June 11, 1940. G. ZERKOWITZ 2,204,169

TURBINE FOR THE EXPANSION OF GAS TO PRODUCE REFRIGERATION

Filed Feb. 15, 1938 2 Sheets-Sheet 1

FIG. 1.

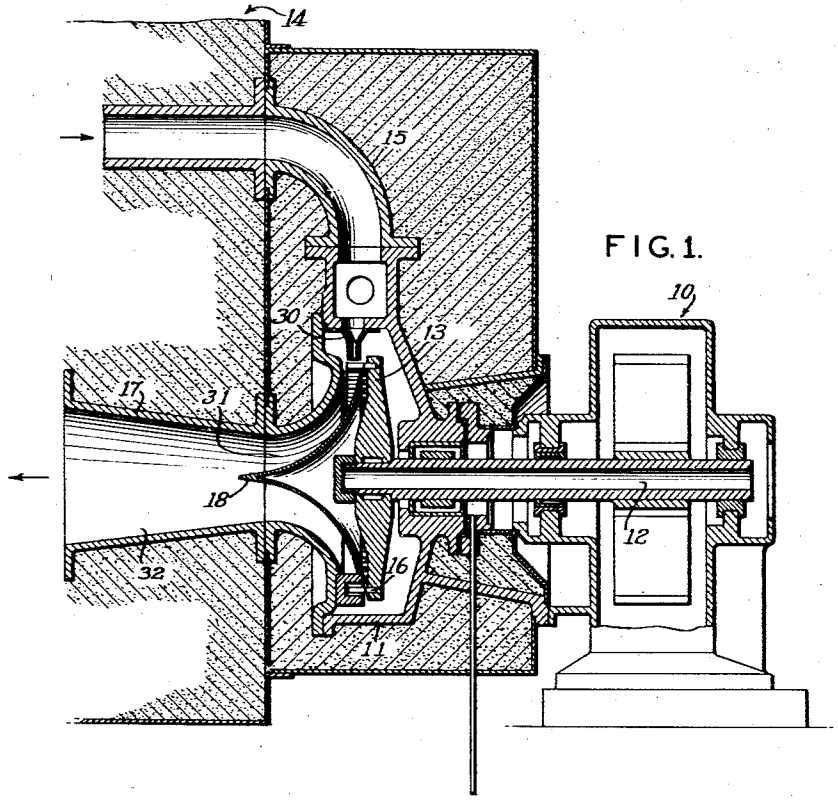
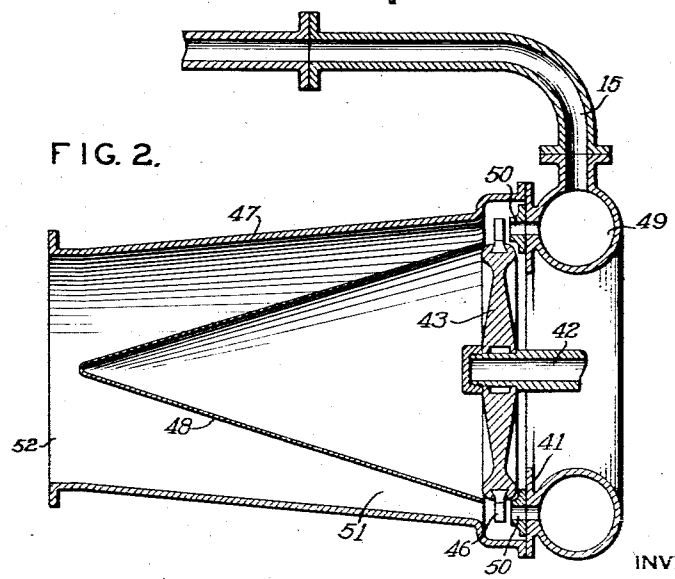


FIG. 2.



INVENTOR
GUIDO ZERKOWITZ
BY
F. L. Greenewald
ATTORNEY

June 11, 1940. G. ZERKOWITZ 2,204,169

TURBINE FOR THE EXPANSION OF GAS TO PRODUCE REFRIGERATION

Filed Feb. 15, 1938 2 Sheets-Sheet 2

FIG. 3.

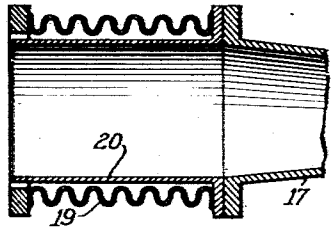


FIG. 4.

