

File.

FILE COPY

O T T A W A

March 6th, 1944.

REPORT

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1606.

Examination of Electrically Welded
2-Inch Mortar Bomb Tails.

(Copy No. 10)

O T T A W A

March 6th, 1944.

R E P O R T

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1606.

Examination of Electrically Welded
2-Inch Mortar Bomb Tails.

=====

Origin of Material:

On February 22nd, 1944, Mr. H.H. Scotland, Inspector of Materials, Inspection Board of United Kingdom and Canada, Ottawa, Ontario, submitted a split tail from a 2-inch mortar bomb for examination. The accompanying letter and requisition (O.T. 4144) stated that as an alternative to unobtainable seamless tubing, cold-rolled annealed strip electric-resistance-welded into tubing is being used. Each tube, before assembly into a tail unit, is subjected to a 75-pound air pressure test.

On February 27th, 1944, twelve samples, 14 inches long, of the welded tubing, from Galt Metal Industries Limited, were also submitted for examination (under Analysis Requisition O.T. 4147). At the same time, Specification I.G. 397A was supplied, this specification governing the production of the 2-inch mortar. The specification states that the steel of the tubing shall conform to B.S. Specification 5009-211 and

(Origin of Material, cont'd) -

shall be of the following composition:

		<u>Per cent</u>
Carbon	-	0.10-0.15
Sulphur	-	0.00-0.06
Phosphorus	-	0.00-0.06
Manganese	-	0.30-0.50
Silicon	-	Trace.

Object of Investigation:

- (1) To determine cause of failure of mortar tail.
- (2) To suggest means of eliminating causes of failure.

Procedure:

(1) Both tail and tube stock were given a careful visual examination.

(2) Cross-sections of fractured tail piece and tube stock were examined under the microscope. Figure 1 shows the typical banded structure of cold-rolled steel of the fractured bomb tail. Figure 2 shows the annealed structure of the tube samples. Figure 3 reveals a large inclusion trapped within the weld of the bomb tail. Figures 4 and 5 show unfused areas at the base of the weld of tube. This defect is typical of eleven of the twelve samples examined. Figure 6 is a macro section photograph of the fracture of the bomb tail.

(3) Two samples of tubing, selected at random, were pickled in a 50 per cent hydrochloric acid solution for 15 minutes at a temperature of 180° F. Figure 7 shows the appearance of the outside of the welds after this treatment. Numerous fine cracks may be seen on the weld surface. Figure 8 shows the unfused area at the roots of the welds.

(4) An analysis of the tube material was made. For the purpose of comparison the specified composition and

(Procedure, cont'd) -

the actual analysis obtained are given below:

		Specification <u>I.G. 397A</u>	Analysis <u>Obtained</u>
		- Per cent -	-
Carbon	=	0.10-0.15	0.04
Phosphorus	=	0.00-0.06	0.004
Sulphur	=	0.00-0.06	0.025
Manganese	=	0.30-0.50	0.34
Silicon	=	Trace.	Trace.

Discussion:

A visual examination revealed no evidence as to the cause of the bomb tail failure. The appearance of the fracture indicates failure originating at a crack on the inside of the tail.

A microscopic examination of the fractured tail gave no clue as to the cause of failure, beyond the presence of a large inclusion in the weld metal running at an angle of 45° to the tail edge. The lines of deformation at the edge of the fracture indicate good ductility of the metal and progressive tearing. The microscopic examination of sections of the tubing, however, reveals an area of lack of fusion at the root of the weld running at an angle of 45° to the edge. Of the twelve samples of the tubing, eleven show this type of defect. It is most probable that this defect is the cause of the failure of the bomb tail.

It would appear that the weld is made not between two square edges but between a joint the edges of which are inclined at 45° to the normal.

It is not surprising that the microscopic examination of the fractured tail piece shows no evidence of this defect. Lack of fusion at the root of the weld is a potent stress raiser. This being the case, when the explosion of the propelling charge

(Discussion, cont'd) -

takes place high stresses are instantaneously applied to the inside of the tube and these stresses are concentrated at the root of this unfused area. This would inevitably result in a progressive failure originating at that point. When the fracture is complete there is, of course, no evidence as to the origin of the failure.

