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APPARATUS FOR DIRECTING AIR TO COMBUSTION PRODUCTS TURBINES

Original Filed Dec. 1, 1943 4 Sheets-Sheet 1

Fig. 1

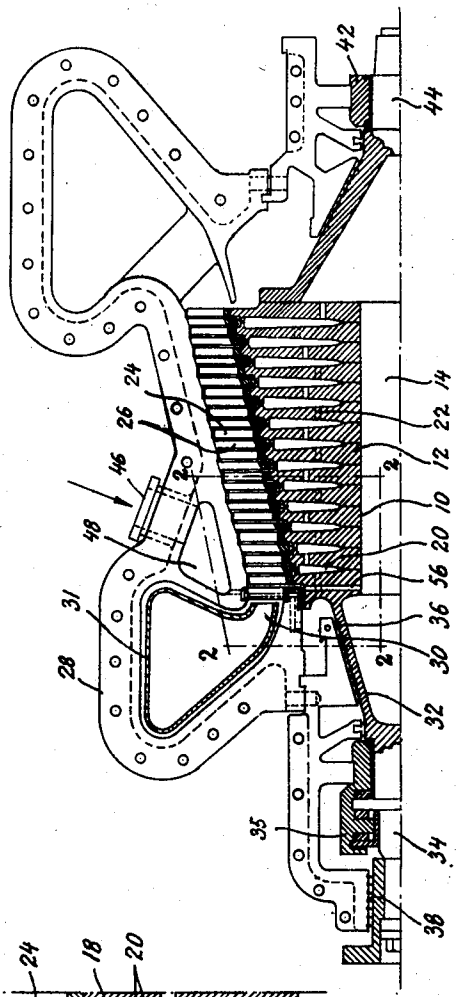
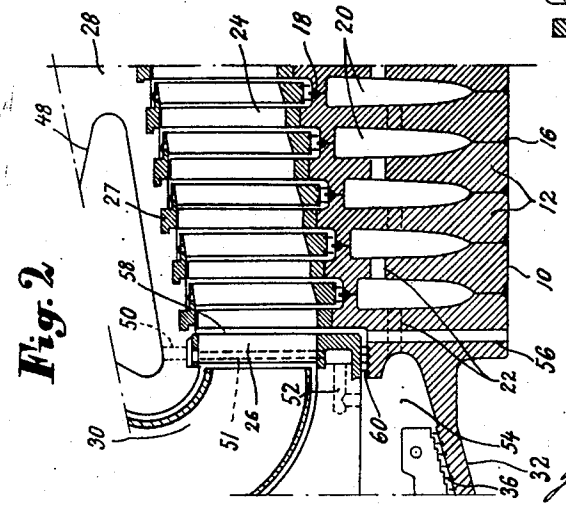



