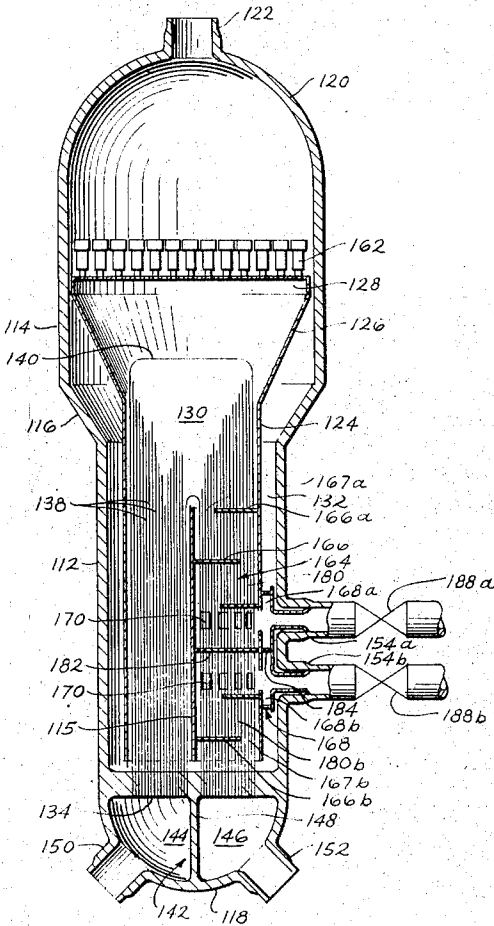


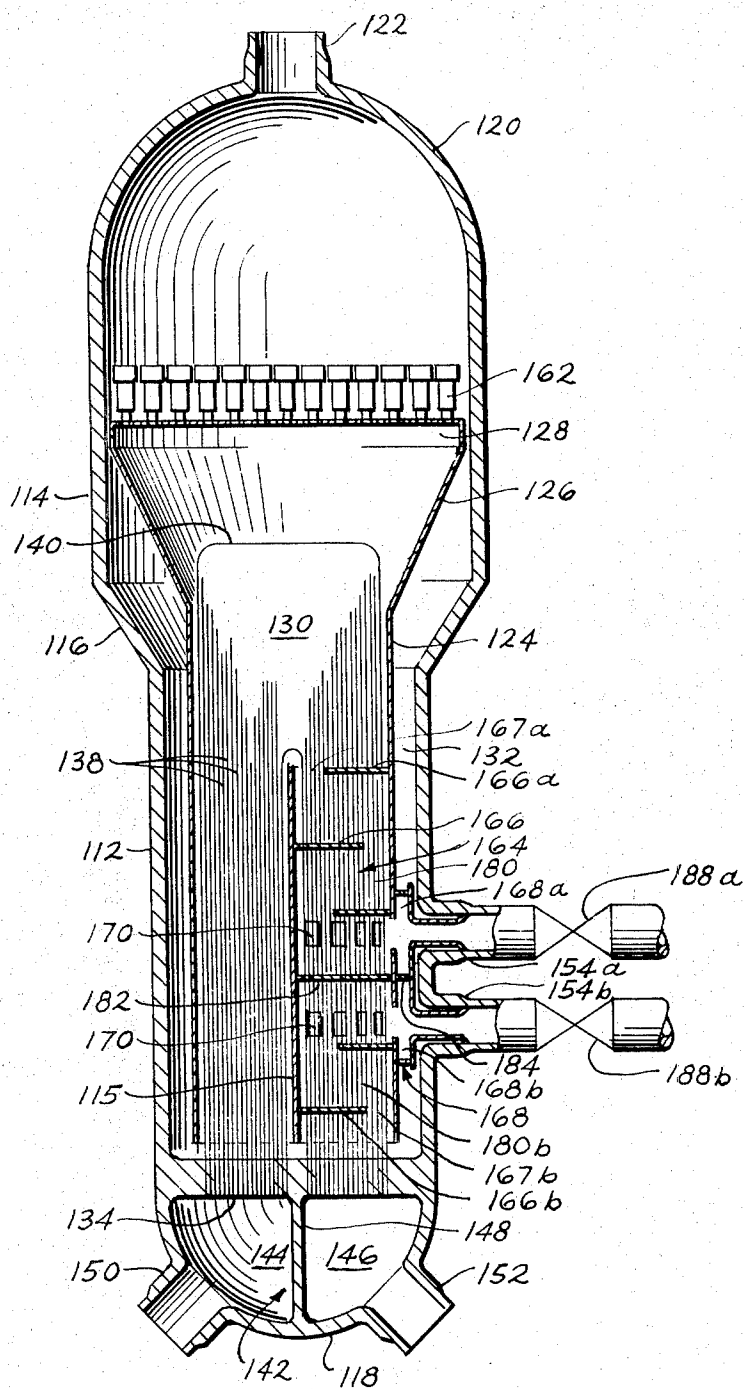
[54]	SPLIT FEED ECONOMIZER	3,547,084	12/1970	Sprague	122/32
[75]	Inventor: Kenneth Earl Webster, Chattanooga, Tenn.	3,576,179	4/1971	Romanos	122/32
		3,706,301	12/1972	Penfield, Jr.	122/32
[73]	Assignee: Combustion Engineering, Inc., Windsor, Conn.	<i>Primary Examiner</i> —Kenneth W. Sprague <i>Attorney</i> —Eldon H. Luther et al.			
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[58]	Field of Search	122/32, 33, 34			
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[57]	ABSTRACT
An economizer compartment for shell and tube vapor generators is disclosed having a baffle plate separating the compartment into two fluidly distinct sections. Separate nozzles deliver feedwater to each compartment and control means are provided to regulate the rate of feedwater flow delivered to each in order to enhance the operating efficiency of the vapor generator.	
18 Claims, 1 Drawing Figure	

