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TURBINE METHOD AND SYSTEM

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Fig. 1

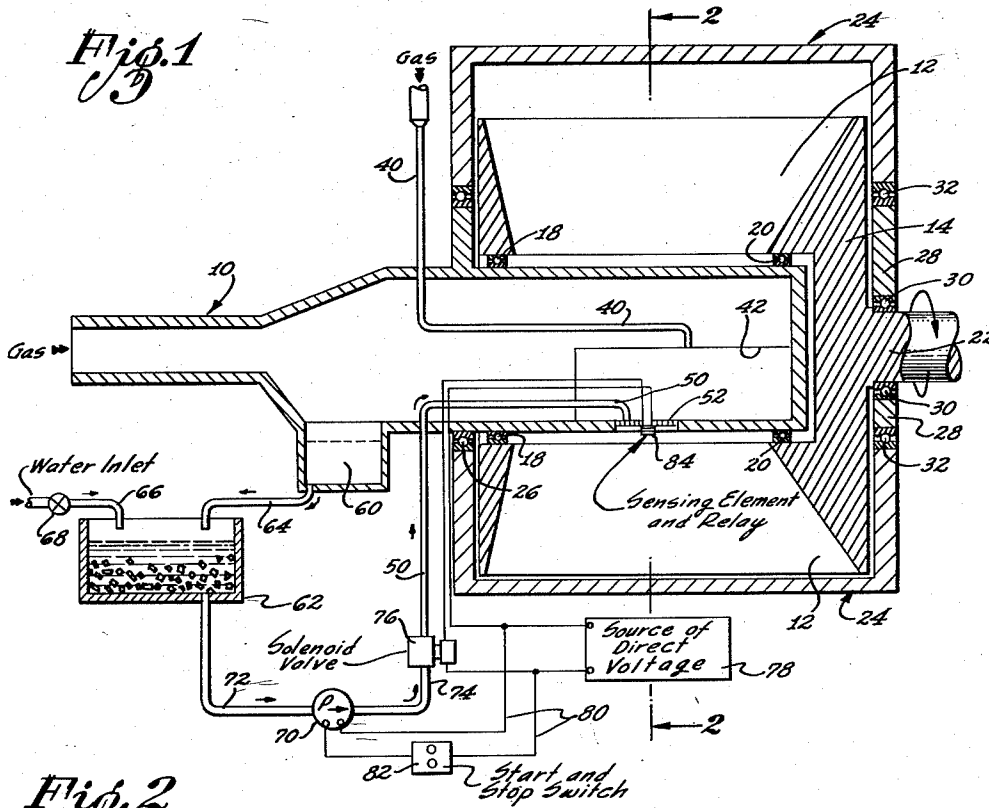
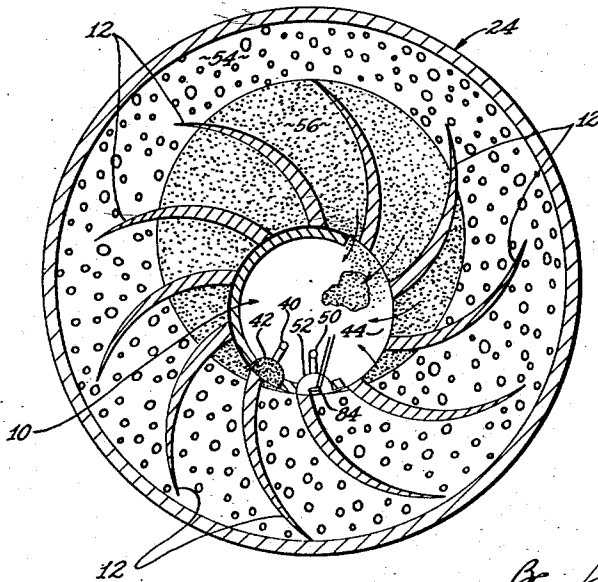


Fig. 2



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1

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TURBINE METHOD AND SYSTEM

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11 Claims. (Cl. 121-1)

The present invention relates to gas or vapor driven turbines of the liquid piston type. The invention is more directly concerned with an improved method and system for enabling such a turbine to be operated with its inlet driving gas or vapor established at a relatively high temperature for increased operational efficiency.