Two facts, then, point to unsatisfactory welding technique. These are, slag inclusions within the weld and unfused areas at the roots of the welds. These may both be caused by improper cleaning of the edges of the strip before welding. On the other hand, it is quite probable that the lack of fusion is due to too low welding current, but the possibility of insufficient pressure holding the edges together cannot be eliminated as a possible cause. All of these causes may be readily eliminated. It is quite reasonable to believe that the welded tubing can prove to be entirely satisfactory provided that care is taken to eliminate the above defects.

It is interesting to note that the banded structure of the fractured tail piece is typical of hot-rolled steels which have not been subsequently annealed. Specification I.G. 397A states that the material shall be in the annealed condition before welding. On the other hand, none of the tube samples shows any evidence of cold work but all are definitely annealed. A visual examination of the tubing before and after pickling indicates that after the welding operation the tubes are given a light draw, insufficient to affect the structure. This final draw is probably for accurate sizing. In brief, it would appear that the processing operations are not the same in all cases.

It is our opinion that the tubes are wholly unsatisfactory for use in the manufacture of mortar bomb tail pieces. The

(Discussion, cont'd) -

possibility of loss of life in the event of failure precludes risking the use of material in this condition.

The chemical analysis of the tube material is within the specification with the exception of the carbon content. This would not in any way be detrimental to welding of the tubing.

CONCLUSIONS:

1. The welding technique used to fabricate the tubing for these mortar bomb tails is open to criticism. Slag inclusions and lack of fusion at the roots of the welds were detected.

2. The failure of the bomb tail was most probably due to lack of fusion at the root of the weld. This type of defect acts as a severe stress raiser and is therefore a fertile source of failure.

3. The tubing, if the samples submitted are representative, is unsatisfactory for use in the manufacture of mortar bomb tails.

4. The chemical analysis of the tube material is within the specification, with the exception of the carbon content. This would have no detrimental effect on welding of the tubing.

Recommendations:

1. The edges of the strip should be cleaned with a wire brush or a grinding operation before welding. This would eliminate the slag inclusions and also one cause of lack of fusion.

2. The welding machine's settings should be

(Recommendations, cont'd) -

(Discussion, cont'd)

checked. It is probable that the welding current is too low.

This is the most frequent cause of lack of fusion.

The pressure rolls aligning the edges to be welded should be checked. It is possible that insufficient pressure is permitting the inner edges of the joint to be spaced too far apart.

CONCLUSIONS:

1. The welding technique used to fabricate the

tubing for these motor pump tails is open to criticism.

Slag inclusions and lack of fusion at the roots of the welds

were detected.

2. The failure of the pump tail was most probably

due to lack of fusion at the root of the weld. The type of

defect acts as a severe stress raiser and is therefore a

likely source of failure.

3. The tubing, if the samples submitted are

NOTE:

An addendum covering additional
tubing samples received
appears on Page 11.

within the specification, with the exception of the carbon

content. This would have no detrimental effect on welding

of the tubing.

Recommendations:

1. The edges of the strip should be cleaned with

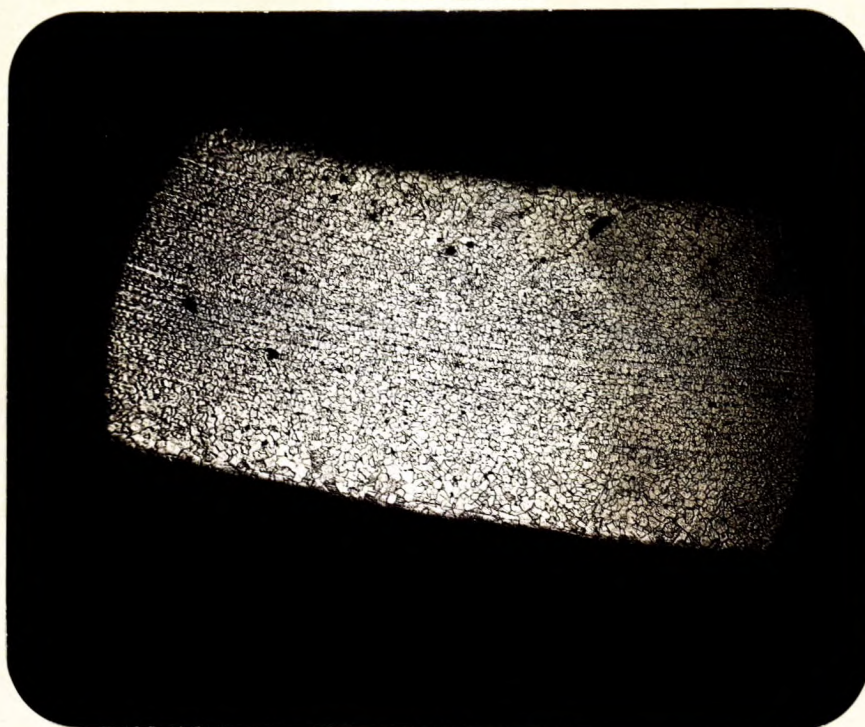
a wire brush or a grinding operation before welding. This

