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MINES BRANCH INVESTIGATION REPORT IR 66-23

FAILURE OF BRASS FITTINGS IN COBALT 60 IRRADIATOR

by

A. COUTURE

PHYSICAL METALLURGY DIVISION

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FAILURE OF BRASS FITTINGS IN COBALT 60 IRRADIATOR

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SUMMARY OF RESULTS

The failures studied in this investigation were apparently produced by stress-corrosion cracking.

Literature shows that nitrous oxide, nitric acid and ozone, which may be present at the surface of the fittings, do not cause stress-corrosion cracking of highly stressed brass components and that ozone inhibits it in certain conditions.

It is recommended that the actual brass fittings be replaced by suitable fittings or by soldered joints wherever feasible and practical.

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INTRODUCTION

Failed brass fittings were received on February 14, 1966, from Mr. C.E. Makepeace, Senior Metallurgist, Atomic Energy of Canada Limited, Commercial Products Division, Ottawa. In the covering letter dated January 24 (ref: DD 200-11 66-1-R69), Mr. Makepeace mentioned that the fittings were removed from the maze in the Johnson and Johnson Ethicon Cobalt 60 Irradiator, Raritan, New Jersey, U. S. A. He suggested that failures may have been due to the overstressing of the fittings during assembly and requested that a metallographic examination of the fittings be performed in order to determine the cause of the failures.

It was also learned during a telephone conversation with Mr. S.P. Daughtrey (Commercial Products Division) that the copper pipes and brass fittings contain air while the outside surfaces of the assembly are in contact with moist air containing traces of nitrogen oxides and ozone. Mr. Daughtrey has previously investigated this type of failure in a report (DD 230-121) entitled "Season Cracking of Brass Compression Fitting Nuts in Wet Storage Co60 Irradiators". That report indicated that both Weatherhead and Swagelok fittings had been used throughout the system and only the Weatherhead nuts had failed. Mr. Daughtrey's tests indicated that brass Swagelok fittings were not susceptible to stress-corrosion cracking when tightened according to manufacturer's specifications, that failure can occur when these fittings are over-tightened, and that Weatherhead fittings, tightened to support a 90 psi pressure, were susceptible to stress-corrosion cracking.

VISUAL EXAMINATION

The fittings supplied for examination are shown in Figure 1. The nut at the bottom of the photograph has five cracks of various widths from hairline to wide open, three going through the flat part of the hexagon and two through the corners. The other two nuts have one crack each through one of the corners of the hexagon. The examination at low magnification of the coupling shown at the top of the photograph did not reveal the presence of any crack.

METALLOGRAPHIC EXAMINATION

a) Nuts

The three nuts shown in Figure 1 were cut and polished at right angles to the path of the cracks and two examples of such cracks are shown in Figures 2 and 3. Cracks are, in general, branched and intercrystalline (at least where their path can be ascertained by comparison of the same field in the "as-polished" and etched conditions). Some cracks appear reasonably clean like those of Figure 2 while others contain a compound or compounds having the appearance of cuprous oxide as in Figure 3. Others are intermediate between those two extremes. The presence of oxide in the cracks would suggest that the crack walls were exposed for some time to an oxidizing medium. However, whether the cracks are lined or not with a compound, they all have the same general configuration.

The general structure of the nuts consists of lead globules and a mixture of alpha and beta phases.

b) Coupling

The coupling shown at the top of Figure 1 was split longitudinally into two halves and metallographically examined. The threads of one end of the coupling were sharply cut and the metal in their vicinity showed no evidence of deformation. On the other hand, most of the threads of the other end of the same coupling show the defect represented in Figure 4. The metal at the sides of the threads was heavily worked and, in some cases, did not adhere at all to the underlying material at the root of the thread. As can be seen in the etched condition (Figure 5), flow lines are curved inwards along both walls of the thread and some of this material had been smeared and indented into the root. It is therefore concluded that such a deformation was caused by a blunt tool upon machining, whereas, a better tool having been used to machine the threads of the other end, no evidence of tearing or deformation could be found.

