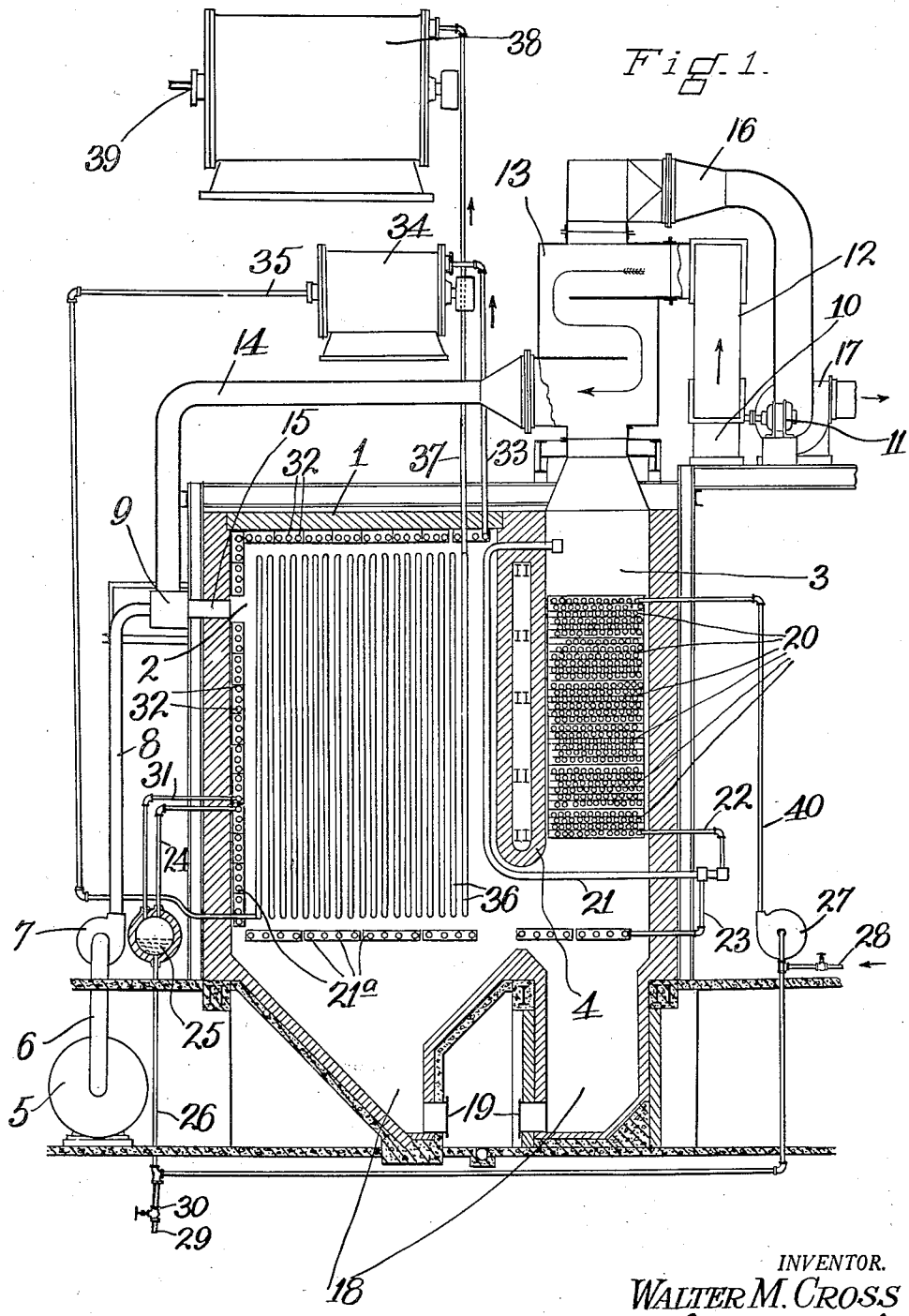
Feb. 21, 1933. W. M. CROSS 1,898,079

STEAM GENERATOR

Filed April 16, 1928 2 Sheets-Sheet 1

Fig. 1.



