Aug. 25, 1953 E. DURHAM 2,649,928

APPARATUS FOR SEPARATING MOISTURE FROM A VAPOR

Filed Nov. 30, 1949 2 Sheets-Sheet 1

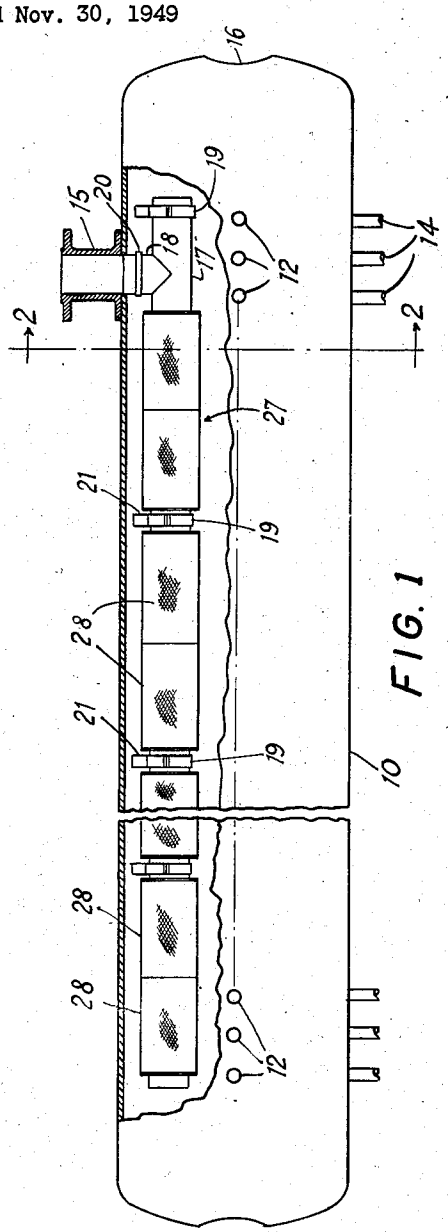


FIG. 1

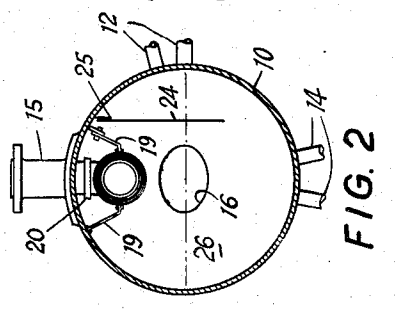


FIG. 2

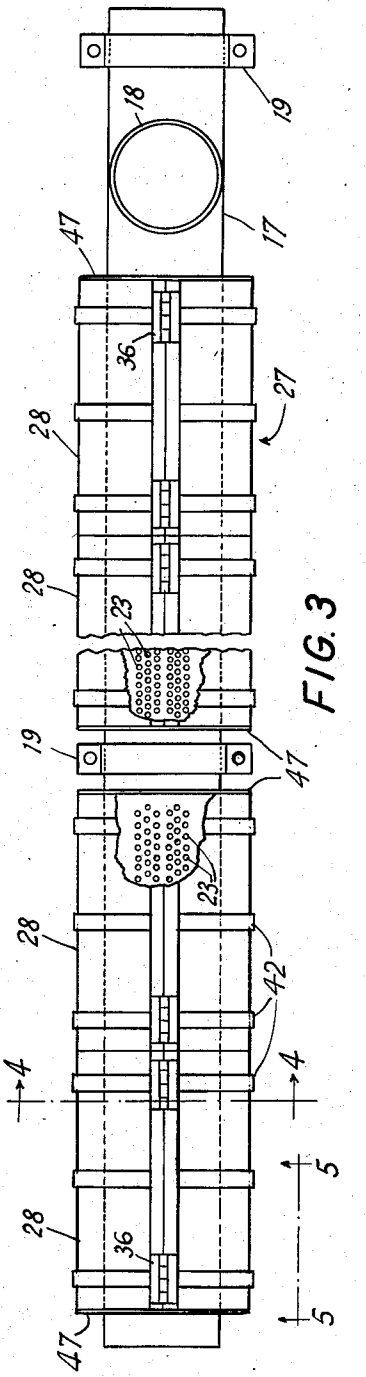


FIG. 3

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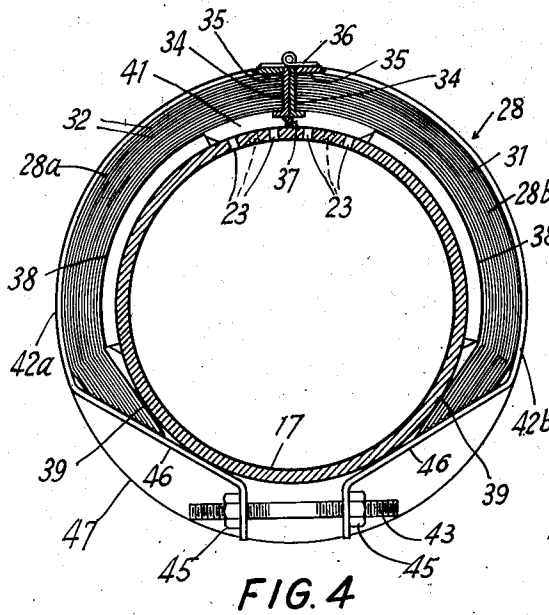


FIG. 4

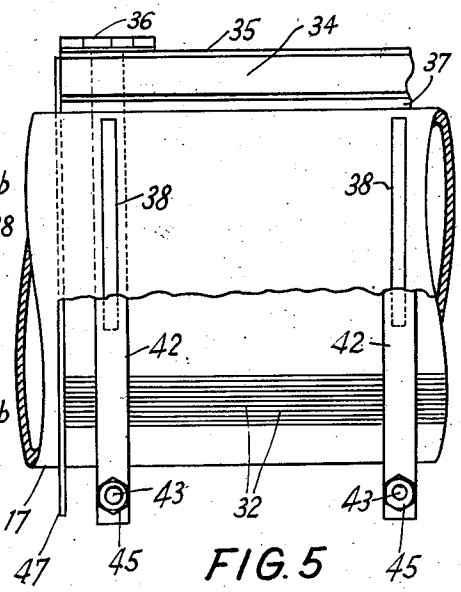


FIG. 5

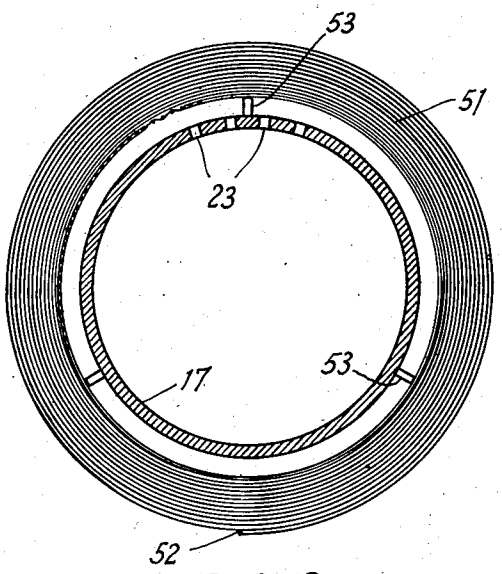


FIG. 6

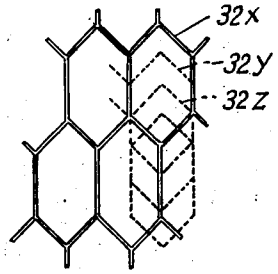


FIG. 7

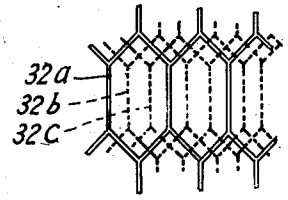


FIG. 8

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APPARATUS FOR SEPARATING MOISTURE FROM A VAPOR

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6 Claims. (Cl. 183—69)

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The present invention relates in general to a separating apparatus adapted to separate moisture from an aqueous vapor passing therethrough. More specifically, my invention is concerned with the construction and operation of means for separating entrained moisture from vapor flowing from a point of vapor generation to a point of use. My invention is therefore applicable to vapor generators, and to steam boilers, in particular, wherein the steam as generated passes into an elevated pressure vessel, such as a steam and water drum, from which the steam is discharged to a point of use, either direct from the drum, or through a superheater, for example, if steam of a higher temperature should be required.

In certain types of steam boilers having an elevated steam and water drum, a steam collector or "dry pipe" is provided in an upper portion of the drum, above the highest operating water level therein, so as to collect steam from horizontally distributed uppermost regions of the boiler steam space for discharge through one or more outlets. In many cases, the quality of steam thus made available has been entirely adequate, but in other instances, for greater efficiency of various steam driven apparatus, for example, a greater "dryness" of steam is required, for which purpose the apparatus of the present invention is especially intended.

