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DEPARTMENT OF MINES AND TECHNICAL SURVEYS

OTTAWA

MINES BRANCH INVESTIGATION REPORT IR 64-3

FAILURE OF "BANJO" FITTINGS IN INFLATABLE LIFERAFTS

by

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COPY NO. 11

JANUARY 22, 1964

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SUMMARY OF RESULTS

During periodic inspection, four 25-man liferafts from three different ships failed to inflate. This was traced to the breakage of five "Banjo" fittings.

These fittings were examined together with other used and new fittings, and evidence of stress corrosion was found in all the fittings which had been in use. Tests on new fittings showed that some of these were susceptible to stress corrosion failure.

It is recommended, therefore, that the brass fittings be replaced by other material which is not susceptible to stress corrosion failure and that care should be taken in the assembly of the fitting to ensure a low stress level in service.

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INTRODUCTION

Pieces from four fractured "Banjo" fittings were brought to Mr. J.O. Edwards of this Division on November 8, 1963, by Mr. H.J. Aspin of the Ships Machinery Inspection Division, Marine Regulations Branch, Department of Transport, Ottawa. The following information was supplied in letters carrying File No. 9410-19: the fractured fittings were discovered during the annual inflation tests of 25-man Elliot liferafts when the rafts failed to inflate. Two rafts from the M.S. "Island Princess", having serial numbers 8407 and 8480, failed to inflate on October 23, 1963. This was the fifth annual test for raft number 8407 and the fourth for raft number 8480. In the first case, both jet nipples from the "T" piece of the filling line, which carries gas from the CO_2 cylinder to the buoyancy chambers, were found broken, and in the second raft one of the jet nipples was broken. All three fittings had failed in the male threaded part of the nipples. Another failure to inflate was discovered during the fourth annual inflation tests of a raft from the M.S. "Queen of Tsawwassen". That time the "Banjo" fitting had failed near the head of the nipple. Some time later a raft from the M.S. "Queen of Sidney" failed to inflate during its third annual servicing because one of the "Banjo" fittings failed near the head.

It is mentioned in the covering letters that the three vessels from which rafts failed to inflate during an annual test carry 25-man Elliot liferafts. When aboard ship the rafts are stored in fiberglass containers and it appears that adequate precautions are taken during handling to avoid the possibility of damage. It was also noted by Mr. R.D. Mills, Steamship Inspector, that heavy frosting occurred on the metal parts of the "T" piece assembly during the inflation tests.

It was requested that the fractured fittings be examined in order to determine the cause of the failures. Subsequently, eight unbroken fittings were supplied by Mr. Aspin, of which five had never been in service, whereas the other three had been in service and subjected to a number of inflation tests.

VISUAL EXAMINATION

The fittings investigated appear as shown in Figure 1. CO_2 gas passes into the fittings through four 3/32 in. diameter holes and flows out into the buoyancy chambers through the smaller end (right hand side of Figure 1), which in this report shall be called the male end. An Allen screw plugs the female thread at the other end (left hand side of Figure 1).

Examination of the five broken "Banjo" fittings revealed that two fractured under the head in the first full female thread, whereas the other three failed in the first or second male thread above the shoulder in the central chamber. Fractures were examined under a low power microscope, but they had been so badly damaged that no useful information could be obtained other than that the three nipples, which had failed in the male threads, showed a greenish and whitish deposit which may or may not have been related to the fracture.

The Allen screw in one of the unused fittings showed a relatively wide crack. Two unused and the three used nipples were Zygloed but the test failed to reveal any crack.

The fittings were covered with a coating, probably aluminium paint, which was seriously damaged on the used nipples.

MERCUROUS NITRATE TEST

Four unused specimens were submitted to the mercurous nitrate test as described in ASTM Designation: B154-51. This is an accelerated test designed to determine if copper alloy parts are susceptible to stress corrosion cracking. Two fittings did not show any crack but the others cracked under the head where failures had been recorded. This indicates that some fittings may be so highly stressed by the Allen screw that they will fail by stress corrosion cracking if the environment is conducive to this type of attack.

X-RAY DIFFRACTION ANALYSIS

The green- white deposit observed on the fracture surfaces was scraped off and analysed by the Mines Branch X-ray Diffraction Laboratory. Cu_2O was positively identified in the deposit and other lines suggested the presence of some copper carbonates.

