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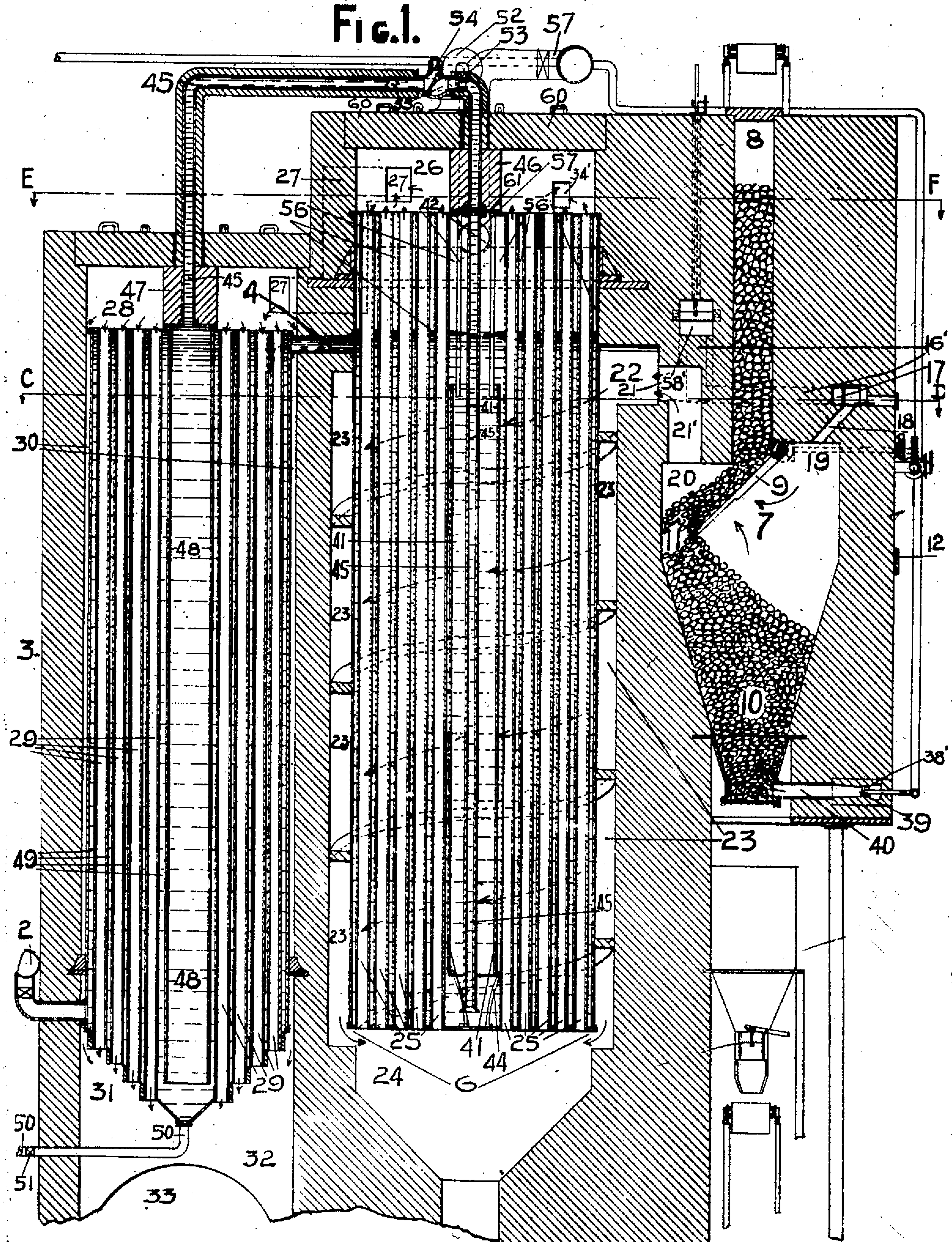
H. L. DOHERTY.
METHOD OF GENERATING STEAM.
APPLICATION FILED NOV. 15, 1911.

1,154,910. Patented Sept. 28, 1915.

4 SHEETS—SHEET 1.

FIG. 1.



Witnesses:
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H. A. Mackenzie

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4 SHEETS—SHEET 2.

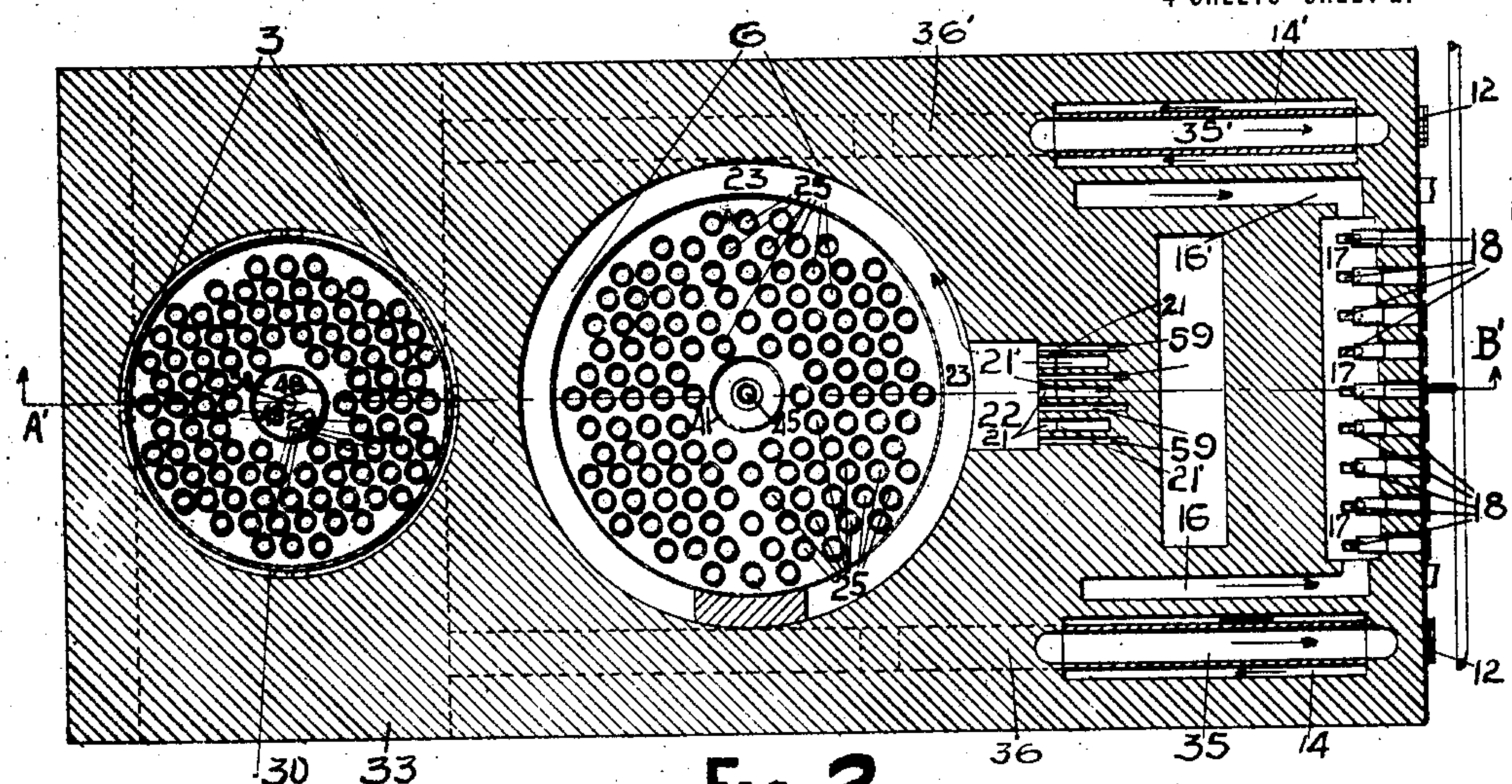

FIG. 2.

