

ELECTROLYTIC DERUSTING

BY

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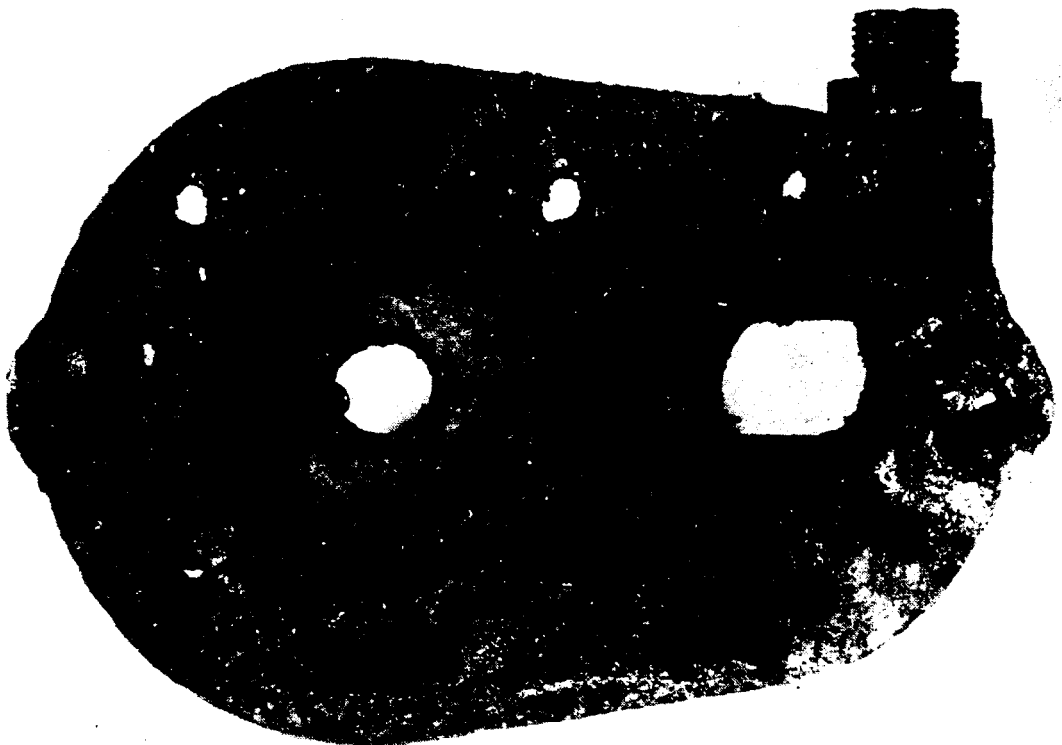
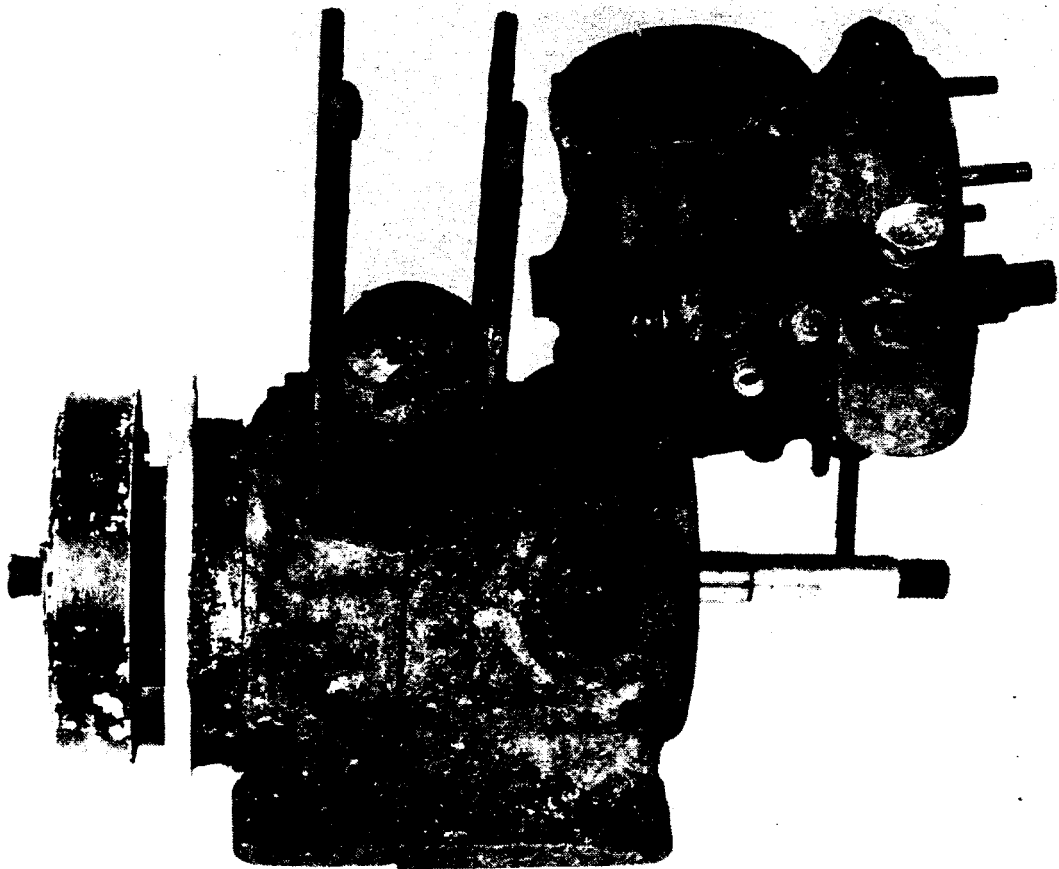
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Synopsis

