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METHOD AND APPARATUS FOR DETECTING SUGAR

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Our invention relates to the detection of sugar in solution; and more particularly to means for detecting the presence of small quantities of sugar in boiler feed-water.

For purposes of economy in sugar manufacture it is the practice to utilize the condensate from evaporators as feed-water for the steam boilers. Small amounts of dissolved sugar may be present in the condensate, and this sugar causes damage to the boilers. The principal object of our invention is to provide means for accurately detecting the presence of sugar in the feed-water, so that water containing sugar in harmful quantities may be diverted from the boilers before damage is caused.

Another object is to provide a method of continuously detecting the presence of sugar in the feed-water flowing from the evaporators to the boilers.

A further object is to provide improved apparatus for carrying out our method.

The invention possesses other objects and features of advantage, some of which, with the foregoing, will be set forth in the following description of our invention. It is to be understood that we do not limit ourselves to this disclosure of species of our invention, as we may adopt variant embodiments thereof within the scope of the claims.

Referring to the drawing the figure of the drawing is a side view, partly in section and partly in elevation, illustrating the improvements of our invention.

In terms of broad inclusion, our method of detecting sugar in solution comprises directing a continuous flow of the solution to be tested along a path; continuously introducing into the solution an agent reactable with sugar to color the solution; and detecting the color as the solution flows along the path. In our preferred apparatus the solution is directed through a duct system including a reaction chamber and a test chamber. The reagent is introduced into the solution in the reaction chamber; and the color is detected by means including a photo-electric cell exposed to a beam of light passing through the solution in the test chamber. A current measuring device connected to the cell is preferably calibrated directly in terms of sugar content.

In greater detail, and referring to the drawing, our preferred apparatus comprises a supply line 2 for solution to be tested. In a sugar detecting system for boiler feed-water this line is preferably an $\frac{1}{8}$ inch tube connected to the condensate pump so that a sampling portion of the water is continuously diverted through our apparatus for testing. A valve 3 interposed in line 2 serves to roughly control the flow. A filter 5 is also preferably interposed in the line. This filter may be

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of the plate and frame type having a filter disk of paper pulp and asbestos, such as an Ertel filter disk.

Line 2 discharges into a tank 4 having an outlet 6 and an overflow baffle 7 for maintaining a constant level of solution. A tube 8, say $\frac{1}{4}$ inch in diameter, projecting upwardly into the tank receives fluid and directs it downwardly through the apparatus. Because of the uniform level maintained by baffle 7, the fluid head in tube 8 is maintained constant. A fine screen 9, say 100 mesh, over the open end of tube 8 guards against the entrance of foreign matter. Valve 10 regulates the flow through tube 8.

A heat exchanger for cooling the solution is interposed in tube 8, and comprises a water jacket 11 surrounding a coiled portion 12 of the tube. Ordinary tap water is circulated through the jacket to bring the solution down to room temperature. This cooling the solution is unnecessary if it is already at room temperature, in which case the heat exchanger may be eliminated.

The solution to be tested is then introduced into a reaction chamber 13 through a nozzle having an enlarged upper portion 14 into which tube 8 discharges. A cylinder 15 in the upper end of the nozzle and having a fine screen at the bottom is disposed about the discharge end of tube 8 for straining out any small particles of foreign matter. The nozzle has a reduced neck portion 17 and a further reduced end portion 18 terminating in a tip 19 disposed centrally within reaction chamber 13. These parts of the nozzle are shaped and proportioned so that under a 4 inch head of water it will deliver into air about 15 cc. of fluid per minute. We prefer to make the nozzle of glass with portion 17 drawn out to about 10 mm. outside diameter and with portion 18 further drawn out to about 7 mm.

Means are provided for regulating the head of solution in the nozzle to control the discharge through tip 19. For this purpose a leveling chamber 21, say 1 inch in diameter, is connected by a rubber tube 22 with a branch duct 23 ported into the side of nozzle portion 18 above tip 19. Chamber 21 has a side outlet 24 for overflow of excess solution, and is so arranged as to maintain the solution at the constant levels 26 and 27 in the chamber and nozzle respectively. Valve 10 in duct 8 is adjusted so that there is a slight discharge through outlet 24 to insure maintenance of a constant fluid level. If it is desired to increase the fluid head in the nozzle, to increase the rate of flow from tip 19, it is only necessary to raise leveling chamber 21.

Means cooperating with the nozzle are provided for introducing into the solution an agent adapted to react with sugar to color the solution. The agent preferably employed is a mixture of

sulphuric acid and alpha-naphthol; which agent reacts with sugar to produce a violet colored solution having a color intensity depending upon the amount of sugar present. A reservoir or bottle 122, having a capacity of say 5 gallons, holds a supply of the reaction agent mixed in the proportions of about 1 gram of alpha-naphthol to about 1 lb. of concentrated acid. A nitrate free sulphuric acid should be used.

