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OTTAWA April 30, 1945.

REPORT

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1855.

Metallurgical Examination of a Welded Steel
Enemy Incendiary Container.

(Copy No. 10.)

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

CANADA

DEPARTMENT
OF
MINES AND RESOURCES

Mines and Geology Branch

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Metallurgical Examination of a Welded Steel Enemy Incendiary Container.

Origin of Material and Object of Investigation:

On February 26, 1945, one welded steel container (see Figure 1), said to have been used by the enemy to contain incendiaries, was submitted, for metallurgical examination, by Dr. R. W. McKay, Directorate of Operational Research, Department of National Defence (Army), Hut No. 1, Cartier Street School, Ottawa, Ontario.

Figure 1.

WELDED STEEL CONTAINER RECEIVED.

(Approximately 2/5 actual size).

Visual Examination:

The welded steel container consisted of a cylinder, approximately 10 inches high by 3-3/4 inches in diameter, made by welding a wall 1/16-inch thick onto a base 11/16 inch in thickness (see Figure 2). The heat resulting from the burning of the incendiary materials had burnt a large hole through the wall of the container (see Figure 1). Some of the molten metal, subsequently solidified, was found adhering to the wall of the container.

Chemical Examination:

A chemical examination made on the cylinder wall and base gave the following results:

		Base	Wall
		- Per Cent -	
Carbon	-	0.18	0.25
Manganese	-	0.37	0.50
Silicon	-	0.01	0.02
Sulphur	-	0.114	0.047
Phosphorus	-	0.088	0.043
Nickel, chromium and vanadium	-	Nil.	Nil.
Molybdenum	-	Trace.	Trace.

Spectroscopic Examination:

A qualitative spectroscopic examination made on a sample of the metal adhering to the cylinder wall yielded the following results: (The elements are listed in decreasing quantitative order of magnitude)

Greatest Quantity				Least Quantity
1	2	3	4	5
Iron Silicon Aluminium	Copper	Manganese	Magnesium Tin Titanium Nickel	Lead Cobalt Molybdenum

-

Hardness Tests:

Hardness tests made on the different materials gave the following readings:

Material		Vickers (20-kg. load)
Wall	-	126-133
Base	-	147-162
Weld metal	-	178-183
Metal adhering to wall	-	337-347

Macro-Examination:

A section was cut vertically through the cylinder, in order to show the method of welding the wall onto the base plate (see Figure 2). A close-up of this weld is seen in Figure 3. The narrow heat-affected zone is characteristic of arc welding.

Microscopic Examination:

Figures 7, 8, 9 and 10 are photomicrographs, all taken at X100 magnification. Figure 7 shows the porosity occurring at the junction of the weld joining the base plate to the cylinder wall. The small cracks along the fusion line probably resulted from inclusions.

Figures 8 and 9 indicate the microstructure of the base plate and wall respectively, consisting of ferrite and pearlite, typical of hot-rolled low-carbon steel.

Figure 10 shows the microstructure, at X100 magnification, of the metal adhering to the wall of the cylinder. This metal probably resulted from the thermite reaction.

Discussion:

The chemical analyses and the micro-examination indicate that the metal used in the manufacture of the cylinder was low-carbon, hot-rolled steel. The sulphur and phosphorus contents of the base plate (0.114 and 0.088 per cent) are considerably above the allowable maximum employed in Canadian industry, whereas the sulphur and phosphorus contents of the wall material (0.047 and 0.043 per cent) approach the upper limits of the Canadian specifications.

The spectroscopic examination of the metal adhering to the wall of the cylinder (see Figure 10), which shows a preponderance of iron, silicon and aluminium, lends support to the opinion that this metal is a ferrous alloy resulting from the thermite reaction. The comparatively high hardness (337 to 347 Vickers) also proves that it is a ferrous alloy.

Welding -

Visual examination of material as received indicates that all welds are of poor quality. This is confirmed by the subsequent microscopic examination. It is also apparent that all welding has been performed by means of an electric-arc process.

The weld joining the cylinder wall to the base plate shows severe arc craters and undercutting (Figure 4). These defects are caused by:

(1) Too high welding speeds,

(2) Use of bare electrodes, which are diffucult to control accurately.

That bare electrodes were used appears to be confirmed by the porous surfaces of all the welds. It should also be recognized that porosity can be the result of welding over rusty or dirty material.

The vertical weld of the cylinder wall shows the

(Discussion, cont'd) -

same types of defects. In addition, it is apparent that the material was either improperly bent to shape, or insufficiently jigged to ensure proper alignment of the edges. No back-up has been used on this weld and, as a result, incomplete penetration has occurred (see Figure 5). These two factors have resulted in a severe notch at the root of the weld (see Figure 6).

In summary, it would appear that the welding is far below standards generally considered acceptable in this country. However, it should be borne in mind that the purpose for which the container was made did not require a high quality of welding.

CONCLUSIONS:

1. The cylinder was made of low-carbon hot-rolled steels welded by the electric-arc process.

2. The steels employed contained higher quantities of sulphur and phosphorus than permitted in Canadian practice.

3. The metal adhering to the cylinder wall is a ferrous alloy of iron, silicon and aluminium, with lesser quantities of copper and manganese, and probably results from the thermite reaction.

4. The welding was found to be considerably below standards considered acceptable in this country.

5. The low quality materials and welding employed in the manufacture of this container do not necessarily imply a shortage of adequate materials or skilled welders, since the purpose for which the container was designed does not require a high-quality product.

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AF:GHB.

