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MINES BRANCH INVESTIGATION REPORT IR 63-68

FAILURE OF A WINDOW CLEANER'S ANCHOR BOLT

by

A. COUTURE

PHYSICAL METALLURGY DIVISION

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Mines Branch Investigation Report IR 63-68

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SUMMARY OF RESULTS

This investigation shows that the broken window cleaner's anchor bolt, which was removed from the Federal Building in Halifax, N.S., was a faulty casting probably damaged prior to its final failure. The two specimens studied are in the "as-cast" condition and contain a highly brittle compound. It is recommended that all the anchor bolts now on the building be replaced by adequate equipment.

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INTRODUCTION

Mr. B.F. Cummings, Acting Chief, Testing Laboratories, Development Engineering Branch, Department of Public Works, requested the assistance of this Division on April 17, 1963, in determining the cause of the failure of a window cleaner's anchor bolt removed from the Federal Building in Halifax, N.S. The original request was made in a letter of April 9, 1963 (File number: 310-34-5), sent by Mr. D.A. Freeze, Director of Directorate of Property and Building Management of the same Department to Mr. N.E. Laycroft, Chief, Testing Laboratories Division, Development Engineering Branch, Department of Public Works. The head of the broken anchor bolt, together with a full bolt, were forwarded to this Division for examination. It was later learned from Mr. E.R. Goffin of the Department of Public Works, that the building from which the anchor bolts were removed, was erected in 1935 and that the failure occurred during the summer of 1961.

MACROEXAMINATION

The outside surface of both specimens was in general, covered with patina, which is a film of corrosion products.

The fracture surface of the broken anchor bolt appeared as shown in Figure 1. Approximately one-third of the surface was covered with a black deposit that adhered to the underlying metal even after prolonged ultrasonic cleaning. The numerous corrugations, which can be seen, are obviously exposed solidification dendrite ends.

The broken bolt was longitudinally split in two halves. One of the halves (Figure 2) had a long shrinkage pipe running from the top of the bolt to the fracture. The wall of the pipe consisted of dendrite ends and the defect resulted from lack of feeding due to improper casting techniques.

The other half of the broken bolt and a similar section through the unbroken bolt were polished and photographed under low magnification (Figures 3 and 4). Figure 3 shows that the section through the broken anchor bolt contained a large amount of macroporosity that seemed to be interconnected especially near the fracture, thus weakening the critical section appreciably. The full bolt, on the other hand, is sounder and the critical section shows no porosity at all. The defect seen on the right hand side of Figure 4 is probably due to an oxide inclusion.

CHEMICAL ANALYSIS

The Mines Branch Analytical Chemistry Laboratory analysed drillings from the full bolt and pieces from the broken bolt and reported the results presented below in Internal Reports MS-AC-63-422, 63-512 and 63-554. The last column gives the corresponding ASTM Specification for leaded yellow brass sand castings.

	Broken Bolt	Full Bolt	ASTM B146-52 Alloy 6C
Copper, %	65.51	64.12	60-65
Zinc, %	31.73	33.88	rem.
Tin, %	1.32	1.08	0.5-1.5
Lead, %	0.83	0.58	0.75-1.5
Iron, %	-	0.02	0.75 max
Manganese, %	-	0.02	
Aluminum, %	-	<0.005	0.5 max
Silicon, %	-	0.006	
Nickel, %	-	none detected	

The amount of material available from the broken bolt was insufficient to determine the minor elements.

It will be seen from the above that the material corresponds to ASTM Specification B146-52 Alloy 6C, which has specified minimum properties of 40,000 psi UTS, 14,000 psi 0.5% YS and 15% El.

MICROSCOPIC EXAMINATION

Some areas along the shorter side of the fractured anchor bolt contain pores that are coated with oxide (Figure 5), in some cases as far as 0.05 in. from the surface. This proves that those pores were in contact with the atmosphere before sectioning and that they were, therefore, interconnected.

