Aug. 5, 1952 A. L. HAMM 2,606,103

CHEMICAL RECOVERY FURNACE WITH HIGH-TEMPERATURE SUPERHEATER

Filed June 13, 1947 2 SHEETS—SHEET 1

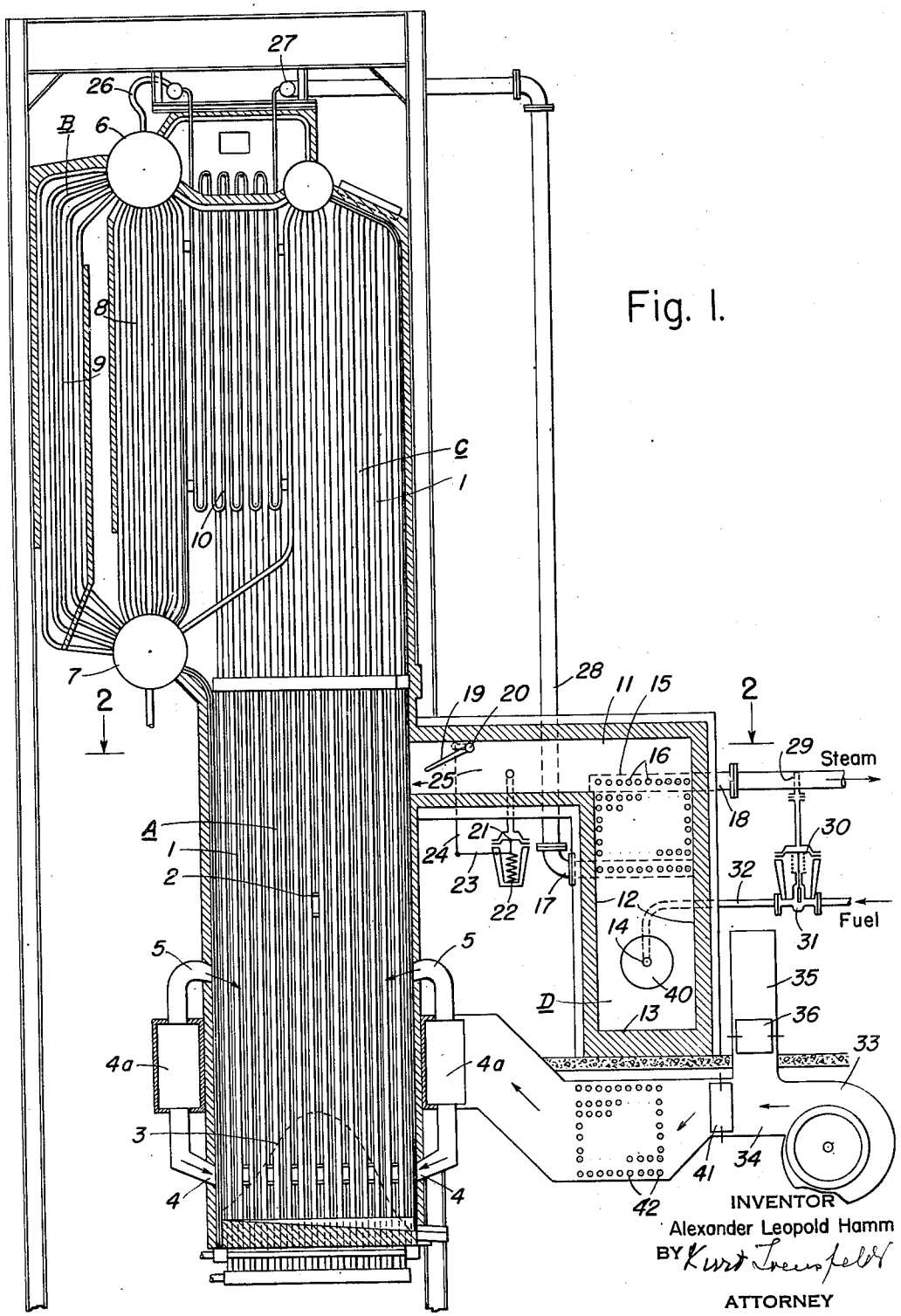

Fig. 1.

