April 20, 1965 H. R. LAWRANCE ETAL 3,178,891

FEEDWATER HEATER

Filed March 16, 1962 5 Sheets-Sheet 1

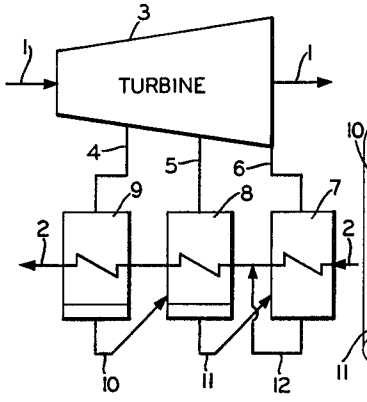
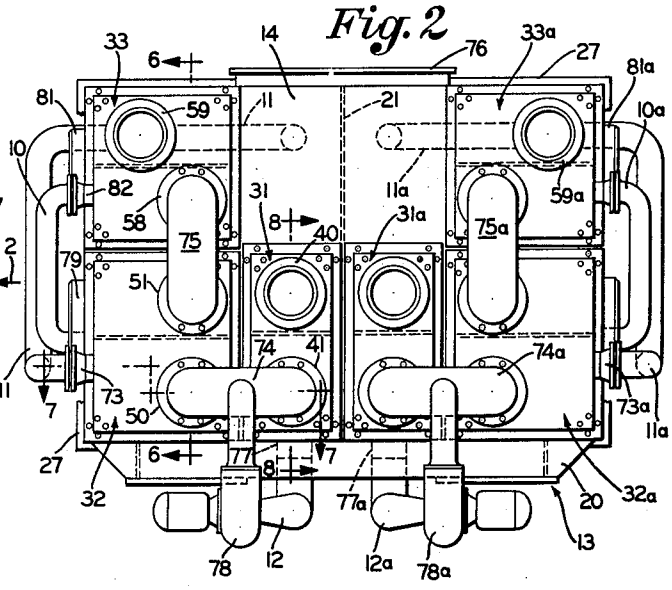