The part of the fracture, which corresponds to the dark area of Figure 1, is coated with a layer of oxide showed in Figure 6. Although the layer of oxide is loosely adherent to the underlying metal in many places, it is, however, continuous and indicates that a large portion of the fracture surface had been exposed to the atmosphere for an appreciable time. The middle part of the fracture surface (Figures 3 and 7) consists of highly porous material which would offer little resistance to crack propagation. The remaining part of the fracture, left hand side of Figure 3, was reasonably sound.

The microstructure of both specimens contained at least five phases: an alpha solid solution, beta, a blue constituent, which is probably tin-rich and which shall be called "delta" because of its resemblance with the delta constituent of tin bronzes, globules of lead and particles of oxide. Figures 8 and 9 are representative of the microstructures of the specimens. As can be seen, although they both have the same constituents, the relative amounts of each vary from one specimen to the other. A large amount of "delta" phase was present in the broken bolt (Figure 8) and formed a continuous network around the grains of alpha. Some beta was apparent inside of pools of delta. In the full bolt, on the other hand, there were large pools of beta separated from the alpha matrix by a thin layer of "delta" (Figure 9). There were also more oxide particles in the broken bolt than in the full one.

Both specimens showed evidence of dezincification corrosion on their outside surface but the full bolt was much more generally dezincified than the broken one. In both cases, the maximum penetration in the sections examined was of the order of 0.002 in. A typical dezincified area from the full bolt is shown in Figure 10. It appears that dezincification started in the beta and "delta" phases and then invaded the whole structure.

DISCUSSION AND CONCLUSIONS

It is apparent from the examination that the broken bolt was an unsound casting with an unsatisfactory metallurgical structure, despite the fact that the chemical composition corresponds to ASTM B146-52 Alloy 6C. Some minor surface corrosion in the form of dezincification had occurred and the bolt had apparently been cracked for some time before final failure. The unbroken bolt showed the same general characteristics although it was a sounder casting, and the amount and distribution of the brittle "delta" phase was not so detrimental.

It would appear, therefore, that it only remains to suggest improved casting techniques to eliminate unsoundness and modification of alloy composition to eliminate the brittle "delta" phase. However, the following is abstracted from CSA Standard Z91-1959 "Code of Practice for Window Cleaning".

5.6.5 "Anchors ..... shall be made of stainless steel, monel metal, or other durable corrosion resistant metals or alloys of equal strength and toughness. Bronze is not recommended for this purpose" (Figure 2, however, illustrates bronze anchors).

7.2 "All metal from which fittings such as ... anchors, bolts, ... etc., are made shall have an ultimate tensile strength of not less than 50,000 psi and an elongation of not less than 15%.

