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COMBUSTION SYSTEM FOR SOAKING PITS

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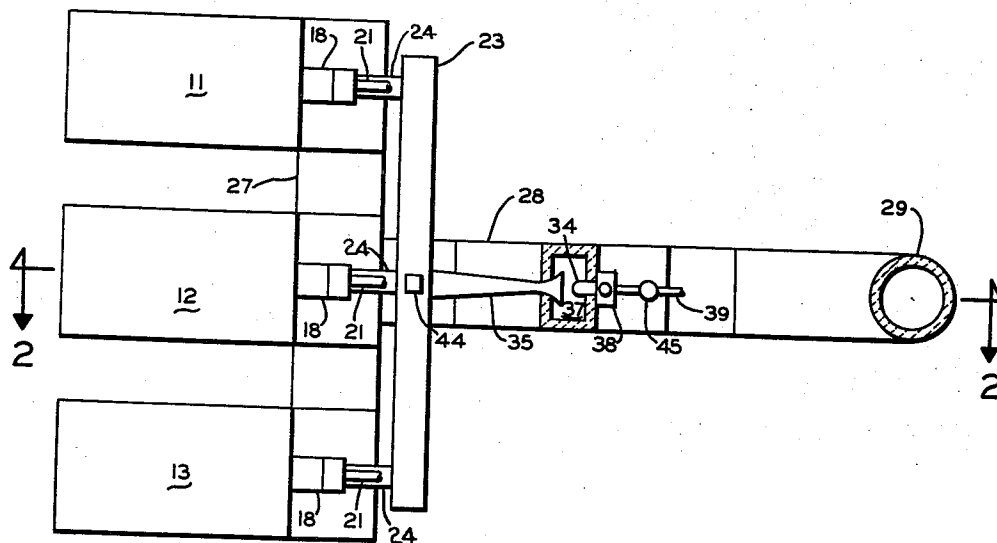


Fig. 1

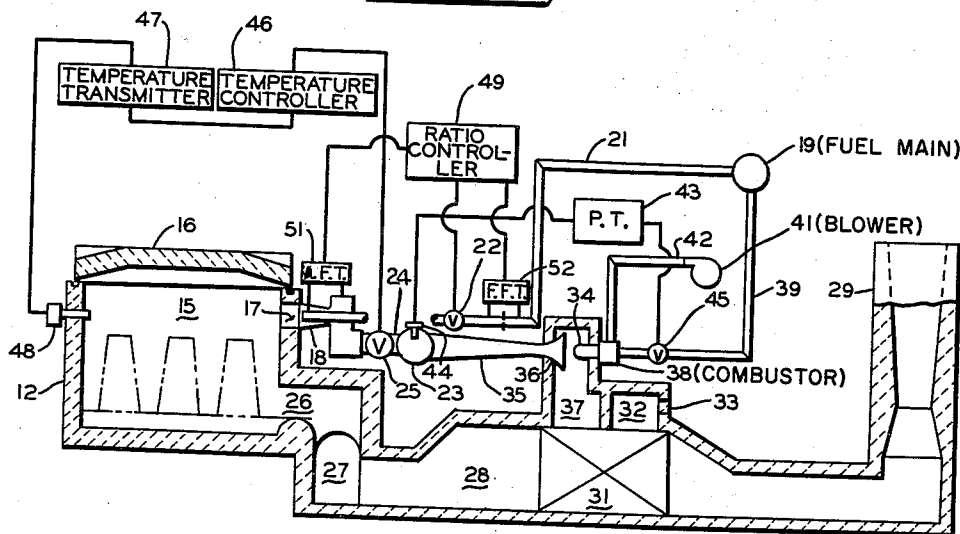


Fig. 2

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COMBUSTION SYSTEM FOR SOAKING PITS
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This invention relates to a combustion system for high temperature furnaces. The invention is particularly well suited for soaking pits which are used in steel mills for heating partially chilled or cold ingots to rolling temperature.