Fig. 1

Fig. 2



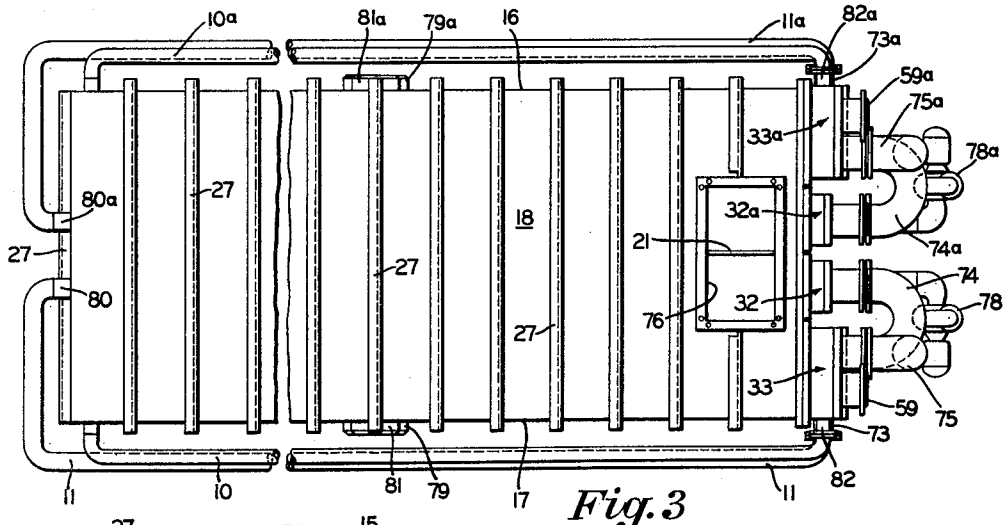


Fig. 3

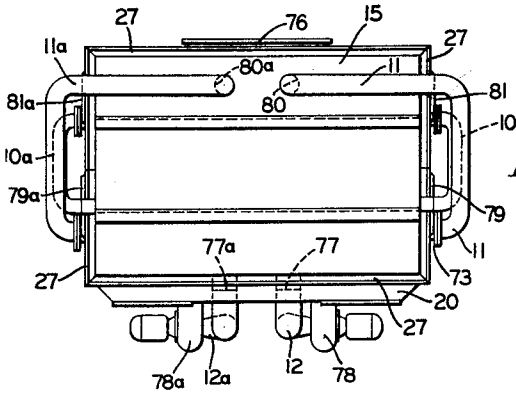


Fig. 4

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FEEDWATER HEATER

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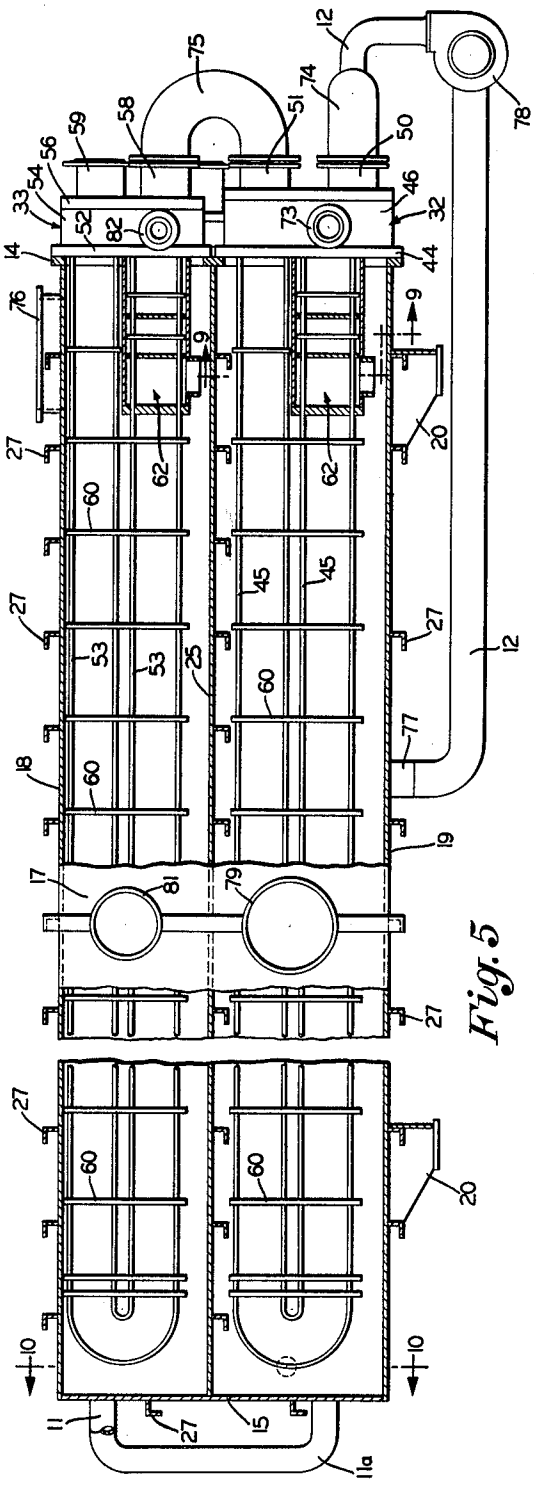


Fig. 5

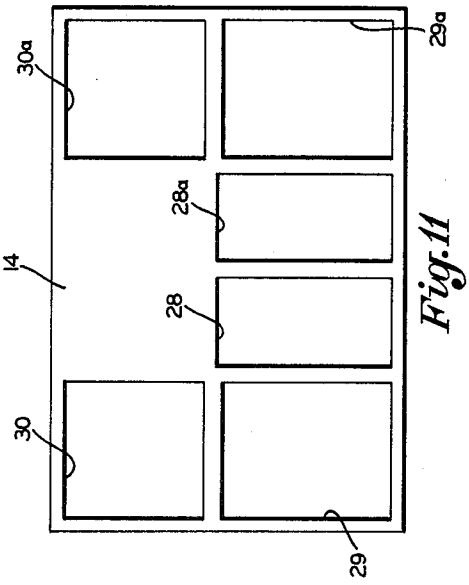


Fig. 11

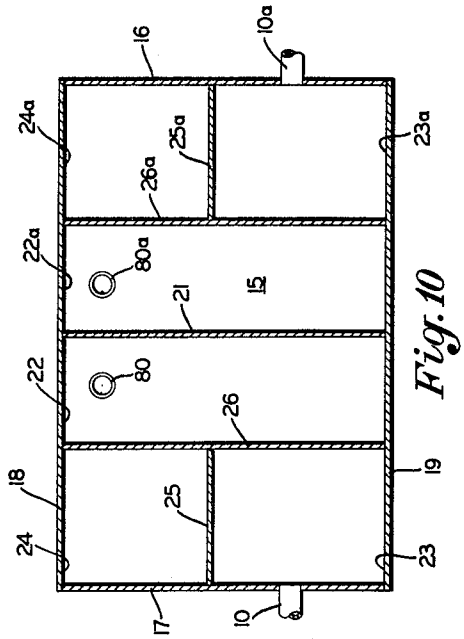


Fig. 10

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FEEDWATER HEATER

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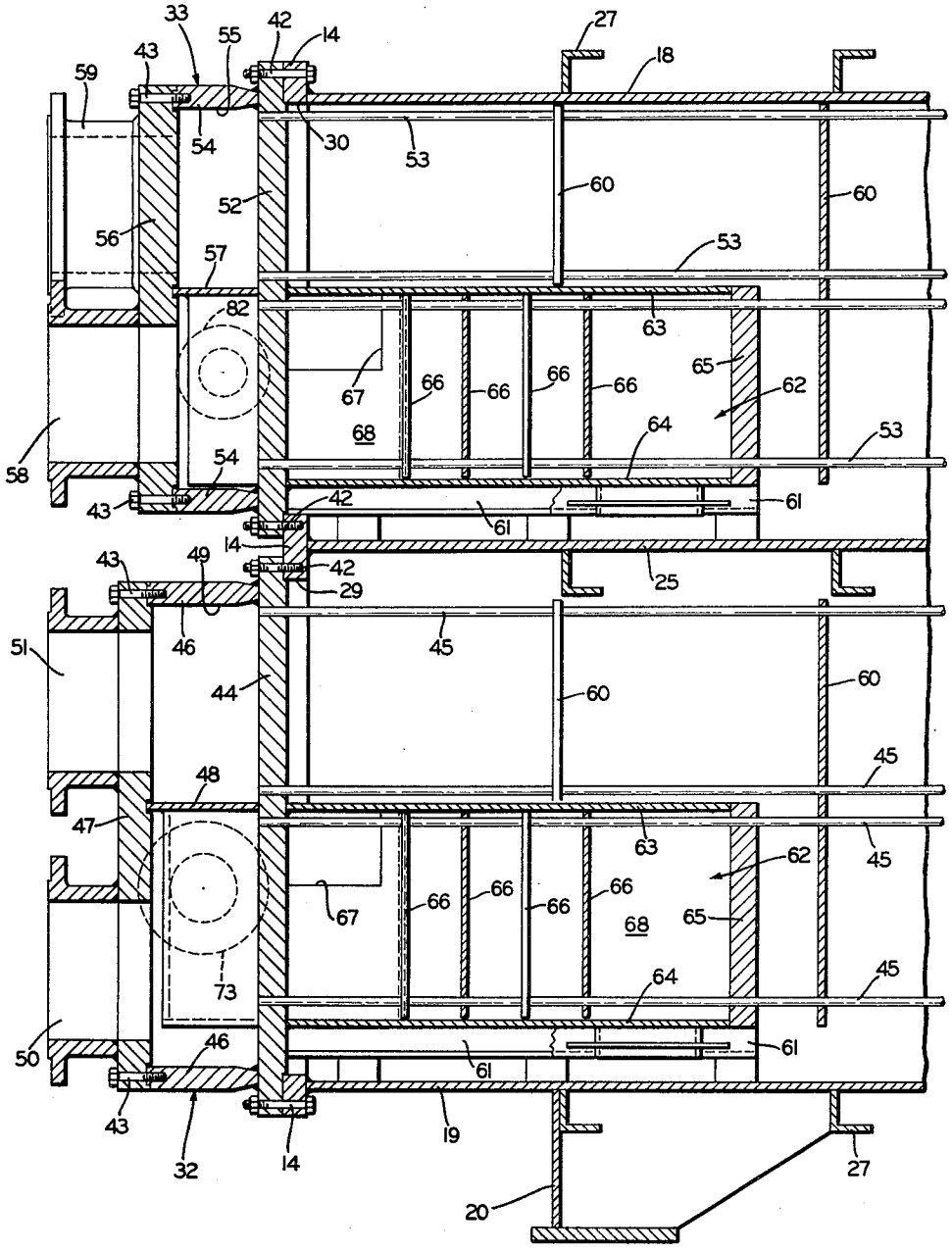