[57] **ABSTRACT**
An economizer compartment for shell and tube vapor generators is disclosed having a baffle plate separating the compartment into two fluidly distinct sections. Separate nozzles deliver feedwater to each compartment and control means are provided to regulate the rate of feedwater flow delivered to each in order to enhance the operating efficiency of the vapor generator.

18 Claims, 1 Drawing Figure





SPLIT FEED ECONOMIZER

BACKGROUND OF THE DISCLOSURE

An economizer has been designed for use in shell and tube vapor generators by means of which incoming feedwater is preliminarily heated by indirect exchange of heat from the heating medium. In this apparatus feedwater enters at an intermediate point along the length of the compartment and is divided into two streams that flow in opposite directions through the compartment. Such apparatus is described in U.S. Pat. application Ser. No. 162,093, filed July 13, 1971 to Scott R. Penfield, Jr. and assigned to the assignee of the present application now U.S. Pat. No. 3,706,301. In that arrangement a single feedwater inlet nozzle is provided for delivering cold feedwater to the economizer compartment. The interior of the compartment is provided with baffles that define two oppositely directed flow passages through which proportioned amounts of feedwater flow. The respective flow streams discharge from opposite ends of the compartment into the interior of the vapor generator where contained flow of the liquid in heat exchange relation with the tubes of the tube bundle causes some of the liquid to be transformed into vapor.

In an economizer of the above-described type, the amount of feedwater flow in the respective flow streams is interdependent since the passages along which the streams flow communicate with a common source and a common discharge plenum. When a portion of the total feedwater flow is established in one flow stream, the remaining portion must flow in the other flow stream. The rate of flow in the respective streams is a direct function of the pressure losses occurring in the streams and also in the pressure gradients occurring in the evaporator section of the vapor generator.

Such characteristics give rise to certain manifest problems in the design of units employing this form of economizer. Firstly, the economizer is difficult to design for most effective operation. While the pressure losses occurring in the two feedwater flow streams can be predicted with a reasonable degree of accuracy, their being a function of available flow area in the respective flow passages through the compartment and of the fluid velocity occurring therein, the pressure gradients in the evaporator section cannot be easily determined due to the composite mode of the operation of the unit, i.e., the recirculated liquid being conducted through the downcomer passage by natural circulation and the incoming feedwater being force fed to the unit under pressure. Additionally, as reactor power changes occur, concomitant changes result in the vapor generator recirculation ratio thereby effecting changes in the evaporator pressure gradient and accompanying changes in the feedwater flow streams through the economizer. Thus, because the most effective amount of heating surface in the two sections of the economizer can be determined for only one value of liquid flow, an inaccurate prediction of evaporator pressure gradient or a change in reactor power will adversely effect the thermal efficiency of the unit.

