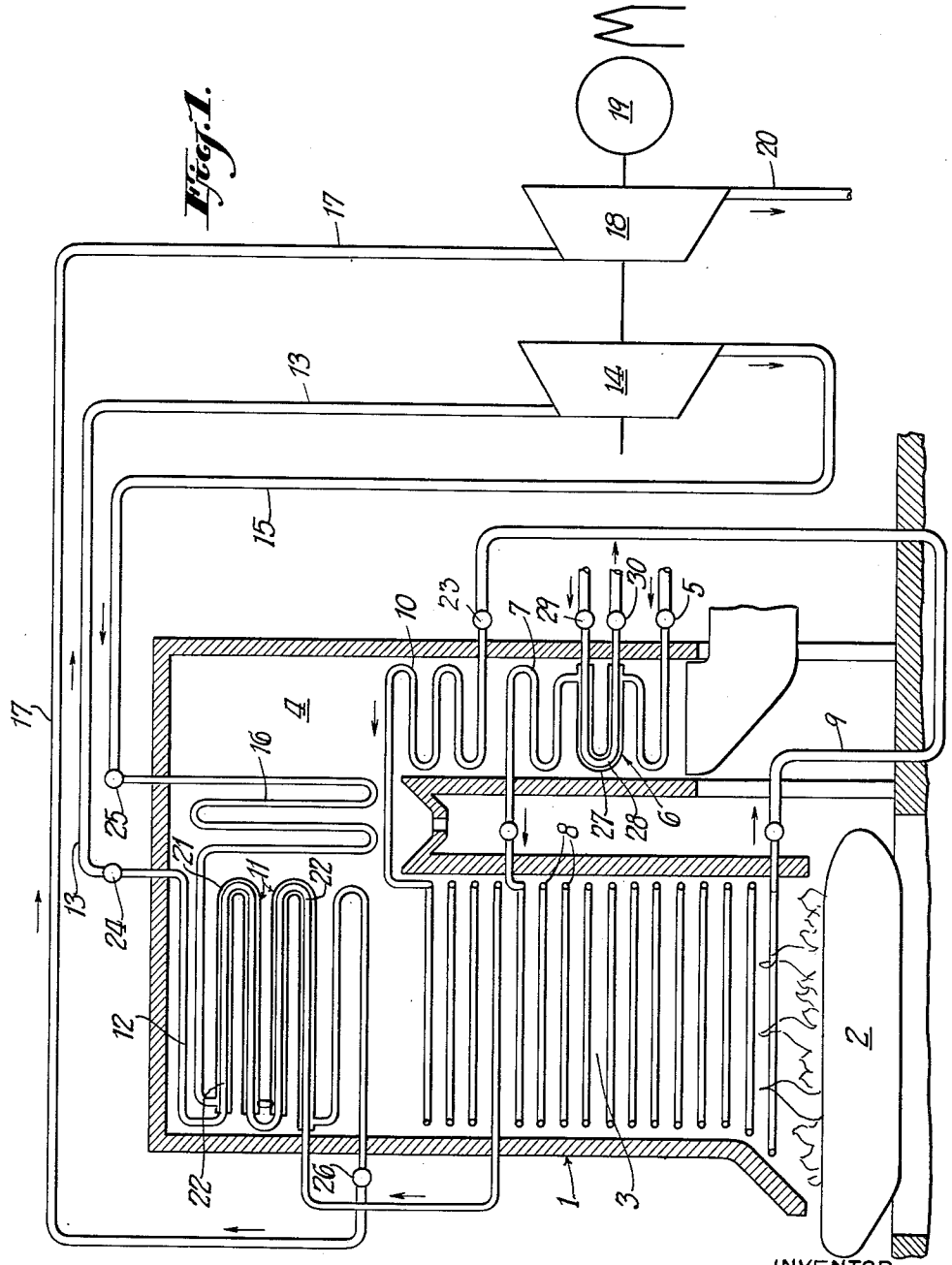
May 9, 1961 A. LIEBERHERR 2,983,262

STEAM GENERATING, SUPERHEATING, AND RESUPERHEATING PLANT

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Fig. 1.