An outline is given of the process of electrolytic derusting of ferrous material, indicating the many applications where it could be used to advantage in the Service. The methods employed for the treatment of small components by tank immersion, for larger articles by suspension in the sea, and for components which must be treated *in situ* are briefly discussed. References are given to C.M.L. reports which describe the process in detail and its application to specific cleaning problems.



PORTIONS OF SMALL I.C. ENGINE AFTER 12 MONTHS' EXPOSURE IN THE OPEN
ALL WORKING PARTS WERE IMMOVABLE WITH RUST

Introduction

The removal of rust from ferrous materials, either as a preliminary to paint application or in order to achieve mechanical efficiency, is a problem which needs no emphasis to the engineer. The necessity for carrying it out, however, and the man-power which it entails, make it imperative that the methods used should be as efficient and economical as possible. With these objects in view, attention has been given in recent years to the development of the electrolytic method of cleaning, which appears capable in many instances of superseding the traditional mechanical, chemical or thermal methods of derusting and of being employed where these methods are inapplicable.

The electrolytic cleaning process consists simply of making the article to be cleaned the cathode of an electrolytic cell and passing a current until the rust has been removed. The possibilities of applying this principle to ships' cleaning problems were demonstrated in the last war by Colonel Cox of the United States, for cleaning cargo tanks of tankers employed by the United States Transportation Corps.^{1, 2} In particular, he showed that the cheapest and most accessible electrolyte available to marine engineers, namely the sea, could be successfully used for certain applications.

Early in 1946 the Admiralty Corrosion Committee sponsored work being undertaken at the Central Metallurgical Laboratory to investigate the principles involved and the possible application of the process to naval service.³ The encouraging results obtained, both in the laboratory and on a semi-large scale in Portsmouth Dockyard, led to full scale trials being put in hand and the wide range of components which have now been subjected to this method of cleaning include ballast tanks of submarines, bathrooms, turbines, superheater headers, small I.C. engines, cooking utensils, decks, outer bottom plating, mine shells, chain cable and boom defence equipment. More recently, attention has been directed to developing the process for the cleaning and, incidentally, the dis-assembly, of smaller corroded components and mechanisms.