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2 SHEETS—SHEET 2

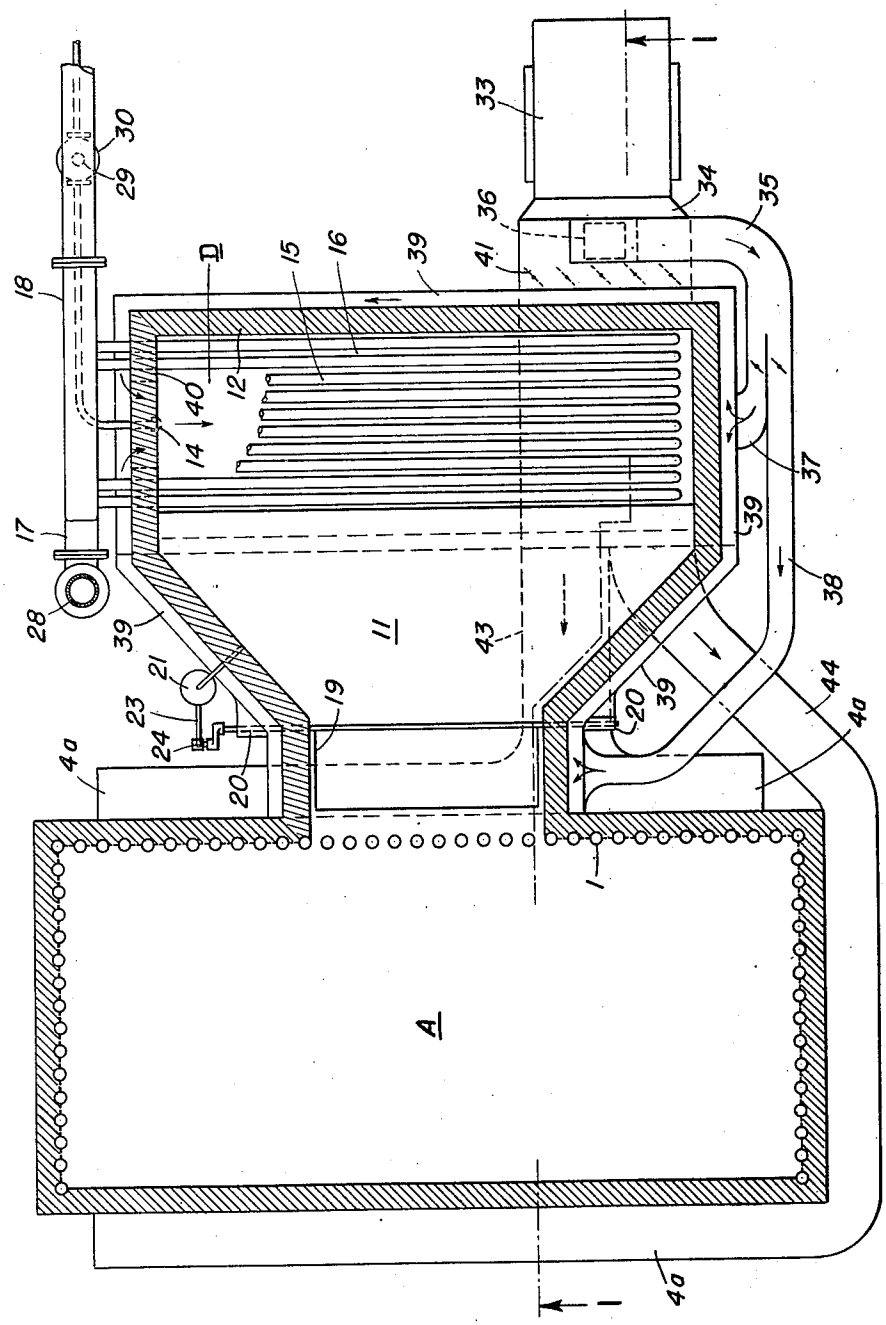

Fig. 2.