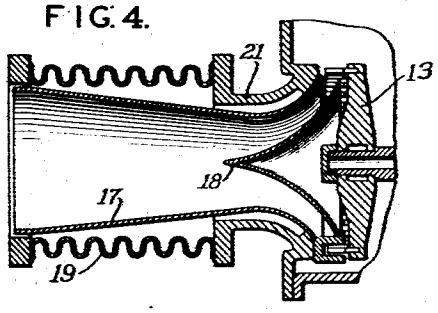


FIG. 5.

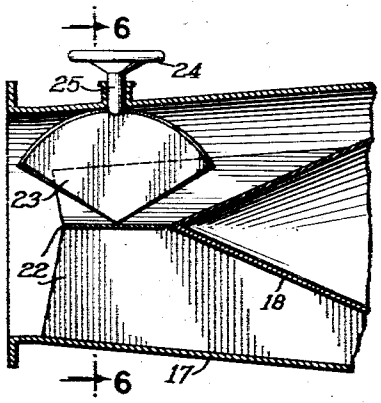
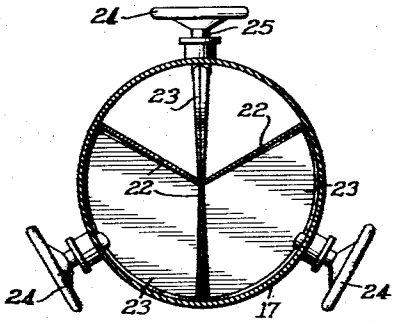


FIG. 6.



INVENTOR
GUIDO ZERKOWITZ
BY
ATTORNEY

Patented June 11, 1940

2,204,169

UNITED STATES PATENT OFFICE

2,204,169

TURBINE FOR THE EXPANSION OF GAS TO PRODUCE REFRIGERATION

Guido Zerkowitz, Trieste, Italy, assignor to Gesellschaft für Linde's Eismaschinen A. G., Hollriegelskreuth, near Munich, Germany

Application February 15, 1938, Serial No. 190,568
In Germany February 27, 1937

16 Claims. (Cl. 62—123)

This invention relates to a turbine for the expansion of gas to produce refrigeration, and more particularly to an improved turbine for expanding compressed gases at low temperatures in the process of separating gas mixtures by fractional condensation or distillation at low temperature.

This application is an improvement on the apparatus disclosed and claimed in my co-pending application Serial No. 69,543, filed March 18, 1936, now issued as Patent No. 2,165,994.

In said copending application, a high speed expansion turbine is described which consists of one or only a few stages, and which has a rotor of small diameter. The rotor of the expansion turbine is overhung so that the shaft on which the rotor is mounted extends toward one side and the shaft bearings are mounted entirely outside of the housing of the turbine. The housing or shell of the turbine is supported by the housing of the driven machine or reduction gear in such manner that the metallic path for the conduction of heat from the rotor is a minimum. It is also pointed out in the copending application that in order to obtain a desired reduction of temperature by expansion, it is not sufficient that the turbine have a good efficiency in the customary sense. The customary efficiency, including the mechanical losses, is only of minor importance in the separation of air, for a high internal efficiency alone is not sufficient in the present case because, as can be readily seen by reference to an entropy diagram, the internal work of a turbine running at low temperatures is increased by heat supplied by the environment, although the final temperature of the expansion is thereby increased. This effect, however, must be avoided in the present case when producing refrigeration, for not only a high internal efficiency of the turbine but also a perfect thermal insulation must be provided, and since the heat drop which is available is generally small, the losses in the inlet and outlet pipes become very important.

It is a principal object of the present invention to provide a turbine having an increased efficiency for the production of refrigeration by the expansion of gases. Another object of the invention is to provide a turbine of the class described in said copending application, which is arranged to recover a substantial amount of the energy of the gases flowing from the blades of the rotor. The above and other objects and the novel features of the invention will be apparent from the following description taken in connection with the drawings in which:

Fig. 1 is a sectional view showing a form of the apparatus applied to a radial flow turbine according to the present invention;

Fig. 2 is a longitudinal sectional view of another form of the apparatus applied to an axial flow turbine according to the invention;

Fig. 3 is a fragmentary sectional view of an alternate construction of the outlet connection of either form of turbine;

Fig. 4 is a similar view of another form of outlet connection;

Fig. 5 is a fragmentary sectional view of an alternative arrangement of the outlet diffuser of either turbine; and

Fig. 6 is a right sectional view taken on the line 6—6 of Fig. 5.