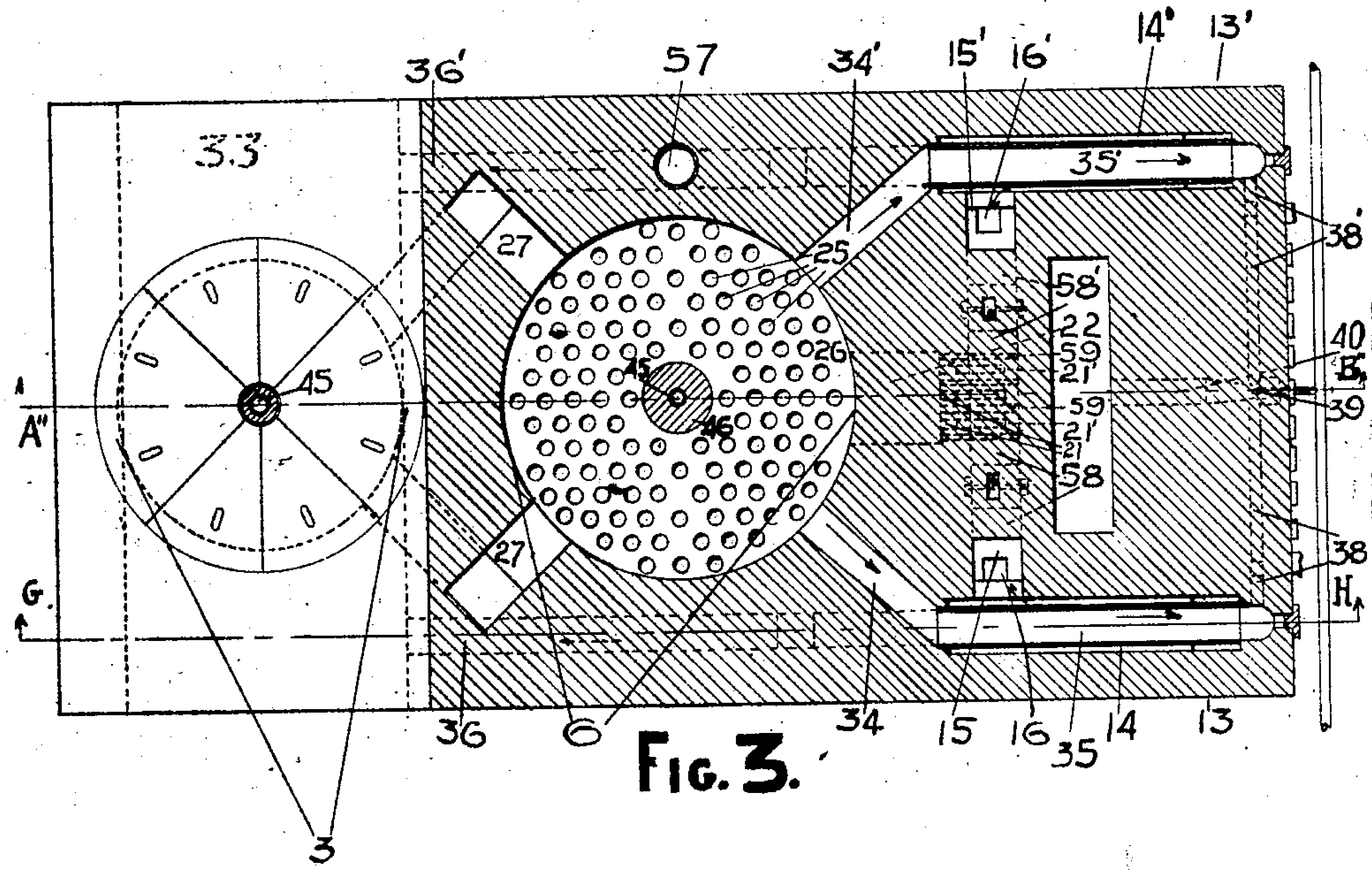

FIG. 3.

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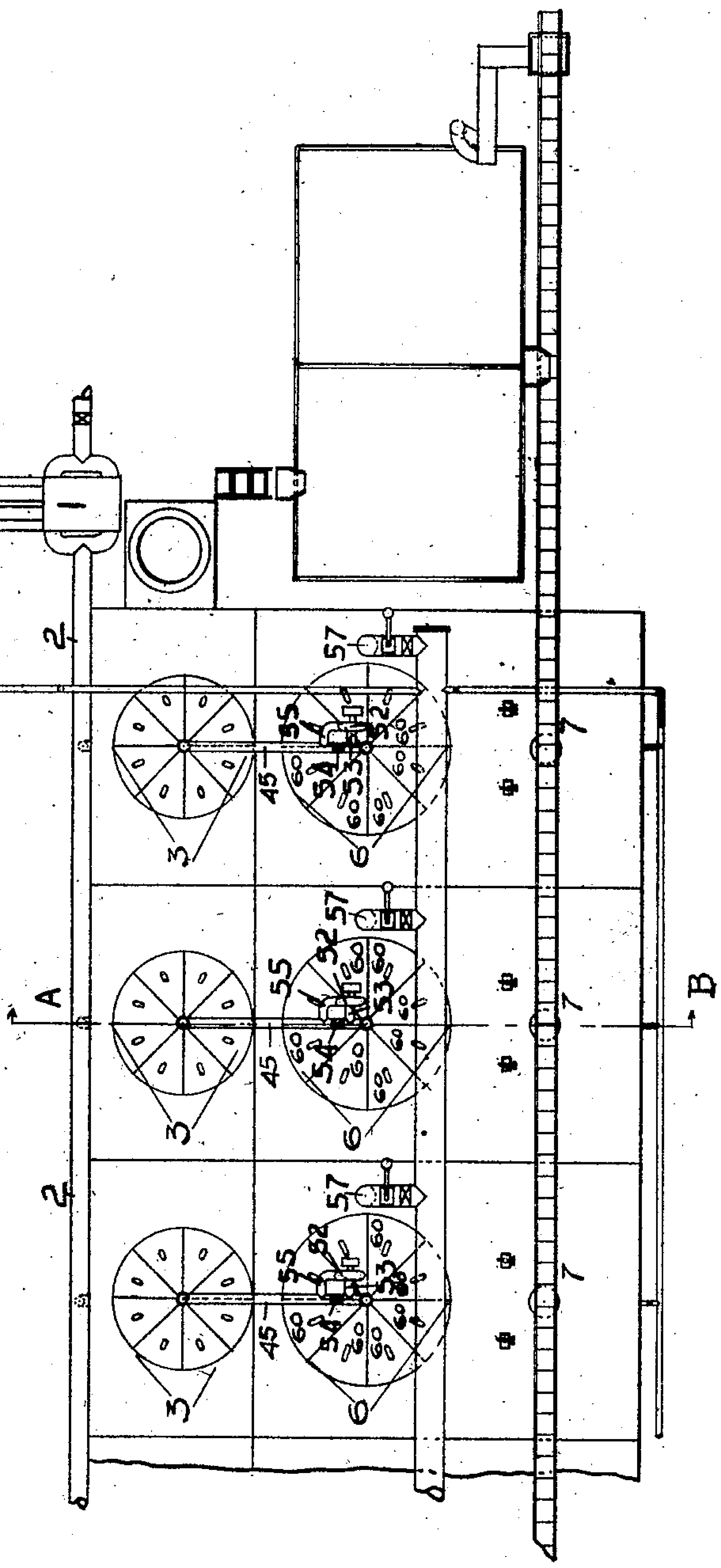
4 SHEETS—SHEET 3.

