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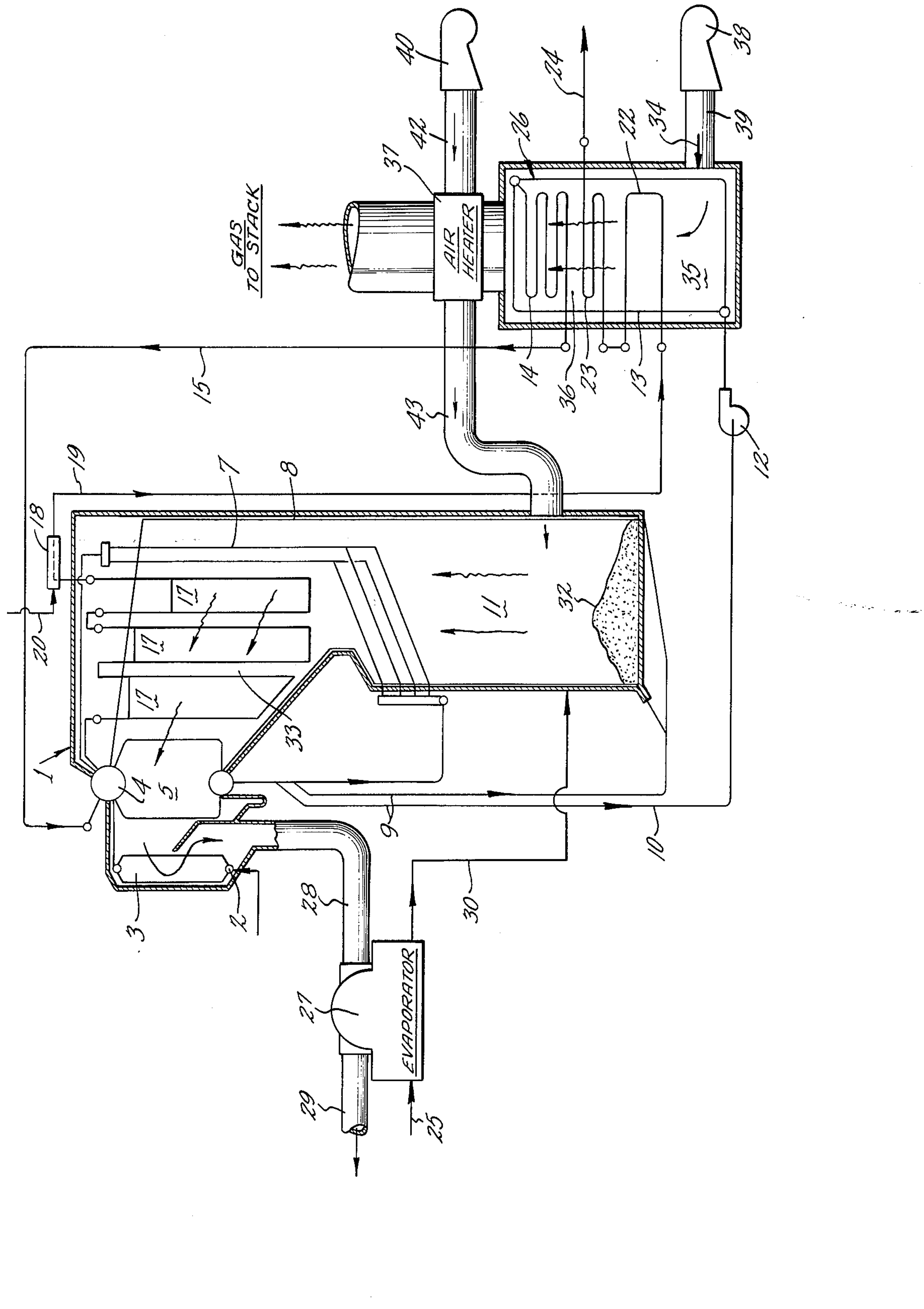

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VAPOR GENERATING APPARATUS

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This invention relates to vapor generating and superheating apparatus and in particular to an apparatus and method for obtaining superheated steam when burning a fuel, the combustion products of which have high fouling characteristics.