The present invention makes possible an increase in the efficiency of a gas or air turbine for the production of low temperatures by providing a diffuser on the discharge side of the rotor blades. According to the invention, the flow energy of discharge is recovered by providing a diffuser after the rotor which consists of a passage limited by two stationary coaxial surfaces of revolution between which the driving medium flows. The sheet metal casing which forms the inner surface of revolution tapers out approximately to a point and extends preferably over a portion only of the length of the diffuser in such a manner that, in flowing through the diffuser, the driving fluid is additionally conducted through the passage formed by the outer surface of revolution alone. By this means there is effected a favorable conversion of energy from the standpoint of flow technique both in the diffuser itself as well as when discharging from the diffuser into the adjacent piping. The diffuser is arranged adjacent the opposite side of the rotor with respect to the bearings. Therefore, it is not necessary to limit its length, and it is possible to select the most favorable ratio of cross sectional increase of the passage according to the laws of fluid flow. The ratio of expansion based upon a unit length is preferably selected to correspond to an orifice angle of from four to twelve degrees. The velocity of the driving fluid when discharging from the diffuser can thus be kept as low as desired and, with low heat losses, can be reduced to five to ten meters per second. Through this arrangement, an appreciable portion of the velocity energy is recovered when discharging from the rotor.

Diffusers constructed according to the present invention are suitable for radial flow turbines as well as for axial flow turbines as illustrated in

Figs. 1 and 2. When, in radial flow turbines, the flow through the rotor is from the outside toward the axis, which arrangement is especially advantageous for nozzle control, the diffuser also serves for simultaneously redirecting the radial flow into an axial flow. To this end the part of the diffuser channel which simultaneously serves for redirecting the flow is preferably constructed with a smaller orifice angle than the subsequent axial portion in which energy conversion only occurs. The inner casing of the diffuser may be constructed of relatively thin sheet copper, brass, or similar material. However, even the outer casing surface can have a relatively thin wall thickness in most cases because the final or discharge pressure of turbines used to produce refrigeration is, as a rule, only slightly higher than the atmospheric pressure. Therefore, despite a great ratio of expansion, neither the weight nor the heat capacity of the turbine is appreciably increased.

Since the turbine may comprise a single stage while the impact must be made variable, as by varying the number of nozzles in operation, the diffusing chamber according to the invention is preferably subdivided by means of practically radial intermediate dividing walls into individual passages, each of which corresponds to a group of nozzles. These dividing walls extend along the entire length of the diffuser and separate it into several individual passages, each of which may preferably be closed off individually by means of a shut-off valve. The number of shut-off valves, which are preferably located near the discharge end of the diffuser, is arranged to correspond to the number of sets of nozzles or to the supply or regulating valves at the entrance to the turbine.

While the discharge tubes of certain turbines for compressible driving fluids have been constructed in the form of diffusers, such diffusers have a poor efficiency due to the fact that a favorable conversion of the velocity energy into pressure energy was impossible because of repeated and irregular redirection of the driving fluid.

Referring now to the drawings and particularly to Fig. 1, a radial flow turbine is shown similar to that shown in Fig. 2 of the copending application previously referred to and described therein. At 10 is shown the driven device for absorbing or utilizing the power. The turbine casing 11 is supported upon the housing of device 10. The hollow shaft 12 of the turbine passes through the right side wall of the housing 11 and is journalled in bearings mounted within the housing 10. The turbine rotor 13 is secured at the left end of the shaft 12. The driving fluid, coming for example from an air separation apparatus indicated at 14 and which is not further illustrated in the interests of clearness, is conducted to the turbine nozzles 30 through the connection 15. The nozzles 30 project the fluid against a ring of blades 16 mounted on the rotor adjacent its rim. The blades 16 project to the left and are disposed parallel to the axis of the rotor, and the fluid flows radially inwardly across the blades leaving them in a radial direction. The diffuser of the present invention consists of an external casing wall 17 and a coaxial internal casing wall or surface 18. The diffuser, in this embodiment of the invention, fulfills both the task of redirecting the radial flow into an axial flow as well as converting the discharge energy of the driving medium leaving the rotor into pressure energy to the greatest possible extent. Both outer casing wall 17 and inner casing wall 18 comprise surfaces of revolution symmetrical about the axis of the rotor 13. The inner casing wall 18 is of conoidal shape and has its base portion adjacent to, but not touching the rotor 13. The wall 18 of the casing has the form of a surface of revolution generated by a curved element revolved about the axis of the rotor and terminating in substantially a point which is substantially on said axis. The casing wall 18 does not extend throughout the entire length of the diffuser. The free-flow cross-section of the diffuser passage is so constructed that the major portion of the energy conversion occurs in the second axial flow portion 32 of the diffuser to the left of the inner surface 18 while the first portion 31 of the passage enclosed between the surface 18 and the outer casing wall 17 is constructed to correspond to a smaller orifice angle and therefore serves mainly for redirecting the driving medium.