Fig. 2



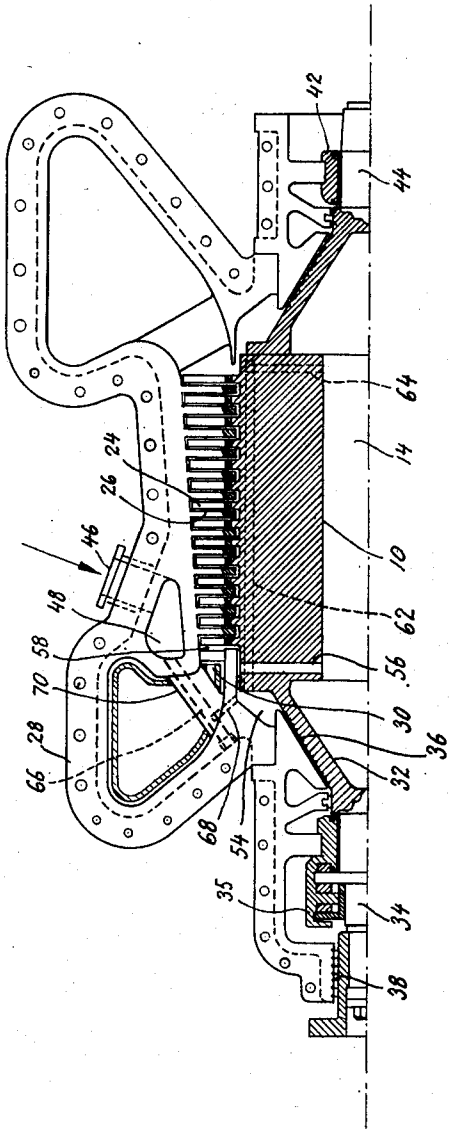

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Fig. 3




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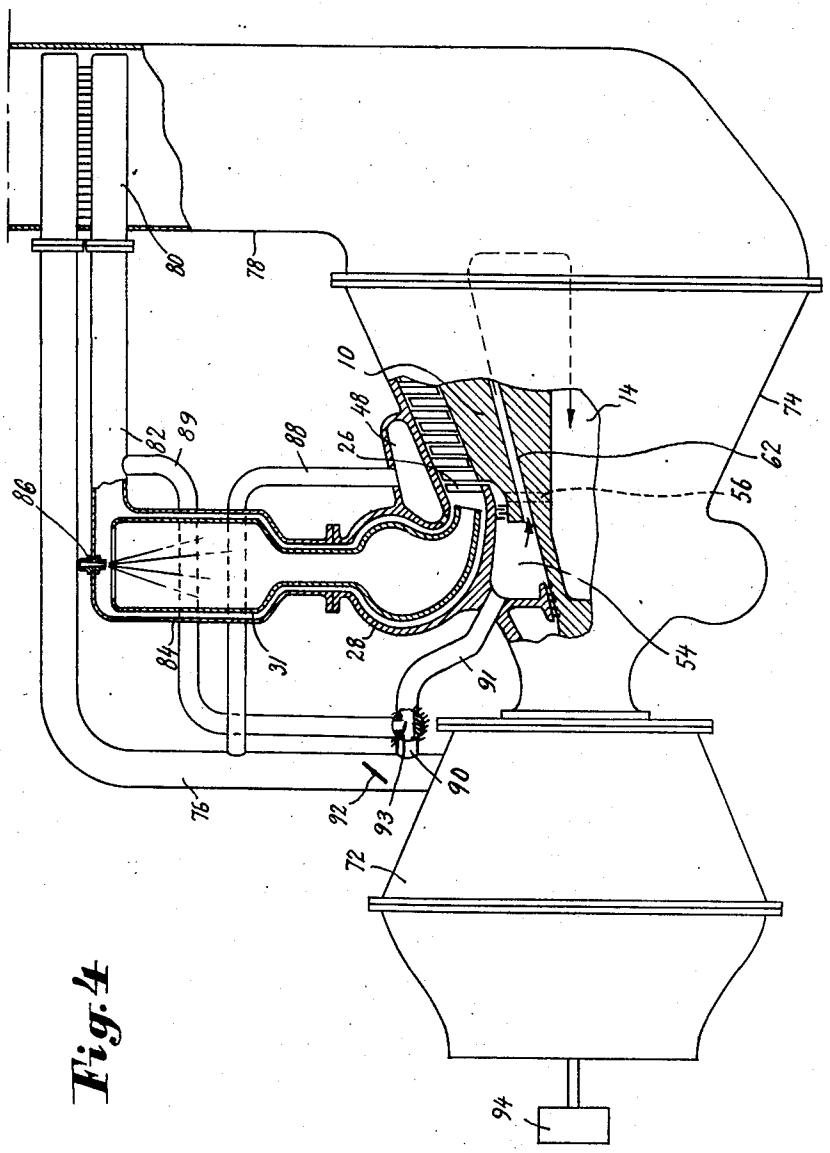