FIG. 4.



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4 SHEETS—SHEET 4.

FIG. 5.

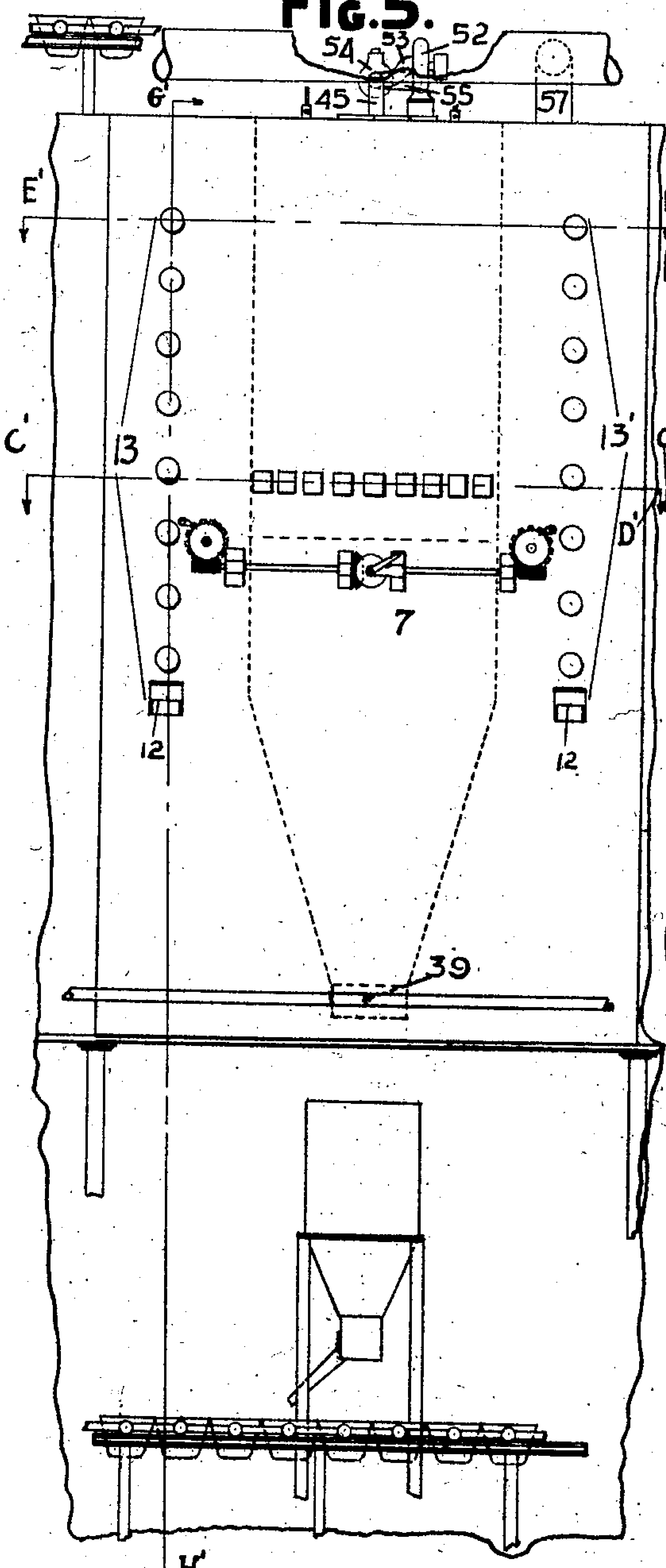
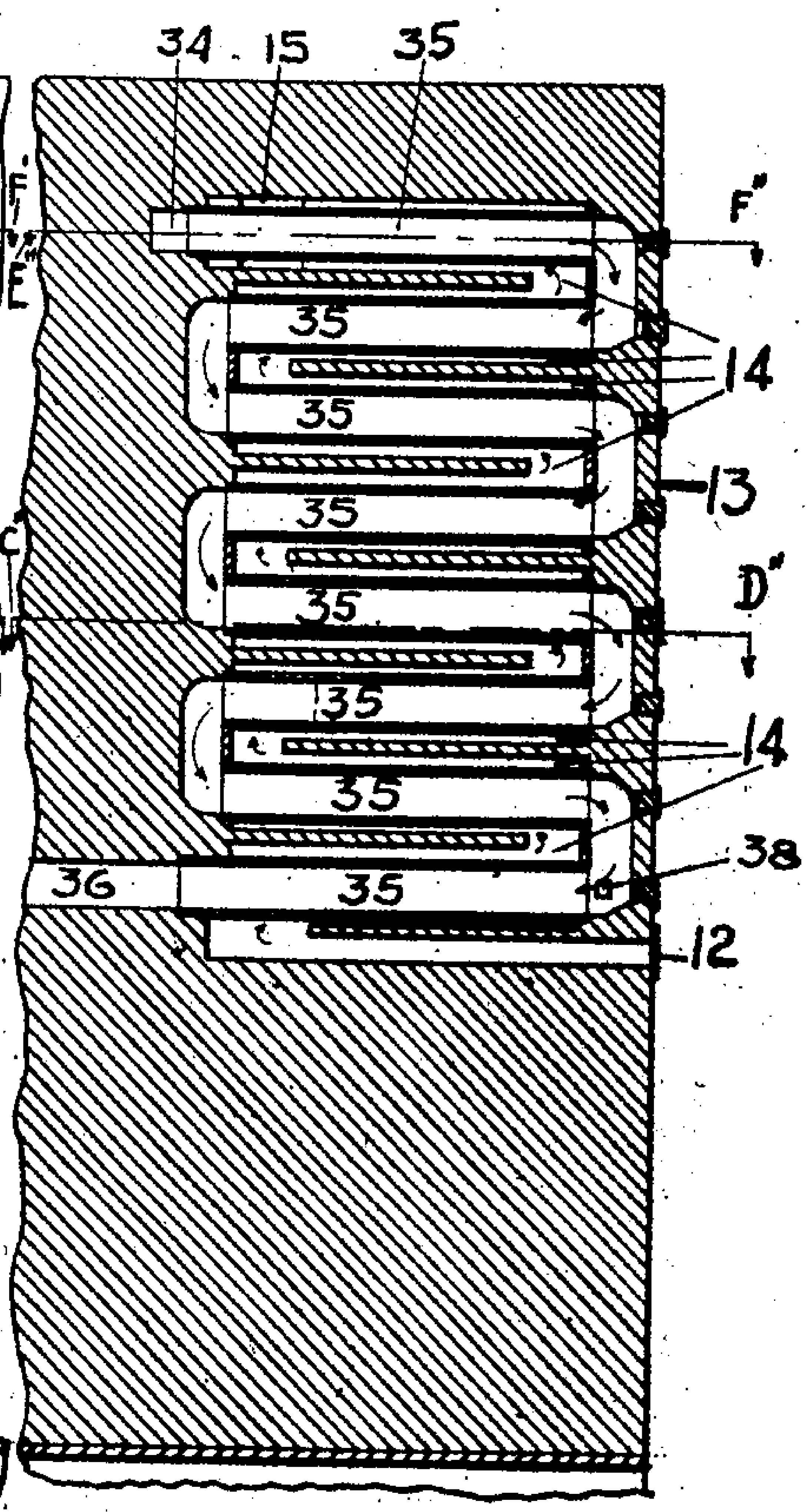


FIG. 6



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UNITED STATES PATENT OFFICE.

