

BOILER DEPOSITS.*

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Two years ago I had the honor of reading a paper before this Society on "Boiler Incrustations," in which I traced the formation of the scale, and the causes which led to the precipitation and hardening of the calcic sulphate, calcic carbonate, magnesic hydrate and other compounds which are usually found to be present, and I pointed out that the scales formed by various kinds of water were so characteristic that one could speak with certainty as to the kind of water from which the incrustation had been formed by an analysis of the scale itself. The analyses given below may be looked upon as typical of the incrustations formed by fresh water, brackish water, and sea water respectively:

Constituents.	River.	Brackish.	Sea.
Calcic carbonate	75.85	43.65	0.97
Calcic sulphate	3.68	34.78	85.53
Magnesic hydrate	2.56	4.34	3.39
Sodic chloride	0.45	0.56	2.79
Silica	7.66	7.52	1.10
Oxides of iron and alumina	2.96	3.44	0.32
Organic matter	3.64	1.55	trace
Moisture	3.20	4.16	5.90
	100.00	100.00	100.00

From this it is evident we may look upon the incrustation from fresh water as consisting of impure calcic carbonate, while that from sea water is impure calcic sulphate, the brackish water from the mouths of rivers yielding, as might be expected, an incrustation in which both these compounds are present in nearly equal quantities. The importance of these differences in the deposit formed is very great, as it enables the shipowner to arrive at a conclusion as to the treatment that the boilers have received during the voyage, by examination and analysis of the scale which those boilers contained. Taking, for instance, the case of a ship which uses fresh water both for filling and make-up, it is manifest that on her return to port the scale should be very slight, and should consist mainly of calcic carbonate, while, if the scale exceeds $\frac{1}{8}$ in., and shows a preponderance of calcic sulphate, it is manifest that such scale could only have been formed by sea water, either leaking in from faulty condensers or being deliberately fed into the boilers. The reception you were kind enough to give that paper, and the frequency with which it has been quoted since, lead me to hope that, in continuing and completing the subject, I shall be performing a not unwelcome task.

So far the deposits taken into consideration have been those formed from the impurities natural to the water itself; but with the introduction of high pressure steam a new and highly dangerous form of deposit has added to the trouble of the marine engineer. As early as 1878 the collapse of the furnaces of the boilers of the s.s. Ban Righ, and a similar misadventure in the screw tug Ich Dien, with no apparent cause to bring about the damage, caused some attention to be paid in marine circles to the action which had taken place, and the only clue to be found was that a certain amount of oily deposit had formed on the tops of the furnaces; and experiments made by Mr. Dunlop, of Port Glasgow, led to the conclusion that this oil, which had distilled into the boiler from the lubricants used in the cylinder, was so bad a conductor of heat that its formation on the plates allowed them to get superheated, with the result that they were unable to withstand the pressure of steam existing in the boiler, and in this way brought about the collapse. Similar cases of collapse became frequent after that date, no less than thirty vessels being disabled from this cause during the last few years. The first case which came under my notice, in which damage to boilers had arisen from this cause, was the case of a large ocean steamer, and through the kindness of Mr. Milton, chief superintendent engineer of Lloyd's, I was able to obtain samples of deposit from all parts of the boilers, and full particulars of the case. The steamer was a large one trading between Liverpool and Boston, averaged twelve days on the voyage, and was fitted with ordinary compound engines. She had three double-ended boilers, with three plain furnaces at each end, and three combustion chambers in each boiler. The furnaces were plain, in one length, and connected at the back end to the tube plates, being flanged up inside the chamber, while the front end plate was flanged inward on to the furnace crowns. The furnace crown was $\frac{1}{2}$ in. plate, and the front bottom plate $\frac{1}{4}$ in., the working pressure being 80 pounds. The boilers were about five and a half years old, and had always been refilled with fresh water at the end of each run, both at Boston and Liverpool; while, as a rule, the waste on the voyage was made up by the use of about 70 tons of fresh water, but during the last voyage sea water was used for this purpose. Every four hours while under steam 4 pounds of soda crystals were put in the hot well, making about 2 cwt. during the run, the total capacity of the boilers being about 81 tons. For lubricating purposes about seven pints per day of valvoline were used in the cylinders. When in port the boilers were allowed to cool down, and the water was run off, and they were swept down with stiff brushes, and were afterward sluiced out with a hose shortly before being refilled with fresh water. No trouble occurred with the boilers until five voyages before the final collapse, when some of the furnaces began to creep in; they were stiffened with rings and stays, and on the succeeding voyages the whole of the furnaces got out of shape, one after another. Examination of these boilers clearly showed that they had never been very heavily scaled, as in parts of the boiler where it would have been impossible to get at them to clear them out, no signs of heavy incrustation were to be found, and the absence of marks of scaling tools also showed that they had never been allowed to get very dirty. On the furnace crowns, where they had collapsed, there was only a slight white scale, not more than $\frac{1}{8}$ in. in thickness, while on the bottom of the furnaces there was a brown oily deposit $\frac{1}{8}$ in. in thickness, which in other parts of the boilers increased to between $\frac{1}{2}$ in. and $\frac{3}{4}$ in. I obtained from Mr. Milton samples of the thin scale from the

