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REPORT

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1509.

Examination of Anti-Tank No. 3 Mine Fuze Magazines.

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(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

OTTAWA September 30th, 1943.

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ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1509.

Examination of Anti-Tank No. 3 Mine Fuze Magazines.

Origin of Problem and Object of Investigation:

In Materials Division Analysis Requisition No. O.T. 3443, dated April 12th, 1943, the Inspector General, Inspection Board of the United Kingdom and Canada, Ottawa, Ontario, requested the examination of some Anti-Tank No. 3 Mine Fuze magazines. Accompanying this requisition was a copy of a memorandum, dated April 9th, File No. 12/4/3, from J. W. Jolly, Inspector of Fuzes, to H. H. Scotland, Inspector of Materials, regarding this material.

It was stated that these cups were drawn from commercially pure zinc sheet by the Burgess Battery Company. Trouble was experienced with some of them when the cups were cannelured to the fuze body, due to cracking. The manufacturing firm suggested that these failures might be due to intercrystalline growth. Defective cups are easily detected by a distinct crackling noise emitted when squeezed in the hand. It was thought that this condition was caused either by overstressing in the drawing or by overheating of the material.

It was requested that an investigation be carried out to determine the cause of the erratic behaviour of the

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

submitted zinc cups and that an opinion be given as to whether cracking of properly made cups could be expected when subjected to temperatures up to 160° F.

Upon receipt of this material at these Laboratories and after a preliminary visual examination, it was felt that an accurate opinion on causes of the trouble could be given only when the complete details of the manufacturing process were known. Such information was thereupon requested, through officials of the Inspection Board of the United Kingdom and Canada, but apparently was unobtainable, as none has been received. However, rather than wait longer and thus further delay the report of the investigation, a general opinion is now advanced.

Description of Samples:

Seven supposedly defective zinc cups were submitted on April 14th, 1943. Three additional zinc cups, referred to as "good", were received on April 28th.

Later, a sample of commercially pure zinc sheet from which cups are made was obtained.

Chemical Analysis:

Chemical analysis was carried out on a "defective" zinc cup.

(a) Spectrographic Analysis (quantitative only) -

Major constituent: Zn.

Minor constituents:

Traces	-	Pb, Ti, Cu.
Faint traces	-	Fe, Ag.
Nil	-	Cd, Al, Sn.

(b) Wet Analysis:

Lead	-	0.09 per cent.
Copper, Titanium	-	None detected.

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Mechanical Properties:

Tensile tests were carried out on specimens cut out in two directions from the zinc sheet. The following results were obtained:

Rolling Direction	Yield strength, p.s.i.	Ultimate tensile strength, p.s.i.	Elongation in 2 inches, per cent
Longitudinal	- Approx. 11,000	18,800	55
Transverse	- Approx. 17,000	24,000	41.5

Metallographic Examination:

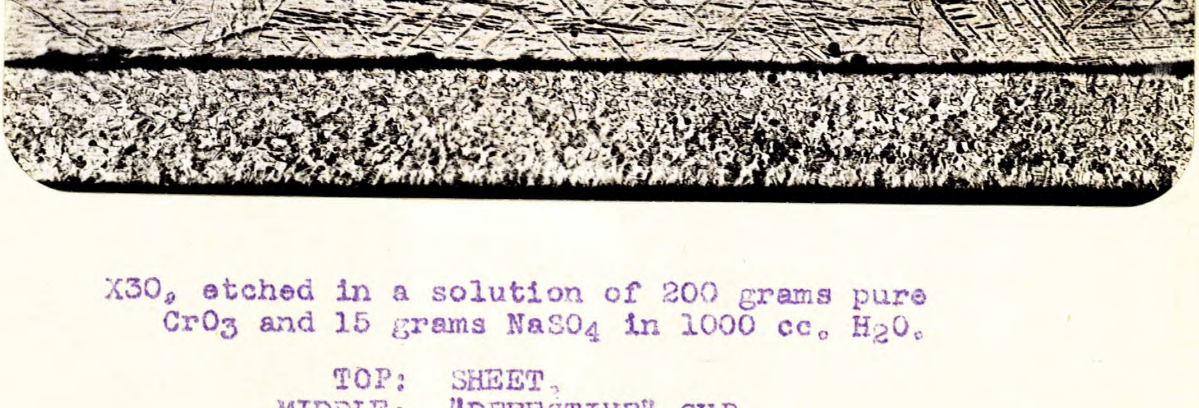
Four samples, two chosen from the supposedly defective and two from the "good" zinc cups, were etched in hydrochloric acid to reveal the macrostructure of the alloy.

