

- [54] **FLOW RESTRICTOR FOR AN EVAPORATOR**  
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[52] U.S. Cl. .... **122/7 R, 138/44**  
[51] Int. Cl. .... **F22d 1/06**  
[58] Field of Search ..... **138/40, 41, 44; 285/178; 122/235 R, 235 C, 7 R**

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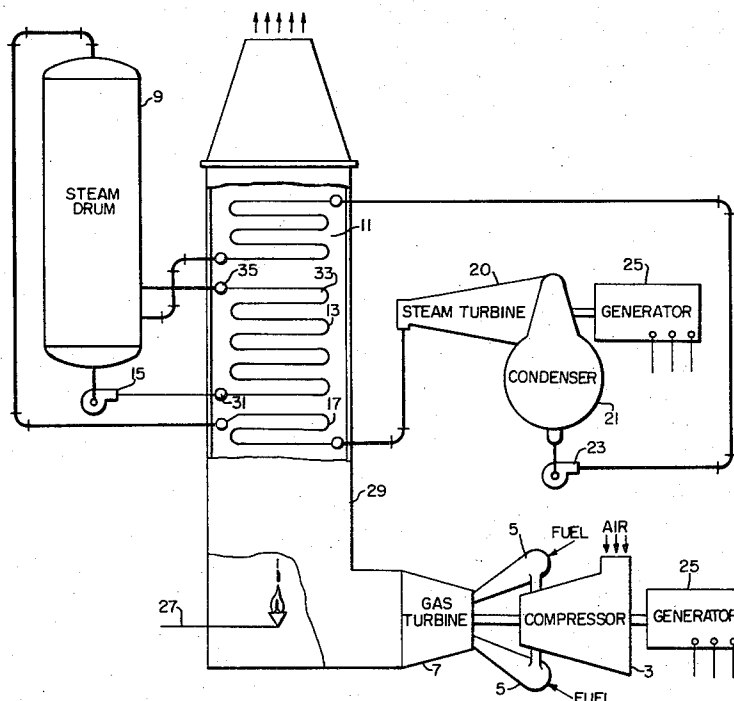
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[57] **ABSTRACT**

Each evaporator tube in a waste heat boiler has a flow restrictor disposed in the inlet thereof, the flow restrictor has a small diameter inlet end which converges into a smaller diameter restricting portion which discharges into the lower end of an outlet portion which is generally the same diameter as the tube, and the inlet and restricting portions are eccentrically disposed with respect to the outlet portion to provide trapless draining of the evaporator tubes.

- [56] **References Cited**  
**UNITED STATES PATENTS**  
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**1 Claim, 3 Drawing Figures**