In Fig. 2 is shown a form of the diffuser according to the invention applied to an axial flow turbine. In this embodiment also the diffuser is formed by outer and inner casing surfaces of revolution 47 and 48 respectively. The rotor 43 is mounted adjacent the end of shaft 42 and has radially extending blades 46 secured to its rim. The blades 46 are impacted by the driving fluid projected to the left by the nozzles 50 which are held by the turbine housing 41 adjacent the right hand edges of the blades 46. The housing 41 is also provided with a manifold 49 which supplies the driving fluid to each of the nozzles 50. The fluid is conducted to manifold 49 by the conduit 15. In this embodiment, the inner surface 48 of the diffuser is conical and has a base which substantially covers the left face of the rotor 43. The outer casing wall 47 is also conical in shape terminating with a discharge end 52 of smaller diameter and has an included angle between its generating elements smaller than the corresponding angle of the inner surface 48 so that a desired ratio of expansion is obtained. The inner surface 48 tapers to substantially a point and extends to the left for a substantial portion of the length of the diffuser. In this form of diffuser the major portion of the energy conversion takes place in the portion 51 included between the surfaces 47 and 48.

Due to the fact that very low temperatures occur inside of the diffuser, it is advisable to take into consideration the contraction caused by the low temperatures by providing connecting means allowing for such contraction such as a section of expansible tubing or by similar means. This may, for example, be arranged as illustrated in Fig. 3 by the provision of a special corrugated expansible tube 19 arranged adjacent to the external casing surface of the diffuser and as a continuation thereof for effecting a gas-tight connection between the turbine and the adjacent piping of the gas separation apparatus. In order that the corrugations thereof will not produce flow losses, there is inserted in the corrugated tube 19 a straight smooth lining tube 20 of thin metal which is secured to the casing at one end only and slidably supported at the other end. If it is desired to reduce the length of such construction, this may be accomplished, as illustrated in Fig. 4, by arranging the corrugated equalization tube 19 outside of and surrounding the outer wall 17 of the diffuser. In this arrangement it is necessary to install an additional casing or an extension 21 of housing 11 which

will complete a gas-tight connection with the turbine housing. In such construction the diffuser wall 17 is slidably supported at its discharge end.

In cases where the turbine of either type consists of a single pressure stage only and where the impact is variable or the number of nozzles in use is varied, the diffuser may be modified as shown in Figs. 5 and 6. In this case the diffuser is divided up into several passages by means of intermediate dividing walls 22 which are radially disposed and preferably extend the full length of the diffuser. Therefore, with partial impact or when less than the full number of nozzles is in operation, the fluid does not flow through that passage formed by the dividing walls 22 which corresponds to the group of nozzles that are not in operation. Shut-off valves 23 are preferably provided in each passage in order to close off the passages not in use. The valves 23, as shown, may be of the plate or butterfly type and be arranged to rotate on radially disposed axes. The stems 25 of the valves 23 extend radially through the external casing 17 and have handwheels 24 mounted thereon. These shut-off valves are preferably located near the discharge end of the diffuser.

I claim:

1. In a turbine for expanding compressed gas at relatively low temperature to produce refrigeration, said turbine having a rotor, a discharge diffuser comprising two stationary surfaces of revolution disposed on the discharge side of the rotor, said surfaces forming inner and outer walls of a discharge passage, said inner wall surface tapering to substantially a point located within the diffuser and extending throughout a portion only of the length of the diffuser.

2. Apparatus according to claim 1, in which the rotor of the turbine is overhung and the diffuser is arranged adjacent the side of the rotor opposite the shaft bearings.

3. A turbine for expanding compressed gas at relatively low temperature to produce refrigeration comprising a rotor of small diameter adapted for expanding the gas in a single stage at high velocity of the rotor, a housing for said rotor, a shaft for said rotor carried in bearings spaced from said rotor and mounted outside the housing of the rotor on one side only of the rotor; and passage means on the opposite side of said rotor constructed and arranged for converting the kinetic energy of flow of the gas discharged from the rotor into pressure energy.

