NAVSHIPS TRANSLATION NO. 1156

ELECTROCHEMICAL PROTECTION OF SHIP HULLS
(Primeneniye elektrokhimicheskoy zashchity korpusa sudna)

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10p.

Sudostroyeniye (Shipbuilding), p.58 - 62, No.5, May 1968

RUSSIAN

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DECEMBER 1968

SCIENTIFIC DOCUMENTATION DIVISION (205)
NAVAL SHIP SYSTEMS COMMAND
DEPARTMENT OF THE NAVY
WASHINGTON,D.C. 20360

ELECTROCHEMICAL PROTECTION OF SHIP HULLS

The existing systems for the paint-and-varnish coatings can not serve as a reliable means of protection from corrosion and the fouling of the ship hull for the inter-docking period. In connection with this, in the domestic (Soviet) and foreign shipbuilding, use is made of the electrochemical protection in combination with the paint-and-varnish coatings.

In the domestic shipbuilding practice, for protecting the region of the stern counter, most susceptible owing to the coupling of the propeller and the hull, the zinc protection materials were used for some time. However, they were produced with an appreciable content of harmful admixtures, and during operation, they soon became coated with a difficultly-soluble residue, in fact ceasing to fill the role of a protecting anode. Therefore, it was first necessary to choose the most effective alloy for the protecting anodes. An alloy based on aluminum and magnesium proved to be such an agent.

In addition, a shortcoming of the protection system of guarding only the region of the stern counter is the local nature of its effect: only a limited region of the ship's hull is protected. In connection with the application of the low-alloy steels diminishing the thickness of the hull plating, a further development of the electrochemical protection was required.

The improved system of cathode protection utilizing the platinized titanium anodes (the motor ship "Svanetiya") and the nondetachable protective coating with the agents, connected to the hull through the ballast resistance (the tanker "Pkhen'yan") proved to be an effective means of protecting the hull from corrosion.

Protective Coating Over Entire Length of the Ship

The refrigerator ships (of the "Sevastopol" type) and the passenger ships (of the "Kirgizstan" type) were the first ones on which use was made of the protective coating of the hull for the entire length of the ship (Fig.1); it was achieved by 6 groups of protective anodes, with 3 groups on each side;each group has a detachable connection (lead-in) to the hull's interior. On the prototype ships (the "Sevastopol" and the "Kirgizstan"), we installed the electrical measuring and control equipment for modifying the potential of the ship's hull by regulating the resistance in the electrical circuit.

The protective anodes were made from the alloy AMTS-10-10 (Mg = 10%, Zn = = 10%, Mn = 0.5%; and the remainder = Al).

The protective anodes were connected with one another successively in groups by reinforcing material, protruding from their ends (Fig. 2). The number of protectors in the groups ranged from 22 to 37; the size of each = 1000 X X 200 X 40 mm, and the weight = 19 kg.

As is evident from Fig. 1, the protectors (galvanic anodes are mounted in such a way on the hull that were located below the waterline during ballast passage; in the central part of the ship, they are in the bow region; in the stern part, they are elevated somewhat as compared with the central part, since in the ballasted passage, as a rule the ships have a trim difference toward the stern and in addition, the perimeter of the submerged part of the frame is smaller in the stern than amidships. The protective anodes are not installed on the ship's bottom surface owing to the possible damage to the bottom plating during docking.

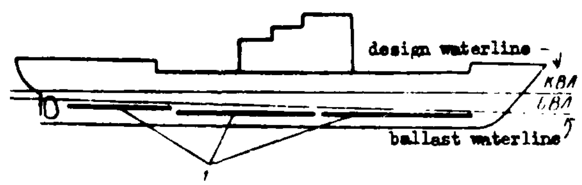

Fig. 1. Diagram Showing Arrangement of Protective Devices on Dry-Cargo and Passenger Ships. 1 - groups of protectors.
Key: a) design waterline; b) BWL (ballast waterline)

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For insulating the protectors from the hull, we used rubber lining 10 mm in thickness, textolite disks in the unit for fastening the protector device, and vinyl plastic bushings.

