United States Patent

[11] 3,574,303

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[21] Appl. No. **763,885**
[22] Filed **Sept. 30, 1968**
[45] Patented **Apr. 13, 1971**

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[54] **MOISTURE SEPARATOR REHEATER FOR PRESSURIZED VAPOR**
16 Claims, 6 Drawing Figs.

[52] **U.S. Cl.** **122/483,** 122/488
[51] **Int. Cl.** **F22g 5/16,** F22b 37/26
[50] **Field of Search** 122/483, 488, 491

[56] **References Cited**
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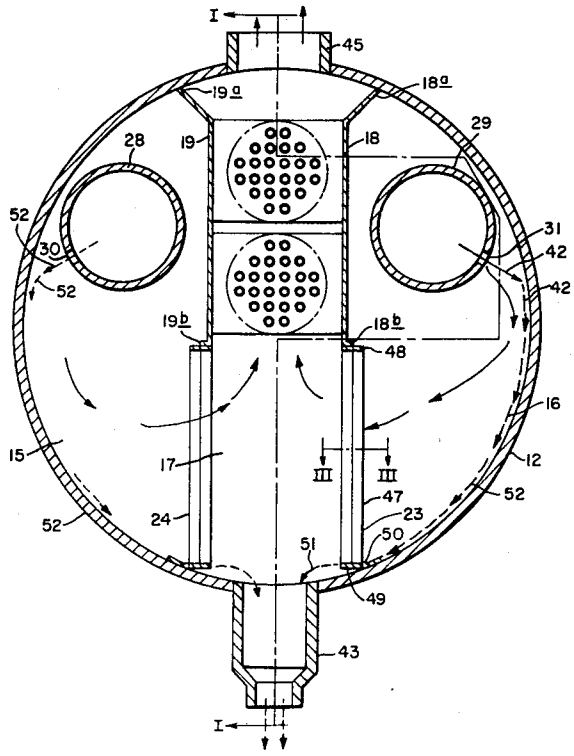
ABSTRACT: This invention provides an improved unitary device for removing moisture from moisture-laden vapor in a highly pressurized state and heating the demoisturized vapor to a dry and/or superheated state, in which an axially elongated casing (closed at its ends) is divided into a pair of oppositely disposed and axially extending moisture-laden vapor collection chambers into which the incoming moisture-laden vapor (such as motive steam for a steam turbine) is individually distributed in a uniform manner by a longitudinally elongated manifold disposed in each chamber, and a centrally disposed and axially extending moisture-free vapor collection chamber wherein the demoisturized vapor is heated and then delivered from the casing. The chambers are defined, in part, by a pair of plate-type moisture separators also extending in axial direction from end to end of the casing and providing a flow path from the moisture-laden vapor collection space to the moisture-free vapor collection chamber.



