VAPOR-FROM-LIQUID SEPARATOR APPARATUS

Filed March 9, 1948 2 Sheets-Sheet 1

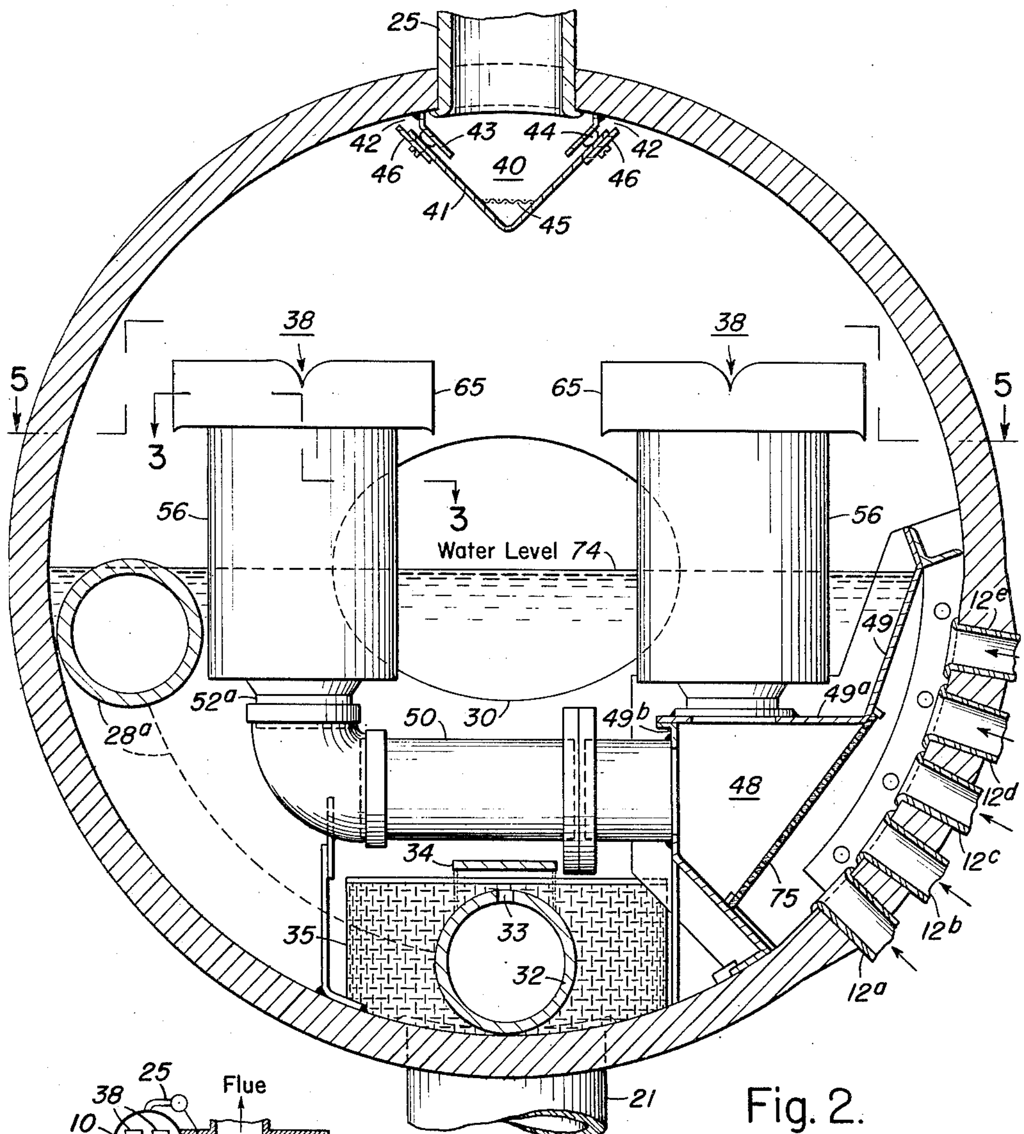

Fig. 2.

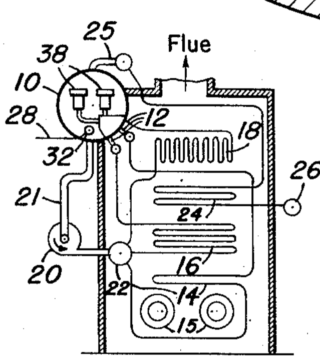

Fig. 1.

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Aug. 11, 1953 T. RAVESE ET AL 2,648,397

VAPOR-FROM-LIQUID SEPARATOR APPARATUS

Filed March 9, 1948 2 Sheets-Sheet 2

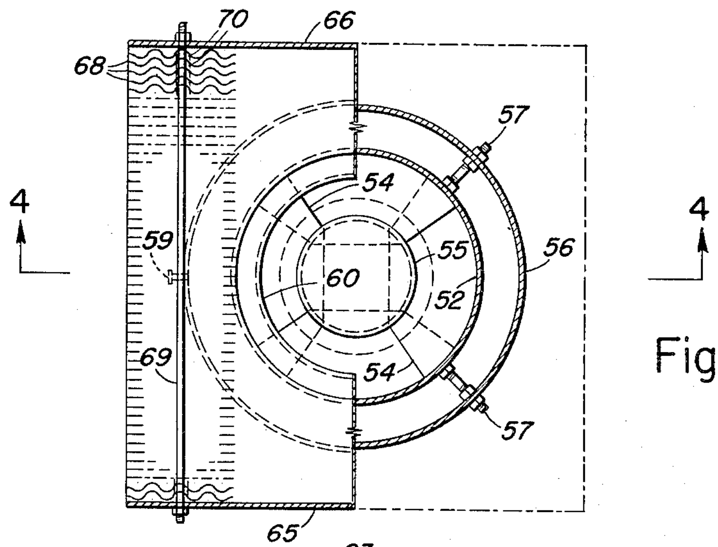

Fig. 3.

