to a chosen curve. It may be of use, for example, if the double blade more closely described in Fig. 21 is present, to conduct the pressure air into the diffuser 7 in the manner given. Both chambers of the double blade show here different sized cross sections. By the blade protruding somewhat into the diffuser at 40 transference losses are avoided similarly as in the case of the embodiment 38 according to Fig. 23. The diffuser is likewise divided into two chambers by the wall 39. The congruent Figures 27 and 28 show a further form of embodiment. Transference losses from the gas passage into the air pressure passage and vice versa are avoided in effective manner the blade channel being closed for this purpose by extending the headpiece 41 towards the left. The head piece distended towards one side can lie before or after the blade, or can be distended towards both sides. Apart from the fact that the head piece 41 prevents transference losses it also lessens the ventilation loss, in

a like manner as the covering bands in the steam turbine stages.

A packing between the gas and pressure air channel can also be attained at the entrance to the diffuser 7 by axial collars 42 (Fig. 26) or radial collars 43 extending from the blade heads. Obviously these packing collars may also be provided on the stationary diffuser 7.

The combustion chamber, like other parts exposed to high temperature, is subjected to a certain over-pressure. If the material is under red-heat temperature the control of the over-pressure may cause difficulties which, however, according to the example of construction in Fig. 27, are easily to be overcome. Internally in 50, for example, is a pressure p^1 and fire temperature. The lining 51 of fireproof material serves to protect the wall 52. A cooling means, likewise under the pressure p^1 , is led through the space 53 between the jackets 52 and 54. The hot wall 52 is therefore subjected to no pressure. On the other hand the wall 54 is materially cooler. If necessary a second cooling chamber 55 may be produced by a further jacket 56 with somewhere about the same inner pressure p^1 . First the outwardly lying cold jacket, for example 56, can be subjected to the pressure $p^1 - p^2$ without consideration.

I claim as my invention:—

1. In combination, a gas turbine having its rotor adapted to compress air, a second turbine adapted to receive the compressed air from said first turbine and further compress it, said second turbine being adapted to be driven by the air compressed by said turbines.

2. In combination, a gas turbine having its rotor blades adapted to compress air, a second turbine also having rotor blades adapted to compress air, a conduit for conducting compressed air from said first turbine to said second turbine for further compression therein, and a conduit for conducting the compressed air from said second turbine into contact with the blades of said second turbine to act as a driving agent therefor.

3. A gas turbine comprising blades adapted to be driven by gases under pressure, passages through said blades for the passage of a gaseous cooling agent, whereby heat is transferred from said gases to said cooling agent, means cooperating with said passages to compress the cooling agent, a heater for transferring an additional amount of heat to said cooling agent, and a conduit for leading said cooling agent from said heater to said blades to act as a driving agent therefor.

4. A gas turbine comprising passages for a driving agent and passages for a gaseous cooling agent, said passages being adjacent to each other to secure a transfer of heat from said driving agent to said cooling

agent, means for effecting compression of said cooling agent by the rotation of the rotor of said turbine, a heater wherein a further transfer of heat to said cooling agent is made, and a conduit for returning said cooling agent from said heater to said rotor to act as a driving agent therefor.

5. A rotary structure having separate passages for a heated gaseous driving agent and for a gaseous cooling fluid, said passages being adjacent to each other so as to secure an exchange of heat between said agent and said fluid, the latter being compressed by the rotation of said structure, a heater receiving such compressed fluid and further increasing its temperature, and a conduit for leading the fluid thus heated to the rotary structure to act as a heated gaseous driving agent therefor.

6. A rotary structure having separate passages for a heated gaseous driving agent and for a gaseous cooling fluid, said passages being adjacent to each other so as to secure an exchange of heat between said agent and said fluid, the latter being compressed by the rotation of said structure, a heater having two paths, one of which receives the exhaust driving agent from the rotary structure, while the other receives the compressed fluid, to further increase its temperature, and a conduit for leading the fluid thus heated to the rotary structure to act as a heated gaseous driving agent therefor.