In general, the vapor-moisture separator herein disclosed comprises a vapor-pervious, non-compacting body or mass interposed in the path of steam approaching the openings into the dry pipe, and providing an extraordinarily large proportion of steam-contacted area for each cubic inch of space occupied by the mass. In practice, such a body or mass may be suitably formed, for example, of metallic screen-like sheets arranged in layers and providing a ramification of tortuous passages of relatively small cross section through which the moisture carrying vapor is directed.

The various features of novelty which characterize my invention are pointed out with particularity in the claims annexed to and forming a part of this specification. For a better understanding of the invention, its operating advantages and specific objects attained by its use, reference should be had to the accompanying drawings and descriptive matter in which I have illustrated and described a preferred embodiment of my invention.

Of the drawings:

Fig. 1 is side elevational view, partly broken away, diagrammatically showing an embodiment of my invention in a horizontally arranged steam and water boiler drum;

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Fig. 2 is a sectional end view of the structure shown in Fig. 1, taken along line 2—2;

Fig. 3 is an enlarged plan view of the separator and dry-pipe assembly included in Fig. 1;

Fig. 4 is an enlarged cross-sectional view of the assembly shown in Fig. 3, taken along line 4—4;

Fig. 5 is a partial side elevation of the assembly shown in Fig. 3, as viewed from line 5—5;

Fig. 6 is a cross-sectional view, similar to Fig. 4, showing a modification; and

Figs. 7 and 8 are enlarged fragmentary views showing the relative positions of separator elements in different layers.

In more detail, the structure illustrated in Fig. 1 includes a cylindrical pressure vessel 10, suitably the upper, horizontal, steam and water drum of a boiler, and having rows of inlet tubes 12, in a side wall, through which moisture carrying steam is discharged into the drum, and rows of downcomer tubes 14, in the bottom wall, through which water is returned to the vapor generating elements, not shown. A steam outlet is provided by nozzle 15 mounted over an opening in the uppermost part of the drum wall. A manway opening 16 of elliptical formation is formed in each end wall of the drum, and a suitable removable closure provided therefor.

A cylindrical dry pipe 17, extending horizontally throughout the greater part of the length of the drum, and removably positioned adjacent the uppermost wall of the drum, is provided with an outlet connection 18 which communicates directly with the steam outlet opening in nozzle 15, through a demountable socketed connection 20, each end of the dry pipe being closed. The dry pipe is supported from the upper drum wall by means of split hanger bands 19 and straps 21, arranged at longitudinally spaced intervals. Between the locations of hangers 19, and throughout the greater part of the distances therebetween, and beyond, the dry pipe is perforated in its upper wall portion with numerous holes 23, as indicated in Fig. 3, to provide entrance for steam into the dry pipe, the combined area of all such holes 23 being considerably greater than the cross sectional area of the outlet connections 18 and 15 so as to avoid restriction of steam flow through the drum due to the dry pipe. The holes or perforations 23 are confined to an arcuate band of less than 45° and of symmetrical arrangement relative to the vertical centerline of pipe 17.

An upright cross baffle 24 is positioned between the steam inlet connections 12 and the dry pipe 17 to provide a primary steam and water

separating stage prior to the entrance of steam into the dry pipe, the upper edge of the baffle lying adjacent an upper wall portion of the drum and being supported therefrom, as by a bar **25**, and its lower edge extending downwardly below the lowest operating water level. The ends of baffle **24** are spaced from adjacent ends of the drum so as to provide the only areas through which steam may pass into the larger drum space **26** within which the dry pipe is located.

Exteriorly of the dry pipe **17**, and mounted thereon, are a series of steam filter or scrubber units **27** which overlie all dry pipe perforations **23**, and which are respectively positioned over perforations in separate groups, with each unit **27** being suitably formed in a single length, or in separate successive lengths or sections **28**, as may be necessary, depending for example on the distance between successive dry pipe hangers **19**, and thereby the maximum longitudinal extent of each group of perforations to be covered. As seen in Figs. 4 and 5, each separator or scrubber section **28** comprises a vapor-pervious, interstitial mass **31** which in the illustrated embodiment is of arcuate formation and concentrically arranged with respect to the dry pipe **17**, the mass or body **31** embracing approximately three-fourths of the total circumference of the dry pipe in symmetrical relation to the vertical centerline thereof.

