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OTTAWA   August 2nd, 1943.

REPORT

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1462.

Welded Packard Merlin Engine Exhaust Stubs
for Mosquito Aircraft.

(Copy No. 11.)

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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Welded Packard Merlin Engine Exhaust Stubs for Mosquito Aircraft.

Origin of Material:

On July 20th, 1943, F/O N. S. Spence, on behalf of the Department of National Defence, Air Service, Ottawa, Ontario, submitted three sets of exhaust stubs for examination. For identification, the sets are numbered one to three inclusive.

Set No. 1, representative of stubs that have been in service and were withdrawn because of welding defects, consisted of two dual outlet stubs. Although neither of these stubs had actually failed, this set is stated to be typical of

(Origin of Material, cont'd) -

stubs which had failed in service.

Set No. 2, consisting of one single and one dual stub, is representative of those which are similar to Set No. 1 but have been re-welded in an attempt to salvage defective stubs.

Set No. 3, consisting of one single stub, was welded with an improved welding technique designed to eliminate the defects of Set No. 1.

W/C A. J. Smith, in a covering letter (dated July 20th, 1943, File No. 935DD-5-5 (AMAE DAI)), gives the following information:

> The stubs are made from inconel and are gas welded with 1/16 in.-diam. inconel gas welding rod and inconel gas welding flux. The parts are not rigidly jigged during welding and the assembly is "normalized" at 650° C. for 20 minutes, when finished.

Object of Investigation:

To determine the nature and extent of the welding defects and submit recommendations for improvement of welding technique.

Procedure:

(1) All three sets were visually examined for surface defects.

(2) Both types of stubs were photographed. Figure 1 shows the general shape of the stubs. Figures 2 and 3 are close-up photographs of welds on the stubs.

(3) All three sets of stubs were subjected to an X-ray examination. Figures 4 to 8 are prints of exographs of some of the welds of Set No. 1. Figure 9 to 13 are prints of exographs of some of the welds of Set No. 2. Figures 14 and 15 are prints of the exographs of the two long welds of Set No. 3.

It should be borne in mind that these reproductions show the reverse of the colours of the exographs and that there is an inevitable loss of sensitivity in the reproduction process.

(Continued on next page)

(Procedure cont'd) -

(4) Set No. 2 was sectioned in various areas to show the nature of the defects revealed by the X-ray examinations. Figures 16 to 23 are photographs of the various defects found.

Discussion:

A visual examination of the exhaust stubs revealed that the weld metal on the inside varied from a thin, sharp film to a broad puddle. In some inside areas the weld metal has not penetrated through the joint, leaving the edges of the sheets exposed. It was also evident that the sheet edge to be welded were not always correctly aligned. Numerous areas showed considerable differences in levels adjacent sheet edges. If the sections are stamped out of large sheet, this may be due to insufficient allowance for the spring-back of material. Both of these conditions result in unequal distribution of service stresses.

Both photographs and exographs show very irregular thickness of welds. Set No. 2 has been re-welded, this set shows the maximum variation in this respect. The high, piled up weld resulting from re-welding merely acts as a stress-raiser and only increases the probabilty of failure in service. Welding over a defect only masks the defect and does not correct it.

The x-ray examination reveals numerous and frequent defects, as is shown by the prints of the exographs. Photographs of typical defects clearly indicate their serious nature.

The following defects were found: Mechanical gouges, lack of fusion, lack of penetration, cracks, gas inclusions, severe reduction of plate thickness at weld edges, and notches at the junction of the weld and sheet material. All of these defects are primary focal points for failure when the part is subjected to the vibrational stresses and high temperatures of service.

Lack of fusion is probably due to incomplete removal

(Discussion, cont'd) -

of the tightly clinging oxide from the surfaces to be welded, or to insufficient heat input. Lack of penetration of the weld metal to the bottom of the joint is due either to insufficient heat input, which reduces the fluidity of the weld metal, or to too high a welding speed. Gas inclusions are probably due to "puddling" the molten metals, resulting in the burning out of the deoxidizing elements, which are important in this type of material, and producing brittle and gassy welds. Cracks probably originate in areas of lack of fusion or penetration, these areas being too weak to withstand the contraction stresses of the cooling weld metal. The severe reduction of plate thickness adjacent to welds is the result of "sucking in" too much plate metal into the weld. Mechanical gouges are the result of careless handling of material either before or after welding.