HENRY L. DOHERTY, OF NEW YORK, N. Y.

METHOD OF GENERATING STEAM.

1,154,910. Specification of Letters Patent. Patented Sept. 28, 1915.

Application filed November 15, 1911. Serial No. 660,452.

To all whom it may concern:

Be it known that I, Henry L. Doherty, a citizen of the United States, and a resident of New York city, in the county of New York and State of New York, have invented certain new and useful Improvements in Methods of Generating Steam, of which the following is a specification.

My invention relates to a method of generating steam.

The objects of my invention are to furnish an improved method of steam generation by which I am able to greatly increase the rate of steam generation per unit of heating surface, to maintain uniform conditions in the steam generating vessel, to purify the feed water, and to secure the maximum possible utilization of the hot gases.

To this end my invention, briefly stated, comprises the heating of the feed water to the temperature at which it will deposit its scaling salts, the preheating of the air supplied for combustion, the balancing of the distribution of the heating gases between the several parts of the apparatus according to a definite and specific plan, whereby I am able to secure the practical maximum utilization of the heat of the gases and the practical maximum rate of generation of steam per unit of heating surface, the maintenance of a uniform condition of the water in the boiler in regard to dissolved and suspended salts, by a system of continuous feed to and withdrawal of water from the boiler to the recuperator, the recuperation of the heat of the blow-off water, as well as various other features which will be described in detail below.

In the drawings, Figure 1 is a vertical cross-section through the apparatus on lines A—B of Fig. 4, A′—B′ of Fig. 2 and A″—B″ of Fig. 3. Fig. 2 is a horizontal cross-section on the lines C—D of Fig. 1, C′—D′ of Fig. 5 and C″—D″ of Fig. 6. Fig. 3 is a horizontal cross-section on the lines E—F of Fig. 1, E′—F′ of Fig. 5 and E″—F″ of Fig. 6. Fig. 4 is a diagrammatic plan of the apparatus. Fig. 5 is a front elevation of the lower part of the furnace. Fig. 6 is a vertical part section through one of the recuperators on the lines G—H of Fig. 3 and G′—H′ of Fig. 5.

The method of operating the apparatus shown to carry out my process is as follows: In starting operations water is supplied by the feed pump 1, through the pipe 2, to the intertubular space of water purifier 3. When this vessel has been completely filled the water flows through the pipe 4 into the steam generating vessel 6. When the water level in the vessel 6 has risen to the proper point the fires are started in the furnace 7.

In the type of furnace illustrated in the drawings, either direct or producer firing may be used. As shown in Fig. 1 the furnace is arranged to be used with direct firing. In this case coarse cinder—or, if preferred, simply fuel—is fed to the feed chute 8, falls through 8 to the grate 9, thence into the lower part, 10, of the furnace chamber. The fuel supplied to 10 banks up, as shown, until it has reached the space 11 between the end of the grate 9 and the wall of the furnace. Kindling is now charged onto the grate 9 and ignited. More fuel is now charged through the chute 8 and a bed of ignited fuel gradually built up on the grate 9. As the fuel is supplied to 9, it banks over the same on its natural angle of repose until it has reached the bottom of the feed chute 8. The chute is now rapidly filled with coal and the furnace is in condition for normal operation.

Air for supporting combustion enters through the air damper 12 of the recuperators 13 and 13′, passes through the air flues 14 and 14′ of the recuperators, discharges from the upper air flues of the recuperators into the main down-cast air passages 15 and 15′. Discharging from the flues 15 and 15′ the air currents each split up into two streams, one stream in each case flowing through flues respectively designated 16 and 16′ to the main primary air flue 17. From 17 the air flows through the nostrils or ports 18 into the inlet space 19 of furnace 7. Passing through the interstices of the grate 9 the air supports the combustion of the fuel thereon and the combustion gases discharge from the space 20 over the fuel bed into the combustion gas flue 21′, thence flow through the chamber 22 into the helical passage 23 around the shell of the steam generating vessel 6. Emerging from 23 into the space 24 the gases pass into the lower ends of the fire tubes 25 of the steam generator 6. Flowing up through the tubes 25 the gases emerge into the space 26, and here divide. One stream passes through the flues 27 into the space 28 above the upper tube sheet of the heater 3, thence flows through the tubes 29 and through the flue 30 surrounding the shell of the heater 3, giving up its heat to the water in the intertubular space of 3. Emerging into the space 31 below the tubes 29 the gases pass through the flue 32 into the main stack flues 33. The other subdivision of the flue gases passes through the two flues 34 and 34′, respectively, to the recuperators 13 and 13′, respectively, thence flows through the combustion gas flues 35 and 35′, respectively, of the two recuperators and discharges from the lowermost flue 35 into the waste gas flues 36 and 36′, which discharge into the flue 37 connected with the stack.

In the operation of the furnace 7 I prefer to work according to the process which is the subject of my application for Letters Patent Ser. No. 660,453, filed Nov. 15, 1911, in which I pass the fuel through at a rate much greater than its rate of combustion, recuperating the heat of the unconsumed fuel, screening the mixture of fuel and ash withdrawn from 10 and returning the overscreen portion in admixture with fresh fuel to the feed chute 8. For the purpose of cooling the fuel in 10, in this particular case, I use a portion of the relatively cool products of combustion discharging from the flues 35 and 35′ of the recuperators by drawing them off from the lowermost flues 35 and 35′ through the cross-flue 38 and 38′ respectively and force them under the action of the injector 39 through the flue 40 into the lower part of the fuel cooler 10 of furnace 7. Passing up through the mixture of fuel and ash occupying cooler 10, this stream of combustion gases joins the main draft current of the furnace and passes out again through the flues 21 and 22 into the gas flues of the steam generator. The purpose of thus circulating the fuel through the furnace at a rate faster than the rate of combustion is to maintain the fuel bed on the grate 9, or in the chamber below the grate when the apparatus is used as a gas producer, in a free and open condition easily permeable by the draft current of the furnace. When using bituminous fuels in the furnace it is a well known fact that it is impossible under ordinary conditions of firing to avoid the formation of clinkers and large masses of pasty fuel due to the softening action of the heat upon the fuel itself and the fluxing action of the ash at high temperatures. By returning the coked coal to the furnace in sufficient proportion I prevent almost entirely the formation of these fuel aggregates and ash clinkers owing to the fact that the coke is not affected by the heat and thus separates the softened fragments of coal and ash by inert material so that the former are prevented from forming aggregates which would block the draft of the furnace. Since I cool the surplus fuel charge before withdrawing the same from the furnace, and also utilize the heat of the gases which have been used in cooling the mixture of fuel and ash, I do not introduce any loss in heat economy by this method of operation.

