March 31, 1953

W. E. TRUMPLER

CENTRIFUGAL MACHINE

2,633,291

Filed Oct. 25, 1946

3 Sheets-Sheet 1

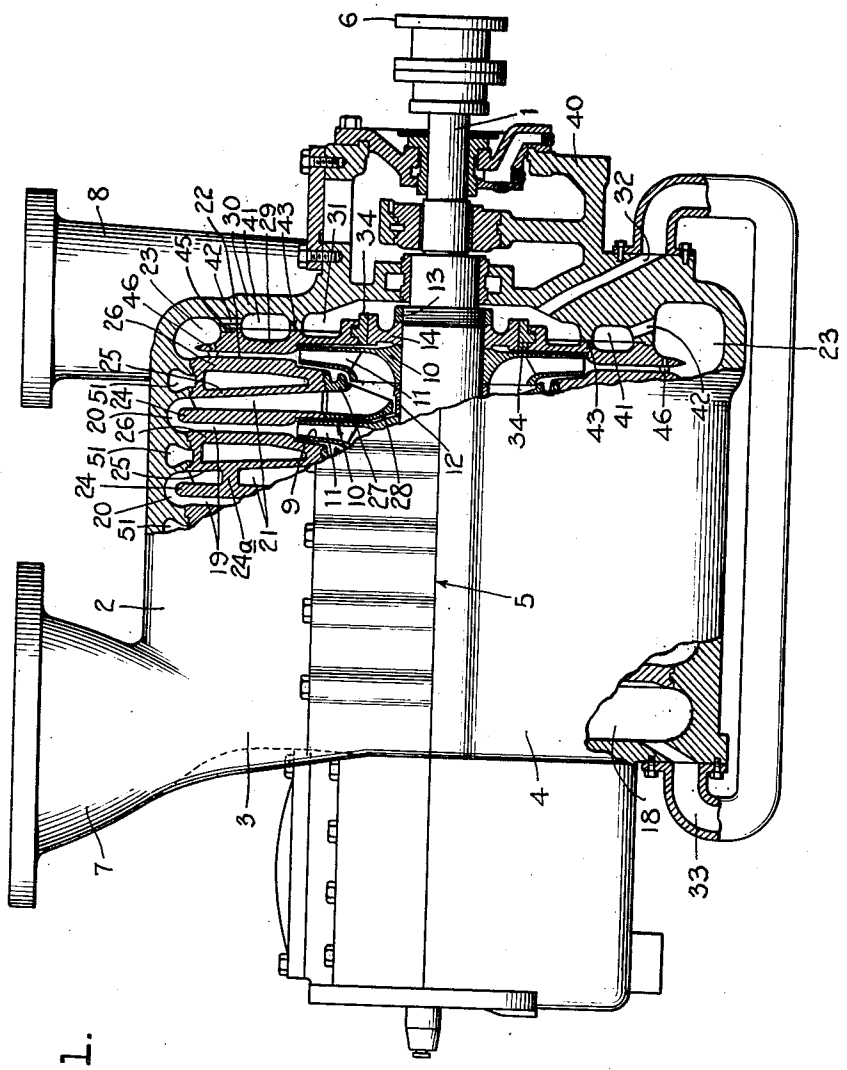



Fig. 1.