Fig. 6

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FEEDWATER HEATER

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Fig. 7

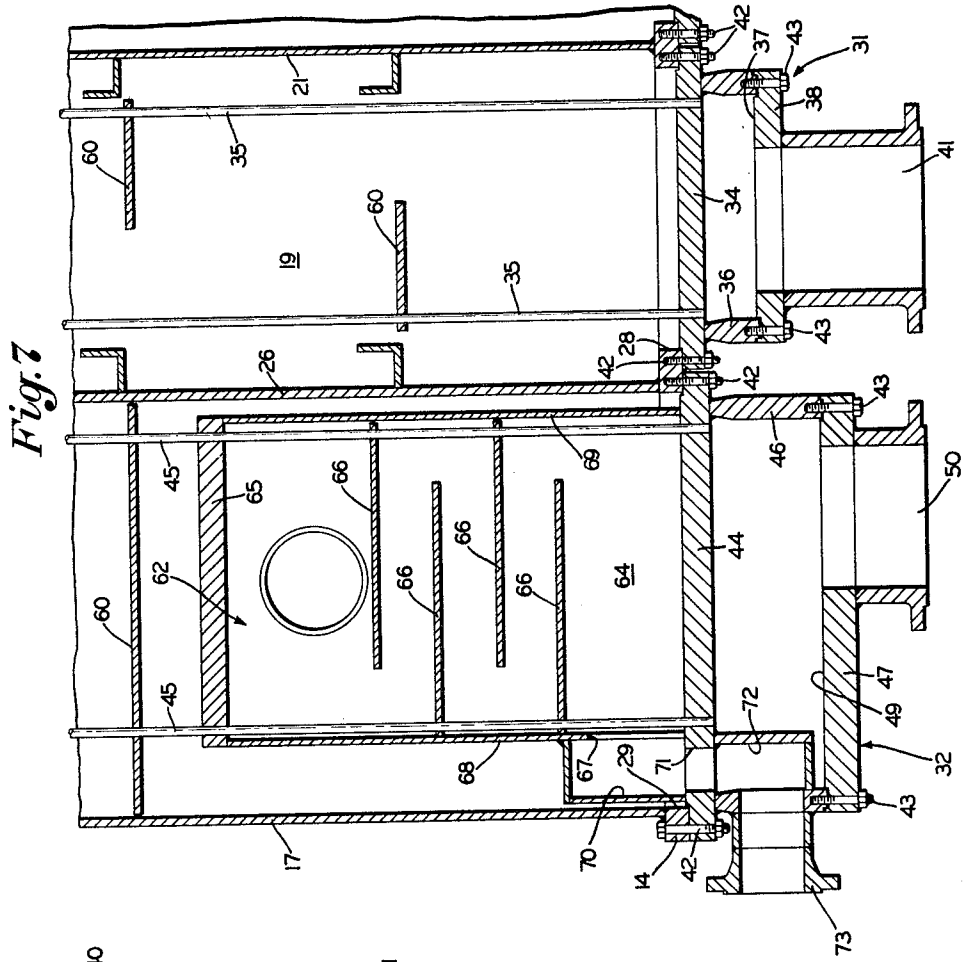
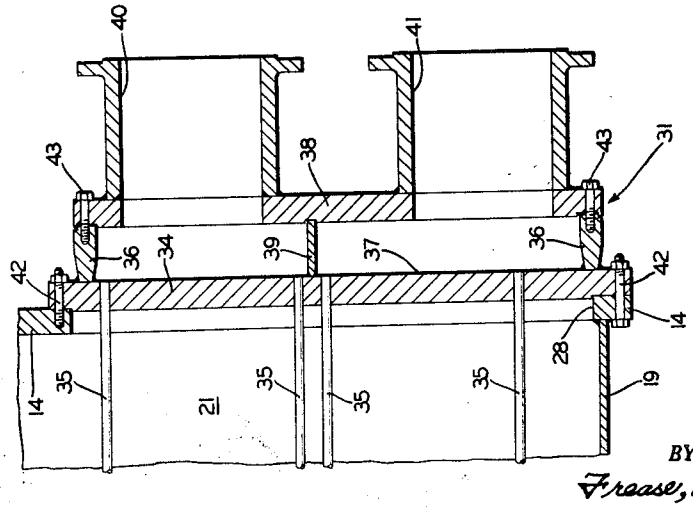