Set Nos. 1 and 2 show the same number, type and frequency of defects. It is apparent, then, that stubs of which these are representative, are unsuitable for service. If salvage of any stubs similar to these is to be attempted it should be accomplished by a 100 per cent X-ray examination. Set No. 3, while showing some defects, indicates a considerable improvement over the other two sets and this improvement may be attributed to welding from both sides of the joints and to better alignment of sections. It is our opinion that Set No. 3 is a borderline case and stubs showing more defects should be rejected.

CONCLUSIONS:

1. As evidenced by the nature and the frequency of the defects found, the welding technique employed is open to strong criticism.

2. The following defects were found: Mechanical gouges, lack of fusion, lack of penetration, cracks, gas inclusions, severe reduction of plate thickness at weld edges, and notches at the junction of weld and sheet material. All of these defects

(Conclusion cont'd) -

are primary focal points for failure when subjected to the vibrational stresses and high temperatures of service.

3. Misalignment of welded plate edges indicates that the jigging is insufficiently rigid. A visual examination of the stubs reveals that the weld metal on the inside may vary from a thin, sharp film to a broad puddle. If the sections are s tamped out of large sheets, this may be due to insufficient allowance for spring-back.

4. The welds are very irregular in thickness, and this prevents uniform distribution of service stresses. Re-welding defective areas results in a high, piled-up weld which acts as a stress-raiser and does not remedy the defects that it masks.

5. Lack of fusion is probably due to incomplete removal of the oxide from the surfaces to be welded, or to insufficient heat input.

6. Lack of penetration is due to insufficient heat input or to too high a welding speed.

7. Gas inclusions are due to "puddling" the molten metal, which burns out the deoxidizing elements and results in brittle and gassy welds.

8. Cracks are due to contraction stresses of cooling weld metal, and originate in weak areas such as those showing lack of fusion or penetration.

9. Severe reduction of plate thickness adjacent to welds is due to the "suching in" of too much metal into the weld.

10. Mechanical gouges are the result of careless handling of the material either before or after welding.

11. All stubs of which Set No. 1 is typical are unsuitable for service.

12. Attempted salvage by re-welding is not permissible.

13. The exographs of Set No. 3 show a considerable improvement over Set Nos. 1 and 2. This improvement is due

(Conclusion cont'd) -

partly to welding both sides of the joints and partly to better alignment. However, some gas inclusions are evident and it is our opinion that these constitute a borderline condition. As a standard, Set No. 3 would be representative of the absolute mimimum of acceptability.

RECOMMENDATIONS:

1. The stubs should be rigidly jigged for welding, to prevent misalignment of sections and to reduce warpage.

2. A root gap of 1/16 in. should be used to permit complete penetration of the weld metal, using a back-up bar if necessary.

3. Sheet edges to be welded should be meticulously cleaned by mechanical means, to remove the tightly clinging oxide. This would eliminate the main cause of lack of fusion.

4. To prevent gas inclusions, puddling of the molten pool should be forbidden.

5. If salvage of stubs typified by Set No. 1 is to be attempted, it should be accomplished by a 100 per cent x-ray examination. Mr. A. Morrison, of the National Research Council, Ottawa, can advise as to the x-ray technique and the firms in the Toronto area possessing suitable x-ray equipment.

6. Every welder should be required to identify his work, and random checks on the welding technique should be made at intervals by means of an x-ray examination. These precautions would deter the individual welder from employing techniques shown to be unsuitable.