In the combustion of most fuels in vapor generators the combustion gases contain particulate matter which creates various amounts of difficulty on the downstream heat exchange surfaces. This is particularly true with fuels such as black liquor as used in, so-called, chemical recovery units. The combustion of this black liquor produces a gas stream which is heavily loaded with chemicals havin a fusion temperature between 1200° F. and 1500° F., these contaminants being primarily sodium carbonate and sodium sulphate. These particles tend to stick to the surfaces within the unit being particularly tenacious when the tube metal temperatures are high. It has been found that it is difficult to avoid excessive buildup of these chemicals and extensive corrosion, when steam is to be superheated to a temperature exceeding about 900° F.

It is obvious that higher steam temperatures than this are often desirable and will increase a steam turbine cycle efficiency.

The nature of the contaminants in the recovery unit gases is such as to create considerable difficulty as to plugging and corrosion in air heaters, where the gas is reduced to temperatures below the dew point determined by the constituents. For this reason it has been common to use steam air heaters to supply preheated air for combustion and to use the flue gases to reduce the moisture content of the black liquor in evaporators designed for this purpose. This has a disadvantage in that the steam which is used for steam air heating must be generated by the recovery unit thereby increasing the steaming duty in the steam drum.

In my invention two separate and independent furnaces are employed. The first constitutes the recovery unit furnace wherein black liquor is burned with the combustion gases thus formed passing over low temperature heating surface and subsequently being used to concentrate the black liquor in conventional evaporators. In the second furnace a clean burning fuel such as oil is burned with the combustion gases passing over high temperature superheater surface as well as low temperature evaporating surface and then passing through an air heater. The air heater is used to preheat air as required and a common circulating system is employed through the evaporative sections of both furnaces, whereby firing in the first furnace will heat the pressure parts of the second furnace. This combination can be employed to convey heat to the air heater via the second furnace.

It is an object of this invention to provide an improved vapor generator.

It is a further object to provide a vapor generator for burning a fuel such as black liquor wherein high preheated air temperature may be obtained without the use of steam heating coils.

It is a further object to provide a vapor generator wherein high preheated air temperature may be obtained during low load operation.

It is a further object to provide a vapor generator having an arrangement of two furnaces wherein both

furnaces can be heated by firing only one of the furnaces.

It is a further object to provide a double furnace vapor generator having apparatus which will deliver preheated air to the furnace being fired during startup.

It is a further object to provide a vapor generator which while burning a primary fuel having high fouling characteristics can generate high temperature steam without fouling of surfaces.

It is a further object to provide an arrangement of vapor generator surfaces whereby only clean gas touches the high temperature superheating and air heater surfaces, while burning a fuel producing clean gas and a fuel producing foul gas.

It is a further object to provide a vapor generator arrangement whereby the air heater receiving its heat from clean gas leaving one furnace can supply preheated air to another furnace which is producing contaminated gas.

It is a further object to proivde a double furnace vapor generator arrangement whereby loss of fire in one of the two units will not drop the steam temperature leaving the combination to saturated steam conditions.

Other and further objects of the invention will become apparent to those skilled in the art as the description proceeds.

With the aforementioned objects in view, the invention comprises an arrangement, construction and combination of the elements of the inventive organization in such a manner as to attain the results desired as hereinafter more particularly set forth in the following detailed description of an illustrative embodiment, said embodiment being shown by the accompanying drawings, wherein, FIG. 1 is a diagrammatic representation of the instant invention including a recovery unit **1**, and an auxiliary unit **26**.

Feedwater is supplied to header **2** from which it passes through the economizer bank **3** to steam drum **4**. Steam generating bank **5**, furnace platens **7** and the tubes **8** lining the walls of the recovery unit furnace **11** all generate steam which is released in the steam drum **4**. Downcomers **9** supply recirculated water to the furnace wall circuits **8** and the furnace platens **7**.

Downcomer **10** conveys water through circulating pump **12** to the furnace wall tubes **13** of the auxiliary unit **26**. This water is then conducted through boiler bank **14** releasing steam in the steam drum **4** after passing through relief tube **15**. It can be seen that there is a single feedwater supply and a single steam release surface for both of these units. Although the auxiliary unit could be designed as a natural circulation boiler, the use of the pump **12** employed in this embodiment simplifies the design problems and increases the flexibility of this system.

