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METHOD OF COOLING AND DEHUMIDIFYING COMPRESSED GASES

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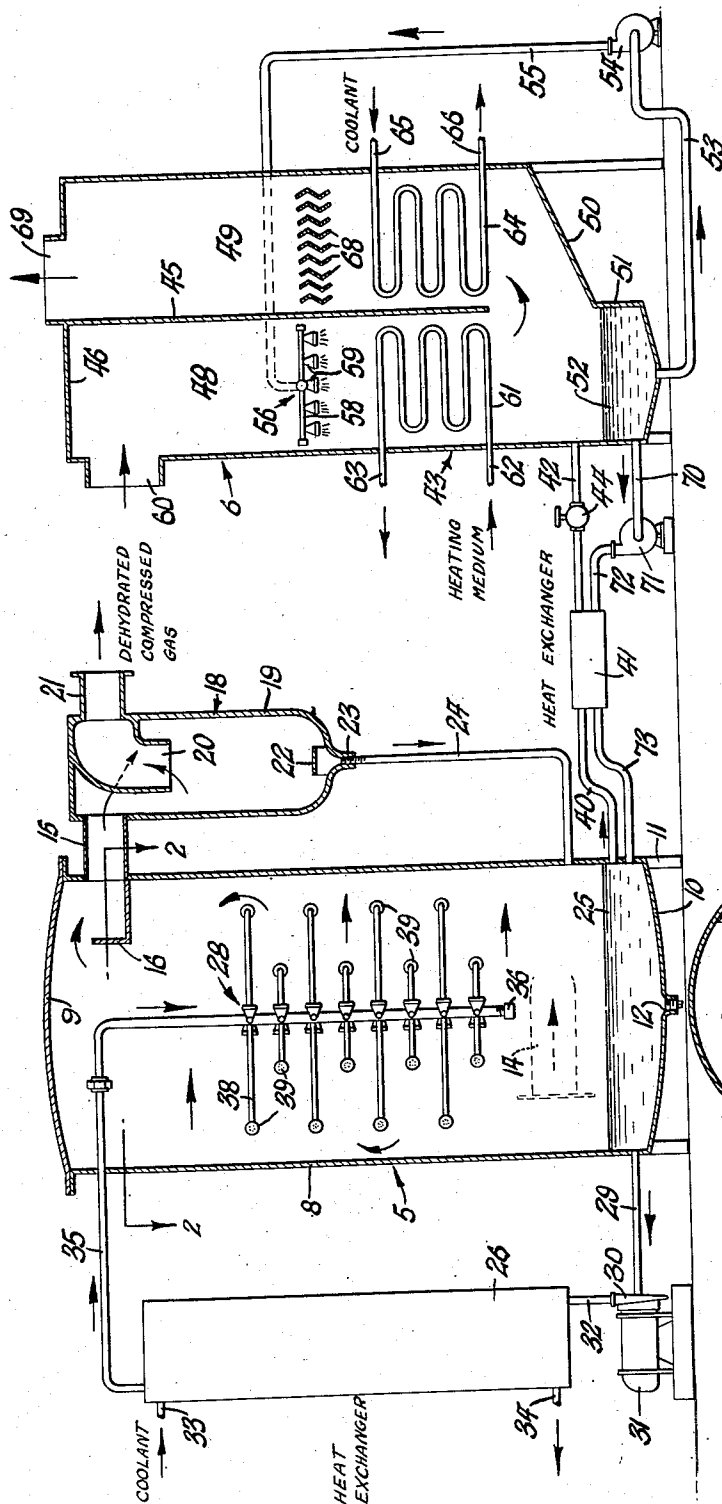


Fig. 1.

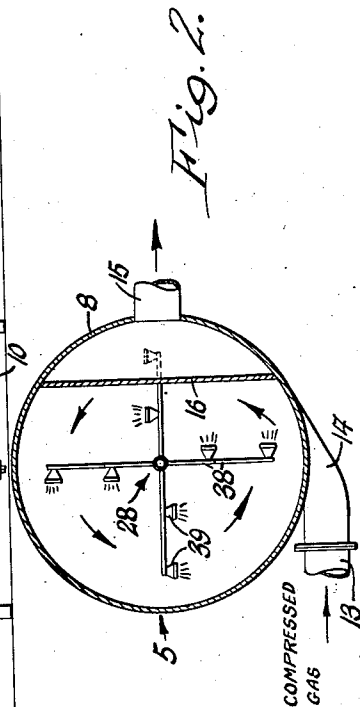


Fig. 2.