Fig. 4

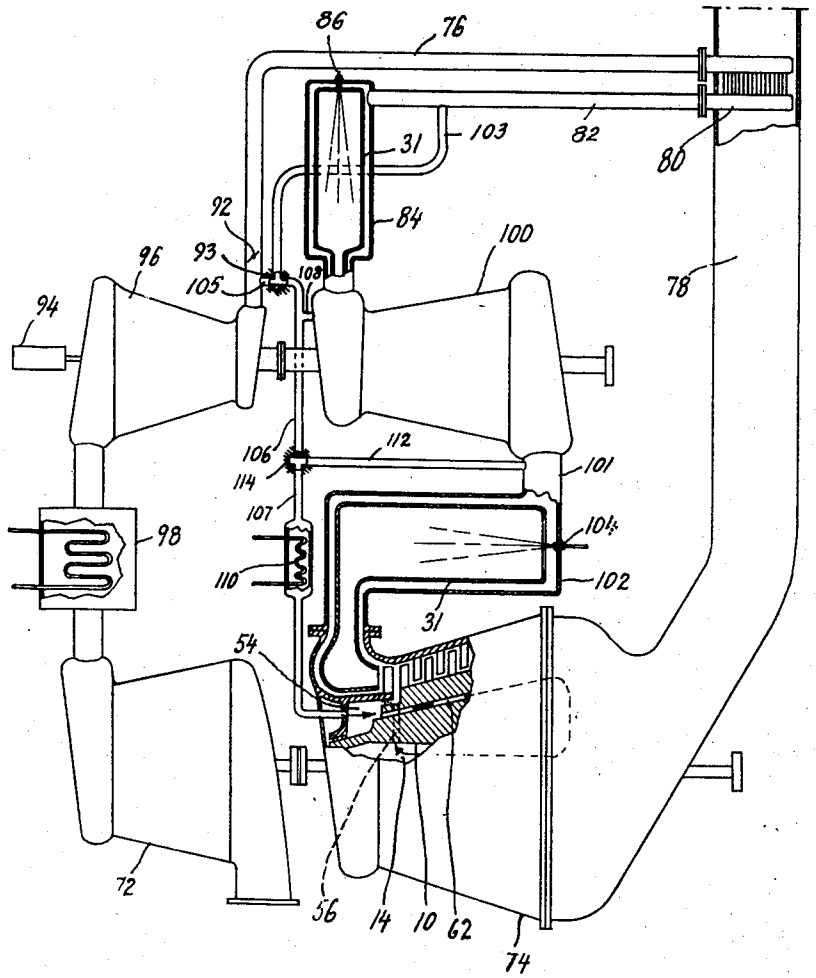
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*Fig. 5*




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Patented Oct. 6, 1953

2,654,220

# UNITED STATES PATENT OFFICE

2,654,220

## APPARATUS FOR DIRECTING AIR TO COMBUSTION PRODUCTS TURBINES

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Original application December 1, 1943, Serial No. 512,474, now Patent No. 2,487,514, dated November 8, 1949. Divided and this application February 25, 1949, Serial No. 78,262. In Sweden January 16, 1943

5 Claims. (Cl. 60—39.66)

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This application is a division of our copending application Serial No. 512,474, filed December 1, 1943, now U. S. Patent No. 2,487,514 granted November 8, 1949.

In turbines, such as gas turbines, operating with hot driving media, it is difficult and calls for much energy effectively to cool the rotating blades proper, inasmuch as their total surface is large and the coefficients of heat transfer between the flowing gaseous working medium and the blade surfaces are very high. It is therefore known instead to cool the rotor of the turbine, air compressed by a compressor contained in a gas turbine plant having been used as the cooling medium for cooling the turbine rotor. This invention has for its object to provide a cooling device, more particularly for turbines of the multi-stage type, with a high cooling effect and with a small consumption of energy. This is accomplished substantially by the fact that the interior of the rotor communicates through channels with the passage containing the blades, preferably with the space behind the first guide blade, so that the gaseous or vaporous cooling medium after having passed the rotor escapes to said passage. According to a further feature of the invention, the cooling agent has, immediately before entering the rotor, a pressure which is somewhat higher than the pressure of the driving medium in that portion of the passage wherein said channels open. In the application of the invention in gas turbine plants, the interior of the rotor communicates with a compressor or some other part of the gas turbine plant through conduits adapted to take off a portion of the working medium and to introduce the same into the rotor.

For example, if 3% of the air quantity delivered by the compressor is used for the cooling of the rotor and such air is introduced behind the first guide blade in a turbine comprising ten rotating blade rims, the loss in work for the gas turbine plant will only be about 0.3%. A reduction of the temperature by 100° C., permitting an increase of the temperature of the driving or working medium by a corresponding amount, results in an increase of the quantity of heat utilized in the turbine of the magnitude of 10%. By the fact that the cooling medium is subjected to pressure, the coefficient of heat transfer between the same and the surfaces of the rotor will be high.