Steam released from the steam drum **4** is conveyed through the primary superheating surfaces **17** of recovery unit **1**, passing through desuperheater **18** to the outlet **19** of the recovery unit. The desuperheating water is supplied through pipe **20** from the feedwater source in order to control the steam temperature at the unit outlet **19**. This steam is then conveyed to the auxiliary unit **26** where it passes through a radiant superheater **22** located in the furnace of the auxiliary unit. This steam is then conveyed through finishing superheater **23** where it is raised to the desired final steam temperature and passed out through steam line **24**. The temperature of the steam leaving the auxiliary unit through steam line **24** is controlled by regulating the firing rate in furnace **35**.

Black liquor containing about 47 percent solids is introduced through pipe **25** where it is introduced into the evaporator **27**, wherein it is passed in direct contact with hot flue gas conveyed through duct **28**, which evaporates and carries out a portion of the moisture through duct **29**. The black liquor containing now about 68 percent solids is conducted through pipe **30** to the furnace **11** where it is introduced forming a pile **32** wherein combustion takes place. The combustion gases thus formed then pass through the flue **33** containing heating surfaces **7**, **17**, **5** and **3** and is conducted to the evaporator through duct **28**.

The auxiliary unit **26** is supplied with oil for combustion through burners **34** whereby combustion takes place in furnace **35**. These relatively clean flue gases then pass over superheater surface **23** and evaporative surface **14** through air heater **37** after which the gases are discharged to atmosphere through a stack (not shown). Forced draft fan **38** supplies air for combustion to the auxiliary unit furnace **35** through duct **39**. Forced draft fan **40** supplies air through duct **42** and through air heater **37** being conveyed via duct **43** to the furnace **11** of the recovery unit.

The combustion gas released in the furnace **11** of the recovery unit contains contaminants which have fusion temperatures in the order of 1200° F. to 1500° F. Since the metal temperature of steam generating surface is relatively low, the deposits which form on these surfaces can be readily removed. The superheating surfaces **17** increase the steam temperature only to about 750° F., at which temperature the surfaces of the superheater material are still sufficiently low to prevent excessive sticking and corrosion of the material. The feedwater supplied at the header is in the order of 350° and the gases passing through flue **33** over the economizer surface **3** are not reduced below the dew point; therefore, low temperature corrosion is avoided. There is no air heater in this system which would condense vapor from the gases initiating the well-known air heater corrosion problems, the gas rather going through the evaporator where a portion of the contaminants are washed out and reintroduced to the furnace, while the heat from the gases is used in drying the black liquor.

The use of water cooled tubes **13** in the furnace of the auxiliary unit **26** simplifies the design, as compared to a separately fired superheater wherein all the furnace walls are subjected to high absorption rates while containing high temperature steam. Furthermore, the use of evaporative surface **14** permits a low temperature sink thereby decreasing the difficulty of reducing the temperature of the gases passing through the flue **36** and simplifying the attainment of high efficiency. The amount of generating surface used in the auxiliary unit may be varied to attain the desired magnitude of auxiliary steam generation from this unit.

Since it is difficult because of the radiant superheater surface in the auxiliary unit to maintain a high firing rate in the auxiliary unit furnace during startup, the startup is initiated in the furnace **31** of the recovery unit. As the fluid within the circulating circuit of the recovery unit is heated, it is circulated by means of pump **12** through the evaporative circuits of the auxiliary unit thereby bringing these sections up to temperature. Forced draft fan **38** passes air through furnace **35** and flue **36** where it picks up heat from furnace wall tubes **13** and vapor generating surface **14** thereby conveying this heat to air heater **37**, where it is transferred to air passing therethrough, the air being supplied by force draft fan **40**. In this manner preheated air is supplied through duct **43** to the recovery unit during startup without use of steam coils. Steam coils may, however, be included in duct **42** to aid during the early periods of startup and to serve as required for air heater protection. During this period of startup, oil may be introduced through burner **34** to aid in the startup of the unit so long as the firing rate is maintained at a low enough level to avoid damage to the radiant superheater **22**.