CHEMICAL ANALYSIS

One new fitting was analysed by the Mines Branch Chemical Laboratory and results, reported in Internal Report MS-AC-64-10, are given below:

Copper, %	Lead, %	Zinc, %	Iron, %
57.75	3.12	38.80	0.16

These results show that the composition of the nipple corresponds to that of British free-cutting brass, which contains approximately 3% less copper and 3% more zinc than its ASTM equivalent.

HARDNESS MEASUREMENTS

The hardness of three nipples, one broken, one used and one unused, was measured on the Rockwell 30-T scale. Results varied from 59 to 64, indicating that the fittings are in a condition equivalent to the quarter hard or half hard temper.

METALLOGRAPHIC EXAMINATION

All used fittings, broken or not, and some new fittings were split longitudinally, polished and examined under the microscope. The specimens possess an alpha-beta microstructure that contains particles of lead and is more or less elongated along the main axis of the nipples. Observations on the extent of the damage of the various specimens are recorded below:

(a) Broken fittings

As mentioned earlier, the five broken "Banjo" fittings investigated had failed either near the head or through the male threads.

The two fittings that had failed near the head present the following features. Failures took place through the first female thread at the bottom of the Allen screw hole and cracks were also apparent at the root of the second thread. No crack was seen in the male threads. However, one specimen has very long cracks (Figure 2) extending from the central chamber towards the first or second male thread above the lower shoulder. Some of the cracks are almost equal to half the wall thickness in that area. The fractures of both specimens are similar to those described below (Figure 3).

Figure 3 was taken from the fracture surface of one of the nipples that failed through the male threads. Although the whole fractures do not present as long secondary cracks as those of Figure 3, every fracture shows one or more similar areas. Some fractures and cracks are coated with a deposit having the appearance of cuprous oxide. One of the fittings that had failed through the male threads shows evidence of dezincification on both sides of the fracture. The lower ends of only two of the fittings that failed in the male threads were available and they both show cracks extending from the central chamber as in Figure 2. In two specimens out of three, cracks were found in the bottom female threads. This damage is similar to that mentioned in the next section as presented in Figure 4.

(b) Unbroken fittings

(1) Used

Out of the three unbroken but used fittings that were examined one had the crack, shown in Figure 4, at the root of the bottom Allen screw thread. The same specimen had a crack in the fillet between the head and the cylindrical part of the fitting and a hairline and branched crack at the root of the top male thread (Figure 5). The other two specimens showed numerous cracks at the root of the bottom Allen screw threads as in Figure 6, or fairly long and branched cracks similar to that shown in Figure 5. Some narrow cracks are full of a substance having the appearance of cuprous oxide.

(2) Unused

The three new specimens examined did not show any crack in the female or male threads or in the inside chamber. However, the two fittings which had been submitted to the mercurous nitrate test, showed a hairline crack in the fillet between the head and cylindrical portion probably as a result of immersion in mercurous nitrate.

DISCUSSION

It is apparent that the problem investigated is of a complex nature and certain points should be emphasized. Broken "Banjo" fittings show evidence of extensive damage in both areas where fractures were reported, namely in the bottom Allen screw threads and in the top male threads. In other words, it appears that, although a given fitting failed in a particular location, incipient failure at the other location was apparent. All used but unbroken fittings showed cracks in both locations and the unused nipples did not have any crack in the susceptible areas.

As fractures and cracks occurred in the most highly stressed sections of the fittings and since the alloy used is highly susceptible to stress corrosion cracking, the most likely cause of failure is stress corrosion. This conclusion is supported by the branched appearance of the cracks, the presence of dezincification and corrosion products on the surface of the cracks and fractures, the use of rod stock in the cold worked condition, and the demonstration by the mercurous nitrate test that the fittings are susceptible to stress corrosion attack in stressed areas such as are caused by the Allen screw, or assembly of the fitting.

