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PATENT SPECIFICATION



DRAWINGS ATTACHED

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COMPLETE SPECIFICATION

Process and apparatus for the Separation of Water and Impurities from Steam

We, SHELL INTERNATIONALE RESEARCH MAATSCHAPPIJ N.V., a Company organised under the Laws of the Netherlands, of 30, Carel van Bylandtlaan, The Hague, The Netherlands, do hereby declare the invention, for which we pray that a patent may be granted to us, 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 process for the separation of steam containing water and solid impurities into dry steam, pure water and water containing impurities, and to an apparatus for carrying out the process.

The term "pure water" means that the water is free from solid suspended particles such as water-insoluble salts and metal oxides, which may be formed during operation in steam generating plants, this water being suitable for returning to the steam generating plant.

It is essential for the steam in steam-consuming installations such as steam turbines to have a very high degree of purity, since, especially in high-speed turbines, the presence of impurities, particularly salts, has a serious effect on such components as the turbine blades which not only excessively reduces their life but may also lead to serious breakdowns resulting in considerable material damage and also affecting the safety of the operators.

In addition to removing solid impurities, it is also essential to remove water particles from the steam, even when the steam is also passed through a superheater before being expanded to produce mechanical energy, since even if the last of the water were to be evaporated in a superheater, salts will inevitably find their way into the steam, i.e. such salts as may pass into the vapour phase. What is worse, salts will be deposited in the superheater, and this has a serious effect on the heat transfer, and there is also a risk of the tubes becoming overheated. At such a high temperature the tube material loses its strength and the tubes may burst under the steam pressure. It is known that at a certain state of equilibrium between the liquid and vapour phases soluble salts and oxides still present in the feed water are mainly in the liquid state, or in other words the equilibrium reached lies on the side of the liquid phase. It is therefore desirable for the steam to be completely or substantially free of water components before it enters a superheater and is supplied to a steam-consuming installation. This also ensures that the impurities and salts will be substantially all discharged with the water. The invention aims at providing a process and apparatus which make possible a substantially complete separation of steam, water and impurities so that practically dry steam is obtained which is free from salts and oxides or other impurities, the media separated from the steam being also separated into water of a quality suitable for returning to the steam generating plant and water containing all or substantially all impurities which cannot be tolerated in this plant.

According to one aspect of the invention, a process for the separation of steam containing water and solid impurities into dry steam, pure water and water containing impurities comprises supplying the steam for treatment to a centrifugal separator through a tangential inlet, passing the steam when inside the separator through a liquid screen of purified water in which impurities and some of the water left in the steam after initial centrifugal separation in the separator are caught, then leading it through a cyclone provided in the separator above the screen, discharging dry purified steam overhead and discharging water from the cyclone through a discharge pipe into a water zone in the bottom part of the separator, into which zone previously separated water together with water from the liquid screen are passed through a central passage inside an annular space provided in the separator

[*Price 4s. 6d.*]

above the water zone and beneath the inlet, in which annular space impure water with the highest concentration of impurities is collected as a result of the centrifugal effect.

According to another aspect of the invention an apparatus suitable for carrying out this process comprises a vertical cylindrical vessel; a tangential inlet connected to the cylindrical wall of the vessel; an annular liquid channel in the vessel situated above the inlet and provided with a supply line for purified water and with means for forming a downwardly directed liquid screen; a vertical cyclone in the vessel situated above the liquid channel, of which cyclone the tangential inlet is situated inside the vessel, the top of the central steam outlet communicates with the discharge line extending outside the vessel, and the bottom of the liquid discharge device issues into a liquid seal provided inside the vessel; an annular collecting channel for impure water in the vessel formed by the cylindrical wall thereof, a wall which is coaxial thereto and a bottom located beneath the inlet of the vessel and provided with a discharge line; and a discharge for water in the bottom part of the vessel.

The process and apparatus ensure a highly effective steam purification and drying in which very high loads are possible and great load variations can be permitted without adverse effect, and are also suitable for prolonged continuous operation and enable a very high proportion of the water separated to be returned to the steam generating plant. Moreover, the apparatus is compact, has no outwardly projecting parts and no moving parts, and does not have to be built into an installation but may be provided as a separate unit in an existing installation.

