FIG. 1

HEAT

FIG. 2

HEAT

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WALL THICKNESS AND TEMPERATURE MONITORING APPARATUS FOR BOILER TUBES

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2 Claims

ABSTRACT OF THE DISCLOSURE

Continuous or intermittent examination of operating conditions and operational safety of the boiler tubes of a boiler, during operation of the boiler, is effected by providing an electric current through the wall material of a boiler tube and measuring the voltage drop between points on the boiler tube.

This application is a continuation of application Ser. No. 806,129 filed Mar. 11, 1969 and now abandoned.

At water tube boilers the heat from hot gases to the water (and vapour) content of the boiler is supplied through a tube wall. The tube wall part where the heat passage takes place is given a temperature exceeding that of the water inside the tube. The magnitude of the increase in temperature depends on the heat amount, on the conductivity of the tube material and on the heat transfer resistances on the gas side as well as on the water side.

A coating (boiler scale) on the tube inside, for example, increases the heat transfer resistance on the inside of the tube, thereby rendering the heat transport more difficult and increasing the temperature of the tube material.

In certain cases such an increase in temperature can have catastrophic consequences for the strength of the tube. As the strength of the material decreases with increasing temperature, the strength is exceeded at a certain material temperature, and the tube breaks.

In certain installations the fuel used and also other operation conditions can involve the risk that the thickness of the tube wall is reduced by corrosion on the furnace side. Corrosion can also be caused on the water side. If by such corrosion the tube material is weakened, this weakening may be such that it results in a breaking of the tube. Tube breaks of this type disturb the operation and can in certain cases involve catastrophic risks for the life and health of the personnel as well as for substantial damages of the installation and the expenditures connected therewith.

Examples of such damages with severe consequences can be taken, for example, from the soda recovery units in the sulphate mills of the cellulose industry. In such plants a tube break includes the risk that water flowing out of the tube gets into contact with molten alkali (for example molten Na₂SO₄, NaOH, Na₂S), which easily can result in a devastating explosion. There are many examples of severe incidents in Swedish industry. In U.S.A. many examples of such very serious accidents have occurred during the last years.

These problems are at present given a high degree of attention in all parts of the world. It is tried, for example, to find methods and means by which it would be possible to control in a reliable way if at exposed places in a boiler the tubes are in an operationally safe state. Different methods have been applied.

One may, for example, at regular intervals replace certain tube pieces by new ones and accurately check the pieces removed. It is thereby to be assumed that the samples taken are representative of the tubes most damaged.

In a shut-off installation the tubes on the fume side can be cleaned carefully and thereafter the tube wall will be tested by using ultrasonic or other type of non-destructive testing.

The two methods mentioned, of course, require that the plant is shut off and cooled, which makes the methods time-consuming and expensive. Besides, the first mentioned method is merely a random test.

In view of the continuous operation now being applied generally, a control of the type mentioned is a tremendous burden, because the operation has to be interrupted (for several days).

Experiments have been made of directly measuring the temperature in the tube wall in that part of the tube which faces towards the furnace where the heat is produced. Such a measuring requires thick-walled tubes specially mounted for this purpose. It can, it is true, provide certain information on the temperature in the measuring place which may be of a certain interest. However, the measuring does not provide a satisfactory orientation on changes in the condition of the tubes, in respect of temperature, external and internal corrosion or internal coatings.

The present invention solves the aforesaid difficulties and problems in a superior way. The invention is defined in the claims and relates to a method of controlling the condition and operational safety of the tubes by measuring the electric resistance of the tube.

The invention is based on the known physical laws as follows.

The electric resistance in a conductor is proportional to the length of the conductor and inversely proportional to its area. The electric resistivity increases according to known laws with the temperature of the conductor.

The part of a partially heated boiler tube which during operation is of interest (in respect of the problems here in question) is that side of the tube which faces inwardly to the furnace. This part, by methods presently known, is entirely inaccessible to such control required for a reliable safety in operation.

The method according to the invention is described below in greater detail with reference to the drawing where:

FIG. 1 shows a partially heated boiler tube in a section and in a schematic view showing how the measuring devices are mounted, and FIG. 2 shows in a section several tubes, which are provided with ribs and welded together.