If the rotor is composed of discs carrying the various rotating blade rims, which are provided with mutual radial spaces, and which are connected with each other radially inside and outside these spaces, the latter may communicate with one another through openings in the discs, said openings being located alternately on different radii. The air will thus have imparted thereto, simultaneously with the axial movement, a rotary movement relative to the rotor discs, which further increases the coefficient of heat transfer between the cooling air and the walls of the rotor discs. It is important, morever, that the outer portions of the rotor be cooled as effectively as possible, and that the path of heat conduction between the root of the blade and consequently the cooled rotor surface be short. Thereby the blade root and the portion of the blade adjacent to the root and subjected to the highest stresses will also be effectively cooled.

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If there are no radial spaces as stated above in the rotor, which is the case, for instance, where the rotor has an integral blade-carrying part, the cooling channels are arranged outside the average diameter of the rotor and preferably near the peripheral portion of the rotor, to insure effective cooling of the blade attachments, besides which the whole rotor is kept at a low temperature inside the channels.

Further objects and advantages of the invention will be apparent from the following description considered in connection with the accompanying drawings which form a part of this specification, and of which:

Fig. 1 is a horizontal view, partly in section, of a gas turbine constructed in accordance with the invention;

Fig. 2 shows the portion of the turbine framed by the lines 2 in Fig. 1, on an enlarged scale;

Fig. 3 shows a gas turbine according to another embodiment and in the same projection as in Fig. 1; and

Figs. 4 and 5 show two embodiments of gas turbine plants, partly in section, said plants being provided with a cooling device in accordance with the invention.

In the various figures, corresponding parts have been designated by the same reference numerals.

In Fig. 1, 10 designates the rotor generally which is composed of a number of turbine discs 12, the inner diameter of which is spaced apart from the axis of rotation, so that an inner axial passage 14 is produced. The discs 12 are preferably connected with each other through welding both at the inner and at the outer peripheral portion thereof, as indicated at 16, 18 (Fig. 2). The spaces 20 provided between the turbine discs and extending nearly out to the blade attach-

ments will thus become sealed against the surroundings. The turbine discs 12 are provided with axial channels 22 which are disposed alternately on different radii and connect the various spaces 20 with each other.

The discs 12 of the rotor carry blades 24 which are arranged, together with stationary guide blades 26 secured in the turbine housing, in a passage 30 having the gaseous working medium flowing therethrough. The outermost turbine disc 12 on the left hand side in Fig. 1 (the high pressure side of the turbine) may, over a preferably conical portion 32, be made integral with a shaft 34 cooperating in known manner with radial and axial thrust bearings 35 secured in the turbine housing. Arranged between the portion 32 and the shaft 34 are packing members 36, 38 on both sides of the bearing 35. The outermost disc 12 on the opposite side of the rotor is connected to a shaft 44 mounted in bearing 42. A small portion of a constituent of the working medium of the gas turbine plant, such as the air which is compressed by a compressor contained in the gas turbine plant, may be conveyed through a socket 46 to an annular chamber 48 in the housing 28 and thence through channels 50 as well as through channels 51 in the first guide blade rim 26 at the high pressure end of the turbine to channels 52 opening into a chamber 54 at the left hand of the disc 12 in the drawings. From the chamber 54, the cooling air flows through the channels 22 to the spaces 20 in the rotor, a relative rotary movement being set up between the cooling air and the walls of the turbine disc, so that high coefficients of heat transfer are obtained. The cooling air then enters the channel 14, which is closed on both sides, and continues through a radial channel 56 in the first turbine disc 12 at the high pressure end of the rotor, whereupon the cooling air is introduced into the space 58 behind the first guide blade 26 and is carried along with the current of driving medium flowing through the passage 30. The space 58 is separated from the chamber 54 by means of packings 60.

The cooling air is taken off at such a point on or behind the compressor that when entering somewhat higher than the pressure in the space 58.

