

Jan. 8, 1946.

M. H. KUHNER

2,392,325

STEAM GENERATING APPARATUS

Filed July 3, 1941

2 Sheets-Sheet 1

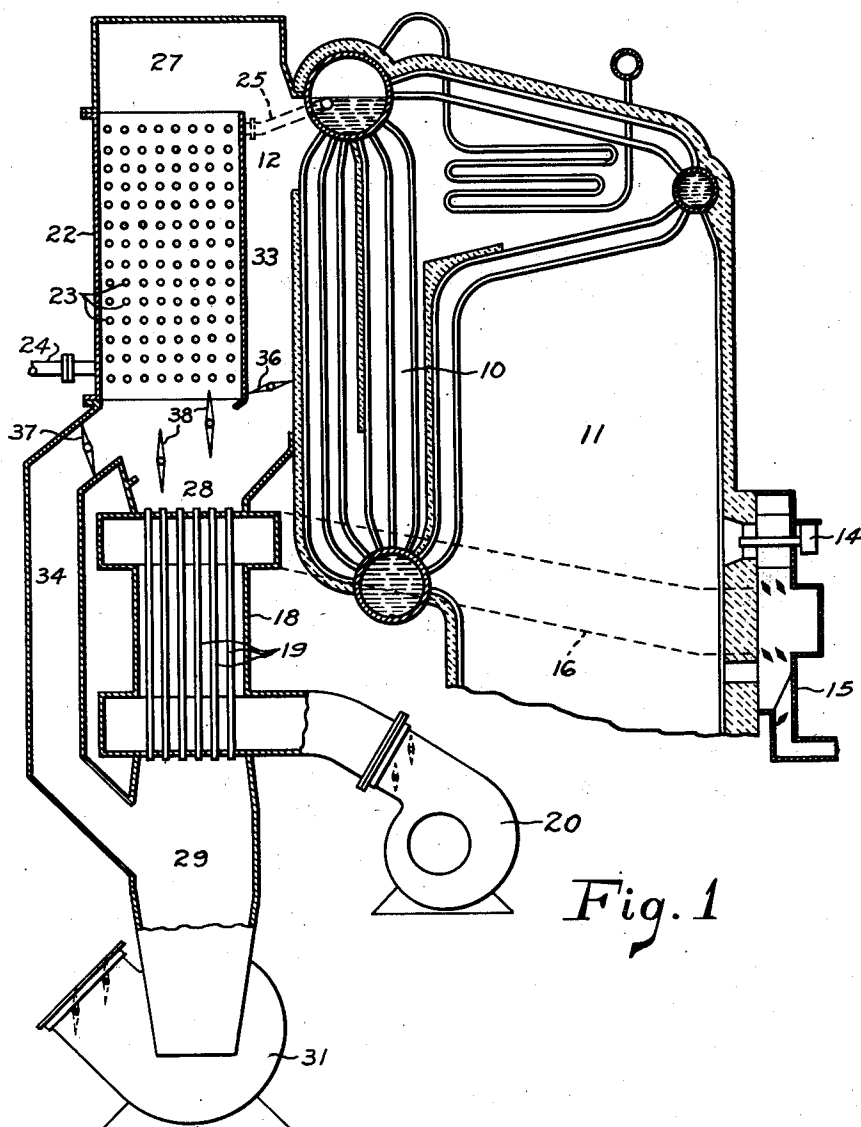


Fig. 1

Inventor

MAX H. KUHNER

By *Albert G. Blodgett*

Attorney

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2 Sheets-Sheet 2

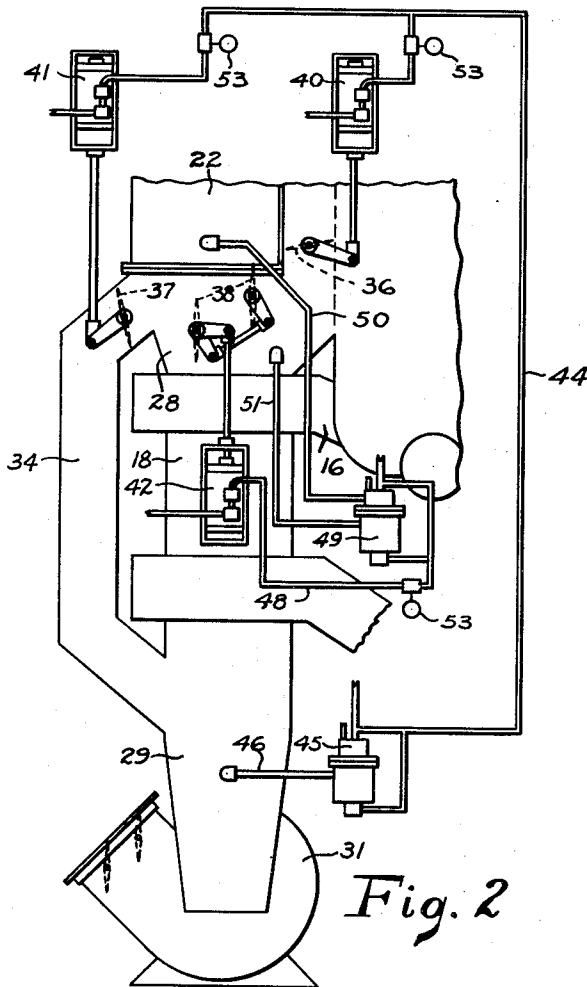


Fig. 2

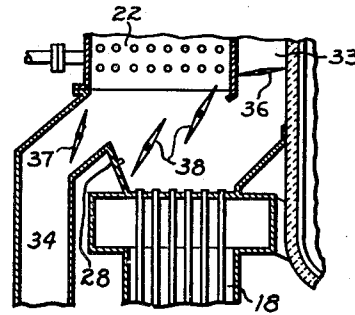


Fig. 3

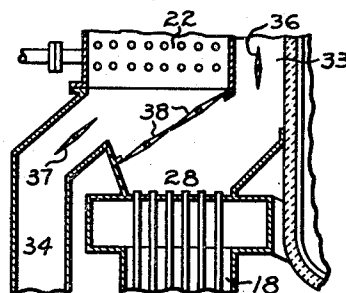


Fig. 4

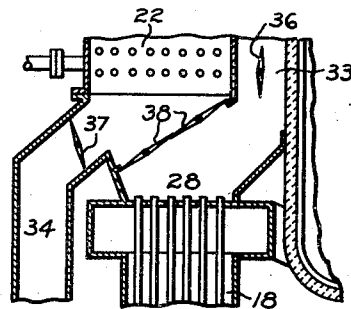


Fig. 5

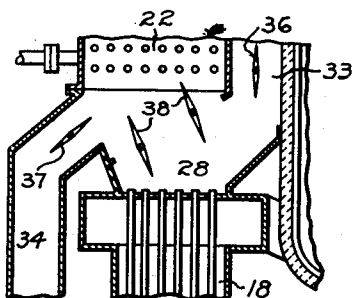


Fig. 6

Inventor
MAX H. KUHNER

By *Albert G. Blodgett*
Attorney

UNITED STATES PATENT OFFICE

2,392,325

STEAM GENERATING APPARATUS

Max H. Kuhnner, Worcester, Mass., assignor to
Riley Stoker Corporation, Worcester, Mass., a
corporation of Massachusetts

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14 Claims. (Cl. 122-1)

This invention relates to the construction and operation of steam generating apparatus, and more particularly to apparatus of this type arranged to generate steam from the combustion products of two fuels having widely different characteristics, although in certain respects the invention is applicable where only a single fuel is utilized.

In many manufacturing plants low grade fuels are obtained as a by-product of the manufacturing procedure. For example, in steel mills large quantities of blast furnace gas are produced, and in wood-working plants considerable bark, sawdust, shavings and similar waste material is available. It is desirable for economic reasons to utilize these fuels for steam generation, but ordinarily they will not produce all the steam which is required, and it is necessary to supplement them with a high grade fuel, such as pulverized coal or oil. This greatly complicates the problem of constructing the heat recovery equipment, including the economizer and air heater, through which the gaseous products of combustion travel after leaving the boiler heating surfaces. For a given rate of steam generation, the volume of the combustion products is very much greater with a low grade fuel than with a high grade fuel. For example, the combustion products of blast furnace gas are approximately seventy percent greater in volume than the combustion products of pulverized coal for the same steam generating rate. If the heat recovery equipment is designed to permit operation at full load with pulverized coal, with a reasonable draft loss and reasonable power requirements for operation of the induced draft fan, it will be found that the draft loss when operating at full load with blast furnace gas will be excessive, and the induced draft fan will require power far in excess of what is economically justified. On the other hand, if the economizer and air heater are enlarged sufficiently to permit operation at full load with blast furnace gas with a reasonable draft loss, the space requirements and cost of this equipment will ordinarily be unjustified. This is particularly true since there will probably be insufficient blast furnace gas available to operate at full load except during a small portion of the time. It should also be noted in this connection that storage of blast furnace gas is not practical, and it must be burned as fast as it becomes available, so that there may be occasions when the ability to operate at very high loads with this fuel is of great importance. Further problems arise from the difficulties in maintain-