When the water in the steam generator 6 has been heated to the boiling point at the pressure under which it is designed to work the boiler the system is ready to be put under normal operating conditions. As the water is evaporated from 6 sufficient water is pumped into 3 to maintain the level in 6 at a constant point. The heated water flows from the intertubular space of 3 through the connecting passage 4 into the intertubular space of steam generator 6. The circulation of the water in 6 is upward around the tubes 25 and in contact with the shell of the boiler and downward through the large central circulation pipe 41. This is a large open-ended pipe which is suspended in the tube-free axial portion of 6 by the hangers 42, and is held in position at its lower end by the pieces 44. By using the pipe 41 to separate the downward-flowing water from the upward-flowing water and steam around the tubes, I prevent local eddies which would carry steam into the downward-flowing water and thus tend to impede the circulation as well as retard the evolution of steam from the water surface of the boiler.

As is indicated in the drawings, the water level in the steam generator 6 is maintained at a considerable distance below the upper tube sheet. The wet steam evolved from the water is thus forced to pass in contact with the upper portions of the flues 25. As I consider it advantageous to discharge the heating gases from the upper ends of these tubes 25 at about 1000° to 1200° F. or above, the walls of the tubes are at a temperature much above that of the steam generation. The steam passing through the open space 56 surrounding the tubes 25 is thus highly superheated before entering the steam off-take 57. By this device, I am able to take off thoroughly dry steam from the generator even when, as sometimes happens, there is considerable spray in the steam as it leaves the water in the generator.

The large free space in the axial portion of 6 permits of ready access to the interior when desired for the purpose of repairing or cleaning. It is only necessary (the fires being drawn and the boiler 6 being free from water) to disconnect the pipe 45, remove the tiles 60, lagging 46, and cover 61 and lift out the lower portion of the pipe 45 and the circulating pipe 41. A workman may then enter the large axial space of the boiler for cleaning the tubes or any other duty required.

Due to the temperature prevailing in 6 and the concentration of the water by evaporation, there is a constant separation of such of the scale-forming salts of the water as have not been separated in heater 3. It is true that by my method of operation the salts thus held by the water as they enter 6 are reduced to a practical minimum. There is, however, a certain residual proportion of salts which is held by the water until its density has been increased by evaporation. As the water is concentrated, therefore, this residual portion of the scale forming salts is separated from the water and either remains in suspension in the water or attaches itself to the heating surface as scale. In order to prevent the accumulation of this separated solid matter, and also to maintain the density of the water in the boiler at a uniform degree, I provide for a continual circulation of water from the generator 6 to the heater and purifier 3. I accomplish this circulation by introducing into the central portion of 6 a pipe, 45, which, as shown, passes through the circulating pipe 41 to near the bottom of the intertubular space of generator 6. The pipe 45 is carried to the heater 3 and enters the same at its central point. As shown, heavy lagging, numbered 46 and 47, respectively, surrounds the pipe 45 where it passes through the gas spaces 26 and 28 of the vessels 6 and 3, respectively.

In the central portion of the intertubular space of heater 3 a large pipe, 48, attached water-tight to the upper tube sheet of 3, is suspended. The pipe 41 enters the upper part of this pipe 48 and discharges into the same the water which it has carried over from the steam generator 6. The water withdrawn through 45 corresponds in composition, of course, to the water filling the generator 6. Owing to the fact, however, that I draw off this portion of the water from 6 near the lower tube sheet and at the lowest point of travel of the downward circulating stream in the boiler, it contains a somewhat larger proportion of the suspended matter of the boiler water than the water in the upper part of 6. As the water flows slowly downward through the pipe 48 it is gradually cooled by the oppositely flowing current of water occupying the intertubular space 49 of the heater 3 and has practically reached the temperature of the entering feed water by the time it emerges from the lower part of 48. Emerging from the bottom of 48 this concentrated and muddy boiler water separates into two streams. The main stream flows upward through the conical space at the bottom of 49 and joins the current of feed water entering from the pipe 2. The other and smaller current is permitted to discharge continuously through the blow-off pipe 50 in the quantity controlled by the valve 51. Since the suspended matter of the water discharging from 48 and the solid material separated from the entering feed water collects for the most part in the conical bottom of 49 it is continually blown off in the current of water discharging through the pipe 50. By properly regulating the volume of water which I draw from the steam generator 6 through the pipe 45 and return to the heater and purifier 3 I am able to prevent the concentration of the boiler water beyond the density which I have selected and also to prevent the accumulation of suspended matter in the boiler water.

The cold feed water entering the lower part of the intertubular space 49 of heater and purifier 3 is subjected to a gradual and uniform heating as it ascends around the tubes 29 by the relatively hotter gases which are flowing downward through the tubes 29. Since the volume of the hot gases passing through the heater and purifier 3 is so fixed that they will contain sufficient heat to heat the feed water up to the temperature at which it will deposit all except a small and unavoidable residue of the scale forming salts, I am able to prevent the introduction of this scale forming matter into the steam generating vessel 6.

The temperature to which it is necessary to heat the feed water in 3 to secure the maximum practical separation of the scale forming salts which the water carries, will vary more or less with different waters and also with the pressure under which the water in 3 is kept, which is, of course, the vapor pressure in the steam generating vessel 6. With the majority of waters, at a temperature of approximately 284° F. about 90% more or less of the calcium sulfate will be deposited provided the water is exposed to this temperature long enough. The separation takes place the more rapidly as the temperature increases however, so that I prefer to heat the feed water in 3 to about 315° F. before introducing it into 6. At this temperature, the separation of the calcium sulfate is fairly rapid so that it is not necessary to have an unduly great capacity for 3 in order to secure a sufficient time of exposure of the feed water to the maximum temperature to insure the proper separation of its sulfate.

The soluble forms of the carbonated scale-forming salts in the water are decomposed at temperatures very much below 284° and the resulting insoluble salts are separated from the water at a fairly rapid rate. Therefore in regulating the operation of 3 it is only necessary to adjust the temperature conditions with special reference to the sulfate, the separation of the carbonates being practically assured under any conditions which will secure the separation of the sulfate.

The feature of the method of heat transfer is that I use a downward flow for the heating fluid and an upward flow for the fluid to be heated. By these features I, to a large extent, prevent the formation of convection currents and am thus able to maintain the maximum possible temperature difference at all levels in the apparatus between the heating and the heated fluid and discharge the hot gases to the stack at a temperature but little above the temperature of the feed water at its place of entrance into the heater and purifier 3.

The water is heated in two stages. The combustion gases from the furnace heat the column of water in the second stage at a temperature sufficient to generate steam and maintain the upper portion relatively hotter than the lower portion. The gases which flow from the second stage after they have generated steam therein flow to the first stage to heat the water. They first contact with the upper portion of the column of water in the first stage substantially at the same point where the hot water is fed to the second stage. The gases then flow downwardly, gradually cooling, and thence to exit. The result is that relatively hot and cooler zones are also maintained in the first stage. The impurities which settle out in the first stage are eliminated at substantially the coolest point. The water which is returned from the second stage is siphoned from the relatively cool zone thereof to the point of removal of impurities or the cooler zone of the first stage.