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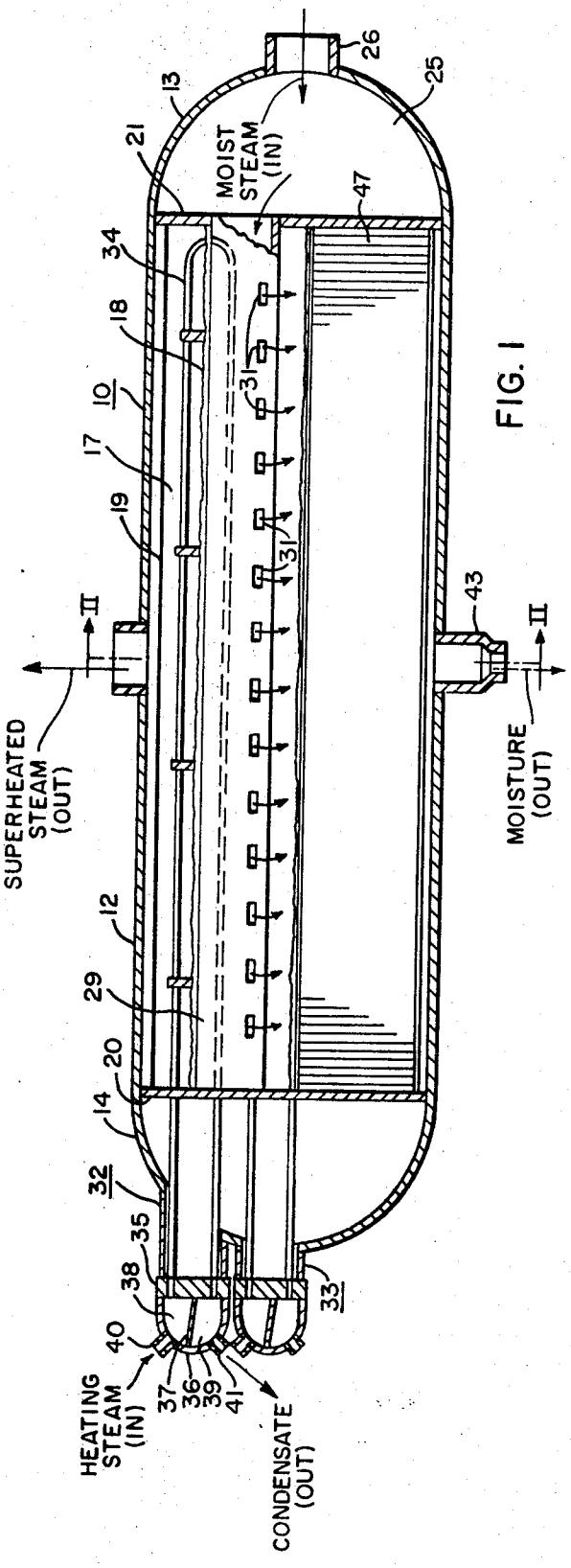

