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R E P O R T

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1761.

Examination of Welded Tail Pieces of
120-mm. Mortar Bombs.

(Copy No. 10.)

Bureau of Mines
Division of Metallic
Minerals
-
Physical Metallurgy
Research Laboratories

CANADA

DEPARTMENT
OF
MINES AND RESOURCES

Mines and Geology Branch

OTTAWA December 15th, 1944.

REPORT
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Introduction:

On November 14th, 1944, Col. W. E. Van Steenburgh, Director of Artillery, Department of National Defence (Army), Ottawa, Ontario, requested the assistance of these Laboratories with regard to welding of tails to 120-mm. mortar bombs. A bomb was submitted for examination which was selected at random from those now welded.

The following information was obtained in conversations with Col. B. P. Ballantyne and Major Leslie (Superintendent, Ballistics Laboratory, Valcartier, Quebec):

Initially the tail pieces were attached to the bomb body by means of a threaded joint. Firing trials revealed that the tail piece would readily break off from the bomb proper, resulting in wild rounds. This threaded joint was subsequently reinforced by a single V (60° included angle), single-pass weld and firing

(Introduction, cont'd) -

trials showed a considerable reduction in the number of wild rounds but not their complete elimination.

It was also stated that the sound of wild rounds in flight was distinctly different from that of a normal round, indicating abnormal interference with the airflow around the projectile. Improper alignment of the tail piece with the body of the bomb was indicated by the fact that some bombs would not go into the mortar barrel.

The welding of all bombs was done at the machine shop of the Valcartier Proof Establishment, Inspection Board of United Kingdom and Canada, Valcartier, Quebec. The Proof Establishment was visited and approximately 45 welded bombs were examined. A check of the welding operation revealed that a Stelco No. 704, 5/32"-diam. welding electrode was used with a Hobart D.C. welding machine driven by a gasoline motor. No jigging of any kind was used, the threaded joint being depended upon to preserve alignment. Welding tests indicated that the welding machine was incorrect in its settings, due to "wander" over a period of time.

No information is available as to the welding of the tail fins to the tail piece proper.

Object of Investigation:

(1) To examine the welding of the mortar bomb with a view to ascertaining to what extent welding may be responsible for wild rounds.

(2) To submit recommendations to improve the welding technique if this proves to be advisable.

Procedure:

(1) The mortar bomb was photographed in the "as received" condition. Figure 1 shows this photograph.

(2) A careful visual examination of the bomb revealed that the tail fins are made by stamping a U-shaped piece, thus forming two fins. There are a total of 6 such pieces, or 12 individual fins. These units are attached to the tail piece by means of two spot welds and two fillet welds on the outside of the unit. Presumably the spot welding is used as a means of alignment and accurate placing of the unit and the subsequent fillet welds are provided for additional strength. Figure 2 shows two spot welds attaching a fin unit to the tail piece and Figure 3 the fillet welds. Note the post-welding machining in each photograph.

The weld joining the tail piece to the bomb body, although machined flush, showed serious welding defects such as slag inclusions, unfilled craters, and undercutting. Figure 4 is a photograph of this weld and shows a long slag inclusion.

(3) The machining shown in Figure 4 was such as to indicate improper alignment of the tail piece with the bomb body. This alignment was checked in the following manner: An accurately machined threaded plug was fitted into the threaded nose hole of the bomb. This plug was then gripped in the chuck of a lathe and the bomb body supported in a jack rest accurately centred on the centre of the machined plug. The bomb was then rotated and the alignment checked by means of a micrometer spring gauge at three areas, namely, at the nose, at the end of the tapered bomb body, and as close to the end of the tail piece as the tail fins would permit. It was found that the nose hole was 0.012 inch off centre, the tapered end of the body 0.003 inch out of alignment, and the

(Procedure, cont'd) -

end of the tail piece 0.011 inch out of alignment.

(4) Macro sections were machined from tail-piece-to-bomb-body welds, through the welding defects and also through the tail fin welds. Figures 5 and 6 show typical defects in the tail-piece-to-bomb-body weld. Figure 7 shows a section through the centre of a spot weld and both fillet welds joining a fin unit to the tail piece.