During normal operation of the unit the heat supplied to preheat the air passing through duct **43** is obtained in

the air heater **37** from the flue gas passing through duct **36**. In prior units where a gas to air heater is not used, but steam coils are used in its place, additional steam must be generated in order to maintain the same steam flow being supplied for useful work. Not only does it require that the steam drum be designed for increased steaming capacity in the order of 5 percent but the heat thus absorbed from the gases requires an increased amount of surface, and more expensive surface. The temperature of the evaporative surface is higher than that of the air heater surface, thereby reducing the gas to surface temperature heat. Thus more surface is required to transfer a given number of B.t.u.'s from the gas to evaporative surface to generate the additional steam, than to transfer the same amount of heat directly to the air being preheated. Since evaporative surface is a pressure part as contrasted to the nonpressure part air heater surface, it is more expensive.

Evaporative surface is located in both the recovery unit and the auxiliary unit, and superheating surface is also contained in both units. The steam to be superheated, however, passes serially through these two units so that the low temperature superheating is accomplished in the recovery unit where there is contaminated flue gas while the high temperature superheating is accomplished in the auxiliary unit where there is clean flue gas. If fire is lost in the auxiliary unit but maintained at its original level in the recovery unit, the steam temperature leaving the recovery unit will be increased. This is true because the heat absorption to the primary superheater **17** remains constant while the steam flow is reduced by the amount generated in the auxiliary unit. Although the steam temperature in the steam line **24** will drop somewhat from the full value, considerable superheat will still be maintained in contrast to prior units using separately fired superheaters, where saturated steam would be delivered at this time, so that consequently equipment operating from this steam source will not be damaged.

It is beneficial that these units be operated in such a manner as to maintain a high firing rate in the auxiliary unit even though the system is operating at reduced load. This permits the attainment of high preheated air temperatures to the recovery unit at the low loads, where furnace temperature within the recovery unit tends to be low and adequate combustion of the black liquor is particularly difficult. This result can be obtained by design of the recovery unit to attain the proper characteristic temperature entering the auxiliary unit or by controlling the recovery unit to obtain this characteristic. Since the firing rate on the auxiliary unit is manipulated to maintain constant steam temperature leaving, the essential requirement to maintain this firing rate constant at lower loads is that the steam temperature entering the auxiliary unit be decreased in such a manner that the heat to be picked up in the steam is essentially constant. In other words; where h_o represents the enthalpy of the steam leaving the auxiliary unit; h_e represents the enthalpy of the steam entering the auxiliary unit; W represents the total steam generated; w represents the steam generated in the recovery unit; s represents the steam generated in the auxiliary unit; and K represents a constant; $(h_o-h_e)W=K$. The enthalpy required entering the auxiliary unit is that represented as follows:

$$h_e=h_o-\frac{K}{W}$$

and since $W=w+s$; then

$$h_e=h_o-\left(\frac{K}{w+s}\right)$$

This relationship must be modified by actual performance calculations due to the increased effectiveness of the superheat surface in the auxiliary unit when lower steam temperatures are entering this unit. In the instant embodiment the recovery unit was properly designed to maintain this characteristic, therefore requiring very little manipulation of the firing rate in the auxiliary unit to control steam temperature over load range. Furthermore, steam temperature leaving the auxiliary unit can be controlled, within design limits, to obtain this characteristic by use of desuperheater **18**.

Since the firing rate in the auxiliary unit is regulated to control steam temperature leaving the auxiliary unit, this firing rate is a function of the entering steam temperature. The preheated air temperature leaving the air heater is a function of the firing rate of the auxiliary unit. Therefore if increased preheated air temperature is desired, this can be accomplished by decreasing the steam temperature entering the auxiliary unit, thereby requiring increased firing rate to maintain the preset outlet temperature, thereby increasing the preheated air temperature. Since the steam temperature entering the auxiliary unit is the steam temperature leaving the recovery unit, the preheated air temperature may be controlled by resetting the steam temperature leaving the recovery unit. The desired steam temperature leaving the recovery unit may be obtained by proper design of the recovery unit to obtain this characteristic over the load range, or by controlling the steam temperature leaving the recovery unit either by desuperheating or any other well known steam temperature control method.