FIG. 1

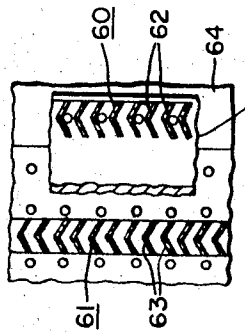

FIG. 5

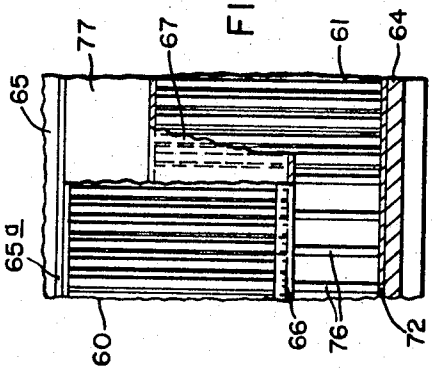

FIG. 6

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FIG. 4

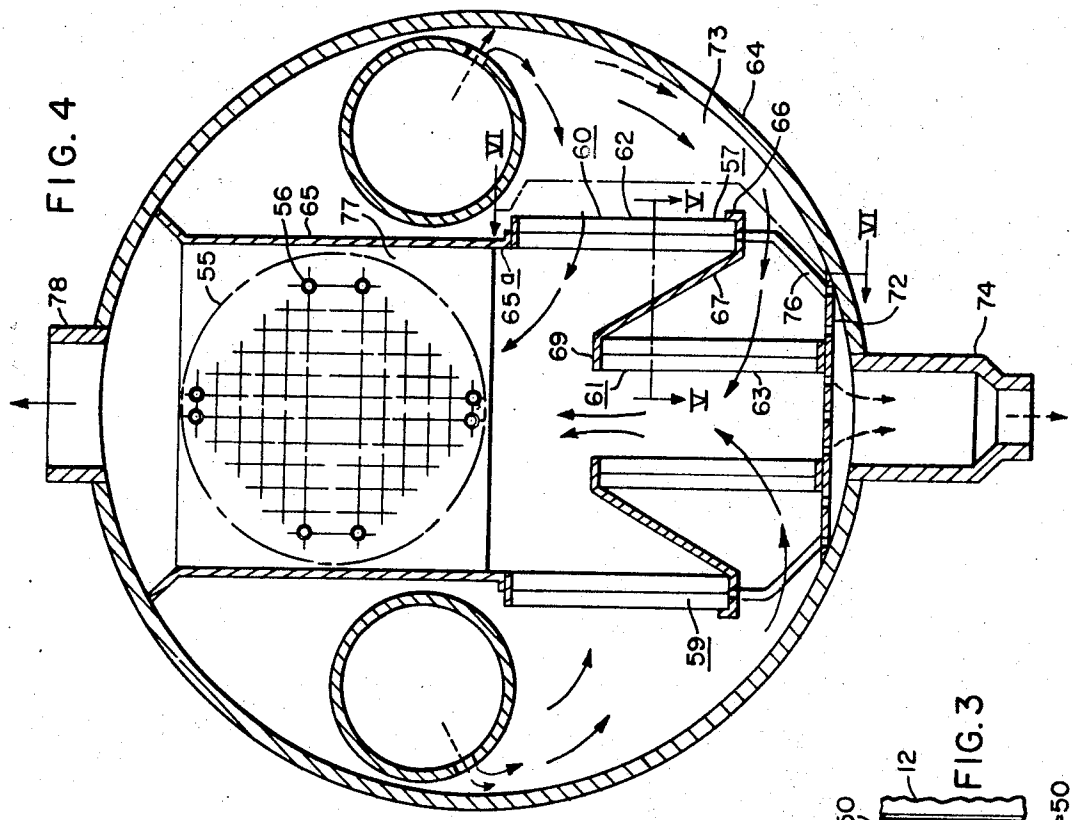


FIG. 3

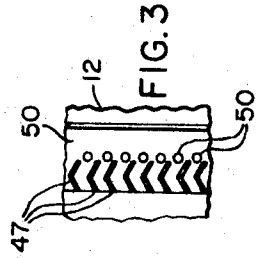
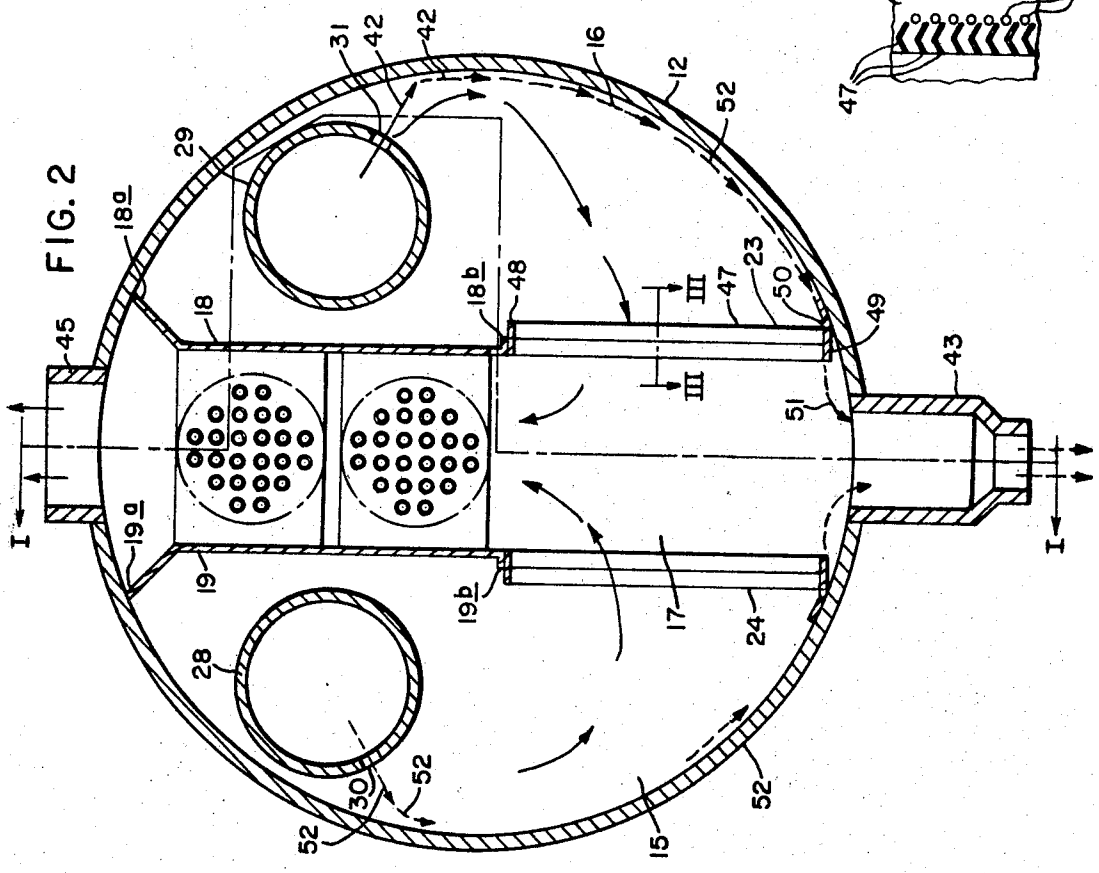