(5) A microscopic examination of three sections reveals a crack in each of the samples shown in Figures 5 and 6. These cracks extend completely through the weld metal to the surface and originate at the welding defects. In the case of the tail fin unit, the spot weld contains a large gas cavity surrounded by numerous cracks.

Figure 8 shows the normalized structure of the tail piece proper and Figure 9 the heat-treated structure of the bomb body. Figure 10 shows the structure of the heat-affected zone of the bomb body at the weld joining the tail piece to the bomb proper. This structure is typical of the heat-affected zones of all welds. Figure 11 shows the structure of the tail fin material.

(6) Chemical analysis was made of the bomb body, tail piece and tail fin units, with the following results:

		Bomb Body	Tail Piece	Tail Fin Unit
		- Per Cent -		
Carbon	-	0.55	0.42	0.05
Phosphorus	-	0.010	0.008	0.010
Sulphur	-	0.029	0.029	0.029
Manganese	-	0.74	0.95	0.02
Silicon	-	0.24	0.21	Trace.
Chromium	-	Trace.	Trace.	None.
Nickel	-	None.	0.18	None.
Molybdenum	-	Trace.	0.12	Trace.

(7) Hardness tests, using a Vickers machine and

(Procedure, cont'd) -

a 10-kilogram load, were made on the normal bomb, tail piece and tail unit materials. In addition, the heat-affected zones of each were tested. The following table lists the results secured:

	Normal Material	Heat-Affected Zone (Vickers)	Weld
Bomb body -	242	484	234
Tail piece -	225	406	234
Tail unit -	108	132	232

A similar hardness testing on the spot weld area produced the following results:

Normal tail piece -	225
Heat-affected zone -	396
Nugget -	298

Discussion:

All welds on the bomb assembly, without exception, show welding defects of a serious nature. The following table lists the welds and the defects found:

Weld	Defects Found
Spot welds. -	Gas cavities and numerous cracks.
Fillet welds of fin units. -	Slag inclusions at roots of welds.
Butt weld joining tail piece to bomb body. -	Slag inclusions at roots of welds; cracks completely through weld metal; cracks along fusion line; unfilled craters.

All of these defects act as severe stress raisers and, as such, can readily cause complete failure on sudden application of stresses.

It is difficult to offer an opinion as to the cause

(Discussion, cont'd) -

of the defects found in the spot welds. In Figure 7 it will be noted that there is considerable projection of the tail-piece material into the fin material. It is improbable that this is a result of the spot-welding technique. It would appear that a stud has been machined onto the surface of the tail piece in the welding area. If this is the case it is very unusual and its necessity is open to question. The gas cavities and cracks in this weld are probably due to either of the following, (1) excessive welding current and/or welding time or (2) too small electrode surface. It must be borne in mind that the tail piece is of such a composition as to be very sensitive to the thermal cycle of welding and that, consequently, hard brittle structures may be produced.

The defects found in the fillet welds are to be expected in view of the difficulty of proper electrode manipulation within the narrow spaces between fin units. It is not thought, however, that slag inclusions at the root of these welds would be a serious source of difficulty, provided that they are kept to a minimum. The possibility does exist that explosions of secondary charges placed between the fins may result in severe distortion of the fins. This action would be enhanced by the presence of welding defects in the fillet welds.

Of the weldings examined, the single-pass butt weld joining the tail piece to the bomb body exhibits the grossest defects. The slag inclusions and unfilled craters are the result of careless or unskilled welding. The cracks found have all originated in these areas of slag inclusion and emphasize their stress-raising effect. The fact that the threaded joint resulted in failure indicates that severe stresses

(Discussion, cont'd) -

are imposed on this joint in firing. The improvement noted after welding would be expected, since the area of metal resisting the stresses is increased. However, the fundamental fault of the joint still remains. This is the severe stress-raising effect of the right-angled joint where the threaded end of the tail piece joins into the tail piece proper. The welding was such as to leave this area unaffected (see Figures 5 and 6). This condition should be rectified as by recommendations previously made (in P.M.R.L. Memorandum V-70, November 28th, 1944), together with changes of electrode and the use of a jig. The extreme hardening of the body and tail piece material, due to the thermal cycle of welding, would be expected from the high hardenability of both materials (see Figure 10). This condition is aggravated by the use of a single-pass technique, and can be considerably reduced by multiple-pass welding.

