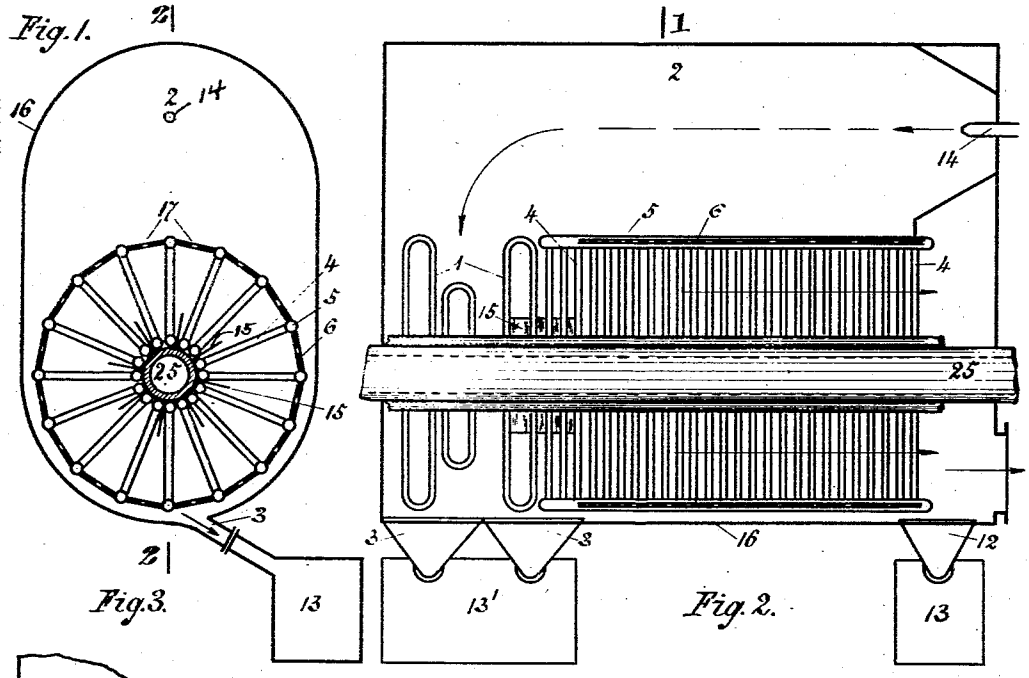
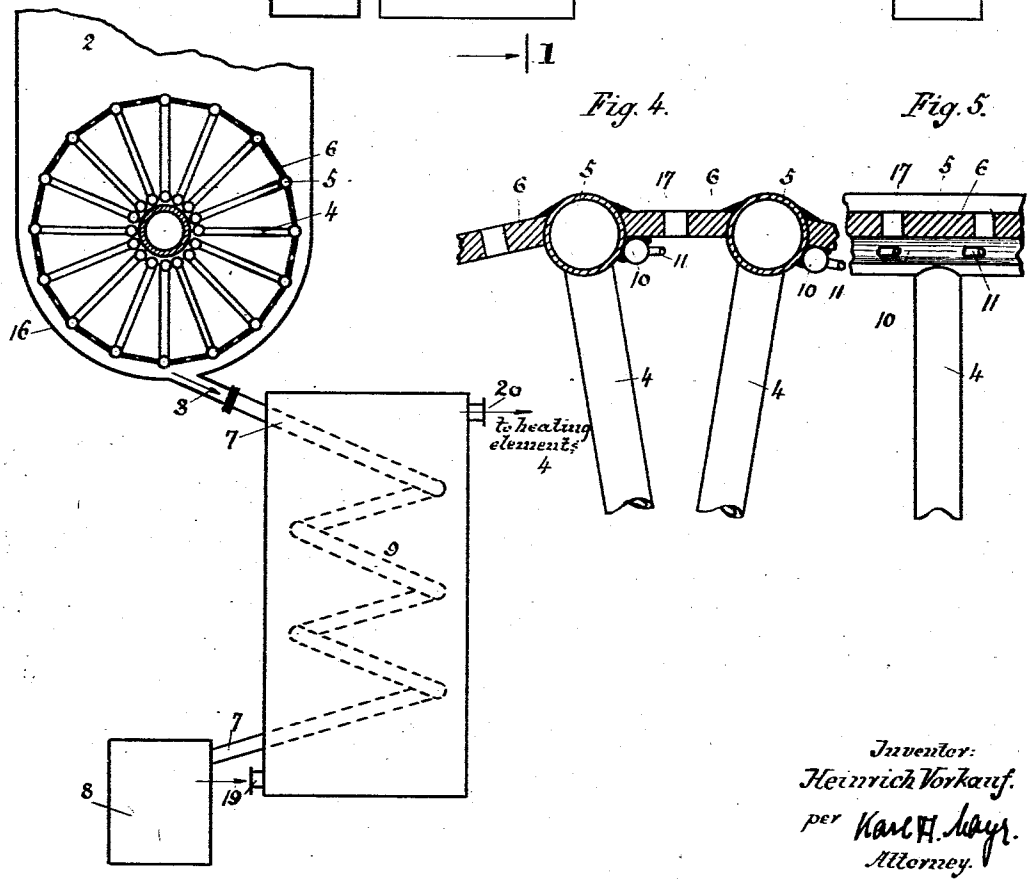
April 14, 1936. H. VORKAUF 2,037,490