Fig. 8



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FEEDWATER HEATER

Filed March 16, 1962 5 Sheets-Sheet 5

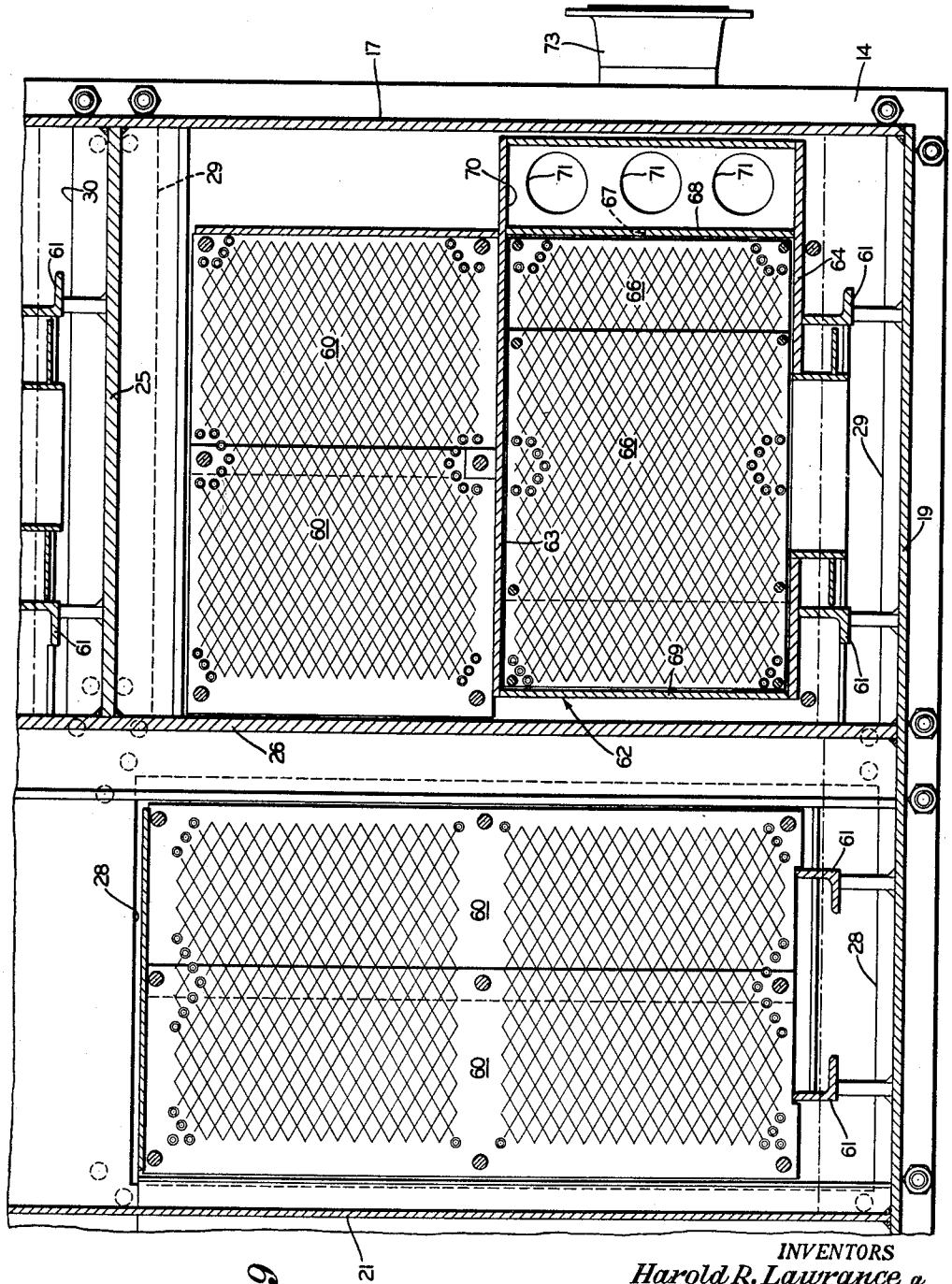


Fig. 9

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3,178,891

FEEDWATER HEATER

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Filed Mar. 16, 1962, Ser. No. 180,947
9 Claims. (Cl. 60—67)

This invention pertains to feedwater heaters and more particularly it relates to packaged feedwater heaters.

Feedwater heaters are used to take steam from one or more extraction points on a turbine to transfer heat from the steam to the boiler feedwater as the water passes from the main condenser hotwell to the boiler.

The economy of using steam bleed from the main turbine for progressive heating of the condensate or boiler feed on its way to the boiler has long been established. General recognition of this economy has brought about the extensive use of feedwater heaters in industrial plants and in large central power-generating stations.

A primary problem in feedwater heater design is to provide the most complete and efficient transfer of heat from the steam in the shell to the water flowing through the heater tubes. To obtain that result the arrangement of the tubes and baffles in the feedwater heater must assure uniform distribution of the steam without an undue high velocity, and provide adequate condensate drainoff and ample opportunity for venting non-condensible gases. Skillful design is also necessary to prevent vibration of the tubes, to assure ample strength of all parts, tightness of all joints, and ease of inspection, cleaning, and renewal of parts.