In the operation of such furnaces it is highly desirable to utilize the heat in the flue gases to preheat the combustion air supply for the soaking pit combustion system. This is accomplished by means of a suitable recuperator having a flue product passage in heat transfer relationship with an air passage.

For a recuperator to be satisfactory for such an application it must be capable of withstanding the deleterious effects of the high temperature combustion products (initially of the order of magnitude of 2400° F.) which flow therethrough. Recuperators constructed of suitable ceramic materials such as those of the type disclosed in United States Patent 1,404,721 to Stein, have been proven extremely well suited for such soaking pit applications. In the operation of such a recuperator the flue products from the soaking pit generally pass through the flue product passage thereof at some sub-atmospheric pressure due to the influence of a draft producing means (e.g., a stack). To minimize leakage or short-circuiting of combustion air flowing through the air passage into the flue gas passage, it is also desirable to maintain the pressure of the air in the air passage at a subatmospheric value. Conventionally, this is accomplished by locating the air pumping means downstream rather than upstream of the recuperator, i.e. with the air passage of the recuperator connected to the suction side rather than the pressure side of the air pumping means.

In such an arrangement of air pumping means and recuperator, however, the air pumping means is exposed to the maximum temperature of the preheated air which, desirably, ought to be as high as possible. Accordingly, prior artisans have exhibited a preference for inspirating-type pumping devices over mechanical devices such as fans, which are inherently more sensitive to high temperatures.

In an inspirating-type pumping device the outlet of the air passage of the recuperator is disposed in communication with the inlet of a venturi whose outlet or diffuser is in communication with the soaking pit combustion system. A stream of high pressure entraining fluid is ejected into the venturi in such a manner as to entrain a stream of preheated air from the recuperator. A drawback to prior art systems of this type is that the entraining fluid is generally at some significantly lower temperature than the temperature of the preheated air from the recuperator. Hence, the temperature of the mixture which is delivered to the soaking pit combustion system is, undesirably, less than the temperature of the air from the recuperator. This drawback was largely overcome, however, in the system described in United States Patent 2,627,398 to Hepburn, wherein a second recuperator (metallic) was provided in the flue product exhaust at a point downstream of the ceramic recuperator for the purpose of preheating the stream of high pressure entraining fluid (also air). The Hepburn system served to increase the temperature of the ultimate combustion air mixture delivered to the combustion system in two ways; first, by virtue of the sensible heat added to the entraining fluid and second, by increasing the entraining power of the entraining fluid, i.e., by reduc-

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ing the quantity of entraining fluid required to entrain a given quantity of air from the ceramic recuperator. In practice, the system described in the aforesaid patent to Hepburn proved capable of delivering preheated combustion air to a soaking pit combustion system at temperatures from 1000° F. to 1500° F. In a typical installation, 30%–35% of this air would consist of entraining air preheated to 700° F. to 900° F. in a metallic recuperator while the balance would consist of entrained air preheated to a temperature from 1000° F. to 1700° F. in the ceramic recuperator.

The present invention is concerned with a novel inspirating-type pumping system for delivering preheated combustion air from a ceramic recuperator to a soaking pit combustion system which eliminates the need for the metallic recuperator of the system described in the aforesaid patent to Hepburn without unduly penalizing the efficiency of the recuperative system. In the present invention it is proposed to utilize a high temperature high pressure stream of entraining fluid comprising a mixture of products of combustion and air. This mixture is obtained from a combustor having an outlet disposed in fluid communication with the inlet of a venturi in inspirating relationship with preheated air from the outlet of the air passage of a ceramic recuperator.

The compressed air which is delivered to the combustor may be cold thereby obviating the need for the metallic recuperator of the jet pump system of the aforesaid patent to Hepburn. The chilling effect and reduced entraining power of cold air jets of prior art jet pump systems is obviated by the high temperature attained by reacting the compressed air with fuel.

