OTTAWA December 15th, 1941.

# REPORT

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1131.

Examination of Copper Draft Tube,
Failed by Pitting.

(Copy No. 14.)

BUREAU OF MINES
DIVISION OF METALLIC MINERALS

ORE DRESSING AND
METALLURGICAL LABORATORIES

CANADA
DEPARTMENT
OF
MINES AND RESOURCES
MINES AND GEOLOGY BRANCH

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### Origin of Material and Purpose of Investigation:

On November 20th, 1941, Mr. A. C. Halferdahl, of the National Research Council, Ottawa, Ontario, submitted a section of copper, taken from a draft tube on one of the corvettes. In an accompanying letter, Mr. Halferdahl gave the following information:

(Continued on next page)

(Origin of Material and Purpose of Investigation, cont'd) -

"The enclosed specimen of copper was left with me by Lieut. Millard, Naval Service. It is from a draft tube on one of the corvettes. The draft tube takes water outside the ship near the bilge section for condensing and cooling purposes. The tubes are 14 inches in diameter by 8 feet long. These tubes are failing by pitting and the specimen enclosed has one such pit which has penetrated."

It was also stated that a memorandum had been written on this item to the effect that "this was a pitting type of corrosion and erosion, enhanced by the presence of fuel oil in the harbour which results in a building up of sulphate-reducing bacteria and these give $H_2S$ and acidity. There is considerable turbulence in the tubes with resultant cavitation or impingement effects. Also dirt, i.e., sand in the harbour water, may be a factor."

"We suggested brass (arsenic bearing) or aluminium bronze, or cupronickel. These are tougher and in such situations are more resistant than copper. One basic factor is design to avoid turbulence of flow, now out of the question."

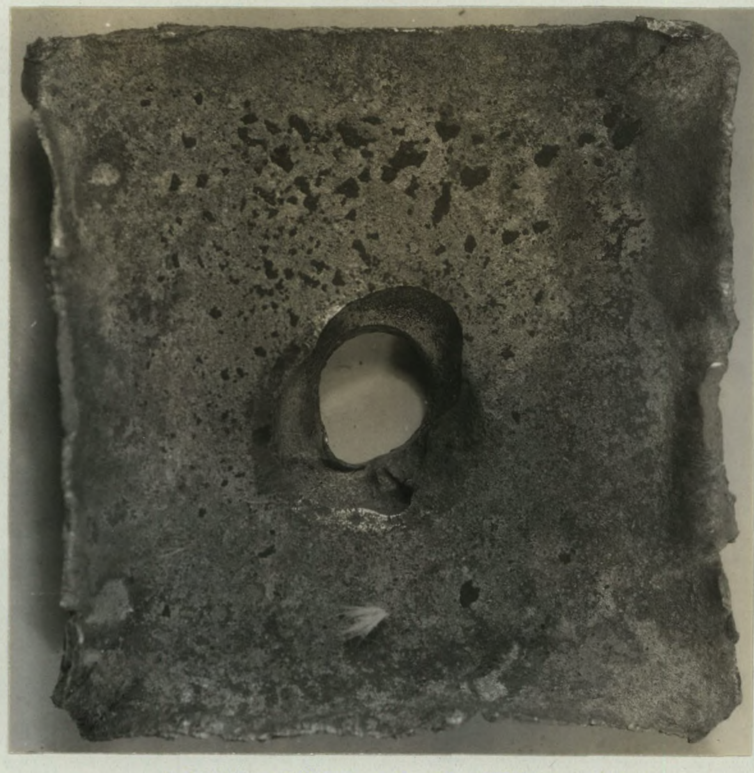
It was mentioned, further, that Lieut. Millard is considering the possibility of lining the tubes with rubber, thus avoiding replacement.

It was stated that the Naval Service would like an expression from the Bureau of Mines of its opinion as to the causes of the failure, as well as any remedial suggestions.

Appearance of Pitting:

The submitted specimen of copper draft tube failing by pitting was approximately 1 inch square and had one such pit which had penetrated. The appearance of the pitting is shown in Figure 1.