As for the nuts, the general structure consists of lead globules with a mixture of alpha and beta phases.

DISCUSSION

The appearance of cracks in the hexagonal nuts studied in this investigation indicate that they are due to stress-corrosion cracking and this confirms Mr. Daughtrey's suggestions.

However, it has been suggested that the presence of oxides of nitrogen and ozone in the moist air which surrounds the assembly might have caused the failure of the stressed fittings. It must be emphasized at this point that not any corrosive environment is capable of causing stress-corrosion cracking of highly stressed brass components. C.H. Hannon in "Atmosphere Affects the Stress-Corrosion Failure of High Brass", Corrosion 13(6), 75-76 (June 1957), says that he "has no new evidence indicating that stress-corrosion of the high brasses may be brought about in atmospheres other than those containing ammonia or possibly compounds of ammonia". Furthermore, A. R. Bailey, in his comprehensive review on "The Stress-Cracking of Brass" published in Metallurgical Reviews 6, 101-142 (1961), states in reference to the cracking of alpha and alpha-beta brasses that "ammonia or ammonia compounds or related compounds such as amines are the only primary agents whose action has been substantiated by the general run of work as bringing about cracking in the laboratory". In other words, the fact that a highly stressed alpha or alpha-beta brass component is in contact with a corrosive environment does not mean that stress-corrosion cracking will necessarily follow. The problem is much more complex.

As far as the possible effects of oxides of nitrogen, nitric acid and ozone are concerned, only two references were found and they are summarized below: Hannon, in the paper already mentioned, reports that no crack developed in stressed specimens exposed for a period of 132 days to a moist nitrous-oxide atmosphere. Other tests in a combined atmosphere of nitrous oxide and ammonia showed that nitrous oxide did not reduce the cracking susceptibility in ammonia. In his literature survey, Bailey says that "copper alloys that are generally attacked by nitric acid would not be expected to be sensitive to stress-corrosion in it". And, he adds that, "brass is not known to suffer intercrystalline penetration or cracking in nitric acid".

Hannon exposed hard temper 70-30 yellow brass strips to a moisture saturated ozone atmosphere for periods of up to one year and samples were then tested in tension. No embrittlement, no change in tensile strength or elongation was found. However, there was formation of a chocolate-brown film which consisted chiefly of cuprous oxide with some cupric and zinc oxides. (It will be remembered that some of the cracks studied in this investigation contain a compound that was claimed to have the appearance of cuprous oxide and this is not uncommon in copper alloys). Furthermore, Hannon reports that highly stressed brass specimens were exposed to a combined atmosphere of ammonia and ozone for up to 240 hours without failure; following that exposure, the ozone source was shut off and the specimens failed within 24 hours. He suggests, therefore, that ozone is not only neutral but it appears to inhibit stress-corrosion cracking in the presence of ammonia.

Machining the coupling with a blunt tool would introduce unnecessary stresses in the metal and, although in the case under investigation such additional stresses were obviously not detrimental as the coupling did not crack, this might lead to stress-corrosion cracking under certain conditions; this emphasizes the possible effects of prior history on the susceptibility to stress-corrosion cracking (c.f. Weatherhead vs Swagelok). To this end, it may be noted that many of the cracks passed through the corners of the nuts where the section thickness was much greater than at the flats. This suggests that residual stresses from the manufacturing operation, as well as the assembly stresses of the joints, were a large factor contributing to failure.