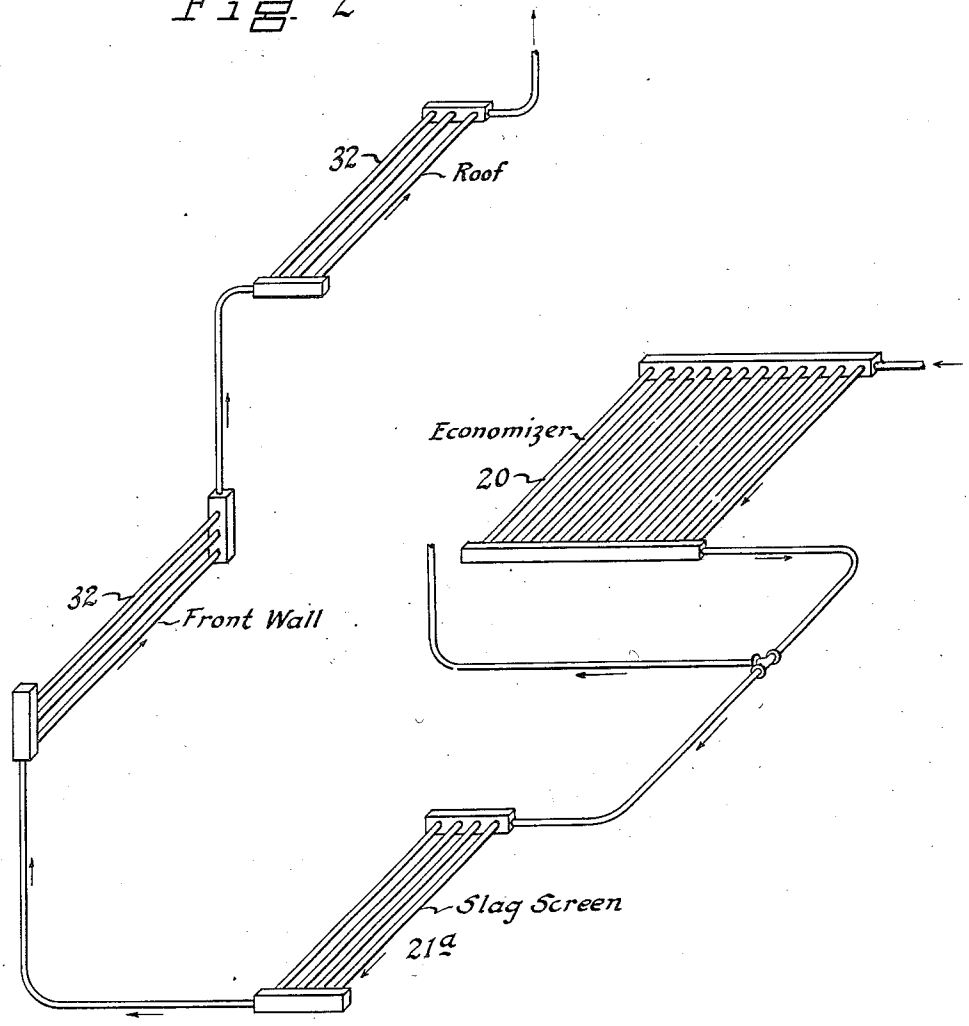
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Fig. 2



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UNITED STATES PATENT OFFICE

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STEAM GENERATOR

Application filed April 16, 1928. Serial No. 270,457.

This invention relates to improvements in steam generators and refers more particularly to a steam generator comprising a convection tube section or economizer and a radiant tube section, said radiant tube section having interposed therein a vapor water separator.

One of the primary objects of the invention is to decrease the cross sectional tube area in the succeeding tube sections of the steam generator as the temperature of the fluid rises in order to increase the velocity thereof. This increase in velocity is affected by manifolding the tubes in the separate banks or sections so that there is a larger number of tubes in the initial tube banks and a smaller number of tubes manifolded in the subsequent sections of the heater.

A further object of the invention is the use of radiant heat tubes in the subsequent tube sections, or what are hereinafter termed as primary and secondary super-heater and re-heating sections.

The steam generating system also utilizes a re-circulating system for returning fluids separated in the vapor water separator.

The efficiency and combustion is produced by pre-heating the air supplied to the combustible fuel, the heat of the flue gases being utilized for this purpose.

Fig. 1 is a sectional elevation of a generator constructed in accordance with the present invention; and

Fig. 2 is a diagrammatic view showing the principle of the invention.