Additionally, prior art apparatus of the hereindescribed type are characterized by the problem of evaporating some of the feedwater in the economizer, especially during periods of low load operation of the system. As system power is reduced the economizer heat-

ing surface requirements are also reduced but, because the amount of heating surface in the economizer is fixed, the result is an excessive amount of heat transfer surface being present for the amount of feedwater being supplied. Thus, there arises the possibility of experiencing steam blanketing of the tubes in the economizer compartment together with its attendant pressure losses and reduction in heat transfer efficiency.

SUMMARY OF THE INVENTION

The present invention provides means for controlling the pressure loss in one or both of the economizer flow streams such that the respective streams can be independently adjusted for maximum efficiency with any desired value of reactor power. This is accomplished by providing the economizer compartment with two fluidly distinct sections through which the feedwater streams flow in opposite directions. Separate feedwater nozzles communicate with each compartment section and independently operable control valves are associated with each in order to balance the flow of liquid through the respective compartment sections to obtain any desired flow differential.

For a better understanding of the invention, its operating advantages and the specific objects obtained by its use, reference should be made to the accompanying drawing and description which relate to various embodiments of the invention.

DESCRIPTION OF THE DRAWING

The single FIGURE is an elevational section of a shell-and-tube vapor generator equipped with an economizer compartment constructed according to the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

In the drawing there is shown a shell-and-tube type vapor generator 110 incorporating the present invention. The vapor generator 110 comprises a vertically elongated pressure vessel defined by a lower cylindrical shell 112 and a larger diameter upper cylindrical shell 114 interconnected with the lower shell by means of a frustoconical transition member 116. The ends of the vessel are closed at the bottom by means of a hemispherically formed closure head 118 and at the top by a dome-shaped cover 120 containing a vapor outlet nozzle 122. The interior of the pressure vessel contains baffle plate members 124, 126 and 128 that cooperate with the walls of the shells to form an interior vapor generation chamber 130 and an outer, annular downcomer passage 132. At the bottom end of the lower shell 112, and intermediate it and the closure head 118, is disposed a tube sheet 134 that extends transversely of the axis of the vessel and connects with the wall of the shell. The tube sheet 134 contains a plurality of tube openings adapted to fixedly receive the ends of U-shaped heat exchange tubes 138 that form a longitudinally extending tube bundle 140 substantially filling the lower region of the vapor generation chamber 130. The tube openings extend through the tube sheet 134 to place the ends of the tubes in fluid communication with a heating fluid chamber 142 which occupies that region of the vessel enclosed between the closure head and the tube sheet 134 and is divided into inlet and outlet portions, 144, 146 respectively, by means of a diametral plate 148. The tubes 138 of the tube bundle 140 are ar-

ranged such that the opposite ends communicate with one of the respective portions of the chamber 142 for the flow of heating fluid through the tubes. The chamber 142 is connected to a source of heating fluid (not shown) by means of inlet and outlet nozzles 150 and 152 that communicate with the respective chamber portions 144 and 146 thereby to effect continuous circulation of heating fluid through the tubes.

Feedwater is supplied to the unit through inlet nozzles 154a and 154b that penetrate lower shell 112. Within the vapor generator the feedwater is caused to flow in heat exchange relation with the tubes 138 where heat is extracted from the heating fluid circulated therethrough to first, effect preheating of the feedwater as hereinafter more fully described and secondly, to cause some of the heated feedwater to be transformed into vapor. The so-created vapor-liquid mixture flows to the upper region of the vapor generation chamber 130 which is formed as a mixture collection chamber 160 as defined by the cooperation between the baffle plates 126 and 128. From the mixture collection chamber 160 the flowing mixture is passed through vapor-liquid separator apparatus, a multiplicity of such separators, indicated as 162, being mounted on baffle plate 128 and connecting with the chamber 160 by means of openings provided in the plate. The separators 162 may be of any well-known construction and are arranged to discharge separated liquid downwardly onto the baffle plate 128 from whence it is required to the downcomer passage 132 to be mixed with the preheated feedwater and recirculated through the unit. The separated vapor, on the other hand, is discharged upwardly from the separators and passed through the vapor outlet nozzle 122 to a point of use.