Although appreciable stresses may be applied to the fittings during assembly, the origin of the corrosive environment required to produce stress corrosion cracking is more difficult to explain. The outside surfaces are in contact with moist sea air and this in itself should be sufficient to cause stress corrosion cracking. As far as the inside cracks are concerned, however, the only sources of corrosive agents are the flexible hose, the CO_2 gas itself and the rubber stopper in the one-way valve to which the male end of the nipple is connected. Carbon dioxide is known to act as an accelerator in promoting cracking caused by other agents, and it is suggested that natural ageing of the rubber or plastic components of the hose probably generated chemical vapours which caused the internal cracking. Similar failures have been caused by organic packing materials, for example.

RECOMMENDATIONS

In view of the disastrous consequences that might result from failure of the liferafts to inflate, it is recommended that:

(1) All "Banjo" fittings now in service be removed as soon as possible;

(2) All such fittings be replaced by fittings of a different design or by fittings made of a different material such as cupro-nickel, nickel-base alloys like Monel, tin bronze or silicon bronze. Stainless steels could also be used but they may be susceptible to stress corrosion cracking in sea water under certain conditions. This also applies to red brass.

(3) New fittings should be stress-relief annealed if applicable and it is suggested that assembly of all fittings should be by torque wrench so that working stresses are minimized. (This also applies to the Allen screw, of course).

(4) It was noted that the one-way valves of the main buoyancy chambers were made of brass. It is suggested therefore that the other brass components of the liferaft be inspected for cracks. Although they appear to carry a heavy protective tin coating and are probably not as severely stressed as the nipples, they may also develop stress corrosion cracks over a number of years resulting in leakage, or perhaps eventual total failure.

CONCLUSIONS

Evidence suggests, that the fittings examined in this investigation failed by stress corrosion cracking. It is recommended that all such fittings now in service be replaced by suitable material.

AC/ls

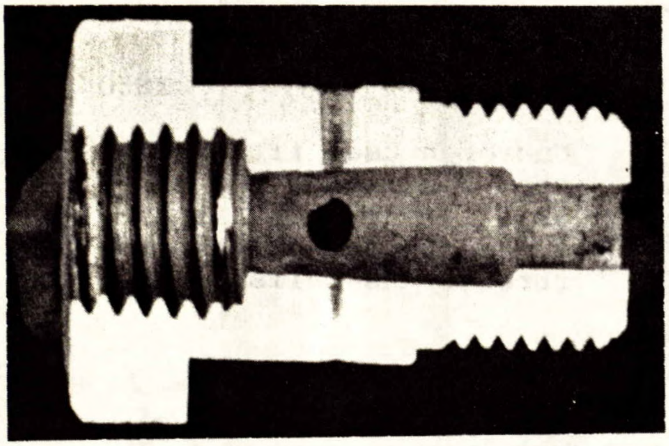

Figure 1 X3

Longitudinal section through an unused fitting, showing central chamber, female threads (Allen screw) on the left, and male threads on the right hand side of photograph. Radial holes are visible.

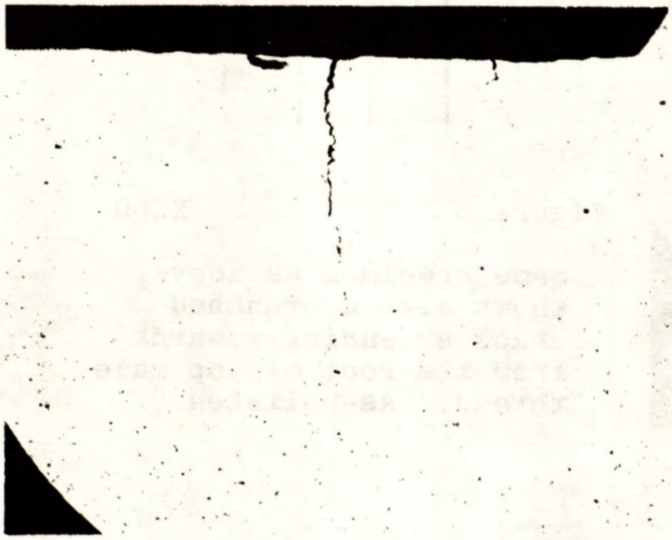

Figure 2 X40

Specimen failed through the Allen screw threads but shows extensive cracks running outwards from the inside chamber towards the male threads. As-polished.

