OTTAWA July 21st, 1941.

REPORT

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1053.

Examination of Defective Brass Outer Sleeve
from Avioflex Hose.

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 Object of Investigation:

On June 30th, 1941, Group Captain A. L. Johnson, for Chief of Air Staff, Air Service, Department of National Defence, Ottawa, Ontario, submitted for examination a section of Avioflex hose with a defective brass outer sleeve, accompanied by two letters (dated June 23rd and June 28th, 1941, respectively) from J. Hall Thomas, for Inspector-in-Charge, British Air commission, 4-202 General Motors Building, Detroit, Michigan. (File D-M6/584).

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

In the accompanying letters the following information was given with regard to the history of the sleeve:

1. Bar material in the "as rolled/drawn" condition was supplied to the machinist. Chemical composition was stated to be approximately:

Copper	-	63 per cent
Zinc	-	35 "
Lead	-	2 "

2. After machining, the part should have received a stress-relieving heat-treatment at 550° F. There is some doubt as to whether this particular part was so heat-treated.

3. The part was electrolytically cadmium plated. In the later communication, this additional information was given:

   (1) The cleaning bath is a proprietary composition containing caustic soda and tri-sodium phosphate.

   (2) After the cleaning, parts are given an acid pickle in an aqueous solution containing two parts of sulphuric acid and one part of nitric acid.

   (3) The plating bath is of patented composition, containing cadmium oxide and sodium cyanide.

4. Finally, it was swaged onto the hose by two opposed dies. There was no rotation in the swaging operation, i.e., it was a direct squeeze.

5. Cracks in the sleeve, which are believed to be in the nature of season cracks, developed after the hose was delivered to Canada.

6. Hardness tests gave the following results:

On hexagon flat	-	Rockwell F - 93.
On piece cut out of sleeve	-	Rockwell F - 99 to F - 101.

(Continued on next page)

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

It was requested that an investigation be made to establish cause of failure and to check -

(1) Chemical composition.

(2) Hardness as given.

(3) Qualitative spectrographic analysis for impurities; in particular, mercury in a sample taken from metal adjacent to the cadmium plating.

(4) Micro-examination to establish whether or not the sleeve had been heat-treated.

Chemical Analysis:

		Per cent
Copper	-	61.61
Zinc	-	34.79
Lead	-	3.26
Tin	-	0.06
Phosphorus	-	Nil.
Iron	-	"
Manganese	-	"
Nickel	-	Trace.

Hardness:

The hardness was checked by Vickers pyramid hardness tester, using a 10-kilogram load. The results were:

Hexagon flat - 116-117 V.P.N., corresponding approximately to Rockwell F - 96.

Section of sleeve - 140-142 V.P.N., corresponding approximately to Rockwell F - 100-101.

Spectrographic Analysis:

The sample was obtained by filing from hose coupling and contained cadmium coating and brass adjacent to the plating. A general qualitative analysis was made, with special attention paid to possible occurrence of mercury.

(Continued on next page)

(Spectrographic Analysis, cont'd) -

The results of the analysis were:

Essential constituents	- Cadmium, copper, zinc.
Minor constituent	- Lead.
Trace	- Tin, iron.
Weak Traces	- Silver, aluminium, mercury, magnesium (?), nickel, silicon.

Micro-Examination:

Figure 1.

X100, unetched.

Hexagonal Section.

Figure 2.

X100, etched.

Sleeve.

Figure 3.

X100, etched.

Hexagon.

(Continued on next page)

(Micro-Examination, cont'd) -

Figure 4. Figure 5.

X500, etched. X500, etched.

Hexagon. Sleeve.

Parts etched in 10 per cent aqueous solution of ammonium persulphate.

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Discussion of Results:

The chemical composition of the material shows that it conforms closely to that given for a free-cutting brass as specified by A.S.T.M., B 16-29; S.A.E. No. 72; and Department of National Defence, C-2-13 (Equipment and Development Staff Division, R.C.A.F.), which is approved as an acceptable alternative for D.N.D. Specification B-13. This analysis is essentially the same as that reported except that the lead content is higher.

The hardness of this material, as determined by the Vickers pyramid hardness tester and interpolated to the Rockwell "F" scale, corresponds closely to that reported.

(Continued on next page)

(Discussion of Results, cont'd) -

The spectrographic analysis confirms the results as obtained by chemical analysis and shows further that only very minor traces of other elements are present which might have deleterious results.

The micrographic examination of the material shows in Figure 1 the uniform dispersion of the lead, indicating that the material as received was properly made. Figures 2 and 3 show that the brass is fine-grained, which indicates that it was finally heat-treated at a low temperature. The elongated grains of Figure 2 show that the metal is in the cold-worked condition. This cold working may, of course, have occurred in the final operation. The presence of small particles of the β-phase in Figures 2 and 3 confirm the results of the chemical analysis. Figures 4 and 5 at higher magnifications confirm these statements.