would eliminate the slag inclusions and also the cause of

lack of fusion.

2. The welding machine's settings should be

Figure 1.

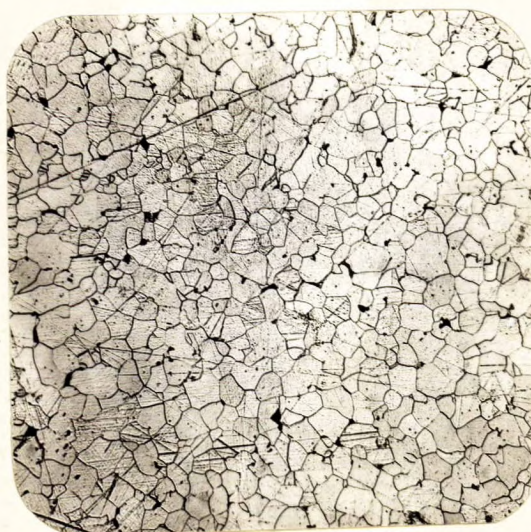


X40, nital etch.

BANDED STRUCTURE OF FRACTURED BOMB TAIL PIECE.

This is typical of hot-rolled, low-carbon steel
not annealed after finish rolling.

Figure 2.



X100, nital etch.

ANNEALED STRUCTURE OF TUBING.

Compare with Figure 1.

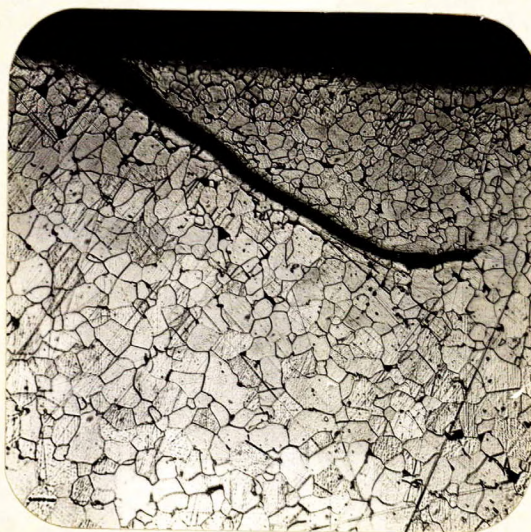
Figure 3.



X100, nital etch.

LARGE INCLUSION WITHIN WELD METAL
OF FRACTURED TAIL PIECE.

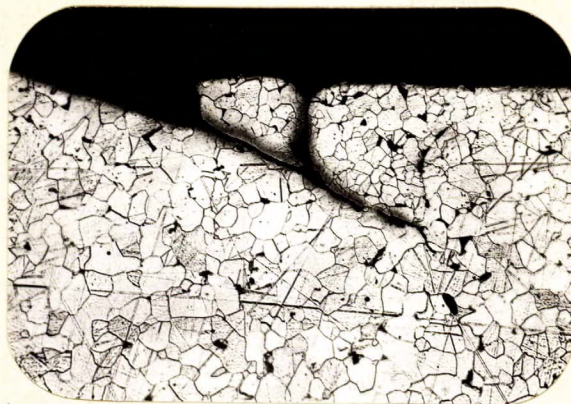
Figure 4.