ing ignition of the low grade fuel when operating at low combustion rates, and from the importance of maintaining the temperature of the gases in the heat recovery equipment above the dew point to avoid corrosion of the metal parts.

It is accordingly one object of the invention to provide a steam generating apparatus particularly adapted for use with fuels having widely different characteristics.

It is a further object of the invention to provide a steam generating apparatus having heat recovery equipment of a size economically justified for burning a combination of high and low grade fuels, and yet capable of operating at full load with the low grade fuel alone without excessive draft loss.

It is a further object of the invention to provide a new and highly advantageous combined arrangement of a steam boiler with an economizer and an air heater.

It is a further object of the invention to provide a steam boiler adapted to be fired with a combination of a high and a low grade fuel, together with heat recovery equipment so arranged as to make possible operation at high efficiency under normal conditions and yet allow operation at full capacity with the low grade fuel, when required, without excessive draft loss.

With these and other objects in view, as will be apparent to those skilled in the art, the invention resides in the combination of parts set forth in the specification and covered by the claims appended hereto.

Referring to the drawings illustrating one embodiment of the invention, and in which like reference numerals indicate like parts,

Fig. 1 is a longitudinal sectional view of steam generating apparatus, including certain heat recovery equipment;

Fig. 2 is a fragmentary elevation of the heat recovery equipment and certain automatic control apparatus associated therewith; and

Figs. 3 to 6 inclusive are fragmentary sectional views showing certain dampers in different positions of adjustment.

The embodiment illustrated comprises a water tube steam boiler 10 of well-known construction having a furnace or combustion chamber 11 and a rear gas outlet 12. On the front wall of the furnace there is mounted a burner 14 suitable for a high grade fuel, such as pulverized coal, and a second burner 15 suitable for a low grade fuel, such as blast furnace gas. Both burners are supplied with air for combustion purposes from a duct 16 which leads from an air heater 18 of a

well-known type having upright tubes 19. The air is delivered to the heater by means of a forced draft fan 20, and after flowing upwardly around the outer surfaces of the tubes 19 the heated air enters the duct 16.

Above the air heater there is located an economizer 22 of well-known construction having a series of horizontal tubes 23. The boiler feed water is supplied to the lower end of the economizer by an inlet pipe 24, and after flowing in a generally upward direction through the tubes 23 this water passes through a pipe 25 into the boiler 10. The upper end or gas inlet of the economizer is connected to the boiler gas outlet 12 by a passage 27, and the lower end or gas outlet of the economizer is connected to the upper end or gas inlet of the air heater 18 by a passage 28. The lower end or gas outlet of the air heater is connected by an outlet passage 29 to an induced draft fan 31.

With the construction as so far described the hot gaseous products of combustion will travel from the furnace 11 through the boiler 10 to the outlet 12, thence through the passage 27 and downwardly through the economizer 22, the passage 28, the tubes 19 of the air heater 18, and the passage 29 to the induced draft fan, which will discharge the gases to a suitable stack (not shown). The temperature of the gases will be reduced by transfer of heat to the water in the boiler 10, to the feed water in the economizer tubes 23, and to the air which surrounds the tubes 19 of the air heater 18. The flow of the gases through the economizer and air heater will be series flow, i. e. all the gases will travel first through the economizer and then through the air heater. This is well suited for highly efficient utilization of the heat in the fuel, since the temperature of the gases leaving the air heater will be relatively low. Furthermore, the economizer and the air heater will be so proportioned as to allow the boiler to be operated at full capacity with such series flow, and without excessive draft loss, so long as pulverized coal is used as the principal fuel and the amount of blast furnace gas burned is not too high. If however it happens that large quantities of blast furnace gas are available, and an attempt is made to operate the boiler at full capacity with this fuel, the volume of the gases will be so increased as to produce a great draft loss through the heat recovery equipment, and an excessive amount of power will be required to drive the induced draft fan 31. The problem cannot be solved by increasing the size of the economizer and air heater, since this would increase the cost and space requirements, all adding to the fixed charges on the installation.

