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O T T A W A July 19th, 1943.

R E P O R T

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1452.

Examination of Zinc-Base-Alloy Die-Cast
Trench Mortar Bomb Tails.

(Copy No. 10.)

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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## Examination of Zinc-Base-Alloy Die-Cast Trench Mortar Bomb Tails.

Abstract

This report describes treatments and gives the results of examinations of a variety of bomb tails and bomb tail materials received over a period of time extending from February 8th to June 5th, 1943.

Origin of Problem and Object of Investigation:

In Materials Division Analysis Requisition No. O.T. 3394, dated February 8th, 1943, the Inspector General, Inspection Board of the United Kingdom and Canada, Ottawa, Ontario, requested an investigation on a lot, being shipped, of forty-eight (48) M.L.2" Trench Mortar Bomb tails, die cast from an experimental zinc alloy by Pressure Castings of Canada, Limited, Weston, Ontario. Three test bars from the same material were also being submitted.

It was stated in an attached memorandum (File No. 4/1/128E), dated January 30th, 1943, from A.D.I. (Shell),

(Origin of Problem and Object of Investigation, cont'd) -

that recently an appreciable percentage of failures (i.e., cracked and broken tails) at the proof firing of these bomb tails had been encountered. In an endeavour to improve this performance, an experimental alloy had been submitted which contained 10 per cent aluminium but otherwise complied with the specified composition of Mazak 3 (Zamak 3).

It was requested that chemical analysis and the following mechanical tests be carried out:

1. Tensile tests at room temperature in the "as received" condition.

2. Impact tests at room temperature,

   (a) in the "as received" condition;
   (b) after ageing for 10 days at 95° C.; and
   (c) after ageing for 10 days in steam at 95° C.

3. Impact tests at -40° C.,

   (a) in the "as received" condition;
   (b) after ageing for 10 days at 95° C.; and
   (c) after ageing for 10 days in steam at 95° C.

It was also requested that the bomb tails be given the following treatments, with approximately equal numbers in each lot treated, and then be returned, properly identified, for proof firing:

(1) Alternate cooling from room temperature to -40° C. (24-hour cycle) for 10 days;

(2) Ageing for 10 days at 95° C.; and

(3) Ageing for 10 days in steam at 95° C.

In a letter dated February 10th, 1943, these Laboratories asked for additional material for impact tests, sufficient for twenty test bars 6 inches in length and ¼ in. by ¼ in. in cross-section. As it was necessary that these

(Origin of Problem and Object of Investigation, cont'd) -

impact test specimens be treated along with the submitted bomb tails, to ensure similar condition of the examined material, the investigation was delayed until the required additional samples could be received. For some unknown reason, these additional samples were not forwarded as requested. However, twenty bomb tails of regular Canadian production (Pressure Castings of Canada, Limited, Weston, Ontario), made from Zamak 3 alloy, were received on April 2nd, 1943, for comparison.

In a further letter (File No. 4/1/128E), dated April 28th, 1943, Lt.-Col. H. H. Anthony, A.D.I.(Shell), for Inspector General, Inspection Board of the United Kingdom and Canada, Ottawa, Ontario, stated that a further lot of bomb tails, of American production--made by the Precision Casting Company, Fayetteville, N. Y.--was being shipped. These bomb tails were die cast from Zamak 3 alloy with the exception that the maximum copper content was increased to 0.25 per cent. It was requested that this lot be included with the previously submitted material and given the same treatments and investigation. This material, consisting of 45 samples, was received on June 5th, 1943.

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Description of Samples Received:

Table I (on the next page) lists all samples received for this investigation. For purposes of identification, the bomb tails were marked as follows:

| | | |
|---|---|---|
| Canadian normal production | - By letters, A to U. | (20) |
| Canadian special alloy | - By numbers, 1 to 48. | (48) |
| American production | - By numbers, 51 to 95. | (45) |

(Continued on next page)

(Description of Samples Received, cont'd) -

TABLE I.

| Description of material | Date received | Number of samples | Material | Identification marks |
|---|---|---|---|---|
| Canadian - special alloy | Feb. 9, 1943. | 48 | Bomb tails | 1-48 |
| | | 3 | Tensile test bars | 1-3 |
| Canadian - normal production | Apr. 2, 1943. | 20 | Bomb tails | A-U |
| American production | June 5, 1943. | 45 | Bomb tails | 51-95 |

AGEING AND LOW-TEMPERATURE TREATMENTS:

1. Low-Temperature Treatment -

In compliance with the request, a number of the bomb tails were submitted to an alternate cooling from room temperature to about -25° C. (the lowest temperature the artificial refrigeration apparatus could reach) for a 10-day period. This test was carried out as follows (24-hour cycle):

(a) Every day, from 5 p.m. to 8 a.m., the samples were placed in a special low-temperature room, where the temperature was kept between -20° C. and -25° C.

