EMERGENCY SHUTDOWN OPERATION OF RECOVERY BOILERS

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This invention relates to improvements in the manner of installation and method of operation of a recovery boiler of the type employed for example in the so-called kraft sulphite pulp process in the paper industry.

More specifically, the invention is directed towards a recovery boiler which constitutes a black liquor recovery unit. In the production of pulp, wood chips are cooked in digestors with a "white liquor" of which the active chemicals are sodium hydroxide and sodium sulphide. This action separates the lignin from the cellulose of the wood, the lignin being the binder material that holds the cellulose fibres together. The cellulose, upon separation from the lignin, provides the pulp for the manufacture of paper.

The residual black liquor containing the spent chemicals and the dissolved lignin is collected, because it is possible to recover the chemicals from this liquor by burning off the lignin. Such recovery of the chemicals is necessary, in order to make the process economically feasible, and this is the prime purpose of a recovery boiler. However, a great deal of heat is generated in the burning process and it has become conventional to convert this heat steam for general use in the plant.

In order to provide a clearer understanding of the typical structure of this type of boiler, which is now extensively used by the industry, reference will now be made to the accompanying drawings, for which purpose a list of such drawings is first set out:

FIGURE 1 shows the main parts of a recovery boiler of the type referred to above, at least those parts relevant to the present considerations;

FIGURE 2 is a larger fragmentary view of the lower part of the boiler shown in FIGURE 1, taken in central section;

FIGURE 3 is a section on the line III—III in FIGURE 2; and

FIGURE 4 is a large scale fragmentary section on the line IV—IV in FIGURE 2.

The drawings so far listed represent a conventional boiler and hence the prior art to the present invention.

The structural aspects of the present invention are illustrated diagrammatically and by way of example only in FIGURES 5 to 10, details of which are as follows:

FIGURE 5 is a view corresponding to FIGURE 2 showing modifications of the structure of the boiler in accordance with the present invention;

FIGURE 6 is a fragmentary section on the line VI—VI in FIGURE 5;

FIGURE 7 is a fragmentary section on the line VII—VII in FIGURE 5;

FIGURE 8 is a central sectional view of a lower portion of the modified boiler;

FIGURE 9 is a view of a typical burner for use in the arrangement of FIGURE 8; and

FIGURE 10 is an enlarged view taken on the line X—X in FIGURE 5.

The additional boiler construction illustrated in FIGURES 1 to 4 comprises essentially a large, rectangular, vertically elongated enclosure 10 hung from steel beams 11 beneath the roof of the building. The enclosure is formed by means of walls composed of an array of vertically disposed tubes 12 (seen in detail in FIGURE 4) joined together by webs 13. In addition to surrounding the interior of the boiler in this manner, some of the tubes 12 extend at 12a to form a sloping floor for the boiler. In operation the tubes contain water, and they are interconnected by headers shown only generally at 13a beneath the floor of the boiler and also communicate with water storage tanks 14 and a combination of spray and screen tubes 15 arranged in the upper part of the enclosure. The tubes 15 which are provided in addition to the tubes 12 that form the bounding walls of the boiler are located generally above the central area where combustion takes place. Since the manner of arrangement and operation of the water system of the boiler is entirely conventional and has not been modified by the present invention, no further description is believed necessary.

A forced draft fan 20 is provided to blow air through ducts 21 and 22 which in turn lead to ducts 23, 24 and 25 which surround the upper wall of the boiler at different levels. As best seen in FIGURE 2, these ducts serve to supply a draft of air to a series of primary air ports 26, a series of secondary air ports 27 above the primary air ports 26, and a series of tertiary air ports 28 arranged at a still higher elevation in the boiler. In practice, these ports are formed by omitting short lengths of web 13 between the tubes 12 and bending short sections of such tubes towards each other to form openings communicating with the interior of the boiler. Apart from an access port 29, which is used when the boiler is shut down and is closed during operation, the air ports 26, 27 and 28 provide the only means of access for air to the interior of the boiler enclosure. An induced draft fan is also provided, and has been illustrated diagrammatically at 30 in FIGURE 1. In practice the installation is normally more complex than has been shown, including a cyclone evaporator where the free gases are brought into contact with the black liquor to increase the solids content thereof. Again, these components are in no way modified by the present invention and a detailed description of them would be irrelevant for the purposes of the present specification.