FIG. 2



MOISTURE SEPARATOR REHEATER FOR PRESSURIZED VAPOR

BACKGROUND OF THE INVENTION

With the advent of nuclear power steam turbine power plants, i.e. power plants in which the high temperature and high pressure motive steam for motivating the turbines is generated by a steam generator heated by a reactor, removal of moisture and reheating of the steam to a superheated state after partial expansion in the high-pressure turbine unit has has become conventional practice, in view of the attendant advantages. More particularly, with the present state of the art, nuclear steam generators do not provide motive steam at as high a temperature as provided by more conventional fossil-fired steam generators. Hence, after partial expansion in the steam turbine system, the steam temperature falls to the saturation temperature with formation of moisture that can have very serious deleterious effects on the succeeding stages of turbine blades unless removed. Reheating of the steam after demoisturizing is also highly desirable, since it permits further expansion in the turbine without formation of additional harmful moisture. In many turbine systems of the above type, two or more moisture separator/reheaters are employed between successively lower pressure units.

In view of the above, moisture separator/reheater devices of this type must handle large volumetric flow rates with minimum pressure drop loss. Hence the size of these units is getting larger to accommodate the steam utilized in larger turbine systems. With this situation, it is desirable to enhance the moisture-separating characteristics and reheating characteristics, so that greater flows can be handled with optimum moisture removal without increase in pressure drop and yet without increasing the physical size of the casing.

SUMMARY

In accordance with the teachings of this invention, the moisture separator/reheater is formed with an axially elongated casing, with its opposite ends closed, and a pair of moisture separators disposed within the casing in transversely spaced relation with each other and extending in axial direction from substantially one end of the casing to the other. The separators are preferably of the stacked plate type (known as the chevron type) and, jointly with suitable partition structure, divide the casing into a pair of oppositely disposed chambers for receiving the moisture-laden steam and a central chamber disposed in fluid flow communication with the pair of chambers by way of the opposed separators and forming a chamber for collecting the demoisturized steam.

The central chamber has a heater tube bundle through which highly heated steam is circulated to heat the demoisturized steam to a dry superheated state before delivery from the casing.

A pair of manifolds, one in each of said pair of chambers, is provided for uniformly delivering the incoming steam thereto along the entire axial extent of the casing, thereby minimizing the pressure drop losses of the steam. Also, since the separators are substantially coextensive with the length of the casing and each of the separators handles 50 percent of the total steam flow, pressure losses due to the separators is also minimized.

The above arrangement permits greater volumetric flows to be handled with high efficiency and without increase in the physical size of the casing, thereby further reducing the total cost of fabrication and, since these units are necessarily large, shipping is simplified.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a longitudinal sectional view of a unitary moisture separator/reheater unit incorporating the invention, the section being taken along line I–I of FIG. 2;

FIG. 2 is a cross-sectional view, or a larger scale, taken on line II–II of FIG. 1;

FIG. 3 is a fragmentary sectional view taken along line III–III of FIG. 2;

FIG. 4 is a view similar to FIG. 2 but showing another embodiment of the invention;

FIG. 5 is a fragmentary sectional view taken on line V–V of FIG. 4; and

FIG. 6 is a fragmentary sectional view taken on line VI–VI of FIG. 4.

PREFERRED EMBODIMENT

Referring to the drawings in detail, in FIG. 1 there is shown a unitary device 10, formed in accordance with the invention, for removing moisture from moisture-laden, saturated vapor (for example, steam) in a highly pressurized state and heating the demoisturized vapor to a dry and/or superheated state. This type of device is generally known in the art and is usually called a "moisture separator/reheater unit." For simplicity of explanation the above term will be used in this specification, and also "steam" and "water" will be employed in the description of the moisture separator/reheater for the same reason, and not by way of limitation.