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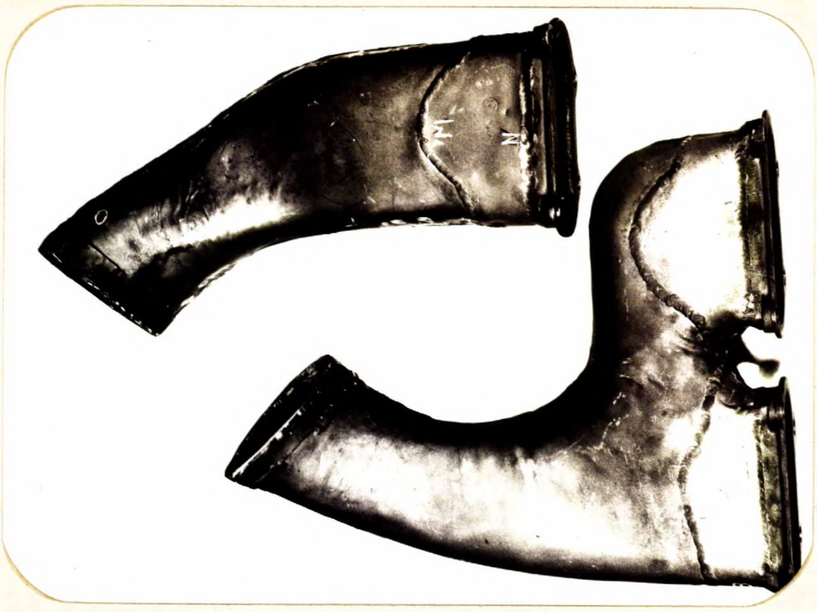
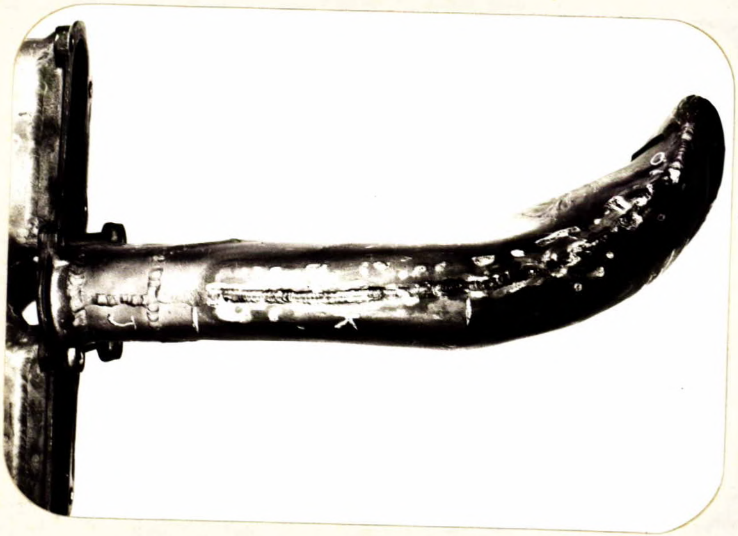
Figure 1.

SET NO. 1.



GENERAL SHAPE OF SINGLE AND DUAL STUBS.

Figure 2.



CLOSE-UP OF WELD.

Note irregular thicknesses.

Figure 3.

CLOSE-UP OF WELD.

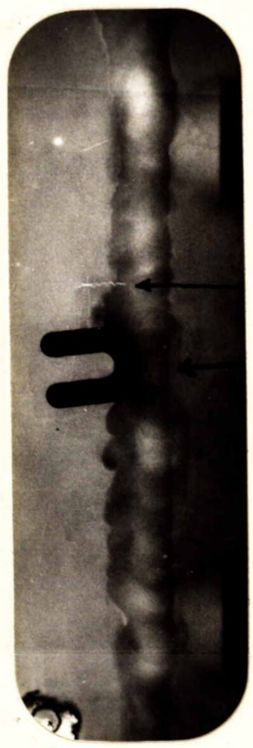
Figure 4. Set No. 1.

PRINT OF EXOGRAPHS OF A LONG WELD. WHITE SPOTS ARE GAS INCLUSIONS.

Note irregular thickness of weld shown by varying shades of grey.

Figure 5.

SET NO. 1.



Crack.

Unfused edge of sheet. Lack of penetration.

Figure 6.

SET NO. 1.

Crack.

Figure 7.

SET NO. 1.

Unfused sheet edges. Lack of fusion and penetration.

Crack.

Figure 8.

SET NO. 1.

Lack of penetration.

