

THE CORROSION OF CONDENSER TUBES.

Under modern naval conditions, which necessitate the employment of a type of boiler particularly susceptible to the kind of feed water used, the assurance of a regular supply of water free from contamination is essential.

The trend of design is to produce more and more power per unit of machinery weight, and in spite of the progress made in this direction, it may be said with fairness that mechanical reliability has not only not been sacrificed, but has been continuously improved upon, and the comparative freedom from mechanical defects has been so marked in recent years that certain defects, when they do occur, have frequently obtained undue prominence.

Whatever the comparative rarity of such defects, the need of instant readiness for action in war demands that the problems connected therewith should be fully investigated with a view to the avoidance of any recurrence.

Regarded as a matter of proportion, the number of recorded failures of Condenser Tubes, as compared with the total number of tubes on service is extremely small, but the fact that the failure of one tube in a condensing plant containing, say, 30,000 tubes, may involve temporary disablement of a vessel, is of sufficient importance to warrant research of an exacting nature.

Corrosion may be defined as the process of attack on a metal or alloy during which oxidation, solution, or oxidation and solution of the metal, or of one or more of the constituents of an alloy, takes place, resulting in the removal of a portion of the metal either uniformly or from irregularly spaced areas giving rise to pits, which if the action be not arrested extend, coalesce or finally develop into perforations.

When the attack is such that the constituents are disintegrated in the proportion in which they are present, the corrosion is said to be *complete*, but when the rate of disintegration of one constituent is greater than that of the others which remain as unaltered metal, the corrosion is said to be *selective*.

An example of this latter known as dezincification is the apparent preferential disintegration of zinc as a result of which the whole or part of the copper appears to be left in the metallic state.

Oxidation, of course, is the immediately observable effect, but the causes which give rise to this action, *i.e.*, whether chemical, electrolytic, or electrochemical have given rise to much discussion, and there is at present no unanimity in regard to the acceptance of any particular theory, and it will be sufficient for practical purposes to give the following explanation of the behaviour of a condenser tube in sea water.

Before being put to service, a tube has usually been exposed for a period to the prevailing atmospheric conditions, and has,

in consequence, a very thin film of oxide tarnish formed upon its surfaces. Apart from this, and from whatever underlying initial cause, the copper and zinc, in the surface layers on immersion, become oxidised to form such a film, which, owing partly to varying degrees of roughness of the metal is of irregular thickness.

This film is resistant to corrosion in the sense that though not unattacked it is appreciably less attacked than the underlying metal.

The constituents of the oxide film dissolve, and react with the salts and oxygen in solution forming basic carbonates and chlorides, which become detached and owing to the solubility of the oxides being of a comparatively low order, the formation of these basic salts is slower than the oxidizing attack on the surface layer which becomes rich in copper.

At certain places, especially if the temperature be raised and the water stagnant, the zinc hydro-oxide may become converted to a porous carbonate and chloride beneath which dezincification can take place, the copper being protected by the basic carbonate, but the more general action is the oxidation of the constituent metals in the proportion in which they are present in the alloy, consequent upon the breaking down of the first formed resistant film.

As already stated, no agreement has yet been reached in regard to the underlying cause of the oxidation effect, and the application of various treatments and remedial processes, must be regarded as experimental at the present stage.

The outstanding points which present themselves are :—

(1) Can any real improvement be made in the material so that every tube can be regarded as incorrodible under ordinary circumstances, or, at least such that every tube may resist corrosion in a regular and predetermined manner, *i.e.*, subject to a uniform rate of deterioration?

(2) Can the present materials be so treated that they may be considered reliable in the sense described above?

(3) What is the best form of protection to apply in known cases of undue corrosion?

With regard to possible improvements in the composition of the material, recent tests have shown that under the present manufacturing limitations, and when due regard is paid to the necessary properties required for Condenser Tubes other than resistance to corrosion (hardness, conductivity, freedom from brittleness) the current Admiralty composition, *e.g.*, 70 : 29 : 1 is the most suitable material. Copper-nickel tubes have been suggested, but their use in this country is precluded by manufacturing difficulties owing to their deleterious effect on dies. Satisfactory results with metals of this nature are stated to have been obtained in the U.S.A., but available evidence is not conclusive.

With regard to possible treatment, it appears that suitable procedure lies in the provision of a slightly copper rich surface layer which shall be resistant to dezincification.

Such a result has been obtained by the preoxidizing process, in which the finished tubes are heated in an oxidising furnace to a temperature of 536° F. The result is a certain volatilisation of the surface zinc and the production of an oxide scale, but the value of this process cannot be commented on until further experience of pre-oxidized tubes under service conditions has been gained.

With a view to arresting known cases of corrosion experiments on the application of resistant varnishes have been made. In the first vessel treated experience was not altogether successful owing to the partial removal of the varnish by the passage of the sea water. Results in a second vessel similarly treated have been more successful.

The most common form of protection of an electrolytic nature is the use of zinc or steel slabs in the water ends and the provision of cast-iron doors; the tubes being protected at the expense of these fittings. At the best, the effect of this form of protection is confined to the tube ends and cannot be said to have proved entirely successful, particularly when it is realised that the use of cast-iron doors, owing to graphitisation may be actually harmful.

Supporters of the Electrolytic theories (who assume the metal to be constituted of anodic and cathodic areas and that attack only takes place at the anode) point to the success of such processes as the "Cumberland" as evidence in support, but it is probable that the effect of this process lies in the formation of a film of calcium carbonate (which has been shown to occur at the cathode), soon after immersion, and that this process is only effective when applied at the commencement of the service life of the tube, and is not necessarily effective as an arrester when once corrosion has actually started.

In connection with this process, it may be remarked that it is important to secure correct contact between tube and tube plate and to this end the supplementing of the ordinary gromet packing by a turn of carefully fitted lead wire has proved successful.

Though little direct evidence is available, it is the opinion of many that corrosion is frequently due to the presence of electrical leaks and to the use of high-powered wireless installations causing currents uncertain in direction and strength within the electrolyte, *i.e.*, the circulating water. That this view is worthy of attention is supported by the experimental fact that under certain conditions dezincification is assisted by the application of an external E.M.F. and in such case as this the provision of a definite system of electrolytic protection appears desirable.

With regard to external causes of corrosion it may be noted that ashes, clinker, ferric hydrate flakes from cast-iron ends, and sand are harmful, the last named from a corrosive as well as an abrasive point of view.

Further, the initial causes of corrosion in the case of practically new tubes may frequently be traced to the condition of the circulating water during extended basin trials, &c.

The question of temperature of circulating water which should not be higher than 95° F. is important in view of the tendency to dezincification under conditions of high temperature; and failures due to the upper rows of tubes not being drowned, or to restriction of supply have not been infrequent.

It is probable that no one system of protection can be relied on to arrest corrosion in all cases and the solution of the problem now appears to be in the treatment of the tube during manufacture, supported by such protective measures as have been found most efficient for the conditions under which the tube will work, particular attention being paid to the severe conditions which may arise in the very early stages.