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METHOD OF COOLING AND DEHUMIDIFYING COMPRESSED GASES

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2 Claims. (Cl. 183—120)

This invention relates to a method of cooling and dehumidifying compressed gases and more particularly where a relatively high degree of dehumidification is required.

With many uses of compressed air, a high degree of dehumidification is desirable, such as with so called instrument air where the compressed air is used for operating delicate pneumatic control instruments the parts of which are particularly susceptible to disadvantageous oxidation of parts in contact with the compressed air and where drops of condensate in the compressed air can put the instrument out of order; also where the compressed air is used for driving equipment having rotating parts where water in the compressed air supplied to drive the equipment washes out the lubricant and causes rapid wear of the equipment; also where the compressed air is used in paint spraying or metallic shot blast equipment where the presence of water in the compressed air causes the paint to blister or rusting of the shot; and also where the compressed air is used under freezing conditions where the moisture in the compressed air tends to freeze on release thereby to freeze up the equipment being served and halting production.

Further, in various processes, particularly heat treating processes, it is desirable to effect a part of the processing in a chemically inert atmosphere to avoid undesired chemical reactions. For example, in the heat treating of certain metals, it is desirable to maintain an inert atmosphere in the heat treating furnace to avoid scaling or other undesired surface change of the metal parts under treatment. Further in the processing of oils it is desirable to effect a part of the processing in a chemically inert atmosphere. Such chemically inert atmospheres are usually maintained at higher than atmospheric pressure so that there is no danger of contamination through leakage, any leakage merely resulting in the loss of a part of the chemically inert gas but not resulting in contamination of the atmosphere.

It has been proposed, as set forth in the Olstad Patent 2,454,883 for Apparatus for Cooling Compressed Gases, dated November 30, 1948, to dehumidify compressed gases by the cooling thereof to a temperature below its dewpoint temperature using surface water or by subjecting the compressed gases to the evaporative cooling effects of streams of air and water. Such cooling media, however, are not available at particularly low temperatures and hence impose definite limitations on the degree to which the compressed gas can be dehumidified by lowering the dewpoint temperature thereof.

It has also been proposed as set forth in the Kals Patent No. 2,568,891, granted Sept. 25, 1951, for Heat Exchange Apparatus to dehumidify gas under pressure by passing it in contact with a low temperature cooling coil maintained substantially below the freezing point of water and spraying an antifreeze liquid over this coil to prevent the frosting thereof. With such a method, as pointed out later in greater detail, while compressed gas of low dewpoint temperature and hence a high degree of dryness can be obtained, refrigeration is required and also, where in the practice of the present invention refrigeration is also required to obtain a very low dewpoint temperature, a very substantially greater expenditure of power for refrigeration is required with this prior process as compared with the practice of the present invention.

It is accordingly one of the principal objects of the present invention to cool and to dehumidify compressed

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gases to a relatively high degree of dryness without the necessity for refrigeration.

It is another important object to dehumidify such gases to a still higher degree of dryness with less refrigeration than has been heretofore necessary for such a result.

Another object is to eliminate all problems of pressure balancing such as usually arise in treating compressed gases.

Another object is to permit of continuous dehumidification of gases under pressure to a very low dewpoint so as to provide gas having a very low moisture content.

Another object is to provide such a process which can be practiced with apparatus which is simple in construction and operation and which requires little supervision.

Another object is to provide such a method which can be readily set to maintain the exact degree of dehumidification desired.

Another object, where refrigeration is used, is to eliminate the danger of freezing of the condensate on the low temperature cooling surfaces.

Another object is to provide such apparatus which is free from the danger of leakage, such being a particularly important objective where deadly gases, such as carbon monoxide, are being handled.

Other objects and advantages of the invention will be apparent from the following description and drawings in which:

Fig. 1 is a schematic representation of apparatus for dehumidifying compressed gases in accordance with the present invention, the apparatus also including a concentrator for maintaining the solution used to effect dehumidification at the required strength.