X100, nital etch.

UNFUSED AREA AT ROOT OF WELD OF TUBING.

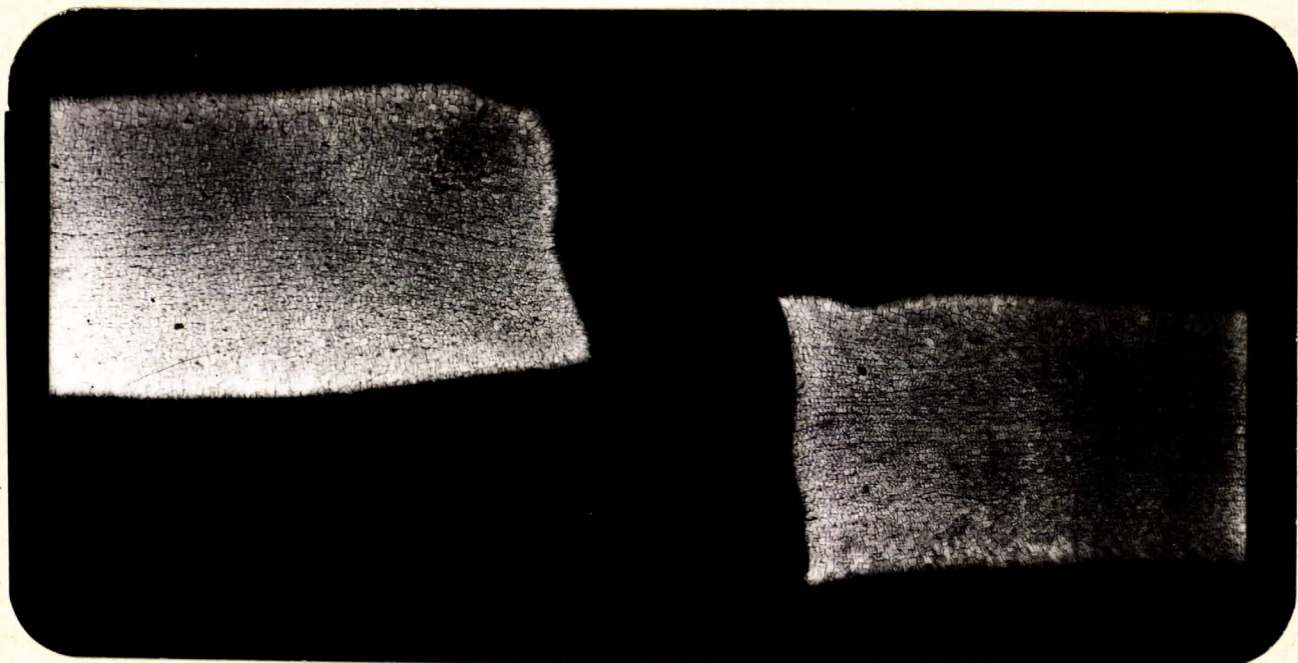
Figure 5.



X100, nital etch.

UNFUSED AREA AT ROOT OF WELD OF TUBING.

Figure 6.