A number of feedwater heaters are frequently used in series to achieve greater efficiency of heat extraction than is possible with a single heater installation. A plurality of low pressure heaters are usually singly mounted in individual shells with a high pressure feedwater pump connected to move the feedwater through the several heaters. In that manner the heaters condense steam as used from the main steam turbine. Such an arrangement involved many conduits or pipes which included extended lengths, turns, inlets, and outlets, as well as extensive insulation and supporting structure. That type of installation is very costly.

In view of the inefficiencies inherent in prior singly mounted feedwater heater installations, it was desirable to provide a new and different heater arrangement having greater efficiency as well as reduced cost of installation and maintenance.

Associated with the foregoing problems has been the gradual development of larger power stations in which the requirements for feedwater heaters increased greatly over prior constructions and as a result required complicated interconnecting conduits. In brief, the requirement of larger power stations simply meant that more valuable space was required in the form of larger floor space and larger housing to contain the installations.

It has been found that a plurality of feedwater heaters can be combined in a single container in which the number of heater units packaged together is dependent upon the need of the user. Such a construction includes individual heater units enclosed in an outer common shell and separated by partition walls so that the pressure within each heater is independent of that of adjacent heaters.

Moreover, it has been found that a most efficient basis for operation of packaged or combined individual heaters

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is to provide the heater units symmetrically on opposite sides of a vertical center wall so that two parallel flow paths for the steam and feedwater are provided. That arrangement involves two separate groups of heaters with each group including two or more heaters through which split streams of steam flow in parallel paths.

As a result, it is expedient to arrange separate heater units in stages of increasing steam pressure, which groups of stages are placed on opposite sides of a vertical center wall so that isolation can be provided to permit operation, if necessary, of only one side of the unit in the event that an emergency causes the stages on the other side to be shut down for repair. The possibility, however, of shutting down one half of the heater is a desirable feature but not necessary for successful operation.

With such an arrangement it has been found that three stages of heaters operate satisfactorily. The heater nearest the vertical center wall is preferably used to condense steam flowing through the turbine exhaust and operates at the lowest pressure steam of any heater in the packaged unit. The feedwater which is preliminarily heated in the heater nearest the vertical center wall then enters a second heater where the steam has a higher temperature and pressure. Thereafter the feedwater flows into a subsequent heater at still higher steam temperature and pressure.

In addition to the advantage of conserving space a packaged heater is desirable for other reasons. All heater units of a packaged heater are contained within the same external walls, and they have common partition walls between them. Moreover, if the units are separate from each other, insulation is required for each unit but the units in a packaged heater are separated merely by partition walls and insulation is required only for the external walls.

Another saving is obtained in the reduction of supporting structures necessary for a packaged heater. At the same time, labor costs of installation are greatly reduced.

Accordingly, it is a general object of this invention to provide a feedwater heater having a plurality of individual heater units contained within a common shell housing.

It is another object of this invention to provide a feedwater heater in which the heater units are divided by single partition walls by which the pressures and temperatures of each unit are isolated from those of adjacent units.

It is another object of this invention to provide a feedwater heater which is used in conjunction with a turbine and on which a turbine can be directly mounted.

It is another object of this invention to provide a feedwater heater in which a plurality of feedwater heater units are separated into two groups on opposite sides of a vertical wall whereby the incoming steam follows a split stream pattern as it enters the packaged heater.

It is another object of this invention to provide a feedwater heater having two separate groups of heater units in which one group may be shut down for emergency repairs and the other group continued in operation without substantially reducing the over-all efficiency of the packaged heater.

Finally, it is an object of this invention to provide a packaged feedwater heater containing a plurality of individual heater units which accomplishes the foregoing desiderata in an inexpensive manner and with simplified maintenance and operation.

These and other objects and advantages apparent to those skilled in the art from the following description

and claims may be obtained, the stated results achieved, and the described difficulties overcome, by the apparatus, constructions, arrangements, combinations, subcombinations, elements, parts, and principles, which comprise the present invention, the nature of which is set forth in the foregoing general statements, a preferred embodiment of which—illustrative of the best mode in which applicants have contemplated applying the principles—is set forth in the following description and shown in the drawings, and which is particularly and distinctly pointed out and set forth in the appended claims forming part hereof.

Generally, the nature of the feedwater heater construction of the instant invention includes an elongated shell housing providing a rectangular shell chamber, the chamber being separated into half-portions by a central vertical partition wall, each chamber half-portion being further subdivided into two or more feedwater heater units by partition wall means, tube bundle and tube sheet means in each feedwater heater unit, the number of feedwater heater units on opposite sides of the central vertical partition wall being equal, the units on one side of the central vertical partition wall being arranged at increasing operating temperatures and in a sequential path of movement for the feedwater, the outlet side of the tube and tube sheet means of each unit being connected to the inlet side of the tube sheet means of an adjacent unit, a conduit for draining steam condensate from the units of higher heating temperature and to the units of the next lower temperature, and a conduit for draining steam condensate from the lowest temperature unit and to the feedwater tube of the next higher temperature unit.

By way of example, a preferred embodiment of the apparatus of the present invention is shown in the accompanying drawings, wherein:

FIGURE 1 is a diagrammatic view of a steam turbine and feedwater heater units showing the paths of flow of steam from stages of the turbine to the heater units and the path of flow of the feedwater through the units;

FIG. 2 is an end view of a packaged feedwater heater showing symmetrical arrangement of an equal number of heater units on opposite sides of a central vertical partition plate;

FIG. 3 is a plan view of the feedwater heater shown in FIG. 2;

FIG. 4 is an end view of the heater opposite the view shown in FIG. 2;

FIG. 5 is a vertical sectional view, partly in elevation, of one side of the heater;

FIG. 6 is an enlarged vertical sectional view taken on the line 6—6 of FIG. 2;

FIG. 7 is an enlarged horizontal sectional view taken on the line 7—7 of FIG. 2;

FIG. 8 is an enlarged vertical sectional view taken on the line 8—8 of FIG. 2;

FIG. 9 is an enlarged vertical sectional view taken on the line 9—9 of FIG. 5;

FIG. 10 is a vertical sectional view taken on the line 10—10 of FIG. 5; and

FIG. 11 is an elevational view of the detached shell flange, showing the symmetrical position of the openings on opposite sides of a vertical center line for the heater.