ROTARY HEAT EXCHANGER

Filed Jan. 9, 1933 3 Sheets-Sheet 1





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ROTARY HEAT EXCHANGER

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Fig. 6.

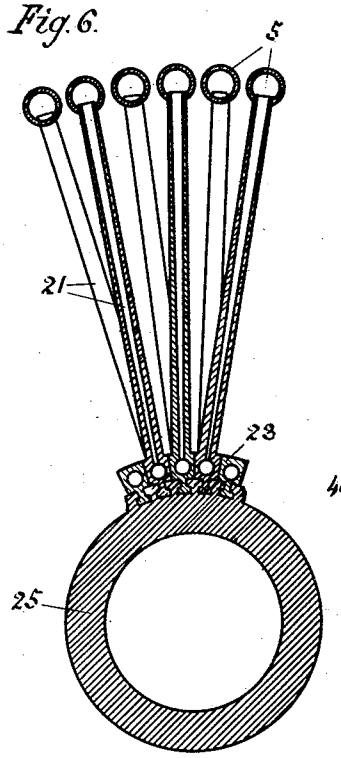


Fig. 7.

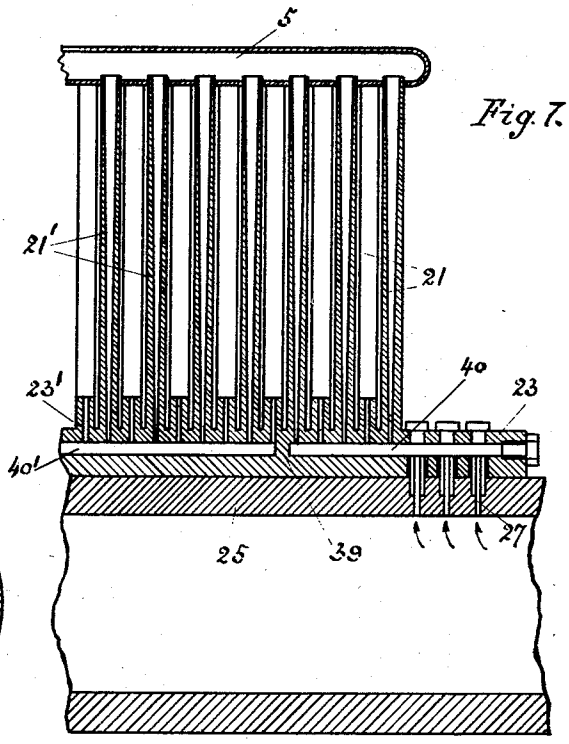


Fig. 8.

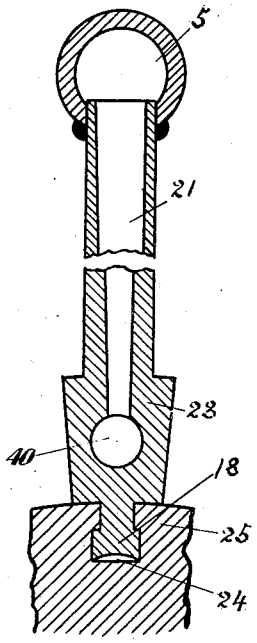
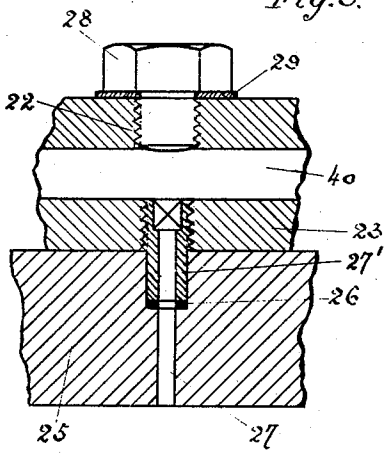


Fig. 9.