The microstructure of the bomb body (see Figure 9) is interesting in that it reveals that the heat treatment, presumably quench-and-draw, has been unsatisfactory in that the suppression of ferrite precipitation has not been accomplished. This and the fine pearlite indicates too slow a cooling rate. The composition and microstructure (see Figure 11) of the tail fin units reveal that these are made by stamping from cold-rolled, low-carbon sheet material.

It is difficult to estimate the effect of misalignment of the tail piece with the bomb body on the trajectory of the projectile. However, measurements on bombs and tails joined only by a threaded joint at Valcartier clearly revealed that the gross misalignment was not due to welding but to inaccurate threading operations. The alignment figures previously reported (Memorandum V-70) are such that it would seem to be reasonable that a definite effect would be produced. It would be interesting

(Discussion, cont'd) -

to know just how much misalignment can be tolerated and still have the bomb pass a bore gauge test. It is felt that expressions of opinion on this point are of doubtful value and that experiments should be conducted to determine the effect of misalignment on the percentage of wild rounds. This could be done by comparing firing trials of bombs showing misalignment but still passing the bore gauge test with trials of those bombs straightened mechanically after welding.

The frequent breakages of tail units in firing when only a threaded joint was used, together with the distinctly different sound of the wild rounds in flight, are significant. Severe stresses on the joint, and also abnormal interference with airflow around the projectile, are indicated. It is quite probable that the serious welding defects found in nearly all tail-to-body welds have resulted in cracking when highly stressed. This would permit gross misalignment of the tail piece as soon as the bomb leaves the barrel. Here, again, firing trials should be employed to give factual evidence to support or refute an opinion. A firing trial of bombs showing the worst defects would be expected to show a higher percentage of wild rounds than is normal.

CONCLUSIONS:

1. All welding examined contains serious welding defects. This being the case, the welding techniques are open to criticism.

2. The following welding defects were found: heavy slag inclusions, cracks in weld metal and fusion zones, gas cavities, and unfilled craters.

3. Microstructures reveal faulty heat treatment of

(Conclusions, cont'd) -

the bomb body, normalized tail pieces, and cold-rolled material in the tail fin units.

4. The bomb body and tail pieces are made from SAE 1055 and SAE 1045 respectively. The alloying elements found are considered to be residuals.

5. Misalignment of the tail piece with the bomb body was found. At Valcartier this misalignment was found to be primarily the result of inaccurate threading operations.

6. Welding may be responsible for wild rounds in the following manners:

(a) Gross welding defects may cause partial or complete rupture of the tail-piece-to-bomb-body weld.

(b) The explosion of secondary charges placed between the tail fins may cause breakage or severe distortion due to welding defects.

Recommendations:

1. The welding of the tail piece to the bomb body should be performed as fully detailed in Memorandum V-70.

2. Firing trials should be conducted with four groups of bombs, as follows:

(a) Those now welded and containing serious welding defects.

(b) Those now welded and showing the worst alignment but still passing the bore gauge test.

(c) Those now welded and subjected to a straightening operation.

(d) Those to be welded with the improved technique and subsequently straightened.

A firing trial of these groups should permit accurate assessment of the importance of the various factors involved.

3. To prevent spot-weld cracks, the welding current

(Recommendations, cont'd) -

should be followed by several surges of current to reduce the cooling rate and thereby avoid the production of hard, brittle structures.

4. The possibility exists that the design of the bomb is such that it is unstable at high velocities. It is considered that a wind-tunnel test to check this factor is highly desirable, provided that air velocities comparable with that encountered in firing trials are obtainable.