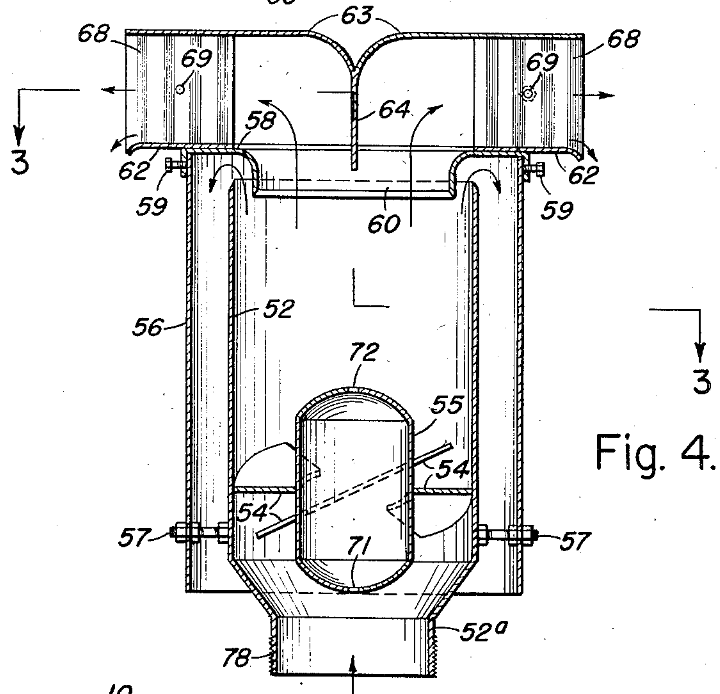

Fig. 4.

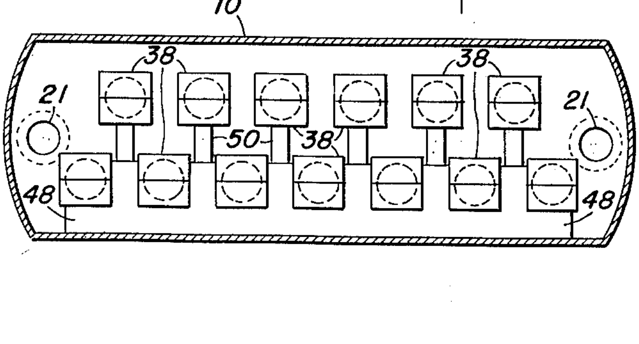

Fig. 5.

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UNITED STATES PATENT OFFICE

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VAPOR-FROM-LIQUID SEPARATOR APPARATUS

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Application March 9, 1948, Serial No. 13,804

3 Claims. (Cl. 183—91)

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Our invention relates to equipment for securing dry steam from mixtures of steam and water as taken from the vaporizing tubes (or other surfaces) of steam generating boilers, and it has special reference to vapor-from-liquid separator devices that are installable in the steam and water drums of such boilers to accomplish the purpose named and that also are useful in other applications.

In modern boilers for both marine and stationary application the steam and water drum usually contains equipment for: (1) distributing incoming feed water; (2) separating steam from water; and (3) delivering steam with a minimum of entrainment of water or solids. The general term "drum internals" covers this class of equipment, which has assumed great importance as the rates of steam liberation have increased.

Broadly stated, the object of our invention is to improve the design, extend the usefulness and better the performance of the steam separator portions of such "drum internal" apparatus.

A more specific object is to increase the quantity of steam of acceptable dryness and purity which may be taken from a steam and water drum of given diameter and length, thereby permitting the size, cost and weight requirements of the drum to be reduced in a given steam-generating installation.

Another object is to enable the drum-contained steam separator units to deliver steam of acceptable dryness and purity even though the water level in the drum may rise substantially above the designed level (such as the drum's center line).

A further object is to overcome difficulties due to "foaming" which heretofore have reduced the attainable separator capacity when dissolved and suspended solids and other unavoidable impurities are present in the boiler water.

A still further object is to enable the drum-contained steam separator units to deliver steam of acceptable dryness and purity even though the solids content of the boiler water may be substantially greater than normally prevalent values and even though exceedingly sharp increases in such solids content (as due to large chemical dosage of the boiler water or to leaky surface condensers which contaminate the feed water) may occur.

An additional object is to assure effective steam separation in the drum and discharge of acceptably dry steam therefrom when the steam and water mixture from the generating tubes comes into the drum at velocities as high as 50 to 75

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feet per second (as compared with the conventional 15 to 25 foot per second rates customary in the past).