The moisture separator/reheater 10 is provided with a tubular axially elongated shell or casing 12 closed at its ends by a pair of oppositely disposed end bells 13 and 14. The interior of the casing 12 as best shown in FIG. 2, is divided into three axially extending chambers, i.e., a pair of oppositely disposed chambers 15 and 16 and a centrally disposed chamber 17, by internal structure including a pair of laterally spaced vertical partitions 18 and 19 extending from the end bell 13 to the end bell 14 and end partitions 20 and 21.

The partitions 18 and 19 are sealingly attached at their upper marginal portions 18^a and 19^a to the outer casing 12 and have their lower marginal portions 18^b and 19^b disposed in vertically spaced relation with the lower portion of the outer casing.

A pair of moisture/separating structures 23 and 24 extend from the marginal portions 18^b and 19^b, respectively to the lower portions of the outer casing and provide fluid flow communication between the outer chambers 15, 16 and the central chamber 17. In other words, as best seen in FIG. 2, the partitions and separators are disposed in parallel chordal planes. The moisture separating structures 23 and 24 extend axially from the end partition 20 to the end partition 21, as best shown in FIG. 1.

The end partition 21 and the end bell 13 jointly define an inlet chamber 25 into which moisture-laden pressurized steam is admitted through an inlet fitting 26.

A pair of tubular manifolds 28 and 29 are received in suitable openings in the end partition 21 and extend longitudinally into the outer chambers 15 and 16 respectively. The manifolds 28 and 29 are in fluid flow communication with the inlet chamber 25 and are provided with a series of outlet openings 30, 31 respectively, along their length to admit moisture-laden steam uniformly into their respective chambers 15 and 16, hereinafter termed moisture-laden steam collecting chambers, for clarity. The manifolds 28, 29 extend in axial direction for substantially the entire length of their associated collection chambers and lie in a common horizontal plane that extends across the central axis of the casing 12. The partitions 18 and 19, on the other hand, extend downwardly below the horizontal plane.

A pair of heaters 32 and 33 are provided to heat the moisture-free steam in the central steam collection chamber 17. The heaters are preferably disposed one above the other and are substantially identical, hence only the heater 32 will be described.

The heater 32 is generally conventional and includes a bundle of tubes 34 of the U- or hairpin-type received at their open ends in a suitable tube sheet 35 and extending through the partition 20 for the full length of the central chamber 17. The tube sheet 35 is preferably of disc shape and is sealingly connected at its periphery to a hemispherical channel head 36 in any suitable manner. Within the channel head 36 there is a partition 37 which, together with the channel head and the tube sheet, defines a heating steam inlet chamber 38 and a

vitiated steam outlet chamber 39. Heating steam from any suitable supply (not shown) is admitted through a suitable inlet 40 into the inlet chamber 38 and traverses the bundle of U-tubes 34 and is then withdrawn from the outlet chamber 39 as vitiated steam and/or condensate through a suitable outlet 41.

The outer casing 12 is further provided with a tubular outlet fitting 43 in its lower portion and in communication with the lower portion of the central chamber 17 and chambers 15 and 16, for delivering collected moisture from the casing; and a tubular outlet fitting 45 in its upper portion in communication with the upper portion of the central chamber, for delivering superheated steam from the casing.

The moisture/separating structures 23 and 24 are substantially identical and of well-known type, hence only the separating structure 23 will be described. The moisture separating structure 23, as more clearly shown in FIGS. 2 and 3, comprises a rectilinear array of vertically extending plate members 47 disposed in uniformly horizontally spaced relation with each other and of generally V-shaped or "chevron" shape in cross section. The array of plate members 47 is mounted in a frame including an upper plate member 48 and a lower plate member 49. The upper plate member 48 is attached to the flanged marginal portion 18a of the partition 18 and the lower plate member 49 is attached to the casing 12 to form a rigid structure. The lower plate member 49 may be provided with a plurality of holes 50 to permit the moisture separated from the moisture-laden steam to drop and collector for removal through the outlet 43 as indicated by the dotted arrows 51.

The outlet ports 31 in the manifold 29 and the outlet ports 30 in the manifold 28 are disposed at a central angle of about 30° with the horizontal, and preferably less than 45°, to direct the moisture-laden steam toward the inner surface of the outer casing 12 to cause impingement of the discrete moisture-laden jets of steam, as it issues therefrom in operation, to strike the casing surface with initial separation of moisture, as indicated by the dotted arrows 52.