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Fig. 11.

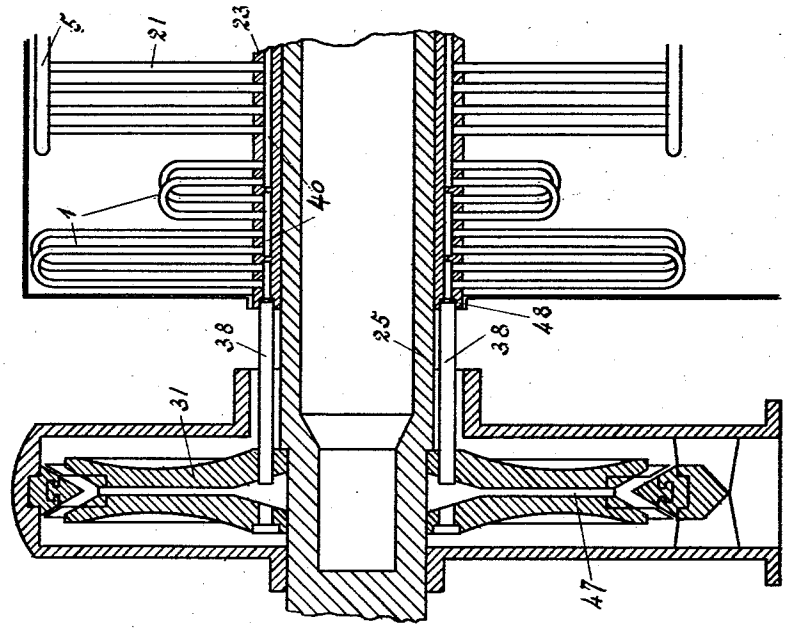
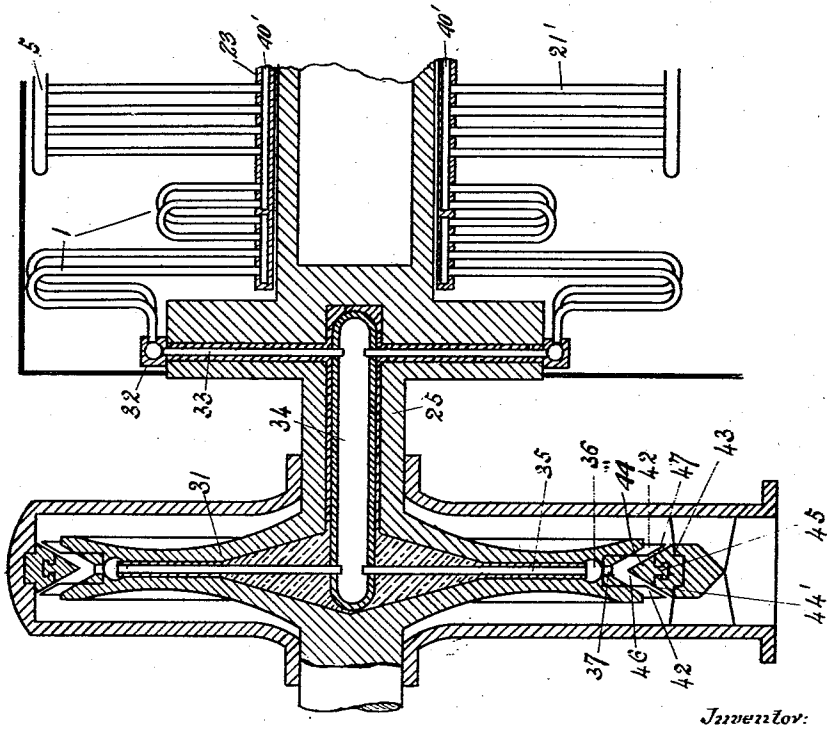


Fig. 10.