Other objects and advantages will become apparent from the following description of an illustrative embodiment of the invention when read in conjunction with the accompanying drawings wherein:

Figure 1 is a simplified schematic representation (in the nature of a vertical section) of a steam generating installation that has a steam and water drum equipped with the improved separator apparatus herein disclosed;

Figure 2 is a transverse section of the steam and water drum of Figure 1 enlarged to show how steam separator devices constructed in accordance with one embodiment of the invention may satisfactorily be installed therein;

Figure 3 is an enlarged top-plan-like representation of one of the new separator units as viewed from line **3—3** of each of Figures 2 and 4;

Figure 4 is a vertical section through the same separator unit as viewed from line **4—4** of Figure 3; and

Figure 5 is a simplified section (to reduced scale) on line **5—5** of Figure 2 showing thirteen of the separator units positioned in two rows within the drum along the length thereof.

The vapor-from-liquid separator devices of our invention are especially well adapted for use on forced circulation steam boilers and on natural circulation steam boilers with liberal circulating head; they may, moreover, advantageously be employed to obtain a high degree of steam and water separation in steam generators of a wide variety of types and capacities. Illustrative of these is the steam generator shown in Figure 1.

The steam generator of Figure 1

There steam and water mixtures are discharged at high velocity into the drum **10** from vaporizing tubes **12** arranged in multiple rows *a—b—c—d—e* (see Figure 2) along the lower right portion of the drum wall; each of these five rows extends lengthwise of the drum and contains a plurality of similar tubes; the tubes in rows *c—d* are fed from a primary vaporizing circuit **14** constituting the side walls, floor and roof of the combustion chamber fired by the furnace's fuel burners **15**; the tubes in rows *a—b* are fed from a secondary vaporizing circuit **16** positioned at a somewhat higher elevation in the boiler furnace; and the tubes in row **12***e* are fed from a third circuit **18** which lines the combustion chamber wall (not shown) opposite the burners **15**.

The illustrative boiler furnace of Figure 1 is further provided with a forced circulation pump 20 (two such pumps may be used in parallel) for passing the water from drum 10's bottom discharge outlet 21 into a main distributing header 22 and thence through the three vaporizing circuits 14, 16 and 18 earlier named; with a superheater 24 in the heating chamber through which saturated steam leaves drum 10 by way of top outlet 25 to have its temperature further raised before entering superheated steam header 26; and with an inlet water connection 28 through which boiler feed water is admitted into the drum in a manner later to be described. To lay the basis for subsequent description it will be assumed that this steam generator of Figure 1 is designed to operate at pressures of 1200 pounds per square inch and higher; also that its three vaporizing circuits 14, 16 and 18 are jointly capable of generating steam and passing same through tubes 12 into steam and water drum 10 at rates up to 240,000 pounds per hour.

The steam and water drum 10

In the illustrative steam generator of Figure 1 the steam and water drum 10 has an internal diameter of 42 inches and a length (see Figure 5) of 10½ feet between drum ends; the steam outlet therefrom takes the form of a single pipe 25 leading out of the drum top midway of the drum length; the water outlet 21 from the drum bottom takes the form of two downcomer pipes (see Figures 1 and 5) respectively leading out of the two drum ends and acting in parallel to carry the drum leaving water into pumps 20 for circulation through header 22 and boiler vaporizing circuits 14, 16 and 18; the vaporizing circuit tubes 12 of drum entering rows *a—b—c—d—e* have the customary small inside diameter (such as one inch); the end man hole opening 30 into the drum has a horizontal dimension of 16 inches and a vertical dimension of 12 inches; and feed water under suitable pressure is admitted by way of connection 28 (see Figure 1) through an inlet pipe that enters the drum by way of a suitable opening (as in the drum rear but not shown).

As the description hereof proceeds it will become apparent that steam and water drums of dimensions, proportions and organizations differing from those just described may also be benefitted by the steam separator improvements of our invention.

The drum internals of Figure 2

As illustratively represented in Figure 2 drum 10 has installed therewithin: (1) feed water distributor means which include submerged pipe 32 perforated as at 33 and supplemented by water baffle 34; (2) steam-from-water separator means which take the form of centrifugal units 38 projecting upwardly out of the water in two lengthwise rows along drum interior (see Figure 5) and organized to act on all steam and water mixture that enters the drum by way of generator tubes 12; and (3) dry pipe means 40 for distributing and further drying the steam on its way from separator units 38 to outlet pipe 25 in the drum top.

The feed water admission means here shown utilize connection 28 (see Figure 1) from which the incoming feed water is conveyed by pipe 28*a* (see Figure 2) into the midpoint (not shown) of the distributor pipe 32 which extends lengthwise through the drum's lower portion as indicated. This distributor pipe 32 is closed at both ends and provided along its top with the spaced openings 33 through which all the incoming feed water must pass in a way assuring diffusion (aided by baffle plate 34 positioned above admission openings 33 along the pipe length) into the main body of drum water submerging the pipe.

For screening any large particles of solid matter out of the water which leaves the drum by way of the two downcomer outlets 21, each of those outlets has positioned around its open top a cylindrical screen 35 organized as shown in Figure 2 to require all outlet-entering water (feed from pipe 33 plus discharge from separators 38) first to pass through the screen. Other equivalent means for diffusing the incoming feed water through the lower body of drum-contained water and for taking the feed and discharge water out of the drum are of course useable with our improved separator units 38.