For measuring the potential of the hull, on each ship we installed three silver-silver shloride reference electrodes, placed in the bow, center, and stern parts of the ship.

The experience gained in operating the indicated ships and the results of the inspections made during docking provide evidence that the protective system with the use of the aluminum protective anodes over the entire length of the ship, in conjunction with the vinyl system of painting favors a reduction in the corrosion of the hull's underwater section.

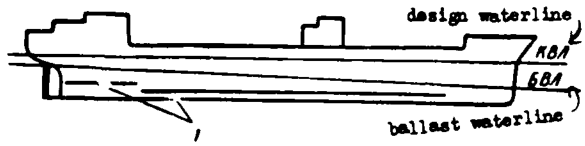

Fig.3. Diagram Showing Arrangement of Protectors on Tankers of the "Prague" Type. 1-group of protectors.

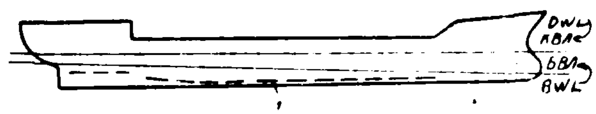

Fig. 4. Diagram Showing the Arrangement of the Protective Devices on Ships of "Sophia" Type 1-group of protectors.

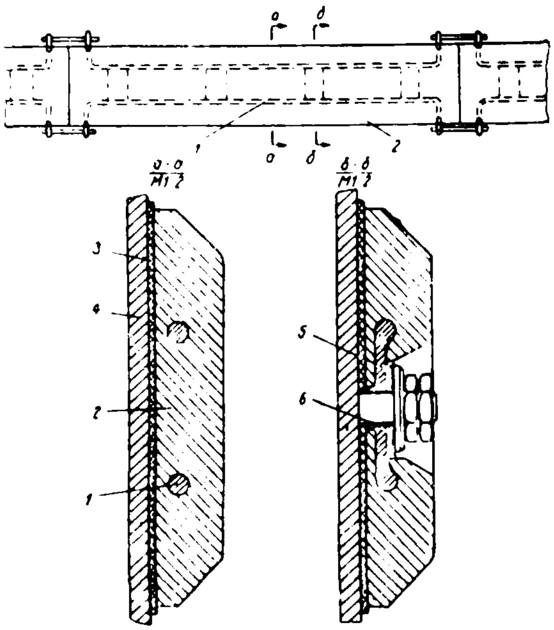

Fig. 2. Fastening of the Protective Devices and Their Interconnection. 1) reinforcement; 2 - protective device; 3 - rubber lining; 4 - outer plating of the hull; 5 - disk; 6 - bushing

For example, during the docking of the motor ship "Sevastopol", it was established that the hull potential reaches the protective value of 0.8-0.85 v; the hull is in good condition and did not have any corrosion damages. The wear on the protective devices ranged from 50-60%.

During the docking period, it was clarified that individual groups of the protective devices were closed onto the hull, and certain of them had been torn off. Similar results were obtained during the docking of the ships "Kirgizstan", "Moldaviya" and "Simferopol", having been operating for 2-2.5 years.

The dock inspection of the referenced ships also indicated that in them, the belt of the variable waterline was protected to a lesser extent than the bottom part. This is explained by the more permanent paint-and-varnish coating on the bottom, which had been painted according to the vinyl system.

The effective range of action of the protective devices made of the AMTS alloy comprised 2-2.5 meters from the place of their installation. The remaining underwater part of the hull, protected to a lesser extent, had sections which had suffered only a slight superficial corrosion.

Of special significance is an effective system of protecting the oil tankers from corrosion. This is occasioned by the following factors: the hulls of the tankers are subjected to corrosion effect from inside and outside; low-alloy steel is utilized for the hull material.

The tanker "Rovno" ("Kazbek" type) was provided with the electrochemical protection; in it, we installed the controllable protective arrangement over the entire ship length, with the devices made of ML-4 alloy. All the protective devices were divided into 6 groups (3 groups on each side). The number of protective devices per group ranged from 27 to 50. Each group of protectors had a lead-in to the hull interior to the electrical measuring and regulating equipment (the bow groups--in the region of the fore peak; the central and stern groups--in the engine room area).