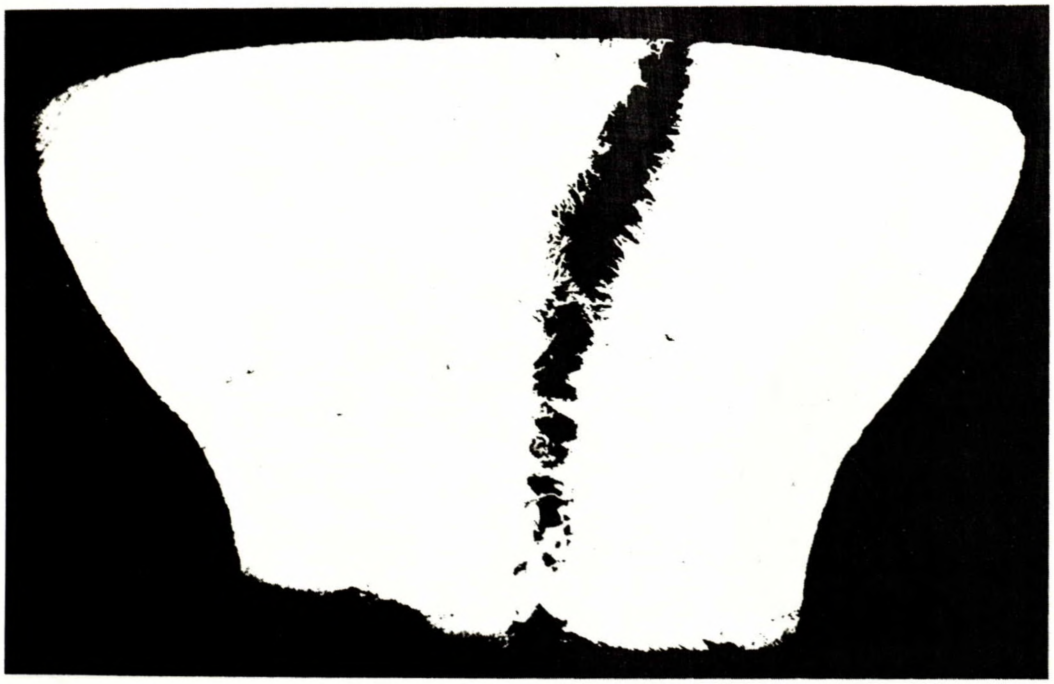
<u>Note:</u> The use of cast devices is prohibited, and they must be condemned where in use".

On these counts, therefore, the anchors should be condemned in that the yellow brass used is certainly no more corrosion resistant than bronze, it does not have an ultimate strength of 50,000 psi, and the anchors are castings.

While it could be argued technically that correctly made anchors of the type examined would give satisfactory service, it must be remembered that this is a safety device where absolute reliability is required. It is recommended therefore that all the anchor bolts be replaced by adequate equipment.

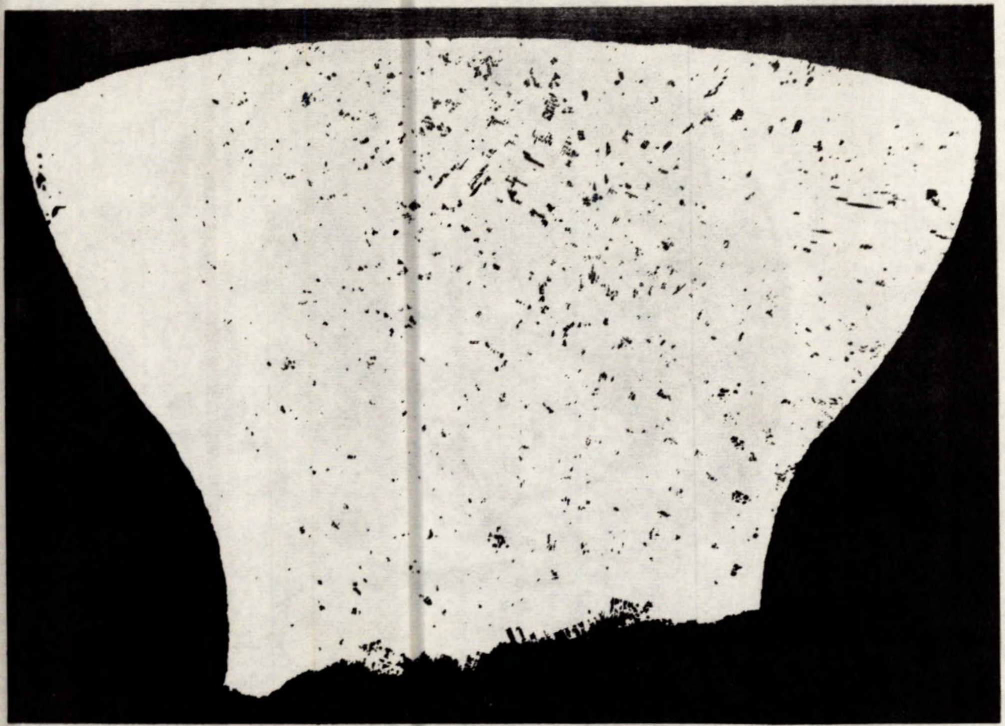
X $4\frac{1}{2}$

Figure 1. Fracture showing oxidized area (right), presumably the site of an old crack, and dendrites.