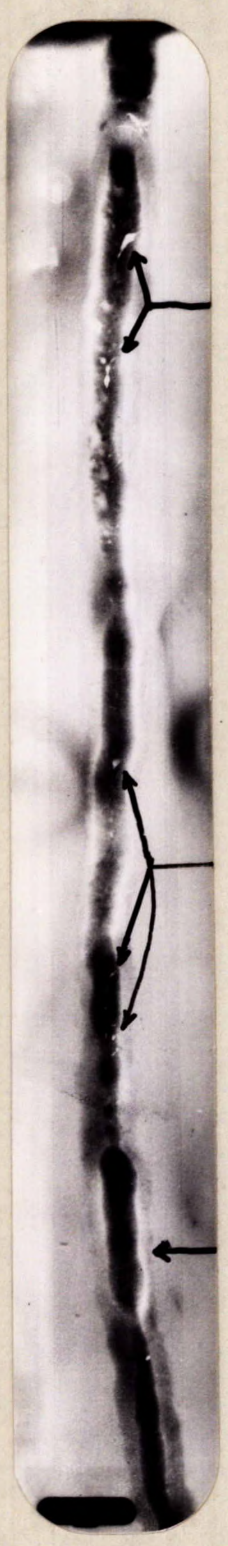
Crack.

Figure 9.

SET NO. 2.

Figure 10.

SET NO. 2.



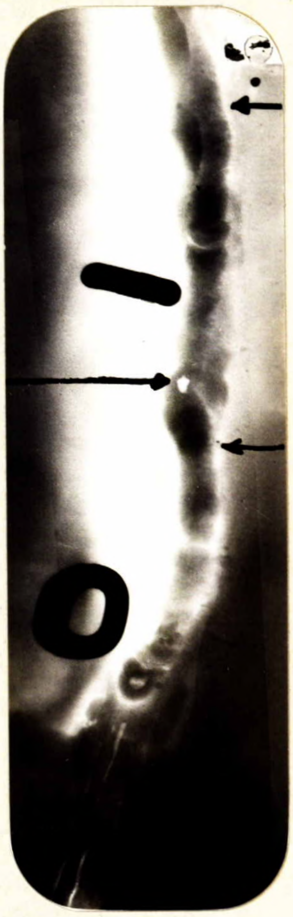
All white spots are gas inclusions.

Gas inclusions.

Severe reduction of plate thickness adjacent to a high-piled up weld.

Figure 11.

SET NO. 2.



Lack of fusion.

Gas inclusion.

Severe reduction in plate thickness adjacent to a high, piled-up weld.

Unfused sheet edges - lack of penetration.

Figure 12.

SET NO. 2.

Gas inclusions.

Lack of fusion.

Crack.

Figure 13.

SET NO. 2.

Mechanical gouge under weld.

Figure 14.

SET NO. 3.

White spots are gas inclusions. Weld fairly irregular in thickness.

Figure 15.

SET NO. 3.

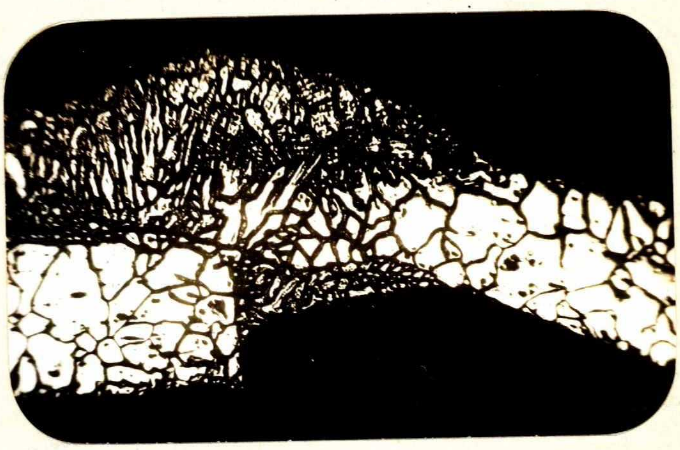
White spots are gas inclusions. White lines along edges of weld (towards bottom of print) indicate "sucking in" of too much plate metal into weld.

Figure 16.

X20 - etched in aqua regia.

MECHANICAL GOUGE IN SHEET MATERIAL.