INVENTOR

William E. Trumpler

BY

ATTORNEYS

March 31, 1953

W. E. TRUMPLER

CENTRIFUGAL MACHINE

2,633,291

Filed Oct. 25, 1946

3 Sheets-Sheet 2

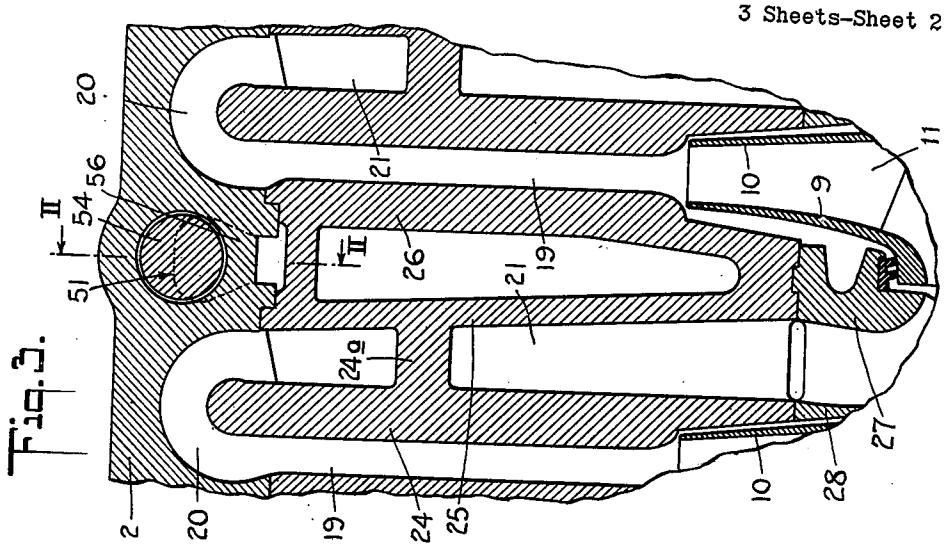



Fig. 3.

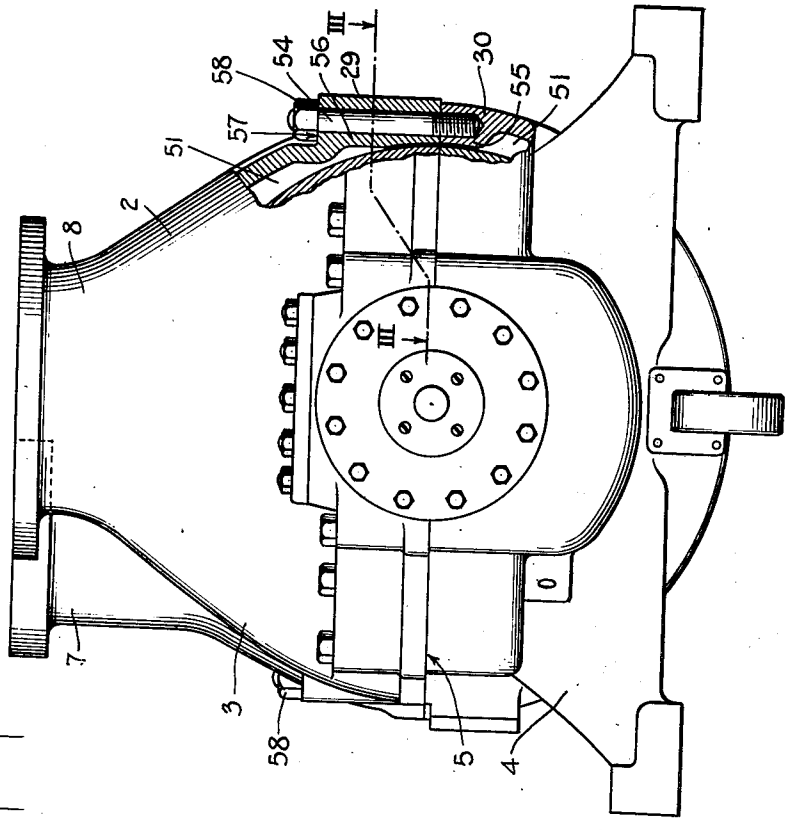



Fig. 2.

INVENTOR
William E. Trumpler

BY

ATTORNEYS

March 31, 1953

W. E. TRUMPLER

CENTRIFUGAL MACHINE

2,633,291

Filed Oct. 25, 1946

3 Sheets-Sheet 3

Fig. 5.

