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APPARATUS FOR TESTING EMBRITTLEMENT CHARACTERISTICS OF BOILER WATERS

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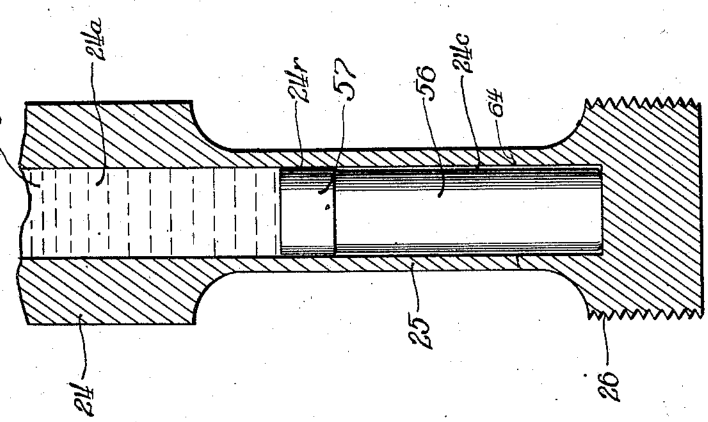
Fig. 2.



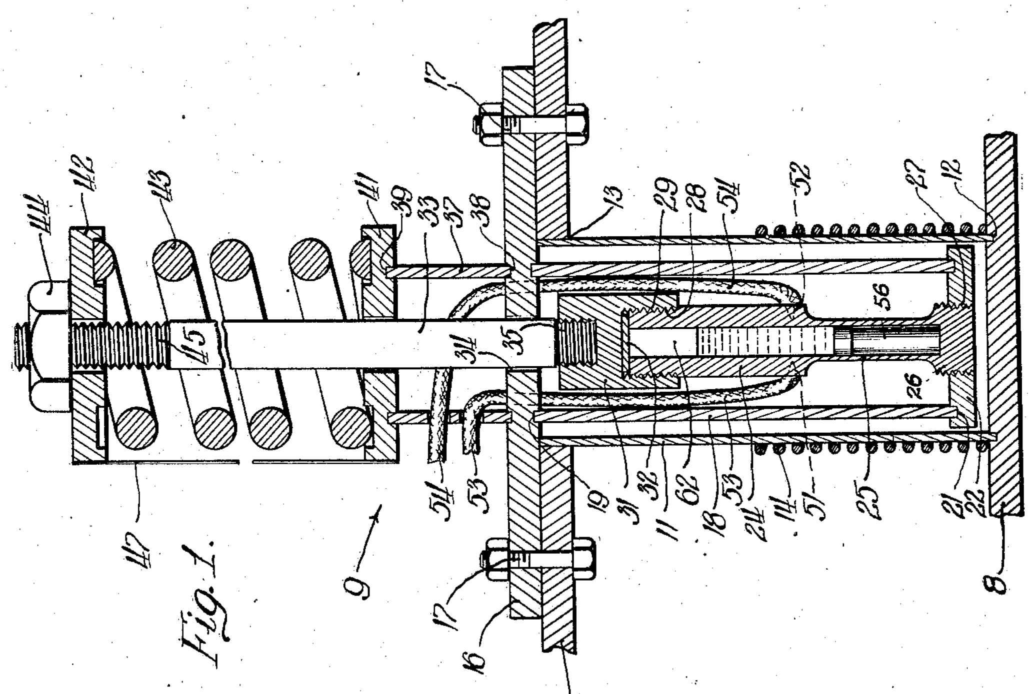


Fig. 1.

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APPARATUS FOR TESTING EMBRITTLEMENT CHARACTERISTICS OF BOILER WATERS

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4 Claims. (Cl. 73—51)

The present invention relates to an improved apparatus for determining the embrittlement characteristics of boiler waters.