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CHEMICAL RECOVERY FURNACE WITH HIGH-TEMPERATURE SUPERHEATER

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5 Claims. (Cl. 23—262)

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This invention relates to superheaters in association with boilers of chemical recovery furnaces and particularly superheaters for relatively high steam temperatures in association with boilers receiving the products of combustion from a smelter furnace in which chemical is removed from the black liquor of wood pulp mills.

It is well known in the operation of the so-called sulphate recovery furnaces from which the products of combustion flow through an associated steam boiler without a superheater, that much less labor is required to clean off the deposits which condense out of the products and adhere to the boiler tubes than is required to clean said deposits from the superheater tubes when a superheater is associated with the boiler. This is due to the difference in metal temperatures between the boiler tubes and the superheater tubes.

In tubes exposed to the products of combustion rising from a sulphate furnace, containing water at temperatures of from 350° F. to 500° F., the tube wall temperature is between about 500 to 650° F. with the outer tube skin temperature slightly higher. These last metal temperatures are present on the tube areas which contact the sodium salts, principally sodium carbonate and sodium sulphate, rising from the furnace in the products of combustion and on to which tube areas these salts condense and adhere. It has been found to be much easier to clean the salt deposits from the surfaces of tubes, as by lancing or by soot blowing, at a temperature of 500° F. than at 650° F. As the tube surface temperatures rise, the difficulties of cleaning the salt deposits from the tubes correspondingly increase.

Steam pressure and temperature requirements for sulphate furnace boilers have lately risen to about 600 to 800 P. S. I. and 825° total temperature. Such high steam temperatures require a large superheating surface exposed to relatively high temperature furnace gases which multiply the difficulties of cleaning the superheater. The metal skin temperature of these superheater tubes rise to about 912° F. and the task and cost of keeping the tubes clean under these conditions has become prohibitively high. Sodium carbonate and sodium sulphate melt at about 1500° F. and may melt as low as about 1200° F. when occurring in mixtures of the products of combustion rising from a sulphate recovery furnace. It is therefore very necessary to keep the tube wall temperatures of the superheaters exposed to such gases as far below 1200° F. as possible to insure satisfactory cleaning of the tubes and consequent good operation.

As mentioned above superheater tube temperatures at about 912° F., corresponding to a steam temperature of 825° F., have been found to be prohibitively high when exposed to the products

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of combustion from a sulphate furnace and with possibly higher steam temperature requirements in the future, the producing of such temperatures by the now accepted designs of superheaters in association with sulphate furnaces, becomes impractical.

In addition to the tube temperature limits which have now been reached, other dependent limits have appeared in the present designs of superheaters for sulphate furnaces.

The higher tube temperatures and the consequent increased accumulation of salt deposits upon the tubes, has required an increased spacing apart of the tubes to avoid bridging across of said deposits from tube to tube. This tube spacing has approached the limit beyond which the long intertube supporting members or spacer pieces will burn.

The height of the furnaces is limited by the furnace gas temperatures necessary to produce the highest steam temperatures now required. In furnaces of substantial width, moreover, the conical shaped fuel bed, essential for successful smelting of the chemical, increases the difference in temperatures of the stratified streams of combustion products which rise through the furnace, causing a relatively higher temperature stream to flow up through the center of the furnace with cooler streams adjacent the walls.

This hotter center stream increases the deposits on the hot tubes thereabove contacted by said stream and if the temperature of said center stream be reduced, the temperature of the streams adjacent the walls are also reduced and consequently the average furnace gas leaving temperature is lowered which produces an undesirable condition for achieving high superheats with a minimum of superheating surface.

It is an object of this invention to minimize the foregoing difficulties by providing improved steam superheating means for obtaining relatively high steam temperatures in superheaters associated with chemical recovery furnaces.

Another object is to provide improved means for controlling the temperature of the steam leaving superheaters associated with chemical recovery furnaces.

A further object is to provide improved means to substantially equalize the temperature of the products of combustion leaving chemical recovery furnaces across the entire cross sectional area of the flow of products.

Other objects of the invention will appear from the following description in which the preferred embodiment of the invention is set forth in detail, reference being made to the accompanying drawings wherein:

Figure 1 is a more or less diagrammatic vertical section, taken on line 1—1 of Fig. 2, through

a smelter furnace and associated boiler for practicing the invention; and

Figure 2 is a section taken on line 2—2 of Fig. 1, on an enlarged scale, showing other details of the improved apparatus organization.