Stopper 123 of the bottle is fitted with a filling funnel 124 having a stopcock 125. A siphon tube 127 also extends through the stopper and has an outer leg discharging into a feed chamber 28 disposed alongside the reaction chamber 13. A stopcock 29 is provided in the siphon tube. The reagent is maintained at a constant level 31 in chamber 28 by an air duct 32 extending through the bottle stopper and having a depending end 33 terminating at the fluid level desired in chamber 28. By this arrangement air is admitted to the bottle to permit the siphon to operate whenever fluid level 31 falls below the end of the air duct. When the fluid closes the air duct the siphon automatically stops. This keeps the fluid level constant within very close limits.

A clamp 34 on a rubber section 36 of the air duct provides means for controlling and closing the passage. During operation, clamp 34 is preferably set to restrict the passage so as to reduce the rate of air flow to a low figure. This permits a closer control over the level of fluid because it precludes sudden entrance of a large volume of air into bottle 122. A rubber tube 37, controlled by a clamp 38, is connected between a branch 39 of the air duct and a suitable air pump to aid in initially starting the siphon. A trap 41 is also preferably interposed in the air duct.

Chambers 13 and 28 comprise the enlarged leg portions of a U-shaped tube 42 so that fluid in feed chamber 28 flows over into the bottom of reaction chamber 13. The tube portion between the chambers has an outside diameter of about 8 mm., and is further narrowed at the restriction 43 to limit the flow to the reaction chamber. The size of this restricted orifice is not critical. Since the viscosity and consequently the flow of sulphuric acid changes considerably with temperature, we immerse tube 42 in a constant temperature bath in a tank 44 having an inlet 45 and an overflow outlet 47. Water at room temperature is circulated through the tank.

A duct 48 having an outside diameter of about 10 mm. is connected at the side of reaction chamber 13 to lead off the treated solution. This duct is arranged to maintain a body 49 of the solution above the body 50 of reaction fluid. The interface 51 between the two liquids is well defined because the density of the reagent is considerably greater than that of water. Because of the self-leveling action in feed chamber 28 the fluid head is maintained constant, and therefore the level of the interface is held constant after the flows have become balanced.

The nozzle provides means for effecting turbulence at the interface 51 to mix a portion of the fluid with the solution. Nozzle tip 19 is immersed in the body of solution in the zone above the reagent; the tip being preferably disposed about $\frac{1}{8}$ inch above the interface 51. When the apparatus is operating the jet of solution issuing from the nozzle plows up the reagent to a depth of about $\frac{1}{8}$ inch below the interface, and thereby mixes a portion of the reagent with the solution. We have found this injector device to be a sim-

ple and effective means to continuously introduce the reagent into the solution.

If it is desired to increase the flow of reagent to the reaction chamber, it is only necessary to raise end 33 of the air inlet duct in feed chamber 28, which has the effect of raising fluid level 31 and thereby increasing the fluid head. On the other hand, if it is desired to increase the flow of solution this is done by raising the leveling chamber 21, which increases the head of solution in the nozzle.

The treated solution, which is colored violet if sugar is present, overflows from the reaction chamber through the duct 42 and empties into a transparent tube forming a test chamber 52. In order to maintain a column of the solution in chamber 52 the latter is formed as one leg of a U-shaped tube, the other upstanding leg 53 of which terminates in an overflow outlet 54. This part of the apparatus is also preferably made of glass; the chamber 52 having an outside diameter of about 15 mm. and the remaining length of the tube leading to outlet 54 having a diameter of about 8 mm. Outlet 54 is arranged at such height that fluid level 55 lies somewhat below the cross duct 48.

The solution being tested thus flows continuously along a main path through the apparatus, namely, along the path from supply line 2, through duct 8, thence through reaction chamber 13, and finally through test chamber 52.

Means are further provided for detecting color in the stream of solution flowing through test chamber 52 to indicate the presence of sugar. This detecting means also preferably measures the color intensity to indicate the amount of sugar in the solution. For this purpose a photo-electric cell 56 is exposed to a beam of light passing through the solution from a light source or lamp 57. In order to maintain a constant voltage for lamp 57 a motor-generator set 58 is preferably employed. The intensity of the lamp is roughly controlled by the generator field rheostat 59. A 60 watt lamp with an inside frosted envelope is preferably used. The lamp is movable in a tube 60 for altering the light incident on chamber 52.

Photo-electric cell 56 may be any suitable make having the proper color sensitivity, so as to produce current variations in response to changes in the color intensity of the solution. We have used a Weston cell, model 594, type 1, with good results. A color filter is not ordinarily employed, but if greater sensitivity is desired in the lower ranges of sugar content a blue filter may be used. Since considerable heat is evolved by the reaction in the apparatus, the cell 56 is protected by cooling with a water jacket 61.

Cell 56 is connected by leads 62 to a current measuring device 63, which may be any suitable micro-ammeter, either of the dial type showing instantaneous values of current or the recording type for making a permanent record. In either case the instrument functions to indicate the presence of sugar and also to indicate the amount thereof in solution. Since the current variations continuously reflect changes in sugar content, the meter may be calibrated directly in terms of sugar concentration. The meter we used was a Leeds and Northrup, model R Micromax, connected in parallel with a 1000 ohm resistance 64 across the leads 62. In order to bring the E. M. F. within the range of the meter, a potentiometer 66 and associated battery 67 was connected in the circuit. A special scale and charts were made

up for the meter so that it read directly in terms of sugar content.