the economizer compartment 164 is disposed in the lower region of the interior of shell 12. Within it the entering feedwater, prior to being admitted to the vapor generation chamber 130, is heated to a predetermined temperature by heat transferred from the fluid flowing through that portion of tubes 138 that extend through the compartment. As shown, the compartment 164 comprises a vertically elongated chamber extending upwardly from a level slightly spaced above the tube sheet 134. It is constructed of a plurality of plate members preferably enclosing the lower temperature legs of the tubes 138 adjacent the discharge ends thereof. The compartment is bounded about its radially outer periphery by the lower portion of the downcomer baffle 124. Its innermost side is defined by a vertical flat plate 165 that extends substantially diametrically through the tube bundle 140 and whose side edges are weldedly attached to the downcomer baffle 124. A number of vertically spaced, transversely extending baffle plates 166 are disposed within the compartment to conduct the feedwater through both sections thereof along sinuous courses that direct the flowing liquid in substantially crossflow relation to the tubes. Both the upper and lower ends of the compartment, as defined by transverse baffle plates, 166a and 166b respectively, are open, as indicated at 167a and 167b, to discharge the preheated liquid from the compartment into the adjacent regions of the vapor generation chamber 130 where evaporation thereof occurs.

According to the present invention the economizer compartment 164 is divided into two separate sections, indicated as 180a and 180b, by means of a transverse baffle plate 182 disposed within the compartment in-

intermediate the ends thereof. The baffle plate 182 is attached about its peripheral edge to upstanding plate 165 and to that portion of the downcomer baffle 124 which forms part of the compartment enclosure. Feedwater is delivered to each of the sections by means of a pair of nozzles 154a and 154b that penetrate the pressure shell 112 and communicate with a distribution plenum 168 defined by plates extending from the outer surface of the downcomer baffle 124. The distribution plenum 168 is itself divided into two vertically spaced portions 168a and 168b by a second transverse plate 184 that extends in aligned relation with the plate 182 between the outer surface of the enclosed portion of the downcomer baffle 124 and the concentrically spaced face plate indicated as 186 of the plenum 168. The portions 168a and 168b of the distribution plenum each connect one of the nozzles 154a and 154b with the adjacent sections of 180a and 180b of the economizer compartment 164. Communication is effected by means of a plurality of circumferentially spaced openings 170 provided in the baffle 124.

The feedwater inlet nozzles 154a and 154b each connect with a source of vaporizable liquid (not shown) by means of separate supply lines which contain independently operable flow regulating valves, indicated as 188a and 188b, for controlling the rate of flow of feedwater to each of the sections of the economizer compartment. The arrangement is such that liquid entering the upper section 180a is caused to flow upwardly through the section in counterflow relation to the heating fluid flowing through the tubes 138. That entering the lower section 180b, on the other hand, flows downwardly in parallel relation to the flow of the heating fluid.

The operation of the hereindescribed vapor generator organization is as follows. With heating fluid, such as pressurized nuclear reactor liquid coolant circulated through the tubes 138 from the heating fluid inlet chamber 144 to the outlet chamber 146, regulated amounts of feedwater are admitted under pressure to the unit through the inlet nozzles 154a and 154b. The feedwater is discharged into the respective sections of 168a and 168b of the distribution plenum from whence it passes through the openings 170 into the adjacent sections 180a and 180b of the economizer compartment. That portion of the feedwater entering section 180a flows sinusoidally along an upward course through the passage defined by the transverse baffles 166 in crossflow relation to the tubes 138, finally emerging from the economizer through opening 167a into an intermediate region of the vapor generation chamber 130. The feedwater entering the other section 180b is directed downwardly in similar fashion emerging from the bottom of the compartment through opening 167b in the space between the lower end plate 166b and the upper surface of the tube sheet 134. The liquid emerging from the compartment at both ends is preferably heated to about saturation temperature whereupon it enters the vapor generation chamber 130 to be passed in heat transfer relation to the heating surface presented by the tubes 138 in the tube bundle 140. In circulating through the vapor generation chamber 130 some of the liquid is transformed into vapor and the so-created vapor-liquid mixture rises to the upper region of the chamber 130 indicated as the mixture collection chamber 160 from whence it is passed through the separators 162. The liquid separated from the mixture