While I have illustrated and described a preferred embodiment of my invention it is to be understood that such is merely illustrative and not restrictive and that variations and modifications may be made therein without departing from the spirit and scope of the invention. I therefore do not wish to be limited to the precise details set forth but desire to avail myself of such changes as fall within the purview of my invention. For instance, the circulation through either the recovery or auxiliary unit could be either natural or forced circulation; the fuel in the auxiliary unit could be any clean burning fuel such as coal, gas, bark, etc.; the preheated air supplied by the air heater could be used both in the recovery unit and auxiliary unit instead of just for the recovery unit as illustrated in the embodiment; where there is increased steam generating surface in the auxiliary unit as compared to the steam superheating surface this auxiliary unit could employ other modes of steam temperature operation control such as gas recirculation, burner tilt and additional desuperheating; and once-through steam generators of either the subcritical or supercritical type could be employed.

What I claim is:

1. An apparatus for generating steam comprising: a chemical recovery unit having a vapor generating section; an auxiliary unit having a vapor generating section and burning a fuel, the combustion products of which have low fouling characteristics; the vapor generating sections of the chemical recovery unit and the auxiliary unit being connected in parallel to deliver steam generated through a common conduit; an air heater receiving as its sole heating medium combustion products from the auxiliary unit which pass therethrough; and means for conveying preheated combustion supporting air from the air heater to the chemical recovery unit.

2. An apparatus as in claim **1** including, an evaporator for concentrating black liquor, this black liquor being the fuel for the chemical recovery unit, combustion products having high fouling characteristics formed by the combustion thereof; and means for conveying the combustion products from the chemical recovery unit to the evaporator.

3. An apparatus for heating fluids comprising: a first furnace; means for burning black liquor therein; an evaporator for concentrating black liquor; a first flue conveying the black liquor combustion products to the evaporator; fluid heating surface disposed in the first flue; a second furnace; means for burning a fuel, having low fouling characteristics, therein; an air heater; a second flue for conveying the combustion products from the second furnace to the air heater; fluid heating surface disposed within the second flue; means for conveying the preheated air from the air heater to the first furnace; and means for conveying the preheated combustion supporting air from the air heater to the second furnace.

4. A vapor generator comprising: a steam drum; a first furnace; means for burning in the first furnace a fuel, the combustion products of which have high fouling characteristics; steam generating tubes lining at least a portion of the walls of the first furnace; means for conveying water from the steam drum to the tubes lining the walls of the first furnace; means for conveying steam from the tubes lining the wall of the first furnace to the steam drum; a second furnace; means for burning a fuel, the combustion products of which have low fouling characteristics, in the second furnace; steam generating tubes lining at least a portion of the walls of the second furnace; steam superheating tubes associated with the second furnace; means for conveying water from the steam drum to the generating tubes lining the walls of the second furnace; means for conveying steam from the generating tubes lining the walls of the second furnace to the steam drum; means for conveying steam from the steam drum to the superheating tubes associated with the second furnace; means for effecting circulation of water through the generating tubes of the second furnace independent of combustion therein; an air heater receiving its heating medium solely from the second furnace; a flue conducting the combustion products from the second furnace to the air heater; fluid heating surface disposed within the flue; and mean for conveying preheated air from the air heater to the first furnace, said air heater transferring heat from combustion products to air and comprising the entire combustion product to air heating means for the air conveyed to the first furnace.

5. A vapor generator comprising: a steam drum; a first furnace; means for burning in the first furnace a fuel, the combustion products of which have high fouling characteristics; evaporative surface of the first furnace communicating with the steam drum; an air heater; a first flue for conveying the combustion products from the first furnace independent of the air heater; primary steam heating surface disposed therein, and connected to receive steam from the steam drum; a second furnace; means for burning in the second furnace a fuel, the combustion products of which have low fouling characteristics; evaporative surface in the second furnace communicating with the steam drum; a second flue for conveying the combustion products from the second furnace to the air heater; secondary steam heating surface disposed in the second furnace, connected to receive steam from the primary steam heating surface; and means for conveying preheated air from the air heater to the first furnace, said air heater transferring heat from combustion products to air and comprising the entire combustion product to air heating means for the air conveyed to the first furnace.