Flow lines of the material, visible on the walls of the examined cups, were normal. The grain size shown in the "bad" samples was very distinctly coarser than in the "good" samples.

Microscopic examination was carried out on cross-sections of the sheet and from both "good" and "bad" cups.

Figure 1 shows the difference in the size and shape of the microstructures.

Figure 1.



X30, etched in a solution of 200 grams pure CrO_3 and 15 grams $NaSO_4$ in 1000 cc. H_2O.

TOP: SHEET.
MIDDLE: "DEFECTIVE" CUP.
BOTTOM: "GOOD" CUP.

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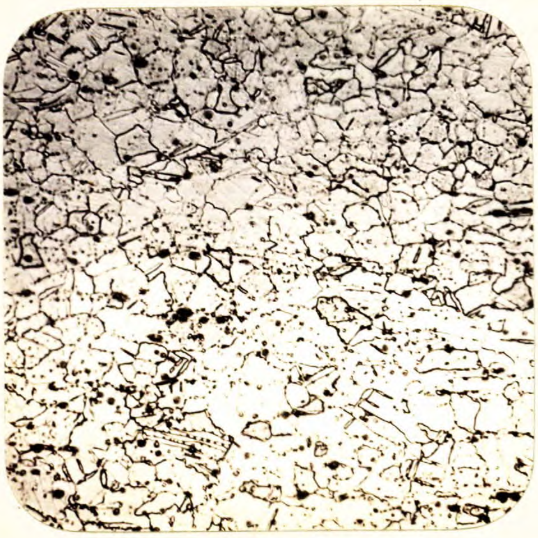
(Metallographic Examination, cont'd) -

Figures 2 to 4 show these microstructures in higher magnification.

Figure 2.



X250, etched.*

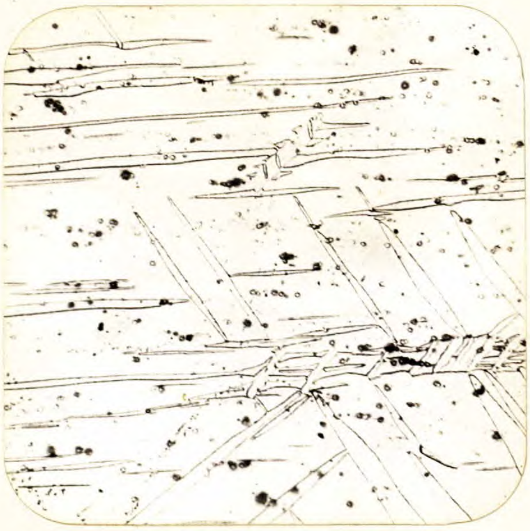
SECTION OF ZINC SHEET.
(Average grain diameter at X75, approx. 0.010 mm.)

Figure 3.

X250, etched.*

SECTION OF "GOOD" ZINC CUP.
(Average grain diameter at X75, approx. 0.010 mm.)

Figure 4.



X250, etched.*

Figure 5.

X250, etched.*

SECTIONS OF "DEFECTIVE" ZINC CUP.

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* Etched in a solution of 200 grams pure CrO_3 and 15 grams $NaSO_4$ in 1000 cc. H_2O.

Discussion of Results:

Spectrographic examination and chemical analysis show that the zinc sheet used for the manufacture of the submitted zinc cups was made from commercially pure zinc of good quality. No harmful amounts of impurities were found.

Mechanical tests and microscopic examination of the zinc sheet show normally expected properties and a very small grain size. The higher value of the tensile strength on the transverse specimen ("across grain") as compared with the longitudinal specimen ("with the grain") is normal for zinc.

Macroscopic and microscopic examination of the zinc cups reveal, in the "good" cup, large, equiaxed grains. The supposedly defective cups show extremely coarse grain and directionality.

Since no exact data on the manufacturing process of the zinc cups were available, the following remarks, of general value, on the behaviour of zinc in deep-drawing operations have been extracted from the literature:

J. D. Jevons - "The Metallurgy of Deep Drawing and Pressing" - London 1941, pp. 308-313.

"The peculiar and interesting mechanical properties of zinc when deformed plastically are usually attributed to the fact that its space lattice is of the hexagonal type. Because of this, the planes upon which slip can occur within its crystals are fewer than for most of the other industrial metals, and this may explain in part why its rate of work-hardening is so low and why a zinc shell is unusually liable to break under press tools by localised 'necking' instead of extending uniformly."