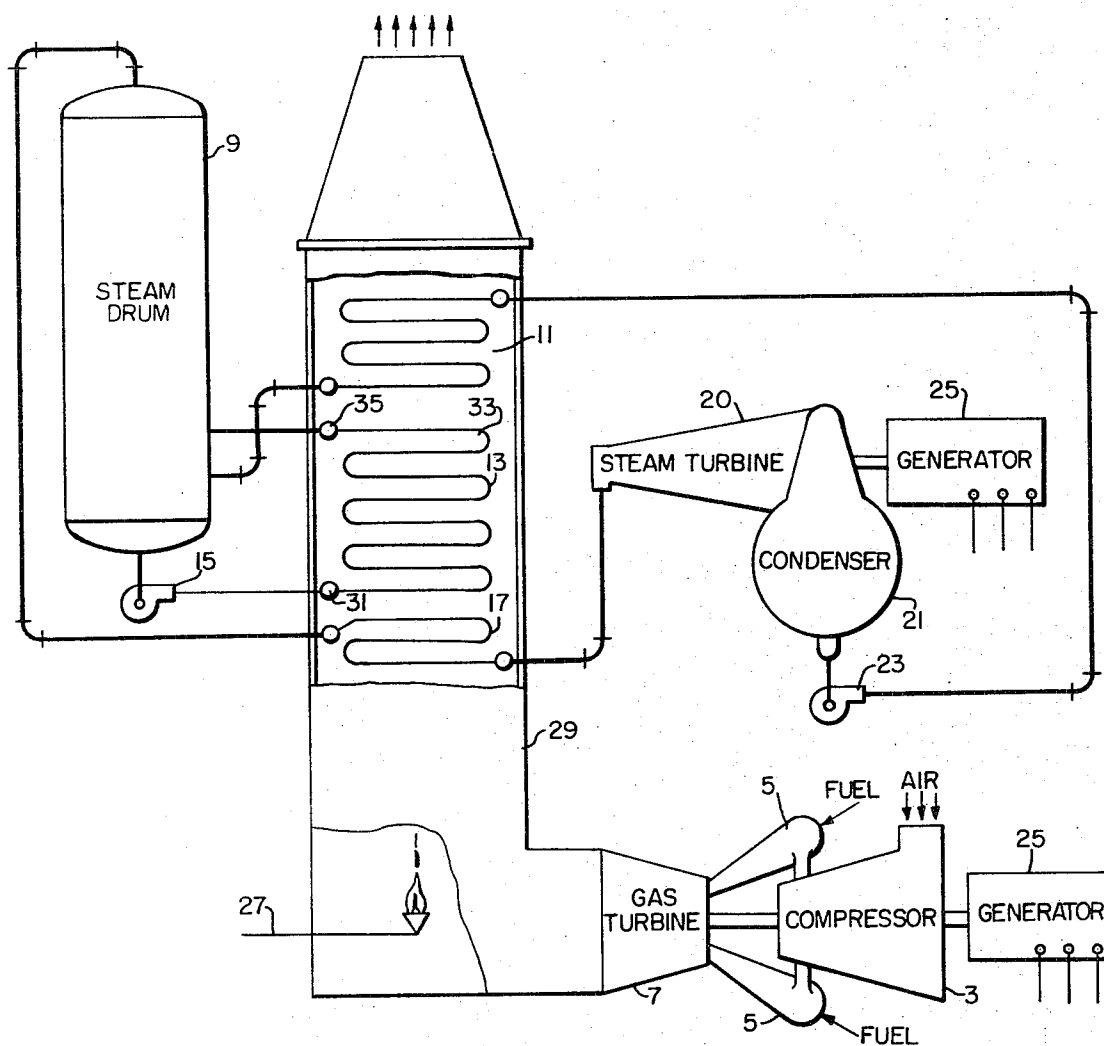


FIG. 1

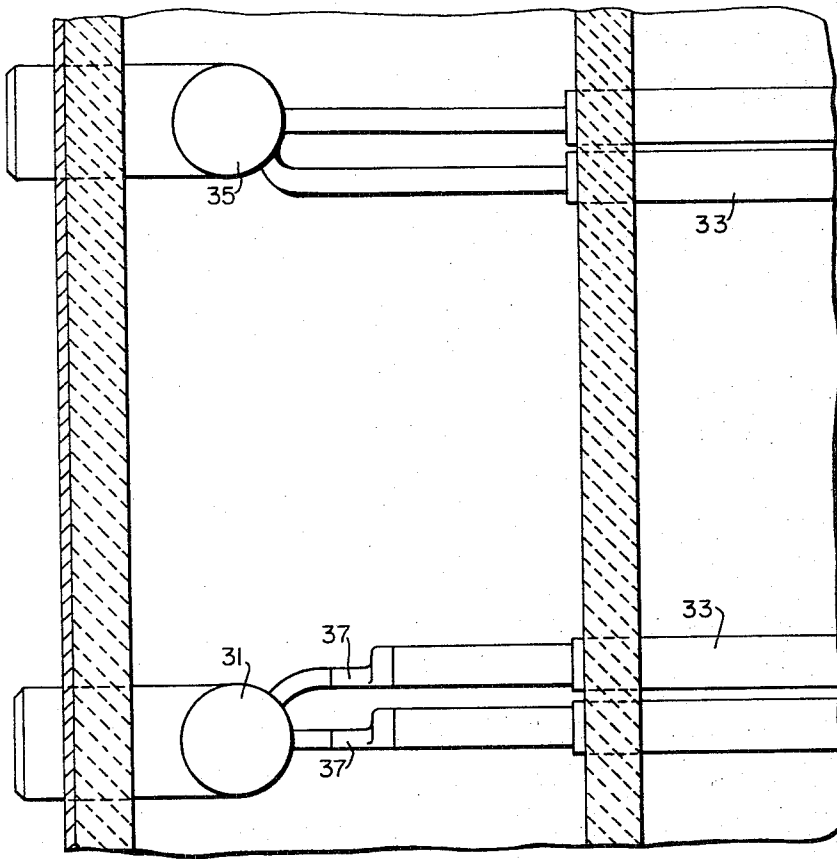


FIG. 2

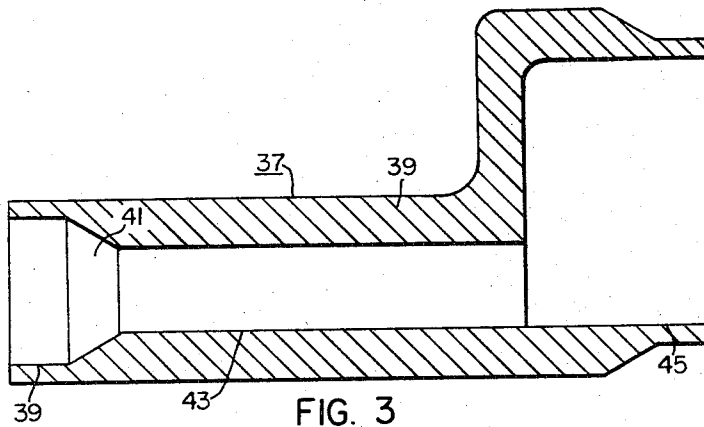


FIG. 3

## FLOW RESTRICTOR FOR AN EVAPORATOR

### BACKGROUND OF THE INVENTION

This invention relates to waste heat boilers and more particularly to a flow restrictor for the inlet ends of the evaporator tubes for such boilers.

Evaporator portions of a waste boiler, like other boiler systems, are susceptible to hydrodynamic instability, where periodic flow oscillations occur and are accompanied by periodic water level oscillations in the steam drum, along with periodic steam pressure oscillations.

To dampen these oscillations, flow restrictors, such as orifice plates could be disposed in the inlet ends of the evaporator tubes. The orifice plates are economical to install, however, chemicals present in the boiler water tend to build up on the upstream side of the orifice plates and eventually plug the openings therein. Therefore, provision must be made to provide access for periodic cleaning. The orifices must also be disposed in a vertical portion of the tube or the tube will not drain properly and therefore, preclude chemical cleaning of the boiler, which has become standard procedure with many of the utility companies utilizing such boilers.

### SUMMARY OF THE INVENTION

In general, a flow restrictor disposed in the inlet end of an evaporator tube, when made in accordance with this invention, comprises a fluid passageway having a plurality of portions which include an elongated restricting portion and a converging portion fluidly connected to the upstream end of the restricting portion. The restricting portion has an opening which is smaller than the opening in the evaporator tubes and the restrictor portion is eccentrically disposed with respect to the tube and so related thereto to provide nontrapping drainage of the tube, when the evaporator is drained.

### BRIEF DESCRIPTION OF THE DRAWINGS

The objects and advantages of this invention will become more apparent from reading the following detailed description in connection with the accompanying drawings, in which:

FIG. 1 is a flow diagram of a waste heat boiler utilized in a combined cycle steam and gas turbine plant;