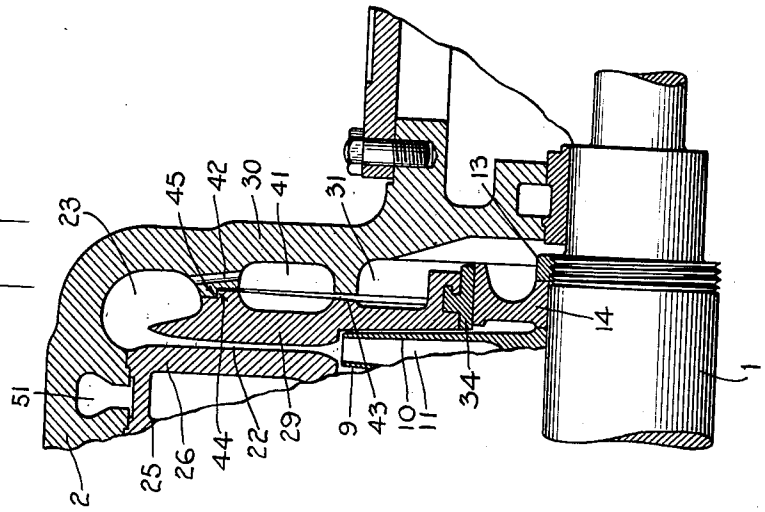
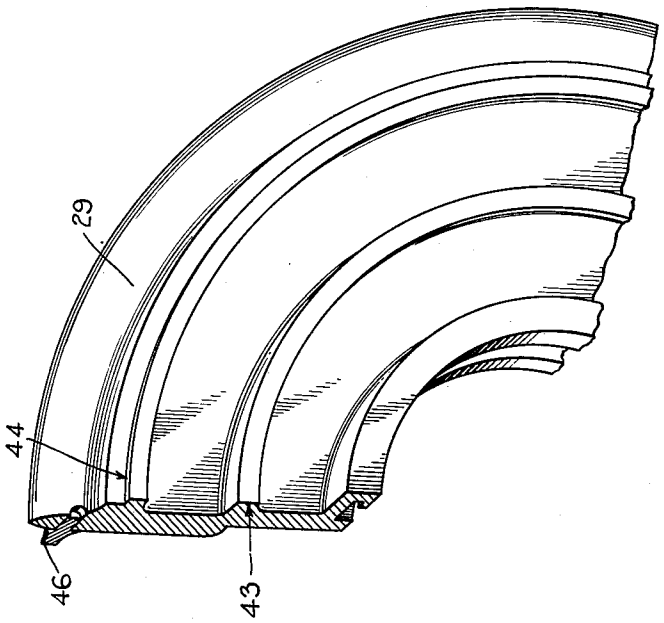



Fig. 4.




INVENTOR

William E. Trumpler

BY J. Stanley Morton

ATTORNEYS

Patented Mar. 31, 1953

2,633,291

# UNITED STATES PATENT OFFICE

2,633,291

## CENTRIFUGAL MACHINE

William E. Trumpler, Olean, N. Y., assignor, by mesne assignments, to Dresser Operations, Inc., Whittier, Calif., a corporation of California

Application October 25, 1946, Serial No. 705,503

4 Claims. (Cl. 230—130)

1

Speaking generally, my invention tends to reduce the stresses resulting from temperature differences in the casings of centrifugal gas compressors and analogous machines, and especially such stresses in the casings of multistage devices of this kind. For brevity hereinafter I refer to such machines solely as "gas compressors."

In certain designs of machines of the kind here concerned, end walls of the casings, or portions of such walls, and especially those at the high pressure ends of the machines, are shielded from any direct, large volume flow of the fluid passing from the inlets to the outlets of the casings. An example of such a structure is shown in the accompanying drawing. As a result of this shielding the shielded areas heat up rather slowly whenever the machines are newly started up, as compared with, say, adjacent portions of the casings, and the temperature differences that result from such actions cause stresses in the casing walls that may rise to dangerously high values unless adequate precautions are taken. The present invention reduces such stresses by flowing hot fluid over such normally-shielded areas when the stresses tend to approach dangerous values, by providing a supplemental passage or passages to direct flows of heated fluid over the shielded areas on such occasions. This fluid flow tends to equalize the temperature differences and thus reduce or avoid the stresses. Preferably this heated fluid is directed back through the wall of the enclosing casing of the chamber at a point preceding the last stage, and usually at the inlet end of the machine, so as to reduce losses. A thermo-responsive gate, subject to the temperature of the heated fluid, is provided for closing such supplemental passage or passages automatically when the temperatures of the shielded area or areas and the adjacent parts of the casing approximate each other as closely as may be thought necessary or desirable; such control of the flow avoids unnecessary loss of compressed fluid, and also may be useful to the end that the passages to be traversed by the fluid under normal conditions, be those best suited for the primary function of the machine.