In the preferred embodiment of the invention a single combustion air supply system is provided for supplying preheated combustion air to a plurality or a battery of soaking pits. In such a situation a single combustion jet is utilized to draw air through a single ceramic recuperator provided in a flue common to all the pits and to deliver the air to a single manifold from whence it is delivered to each pit in customary fashion. To insure proper operation of the burner means provided for each pit it is important in such an arrangement to maintain the pressure of the preheated air in the combustion air manifold at a relatively constant value despite the varying air demands of the individual pits. To accomplish this, it is necessary to provide means to modulate the quantity of preheated air drawn through the ceramic recuperator in response to a signal indicative of the pressure of the combustion air in the manifold. This, in turn, may be accomplished by controlling the operation of the jet pump combustor since the quantity of preheated air from the ceramic recuperator which will be entrained by the jet of entraining fluid is a function both of the mass and the temperature of the entraining jet.

It has been found that the most simple way in which the combustor may be feasibly operated to provide a jet of variable entraining effect is to modulate only the flow of fuel to the combustor while allowing the flow of compressed air to remain at a constant value thereby providing a jet of entraining fluid of relatively constant mass and variable temperature. Without elaborate compensating equipment, it is not feasible to modulate both the flow of fuel and air to the combustor since the ratio of entrained fluid to entraining fluid decreases as the flow of entraining fluid decreases in a system where the jet pump must operate at constant pressure rise. The consequence of this characteristic is that the oxygen content of the mixture of entraining fluid and entrained fluid delivered to the manifold would, undesirably, decrease significantly at lower flow values due to the increased importance of the effect of oxygen consumption by the fuel stream delivered to the combustor. It has been shown that the oxygen content of the air delivered to

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the preheated air manifold in a system where only combustor fuel flow is modulated will remain within the range of 19% to 20% for the entire range of flow rates, whereas in a system wherein both the flow of fuel and air to the combustor are modulated the oxygen content of the preheated air can vary over a range extending from 13% to 20% without the necessary compensating equipment.

For a further consideration of what is considered to be novel and inventive attention is directed to the following portion of the specification, the drawing, and the appended claim.

In the drawing:

FIG. 1 is a plan view of a plurality of soaking pits, shown as three (3) in number for purposes of illustration, having a common system for supplying preheated air constructed in accordance with the present invention; and

FIG. 2 is a sectional view taken on line 2—2 of FIG. 1 with appropriate control instrumentation added.

Referring more particularly to FIG. 1, numerals 11, 12, and 13 represent individual soaking pits for reheating for rolling a plurality of partially chilled or cold ingots, indicated in outline by discontinuous lines in FIG. 2. Each pit comprises wall means forming a combustion and heating chamber 15 which is normally closed by a removable cover 16. Heating flame enters chamber 15 through a firing port 17 whose inlet is coincident with the outlet of a burner 18. Fuel is delivered to burner 18 from a suitable source, such as main 19, by means of conduit 21 which has a flow control valve 22. Preheated combustion air is delivered to each burner by a conduit 24 having a flow control valve 25.

Flue gas (products of combustion) is vented from each chamber 15 by means of an outlet port 26 to a flue gas exhaust manifold 27 which is common to all the soaking pits. Flue gases from exhaust manifold 27 are drawn through exhaust duct 28 toward stack 29 by the draft created thereby and are thence exhausted into the atmosphere.

Disposed within exhaust duct 28 is an indirect heat exchanger or recuperator 31 having an air passage in indirect heat exchange relationship with flue gases flowing therethrough. Recuperator 31 must be constructed of suitable refractory materials, as in the manner described in United States Patent 1,404,721 to Stein, because available metallic materials are not as well suited to withstand the deleterious effects of the high temperature of the flue gases flowing therethrough. Air is drawn from the atmosphere into inlet housing 32 of recuperator 31 through inlet port 33 by virtue of the draft produced by a jet pump comprising a nozzle 34 adapted to inject a stream of motive fluid into venturi tube 35, which has an inlet portion 36 disposed in air outlet housing 37 of recuperator 31 in fluid communication with preheated air. The mixture of motive fluid from nozzle 34 and preheated air from housing 37 is delivered by venturi tube 35 to air manifold 23 for distribution to the individual pits.