The water circulating apparatus comprises the pipes 45 and 48, forming in effect a siphon. Under normal operating conditions the circulation of the water from 6 back to 3 is automatically established by the fact that I have in that leg of the siphon which is formed by pipe 48 and part of 45 a column of water which is of considerably greater density than the column occupying the other leg of the siphon in 6. Under this siphonic action there is established a rapid and uniform circulation of the concentrated and muddy boiler water back to and through the heater 3, as already described in full. If, for any reason, this siphonic action is not established (which under certain conditions of pressure may be the case) I artificially stimulate the circulation by operating the circulating pump 52. This circulating pump 52 is, as shown, located on a by-pass around the check valve 54. When the pump is operating, water is drawn up through the portion of the pipe 45 on the steam generator side of the valve 54 and forced by the pump, through its discharge pipe 55, into that part of the pipe 45 which is on the heater side of valve 54. The check valve 54, of course, prevents any backward circulation of the water through 45.

As before stated, and as illustrated in the drawings, I maintain the water level in the steam generator 6 at a point considerably below the upper tube sheet. The steam ascends through the space thus left in the upper part of the intertubular space 56 of the steam generator 6 in intimate contact with the surfaces of the fire tubes 25. Since the steam arising through this space has a high velocity there is no backward circulation of the steam into contact with the surface of the water in the intertubular space. I am thus able to secure a decided superheating of the steam before it is drawn off from the steam generator through the pipe 57.

When using indirect or producer firing in the furnace 7, the grate 9 is revolved downward through an angle of 90 degrees and thus permits the fuel to fill the chamber 10 until it has established a surface on its natural angle of repose in each of the chambers 19 and 20. The primary draft now enters as before through the nostrils 18, passes from the fuel surface in 19 laterally through the fuel column and emerges as producer gas from the fuel surface in space 20. Passing through the flue 21′ and nostrils 21 into the combustion chamber 22 of the generator 6 the gas is mingled with a current of air from the recuperators 13 and 13′, respectively, which is withdrawn from the main air current leaving the recuperators through the flues 58 and discharges through the nostrils 59 in contact with the gas in the combustion chamber 22. Combustion is thus established in immediate contact with the shell of the generator 6 and the combustion gases flow through the helical passage 23 and thence through the tubes 25, as already described.

In the operation of my steam generating apparatus I so regulate the heat distribution to the vessels 6 and 3 and recuperators 13 and 13′ that I so coördinate the working of the several parts of the apparatus as to secure practically the maximum efficiency of heating.

In ordinary boiler operation it has been the aim to cool the combustion gases to as low a temperature as possible before discharging them from the boiler. In some cases a further recuperation of the heat of these gases has been secured by passing them through a fuel economizer, so-called, to heat the feed water. This heating of the feed water, however, has been merely incidental and not combined as a functional part of the steam generating process in the manner which I reveal in this present application. On the contrary, I purposely withdraw the heating gases from the tubes of the steam generating vessel proper while they are still at a comparatively high temperature. I thus am able to secure in the steam generator a very high temperature differential between the water side and the fire side of the heating surfaces.

While in ordinary practice the flue gases may be discharged from the boiler at temperatures as low as 600 degrees, by my method of operation I aim to withdraw them not lower than 1200 degrees. I am thus able to secure an average temperature difference throughout the heating surfaces which is more than double that which would be secured in a boiler from which the heating gases are withdrawn at temperatures approximating 600 degrees. In order to secure this, it is, of course, necessary to pass the heating gases through the flues at a very much higher velocity than is used in ordinary boiler practice. This of itself greatly aids the efficiency of heat transmission, as it is well known that the velocity of flow of the fluids along the heat transmitting surface greatly affects the rate of heat transmission through the surface. From the combined effects of this high velocity and high heat differential which I maintain between the surfaces I am able to nearly treble the rate of steam generation per unit of heating surface, as compared with boilers operated by the ordinary methods.

As stated above, I am aware that it has been attempted before to recuperate a portion of the heat of the flue gases discharging from the steam generating portion of the boiler by passing them through a feed water heater to preheat the feed water. This, however, is simply an incidental and single feature of my method. What I claim as novel in the distribution of the heating gases by the method which I have revealed above, is the specific proportioning of the distribution of the flue gas between the several parts of my apparatus in such a way that the coordinate action of these several parts will secure the practical maximum in efficiency.

The apparatus which I herein show and describe I reserve the right to claim in another application.

It is to be understood that I do not limit my invention to use in the generation of steam only. It may, of course, be used in the concentration of liquids by evaporation. Only in this case the pipe 48 of 3 is carried down through the lower tube sheet and the concentrated liquid withdrawn from the system at this point without being returned to the vapor-generating chamber.

Having described my invention, what I claim is:

1. The process of generating steam which comprises forming hot combustion gases, heating water with such gases in two stages, passing the gases in heat interchanging relationship with water in each of said stages to form relatively hot and cool zones therein, maintaining the temperature of the gases in the first stage at a point where they will cause substantial settlement of contained impurities in such stage and preheat the water therein, conducting such preheated water to the hotter zone of the second stage, conducting water from the cooler zone of the second stage past the hotter zone of the first stage to the cooler zone thereof, collecting and discharging impurities which settle out in the second stage and conducting away the steam formed in the second stage.

2. The process of generating steam which comprises heating water with hot combustion gases in two successive stages, the gases being conducted in heat-interchanging relationship with such water in each such stage to form relatively hot and cool zones in such water, conducting steam away as formed from the hot zone of the second stage, conducting water from the cooler zone of the second stage to the cooler zone of the first stage, conducting water from the hotter zone of the first stage to the hotter water of the second stage and eliminating impurities of the water from the cooler zone of the first stage.

3. The process of generating steam which comprises forming hot combustion gases in a suitable furnace, maintaining separate columns of water whereby the gases may heat such water in two stages, passing the gases in heat interchanging relationship over the second column to form relatively hot and cool zones therein, then passing such gases in heat interchanging relationship over the first column to form relatively hot and cool zones therein, conducting the water from the hottest zone of the first column to the hottest zone of the second column, simultaneously conducting water from the coolest zone of the second column past the hottest zone of the first column to the coolest zone thereof, eliminating settled impurities from the coolest zone of said first column and collecting steam generated in the second column.

4. The process of treating water for raising steam which comprises generating hot combustion gases in a suitable furnace and heating water therewith in two separate stages, passing the gases to the second stage at a temperature sufficient to generate steam, dividing the gases after they have passed said second stage into two streams, conducting one such stream to the first stage at a temperature sufficient to cause settlement of impurities in the water thereof, and conducting the gases of the other stream to a point outside either heating stage, conducting the water from said first stage after it has been heated by said first stream of gases to the second stage, conducting water from the second stage to the first stage after it has been traversed by the gases direct from said furnace, and collecting the steam generated in said second stage.

5. In the generation of vapor from liquid containing dissolved salts by the heat of hot combustion gases, the process which

comprises, first, heating said liquid to a temperature of 284° F. or above, and, second, heating the so-treated liquid to evaporation, the said heating operations being carried out by forming hot combustion gases by burning fuel with preheated air, establishing heat-transferring relationship between the said hot combustion gases and liquid that has undergone the first heating operation, and accelerating the velocity of said combustion gases while the same are in heat-transferring relationship with said liquid during the said second heating operation so that the quantity of heat abstracted from said gases during said second heating operation will be restricted to that which will leave sufficient heat in said gases to preheat the air used in burning said fuel and to carry out said first heating operation, dividing the combustion gases from the said second heating operation into two streams, the volume of gases in the first of said streams being that required to supply to said first heating operation the quantity of heat required to heat said liquid to the desired temperature, establishing heat-transferring relationship between the first of said streams and said liquid and between the second of said streams and the air required to burn said fuel.