6. An apparatus for generating vapor comprising: a first steam generating unit having, a first furnace, steam generating surface, steam superheating surface, means for burning in the first furnace fuel, having high fouling characteristics; a second steam generating unit having, a second furnace, steam generating surface including a boiler bank, steam superheating surface, means for burning in the second furnace fuel having low fouling characteristics; means for conveying steam generated in both furnaces to the steam superheating surface of the first unit, and thence to the steam superheating surface of the second unit; and air heater receiving its heating medium solely from the second furnace; means for conveying the combustion products from the second furnace to the air heater; and means for conveying preheated combustion supporting air from the air heater to the first furnace, said air heater transferring heat from combustion products to air and comprising the entire combustion product to air heating means for the air conveyed to the first furnace.

7. An apparatus for generating steam comprising: a chemical recovery unit having a vapor generating section and a vapor superheating section; an auxiliary unit having a vapor generating section and a vapor superheating section, and burning a fuel the combustion products of which have low fouling characteristics; the vapor generating sections of the chemical recovery unit and the auxiliary unit being connected in parallel; the steam superheating section of the chemical recovery unit receiving its steam from the vapor generating sections; the vapor superheating section of the auxiliary unit receiving its steam from the steam superheating section of the chemical recovery unit; an air heater connected to receive combustion products which have left the auxiliary unit as the predominate heating medium therefore; and means for conveying preheated combustion supporting air from the air heater to the chemical recovery unit.

8. An apparatus as in claim 7 where the steam superheating section of the chemical recovery unit is designed to operate at a steam temperature less than 900° F.

9. A vapor generating installation comprising in combination a chemical recovery vapor generator and an auxiliary vapor generator fired with a relatively clean fuel, said chemical recovery vapor generator having a vapor generating system, said auxiliary vapor generator having a vapor generating system connected into and in parallel relation with the vapor generating system of the chemical recovery vapor generator, first superheating means in the chemical recovery vapor generator operative to superheat the vapor generated in said systems, second superheating means in said auxiliary vapor generator connected to receive the superheated steam from said first means and heat it to a desired final temperature, an air heater receiving its heating medium solely from the auxiliary vapor generator, means to deliver preheated combustion supporting air from the air heater to the chemical recovery vapor generator, said vapor generating installation having the characteristic that when the auxiliary vapor generator is fired at approximately full rating and the chemical recovery vapor generator is fired at a variable rating the enthalpy of the superheated vapor leaving said first superheating means has in general a value defined by the equation

$$h_e = h_o - \left(\frac{K}{w+s}\right)$$

where h_e represents the enthalpy of the steam leaving said first superheating means; h_o represents the enthalpy of the steam leaving the auxiliary vapor generator; w represents the quantity of steam generated in the chemical recovery vapor generator; s represents the quantity of steam generated in the auxiliary vapor generator and K represents a constant.

10. In a system including a first steam generating unit having a superheater, and means for regulating the steam temperature leaving the superheater, a second steam generating unit having a superheater receiving steam from the superheater of the first unit, an air heater receiving gas from the second unit and delivering preheated air from the air heater to the first unit the method of operation comprising; firing the first unit to obtain the desired steam flow, firing the second unit to obtain the desired final steam temperature, detecting the preheated air temperature, resetting the desired steam temperature leaving the first unit to a predetermined value such that the resulting firing rate in the second unit to obtain the desired final steam temperature operates through the air heater to produce the desired preheated air temperature, and regulating the steam temperature leaving the first unit to obtain this desired steam temperature leaving the first unit.

11. A method of generating steam comprising: burning fuel in a first combustion zone forming first combustion gases; passing the first combustion gases in heat exchange relationship with water, thereby generating steam; burning fuel in a second combustion zone forming second combustion gases; passing the second combustion gases in heat exchange relationship with water, thereby generating additional steam; passing the first combustion gases in heat exchange relationship with the steam generated by passing the first and second combustion gases in heat exchange relationship with water, superheating the steam; subsequently passing the second combustion gases in heat exchange relationship with the thus superheated steam to heat the steam to a final steam temperature, further cooling the second combustion gases to a discharge temperature, independent of said first combustion gases; regulating the fuel to the first combustion zone to obtain the desired steam generation; and regulating the fuel to the second combustion zone to obtain the desired final steam temperature.