All prior devices for this purpose, with which we are familiar, have not given sufficient certainty and accuracy in their performance to insure reliable test data. Such prior devices frequently give conflicting or irreconcilable results on successive tests and, even when operated under the most rigorous conditions, give results which are so variable as to mean that any findings based thereon can, at best, represent only rough approximations. One of the objections to these prior devices is that they do not simulate with any substantial degree of accuracy the physical and chemical conditions which are actually present in a boiler. Some of the difficulties encountered can be illustrated by reference to caustic embrittlement caused primarily by sodium hydroxide (NaOH). Prior experimental work has indicated that a substantial sodium hydroxide content in boiler water contributes materially toward embrittlement, this constituent entering in the form of sodium carbonate in the feed water, which rapidly breaks down to form sodium hydroxide in the boiler. Embrittlement occurs almost exclusively in riveted seams, tube joints, the flanges of blow-off connections, and other joints and seams which are below water level. Proofs established to date show rather conclusively that the sodium hydroxide enters even the most minute capillary spaces in these seams or joints and tends to create a concentrated caustic solution therein. The concentration appears to be brought about by an outward flow of steam bubbles from these capillary spaces and an inward flow of water into said spaces, the inward flow of water tending to carry additional caustic into the capillary spaces and thereby tending to increase the concentration of the solution therein. Such outward flow of steam and inward flow of water is intensified with various fluctuations or changes occurring in the boiler operation, i. e., fluctuations in steam pressure, in temperature, in water level, and the like. Frequent blowing down of the boiler and other attempted remedies of a mechanical nature seem to be of little avail for preventing such concentrated caustic solutions from collecting in the capillary spaces, or for removing them from the spaces once they have collected therein. As a result, the concentration of sodium hydroxide keeps on increasing until after sufficient time, caustic embrittlement of the metal adjacent to the capillary space occurs to a sufficient degree to cause the boiler to leak or explode. The serious consequences of boiler explosions arising from embrittlement make it all the more imperative that test data on the embrittlement characteristics of boiler waters be accurate and reliable.

Another factor which appears to be of importance in causing embrittlement is stress in the metal. Embrittlement cracking is practically always intercrystalline, i. e., following the grain boundaries of the metal, and this cracking appears to be accelerated by increasing the tensile stress in the metal. Hence, complete testing of the embrittlement characteristics of different boiler waters, and complete testing of the resistivity of different boiler steels and alloys to the action of embrittlement, requires the ability to put the test specimen of metal under varying degrees of stress.

The devices which have heretofore been employed to make such tests have been particularly inadequate from the standpoint of accurate determination of the concentration of the sodium hydroxide solution. The concentration which would be likely to arise in a typical capillary space of a conventional boiler supplied with feed water of known properties and operating under typical conditions has heretofore been largely a matter of guess. Hence, prior efforts to test boiler waters by first making up a solution in which the sodium hydroxide is of known concentration and then introducing this solution into the testing device have not been dependable because of the uncertainty of knowing the concentration which would be likely to arise in a capillary space under the typical conditions above mentioned. This difficulty is decidedly increased where the actual boiler water to be tested contains varying proportions of sulphates, chlorides, phosphates, or other constituents which may either accelerate or inhibit the embrittling action of the sodium hydroxide. The degree of concentration which any of these more involved solutions or compounds would be likely to develop in a capillary space is almost entirely conjectural. Thus, efforts to test the efficacy of different chemical agents to be introduced into objectionable boiler water in order to inhibit embrittlement have been rendered difficult and uncertain because the proper concentrations to be employed in the test solutions have not been known.

Another objection to some of these prior devices for testing embrittlement characteristics has been the laborious work involved in conducting such tests.

One of the principal objects of the present invention is to provide an improved apparatus for testing the embrittlement characteristics of boiler water which will simulate with a high degree of accuracy the actual conditions occurring in a typical boiler. To this end, according to the preferred practice of our invention, the solution to be tested is boiled in a chamber which is characterized by an upper chamber area, a lower capillary space, and a restriction which establishes communication between the upper chamber area and said lower capillary space. The restriction functions in the nature of a valve for allowing steam to travel in one direction and the solution to travel in the other direction. That is to say, bubbles of steam in the lower capillary space are caused to pass upwardly through said restriction into said upper chamber area, and solution in said upper chamber area is caused to pass downwardly through said restriction into said lower capillary space. With steam constantly leaving the lower capillary space, the solution concentrates therein. Each additional amount of solution entering the lower capillary space brings with it a small additional amount of sodium hydroxide or other chemicals which may be present in the boiler water being tested. The action simulates an extremely intense or rapid activity of a typical capillary space within a boiler, corresponding to extremely rapid fluctuations in steam pressure, in temperature, in water level, in blow-off operations and the like. Thus, the test accelerates in point of time the concentrating action of a typical capillary space within a boiler. By virtue of this mode of operation, the solution which is introduced into the testing chamber can be of the same degree of concentration of all of its constituents as is actually used or intended to be used in the boiler. Thus, the elements of uncertainty in obtaining the proper proportions and concentrations for prior testing methods have been eliminated.