Fig. 2 is a horizontal section taken on line 2—2, Fig. 1.

In the following description it will be assumed that the compressed gas to be dehumidified will be compressed air from a compressor having an aftercooler in which a part of the heat of compression has been removed, the apparatus forming the subject of the invention operating both to dehumidify air and also to further reduce the temperature of the compressed air. In general, the apparatus shown comprises a dehydrator, indicated generally at 5, and a concentrator, indicated generally at 6, the solution used as the dehydrating medium in the dehydrator being recirculated through the concentrator so as to maintain its desired strength and effectiveness.

Referring more particularly to the dehydrator, this dehydrator is shown as comprising a vertical cylindrical sheet metal casing 8 having outwardly dished upper and lower end heads 9 and 10 and supported on legs 11. The lower end head 10 forms a sump and is shown as provided with the usual drain 12.

As best shown in Fig. 2, the compressed air is supplied to the apparatus from a pipe 13 which can be connected directly with an air compressor although preferably the compressed air is precooled before being admitted to the dehydrator by passage through the usual aftercooler of the compressor. Neither the compressor nor its aftercooler is shown. The compressed air from the pipe 13 is admitted to the casing 8 through a tangential inlet 14, this tangential inlet serving to initially direct the compressed air to rotate in the casing 8 in a counterclockwise direction as viewed in Fig. 2. This air forms a column moving helically upward through the casing and leaves through an outlet pipe 15 which extends radially from the wall of the casing 8 and is located near the upper end head 9.

An L-shaped baffle 16 is secured in the casing 8 in advance of the outlet pipe 15, the purpose of this baffle being to reduce the amount of entrained solution carried out of the casing 8 with the compressed air.

The compressed air then passes through a liquid-from-air separator 18 which can be of any conventional form. As shown, this separator comprises a cylindrical shell 19 connected at its upper end with the dehydrator compressed air outlet pipe 15, the air initially passing around an outlet 20 having a downturned end arranged axially of the shell 19. This outlet 20 communicates with an outlet neck 21 which connects with the pipe used to distribute the dehydrated compressed air. The bottom of the separator 18 is shown as being dished and as having an internal bridge-like baffle 22 over a solution drain

outlet 23. The solution from this outlet flows through a pipe 24 to the bottom of the casing 5.

The solution used to dehumidify the compressed air passing through the casing 8 is preferably an aqueous solution of an organic substance having a boiling point higher than the normal boiling point of water, examples of such substances being the polyhydroxy organic compounds, such as triethylene glycol. However, other hygroscopic substances, such as lithium chloride can also be used. In accordance with the present invention, a body 25 of such solution is maintained in the sump or bottom 10 of the casing 8 and is continuously recirculated through a heat exchanger 26 and a spray tree 28. For this purpose a solution outlet line 29 connects the bottom of the casing 8 with the inlet of a recirculating pump 30 continuously driven by an electric motor 31. The outlet line 32 from the pump connects with one inlet of the heat exchanger 26 which can be of the shell-and-tube type. In dehydrating compressed air coolant is supplied to this heat exchanger 26 from an inlet pipe 33, this coolant passing in heat exchange relation with the solution from the pump 30 and leaving through a coolant outlet pipe 34. The outlet line 35 for the recirculating solution from the heat exchanger 26 extends through the side wall of the casing 8 near its upper end and thence downwardly along the axis of the shell 8 and is capped, as indicated at 36, at its lower end. This axially extending part of the pipe 35 is provided with a plurality of radially extending branch pipes 38 shown as arranged in vertical spaced groups each having one or more spray nozzles 39 through which the recirculated solution is discharged into the helically moving, rising column of air in the casing 8, and to assist the helical movement of the rising column of air each nozzle is directed horizontally to project in a counterclockwise direction as viewed in Fig. 2.

The solution so recirculated abstracts moisture from the compressed air and accordingly is diluted as it is used. In order to maintain the strength of the solution it is necessary to concentrate it by evaporating water from it so as to maintain a high concentration of the substance used as the dehydrating agent.