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STEAM GENERATING, SUPERHEATING, AND RESUPERHEATING PLANT

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Fig. 3.

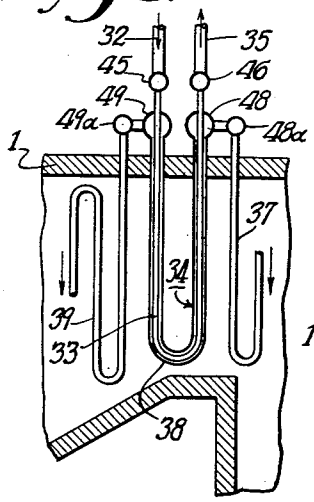


Fig. 2.

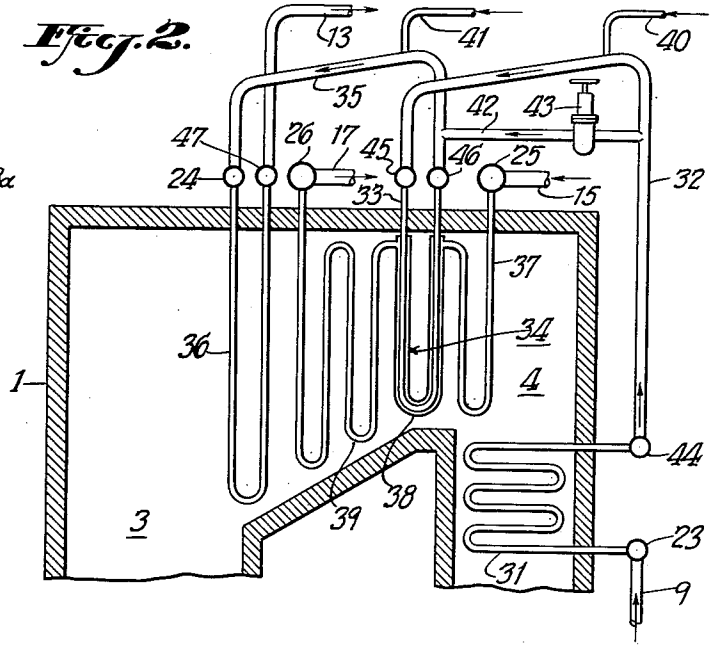


Fig. 4.

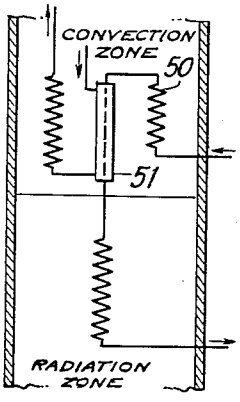


Fig. 5.

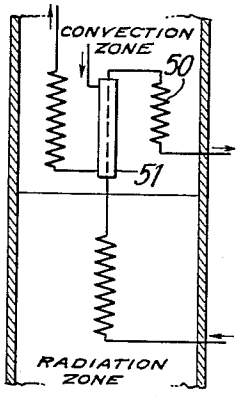


Fig. 6.

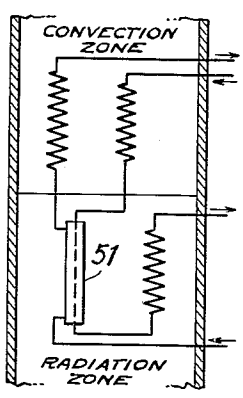
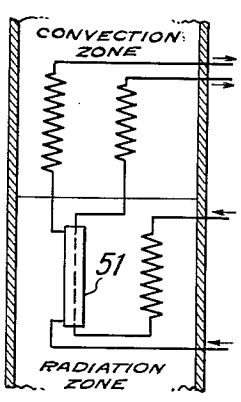


Fig. 7.



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2,983,262

STEAM GENERATING, SUPERHEATING, AND RESUPERHEATING PLANT

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5 Claims. (Cl. 122—478)

The present invention relates to a steam generating, superheating and resuperheating plant.