In operation, moisture-laden steam to be freed of moisture and reheated to a dry superheated state, is admitted through the inlet 26 into the end chamber 25 and thence in two separate parallel circuits through the manifolds 28 and 29. The steam is thence admitted into the respective moisture-laden steam collection chambers 15 and 16 in a plurality of jets through the associated ports 30 and 31. Some moisture is initially removed, upon such admission, as previously described by the jet impingement of the relatively heavy moisture particles against the inner surface of the casing 12, and the partially moisture-free steam then flows in two horizontally opposed and elongated streams through the moisture separators 24 and 23. In passing through the moisture separators 23 and 24, the remaining moisture is substantially removed by impingement on the V-shaped plates 47 and drops to the bottom of the casing 12, while the two substantially moisture-free but saturated steam streams turn upwardly in the moisture-free steam collection chamber 17 and then merge and flow upwardly past the tube bundles of the reheaters 33 and 32. In passing around the past the U-tubes of the reheaters, the steam is heated to a dry superheated state and then issues from the steam outlet 45.

FIGS. 4, 5 and 6 illustrate a second embodiment of the invention that is generally similar to the first embodiment, but employs a single bundle 55 of reheater tubes 56 (as shown in cross section) and dual moisture separator structures 57 and 59.

The moisture separator structures 57 and 59 are preferably identical, hence only the structure 57 will be described. The structure 57 employs two arrays 60 and 61 of vertically extending and horizontally spaced plate members 62 and 63, respectively. These plates are of V or chevron cross-sectional shape and similar to the plates 47 in the first embodiment.

The plate array 60 extends substantially the full axial length of the casing 64 (as in the first embodiment) and is attached at its upper end to the lower end 65a of the internal partition 65 and at its lower end to a flange of a Z-shaped plate member 67.

The plate array 61 is coextensive with the plate array 60 but is disposed in horizontally spaced relation therewith and at a lower level. The plate array 61 is attached at its upper end to an opposite marginal flange 69 of the plate member 67. A horizontally disposed perforated plate 72 is mounted in a central position adjacent the bottom of the outer casing 64 and the lower end of the plate array 61 is supported by the perforated plate 72 and attached thereto.

The Z-shaped plate 67 is effective to divide the stream of moisture-laden steam from the collection chamber 73, so that the upper portion of the stream flows through the upper plate array 60 and the lower portion of the stream flows through the lower plate array 61. Moisture separated from the steam stream by the plate array 61 drops through the perforated plate 72 for removal through the condensate outlet 74, while moisture separated from the steam stream by the plate array 60 is directed through the plate 72 by a plurality of tubes 76 depending from the flange 66.

After removal of moisture, the moisture-free streams merge in the moisture-free steam collection chamber 77 and turn upwardly to pass around the reheater tubes 56 with attendant heating to a dry superheated state and issue from the casing 64 through an upper tubular outlet 78.

Both of the above embodiments provide optimum moisture separation characteristics to the moisture separator/reheater structure and thus permit the use of smaller diameter outer casings with attendant reduction in manufacturing costs. The second embodiment provides an efficient and space saving arrangement for large moisture/separating plate structures by the arrangement of the separator plate arrays 60 and 61, without sacrifice in pressure drop, thereby permitting even greater savings in size of the casing and hence of the entire unit.

I claim:

1. A unitary moisture separator and reheater for vapor, comprising:

an axially elongated tubular outer casing structure enclosed at its opposite ends;

a pair of partitions disposed in opposed spaced relation with each other within said casing and extending to axial direction;

a pair of moisture/separating structures disposed in opposed spaced relation within said casing and extending in axial direction;

means associated with said partitions and said moisture/separating structures to jointly divide said casing into a pair of oppositely disposed moisture-laden vapor collection chambers and a centrally disposed moisture-free vapor collection chamber, said chambers extending substantially from end to end of said casing;

an inlet in said casing and means connecting said inlet to said pair of chambers for admitting moisture-laden vapor to said pair of chambers;

said moisture separators providing a flow communication between said pair of chambers and said central chamber and effective to remove moisture from the vapor flow therethrough;

means disposed in said central chamber for heating said demoisturized vapor to a dry and superheated state; and

an outlet in said casing disposed in communication with said central chamber for delivering the dry superheated vapor from the casing.