It should be noted that on the one hand the drying of steam by means of a centrifugal separator is a process known per se, and that on the other hand the washing of steam by passing it through a liquid screen is also known per se.

The cyclone in the apparatus should have a high separating effect, and it is preferred to use a cyclone of a special design which has a cylindrical jacket and is provided with a flat bottom to which a liquid discharge pipe is connected, and which is provided at some distance from the bottom with a catch pot or thief which is open at the top and has an outwardly bent edge, and which is provided with a flat bottom to which a liquid discharge pipe is also connected, the thief being secured to the bottom of the cyclone by means of a plurality of supports.

The thief may widen towards the bottom in the form of a cone, its lower end being provided with a plurality of radial internal baffles, the bottom having an opening to which is connected the liquid discharge pipe.

The outside of the thief is preferably provided with a plurality of radial baffles extending out to near the cyclindrical jacket of the cyclone.

The baffles inside and outside the thief serve both to counteract the rotation of the gases and to create only a low pressure drop in the cyclone.

The central steam discharge of the cyclone may communicate with the steam discharge line through an additional water-separating chamber provided with a liquid discharge pipe issuing into the liquid seal in the vessel.

The applicants' experiments have shown that a cyclone of this design has the attractive advantage that the resistance on both the liquid and the steam sides is independent of the moisture content of the steam. In addition, on the steam side the pressure drop is lower than in a known high-efficiency cyclone, while the efficiency of the separation is even slightly higher than in that cyclone. This advantage is particularly apparent with high liquid loads.

A specific embodiment of the invention will now be described by way of example with reference to the accompanying drawing, which is a diagram of the apparatus.

The apparatus consists of a vertical cylindrical vessel 1, the height of which is approximately six times the diameter. The height-diameter ratio of the vessel is usually between 4 and 8, this ratio depending on the operating conditions. If, for example, it is desired to provide the lower section with a water zone of a fairly large capacity the volume required may be obtained by giving the vessel a considerable height.

The vessel 1 is provided with a tangential inlet 2 for the steam to be treated. An annular channel 3 for purified water and a cyclone 4 are provided inside the vessel 1 above this inlet 2. An annular collecting channel 5 for impure water and a liquid seal 6 are present inside the vessel below the inlet 2. The lower part 7 of the vessel is the liquid space and a bottom part of the vessel is provided with a discharge 8 for purified water. The top of the vessel 1 has a dry purified steam discharge line 9 connected to the cyclone 4. The vessel is also provided with a tangential supply line 10 for purified water, which line is connected to the liquid channel 3, and with a discharge line 11 for impure water, which line is connected to the collecting channel 5.

The cyclone 4 has a cylindrical jacket 12 and a flat bottom 13. A tangential inlet 14 communicates with the interior of the top of the vessel 1. The top of the cyclone is provided with a central discharge pipe 15 for the steam. Surrounding this discharge pipe is a ring 16 preventing a water film from flowing inwardly along the upper wall of the cyclone. The presence of such a ring is, however, not essential to this embodiment since the discharge pipe 15 issues into an additional water-separation chamber 17 in which is col-

lected any water entering this chamber as a film from the pipe 15. The steam discharge line 9 is connected to the chamber 17.

A thief 18, the top of which is provided with an outwardly bent edge 19, is at some distance from the bottom 13 of the cyclone 4. The thief 18 is secured to the bottom 13 of the cyclone by means of a plurality of vertical supports 25. The thief widens towards the bottom in the form of a cone, its lower end being provided internally with a plurality of radial baffles 21 so shaped that the periphery of the bottom 13 is left free. It also has external baffles 20 extending radially towards the cyclone jacket 12.

A water discharge line 22 is connected tangentially to the bottom 13 of the cyclone. The bottom of the thief 18 is provided with an opening to which is connected, also tangentially a discharge pipe 23 for discharging water collected in the thief 18. The chamber 17 is also provided with a water discharge line 24. The lines 22, 23 and 24 issue near the bottom of a box which is open at the top and forms the liquid seal 6.