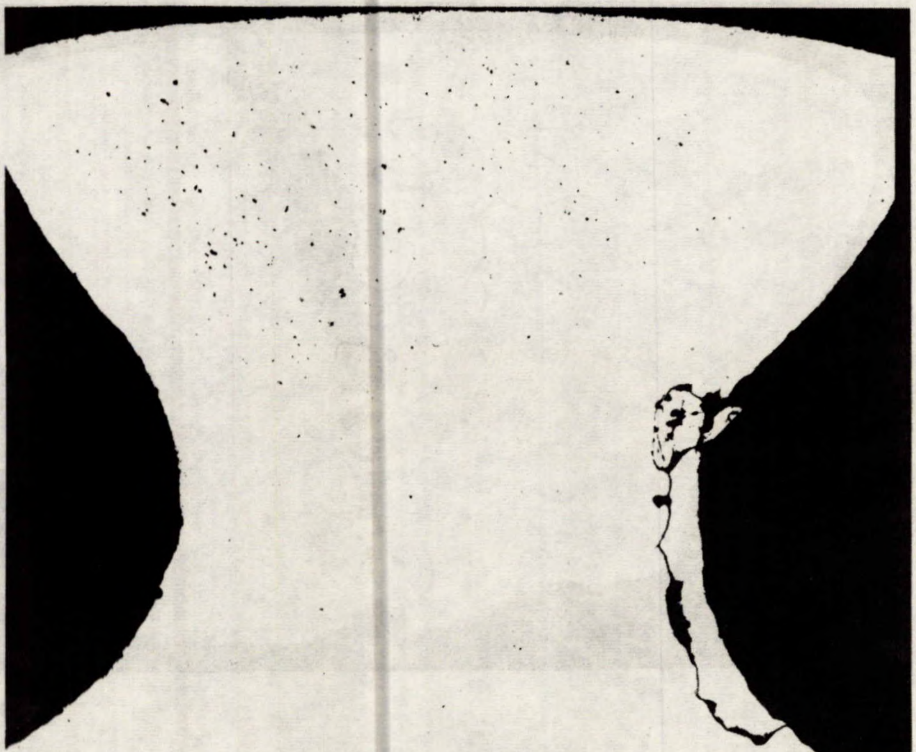
X6

Figure 2. Section through middle of broken anchor bolt showing shrinkage pipe caused by improper feeding.



X6

Figure 3. Other half of bolt from Figure 2 after polishing shows very severe general porosity.



X6

Figure 4. Section through full bolt after polishing shows much less porosity than Figure 3. Oxide inclusion (right).

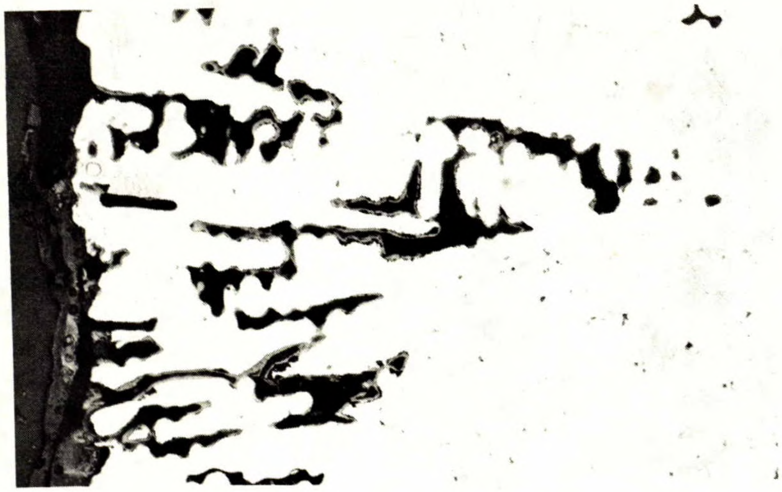


Figure 5 X100
Broken anchor bolt. The presence of an oxide coating on cavities walls indicates that cavities are open to the surface (left). As-polished.