The dry pipe means 40 here shown are the same as those disclosed and claimed in U. S. Patent No. 2,594,490, issued April 29, 1952, to W. S. Patterson. They comprise a V-shaped plate 41 positioned beneath offtake 25 and extending in either direction therefrom for substantially the entire length of the drum but with the two plate edges spaced from the drum top as indicated at 42; a pair of baffle strips 43 welded along the drum top interior as shown and further functioning as supports for V-plate 41; plate holding spacers 44 provided at intervals along the drum length to secure (as through cap screw connections) V-plate 41 (and taper strips 46) to support strips 43; a horizontal screen 45 spanning a portion of the V-plate bottom; and taper strips 46 adjustably fixed to the sides of V-plate 41 and shaped to give each side steam-admission space 42 a minimum dimension at the location of steam outlet 25 and a progressively widening dimension as the outlet location is departed from lengthwise of the drum.

The V-plate portion beneath screen 45 preferably has one or more drain holes (not here shown) passed downwardly therefrom through the plate material so that such water as may accumulate in the V-plate 41 may be drained to a point of lower pressure. Other forms and arrangements of dry pipe apparatus are of course usable with the improved separator units 38 now to be disclosed.

The new separator units 38

Single drum boilers (as typified by Figure 1) require very efficient and compact means to meet current demands for high capacity and steam purity. In such boilers steam and water mixture entering the drum 10 from tubes 12 may consist of two to fifteen or more parts of water for each part of steam by weight, but the steam delivered from the drum through outlet 25 preferably should contain less than one quarter of one percent moisture. Moreover, this low moisture content in the delivered steam must be maintained notwithstanding that the boiler water from which steam is generated (and which enters drum 10 through tubes 12 along with the steam) contains substantial quantities of dissolved and suspended solids and other impurities which cannot be avoided.

To provide steam of such dryness the units 38 of Figures 2 through 5 have upwardly passed therethrough from a compartment 48 all of the steam and water mixture that is delivered into the drum 10 by tubes 12; that compartment 48 is enclosed by partition walls 49 which are organized as shown around the ends of tubes 12 and which extend along the entire tube-entering length of the drum to divide the enclosed compartment space from the remainder of the drum interior; and seven separator units 38 constituting a right row are mounted along horizontal compartment wall 49a while six other similar units 38 constituting a left row are supported in similar upright position through supply pipes 50 which connect into vertical compartment wall 49b.

It will be evident that either a lesser or greater number of units 38 are useable depending upon drum size and quantity of steam to be separated and that arrangement in less or more than two rows is possible; in fact, only a single unit may be found adequate in certain situations. Also the arrangement of the compartment 48 may differ from that here represented.

As here illustratively shown by Figures 2–3–4 each of the units 38 comprises an inner upright primary tube 52 connected at its bottom with compartment 48 and having substantially straight side walls which terminate in an open top; spinner blades 54 mounted in the lower portion of the tube 52 intermediate it and a central core piece 55; an outer upright skirt tube 56 of larger diameter than the first surrounding primary tube 52 in the spaced concentric relation shown and deriving mechanical support therefrom as through studs 57 spaced around the tube circumference; a disc-like baffle 58 secured to the top of outer tube 56 as by the aid of clamp studs 59 and spanning the annular space between inner and outer tubes 52 and 56; a steam-collector nozzle or sleeve 60 supported (as by integral attachment) from baffle 58 above the top of inner upright tube 52 in concentric relation thereto and with the sleeve bottom spacedly projected into the tube top as shown; an upper compartment communicating with the top of nozzle 60 and defined by lower plate 62, upper plates 63 centrally joined with a straightening vane 64 (see Figure 4), and side plates 65 and 66 (see Figure 3) which close the compartment except for the left and right outlet openings indicated by the Figure 4 arrows; and a stack of corrugated scrubber plates 68 positioned in each of these two outlet openings and there supported in any suitable manner as by the aid of through bolts 69 and plate-from-plate spacers 70.

The illustrative unit shown employs four spinner blades 54 each inclined from the horizontal at an angle of the general order shown with weld connections to the inner wall of primary tube 52 and interfittings into the represented slots in central core piece 55. Obviously either a greater or lesser number of these blades may be used and each may be tilted either more or less than indicated. The named core piece 55 may satisfactorily be provided with drain and vent openings 71 and 72 in the bottom and top thereof. In the represented design the steam collector sleeve or nozzle 60 has a cross sectional area related to that of primary tube 52 in a manner later to be made evident.

Each of this unit's two scrubber plate assemblages 68 (left and right) includes a comparatively large number of corrugated plates 68; each plate is rectangular as shown and is spaced a short distance from adjacent plates in the scrubber stack; all of these plates in each stack are mounted with their corrugation ridges running substantially vertically (as indicated) so that water collecting on and between ridges can freely run down to the bottom plate edge for discharge out of the separator over the downturned lip of lower compartment plate 62; and the ridge-to-ridge spacing along the horizontal on each plate 68 side may be of the general order represented.

As the description proceeds it will become apparent that other equivalent mechanical constructions for unit 38 are possible and that the unit itself (or individual parts thereof) may be made either larger or smaller (or otherwise altered) depending upon available drum space and steam separating requirements.