The rotor 10 may be made from steel of the martensitic or some equivalent type. On the other hand, the blades 24 are made from austenitic or some equivalent steel having a high heat resistivity. The latter steel at the same time has a coefficient of heat expansion about 50% greater and a less heat conductivity than martensitic steels. Thus, the rotor proper as well as the turbine housing may be constructed from a cheaper steel having a good heat conductivity and a small coefficient of expanasion, which results in the disadvantages of different expansions of the rotor and the housing upon changes in temperature being reduced to a great extent. The blades occupy a comparatively small portion of the radial extension of the turbine, by reason of which a greater heat expansion on the part of the blades is of little import. The turbine housing 28 is preferably made from a material having a coefficient of heat expansion of the same magnitude as that of the rotor material. Furthermore, the housing 28 may be protected against the hot working medium by means of rings 27 from austentitic or some equivalent steel, in which the guide blades 26 are secured. Provided in the inlet passage of the turbine is a partition or jacket 31 having a cooling agent flowing thereabout on the outside.

The embodiment according to Fig. 3 differs from the preceding one substantially only in that the rotor 10 is made with an integral blade-carrying part. This part is provided with channels 62 for the cooling air extending axially therethrough, said channels being located outside the average radius of the rotor as near to the points of attachment of the blades 24 as possible. The channels 62 are not through-passages at the right hand end of the rotor 10 in the drawing, but communicate through radial channels 64 with the central channel 14. The cooling air is conveyed from the space 48 to the chamber 54 through passages 66, 68 in reinforcing members 70 located in front of the first guide blade and in the housing 28.

The gas turbine plant illustrated in Fig. 4 comprises a compressor 72 which is driven by the gas turbine 74, the blade-carrying rotor 10 of which may form an integral part as in the embodiment according to Fig. 3. The air compressed in the compressor flows through a conduit 76 to a heat exchanger 80 arranged in the outlet conduit 78 from the turbine, and further through a conduit 82 to a combustion chamber 84 into which the fuel is introduced through a nozzle 86. Disposed in the combustion chamber 84 is a partition or cooling jacket 31 in which the hot working medium flows. The space around the cooling jacket 31 is traversed by comparatively cold air adapted to cool the wall of the combustion chamber and the turbine housing, said air then entering the blade system together with the hot working medium. Through a pipe 88, cooling air is supplied to the annular chamber 48 in the turbine housing. From this chamber, the cooling air may then be introduced into the space between the jackets 31 and 84, or may be conveyed to the blade system. Through a conduit 89, 91 extending from the conduit 82, cooling air is conveyed to the chamber 54 and thence through the channels 62, 14, 56 to the rear side of the first guide blade rim 26 in the turbine. A conduit 90 extending from the conduit 76 may be connected with the conduits 89, 91, a three-way valve 93 being inserted therebetween so that the cooling air may be taken from either the conduit 82 alone or from said conduit and the conduit 76. The air coming from the conduit 82 is warmer than that from the conduit 76, and by this arrangement the setting up of stresses in the rotor material by too great differences of temperature in its various parts is avoided. In this guide blade rim, the drop of heat may be so great, without any detrimental effect, that a sufficient drop of pressure is obtained to keep a sufficient quantity of air in circulation through the cooling passages of the rotor in normal operation.

It is advantageous to form the turbine in such manner that the rotor may be heated up more slowly than the housing, so that expansion of the latter in advance of the former during starting or warm-up periods will enlarge rather than reduce clearances. When the turbine is cut off, the opposite will then be the case, in that the rotor will cool down more slowly, whereby the clearances between the turbine blades and the housing are reduced and the sealing edges between the latter may be worn to greater clearances in normal operation of the turbine. To obviate disadvantages of this kind, there is provided a valve 92 in the conduit 76 behind the

outtake for the conduit 90, viewed in the direction of flow of the air. The valve 92 is closed more or less, while the fuel supply through the nozzle 86 is cut off at the same time. All air from the compressor 96 now flows through conduits 90, 91 to the interior of the rotor. To this end the valve 93 may be operated automatically to open the passage between the said conduits when the valve 92 is closed. Through the kinetic energy of the rotating masses, the rotor is kept running for a while, and the rotation may be maintained for a longer time with the aid of the starting motor 94, if required. In this way, an efficient cooling of the rotor may be had also when the rotation is slow.