FIG. 2 is a partial sectional view of a portion of an evaporator of the waste heat boiler; and

FIG. 3 is a sectional view of a flow restrictor made in accordance with this invention.

### DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to the drawings in detail, FIG. 1 diagrammatically shows a waste heat recovery system for recovering waste heat from the exhaust of a gas turbine 1, wherein air enters a compressor 3, is compressed, and the pressurized air flows to a plurality of combustion chambers or combustors 5, wherein the air is mixed with a fuel, such as natural gas or fuel oil, is ignited, and is burned raising the temperature of the mixture. The high temperature mixture, or motive fluid is then expanded in a gas turbine unit 7 to produce rotating mechanical energy. The exhaust gases leaving the gas turbine unit 7 still contain a large quantity of heat

energy and if exhausted to the atmosphere, this heat energy would be wasted. The other equipment shown is the heat recovery steam generator portion of the system and comprises a vertical steam drum 9, an economizer heat exchanger 11 for heating the feed water or condensate being fed to the drum 9, an evaporator heat exchanger 13 for evaporating or boiling water pumped from the drum 9 by a circulating pump 15, and a superheater heat exchanger 17 for superheating the steam flowing from the drum 9. The steam produced in the evaporator 13 is saturated steam and contains a large quantity of moisture, therefore to protect the superheater 17 from premature failure caused by scaling, which results from dissolved solids being deposited on the walls of the tubes forming the superheater as the entrained moisture in the steam is evaporated, it is necessary to remove as much moisture as possible from the steam before it enters the superheater. To accomplish this, the steam drum 9 is disposed vertically to provide multiple stages of moisture separation as described in another application, filed by me Aug. 31, 1971 and having Ser. No. 176,597 now Pat. No. 3,751,886 assigned thereto. Superheated steam produced in the superheater 17 flows to a steam turbine 20 and the exhaust steam from the steam turbine 20 is condensed in a condenser 21. A condensate pump 23 returns the condensate back through the economizer 11 to the steam drum 9 forming a closed cycle.

