

[54] METHOD AND APPARATUS FOR DRYING GASES

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[51] Int. Cl. F25b 9/02

[58] Field of Search 62/5

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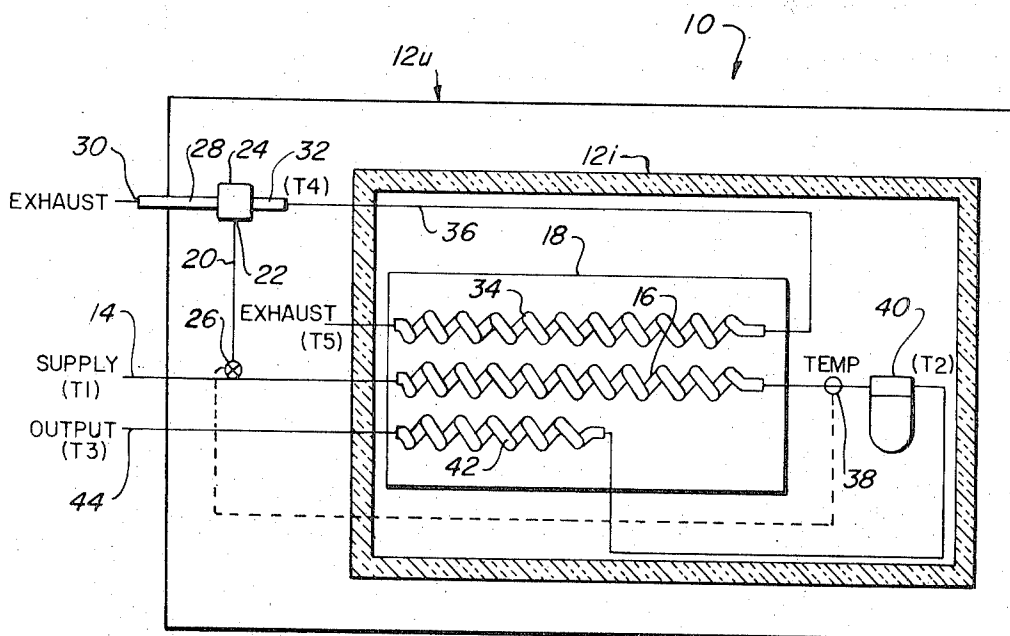
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[57]

ABSTRACT

This invention relates to a method and apparatus for drying compressed gas that is to be used at or near the supply pressure in which the temperature sensor of a thermostatically controlled valve responds to the temperature of the incoming wet gas leaving a heat exchanger by cycling on and off a supply of gas to a vortex tube. The cold side of the vortex tube is the prime source of refrigerant for the heat exchanger supplemented by the partially dried gas following removal of the condensate therefrom which is recycled so as to re-enter the exchanger at a point where its temperature is the same or slightly lower than that of the prime source of refrigerant. The invention also contemplates exhausting the hot gases from the vortex tube to the atmosphere outside the main dryer housing while dumping the cold vortex tube fraction inside a housing within the latter as it leaves the heat exchanger. The invention further encompasses using a portion of the incoming wet gas as the supply for the vortex tube.