Operation of new separator unit

During normal operation of the steam generator of Figure 1 the water level in drum 10 stays close to the drum's center line as indicated at 74 in Figure 2; and under such conditions the top edges of upright tubes 52 and 56 in each separator unit 38 are several inches above the drum water line while the scrubber plates 68 are even further above the water level. The steam and water mixture entering the separator units 38 from compartment 48 is preferably passed through a perforated plate 75 suitably positioned in that compartment (see Figure 2) to prevent impact of steam-water mixture from evaporator tubes 12a—b—c on the inlet connections to the separator units 38.

Steam and water mixture passing from compartment 48 upwardly through the inner primary tube 52 of each unit 38 is whirled by spinner blades 54 (either clockwise or counterclockwise) so that upon reaching the tube top the mixture rapidly swirls around the tube interior. The heavier (water) portions of the mixture thus follow helical paths in advancing upwardly along the wall of the tube 52. In certain special installations it may be desirable to set spinner blades 54 to swirl the mixture clockwise in some of the units 38 and to produce a counterclockwise swirl in other of the separator units within the same drum.

The water content of the mixture has a density from as low as four to as high as one hundred times as great as the steam content, depending upon the mixture pressure; hence the heavier water thus acted upon by centrifugal force due to the whirling is concentrated near the wall of upright tube 52 while the lighter steam is concentrated toward the tube center. Reduced diameter sleeve 60 (projecting down into the top of primary tube 52) conducts this central concentration of steam directly up through the sleeve and at the same time allows the outer concentration of whirling water to pass outside of the sleeve as indicated by the arrows. Baffle 58 thereupon deflects this discharge water downwardly into the space between inner and outer tubes 52 and 56, through which space the water falls (and is forced by pressure from above) downwardly as indicated around the exterior of primary tube 52 and thence into the body of drum water (see level 74 of Figure 2) inside of outer skirt tube 56.

The separator discharge water from tube 56 is in this way effectively prevented from intermingling with the steam in the drum space above water level 74, the bottom of confined tube 56 being considerably below the drum water level as Figure 2 indicates. This confinement is particularly beneficial when the boiler water from which the steam is generated contains dissolved and suspended solids and other unavoidable impurities, the presence of which tends to produce "foaming" as later discussed.

Upon proper proportionment of the annular water discharge space (see Figure 4) around the lower edge of steam collector nozzle 60 relative to the total area for whirling steam and water mixture inside the upright primary tube 52, a considerable portion of the total water will in this "first" stage of separation be skimmed off from the steam and discharged from the unit 38 downwardly through the space between inner and outer tubes 52 and 56; the central stream of thus partially dried steam (which still contains a certain quantity of entrained moisture) will thereupon continue upwardly through nozzle 60 for subjection to the "second" stage of separating action.

In the illustrative unit 38 of Figures 2-3-4 said "second" stage of separation occurs in the uppermost secondary drier compartment containing the left and right stacks of scrubber plates 68. In passing upwardly out of nozzle 60 into that compartment, as indicated by the arrows of Figure 4, the total flow of mixture divides at central straightening vane 64 into left and right outlet paths which respectively include the represented left and right stacks of corrugated plates 68. As here used, vane 64 translates the initial rotary flow of the steam into linear flow for entry into the scrubbers 68. Figure 3 shows that to pass between those narrowly separated plates 68 in each stack the mixture must successively change its direction in zig-zag fashion; and in consequence of this particles of entrained moisture encounter the vertically extending plate ridges and impinge thereon for downward drainage therefrom under the action of gravity.

By the time the steam has reached the outer edge of each scrubber plate stack substantially all of the entrained moisture is in this way removed therefrom. Gravity now carries said removed moisture downwardly through the plate valleys between ridges to the lower support member 62 at the base of each stack. From that point collected water is urged by the outflowing steam stream thereabove to the outer edge of member 62 (see Figure 4) from which downturned edge the water drips (again see arrows of Figure 4) downwardly into the main body of drum water therebeneath.

The steam finally emerging from the separator unit by way of secondary drier plates 68 thus has been successively subjected to a "first" stage of water separation at the top of upright tube 52, and thereafter to a "second" stage of moisture separation in the scrubber-plate assemblage 68 of the left and right separator outlets. Steam thus passed through and acted upon by each unit is found to have been relieved of moisture to a remarkably high degree.

Separator units 38 show superior effectiveness

The new separator units herein disclosed perform outstandingly well under conditions of practical steam generator operation. One test set up for verifying this performance made use of the earlier described steam generator of Figure 1 equipped with the 42 inch by 10½ foot drum of Figures 2 and 5 having positioned therein, according to the plan of Figure 5, thirteen of the separator units 38 of Figures 2-3-4 and being further provided with the dry-pipe apparatus 40 of Figure 2 plus the feed water and other parts shown.

The tests were made under a boiler pressure of 1250 P. S. I. The thirteen separator units 38 functioned so effectively that steam containing less than one quarter of one percent moisture could be taken from the single drum outlet 25 at the high rate of 240,000 pounds per hour with water level 74 substantially at the drum center line and with approximately four grains per gallon of dissolved solids in the boiler water. This called for delivery of over 18,400 pounds of dry steam per hour by each of the thirteen separator units 38. The limit of the stated steam flow rate was imposed not by the separator units 38 under test but instead by portions of the Figure 1 steam generating unit external to the steam and water drum 10.