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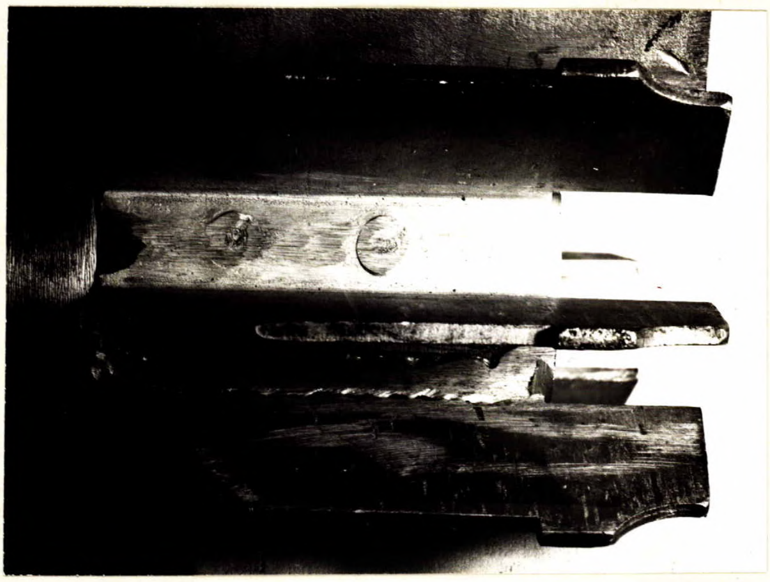
Figure 1.

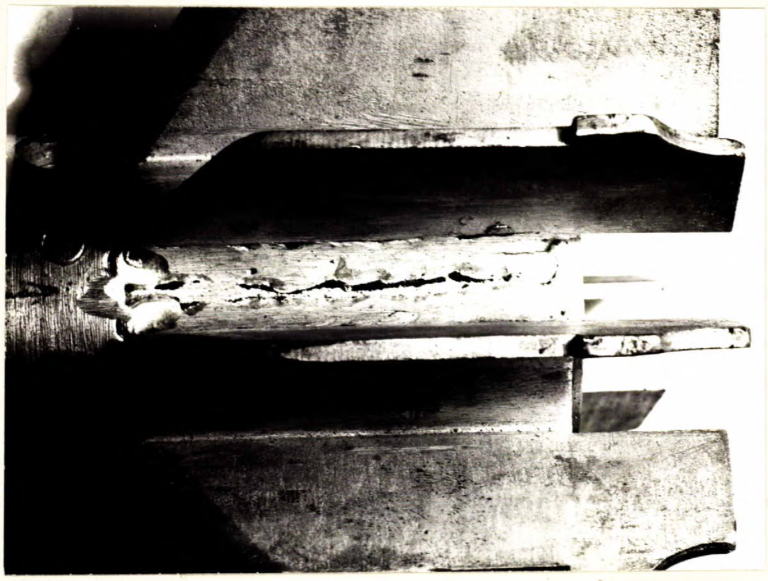
MORTAR BOMB AS RECEIVED.

Figure 2.



TOP OF SPOT WELDS JOINING TAIL FIN
UNIT TO TAIL PIECE.

Figure 3.



FILLET WELDS JOINING TAIL FIN
UNITS TO TAIL PIECE.

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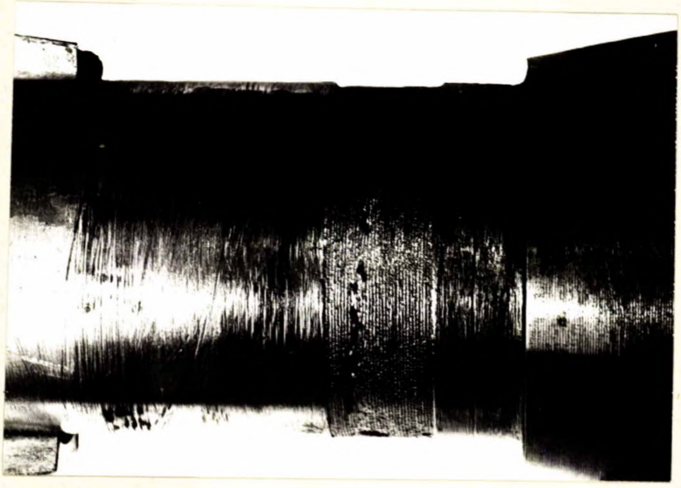
Figure 4.



