United States Patent [19]

Huebner

[11] **3,859,005**

[45] **Jan. 7, 1975**

[54] **EROSION REDUCTION IN WET TURBINES**

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[22] Filed: **Aug. 13, 1973**

[21] Appl. No.: **387,996**

[52] **U.S. Cl.** **415/1,** 415/168, 55/2, 55/101, 416/224

[51] **Int. Cl.** **F01d 1/00**

[58] **Field of Search** 415/1, 168; 55/2, 101, 55/107

[56] **References Cited**

UNITED STATES PATENTS

3,066,912	12/1962	Schepper, Jr.	415/168
3,274,757	9/1966	Wapler	415/168
3,370,646	2/1968	Hopper	55/1
3,562,509	2/1971	Kahl, Jr.	55/101
3,601,313	8/1971	Berg	55/101
3,697,191	10/1972	Heymann	415/168
3,720,045	3/1973	Murphy	415/168

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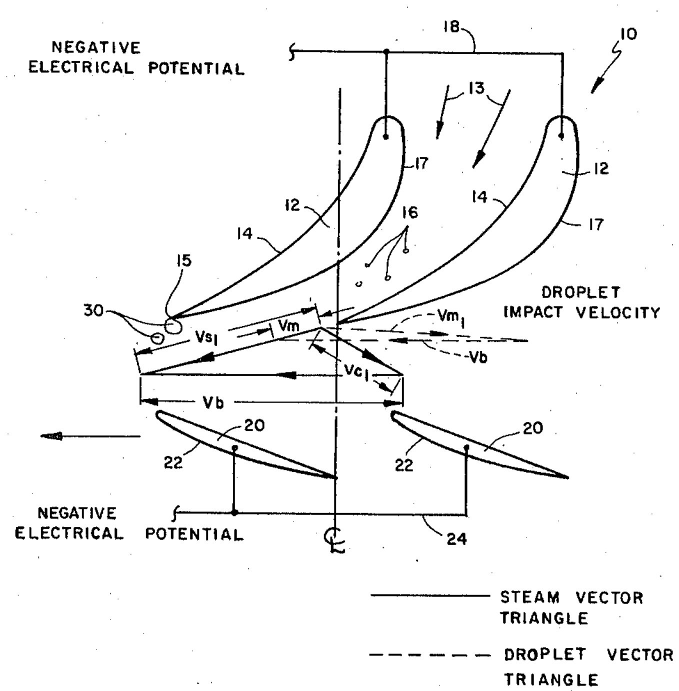
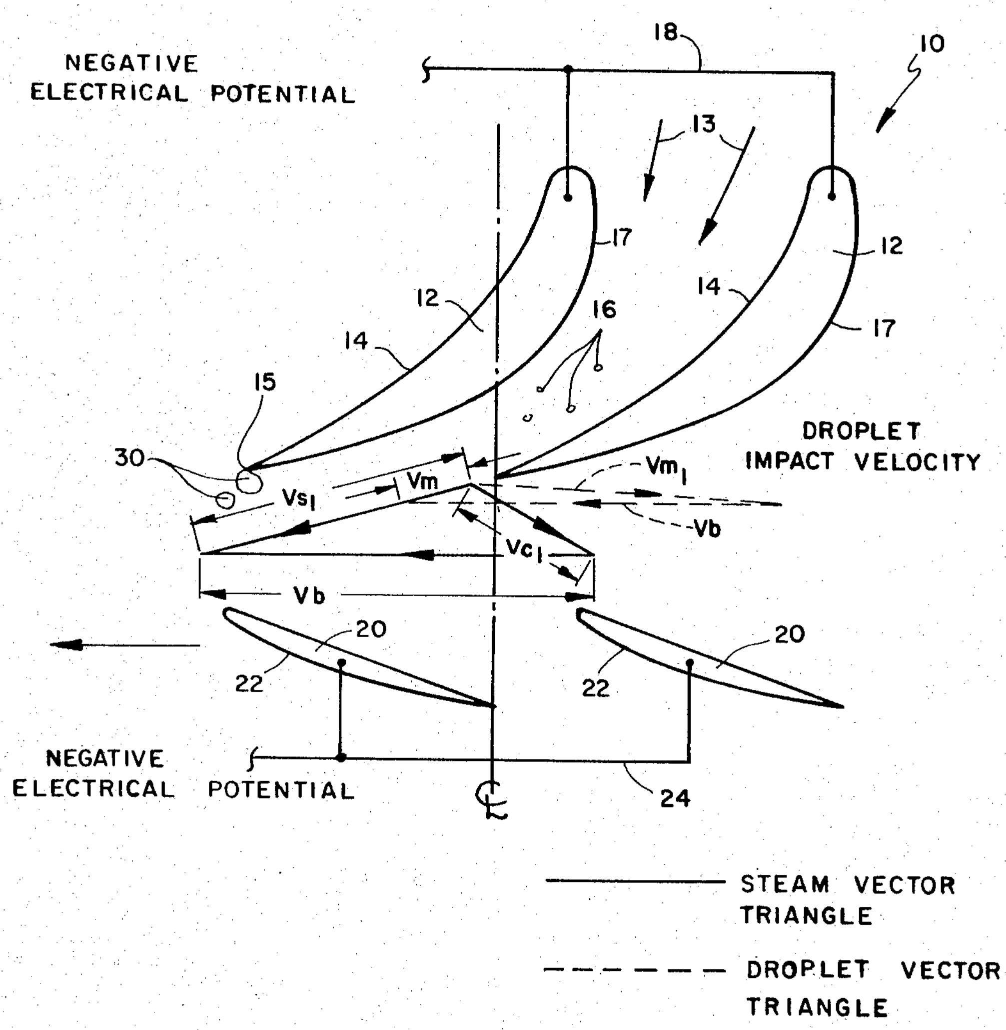
[57] **ABSTRACT**