7. A rotary structure having separate passages for a heated gaseous driving agent and for a gaseous cooling fluid, said passages being adjacent to each other so as to secure an exchange of heat between said agent and said fluid, the latter being compressed by the rotation of said structure, a heater having an external supply of heat and receiving such compressed fluid and further increasing its temperature, and a conduit for leading the fluid thus heated to the rotary structure to act as a heated gaseous driving agent therefor.

8. A rotary structure having separate passages for a heated gaseous driving agent and for a gaseous cooling fluid, said passages being adjacent to each other so as to secure an exchange of heat between said agent and said fluid, the latter being compressed by the rotation of said structure, a heater having two paths, one of which receives the exhaust driving agent from said rotary structure, while the other receives the compressed fluid to further increase its temperature, a second heater having an external supply of heat, a conduit for leading the heated compressed fluid from the first heater to the second heater, and a conduit for leading the heated compressed fluid from the second heater to the rotary structure to act as a heated gaseous driving agent therefor.

9. A rotary structure having separate pas-

sages for a heated gaseous driving agent and for a gaseous cooling fluid, said passages being adjacent to each other so as to secure an exchange of heat between said agent and said fluid, the latter being compressed by the rotation of said structure, a heater receiving such compressed fluid and having an inlet for an agent which will form a combustible mixture with said compressed fluid, to produce combustion in said heater, and a conduit for leading the combustion gases to the rotary structure to act as a heated gaseous driving agent therefor.

10. A rotary structure having separate passages for a heated gaseous driving agent and for a gaseous cooling fluid, said passages being adjacent to each other so as to secure an exchange of heat between said agent and said fluid, the latter being compressed by the rotation of said structure, a heater having two paths, one of which receives the exhaust driving agent from said rotary structure, while the other receives the compressed fluid to further increase its temperature, a second heater receiving the heated compressed fluid from the first heater and also having an inlet for an agent adapted to form a combustible mixture with said fluid, to produce combustion in said second heater, and a conduit for leading the combustion gases to the rotary structure to act as heated gaseous driving agent therefor.

11. The combination with a rotary engine structure having separate inlets for the supply of two motive agents, of a combustion chamber, a conduit for leading the exhaust of one of said motive agents to said combustion chamber, the latter having an inlet for the supply of a medium to produce combustion in conjunction with said exhaust, and a conduit for leading the combustion products from said chamber to the inlet for the other motive agent to act as a driving agent for the rotary engine structure.

12. The combination with a rotary engine structure having separate inlets for the sup-

ply of two motive agents, a two-path heater, a conduit for leading the exhaust of one of said motive agents to one of the paths of said heater, a conduit for leading the exhaust of the second motive agent to the other path of said heater, a combustion chamber, a conduit for leading from said heater, the exhaust heated in one path thereof, to said combustion chamber, the latter having an inlet for the supply of a medium to produce combustion in conjunction with said exhaust, and a conduit for leading the combustion products from said chamber to the inlet for the other motive agent, to act as a driving agent for the rotary turbine structure.

13. A rotary structure comprising a combustion chamber, a turbine adapted to be driven by the gases from said combustion chamber, passages through the blades of said turbine for the passage of a cooling fluid, means co-operating with said blades to compress said fluid, a second turbine having hollow blades, a conduit for conducting said cooling fluid from said passages to said hollow blades, a diffuser cooperating with said hollow blades to further compress said fluid, and means for conducting said fluid from said diffuser to the rotor of said second turbine to act as a driving agent therefor.

14. In combination, a gas turbine having blades provided with passages for conducting cooling air therethrough, a diffuser co-operating with said blades to compress said air, a second turbine having hollow blades, a conduit for conducting said cooling fluid from said diffuser to the interior of said hollow blades, a second diffuser cooperating with said hollow blades to further compress said air, and a conduit for conducting said fluid from said second diffuser to the rotor of said second turbine to act as a driving agent therefor.

In testimony whereof I affix my signature at Berlin, this 25th day of January, 1922.

CHRISTIAN LORENZEN.