MACHINED SURFACE OF TAIL-PIECE-TO-BOMB-BODY WELD.

Note heavy slag inclusion.

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Figure 5.

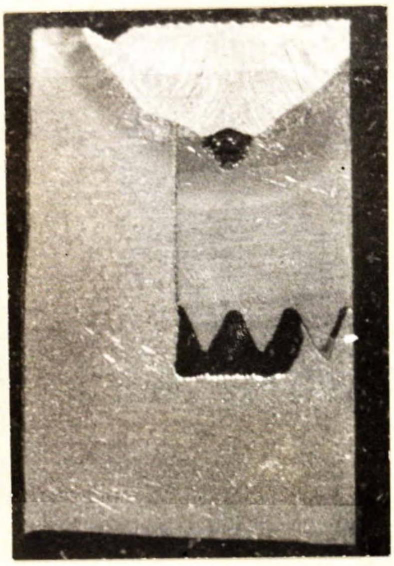
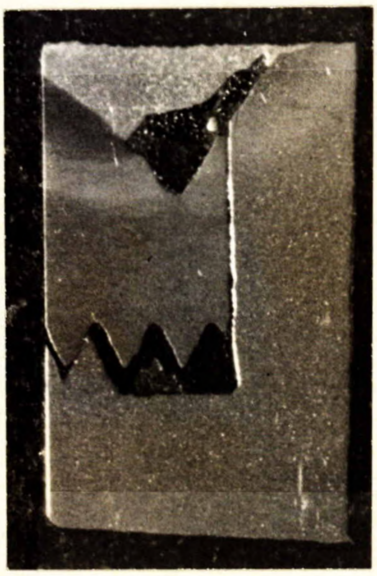


Figure 6.



MACRO SECTIONS OF TAIL-PIECE-TO-BOMB-BODY WELD.

Note heavy slag inclusions at roots of welds. Note, also, that machining is not evenly distributed between bomb body and tail piece. The right-angled change of section at bottom of joint is a severe stress raiser.

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Figure 7.

MACROPHOTOGRAPH OF WELDS JOINING
TAIL FIN UNITS TO THE TAIL PIECE.

Note slag inclusions at roots of fillet welds. Note, also, gas cavities and cracks in the nugget of the spot weld. The projection of the nugget into the fin material is probably the result of a machined projection on the outer surface of the tail piece.