within the separators is discharged into the downcomer passage 132 to be recirculated through the unit. The recirculated liquid enters the vapor generation chamber 130 at the lower end of the downcomer passage 132 and is caused to be mixed with that part of the preheated liquid that is discharged from the lower section 168b of the economizer compartment 164, the latter entering the chamber 130 at approximately the same temperature as the recirculated liquid. The separated vapor that emerges from the separators 162, on the other hand, is discharged from the upper end of the vapor generator through the outlet nozzle 122 and is conducted to a point of use.

It will be observed that in disposing the economizer compartment 164 in spaced relation from the interior surface of the shell 112 and tube sheet 134, these latter members are protected against the imposition of undue thermal stresses that would otherwise occur were cold feedwater permitted to come in contact with them. By virtue of the fact that the feedwater flow within the economizer compartment is split and directed in two opposite directions several other attendant advantages also result. Firstly, the lower end plate of the compartment, indicated as 166b, is washed with liquid at about saturation temperature thereby reducing the differential temperature that would otherwise exist between it and the tube sheet 134 were it to be contacted by unheated feedwater. The resultant bending stresses imposed upon the short tube lengths extending between the lower plate 166b and the tube sheet 134 are therefore concomitantly reduced. It will be further recognized that the feedwater leakage from the economizer compartment into the adjacent region of the vapor generator presents no serious problem because that feedwater which is leaked through the tube spaces provided in the lower end plate is heated to an elevated temperature and therefore the problem of shocking the adjacent, high temperature parts of the vapor generator is eliminated. Still further, since only heated feedwater is permitted to emerge from the lower end of the compartment as leakage, it is unnecessary to seal the holes in the end plate 166a through which the tubes pass. This, of course, results in significant savings in fabrication costs. It additionally avoids the problem of having to otherwise accommodate the longitudinal differential expansion occurring between the plate members of the economizer compartment 164 and the tubes 138 during operation of the vapor generator.

Moreover, by forming the economizer compartment of two separate sections and supplying each with feedwater by lines containing independently operable flow regulating valves the interdependence between the two flow streams prevalent in prior art units of this type with its attendant adverse effects is eliminated. Additionally, the supply of feedwater to the respective economizer sections can be accurately controlled in order to maintain maximum heat transfer efficiency over the full operational range of the vapor generator.

Still another advantageous feature of the invention is that the heat transfer efficiency in the economizer can be altered by manipulating the control valves to accommodate reduced system power requirements thereby to avoid the problem of steam blanketing in the economizer. In the present invention this is avoided by the ability to proportion feedwater flow to the two sections. If evidence of steam blanketing occurs in either of the sections more liquid can be supplied to that section to

the exclusion of the other thereby reducing the steaming in the affected section.

It will be understood that various changes in the details, materials, and arrangements of parts which have been herein-described and illustrated in order to explain the nature of the invention, may be made by those skilled in the art within the principle and scope of the invention as expressed in the appended claims.

What is claimed is:

1. In a shell-and-tube heat exchanger for the generation of vapor by the indirect transfer of heat from a heating fluid to a vaporizable liquid including a pressure vessel enclosing a bundle of heat exchange tubes and defining a vapor generating chamber, means for circulating heating fluid through said tubes, and means for supplying vaporizable liquid to said vapor generating chamber, the improvement comprising:

- a. plate means defining a compartment enclosing a portion of the heat transfer surface of said tubes and dividing said vapor generating chamber into an economizer section and an evaporator section;
- b. means defining openings at oppositely spaced ends of said compartment for discharging preheated liquid to said evaporator section;
- c. means within said compartment dividing the same into two fluidly distinct sections each communicating with one of said openings; and
- d. means for supplying vaporizable liquid to each of said compartment sections.