For measurement of the hull potential, we installed on board two chloro-silver electrodes for comparison: one amidships (in the log and echo-sounder shaft), and the other in the cofferdam (in the engine room area). During docking after two years of operation, it was established that the protective system had exerted a positive influence on the condition of the underwater surface, having avoided in a large part of the hull the development of pitting. At the same time, however, it appeared that we had not succeeded in preserving the insulation of the protector groups from the hull.

The protective devices were insulated from the hull by the rubber lining, and from the attaching pins by the textolite disks and the vinyl plastic bushings; the protectors' insulation proved insufficient, and the individual protective devices as well as the entire group of protectors became short-circuited on the hull. The magnesium protectors short-circuited on the hull, having a high current output, disrupted the integrity of the adjacent paint-and-varnish coating and constituted the cause for its premature breakdown.

On the tankers of the "Prague" type, we used a similar system of protective coating, but in distinction from the "Rovno" tanker, the number of the groups of protective devices was two on either side (Fig.3). The protectors had a lead(cable) into the hull's interior in the engine room area. The total number of /60 protectors (anodes) is around 300; their size is 1000 X 170 X 80 mm. The protectors are intended for two years' operation. The protectors were insulated from the hull in the same manner as on the "Rovno" tanker. On the tanker "Ulan-Bator", for the insulation of the protectors from the mounting pins, we applied the Kapron (synthetic fiber) disks and bushings. Two silver-silver chloride reference electrodes located in the shaft of the log and the echo sounder (sonic depth finder) and in the engine room area provided the readings of the hull potential.

It was established by dock inspections that on these tankers, just as on the tanker "Rovno", the protectors became short-circuited to the hull and became prematurely activated, while the paint-and-varnish coating was disrupted. It became clear that it was necessary to pay particular attention to the arrangement of the protective devices in the bow of the ship, where they could be damaged by the anchor chain or by objects floating on the surface during the ship's running in ballast, since in this case the bow draft is relatively slight. Therefore, on the tankers "Prague", "Bucharest", and "Ulan-Bator", the extent of the bow protective group was limited, and on these ships, we did not find mechanical damages or the tearing-away of the protectors. Analyzing the experience gained in the operation of tankers (of the "Rovno" and "Prague" types), equipped with a disengageable protective system over the entire length of the ship, it should be noted that in effect, it is quite difficult to provide a detachable protective shield, since in the presence of a large number of protective devices in groups, it is difficult to avoid their short-circuiting on the hull, as a result of which the effect obtained from the employment of the protective system is appreciably reduced.

Taking this into account, on the "Pkhen'yan" tanker we installed the non-disconnecting shielding with the protectors made of ML-4 alloy.

Such a protection system differs basically from the previous ones. Here we have no protector groups. Each protector is connected separately to the hull through the ballast resistance. The total number of protectors is around 300 items, insulated from the ship hull by a rubber spacer, and from the mounting pins by Kapron bushings. In this way, the protective shield is made noncontrollable. After a year of operation, a dock inspection was conducted. In this connection, it was established that the protective shield provides complete protection of the hull's underwater part against corrosion; the entire underwater part of the hull along the ballast waterline (B/L) is covered with a thin uniformly dense layer of cathodic deposits; as a rule, the wear on the protective devices amounts to 50-60%; the protectors had no mechanical damages; the design for attaching the protectors is reliable and provides a normal functioning of the protective system.

The paint-and-varnish coating on the hull's underwater part before and after cleaning is as follows: in the zone of the variable waterline, the paint is lacking completely and the ship hull was coated with a continuous thin layer of rust; below the variable waterline, 5-10% of the antifouling paint was preserved. Along the length of the ship, 10% of the anticorrosive coating was preserved in the bow of the hull; amidships and in the stern, 50-60% was preserved. The preserved sections have good adhesion with the hull. No disruptions in the varnish and paint coating in the region of the protectors were found. The corrosion condition of the hull's underwater part was good.