8 Claims, 2 Drawing Figures



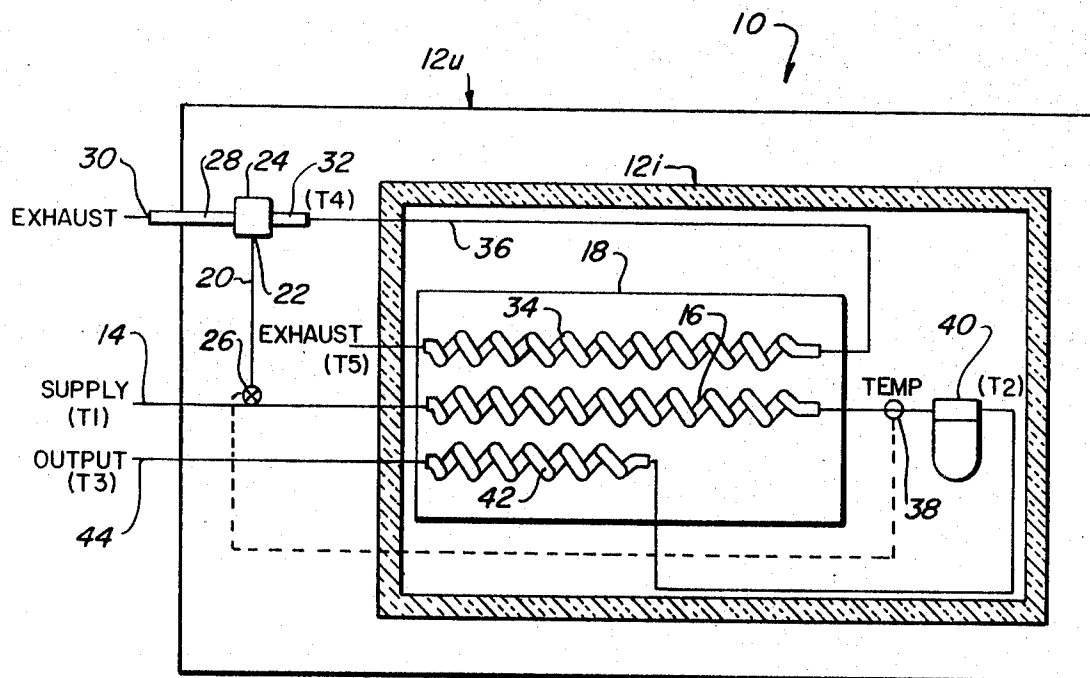


Fig. 1

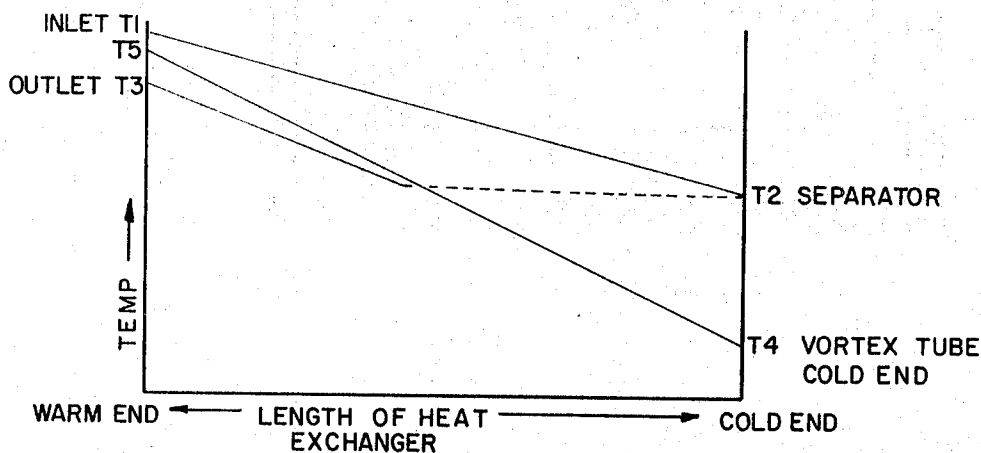


Fig. 2

METHOD AND APPARATUS FOR DRYING GASES

In copending U.S. application Ser. No. 437,862, filed Jan 30, 1974 filed concurrently herewith of which I am a co-inventor, we disclose an improved vortex tube air dryer primarily suited for use in pneumatic systems wherein the working pressure is substantially reduced below that of the supply pressure. A closed loop system of this type enables the dried gas fractions issuing from the hot and cold ends of the vortex tube to be remixed prior to use while still providing a sufficient pressure differential across the latter for good refrigeration efficiency. With the supply and working pressures essentially the same, however, such an apparatus becomes unsuitable for obvious reasons, yet, the same differential pressure condition across the vortex tube must be present as in the aforementioned high-low pressure system if the refrigeration efficiency is to remain up where it should be. It is to just such a pneumatic system that the present invention relates, namely, one in which the supply and working pressures are about the same.