The wall tubes 12 are surrounded on the outside by a layer of thermal insulation 31 and, below the line 32 which is referred to as the "full stud line," the inside faces of the tubes 12 are provided with projecting studs 33 which serve at least temporarily to retain black liquor which is sprayed onto them, to cake and ultimately drop down onto the char bed.

Prior to the boiler being placed in service a fire bed 40 is formed above the lower tubes 12a. This fire bed is made of chrome dust which is hammered down into hard, brick-like form.

A spray 41 for the black liquor is provided in one of the walls of the boiler. A typical such black liquor spray is arranged to oscillate and to spray the black liquor all around the inside of the boiler walls, and across the sides of the tubes. Typically, a few such burners will be provided at a level above the primary ports 26, and some will be located above the secondary ports 27.

When the boiler is started up, black liquor is sprayed onto the fire bed 40 from the spray 41 and oil is sprayed in through the burners 42 and ignited by any suitable means. The burning oil is carried with the black liquor and, after operation for a short time, there builds up in the centre of the boiler enclosure a roughly conical heap of burning material which is represented diagrammatically in FIGURES 1 and 2 by the broken line 44.
This heap of burning material is referred to as the char bed and will burn at a temperature typically somewhere within the range of 1200°F to 1500°F, but sometimes in part as high as 1800°F. Once the fire has thus been thoroughly started, the oil burners are turned off and no further oil is normally applied to the boiler. Indeed the burners are normally withdrawn from the walls at this time to prevent combustion from the black liquor which continues to be supplied from the spray 41. The char bed yields a liquor called smelt which contains the chemicals to be recovered, the lignin having provided the source of heat and being largely converted to gas. In addition to combustion of the lignin, the sodium sulphate in the black liquor combines with carbon to produce sodium sulphide, carbon monoxide and carbon dioxide. Sodium carbonate is also formed from the lignin. The smelt is drained off through a duct 45 for further treatment in a conventional manner in a hot water dissolving tank 46.

The forced draft fan 20 and the induced draft fan 30 combine to maintain a continuous flow of air upwardly from the char bed through the boiler, thus maintaining and encouraging combustion at the char bed and removing the products of combustion which thus heat the surfaces 15 in the upper part of the boiler, while the char bed itself mainly imparts its heat to the water in the wall tubes 12.

The air supplied through the primary ports 26 is at a comparatively low pressure in order to promote a reducing atmosphere in the burning mass of char. The secondary ports 27 which are about 5 to 6 feet above the primary ports 26 have air supplied through them at a slightly higher pressure, in order to promote burning of combustible materials rising from the glowing mass of the char bed, while the air supplied to the tertiary ports 28 is at a still higher pressure, being designed to further and complete the combustion process.

As has been mentioned, the oil burners 42 are not permanently fixed in the unit. They are inserted through ports at approximately the level of the secondary ports 27, and when they are needed. Normally these burners 42 are only required for starting up the boiler, for operation under adverse operating conditions (as will be more specifically described below), and for burning down the char bed when shutting down the boiler. For shut down, the supply of black liquor is turned off and sufficient oil is supplied to ensure that the char bed is fully consumed. Typically, such a shut down operation takes from 4 to 6 hours.

When the boiler is operating normally, the char bed assumes the shape of an irregular heap the sides of which are approximately on a level with the primary ports 26, while its high points are approximately on a level with the secondary ports 27. Drying combustible material is continuously falling on top of this heap, as the organic material is burnt off. Such combustible material comes directly from the spray 41 and also falls from the side and back walls on which it has become partially dried and caked as it runs down the faces of the wall tubes 12.