To this end a solution outlet line 40 connects with the bottom of the casing 8 below the level of the liquid in this casing, the solution being shown as being moved through this line by the pressure of the compressed air passing through the shell 8. This solution then passes through a heat exchanger 41 and thence through a pipe 42 to the casing 43 of the concentrator 6. The line 42 is shown as having a valve 44 to control the rate of feed of the dilute solution to the concentrator 6.

The concentrator casing is shown as being of rectangular form in horizontal section and as having a central vertical partition 45 extending downwardly from this top wall 46 so as to provide a downflow pass 48 and an upflow pass 49, the partition 45 being spaced from the bottom of the casing to permit air to flow from the bottom of the downflow pass 48 over to the bottom of the upflow pass. This bottom of the casing 43 is shown as comprising an inclined part 50 under the upflow pass 49 and draining into a sump 51 under the downflow pass 48, this sump containing a body 52 of the solution which is recirculated through the concentrator. This recirculation is through a pipe 53 leading from the bottom of the sump 51 to a recirculating pump 54. The outlet line 55 from this pump is shown as extending through the side wall of the downflow pass 48 of the casing 43 and as terminating in a spray tree 56. The spray tree is shown as comprising a plurality of horizontal branches 58 carrying downwardly directed nozzles 59 which discharge the solution downwardly into the air in the downflow pass 48.

Fresh air is preferably used for concentrating the solution, this fresh air entering the upper end of the downflow pass 48 through an inlet 60. This air flows downwardly past the sprays issuing from the nozzles 59 and past a heater conventionally indicated at 61. This heater can be supplied with a heating medium from an inlet 62, the heating medium leaving at 63.

The air from the downflow pass 48 passes under the central partition 45 and flows up the upflow pass 49. This air passes a reflux condenser which is shown conventionally as being a cooling coil 64, the coolant entering at 65 and leaving at 66. From the reflux condenser, the air is shown as passing through a plurality of elimi-

nator plates 68 the purpose of which is to whip the air back and forth so as to remove entrained solution therefrom. The air leaves the upflow pass through an exhaust outlet 69 from which it is discharged back to the outer atmosphere.

In this recirculation from the nozzles 59 of the spray tree 56 against the heater 61 and into the stream of fresh air passing down the downflow pass 48 mixed vapors of water and the organic substance are transferred to the stream of air, this transfer being principally of water vapor so that the solution so sprayed into the air stream is continuously being reconcentrated. The reconcentrated solution leaves the body of solution 52 through an outlet pipe 70 connected with the inlet of a return pump 71. The outlet 72 of this pump connects with the heat exchanger 41 in which it passes in heat exchange relation with the cool dilute solution entering the concentrator 6. From the heat exchanger 41 the concentrated solution passes through a pipe 73 to the body 25 of solution maintained in the sump 10 of the dehydrator 5.

As an example of the operation of the apparatus in obtaining a high degree of dehumidification of, say, compressed air without the use of mechanical refrigeration, it will be assumed that the apparatus is to handle 2700 cubic feet per minute of free air having a dry bulb temperature of 64° F. and saturated with moisture. It will also be assumed that this free air is compressed to 110 pounds gage pressure and that it is necessary to dehumidify this compressed air to have a dewpoint temperature of 55° F.

This could not be done without mechanical refrigeration with any of the prior art processes mentioned. Thus surface water is not available in the summertime at temperatures below 55° F. to cool the compressed air to this temperature and establish its dewpoint temperature at the required 55° F. Also since it is assumed that the outside air is saturated, evaporative cooling would be ineffective and in any event could not be used to achieve a temperature below the assumed 64° F. since this is also the wet bulb temperature of the outside air.

With the present apparatus, using as the spray liquid an aqueous solution of a polyhydroxy compound having hygroscopic properties, such as triethylene glycol, and at a concentration in the order of 92%, it is only necessary to maintain this solution at a temperature of 98° F. to bring the dewpoint temperature of the compressed air to the required 55° F. the compressed air being reduced in temperature to 99° F. by contact with the spray solution. This can obviously be accomplished without refrigeration since the temperature of the spray liquid can be easily maintained at 98° F. with a coolant having a temperature of 70° F. and for which surface water or evaporative cooling as described in said Olstad patent 2,454,883 can be used.