Referring now to Figure 1, the reference character A denotes the smelter furnace, the four walls of which are lined with exposed finned tubes 1 spaced on close centers and connected with the boiler proper B for water circulation therethrough. In effect these finned tubes 1 constitute a continuous metallic wall which line the interior of the furnace and the inner face of which is exposed to radiant heat. Immediately above the smelter furnace A is a chamber C, similarly lined with finned tubes 1, to the rear of which is the boiler proper B, the appurtenances of which (such as evaporator, exhaust fan and flues) are not shown. The furnace chamber A and the chamber C are superimposed as represented. The furnace A is of the general type shown in my United States Patent 2,319,399, issued May 18, 1943.

The black liquor evaporated to the desired concentration, approximately 65% to 70% solids, is introduced into the furnace chamber by the nozzles 2, the black liquor being supplied to the nozzles at a pressure from about 15 to 20 pounds per square inch and at a temperature of from 220° to 240° F. Owing to the reduction in pressure at the spray nozzles, some of the moisture contained in the sprayed particles flashes into steam, thus further decreasing the moisture content of the particles. The sprayed particles gravitate in counterflow with the rising flame and gas stream from the smelting zone and are dried in space. The dried particles collect on the hearth in the form of a conical bed of fuel 3 with its highest portion at the middle portion of the furnace. Preheated air for combustion is admitted into the fuel bed by means of air nozzles 4 from the supply ducts 4a. The chemical associated with the combustible is smelted and flows out in molten form from the hearth. The combustibles in the gases rising from the fuel bed are burned, for which purpose additional preheated air is admitted above the fuel bed by means of the air nozzles 5, preferably downwardly inclined.

Referring now to the boiler proper B, this comprises a steam and water drum 6, a mud drum 7 and connecting banks of upright tubes 8 and 9. The banks are baffled to provide vertical passes; the entrance to the first pass being below the steam and water drum 6. Immediately in advance of the tubes 8 with respect to the furnace gas flow, there is a vertically disposed superheater 10. suspended from above the boiler setting as indicated.

The products of combustion rising from the fuel bed 3 on the furnace hearth entrain chemicals, mostly sublimated sodium salts, which yielding heat to the heat absorbing surfaces of the furnace, superheater and boiler, condense into plastic and eventual solid states. The globules or particles of condensed chemicals occasion difficulties by impinging upon and building up on the tubes of the heat absorbing surfaces, particularly upon the hotter superheater surfaces, which are located within the chamber C through which the gases flow on their way to the boiler convection banks.

The heat absorbed by the exposed water cooled tube wall surfaces is sufficient to lower the temperature of the gases leaving the top of the chamber A and entering the bottom of the chamber C to approximately 1800 to 2200° F., well above the melting point of the chemicals. The predominant salts in the furnace gases, sodium carbonate and sodium sulphate, melt at about 1500° F. and may melt at as low as about 1200° F. when present in mixtures of gases such as may occur in recovery furnaces. Above these temperatures the salts are successively in a semi-plastic and vapor state and below they may be sufficiently plastic to adhere to the heat absorbing tubes.

I have found that heat absorbing tubes, such as superheater tubes may be exposed to furnace gases at temperatures at and below about 1400° F. without objectionable salt deposits thereon when the furnace gases flow longitudinally of the tubes. For satisfactory operation then, the heat absorbing tubes must be arranged in the upper chamber C so the gases will flow substantially parallel thereto for a distance until the gases have been cooled to not over about 1200° F. and thereafter the gases may flow transversely to the tubes. As mentioned above, I have found that the higher temperatures of the superheater tubes, such as occur when approaching steam temperatures of about 825° F., are an added influence to the adherence of salts onto the tubes.