There remain, as might be expected, certain common features and components in both applicant's high-low pressure air dryer and the instant high-high pressure air dryer. For instance, both include a vortex tube, a separator for the condensate and a heat exchanger, all of conventional design; however, in the unit forming the subject matter of this application, no pressure relief valve is used or needed and, instead, a thermostatically controlled valve monitors the temperature of the cool gas leaving the heat exchanger and entering the separator so as to adjust the flow of air to the vortex tube in accordance with the cooling load. It is prior knowledge that the supply of air to the vortex tube can consist of a fraction of the air leaving the dryer, or a fraction of the air leaving the separator prior to returning same to a three pass heat exchanger. Prior to this invention, the vortex tube has never been a fraction of the air entering the dryer, which method has proved to be superior to the other two.

Instead of the double pass heat exchanger of applicant's high-low pressure dryer, a triple pass exchanger is used with the cool partially dried gas being recycled to the exchanger and used to carry part of the refrigeration load. The most unique aspect of this recycling step is, however, the introduction of the cool partially dried gas back into the heat exchanger at a point within the latter where it is almost the same temperature if not slightly cooler than the temperature the cold fraction from the vortex tube has reached at the point of entry so that the latter fraction is not called upon to further cool the already dried gas thus adding unnecessarily to the refrigeration load with no useful purpose being served by so doing. On the contrary, this recycled dry gas cooperates with the cold gas fraction from the vortex tube to supply the total refrigeration necessary to cool the incoming supply of wet gas.

Another significant feature of the dryer and method of using same is the control system whereby the tapping off of gas to supply the vortex tube refrigerating element is thermostatically controlled in accordance with cooling demands. In other words, the temperature of the cold gas leaving the heat exchanger is sensed and, unless it is above a pre-set temperature, a non-modulating valve controlled by such sensor shuts the vortex tube out of the system. Thus, the vortex tube only functions and consumes gas when the demand exists therefor because the gas fraction bled off to supply the vortex tube is lost to the atmosphere.

A lesser, but nonetheless important, feature of the invention is that of dumping the warm gas issuing from the hot side of the vortex tube outside the main dryer housing while, at the same time, exhausting the relatively cooler fraction of the gas from the cold side of the vortex tube outside an insulated compartment within said housing as it leaves the heat exchanger. By so doing, the ambient temperature inside the dryer housing is somewhat cooler than outside and, therefore, less of a demand is placed upon the refrigeration system in terms of energy wasted to cool the compartment containing the heat exchanger, trap and temperature sensor.

It is, therefore, the principal object of the present invention to provide a novel method and apparatus for drying compressed air to be delivered at a working pressure near that of the supply pressure.

A second objective of the invention is the provision of a dryer wherein the compressed air system itself provides the energy required for operation in the form of air bled off and fed to a vortex tube refrigerating element.

Another object of the within described invention is to provide a method and apparatus of the class described wherein the air leaving the dryer is reheated to both prevent pipe sweating and to increase its effective volume by thermal expansion.

Still another objective is the provision of drying apparatus controlled on a demand basis so as to consume little air during periods when no refrigeration is called for, yet, operating the vortex tube refrigerating element in a most efficient manner whenever the need therefor arises.

an additional object of the invention herein disclosed and claimed is to provide the heat exchanger, trap and temperature sensor with an insulated environment and then keep it cool by exhausting the fraction of gas leaving the cold side of the vortex tube in the housing surrounding same as it leaves the heat exchanger.

Further objects of the invention are to provide a method and apparatus for drying wet gases that is efficient, versatile, safe, reliable, trouble-free, inexpensive, readily adaptable to existing compressed gas systems and one that requires no supplemental source of energy apart from the gas itself.

Other objects will be in part apparent and in part pointed out specifically hereinafter in connection with the description of the drawings that follows, and in which:

FIG. 1 is a flow diagram in which the drying apparatus has been illustrated in schematic form; and,

FIG. 2 is a graph representing the temperature profiles of the gas streams within the three passes of the heat exchanger.