(b) From 8 a.m. to 11 a.m., the samples were taken out and held at room temperature.

(c) From 11 a.m. to 2 p.m., they were placed again in the low-temperature room.

(d) From 2 p.m. to 5 p.m., the samples were at room temperature.

The following bomb tails were given the above low-temperature treatment:

| | Designations |
|---|---|
| 4 of Canadian normal production | - R to U |
| 14 of Canadian special alloy | - 1 to 12 |
| 12 of American production | - 71 to 82 |

(Continued on next page)

(Ageing and Low-Temperature Treatments, cont'd) -

2. Ageing at 95° C. -

Ageing at 95° C. was carried out, over a 10-day period, in a constant-temperature laboratory oven with automatic thermoregulation. The following bomb tails were treated:

| | Designations |
|---|---|
| 4 of Canadian normal production - | A to D |
| 14 of Canadian special alloy - | 17 to 30 |
| 12 of American production - | 59 to 70 |

3. Ageing in Steam at 95° C. -

Ageing in steam at 95° C., over a 10-day period, was carried out in a specially designed steam chamber with the necessary close temperature control. The following bomb tails were treated:

| | Designations |
|---|---|
| 4 of Canadian normal production - | K to N |
| 14 of Canadian special alloy - | 33 to 46 |
| 12 of American production - | 83 to 94 |

-

Chemical Analysis:

| | Canadian Normal Production | American Production | Canadian Experimental Alloy |
|---|---|---|---|
| | - Per cent - | | |
| Aluminium - | 3.82 | 3.73 | 10.30 |
| Copper - | 0.01 | 0.16 | 0.005 |
| Magnesium - | 0.025 | 0.047 | 0.032 |
| Iron - | 0.002 | 0.005 | 0.011 |
| Lead - | 0.0002 | 0.0004 | 0.0002 |
| Cadmium - | Trace only.* | Trace only.* | Trace only.* |
| Tin - | Trace only.* | Trace only.* | Trace only.* |

* Less than 0.0001 per cent.

All determinations except that for aluminium were

(Chemical Analysis, cont'd) -

made on 100-gram samples.

Limits for the chemical composition of "Zamak 3" ("Mazak 3") are given as follows:

| | British Standard Specification No. 1004:1942. | A.S.T.M. Spec. B86-41, Alloy XXIII. |
|---|---|---|
| | - Per cent - | |
| Aluminium - | 3.9-4.3 | 3.5-4.3 |
| Copper - | 0.10 max. | 0.10 max. |
| Magnesium - | 0.03-0.06 | 0.03-0.08 |
| Iron - | 0.10 max. | 0.10 max. |
| Lead - | 0.005 max. | 0.007 max. |
| Cadmium - | 0.005 max. | 0.005 max. |
| Tin - | 0.002 max. | 0.005 max. |

-

Mechanical Tests:

Tensile Tests -

Tensile tests were carried out on three sand-cast experimental alloy 0.572-inch-diameter test specimens. The following results were obtained:

| Specimen No. | Ultimate tensile strength, p.s.i. | Elongation in 2 inches, per cent |
|---|---|---|
| 1 | 29,200 | 0.5 |
| 2 | 27,400 | 1.0 |
| 3 | 26,150 | 0.5 |

All fractures revealed that the metal was far from sound, a number of holes and considerable porosity being evident. Because of this and of the fact that the material was sand-cast rather than die-cast, the above values cannot be considered as representing the physical properties of the alloy in the bomb

(Mechanical Tests, cont'd) -

Tensile Tests, cont'd -

tails.

Additional die-cast test bars were requested but were not received.

Impact Tests -

Since normal impact test specimens (3 in. x ½ in. x ¼ in.) were not available, small samples were cut from the fins of the bomb tails.

For these tests, a Baldwin-Southwark impact testing machine for moulded insulating materials was used. The capacity of this machine is 2 foot-pounds, but additional weights are supplied to extend the range to 4 foot-pounds.

The specimens used had the following dimensions: length, 2-1/8 inches; width, 5/16 inch; thickness, approximately 0.07 inch (depending on the thickness of the fins). A V-notch, 1/32 inch deep, was cut in the specimens to ensure uniformity of the test.

The specimens cut from bomb tails of American origin were slightly thicker (difference, approximately 0.0015 inch).