The material used in fabricating each filter section **28**, to provide the mass **31**, is of a generally screen-like character and, for the purpose of this invention may be one of several forms which are commercially available, including for example such products as expanded metal and hardware cloth. The form indicated herein and actually employed by applicant is a form of expanded metal commonly known as metal lath and ordinarily utilized as an anchoring groundwork for mortar, plaster, or cement. As is well known, the metal lath provides an all-over pattern of approximately diamond-shaped openings, of greater length than width, distributed throughout the sheet and separated by strands or ribs which extend transversely to the plane of the sheet, at varying inclinations thereto. Each strand or rib has a thickness dimension less than its width and presents that thickness dimension toward opposite surfaces of the material. As viewed from the edge of the sheet, the ribs present a generally saw-toothed appearance at opposite sides. When such sheets are assembled in mutually contacting layers, the serrated formation of the facing surfaces serves to maintain a considerable area of each sheet in spaced relation to the next successive sheet, and thus results in an extremely large proportion of the total available metal surface being exposed to the steam passing through the layered mass of sheets. A desirable form of metal lath available for the purpose is one which provides diamond-shaped openings having a length of approximately ½ inch and a width of approximately ¼ inch. The number of layers required may range from about 10 to 15, to meet the majority of service requirements.

It may be found that when a front surface A of one sheet is assembled in adjoining relation to the back surface B of a second sheet, the openings in both sheets will tend to match, and thereby reduce the extent of surface exposed to steam passing through the openings. In that event the front surfaces A, A of the first and second sheets may be arranged in facing relation and the back surfaces B, B of the second and third sheets, and so on throughout the mass, so as to result in a lateral displacement of each opening in one sheet from the corresponding opening in the next sheet, as indicated in Fig. 8, at positions **32***a*, **32***b*, and **32***c*. When the sheets in successive layers are rolled to arcuate form as in Fig. 4 and Fig. 6, in which form the successive layers are of substantially concentric curvature, an additional displacement of openings from one layer to the next is automatically effected in the direction of curvature, as indicated in Fig. 7, at positions **32***x*, **32***y*, and **32***z*, due to change in radius. In reference to Figs. 7 and 8, it is assumed that the longitudinal axis about which the sheets are curved is a line parallel to the bottom margin of the drawing. Thus, with successive layers curved about a common horizontal axis, as herein disclosed, each opening is elongated in the direction of curvature whereby the length dimension of each opening lies in a vertical plane normal to the common axis of curvature.

In providing adequate surface area throughout the mass **31**, the resulting overall diameter of each section **28** may be greater than the minimum transverse dimension of the manway opening **18**, and thus prevent the insertion of sections into the drum for assembly on the dry pipe. Individual lengths or sections **28** may therefore be conveniently formed in complementary half-sections or elements **28***a* and **28***b*, and a suitable hinge or other form of separable connection provided so as to enable each element to be separately passed through the elliptical opening **16** either for assembly within the drum, or after assembly, for removal from the drum.

An assembly of two half-sections or elements is detailed in Figs. 3, 4 and 5 wherein at the upper end of each element, the edges of individual sheets **32** are brazed or welded to the upright leg of an angle **34** extending longitudinally throughout the width of the sheets and constituting a base member of the element. A capping bar **35** is welded to the top end of each angle **34**, and thereby combining therewith to define a channel or recess within which the ends of all layers of the element are assembled and supported. The two half-sections are connected adjacent opposite longitudinally spaced ends by means of hinges **36** each having its leaves connected to the respective capping bars **35**. A spacer bar **37** is welded to the bottom leg of only one angle **34** at a position intermediate the two uppermost longitudinal rows of dry pipe perforations **23**. Other spacer bars **38** extend circumferentially of the dry pipe **17**, and are welded thereto at their opposite ends, as indicated, the bars **38** being angularly displaced from the perforated area of the pipe and being arranged at longitudinally spaced positions adjacent the ends of each half-section, and intermediate the ends. The longitudinal spacer bar **37** and the circumferential spacer bars **38** thus combine to maintain each complete filter section **28** at a predetermined minimum radial distance from the wall of the dry pipe when in the final assembled position.