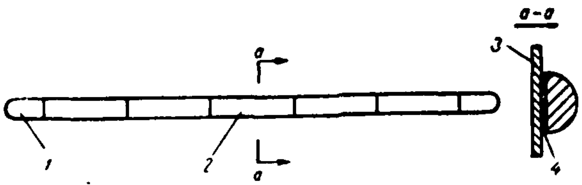

Fig.5. Group of the Protectors.
1 - terminal; 2 - linear; 3 - hull plating; and 4- rubber lining.

A few of the protective devices (around 10%) proved to be short-circuited on the hull. Their wear comprised 80-100%. The presence of the short-circuited protective devices indicates the necessity of a more careful performance of the assembly tasks during the installation of the protective devices.

The wear of the majority of the protective devices by 50-60% during a year of operation indicates the need for increasing the ballast resistance for providing the proper service life of the protectors during the time between dockings.

Thus, for the high-tonnage oil tankers, it is advantageous to accomplish the shielding with the magnesium protective devices only based on the type of shielding on the "Pkhen'yan" tanker, i.e. nondetachable and connected to the hull through the ballast resistance.

The inadequacies revealed during the process of operation were taken into account and eliminated on the tankers equipped with the protective shield over the ship's entire length.

For example, in the series-produced ships of the "Sophia" type and on other types of tankers presently under construction, the continuous chain of protective devices was replaced by the separate groups (Figs. 4 and 5). This made possible a considerable reduction in the weight of the protectors, without diminishing the effectiveness of their action. Each group of protectors consists of two terminal and of 5-7 linear protectors. Each protector is connected separately to the hull through the ballast resistance. For improving of the streamlining, the protective devices have a half-round section with a radius of 100-150 mm. In the central part of the ship, the groups of the protectors are installed on the lateral keels; this permits one to avoid the possible concentration of stresses in the bilge area during the installation of protectors' fastening pins. In addition, the material in the protectors has been improved.

In the region of the stern knuckle, protectors are installed made of the alloy AMTSpch: in the remaining sectors, the protectors made of ML-4vch are installed.

Impressed Current Cathodic Protection System

As compared with the protector type of shielding, the impressed current cathodic protection system has a considerably larger radius of effect and a higher effectiveness; it can be regulated, detachable and automatically controllable (the motor ships Svanetiya and Osetiya). With properly chosen parameters of design and operation, the cathodic system can function for a relatively longer time without replacement, whereas the protector (galvonic) system is intended for the period between layovers in dock and must be restored during each docking of the ship. Therefore the cathodic dystem is economically more advantageous. In addition, it has a considerably less weight than the protector-type shielding.

The indicated advantages of the impressed current cathodic protection system permitted its broad application on the passenger and dry-cargo ships of medium and heavy tonnage.

The cathodic protection system was used to equip the refrigerator ships of the type "Arsen'yev", the lumber ships of the "Pavlin Vinogradov" type and the "Kirgizstan" line of passenger ships.

On the refrigerator ships and lumber ships, we used the platinized ferro-silicon anodes, while on the passenger ships, we employed the platinized titanium anodes.

Since all these ships have reinforced hulls for navigating through ice, the anodes were installed flush with the hull in hull slots provided especially for this purpose. The number of anodes comprised 7 - 10 per side. As a power source, we utilized a dc generator.

For monitoring and regulating the potential of the hull, we installed 3 silver-silver chloride electrodes (comparison type), in the bow, amidships and in the stern of the ship.

In the capacity of the screens near the anodes, we utilized additional paint-and-varnish layers (2 layers of EKZhS-40) in a radius of 1.5-2 m from the anode's center. As the operating experience demonstrated, initially the application of the cathodic protection system was associated with the exposure of a number of disadvantages and with the need to improve and make final adjustments to the system. Among the defects, we might mention: the inadequate insulation of the anodes from the hull and the near-anode shielding, the erratic readings of the reference electrodes, and the large number of the anodes.