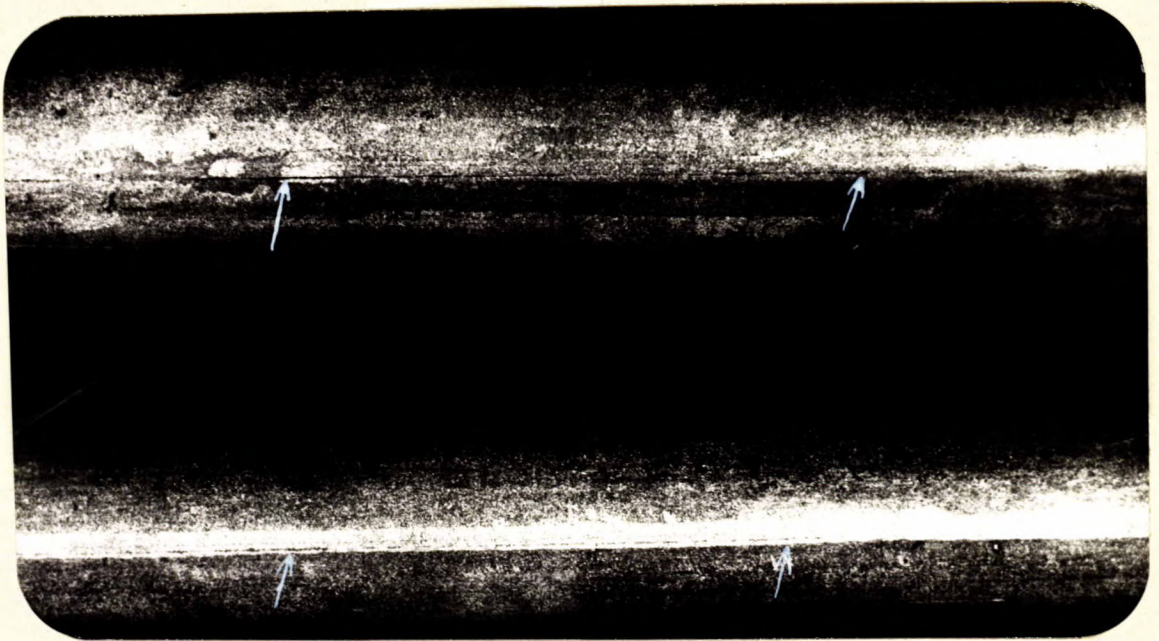


X30, nital etch.

EDGES OF FRACTURE OF BOMB TAIL.

Note lines of deformation and
banded structure.

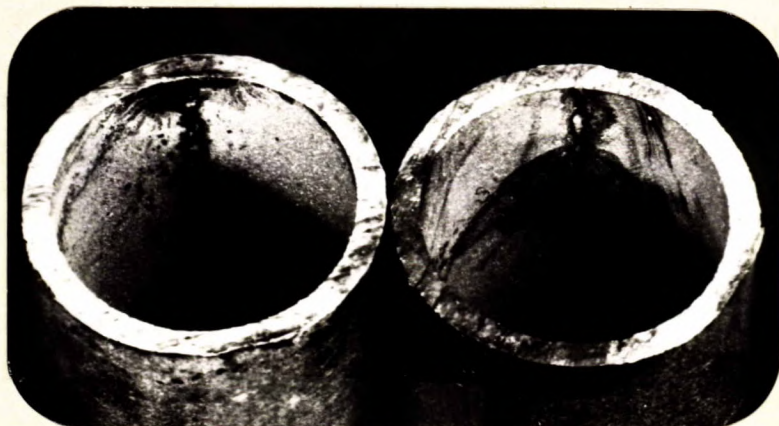
Figure 7.



OUTSIDE SURFACE OF WELDS OF TUBES AFTER
PICKLING IN HYDROCHLORIC ACID (HCl).

Note fine surface cracks.

Figure 8.



INSIDE SURFACE OF WELDS OF TUBING AFTER PICKLING.

Note lack of fusion at root of weld.

REPRODUCTION OF THIS DOCUMENT IS PROHIBITED
WITHOUT THE WRITTEN PERMISSION OF THE
NATIONAL BUREAU OF STANDARDS

ADDENDUM TO REPORT OF INVESTIGATION NO. 1606.

On March 3rd, 1944, Mr. J. M. Gilmartin, I.O., on behalf of Mr. H. H. Scotland, Inspector of Materials, Inspection Board of United Kingdom and Canada, Ottawa, Ontario, submitted additional samples of tubing for examination. These specimens were taken from stock of the Standard Tube Co. Ltd., Woodstock, Ontario. This company welds, anneals, and draws the tubing to size.

The samples were pickled and revealed the same defects as referred to previously in this report; if anything, the material was in worse condition than that originally examined. It is said to be representative of a large amount of tubing completely processed. It was considered that no useful purpose would be served by giving these additional samples a more thorough examination and including the evidence so found in the present report.

The pronounced lack of fusion on the inside of the tubing is clearly visible and a rough check of material in stock would detect any tubing which might be satisfactory.

HJN:GHB.
March 6th, 1944.