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EXAMINATION OF BRASS PIPING FROM CANADIAN OXYGEN CO. LTD., VICTORIA ISLAND, OTTAWA, ONTARIO

by

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PHYSICAL METALLURGY DIVISION

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SUMMARY OF RESULTS

Samples of brass pipe from an explosion and fire were examined to determine if a break in these lines had been responsible for the accident.

The investigation indicated that the various abnormalities observed in the pipe had been caused by fire damage, and that the pipe had probably been in good condition at the time of the fire.

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INTRODUCTION

On November 23, 1962, members of the staff of the Physical Metallurgy Division were requested to view the site of a fatal explosion and fire at an acetylene filling plant. It was believed that the accident had been caused by a fracture in the filling lines, and it was requested that the lines be examined to determine, if possible, the point of original failure. Most of the piping was of ferrous material, but some lengths of brass pipe had been in service, and it is the examination of these that is covered in this report.

VISUAL EXAMINATION

Much of the brass pipe had been badly damaged by the fire. Sections were missing, and many of the remaining pieces had fused ends, and evidence of incipient melting on the sides. Several pieces showed brittle fractures, and there was a pink colouration on the outside of some lines, giving them the appearance of copper rather than brass tube. Light scraping showed that this colouration was a very thin deposit, probably cuprous oxide, but it may have been copper formed by oxidation and subsequent reduction during the fire.

SAMPLES

Sections were taken from the pipe as follows, for more detailed examination.

Exhibit E - Feeder line to bank No. 1.

Section A: This section showed a brittle fracture at one end, incipient melting over the surface, and partial melting at the other end.

Section B: This section showed a brittle fracture at one end with some evidence of partial melting at this end. The other end terminated in a threaded fitting and there was partial melting of the brass packing nut on a valve in this section.

Exhibit F - Feeder line to bank No. 6.

Section showed melting at both ends probably induced by lower melting point brazing alloy used to form T junctions between the pipe examined, and the smaller diameter pipe leading to the individual cylinders. Little indication of melting on the surface of the pipe was seen.

EXAMINATION OF FRACTURES

The "brittle" fractures in Exhibit E were examined under a low power microscope. Both showed the same general structure of individual crystal facets covering the whole surface of the fracture, with some additional evidence of partial melting in the form of discrete globules of metal. In view of the similarity of these two samples and the fact that they probably came from the same length of pipe, further examination of Exhibit E was concentrated on Section A.

CHEMICAL ANALYSIS

The composition of the pipes, was determined by the Analytical Chemistry Subdivision of the Mineral Sciences Division[1] and their analysis is reported below, together with the approximate melting point of the material.

TABLE 1

Chemical Analysis

	Approximate Melting Point	Copper, %	Zinc, %	Lead, %	Nickel, %
Exhibit E	925°C (1695°F)	67.32	32*	0.61	-
Exhibit F	1025°C (1870°F)	84.66	15.22	none detected	0.16

*by difference

These analyses correspond to ASTM Specification B135-60 Alloy 3 and Alloy 1 respectively.

METALLOGRAPHIC EXAMINATION

Sections were cut through the fractured end of Exhibit E. The grain size was reasonably fine (0.09 mm) and lead particles were shown to be concentrated at grain boundaries, indicative of heating to temperatures very close to the melting point of the alloy. Some grain boundary penetration was noted at both inside

(1) Mineral Sciences Division, Internal Report MS-AC-1409, E. MacEachern.

and outside surfaces. This may be due to corrosion, but is more likely to be caused by surface oxidation during the fire, and in no case does this extend to a depth greater than one grain. Marked pitting is seen on the outside surface, and some beta phase is also seen in this area. Both these phenomena are thought to be due to local melting caused by surface migration of the lower melting point brazing alloy used to make the T junctions joining the small pipes to the larger pipe under examination. The fracture showed no distinguishing features, its intercrystalline nature presumably being due to the grain boundary distribution of the lead particles.

Exhibit F showed a much coarser grain size, (0.35 mm) and again there was some slight grain boundary penetration at the surface. There were a number of dot-like inclusions distributed through the structure, and on the outside surface a second phase was apparent in some grain boundaries. This presumably came from the brazing alloy and, as it had the general appearance of a nickel - tin compound, it is thought to be responsible for the 0.16% nickel reported in the analysis of this pipe.

DISCUSSION

In the letter from the Ontario Fire Marshall, a number of specific question were asked, and it appears most convenient to deal with these and the discussion at the same time.

(a) nature of the metals, composition and melting points.

Both pieces of pipe examined are brass, the composition and melting point being given in Table 1.

(b) any evidence of corrosion erosion, etc, occurring prior to the fire.

The pipes showed no evidence of severe corrosion which may have led to catastrophic failure. Various phenomena were observed which might have been due to corrosion but it was thought more likely that these were caused by the fire. (cf., pitting on the outer surface of Exhibit E, and minor grain boundary penetration).

(c) any evidence that ageing or other factors had appreciably affected the strength of the pipe prior to the fire.

No conclusions can be reached on this point, other than effects such as fatigue or stress corrosion cracks were not present. The question was raised as to whether the working pressure of the pipe (300 psi) was excessive. From the formula

$$P = \frac{2\,t\,S}{D}$$ where P = pressure psi
t = thickness of pipe wall
D = outside diam of pipe in inches
and S = allowable stress in material (about 7000 psi for brass)

it is calculated that at 300 psi, the stress S in the wall of the pipe is $\frac{300 \times .825}{2 \times .125} = 1000$ psi. It will be seen that at this low stress, the pipe should be in little danger of failure due to pressure overloads.

(d) any evidence to indicate that the breaks in the pipe had occurred prior to the fire.

The "brittle" fractures in the pipe examined were consistent with failure due to overheating.

(e) any evidence to indicate that the explosive chemical compound known as copper acetylide had formed prior to the fire.

There are notations in the literature warning against the use of some copper alloys with acetylene, such as the one extracted below from "Metals Handbook, Properties and Selection of Metals," 8th Edition, American Society for Metals 1961, page 981, Table 8. - "Acetylene forms an explosive compound with copper when moist, or when certain impurities are present and the gas is under pressure. Alloys containing less than 65% copper are satisfactory under this use. When the gas is not under pressure, other copper alloys are satisfactory." However, from Butts - "Copper, the Metal Its Alloys and Compounds". American Chemical Society Monograph Series, published by Reinhold Publishing Corp., New York, 1954, pp. 839-841, it appears unlikely that explosive copper acetylide would form in the pipes under the conditions of service. It is suggested that moisture is essential to the reaction, which might also be promoted by the presence of ammonia and/or sulphur compounds. In the present case, the acetylene gas is carefully dried, and passed through a reaction tower to strip out sulphur compounds. Any ammonia would probably be absorbed by the tower also. The fact that the insides of the tubes examined show no serious deterioration due to corrosion suggests that the above measures were effective in removing the contaminants, and that copper acetylide would therefore not form.

CONCLUSION

While it cannot be categorically stated that the brass pipe did not fail, all the evidence suggests that this was not the case, and that the pipe was in sound condition at the time of the explosion and fire.

JOE/ls