I have further found that due to the conical shaped fuel bed 3 on the furnace hearth with its highest portion in the middle portion of the furnace, the difference in temperatures between the stream of combustion products rising centrally through the furnace and the streams rising adjacent the end walls, is greater than usual. This central hotter stream maintains the salts entrained therein at a higher temperature than those entrained in the adjacent cooler streams and thereby increases the relative amount of salt deposits on the superheater tubes contacted by the hotter stream. To lower the temperature of this central hot stream by cooling all of the products with additional furnace heat absorbing surface will tend to reduce the average furnace gas leaving temperature and thereby tends to defeat the attainment of the higher superheats with a minimum of superheater surface. As mentioned above, it is very necessary at the higher superheats, to keep the tube wall temperatures of the superheater as low as possible to insure satisfactory cleaning of the tubes and consequent good operation, and to attain a maximum heat head between the surrounding gases and the tube surface.

According to the invention, I accomplish a relatively closer equalization of the temperatures of the products of combustion entering the superheater tubes across the entire cross sectional area of the furnace and thereby obtain a relativelly advantageous higher average temperature of the products entering the superheater. Furthermore I reduce temperature of the superheater tubes and thereby reduce the amount of salts deposited thereon and obtain a greater heat head between the gases and tubes. Still further, I control the temperature of superheat independently of the sulphate furnace operation. The foregoing is accomplished as follows.

Offset from the recovery furnace A is a separately fired superheater furnace D, the offtake flue 11 of which is connected into furnace A at such a location that the flue gases therefrom discharge into the central hot stream of the products of combustion rising through recovery furnace A before the products enter the heating surface of the pendant superheater 10. The temperature and volume of flue gases from the superheater furnace D upon admixture with the

products of combustion from the recovery furnace A, reduces the temperature of the products, and tends to equalize the temperatures across the entire cross sectional area of the main recovery furnace.

Separately fired superheater furnace D (at the side of main furnace A) comprises walls 12 and a floor 13 and may satisfactorily be heated by an oil or other fuel burner 14 which projects through one of those walls. A superheater 15 is located in the offtake 11 of this auxiliary furnace and comprises a multiplicity of parallel return bent tubes 16 connected at their ends respectively into the inlet header 17 and the outlet header 18. The off-take flue 11 from furnace D is connected through the side wall of the main recovery furnace A so as to discharge the flue gases from said superheater furnace into the recovery furnace. The side wall tubes 1 of the recovery furnace A where they cross the discharge of flue 11 have their fins omitted (see Fig. 2) so as to provide openings between tubes for the flow of gases from flue 11.

A damper 19 hinged at 20 is provided in flue 11 whereby to control the velocity of flow of gases into the recovery furnace A. Automatic means may be provided to control the damper 19, such as a diaphragm 21 responsive to the pressure within flue 11. As the pressure within the flue increases the diaphragm 21 moves downwardly against an opposing spring 22 and through lever 23 and connecting rod 24 raises the damper 19 to open the orifice 25 through which gas from flue 11 discharges into recovery furnace A. As the pressure in flue 11 drops the diaphragm 21 rises and lowers damper 19 thereby closing the area of orifice 25. Such means for operating the damper may generally be called motor means.

The pendant superheater 10 in recovery furnace chamber 6 is connected to the upper steam and water drum 6 by tubes 26. The outlet header 27 of said superheater 10 is connected by means of pipe 28 to the inlet header 17 of superheater 15 of the separately fired superheater furnace D. The outlet header 18 of superheater 15 carries superheated steam to the place of use. Thermostatic means 29 may be connected into this outlet pipe 18 and a diaphragm 30, responsive to said thermostatic means 29, may be connected to a valve 31 in the fuel line 32 to the burner 14 of the superheater furnace D. As the temperature of the steam from pipe 18 rises the fluid in the thermostat 29 and above the diaphragm 30 expands and thereby partly closes valve 31 in the fuel line to thereby reduce the superheat. In this manner final temperature of the steam leaving the recovery unit is controlled.