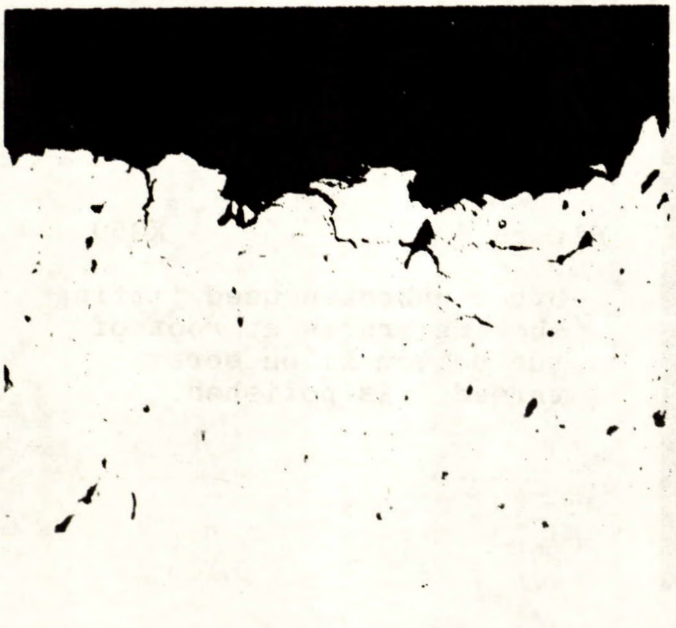

Figure 3 X250

Fracture of nipple broken through the male threads. Although the whole fracture does not present as many sub-cracks, all fractures contain similar fields as are shown here. As-polished.

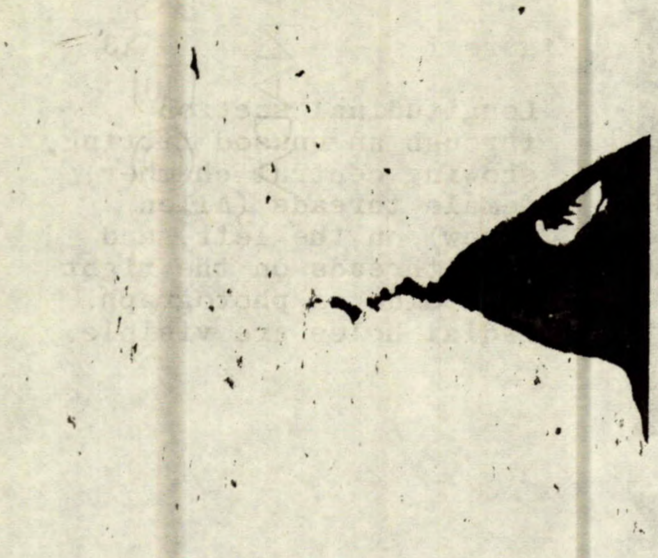

Figure 4 X250

Unbroken used fitting showed a wide crack originating at the root of the bottom Allen screw thread. As-polished.

Figure 5 X250

Same specimen as above, shows also a branched crack extending inwards from the root of top male thread. As-polished.

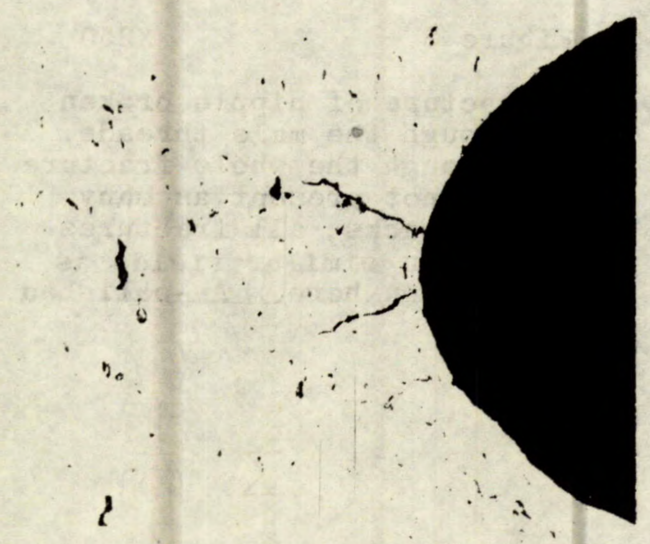

Figure 6 X250

Other unbroken used fitting showing cracks at root of the bottom Allen screw thread. As-polished.