It was found, experimentally, that the impact strength of such single test specimens was too low for accurate measurements at low temperatures. Therefore, it was decided to measure the impact value of two specimens placed side by side in a special adapter held between the jaws of the machine. For the room-temperature tests the 0-4 foot-pounds range was used; and for low-temperature tests, the 0-2 foot-pounds range.

The low temperatures used for this testing were obtained by placing the specimens in a box containing dry ice (solid carbon dioxide) and a thermoregulator. The temperature was maintained at -41° C. to -42° C. The specimens remained at

(Mechanical Tests, cont'd) -

Impact Tests, cont'd -

this temperature for 30 minutes before testing and were quickly placed in the adapter which was itself cooled by surrounding dry ice. The specimens were handled with tongs which were kept at the temperature of the ice-box.

The results of these tests are given in Table II.

It must be understood that the values obtained in these impact tests are comparable only among themselves, as the specimens were not of standard dimensions and therefore cannot be compared with any data for normal specimens.

TABLE II.

Results of Impact Tests.

| Origin of samples | Previous treatment of samples | ROOM TEMPERATURE | | LOW TEMPERATURE (-40° C.) | |
|---|---|---|---|---|---|
| | | Bomb Tail No. | Imp. value, ft.-lb | Bomb Tail No. | Impact value, ft.-lb. |
| Canadian - normal production | As submitted | I | 2.46 | J | 0.32 |
| | Low-temp. treated | T | 2.20 | U | 0.39 |
| | Dry aged | C | 1.98 | D | 0.31 |
| | Steam aged | M | 1.94 | N | 0.33 |
| Canadian - special alloy (10% aluminium) | As submitted | 47 | 0.90 | 48 | 0.29 |
| | Low-temp. treated | 11 | 1.00 | 12 | 0.28 |
| | Dry aged | 29 | 1.36 | 30 | 0.36 |
| | Steam aged | 45 | 1.40 | 46 | 0.33 |
| American production | As submitted | 57 | 2.60 | 58 | 0.29 |
| | Low-temp. treated | 81 | 1.40 | 82 | 0.38 |
| | Dry aged | 69 | 2.08 | 70 | 0.44 |
| | Steam aged | 93 | 1.46 | 94 | 0.31 |

Each of the above results is an average from three impact values obtained on samples from the same bomb tail.

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Microscopic Examination:

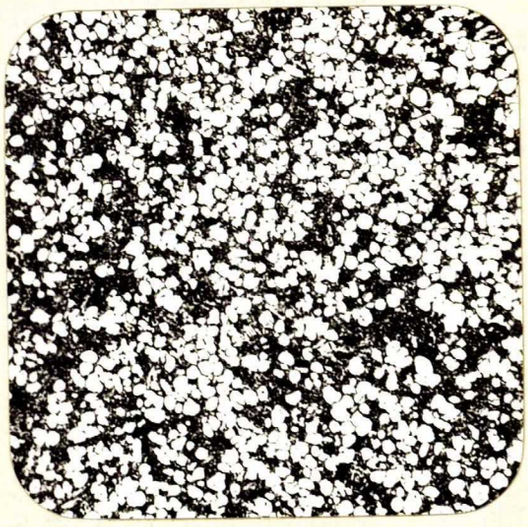
Figures 1 to 6 show the average microstructure of the three lots of bomb tails in the "as received" condition and after

(Microscopic Examination, cont'd) -

ten days of ageing in steam at 95° C.

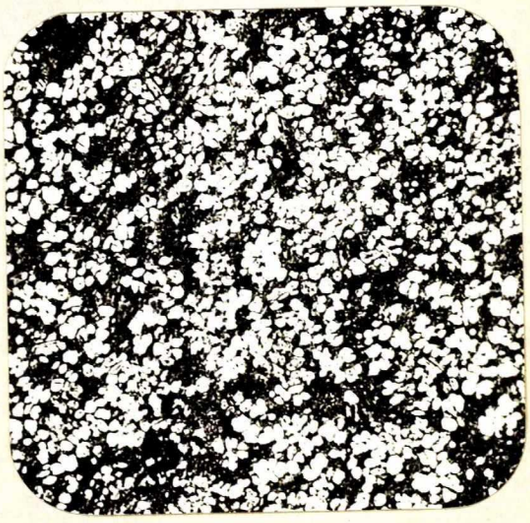
The microspecimens were etched as given in the A.S.M. Metals Handbook, 1939 Edition, pp. 1768-9 (solutions Nos. 4, 5, and 2). All reproduced microstructures show $\alpha$-primary crystals in $\alpha + \beta'$ eutectic.