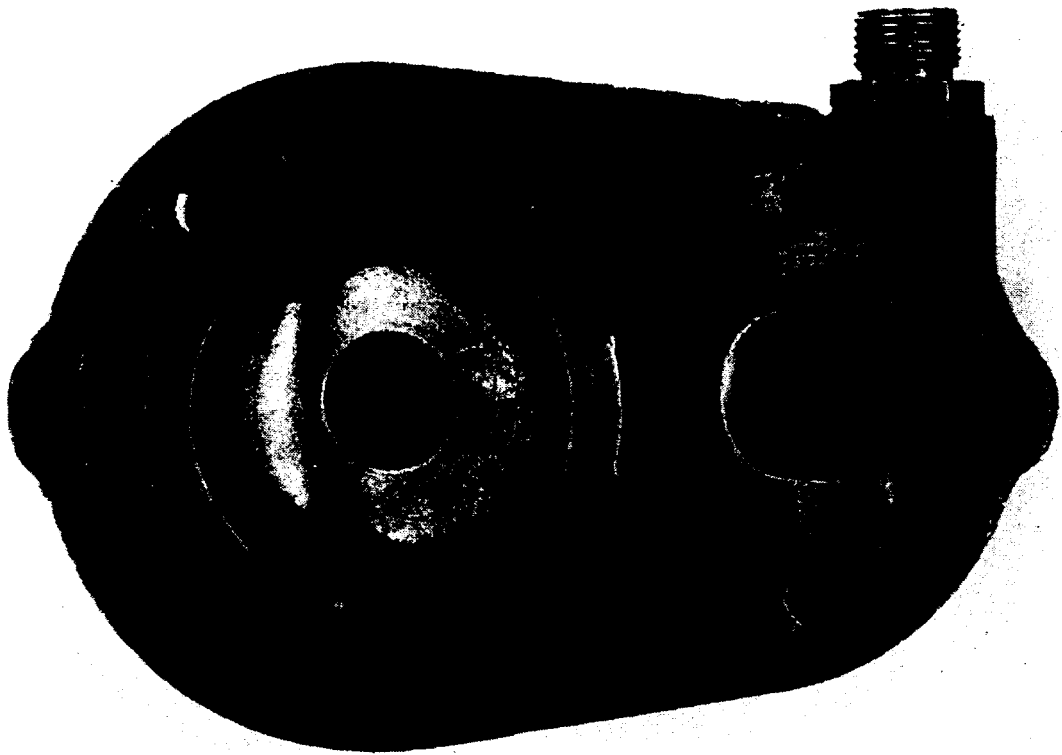
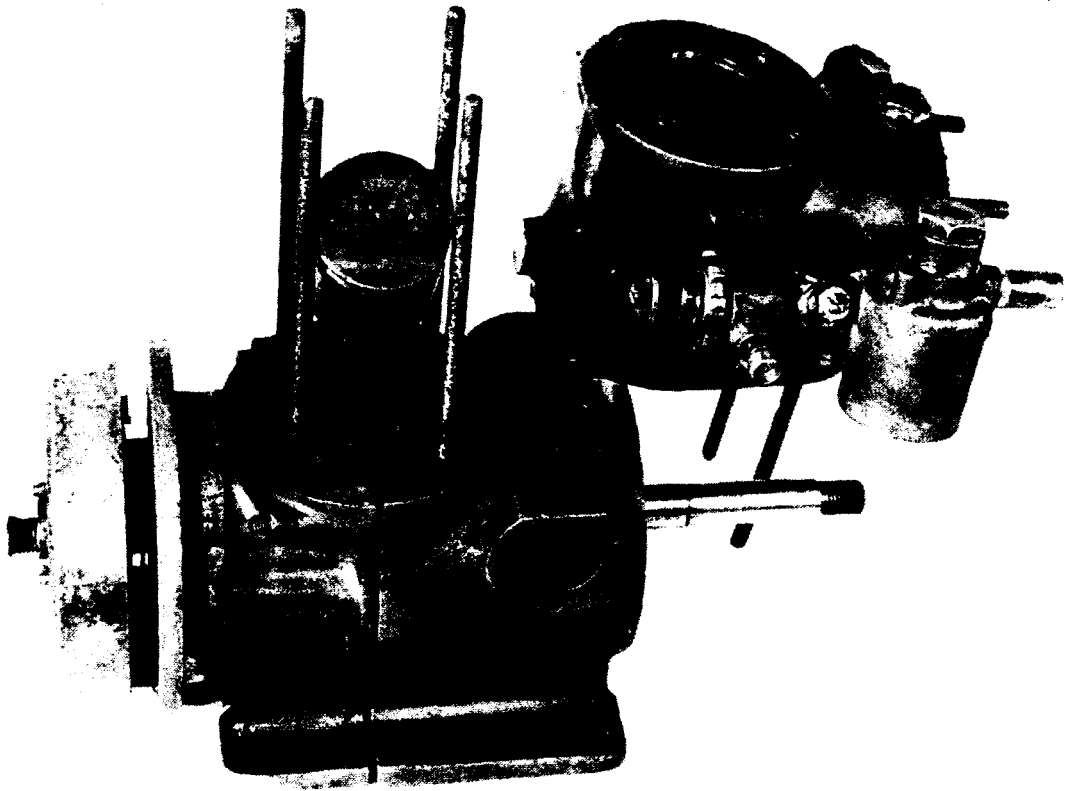
OUTLINE OF THE PROCESS

Before describing the detailed application of the process, a number of general considerations will be discussed.

Briefly, the process consists of passing a direct electric current at low voltage (up to 12 volts), and of as high an amperage as can conveniently be obtained, through an electrolyte, the article to be cleaned being made the cathode, and either a steel tank or an array of iron or steel plates or bars the anode ; alternatively, an inert anode of carbon may be used.

The electrolytes which have been used for Admiralty purposes are seawater or a dilute solution of caustic soda ; in either case the electrolyte undergoes decomposition by the current, hydrogen gas being generated at the cathode. The hydrogen so produced has a reducing, scouring and lifting effect on the rust, as the action takes place at the interface of the rust film and the parent metal.

The main advantages of the electrolytic process over other methods of de-rusting are : (a) Cleaning is achieved without any attack of the metal surface which is, in fact, cathodically protected during the process ; the method is therefore eminently suitable for machinery components the dimensional tolerances of which are important ; (b) The process is particularly effective in loosening assemblies which cannot otherwise be taken apart because of adherent rust or scale ; (c) There is no dust or noise associated with the process and no distortion or bruising of the article being cleaned ; (d) It is economical in man-power and material and no skilled attention is required.