Thus, under the assumed conditions, 2700 C. F. M. of free air at 64° F. saturated with moisture is compressed to 110 lbs. gage pressure and admitted through the tangential inlet 14 of the spray chamber 5. This compressed air, after passing through the after cooler of the compressor, can be assumed to have a temperature of 108° F. This compressed air, entering the spray chamber 5 tangentially, moves upwardly therein in a helical path to provide an upwardly moving rotating column, this helical movement being assisted by the projection of the sprays from the nozzles 39 which are spraying the hygroscopic solution being recirculated by the pump 30 through the heat exchanger 26, spray tree 28, spray nozzles 39, sump 10 and back to the pump 30.

The compressed air leaves the spray chamber 5 through its outlet 15 at a temperature of 99° F. and at a dewpoint temperature of 55° F., the sensible cooling of from 108° F. to 99° F., representing 103,700 B. t. u. per hour being effected by maintaining the temperature of the spray liquid 25 at 98° F. and the moisture removal to provide the low dewpoint temperature being effected by absorption into the hygroscopic spray liquid. The leaving compressed air passes through the liquid-from-air separator 18 in which entrained liquid is removed and returned through the line 24 to the body 25 in the sump 10 of the spray chamber 5.

This sensible heat of 103,700 B. t. u. per hour is removed from the spray solution by passing it through the heat exchanger 26 to which, as indicated, coolant is supplied at 70° F. to restore the temperature of the sprays from the nozzles 39 to 98° F. As indicated, cooling liq-

uid at this relatively high temperature of 70° F. can readily be supplied without refrigeration.

In contrast if the assumed 2700 cubic feet of free air per minute saturated at a temperature of 64° F. and compressed to 110 pounds gage pressure and aftercooled on leaving the compressor to 105° F. were to be dehumidified by lowering its temperature to its assumed 55° F. dewpoint temperature, as described in the said Kals patent, it would be necessary to remove 157,000 B. t. u. per hour of both the sensible and latent heat from the compressed gas and to obtain cooling to the necessary 55° F. dry and wet bulb temperature would require a coolant temperature of not substantially more than 40° F. Necessarily, therefore, refrigeration would be required to obtain the 55° F. dewpoint temperature of the compressed air whereas in the practice of the present invention the necessity for such refrigeration is avoided and at the same time exact control of the dewpoint temperature of the leaving compressed air is obtained.

The moisture so absorbed into the spray water 25 must be continuously removed in order to maintain it at the assumed concentration of 92%. To so maintain this concentration, spray solution from the body 25 in the sump of the spray chamber is continuously discharged through line 40, and heat exchanger 41 to the body 52 in the sump 51 of the concentrator 6. This body of liquid is at the assumed concentration of 92% and is maintained at this concentration by recirculation by the pump 54 through the spray nozzles 59. The downward sprays from these nozzles induces a relatively slow flow of fresh air from the fresh air inlet 60 through the downpass 48, uppass 49 and out through the outlet 69. This spray water is also heated by repeated contact with the heating coils 61 and transfers this heat to the air stream so as to increase its absorptivity. As a result the air is substantially saturated at an elevated temperature and because of the higher boiling point of the organic substance in the solution and because of its substantially complete saturation with water vapor very little of the organic substance is evaporated. The spray liquid is accordingly concentrated and after passing the heating coil 61 falls back to the body of liquid 52. The dilute liquid from the liquid body 25 in the spray chamber 5 so flowing to the liquid body 52 in the concentrator 6 is replaced by concentrated liquid moved by the pump 71 from the liquid body 52 to the liquid body 25.

Further to minimize loss of the substance in the solution which renders it hygroscopic, the air flowing up the upflow pass 49 of the concentrator 6 encounters the cooling coil 64 which acts as a reflux condenser. The cooling of the air causes it to become saturated and also condense some of its moisture. Because of the differences in absorptivity, the condensate from the reflux condenser 64 is composed largely of the small amount of hygroscopic substance vaporized into the air by the spray nozzles 39. This recovered substance flows back to the sump 51 to rejoin the body 52 of solution.