These difficulties are avoided in accordance with the present invention by providing a construction such that when the draft loss through the economizer and air heater in series exceeds a predetermined amount, these apparatuses may be connected in parallel so that only a portion of the gases will flow through each. This will reduce the draft loss, at some sacrifice of heat utilization, but with a considerable increase in the over-all efficiency of the installation when all factors are considered. For this purpose a passage 33 is provided leading from the boiler outlet 12 to the upper or inlet end of the air heater 18, and a second passage 34 is provided leading from the lower or outlet end of the economizer 22 to the passage 29. The passage 33 forms a by-pass for the economizer, and the passage 34 forms a by-pass for the air heater. In order to control the flow

of the gases in a desired manner a damper 36 is mounted in the passage 33, a damper 37 is mounted in the passage 34, and a damper 38 is mounted in the passage 28. Because of the width of the last-mentioned passage, the damper 38 is preferably of the double-vane type. The economizer by-pass 33 connects with the passage 28 at a point posterior to the damper 38, whereas the air heater by-pass 34 connects with the passage 28 at a point anterior to the damper 38. Consequently when this damper is closed, gases cannot flow from the by-pass 33 into the by-pass 34. Preferably the by-passes 33 and 34 are connected to opposite sides of the passage 28, as this greatly simplifies the duct construction.

It will be apparent that with the dampers 36 and 37 both closed, as shown in Fig. 1, all the gas will be compelled to flow through the economizer and air heater in series. If however, as shown in Fig. 4, the dampers 36 and 37 are open and the damper 38 closed, the economizer and air heater will be connected in parallel, each receiving a portion only of the gas, so that the draft loss will be comparatively low.

The several dampers are preferably so constructed and arranged that they may be controlled by automatic regulating mechanism during the normal operation of the apparatus. For this purpose, as shown in Fig. 2, a regulator 40 is connected to the damper 36, a regulator 41 is connected to the damper 37, and a regulator 42 is connected to the damper 38. Each of these regulators is of a well-known type including a reversible motor operated by compressed air, the construction being such that the motor will assume predetermined positions dependent upon variations in the pressure of air or other fluid transmitted to the regulator through a so-called "impulse line." The regulators illustrated are of the type disclosed in the patent to Donaldson No. 2,044,936, granted June 23, 1936. The two regulators 40 and 41 are connected to a single impulse line 44 leading from a master regulator 45 of the type disclosed in the patent to Donaldson No. 2,177,823, granted October 31, 1939. This master regulator is connected by a control pipe 46 to the passage 29 which leads to the inlet of the induced draft fan 31. These various parts are so constructed and arranged that so long as the suction in the passage 29 remains below a predetermined value, say ten inches of water column, the pressure in the impulse line 44 will be such that the regulators 40 and 41 will hold their respective dampers 36 and 37 closed. If however the draft loss increases sufficiently to cause the suction in the passage 29 to exceed ten inches of water column, the master regulator 45 will alter the pressure in the impulse line 44 and cause the regulators 40 and 41 to open the dampers 36 and 37. Preferably the regulator 41 is adjusted to open its damper 37 slightly in advance of the damper 36, as indicated in Fig. 3, the arrangement being such that if the suction in the passage 29 continues to increase so that the damper 37 reaches its fully open position, the damper 36 will then start to open.