Referring next to the drawings for a detailed description of the present invention and, initially, to FIG. 1 for this purpose, reference numeral 10 has been selected to refer to the dryer in a general way and all elements thereof will be seen to have been housed inside a main housing 12u. A supply of wet gas at an elevated pressure enters the dryer through a supply line 14 which passes through both the wall of the main housing 12u and the wall of insulated compartment 12i inside the latter where it is connected to deliver same to the first pass 16 of a triple pass heat exchanger 18. A branch line 20 of this supply line 14 that is connected thereto inside the main housing but outside the insulated com-

partment therein bleeds off a portion of the incoming wet gas and feeds it to the center tap or inlet 22 of vortex tube 24 whenever non-modulating thermostatically controlled valve 26 in said branch line is open. Also, when the latter valve is open, gas is delivered to the vortex tube at essentially full supply line pressure. The relatively warm fraction of gas leaving the hot side 28 of the vortex tube 24 is exhausted to the atmosphere outside the main housing 12u through hot gas exhaust line 30 so that it will not heat up the space inside the main housing surrounding the insulated compartment in the housing surrounding same thus adding to the cooling load. The relatively cold fraction coming out of the cold side 32 of the vortex tube 24 is fed directly into the insulated compartment and then on into the second pass 34 of the heat exchanger, preferably to flow in counter-current heat exchange relation to the wet gas flowing through the first pass, and comprises the primary source of refrigeration for the latter. As this relatively colder fraction of gas leaves the second pass 34 of the heat exchanger, however, its temperature will generally be cooler than the ambient temperature existing outside the insulated compartment. Therefore, in the preferred embodiment of the instant invention this gas fraction leaving the second pass of the heat exchanger is exhausted to the atmosphere inside the housing where it will tend to maintain a cooler environment inside than outside thus contributing to the overall efficiency of the system by saving the refrigerating capacity to cool the incoming wet gas. In other words, by enclosing the heat exchanger, trap, temperature sensor and piping carrying cold gases inside an insulated compartment within the main housing, which may or may not be insulated, and exhausting the gas from the second pass inside this housing, the overall efficiency of the system is improved due to so little refrigeration capacity being used to cool compartment 121.

The non-modulating valve 26 is thermostatically controlled by a temperature sensor 38 connected to receive the cool wet gas as it leaves the first pass of the heat exchanger but before it enters separator 40 where the condensate is stripped therefrom in the conventional manner. The operation of valve 26 is simple in that it opens and admits a fraction of the wet gas being supplied to the system to the inlet of the vortex tube whenever the temperature of the wet gas exiting from the first pass rises above a preset level. This means, of course, that the refrigeration furnished by the vortex tube operates only on a cooling demand basis and, equally important, when it operates, the the supply of wet gas to the vortex tube is at full line pressure which, in accordance with the well-known characteristic of such units, produces maximum cooling due to the greatest available pressure differential being impressed thereacross. It is only an on/off type non-modulating valve that will function as intended because a modulating one would supply wet gas to the inlet of the vortex tube at a reduced pressure which will adversely effect the cooling efficiency of the system due to the diminution of the pressure differential thereacross.

The incoming wet gas moving through the first pass of the heat exchanger in countercurrent heat exchange relation to the cold gas fraction in the second pass alongside thereof is, of course, cooled which causes some of the moisture contained therein to condense. This condensation is removed in separator 40, whereupon, the gas thus dried is recycled to the third pass 42

of the heat exchanger before exiting from the system through outlet 44 to meet the downstream demands. By recycling this partially dry and cool gas back through the heat exchanger in heat exchange relation to the incoming wet gas, some of the cooling load is assumed by the latter thus lessening the cooling demands that must be met by the vortex tube. The result is a beneficial one in yet another way because, instead of the exiting dry gas remaining cool and causing the downstream pipes to sweat, it is warmed up and thermally expanded.

