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PREVENTING EROSION OF METALS

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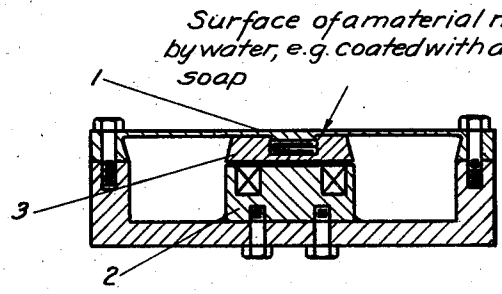


Fig. 1

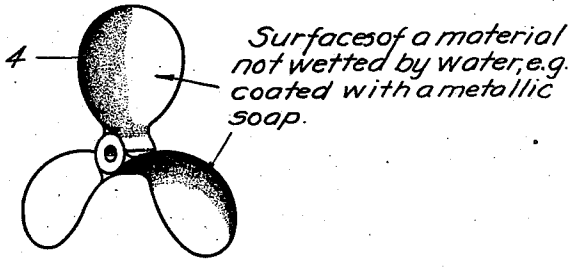


Fig. 2

INVENTOR.
Edward W. Smith

BY

ATTORNEY.

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PREVENTING EROSION OF METALS

Edward W. Smith, Melrose, Mass., assignor to Submarine Signal Company, Boston, Mass., a corporation of Maine

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The present invention relates to a method for the protection of metals and more particularly to a method for preventing the erosion of metals which are in contact with liquids in which cavitation occurs.

For some time it has been observed that the surface of diaphragms of submarine signaling apparatus which are vibrating at relatively large amplitudes become pitted or eroded after being in use for some time. The same is also true of the diaphragms of acoustic apparatus used in the treatment of liquids for the destruction of bacteria or the production of dispersions and the like. Similar erosion also is found on ships' propeller blades, as well as in conduits for liquids flowing at high velocities. It is believed that most of the investigators in this field are agreed that the cause of this erosion of the metal surfaces in some way involves cavitation of the liquid.

In the accompanying drawing Fig. 1 represents in a transverse section a submarine signaling device having a vibrating diapragm in accordance with the present invention, and Fig. 2 represents a perspective view of a ship's propeller in accordance with the present invention.

According to the present invention the erosion produced by cavitation is eliminated by providing the metal with a surface which is not wetted by the liquid in contact with which it is to work. This may be accomplished either by choosing a proper metal or by coating the metal with a substance which is not wetted by the liquid.

The mechanism whereby the erosion in question is brought about under the influence of cavitation is not altogether understood. Heretofore, it has been assumed that the pitting of the metal was due to a hammering action coincident with the collapse of the bubbles formed when cavitation takes place. It appears, however, that this theory of the action of cavitation is incorrect and while I do not wish to be limited by the details of the action suggested below, my theory of the action of cavitation is as follows.

An examination of diaphragms which have been badly eroded by cavitation indicates that the metal was forcibly torn out from the surface of the diaphragm. If this is true, it is necessary that tremendous forces be applied in order to produce this effect, for these forces must be capable of overcoming the cohesive forces existing between the molecules of the metal.

It is a well known fact that the surface tension of water, for instance, at ordinary room temperatures, is approximately 73 dynes per centimeter. The work done in breaking a column of liquid so as to result in the formation of a new surface will be equal to the surface energy resident in the new surfaces so formed. If it be assumed that separations of the order of molecular distance, that is, 10^{-8} power centimeters, are to be brought about, it can readily be shown that a force of approximately 16,500 pounds will be required to bring about a cleavage in a water column of one square centimeter in cross section. Forces of this order of magnitude are great enough to bring about a removal of molecules from a metal surface if they are properly applied.

Moreover, it appears that the surface tension of a liquid at the boundary between the liquid and a metal or other material is tied up with the ability of the molecules of the liquid to diffuse into the metal or other surface material. As stated above, the surface tension of water in contact with air is approximately 73 dynes per cm. whereas the surface tension of water in contact with mercury is approximately 392 dynes per cm. and in contact with water the surface tension of water is zero. It is reasonable to conclude from these figures that water or other liquid has very little affinity for a substance, contact with which produces a high surface tension in the water and, furthermore, that the water molecules can diffuse into such substances only with the greatest difficulty.

On the other hand, when in contact with substances which produce a low surface tension in the water, the water molecules can diffuse much more readily into the surface of such substances. Stated in another way, it is generally true that the surface tension of the liquid will be inversely proportioned to the ease with which it "wets" the material with which it is in contact.