Similar numerals refer to similar parts throughout the drawings.

In FIG. 1, the flow lines for steam **1** and feedwater **2** are shown diagrammatically with the steam entering a turbine **3**. Separate streams **4**, **5**, and **6** of steam are extracted at three stages along the turbine, the steam **4** being hotter than the steam **5** which in turn is hotter than the steam **6**. As the feedwater **2** passes through heater units **7**, **8**, and **9** of successively higher temperature and pressure, the feedwater absorbs heat from the steam **6**, **5**, and **4**, respectively. The condensed steam **4** in the heater unit **9** is pumped from the bottom of the heater through a conduit **10** to the shell of the heater unit **8** where it combines with the steam **5** entering said heater unit. Likewise, the condensed steam **5** in the heater unit **8** is pumped from the bottom of the heater through a conduit **11** into the chamber of the heater unit **7** where it combines with the steam **6** for heating the incoming feedwater **2**. The resulting condensed steam in the heater unit **7** is pumped from the bottom of the heater through a conduit **12** into the feedwater stream between the heater units **7** and **8**, as shown.

As shown in FIGS. 2–11, a feedwater heater construction is generally indicated at **13**, which includes a front end wall **14**, a rear end wall **15**, side end walls **16** and **17**, top wall **18**, and bottom wall **19**. The feedwater construction **13** is preferably an elongated rectangular structure having spaced support members **20**. The walls **14–19** provide an inner chamber which is divided into right and left half-portions by a vertical partition wall **21** which extends longitudinally between front and rear end walls **15** and **16** and vertically between top and bottom walls **18** and **19**.

Each half-portion of the chamber is likewise separated into a plurality of smaller longitudinal chambers or compartments **22**, **23**, and **24** by partition walls **25** and **26**, as shown for the left-hand side of the device as viewed in FIG. 10. Inasmuch as the right and left sides of the heater **1** are identical in size and construction, a description of one side is understood to include a description of the other side. Corresponding elements on the right side are similarly numbered with the letter "*a*" added as a suffix. For example, the right-hand side of the device includes chambers **22***a*, **23***a*, and **24***a*, and partition walls **25***a* and **26***a*.

The various walls **15–19**, **25**, and **26** are reinforced by a plurality of spaced angle members **27** of similar construction, which members reinforce the surfaces of the walls and prevent them from sagging.

As shown in FIG. 11, the front end wall **14** is provided with a plurality of rectangular openings **28**, **29**, and **30**, which openings are aligned with the several chambers **22**, **23**, and **24**, respectively (FIG. 10). The chambers **22–24** and the openings **28–30** are symmetrically disposed on opposite sides of the vertical partition plate **21**. As shown in FIGS. 2, 6, and 8, a tube and tube header assembly **31**, **32**, and **33** are mounted in the openings **28–30** and chambers **22–24**, respectively.

In FIG. 8, the assembly **31** is provided with a tube sheet **34**, a plurality of U-tubes **35**, a header wall **36** extending outwardly from the tube sheet and forming a header chamber **37**, and a header cover **38**. The chamber **37** is divided into upper and lower portions by a partition plate **39** and a feedwater inlet **40** and a feedwater outlet **41** are connected to the upper and lower portions, as shown. The tube sheet **34** is secured to the front wall **14** by similar studs **42** and the cover **38** is secured to the header wall **36** by bolts **43**.

In a similar manner, the tube and tube header assembly **32** (FIG. 6) includes a tube sheet **44**, U-tubes **45**, a header wall **46**, and a header cover **47**. A partition plate **48** separates the header chamber **49** into lower and upper portions to which feedwater inlet **50** and feedwater outlet **51** are connected, respectively.

Likewise, the tube and tube header assembly **33** (FIG. 6) includes a tube sheet **52** with U-tubes **53**, header walls **54** forming a header chamber **55**, and header cover **56**. A partition plate **57** separates the chamber **55** into lower and upper portions to which a feedwater inlet **58** and a feedwater outlet **59** are connected, respectively. The tube sheets **44** and **52** are secured to the front end wall **14** by similar studs **42** and the tube covers **47** and **56** are secured to their respective assemblies by similar bolts **43**.

At spaced longitudinal intervals of the tube bundles **35**, **45**, and **53**, a plurality of similar tube support plates **60** are provided, as shown in FIGS. 5 and 9. The plates **60** are of conventional construction and are preferably staggered (FIG. 9) to provide a zigzag path for the steam as it moves through the several chambers **22**, **23**, and **24**

in contact with the tubes. The plates are mounted on each end and supported by spaced members 61 of substantially similar construction in each chamber 22, 23, and 24 and which extend longitudinally along the bottom of each chamber.

Accordingly, the feedwater heater construction 13 is composed of a plurality of feedwater heater units which operate substantially independently of each other to the extent that each separate heater unit receives steam from a different stage of the turbine 3 and operates at a different temperature and pressure. All of the feedwater heater units are contained within the same outer housing walls 14–19 and all of the heater units heat the same feedwater in successive stages from an inlet temperature of approximately 100° to an outlet temperature of approximately 255° F.

