The Embrittlement of Boiler Plates.

THAT boiler plates may become brittle in the course of time and in certain circumstances is now a well-established fact. All the conditions, however, which govern the phenomenon are by no means completely known, and the problem raises points both of great practical and of scientific importance. A paper entitled "The Cause and Prevention of Embrittlement of Boiler Plates," by S. W. Parr and F. G. Straub, Bulletin No. 155 of the University of Illinois Engineering Experiment Station, which deals with the subject at some length, is therefore of considerable interest.

It is first shown that of the recorded examples of brittle boiler plates in America, there are certain areas where the trouble is more evident than in others. This at once suggests that the water is the cause of the failures, and this is strengthened by the fact that in these localities the waters used are characterised by an almost complete absence of sodium sulphate and by the presence of free sodium bicarbonate. It is to the latter salt that the authors attribute the primary responsibility for the embrittlement. The type of boiler used is not believed to have any influence, since failure due to brittleness has occurred in a considerable number of different makes and designs, both fire- and water-tube. Further, the writers reach the very interesting conclusion that the steel from which the plates are made has *per se* no effect either. Their reasons for coming to this conclusion are as follows: Six different types of steel which had become brittle in actual boiler service were examined. The carbon content ranged from 0·14 to 0·26 per cent., the manganese from 0·26 to 0·54, the phosphorus was consistently low, and the sulphur varied from 0·018 to 0·046 per cent. Micrographic examination also indicated that good steel was just as liable to fail as low-grade, dirty material. In the experimental work described, steels were investigated in which the range of composition was:

Carbon	0·023-0·30	per cent.
Manganese	0·017-0·45	,, ,,
Sulphur	0·007-0·027	,, ,,
Phosphorus	0·003-0·012	,, ,,

Apart from the question of the yield point, variation of the composition of the steel within this range had very little, if any, effect on the rate of embrittlement.

The experimental work on short-time, accelerated tests confirmed what had been previously believed, namely, that stress and the nature of the solution each played essential parts in causing brittleness. So far as the former factor is concerned, it is shown that this must exceed the yield point of the steel before failure commences. There are also indications that, provided this stress intensity is attained, the actual value of the stress is not of prime importance. As, therefore, the yield point of the material is raised, so will also be the stress to which the steel may be subjected in service without failure due to brittleness ensuing. Thus 3·5 per cent. nickel steel showed in the tests no abnormality other than the increased stress required to induce embrittlement. A steel severely cold-worked previous to test also appeared to require a rather higher stress to initiate the trouble than the same steel in the annealed condition. In connexion with the latter factor the temperature used in the annealing of the steels had very little effect. A fact recorded which is, however, somewhat difficult to reconcile with the foregoing is that with high sulphur and phosphorus contents the steel is more liable to become brittle; for example, a decided increase in the rate of embrittlement is recorded for a material with 0·215 per cent. of sulphur and 0·126 per cent. of phosphorus compared with normal steel. The explanation offered for this effect of these elements is not convincing.

The examination of the surface of embrittled plates shows no corrosion, but there is, as in all cases, a layer of magnetic oxide of iron. So long as this is compact and complete, further attack on the metal is inhibited, but if for any reason the coating is broken, the unprotected metal surface is then again laid open to chemical attack from the solution. The importance of the yield-point stress is thus apparent. Under this stress there will be sufficient plastic deformation of the metal to fracture the oxide film and the attack will recommence.

So far, then, as the prevention of this embrittlement is concerned, one of the methods by which this could be done would be by cutting down the actual stress to a value below the yield point. This the authors regard, however, as being impractical. The failure is associated with the seams where the different plates are riveted together, the cracks produced running in general from one rivet hole to another and not extending into the body of the plates beyond the lap of the seam. Now, both in the operation of riveting and under the conditions of service, greatly concentrated, localised stresses must occur in such positions, and stresses exist there considerably exceeding the yield point even when the steel plate as a whole is far below its yield stress.

It follows, therefore, that the only effective protection will come from the consideration of the water used. As has already been mentioned, the characteristics of those natural waters which in the United States have led to this type of failure are the presence of sodium bicarbonate and a low concentration of the sulphate. In time, then, a caustic condition will be set up in the boiler with the sodium hydroxide in excess of sodium sulphate, and it is to this caustic soda directly that the embrittlement is ascribed. The reaction assumed to be responsible is represented by the equation

$$3Fe + 4OH' = Fe_3O_4 + 4H .$$

The hydrogen then passes into solid solution in the steel and leads to brittleness. This attack is shown to be a surface phenomenon by measurement of the e.m.f. of the original and brittle steel against caustic soda solutions and by the grinding off of the affected surface, when the e.m.f. value becomes again that of the untreated steel. In accelerated tests it was shown that a concentration of 350 gm. of caustic soda per litre is required to initiate the failure. This value, it is supposed, may in time be reached between the plates where they overlap, but it is also realised that such figures from accelerated tests need not necessarily apply to conditions in service, and that under prolonged application of stress even lower concentrations may be equally important.

Passing on to consider the treatments of the water which are possible and would lead to inhibition, the authors' view is that neutralising the alkalinity of the water with sulphuric acid could not be carried sufficiently far without endangering the boiler. It was found, however, that increasing the concentration of sodium sulphate or carbonate in relation to that of the hydroxide retarded and eventually prevented the attack. This effect has been studied for several years on an actual boiler, in which the feed-water was maintained with a ratio of sulphate to carbonate of 2 by neutralising about 70 per cent. of the alkalinity with sulphuric acid. After ten years of operation the boiler is in perfect condition, whereas a similar plant using, apart from the water treatment, identical conditions, was condemned after nine years.