top furnaces, and of the deposit from various parts of the boiler, and also specimens of cut-out portions of the boiler plates, Liverpool water, valvoline, and soda crystals put into feed water, and of all these analyses were made. The boiler plates were as good as the day they were put in, and showed no structural signs of having undergone any change, while the analyses of the Liverpool water and the soda crystals used showed that they could have taken no part in the action which had led to collapse.

The valvoline on analysis gave:

I.—Valvoline.

Vegetable and animal oil	nil
Mineral oil	100 per cent.
Acids (free)	nil
Boiling point	371 deg. C.
Specific gravity	0.889

II.—Scale from Furnace.

	From top.	From below.
Calcic sulphate	84.87	59.11
Calcic carbonate	5.90	6.07
Magnesic hydrate	2.83	11.29
Iron, alumina and silica	2.37	2.85
Organic matter and oil	3.23	19.54
Moisture	0.80	1.14
Alkalies	nil	nil
	100.00	100.00

III.—Deposit from Tubes.

	Scale on tubes.	Deposit above scale.
Scale sulphate	50.92	11.60
Calcic carbonate	4.18	0.82
Magnesic hydrate	14.12	22.21
Iron, alumina, silica, etc.	7.47	9.14
Organic matter and oil	21.06	50.20
Moisture	1.17	4.23
Alkalies	1.08	1.80
	100.00	100.00

IV.—Deposit from Bottom of Boiler.

Calcic sulphate	22.52
Calcic carbonate	nil
Magnesic hydrate	7.09
Silica, alumina, and iron	34.85
Organic matter and oil	27.95
Moisture	5.79
Alkalies	1.80
	100.00

On careful examination of the organic matter and oil present in these deposits, it was found that quite one-half of it was "valvoline," in an unchanged condition, which had collected round small particles of calcic sulphate. A consideration of these analyses, at first sight, yields no clue as to the cause of the collapse, the scale upon the furnace tops being not only free from oil, but perfectly harmless both in quantity and quality; but, on going more deeply into the question, it is evident that this scale cannot be in the condition in which it was originally formed, as the deposits from both top and bottom of tubes, from the bottom of the furnaces, and from the shell of the boiler are all rich in oily matter; and it is impossible that, during this deposition, the furnace tops could have escaped while all other parts of the boiler became coated with it. Experiments, however, reveal the actions which had been at work and led to the formation of the deposit, and its absence upon the injured portions of the plates. The pressure at which the boilers were worked was 80 lb., corresponding to a temperature of 155 deg. C. or 311 deg. Fah., which is so far below the boiling point of the valvoline that it was evident that it had not distilled over in the ordinary way, and experiments were made to see if it could be distilled in steam at a lower temperature. A retort containing valvoline was carefully heated over a sand bath, its temperature being ascertained by a thermometer, and steam was then blown through it, with the result that at 248 deg. Fah., or 120 deg. C., the steam became "greasy" and the oil commenced to pass over with it.

