The Corrosion of Condenser Tubes.

THE Seventh Report to the Corrosion Research Committee of the Institute of Metals (*J. Inst. Metals*, **32,** 81; 1924) rendered it increasingly clear that corrosion (and resistance to corrosion) depends to a very great extent on the behaviour and properties of films, consisting chiefly of corrosion products, which form more or less completely on the surface of the metal. The Eighth Report, recently published, carries this aspect of corrosion considerably further so far as one type of wastage is concerned, namely, the 'impingement attack' produced by rapidly moving sea-water, particularly where free air is present, or where intermittent cavitation occurs.

This form of corrosion is well known to engineers; it results in a water-worn appearance of the tubes, and is due to the erosion of the protective film. Such films, even where they cannot be seen, may be inferred, for example, where a clean specimen of an alloy suffers attack while a specimen of the same material, previously immersed in slowly moving sea-water for a few days, is unaffected. Up to the present the investigation of the properties of such films has been tedious and, to some extent, uncertain, and the development in the present report of a method of examination which is both rapid and direct represents an achievement of great value.

The fact that a specimen of metal, when covered with a layer of corrosion products, has an electrical potential different from that of the same metal in a clean condition was already well known, but the difficulties involved in the measurement of this potential are by no means inconsiderable. In order to avoid inaccuracies due to polarisation and variations in the electrical resistance of the film, some form of null method was required which would take only the smallest possible current even when out of balance. It was therefore decided to use a three-electrode valve for the purpose, an idea which is, of course, quite well known, but has worked extremely well. An ordinary Marconi Osram D.E.R. valve is used with 33 volts on the anode and a negative bias of 1·5 volts on the grid. A sensitive moving coil instrument is placed in the anode circuit to indicate changes of the anode current. A potential divider, in series with a resistance, is connected across the filament battery, and is arranged so that a potential of from 0 to 500 m.v. may be applied in opposition to the unknown potential when this is in series with the grid bias battery. The potential thus applied is shown by a second moving coil instrument. A change-over switch is placed in the grid circuit, as shown in Fig. 1. When the switch is in the right-hand position, the millivoltmeter and the portion of the potential divider in use are short-circuited, and the positive pole of the grid bias battery is connected direct to the negative lead to the filament. Under these conditions the anode current shown by the instrument in the anode circuit corresponds with the normal grid potential and is noted.

By moving the change-over switch to the left-hand position the potential to be measured is connected in series with the grid bias battery, making the grid more negative and causing the anode current to fall. The unknown potential is then balanced out by adjusting the potential divider, and the point of balance is shown when the anode current returns to the value previously noted. When this is the case the reading of the millivoltmeter gives the value of the unknown potential. A third set of contacts is arranged to open the anode circuit during the operation of the change-over switch.

In carrying out potential measurements during corrosion tests, the specimen used is a small disc, cut from a condenser tube, with a wire soldered to the back. The discs are cemented into ebonite holders with Chatterton's compound, the wires from the discs being run inside separate rubber tubes to insulate them from the sea-water or other corroding medium. The potential is measured between the specimen and a calomel electrode placed in a separate vessel connected with the tank in which the corrosion is occurring by means of a syphon. As the measurements are only relative, there is no need to use a standardised calomel electrode, the one actually used being made up with sea-water instead of potassium chloride solution. This avoided the necessity of taking precautions to prevent the diffusion of the sea-water into the electrode vessel.

In all the alloys tested, the calomel electrode has been the positive pole. The formation of a protective film makes the specimen more cathodic, with a diminishing potential difference between the specimen and the electrode. The breakdown of the film in a similar manner is shown by an increase of the difference of potential. This difference has little direct practical significance of itself. What is of importance, however, is the potential difference between the film-covered metal and the same metal without a film. This may be described as the 'film-potential' which, therefore, is simply the electrode potential of the clean metal minus that of the specimen covered with a film. Obviously the film-potential increases as film formation takes place and falls in the event of a film breakdown (Fig. 2). For the purposes of the present work it was taken that the clean metal was not very different from one freshly cleaned with sand paper or a steel brush.

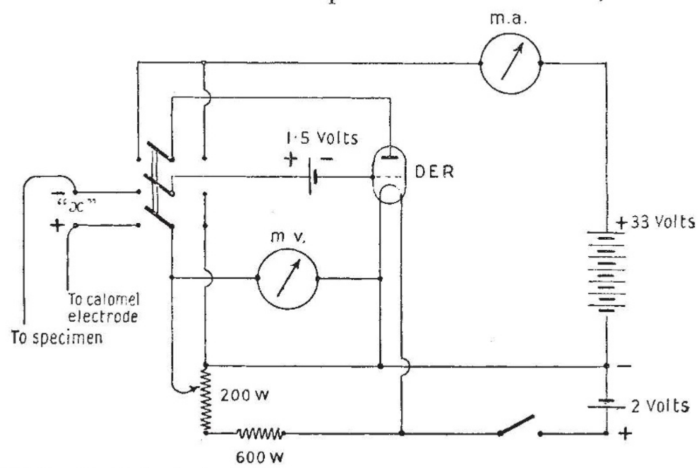

FIG. 1.—Circuit of valve 'potentiometer' used for measuring changes in 'film potential' during corrosion tests. By courtesy of the Institute of Metals.

In order to test the method, some experiments were carried out on a 70 : 30 brass tube containing 0·02 per cent of arsenic and on a special brass tube containing 2 per cent of aluminium. The curves obtained showed important differences in the behaviour of the film on the two alloys, particularly when the film was scratched under conditions of violent air-bubble impingement. In the case of the ordinary brass this resulted in rapid attack, but in that of the aluminium brass the injury healed up and the potential reached the original figure in less than twenty-four hours.