The apparatus operates as follows. The steam to be treated enters the apparatus via the tangential inlet 2, and as a result of the centrifugal action that part of the water having the highest salt concentration and the generally heavier impurities are flung against the wall, move down the wall and arrive in the collecting channel 5. The steam with the remaining water and impurities then passes through a liquid screen of purified water originating from the channel 3 which is fed from the line 10. This channel consists, in the present embodiment, of an open annular gutter from which the purified water overflowing the inner wall rains downwards as a screen.

In this water screen minute water particles in particular are combined to form larger ones and the remaining impurities are collected. As the water moves further down it is also given a rotating component of motion so that in this case also those of the water drops which now contain the solid impurities are again flung outwards so that finally they also arrive in the collecting channel 5. Some of the material collected in this channel containing the major part of the solid impurities is removed via the line 11; the water substantially free from impurities flowing over the upper edge of the channel 5 passes through the central passage bounded by the annular channel 5 and arrives in the liquid space 7 of the vessel.

It is not, of course, essential for the liquid screen to be formed from a channel having the shape of an open annular gutter. Thus, it is possible, for example, to connect the supply line 10 to an annular line having the shape of a closed circular pipe provided with a large number of spraying apertures regularly spaced along its periphery. Hence in this case it is also possible to direct the screen slightly inwards or outwards if the design makes this desirable so that a screen is formed which is approximately in the shape of the surface of the cone.

The steam freed from the greater part of the water rises in the vessel 1 and enters the cyclone 4 through the tangential supply line 14. In this cyclone substantially all remaining water is caught, the water being separated from the steam in a manner usual in the cyclone technique. The thief 18 has the following function. Most of the water which, as a result of the inwardly-directed secondary gas flow prevailing near the bottom of the cyclone, moves at this point inwardly from the periphery of the cyclone, for example in the form of small droplets, arrives on the edge 19 of the thief 18. Water creeping over the edge 19 reaches the inside of the thief and has no further opportunity of becoming atomized and entrained by the upward gas stream. A portion of this water will leave the edge 19 and arrive again in the gas stream in the form of drops. The position and design of the edge are such that the drops are moved again towards the cyclone jacket by centrifugal action, since both the rotation and the vertical flow of the gas in the thief are considerably less powerful than in the actual cyclone space above, owing to the thief widening downward and the presence of the baffles 21.

The baffles 20 on the outside of the thief are also designed to counteract gas rotation while enabling the water to flow freely down the cyclone jacket.

Any water which may still be entrained by the gas stream or which creeps along the wall of the pipe 15 as a film is finally collected in the chamber 17. At the places where the water is collected, i.e. at the bottom of the cyclone, on the bottom of the thief 18 and on the bottom of the chamber 17, it is removed through the lines 22, 23 and 24, respectively to the box 6 serving as a liquid seal.

It is not essential to have a box of this type, since the lines may equally well be extended to reach into the liquid space 7, which then also serves as a liquid seal. They may, however, be a highly varying liquid level in the latter space since this space is very suitable as a buffer for the water supplied to the steam generating plant. It would then be necessary to extend the lines to near the bottom of the vessel. This is rendered superfluous by the presence of the liquid seal 6, while moreover the space 7 may on occasion be temporarily free from liquid. Since the pressure drop of the above cyclone is so favourable on the gas side there is hardly any risk of water being sucked upwards through the line 24 when there is no static head, so that line 24 may be reduced in length. This advantage also has a favourable effect on the overall height of the apparatus, which may thus be less than it would have to be if a different type of cyclone with

a chamber 17 were used.

WHAT WE CLAIM IS:—

1. A process for the separation of steam containing water and solid impurities into dry steam, pure water and water containing impurities which comprises supplying the steam for treatment to a centrifugal separator through a tangential inlet, passing the steam when inside the separator through a liquid screen of purified water in which impurities and some of the water left in the steam after initial centrifugal separation in the separator are caught, then leading it through a cyclone provided in the separator above the screen, discharging dry purified steam overhead and discharging water from the cyclone through a discharge pipe into a water zone in the bottom part of the separator, into which zone previously separated water together with water from the liquid screen are passed through a central passage inside an annular space provided in the separator above the water zone and beneath the inlet, in which annular space impure water with the highest concentration of impurities is collected as a result of the centrifugal effect.