In providing for such a supplemental flow, use can be made of certain chambers and passages frequently found in machines of the kind here concerned. This also is shown hereafter. It is not altogether a necessary element of the invention however as will be apparent.

Again, it is desirable, at least in various instances, that portions of the passages through which the fluid passes in its travel from port to port be formed in the wall of the machine casing.

2

For manufacturing reasons such a construction usually requires the casing to be split into sections along lines more or less parallel to the shaft, and these sections bolted together. As contemplated heretofore such casing sections are provided with exteriorily projecting flanges or bosses to receive the bolts. Necessarily such external localized concentrations of metal also cause temperature differences, and accordingly localized stresses in the casing wall as is well known. Such localized stresses may not be objectional in relatively low pressure machines, but may become undesirably high in high pressure machines. The accompanying drawings illustrate a construction in which such stresses are lessened, as it were, by placing the bolts and their bosses substantially within the circumference of the casing, and more or less at passages carrying the fluid so far as possible or convenient, so that their temperatures at all times correspond more nearly than heretofore to the temperatures of the adjacent portions of the casing structure. Such a casing construction can be used with the present invention, but the invention is not limited to machines whereof the casing is so constructed as will be apparent.

The foregoing is illustrated by the multistage compressor for air or other gas shown in the accompanying drawings in which: Fig. 1 is a side view, partly in section, of the machine. Fig. 2 is an end view of the same machine, also partly in section. Fig. 3, drawn to a larger scale, is a section about on the line III—III of Fig. 2. Fig. 4 is a projection of a portion of one of the interior walls of the machine. Fig. 5 is a sectional view of a portion of the high pressure end of the machine showing the supplemental passage open for heating the adjacent end wall of the casing.

The rotary shaft 1 of the machine shown in the drawings, is supported in appropriate bearings in or at the ends of its enclosing casing 2 which is formed of upper and lower sections or mating members 3 and 4. As is customary the bearings may include a thrust bearing or bearings for the shaft. The division between the two sections 3 and 4, parallel to the shaft 1 and in the same plane across the ends of the casing, is at 5. Bolts hold the two sections together. A coupling 6 provides for the connection of the shaft 1 to a prime mover for driving (rotating) the shaft. The inlet 7 for the gas is at one end of the casing 2, and the outlet 8 for the gas compressed within the casing is at its other end. At each stage between the inlet and the outlet ports an impeller is mounted rigidly on the shaft 1, e. g. by press fit with or without keys. For example, each im-

