

May 19, 1964

J. HÄNNY ETAL

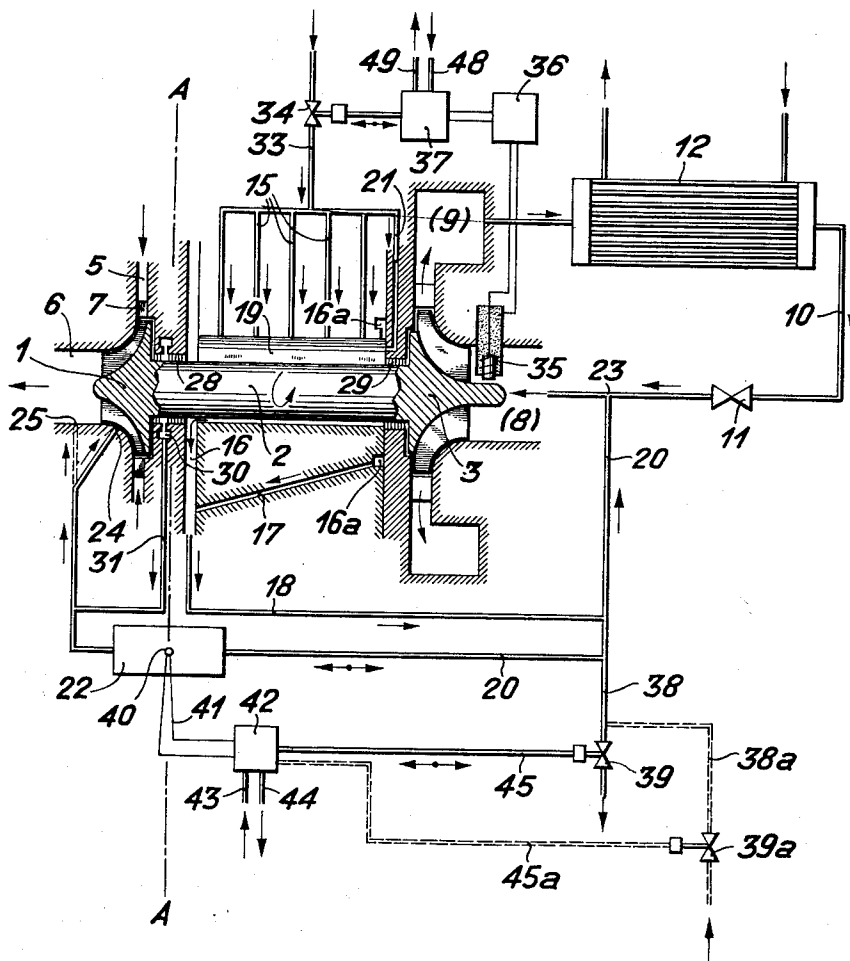
3,133,425

APPARATUS FOR COOLING GASEOUS MEDIA

Filed Sept. 25, 1962

3 Sheets-Sheet 1

Fig. 1



Inventors:

Jost Hännny
Herbert Sixsmith

BY

Permis Edwards Malou Barrow & Co., Inc.
ATTORNEYS

May 19, 1964

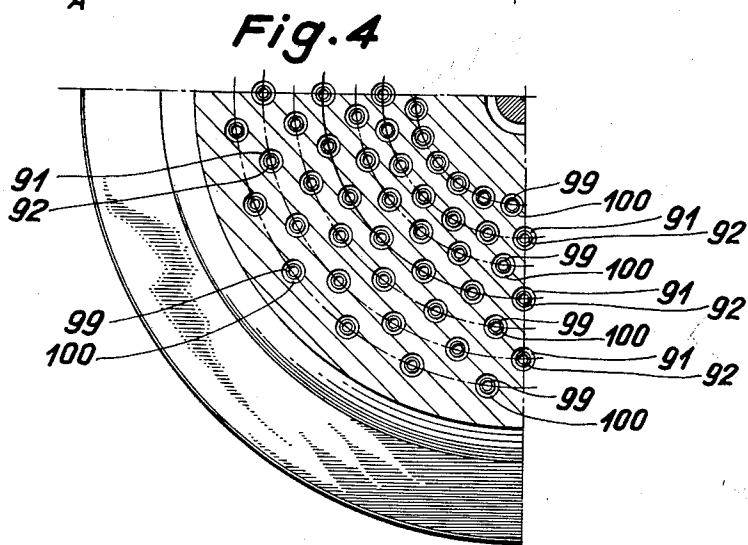
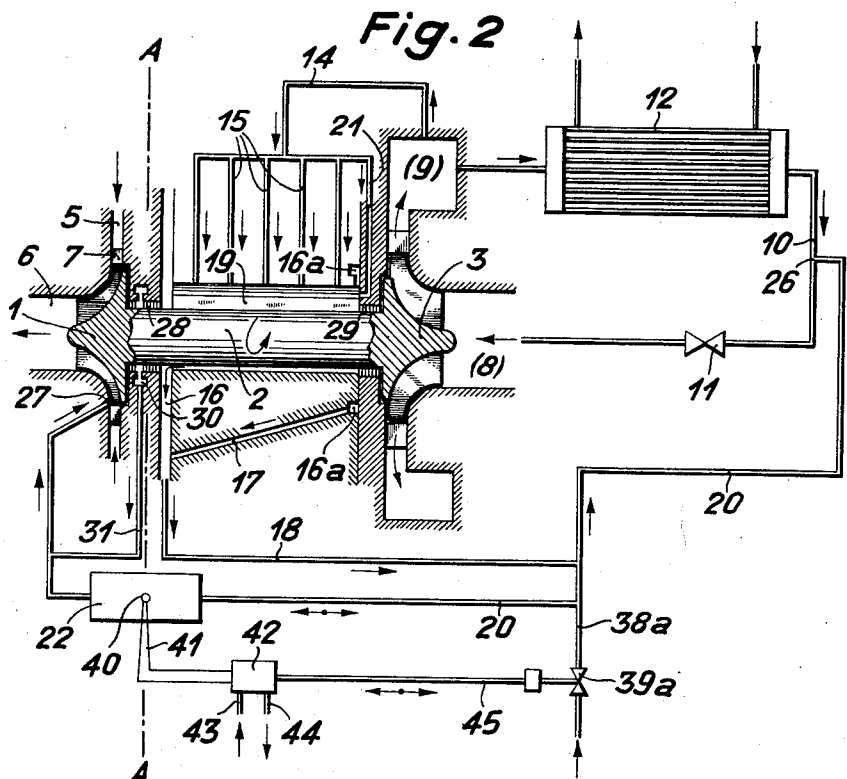
J. HÄNNY ET AL

3,133,425

APPARATUS FOR COOLING GASEOUS MEDIA

Filed Sept. 25, 1962

3 Sheets-Sheet 2



Inventors:

Jost Hännny
Herbert Sixsmith

BY

Penner Edmunds, Mott & Burrum Taylor
ATTORNEYS

May 19, 1964

J. HÄNNY ETAL

3,133,425

APPARATUS FOR COOLING GASEOUS MEDIA

Filed Sept. 25, 1962

3 Sheets-Sheet 3

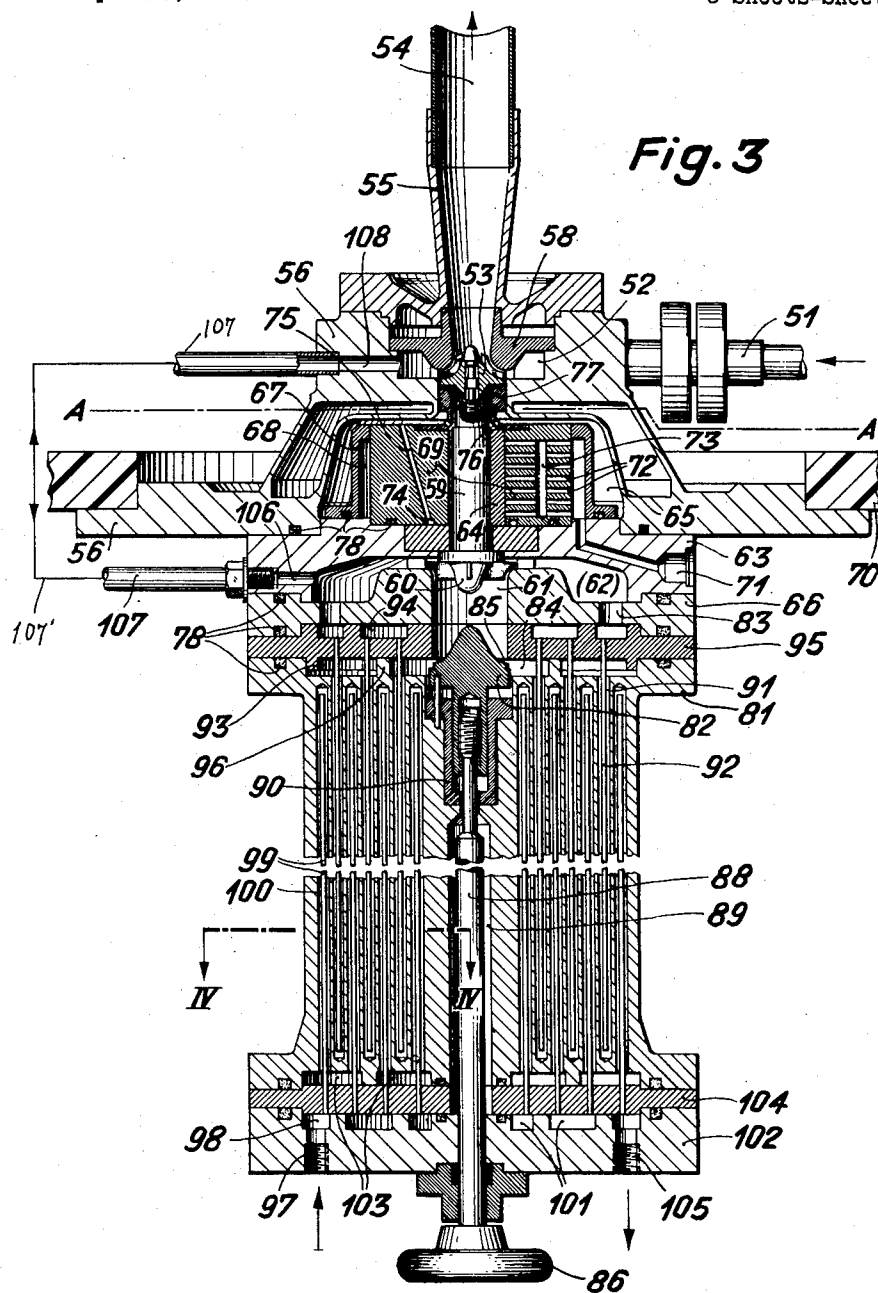


Fig. 3

Inventors:

Jost Hännny
Herbert Sixsmith

BY

Permis Edmunds, Walter D. Barrett, Taylor
ATTORNEYS

1

3,133,425

APPARATUS FOR COOLING GASEOUS MEDIA
Jost Hämy, Rychenberg 297, Winterthur, Switzerland,
and Herbert Sixsmith, 1133 Mapleton Ave., Boulder,
Colo.

Filed Sept. 25, 1962, Ser. No. 226,485

Claims priority, application Switzerland Oct. 4, 1961

14 Claims. (Cl. 62—172)

The present invention relates to a system for cooling gaseous media, wherein an expansion turbine which is situated in the low-temperature zone of the system and which serves for expansion of a gas in order to perform work, drives a turbo-compressor which is situated in the high temperature part of the system and which is connected to the turbine by way of a shaft borne in a gas bearing, a gas being circulated in a closed circuit through a heat exchanger and an adjustable throttling element in the braking part of the system containing the turbo-compressor, and wherein the same type of gas is used in the expansion turbine, the braking part and the gas bearing for the shaft. The compressor and its associated elements absorb mechanical energy from the turbine and are herein sometimes referred to as the braking part of the system.

The system of the invention may be used, singly or in association with plural such systems, for the cooling of gases, for example in compression type refrigerating plants for refrigeration, for gas liquefaction, or in rectifying plants. Systems according to the invention may be used both in parallel and in series arrangements.

Since the pressures in the turbine and the closed compressor circuit are substantially independent of one another, substantial forces are exerted in the axial direction on the shaft carrying the turbine and the compressor if the gas pressure fluctuates in either the turbine or the compressor. The object of the invention is to allow a pressure variation in one of the two circuits to become operative in the other circuit as well, as quickly as possible. According to the invention therefore, a region of the system braking part formed by the compressor, the heat exchanger and the throttling element is connected to a region of the turbine by way of a pressure equalization pipe.