In the embodiment according to Fig. 5, 72 designates a low pressure compressor and 96 a high pressure compressor, the conduit between them having an air cooler 98 arranged therein. 74 denotes the low pressure turbine driving the compressor, and 109 designates the high pressure turbine driving the compressor 96. The air compressed in the compressor 96 to its final pressure flows through the conduit 76, the heat exchanger 80 and the combustion chamber 84 to the gas turbine 100 and from the latter to a combustion chamber 102, into which the fuel is introduced through a nozzle 104 to reheat the working medium, before the same enters the turbine 74. The turbine 74 also drives a generator (not shown), for example. In both turbines, the rotor is provided with a system of cooling passages according to the invention.

Extending from the conduit 82 and preferably also from the conduit 76 are conduits 103 and 105, respectively, which by the three-way valve 93 are connected to a conduit 106. Cooling air is supplied through said conduits and a branch conduit 108 to the rotor of the high pressure turbine 100. The conduit 106 communicates with a conduit 112 extending from the outlet 101 of the high pressure turbine to the cooling system of the low pressure turbine, as well as with a conduit 107 opening into the chamber 54 of the low pressure turbine. The conduit 107 may have a cooler 110 connected into the same. Provided between the conduits 106, 107 and 112 is a three-way valve 114 adapted to cut off the conduit 106 in normal operation, when cooling medium passes through the conduits 112, 107 and through the cooler 110 to the low pressure turbine. When the gas turbine plant is put out of operation, the valve 114 is shifted simultaneously with the closing of the valve 92, so that cooling air will now pass through the conduits 106 and 107 to the low pressure turbine. The valve 93 then also takes a position to allow a flow of air through the conduits 105 and 106. Thus, powerful cooling of both rotors will be obtained.

Novel features of turbine structure per se not claimed herein form the claimed subject matter of our aforesaid U. S. Patent No. 2,487,514.

While different modifications of gas turbine systems have been shown herein by way of illustration, it is to be understood that the scope of the invention is not to be limited thereby but is to be determined by the scope of the appended claims.

What we claim:

1. A gas turbine system comprising an elastic fluid gas turbine, said turbine comprising stator and rotor structures providing between them a channel for expansion of gaseous motive fluid, compressor means for compressing a gaseous constituent of said motive fluid, said rotor being provided with interior passages for flow of a gaseous cooling medium through the rotor, said passages having outlet means opening into said channel at a place spaced from the inlet end of the channel where the pressure of the motive fluid expanding in the channel is less than the pressure thereof at the inlet to the channel, main conduit means having heating means therein and connecting the discharge side of said compressor means with said inlet of the channel, secondary conduit means connecting the discharge side of said compressor means with said cooling passages for flow of a portion of the compressed gaseous medium through the rotor and discharge of substantially all of said portion through said outlet means to said channel for expansion therein with the motive fluid admitted through said inlet, and valve means for selectively controlling the flow of fluid from said compressor means through said secondary conduit.

2. A system as defined in claim 1, in which said valve means comprises a valve in said main conduit behind the inlet of said secondary conduit considered in the direction of flow of fluid through the main conduit.

3. A system as defined in claim 1, including a by-pass conduit and regulating means therein for by-passing a selected quantity of fluid heated by at least a portion of said heating means from said main conduit to said secondary conduit to control the temperature of the fluid admitted to said cooling passages.

4. A system as defined in claim 3, including valve means for controlling the relative pressures and amounts of fluid delivered from the main conduit and the by-pass conduit to said secondary conduit, whereby to regulate the temperature and amount of fluid delivered to said cooling passages.

5. In a gas turbine system, a turbine having a bladed rotor providing cooling passages for cooling the blade carrying structure of the rotor, air compressing means for compressing air to be used as a constituent of the motive fluid for the turbine, conduit means including a combustion chamber connecting said compressor means with said turbine for supplying hot products of combustion as motive fluid thereto and additional conduit means including an air heater separate from said turbine and from said combustion chamber and valve means for supplying to said cooling passages a controlled portion at regulated temperature of the air delivered by said compressor means.

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