All the description of structure and operation which has so far been provided in this specification relates to conventional boiler construction and operation.

One of the principal difficulties in operating this type of boiler is the danger of explosion. In recent years several such accidents have been seriously injured in pulp mill explosions, and extensive damage to plant has been incurred. The danger of explosion arises from leakage of water from the tubes some measure of which is virtually inevitable at some time or other. There are so many tubes, all subjected to rigorously adverse conditions as a practical matter, it is impossible to operate for any length of time without tolerating a certain amount of water leakage. Serious leaks require immediate shut down of the boiler, but naturally it is desirable to keep the number of shut downs to a minimum. The operating time lost by a shut down is substantial and this is particularly true in the case of an emergency shut down when no time had been available for first consuming the char bed. If the boiler is allowed to cool with the char bed unconsumed, its subsequent removal when cold is a lengthy, expensive and at times dangerous undertaking.

It therefore becomes necessary to accept the fact that operation with a certain degree of water leakage onto the char bed is economically essential. Procedures have been worked out and are in operation for minimizing the danger resulting from water leaks. Moreover, at any time when the danger appears to be becoming excessive there is immediately put into effect an emergency shut down procedure. Notwithstanding the occurrence of serious explosions have taken place in recent years and it has become apparent that reliance on the present emergency shut down procedures is insufficient for the protection of property and lives.

To explain the reason why water leakage can lead to an explosion, assume that a leak develops in one of the tubes 12 or 15 and that water falls down onto the hot char bed. The chemical reaction between water and the char bed and its smelt chemicals is complex, but for the present purposes, the important aspect of the reaction is that the falling water forms a hot "fire spot" on the char bed, that is an area of reduced temperature, and under these conditions the water and sodium sulphide react to form sodium sulphate and hydrogen. It is this hydrogen which becomes mixed with air above the char bed to form an explosive mixture.

Normal operating procedure calls for a pressure slightly below atmospheric in the vicinity of the char bed. In other words, the induced draft fan 30 is arranged together with the natural tendency of the hot gases to rise, to exceed in pressure drop the pressure gain from the forced draft fan 20. This is the preferred mode of operation, but cannot always be maintained. Often the first indication that a water leak exists is a tendency for the pressure in the boiler in the vicinity of the char bed to rise slightly, such increased pressure being due to the generation of steam from the leaking water and the resulting excess of vapor in the boiler. There are, of course, other ways in which a leak may be detected, either by a drop of pressure in the water system itself or by visual or aural detection.

Present operating procedure provides that once the existence of a leak has been detected, the situation is carefully watched by the operating engineer and efforts are made to prevent the pressure at the char bed rising excessively. For example, the dampers on the forced draft fan 20 may be partly closed, to reduce the input of air to the lower end of the boiler. It is not uncommon for boilers of this type to continue to operate for weeks with one or more small leaks, until a routine maintenance shut down becomes due. However, as soon as a leak shows any tendency to become too large, the crew initiates the shut down procedure. Depending upon the seriousness of the leak, this may take the form of either the emergency or the normal shut down procedure. As already explained, the normal shut down procedure consists of turning off the supply of black liquor while returning the oil burners to the boiler to slowly burn away the char bed. The burners are adjusted to lower the boiler temperature gradually until it is safe to turn the burners off altogether and allow the assembly to cool down to atmospheric temperature.