This experiment is, I think, important, as it shows that, in testing the capabilities of a lubricant, the fact that it has a boiling point well above the temperature of the steam is no guarantee that none of it will find its way into the boiler. Having thus entered the boiler, the minute globules of oil, if in great quantity, coalesce to form an oily scum on the surface of the water, or, if present in smaller quantities, remain as separate drops, but show no tendency to sink, as their specific gravity being 0.889, they are lighter than the water, and the difference in gravity is probably even greater at the temperature existing in the boiler. Slowly, however, they come in contact with small particles of calcic sulphate and other solids separating from the water and sticking to them, they gradually coat the particles with a covering of oil, which in time enables the particles to cling together or to the surfaces with which they come in contact. These solid particles of calcic carbonate, calcic sulphate, etc., are heavier than the water, and, as the oil becomes more and more loaded with them, a point is reached at which they have the same specific gravity as the water, and then the particles rise and fall with the convection currents which are going on in the water, and stick to any surface with which they come in contact, in this way depositing themselves, not as in common boiler incrustations, where they are chiefly on the upper surfaces, but quite as much on the under sides of the tubes as on the top, their position being regulated by whether they come in contact with the surface while descending or ascending. The deposit so formed is a wonderful non-conductor of heat, and also from its oily surface tends to prevent intimate contact between itself and the water. On the crown of the furnaces this soon leads to overheating of the plates, and the deposit begins to decompose by the heat, the lower layer in contact with the hot plates giving off various gases which blow the greasy layer, ordinarily only $\frac{1}{4}$ in. in thickness, up to a spongy, leathery mass often $\frac{1}{2}$ in. thick, which, because of its porosity, is an even better non-conductor of heat than before, and the plate becomes heated to redness, and, being unable to withstand the pressure of steam, collapses. During the last stages of this overheating,

however, the temperature has risen to such a point that the organic matter, oil, etc., present in the deposit burns away, or, more properly speaking, is distilled off leaving behind, as an apparently harmless deposit, the solid particles round which it had originally formed. Such a deposit is much more likely to be produced with boilers containing fresh or distilled water, as the low density of the liquid enables the oily matter to settle more quickly, while with a strongly saline solution it is very doubtful if this sinking point would ever be reached; it is evident also that, when oil has found its way into the boiler and is causing a greasy scum on the surface, the most fatal thing that can be done is to blow off the boilers without first using the scumcocks, because as the water sinks so the scum clings to the tops of the furnaces and other surfaces with which it comes in contact, and, on again filling up with fresh water, it still remains there, causing rapid collapse. A very remarkable instance of this is to be found in the case of a large vessel in the Eastern trade, in the boilers of which an oil scum had formed. The ship having to stop some days at Gibraltar, the engineer took the opportunity of blowing out his boilers, and refilling with fresh water, with the result that, before he had been ten hours under steam the whole of the furnaces had come in. Under some conditions the oil-coated particles coalesce and form a sort of floating pancake, which, sinking, forms a patch on the crown of the furnaces at one particular spot, and under these conditions the general result is the formation of a "pocket."