Figure 1.



APPEARANCE OF FAILURE DUE
TO CAVITATION.

(Approximately X3 magnification).

Spectrographical Analysis:

| | | |
|---|---|---|
| Trace | ...... | Silicon, Magnesium. |
| Faint trace | ...... | Iron. |

Chemical Composition:

| | | Per cent |
|---|---|---|
| Copper | - | 99.99 |
| Arsenic | - | nil |

Hardness: (By Vickers Hardness Tester)

60 Vickers Pyramid Number.

Discussion of Results:

Corrosion of copper and copper alloys in sea water is accelerated by aeration and the rapid flow of water. A peculiarity of copper alloys under such conditions is that a single specimen may have a high general resistance yet in a localized spot or two be very rapidly attacked. Copper alloys corroding even slightly in sea water develop at their surfaces liquid and solid films of corrosion product that have a suppressive effect on further corrosion. The movement of sea water, particularly when carrying entrained air bubbles and when turbulent, often upsets the full protective effect of these films. Where locally upset, conditions are extremely favourable for the commencement of an attack, a complex group of factors, both chemical and physical, that will ultimately lead to failure.

In agreement with the observations made by the National Research Council, it is apparent that the cause of failure of this copper draft tube was a pitting type of erosion-corrosion, due in all probability to what is known as impingement attack or destructive cavitation. Practically all the conditions that cause such types of failure are present in this case. With the intake of water there is certain to be considerable turbulence in the draft tube with entrapped air-bubbles also being taken in at the outboard end. This condition would be aggravated considerably at sea in stormy weather by a churning action in the draft tube when the ship is rolling and pitching. When the air-bubbles leave the

(Discussion of Results, cont'd) -

water and impinge on the metal, the layers of corrosion products which may have been deposited previously on the surface, and which served as a partial protective coating, would be removed. This removal would allow corrosion to continue unchecked at these points. The specimen submitted showed that the pit was free from any corrosion product and also that it was undercut, both of these conditions being generally considered good indications of failure due to impingement attack. The undercutting may be observed in Figure 1.

The original pitting condition could be initiated also by the entry of foreign material carried in the sea water, animal and vegetable organisms, sea shells, slag and ashes from the ships in convoy, and flotsam and jetsam present in the sea water everywhere.

Another very possible initial cause of attack may be due to the fact that sea waters, both in harbours and off-shore at sea, contain at times appreciable amounts of fuel oil. Since the outboard or inlet end of the draft tube is well below the water line, any taking in of oil with the water would probably occur only during heavy weather or in areas where enemy action has taken place. Oil might also be taken in when used in rescue work in heavy weather, especially as the ship is "laying to" and probably rolling heavily. However, the concentration of oil would not need to be high, as instances are on record where oil drops have been in contact with the metal for

(Discussion of Results, cont'd) -

a period long enough to set up differential aeration; the oil would later be carried away, but on the originally attacked area the pitting would continue, with ultimate perforation of the metal. The appearance of a failure due to this cause would be somewhat similar to that caused by impingement attack, except possibly that corroded annular rings or "horseshoes" would be apparent about the cavity.

In port, there would be some possibility of oil pollution in the intake water and also strong possibilities that the water, varying from fresh, brackish, to typical sea water, might be contaminated with sewage and various corrosive effluvia of all kinds from industrial establishments on shore, in addition to silt, sand, etc., which could initiate or aggravate the conditions leading to failure.

A contributory cause of initiating attacks that may lead to ultimate failure might be stray electrical currents. These might arise from faulty electrical installations or lay-out on board ship, or possibly from a recently developed protective device against magnetic mines known as a Degaussing Girdle. The girdle consists of ordinary insulated cable which, when energized in a special way by an electric current, neutralizes the natural magnetic field of a steel ship.