Let us assume, now, that we have water in contact with a metal such as, for example, a vibratory diaphragm as shown in Fig. 1 and which is vibrated at cavitational velocity by the action of electromagnet 2 upon the armature 3; or a propeller blade as shown at 4 in Fig. 2; or a conduit through which water is flowing at a high velocity. It will be apparent that some of the water molecules can migrate or diffuse into the surface of the metal of the diaphragm and form a bond therewith. If the surface tension of the water in contact with such a metal is relatively low, the diffusion of the water molecules into the metal will be relatively high. In other words, the water will wet the diaphragm. If such a diaphragm which is wetted by water is

then set into motion at cavitational amplitudes, the bonding between the liquid and the diaphragm which results from the diffusion of the liquid into the diaphragm can only be broken by high diaphragm velocities such as are obtained when cavitational amplitudes are reached. When the diaphragm pulls away from the water at such a velocity, forces of the magnitude above referred to will be applied. The cohesive forces between the metal molecules are, however, of the same order of magnitude and may even be slightly less than the cohesive forces between the water molecules. Consequently, particles of the metal may pull away from the mass of the diaphragm itself. Now, if the material of the diaphragm were made of such a substance that the water molecules could not diffuse into it or, in other words, if the water did not wet the diaphragm, the attainment of cavitational amplitudes would not be accompanied by disruptive action in the diaphragm, but a separation, if any, would take place at the diaphragm-water interface or in the water.

According to the present invention a vibrating diaphragm or a propeller blade or other body subjected to relative motion in contact with a liquid at cavitational velocity is made of a substance which will not be wetted by the liquid with which it is in contact. Stated in another way, the body in question is made of a material which produces at the interface a high surface tension in the liquid which is in contact with it. As an example, a vibratory diaphragm or a propeller blade or a water conduit may be made of self-lubricated bearing brass or bronze, which is not appreciably wetted by water. This material is a brass or bronze containing graphite, the surface tension of liquids in contact with it being greater, the greater the amount of graphite.

Inasmuch as the entire phenomena of erosion by cavitation, as above discussed, resides in the surface of the material in contact with the liquid, it is not necessary that the entire metal be made of a substance which will not be wetted by the liquid, provided a surface can be formed on the metal which has the properties above referred to. As an example of this, a bronze diaphragm can be protected by treating the surface with mercury so as to form an amalgam and thus to present a mercury surface to the water with which it is to be in contact. Since the mercury has a very high affinity for bronze and since the surface tension of water in contact with mercury is very high so that there is only a very slight degree of wetting of the mercury, there will be substantially no erosion of the diaphragm surface even at cavitational amplitudes.

Other materials not readily wetted by water may be used with equal effectiveness as a protective coating for the metal surface, provided that they have a relatively high affinity for the metal. For example, some of the metallic soaps used for high pressure lubricants have an affinity for metals such as bronze or steel. In this case the metallic end of the soap molecule becomes affixed to the diaphragm and leaves the long chain hydrocarbon end of the molecule in contact with the liquid. Since the latter is not wetted by the liquid, such as water, to any appreciable extent, there will be no erosion of the diaphragm.

From the above discussion and the illustrative examples given, it will be readily understood by those skilled in the art that according to my invention it is merely necessary, in order to prevent the erosion of a body by cavitation, to choose a substance whose surface will be wetted to a minimum extent by the liquid which is in contact with it or, in other words, the surface of the substance should be chosen such that the surface tension of the liquid in contact with it is as high as possible.

Having now described my invention, I claim:

1. A body having a surface adapted to be submerged in and moved relatively to a liquid with a velocity large enough to produce cavitation, said body having its said surface formed of a material such that the surface tension of the said liquid in contact with said surface is very high and the material is not substantially wetted by the liquid, whereby erosion of the body by cavitational action is inhibited.

2. A body having a surface adapted to be submerged in and moved relatively to a liquid with a velocity large enough to produce cavitation, said body having its said surface coated with a substance which has a high affinity for the body but for which the liquid has substantially no affinity, whereby erosion of the body by cavitational action is inhibited.

3. A vibratory diaphragm having a surface adapted to be submerged in and vibrated in contact with a liquid with a velocity large enough to produce cavitation, said diaphragm having its said surfaces formed of a material such that the surface tension of the said liquid in contact with said surface is very high and the material is not substantially wetted by the liquid, whereby erosion of the diaphragm by cavitational action is inhibited.

4. A vibratory diaphragm having a surface adapted to be submerged in and vibrated in contact with a liquid with a velocity large enough to produce cavitation, said diaphragm having its said surface coated with a substance which has a high affinity for the diaphragm material, but for which the liquid has substantially no affinity, whereby erosion of the diaphragm by cavitational action is inhibited.

5. A vibratory diaphragm having a surface adapted to be submerged in and vibrated in contact with a liquid with a velocity large enough to produce cavitation, said diaphragm having its energy radiating surface coated with a metallic soap.

6. A ship's propeller blade adapted to be rotated in the water with a velocity large enough to produce cavitation, said propeller blade having its surface formed of a material such that the surface tension of the water in contact with it is very high and the material is not substantially wetted by the water, whereby erosion of the propeller blade by cavitational action is inhibited.

7. A ship's propeller blade adapted to be rotated in the water with a velocity large enough to produce cavitation, said propeller blade having its surface coated with a substance which has a high affinity for the propeller blade, but for which water has no substantial affinity, whereby erosion of the propeller blade by cavitational action is inhibited.

8. A ship's propeller blade adapted to be rotated in the water with a velocity large enough to produce cavitation, said propeller blade having its surface coated with a metallic soap.

9. A body having a surface adapted to be submerged in and moved relatively to a liquid with a velocity large enough to produce cavitation, said body having its said surface coated with a metallic soap.

EDWARD W. SMITH.