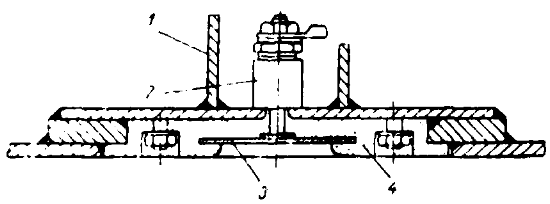

Fig. 6. Unit for Fastening the Improved Anode on the Motor Ship Svanetiya. 1 - lead-in cover; 2 - stuffing box; 3 - anode; 4 - fiberglass.

The elimination of the defects required the conduct of many scientific-research and experimental-design activities. The improved system was installed of the ships "Svanetiya", "Osetiya" and others.

The typical features of the improved system of cathodic protection are: automatic control; a new design layout of the anode unit, excluding the chance of its becoming short-circuited to the hull; a reduction in the number of the anodes, and accordingly an increase in the dimensions of the near-anode shield (for instance, on the "Usetiya"); and an improved design of the reference electrode.

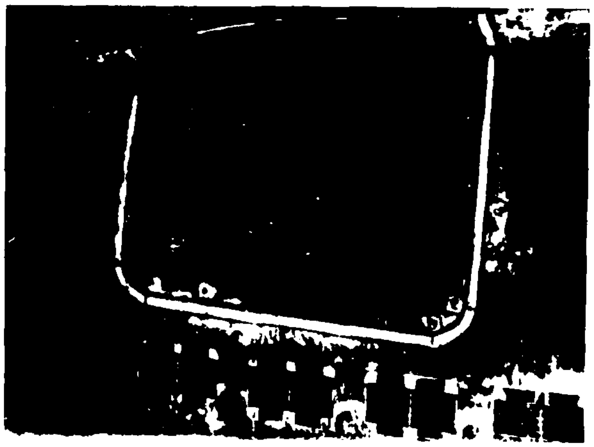

Fig. 7. View of Anode with Near-Anode Shield on Motor Ship "Usetiya".

The automatic control provided for powering the system from the shipboard electrical network through special power sources, controlling automatically the protective potential of the ship hull within prescribed limits and excluding the possibility of the improper polarity of the anodes and hull. The sensors (pickup devices) for the automatic control of the potential are the reference electrodes, which are no longer installed in the bottom section of the ship but in the side part, in order that the gas bubbles(released during the operation of the comparison electrode) and distorting the readings, can be easily removed.

From a design standpoint, the anode unit (Fig.6) is made quite different than the previous units.

The platinized titanium anodes (and subsequently, the platinic-titanium ones), capable of carrying a high current load, were pressed into a fiberglass base having excellent insulating and strength qualities. This base also comprises the minimal circum-anode shield, and through it the anode unit is attached to the ship's hull.

Considerable attention was paid to the selection of the material and the design of the shield (screen) around the anode, which comprises one of the main elements in assuring the operational effectiveness of the cathodic protection system.

On the motor ship "Osetiya", the shields surrounding the anodes have a dimension of 2.5 X 2.5 m, a thickness of 5 mm, and are made of fiberglass (Fig.7). Such sizes of the screens permitted an appreciable reduction in the number of anodes. To avert possible damages to the edges, the shields around the perimeter were fitted with steel strips welded to the hull.

The improvement in the cathodic protection greatly enhanced its functioning. For instance, after a year's operation of the improved setup on the motor ship "Svanetiya", during the ship's docking the condition of the hull and of /62 the paint-and-varnish coating was so good as compared with previous moorings that it was considered feasible to paint the hull not in accordance with the complete system, i.e. 4 layers of EKZHS-40 and 2 layers of anti-fouling paint, but with application of only 1 layer of EKZHS-40 and 2 layers of the anti-fouling paint.

CONCLUSIONS

The operating experience gained with using the protector-type (galvanic) shielding and the impressed current cathodic protection system on the transport ships revealed a number of shortcomings in the protective systems; to eliminate them, extensive work was undertaken. The improved systems of electrochemical protection effectively guarded the underwater section of the hull from corrosion and promoted a better state of preservation of the paint-and-varnish coating, reducing the marine on the hull.

The positive results attained in the application of the electrochemical protection of the hull from corrosion testify to the necessity for its broad introduction, with a simultaneous further improvement.

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