Nor did the reported tests with the Figure 1 steam generator establish an upper limit when the boiler water was totally free of contaminating solids. It can, however, be expected (for reasons later to be made evident) that under such "pure" boiler water conditions the capacity of each separator unit 38 to deliver acceptably dry steam will be even higher than the above-stated value attainable with boiler water containing dissolved solids in small quantity (four grains per gallon).

The reported tests verified prior data showing that as the solids content in the boiler water is increased, the output of acceptably dry steam which can be taken from a steam and water drum (such as 10) becomes progressively less. But notwithstanding this tendency the steam delivery rates attainable with our new separator units continued far to surpass the best performance of all comparable steam separator devices known to the prior art.

Thus, with boiler water containing 88 grains per gallon dissolved solids (water alkalinity then over 0.38%) it was at the earlier stated pressure of 1250 P. S. I. possible to withdraw from drum 10 of the steam generator 193,000 pounds per hour of steam containing twenty-three hundredths of one percent moisture. Total circulation by pumps 20 then was 840,000 pounds of steam-water mixture per hour, and the water level 74 in drum 10 then was three inches above the drum center line. Such elevated level decreased the total steam space below top outlet 25 and thus imposed on the separator units 38 a more severe duty than had the level been at or below the drum center line. Even so, each of the units 38 delivered over 15,000 pounds of acceptable dry steam per hour; with lower drum levels (and hence more steam space above the water surface 74) still higher delivery rates could have been attained.

The concentration of dissolved solids in the boiler water was thereupon raised to 103 grains per gallon. At the earlier-stated pressure of 1250 P. S. I. and again with a total pump circulation of 840,000 pounds per hour there were then withdrawn from the drum 190,000 pounds per hour of steam containing thirteen hundredths of one percent moisture. Water level was one-quarter inch below the drum center line; however, the full separator unit capacity was not reached during this test so that an even higher delivery rate could (without carryover of steam into the drum's top outlet 25) undoubtedly have been attained.

Steam of the foregoing dryness as released into the drum 10 by our new separator units 38 contains such an exceedingly small quantity of entrained moisture that the dry-pipe apparatus 40 seldom is called upon to impart any further drying during passage of the steam out of the drum. In the described situation the dry pipe apparatus therefore functions principally as an aid to proper distribution of the steam flowing into the single outlet pipe **25** (see Figure 2) from the several separator units **38** positioned lengthwise of the drum (see Figure 5).

The reported tests still further confirmed that the pressure head required to operate our new separator units **38** is well within the mixture-circulating capacity of all forced-circulation boilers and also of natural-circulation boilers with liberal circulating head. Measurements during the above 1250 P. S. I. boiler operation with steam separation rate (by thirteen units) of 185,000 pounds per hour and mixture circulation of 820,000 pounds per hour showed a pressure drop of fifty inches of 70° F. water (approximately 1.8 P. S. I.: 27.76 inches equalling one P. S. I.) between the interior of compartment **48** (which feeds the separator units) and the steam space within drum **10** surrounding the separator unit discharge outlets.

The performance-test program which provided the foregoing data additionally established that the efficiency of our new separator units **38** is not adversely affected by operation: (*a*) at drum pressures below 1250 P. S. I. (runs were made at 930 P. S. I. and at 650 P. S. I.); or (*b*) in which the rate of steam-water mixture circulation (by pumps **20**) through vaporizing circuits **14—16—18** (terminating in drum tubes **12**) is increased above the rates earlier mentioned.

Moreover, with the unique separator organization of our invention it becomes possible to bring the steam-water mixture into the drum by way of tubes **12** at flow velocities substantially higher than have been permissible heretofore. Past practice has limited mixture-entry speeds (through tubes **12**) to from fifteen to twenty-five feet per second; with the new separator facilities here disclosed (see Figure 2 particularly) the steam-water mixture from generating tubes **12** may satisfactorily be brought into the drum at greatly increased velocities typified by flow speeds of from fifty to seventy-five feet per second. In the represented test boiler of Figure 1 such higher mixture-entry velocities accompanied total pump circulation rates having values as stated by the preceding paragraphs.

Salient features of new separator design

The boiler-water solids named in presenting the foregoing test data were typical of those customarily encountered in the practical operation of steam generating boilers. In the tests stated, such solids were predominantly soda ash and sodium chloride accompanied by lesser amounts of disodium phosphate and starch and suspended impurities such as calcium salts and iron oxide (the suspended and undissolved constituents adding about 10% to the "dissolved" contents earlier given). Their presence greatly increased the tendency for "foaming" to occur in the steam and water drum **10** with accompanying tendency for entrained moisture and associated solids to pass as "carry-over" from the drum steam space into outlet **25**.

Foaming, like the suds on a glass of good beer, is the building up of bubbles on the drum water surface **74** (see Figure 2) until they reach the steam outlet **25**. Foam develops when the water film around the steam bubble, as it is generated at the heating surface, becomes stabilized by dissolved and suspended solids in the water. In other words, the bubble skin becomes tough and does not break readily when the bubble emerges. If the rate at which foam is delivered to the drum exceeds that at which it is destroyed, froth eventually fills the drum. Main causes are quite generally recognized to be (*a*) high dissolved and suspended-solids content; (*b*) high alkalinity; and (*c*) presence of oil that saponifies with the alkalinity to form soap. Moreover, higher than normal water level in the drum **10** accentuates difficulties due to foaming because of the resultant reduction in steam space between the water surface and the steam offtake.