The filter sections **28***a* and **28***b* terminate below the longitudinal centerline of the dry pipe and, at positions below the lower end of each spacer bar **38**, the lower end portions of all plates **32** of each section are bent inwardly toward the dry pipe so as to bring the innermost plate into arcuate contact with the wall of the pipe throughout the width of the plate, and throughout an appre-

ciable length of arc, as at 39, and thereby provide an effective seal which substantially precludes the by-passing of steam through the gap which would otherwise remain between the lower ends of mass 31 and the dry pipe. The seal at points 39 is maintained by a series of retainer clamps 42 which are positioned directly over the respective circumferential spacer bars 38, as indicated in Fig. 5. Each clamp 42 is suitably formed in two sections 42a and 42b which are connected at their upper ends to capping bars 35, and which at their lower ends are connected by an adjustable clamping means such as a threaded stud bolt 43, fitted with nuts 45. Each retainer clamp 42 is, for the most part, circular so as to conform to the circular contour of the mass 31, whereas its lower end portions 46 are substantially straight and extend in substantially tangential relation to the wall of the dry pipe in conformity with the generally tangential alignment of the lower plate edges which, as seen in Fig. 4, are arranged in stepped succession.

In the assembled position on dry pipe 17, each complete filter unit 27, of one or more sections 28, is engaged at opposite ends by retaining rings 47 which are welded to the dry pipe so as to prevent longitudinal displacement of the unit from its predetermined operative position over a group of dry pipe perforations 23. The rings 47 also serve to seal the ends of the unit so as to prevent the bypassing and leakage of steam which might otherwise occur at those ends, due to longitudinal inflow and outflow. Thus, with the provision of lateral seals 39 and end seals 47, all steam entering the intermediate annular space 41, between the mass 31 and dry pipe 17, is compelled to pass through the interstices distributed throughout the mass. In the form shown, where each separator unit 27 comprises two sections 28 in axially abutting relation, it will be noted that no retaining ring is required between the adjoining ends.

Fig. 6 illustrates a modified arrangement of moisture separator or steam scrubber wherein the layers of screen-like material, instead of being formed of individual sheets, superposed one upon another, are formed as successive convolutions of a continuous sheet, or series of sheets, tightly rolled, so as to provide the spool-like structure or mass 51. The end of the outermost convolution may be suitably secured to the convolution directly beneath by a weld, for example, at 52, or other convenient holding or banding means provided so as to maintain the spool intact. The spool is mounted on dry pipe 17 in radially spaced relation thereto, utilizing longitudinally arranged bars 53, as shown in Fig. 6, or circumferentially arranged bars 38, as shown in Fig. 4. Retaining rings 47 arranged as shown in Fig. 5 may be utilized for maintaining the spool in predetermined position longitudinally of the pipe and additionally, for sealing the ends of the spool against longitudinal inflow or outflow of steam.

In each form of separator herein disclosed, the total vapor flow area afforded through either the mass 31, or mass 51, is considerably greater than the flow area afforded through the dry pipe perforations 23. As a result, the velocity of vapor flow through mass 31 or 51 is relatively lower, so that moisture which collects on the exposed metal surfaces by adhesion is permitted to accumulate thereon instead of being carried along into dry pipe 17 by the steam or other vapor. With the progressive separation of moisture in this manner, and the resulting formation into droplets, the accumulated liquid flows downwardly through the mass under the influence of gravity for discharge from a lower region of the curved filter assembly, and thus into the water space of drum 10. Drainage of collected moisture is facilitated by the arrangement of openings as in Figs. 7 and 8, with the longer dimension of each opening in the direction of curvature, wherein the strands which define each opening are formed with parallel side portions which lie in substantially vertical planes, and with intersecting end portions which extend at acute angles to such planes. With separators of the specific forms shown, moisture carryover is, for all practical purposes, eliminated or at least decreased to an acceptable minimum as compared with the carryover heretofore resulting from use of the dry pipe alone, throughout a corresponding range of loads. Moreover, as loads are increased, the point at which moisture carryover tends to increase more rapidly occurs at a much higher load with the separator unit installed than with the dry pipe alone. Furthermore, these forms of moisture separators are especially adapted to function with negligible additional pressure drop over the normal pressure drop attributable to the dry pipe per se, throughout corresponding load ranges.

While both forms afford substantially the same advantages from an operational standpoint, it is obvious that each includes certain specific features which render it more adaptable to certain conditions than the other. For example, the form detailed in Figs. 4 and 5 is particularly adapted for use in pressure vessels where the size of access opening is the limiting factor, as previously described. On the other hand, the form detailed in Fig. 6 is of simpler construction and therefore entails lower fabrication costs, although requiring a relatively larger size of access opening to permit the insertion and removal of separator units 27. The latter form also affords increased moisture separating capacity together with somewhat better drainage action which can reasonably be attributed to the increased area of moisture collecting surface provided, and the increased arcuate extent of such surface. Moreover, in the form shown in Fig. 6, the mass 51 may be initially formed in one or more sections for assembly over the dry pipe within the drum or, if desired, may be formed directly on the dry pipe and the complete combination thereafter assembled within the drum.