2. The improvement as recited in claim 1 wherein said vaporizable liquid supply means comprises individual feedwater nozzles communicating with each of said compartment sections.

3. The improvement as recited in claim 2 including separate lines connecting each of said feedwater nozzles to a source of vaporizable liquid, and means in said lines for independently regulating the flow of liquid through each.

4. The improvement as recited in claim 1 wherein said compartment includes a plurality of baffle plate members for directing each part of said vaporizable liquid in generally cross flow relation to the tubes extending through said compartment.

5. The improvement as recited in claim 1 wherein said tubes are disposed in generally parallel relation and conduct said heating fluid in similar directions through said compartment in substantial countercurrent relation to one of said parts of vaporizable liquid and substantial cocurrent relation to the other of said parts.

6. The improvement as recited in claim 2 wherein said divider means comprises a transverse plate dividing said compartment into two longitudinally spaced sections.

7. A shell-and-tube heat exchanger for the generation of vapor by the indirect transfer of heat from a heating fluid to a vaporizable liquid comprising:

- a. a generally vertically elongated cylindrical shell;
- b. transversely extending tube sheet means dividing the interior of said shell into a vapor generating chamber and heating fluid chamber means;
- c. a bundle of heat exchange tubes extending through said vapor generating chamber and having their ends attaching said tube sheet means in communication with said heating fluid chamber means for circulating heating fluid through said tubes;

- d. means for supplying vaporizable liquid to said vapor generating chamber;
- e. means for preheating said vaporizable liquid including:
 - i. a plurality of plates defining a longitudinally extending compartment disposed within said vapor generating chamber and defining evaporator and economizer sections therein;
 - ii. means defining openings adjacent the oppositely spaced ends of said compartment for discharging preheated liquid to said evaporator section;
 - iii. means within said compartment dividing the same into two fluidly distinct sections each communicating with one of said openings; and
 - iv. said vaporizable liquid supply means connecting with each of said compartment sections.

8. A heat exchanger as recited in claim 7 wherein said compartment is defined by plate members enclosing a portion of said tube bundle.

9. A heat exchanger as recited in claim 8 wherein said compartment is disposed in spaced apart relation to the interior surface of said shell-and-tube sheet to define passage means for conducting heated liquid.

10. A heat exchanger as recited in claim 9 wherein said tube bundle comprises a plurality of vertically extending, generally U-shaped tubes and including a downcomer baffle surrounding said tubes in concentrically spaced relation to the internal surface of said shell to define an annular downcomer passage.

11. A heat exchanger as recited in claim 10 wherein said compartment is defined about its outerperiphery by a portion of the lower end of said downcomer baffle and about its inner periphery by a vertically extending planar plate whose end edges attach the inner surface of said downcomer baffle.

12. A heat exchanger as recited in claim 11 wherein said divider means comprises a transverse plate dis-

posed within said compartment intermediate the ends thereof to define two longitudinally spaced sections, said transverse plate being sealingly attached about its peripheral edge to said downcomer baffle and said planar plate.

13. A heat exchanger as recited in claim 12 wherein said vaporizable liquid supply means comprises individual feedwater nozzles communicating with each of said compartment sections.

14. A heat exchanger as recited in claim 13 including separate lines connecting each of said feedwater nozzles to a source of vaporizable liquid, and valve means in said lines for regulating the flow of liquid through each.

15. A heat exchanger as recited in claim 11 wherein said compartment includes a plurality of vertically spaced, transversely extending baffle plate members for directing each of the parts of the flow of vaporizable liquid in generally crossflow relation to the tubes extending through said compartment.

16. A heat exchanger as recited in claim 11 including transversely extending plates defining the upper and lower ends of said compartment, said plates containing means defining openings for establishing fluid communication between the interior of said compartment and the adjacent region of said evaporator section.

17. A heat exchanger as recited in claim 16 wherein the liquid discharged from said compartment to said evaporator section is at about saturation temperature.

18. A heat exchanger as recited in claim 17 wherein the lower end of said downcomer baffle is vertically spaced from the adjacent tube sheet and the lower end of said downcomer passage is in open fluid communication with said evaporator section adjacent the lower end of said compartment.

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