12. A method as in claim 11 including also the step of: passing the second combustion gases in heat exchange relation with combustion supporting air for said first combustion zone, maintaining the steam temperature leaving the first furnace throughout a predetermined load range such that an essentially contant firing rate is achieved in the second combustion zone when the fuel to said second combustion zone is regulated to obtain the desired final steam temperature.

13. A method of starting a steam generator comprising: burning fuel in a first combustion zone, generating hot gases; passing water in heat exchange relation with the hot gases, heating the water; passing air through a second zone; passing this air in heat exchange relation with the heated water, heating the air; passing the heated air in heat exchange relationship with combustion supporting air, heating the combustion supporting air; and conveying the heated combustion supporting air to the first combustion zone to support combustion therein.

14. In a steam generator organization comprising a chemical recovery unit having vapor generating surface, an auxiliary unit having vapor generating surface in communication with the vapor generating surface of the chemical recovery unit, means for burning a fuel, the combustion products of which have low fouling characteristics in the auxiliary unit, an air heater receiving combustion products from the auxiliary unit as its heating medium and means for conveying preheated combustion air from the air heater to the chemical recovery unit, the method of initiating operation of the unit comprising: burning fuel in the chemical recovery unit, generating hot gases; passing these gases in heat exchange relation with the vapor generating surface of the chemical recovery unit, heating water contained therein; passing the water thus heated through the vapor generating surface of the auxiliary unit; passing air through the auxiliary unit in heat exchange relation with the vapor generating surface therein; conveying the air thus heated to the air heater; and passing incoming combustion supporting air in heat exchange relation with the heated air passing through the auxiliary unit, and conveying this preheated combustion supporting air to the chemical recovery unit to support combustion therein.

15. In a vapor generating system operable throughout a predetermined load range the method comprising burning at a first location residual liquor obtained in the manufacture of pulp and creating a hot combustion gas stream thereby, burning a relatively clean burning fuel at a second location and creating a hot combustion gas stream thereby, generating vapor by passing a vaporizable fluid in heat exchange relation with said first burning zone and the combustion gas stream associated therewith and in heat exchange relation with said second zone and the combustion gas stream associated therewith, superheating this vapor by imparting heat thereto from the burning liquor and the combustion gas stream created thereby and thereafter further superheating this vapor by imparting

heat thereto from the burning of the relatively clean burning fuel and the combustion gas stream created thereby, passing air in heat exchange relation with the combustion gas stream created by the burning of the relatively clean burning fuel, conveying this heated air to the first location to be used as combustion supporting air, maintaining the temperature of the finally heated steam at a generally predetermined value throughout said load range and maintaining the enthalpy of the steam as it enters into heat exchange relation with the clean burning fuel and the combustion gas stream created thereby such that the heat to be imparted to this steam by this burning fuel and combustion gas stream to achieve the desired final temperature is generally constant throughout said predetermined load range on the steam generating system.

16. In a vapor generator system having a chemical recovery unit fired with residual liquor and an auxiliary vapor generator fired by a relatively clean burning fuel the improved method of operation comprising establishing a flow of a vaporizable fluid and imparting heat to this fluid from both the chemical recovery unit and the auxiliary steam generator to vaporize a portion thereof, superheating this vapor by imparting heat thereto from the chemical recovery unit, varying the firing rate in the chemical recovery unit through a predetermined range, throughout this range maintaining the enthalpy of the superheated steam produced in the chemical recovery unit generally at a value defined by the formula

$$h_o - \frac{K}{(w+s)}$$

where h_o represents the enthalpy of the vapor leaving the auxiliary vapor generator, K is a constant, w represents the quantity of steam generated in the recovery unit and s represents the quantity of steam generated in the auxiliary unit, additionally heating the superheated steam by imparting heat thereto in the auxiliary unit, heating air by imparting heat thereto from the auxiliary unit, and using this heated air to support the combustion of the residual liquor in the chemical recovery unit, and firing said auxiliary unit to maintain the enthalpy of the steam egressing therefrom generally at a predetermined value during the variation of the firing of the chemical recovery unit through said predetermined range.

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