Another object of the invention is to provide an improved means for establishing any desired degree of stress in the metal which is being subjected to the embrittling action of the solution during the test. According to the preferred embodiments of the invention, this metal constitutes the outer wall of the test chamber, and improved means is provided for establishing any desired degree of tensile stress in said metal. In this regard, it will be evident that our invention can also be advantageously employed for testing the resistivity of different boiler steels or alloys to the embrittling action of different solutions.

Another object of the invention is to provide an improved apparatus by which these testing operations can be conducted more expeditiously and with much less of the preliminary work and other labor which was necessary in using prior devices.

Other objects and advantages of the invention will be apparent from the following detail description of the preferred embodiment of the invention.

In the accompanying drawing:

Figure 1 is an axial sectional view, partly broken away, showing our testing apparatus; and

Figure 2 is a sectional view on a larger scale showing the lower capillary portion of the testing chamber.

Referring to Figure 1, the vertically spaced horizontal plates 7 and 8 represent the top and bottom walls of a testing table or other suitable supporting structure, preferably accommodating a suitable number of these testing units, indicated generally at 9. The lower end of each testing unit 9 is adapted to be inserted down into a cylindrical shell 11 which is secured between the upper and lower plates 7 and 8. The lower end of said shell preferably seats in an annular groove 12 formed in the lower plate 8, and the upper end of said shell fits within a circular opening 13 formed in the upper plate 7. Encircling said shell is an electrical resistance element 14 which serves to heat the testing unit, the heating element being slightly spaced from the shell, or the shell being constructed of suitable material for contact of the heating element therewith. While we prefer to employ an electrically heated cell, substantially as described, nevertheless it will be understood that other heating methods may be employed.

Each testing unit 9 comprises a mounting plate 16 on which the several parts of the testing unit are assembled. Such mounting plate is adapted to be detachably secured to the top surface of the upper supporting plate 7, over the furnace cell 11, through the instrumentality of suitable securing devices such as the bolts 17, or studs secured to the plate 7 and adapted to extend up through apertures in the mounting plate 16. A cylindrical sleeve 18 extends downwardly from the mounting plate 16, such sleeve serving to sustain the tensile stress transmitted through the test chamber, and also serving to confine the steam and hot liquid upon fracture of the test chamber. The upper end of this confining sleeve 18 is removably seated in an annular groove 19 formed in the underside of the mounting plate 16, and the lower end of said sleeve is removably seated in an annular groove 21 formed in a lower end head or cap 22.

The metallic test specimen or chamber is indicated in its entirety at 24, the lower intermediate portion of this chamber being formed with a reduced wall thickness 25 where fracture occurs when the chamber is disrupted. The lower end of the specimen is provided with an enlarged threaded head 26 which is adapted to screw into a threaded bore 27 in the end cap 22. The upper end of the specimen is threaded at 28 for screwing into a tapped bore 29 in the lower end of a coupling head 31. A closure plug 32 of suitable material is seated in the upper end of the bore 29, the upper end of the testing member being forcibly screwed against this closure plug so as to form a pressure-tight joint.

A tension rod 33 passes downwardly through an opening 34 in the mounting plate 16 and has a lower threaded end 35 which is screwed into a tapped bore in the upper end of the coupling block 31. Surrounding this rod on the upper side of the mounting plate 16 is a cylindrical spacing sleeve 37 which has its lower end removably seated in an annular groove 38 formed in the mounting plate. The upper end of said sleeve is removably seated within an annular groove 39 formed in the underside of a circular pressure plate 41 through which the rod 33 passes. Adjustably mounted on the upper portion of said rod is a thrust plate 42, and confined between this thrust plate and the lower pressure plate 41 is a heavy compression spring 43. A nut 44 screwing downwardly over the threaded upper end 45 of the spring rod 33 adjusts the position of the upper plate 42 and thereby enables any desired compression pressure to be established in the spring 43. The stress of said spring is transmitted in an upward direction through the spring rod 33 so that this stress establishes a tension in the thin-walled portion 25 of the testing chamber 24. As a convenient expedient for instantly indicating the fracture of the thin-walled portion 25, we have adopted the practice of pasting a strip of paper 47 to the edges of the upper and lower thrust plates 42 and 41 as soon as the desired pressure has been established in the spring 43, it being obvious that this strip of paper will be disrupted as soon as the spring rod 33 snaps upwardly with the failure of the thin-walled portion 25.

