PATENT SPECIFICATION

708,452

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COMPLETE SPECIFICATION

Improvements in or relating to a System for the Cooling of Compressed Gas

I, ROBERT VON LINDE, a German Subject, of Mathildenstr., 27, Planegg bei Munchen, Germany, do hereby declare the invention, for which I pray that a patent may be granted to me, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to a system for cooling a compressed gas current, of the type in which a compressed gas current is caused to rotate at a high speed along the circumferential direction defined by the inner wall of a hollow body of a geometrical shape generated by rotation, whereby it is expanded and divided into a heated partial current issuing from the peripheral zone of this hollow space and a cooled partial current coming from the axial zone thereof as described in the specification of Patent No. 405,781. It has been found by experiments that the fall of temperature occurring in the partial stream taken from the core zone of the hollow body and applicable for cooling purposes depends substantially on the ratio z = cold partial flow/total amount of gas. Numerous tests carried out with compressed air and other compressed gases have shown that the maximum reduction of temperature in this "core flow" occurs at $z = 0{,}25$—$0{,}3$.

Now, according to the present invention it has been found that the compressed gas can be cooled down particularly efficiently if the compressed gas before its expansion is subjected to an exchange of heat with the cooled core flow and if the share of cold partial current is at least 70 per cent. of the total amount. True, only a small drop in temperature is produced in this case in the partial flow applicable for cooling purposes. However, since this partial flow forms a substantial share of the total amount of compressed gas and hence is able to cool this amount of compressed gas effectively before it enters into the hollow body, the apparatus in accordance with the present invention in operation produces very quickly a reduction of the temperature in the compressed gas proceeding to a very low final temperature.

According to a further feature of the invention this intensive fall of temperature can be utilised, for instance, for freeing the compressed gases or air from entrained liquefiable components, more particularly steam, to an extent hitherto unattainable unless absorbents were used which have to be continuously replenished.

By my novel apparatus already at compression pressures of 6 to 10 atmospheres gauge pressure, degrees of dryness can be reached which in case of the known gas drying plants using a compressor and a water-cooled separator could be attained only at the expense of a substantially higher compression output. My novel apparatus, therefore, can be used with advantage in plants for producing and utilising protective gases for furnaces for the heat treatment of metal or metallic work pieces, since in such plants the contents of steam in the gas should be as low as possible.

According to a further important feature of the present invention a partial flow utilisable for cooling purposes with a particularly favourable efficiency can be taken from the hollow body of rotation by shaping the guide device causing the rotation of the gas in the hollow body in such a manner that the gas is forced to rotate at supersonic speed. This may be achieved, for instance, by constructing the nozzle for feeding the compressed gas into the hollow body of rotation in the form of a so-called de Laval nozzle which is slightly conically expanding in the direction of flow, as known *per se*.

Other and further objects, features and advantages of the invention will be pointed out hereinafter and appear in the appended claims forming part of the application.

In the accompanying drawings several now preferred embodiments of the invention are shown by way of illustration and not by way of limitation.

Fig. 1 is a diagrammatic view of a plant having the invention applied thereto,

Fig. 2 is a cross sectional view through the device for producing the fall of temperature,

Fig. 3 is an axial section thereof, on a somewhat larger scale,

Fig. 4 is a cross section through a particularly favourable modification of such a device, and

Fig. 5 is a graph.

Similar reference numerals denote similar parts in the different views.

Referring now to the drawing in greater detail, and first to Fig. 1, it will be seen that a precooler 6 is arranged around the delivery pipe 5 of a gas compressed to a pressure of about 6 to 10 atmospheres gauge pressure by means of a compressor (not shown). The part of moisture of the gas depositing in this cooler is separated in a collecting vessel 8 constructed in the form of a steam trap, and removed through a discharge branch 7. The gas saturated at the end temperature reached in the cooler 6 and at the compression pressure passes through a duct 9 into a counterflow heat exchanger 10 comprising an inlet chamber 12^1 and an outlet chamber 13^1 formed by two partition walls 12 and 13. Tightly inserted in the partition walls are cooling tubes 11 which are open at both ends. The compressed gas issuing from these tubes into the outlet chamber 13^1 of the heat exchanger 10 flows through a short pipe 14 into a nozzle 16 (Figs. 2 and 3) opening tangentially into a hollow body 15 of a geometrical shape generated by rotation.

Arranged in this hollow body which has the shape of a cylindrical tube, is a diaphragm 17 having an axial bore 18. An expanded partial current issuing through this aperture is permitted to flow off through a pipe 19 into the hollow space formed by the heat exchanger 10 and from said hollow space via pipe 21 into a consumer pipe 23. Another partial current, on the contrary, coming from the gas rotating at high velocity along the inner wall of the hollow body 15 and being heated thereby, passes through an annular slot 20 into a branch pipe issuing into the consumer pipe 23. The size of the passageway formed by the annular slot at the front edge of the tube 15 can be changed by a valve head 25 by means of a handle 24.