The purpose of the damper 38 is to prevent reverse or upward flow of gas through the passage 28 when the dampers 36 and 37 are both open. If such reverse flow could take place there would be no appreciable heat recovery from the gases leaving the boilers, since both the economizer and the air heater would be by-passed by the series connection of the passages 33, 28 and 34. In order to obtain the desired automatic

control of the damper 38, the regulator 42 is connected to an impulse line 48 leading from a master regulator 49 similar to the regulator 45. This regulator 49 is connected to two control pipes 50 and 51, these pipes communicating with the passage 28 respectively anterior to and posterior to the damper 38. Thus the regulator 49 is subjected to the pressure drop or differential across the damper 38, and the parts are so adjusted as to maintain this drop at a predetermined small value, such as one-tenth inch of water column. Whenever this pressure drop becomes less than the established value, the damper 38 will be closed by its regulator 42. Thus there can be no flow of gases from the passage 33 into the passage 34 so long as the parts are under automatic control.

Under some circumstances it may be desirable for the operator to assume manual control of the dampers. In order to make this possible, a separate manual control station 53 is provided in the impulse line for each of the regulators 40, 41, and 42. These stations 53 are of well-known construction, and they make it possible for the operator to establish, by a hand adjustment, a predetermined impulse pressure for each damper regulator, so that each damper will be held in a corresponding predetermined position.

The operation of the invention will now be apparent from the above disclosure. When starting up the steam generator from "cold" condition, the dampers 36, 37, and 38 will all be opened wide under manual control, as shown in Fig. 6. This will allow the boiler gases to flow successively through the passages 33, 28, and 34, by-passing the economizer and air heater. There will thus be no danger of steaming in the economizer or condensation of water vapor in the air heater. This initial warming up is preferably accomplished with pulverized coal, since blast furnace gas will not burn well without preheated air. After the boiler has been brought up to its full working pressure, low load operation can be obtained with blast furnace gas by opening damper 36 and closing dampers 37 and 38, as shown in Fig. 5. This will cause all the combustion gases to flow through the passage 33 and the air heater 18, affording the maximum preheat for the combustion air, and making possible stable combustion of the blast furnace gas. Under normal load conditions the dampers will be controlled automatically, and so long as the suction in the passage 29 remains below ten inches of water column, the dampers 36 and 37 will remain closed, as shown in Fig. 1. The gas flow will thus be in series through the economizer and air heater, with the maximum recovery of heat. The damper 38 will be controlled by the master regulator 49 and will close only enough to maintain a very slight pressure drop of one-tenth inch of water column across the damper. If now the boiler load increases, or if more blast furnace gas is burned, the quantity of gases leaving the boiler outlet 12 will increase. This will produce an increased draft loss through the boiler, the economizer and the air heater, so that the suction in the passage 29 will increase, causing a greater power requirement for operation of the induced draft fan 31. As soon as this suction reaches the predetermined value of say ten inches of water column, the master regulator 45 will respond thereto and alter the pressure in the impulse line 48, causing the regulator 41 to start to open the damper 37, as shown in Fig. 3. This will check the rise in the draft loss by causing part of the gases to by-pass the air heater. At the same time

the damper 38 will close still further because of the decrease in the gas flow past the same. If the draft loss continues to increase, the damper 37 will open fully, the damper 36 will open, and the damper 38 will close, as shown in Fig. 4. This will connect the economizer and air heater in parallel, with part of the gases flowing through the economizer and the passage 34, while the remaining gases flow through the passage 33 and the air heater. There will be no flow through the passage 28. Because of the increased flow area available, the steam generator can be operated at high loads with blast furnace gas without excessive draft loss or excessive power requirements for the induced draft fan. As soon as the load on the boiler decreases sufficiently, or the quantity of blast furnace gas being burned decreases sufficiently, the heat recovery equipment will be restored automatically to series operation.

From the above disclosure it will be apparent that the invention makes possible highly efficient recovery of the heat from the furnace gases except on the very few occasions when unusually large amounts of blast furnace gas must be burned, and yet even on such occasions there is no excessive demand for power to drive the induced draft fan. Hence a motor of the usual size and construction may be employed. Furthermore the economizer and air heater can both be of normal size in proportion to the steam generating capacity, and the fixed charges on the investment will therefore be moderate.

Having thus described my invention, what I claim as new and desire to secure by Letters Patent is:

1. Steam generating apparatus comprising a steam boiler, a fuel-burning furnace associated therewith, the gaseous products of combustion from the furnace passing through the boiler to generate steam therein, an economizer having an inlet and an outlet for gases, an air heater having an inlet and an outlet for gases, means to conduct gases from the boiler to the economizer inlet, a passage connecting the economizer outlet to the air heater inlet, a damper in the passage, an economizer by-pass connecting the boiler with the said passage posterior to the damper, an air heater by-pass connecting the said passage anterior to the damper with the air heater outlet, and a separate damper in each by-pass.