For maintaining the test chamber 24 at a constant or regulated temperature, and for indicating or recording this temperature, we provide suitable thermocouples in the test chamber. These thermocouples, which are preferably of iron and constantin, are diagrammatically indicated at 51 and 52, being peened into holes previously drilled in the test chamber 24, preferably at a point just above the thin-walled portion 25. Leading from these thermocouple elements are conductors 53 and 54 which pass upwardly through one or more apertures in the mounting plate 16 and which then extend outwardly through one or more apertures in the upper spacing sleeve 37. The use of these thermocouples and the connection thereof with suitable regulating, indicating or recording apparatus, is old and well known and need not be described in detail.

Referring now to Figure 2, the interior of the testing chamber 24 is divided into different chamber areas by disposing a removable metallic plug or filler 56 in the lower end of the chamber bore. The chamber bore is preferably of uniform diameter from end to end, and this plug or filler member is adapted to be inserted into the upper end of the bore when the chamber is unscrewed from the coupling head 31. The upper end of the plug 56 is formed with a head portion 57 of slightly larger diameter than the main shank of the plug. The disposal of the plug in the bore serves to divide the bore into a plurality of chamber areas. For example, the space above the plug constitutes a relatively large chamber area 24a, whereas the space below the head 57 of the plug constitutes a relatively small chamber area 24c. This small chamber area can be made of different proportions relatively to the upper chamber area 24a, as desired, although it is preferably formed of relatively small size so that it functions analogously to a capillary space in a boiler. The space surrounding the upper head 57 of the filler plug 56 is of still smaller size, this space constituting a restricted passageway 24r which establishes communication between the upper chamber area 24a and the lower capillary space 24c. The capillary space is, of course, opposite the thin-walled portion 25 of the test specimen 24. The natural boiler water, or the synthetic solution to be tested, is indicated at 61, a predetermined volume of this liquid being introduced into the test specimen so that a steam space 62 remains above the liquid level (Figure 1).

Referring now to the operation of the apparatus, the test can be initiated with the specimen "cold loaded" or with the specimen "hot loaded." If the specimen is to be cold loaded, the spring load is imposed on the test chamber with the apparatus in a cold state, prior to its introduction into the furnace. In this procedure, the furnace may be brought up to the desired temperature after the testing unit has been placed therein, although, preferably, the furnace is heated to the desired temperature before the testing unit is inserted therein. If the specimen is to be hot loaded, the testing unit is inserted into the hot furnace with no substantial spring pressure imposed on the testing chamber; it is maintained in the furnace in this condition at a desired temperature for a definite period, and thereupon the spring load is imposed on the test chamber by screwing the nut 44 downwardly along the threaded end 45 of the spring rod 33. Hot loading usually results in fractures of the test chamber at lower temperatures and lower spring pressures than cold loading.

The boiling of the solution 61 results in a relatively rapid rate of steam generation within the relatively small volume of liquid confined in the capillary space 24c. As previously described, these bubbles of steam pass upwardly from the capillary space through the restriction 24r into the upper chamber area 24a and steam space 62. With this emission of steam from the capillary space, small quantities of the solution 61 pass downwardly from the upper chamber area 24a through the restriction 24r and into the capillary space 24c. In this operation, the restriction 24r functions in the nature of a valve for allowing steam to travel upwardly and solution to travel downwardly, the restriction serving to inhibit or restrict any upward flow of solution from the capillary space back into the upper chamber area. Each additional amount of solution traveling down into the lower capillary space 24c brings with it a small additional amount of sodium hydroxide and such other chemicals as may be present in the solution being tested. In this manner, a concentration of these chemicals rapidly accumulates in the capillary space. As previously stated, the action simulates an extremely intense or rapid activity of a typical capillary space within a boiler, corresponding to extremely rapid fluctuations in steam pressure, in temperature, in water level, in blow-off operations, and the like. Thus, the test may be made to accelerate, in point of time, the concentrating action of a typical capillary space within a boiler. By virtue of the fact that the concentration is effected in a manner analogous to the way in which a capillary space within a boiler effects concentration, the results obtained are an accurate measure of the embrittling characteristics of the solution. Furthermore, the uncertainties residing in the previous practice of preliminarily concentrating the solution before introducing it into a test specimen are completely eliminated.