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UNITED STATES PATENT OFFICE

2,037,490

ROTARY HEAT EXCHANGER

Heinrich Vorkauf, Berlin, Germany, assignor to Herpen und Vorkauf, Ingenieure, Berlin, Germany

Application January 9, 1933, Serial No. 650,817
In Germany January 9, 1932

19 Claims. (Cl. 257—235)

This invention relates to steam or vapor generators of the revolving type, particularly such generators as rotate at sufficiently high speeds to be directly coupled to a turbine or the like.

Such an arrangement has been disclosed in my copending application Ser. No. 611,849, filed May 17th, 1932 which has matured into Pat. No. 1,994,009.

The generator may be fired by any fuel such as gas, oil, coal, or powdered coal. Particularly in the latter case, it is unavoidable that a considerable amount of ashes and perhaps unburnt fuel is carried by the hot combustion gases over to the heat absorbing elements. In the generator according to my invention, heating surfaces revolve through the hot gases and cause a rotating movement also of the latter. The hot combustion gases are very light compared to the weight of the particles of ash or unburnt fuel which are carried along by the gases. This dust is therefore thrown outwards by centrifugal forces as soon as the gas with the therein suspended solid or molten particles revolves at sufficient speed. The dust can be collected in suitably arranged pockets or the like and removed.

Whereas in the usual steam generator or other combustion apparatus separate dust precipitators are arranged, which are entered by the gases after they have left the generator, an arrangement according to my invention combines vapor generator and dust precipitator in one piece of equipment. A further advantage of my invention is that the dust or fly ash is removed from the gas while it is still very hot. At high temperatures the specific weight of the combustion gas is small compared to the weight of the dust or ash particles; this materially facilitates the removal of the dust by centrifugal action.

Preferably the combustion gases pass through my vapor generator in a direction substantially parallel to its axis of rotation. The heating elements apply a circular component of movement to the gases, so that each gas particle travels along a screwline through the apparatus. The dust particles are thrown outwards in a radial direction and are collected in receptacles arranged for this purpose. To remove the dust from these receptacles, a certain amount of the gas is allowed to pass through the pockets to accelerate the removal and to arrange for a pneumatic further transportation of the ash at the same time. The gas is under a considerable pressure at the circumference of the revolving part of my generator and also in the pockets for receiving the fly ash, due to the high rotational speed; this pressure can advantageously be used for the removal and transportation of the ashes. The gas carrying the ash has still a high temperature and heat content, and it is desirable to conduct these gases through a heat exchanger and transmit their heat e. g. to the fluid for feeding the generator or/and to the air for combustion.

The fact that the main heating surfaces of my boiler are revolving can also be utilized in another way. If, e. g., the revolving evaporator is arranged at the bottom of a combustion chamber fired with pulverized fuel, unburnt material will fall on the revolving heating surfaces and are thrown back again and again into the combustion chamber, thus securing a perfect combustion. How often the particles may be thrown back into the hot flame depends on the length of the combustion chamber and the revolving heat absorbing elements. The particles may also be conducted into a collecting pocket from which they are removed.

At high speeds, the centrifugal forces set up high stresses in the construction materials of the heat transmitting surfaces; the heat absorbing parts of the generator as well as the supply and discharge tubes for the feed water and steam respectively must be of a design suitable to withstand these stresses.

Designs have been conceived in which the generating or heat absorbing parts consist of rotating discs and a plurality of individual thimbles disposed on a hollow shaft. In such arrangements, the liquid to be evaporated enters from the center into the evaporating elements, and the generated vapor must return through the same elements to the center, whereby feed fluid and vapor circulate in opposite directions to each other through the same elements and obstruct each other's free flow. According to the present invention, the evaporating elements are fed from one side with the fluid, and the vapor or mixture of fluid and vapor is withdrawn at the other side. To accomplish this, the evaporating elements are connected on their outer ends by means of headers, tubes, or the like. In the center the evaporating elements are either directly connected to the center conduit or they are connected to intermediate conduits arranged substantially around the center piece, shaft or conduit. The evaporating elements are preferably radially arranged with respect to the center piece, so that the materials are stressed parallel to the center line of the elements, and the centrifugal forces caused by

the outer connecting headers are absorbed by the spoke like evaporating elements.

It is desirable to form groups of evaporating elements by suitable connection of the elements to the headers at the circumference and at the center of the apparatus. These groups of radial elements should be parallel to the rotating axis of the device and may be inserted in grooves on the connecting headers which are also in an axial direction.

This invention further relates to arrangements for the supply of the fluid to and the withdrawal of the fluid, fluid-vapor mixture, or vapor from the heating elements.