Copending application Ser. No. 605,801, filed August 23, 1956, in the names of Emerson L. Kumm and Wilbur D. Crater, entitled Gas Turbine, which was assigned to the assignee of the present application, discloses and claims a liquid piston turbine which includes a series of vanes that are arranged to rotate about a fixed hub in response to a high pressure inlet gas or vapor, this gas being introduced between successive ones of the vanes through an inlet port in the hub.

The driving gas introduced into the turbine of the copending application is trapped between the vanes by a rotating body of liquid which is referred to as a "liquid piston." The liquid for this piston is also introduced through the stationary hub. The liquid piston surrounds the vanes and rotates with the vanes. The outer casing of the turbine described in the copending application is permitted to rotate freely in eccentric relation with the rotation of the vanes. This eccentric relation of the vanes and casing allows the driving gas to expand in the turbine and to do work on the vanes and on the liquid piston. This expansion of the driving gas causes the vanes to rotate about the stationary hub. The driving gas is subsequently discharged through an outlet or exhaust port in the hub.

As pointed out in the copending application, turbines of the type described in the preceding paragraphs are capable of generating driving shaft power from the high pressure inlet gas, and of generating this power more efficiently than most other types of gas turbines, this being especially evident in the smaller units and in units having relatively low rotational speeds.

The gas consumption of the liquid piston turbine described above decreases for a particular output power when the temperature of the inlet driving gas is increased. Therefore, the efficiency of the turbine increases with an increase in temperature of the inlet driving gas. It is evident, therefore, that from a standpoint of efficiency, it is more desirable to establish the inlet temperature of the driving gas at as high a value as possible. The maximum temperature of the gas is, of course, limited by the maximum temperature under which the mechanical components of the turbine will operate, and also by the maximum temperature conditions under which the liquid piston will exhibit relatively low vapor pressure and will retain its liquid properties.

Alloy steels and other materials generally used in turbine construction will operate in extremely high temperature ranges, so that the upper limit of temperature operation of the turbine is dictated by the liquid piston, for practical purposes, rather than by the other mechanical components.

2

Water is not a satisfactory substance for the liquid piston when high temperature operation is desired. This is because a liquid piston composed of water exhibits inordinately high vapor pressures at elevated temperatures. Oil, likewise, is not a suitable substance for the liquid piston in the higher temperature ranges. This is because most oils form carbon deposits and also partially vaporize at temperatures above 500° F. For these reasons, it is clear that a liquid piston formed of usual known types of oil is not satisfactory for desired operation in the high temperature range of, for example, around 1,000° F.

Mercury is a possible substance for use as the liquid piston in such high temperature operation. However, mercury at the present time is extremely expensive. Moreover, mercury vapor is toxic and therefore extreme care must be exercised in the use of this substance.

The problem resolves itself, therefore, into the requirement for a substance that may have a liquid form at normal ambient temperatures to enable it to be conveniently introduced into the turbine, and yet a substance that will retain its liquid properties in the elevated temperature ranges and exhibit relatively low vapor pressures. The substance, in addition, must not be materially corrosive and it must be capable of being easily removed from the interior of the turbine casing at the end of each operation of the turbine.

A salt mixture is presently known which becomes molten at a relatively low temperature (around 300° F.), and which exhibits negligible vapor pressure for temperatures up to at least 1,000° F. This salt mixture has essentially the following composition:

	Percent, by weight
Sodium nitrite (NaNO_2)	40
Sodium nitrate (NaNO_3)	7
Potassium nitrate (KNO_3)	53

The salt mixture referred to above has the property of being readily soluble in water. In accordance with the present invention this property is utilized to form a salt solution which is used in the normal ambient temperature range and which solution is introduced into the turbine to function as the liquid piston. Then, the inlet temperature of the driving gas of the turbine is very high. This high temperature of the driving gas increases the internal temperature of the turbine and vaporizes the water from the salt solution. The salt solution, therefore, becomes more and more concentrated and passes from a solution to its molten state without losing its liquid properties as the temperature of 300° F. is approached and passed. The molten salt mixture then continues to function at the high temperatures as the liquid piston, and the molten salts desirably exhibit negligible vapor pressure at these high temperatures.