It will be understood that if the solution has embrittling characteristics, an intercrystalline cracking will start in the thin wall section 25 of the chamber, such cracking working progressively outwardly from the inner to the outer surfaces of said section, substantially as indicated at 64. When the strength of the wall is reduced below that of the tensile stress imposed thereon, the specimen disrupts endwise and the steam and hot liquid is vented into the confining sleeve 18. Because of the relatively small capacity of the test chamber, no damage is done when the contents of the chamber explode into this confining sleeve. The striking of the coupling head 31 against the underside of the mounting plate 16 limits the upward movement of the spring rod 33. The duration of the test before fracture, if fracture occurs, the temperature, and the spring loading, are all factors which are considered when making isolated or comparative tests to determine the embrittling characteristics of natural boiler waters or of synthetic solutions containing agents intended to inhibit embrittlement cracking.

The provision of the restriction 24r in the test chamber is not essential, but such restriction is advantageous. For example, it represents the most adverse or aggravated instance of a capillary space within a boiler, corresponding to an outlet therefrom which is so restricted or so positioned or located that egress of liquid therefrom is decidedly restricted. It is also within the purview of our invention to vent steam at the upper end of the chamber area, if desired, but we deem it preferable to maintain the chamber sealed, thereby avoiding an artificial concentration of the solution and more closely approximating actual conditions within a typical boiler.

The cross-sectional area of the test specimen of metal is relatively small, so that the external source of force or energy required to maintain this specimen under tensile stress loads of from 20,000 to 60,000 pounds per square inch need not be very large. Typical testing temperatures ordinarily range from 300° to 600° F., although higher or lower temperatures may be employed. Typical durations of test before fracture occurs range from a couple of hours to days or weeks, with possibly no fracture at all after a relatively long test period, depending upon the solutions and inhibitants undergoing test. A recording device may be employed which will automatically record the time when fracture occurs.

While we have illustrated what we regard to be the preferred embodiment of our apparatus, nevertheless it will be understood that such is merely exemplary and that numerous modifications and rearrangements of structure and operation may be made without departing from the essence of the invention. For example, while we prefer to maintain a tensile stress in the test specimen of metal through an external source of force or energy, as exemplified by the action of the spring 43 exerting a tensile stress in the wall of the chamber 24, we also regard it to be within the scope of the invention to dispense with this external source of force or energy and to rely upon the internal pressure of the steam alone to stress the test specimen of metal.

We claim:

1. Apparatus for determining the embrittlement characteristics of boiler waters, comprising a chamber adapted to receive a sample of the boiler water to be tested and formed with an upper chamber area, a lower capillary space and a restriction which establishes communication between the two, said chamber comprising an enclosing metallic wall of known characteristics which is subjected to the embrittling action of the water in said capillary space, means for establishing a stress in said enclosing metallic wall, and means for boiling the water in said chamber to cause bubbles of steam in said capillary space to pass upwardly through said restriction into said upper chamber area and to cause water in said upper chamber area to pass downwardly through said restriction into said capillary space, whereby to effect a concentration of the embrittling constituents of the water within said capillary space in simulation of conditions within a typical boiler.

2. Apparatus for determining the embrittlement characteristics of boiler waters and the like, comprising a chamber adapted to receive a specimen of the boiler water to be tested and formed with a relatively large chamber area, a relatively small capillary space and a restriction which establishes communication between the two, said chamber comprising an enclosing metallic wall of known characteristics which is subjected to the embrittling action of the water in said enclosing metallic capillary space, means for establishing a stress in said enclosing metallic wall, and means for boiling the water in said chamber to cause bubbles of steam in said capillary space to pass therefrom through said restriction into said relatively large chamber area and to cause water in said relatively large chamber area to pass therefrom through said restriction into said capillary space.

3. Apparatus for determining the embrittlement characteristics of boiler waters and the like, comprising a chamber adapted to receive a specimen of the boiler water to be tested and formed with a restricted capillary space, said chamber comprising an enclosing metallic wall of known characteristics which is subjected to the embrittling action of the water in said capillary space, means for boiling the water in said chamber to concentrate any embrittling constituents within said capillary space, and means for subjecting said enclosing metallic wall to stress in the testing operation.

4. Apparatus for determining the embrittlement characteristics of boiler waters and the like, comprising a chamber adapted to receive a specimen of the boiler water to be tested, a filler member in said chamber comprising an enlarged head portion, said filler member dividing said chamber into an upper chamber area, a lower capillary space and a restriction which establishes communication between the two, means for creating a tensile stress in said chamber, and means for boiling the water in said chamber.

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