The emergency shut down procedure as conventionally practiced is essentially designed to lower the temperature in the boiler as quickly as possible, but no attempt is made to put the fire out or control the fire as a practical matter, it is impossible to operate for any length of time without tolerating a certain amount of water leakage. Serious leaks require immediate shut down of the boiler, but naturally it is desirable to keep the number of shut downs to a minimum. The operating time lost by a shut down is substantial and...
extent at this stage in an effort to prevent the fire cooling down too quickly, especially at local areas. Also the black liquor line may be reopened for a minute or so in an effort to form an insulating blanket over the char bed. However, once the emergency shut down procedure has begun in earnest, no oil and no black liquor will normally be fed into the boiler and the forestay damper will be fully closed. The basic aim being to cool down the char bed as soon as possible. In a short time the char bed will go completely black, the temperature already having begun to fall significantly. Even so, the whole cooling down process takes several hours. Meanwhile, the induced draft fan is kept running in an endeavour to remove as much as possible of the potentially explosive gases that can be expected to be formed by the interaction of water with the still hot char bed. Indeed it is at this time, i.e. while cooling down from normal operating temperature, that the conditions are most conducive to the formation of substantial quantities of hydrogen. In a recent accident, it was found that the induced draft fan had lost power at this stage, because of falling steam pressure.

Not only may black liquor be sprayed on the bed at this time to provide a relatively cool insulating blanket over the molten char, but it has even been suggested that steam injected into the boiler at this time to attempt to smother the fire as quickly as possible. This basic concept of trying to lower the temperature as quickly as possible is inherent in all presently practiced versions of the emergency shut down procedure, some details of which may vary between various installations and in the light of circumstances, at the direction of the various engineers in charge.

Notwithstanding these precautions, there have been a number of recent instances when such emergency procedure have proved insufficient. Explosive combinations of gases, especially hydrogen and oxygen have built up in the boiler while the fire was still hot enough to ignite them. The resulting explosions have been costly both in lives and material.

The basic concept underlying the present invention is that any attempt to smother the fire under the emergency condition of excessive water leakage is essentially mis-guided, and that, conversely, the procedure which is far safer is to take steps to increase the temperature of the char bed in order to consume this bed as quickly as possible while keeping the same at a temperature high enough that either no significant amount of hydrogen is produced or any hydrogen that is generated is burnt, before it has been permitted to accumulate. For example, the temperature of a typical portion of the char bed should be raised to at least 2000°F. and preferably more to the region of 2400°F.

The preferred manner of achieving this end will now be described in relation to FIGURES 5 to 10, in which connection it is to be understood that the apparatus and methods now to be described are provided merely as example of ways in which the foregoing broad concept of the invention may be practiced. Alternatives within this broad concept also form part of the present invention, even though some of the structure employed may differ in detail.

In order to achieve an effective increase in the operating temperature of the char bed, even in the face of the leaking water which tends to cool the char bed, it is preferable to substantially prevent any excess of air entering the boiler (through the primary, secondary and tertiary ports) from which it would provide burners for generating intensely hot flames and for supplying oxygen to the char bed, these burners being located adjacent the boiler floor structure in order to direct the hot flames and oxygen directly at the char bed and particularly at the lower part thereof below and at the level of the primary ports. By reason of the intensely hot flames and oxygen directed against the char bed the same is quickly consumed (no additional black liquor being supplied) in a much quicker time than is normal with the presently practiced routine or emergency shut down procedures.

FIGURE 9 illustrates generally a typical form of burner that could be used for this purpose. The burner itself is conventional, but its application at this particular location in a recovery boiler is novel. The burner consists of an oil supply line 50 which feeds an atomizer mechanism 51 by which the oil fuel is jetted from head 52 towards the char bed. Oxygen is supplied through pipe 53 to an annular header 54 from which it issues at orifices 55 to ensure an oxygen-enriched atmo-sphere in the vicinity of the char bed. Louvres 56 can be adjusted to admit some air, if desired, or to exclude all air from the device.