peller may consist of two spaced disc-like members 9 and 10 connected by a number of more or less radial vanes 11. The impellers are held in place lengthwise of the shaft by cylindrical spacers 12 surrounding the shaft between adjacent impellers, and a collar 13 threaded to one end of the shaft 1 and acting through a ring-like balancing drum 14, which also is mounted to turn with the shaft 1, to hold the impellers 9—10 and spacers 12 against each other and the last of the line against another collar toward the opposite end of the shaft. A more or less circular passage 18 at the inlet end of the machine casing conducts gas from the inlet 7 to the inlet of the first impeller. Between each two impellers 9—10 a diffuser 19, more or less disc-like, conducts the gas from the outlet of one impeller to a passage 20 cut circumferentially in the inner wall of the casing 2, while a vaned or bladed return passage 21 conducts the gas from 20 to the inlet of the succeeding impeller. A more or less disc-like open diffuser 22 conducts the gas from the last impeller to a volute passage 23 leading to the outlet 8. The passages 19 and 21 and one side of passage 22 are provided by stationary circular radial (i. e. more or less radially extending) walls 24, 25, 26, 27 and 28, which are carried by the interior of the casing 2; e. g. each set of the walls 24, 25 and 26, with spirally curved vanes 24a tying wall 24 to 25, may be parts of a single casting called a diaphragm which is held in place by recesses formed in the inner surface of the casing wall as shown, and each pair of walls 27 and 28, also with vanes tying them together, may constitute a single-piece inlet guide vane ring which is carried by and at the center of the related diaphragm. The opposite side of passage 22 is formed by a disc-like radial wall-member 29 which substantially parallels the end wall 30 of the casing and encircles the balancing drum 14. This member 29 is a separate member, i. e. is separate from the end-wall 30 of the casing. The member 14 constitutes, as it were, a piston head attached to the shaft and rotates with small clearance in the wall 29. It more or less resists end thrust of the shaft 1; to this end the balancing drum 14 is exposed at one side to high pressure gas (the pressure adjacent the outlet of the last impeller in the present instance) and at its opposite side to the lower pressure of a chamber 31 which is formed in the end wall 30 of the casing. This end wall 30 is located adjacent the casing outlet 8, and the chamber 31 is connected by a passage 32 and pipe 33 to, say, the intake passage 18 as has been customary heretofore. A circular sealing ring 34 may be inserted between the edge of wall 29 and piston 14 to keep the crevice between them as reasonably gastight as may be.

As thus far described the machine is substantially conventional, and is subject to considerable variation in construction. In operation the impellers are rotated at an appropriately high rate of speed by the prime mover connected to the shaft 1 at the coupling 6. As a result the gas (air or other gas) is taken in at the inlet 7, at atmospheric or other pressure, is compressed as it passes through the casing, and from the last stage is discharged into the passage 23 from which it passes under pressure through the outlet 8. Due to internal reactions, the compressing gas, acting on the impellers, tends to force the shaft 1 to the left in the present instance. This end thrust is resisted by the compressed gas acting on the left-hand face of the piston 14, inasmuch as the pressure at the opposite face of this piston 14, i. e. the pressure in the chamber 31, is lower than the pressure at the left of the piston. The thrust bearing or bearings before mentioned sustain any resultant endward thrust on the shaft there may be. Gas that escapes between this piston 14 and the shoe 34 that engages the piston circumference, escapes through the passages 32 and 33.

As the gas is compressed toward the right-hand end of the compressor its temperature rises of course, more or less progressively, from end to end of the compressor, and at the right-hand end of the compressor the temperature may be much higher than the temperature of the gas entering the inlet 7 and flowing in the inlet passage of the machine. Since in the course of the compression the gas flows in close contact with the impellers and the various passage-forming internal walls of the compressor mentioned before, and also in close contact with the side wall of the casing 3—4 itself (i. e. at the passages 20), these parts heat up rather rapidly whenever the compressor is started up, and also the temperature difference between the two ends of the compressor tends to be distributed reasonably uniformly along the casing side wall from one end of the machine to the other, speaking generally. However, any casing-holding bolts and added metal placed outside the casing as proposed heretofore, interfere with such uniform distribution of this temperature difference. Further, the portion of the wall 30 facing the piston or balancing drum 14, and also the portion that faces the internal wall 29 (which is used, say, in order to give desired proportions to such a passage as 22) are shielded by the balancing drum and wall 29 from direct contact with the adjacent gas flow. It will be noted that both the elements 14 and 29 are separate from the end wall 30.

As a result of this shielding the shielded areas tend to heat up more slowly than the adjacent and other portions of the casing when the machine is started up, and at various times considerable differences in temperature may exist between adjacent portions of the casing because of the shielding. Accordingly considerable internal stresses may be created in the casing metal by the temperatures of the parts.