APPEARANCE OF SAME COMPONENTS AFTER ELECTROLYTIC CLEANING—MOVEMENT OF THE ENGINE WAS PERFECTLY FREE AND GUDGEON PIN AND PISTON RING COULD BE READILY REMOVED

The principal limitation of the method is that it will not remove mill-scale since this is a good conductor of electricity and because it is so non-porous and tightly adherent that the electrolyte cannot penetrate. There is also the possibility that the process is less effective for cleaning cast iron but this is at present undergoing further investigation. Certain precautions must be observed when dealing with composite assemblies involving non-ferrous parts. Thus, if aluminium fittings are present, the article must not be derusted in caustic soda solution or the fittings will be dissolved; even if sea-water is used as the electrolyte there may be some pitting of the aluminium by the caustic soda generated by the electrolysis. Zinc, lead, tin and solder tend to dissolve in a caustic soda electrolyte and later may be deposited on the iron being derusted. This drawback can be overcome, however, by reversing the current for a few minutes, thus making the component the anode, whereby any deposit of these metals would be dissolved.

The *modus operandi* of the process is governed by the type of article to be cleaned, three major variants being necessary to deal respectively with the following three classes of article :—

- (a) Small components which can be immersed in a tank.
- (b) Larger articles which cannot be immersed in a tank of convenient size, but can be suspended in the sea.
- (c) Components which must be dealt with *in situ*.

The low-voltage high-current D.C. supply required may be obtained from A.C. mains by an appropriate assembly of transformers and electro-plating rectifiers and such an arrangement, having no moving parts, may be employed continuously without skilled attention. Alternatively, D.C. degaussing generators, as used in H.M. ships are satisfactory; these generators are usually driven by D.C. motors and are capable of delivering 2000 amps. at 10 volts.

In view of the low voltage used, the source of supply should not be too far away from the area of operations, or the resistance of the cables will reduce the current available at the anode. Incidentally, because of the low voltage and the low resistance of the electrolyte, a wide range of materials can be used for insulating the anode system from the cathode. Thus, even wet rope or wooden battens offer sufficient resistance to prevent "shorting."

The relationship between current density (C.D.) and the time required for cleaning is such that at low currents of $\frac{1}{2}$ amp/sq. ft. and less, the time increases rapidly with decreasing C.D., but at higher currents of 3 amps/sq. ft. and more, the decrease in time is small compared with the increase in current. In general, it has been found that the most suitable current density is between 1 and 2 amps/sq. ft. of cathode area when using sea-water, although somewhat higher values may be advantageous with caustic soda solution. Within this range, the time required to clean may vary between 6 and 48 hours or more, depending upon the state of the surface.

In some instances it may happen that patches of very recalcitrant rust need an undue time to effect their removal electrolytically. In such cases, it would clearly be uneconomical to continue the process for say 30 hours when all but these patches had been cleaned in 10 hours. For practical purposes, therefore, the time for cleaning should be regarded as that required to reach a stage when at least 90% of the rust has either become detached or loosened to such an extent that it can be readily removed by hosing down or by light brushing; relatively little mechanical effort should then suffice to remove the remainder. If paint is present which is tightly adherent, the normal period of cleaning will probably not remove it, and ordinarily it is desirable to allow it to remain if the adhesion is good at the conclusion of the electrolytic process.

Bituminous type paints in particular are usually little affected by the normal period of cleaning.

During the process, hydrogen is given off at the approximate rate of 1 cu. ft./70 amp. hrs. and since this introduces the risk of explosion, it is necessary to ensure adequate ventilation. To give a reasonable margin below the safety limit of air-hydrogen mixtures it has been determined that the hydrogen in the mixture should not exceed 1%.

APPLICATION OF THE PROCESS TO SMALL COMPONENTS CAPABLE OF TANK IMMERSION⁴

For this application, 4% caustic soda solution is used as the electrolyte. This has a number of advantages over sea-water where only a limited volume of electrolyte is required. Thus, in the first place, it does not introduce chlorides, which are undesirable when dealing with machinery components. Secondly, when caustic soda is electrolysed, only oxygen is liberated at the anode; consequently a steel anode is not attacked and the electrolyte may therefore be contained in a mild steel tank, the latter itself being used as the anode. Thirdly, there is no deposition of salts on the article being cleaned as occurs in using sea-water. With the latter electrolyte, a film which has been stated^{1, 2} to consist of the oxy-chlorides of calcium and magnesium is deposited and whilst this may be unobjectionable (and in fact according to Cox is advantageous) in dealing with large structural items, it would be undesirable on machinery components.

The size of the tank is not important, but 5 ft. × 5 ft. × 4½ ft. made of ¼ in. mild steel sheet and holding 500–600 gallons of electrolyte would be appropriate for most purposes. The top of the tank should preferably be flanged over for about 2 inches; this gives added rigidity and provides a seating for the insulators to which are secured the copper bus bars connected to the cathode leads. The anode lead is, of course, attached directly to the tank. It is desirable to have a spare tank adjacent to the de-rusting tank to receive the caustic soda solution when the removal of sludge becomes necessary.