Air for combustion of the fuel in the separately fired superheater furnace D as well as for use in the recovery furnace A may satisfactorily be provided by means of fan 33 discharging into duct 34. A vertical branch duct 35 from duct 34 is provided with a control damper 36 and delivers air via conduits 37 and 38 to a casing 39 surrounding the separately fired superheater furnace D and its flue 11. The casing 39 is offset from the interior refractory walls 12 of the furnace so as to provide free circulation of air around said walls to cool them. At the opposite side of the furnace from conduits 37 and 38 the air space between casing 39 and wall 12 is connected into the furnace through the air admission opening 40 surrounding the fuel burner 14. Air for combustion to burner 14 is thereby heated by withdrawing heat from the furnace walls 12.

The main fan discharge duct 34 conducts air past the branch duct 35 and is provided with dampers 41. Air passing through said duct 34 flows over a bundle of steam heating coils 42 (see Fig. 1) where its temperature is controlled and thence passes to the main supply ducts 4a of the recovery furnace A via conduits 43 and 44 (see Fig. 2).

When employing the invention, the chemical recovery furnace A is operated in the usual manner with the temperatures of the products of combustion entering the pendant superheater 10 being substantially the same as heretofore found satisfactory for safe, practical operation. Because the superheater 10 receives the coolest, saturated steam from the boiler and only heats this steam through a portion of the total temperature required, its hottest tube temperature may be chosen to be substantially less than or at most equal to the hottest tube temperatures heretofore found practical. The extent of possible salt deposits upon the superheater tubes is thereby maintained within permissible limits.

Superheating is then completed by passing the steam from superheater 10 through the separately fired superheater 15. The fuel used by burner 14 in the separately fired superheater furnace D is chosen so that its products of combustion will neither cause objectionable deposits upon the tubes of superheater 15 nor will injure the structure of the tubes at the high temperatures required to effect the higher steam temperatures. Nor shall said fuel have an ash that may be detrimental to the recovery process, should the ash carry over into the recovery furnace A.

The flue gases leaving flue 11 from the separately fired superheater furnace D have been cooled by superheater 15 to such a temperature that its admixture with the hotter central stream of products of combustion rising in the recovery furnace will temper said stream and tend to equalize the temperature of all of the gases and products rising into the chamber C.

While I have shown and described the preferred embodiment of my invention, it will be understood that changes in construction, combination and arrangement of parts may be made without departing from the spirit and scope of the invention as claimed.

I claim:

1. In a system for recovering chemicals and generating and superheating steam from the combustion of black liquor of wood pulp mills, the combination of a smelter furnace having an open top and provided with means for spraying the black liquor into the furnace interior and for burning same in the lower portion thereof, a separate second furnace provided with a burner for firing a separate fuel, a flue connecting the offtake of said second furnace with said smelter furnace interior at a location in the smelter furnace wall above said black liquor spraying and burning means and serving to convey and discharge the combustion gases from the second-furnace fuel transversely into the smelter furnace thereby causing mixture of those gases with the rising gaseous products which result from combustion of said liquor, a vertical upper extension of said smelter furnace defined by generally vertical walls extending upwardly from said open top of the smelter furnace to form an upright

chamber into which there passes the aforesaid rising mixture of liquor combustion products and second-furnace flue gases, a steam boiler successively arranged with respect to said chamber to receive from the chamber's upper portion the said mixture of products and gases from both furnaces, a first steam superheater within said upright chamber located in major part in the upper portion thereof with the longitudinal axis of its tubes disposed generally vertically to substantially parallel the flow thereover of said mixed products and gases and being connected to said boiler to receive directly therefrom saturated steam which in passing through said tubes has superheat imparted thereto, a second steam superheater in said second furnace being exposed to the flow of said second-furnace combustion gases, connecting means between the inlet of said second superheater and the outlet of said first superheater whereby the steam from said first superheater in passing through the second superheater by way of said connecting means has its temperature still further raised while said second-furnace gases in yielding heat to that steam become partially cooled before entering the smelter furnace, water cooled metallic surface lining the walls of said smelter furnace and of said upright chamber, said surface being connected in water circulation with said boiler and being effective to cool the aforesaid mixture of products and gases entering said first superheater whereby to minimize deposition of gas-entrained chemical on the first superheater, means including a valve for adjusting the rate of delivery of fuel to said second furnace whereby to control the final temperature of the steam which leaves said second superheater, adjustable flow restricting means within said second-furnace flue for adjusting the velocity of discharge of the second-furnace combustion gases into the smelter furnace, and motor means responsive to the combustion gas pressure within said second furnace for opening and closing said flow restricting means as required to hold the aforesaid discharge velocity within a range assuring effective mixing of the second-furnace combustion gases with the smelter furnace's liquor combustion products.