The design of a revolving vapor or steam generator according to my invention is suitable for high internal pressures and particularly adapted to withstand great stresses set up by centrifugal forces. Although it can be used for steam or any vapor, it is especially well suited for evaporating matters of high specific weight, such as mercury.

Figs. 1–11 show by way of example embodiments of my invention.

Fig. 1 is a cross sectional view through the generator on the line 1—1 of Fig. 2.

Fig. 2 is a longitudinal section through the generator along line 2—2 of Fig. 1.

Fig. 3 shows an arrangement for further transport of ash by part of the combustion gases.

Fig. 4 is a detail drawing showing the plates connecting the heating elements and sootblowers.

Fig. 5 is another detail view of the plates and sootblowers.

Fig. 6 is a cross section through part of the heating elements.

Fig. 7 is a longitudinal section through the rotating shaft and part of the heating elements.

Fig. 8 is a section through an individual heating element.

Fig. 9 is a detail section showing the connection of the rotating shaft with a header for the heating elements.

Fig. 10 is a cross sectional view through one end of the vapor generator and a turbine connected to it, showing particularly the connections between generator and turbine.

Fig. 11 is a cross section as is Fig. 10 but showing another method of conducting the steam from the generator to the turbine.

Referring more particularly to the drawings:

Figs. 1 and 2 show cross sections through a revolving steam generator, more particularly of such a generator adapted to use pulverized coal as fuel. The products of combustion or combustion gases enter the generator proper through an opening between the superheater elements, whereby the rotating heating elements accelerate the combustion gases in a circumferential direction. The gases also rotate within the heating surfaces at considerable speed, this speed, of course, being slower than the circumferential speed of the heating elements; the centrifugal force which is in proportional relation to the speed of rotation throws unburnt dust particles to the outside, either back into the combustion chamber 2 or into the pockets 3. Since the velocity necessary to precipitate the small particles is only gradually attained by the gas stream, the separation will not be completed until the gases have traveled a certain distance in axial direction. It is necessary that the drum formed by the heating elements is left open to this point. As obvious from the drawings, the spaces between the headers 5 which connect the individual vapor generating tubes 4 are closed by means of closing plates 6. Thus the tube system is closed on the outside and forms a drum through which the gases travel in a direction substantially parallel to the axis of the drum. The closing plates 6 may be provided with openings 17. It is advantageous to leave the system open on its outer circumference at the end where the gases enter to such an extent that an essential part of the dust particles carried along by the combustion gases is thrown out into pockets 3 which deliver it to collector 13'.

The generator may be fired by means of a burner 14 as shown in Fig. 2. The flame travels through the chamber 2 before encountering the heating surfaces. Since the flame is above the drum formed by the heating elements, solid particles will fall on the rotating heating surface and will be carried along by the elements and either thrown back into the combustion chamber or out into the collecting pockets. The generator is surrounded by a casing 16. No dust collecting pockets are arranged along a certain part of the generator. For example, in the design disclosed in Fig. 2 there are only collectors at the far left and at the far right end of the heating elements 4. This is to allow unburnt coal particles which fall in between the heating elements through openings 17 to be completely burnt or to be thrown back into the combustion chamber 2 and to prevent unburnt coal particles from being thrown into the collectors. The funnels 3 receive only ash because the gases entering the heating elements at the far left side have traveled through the whole length of the combustion chamber and contain practically no unburnt matter. The same is the case with the gas leaving the system. Any unburnt material has been thrown back into the combustion chamber so often that it has plenty of chances to be burnt by the time the gases reach the outlet of the system. The collectors 12 at the gas outlet are separated from the burner and the combustion chamber.

The particles carried by the combustion gas have very high temperatures at the point where the gas leaves the combustion chamber and enters the superheater and are in a liquid or paste like state. They must be cooled before entering the collecting funnel to facilitate their further transport. This cooling or "granulating" effect is assured in a construction as per Fig. 2 where the gases come in contact with the relatively cool heating surfaces of the tubes 1 in which the steam is superheated.

In order to effectively revolve the gases which enter close to the center of rotation where the circumferential speed is comparatively slow, vanes or guide plates 15 may be provided.