A method to reduce the erosive effect associated with wet turbines includes the following: An electrical potential is applied to the stationary surfaces on which droplets form, thus reducing the size of the droplets. Additionally, an electric potential is applied to the turbine blades themselves, the charged droplets and charged turbine blades thus are affected by the repulsive Coulomb forces which repel the droplets from the surface of the charged blades, thus minimizing turbine blade erosion.

4 Claims, 1 Drawing Figure




NEGATIVE ELECTRICAL POTENTIAL
18
10
13
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12
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30
DROPLET IMPACT VELOCITY
Vm
Vs1
Vm1
-Vb
Vc1
Vb
20
22
NEGATIVE ELECTRICAL POTENTIAL
24
STEAM VECTOR TRIANGLE
DROPLET VECTOR TRIANGLE

EROSION REDUCTION IN WET TURBINES

This invention was made in the course of the performance of work under a contract with the Department of the Navy.

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to turbine blade erosion problems associated with wet turbines.

More particularly, this invention relates to a method to reduce the droplet size of condensed water associated with steam turbines and to reduce the relative velocity between droplet and turbine blade, thereby minimizing the damaging effect of the droplets colliding with the turbine blades.

2. Prior Art

Several patents deal with the problems of turbine blade erosion in wet turbines. Most of these patents deal with ways to divert fluid that contacts the turbine blades so that the damaging effect of the fluid on the blades is minimized. For example, U.S. Pat. No. 3,304,056 describes a turbine blade with an insertable segment which is positioned along the leading edge of the blade, the segment having a plurality of radially extending grooves which direct the fluid radially outwardly along the grooves and off the end of the turbine blade tip. The insertable segment is fabricated from a material that resists the erosive effect of the fluid. While the patent describes a means to divert the erosive fluid and to protect the turbine blades, the patent does not describe a means to reduce the droplet size of the damaging fluid, thereby minimizing the effect, as does the method of the present invention.