2. In a system for recovering chemicals and generating and superheating steam from the combustion of black liquor of wood pulp mills, the combination of a smelter furnace having an open top and provided with means for spraying the black liquor into the furnace interior and for burning same in the lower portion thereof, a separate second furnace provided with a burner for firing a separate fuel, a flue connecting the offtake of said second furnace with said smelter furnace interior at a location in the smelter furnace wall above said black liquor spraying and burning means and serving to convey and discharge the combustion gases from the second-furnace fuel transversely into the smelter furnace thereby causing mixture of those gases with the rising gaseous products which result from combustion of said liquor, a vertical upper extension of said smelter furnace defined by generally vertical walls extending upwardly from said open top of the smelter furnace to form an upright chamber into which there passes the aforesaid rising mixture of liquor combustion products and second-furnace flue gases, a steam boiler successively arranged with respect to said chamber to receive from the chamber's upper portion the said mixture of products and gases from both furnaces, a first steam superheater within said upright chamber located in major part in the upper portion thereof with the longitudinal axis of its tubes disposed generally vertically to substantially parallel the flow thereover of said mixed products and gases and being connected to said boiler to receive directly therefrom saturated steam which in passing through said tubes has superheat imparted thereto, a second steam superheater in said second furnace being exposed to the flow of said second-furnace combustion gases, connecting means between the inlet of said second superheater and the outlet of said first superheater whereby the steam from said first superheater in passing through the second superheater by way of said connecting means has its temperature still further raised while said second-furnace gases in yielding heat to that steam become partially cooled before entering the smelter furnace, water cooled metallic surface lining the walls of said smelter furnace and of said upright chamber, said surface being connected in water circulation with said boiler and being effective to cool the aforesaid mixture of products and gases entering said first superheater whereby to minimize deposition of gas-entrained chemical on the first superheater, an outlet conduit for the steam which leaves said second superheater, means including an element responsive to the final superheat temperature of said leaving steam in that conduit and a valve controlled by said element for adjusting the rate of delivery of fuel to said second furnace as required to hold said final temperature substantially constant, and means including a damper adjacent the discharge end of said second-furnace flue for adjusting the velocity of discharge of the second-furnace combustion gases into the smelter furnace.

3. In a system for recovering chemicals and generating and superheating steam from the combustion of black liquor of wood pulp mills, the combination of a smelter furnace defined by generally vertical walls; means for spraying the black liquor into the furnace interior and for burning same in the lower portion thereof and producing combustion gases laden with vaporized chemical salts; a separate second furnace provided with burner means for firing a separate fuel and producing products of combustion free of vaporized chemical salts; a flue connecting the off-take of said second furnace with said smelter furnace interior at a location in the smelter furnace wall above said black liquor spraying and burning means and serving the convey and discharge at relatively high velocity the combustion gases from the second-furnace fuel transversely into the smelter furnace thereby causing mixture of those gases with the rising gaseous products which result from the combustion of said liquor and as a consequence thereof causing an increase in volume and velocity of said rising gaseous products; a vertical upper extension of said smelter furnace defined by generally vertical walls extending further upwardly from the smelter furnace top to form an upright chamber that receives from the smelter furnace the aforesaid rising mixture of liquor combustion products and second-furnace flue gases; a steam boiler successively arranged with respect to said chamber to receive from the chamber's upper portion the said mixture of products and gases from both furnaces; a first steam superheater within said upright chamber located in major part in the upper portion there-

of with the longitudinal axis of its tubes disposed generally vertically to substantially parallel the high velocity flow thereover of said mixed products and gases and being connected to said boiler to receive directly therefrom saturated steam which in passing through said tubes has superheat imparted thereto; a second steam superheater in said second furnace being exposed to the flow of said second-furnace combustion gases that are free of vaporized chemical salts; connecting means between the inlet of said second superheater and the outlet of said first superheater, whereby the steam from said first superheater in passing through the second superheater by way of said connecting means has its temperature still further raised while said second-furnace gases in yielding heat to that steam become partially cooled before entering the smelter furnace; and water cooled metallic surface lining the walls of said smelter furnace and of said up-right chamber and being connected in water circulation with said boiler, the amount of said water-cooled surface that is interiorly exposed in said smelter furnace and in the portion of said chamber below said first superheater being sufficient to lower the temperature of the aforesaid mixture of products and gases entering that superheater from both furnaces whereby to minimize deposition of gas-entrained chemicals on the first superheater.