Depending upon the pressure conditions prevailing in the gas circuits of the compressor and turbine, it is advantageous to connect the pressure equalization pipe to the low or to the high pressure side of the compressor, or to an intermediate region of the compressor circuit. At the other end the pressure equalization pipe may similarly be connected to the inlet or to the outlet, or to an intermediate region of the turbine.

The use of the system also makes it necessary for the turbine part usually to be at a much lower temperature level than the braking part of the system. If a sudden pressure drop occurs at the turbine, then apart from the already-mentioned inadmissible axial thrusts, hot gas will flow from the braking part through the pressure equalization pipe into the cold part of the system, and this means a loss or wastage of "cold." It is therefore advantageous to dispose a heat exchanger constructed as a regenerator in the pressure equalization pipe.

If the gas bearing for the shaft is fed from an external gas source, the amount of gas fed to the bearing being controlled, for example, in dependence on the speed of the shaft, a corresponding quantity of gas must be continually withdrawn from the system. The quantity to be withdrawn may readily be controlled by providing a temperature measuring device in the regenerator, said device controlling an adjusting means in a pipe through which gas is withdrawn from the system.

In some cases it may also be desirable—for example

2

if a certain quantity of gas continually escapes from the system—to enable this gas to be replaced in a controlled manner. It is therefore advantageous to provide in the regenerator a temperature measuring device which controls an adjusting means in a pipe through which gas is fed into the system in dependence on the temperature of the gas in the regenerator.

According to one advantageous embodiment of the invention, the braking part of the system is constructed as a self-contained unit in which the heat exchanger is directly fitted to the compressor, and in which an axially slidable throttling element is disposed in coaxial relationship to the compressor and surrounded by the heat exchanger. By this step, the "cold" loss may be reduced advantageously, since this embodiment of the invention results in a relatively small volume for the compressor circuit, so that with otherwise identical conditions the quantity of gas flowing into the turbine becomes relatively small.

Finally it is advantageous to provide a pipe within the low-temperature zone in order to connect the pressure equalization pipe with an annular chamber inside the labyrinth which is between the turbine and the gas bearing. The purpose of this pipe in the low-temperature zone is that in cases where there is a lower pressure prevailing in the pressure equalization pipe than at the inlet edge of the turbine wheel and a small quantity of cold gas flows continually from the turbine inlet side through the labyrinth, it prevents this cold gas from passing to the hot braking part of the system and, in the steady state of operation, it prevents the same quantity of gas—but in the hot state—from flowing continually into the cold turbine circuit.

Further features of the invention will be apparent from the following description of exemplary embodiments taken in conjunction with the drawings in which:

FIGS. 1 and 2 are diagrammatic views of systems for cooling gases according to the invention, wherein a compressor circuit is connected to the expansion turbine to constitute a "braking part" or energy absorbing means.

FIG. 3 is an axial section, much simplified, of a gas cooling system according to the invention having a braking part of relatively small volume and wherein the pressure equalization pipe leads from the compressor delivery side to the feed duct for the cold medium to the turbine; and

FIG. 4 is a sectional view at an enlarged scale taken on the line IV—IV of FIG. 3.

In FIG. 1, the pressure equalization pipe leads from the suction side of the compressor to a region of intermediate pressure in the turbine or to the exit, low-pressure side of the turbine, and in this embodiment of the invention the gas bearing for the shaft is fed from an external gas source and the gas bearing pressure is controlled in dependence on the speed of the shaft. In FIG. 2, an intermediate region of the compressor circuit is connected by the equalizing pipe to the high pressure or inlet side of the turbine. In this example, the gas bearing is fed directly from the compressor circuit so that the gas bearing pressure increases in accordance with the compressor circuit pressure, which latter rises with the speed.

In the various figures, like parts have been given like reference characters.