The resuperheater of the plant according to the invention includes a heat transfer apparatus which is placed inside the steam generator for receiving heat from the products of combustion by convection or radiation and in which heat is indirectly exchanged between a high pressure operating fluid, which is heated in tubes forming part of the generator, and the steam to be resuperheated.

The present application is a continuation-in-part application of the copending application Serial No. 485,061, filed January 31, 1955, now Patent No. 2,878,791.

The heat transfer apparatus is formed by a group of outer tubes or conduits and a group of tubes disposed inside the outer tubes. If the steam to be resuperheated, which is partly expanded, is conducted through the outer tubes and the high pressure fluid is conducted through the inner tubes, the partly expanded steam exchanges heat with the combustion gases and with the high pressure fluid. If the combustion gases and/or the high pressure fluid are hotter than the steam to be resuperheated, the resuperheating process requires considerably less heating surface and is performed more quickly than in an arrangement in which a part of the heat is indirectly transferred outside of the steam generator from high pressure steam to the steam to be resuperheated, and in which another part of the heat is transferred inside the steam generator from hot combustion gases to the steam to be resuperheated. Radiation losses such as are caused by an indirectly heated resuperheater portion placed outside of the steam generator are avoided with the arrangement according to the invention. No insulation is required for the heat transfer apparatus. Aside from this, no additional space is required outside of the steam generator and pressure losses caused by the high pressure steam pipes connecting an indirect resuperheater with the tubular heating surfaces of the steam generator are eliminated. The temperature of the steam leaving the inner tube or tubes of the heat transfer apparatus is considerably higher, if the heat transfer apparatus is exposed to the hot combustion gases than if the apparatus is placed outside of the steam generator, and fuel is saved. The high pressure steam and the low pressure steam may flow in counterflow relation or in the same direction, in contradistinction to heat transfer apparatus arranged outside of the steam generator in which apparatus the high pressure and the low pressure steam must flow in counterflow relation to obtain the desired heat transfer.

The heat transfer apparatus according to the invention may be used for regulating the resuperheat temperature. In this case heating or cooling means and temperature control means are connected with the tubular heating surfaces for the high pressure fluid, so that the high pressure fluid cools the partly expanded steam when

the latter is too hot, and heats the partly expanded steam when the latter is too cool.

Though it may appear advantageous to arrange a plurality of inner tubes in each outer tube of the heat transfer apparatus, for improving heat transfer, pressure, and constructional conditions, it will be preferable in most cases to arrange only one tube inside each outer tube, particularly if the tubes are bent in hair pin like fashion. If several hair pin units are connected in series, the heat transfer apparatus may be arranged in zig-zag manner.

If, as in conventional arrangements, the indirect heat transfer apparatus is placed outside of the steam generator, the individual heating tubes of the latter must be connected by means of a header or collector, and a conduit must be provided to connect the header with a header connecting the individual elements of the indirect heat transfer apparatus. This is unnecessary, if the heat transfer apparatus is arranged inside the steam generator according to the invention, so that pressure losses and cost are reduced. In certain cases, for example, if the temperature of the fluid on one side of the heat transfer apparatus must be controlled by injecting water, the provision of a header may be advisable to interconnect the tube sections conducting the fluid whose temperature must be controlled. The sections of the tubes conducting the other fluid, however, may be serially interconnected, avoiding headers. Collectors are also desirable, if the different tube sections are not uniformly heated. Since headers for this purpose are usually provided anyway in connection with the tubular heating surfaces of a steam generator, the tubes of individual sections of the heat transfer apparatus arranged according to the invention may be connected in series.

Though in this specification and in the claims the word "steam" is used to specify the operating fluid of the plant, the invention is not limited to plants using steam as operating fluid but is equally well applicable to plants using other vapors as operating fluid.

The novel features which are considered characteristic of the invention are set forth with particularity in the appended claims. The invention itself, however, and additional objects and advantages thereof will best be understood from the following description of embodiments thereof when read in conjunction with the accompanying drawing in which:

Fig. 1 is a diagrammatic part sectional illustration of a steam plant according to the invention;

Fig. 2 is a diagrammatic part sectional illustration of a modified portion of a steam generator according to the invention;

Fig. 3 is a part sectional diagrammatic illustration of a modification of the part shown in Fig. 2;

Figures 4 to 7 diagrammatically illustrate modifications of the arrangement of the superheater and reheater in the radiation and in the convection zone of the steam generator.