At the end of an operation of the turbine, the turbine may be permitted to cool down allowing the salt mixture to crystallize and to be deposited on the internal surfaces of the turbine. However, the crystallized mixture can readily be washed out by water and formed into a solution that may be stored and held in readiness for the next cycle of operation of the turbine. Alternately, the salt mixture can be washed out of the turbine by water at the end of an operation of the turbine before it has crystallized.

The salt mixture referred to above is ideal for the purpose of the present invention because it exhibits a relatively low melting point (about 300° F.), because it is readily soluble in water, and because it has negligible vapor pressure at the elevated temperatures (of the order of 1000° F.). Also, this salt mixture is suitable because of its non-corrosive properties, and also because

it will continue to exhibit liquid properties as it passes from its dissolved state in solution to its molten state as the temperature is increased.

It is evident, however, that the process and system of the invention is not limited to the particular substance or mixture described above, and that other mixtures and substances exhibiting similar favorable characteristics can also be used.

The various features and advantages of the process and system of the present invention will be readily understood from the following detailed description, when read in conjunction with the accompanying drawing.

In the drawing, which is to be regarded as merely illustrative:

Figure 1 is a sectional somewhat schematic view of a liquid piston turbine similar in some respects to the one disclosed in the copending application referred to previously, and which turbine has been modified to incorporate the improved system and method of the present invention; and

Figure 2 is a cross-sectional view, substantially on the line 2—2 of Figure 1, showing the rotatable turbine vanes together with the encircling liquid piston, and also schematically showing the entrapped gas between successive ones of the vanes.

The turbine illustrated in the drawing includes the stationary hollow hub 10 which is supported on any suitable base (not shown). A series of radial vanes 12 are supported by a pair of spaced end brackets 14 and 16. The resulting unitary vane assembly is supported for rotation about the stationary hub 10 by bearings 18 and 20. A drive-shaft 22 is formed integral with the bracket 14 and extends through one end of the turbine co-axial with the axis of the hub 10.

An outer casing 24 is freely rotatable about an axis spaced from and parallel to the axis of the hub 10. The casing 24, therefore, is rotatable in eccentric relation with the vanes 12. The casing is supported for such eccentric relation at one side by a bearing 26 which is positioned between it and the hub 10. The casing is supported on the other side by an eccentric disc-like member 28. The disc-like member 28 is stationary and the shaft 22 is rotatably mounted in this stationary member by means of a bearing 30. The casing 24 is rotatably mounted on the disc-like member 28 by means of a bearing 32.

The construction described above permits the vanes 12 and the drive-shaft 22 to rotate about the axis of the hub 10, and it also permits the casing 24 to be freely rotatable in eccentric relation with the vanes about a second parallel axis.

The driving gas or vapor is introduced to the unit through a feed line 40. This feed line extends into the hollow hub 10 and along that hub to an inlet port 42 leading to the interior of the casing 24. The driving gas is subsequently exhausted from the turbine through an exhaust or outlet port 44 in the stationary hub 10, and then through the interior of the hub to a suitable exhaust line (not shown). The exhaust line may be appropriately coupled to the left hand end of the hub in Figure 1.

A liquid salt solution is introduced to the turbine through a pipeline 50. This latter pipeline extends into the hollow hub 10 and along the hub to an inlet port 52 also leading to the interior of the casing. This latter inlet port is angularly positioned on the periphery of the hub between the inlet port 42 and the exhaust port 44.

In the manner fully described in the copending application referred to above, and when a liquid is introduced through the line 50 to the interior of the casing 24, a driving gas introduced through the inlet port 42 is trapped between successive ones of the vanes 12 by the liquid piston resulting from the introduction of the liquid. This liquid piston is represented by the area 54 in Figure 2, and the introduced driving gas is represented by the stippled area 56 in that figure.

As clearly shown in Figure 2, the driving gas expands

doing work on the vanes and on the liquid piston, this being permitted by the eccentric relation between the axis of rotation of the casing 24 and of the vanes 12. The work done by the expanding driving gas causes the vanes 12 to rotate about the hub 10 and produce a driving torque on the shaft 22. The expanded driving gas then escapes through the exhaust port 44.