Figure 17.



X20 - etched in aqua regia.

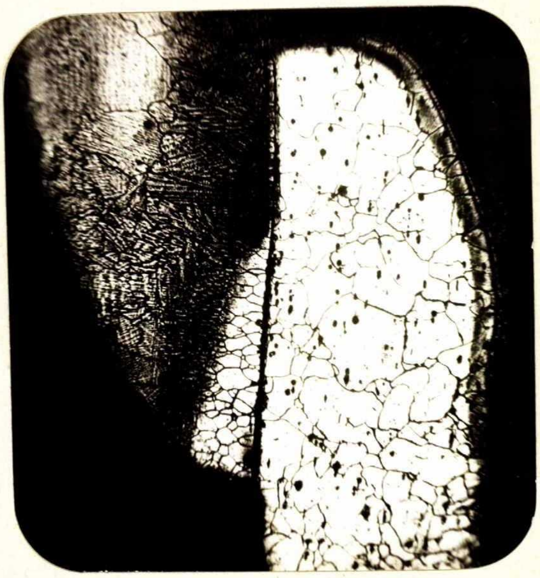
MISALIGNMENT OF SHEET EDGES AND INCOMPLETE PENETRATION.

Figure 18.

X20 - etched in aqua regia.

CRACKED COMPLETELY THROUGH WELD AND SHEET MATERIAL.

Figure 19.



X20 - etched in aqua regia.

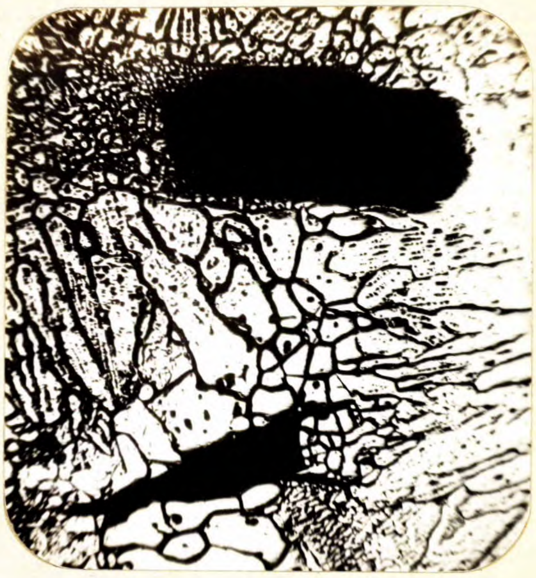
LACK OF FUSION BETWEEN WELD AND SHEET MATERIAL.

Figure 20.

X20 - etched in aqua regia.

INCOMPLETE PENETRATION, RESULTING IN A NOTCH AT THE BASE OF THE WELD. ALSO SMALL GAS INCLUSIONS.

Figure 21.



X20 - etched in aqua regia.

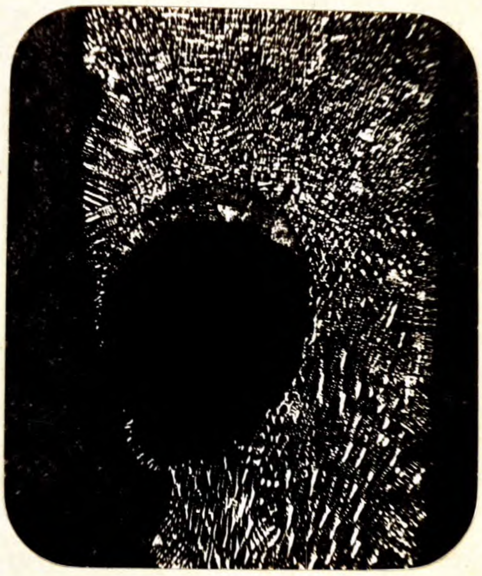
COMPLETE LACK OF PENETRATION SHEET EDGES UNFUSED. ALSO CRACK.

Figure 22.

X20 - etched in aqua regia.

SEVERE REDUCTION IN SHEET THICKNESS ADJACENT TO A WELD.

Figure 23.



X20 - etched in aqua regia.

GAS INCLUSION IN WELD .

(All above were taken from Set No. 2.)

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