For derusting a number of small objects which are not in good electrical contact, such as shackles, grips, bolts or the links of chain cable, it is particularly important that sea-water should not be used as the electrolyte because the imperfect contact will result in some parts of the components becoming anodic with consequent pitting and wastage; this does not occur with caustic soda. The most satisfactory way of dealing with such articles, other than chain cable, is to place them in a large-mesh iron wire basket which can be shaken occasionally as derusting proceeds, thereby ensuring that adequate electrical contact is obtained. Chain cable should be bundled with binding wire, which must be of iron, as copper rubbed off from copper or brass wire would be a site of subsequent corrosion.

When operating the electrolytic process in this way, consideration should be given to installing, in addition, tanks for preliminary and subsidiary treatment of the articles. Thus it is of great assistance to submit the articles to be cleaned to a preliminary degreasing operation, since surfaces contaminated with oil and grease, being poor conductors of electricity, may otherwise require prolonged treatment in the electrolytic cleaning tank.

After derusting, it is advisable to remove traces of caustic soda retained on the surface of the articles. This can be accomplished by a dip in fresh water. In addition, to complete the neutralization of the caustic soda, and also to provide some slight temporary anticorrosive treatment prior to returning the articles to service or to giving them a more permanent treatment in store, a

final dip in a dilute (2%) phosphoric acid solution is an advantage. A mild steel tank provided with a lead lining should be used for holding the phosphoric acid solution. A further tank containing de-watering oil should be provided for a fitting shop plant to receive small components awaiting reassembly after derusting.

As previously stated, when using caustic soda as the electrolyte, no attack of the anode takes place, contrary to the action which occurs with a sea-water electrolyte. Hence it is possible to reverse the process and make the article the anode without detriment. If cyanides are added to the caustic soda solution, a practice which is commonly adopted by commercial firms, and the polarity is reversed for a short time at the completion of cleaning, a much brighter appearance to the cleaned article is produced. In applying and developing the process for Service use, however, it has been the policy to sacrifice this bright appearance in order to avoid the very considerable health hazards involved and the elaborate precautions that would be necessary in using and electrolysing cyanide solutions. In the authors' experience, perfectly satisfactory derusting can be obtained for general purposes, without the use of cyanides. The addition of other salts, such as sodium carbonate, sodium silicate, trisodium phosphate and borax, which are often present in commercial electrolytes for wetting and emulsification purposes, are also considered generally unwarranted for ferrous material, although electrolytes consisting of suitable mixtures of these salts without caustic soda are necessary for cleaning aluminium and its alloys.

APPLICATION OF THE PROCESS TO LARGER ARTICLES BY SUSPENSION IN THE SEA

For this application either iron or carbon may be used as the anode. Carbon electrodes have the advantage that they are not attacked by the chlorine generated by electrolysis but, on the other hand, they are fragile and initially expensive, whereas any scrap material of suitable dimensions can be used for metal anodes. Generally speaking, therefore, iron anodes are to be preferred, and carbon anodes should only be used when cleaning a large number of similar objects such as buoys or mines ; for this purpose, an array of carbon electrodes could be set up and would prove economical in operation.

The articles which have so far been dealt with under the supervision of C.M.L. by suspension in the sea, include 1st class cylindrical buoys and mine casings, although the latter are small enough to be a practicable proposition for tank processing with caustic soda. The anode array for the cleaning of a large buoy, approximately 15 ft. × 8 ft. × 8 ft., consisted of two lengths of steel pipe 10 in. in diameter and 10 ft. long, slung in a rope saddle passed over the floating buoy so as to be 18 ft. below the surface of the water on each side of the buoy and 10 ft. apart. The buoy could thus be treated a segment at a time by rolling it over as required. Complete immersion enabling derusting to be carried out in one operation, would have been preferable but such a buoy could not be flooded, and other methods of sinking it would have presented difficulty. The electrolytic cleaning of buoys has also been carried out by the Canadian Naval Research Establishment at Halifax, N.S.⁵

As previously stated, during the process using sea-water as the electrolyte, a cathodic film of insoluble calcium and magnesium salts is deposited on the surfaces being cleaned. This film possesses little protective value of its own although attempts have been made by silicate washes to improve its qualities in this respect.² Cox considered the film to form a good basis for paint, but the authors are of the opinion that there is a danger of alkali remaining adsorbed

by the film even after hosing down with fresh water. Hence where it is necessary to apply a paint coating, only paints with non-saponifiable media, such as the bituminous type, should be used. It is advised, however, in order to eliminate restrictions of this nature that more positive steps are taken to remove all traces of alkali. The best way of doing this is to brush the surface after the completion of the electrolytic process to remove the attached, but loosely adherent, rust and scale; this should preferably be followed by hosing down with fresh water. After draining, a 2% solution of phosphoric acid should be hosed or sprayed on, to neutralize any residual alkali, and the paint subsequently applied when the surface is dry.