The feedwater enters the heater construction 13 and passes first through the heater unit in chamber 22 and subsequently through the heater units in chambers 23 and 24. The operational temperature and pressure of the first unit are relatively low. However, in the chambers 23 and 24 the units operate at increasingly higher temperatures and pressures, for which reason the units in those chambers are additionally provided with steam subcooling zones generally indicated at 62 in FIG. 6.

The zones 62 in both chambers are identical so that the description of one includes a description of the other. The zone 62 is a boxlike structure enclosing a longitudinal portion of the bundle of tubes at the feedwater entry end of the unit. Each zone is enclosed within a pair of upper and lower plates 63 and 64 which extend outwardly from the inner surface of the tube sheet 44 and 52. The end of the zone 62 opposite the tube sheet includes an end plate 65.

The tubes within the zones pass between spaced baffle plates 66 which are staggered at longitudinal intervals to provide a devious or zigzag path for the steam. In the desuperheat zones 62, the heat in the steam is removed as much as possible for the existing operating conditions, whereupon the condensed steam settles upon the bottom plate 64 and fills the zone until it exits through an opening 67 in one of a pair of zone side plates 68 and 69 (FIGS. 6 and 7). The condensate then flows into a chamber 70 from which it passes through vertically spaced openings 71 in the particular tube sheet involved (FIGS. 7 and 9). The openings 71 in turn communicate with an outlet compartment 72 which in turn communicates with an outlet nozzle 73, as shown in FIG. 7.

In operation, the packaged feedwater heater construction 13 operates in the manner generally indicated with respect to the diagrammatic view in FIG. 1. More particularly, the feedwater enters the feedwater heater construction through a feedwater inlet 40 (FIGS. 2 and 8) and after passing through the U-tubes 35 it leaves the first feedwater heater unit assembly 31 through the feedwater outlet 41.

The feedwater then flows through an elbow connector 74 (FIGS. 2, 3, and 5) and into the second feedwater heater unit assembly 32 through the feedwater inlet 50. After passing through the U-tubes 45 the feedwater leaves said assembly through the outlet 51 and enters an elbow connector 75 where it enters the third feedwater heater unit assembly 33. Thereafter the feedwater passes through the U-tubes 53 and passes out of the assembly 59.

The stream 6 of steam from the coolest stage of the turbine (FIG. 1) enters the feedwater heater through a steam inlet opening 76 in the top wall 18 (FIGS. 2 and 3). Because of the vertical partition wall 21, the steam is divided into a split stream, half of which passes through the heater unit assembly 31 on the left side of the wall, and the other half of which passes through a similar heater unit 31*a* on the right side of the wall.

The steam in the chambers 22 and 22*a* (FIG. 10) condenses upon yielding its heat to the incoming feedwater in the tubes 35 and the condensate collects on the bottom wall 19 from where it is drained through an outlet 77 (FIGS. 2, 4, and 5) from where it is transported through a conduit 12 by means of a pump 78 into the elbow connector 74 (FIG. 2). In that manner the cooled condensate from the first feedwater heater unit enters the stream of feedwater passing through the remaining feedwater heater units of the feedwater heater construction 13.

The stream 5 of steam (FIG. 1) which is extracted from an intermediate portion of the turbine 3 enters the intermediate feedwater heater unit through a steam inlet 79 which communicates with the chamber 23 (FIG. 5). When the steam yields its heat to the feedwater in the tubes 45 the steam is substantially completely condensed and it enters the subcooling zone 62 from which it ultimately flows through the nozzle 73.

The condensate is then pumped through the conduit 11 and is directed into the chamber 22 through an opening 80 (FIG. 10) in the rear wall 15 where the remaining heat in the condensate mixes with the steam entering said chamber and is transferred to the feedwater in the tubes 35.

The stream 4 of steam (FIG. 1) which is extracted from an early stage of the turbine 3 enters the last feedwater heater unit through steam inlet 81 (FIGS. 2 and 5) where it contacts the U-tubes 53 and is condensed upon yielding its heat to the feedwater therein. The feedwater then leaves the feedwater heater construction through the outlet 59.

The condensate in the chamber 24 accumulates on the partition wall 25 from where it ultimately moves through the feedwater heater zone 62 and out through an outlet nozzle 82. The condensate then passes through the conduit 10 and enters the chamber 23 where it mixes with the steam and condensate of that unit for the purpose of yielding its remaining heat to the feedwater passing through the tubes 45 of that unit.

The device of the present invention provides a packaged feedwater heater including a plurality and preferably three heater units contained in one housing on the same support structure. The heater is a split steam heater because the entire housing is divided so that two half-portions of the steam and two half-portions of the feedwater pass through similar half-portions of the heater.

Among the advantages inherent in the foregoing packaged feedwater heater is that of providing a unified assembly of several feedwater heater units. Such a construction provides many economies not only in the reduced number of parts involved as compared with prior separate units, but also in the economy of space where space is at a premium, such as on board a ship.

Another benefit derived from the foregoing feedwater heater is the advantage of a split steam heater. By dividing the housing into two half-portions it is possible in the event of an emergency to shut down one half-portion for repair while maintaining the other portion without undue difficulty. For that purpose it is merely necessary to close the supply of feedwater entering the side which is shut down.

In the foregoing description certain terms have been used for brevity, clearness and understanding, but no unnecessary limitations have been implied therefrom as such words are used for descriptive purposes and are intended to be broadly construed.

Moreover, the embodiment of the improved construction illustrated and described herein is by way of example and the scope of the present invention is not limited to the exact construction shown.

Having now described the invention, construction, operation and use of a preferred embodiment thereof and the advantageous, new and useful results obtained thereby; the new and useful feedwater heater and reasonable mechanical equivalents thereof obvious to those skilled in the art are set forth in the appended claims.