Further interesting information also has been given by Engineer Commander J. F. Bell, R.N., to the effect that condenser tubes which previously had given good service with a long expectancy of life began giving trouble shortly

(Discussion of Results, cont'd) -

after the introduction of wireless telegraphy aboard the ship. This necessitated a change in specification for the tubes. Later, with the increase in power for wireless telegraphy sending apparatus, condenser-tube trouble reappeared, making it necessary again to revise the specifications. It is difficult to say whether or not the trouble experienced with the tubes was related to the installation and to the later increase in power of wireless telegraphy. However, it would appear that some relationship exists.

The material used in this particular tube was copper of very high purity, as shown by both chemical and spectrographic examination. Some difference of opinion exists regarding the advisability of the addition of very small amounts of arsenic. It appears that arsenical copper may be slightly more resistant to sea action than pure copper, but this advantage is neutralized by a greater fall in tensile strength under such conditions. For this reason, it is not considered advisable to use arsenical copper in salt or brackish waters.

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## Suggestions for Remedial Measures:

There are several problems in considering the most suitable material for draft tubes and there is no one single metal or alloy that could be recommended as best for all conditions of service. Important factors to be considered are the chemical composition of the water; the

(Suggestions for Remedial Measures, cont'd) -

conditions incidental to the design and operation, such as the velocity of the intake water in the tube; possibility of air entrainment; and presence or absence of suspended solids. All of these factors affect the life of the tube and have an important bearing in determining which alloy will give longest life and best performance.

Alloys that might be used for this purpose include red brass, admiralty brass, aluminium brass, and cupro-nickel.

Most of the information available concerns condenser tubes where the service is considerably more severe than in draft tubes. However, the conditions that may cause failure in whatever material is used are similar in both cases.

RED BRASS (copper 85 per cent, zinc 15 per cent) in contact with sea water offers much better resistance than copper. Its low zinc content makes it little liable to dezincification and it is not as susceptible to stress-corrosion or season cracking as are the yellow brasses. Dezincification is a form of corrosion of brasses in which under corrosive conditions the metal dissolves as an alloy and the copper replates in a spongy metallic form. Brasses containing a relatively high zinc content have the property of forming protective films which are resistant to impingement attack, but such brasses often show the dezincification type of corrosion. Copper-zinc tubes containing ore than 15 per cent zinc are occasionally subject to dezincification. The use of red brass is not recommended where water velocity

(Suggestions for Remedial Measures, cont'd) -

would be over 8 feet per second.

ADMIRALTY BRASS (copper 70 per cent, zinc 29 per cent, tin 1 per cent) has better resistance than red brass and is very commonly used, especially on fresh water, slow-speed ocean-going freighters, and for tugs, harbour craft and slower vessels with reciprocating engines. Where there is a tendency to dezincify, the presence of 0.01 to 0.02 per cent arsenic favours the resistance, but its use may lead to intercrystalline corrosion. The mechanism of the action of arsenic in inhibiting dezincification is not fully understood. It is believed that it helps the formation of a tough, adherent, protective film on the surface of the metal. With regard to tubing, the British practice of using hard drawn tubes gives better resistance to the mechanical forms of attack, air impingement, and erosion, whereas the soft American tubes better resist chemical and electrochemical forms of corrosion. Each type has its own particular merits. Tinning of the surface subject to attack is frequently of value in improving surface life under adverse conditions. However, in some fresh waters this is not always true; the tin-coat will delay the setting-in of the attack, but once the tin has been removed, the attack is accelerated.

The chemical composition and physical properties of admiralty brass are given in the specifications of A.S.T.M. B-111-40T.

(Continued on next page)

(Suggestions for Remedial Measures, cont'd) -

ALUMINIUM BRASS (copper 76 per cent, zinc 22 per cent, aluminium 2 per cent).

The addition of aluminium to copper-alloy tubes makes them superior to the brasses mentioned previously. They then possess the property of forming a tenacious, self-healing film which renders the tube highly resistant to impingement attack. These are the most durable tubes available at moderate cost for turbine-driven ships. They have been found superior to admiralty brass aboard vessels where the latter are subject to early deterioration by impingement. They show remarkable ability to resist the corrosive and erosive effects of entrance end turbulence and air-bubble attack. This resistance is attributed to the rapid formation of a strong continuous film of aluminium oxide. In some instances tubes of this alloy have resisted the attacks of brackish and polluted harbour waters better than the copper-nickel alloys.