In FIG. 1, the designations 1, 2, 3 and 4 refer to different parts of a tube cross-section. The tube is provided with connecting terminals 5 and 6 for electric current. A voltmeter 9 is connected to the tube via a pair of measuring terminals 7 and 8. At the measuring, an electric current with known and constant amperage is supplied from a source 10 of constant current to the connecting terminals 5 and 6. The current passes through the current path in the tube, which path comprises the connecting terminal 5, tube part 4 and connecting terminal 6, and through the current path comprising the connecting terminal 5, tube part 2 and connecting terminal 6, the current intensity in the two paths being inversely proportional to the resistance of the paths.

If the tube part 4 the resistance increases, also the current intensity through tube part 2 increases and thereby increases the voltage drop between the measuring terminals 7 and 8. An increase in resistance in tube part 4, thus,
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is mirrored as a greater deflection on voltmeter 9. Such an increase in resistance can have its reason in a temperature increase in the tube part 4 or in a reduced sectional area for the current through the tube part 4.

Under normal conditions the voltmeter 9 indicates voltages corresponding to values being characteristic of the operation. If during operation the tube wall in the parts 1-4-3 is weakened by external and/or internal corrosion, the voltage on voltmeter 9 increases. Such is also the case if the temperature of the tube material due to the prevailing operational conditions increases. Such a temperature increase, for example, may be caused by internal coatings on the tube or by too high load. In any case, a voltage increase on the voltmeter 9 signals unpermitted operation conditions.

At a newly mounted tube the voltage drop between the measuring terminals 7 and 8 is determined under isothermal conditions. The relation between this voltage drop and the temperature in the heated tube part 4 can thereby be determined empirically.

The temperature in tube part 2 which normally follows the temperature of the water, must be measured. This can be carried out, for example, by thermocouple elements or corresponding thermometers. The temperature measured is thereafter to be used for the correction of further evaluations of the main measurement.

The temperature in the tube water is measured separately.

In certain boilers the tubes are in mutual electric contact with each other. FIG. 2 shows such a tube arrangement where the tubes 11 are provided with ribs 12 joined together by welds 13 to form a tube board. It is there possible to control several tubes by the same measurement, in that the constant current is supplied to the connecting terminals 5 and 6 which are not mounted on the same tube, and the voltage drop is measured between the measuring terminals 7 and 8 which are not mounted on the same tube, either.

The measuring of the voltage can also be made directly between the connecting terminals 5 and 6. This can be of advantage at entirely heated tubes, on which the connecting terminals 5 and 6 are separated in the longitudinal direction of the tube.

Every tube or tube board may be provided with several pairs of connecting terminals or and several pairs of measuring terminals, depending on the geometric design of the tube.

The control measurements in operation can be carried out manually or automatically with cyclic switching to the current source and measuring device. At unusual conditions, alarm and actions, such as shut down, can be released automatically.

By utilizing the invention it is, thus, possible to control the condition of the tubes in operation and thereby to prevent such explosions, as they so frequently have occurred during the last years.

I claim:

1. Apparatus for continuously or intermittently monitoring operating conditions of a boiler tube during boiler operation, such as the wall thickness and the temperature thereof, comprising a pair of spaced current terminals mounted on the outer surface of a boiler tube wall in a cross-sectional plane thereof, said terminals being mounted on that side of the tube wall remote from the direct source of heat for heating the boiler tube so as to provide two current paths through a cross-section of the tube wall, a source of constant amperage electric current, means connecting the source of current with said current terminals, a pair of spaced measuring terminals mounted between said current terminals on the outer surface of the boiler tube wall in the same cross-sectional plane as said current terminals and on the same side of the boiler,

and means for measuring and monitoring the voltage drop between said measuring terminals whereby an increased temperature caused by increased deposits or by decreased tube wall thickness in either of said current paths is reflected by an increased voltage drop on said measuring and monitoring means.

2. Apparatus as claimed in claim 1 wherein the current terminals are used also as measuring terminals.

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