The sectional elevation of the generator is illustrated in Fig. 1 with the power sources shown diagrammatically and parts of the pre-heater broken away. Referring to the drawings, at (1) is the furnace setting consisting of a combustion chamber (2) and a convection tube chamber (3) separated by a bridge wall (4). Fuel supply, preferably coal, is pulverized in the pulverizer (5) and is passed by means of a duct (6) through the fan (7) and line (8) to the burner (9), and air is introduced through the fan (10) driven by a motor (11) and passes through a duct (12) and pre-heater (13) through the pipe (14) to be combined with the pulverized fuel at the burner (9).

The combustible mixture is injected into the combustion space through a port (15) gases of combustion passing from the bottom of the combustion chamber under the bridge wall (4) and upwardly through the tube chamber (3) being finally discharged through the air pre-heater (13) and out through the flue (16), these gases being exhausted by a fan (17) to the stack.

Below the combustion chamber and convection chamber are ash pits 18 equipped with ports 19 for removing ashes.

In the drawings the convection bank of tubes positioned in the tube chamber (3) is shown divided into six separate banks of tubes designated as (20). Each row of tubes is is manifolded, as indicated diagrammatically so that the water introduced to the convection bank flows through all of the tubes of the upper row simultaneously, thence through the next successive row of tubes below in the top bank, thus passing through each row of tubes of the separate banks to the bottom row of the lower bank. From the bottom row in the lowest bank the fluid passes to a set of tubes hereinafter designated as the primary radiant tube section. This tube section consists of tubes 21 arranged upon and supported by the bridge wall 4 and also tubes 21^a. Tubes 21^a have their lower extremities on the floor of the furnace and extend part of the way up the front wall thereof. These tubes 21^a extend around the lower end of the bridge wall and protrude out of the rear of the furnace. These tubes, including tubes (21) and (21A), are manifolded in groups of fours, while the preceding convection bank tubes were manifolded in groups of twelve. This grouping of the tubes in sets of fours considerably decreases the cross section area of the tubes relative to the preceding convection sets. A transfer line (22) serves to direct the fluid from the final group of convection tubes to the initial tubes of the primary radiant tube section. After passing through the tube section (21) the fluid is conducted by means of the line (23) to the tube (21A). The tube section comprising the radiant tubes arranged upon the bridge wall and designated as (21) and

the tubes arranged on the floor of the furnace and partly up the front wall of the combustion chamber is hereinafter considered as the primary radiant tube section and the tubes in this section are manifolded in groups of four.

The fluid from this section is discharged through the line (24) into a vapor water separator (25). The water separated in this chamber (25) is drawn off through the line (26) and re-cycled to the suction of the pump (27) where it is combined with the fresh supply of fluid introduced through the line (28). A blow-off line (29) controlled by a valve (30) serves as a means for preventing to great a concentration of impurities in this re-circulated fluid. The vapor accumulating in the separator is directed through the pipe (31) to the front wall and roof tubes (32) of the furnace, which tubes shall be hereinafter considered as the secondary radiant tube section. These tubes are manifolded in groups of three as indicated diagrammatically which further reduces the cross sectional area of the tubes, relative to the preceding primary radiant heater which tubes were grouped in sets of four. This decrease in grouping and manifolding of the tubes as suggested is to increase the velocity of the fluid as its temperature increases, and as it advances through the generator. The discharge (33) from this tube section directs the fluid to the high pressure power source (34) shown in the drawings as the high pressure turbine, any type of prime mover utilizing a fluid as a power generating means is contemplated. The exhaust from the power source (34) passes through the line (35) and is introduced into a bank of re-heating tubes (36) manifolded for a single pass and positioned on the end walls of the combustion chamber. The discharge from the re-heater consists of a line (37) which directs the fluid to the low pressure power source (38) from which the expanded fluid is discharged through the line (39) to a condenser not shown.

Briefly following the passage of the fluid through the generator a supply is introduced through the line (28) and charged by means of a pump (27) through the line (40) into the upper row of tubes of the convection bank, passing successively through the rows which are manifolded. The liquid is raised in temperature and discharged from the lowest row of tubes into the primary radiant tube section which is divided into two banks, one bank being arranged upon the bridge wall and the other upon the floor of the furnace and on the front wall of the combustion chamber. The tubes in this primary radiant bank are manifolded in groups of four and on introduction to this primary tube section the velocity is considerably increased as is the temperature as compared with the temperature and velocity in the convection bank. Also the velocity increases as the temperature rises in the primary tube section.