APPLICATION OF THE PROCESS TO COMPONENTS IN SITU

Large Tanks and Compartments⁶

In the case of large tanks or compartments of ships, sea-water is used as the electrolyte because of its ready availability and cheapness. In this connection it should be mentioned that the electrolytic cleaning of submarine ballast tanks has now become a routine practice in some dockyards.

For this class of work, steel and not carbon anodes must be used, since by using a carbon electrode chlorine is freely evolved and will constitute a health hazard in a confined space. In order to obtain effective cleaning, it is necessary to construct an anode network within the tank. The structural details will, of course, vary with the size and shape of the tank, but the main considerations to be taken into account are described below. If painting is necessary after cleaning, the procedure to be adopted should be similar to that described previously.

Shape of the Anodes

An anode rod can be any length of steel (scrap if available), whether rod, tube or angle-bar, but it is not advisable to use a rod of less than 1 in. diameter, or equivalent sectional area, for structural reasons and from considerations of electrical conductivity. Few areas to be cleaned are so simple that there are no projecting parts, and this means that preferential wastage of the rod at points nearest the cathode will occur, with consequent weakening and collapse of the section if the rod is too thin. Similarly, if the end of a rod is near to a part of the cathode, shortening and collapse may occur, although this effect may be offset by increasing the anode area by means of a small plate fixed to the end of the rod.

Anode Network

The next item to be considered is the disposition of the rods which will act as the equivalent of a large plate anode. It is advisable to place each rod at a distance of not more than approximately 3 ft. from the cathode and to consider its radius of action to be about $4\frac{1}{2}$ ft. on each side of the nearest part of the cathode. One horizontal anode will therefore clean a tank which is 6 ft. broad and 9 ft. deep. The length is immaterial, since the rod is made to suit. In order to clean the ends of the tank, a plate about 1 sq. ft. in area is fixed to each end of the rod, which terminates about 3 ft. from the tank ends. In general, therefore, one rod with plate ends will clean an area of $108 + 24L$ sq. ft. of tank surface (when L is the length of the tank in feet).

Structural Details

Approximately 1 lb. of iron is dissolved from an anode for every 435 amp. hrs., so to be on the safe side the network should contain at least 1 lb. for every 100 amp. hrs., to prevent collapse. Joints in the network which are

under water may be bolted together, but those in the bus bars carrying the main electric supply should be welded. In general, the anode network may be fixed by ropes and wooden battens ; if it approaches nearer than 6 inches to any projection on the tank, that area of anode should be shielded with rubber tubing. If a deep cavity has to be cleaned at the same time as the surfaces, an auxiliary anode rod can be suitably supported therein and connected to the main network.

The cables carrying the current should not be connected directly to the network. This is to avoid the sea-water becoming contaminated with copper which might deposit on the surface and subsequently set up extensive corrosion. It is necessary, therefore, to run an iron bus bar from a convenient part of the network to some spot where there is no chance of it being wetted by the electrolyte. It has been found that a bus bar, 3 in. \times 1 in. in section, is quite suitable for carrying 1000 amps.

Turbines ⁷

The value of the electrolytic cleaning process is evident when turbines require cleaning since the removal of corrosion products from the blades by mechanical means, and without damage, in the restricted spaces between blades and between rows is particularly difficult and time-consuming. An illustration of how the method is carried out can best be given by the following brief account of the cleaning of an H.P. turbine in H.M.S. *Indomitable*.

Experimental Details

The process was carried out in two stages. In the first stage, the top half of the casing was cleaned after raising it well above the bottom half ; in the second stage the rotor and bottom half of the casing were cleaned together, the rotor resting in its bearings.