2. Steam generating apparatus comprising a steam boiler, a fuel-burning furnace associated therewith, the gaseous products of combustion from the furnace passing through the boiler to generate steam therein, an economizer having an inlet and an outlet for gases, an air heater having an inlet and an outlet for gases, means to conduct gases from the boiler to the economizer inlet, a passage to conduct gases from the economizer outlet to the air heater inlet, a damper in the passage, an economizer by-pass connecting the boiler with the said passage posterior to the damper, and an air heater by-pass connecting the said passage anterior to the damper with the air heater outlet.

3. Steam generating apparatus comprising a steam boiler, a fuel-burning furnace associated therewith, the gaseous products of combustion from the furnace passing through the boiler to generate steam therein, an economizer having an inlet and an outlet for gases, an air heater having an inlet and an outlet for gases, means to conduct gases from the boiler to the economizer inlet, a passage to conduct gases from the economizer outlet to the air heater inlet, a damper in the

passage, an economizer by-pass connecting the boiler with one side of the said passage posterior to the damper, and an air heater by-pass connecting the opposite side of the said passage anterior to the damper with the air heater outlet.

4. Steam generating apparatus comprising a steam boiler, a fuel-burning furnace associated therewith, the gaseous products of combustion from the furnace passing through the boiler to generate steam therein, an economizer having an inlet and an outlet for gases, an air heater having an inlet and an outlet for gases, means to conduct gases from the boiler to the economizer inlet, a passage to conduct gases from the economizer outlet to the air heater inlet, an economizer by-pass connecting the boiler with the said passage, an air heater by-pass connecting the said passage with the air heater outlet, and means in the said passage to prevent flow of gases from the economizer by-pass to the air heater by-pass.

5. Steam generating apparatus comprising a steam boiler, a fuel-burning furnace associated therewith, the gaseous products of combustion from the furnace passing through the boiler to generate steam therein, an economizer having an inlet and an outlet for gases, an air heater having an inlet and an outlet for gases, means to conduct gases from the boiler to the economizer inlet, a passage to conduct gases from the economizer outlet to the air heater inlet, an economizer by-pass connecting the boiler with one side of the said passage, an air heater by-pass connecting the opposite side of the said passage with the air heater outlet, and means in the said passage to prevent flow of gases from the economizer by-pass to the air heater by-pass.

6. Steam generating apparatus comprising a steam boiler, a fuel-burning furnace associated therewith, the gaseous products of combustion from the furnace passing through the boiler to generate steam therein, an economizer and an air heater arranged to receive gases from the boiler, and automatically operable means responsive to variations in the volume of gases and arranged to direct the gases through the economizer and air heater in series when the volume of the gases is not excessive and in parallel when the volume of the gases is excessive.

7. Steam generating apparatus comprising a steam boiler, a fuel-burning furnace associated therewith, the gaseous products of combustion from the furnace passing through the boiler to generate steam therein, an economizer having an inlet and an outlet for gases, an air heater having an inlet and an outlet for gases, means to conduct gases from the boiler to the economizer inlet, a passage connecting the economizer outlet to the air heater inlet, a damper in the passage, an automatic regulator arranged to control the damper in accordance with the drop in gas pressure across the damper and to maintain said drop at a small predetermined value, an economizer by-pass connecting the boiler with the air heater inlet, an air heater by-pass connecting the economizer outlet with the air heater outlet, and a separate damper in each by-pass.

8. Steam generating apparatus comprising a steam boiler, a fuel-burning furnace associated therewith, the gaseous products of combustion from the furnace passing through the boiler to generate steam therein, an economizer having an inlet and an outlet for gases, an air heater having an inlet and an outlet for gases, means to conduct gases from the boiler to the economizer inlet, a passage connecting the economizer outlet to the

air heater inlet, means to prevent reversal of the gas flow in the passage, an induced draft fan, a passage connecting the air heater outlet to the fan, an economizer by-pass connecting the boiler with the air heater inlet, an air heater by-pass connecting the economizer outlet with the air heater outlet passage, a separate damper in each by-pass, and automatic control mechanism arranged to open the by-pass dampers when required to prevent overloading of the induced draft fan.