The new separator design herein disclosed functions with remarkable effectiveness in minimizing foaming and bubble formation at the surface of drum water **74**. The water separated out of the whirling mixture at the top of inner primary tube **52** is by the surrounded outer skirt tube **56** closely confined around the primary tube exterior. That confinement compels the named tube discharge water to enter the main body of drum water **74** within a narrowly confined area substantially inside of and above the lower end of outer skirt tube **56** (see Figure 2).

Accordingly, the bubbles which may be present in the downflowing stream of discharge water tend to be crushed upon contact with the body of drum water, notwithstanding that the bubble skin may be tough because of a high solids content in the boiler water. Moreover, the tendency for new bubbles to form upon impingement of the discharge water stream with the drum water body, is minimized by the pressure under which such impingement occurs and by the narrow confines of the annular space between inner and outer tubes **52** and **56**.

Our investigations (including intensive study and experiment conducted over a period of several years) have further shown that the complete separator unit **38** performs best when the steam collector sleeve **60** has a cross sectional area within the range of from approximately 80% to about 90% the cross sectional area of primary tube **52**. During development of our new unit it was noted that the separator efficiency progressively improved as the collector sleeve size was increased from 52% to 82% of the primary tube area; that the separator efficiency remained practically unchanged as the sleeve size was further increased from 82 to 90% of the tube area; and that sleeve size increases above 90% of the tube area caused the separator efficiency progressively to decrease, a sharp falling off being noted when the sleeve area was 95% of the tube area. These observations thus indicate the optimum area for collector sleeve **60** to be from about 82 to 90% of the area of primary tube **52** when the separator unit is constructed and operated as herein disclosed.

By our investigations we have still further established that the drying effect of secondary scrubber plates **68** on the outflowing steam passed therethrough (after leaving collector sleeve **60**) is markedly improved due to the preliminary treatment received by the steam within primary tube **52** containing spinner blades **54**. In addition to separating water from the incoming mixture the last named parts are found also to break up foam bubbles by physically scrubbing them against the primary tube wall (during the earlier-mentioned helical advancement therealong) and the core piece **55** as and after the mixture passes upwardly through the whirl-imparting blades **54**. Such preliminary break up reduces the foam content of the steam prior to entry into scrubber plates

68 and thereby enables those plates to accomplish final moisture removal far more effectively than otherwise would be the case. Still other factors not yet fully understood seem also to contribute to the named effect.

There accordingly exists between the primary separator parts and the secondary drier parts of the complete unit 38 a unique and wholly unexpected coaction which substantially adds to the separator unit's overall performance, as earlier-given test results so strikingly show. In consequence the effectiveness of our complete separator unit greatly exceeds the direct summation of the results attainable from the primary separator parts and from the secondary drier parts when same function individually and without the unique coaction just explained.

It will thus be seen that our new separator design has gone a long way toward overcoming the "foaming" difficulties which in the operation of prior art separators have so seriously limited the effective output capacity of the separator when the steam and water mixture passing therethrough has come from boiler water containing solids of the concentrations typically encountered in practice.

It would of course be possible to arrange all of the secondary drier plates 68 in a single stack and pass therethrough all of the steam from collector sleeve 60. Our experiments, however, have shown such "single-stack" organization to be less desirable than the "two-stack" arrangement here disclosed. Latter has the obvious advantage of greater compactness; moreover, the resultant "balanced" design gives more uniform distribution of discharge steam into the upper space of drum 10 as well as helping to reduce the total pressure drop through the complete unit and contributing to the primary-part coaction earlier named. In each installation all of these secondary driers 68 may be aligned to discharge crosswise of the drum as Figure 5 indicates; they may be reset (upon loosening clamp screws 59) to discharge lengthwise of the drum or in any other angular direction desired; or some may be set for one discharge direction and some for another.

Other advantages of the new steam separator design herein disclosed include simplicity, low cost, ease of assemblage and ready installation. All separator parts lend themselves to easy manufacture and their combined cost is comparatively small. The lower or "primary" assemblage including upright tubes 52 and 56 plus spinner blades 54 and core 55 can be completely put together outside of the drum 10; as can also the upper or "secondary" assemblage including scrubber plate stacks 68, horizontal baffle 58 nd nozzle 60.

The lower tube assemblage 52—56, when detached from the upper assemblage 60—68 (through a loosening of clamp studs 59), can then be brought through the standard 12 x 16 inch man hole opening 30 and connected with compartment 48 (see Figure 2) through the medium of screw threads 78 (see Figure 4) on the lower end of upright tube 52's reduced diameter portion 52a. Thereafter, the upper assemblage 60—68 may be brought into the drum through man hole 30, placed on the top of upright tube 56 (see Figure 4), and there secured through a tightening of clamp studs 59. Such installation requires comparatively little time; all thirteen of the units 38 having been installed in drum 10 (see Figure 5) by one man in only three hours.