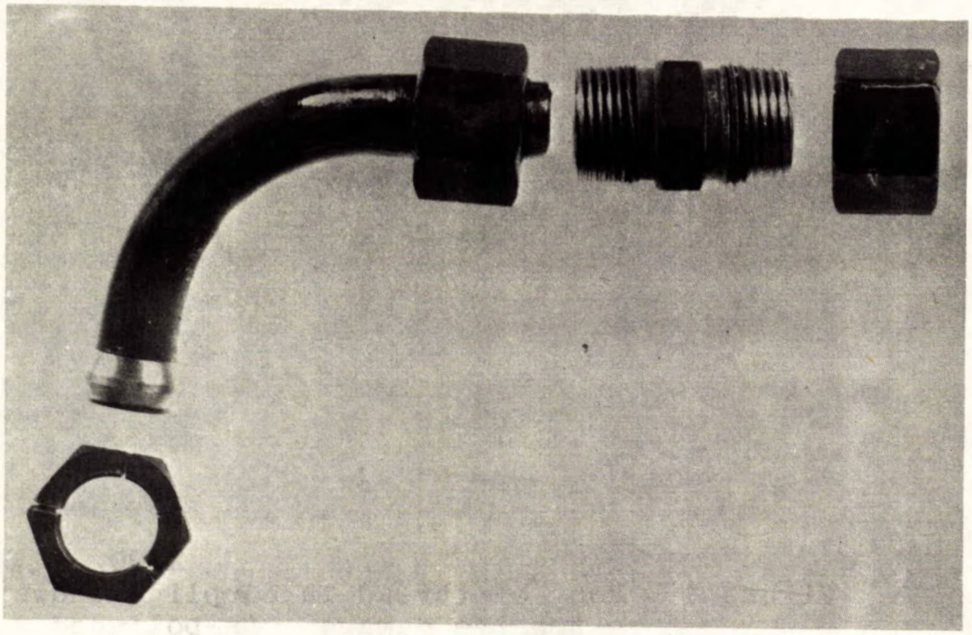
CONCLUSIONS

1) It appears that the failures studied in this investigation were produced by stress-corrosion cracking.

2) The literature indicates that nitrous oxide, nitric acid and ozone do not cause stress-corrosion cracking of highly stressed brass components and that ozone might inhibit it in certain conditions.

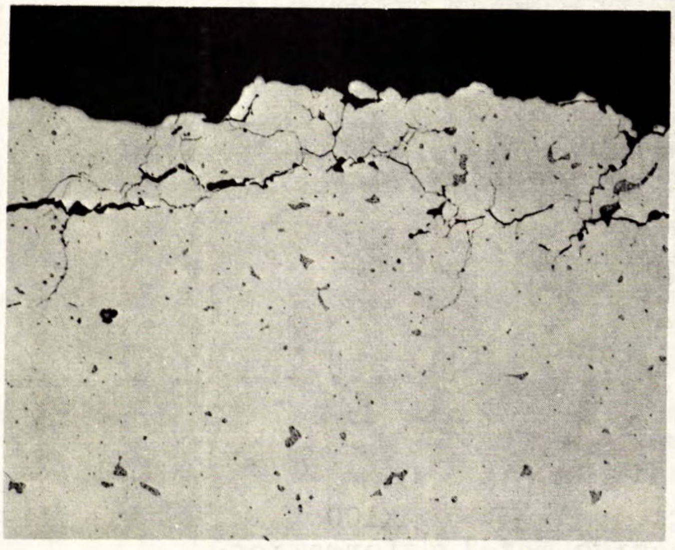
3) It is suggested, as Mr. Daughtrey already did, that the brass fittings be replaced by suitable fittings or by soldered joints wherever feasible and practical. If soldered joints are used, it is suggested that forged copper or cast bronze (leaded red brass) fittings be used since these would be much less susceptible to this type of failure than those made from free-machining yellow brass.