If the cross section of the passageway in this annular slot 20 is adapted to the width in the clear of the diaphragm aperture 18 in such a manner that the cold partial current entering into the heat exchanger 10 comprises at least 70 per cent. of the total amount of gas fed through the nozzle 16 ($z=0,7$), the cooling d_t attainable in the hollow body 15 as shown in Fig. 5 of course substantially less than the maximum value of about 60° C. attainable in case of $z=0,25$ to 0,3. Yet, as shown by the curve *a*, the compressed gas is cooled to a particularly low temperature if z is greater than 0,7 and preferably approximately 0,9. It is remarkable that in this range even the efficiency η of the transformation of energy has already surpassed its maximum value which has been reached approximately at the value $z=0,6$. The curve *a* shows the course of the temperature drop attainable in the compressed gas, in case of complete elimination of the feed of heat from outside, i.e., in case of complete insulation of the heat exchanger and in case of complete exchange of temperature between the gas currents interchanging their heat, while the curve *b* shows the course of the temperature drop that can still be attained in a relatively imperfect heat exchanger.

Owing to the low temperatures attainable in the heat exchanger 10 in accordance with the present invention, the components fed with the compressed gas and to be precipitated by cooling are deposited almost completely. If these components remain liquid, they can be separated automatically in a second separator 28 which is constructed similar to the condensation water remover or steam trap 8. Where the substances to be deposited, such as, the gas moisture, at the low temperatures form solid deposits on the heat exchanging surfaces, the operation can be carried out with two heat exchangers of similar construction which are adapted to be inserted alternately in the gas ducts while the other heat exchanger in turn is cut out for thawing off the deposits.

However, it is also possible to avoid the formation of deposits of hoar frost and to maintain continuous operation with only one heat exchanger by feeding to the chamber of the heat exchanger 10 before the partition wall 12 as per Fig. 1, through a pipe 27, a solvent preventing freezing up which solvent is distributed, for instance, in a porous substance 29 and absorbed by the compressed gas passing through this substance. This solvent wets the inner walls of the tubes 11, thereby causing continuous removal of the components deposited by the cooling process, more particularly the gas moisture, in a liquid state, by the separator 28.

If the mouth of the pipe 19 in the hollow body 15 has an internal diameter corresponding to the diaphragm aperture 18, the diagram 17 can be dispensed with. The compressed gas issues at the velocity of sound from the nozzle 16 shown in Fig. 2. However, it is also possible, by shaping the feed nozzle 30 for the gaseous working agent in the manner shown in Fig. 4. to reach supersonic velocities which cause a substantial increase of the velocity of rotation in the hollow body 15 and thus a substantially higher cooling action. In the example shown in Fig. 4 this is achieved by a slightly conically-shaped so-called de Laval nozzle 30 whose narrowest cross section faces the feed pipe 14.

The system according to the present invention can be used with particular advantage in plants for the production and use of protective gas in which in *per se* known manner a combustible gas and air are burnt at such a proportion of mixture that the atmospheric oxygen is completely used up, and in which the pressured gases of combustion are cooled down for removing the moisture contents. The plant according to the present invention permits to utilise a part of the work of compression employed in the form of a refrigeration output which is particularly effective for this purpose and to reach degrees of dryness which hitherto could have been realised only by the use of compression pressures which cannot be justified economically.

In Patent No. 678,420 there is claimed an air cycle air conditioning system, comprising an expansion device includng an air inlet for working air and an air outlet to discharge said working air at a reduced temperature and at a pressure below atmosphere after passing through said expansion device, nozzle means for introducing a fine spary of water into the working air for evaporative cooling thereof, a heat exchanger connected to said air outlet and providing a path for said working air after leaving said expansion device, a compression device for maintaining the working air at said pressure below atmosphere and including an air inlet for the working air leaving said heat exchanger and an air discharge outlet, means to regulate the flow of water through said nozzle means whereby the moisture content of the working air issuing from said air discharge outlet is capable of regulation to obtain total saturation, duct means to conduct conditioning air through said heat exchanger along a path separate from the working path but in heat exchange relation with respect thereto, and means to maintain a flow of said conditioning air.

There is also claimed in this patent an air cycle air conditioning system according to the above quoted claim characterized by said expansion device comprising a Hilsch tube, said tube having a pair of oppositely extending air outlets each of a different diameter, a spray chamber directly connected to said air outlet of larger diameter and having mounted therein the nozzle means and the heat exchanger being directly connected to the air outlet of smaller diameter.