6. In the generation of vapor from liquid containing dissolved salts by the heat of hot combustion gases, the process which comprises, first, heating the said liquid to or above 284° F. to separate dissolved salts therefrom and withdrawing the separated salts from said liquid, and, second, heating the so-treated liquid to evaporation, the said first heating operation being carried out by establishing heat-transferring relationship between said liquid and the partially spent combustion gases from the said second heating operation, the said second heating operation being carried out by establishing heat-transferring relationship between the liquid from the first of said heating operations and the said hot combustion gases and so accelerating the velocity of said combustion gases while the same are in heat-transferring relationship with said liquid during the said second heating operation that sufficient residual heat will be left in said gases to supply sufficient heat for the first of said heating operations.

7. In the generation of vapor from liquid containing dissolved salts by the heat of hot combustion gases, the process which comprises, first, heating said liquid to 284° F. or above to separate dissolved salts therefrom and withdrawing the separated salts from said liquid, and, second, heating the so-treated liquid to evaporation, the said heating operations being carried out by forming hot combustion gases by burning fuel with preheated air, establishing heat-transferring relationship between the said hot combustion gases and liquid that has undergone the first heating operation, and accelerating the velocity of said combustion gases while the same are in heat-transferring relationship with said liquid during the said second heating operation so that the quantity of heat abstracted from said gases during said second heating operation will be restricted to that which will leave sufficient heat in said gases to preheat the air used in burning said fuel and to carry out the said first heating operation, dividing the combustion gases from the said second heating operation into two streams, the volume of the gases in the first of said streams being that required to supply to said first heating operation the quantity of heat necessary to heat said liquid to the desired temperature, establishing heat-transferring relationship between the first of said streams and said liquid and between the second of said streams and the air required to burn said fuel.

8. In the generation of vapor from liquid containing dissolved salts, the process which comprises, first heating said liquid to separate dissolved salts, second, heating liquid which has been treated by the first heating operation to evaporate a portion of the same, third, continuously returning unevaporated liquid from the said second heating operation to the liquid undergoing the said first heating operation, establishing counter-current heat-transferring relationship between the said returned liquid and the said liquid undergoing the said first heating operation, whereby the said returned liquid is cooled to substantially the temperature at which the said liquid enters the said first heating operation, blowing off a portion of the cooled returned liquid and mingling the remainder of said returned liquid with the liquid supplied to the said first heating operation.

9. In the generation of vapor from liquid containing dissolved salts, the process which comprises, first, subjecting the said liquid to a heating operation and, second, subjecting the heated liquid to an evaporating operation, maintaining a substantially uniform condition in the liquid undergoing said evaporating operation by continuously withdrawing from said liquid a regulated portion of the same and bringing the withdrawn liquid into counter-current heat-transferring relationship with the liquid undergoing said first heating operation, whereby the said returned liquid is cooled to substantially the temperature at which the said liquid is supplied to said first heating operation, the said liquid being withdrawn at a rate such that the concentration of the liquid undergoing the said evaporating operation will not exceed a predetermined degree,

ejecting from the circulation more or less of the cooled withdrawn liquid, and transferring from the said heating operation to the said evaporating operation a volume of the heated liquid equal to the liquid evaporated in and the liquid withdrawn from said evaporating operation.

10. In the generation of vapor from liquid containing dissolved salts, the process of maintaining a substantially uniform condition as regards suspended matter in the liquid undergoing evaporation, which comprises, subjecting the liquid to be evaporated, first, to a heating operation and, second, to an evaporating operation, continuously withdrawing from the liquid undergoing said evaporating operation a portion of the same which will contain a quantity of suspended matter substantially equal to the quantity precipitated in the said liquid during the period of the withdrawal of said portion, conducting the portion of liquid withdrawn from said evaporating operation to the liquid undergoing the said heating operation, separating suspended matter from said withdrawn liquid, mingling the withdrawn liquid after separation of said suspended matter with the liquid being supplied to the said heating operation, and transferring liquid from said heating operation to said evaporating operation at a rate equal to that at which the liquid undergoing said evaporating operation is diminished by evaporation and the withdrawal of a portion of the same.

11. In the generation of vapor from liquid containing scaling salts, the method of maintaining a substantially uniform condition in the liquid undergoing evaporation, which comprises, subjecting the liquid to be evaporated to heating to that temperature at which the major portion of its scaling salts will separate from said liquid, subjecting the liquid which has been partially purified by said heating operation to an evaporating operation, continuously withdrawing from the liquid undergoing the said evaporating operation a portion of the same that will contain a quantity of suspended matter substantially equal to the quantity precipitated in the said evaporating operation during the withdrawal of said portion of liquid, conducting the said portion of liquid to the liquid undergoing said heating operation, establishing heat-transferring relationship between the portion of liquid withdrawn from the said evaporating operation and the liquid undergoing said heating operation, whereby the said portion of liquid is cooled to substantially the temperature at which the said liquid is supplied to said heating operation, separating suspended matter from the said portion of withdrawn liquid, mingling the cooled and clarified withdrawn liquid with the liquid supplied to said heating operation, and transferring liquid from said heating operation to said evaporating operation at a rate equal to that at which the liquid undergoing said evaporating operation is diminished by evaporation and withdrawal.

12. In the generation of vapor from liquid containing scaling salts, the process of maintaining a substantially uniform condition in regard to concentration and suspended matter in the liquid undergoing evaporation, which comprises subjecting the liquid to be evaporated to heating to that temperature at which the major portion of its scaling salts will separate from said liquid, subjecting the liquid which has been partially purified by said heating operation to an evaporating operation, continuously withdrawing from the liquid undergoing the said evaporating operation a portion of the same such that it will contain a quantity of suspended matter substantially equal to the quantity separated in the said evaporating operation during the period of the withdrawal of said portion of liquid, conducting the said portion of liquid to the liquid undergoing said heating operation, establishing heat-transferring relationship between the portion of liquid withdrawn from the said evaporating operation and the liquid undergoing said heating operation, whereby the said portion of liquid is cooled to substantially the temperature at which the said liquid is supplied to said heating operation, concentrating suspended matter carried by said portion of liquid withdrawn from said evaporating operation in a minor part of said portion, ejecting the said minor part of the withdrawn liquid and said suspended matter from the circulation, mingling the remaining part of the cooled and clarified withdrawn liquid with the liquid supplied to said heating operation, and transferring liquid from said heating operation to said evaporating operation at a rate equal to that at which the liquid undergoing said evaporating operation is diminished by evaporation and withdrawal.