The same numerals designate the same parts in all figures.

Referring more particularly to Fig. 1 of the drawing, numeral **1** designates a steam generator which is heated by a combustion apparatus **2**. Numeral **3** designates a combustion chamber in which radiant heat and combustion gases are produced. The combustion gases continue to pass through a flue **4**. An operating fluid, such as water, is supplied to the steam generator through an inlet header **5**. The water flows through tubes **27** and **7** forming a combustion gas heated feed water preheater, generally known as an economizer. The preheated feed water enters a tubular heating surface **8** which is used for lining the walls of the combustion chamber **3** and is ex-

posed to radiant heat. The steam formed in the heating surface section **8** is conducted through a conduit **9** into a first superheater **10** at least part of which is exposed to radiant heat in the combustion chamber **3**. The superheated high pressure steam flows through a heat transfer apparatus or heat exchanger **11** which will be described later. The high pressure steam leaving the apparatus **11** passes through a tubular superheating section **12** and therefrom through a steam main **13** into the high pressure part **14** of a prime mover, such as a steam turbine. The steam which is partly expanded in the prime mover **14** is conducted through a conduit **15** into a tubular resuperheater section **16** and therefrom into tubes **21** which surround tubes **22** which conduct high pressure steam through the heat transfer apparatus or heat exchanger **11**. The resuperheated steam is conducted through a conduit **17** into a low pressure part **18** of the steam turbine plant. The high pressure turbine **14** and the low pressure turbine **18** have a common shaft for driving an electric generator **19**. The steam exhausting from the low pressure turbine **18** is removed through a conduit **20**. In the illustrated embodiment of the invention, the part of the steam generator, in which heat is transferred by conduction and convection and not by radiation, is too small to accommodate the total required resuperheating surface. It is therefore necessary to arrange a part of the resuperheater in the combustion chamber where it is exposed to radiant heat and where it is preferably used for lining a wall portion of the combustion chamber. In the heat transfer apparatus **11**, the resuperheating surface is heated by superheated high pressure steam, as is done in conventional indirectly heated resuperheaters which are arranged outside of the steam generator and which cause radiation losses. Such losses are avoided with the arrangement according to the present invention. Furthermore, a heat transfer apparatus arranged according to the invention can be much smaller to do the same work as does a conventional steam heated resuperheater.

The heat transfer apparatus **11** includes a plurality of tubes arranged in parallel with respect to the flow of steam therethrough. The plant according to the invention can be so arranged that the superheaters **10** and **12**, the resuperheater **16**, and the heat transfer apparatus **11** all have the same number of parallelly arranged tubes. The number of headers can thereby be greatly reduced, because each inner tube **22** of the apparatus **11** can be connected with a tube of the superheaters **10**, **12** for the high pressure steam, and each outer tube **21** can be connected with a tube of the resuperheater **16**. Only the following headers are required: a header **23** at the inlet of the superheater **10**, a header **24** at the outlet of the superheater **12**, a header **25** at the inlet of the resuperheater **16**, and a header **26** connected to the outlets of the outer tubes **21** of the heat transfer apparatus **11**.

The feed water preheater or economizer **27**, **7** also includes a plurality of tubular elements arranged in parallel with respect to the flow of the fluid therethrough. The part of the economizer formed by the tubes **27** is constructed as a heat transfer apparatus **6** including outer tubes **27** through which the feed water is conducted, and inner tubes **28** arranged inside the tubes **27** for conducting a heating fluid which is supplied from a header **29** and returned into a header or collector **30**. The heating fluid is preferably taken from the circuit of the operating fluid of the steam plant at a point where the temperature of the operating fluid is higher than that of the feed water entering the heat transfer apparatus **6**. The heating fluid may be steam bled from the turbine plant. The feed water passing through the outer tubes **27** is thus heated by the inner tubes **28**. It may be heated simultaneously by the combustion gases passing outside of the tubes **27**. The combustion gases prevent in any case heat radiation and losses to the outside.