According to the preferred form of the present invention the boiler structure is modified to introduce a number of such burners 49 into the walls of the enclosure at approximately the level of the primary ports. Typical location of these burners 49 is indicated in FIGURES 5, 7 and 8, in which views the burners themselves are only shown diagrammatically. FIGURE 8 also shows (purely symbolically and by way of example) that each of the primary ports 26 is provided with a movable damper 60 by which such port can be fully closed. Simultaneous operation of the dampers 60 is provided for by a mech-anism such as the rod 61 and control lever 62. Similar mechanisms are fitted to the secondary and tertiary ports. FIGURE 5 indicates levers 62 are controlling louvres on the primary and secondary ports. A similar lever 62a is provided for controlling closure of the tertiary ports 28. It will be appreciated that the specific construction of these parts may differ widely from installation to installation, especially having regard to the particular problems presented at each installation by the location of other parts. The issue of importance from the point of view of the present invention is that each of the air admission ports should be capable of being closed when the burners 49 are in operation.

It is anticipated that the burners 49 would normally form part of the permanent structure of the boiler, rather than being constructed for insertion and withdrawal in the manner of the conventional oil burners 42 (which may still be employed for normal operation). On the other hand, if, preferred in any particular installation, the burners 49 may be made capable of being withdrawn from the boiler, with appropriate provision then being made for closing the ports through which they operate, for example a downwardly slideable damper 57 as shown in FIGURE 5.

The additional apparatus provided by the present invention is designed primarily for use during emergency conditions, and specifically to enable a new and improved emergency shut down procedure to be employed. Alternatively, the burners 49 may entirely replace the conventional burners 42 and be used to perform the function of the burners 42 during the firing up process, in which case the additional apparatus will be used during normal and during emergency operating conditions. Nevertheless, its prime purpose is to make possible the new and improved shut down procedure which consists essentially of increasing the temperature of the char bed, rather than decreasing it, as has been the practice heretofore. This new procedure enables the char bed to be consumed in a relatively short time (typically half an hour) under conditions which are not conducive to the formation of explosive gases in any dangerous quantity. Once the char bed has been consumed the burners 49 are shut down.

When a boiler is operated under this new emergency shut down procedure, oil is supplied under pressure in each of the lines 50 and oxygen in each of the lines 53. It is important to stress that the particular form of burner shown in FIGURE 9 is merely illustrated by way of example. Numerous suitable burners are commercially available, the important consideration being that an extremely hot consuming flame be generated, a result best
achieved by the use of added oxygen supplied from a convenient source, plus the necessary fuel for the burner which may be oil, or could be gas. The supplying of oxygen to the flames makes them independent of the environmental conditions in the boiler. There will always be a flame, and will not be extinguished by water. Such burners throw a short, hot flame and are arranged low down in the boiler (at or adjacent the level of the primary ports) with their flames projected directly towards the centre of the boiler enclosure to consume the char bed as quickly as possible. As the char bed is consumed the burners may be adjusted to increase the flame length and project further into the centre of the char bed. Any excess air entering the boiler is kept to a minimum by shutting (or, if preferred in a particular case, nearly shutting) all the dampers 60 on the normally open primary, secondary and tertiary ports, these latter being capable of normal operation during normal operation of the boiler simply by fully opening the dampers 60. If preferred some of the dampers can be separately controlled.

The induced draft fan 30 is run at full speed during an emergency shut down procedure, for which purpose such fan should be powered from a source independent of the steam pressure available in the boiler at this time. The force draft fan 20 is normally shut off, although its condition will not normally be critical, since its admission ports will be closed. In the event that the engineer in charge decides to admit a small quantity of air to the boiler through the ports, it may be desirable to maintain the force draft fan running at low speed. It will be appreciated that the degree of severity of the leak and the pressure conditions resulting therefrom may call for variations in the details of the emergency shut down procedure at the discretion of the engineer in charge. For example, it might be that in a particular boiler it is found better merely to close the primary and secondary ports and leave open or partly open the tertiary air ports. Nevertheless, it will be desirable to provide some dampers or other means for closing at least the primary air ports and preferably also the secondary and tertiary air ports, so that the engineer in charge has full control over any small amount of excess air that he may decide to permit to enter the boiler. The reason for possibly permitting a certain amount of air to enter the boiler (for example through the burner louveres 56) is that it is desired at all times during the new emergency shut down procedure to maintain a steady current of gases travelling upwardly in the boiler (principally induced by the induction fan 30) to remove from the interior of the boiler any small amounts of potentially explosive gases that may be generated and to prevent their accumulating.