2. An apparatus suitable for carrying out the process as claimed in ~~Claim~~ 1, comprising a vertical cylindrical vessel; a tangential inlet connected to the cylindrical wall of the vessel; an annular liquid channel in the vessel situated above the inlet and provided with a supply line for purified water and with means for forming a downwardly directed liquid screen; a vertical cyclone in the vessel situated above the liquid channel, of which cyclone the tangential inlet is situated inside the vessel, the top of the central steam outlet communicates with a discharge line extending outside the vessel, and the bottom of the liquid discharge device issues into a liquid seal provided inside the vessel; an annular collecting channel for impure water in the vessel, formed by the cylindrical wall thereof, a wall which is coaxial thereto and a bottom located beneath the inlet of the vessel and provided with a discharge line; and a discharge for water in the bottom of the vessel.

3. An apparatus as claimed in claim 2 in which the annular liquid channel consists of an annular gutter formed by the cylindrical wall of the vessel, an inner wall concentric thereto and a bottom, the top edge of the inner wall serving as a weir, which forms a vertical downwardly-directed cylindrical liquid screen during operation.

4. An apparatus as claimed in claim 2 or claim 3 in which the cyclone has a cylindrical jacket and a flat bottom to which a liquid discharge pipe is connected and is provided at some distance from the bottom with a thief, which thief has an open top with an outwardly bent edge and a flat bottom to which a liquid discharge pipe is connected, the thief being secured to the bottom of the cyclone by means of a plurality of supports.

5. An apparatus as claimed in claim 4 in which the thief widens towards the bottom in the form of a cone, its lower end being provided with a plurality of radial internal baffles, the bottom having an opening to which the liquid discharge pipe is connected.

6. An apparatus as claimed in claim 4 or claim 5 in which the outside of the thief is provided with a plurality of radial baffles extending out to near the cylindrical jacket of the cyclone.

7. An apparatus as claimed in any of claims 3 to 6 in which the central gas or vapour discharge of the cyclone communicates with the gas or vapour discharge line via an additional water-separating chamber provided with a liquid discharge pipe issuing into the liquid seal within the vessel.

8. An apparatus as claimed in any of Claims 2 to 7 in which the liquid seal is formed by a box within the vessel and open at the top, which is filled with liquid during operation and into which the liquid discharge pipe (or pipes) of the cyclone issues (or issue) near the bottom.

9. A process for the separation of steam containing water and solid impurities into dry steam, pure water and water containing impurities, substantially as described with reference to the accompanying drawing.

10. An apparatus for the separation of steam containing water and solid impurities into dry steam, pure water and water containing impurities, substantially as described with reference to the accompanying drawing.

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a chamber 17 were used.

WHAT WE CLAIM IS:—

1. A process for the separation of steam containing water and solid impurities into dry steam, pure water and water containing impurities which comprises supplying the steam for treatment to a centrifugal separator through a tangential inlet, passing the steam when inside the separator through a liquid screen of purified water in which impurities and some of the water left in the steam after initial centrifugal separation in the separator are caught, then leading it through a cyclone provided in the separator above the screen, discharging dry purified steam overhead and discharging water from the cyclone through a discharge pipe into a water zone in the bottom part of the separator, into which zone previously separated water together with water from the liquid screen are passed through a central passage inside an annular space provided in the separator above the water zone and beneath the inlet, in which annular space impure water with the highest concentration of impurities is collected as a result of the centrifugal effect.

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6. An apparatus as claimed in claim 4 or claim 5 in which the outside of the thief is provided with a plurality of radial baffles extending out to near the cylindrical jacket of the cyclone.

7. An apparatus as claimed in any of claims 3 to 6 in which the central gas or vapour discharge of the cyclone communicates with the gas or vapour discharge line via an additional water-separating chamber provided with a liquid discharge pipe issuing into the liquid seal within the vessel.

8. An apparatus as claimed in any of Claims 2 to 7 in which the liquid seal is formed by a box within the vessel and open at the top, which is filled with liquid during operation and into which the liquid discharge pipe (or pipes) of the cyclone issues (or issue) near the bottom.

9. A process for the separation of steam containing water and solid impurities into dry steam, pure water and water containing impurities, substantially as described with reference to the accompanying drawing.

10. An apparatus for the separation of steam containing water and solid impurities into dry steam, pure water and water containing impurities, substantially as described with reference to the accompanying drawing.

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