Referring to FIGS. 1 and 2, the chain-dotted line A indicates the separation between the hot and the cold parts of the system. The rotor 1 of the turbine, lying in the cold part of the system, is mounted on the same shaft 2 as the rotor 3 of the turbo-compressor. The turbine is situated in the gas stream, for example hydrogen or helium, of a low-temperature refrigeration plant. The cold gas to be expanded is fed to the turbine through the chamber 5 and after expansion in the turbine flows out

through the pipe 6. Reference character 7 denotes the guide blades at the turbine inlet. The turbo-compressor at higher temperature is situated with its suction side 8 and is pressure side 9 in a separate additional closed gas circuit indicated at 10 which is fed with the same type of gas as the turbine 1. This circuit includes the throttling element 11 having an adjustable cross-section and, in series therewith, a heat exchanger 12, which may be water-cooled for example. The energy transmitted by the turbine 1 to the compressor and transmitted from the latter by compression to the gas in circuit 10 is discharged through the heat exchanger 12 to a heat sink, not shown. By adjustment of the cross-section of the opening in the throttling element 11 the output and speed of the turbine and hence its refrigerating capacity can be controlled. Adjustment of the throttling element may be effected manually or automatically, for example under the control of a temperature in the refrigerating circuit.

According to the invention, in order rapidly to equalize any pressure fluctuations, the two circuits are connected together by a pipe 20 in which is incorporated a heat exchanger 22 constructed as a regenerator. The latter is so arranged that when the pressure in the pipe 20 is equalized, the exchanger 22 is filled partially with cold and partially with hot gas. If a pressure drop occurs at the turbine—and if the pressure drop at the turbine is not excessive and not unduly prolonged—the gas flowing from the braking circuit 10 towards exchanger 22 is pre-cooled before it flows on into the turbine. If the pressure then rises again on the turbine side, cold gas flows through the regenerator 22 into the braking circuit and, being heated up in the regenerator 22, transfers its cold to the filler material of that regenerator so that the latter cools off again, at least on the turbine side thereof.

In FIG. 1, the equalization pipe 20 branches off from the region 23 on the compressor suction side in circuit 10 and leads to a region 24 of intermediate pressure in the circuit of the turbine 1. The broken line shows a feed to a region 25 at the low pressure exit from the turbine.

The shaft 2 is mounted in a gas bearing, for example a segment bearing, one segment 19 being shown in the drawings. In FIG. 1, the gas for the bearing is fed to the distributing conduits 15 through the pipe 33 containing an adjustable throttling element 34, from an external gas source (not shown), for example a pressure gas cylinder. The gas pressure in the bearing is adjusted by the throttling element 34 in dependence on the shaft speed. The speed of the shaft is measured in known manner by a pick-up system 35 as an electrical high-frequency alternating current voltage, which is then converted into a direct current voltage in the transducer 36, the magnitude of the direct current voltage being an indication of the frequency of the alternating current voltage and hence of the speed of the shaft 2. The direct current voltage leaving the transducer 36 is used to adjust the element 34 by way of an electro-pneumatic transducer 37 of known construction, to which a compressed air supply 48 and discharge 49 respectively are connected.

The gas leaving the bearing collects in the chambers 16 and 16a and is fed through the conduits 17 and 18 into the pressure equalization pipe 20.

Since gas is continually fed from outside to the system through the pipe 33, an outlet pipe 38 is connected to the pressure equalization pipe 20 in order to discharge a specified quantity of gas, said outlet pipe 38 containing an adjustable throttling element 39. The cross-section of the opening of the throttling element 39 is adjusted in dependence upon the temperature of the gas at a region of the regenerator 22. To this end, the temperature is measured at the point 40 in the regenerator 22 by means of a thermocouple 41. The direct current voltage delivered by the thermocouple 41 serves to control an electro-pneumatic transmitter 42, to which compressed air supply and discharge lines 43 and 44 are connected. The throttling element 39 is adjusted in dependence on the

said temperature by means of the transmitter 42 by way of a control line 45 in such manner that as the temperature rises the throttling element is opened more widely and when the temperature drops it is opened less widely, since an increase of the temperature at the point 40 means that here is an excessive quantity of gas entering the hot part of the system as a result of the additional introduction of gas from the external gas source, so that the excess gas tends to flow into the cold turbine part. On the other hand, when the temperature drops at the point 40, an excessive quantity of gas is being taken from the hot part of the system so that cold gas tends to flow from the turbine into the compressor circuit.

In the embodiment of the invention shown in FIG. 2, feeding of the bearing is effected from the high pressure side 9 of the compressor through a conduit 14 and the distributing conduits 15. The gas flowing from the bearing collects again in the chamber 16 and 16a and in this example is returned to the compressor circuit through the conduits 17 and 18 and the pressure equalization pipe 20.