The reason for the failure of the part was undoubtedly due to the spontaneous development of cracks, known as season-cracking, a common cause of failure in the various kinds of brasses. It is fairly definitely established that such cracking is due to some corrosive media on a part in which the stresses have not been completely removed. Also a contributing factor is possibly due to severe external strains set up in assembling the hose in service.

The material used in this part is one of the most readily machineable of the yellow brasses, known as leaded high brass. It is one of the standard grades made by the mills and is used especially for drawn or formed parts on which a clean thread must be cut. This property of free-cutting is obtained by the addition of lead to the copper-zinc alloy

(Discussion of Results, cont'd) -

and is gained at the expense of its drawing capacity. Furthermore, this material is very susceptible to failure, particularly in drawn or otherwise strained metal, after a lapse of time, by ruptures or fissures known as season-cracking. The susceptibility of copper-zinc alloys to cracking increases with increasing zinc content.

The probability that such season-cracking may occur can be lessened and largely overcome by a stress-relieving heat-treatment at 550° F. Such treatment does not materially soften the metal or reduce its tensile strength, but it is sufficient to remove the internal stresses which severe cold-working has produced. In brass intended for severe cold-working, the lead should be kept as low as possible because of its tendency to promote "fire-cracks" (to crack during rapid heating after cold-working). The heat-treatment as developed for any particular part should be conscientiously carried out as soon as conveniently possible. Season-cracking is known to have occurred where traces of the cutting lubricant have remained in contact with the metal for some time before the heat-treatment.

The tendency of such material to develop season-cracking or to ensure that tensile stresses have been properly relieved may be determined by the mercurous nitrate test as given by the A.S.T.M. B 21-29, Section 7, or A.S.T.M. B 21-40T, Section 7. This test follows: A 6-inch length of the test specimen, but in no case less than two times its diameter, shall stand, without cracking, on immersion for 15 minutes in an aqueous mecurous nitrate solution containing 100 g. of mercurous nitrate and 13 ml. of nitric acid (sp. gr. 1.42) per litre of solution.

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(Discussion of Results, cont'd) -

This procedure enables one to determine if the tensile stresses in the sample are of high magnitude. If such stresses are high, the article may crack. The mercurous nitrate test is designed to determine whether the internal stresses have been properly broken up and rendered safe. When stresses are not properly removed during manufacturing operations, it may season-crack when exposed to the atmosphere or certain types of corrosion. The conditions of the test have to be determined by those in charge of the work who are conversant with the service requirements. One factor of considerable importance in connection with the test is the character of the surface of the specimen. Cases are on record where the simple polishing of the surface gave results many times better than similar specimens with the surface in the original condition. This test is considered to be a qualitative test only, that is, it will show whether the material has had the proper stress-relieving treatment, but cannot be used for predicting the life or the behaviour of material under service conditions. It was not possible to determine whether or not this part had been so tested.

The material in this part was protected by being electrolytically cadmium plated. The possibility of the failure being initiated by caustic embrittlement caused by the alkaline cleansing has been considered but is not believed to have been the cause of the trouble. From a manufacturing viewpoint, there are other more efficient detergents which are now being used in preference to caustic soda and tri-sodium phosphate. There is a possibility of traces of acid remaining

(Discussion of Results, cont'd) -

after the pickling operation previous to electro-plating as a source of failure. The composition of the plating bath as given is typical for deposition of cadmium coatings. Any area of a part not effectively covered by a protective coating exposed to atmospheric conditions where unusually high proportions of ammonia, salt, ozone or acid fumes are found could be a factor in causing failure.

The final manufacturing operation, consisting of swaging onto the hose by a direct squeeze, is admittedly a severe case of cold-working. It may also cause breaking of the cadmium plating. This condition is further aggravated by the rigidity of the hose, which is a semi-flexible metal hose, covered first by rubber, then by a flexible woven wire sheathing and finally on the exterior by rubber. Obviously, it is impossible to give the part any stress-relieving treatments. Presuming that the original material was properly made, and that the various manufacturing operations and processes were performed exactly according to specified procedures, which appear to have been followed in this particular case, undoubtedly the final operation in itself stresses the part to make it liable to season-cracking under certain types of corrosion.

There is also a possibility of an additional contributing cause for failure due to external strains set up in assembling the hose in service, which are not affected, of course, by prior heat-treatments. Cases are on record where fully annealed pipe has stress-corrosion cracked in service on account of circumferential and tangential stresses set up by faulty assembling. Workmen who have been accustomed to assembling couplings and pipe made from wrought iron or steel

(Discussion of Results, cont'd) -

naturally will use excessive pressure on brass unless properly instructed.

Conclusions:

In view of the severe cold-working this hose coupling has to withstand without the possibility of a final stress-relieving heat-treatment being given, consideration should be given to using another type of brass which will withstand such conditions. Brasses high in copper and low in zinc are much less liable to season-cracking or corrosion under conditions of atmospheric exposure than those which contain a higher percentage of zinc. This probable prevention of season-cracking would have to be obtained at the expense of the machineability of the material in the part.

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