Figure 1.



X250, etched.
Sample I, "As Received".

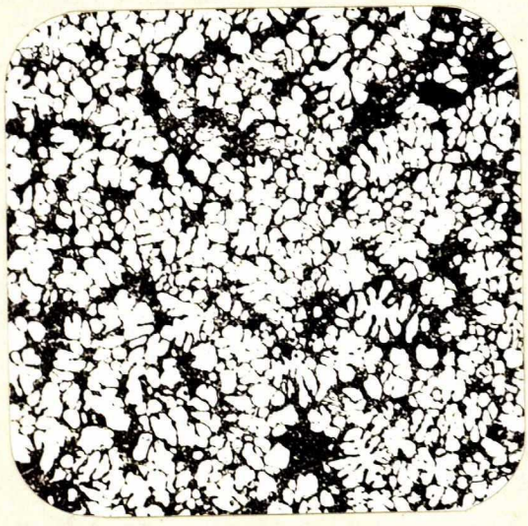
Figure 2.



X250, etched.
Sample M, after 10-day steam ageing.

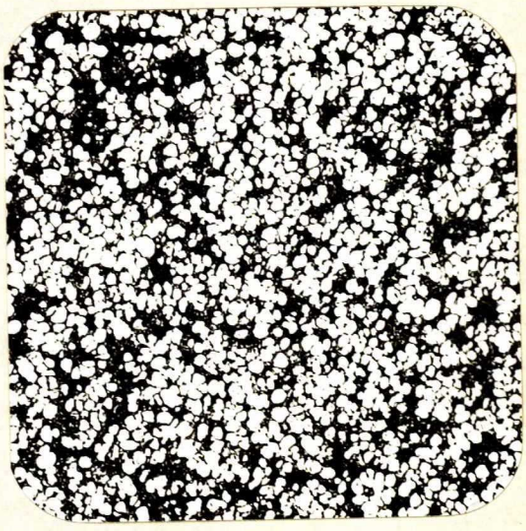
CANADIAN NORMAL PRODUCTION.

Figure 3.



X250, etched.
Sample 57, "As Received".

Figure 4.



X250, etched.
Sample 93, after 10-day steam ageing.

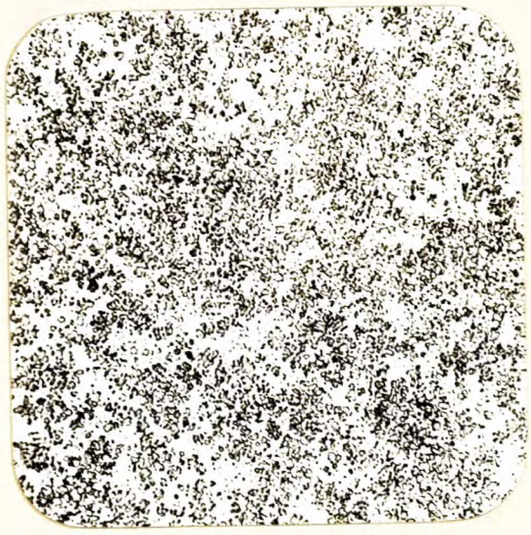
AMERICAN PRODUCTION.

(Microscopic Examination, cont'd) -

Figure 5.

X250, etched.
Sample 47, "As Received".

Figure 6.



X250, etched.
Sample 45, after 10-day steam ageing.

CANADIAN SPECIAL ALLOY.

Discussion of Results:

The results of the chemical analysis show that the examined samples from the Canadian normal production are made from zinc of a very high purity, but reveal a rather low content of magnesium.

The American-made bomb tails show a rather high magnesium content, although well below the allowable limits. The comparatively high copper content is probably due to the desire to obtain better casting properties of the alloy.

The results of the tensile tests are not representative of the quality of the experimental alloy die castings, due to unsoundness of the material and to the different casting method used.

The impact tests were made on especially small specimens, therefore the values obtained are not comparable with any data for normal-sized specimens.

The results of the impact tests show the expected

(Discussion of Results, concluded) -

drop in the low-temperature range. The Canadian normal production showed the most uniform results.

Return of Material:

As requested, the remaining bomb tails from the submitted lots were returned, upon completion of this investigation, to the Inspection Board for proof firing; date, July 17th, 1943.

CONCLUSION:

The metallurgical examination of the submitted bomb tail lots revealed no particular advantage gained by using the special zinc alloy or the American-produced bomb tails, as compared with the Canadian normal production.

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