Whereas the collecting pockets 12 and 3 according to Figs. 1 and 2 discharge into closed receives 13 and 13' which may be emptied from time to time or from which dust may be withdrawn by hydraulic or other means, Fig. 3 shows a pneumatic dust removing system. The fast rotation of the heat absorbing elements causes an increase of gas pressure at the circumference which can be used to blow a certain amount of the combustion gas through the pocket 3. By this gas the dust is carried through conduit 7 and conveyed into a receiver 8 which may contain water or the like, wherein the dust settles down or is floated away with the liquid. To avoid a loss of the heat still contained in the hot gases, conduit 7 may be arranged to go through a heat exchanger 9, where the heat contained in the

gas is transmitted, for example, to the feed water or the combustion air. In the former case, water would be supplied to the heat exchanger 9 through inlet 19 and would leave the exchanger at the outlet 20 and be conducted to the heating elements 4 via the hollow shaft 25. In the latter case, air would be forced through the heat exchanger 9 and would be conducted therefrom to the burner 14.

Figs. 4 and 5 show sootblowing arrangements. By these means, dust which collects on the inside of the plates 6 is removed and blown towards the gas outlet of the generator where it is thrown into the pockets 12 as shown in Fig. 2. For example, a blow pipe 10 may be welded to the plates 6 and provided with nozzles 11 pointing in the axial direction of the gas flow and towards the gas outlet.

As before said, the plates 6 may be provided with openings 17 through which the fine dust circulates back to the combustion chamber. The number and/or size of the openings may be reduced towards the outlet of the apparatus, because the amount of dust carried along by the gases becomes less and less along the path of the gases, and the possibility that unburnt combustibles would fall directly from the burners into a comparatively cold gas stream becomes greater.

It is obvious from the aforesaid that the invention is applicable to directly fired vapor generators, but it can also well be used for waste heat boilers; the application of the idea is particularly desirable where waste gases must be handled which contain large amounts of dust, such as those in cement or similar plants.

Fig. 6 represents a cross section through the revolving heat exchanger or evaporator. In this case the evaporating elements proper consist of tubes 21. The center lines of the tubes are radial, whereby the centrifugal forces cause only tensile stresses within the tubes, and the highest admissible stress can be applied to the tube material. The individual tubes 21 are connected on the outside by means of tubes 5 and at the circumference of the shaft 25 by means of hollow ledges 23.

Fig. 7 is a cross sectional side view through a group of heat absorbing elements. The fluid may pass into the hollow ledge 23, through channels 27 and passes through the three tubes 21 at the right end of the group to the outer connecting header 5. It is then distributed from this header into the several heat absorbing tubes 21' whence it circulates back to the left part of the ledge 23' which is separated from the right part 23 by a partition 39.

Fig. 8 shows a section through one individual tube element and a way of mounting it to the center piece.

In order to increase the strength of the heat absorbing tubes 21, the tube walls may be made heavier towards the center of the apparatus and lighter towards the outside, thus taking care of the stresses caused by the centrifugal forces which increase towards the revolving center piece 35 of the apparatus. This can be accomplished by giving the interior of the tubes a cone shaped configuration as shown in Fig. 3. One could also make the exterior of a cone shaped configuration and leave the interior of the tubes cylindrical. Or one can combine both ways of obtaining an increasing strength of the tube wall towards the end of the element which is attached to the center piece 25. The hollow ledge 23 and the evaporating elements 21 could be machined from one piece in order to improve the strength. The connecting header 5 may be attached to the elements 21 by welding.

The hollow ledge 23 may be provided e. g. with a T shaped or dovetailed extension 18, so that the whole group of heat absorbing elements can be held in a groove, which is parallel to the axis of the rotating shaft. Since, due to its external heating and the steam circulating through it, the ledge will attain higher temperatures than the shaft 25 which is cooled by the fluid, the supply of which is advantageously arranged through a bore in the shaft, it is desirable to prevent a direct flow of the heat from the ledge to the shaft and to provide an insulating air space 24 between ledge and shaft.

Fig. 9 shows how the fluid may be conducted from the hollow shaft 25 to the ledges 23. The packing 26 serves against leakage between the shaft and the outside, whereas the threaded bushing 27' will sufficiently tighten up ledge 23 against leakage to the outside. The threaded bushing 27' which will be well calked to prevent unscrewing, holds the ledge 23 in position and prevents its movement in an axial direction. The screwing in and calking of the bushing is facilitated by the bore 22 located opposite the bore for the bushing. Bore 22 is closed by the plug 28 with packing 29.