FIG. 1 also shows a generator 25 coupled to each turbine for changing the rotating mechanical energy to electrical energy, however, the turbines may be coupled to a single generator by providing gearing or other connecting means therebetween.

The gas turbine 7 has an open cycle, that is, the motive fluid is not recirculated therethrough. An afterburner 27 is shown and provides additional heat for generating steam and controlling the temperature of the steam leaving the superheater 17. However, the use of the after-burner 27 is optional and other means may be provided for controlling the temperature of the steam leaving the superheater 17.

As shown in FIG. 1, the superheater 17, the evaporator 13, and economizer 11 heat exchangers are disposed in an exhaust duct 29 in series and in the order as set forth, so that the hottest exhaust gases flow over the superheater 17 and the coolest exhaust gases flow over the economizer 11, to provide maximum mean temperature difference for the respective heat exchangers.

As shown in FIGS. 1 and 2, the evaporator 13 is disposed in the exhaust duct 29 and comprises an evaporator inlet header 31, a plurality of serpentine shaped finned evaporator tubes 33, which follow a sinuous path upwardly, and an evaporator outlet header 35. The inlet and outlet headers 31 and 35, respectively, are disposed in a stagnant gas area and out of the main flow stream of exhaust gas. A restrictor 37 is disposed adjacent the inlet end of each evaporator tube 33 and adjacent the inlet header 31.

As shown in FIG. 3, the restrictor 37 comprises a tubular housing 39 having a hole of various cross sections bored therethrough to form a flow path for the influent water. The inlet end 39 of the restrictor 37 has a cylindrical bore or cross section, which connects with a tapered bore 41, which converges in a downstream direction forming a frustoconical or converging portions

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having side walls, which form an angle of approximately 30° with the axis thereof.

The bore of the inlet end of the flow restrictor and the major diameter of the frustoconical portion are smaller than the inside diameter of the tube 33 in order to permit the use of a smaller inlet header and thus reduce cost of the waste heat boiler.

A cylindrical shaped elongated restricting portion 43 connects to the downstream end or minor diameter of the frustoconical converging portion 41. The restricting portion 43 has a length considerably longer than the diameter of its bore to allow the flow to recover after the vena contracta, which occurs in the inlet end of the restricting portion of the flow path.

The restriction portion 43 expands suddenly into an outlet portion 45 which is generally the same diameter as the inside diameter of the tube 33.

The restricting portion 43 is eccentrically disposed with respect to the outlet portion 45. The restricting portion 43 and the outlet portion 45 are both cylindrically shaped and in the embodiment shown so disposed that a line defining the lower boundary of each is rectilinear. However, the center lines of the two portions are spaced apart a distance greater or equal to the difference of the radii thereof in order to provide nontrapping drainage of the fluid in the evaporator tubes 33 when the fluid is drained from the evaporator 13. With the portions of the flow restrictor being so arranged, the restrictor 37 provides the necessary pressure drop

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in the inlet of the evaporator 13 to preclude instability therein and to provide nontrap drainage of the evaporator tubes 33, permitting the evaporator 13 and waste boiler to be acid or chemically cleaned without the danger of the acid or cleaning solution being trapped in nondraining portions of the evaporator.

What is claimed is:

1. A boiler having an evaporator tube, said evaporator tube comprising a plurality of portions which comprise a serpentine portion disposed in communication with hot gases passing through the boiler, an elongated restricting portion disposed upstream of said serpentine portion, a converging portion fluidly connected to the upstream end of said restricting portion, and a tubular portion disposed upstream of the converging portion, said restricting portion having an opening which is smaller than the opening in said serpentine portion and said restricting portion being eccentrically disposed with respect to said serpentine portion and so related thereto that a line defining the lower boundary of the restrictor portion and a line defining lower boundary of the adjacent serpentine portion are coincident and rectilinear, said converging portion being generally frustoconically shaped, and having a major diameter of said tubular portion, whereby said serpentine portion, restricting portion converging portion and tubular portions are cooperatively associated to provide nontrapping drainage of said evaporator tube.

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