The motive fluid which is delivered to venturi tube 35 by nozzle 34 comprises products of combustion from a combustor 38 which is disposed in fluid communication with nozzle 34. It is to be expressly noted that the term "products of combustion," as used in this regard, is intended to include a mixture of combustion products and air in excess of that required for combustion. Fuel for combustion is delivered to combustor 38 from fuel main 19 by means of combustor fuel conduit 39. Air is delivered to combustor 38 at a moderate pressure, preferably of the order of magnitude of 3 p.s.i.g., from a blower 41 by means of a combustor air conduit 42.

In the operation of the system, it is desirable that the combustion system for each pit be capable of operation independent of influence of the operation of other pits. To achieve this, it is necessary that the pressure of the

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mixture in manifold 23 be maintained at a constant value. Accordingly, control means are provided to control the operation of the jet pump in response to a signal from pressure transmitter 43 indicative of manifold pressure as sensed by element 44. Accordingly, a flow control valve 45 is provided in combustor fuel conduit 39 to control the flow of fuel to combustor 38 in a manner that is an inverse function to the signal from pressure transmitter 43. It is noted that the flow of air from blower 41 to combustor 38 is independent of the rate of fuel. It is desirable that the air and fuel flow to combustor 38 be controlled in this manner because of the inherent characteristic of jet pump devices to require an increased ratio of motive fluid to entrained fluid when operated at reduced flow against a constant pressure. An increase in the ratio of motive fluid to entrained fluid would cause an undesirable decrease in the oxygen content of the resultant mixture delivered to manifold 23, were it not for the increase of the percentage of oxygen in the motive fluid which results from the increased ratio of air to fuel consumed by combustor 38 when only fuel flow is throttled.

The flow of fuel and preheated air to burner 18, unlike the flow of fuel and air to combustor 38, are controlled in ratio to each other by means of flow control valves 22 and 25. One of valves 22 and 25 is operated by a signal from temperature controller 46 so as to control flow through the respective conduit in a manner that is an inverse function of the signal transmitted from temperature transmitter 47 to controller 46, which, in turn, is proportional to temperature within chamber 15, as sensed by thermal element 48. The other of valves 22 and 25 is controlled in response to a signal from ratio control device 49 which, in turn, is responsive to a signal from air flow transmitter 51, indicative of air flow through conduit 24, and a signal from fuel flow transmitter 52, indicative of fuel flow through conduit 21.

As will be evident to those skilled in the art, various modifications and alternatives can be made to the embodiments of this invention without departing from the spirit or scope of the disclosure or the claim.

I claim:

In soaking pit apparatus having wall means defining a plurality of combustion and heating chambers, a burner associated with each chamber for delivering heating flame thereto, a single exhaust passage in fluid communication with each chamber for exhausting combustion products therefrom, recuperator means disposed in said exhaust passage and having an air passage in indirect heat transfer relationship with the flow of combustion products through the recuperator, improved jet pump means for drawing heated air through said recuperator and delivering heated air to the burner associated with each of said chambers comprising, in combination: a manifold for receiving combustion air; a venturi tube having a diffuser portion in fluid communication with said manifold and an inlet portion communicating with the outlet of the air passage of the recuperator; a combustor adapted to promote the combustible reaction of a stream of fuel and a stream of air to produce a stream of products of combustion, said combustor being disposed in fluid communication with the inlet portion of the venturi tube whereby a stream of products of combustion will flow from the combustor into the venturi tube in inspirating relationship with preheated air from the recuperator; combustor fuel and air conduit means for delivering streams of fuel and air to said combustor for reaction; means sensitive to the pressure within the manifold for controlling the rate of flow of fuel to said combustor independently of the rate of flow of air in a manner adapted to maintain manifold pressure relatively constant; a burner fuel conduit associated with each of said chambers for delivering

fuel to the burner associated therewith; a burner air conduit associated with each of said chambers for delivering air from the manifold to the burner associated with the respective chamber; and means responsive to temperature within each chamber for controlling the flow of fuel and air to the respective burner through the respective burner fuel conduit and burner air conduit. 5

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