Now, it is most important that the partially dried gas in the third pass not pass in heat exchange relation to the cold gas in the second pass, at least to any appreciable extent. In other words, if the dry gas in the third pass moved in heat exchange relation to the cold gas in the second pass for the full length of the heat exchanger, some heat would be transferred by the dry gas to the cold gas thus lessening the cooling capacity of the latter to remove heat from the incoming gas and, at the same time, further cooling the dry gas which serves no useful purpose and, in fact, is responsible for downstream sweating. If, on the other hand, the dry gas is returned to the heat exchanger at a point where its temperature nearly equals or is, perhaps, somewhat lower than that of the cold gas in the second pass at the point where it enters, little, if any, heat will be exchanged between these two flowing gases, especially if they are flowing in concurrent flow relation to one another as shown. Thus, the last bit of cooling capacity is taken from the system and utilized as a means for removing more water from the wet gas while re-warming the partially dried outlet gas before returning it to the system to satisfy downstream demands.

Looking briefly at the graph of FIG. 2, it will be seen that the incoming wet gas enters the exchanger at temperature T1 and is cooled by both the cold gas from the vortex tube in the second pass and the relatively cooler dry gas in the third pass until it reaches temperature T2. The condensate condensing at temperature T2 is removed in the separator and the gas thus dried re-enters the third pass of the heat exchanger at essentially temperature T2. It re-enters the heat exchanger, however, at a point where the cold gas in the second pass flowing concurrently therewith has been warmed by the incoming wet gas to a point where its temperature is as high or even slightly higher than the dry gas, all of which is clearly evident in the graph. The dry gas is warmed due to transfer of heat from the incoming wet gas until it exists to the pneumatic system at temperature T3 which is just slightly cooler than said incoming gas.

The gaseous fraction from the cold side of the vortex tube enters the second pass of the heat exchanger at temperature T4 and it, together with the dry recycled gas absorb heat from the incoming wet gas as previously noted. The gaseous fraction from the cold side of the vortex tube is exhausted to the atmosphere inside housing 12u at temperature T5 which, once again, is just slightly cooler than the incoming wet gas and also cooler than the ambient temperature outside the latter. Regardless of whether the main dryer housing 12u happens to be insulated or not, the temperature inside it will be somewhat cooler than the ambient temperature existing outside thereof because the relatively cooler air from the second pass is exhausted therein. Under most conditions, however, the main dryer housing will

be uninsulated and at substantially the same temperature as exists outside thereof.

Finally, with respect to alternate sources of gas to power the vortex tube refrigerating element, it has already been mentioned that recycled dry gas can be tapped just after it leaves the heat exchanger and before it leaves the dryer altogether or, alternatively, this same dry gas can be tapped downstream of the separator but before it re-enters the heat exchanger. Neither of the above systems functioned as well as the one illustrated in FIG. 1. For instance, when the dry gas leaving the dryer was used to power the vortex tube, the dryer performance fell off when compared to that of the preferred embodiment, especially under standby conditions when no gas flow demands were placed upon the system. The reason for this poorer performance is believed to be attributable to the fact that the vortex tube is called upon to not only cool the environment contained within the insulated compartment but, in addition, to cool its own supply of gas.

The second alternative system also proved less satisfactory than that illustrated in FIG. 1 because of poorer dryer performance. Two factors are responsible, the first of these being the fact that there is a greater mass of gas flowing through the first pass of the heat exchanger than the third because part of it is tapped off in between to power the vortex tube. On standby operation, therefore, there is no gas passing through the third pass and, therefore, no supplementary cooling.

The other factor responsible for decreased dryer efficiency is attributable to the use of the cooler dry gas prior to its being rewarmed when recycled. While the colder gas entering the vortex tube enables it to furnish colder gas to the heat exchanger, it also establishes a greater temperature differential between the ambient temperature existing outside the insulated compartment and the conduit carrying the cold gas fraction thus resulting in an increased heat gain from the environment. Although the vortex tube can be adjusted to deliver cold air at the same temperature as the FIG. 1 preferred embodiment, to do so demands a shift in the ratio of warm to cold air issuing therefrom. Since it is well known that a 60-40 distribution between cold and warm air issuing from a vortex tube is optimum for best efficiency, an adjustment which would raise the temperature of the cold side fraction back up to that of the FIG. 1 system would mean the percentage of cold air would have to be considerably above its 60 percent preferred fraction thus diminishing the drying efficiency. The instant dryer can easily maintain the separator below 50°F. when the ambient temperature and incoming wet air are both at 70°F. Under standby conditions with the vortex tube cycling on and off, an average of about 0.3 scfm of air is all that is consumed to maintain a 50°F. pressure dew point. When, on the other hand, the downstream demands call for a flow through the dryer of 10 scfm or so, the vortex tube will consume 4 scfm to maintain a 50°F. pressure dew point. Higher flows, of course, result in a rise in the pressure dew point above 50°F.