Fig. 2 illustrates a modified arrangement according to the invention. The parts of the plant not shown in Fig. 2 correspond to the respective parts shown in Fig. 1. Steam produced in the heating surface section **8** of the steam generator is conducted through a conduit **9** and a header **23** into a first superheater **31** from which the superheated steam flows through a header **44**, a conduit **32**, and a header **45** into inner tubes **33** of a heat transfer device **34**. The high pressure steam leaving the tubes **33** is collected in a header **46** and passes through a conduit **35** and through an inlet header **24** into a second superheater **36**. The high pressure steam superheated in the second superheater **36** is collected in a header **47** and conducted through a steam main **13** to a high pressure turbine. The partly expanded steam exhausting from the high pressure turbine is conducted through a conduit **15** and a header **25** into a first combustion gas heated resuperheater **37** and therefrom through outer tubes **38** of the heat transfer apparatus **34**. The partly expanded steam leaving the tubes **38** is conducted through a second combustion gas heated resuperheater **39** at whose outlet a header **26** is provided which is connected, by means of a conduit **17**, with the inlet of a low pressure turbine.

The heat transfer apparatus or heat exchanger **34** constitutes a resuperheater which is heated by high pressure steam as well as by combustion gases. In the arrangement illustrated in Fig. 2, the combustion gases heat the partly expanded steam from the outside, whereas the high pressure steam flowing through the inner tubes **33** heats the partly expanded steam from the inside. The heat transfer apparatus can be used to serve not only as a resuperheater, but also as a temperature regulator for the steam to be resuperheated. The temperature of the high pressure steam can be controlled by injecting water from a conduit **40** into the high pressure steam conduit **32** which supplies heating steam to the heat transfer device **34**, and by injecting water through a conduit **41** into the high pressure steam conduit **35** through which heating steam is removed from the heat transfer apparatus **34**. The amount of water injected through the conduit **40** into the conduit **32** is so controlled that the temperature of the steam in the inner tubes **33** is lower or higher than the temperature of the partly expanded steam flowing through the outer tubes **38** for cooling or heating, respectively, the partly expanded steam. The amount of water injected through conduit **41** into the conduit **35** is controlled to produce the desired steam temperature at the outlet of the high pressure superheater **36**. A conduit **42** is provided interconnecting the conduits **32** and **35**, in which conduit a throttling means or valve **43** is arranged for controlling the flow of high pressure steam through the conduit **42**. If the high pressure steam is cooled too much in the heat transfer device **34** and/or by injection of water from the conduit **40**, hot high pressure steam from conduit **32** can be by-passed through the conduit **42** around the device **34** and conducted into the superheater **36**.

Since the water injection must affect all parallelly arranged tubes of the heat transfer device and of the high pressure steam superheater, headers **44**, **45**, **46**, and **47** must be provided in addition to the headers forming part of the system shown in Fig. 1. No headers are needed for interconnecting the tubular elements forming the resuperheater heating surfaces **37** and **39** with the outer tubes **38** of the heat transfer device **34**.

Fig. 3 illustrates a modification of the heat transfer apparatus forming part of the system according to Fig. 2. If the individual parallelly arranged tubular elements of the heat transfer apparatus **34** and/or of the resuperheaters **37** and **39** are not uniformly heated, the provision of additional headers **48**, **48***a*, **49**, and **49***a* may be advisable. The header **48***a* mixes the steam coming from the tubes **37**, and the header **48** distributes the mixed steam into the outer tubes **38**. The header **49** mixes the steam heated in the tubes **38**, and the header **49***a* distributes the steam into the tubes **39**.