13. In the generation of vapor from liquid containing scaling salts, the process which comprises, subjecting the initially cold liquid to heating by establishing heat-transferring relationship between an upwardly flowing body of said liquid and a downwardly flowing body of heating gases, whereby the said liquid is heated to 284° F. or above and the major portion of its scaling salts separated, subjecting partially purified liquid from said heating operation to an evaporating operation, withdrawing from the liquid undergoing said evaporating operation a portion of the same such as will contain a quantity of scaling salts substantially equal to the increment of scaling salts received by the liquid undergoing said evaporating

operation, conducting the withdrawn liquid to the liquid undergoing said heating operation, establishing heat-transferring relationship between the said upwardly flowing body of the liquid undergoing said heating operation and a downwardly flowing body of said withdrawn liquid, whereby the said withdrawn liquid is cooled to substantially the temperature at which the said liquid is supplied to said heating operation, concentrating suspended matter separated from the two bodies of liquid in a portion of the cooled withdrawn liquid, ejecting from the circulation the portion of said cooled withdrawn liquid containing said suspended matter, mingling the remainder of said cooled withdrawn liquid with the fresh liquid supplied to said heating operation and transferring liquid from said heating operation to said evaporating operation at a rate equal to the rate of evaporation of liquid in and withdrawal of liquid from said evaporating operation.

14. In the generation of vapor from liquid containing scaling salts, the process which comprises, subjecting said liquid, first, to a heating operation and, second, to an evaporating operation, maintaining a circulation of liquid from the body of liquid undergoing said heating operation to the body of liquid undergoing said evaporating operation and from the second of said bodies of liquid to the first of said bodies of liquid, ejecting from the stream of liquid flowing from the said second body of liquid to the said first body of liquid a portion of said liquid which will be the quantity of liquid flowing to the said second body of liquid inversely as the ratio of concentration of the liquid in said evaporating operation.

15. In the generation of vapor from liquid containing scaling salts, the process which comprises, subjecting said liquid, first, to a heating operation and, second, to an evaporating operation, maintaining a circulation of liquid from the body of liquid undergoing said heating operation to the body of liquid undergoing said evaporating operation, and from the second of said bodies of liquid to the first of said bodies of liquid, the volume of the liquid flowing from the second of said bodies of liquid to the first of said bodies being so proportioned relative to the volume of liquid flowing to the second of said bodies of liquid as to prevent an increase in the quantity of suspended matter in the second of said bodies of liquid beyond a predetermined proportion, transferring heat from the liquid flowing from said second body of liquid to said first body of liquid to the said first body of liquid, ejecting from the said liquid flowing from said second body of liquid to said first body of liquid a portion of said liquid which will be to the quantity of liquid flowing to the said second body of liquid inversely as the ratio of concentration of the liquid in said evaporating operation.

16. In the generation of vapor from liquid containing scaling salts, the process which comprises, first, heating said liquid to that temperature at which it will deposit the practical maximum of its scaling salts, separating suspended matter from the heated liquid, subjecting the heated and purified liquid to evaporation, whereby vapor is generated and the residual liquid concentrated, continuously withdrawing a portion of the concentrated liquid undergoing evaporation and returning said liquid to the body of liquid undergoing said heating operation, whereby a portion of the suspended matter in the concentrated liquid undergoing evaporation is carried over into the liquid undergoing heating, the volume of the withdrawn liquid being so proportioned to the volume of the liquid supplied to the body of liquid undergoing evaporation that the proportion of suspended matter in the said liquid is maintained at the predetermined proportion, transferring to the liquid undergoing said heating operation the sensible heat of the liquid returned to the same, separating suspended matter from the returned liquid, concentrating suspended matter in a portion of said returned liquid, rejecting said portion of returned liquid and said suspended matter, the volume of the rejected liquid being to the volume of the liquid supplied to the body of liquid undergoing evaporation inversely as to the ratio of concentration of the liquid in the said body of liquid, and mingling the remainder of said returned liquid with the fresh liquid supplied to the body of liquid undergoing said heating operation.

17. In the generation of vapor from liquid containing salts, by the heat of hot combustion gases, the process which comprises, first heating said liquid to or above 284° F. to separate dissolved salts therefrom, whereby the said liquid is purified, subjecting the heated and purified liquid to an evaporating operation to evaporate the major portion of said liquid and to concentrate the minor portion of said liquid, the said heating and evaporating operations being carried out by forming hot combustion gases by burning fuel with preheated air, establishing heat-transferring relationship between the said hot combustion gases and the liquid undergoing evaporation, and accelerating the velocity of said combustion gases while the same are in heat-transferring relationship with the said liquid undergoing evaporation so that the quantity of heat abstracted from said gases during said evaporating operation will be restricted to that which will leave sufficient heat in said gases to preheat the air used in burning said fuel and to carry out the said heating operation, divid-

ing the combustion gases from the said evaporating operation into two streams, establishing heat-transferring relationship between the first of said streams and the liquid to be heated and between the second of said streams and the air to be used in the combustion of said fuel, continuously withdrawing concentrated liquid from the body of liquid undergoing evaporation and establishing heat-transferring relationship between said withdrawn liquid and the body of liquid undergoing said heating operation, whereby the said withdrawn liquid is cooled, rejecting a portion of the cooled withdrawn liquid, and mingling the remainder of the said withdrawn liquid with fresh liquid supplied to the said heating operation.

18. In the generation of vapor from liquid containing scaling salts by the heat of hot combustion gases, the process which comprises, first heating said liquid to or above 284° F. to separate scaling salts therefrom, whereby the said liquid is purified, subjecting the heated and purified liquid to an evaporating operation to evaporate the major portion of said liquid and to concentrate the minor portion of said liquid, the said heating and evaporating operations being carried out by forming hot combustion gases by burning fuel with preheated air, establishing heat-transferring relationship between the said hot combustion gases and the liquid undergoing evaporation and accelerating the velocity of said combustion gases while the same are in heat-transferring relationship with the said liquid undergoing evaporation so that the quantity of heat abstracted from said gases during said evaporating operation will be restricted to that which will leave sufficient heat in said gases to preheat the air used in burning said fuel and to carry out the said heating operation, dividing the combustion gases from the said evaporating operation into two streams, establishing heat-transferring relationship between the first of said streams and the liquid to be heated and between the second of said streams and the said air, continuously withdrawing concentrated liquid from said evaporating operation, the volume of concentrated liquid withdrawn during a given interval of time being such as will contain a quantity of suspended matter substantially equal to the increment in suspended matter received in the same length of time by the body of liquid undergoing evaporation, conducting the withdrawn liquid to the body of liquid undergoing said heating operation and bringing the same into heat-transferring relationship therewith to cool said withdrawn liquid, concentrating suspended matter in a portion of said withdrawn liquid having a ratio to the volume of purified liquid supplied to said evaporating operation approximately equal to the inverse of the ratio of concentration of said liquid in said evaporating operation, rejecting said portion of the withdrawn liquid and its contained suspended matter, and mingling the remainder of said withdrawn liquid with the fresh liquid supplied to said heating operation.

19. The process of treating water for raising steam which comprises generating hot combustion gases in a suitable furnace and heating water therewith in two separated heating stages, the gases coming direct from the furnace being employed to heat the water in the second or actual evaporation stage and being thereby cooled to a temperature not lower than approximately 1200° F., and the effluent gases at this temperature being employed to heat water in the first stage to a temperature sufficiently high to precipitate the major portion of the scale-forming substances contained therein prior to entering the second heating stage.

Signed at New York city in the county of New York and State of New York this 14th day of November A. D. 1911.

HENRY L. DOHERTY.

Witnesses:

FRANK L. BLACKBURN,

H. A. MACKEOGH.