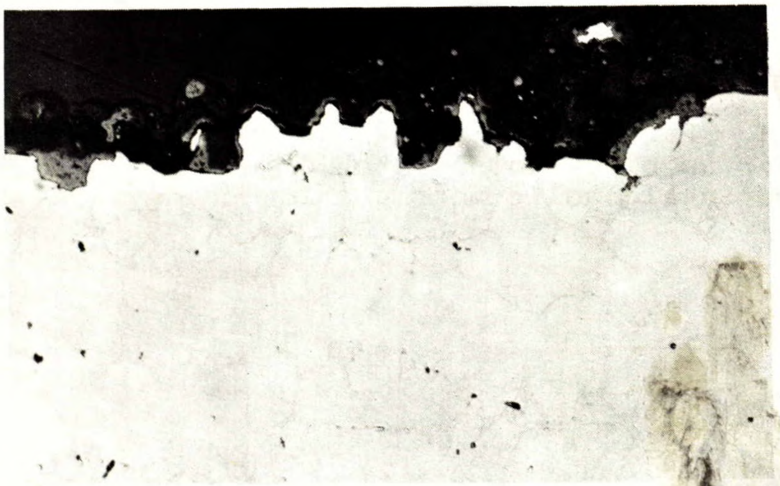


Figure 6 X150
Section through the fracture of the broken anchor bolt. The presence of an oxide layer on part of the fracture indicates that a crack had taken place sometime before the final failure. As-polished.

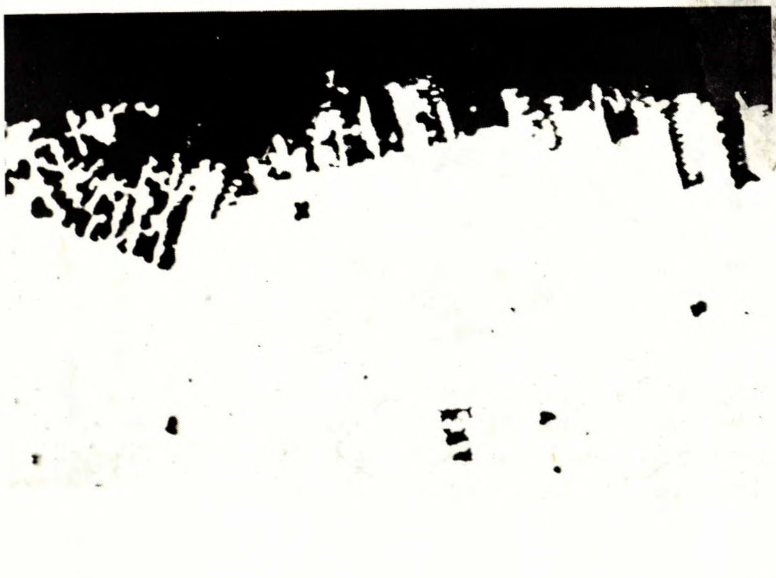
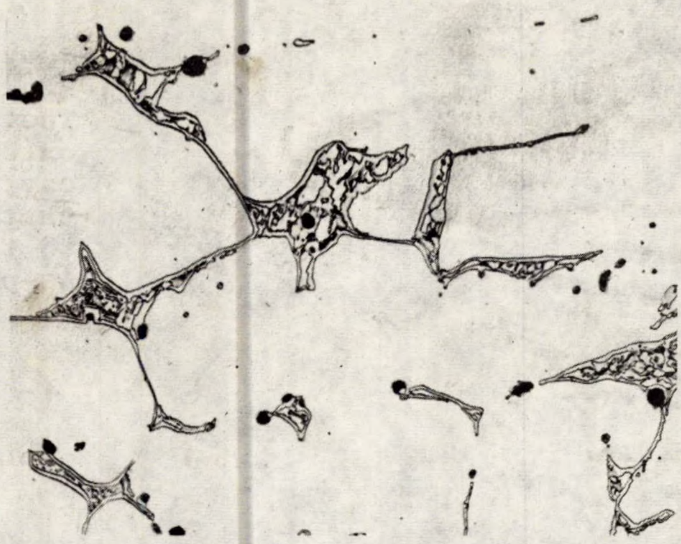
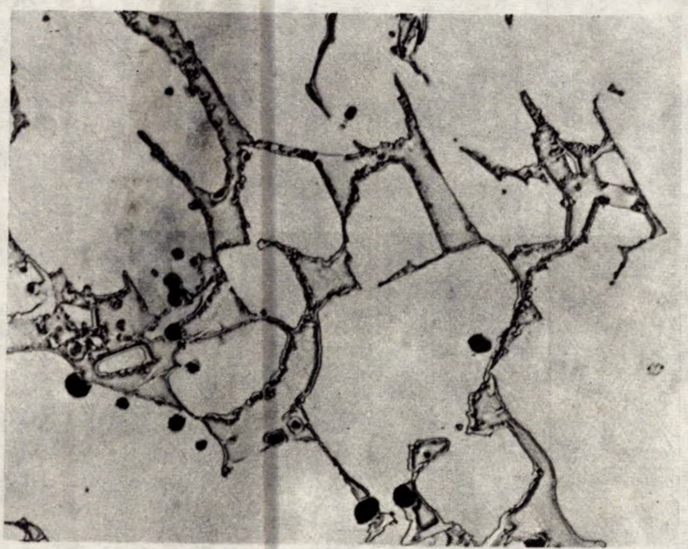