Fig. 4 diagrammatically illustrates a modified arrangement of the superheater and reheater section according to the invention. A first part 50 of the high pressure superheater is arranged in the convection zone of the steam generator. The heat transfer apparatus or heat exchanger 51 is also placed in the convection zone; the low pressure steam which is reheated in the apparatus 51 is further heated in a reheater portion which is arranged downstream of the apparatus 51 and also in the convection zone. The high pressure and the low pressure steam flow in parallel relation through the apparatus 51 and the high pressure steam leaving the apparatus 51 is superheated to the finally desired temperature in the radiation zone of the steam generator.

Fig. 5 illustrates an arrangement which is like that shown in Fig. 4, the high pressure steam, however, being first heated in the radiation zone of the steam generator before entering the apparatus 51 and being again heated in the convection zone of the steam generator after leaving the apparatus 51. The high pressure steam and the low pressure steam flow in counterflow relation through the apparatus 51.

In the arrangements shown in Figures 6 and 7 the apparatus 51 is in the radiation zone of the steam generator, the low pressure steam, after being heated in the apparatus 51 being further heated by the combustion gases in the convection zone of the steam generator.

In the system shown in Fig. 6 the high pressure steam is heated in the convection zone prior to entering the apparatus 51 and the high pressure steam leaving the latter is further superheated in the radiation zone of the steam generator. High pressure and low pressure steam flow in counterflow relation through the apparatus 51.

The system shown in Fig. 7 is like that illustrated in Fig. 6 with the exception that the direction of flow of the high pressure steam is reversed so that the high pressure steam and the low pressure steam flow in parallel relation through the heat exchanger 51.

The system according to the invention is particularly useful in connection with a forced flow steam generator of the once-through type. It can be applied to steam or vapor power plants operating at, above, or below the critical pressure of the operating fluid. The elements of the heat transfer apparatus may be arranged in the form of packages or may be arranged in a plane, so that it can be used, for example, for lining or forming the combustion chamber wall or for forming baffles in large steam generators.

What is claimed is:

1. In a steam generating power plant operating under the reheat cycle and under variable load conditions, a steam generator comprising fuel burning means generating products of combustion, a superheater means having two sections exposed to said products for superheating primary steam, a reheater means exposed to said products for reheating secondary steam, a heat exchanger means having a first tube serially connected to said reheater means for flow of secondary steam through said first tube, said first tube having an outer surface exposed substantially entirely to said products of combustion for heating the secondary steam flowing in said first tube, and a second tube placed inside said first tube, in spaced relation to and longitudinally of said first tube, said second tube being interposed between said two sections for serially connecting said two sections of said superheater means for flow of primary steam in series relation through one of said sections, through said second tube of said heat exchanger means, and through the second section of said superheater means, said first tube and said second tube of said heat exchanger means being organized for heat exchange between the said primary steam flowing through said second tube and the said secondary steam flowing through said first tube and for heat insulation of said second tube by the secondary steam in said first tube against the heat of said products of combustion, heat exchange between said primary steam and said secondary steam being restricted exclusively to said first and second tubes of said heat exchanger means.

2. In a steam generating plant as defined in claim 1, a combustion chamber wherein said fuel burning means generate the products of combustion, and a flue connected to and receiving hot products of combustion from said combustion chamber, one section of said superheater means being placed in said flue, the second section of said superheater means being placed in said combustion chamber, and said heat exchanger means being placed in said flue.

3. In a steam generating plant according to claim 2 and wherein said second tube of said heat exchanger means is connected to the section of said superheater means which section is placed in said combustion chamber to receive steam from the section which is placed in said combustion chamber, and said second tube of said heat exchanger means is connected to the superheater section which is placed in said flue, for discharging steam into the superheater section which is placed in said flue.

4. In a steam generating plant according to claim 2 and wherein said second tube of said heat exchanger means is so connected to said sections of said superheater means as to receive steam from the section placed in said flue and to discharge steam into the section placed in said combustion chamber.

5. In a steam generating plant as defined in claim 1, a combustion chamber wherein said fuel burning means generate the products of combustion, and a flue connected to and receiving hot products of combustion from said combustion chamber, one section of said superheater means being placed in said flue, the second section of said superheater means being placed in said combustion chamber, and said heat exchanger means being placed in said combustion chamber.

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