Arrangements for Treating Top Half of Casing

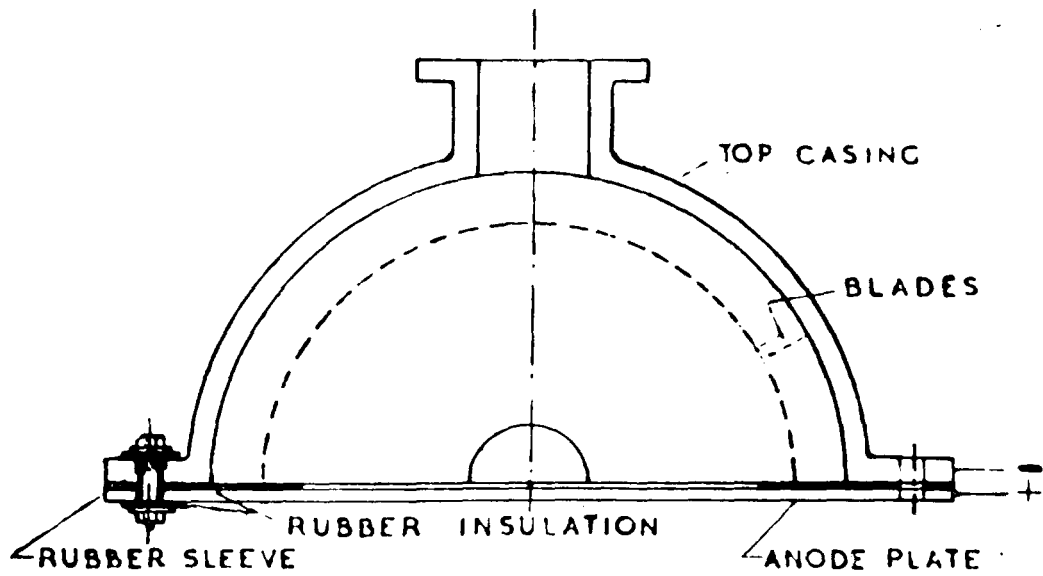
The plate which was fixed across the flange of the casing to contain the electrolyte was also used as the anode. This plate was of mild steel about $\frac{1}{2}$ in. thick. It was insulated electrically from the case by the use of insertion rubber which extended inside for about 6 in. from the edge of the casing. The bolts &c. holding the plate in position were insulated from both casing and anode plate. Power leads were taken from suitable connections on the anode plate and on the casing.

Arrangements for Treating Lower Half of Casing and Rotor

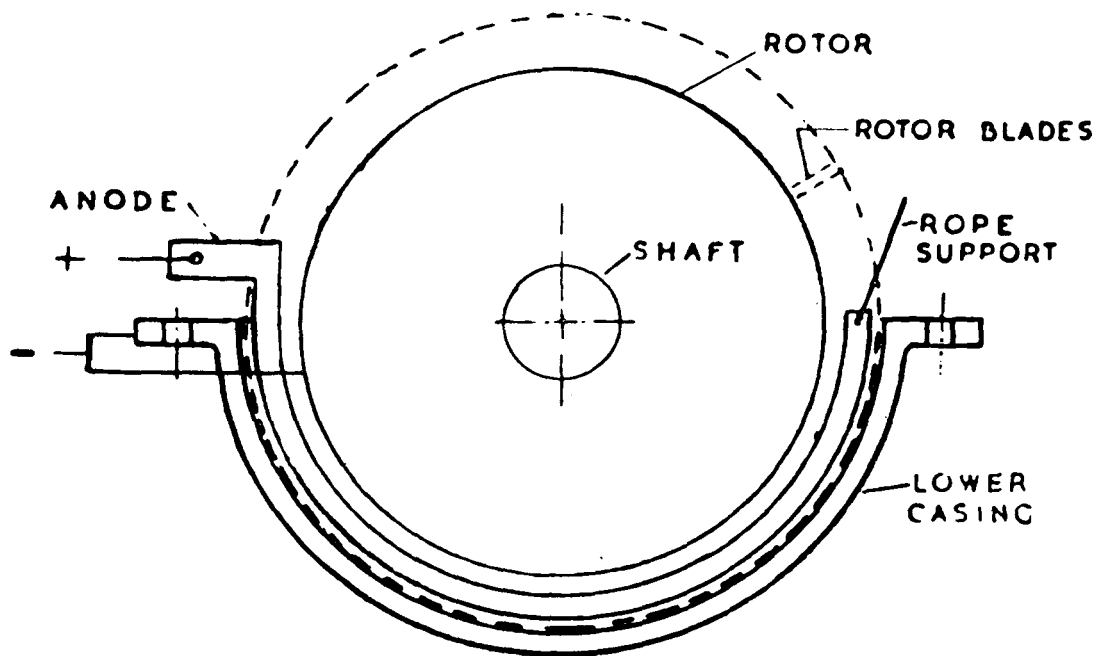
The anodes for this portion of the turbine were semi-annular rings of mild steel about $\frac{3}{16}$ in. thick, 2 in. wide and 3 ft. 6 in. in diameter. To avoid shorting on to the blading they were completely encased in a close fitting canvas cover and slipped between the expansions, as only here was there enough room to insert them. Six anodes were used and connected in parallel to the positive lead from the power supply. The negative lead was connected to the lower half of the casing and to the rotor, by means of a clamp on the impulse wheel. The rotor was cleaned in three runs, the shaft being rotated 120° between each run.

Electrolyte

In view of the fact that corrosion of stainless iron turbine blading is probably always due in some measure to salt water contamination, it is clearly inadvisable to use sea-water as the electrolyte. A 4% solution of caustic soda was therefore used. Incidentally, by taking advantage of the fact that the anode suffers no attack in caustic soda solution it is possible that a complete



TOP HALF OF CASING.



BOTTOM HALF OF CASING.