The chemical composition and physical properties of aluminium brass are given in the specifications of A.S.T.M. B-111-40T.

COPPER-NICKEL (copper 70 per cent, nickel 30 per cent; and copper 75 to 80 per cent, nickel 19 to 23 per cent, zinc 1 to 6 per cent).

These are the highest-quality condenser-tube alloys commercially available. They have reliability, long life, and resistance to corrosive attack in either flowing or standing water. They are not subject to

(Suggestions for Remedial Measures, cont'd) -

dezincification and are of particular value where resistance to impingement attack is required. It is believed that the merit of copper-nickel alloys for these conditions is due to the fact that the protective layers of corrosion product both resist breakdown in high degree and are self-healing.

The chemical composition and physical properties of this material are given in A.S.T.M. specification B-111-40T.

Protective Treatment of Tubes -

One method for protecting tubes from attack has been to coat the interior of the tubes with an asphalt composition. Apparently this material is satisfactory when the ship is in relatively cold waters but not equally so in warm waters where the coating tends to move, leaving bare patches.

The suggestion of lining the tubes with rubber would seem to possess considerable merit. Rubber-lined pipes are used to quite an extent in the mining industry under very adverse conditions. After several years of experimental work the U. S. Bureau of Ships has now developed a plastic condenser-tube-end protector to combat the effects of inlet-end impingement attack. Tube-end protectors under trial were fabricated from bakelite, neoprene, and combinations of bakelite and neoprene. It is stated that these inserts have a long service life and ideally protect the inlet ends of these tubes. For

(Suggestions for Remedial Measures, cont'd) -

(Protective Treatment of Tubes, cont'd) -

condenser-tube conditions, it has been definitely established that bakelite was not adversely affected by high temperatures and by the corrosive effects of sea water since it is chemically and physically inert with respect to the surrounding metals in close proximity.

For draft tubes, where temperature is not a factor, it would seem that the use of all the above-mentioned plastics would merit further investigation.

Possibility of Substitution of Steel for Non-Ferrous Tubes -

Another possibility for consideration is the comparatively recent development of silicon impregnation, or siliconizing, commercially known as "Ihrigizing". This process, which is patented, consists of impregnating iron and steel with a silicon-rich case, containing about 14 per cent silicon, and is reported to have greatly improved the resistance of the steel to corrosion, heat, and wear. Forged, rolled or cast low-carbon steel, with as low a sulphur content as possible, is particularly suited for the operation. Briefly, the steel articles are subjected to the action of silicon carbide and chlorine at temperatures of 1700 to 1850 degrees Fahr. Instead of silicon carbide, ferrosilicon, or mixtures of the two, may be used. Parts may be processed in a rotary- or a pot-type furnace, and the chlorine is added when the parts are at treating temperature. The case may be made almost any desired depth

(Suggestions for Remedial Measures, cont'd) -

(Possibility of Substitution of Steel for Non-Ferrous Tubes, cont'd) -

from 0.005 to 0.100 inch. The object of silicon impregnation is to produce an article cheaply that is resistant to corrosion. Because the alloy is only in the surface layers which are exposed to the corrosion, the core or major portion of the piece is inexpensive common steel. Parts can also be fabricated from common steel more economically than from most corrosion-resistant alloys, and as the last operation given the silicon impregnation treatment. One particular application where steel treated by this process has been used very successfully is on water-pump shafts in heavy-duty internal combustion engines. Silicon impregnation is also reported to be quite serviceable on valves, fittings and tubing in the chemical, paper and oil industries. It would appear that the possibilities of this process of steel tubing treatment might be worthy of further investigation, for such applications as in draft tubes.

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## Conclusion:

The above report outlines the various methods that might be used in this service. With the exception of the last two listed, which may be regarded as experimental, the materials are given in their order of merit. In selecting a material this should be kept in mind.

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