Having thus developed a method capable of yielding rapid and conclusive results, the work was continued on more practical lines, the main results of

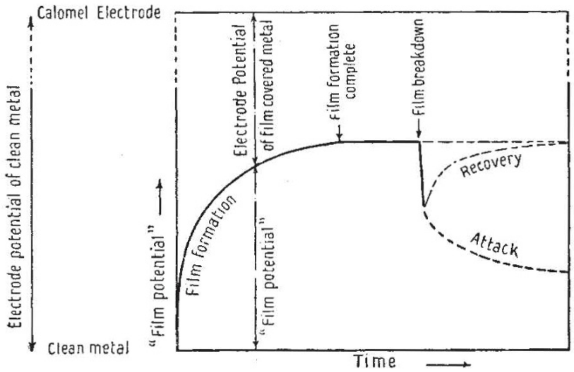

FIG. 2.—Diagrammatic curve of 'film potential' plotted against time, showing the relationship between 'film potential' and electrode potential. By courtesy of the Institute of Metals.

which may be summarised. It is shown in the first place that, even where there is no intermittent cavitation, that is, the collapse of 'vacuum bubbles,' impingement attack can still take place as a result of air-bubble impingement. The size of these air-bubbles plays an important part in causing this type of corrosion, and, where the bubbles entangled in the water are very small, they appear to be comparatively harmless even under conditions of strong impingement. There are, therefore, two main causes of impingement attack, intermittent cavitation and air-bubble impingement, but in both cases the effect is known to be dependent on the occurrence of swirling motions in the water. Rotatory motion of the water should therefore be prevented both in the inlet water-box and inlet piping, if necessary by positive arrangements to guide the water. Air bubbles in the water, except very small ones, should be avoided, and the suggestion is made that a grid in front of the tubeplate of the condenser may be so designed that any bubbles passing through it are broken up sufficiently finely as to be harmless when they enter the tubes.

When the conditions cannot be moderated by mechanical means, the most hopeful solution of the problem would appear to be the use of tubes of a material specially resistant to this form of attack. Of such tubes already on the market those of 70 : 30 cupro-nickel seem to be quite satisfactory, but other materials, such as the aluminium-brass, to which attention has already been directed, appear to be at least as good.

F. C. T.

The Swedish State College of Forestry Centenary Celebrations, 1928.

ON Oct. 14–16 the State College of Forestry, situated in the vicinity of Stockholm, celebrated its centenary. This College, formerly known as the Forestry Institute, was founded on Oct. 15, 1828, by that far-seeing man, Israel Adolf av Ström, who even at that distant date endeavoured to arouse his countrymen to a realisation of the economic importance of the forests of the country. The change in materials used for construction, especially in ships and buildings, witnessed the rise in demand for coniferous timbers, and during the second half of last century Sweden was mainly occupied in capturing and maintaining her hold on the European softwood timber markets. The advice of the few, who understood the danger which the more or less unrestricted lumbering in the forests which had been acquired by the great timber companies and in those numerous areas of varying size (designated farm-forests), owned by tenant farmers, went unheeded. The power of the lumbering interests predominated and the country undoubtedly prospered thereby. Before the end of the century, however, the Government became alarmed at the position and appointed a committee to consider what legal restrictions could be placed on the unchecked exploitation combined with a want of effective management in the greater bulk of the privately owned forests of the country. As a result of the committee's report a General Forest Law was enacted in 1903 and brought into force in 1905, which made it imperative that all areas of forest felled should be replaced by a new young tree crop within a reasonable period. At the same period a revival in the scientific aspects of forestry took place, and in order to endeavour to associate the scientific and commercial aspects of this question the Swedish Forestry Association was founded in 1903.

It is not the purpose of this notice to trace the great progress which the present century has witnessed in forestry matters in Sweden. The War acted as a setback to some extent, in so far that fellings were greatly increased to take advantage of the fantastic prices prevailing in the European markets. But perhaps, as a natural outcome of the extraordinary fellings made to take advantage of exceptional prices, the swing of the pendulum focused the attention of both the State authorities and those engaged in and dependent upon the enormous export trade upon the question of their ability to maintain the position, one vital to the country. To Great Britain the matter is of considerable importance, since we depend at present for a considerable amount of our coniferous imports—timber in various semi-fashioned and fashioned forms, pit-wood and, to an increasing degree, wood-pulp.

This being the position, it is not surprising that in the forestry revival the State College of Forestry became an important centre, since the State forestry probationers are trained there, and many of the larger timber companies either select fully-trained young men from the College or nominate their own probationers to proceed to the College. In some cases these men remain for a longer period as research students at the centre before joining their companies; for many of the latter undertake forest research work of their own and have their own research laboratories. This has been necessitated since conditions vary in different parts, and it is well recognised that it is impossible to localise forestry research for the whole country at any one centre. The timber companies of Sweden own a considerable portion of the most valuable forest land, the State forests occupying for the most part the less valuable soils in the north. The companies have a large capital invested in their undertakings and they have now realised to the full, a recognition which has only come slowly with the lumbering interests and is still absent in many parts of the world, that if this capital is to be safe in the future they must reafforest areas felled over so as to have a succession of crops to provide materials to keep their mills and other industries running. In other words, that primeval forests cannot last for ever. Sweden had arrived at that realisation by the beginning of the present century.

The importance attached to the centenary celebrations of the State College is therefore understandable. The King of Sweden graced the proceedings on two occasions, whilst the Crown Prince was present