Summary

From the foregoing it will be seen that we have improved the design, extended the usefulness and bettered the performance of vapor-from-liquid separator apparatus for steam generator and other comparable use; that we have increased the quantity of steam of acceptable dryness and purity which may be taken from a steam and water drum of given diameter and length (thereby enabling the size, cost and weight requirements of the drum to be reduced in a given steam-generating installation); that we have enabled the drum-contained steam separator units to deliver steam of acceptable dryness and purity even though the water level in the drum may rise substantially above the designed level (such as the drum's center line); that we have overcome difficulties due to "foaming" which heretofore have reduced the attainable separator capacity when dissolved and suspended solids and other unavoidable impurities are present in the boiler water; that we have enabled the drum-contained steam separator units to deliver steam of acceptable dryness and purity even though the solids content of the boiler water may be substantially greater than normally prevalent values and even though exceedingly sharp increases in such solids content (as due to large chemical dosage of the boiler water or to leaky surface condensers which contaminate the feed water) may occur; and that we have assured effective steam separation in the drum and discharge of acceptably dry steam therefrom when the steam and water mixture from the generating tubes comes into the drum at velocities as high as 50 to 75 feet per second (as compared with the conventional 15 to 25 foot per second rates customary in the past).

The here disclosed employment of our new vapor-from-liquid separator apparatus to accomplish separation of steam from water obviously is illustrative rather than restrictive since devices constructed in accordance with our invention may with comparable advantage also be employed to separate some other vapor from some other liquid.

Hence, even though an illustrative embodiment of the invention has been disclosed and described, it is to be understood that the invention is not to be limited to practices, form or arrangement shown but contemplates other alternatives and mechanical equivalents of the apparatus herein illustrated and falling within the scope of the appended claims.

What we claim is:

1. In a steam separator, an upright primary tube through which steam and water mixture is upwardly passed, means in said primary tube for imparting to said upflowing mixture a whirling motion which throws water therefrom outwardly against the tube wall for discharge over the tube's top edge and which allows moist steam separated from the water to continue upwardly out of the tube's central portion, an upright steam collector sleeve of smaller diameter than said primary tube positioned thereabove to carry said moist steam upwardly from the tube's central portion, an enclosure in communication with the top of said collector sleeve for receiving the steam mixture issuing therefrom and for directing same out of the separator in two opposed paths of substantially horizontal flow, a steam-flow straightening vane extending downwardly from the enclosure top intermediate said opposed paths and across the collector sleeve at its approximate center, a stack of spaced corrugated plates dis-

posed in each of said two opposed flow paths with the plate ridges substantially vertical whereby collector sleeve discharge steam in passing from said enclosure through each stack is by the plates therein subjected to a scrubbing action which transfers from the steam to the vertical plate ridges still further moisture that forms into water drops which run down the ridges, and baffle means extending outwardly from said sleeve beneath the lower edges of the corrugated plates in each of said two stacks to receive said down-running water and cause same to be carried out of each plate stack at the steam-exit side thereof by the separator discharge steam flowing away from the sleeve above the water between the plates.

2. In a vapor-from-liquid separator, an upright primary tube through which vapor and liquid mixture is upwardly passed, means in said primary tube for imparting to said upflowing mixture a whirling motion which throws liquid therefrom outwardly against the tube wall for discharge over the tube's top edge and which allows vapor from the mixture to continue upwardly out of the tube's central portion, an upright vapor collector sleeve of smaller diameter than said primary tube positioned thereabove to carry said vapor upwardly from the tube's central portion, an enclosure in communication with the top of said collector sleeve for receiving the vapor mixture issuing therefrom and for directing same out of the separator in two opposed paths of substantially horizontal flow, a vapor-flow straightening vane extending downwardly from the enclosure top intermediate said opposed paths and across the collector sleeve at its approximate center, a stack of spaced corrugated plates disposed in each of said two opposed flow paths with the plate ridges substantially vertical whereby collector sleeve discharge vapor in passing from said enclosure through each stack is by the plates therein subjetced to a scrubbing action which transfers from the vapor to the vertical plate ridges still further liquid that forms into drops which run down the ridges, and baffle means extending outwardly from said sleeve beneath the lower edges of the corrugated plates in each of said two stacks to receive said down-running liquid and cause same to be carried out of each plate stack at the vapor-exit side thereof by the separator discharge vapor flowing away from the sleeve above the liquid between the plates.

3. In a steam separator, an upright primary tube through which steam and water mixture is upwardly passed, means in said primary tube for

imparting to said upflowing mixture a whirling motion which throws water therefrom outwardly against the tube wall for discharge over the tube's top edge and which allows moist steam separated from the water to continue upwardly out of the tube's central portion, an upright steam collector sleeve of smaller diameter than said primary tube positioned thereabove to carry said moist steam upwardly from the tube's central portion, an outlet passage in communication with the top of said collector sleeve for receiving the steam mixture issuing therefrom and for directing same out of the separator in a flow path which extends radially with respect to said collector sleeve's vertical axis and which is substantially horizontal, a steam-flow straightening vane extending downwardly from the top of the outlet passage and in the vicinity of the collector sleeve's approximate center, spaced corrugated plates disposed in said radially directed flow path with the plate ridges substantially vertical whereby collector sleeve discharge steam in passing from said outlet passage between said corrugated plates is therein subjected to a scrubbing action which transfers from the steam to the vertical plate ridges still further moisture that forms into water drops which run down the ridges, and baffle means extending outwardly from said sleeve beneath the lower edges of the corrugated plates to receive said down-running water and cause same to be carried out from between said plates at the steam-exit side thereof by the separator discharge steam flowing away from the sleeve above the water between the plates.

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