To prevent such effects, or at least to minimize or reduce them as compared with prior practices, I provide for the flow of hot compressed gas over at least the shielded portions, substantially, of the end wall 30 when the difference between the average of the temperatures of the end wall, as it were, and the temperature of adjacent parts of the machine, tend to exceed some safe value, e. g. during the starting up periods and when the end metal is comparatively cold. Preferably the hot gas is caused to flow over a number of distributed parts of the end wall, as by means of a number of channels radiating star-fashion from the shaft axis, or by means of an annular passage over the face of the end wall. Obviously a passage or passages for such a flow of gas can be provided in various ways, and can be opened or closed if and as may be desired, in various ways. In the present instance, and preferably the passage is an annular passage 41 extending over shielded portions of the end wall 30 and connecting the outlet passage 23 to the space 31 back of the balancing drum 14, whence the gas flowing through it may escape through an orifice in the outer wall of the enclosing casing at a point preceding the last stage of the compressor, for example through the passage 32 which leads to the orifice at 33. If the outer portion of wall

30 joins 29 as in the present instance, the passage 41 can be connected to 23 by a number of intermediate passages 42. Preferably the flow is permitted only when the end wall 30 is at a noticeably lower temperature than adjacent parts; this avoids unnecessary loss of compressed gas. Accordingly the passage may be opened or closed under thermal control. Although not necessary, the internal wall 29 may be used to exercise such thermal control of the gas flow. This is possible because the temperature of the wall 29 follows the gas temperature more closely than the temperature of the end wall 30. To this end the inner wall 29 and the end wall 30 may be provided with a gate closing the passage 41 (or 41—42) when the difference between the temperatures of the two walls is less than some amount that represents safe temperature differences in the casing wall, but which is opened by the disproportionate expansion of the internal wall, relative to the end wall, when the difference between the temperatures of the internal wall and the end wall tends to exceed the safe amount. For this purpose one or both of the walls 29 and 30 can be provided with a gate, e. g. in the form of an annular longitudinally projecting flange at 43, to close the annular space 41 (or 41—42) inwardly of the outer circumferences of the walls (say at the drum chamber 31), and also the wall 29 provided with an annular shoulder 44 facing radially outward and the end wall 30 provided with a cooperating annular shoulder 45 facing radially inward, these two shoulders being placed outwardly, radially, from the gate 43, and also somewhat away from the face of the internal wall 29 so that this wall 29 is dished, as it were, inwardly of the machine and away from the gate (see Figs. 4 and 5). These shoulders may support the wall 29 on the end wall 30. Spacers 46 can be used to maintain the distance of 29 from the adjacent wall 26 and thereby the continued engagement of the shoulders 44 and 45. The shaping and proportions of the two walls 29 and 30 are such that the gate at 43 is closed (Fig. 1) when the difference between the temperatures of the two walls is less than some safe amount, but as this difference approaches this amount the resistance to radial expansion of wall 29 imposed on shoulder 44 by shoulder 45, causes the inner circumference of wall 29 (i. e. at shoe 34) to move longitudinally inwardly, to the left, and thus open the gate 43 (Fig. 5) and thus permit the flow of hot gas from 23 through passage 41 until the temperatures of 29 and 30 again approach each other more closely.

As before indicated I prefer, although I do not consider it essential to the present invention, the sectionalized, e. g. horizontally split, form of casing of which the casing 2 (3—4) is an example, but as also indicated the bolts required by such casings, and added metal for those bolts, as proposed heretofore, create local temperature stresses. To reduce these stresses, especially in high pressure machines, I prefer to locate bolts 54 that hold the sections (e. g. 3 and 4) together, within the circumference of the casing and adjacent the gas flow, so far as this is reasonably possible. This is illustrated in Figs. 2 and 3 especially. Annular chambers 51 may be provided in the casing wall between passages 20 and such bolts 54 may pass into them, and extra metal required for the bolts, such as 55 into which the bolts may be screwed and 56 to sustain the pull of the bolts, can be located more or less within such grooves or chambers 51; also the casing wall can be indented at such grooves or chambers to



provide more or less of the surfaces 57 required for the bolt heads or for nuts at the bolt ends. As before pointed out, it will be understood that this casing construction is merely one that I prefer and the invention is applicable to other forms of casing also.