It will be noted that the liquid piston 54 rotates with the vanes 12, and that the casing 24 is allowed to rotate with the liquid piston so as to reduce friction losses between the casing and the liquid piston. This construction is described in the copending application referred to above.

To adapt the turbine for operation in accordance with one embodiment of the present invention, an overflow sump 60 is formed in the hub 10. A reservoir 62 also is provided, and a pipeline 64 connects the sump to the reservoir. A water inlet line 66 extends from the reservoir to a suitable water source, and a valve 68 is provided in that line to control the introduction of water to the reservoir.

An electrically operated pump 70 has its inlet coupled to the reservoir through a pipeline 72. The outlet of this pump is coupled to a pipeline 74, and a solenoid-operated valve 76 couples the latter pipeline to the pipeline 50.

The pump 70 is connected to a source of direct voltage 78 through a pair of electric leads 80, and a manually operated start-and-stop switch 82 is included in circuit with one of these leads.

An examination of Figure 2 will reveal that the liquid piston just touches the surface of the hub 10 at a point adjacent the liquid inlet port 52 and that the remainder of the periphery of the hub is contacted by the entrapped gas in the area 54. This fact is taken advantage of in copending application Ser. No. 576,184 which was filed April 4, 1956, in the name of the present inventor and which was assigned to the present assignee.

In that application, a sensing element is positioned on the periphery of the hub adjacent the liquid inlet port, and that element is used to control the flow of the liquid to the turbine. The control is such that the proper amount of liquid is maintained in the casing for the liquid piston in the presence of the continual escape of the liquid.

The present invention utilizes the control described in the latter copending application, and such a control is indicated by the block 84. The solenoid control portion of the valve 76 is connected to the source of direct voltage 78 through the sensing element 84. In the manner fully described in the copending application, when the element is in a relatively cool condition because it is covered by the liquid piston, the solenoid valve is deenergized and closed. However, when the temperature of the sensing element rises because it is no longer covered with liquid, the sensing element closes. This closure of the sensing element energizes and opens the solenoid valve 76 so that more liquid may be fed into the turbine. This flow continues until the liquid piston has been sufficiently replenished so that it once again covers the sensing element 84. The sensing element then cools down and opens. This opens the circuit to the solenoid valve 76, and the valve closes and terminates the flow of liquid to the turbine.

In practicing the present invention, the salt solution is placed in the reservoir 62. When the turbine operation is first initiated by the introduction of hot driving gas through the feed line 40, the temperature of the sensing element 84 immediately rises to the temperature required to cause it to close and energize the solenoid valve 76. The valve, therefore, opens and a sufficient amount of the salt solution is fed into the turbine to form a liquid piston. When the liquid piston covers the element 84, the flow of liquid through the pipeline 50 is terminated. The hot driving gas introduced through the line 40 is now trapped between the vanes 12, and the turbine is

5

rapidly brought up to speed in the manner described in the copending applications referred to above.

The excess salt solution flows out the exhaust port 44 and back through the hub 10 to be accumulated in the sump 60. The solution then flows back to the reservoir 62 through the pipeline 64 for recirculation.

Now, as the internal temperature of the turbine increases, the water or other solvent of the salt solution is vaporized off, and the solution becomes more and more concentrated. The vapor escapes through the exhaust port 44. Gradually, and as the internal temperature is continually increased, the liquid piston is transformed from a solution into molten salts. The sensing element 84 continues to control the feed of the liquid piston, and it causes more of the solution to be fed to the interior of the turbine whenever depletion of the molten salts requires it.

When the operation of the turbine is terminated, it is allowed to cool down, and the salts crystalize within the casing. To remove the salts, it is merely necessary to cause the pump 70 to circulate the solution from the reservoir 62 through the system. It is evident that more water may be added to the solution by the valve 68 whenever additional solvent is required. Also, the solenoid valve 76 may have a manual control, or by-pass, to permit the flow of the solution through the pipelines 74 and 50, at this time and when the valve 76 would normally be closed.