ARRANGEMENTS OF ANODES FOR CLEANING TURBINE

turbine could be derusted in one operation since the insulated rotor could be used as anode until the casing had been cleaned, after which the current could be reversed in order to clean the rotor. Watertight packing would, of course, be necessary between the two halves, and around the rotor spindle, so that the whole turbine becomes a tank containing the electrolyte.

Power

The power was supplied from a generator in the ship which could supply enough current (300 amps. was used) up to a pressure of about 16 volts.

Safety Precautions

It has already been pointed out that hydrogen is evolved during electrolytic cleaning and that the concentration in air must not exceed 1%, to avoid risk of explosion; this is of particular importance in all inboard work. It is preferable first to dilute the evolved gas by an air blast to less than 1% concentration, before using exhausting fans. This two-stage ventilation was adopted in H.M.S. *Indomitable*, and there was not, at any time, a dangerous concentration of hydrogen.

Removal of Loosened Rust and After-Treatment of the Turbine

After electrolysis for about 48 hours at a current density of about 5 amps. per sq. ft. cleaning was complete. The electrolyte was removed, and the turbine was then hosed down with fresh water and kept wet until the removal of loosened rust was completed by light wire brushing. If this work could not have been completed in one day, a thorough application of de-watering oil as a fine spray, immediately after hosing down, would have kept the loosened rust in suitable condition for removal next day; the oil would have been removed by hosing before re-commencing work on the loosened rust.

After a final hosing down, a 20% solution of sodium nitrite was sprayed on to the surfaces to act as a temporary inhibitor against further corrosion.

Outer Bottom Plating

The application of the process for cleaning outer bottom plating has been studied only to a limited extent, the most ambitious trial being that carried out on a submarine, H.M.S. *Acheron*, whilst in dock. In this case the anode array consisted of an assembly of steel plates suspended around the hull from the shores used in docking. The current from four generators in parallel was led into the array at several points to equalize the current distribution. Employing a current density of 0.2 amps/sq. ft., the operation was completed in about four days when patches of rust up to $\frac{1}{16}$ in. in thickness had flaked off and others were easily removable by light scraping. An important feature of the trial was the effective derusting which was achieved under the casings of the submarine, where access is difficult by other methods.

In certain ships of the Reserve Fleet, successful experiments have been carried out on the descaling of water line areas of outer bottom plating. Various anodes were tried, such as lengths of expanded steel, steel rods, carbon rods secured by canvas backing and 3 in. steel wire rope. The latter type of anode although extremely easy to fix was found to have a very limited life and on the whole an array of steel rods is probably the most serviceable.

Decks⁸

The process has been used experimentally for derusting the decks of ships in the Reserve Fleet, in view of the shortage of man-power. Initially, the technique used was to cover a badly rusted portion of the deck with a paste of sea-water and asbestos fibre approximately $\frac{1}{2}$ in. thick and 2 ft. \times 2 ft. in area. An iron anode was then placed over the paste and a current of 100 amps. passed. The rust was removed in thick flakes after about half an hour, leaving a dull surface free from rust, which was very suitable for painting. Subsequently, an improved technique was adopted which consisted of iron mesh electrodes contained in canvas bags filled with sea-water. The average current

consumption using this method was 70 amps. with a voltage drop of 3-4 volts between deck and anode.

CONCLUSIONS

From the examples that have been given of the wide variety of articles which have been cleaned successfully by the electrolytic process, it will be clear that the method is capable of being applied to almost any rusted surface. The technical limitations of the process are few, whereas the numerous advantages which it possesses over other methods of cleaning would appear to warrant its widespread adoption in the Service.

In this connection, mention should be made of the fact that the process has received considerable attention commercially, especially since the war, stimulus for this development having arisen from the large amount of ferrous material which required salvaging as a result of damage or neglect. The success which the process has achieved commercially, coupled with forceful advertising, has led to the belief in certain quarters that the commercial process is superior to that developed within the Admiralty, either as a result of mysterious ingredients in the electrolyte or by the use of special anodes. This is not so, except that cyanides are generally incorporated in the electrolytes used commercially, in order to produce a brighter appearance to the cleaned article. Since, however, such differences in appearance are of more psychological than technical value, the introduction of cyanides in the development of the process for Admiralty use has been avoided, in view of the dangers, restrictions and precautions that would be attendant on the use of highly poisonous substances in ships and dockyards.

The authors would like to think that the preference that has occasionally been expressed for the commercial process is due to lack of knowledge of the capabilities of the process developed within the Admiralty and not to the proverbial inattention accorded to indigenous prophets.

ACKNOWLEDGEMENT

The authors are pleased to place on record that Mr. F. W. Helsby, B.Sc., A.I.M.E., F.R.I.C., whilst a member of the Central Metallurgical Laboratory, was largely responsible for demonstrating the possibilities of the electrolytic process for Admiralty purposes.

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