4. A turbine for expanding compressed gas at relatively low temperature to produce refrigeration comprising an overhung rotor of small diameter and adapted for expanding the gas in radial stages at high velocity of the rotor, a housing for said rotor, a shaft for said rotor carried in bearings spaced from said rotor and mounted at one side of the rotor and outside of the housing of the turbine; and passage means adjacent the side of the rotor opposite the shaft bearing constructed and arranged for converting the kinetic energy of flow of the gas discharged from the rotor into pressure energy.

5. A turbine for expanding compressed gas at relatively low temperature to produce refrigeration comprising an overhung rotor of small diameter provided with blades and adapted for expanding the gas in a single stage at high velocity of the rotor; a housing for said rotor; a shaft for said rotor carried in bearings spaced from said rotor and mounted outside the housing of the turbine; and a diffuser disposed adjacent said rotor adjacent the side opposite the shaft bearing to receive gas discharged from the blades of the rotor, said diffuser comprising a discharge passage having walls arranged to provide an expansion of gas at a rate that effects the desired conversion of the energy of flow into pressure energy.

6. A turbine for expanding compressed gas at relatively low temperature to produce refrigeration comprising an overhung rotor of small diameter adapted for expanding the gas in radial flow stages at high velocity of the rotor; a housing for said rotor; a shaft for said rotor carried in a bearing spaced from said rotor and mounted outside the housing of the turbine; and discharge means adjacent the side of the rotor opposite the shaft bearing for redirecting the radial flow of the gas into axial flow and for converting the energy of flow of the gas discharged from the rotor into pressure energy.

7. In apparatus including a turbine for expanding compressed gas at relatively low temperatures to produce refrigeration for delivery to cold gas receiving means, said turbine having a rotor provided with blades, a discharge diffuser disposed adjacent the discharge side of the rotor to receive and conduct gas discharged from the rotor blades, said diffuser having inner and outer casing walls, said inner casing wall extending throughout a portion only of the length of the diffuser and tapering to substantially a point within the passage formed by the outer casing wall, and means for effecting a gas-tight connection between said turbine and the cold gas receiving means while permitting expansion and contraction of said outer casing wall.

8. In apparatus including a turbine for expanding compressed gas at relatively low temperatures to produce refrigeration, said turbine having a rotor provided with blades, a discharge diffuser disposed adjacent the discharge side of the rotor to receive and conduct gas discharged from the rotor blades, said diffuser having inner and outer casing walls, said inner casing wall extending throughout a portion only of the length of the diffuser and tapering to substantially a point within the passage formed by the outer casing wall, and an expansion joint adjacent the discharge end of said diffuser, said joint comprising a corrugated gas-tight outer sleeve and a smooth thin-walled lining secured at one end only thereof to the casing.

9. In apparatus including a turbine for expanding compressed gas at relatively low temperatures to produce refrigeration for delivery to cold gas receiving means, said turbine having a housing and a rotor provided with blades therein, a discharge diffuser disposed adjacent the discharge side of the rotor to receive and conduct gas discharged from the rotor blades, said diffuser having inner and outer casing walls, said inner casing wall extending through a portion only of the the length of the diffuser and tapering to substantially a point within the passage formed by the outer casing wall, and means for effecting a gas-tight connection between said turbine and the cold gas receiving means while permitting expansion and contraction of said outer casing wall, said connecting means comprising a corrugated gas-tight tube surrounding the discharge portion of said outer casing wall and the diffuser, and a rigid gas-tight casing connecting the corrugated tube to the housing of the rotor, the discharge end of the outer casing wall of the

diffuser being freely slidable axially relatively to the corrugated tube.

10. In apparatus including a turbine for expanding compressed gas at relatively low temperatures to produce refrigeration, said turbine comprising gas inlet nozzles, and a rotor having blades opposite said nozzles, a discharge diffuser disposed adjacent the discharge side of the rotor to receive and conduct gas discharged from the blades thereof, said diffuser having inner and outer casing walls, said inner casing wall extending through a portion only of the length of the diffuser and tapering to substantially a point within the passage formed by the outer casing wall, and radial partitions disposed in said diffuser for dividing said diffuser lengthwise into a plurality of passages, each of said passages being arranged to conduct gas discharged from a group of nozzles of the turbine.