U.S. Pat. No. 3,697,191 discloses another apparatus to divert or redirect the fluid contacting turbine blades so as to minimize the erosive effect. An annular array of circumferentially spaced nozzle blades attached to a low pressure stage of an axial-flow steam turbine are modified to redirect fluid that is potentially damaging to the blades upon contact. The stationary nozzle blades have a first slot adjacent their trailing edge and adjacent a turbine casing, a second slot adjacent the trailing edge and adjacent a rotor, and a conduit connecting the slots so that water collected on the stationary nozzle blades is aspirated by the first slot flowing through a conduit and ejected from the second slot in atomized form, which approaches the rotating blades at a location where tangential velocity of the rotating blades is substantially lower, thus reducing the erosive effect of the water droplets on the turbine blades. This patent, however, does not describe a means to reduce the droplet size of the fluid passing through the turbine, thus minimizing the erosive effect of the droplets against the turbine blades, as does the present invention.

SUMMARY OF THE INVENTION

This invention describes a method and means to reduce the droplet size of the fluid passing through a wet turbine, such as a steam turbine, thus minimizing the erosive effect of the droplets impacting the turbine blades. A major portion of the erosive damage which shortens the life of turbine blades in a wet turbine results from droplet formation in the turbine and impingement at relatively high velocity on the turbine blades.

Additionally, overall turbine efficiency is affected by the presence of moisture in the steam. The steam velocity and the velocity of the moisture particles entrained in the steam pass through stationary blades of the turbine, the particles impacting adjacent rotating blades, resulting in a negative work force. The negative work force can be calculated when the weight of moisture per pound of steam and the velocity of the water droplets entrained in the steam are known. The foregoing information was taken from Mechanical Engineers' Handbook, (1958), pages 9–74, 9–75. By maintaining portions of the turbine at an electric potential on the order of 10 kV, the size of the drops formed in the turbine and the relative velocity between blades and drops will be substantially reduced, leading to a decreased turbine blade erosion rate. This modification, i.e., electric potential on the water drops, to conventional wet turbine operations will result in a smaller amount of working fluid which appears in the liquid phase, thus reducing the loss of turbine efficiency. It has been determined through experimentation that highly charged drops are unstable and tend to greater stability by division into two or more drops. The physical basis for this effect is that, contrary to surface tension forces which minimize surface-free energy by decreasing the surface-to-volume ratio, surface-charge forces minimize surface-free energy by promoting an increase in surface area per unit volume. When this concept is applied to the process of drop formation in wet turbines, the drops forming from films of liquid, such as water, which develop on stationary surfaces, such as stator blades that surround rotating turbine blades, it can be expected that electrification of these surfaces will cause reduction in the size of the individual drops formed and decrease the total amount of the liquid appearing in the form of drops. The relatively large drops on nonelectrified surfaces at high impact velocities are the principal cause of erosion to the blades, as heretofore described. Those drops that are formed by the electrification process will be highly charged either negatively or positively. By similarly charging the rotating turbine blades themselves, the repulsive Coulomb forces, resultant from two like charges, will substantially reduce the relative velocity of impact of the drops already reduced in size upon the rotating turbine blades.

Therefore, it is an object of this invention to reduce the size of fluid droplets which pass through and impinge upon the surfaces of the rotating blades, thereby substantially reducing turbine blade erosion.

More specifically, it is an object of this invention to reduce the size of the droplets of fluid passing through a wet turbine by imparting an electric potential on the fluid, as well as applying a like electric potential to the rotating blades themselves, thus further reducing the impact of droplets on the blades due to the Coulomb effect, thereby decreasing the impact of the droplets on the rotating turbine blades.

Thus, an advantage over the prior art is the reduction in size of the droplets which impact turbine blades in a wet turbine.

Still another advantage over the prior art is the application of an electric potential, both on the fluid droplets and the turbine blades themselves, so that the two electrically charged objects, namely, the fluid droplets and the turbine blades, repel one another, thus reducing the relative velocity with which the droplets impact upon the turbine blades.

Yet another advantage over the prior art is the improvement of overall turbine efficiency by reducing the size and impact of moisture particles entrained in steam.

The above noted objects and advantages of the present invention will be more fully understood upon a study of the following detailed description in conjunction with the detailed drawing.