While in accordance with the provisions of the statutes I have illustrated and described herein the best form of my invention now known to me, those skilled in the art will understand that changes may be made in the form of the apparatus disclosed without departing from the spirit of the invention covered by my claims, and that certain features of my invention may sometimes be used to advantage without a corresponding use of other features.

I claim:

1. In combination, a pressure vessel having inlet openings through which a mixture of vapor and liquid is introduced and having a vapor outlet, a vapor collecting member within an upper interior space of said vessel and having vapor inlet openings in an upper wall portion thereof, said member having a vapor outlet connected to the vapor outlet of said vessel, and moisture separator means overlying said vapor inlet openings in spaced proximity to said member and being sealed to said member and wholly supported

thereon beyond the area occupied by said openings, said separator means comprising a vapor-pervious mass formed of screen-like material arranged in successive mutually contacting layers of substantially concentric curvature and providing openings in each of a majority of said layers laterally displaced in at least one direction from corresponding openings in the next successive layer, said openings being elongated in the direction of curvature of said layers.

2. In combination, the structure as claimed in claim 1 and further characterized by said openings in said screen-like material being defined solely by strands of the material constituting said material, each of said strands having a thickness dimension less than its width and presenting said thickness dimension toward opposite surfaces of the material.

3. In combination, a vapor collector of generally tubular formation adapted to extend horizontally within a space containing moisture-carrying vapor under pressure, said collector having a series of vapor inlet openings in and longitudinally distributed throughout an upper wall portion thereof, moisture separating means wholly supported on said collector and comprising a vapor-pervious mass overlying said openings in spaced relation to the wall of said collector, said mass being formed of screen-like material of the nature of metal lath arranged in successive mutually contacting layers of substantially concentric curvature relative to said collector and having portions extending downwardly at opposite sides of said collector, and means for sealing said mass at opposite ends and for sealing corresponding ends of the space separating said mass from said collector, said material having openings elongated in the direction of curvature of said layers.

4. In combination, a vapor collector of generally tubular formation adapted to extend horizontally within a space containing moisture-carrying vapor under pressure, said collector having a series of vapor inlet openings in and longitudinally distributed throughout an upper wall portion thereof, moisture separating means wholly supported on said collector and comprising a vapor-pervious mass overlying said openings in spaced relation to the wall of said collector, said mass being formed of metallic screen-like material of the nature of metal lath arranged in successive mutually contacting layers of substantially concentric curvature relative to said collector and having portions extending downwardly at opposite sides of said collector, and means for maintaining said mass in predetermined position longitudinally of said collector and for simultaneously sealing opposite ends of the space separating said mass from said collector, said material having its screen openings elongated in the direction of curvature of said layers.

5. The combination which comprises a vapor collector of generally circular cross section having a vapor outlet and adapted to extend horizontally within a space containing moisture-carrying vapor under pressure, said collector having vapor inlet openings in and longitudinally distributed throughout an upper wall portion thereof, moisture separating means comprising a vapor-pervious interstitial mass of arcuate formation overlying said openings and concentrically arranged with respect to said collector in radially spaced relation thereto, said mass embracing at least the upper half circumference of said collector and being longitudinally divided into separably connected sections each having a lower marginal area in vapor sealing engagement with said collector at a region below the centerline position thereof, means restraining said sections against radially outward displacement with respect to said collector, and means engaging said sections at opposite ends for preventing longitudinal displacement thereof.

6. The combination which comprises a vapor collector of generally circular cross section having a vapor outlet and adapted to extend horizontally within a space containing moisture-carrying vapor under pressure, said collector having vapor inlet openings in and longitudinally distributed throughout an upper wall portion thereof, moisture separating means comprising a vapor-pervious interstitial mass of arcuate formation overlying said openings and concentrically arranged with respect to said collector in radially spaced relation thereto, said mass embracing the major portion of the total circumference of said collector and being transversely divided into a group of longitudinally successive sections in axially abutting relation, with each section of said group longitudinally divided into separable pin-connected sections each having a lower marginal area in vapor sealing engagement with said collector, means restraining said separable sections against radially outward displacement with respect to said collector, and means engaging opposite ends of said group of axially abutting sections for preventing axial displacement of each relative to another and to said collector.

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