11. In apparatus including a turbine for expanding compressed gas at relatively low temperatures to produce refrigeration, said turbine comprising gas inlet nozzles, and a rotor having blades opposite said nozzles, a discharge diffuser disposed adjacent the discharge side of the rotor to receive and conduct gas discharged from the blades thereof, said diffuser having inner and outer casing walls, said inner casing wall extending through a portion only of the length of the diffuser and tapering to substantially a point within the passage formed by the outer casing wall, radial partitions disposed in said diffuser for dividing said diffuser lengthwise into a plurality of passages, each passage conducting gas discharged from a group of nozzles of the turbine; and stop valves disposed in said passages adjacent the discharge end of the diffuser whereby the passage corresponding to a group of nozzles not in use may be closed off.

12. In apparatus including a turbine for expanding compressed gas at relatively low temperatures to produce refrigeration, said turbine having a rotor provided with blades, a discharge diffuser disposed on the discharge side of the rotor to receive and conduct gas discharged from the blades thereof, said diffuser having inner and outer casing walls, said inner casing wall extending through a portion only of the length of the diffuser and tapering to substantially a point within the passage formed by the outer casing wall, the inner and outer walls being arranged so that the cross-sectional area of the outlet end of the diffuser exceeds the cross-sectional area of the inlet of the diffuser by an amount which provides an increase of cross-sectional area in respect to the length of the diffuser at a rate corresponding to an orifice angle of from 4 to 12 degrees.

13. A turbine for expanding compressed gas at relatively low temperature to produce refrigeration comprising an overhung rotor of small diameter adapted for expanding the gas in a single stage at high velocity of the rotor; a housing for said rotor; a shaft for said rotor carried in bearings spaced from said rotor and mounted outside the housing of the turbine, said shaft extending toward one side of the rotor; and a discharge diffuser disposed adjacent the opposite side of the rotor from that toward which the shaft extends, said diffuser comprising two stationary coaxial surfaces of revolution forming inner and outer walls of a discharge passage, and said inner wall surface tapering to substantially a point located within the diffuser.

14. A turbine for expanding compressed gas at relatively low temperature to produce refrigeration comprising nozzles arranged in groups; an overhung rotor of small diameter, said rotor being provided with blades opposite said nozzle adapted for expanding the gas in a single pressure stage at high velocity of the rotor; a housing for said rotor; a shaft for said rotor carried in bearings spaced from said rotor and mounted outside the housing of the rotor, said shaft extending toward one side of the rotor; a diffuser disposed adjacent the side of the rotor opposite to the side toward which the shaft extends, said diffuser comprising two stationary coaxial surfaces of revolution forming inner and outer walls of a discharge passage, and said inner wall surface tapering to substantially a point within the diffuser; radial partitions disposed in said diffuser for dividing said diffuser lengthwise into a pluralty of passages, each of which conducts gas discharged from a group of nozzles of the turbine; and shut-off valves disposed in said passages adjacent the discharge end of the diffuser.

15. A turbine for expanding compressed gas at relatively low temperature to produce refrigeration comprising nozzles arranged in groups; an overhung rotor of small diameter, said rotor being provided with blades opposite said nozzle adapted for expanding the gas in radial stages at high velocity of the rotor, a housing for said rotor; a shaft for said rotor carried in bearings spaced from said rotor and mounted outside the housing of the turbine, said shaft and bearings being disposed at one side of the rotor; a diffuser disposed adjacent the opposite side of the rotor, said diffuser having inner and outer walls forming a discharge passage, said inner wall surface tapering to substantially a point located within the diffuser; radial partitions disposed in said diffuser for dividing said diffuser lengthwise into a plurality of passages; each passage conducting gas discharged from a group of nozzles of the turbine; and means for connecting a discharge conduit to said turbine to receive the gas discharged therethrough, such means being arranged to allow expansion and contraction of said diffuser.

16. A turbine for expanding compressed gas at relatively low temperature to produce refrigeration comprising an overhung rotor of small diameter adapted for expanding the gas in a single stage at high velocity of the rotor; a housing for said rotor; a shaft for said rotor carried in bearings spaced from said rotor and mounted outside the housing of the turbine, said shaft extending toward one side of the rotor; and a discharge diffuser disposed adjacent the opposite side of the rotor from that toward which the shaft extends; said diffuser comprising two stationary coaxial surfaces of revolution forming inner and outer walls of a discharge passage; said inner wall surface tapering to substantially a point located within the diffuser, and the axis of rotation of said surfaces of revolution being in alignment with the axis of said rotor.

GUIDO ZERKOWITZ.