What is claimed is:

1. A packaged feedwater heater for steam turbine having a plurality of steam extraction points of varying temperature and pressure including,

(*a*) shell housing walls providing a horizontal shell chamber,

(*b*) a plurality of partition walls extending between the shell housing walls and dividing the chamber into a plurality of separate horizontal adjacent compartments,

(*c*) tube sheet means for each compartment,

(*d*) tube bundle means for condensing steam to steam condensate in each compartment connected with the tube sheet means for said compartment,

(*e*) each compartment and its tube sheet and tube bundle means constituting a feedwater heater unit,

(*f*) the tube bundles in the several units being connected in series to provide progressively higher heating stages,

(*g*) means for introducing feedwater to be heated into the tubes of the tube bundle of the lowest heating stage unit,

(*h*) means connecting the compartment for each heating unit to a separate turbine steam extraction point,

(*i*) the heating unit of the first stage being connected to an extraction point of turbine steam having the lowest temperature and pressure, and

(*j*) the heating unit of the last stage being connected to an extraction point of turbine steam having the highest temperature and pressure.

2. The feedwater heater construction as set forth in claim 1 in which conduit means is provided for draining steam condensate from the units of higher heating temperature and to the units of the next lower temperature.

3. The feedwater heater construction of claim 2 in which the conduit means is provided for draining condensate from the lowest temperature unit and to the feedwater tubes of the next higher temperature unit.

4. A packaged feedwater heater for steam turbine having a plurality of steam extraction points of varying temperature and pressure including,

(*a*) shell housing walls providing a horizontal shell chamber,

(*b*) a partition wall extending between the shell housing walls and dividing the chamber into separate horizontal adjacent chamber portions,

(*c*) each chamber portion being subdivided by additional partition walls into at least two separate compartments,

(*d*) tube sheet means for each compartment,

(*e*) tube bundle means for condensing steam to steam condensate in each compartment connected with the tube sheet means for said compartment,

(*f*) each compartment and its tube sheet and tube bundle means constituting a feedwater heater unit,

(*g*) the tube bundles in the several units on one side of the partition wall being connected in series to provide progressively higher heating stages,

(*h*) means connecting the compartment of each unit to a separate turbine steam extraction point, and

(*i*) the steam extracted for the first unit having a lower temperature and pressure than the steam extracted for the last unit.

5. The feedwater heater construction as set forth in claim 4 in which conduit means is provided for draining steam condensate from the unit of higher heating temperature and to the unit of the next lower temperature.

6. The feedwater heater construction of claim 5 in which the conduit means is provided for draining condensate from the lowest temperature unit and to the feedwater tubes of the next higher temperature unit.

7. A packaged feedwater heater for steam turbine having a plurality of steam extraction points of varying temperature and pressure including,

(*a*) elongated shell housing walls providing a horizontal shell chamber,

(*b*) a partition wall extending between the shell housing walls and dividing the chamber into separate horizontal adjacent chamber portions,

(*c*) each chamber portion being subdivided by additional partition walls into at least two separate compartments,

(*d*) tube sheet means for each compartment,

(*e*) tube bundle means for condensing steam to steam condensate in each compartment connected with the tube sheet means for said compartment,

(*f*) each compartment and its tube sheet and tube bundle means constituting a feedwater heater unit,

(*g*) the tube bundles in the several units on one side of the partition wall being connected in series to provide progressively higher heating stages,

(*h*) the tube sheet means for the several heater units being disposed at one end of the shell housing,

(*i*) the tube sheet means for each unit having feedwater inlet and outlet openings,

(*j*) means for interconnecting the outlet and inlet openings between the tube sheet means of successive units,

(*k*) conduit means for draining steam condensate from the unit of a higher stage to the unit of the next lower temperature, and

(*l*) conduit means for draining condensate from the unit of the lowest temperature and to the tube bundle in the next higher temperature unit.

8. A packaged feedwater heater for steam turbine having a plurality of steam extraction points of varying temperature and pressure including,

(*a*) elongated shell housing walls providing a horizontal shell chamber,

(*b*) a vertical partition wall extending between the shell housing walls and dividing the chamber into separate horizontal adjacent chamber portions,

(*c*) each chamber portion being subdivided by additional partition walls into three compartments,

(*d*) tube sheet means for each compartment,

(*e*) tube bundle means for condensing steam to steam condensate in each compartment connected with the tube sheet means for said compartment,

(*f*) each compartment and its tube sheet and tube bundle means constituting a feedwater heater unit,

(*g*) the tube bundles in the several units being connected in series with tube bundles on the same side of the partition wall to provide progressively higher heating stages,

(*h*) the heater units comprising first, second, and third stages on each side of the partition wall,

(*i*) the first, second, and third stages of the units on one side of the partition wall operating at temperatures and pressures corresponding to the first, second, and third stages of the units on the other side of the partition wall,

(*j*) the compartments of the first stages being connected to an extraction point of turbine steam having a minimum temperature and pressure,

(*k*) the compartments of the second stages being connected to an intermediate extraction point of turbine steam, and

(*l*) the compartments of the third stages being connected to an extraction point of turbine steam having higher temperature and pressure.

9. The feedwater heater construction as set forth in claim 8 in which conduit means is provided for draining steam condensate from each third stage to the corresponding second stage, in which conduit means is provided for draining condensate from each second stage to the corresponding first stage, and in which conduit means is provided for draining condensate from the first stage to the tube bundle in the corresponding second stage.

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2,566,732	9/51	Krieg	60—67 X
2,643,519	6/53	Powell	60—67
2,964,910	12/60	Sonnefeld	60—67
2,991,620	7/61	Nekolný	60—67
3,016,712	1/62	Taylor	60—67

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