9. Steam generating apparatus comprising a steam boiler, a fuel-burning furnace associated therewith, the gaseous products of combustion from the furnace passing through the boiler to generate steam therein, an economizer having an inlet and an outlet for gases, an air heater having an inlet and an outlet for gases, means to conduct gases from the boiler to the economizer inlet, a passage connecting the economizer outlet to the air heater inlet, means to prevent reversal of the gas flow in the passage, an induced draft fan, a passage connecting the air heater outlet to the fan, an economizer by-pass connecting the boiler with the air heater inlet, an air heater by-pass connecting the economizer outlet with the air heater outlet passage, a separate damper in each by-pass, and automatic control mechanism arranged to open the by-pass dampers when the suction in the air heater outlet passage exceeds a predetermined value.

10. Steam generating apparatus comprising a steam boiler, a fuel-burning furnace associated therewith, the gaseous products of combustion from the furnace passing through the boiler to generate steam therein, an economizer having an inlet and an outlet for gases, an air heater having an inlet and an outlet for gases, means to conduct gases from the boiler to the economizer inlet, a passage connecting the economizer outlet to the air heater inlet, a damper in the passage, an automatic regulator arranged to control the damper in accordance with the drop in gas pressure across the damper and to maintain said drop at a small predetermined value, an induced draft fan, a passage connecting the air heater outlet to the fan, an economizer by-pass connecting the boiler with the air heater inlet, an air heater by-pass connecting the economizer outlet with the air heater outlet passage, a separate damper in each by-pass, and automatic control mechanism arranged to open first the air-heater by-pass damper and then the economizer by-pass damper when the suction in the air heater outlet passage exceeds a predetermined value.

11. In a fluid heating unit having a pair of heat exchangers arranged to receive heating gases generated therein, the method of burning two fuels of different calorific values which comprises burning the higher calorific fuel therein and passing the heating gases generated through both of said heat exchangers in series, and at other times burning the lower calorific fuel therein and passing the heating gases generated through both of said heat exchangers in parallel.

12. In a steam generating unit having an economizer and an air heater connected to its gas outlet, the method of burning two fuels of different calorific values which comprises burning the higher calorific fuel and directing the gaseous products of combustion leaving the gas outlet through the economizer and the air heater in series, and at other times burning the lower calorific fuel and directing the products of combustion

tion leaving the gas outlet through the economizer and air heater in parallel.

13. In a vapor generating unit having a vapor generating section and a pair of heat exchangers arranged to receive heating gases produced by the combustion of fuels in an associated furnace chamber, the method of burning fuels of substantially different calorific values in said furnace chamber and directing said heating gases into heat transfer contact with said vapor generating section and thereafter into heat transfer contact with said heat exchangers without exceeding a predetermined draft loss throughout the operating range which comprises burning said fuels in said chamber at substantially different volumetric rates of production of said heating gases, directing said heating gases at low volumetric rates of production through said heat exchangers in series, and directing said heating gases at high volumetric rates of production through said heat exchangers in parallel without varying the amount of heat exchanger surface contacted by said heating gases.

14. A fluid heater unit comprising a furnace chamber, a vapor generating section arranged to receive heating gases produced in said furnace chamber, a pair of heat exchangers arranged to receive said heating gases from said vapor gen-

erating section, means for burning fuel of relatively high calorific value in said furnace chamber and thereby producing heating gases at a relatively low weight rate for a given rate of vapor generation, separate means for burning fuel of relatively low calorific value in said furnace chamber and thereby producing heating gases at a relatively high weight rate for the same rate of vapor generation, and damper controlled conduit means associated with said pair of heat exchangers and operable for passing said heating gases at low weight rates of production through said pair of heat exchangers in series and at high weight rates of production through said pair of heat exchangers in parallel comprising a substantially unobstructed heating gas conduit opening to one end of one of said heat exchangers, a second heating gas conduit opening to a space connecting adjacent ends of said first and second heat exchangers, a control damper in said second conduit, and damper means between said heat exchangers arranged in one operating position to provide a heating gas flow path through said pair of heat exchangers in series from said first heating gas conduit, and in a second operating position to provide a heating gas flow path through said pair of heat exchangers in parallel.

MAX H. KUHNER.