As a second example of the operation of the apparatus, it will be assumed that it is necessary to have compressed air with a dewpoint temperature of 20° F. as compared with the previous example where the required dewpoint temperature of the leaving compressed air was 55° F. With such a required dewpoint temperature of 20° F. the dry bulb temperature of the leaving compressed air would be 43° F. Otherwise it will be assumed that the same conditions obtain, that is, that the apparatus is to handle 2700 cubic feet per minute of free air saturated at 64° F. and that this air is compressed to 110 pounds gage pressure and leaves the aftercooler of the compressor saturated at 108° F.

On this second example refrigeration is required, but, as pointed out later, much less refrigeration is required as compared with a system wherein such dehumidification is obtained by cooling the compressed air to the required dewpoint temperature of 20° F.

With such a required leaving dewpoint temperature, the spray solution recirculated by the pump 30 from the liquid body 25, heat exchanger 26, spray tree 28 and its nozzles 39 back to the liquid body 25 would be maintained at a temperature of 40° F. and would have the same assumed concentration of 92%.

The compressed air at the assumed 110 pounds gage pressure and at 108° F. entering through the tangential inlet 14 is brought by contact with the sprays from the nozzles 39 to a dry bulb temperature of 43° F. and to a

dewpoint temperature of 20° F. as required. The maintaining of the required 40° F. temperature of the body 25 of spray solution is achieved by its passage through the heat exchanger 26 in heat exchange with a coolant cooled by mechanical refrigeration and the concentration of this spray solution is maintained by recirculation through the concentrator 6 as previously described.

While mechanical refrigeration is required to bring the compressed air to this assumed 20° F. dewpoint temperature, much less refrigeration is required than if the same dewpoint temperature were obtained by cooling this compressed air to this temperature as described in the said Kals patent. Thus the present process as above described requires the removal of 880,500 B. t. u. per hour with 30° F. refrigeration to maintain the coolant at the said 40° F. temperature. This involves the expenditure of 73 horsepower per hour. To cool the same compressed air to the required dewpoint temperature of 20° F. would involve the removal of 940,000 B. t. u. per hour with a refrigerant at 5° F. and with the expenditure of 156 horsepower per hour.

It will accordingly be seen that the present invention provides a method of dehumidifying compressed gases to a high degree of dryness with the expenditure of little if any refrigeration and in which the dewpoint temperature of the leaving air can be accurately controlled. It will further be seen that there is no problem of balancing pressures. It will further be seen that while solutions of organic hygroscopic substances, such as polyhydroxy compounds, are preferred, the invention can be practiced with solutions of inorganic hygroscopic substances, such as aqueous lithium chloride solutions.

We claim:

1. The method of dehydrating compressed gas which comprises spraying into a stream of said compressed gas a multiplicity of sprays of an aqueous solution having a hygroscopic substance the boiling point of which substance is higher than the normal boiling point of water, withdrawing a part of said solution and passing it in indirect heat exchange relation with a coolant to abstract heat from said solution, returning said withdrawn part to said sprays, withdrawing another part of said solution, heating said another part of said solution to a degree that the heat will vaporize most of the water but not affect the hygroscopic substance, contacting an extended surface of said heated solution with a stream of air to transfer from said heated solution to said stream of air mixed vapors of said water and substance whereby said heated solution is concentrated with respect to said substance, thereafter completely saturating the air with water vapor to condense substantially all the hygroscopic substance from the air in the form of an aqueous solution thereof, and returning said concentrated part of said solution for repeated contact with said compressed gas.

2. The method of dehydrating compressed gas which comprises spraying into a stream of said compressed gas a multiplicity of sprays of an aqueous solution having an organic hygroscopic substance the boiling point of which substance is higher than the normal boiling point of water, withdrawing a part of said solution and passing it in indirect heat exchange relation with a coolant to abstract heat from said solution, returning said withdrawn part to said sprays, withdrawing another part of said solution, heating said another part of said solution to a degree that the heat will vaporize most of the water but not affect the hygroscopic substance, spraying said heated solution into a stream of fresh air to transfer from said heated solution to said stream of fresh air mixed vapors of said water and organic substance whereby said heated solution is concentrated with respect to said organic substance, cooling said stream of fresh air after contact with said heated solution to a temperature below the dewpoint temperature thereof to effect reflux condensation of said organic substance and returning said concentrated part of said solution for repeated contact with said compressed gas.

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