The invention provides, therefore, an improved method and system which permits a liquid piston for a turbine to be conveniently formed and controlled throughout an extremely wide temperature range. Moreover, the method and system of the invention provides for a liquid piston which allows an extremely high temperature driving gas to be used for increased overall efficiency of the assembly.

Although the now preferred embodiment of the present invention has been shown and described herein, it is to be understood that the invention is not to be limited thereto, for it is susceptible to changes in form and detail within the scope of the appended claims.

I claim:

1. In a liquid piston turbine which comprises a plurality of radial vanes mounted for rotation about a central axis, and an outer casing enclosing the vanes, the combination of: a liquid piston comprising a salt solution included in said casing; and means for introducing a gas between successive ones of said vanes to be entrapped between said vanes by said solution, and said gas having a sufficiently high temperature to convert said salt solution to a liquid salt.

2. In a liquid piston turbine which comprises a plurality of radial vanes mounted for rotation about a central axis, and an outer casing enclosing the vanes and rotatable about an axis parallel to and spaced from said central axis, the combination of: a liquid piston comprising a salt solution included in said casing and rotatable with said casing; means for introducing a gas between successive ones of said vanes to be entrapped between such ones by said solution so that expansion of said gas produces rotation of said vanes, and said gas having a sufficiently high temperature to convert said salt solution to a liquid salt; and means for exhausting said gas from between said successive pairs of said vanes upon the expansion of said gas and the performance of work thereby on said vanes.

6

3. In a liquid piston turbine which comprises a plurality of radial vanes mounted for rotation about a central axis, and an outer casing enclosing the vanes and rotatable about an axis parallel to and spaced from said central axis, the combination of: a liquid piston comprising a salt solution included in said casing and rotatable with said casing; means for introducing a gas between successive ones of said vanes to be entrapped between such ones by said solution so that expansion of said gas produces rotation of said vanes, said gas having a sufficiently high temperature to convert said salt solution to a liquid salt; a reservoir for said salt solution; means including a pump for circulating the salt solution from the reservoir to the interior of said casing to replenish said liquid piston and for returning excess solution to said reservoir; and means for exhausting said gas from between said successive pairs of said vanes upon the expansion thereof and the performance of work thereby on said vanes.

4. The combination set forth in claim 3 and which further includes means for controllably introducing water to said reservoir.

5. The combination set forth in claim 3 and which further includes automatic means for controlling the introduction of the solution from said reservoir to the interior of said casing.

6. In a liquid piston turbine unit which comprises a plurality of radial vanes mounted for rotation about a central axis, and an outer casing enclosing the vanes, the combination of: a liquid piston included in said casing and comprising a salt mixture of sodium nitrite, sodium nitrate and potassium nitrate in solution; and means for introducing a gas between successive ones of said vanes to be entrapped between such ones by said solution, said gas having a sufficiently high temperature to convert said solution into liquid salts.

7. The combination defined in claim 6 in which said salt mixture is, by weight, essentially 40% sodium nitrite, essentially 7% sodium nitrate, and essentially 53% potassium nitrate.

8. The method of driving a series of radial vanes about a central axis which comprises surrounding the vanes with a salt solution, and introducing a gas between successive ones of said vanes of sufficiently high temperature to convert the salt solution to a liquid salt.

9. The method of driving a series of radial vanes about a central axis which comprises surrounding the vanes with a salt solution comprising a sodium nitrite, sodium nitrate and potassium nitrate; and introducing a gas between successive ones of said vanes of sufficiently high temperature to convert the salt solution into liquid salts.

10. The method of driving a series of radial vanes about a central axis which comprises surrounding the vanes with a salt solution substantially comprising, by weight, 40% sodium nitrite, 7% sodium nitrate and 53% potassium nitrate; and introducing a gas between successive ones of said vanes of a sufficiently high temperature to convert the salt solution into liquid salts.

11. The method of causing rotational motion of a series of driving elements which comprises surrounding the elements with a solution of at least one soluble substance, and introducing a driving fluid between successive ones of said elements of sufficiently high temperature to evaporate the solvent from said solution and to liquefy said substance.

No references cited.