Figs. 10 and 11 show two examples as to how the vapor or superheated vapor may be conducted from superheating elements 1 to the turbine diaphragm 31 which sits on the same shaft as the evaporating elements 21 and the superheating elements 1.

Fig. 10 shows an arrangement whereby the steam or vapor, or steam or vapor and fluid mixture passes from the headers 5 through the elements 21' to the bores 40' and to the superheater elements 1. The superheated steam or vapor is collected in ring-headers 32. From ring-headers 32 it passes through a plurality of radial tubes 33 on to the axial collector 34 which is arranged in the center of the shaft 25 and which is well insulated against the shaft. Radial tubes 35 disposed within the hollow diaphragm 31 conduct the vapor from the collector 34 to another circumferential or ring collector 36. From here the steam or vapor passes through the nozzles 37 and enters the turbine buckets 42. Ring 43 is stationary and serves with its faces 44 and 44' as guide for the steam or vapor. Ring 43 may be provided with an exchangeable ring of special corrosion proof material, as its circumferential point 46 is directly exposed to the vapor which is discharged at high velocities from the nozzles 37.

Fig. 11 shows an alternative arrangement. Here the vapor coming from the bores 40 is conducted towards the turbine diaphragm 31 through tubes 38 which may be welded to the ledges 23. The tubes 38 may be connected to the diaphragm by means of rolling in or in some other manner which is suitable. Radial bores or openings 47 conduct the vapor towards the revolving turbine nozzles 37.

What I claim is:

1. In a fast rotating heat exchange apparatus, a shaft, a set of inner headers, heating elements and a set of outer headers, said inner headers being located adjacent to said shaft, said heat absorbing elements being connected to said inner headers and said outer headers.

2. In a fast rotating heat exchange apparatus, a shaft, a set of inner headers, heating elements

and a set of outer headers, said inner headers being located adjacent to said shaft, said heat absorbing elements being connected to said inner headers and said outer headers, said heat absorbing elements lying in planes parallel with respect to said shaft.

3. In a fast rotating heat exchange apparatus, a shaft, a set of inner headers, heating elements and a set of outer headers, said inner headers being located adjacent to said shaft, said heat absorbing elements being connected to said inner headers and said outer headers, said headers having partitions, the heat absorbing elements connected to the headers between said partitions forming groups and a fluid within said heating elements, said fluid circulating serially from one of said groups to the other group.

4. In a fast rotating evaporataing apparatus, a shaft, tubular heat absorbing elements radially connected to said shaft, the cross sectional dimensions of said tubular heat absorbing elements being heavy adjacent to said shaft and becoming lighter with increasing distance from said shaft.

5. In a fast rotating evaporating apparatus, a hollow shaft, a set of hollow inner headers, heating elements and a set of outer headers, said inner headers being located adjacent to said shaft, bores in said inner headers and in said shaft, said bores connecting the hollow of said shaft with the hollow of said headers, said heating elements connecting said inner headers and said outer headers.

6. In a fast rotating heat exchange apparatus, a hollow shaft, inner headers, tubular heat absorbing elements, outer headers, a ring shaped collector, radial conduits, and a drum shaped collector, whereby an operating fluid may flow from said hollow shaft into said inner headers, therefrom through said tubular heat absorbing elements to said outer headers, from said outer headers into said ring collector, and from said ring collector through said radial conduits into said drum shaped collector.

7. In a fast rotating heat exchange apparatus, a hollow shaft, inner headers, tubular heat absorbing elements, outer headers, a ring shaped collector, radial conduits, and a drum shaped collector, whereby an operating fluid may flow from said hollow shaft into said inner headers, therefrom through said tubular heat absorbing elements to said outer headers, from said outer headers into said ring collector, and from said ring collector through said radial conduits into said drum shaped collector, a hollow connecting shaft directly connected to said first mentioned hollow shaft, said drum shaped collector being located within said hollow connecting shaft.

8. In a fast rotating heat exchange apparatus, a shaft, tubular heat absorbing elements mounted on said shaft, headers connecting said heat absorbing elements, and a plurality of conduits connected to said headers, said conduits being substantially parallel to said shaft.

9. In a fast revolving heat exchange apparatus, a shaft, heat absorbing elements, dovetails on said elements, grooves in said shaft, said dovetails fitting into said grooves.