A curious fact, which is worthy of attention, is that in most of these oily deposits copper is to be found in considerable quantity. In an analysis of a deposit from the furnace of a vessel in which a "pocket" had formed from the above-mentioned cause, the scale showed, as in the case already cited, no reasonable cause for the injury at the damaged part of the boiler, while the deposit from the under side of the furnace tubes showed clearly the presence of large quantities of oil matters, which were partly combined with copper:

Constituents.	Scale.	Deposit.
Calcic sulphate	90.354	1.02
Calcic carbonate	1.200	nil
Ferric oxide		56.90
Oxide of alumina	3.200	2.30
Oxide of copper	nil	1.90
Magnesic hydrate	2.821	1.80
Organic matter	1.600	10.46
Silica		17.84
Sand, etc.	0.825	7.78
	100.000	100.00

It is a fact that even mineral oils have a considerable solvent action upon copper and its alloys, and it is evident that the copper in the oily deposits had been obtained from the fittings of cylinder and condenser. Fortunately this copper is so well protected by oil that in most cases it is extremely unlikely to come in contact with, and deposit on, the metal of the boiler; but, if it did, very serious galvanic mischief would be the result.

The next point I attempted to determine was the effect which these oily deposits had in allowing excessive heating of the plates to take place, and retarding the heating of the water. A clean iron vessel was taken, and a known volume of water placed in it, and heated by a carefully regulated Bunsen flame, the water being raised to the boiling point in ten minutes; this experiment was repeated a second time with the same result, and the vessel was then lined with a coating of deposit found in the bottom of the boilers which had collapsed, and rendered binding by admixture with a small trace more valvoline. This coating was laid on $\frac{1}{8}$ in. in thickness, and the former experiment repeated, the same flame being used and the same volume of water taken, with the result that it took fifteen minutes before the boiling point was reached, showing that, even if no damage resulted to the plates from overheating, such a deposit would cause a large increase in the fuel used. In attempting to ascertain to what extent extra heating of the plate took place from this cause, I employed a series of substances of known igniting and melting point, raised the water in the various vessels to the boiling point, and then brought the clean bottom of the vessel in quick contact with the test substance, and took the results as indicating the temperature of the exterior of the plates:

Clean vessel... Sulphur did not melt	below 115 deg. C. = 239 deg. F.
Coated vessel... Sulphur melted, but did not inflame	above 115 deg. C. = 239 deg. F. below 250 deg. C. = 482 deg. F.
Gun-cotton ignited	above 200 deg. C. = 392 deg. F.

So that the $\frac{1}{8}$ in. of deposit caused with a slow heat a rise in temperature of the plate from under 115 deg. C. or 239 deg. Fah. to over 200 deg. C. or 392 deg. Fah. It is manifest, however, that the fiercer the heat the more marked will this overheating become, and in the next series of experiments the Bunsen flame was replaced by an atmospheric blowpipe, and the temperature attained tested in the same way as before.

Clean vessel... Sulphur did not melt	below 115 deg. C. = 239 deg. F.
Coated vessel... Gun-cotton ignited	above 200 deg. C. = 392 deg. F.
Tin melts	228 deg. C. = 444 deg. F.
Sulphur ignites	250 deg. C. = 482 deg. F.
Lead melts	324 deg. C. = 613 deg. F.
Zinc melts (just)	423 deg. C. = 793 deg. F.

While, on replacing the atmospheric burner by an oxy-coal gas flame, I found no difficulty in fusing a hole in the bottom of the vessel, which was made of thin wrought iron plate, showing that a temperature of 1,500 deg. C., = 2,732 deg. Fah., had been attained, and it is therefore manifest that, with the fierce heat existing in the boiler furnaces, given an oily deposit only $\frac{1}{8}$ in. in thickness, the plates will readily be heated to a temperature at which they are totally unable to withstand a pressure of 80 lb. of steam, and collapse of the furnace crowns must follow.

The great points to be sought in a good lubricating oil are that it shall be a pure mineral oil, and that its boiling point shall be well above any temperature likely to be attained in the cylinder. Oils satisfying these requirements can readily be obtained, but users of lubricants must remember that, in order to obtain them free from any constituents of dangerously low

* A paper recently read before the Institution of Naval Architects, London.