4. In a system for recovering chemicals and generating and superheating steam from combustion of waste liquor of wood pulp mills, the combination of a smelter furnace defined by generally vertical walls; means for spraying the waste liquor into the furnace interior and for burning same therein and producing combustion gases laden with vaporized chemical salts; a separate second furnace provided with means for firing a fuel other than waste liquor of wood pulp mills and generating therein products of combustion free of vaporized chemical salts; a flue connecting the off-take of said second furnace with said smelter furnace interior at a point in the smelter furnace wall above said waste liquor spraying and burning means for discharging said second furnace products of combustion into the smelter furnace interior, causing admixture with said smelter furnace combustion gases therein and a substantial increase in the volume and velocity of said gases; an upper extension of said smelter furnace defined by walls extending further upwardly from the smelter furnace top and above said second furnace off-take flue connection to form an upper chamber; steam boiler heating surface successively arranged with respect to said upper chamber; a first steam superheater located within the upper chamber above said second furnace flue connection and being arranged in heat transfer relationship with the mixture of the aforesaid vaporized salt laden combustion gases arising from the smelter furnace and the products of combustion discharged from said second furnace off-take flue, said first superheater having a saturated steam inlet connected to said steam boiler and also having a superheated steam outlet; a second steam superheater located within said second furnace and having a superheated steam inlet connected to the superheated steam outlet of said first superheater, said second steam superheater being arranged in heat transfer relationship with said second-furnace-products of combustion which products are free of vaporized chemical salts, whereby the saturated steam from said boiler can by flowing successively through the first and second superheaters have the degree of its superheat considerably increased without excessive deposition on the heating surfaces of the first superheater of gas entrained chemical that results from the burning of the aforesaid waste liquor.

5. In a system for recovering chemicals and generating and superheating steam from combustion of waste liquor of wood pulp mills, the combination of a chemical recovery furnace defined by generally vertical walls; means for spraying the waste liquor into the furnace interior and for burning same therein and producing combustion gases laden with vaporized chemical salts; a separate second furnace provided with means for firing a fuel other than waste liquor of wood pulp mills and generating therein products of combustion free of vaporized chemical salts; a flue connecting the off-take of said second furnace with said chemical recovery furnace interior at a point in the recovery furnace wall above said waste liquor spraying and burning means for discharging said second furnace products of combustion into the smelter furnace interior, causing admixture with said smelter furnace combustion gases therein and a substantial increase in the volume and velocity of said gases; a vertical upper extension of said recovery furnace defined by walls extending further upwardly from the recovery furnace top and above said second furnace offtake flue connection to form an upper chamber; steam boiler heating surface successively arranged with respect to said upper chamber; a first steam superheater located intermediate said upper chamber and said boiler above said second furnace flue connection and being arranged in heat transfer relationship with the mixture of the aforesaid vaporized-salt-laden combustion gases arising from the smelter furnace and the products of combustion discharged from said second furnace off-take flue and having a saturated steam inlet connected to said steam boiler and also having a superheated steam outlet; a second steam superheater located within said second furnace and having a superheated steam inlet connected to the superheated steam outlet of said first superheater, said second steam superheater being arranged in heat transfer relationship with said second furnace products of combustion free of vaporized chemical salts, whereby the saturated steam from said boiler can by flowing successively through the aforesaid first and second superheaters have its superheat temperature raised to an exceedingly high value without objectionable deposition on the heating surfaces of the first superheater of gas entrained chemical that results from the burning of the aforesaid waste liquor.

ALEXANDER L. HAMM.

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