It is clear, however, that the treatment must be done under expert supervision. The same applies equally to the addition of aluminium or magnesium sulphate. This treatment is very effective when used in connexion with settling tanks and filters which remove the possibility of scale-forming ingredients entering the boiler, but if used in excess, the salts are distinctly harmful and the quantities added need careful control. Undecomposed sodium carbonate acts as an inhibitant, and cases are on record where the sulphate-carbonate ratio of the water was exceedingly low without any indications of brittleness due to high sodium carbonate content. It is, however, well to regard the carbonate as the potential source of the hydroxide. The authors finally consider that the best ratio to adopt as standard in water treatment for boilers is that of the combined sodium sulphate and carbonate to the hydroxide. Although they are not yet prepared to suggest hard and fast figures, they believe that when this ratio exceeds 2, it is sufficient to stop the embrittlement.

F. C. T.

Whales and Dolphins.[1]

THE scientific heads of the British Museum for many years (just as Dr. R. Knox, Prof. Goodsir, and Principal Sir William Turner did in the northern capital) have devoted much attention to the cetaceans, as seen in Dr. Gray's Catalogue, Sir R. Owen's *Kogia*, and the important publications of Sir William Flower—to whom the public owe the interesting Whale Gallery at the Natural History Museum, South Kensington, with drawings from life by his daughter. It was, however, reserved to the director who has just retired, Sir Sidney Harmer, to systematise the means for obtaining information of all the species—of this most intelligent and interesting as well as much persecuted group—caught or stranded on British shores. In the publication before us he has further added to the indebtedness of the public and men of science by summarising the results of his labours, which, by aid of the officials of the Board of Trade and others, have largely extended our information.

In few groups are there more striking examples of maternal solicitude than in the Right whale, or more conspicuous social instincts than in the Pilot whale. Such is proved by the cruel methods of the old whalers in harpooning the helpless young in order to secure the anxious mother, whilst in the latter group a single example will suffice—thus when more than two hundred were embayed with their leader, an old male, in Scalloway harbour (a kind of pocket with a narrow entrance), the leader dashed through both the inner and the outer cordons of boats and reached the open sea, but when he found he was alone he turned shorewards, again rushed past both lines of boats, and was killed in the midst of his followers in Scalloway harbour, where to this day their skulls make suitable wedges to support the boats.

The first part of Sir Sidney's memoir gives practical information as to measurements of specimens, the different kinds of Cetacea and their sex-characters, illustrated by excellent figures. A brief account of toothed and whalebone whales follows. As an appendix to the list of porpoises, the fact is recorded that in summer in Shetland no less than 100 to 150 may occasionally be seen disporting themselves close inshore in Bressay Sound—probably attracted by a shoal of fishes. The female porpoise gives birth to her young often in June, and she may be watched swimming in circles close inshore with it, or resting on her side with a flipper in the air as it suckles. To Sir Sidney's remarks on the various forms it may be added that some of the larger dolphins occasionally 'breach' like the Humpback whale from the side of a huge wave, again noisily striking the water. The Killer, besides occurring on the east coast, may often be seen in the Sound of Raasay, not far from Portree in Skye, the long dorsal fin projecting above water, steadily propelled as if from a powerful screw.

The author makes important remarks on Cuvier's whale, formerly thought to be rare, especially in connexion with the prenarial basin of the male, about which he hazards the reasonable view that it "is occupied by derivatives of the two narial passages, perhaps diverticula which lie in the basin and are separated ventrally by the reduced prenarial part of the mesorostral." He also discusses skin-markings of whales, with remarks on age and disease, and the sizes of the newly born—quoting from Mr. R. C. Haldane's paper of 1905 (*Ann. Scottish Nat. Hist.*, No. 54) the fact that the young Finner when born is about 20 feet long, and that "sucking calves of 40 feet have been seen."

Tables follow with the Cetacea stranded in 1925 and 1926—27 in the former and 47 in the latter year. In his brief remarks on some of these the author observes that a white-sided dolphin caught in the beginning of August in the Loch of Stenness (near Stromness) at a time when Salps in large numbers pass from the Atlantic to the North Sea may have been attracted by them. Unfortunately, the contents of the stomach were not reported. This view would interest some in connexion with the Fishery Board for Scotland, who took the view that the hordes of Salps ousted the herrings from their usual haunts, the fact being that herrings and other fishes (if not whales) have, like birds and many invertebrates, a relish for Salps or part of them.

Under the tenth head a summary of the characters of the British toothed and whalebone whales, and a key for determining species, are given—a useful guide for all who come in contact with them, especially in such cases as True's Beaked whale, which has only occurred twice on the coasts of Britain.

Appended to the report are seven very useful quarto maps of the British Isles, the first indicating the stations where all the Cetacea during 1925 and 1926 were obtained, the field being generally dotted—with perhaps a denser grouping in the north. The second map is devoted to the common Dolphin, with maximum stations for 1913–1926 to the south and west, the latter areas also being in the ascendant for the Bottle-nosed and the White-beaked Dolphins. The other maps for the Killer, Hyperoodon, Cuvier's, Sowerby's, and True's Beaked whales, as well as the whalebone and spermaceti whales, are equally instructive for the period.

In dealing with the scientific names of the various species, the author throughout has unfortunately refrained from adding the name of the authority for each, probably to avoid complication.

The publication of this report will do much to facilitate the recognition of cetaceans by the public as well as to afford useful information to men of

[1] Report on Cetacea stranded on the British Coasts from 1913 to 1926. (No. 10.) By Sir Sidney F. Harmer. Pp. 91+7 maps. (London: British Museum (Natural History), 1927.) 7*s*. 6*d*.