If gas continually escapes from the system as a result of a leak, it is advantageous to provide an additional means for continually introducing a quantity of gas into the braking circuit. FIG. 2 therefore shows a line 38a leading into the pressure equalization pipe 20 and in which gas can flow through a throttling element 39a from an external gas source into the braking circuit. The amount to be supplied is controlled by the temperature-sensitive device 41 in the regenerator 22 by means of the element 42 in a similar manner to that described hereinbefore with reference to FIG. 1 in connection with the amount of gas to be withdrawn from the circuit. In the event of a gas temperature increase in the regenerator 22, the throttling element 39a is moved in the direction to close it while it is moved in the direction to open it in the case of a temperature drop.

If the quantity of gas supplied to the system in the steady state of operation in FIG. 1 is not sufficient to cover any leakage losses, it is possible to introduce gas additionally into the compressor circuit through the pipe 38a even in the embodiment shown in FIG. 1, if the temperature drops further in the regenerator 22 despite complete closure of the throttling element 39 (FIG. 1). This is indicated in FIG. 1 by a broken line control valve 39a which is additionally influenced by the transmitter 42 by way of a line 45a and which is situated in a line 38a which is connected to an external gas source (not shown), the control valve 39a being opened after closing of the throttling element 39 and being adjusted in the same way as has been described with reference to valve 39a in FIG. 2.

If the system is arranged vertically—in which case FIGS. 1 and 2 must be imagined as being rotated through 90°—the compressor circuit is situated vertically below the turbine. In order to mount the segments 19 in the axial direction in these conditions, a further pipe 21 may be provided, through which gas is supplied to the bottom end face of the segments 19.

To seal the gas bearing off from the turbine 1 and from the compressor, labyrinth packings 28 and 29 are provided. The labyrinth 28 on the turbine end of the shaft has an annular chamber 30, from which another pipe 31 in the cold part of the plant leads to the pressure equalization pipe 20. During operation, therefore, a small quantity of cold gas can thus flow continuously from the inlet edge of the turbine rotor 1 into the pressure equalization pipe 20 if the connections of the pipe 20 to the compressor and turbine gas circuits are so selected that a lower pressure prevails in pipe 20 than at the high pressure end of the turbine rotor, to which labyrinth 28 is adjacent.

FIG. 2 shows the pipe 20 running from a point 26 of the compressor circuit situated between the cooler or heat exchanger 12 and the throttling element 11. In this embodiment, the pipe 20 discharges, into the turbine circuit, immediately in front of the turbine rotor inlet edge at the region 27.

The embodiment of the invention shown in FIG. 3 is particularly favorable, in that the braking part of the system is there constructed to occupy only a relatively small volume. In the example according to FIG. 3, the high pressure outlet chamber 62 of the compressor is connected by the pressure equalization pipe 107 to the high pressure side of the turbine.

The cold gas (to be further cooled by expansion) flows through the feed pipe 51 (FIG. 3) into the high pressure chamber 52 of the expansion turbine 53. After expansion it leaves the turbine through a funnel-shaped diffuser 55, fastened on the housing 56 of the turbine 53, and then through the pipe 54. The exit passage from the turbine is formed by a guide 58 which is also fastened in the housing 56. The turbine housing 56 itself is held on the insulating plate 70 of the low temperature plant (not shown) which is disposed in a vacuum.

The turbine 53 is connected to the turbo-compressor rotor 60 by way of the shaft 59. The ducts 61 and 62 on the suction and delivery sides of the compressor are situated in a compressor housing 63 fastened on the turbine housing 56. The compressor housing generally indicated at 63 is composed of a number of parts. The annular chamber 62 is thus partly bounded by an intermediate piece 66, which also contains the compressor inlet or suction duct 61 and which has bores 83 for the escape of gas from the annular chamber 62.

The transition between the cold and hot parts of the system is diagrammatically indicated by the chain dotted line A, the cold part being situated above the line. The shaft 59, which can extend horizontally or vertically depending upon the construction of the complete plant, is mounted in a gas bearing which is provided with segments 64 and which is incorporated in a cavity 65 in the turbine housing 56. The chamber 65 is divided by a shell-like intermediate part 67 so as to form an inner chamber 68. This accommodates the bearing segments 64 and the fixed bearing parts 69. The gas for the shaft bearing is introduced into the chamber 68 through a conduit 71 in the compressor housing 63 from an external gas source, for example a pressure gas cylinder (not shown), and the gas is then fed from said chamber 68 through the distributing conduits 72 and the equalization chamber 73 to the segments 64. After passing through the bearing, the gas flows through the annular chamber 74 and the conduit 75, and the apertures 76 in the part 77, into the chamber 65, from which it is withdrawn from the system through a conduit (not shown).