10. In a heat exchanging apparatus rotating heat absorbing elements arranged around a center of rotation and heated by hot gases containing particles of greater specific weight than the specific weight of the gases, a closure around and connected to said heat absorbing elements, and openings in said closure adapted to permit the escape of the particles contained in the heating gases and thrown towards said enclosure under the influence of centrifugal forces set up in the hot gases and particles by said rotating heat absorbing elements.

11. In a heat exchanging apparatus rotating tubular elements radially arranged about a center of rotation, said elements being heated by hot gases, and forming passages for a heat absorbing medium and a closure around and connected to some of said heat absorbing elements, said closure forming a duct for the gases heating said elements within said duct.

12. In a heat exchanging apparatus rotating tubular elements radially arranged about a center of rotation and heated by hot gases containing soot, a closure around and connected to some of said heat absorbing elements, said closure forming a duct for the gases heating said elements within said duct, and sootblowers within said closure.

13. In a heat exchanging apparatus rotating tubular elements radially arranged about a center of rotation and heated by hot gases containing soot, a closure around and connected to some of said heat absorbing elements, said closure forming a duct for the gases heating said elements within said duct, sootblowers within said closure, and nozzles on said sootblowers, said nozzles pointing substantially parallel to said center of rotation.

14. In a heat exchanging apparatus rotating heat absorbing elements arranged around a center of rotation and heated by hot gases containing particles of greater specific weight than the specific weight of said gases, an enclosure around a plurality of said heat absorbing elements, said enclosure together with said heat absorbing elements forming a substantially cylindrical body, openings at both ends of said cylindrical body, the hot gases entering through the opening at one end and leaving said body through the opening at the other end, pockets adjacent to said ends of said cylindrical body, said pockets adapted to receive particles moving outwards under the influence of centrifugal forces set up in the hot gases and particles by said rotating heat absorbing elements.

15. In a heat exchanging apparatus a rotating hollow shaft, tubular heating elements substantially radially arranged around said shaft and heated by hot gases containing solidified particles and moving substantially parallel to said shaft, and vanes substantially parallel and connected to said shaft in between said tubular elements and rotating with said shaft, said vanes assisting the rotating tubular elements in the promotion of a rotational movement of the heating gases and particles contained therein and throwing the particles out of the path of the gases.

16. In a quickly rotating heat exchange apparatus a hollow shaft, inner headers, tubular heat absorbing elements, outer headers, a ring-shaped collector, radial conduits, a drum-shaped collector whereby an operating fluid may flow from said hollow shaft into said inner headers, therefrom through said tubular heat absorbing elements to said outer headers, from said outer headers into said ring collector and from said ring collector through said radial conduits into said drum-shaped collector, a hollow connecting shaft directly connected to said first mentioned hollow shaft, said drum-shaped collector being located within said hollow connecting shaft, and a second set of radial conduits with one end connected to said drum-shaped collector, and

nozzles at the other ends of said last mentioned radial conduits.

17. In a quickly rotating heat exchange apparatus a shaft, a set of inner headers, heating elements and a set of outer headers, said inner headers being located adjacent to said shaft, said heat absorbing elements being connected to said inner headers and said outer headers and being heated by hot gases, said outer headers being paralled to said shaft and strips connected to and in between said outer headers, said strips together with said outer headers forming a cylindrical enclosure serving as a duct for the hot gases.

18. The method consisting in conducting hot gases containing solid particles first over tubular heat absorbing surfaces which rotate around an axis substantially perpendicular to said tubes, in imparting a rotating motion to said gases by said surfaces, in simultaneously diverting the flow direction of said gases while they pass over said surfaces, in thereby positively diverting the direction of movement of said solid particles from that of said gases, and in throwing said particles into pockets, in splitting up part of the gases, and in using the centrifugal pressure set up in said gases by said rotating motion for blowing said particles out of said pockets.

19. The method consisting in conducting hot gases containing solid particles first over tubular heat absorbing surfaces which rotate around an axis substantially perpendicular to the tubes, in imparting a rotating motion to said gases by said surfaces, in simultaneously diverting the direction of flow of said gases while they pass over said surfaces, in thereby positively diverting the direction of movement of said solid particles from that of said gases, in throwing said particles into pockets, in splitting up part of the gases, in using the centrifugal pressure set up in said gases by said rotating motion for blowing said particles out of said pockets, and in transporting said solid particles by said part of the gases and said pressure from said pockets into and through a heat exchanger in which the heat still contained in the particles and gases is usefully absorbed by other media.

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