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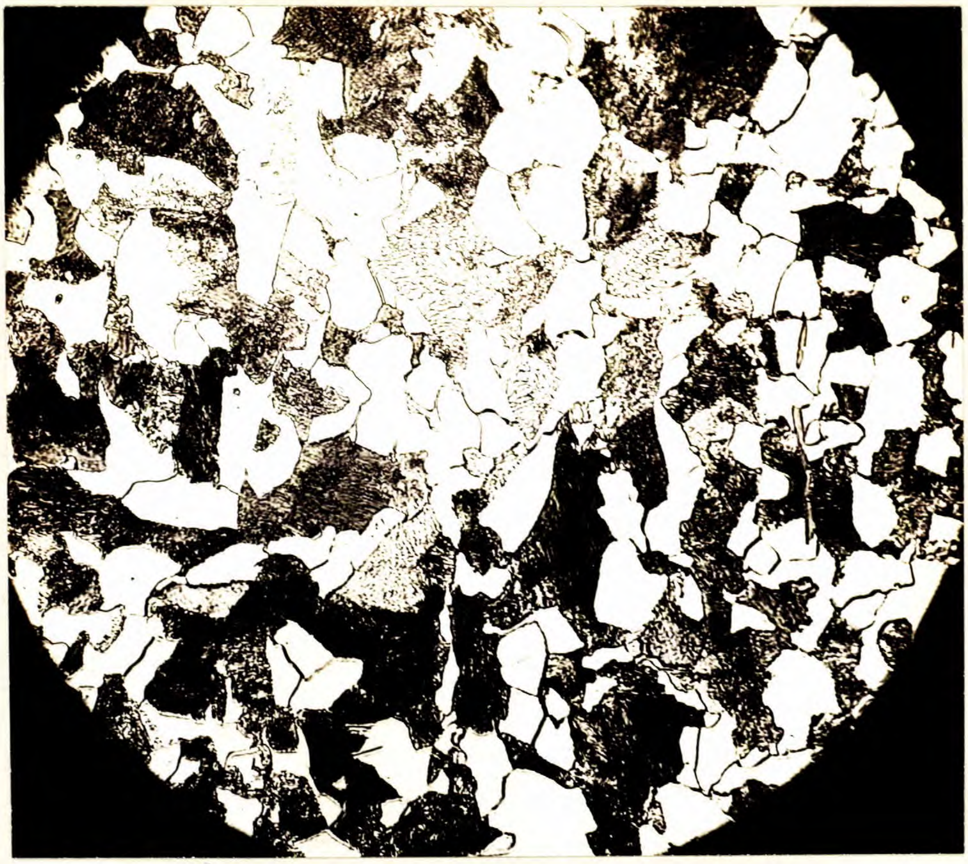
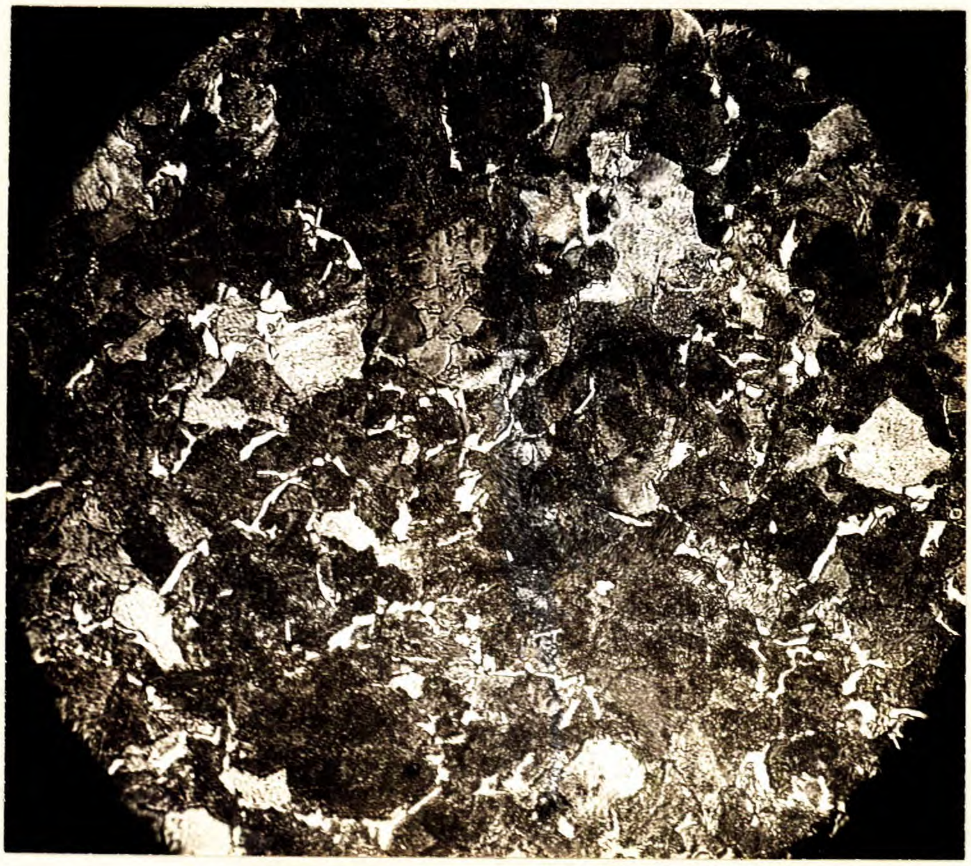
Figure 8.



X500, etched in 2 per cent nital.

NORMALIZED STRUCTURE OF THE TAIL PIECE.

Figure 9.