Subject to the above disclaimer, what I claim is:—

1. An arrangement for conditioning a current of compressed gas which is caused to flow with a high gyratory helical motion along a surface of revolution within a hollow body, whereby the gas is expanded and divided into a partial current of elevated temperature issuing from the circumferential zone of this hollow body and into a partial current of reduced temperature coming from the central zone thereof characterised by cooling the compressed gas before its expansion by interchanging its heat with the cooled partial current, in that the partial current issuing from the central zone of said hollow body amounts to at least 70% of the total current of gas.

2. An arrangement according to claim 1, characterised in that the compresed gas is fed by a De Laval type nozzle arranged tangentially on the hollow body for accelerating the gas entering said body to supersonic speed.

3. An arrangement according to claim 1 or 2, forming a part of a plant for the production and for the feeding of controlled protective atmospheres to furnaces for the heat treatment of metal or metallic work pieces.

4. An arrangement for cooling a stream of compressed gas, constructed and operated substantially as shown and described.

5. A plant for cooling and removing the moisture contents of protective gas for furnaces, constructed and operated substantially as shown and described.

6. A method of cooling a compressed

gas current, substantially as described.

7. A method of cooling and removing the moisture contents of a protective gas for furnaces, substantially as described.

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708,452 COMPLETE SPECIFICATION
1 SHEET

This drawing is a reproduction of the Original on a reduced scale.

Fig.1

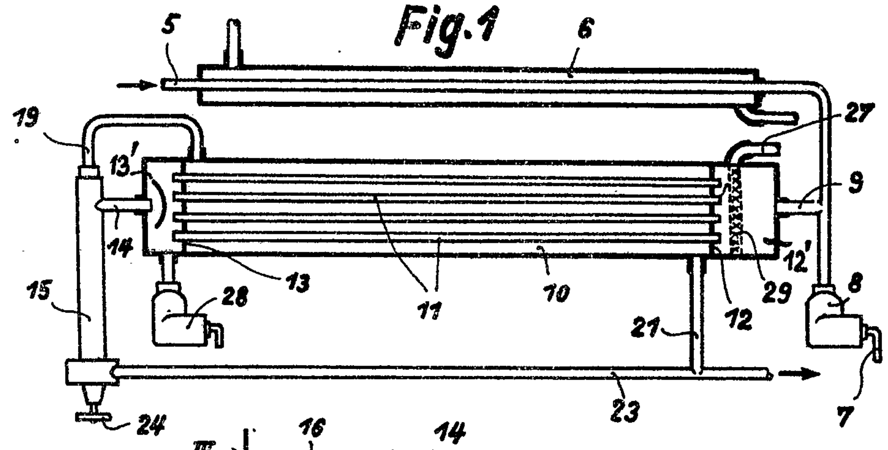

Fig.2

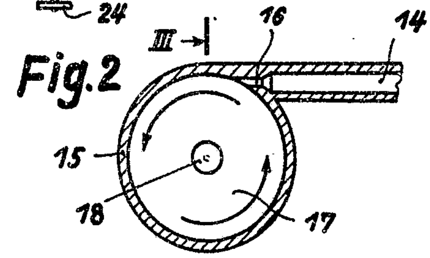

Fig.3

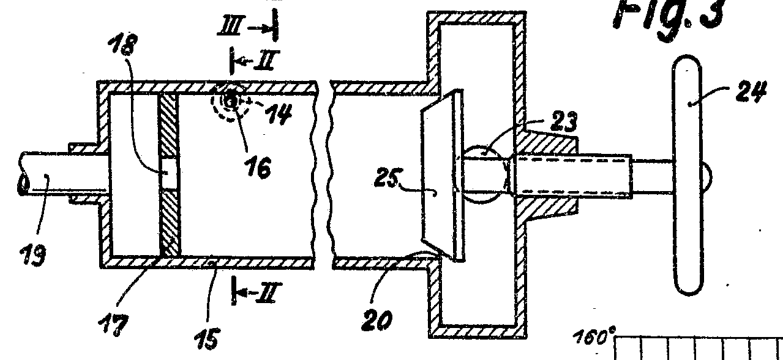

Fig.4

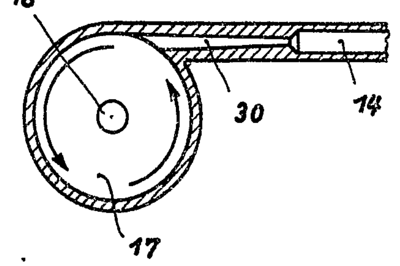

Fig.5