What is claimed is:

1. The gas drying apparatus which comprises: a triple pass heat exchanger having the inlet to its first pass connectable to a source of wet gas under pressure, a vortex tube operative to split an incoming stream of gas

into a relatively warmer fraction and a relatively cooler fraction connected to deliver the latter to the second pass of the heat exchanger for movement therein in heat exchange relation to the wet gas moving through said first pass, a separator effective to remove the condensate condensed from the wet gas in the heat exchanger connected to receive the partially dried gas issuing from the first pass of the latter, first conduit means connected to receive the partially dried gas from the separator following removal of the condensate therefrom and recycle same into the third pass of the heat exchanger for flow therethrough alongside the gases flowing in said first and second passes so as to maximize heat transfer from the wet gas in said first pass without warming the cold gas in said second pass, second conduit means connected to receive a portion of the gas entering the first pass and deliver same to the vortex tube, and thermostatically controlled valve means connected in the second conduit means operative upon actuation to shut off the gas supply to the vortex tube whenever the temperature of the gas leaving the first pass of the heat exchanger falls below a preset minimum.

2. The gas drying apparatus as set forth in claim 1 in which: the gases in the second and third passes of the heat exchanger flow in concurrent flow relation to one another and countercurrent flow relation to the gas in the first pass.

3. The gas drying apparatus as set forth in claim 1 in which: the first conduit means delivers the partially dried gas to the third pass at a point intermediate the ends of the heat exchanger, said point being selected such that the temperature of said partially dried gas returning to the heat exchanger is at or below the temperature of the relatively warmer gas fraction moving alongside thereof in the second pass.

4. The gas drying apparatus as set forth in claim 1 in which: the thermostatically controlled valve means includes a temperature sensor; a housing houses the heat exchanger, separator, sensor and both conduit means; and, in which the relatively hotter gas fraction is exhausted to the atmosphere outside said housing.

5. The gas drying apparatus as set forth in claim 4 in which: the relatively colder gaseous fraction leaving the second pass of the heat exchanger is exhausted to the atmosphere within said housing.

6. The method of drying a wet gas under pressure which comprises the steps of: condensing some of the moisture from the incoming wet gas by passing it in heat exchange relation to the relatively colder fraction of the same gas issuing from the cold side of a vortex tube, stripping the condensate from the incoming gas thus cooled, recycling the stripped gas in heat exchange relation to the incoming wet gas so as to cool and condense additional moisture from the latter, said recycled gas being returned at a point where its temperature is equal to or below that of the relatively warmer fraction from the vortex tube flowing alongside thereof, determining the temperature of the cool gas prior to removing the condensate therefrom, tapping off a portion of the incoming wet gas to supply the vortex tube, and cutting off the flow of incoming wet gas to said vortex tube whenever the temperature of the cool gas falls below the predetermined minimum.

7. The method as set forth in claim 6 in which: the relatively warmer fraction of gas exiting from the hot side of the vortex tube is exhausted to the atmosphere at a point remote from where the condensation takes place.

8. The method as set forth in claim 6 in which: the relatively colder fraction of gas is used to cool the environment in which the condensation is carried out following its use for the latter purpose.

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,858,403 Dated January 7, 1975

Inventor(s) Myron Dunn

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 1, Line 37, after "been" insert --supplied air
by using--

Column 1, Line 49, "hs" should read --has--

Column 2, Line 14, "it" should read --It--

Column 2, Line 31, "calaed" should read --called--

Column 2, Line 35, "an" should read --An--

Column 3, Line 42, "therefom" should read --therefrom--

Column 3, Line 50, delete "the" (second occurrence)

Signed and sealed this 1st day of April 1975.

(SEAL)

Attest:

RUTH C. MASON
Attesting Officer

C. MARSHALL DANN
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