The apparatus thus described provides means for continuously indicating the presence of small quantities of sugar in boiler feed water. A sugar content of the order of 50 parts per million in the feed water can cause damage to the boilers. Our apparatus accurately indicates the sugar content in this lower range of concentration.

If desired, the photo-electric cell may be connected to a signal circuit to give an alarm when the concentration reaches a predetermined value, say 50 parts per million. We prefer to provide the indicating meter however, because a continuous indication and record of the sugar concentration is more useful to the operating department of a factory.

We claim:

1. Apparatus for the continuous detection of a dissolved substance in solution, comprising a reaction chamber for retaining a body of a fluid responsive in the presence of said substance to color the solution, a fluid supply conduit connected to the bottom of said chamber, a nozzle disposed within said chamber for injecting the solution into the fluid body to mix a portion of the fluid with the solution, means connected to the nozzle for feeding a continuous supply of solution thereto, an auxiliary chamber connected to the nozzle and having an overflow outlet, said auxiliary chamber being vertically adjustable for regulating the head of solution in the nozzle, an outlet passage connected to said reaction chamber above the nozzle outlet for withdrawing the mixture of fluid and solution from the reaction chamber, and means associated with said outlet passage for detecting color conditions in the withdrawn mixture passing therethrough.

2. Apparatus for the continuous detection of a dissolved substance in solution, comprising a reaction chamber for retaining a body of a fluid responsive in the presence of said substance to color the solution, a feed chamber, a conduit connecting the bottom of the feed chamber with the bottom of the reaction chamber, a closed reservoir for holding a supply of said fluid, a syphon leading from the reservoir to the feed chamber, an air duct opening at one end into the reservoir and terminating at the other end in the feed chamber for controlling the syphon, means including a nozzle mounted in said reaction chamber and located above the fluid conduit connection into the reaction chamber for injecting solution into the body of fluid in the reaction chamber to mix it with a portion of said fluid, an overflow passage opening into the reaction chamber at a point above the end of said nozzle for withdrawing the mixture from the reaction chamber, and means associated with said overflow passage for detecting color conditions in the withdrawn mixture passing therethrough.

3. The method of continuously determining sugar in solution, which comprises the steps of providing a confined body of a liquid reagent, which is but slightly miscible with said solution, said reagent being responsive in the presence of sugar to color said solution, maintaining on the body of the reagent a layer of the solution to be tested, continuously injecting a stream of the solution through the body of the superposed solution and partially into the body of reagent to effect mixing at the interface only of the two bodies, then withdrawing a continuous flow of the

resulting mixture, and finally measuring the color of said mixture in terms of the sugar content.

4. The method of continuously determining sugar in solution, which comprises providing a confined body of a liquid reagent, superposing a body of the solution upon said body of said reagent, which is but slightly miscible with said solution, said reagent being responsive in the presence of sugar to color the solution, thereby effecting mixing at the interface only between the bodies and renewing the body of solution by injecting a controlled jet of the solution through the body thereof immediately above the interface between the bodies and partially into the body of said reagent, renewing the body of the reagent by introducing into the bottom thereof a controlled flow of the reagent, passing a continuous flow of the mixed solution and reagent through a testing chamber, and measuring the intensity of the color thereof as the mixture flows through the chamber.

5. An apparatus for the continuous detection of sugar in solution which comprises a reaction chamber, a nozzle extending into the chamber, means connected to the nozzle for supplying the nozzle with a continuous flow of the solution, a feed chamber positioned at the level of the reaction chamber and connected into the bottom of the reaction chamber, means for supplying the feed chamber with a liquid agent reactable in the presence of sugar to color the solution, means to maintain the agent at substantially constant levels in the feed chamber and the bottom of the reaction chamber, a transparent test chamber, a passage connecting one end of the test chamber to the reaction chamber at a point above the outlet end of the nozzle, a discharge passage connected to the bottom of the test chamber and constructed as to have such a rate of discharge as to keep the test chamber filled, means for passing a beam of light through the test chamber, and means including a photo-electric cell exposed to said beam for detecting said color.

6. An apparatus for the continuous detection of a constituent in a flowing stream of liquid, comprising a reaction chamber and an overflow outlet opening in its side intermediate its height, conduit means leading from a source of said liquid and terminating in a restricted nozzle extending into said chamber with its discharge end positioned below said overflow outlet opening, said nozzle having a side outlet above its discharge end, and a leveling vessel connected to said outlet whereby the head of liquid and resulting flow from the restricted nozzle may be adjusted, means for supplying a liquid reagent to said reaction chamber comprising a constant level chamber with provision for maintaining the liquid level therein above the level of said outlet opening, a restricted conduit connecting and communicating with the lower end of said constant level chamber and with the bottom of said reaction chamber below the said nozzle discharge and a conduit connected to said overflow outlet opening and having a transparent portion, and means adjacent the transparent portion for detecting color conditions in the liquid passing there-
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