On discharge into the vapor water separator something over 70% of the fluid has become vaporized. At this point the liquid is separated from the existing vapor, the liquid carrying off with it impurities contained in the fluid. The vapor is returned to the secondary radiant tube section which tubes are positioned on the front wall and on the roof of the combustion chamber. These tubes are manifolded in groups of three which further increases the velocity of the vapor, relative to the velocity of the fluid in the tubes of the primary tube section. The super-heated vapor is discharged from this tube section to the high pressure power source and the exhaust from this power source re-heated in the tubes (36). This re-heated vapor is utilized in the low pressure power source and discharged finally through the line (39) to the condenser.

The combustion gases as suggested are passed from the combustion chamber (3) through the pre-heater (13) and to the stack through the flue pipe (16) and exhauster fan (17).

A typical example of the operation of the steam generator utilizing pulverized coal as fuel is as follows: 116,500 pounds of water were introduced per hour through the line (38) and heated in the convection section to a temperature of approximately 600° F. The average velocity of the fluid over the heating surface in this section was approximately 5.7 feet per second. Through the primary radiant tube section the fluid passed at an average velocity of approximately 61.2 feet per second. On discharge from this section substantially 70% of the fluid was in the vapor phase, the temperature remaining approximately the same.

In the secondary radiant tube section the velocity of the fluid was increased to an excess of 100 feet per second due to the decrease in the cross sectional area of the tubes in the manifolded groups. The temperature from the secondary tube section is in excess or 850° F. The pressure at this point was approximately 1400 pounds. The friction lost between the discharge of the pump (27) and the outlet pipe (33) was about 207 pounds. In this example the water recirculated to the pump 27 amounted to something less than 30% of the original amount of water introduced to the steam generator. The loss of re-circulated fluid by blowing down to prevent concentration of impurities will depend upon the control and purity of the charging fluid.

I claim as my invention:

1. In a steam generator a convection tube section and radiant tube sections connected together to permit flow successively therethrough, the cross-sectional tube area of each

section progressively diminished with the rise of temperature of the fluid, so that the fluid velocity in each tube section is increased over that in each preceding section, a vapor water separator interposed between the radiant tube sections, a connection between the separator and the convection tube section for returning the separated water thereto and generating steam therewith.

2. In a steam generator a convection tube section and radiant tube sections connected together to permit flow successively therethrough, the cross-sectional tube area of each section progressively diminishing with the rise in temperature of the fluid so that the fluid velocity may be increased over that in each preceding section, and a reheater tube section for reenergizing the steam after partial expansion connected by a circuit to the final radiant tube section.

3. In a steam generator a convection tube section and radiant tube sections connected thereto, the cross-sectional tube area of each section progressively diminishing with the rise in temperature of the fluid so that the fluid velocity may be increased over that in each preceding tube section, a vapor water separator interposed in the fluid line between the radiant tube sections, a connection between the separator and the convection tube section for returning the separated water thereto and a reheater tube section for reenergizing the steam after partial expansion connected by a circuit to the final radiant tube sections.

4. In a steam generator a fluid heating tube section, a primary superheater tube section and a secondary superheater tube section, said sections being connected together for successive flow therethrough, said tube sections so constructed and arranged as to increase the fluid velocity in each section over that in the preceding tube section from the fluid heating section to the secondary superheater section.

5. In a steam generator a fluid heating tube section, a primary superheater tube section, and a secondary superheater tube section, said connections being connected for successive flow therethrough, the cross-sectional tube area of the sections progressively diminishing with the rise of the fluid temperature so that the velocity of the fluid in the primary superheater tube section is greater than that in the fluid heating tube section and the velocity of the fluid in the secondary superheater tube section is greater than that in the primary superheater tube section.

6. A process of generating high velocity steam comprising passing fluid through a steam generating zone at a progressively increasing velocity, separating the fluid into its vapor and liquid phase at a point where a substantial amount of the fluid is in the vapor phase, passing said vapor phase to part of said zone and diverting the liquid phase to a part of said zone to be generated into steam.

WALTER M. CROSS.