2. The structure recited in claim 1, wherein the inlet connecting means includes a pair of axially elongated manifolds disposed in the pair of chambers and extending coextensively with said moisture/separating structures.

3. The structure recited in claim 1, wherein the moisture separators each comprise:

a plurality of vertically extending vapor-deflecting plate members disposed in mutually horizontally spaced relation;

a trough for collecting the moisture; and

means for draining the collected moisture from the casing.

4. The structure recited in claim 3, wherein the inlet connecting means includes a pair of manifolds disposed in the pair of chambers and extending in axial direction.

5. The structure recited in claim 2, wherein each of the manifolds is provided with an axially spaced array of orifices and said orifices are disposed in a manner to direct the moisture-laden vapor into impingement with the casing to effect initial separation of moisture from the vapor.

6. The structure recited in claim 1, wherein each of the moisture/separating structures comprises a first and a second tier of vertically extending vapor-deflecting plate members disposed in parallel flow relation with each other.

7. The structure recited in claim 6, wherein:

the first tier has inner and outer edge portions and the second tier has inner and outer edge portions;

the inner edge portion of the first tier and the outer edge portion of the second tier being connected to each other; and

the outer edge portion of the first tier being connected to the casing, and the inner edge portion of the second tier being connected to its associated partitions.

8. The structure recited in claim 7, wherein the first and second tiers are disposed in partially overlapping relation with each other and define separate and parallel flow paths for vapor from the inlet chambers to the outlet chamber.

9. A unitary moisture separator and reheater for vapor comprising:

an axially elongated tubular outer casing structure;

a pair of partitions disposed in opposed side-by-side spaced relation with each other within said casing and extending in axial direction;

said partitions having outer edge portions disposed in sealing abutment with the outer casing;

a pair of moisture/separating structures disposed in opposed side-by-side spaced relation within said casing and extending in axial direction;

said moisture/separating structures having outer edge portions in sealing abutment with said casing;

said partitions and said moisture/separating structures having mutually abutting inner edge portions, whereby said partitions and said moisture/separating structures jointly divide said casing into a pair of oppositely disposed moisture-laden vapor collection chambers and a centrally disposed moisture-free vapor collection chamber;

an inlet for moisture-laden vapor to be heated and means connecting said inlet to said pair of chambers;

said moisture separators being effective to remove moisture from the moisture-laden vapor and providing a flow communication between said pair of chambers and said central chambers for the demoisturized vapor;

means disposed in said central chamber for heating said demoisturized vapor; and

an outlet for the heated vapor disposed in communication with said central chamber.

10. The structure recited in claim 8, wherein the inlet connecting means includes a pair of axially elongated manifolds disposed in the pair of chambers and extending coextensively with said moisture/separating structures.

11. The structure recited in claim 8, wherein the moisture separators each comprise a plurality of vertically extending vapor-deflecting plate members disposed in mutually horizontally spaced relation, a trough for collecting the moisture and means for draining the collected moisture from the casing.

12. The structure recited in claim 10, wherein the inlet connecting means includes a pair of manifolds disposed in the pair of chambers and extending in axial direction.

13. The structure recited in claim 9, wherein each of the manifolds is provided with an axially spaced array of orifices and said orifices are disposed in a manner to effect impingement of the issuing jets against the casing to effect initial separation of moisture from the vapor.

14. The structure recited in claim 8, wherein:

each of the moisture/separating structures comprises a first and a second tier of vertically extending vapor-deflecting plate members; and

said first and second tiers being of a greater total height than the spacing between the abutting inner edge portions of the partitions and the abutting outer edge functions of the moisture/separating structures and defining parallel opposed flow paths for the vapor from the pair of chambers.

15. The structure recited in claim 13, wherein:

the first tier has inner and outer edge portions and the second tier has inner and outer edge portions; and

the inner edge portion of the first tier and the outer edge portion of the second tier being connected to each other, the outer edge portion of the first tier being connected to the casing, and the inner edge portion of the second tier being connected to its associated partitions.

16. The structure recited in claim 15, wherein the first and second tiers are disposed in partially overlapping relation with each other and define separate and parallel flow paths for vapor from the inlet chambers to the outlet chamber.