AC/sg



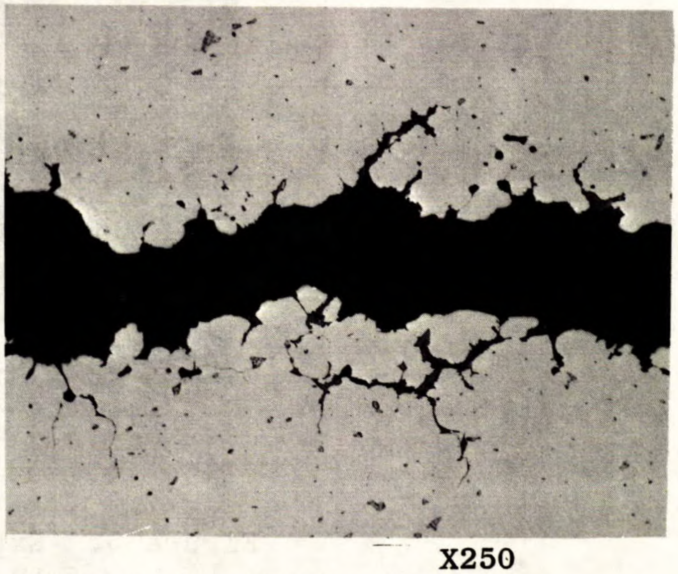
Approx. X1¼

Figure 1. Fittings sent for examination. Nut at the bottom has five cracks, other nuts have one crack each. Coupling is not cracked.



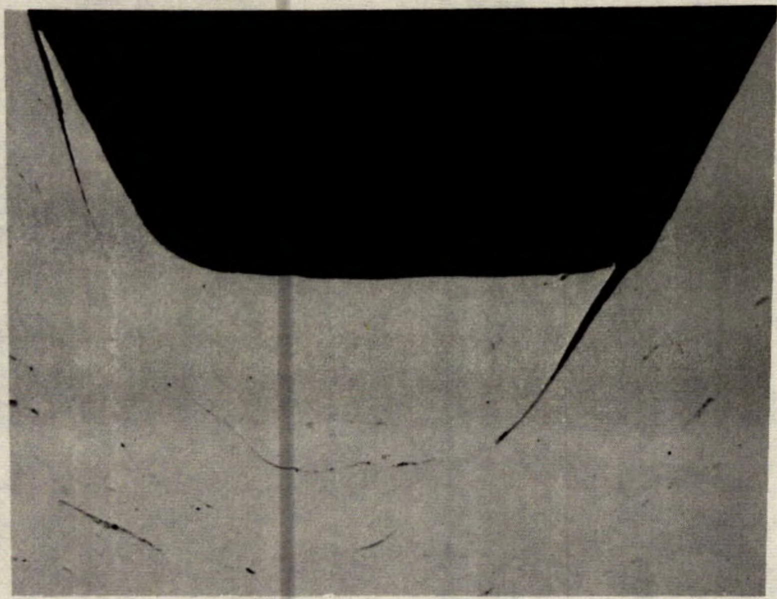
X250

Figure 2. Crack wall at top shows numerous branched cracks commonly found in failures by stress-corrosion cracking. As-polished.

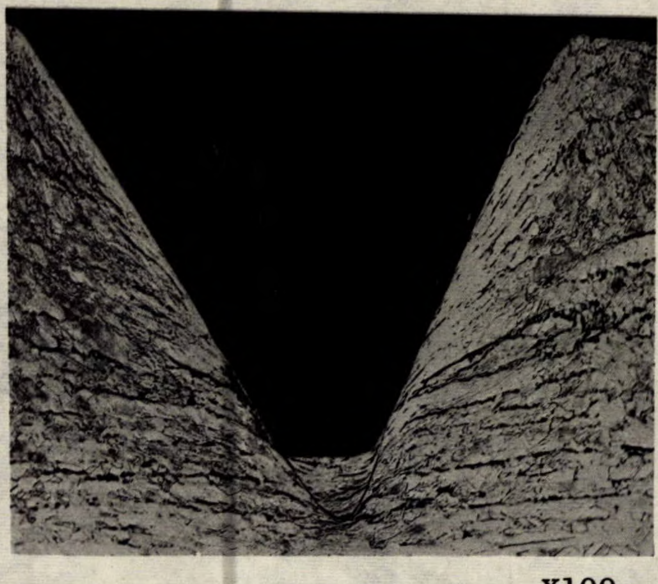


X250

Figure 3. Cracks tend to branch out from the main crack. Cracks contain a compound, which is probably cuprous oxide. As-polished.



X500
Figure 4. Root of thread in coupling shows extensive damage. As-polished.



X100
Figure 5. Extensive metal deformation in thread vicinity is probably due to blunt tool. Etched in alcoholic ferric chloride.