As a further and preferred feature of the present invention, it is convenient to insert one or more ignitors 70 to project into the boiler, preferably at or in the vicinity of the level of the tertiary ports 28. The location of an ignitor is shown in FIGURE 5, and a larger scale view of the device itself is shown in FIGURE 10. Like the burners 49, ignitors of this type are standard items available commercially. Most employ gas and have suitable provision for igniting the gas and projecting the flame through orifices 71 at the end of the ignitor 70 which projects into the interior of the boiler enclosure. In addition to the gas each ignitor is supplied with oxygen so that it cannot be extinguished by water or by lack of oxygen. Thus even under the most adverse conditions there will be a flame that makes them independent of flammable gases. The fuel gas used in the ignitors should be capable of burning regardless of the ambient temperature. The ignitor or ignitors thus ignite any combustible gas that may have risen from the char bed and thus further discourage the accumulation of any such gases in explosive quantities. Alternatively, or additionally, one or more further such ignitors may be inserted into the boiler at the level of the black liquor spray 150.

If desired, such ignitors once provided in accordance with the preferred form of the present invention may be used at all times, not only during the new emergency shut down procedure. For example they could be used during the firing up procedure, during normal operation, or during the normal shut down procedure.

1. In the operation of a recovery boiler of the type employed in the sulphate pulp process, normal operation of said boiler comprising forming a burning char bed in a vertically extending closure having air admission ports, including a draft flowing upwardly in said enclosure to draw gases out of an upper part thereof and feeding black liquor onto said char bed to maintain the same at an elevated temperature; a method of effecting emergency shut down including performing substantially simultaneously the steps of:

(a) elevating the temperature of substantially the whole of the surface of said char bed to a temperature substantially above said elevated temperature,

(b) halting feeding of the black liquor to allow the char bed to be consumed without replacement,

(c) maintaining an oxygen-enriched atmosphere in the vicinity of said char bed to encourage the full combustion thereof and to discourage liberation of combustible gases, and

(d) maintaining said upwardly flowing draft.

2. A method according to claim 1 wherein said char bed surface is elevated to a temperature of approximately 2,400° F.

3. A method according to claim 1 wherein oxygen is supplied to said char bed during said emergency shut down.

4. In the operation of a recovery boiler of the type employed in the sulphate pulp process, the normal operation of said boiler comprising forming a burning char bed at a temperature within the range of 1200° to 1800° F., and maintaining said burning char bed by feeding black liquor thereto, while confining said char bed in an enclosure including inducing in said enclosure a draft of gases flowing upwardly from the char bed to be exhausted from an upper part of said enclosure; a method of effecting emergency shut down including performing substantially simultaneously the steps of:

(a) elevating the temperature of substantially the whole of the surface of said char bed to at least 2000° F.,

(b) halting feeding of the black liquor to allow the char bed to be consumed without replacement,

(c) maintaining an oxygen-enriched atmosphere in the vicinity of said char bed to encourage the full combustion thereof and to discourage liberation of combustible gases,

(d) and maintaining said upwardly flowing draft.

5. The method of claim 4, wherein said oxygen-enriched atmosphere is generated by supplying oxygen to said char bed while restricting the flow of air thereto.

6. The method of claim 4, including providing igniting means in said draft above the char bed to ignite any combustible gases therein.

References Cited

UNITED STATES PATENTS

1,137,780 5/1915 Moore ........................................ 23—48
2,416,462 2/1917 Wilcoxson .................................. 23—277
2,550,670 5/1951 Dalin ........................................ 23—262

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