Reference 78 denotes the packings required to seal the individual chambers from one another or from the atmosphere.

The system braking part comprises the compressor housing 63 which contains the compressor 60 with its feed 61 on the suction side and its annular chamber 62 on the high pressure outlet side, the heat exchanger 81 directly following the compressor housing 63, and the throttling element 82.

After leaving the annular chamber 62, the gas flows alternately through the inner and outer chambers formed by tubes 92 which are situated concentrically in bores 91 in the heat exchanger block 81 and which are arranged serially in the direction of flow, the transition from one double tube 91, 92 to the next being effected by way of annular intermediate chambers 93 and 94 respectively. The connecting chamber 94 is situated in another component 95 which also accommodates the ends of the tubes 92. It is disposed between the intermediate piece 66 and the heat exchanger block 81. In the heat exchanger 81, the annular chamber 93 is separated from an annular chamber 84 by an annular projection 96.

After cooling in the heat exchanger 81 the gas passes to the annular chamber 84, the connection 85 of which to the suction side 61 of the compressor is adjustable by the throttling element 82. The latter is arranged coaxially with respect to the compressor 60 and is adjusted by a

handwheel 86 through an adjusting mechanism. Moreover, in known manner it is possible to control the adjustment of the throttling element 82 automatically, for example in dependence on a temperature of the cold circuit, although this has not been shown. The object of the throttling element 82 is to make the speed of the expansion turbine adjustable within certain limits. To this end the element 82 is axially slidable by way of a spindle 88 extending in a central bore 89 in the heat exchanger 81, and is guided in a sleeve 90. The latter is also disposed in a widened part of the aperture 89.

The flow path for the cooling water is of the same construction as that for the gas. The cooling water flows through the bore 97 and the annular chamber 98 into the tubes 99 which extend in the bores 100 of the heat exchanger 81. Individual parts 99 and 100 respectively situated in series relationship in the direction of flow are connected together by annular chambers 101 in the end 102 and annular chambers 103 in the heat exchanger block 81. The ends of the tubes 99 are held in a component 104 disposed between the heat exchanger block 81 and the end 102. The cooling water leaves the system through the bore 105 in the end 102.

As seen in the cross-section of the heat exchanger block 81 (FIG. 4), the bores 91 for the gas and the bores 100 for the cooling medium are arranged in alternate and offset relationship on the circumferences of circles having different radii.

The compressor housing 63 has a bore 106 which connects the annular chamber 62 of the compressor 60 on the pressure side to the pressure equalization pipe 107 fastened on the housing 63. The path of the pipe 107, and more particularly its passage through the insulating plate 70 of the refrigerating plant situated in the vacuum, is shown only diagrammatically at 107'. In this embodiment, the pressure equalization pipe 107 leads into a bore 108 in the turbine housing 56, said bore connecting the conduit 107 to the high pressure chamber 52 of the turbine 53. The regenerator shown in FIGS. 1 and 2 may of course also be provided in the embodiment of FIGS. 3 and 4, the control of a quantity of gas leaving or entering the plant again being possible as by means of elements such as those shown at reference characters 38 to 45 in FIG. 1.

Depending upon the pressure prevailing in the two circuits, the connections established by the pressure equalization pipes (20 in FIGS. 1 and 2 and 107, 107' in FIG. 3) between the gas flow in the turbine and the gas flow in the compressor may be arranged in manners different from those shown in the drawings. Thus the pressure equalization pipe 20 in FIGS. 1 and 2 may extend from the region 23 in the braking circuit 10 to the region 27 of the turbine shown in FIG. 2 or from the region 26 in FIG. 2 between the heat exchanger 12 and the throttling element 11 to regions such as 24 and 25 shown at the turbine in FIG. 1. Similarly, it is possible to combine the run of the pipe shown in FIG. 3 and that shown in FIGS. 1 and 2, i.e. the pipe 107 in FIG. 3 may lead into the turbine flow at regions such as those shown at 24, 25 or 27 in FIGS. 1 and 2. Conversely, it may also be advantageous to connect the pipe 20 from the zones 23 and 26 of the compressor circuit 10 in FIGS. 1 and 2 to the turbine high pressure chamber as shown at 52 in FIG. 3.