Figure 7 X33
Section through the fracture of the broken anchor bolt (Figure 3). Fracture progressed through a highly porous area. As-polished.



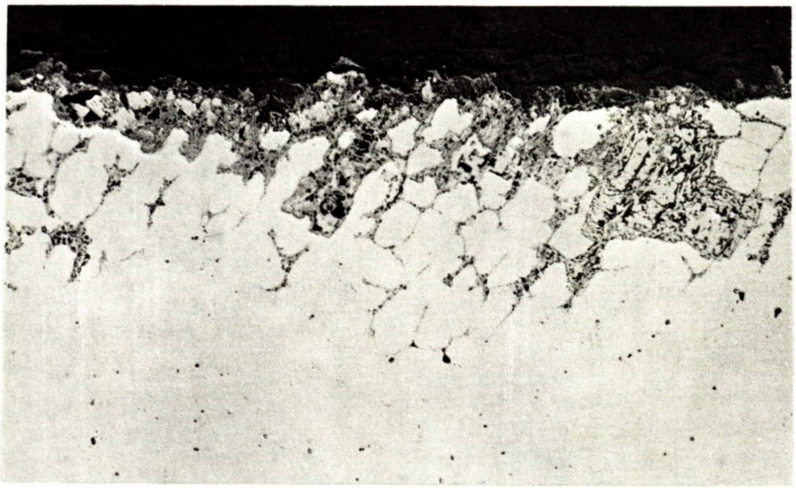
X500

Figure 8. Broken anchor bolt. Alpha phase with "delta" and some beta in delta areas. Particles of lead and oxides appear as black dots. Etched for 2 sec in alcoholic ferric chloride.



X500

Figure 9. Full anchor bolt. Same phases as in Figure 8, but beta is more abundant and there is less "delta". Etched for 2 sec in alcoholic ferric chloride.



X100

Figure 10. Typical section at the edge of the full anchor bolt showing dezincification. The dark areas consist of redeposited copper. The beta and "delta" phases are attacked in the first stage and, later on, the attack becomes general. As-polished.