BRIEF DESCRIPTION OF THE DRAWING

The FIGURE shown is a schematic diagram of a typical wet turbine illustrating the destructive turbine erosion forces involved by use of steam and droplet vector triangles. The application of an electrical potential to the stationary and rotating blades to counteract these forces is additionally shown.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to the drawing, the steam turbine generally designated as **10** is comprised typically of a row of upstream stationary stator blades **12** which direct steam **13** between the stator blades and onto an adjacent downstream row of rotating turbine blades **20.** Entrained in the steam **13** are water droplet particles **16.** These droplets **16** are collected on the concave pressure face **14** of the cylinder stator blades **12,** forming a film that is drawn towards the trailing edge **15** by the drag of the steam **13.** The film grows and, in a region of separated flow, may even pass around the trailing edge **15** onto the convex face **17** before being torn away by the shearing action of the main steam flow **13.** Relatively large drops **30** (typically 50 to 800 microns in diameter, compared with a mean diameter of less than 0.5 micron) are produced and have to be accelerated from rest by the steam **13.** These larger drops arrive at the inlet plane of the moving blades **20** at only a fraction of the absolute velocity of the steam **13** and are subsequently struck by the surfaces **22** of the following blade row. The larger drops **30** impact the rotating blades **20** and result in the erosion damage.

As indicated in the FIGURE by the steam and droplet vector triangles, the steam velocity indicated by V_{s_1} and moisture (droplets) V_m, leaving the stationary blades **12,** and with bucket velocity V_b, the velocities relative to the moving blades **20** of the steam are V_{c_1} and of the moisture V_{m_1}. The component of the moisture or droplet velocity relative to the moving blades **20** in the direction of their motion is proportional to the force acting on the back of the blades **20** and results in negative work.

By maintaining the stationary blades **12** at, for example, a negative electrical potential, through lead **18** from a power source (not shown) on the order of 10 kV, the size of the drops **30** formed will be substantially reduced. As stated before, the physical basis for this is that, contrary to surface tension forces which minimize surface-free energy by decreasing the surface-to-volume ratio, surface-charge forces minimize the surface-free energy by promoting an increase in surface area per unit volume. When this concept is applied to the process of drop formation in wet turbines, the drops forming from films of liquid which develop on stationary surfaces, as heretofore stated, it can be expected that electrification of these surfaces will cause reduction in the size of the individual drops formed. The drops formed, of course, will be highly charged. It should be pointed out here that the electric potential on the blades **12** and **20** could be positive, as well as negative, the important feature being that the charges be the same, whether they be negative or positive.

It should be further pointed out that if only the stator blades receive the electrical charge, the resultant reduction in size of the droplets **30** will result in less damage to the rotating blades even though the rotating blades are uncharged. A lessening of the negative forces caused by the impact of the droplets on the rotating blades **20** will result due to the smaller size of the droplets.

However, a greater advantage can be realized when both the stationary blades **12** and the rotating blades **20** are charged, either negatively or positively, so that the repelling forces, or the Coulomb effect, can further reduce impact velocity as well as the size of the droplets passing through the turbine **10.** By charging the rotating blades **20** through leads **24** from a power source (not shown), both the relative velocity V_{m_1} and its component in the direction of the blade motion will be reduced significantly by the Coulomb forces between the charged drops **30** and the charged moving blades **20.**

The principle of reducing liquid droplet size, as heretofore described, will have application in other than steam turbines. Any turbine that utilizes a gaseous medium as a driving source where there is likely to be a liquid condensate of reasonable electrical conductivity entrained therein would benefit from this invention as far as turbine blade erosion is concerned.

I claim:

1. A method to reduce turbine blade erosion associated with wet turbines comprising the step of applying an electrical charge to the turbine upstream of the rotating blades so as to electrically charge said liquid adhering to the surface of said turbine to reduce the size of droplets being torn away from said surface, thereby minimizing erosion damage to said rotating blades.

2. The method of claim **1** further including the step of charging said rotating blades with an electrical potential, said electrical potential being the same potential as the charged liquid droplets torn away from said surface, wherein the Coulomb effect will repel the charged droplets approaching said rotating turbine blades, thereby further reducing turbine blade erosion.

3. The invention as set forth in claim **1** wherein the wet turbine is a steam turbine.

4. The invention as set forth in claim **1** wherein the liquid droplets are water droplets.

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