More generally, the embodiments of the invention hereinabove described are exemplary rather than exhaustive of the invention, the scope of the invention being instead set forth in the appended claims.

We claim:

1. Apparatus for cooling gaseous media comprising an expansion turbine through which a gas to be cooled may be expanded, a turbo-compressor, a shaft supported in a gaseous bearing, said shaft coupling said turbine and compressor together, means defining for said compressor a closed path within which a gas is circulated by said

compressor, a heat exchanger and an adjustable throttling device disposed in series in said path, and pressure equalization means connected between said turbine and said path.

2. Apparatus for cooling gaseous media comprising an expansion turbine through which a gas to be cooled may be expanded, a turbo-compressor, a shaft supported in a gaseous bearing, said shaft coupling said turbine and compressor together, means defining for said compressor a closed path within which a gas is circulated by said compressor, the gas in said turbine, compressor and bearing being of substantially the same chemical composition, a heat exchanger and an adjustable throttling device disposed in series in said path, and pressure equalization conduit means connected between said turbine and said path.

3. Apparatus according to claim 2 wherein said conduit means open into said closed path adjacent the low pressure side of said compressor.

4. Apparatus according to claim 2 wherein said conduit means open into said closed path adjacent the high pressure side of said compressor.

5. Apparatus according to claim 2 wherein said conduit means open into said path at a point of pressure intermediate the high and low pressure sides of said compressor.

6. Apparatus according to claim 2 wherein said conduit means open into said closed path at a point between said heat exchanger and throttling device.

7. Apparatus according to claim 2 wherein said conduit means connect to said turbine at the high pressure side thereof.

8. Apparatus according to claim 2 wherein said conduit means connect to said turbine at the low pressure side thereof.

9. Apparatus according to claim 2 wherein said conduit means connect to said turbine at a point intermediate the high and low pressure sides thereof.

10. Apparatus according to claim 2 including a regenerative heat exchanger disposed in said conduit means.

11. Apparatus according to claim 10 including means to supply gas under pressure to said blaring, means

to control the rate of flow of gas from said last-named means to said bearing as a function of the speed of said shaft, an adjustable valve for withdrawal of gas from said apparatus, and means to control the opening of said valve in response to the temperature of said regenerative heat exchanger.

12. Apparatus according to claim 10 including means to supply gas under pressure to said apparatus, an adjustable valve controlling the flow of gas from said last-named means into said apparatus, and means responsive to the temperature of said regenerative heat exchanger to adjust said valve.

13. Apparatus for cooling a gas comprising an expansion turbine in a cold zone of said apparatus through which a gas may be expanded in order to cool the same, a turbo-compressor in a warm zone of said apparatus for the absorption of energy from said turbine, a shaft supported in a gaseous bearing, said shaft coupling said turbine and compressor together, a labyrinth seal on said shaft adjacent said turbine, means defining for said compressor a closed path within which a gas is circulated by said compressor, the gas in said turbine, compressor and bearing being of substantially the same chemical composition, a heat exchanger and an adjustable throttling device disposed in series in said path, a pressure equalization conduit connected between said turbine and said path, and a further conduit extending within said cold zone from said labyrinth to said pressure equalization conduit.

14. Apparatus according to claim 1 wherein the turbo-compressor and heat exchanger constitute a self-contained unit in which the heat exchanger is arranged coaxially of and immediately adjacent to the compressor, and in which the throttling device is disposed coaxially within the heat exchanger.

References Cited in the file of this patent

UNITED STATES PATENTS

2,973,136	Greenwald	Feb. 28, 1961
3,038,318	Hanny	June 12, 1962

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,133,425

May 19, 1964

Jost Hännny et al.

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 3, line 67, for "elemen" read --element--;
column 4, line 6, for "here" read -- there --; line 13,
for "circui" read --circuit --; column 7, line 41, for
"blaring" read -- bearing --.

Signed and sealed this 10th day of November 1964.

EAL)

test:

RNEST W. SWIDER
Testing Officer

EDWARD J. BRENNER
Commissioner of Patents