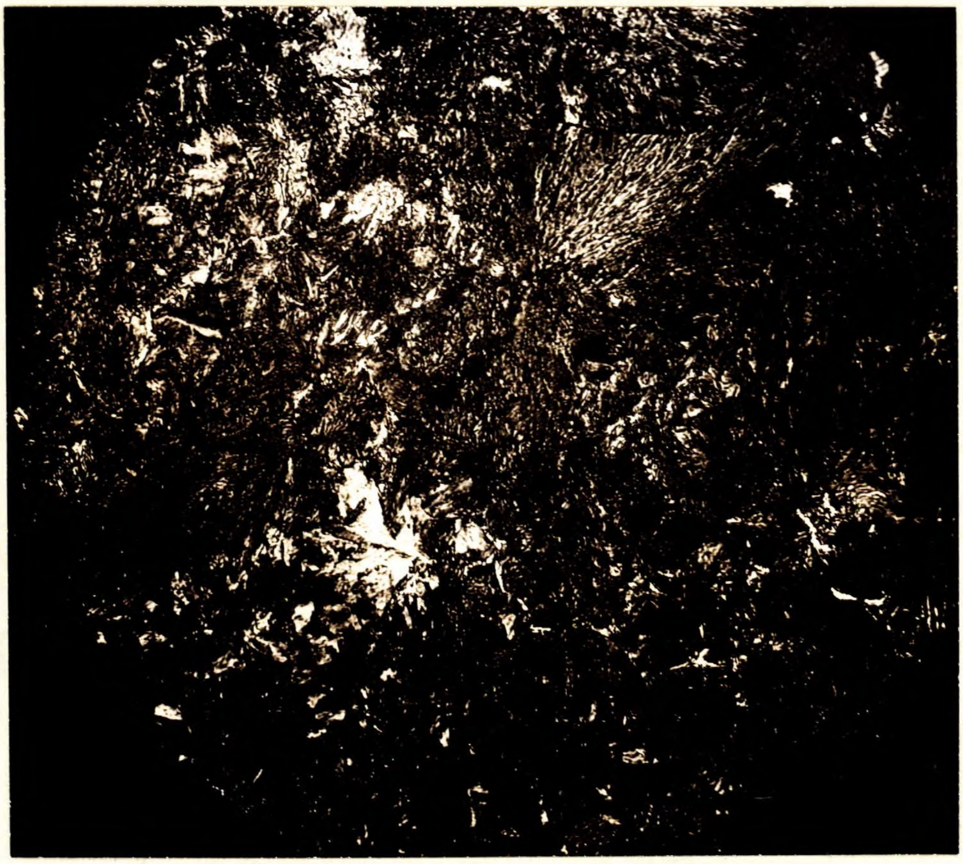


X500, etched in 2 per cent nital.

NORMAL STRUCTURE OF BOMB BODY.

Fine pearlite with ferrite (white constituent) in grain boundaries.

Figure 10.



X500, etched in 2 per cent nital.

TYPICAL STRUCTURE OF HEAT-AFFECTED ZONE OF BOTH BOMB BODY AND TAIL PIECE MATERIALS.

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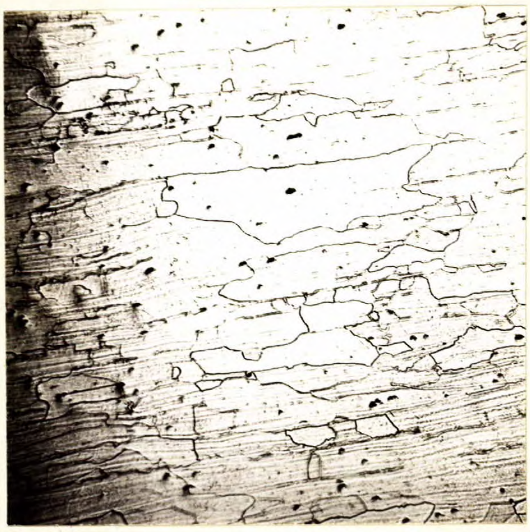
Figure 11.



X100, etched in 2 per cent nital.

COLD-ROLLED STRUCTURE OF LOW-CARBON TAIL FIN UNITS.

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