". . . the question arises as to why so much trouble is experienced when these operations are attempted by those unfamiliar with the peculiarities of the metal. The answer is two-fold. First, the ductility of zinc varies very greatly with temperature to a maximum at about 150° C. with, however, some decrease of tenacity. For this reason it is usually necessary to deep draw and press this metal at a raised temperature. Secondly, the temperature of recrystallisation of zinc is so low that annealing usually occurs spontaneously soon after--if not actually during--press operations owing to the

(Discussion of Results, cont'd) -

rise in temperature which these operations produce in the metal. For this reason an undesirably large crystal size is attained very readily; once attained, it cannot be refined, and it will be appreciated that sheet or partly-formed shapes are very easily transformed into scrap metal.

"Two specially-prevalent defects need to be watched for when zinc sheet destined for deep drawing or pressing is purchased: too large a crystal size and, secondly, very pronounced directionality. In zinc of ordinary quality, too small a crystal size will engender low ductility and cause the metal to break in the press: in either ordinary or specially-heated varieties of zinc too large a crystal size will engender low tenacity which will also cause the metal to break or, if it does not actually break, to acquire a very rough 'orange-peel' surface. 'Directionality' is sometimes so marked that a round shell tends to become distorted and the height of the 'ears' may be so great that, using blanks of normal size, the intervening troughs will extend below the line to which the top of the shell is trimmed, thus spoiling the product. For this reason thorough testing of purchased sheet is always advisable."

". . . In view of the peculiarities indicated . . . the following three essential conditions must be observed:

(1) The sheet must be of high purity, such as the well-known 99.99 per cent variety, and must have a suitable crystal size which will depend on the nature of the article and operation but should never be more than 0.05 mm. adjudged 'average grain size.'

(2) The sheet must be deep drawn or pressed warm. The temperature, which may be somewhat critical, will vary a little according to the nature of the operation, the speed of the draw and other factors, but will generally lie between 25° and 50° C. . . .

Blanks may be heated conveniently in a bath containing water or dilute 'suds'; careless warming over a hot-plate or in an indifferently-controlled air-oven must be strongly deprecated because it is impossible to heat blanks to exactly the desired temperature in this way.

The critical nature of the temperature to which blanks must be heated is well illustrated by the production of a shell (shown in the book). If the blanks having a satisfactory crystal size are heated to 20 to 30° C., they break in the press owing to insufficient ductility; if they are heated to 30 to 40° C., the shell can be formed satisfactorily; when they are heated to 40 to 50° C., the crystals grow to such a large size during the spontaneous annealing which occurs as a result of the first draw that failure occurs during the second draw. These values are to be regarded merely as illustrative; other values may obtain under different conditions.

(3) The temperature of the tools must be kept reasonably

(Discussion of Results, cont'd) -

> constant in order to avoid dangerously large variation in the grain size of the finished product. Using zinc blanks of initially satisfactory crystal size and heated to a constant temperature it will be found that, as the tools get hotter and hotter during a prolonged run, the crystal size of the product may increase to a most undesirably large value. This defect can be minimised to some extent by warming the tools artificially before a run is started and by warming blanks to the temperature found suitable for continued production; and, sometimes, by judicious cooling of the tools during action."

Other important factors are: tools (radius of drawing dies, clearance, friction due to improper surface conditions of the tools, etc.) and lubricants.

". . . Annealing. A peculiarity in the manipulation of zinc is that no annealing is necessary, because the pure metal recrystallises readily--and sometimes almost instantaneously--at the temperature attained during most press operations. Indeed, as has been pointed out already, one of the main problems encountered in the pressing of zinc is how to keep crystal growth within safe limits when blanks are warmed to the temperature necessary to ensure good behaviour under the press.

"Crystal growth may continue to take place for some time after the metal leaves the tools if cold-worked articles are allowed to cool down in air. For this reason, when an article has to be shaped in more than one stage, it is the practice in some shops to make a point of carrying out successive operations as quickly as possible and not allowing partially-drawn shapes to stand about for more than a few minutes."

CONCLUSIONS:

The failure of some of the zinc cups is due to extremely coarse grain and directionality of the material, caused probably by improper processing conditions (e.g., ununiform heating before deep-drawing, heating-up of tools, unsuitable temperature in the lacquering process, etc.). However, in the absence of any definite information on manufacturing procedures it is impossible to state definitely the cause of the trouble.

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