The operation of the machine illustrated in compressing gas has been described above, and it has been pointed out that in starting up the machine the temperatures of the shielded areas, e. g. the portions of the end wall 30 facing the balancing drum 14 and the internal wall 29, tend to rise more slowly than the temperature of adjacent parts of the machine exposed to direct contact with the flowing gas. With the arrangement of the invention however, the temperature rise in the wall 29, relative to the temperature rise in 30, causes the wall 29 to dish farther to the left and thereby open the gate at 43 as before indicated, and this permits hot gas to flow over the whole of 30 as before described. This in turn heats the end wall 30 more rapidly than otherwise, and accordingly reduces the temperature differences, and accordingly the stresses, within the wall of the casing. As the temperature of the end wall 30 rises however, its consequent radial expansion relieves the pressure at the shoulders 44 and 45, and this permits radial expansion of the internal wall 29, and as this occurs its inner circumference returns toward the right until the gate at 43 closes again and the supplemental flow is stopped. At the same time the proximity of the bolts 54 to the gas and their non-exposure outside the casing causes the temperature of these bolts and their supporting metal to rise more rapidly and more nearly with the temperature of the casing wall than heretofore, thus further reducing the casing stresses. I. e. conjointly the supplemental gas flow and the bolt placement tend to minimize the stresses in the casing wall created by the temperatures.

It will be understood of course that my invention is not limited to the details described and illustrated except as appears hereafter in the claims.

I claim:

1. A gas compressor having a casing having an inlet and an outlet and an end wall, and having at least one element that shields at least a portion of said end wall of the casing from contact with fluid flowing from the inlet to the outlet of the casing, characterized by the fact that said compressor includes means providing a passage to guide a flow of fluid, having a temperature at least approximating the temperature of the fluid in a portion of said casing adjacent said end wall, over at least said portion of said end wall, and a thermo-responsive gate subjected to the temperature of said fluid is provided to open and close said passage.

2. A centrifugal gas compressor having a casing having an outlet and a wall adjacent said outlet, and at least one impeller, and having a substantially radially extending wall, adjacent said casing wall, forming one side of at least a part of the gas passage leading from said impeller to said outlet and forming with said casing wall a passage for the flow of compressed gas over at least a portion of said casing wall, said radial wall and said casing wall having cooperating normally-engaging portions to close the second mentioned passage against flow of compressed gas therethrough, and having engaging shoulders to cause thermal expansion of said radial wall, produced by the temperature of the gas and exceeding thermal expansion of the casing wall, to take

place in a direction to disengage said cooperating normally-engaging portions of said two walls.

3. The subject matter of claim 2, characterized by the fact that said normally-engaging portions of the two walls face substantially axially of the adjacent impeller, said shoulders are more remote from the axis of said impeller, radially, than said normally-engaging portions, the inner circumference of said radial wall is free to move axially of the said impeller, and the radial wall is dished toward said impeller.

4. The subject matter of claim 2, characterized by the fact that the compressor has a thrust-resisting piston head on its shaft one face of which is exposed to high pressure fluid, and has a passage to lead fluid from the opposite face of the piston head, and said passage for the flow of high pressure fluid over said casing wall opens to said passage which leads fluid from the piston head.

WILLIAM E. TRUMPLER.



## REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

| Number | Name | Date |
|---|---|---|
| 890,355 | Goeriz | June 9, 1908 |
| 1,037,243 | Guy | Sept. 3, 1912 |
| 1,221,822 | Bodinson | Apr. 10, 1917 |
| 1,373,896 | Loewenstein | Apr. 5, 1921 |
| 1,957,699 | Dahlstrand | May 8, 1934 |
| 2,221,225 | Weis et al. | Nov. 12, 1940 |
| 2,304,993 | Franck | Dec. 15, 1942 |
| 2,305,226 | Stalker | Dec. 15, 1942 |
| 2,407,987 | Landberg | Sept. 24, 1946 |

FOREIGN PATENTS

| Number | Country | Date |
|---|---|---|
| 171,467 | Switzerland | Nov. 16, 1934 |