Figure 2.

(Etchant, 2 per cent nital.)

METHOD OF ARC-WELDING WALL ONTO BASE.

Note low centre of weld.

(Approximately to size).

Figure 3.

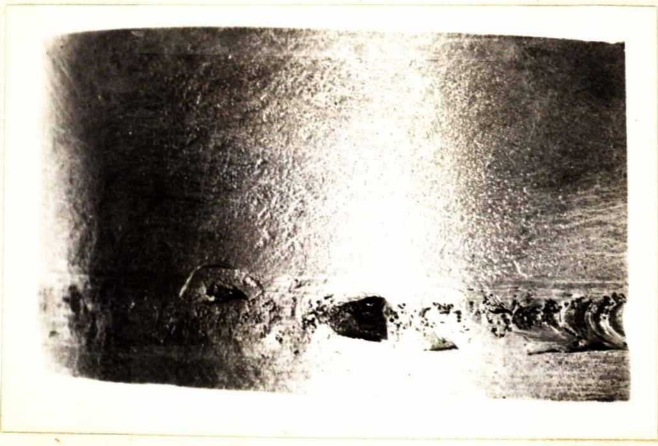
(Etchant, 2 per cent nital.)

ONE OF THE WELDS IN FIGURE 2.

Note narrow heat-affected zone characteristic of arc welding.

(Approximately 2 1/4 times actual size).

Figure 4.



ARC CRATERS IN WELD JOINING WALL TO BASE PLATE.

Probably resulting from either

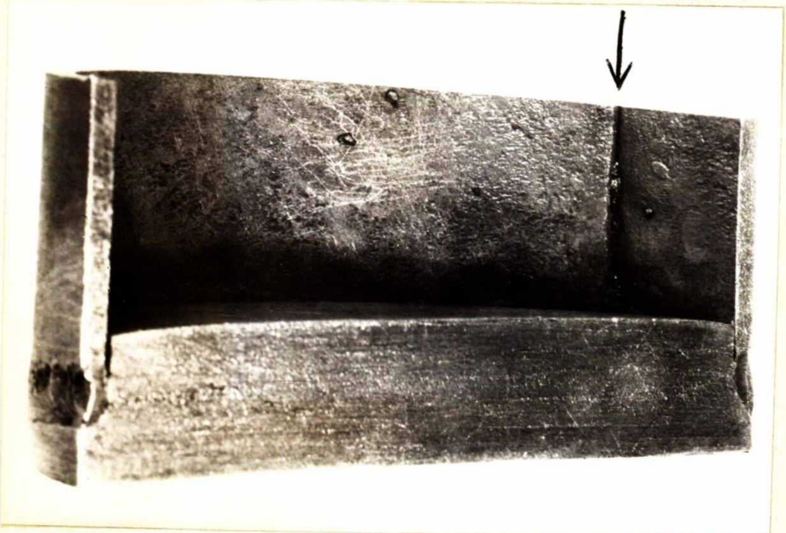
(1) too high a welding speed, or

(2) use of bare electrodes, which are difficult to control accurately.

Note undercutting at right.

(Approximately 3/4 actual size).

Figure 5.



INSIDE OF VERTICAL WELD OF CYLINDER WALL.

Note severe notch at root of weld.

(Approximately full size).

Figure 6.

X11½, nital etch.

POOR WELD IN WALL OF CYLINDER.

Note: (1) Porosity along fusion line, possibly resulting from improper joint cleaning prior to welding.

(2) Misalignment of edges to be welded, resulting in pronounced root notch.

(3) White upper portion is metal from thermite reaction.

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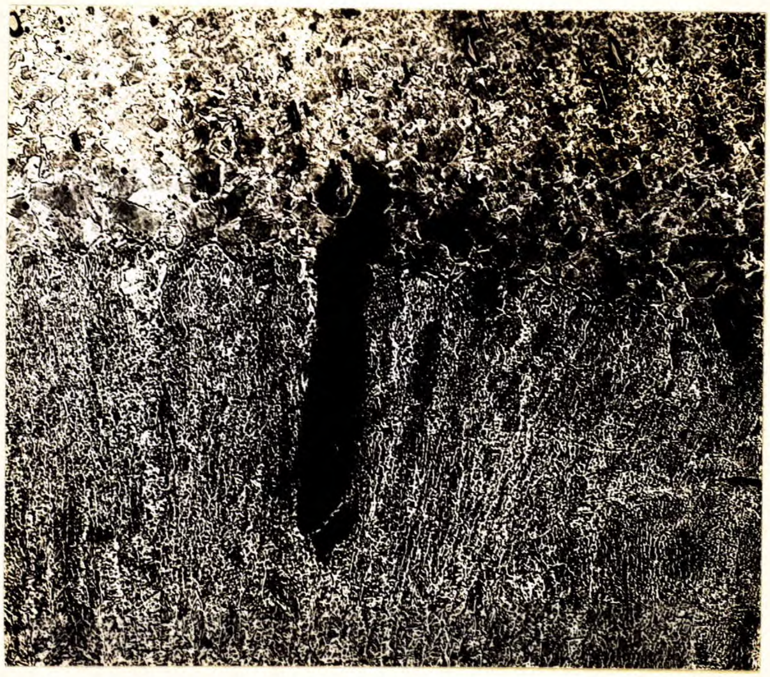
Figure 7.



X100, nital etch.

POROSITY AT JUNCTION OF WELD JOINING BASE PLATE TO CYLINDER WALL.

Note small cracks along fusion line, resulting from inclusions.

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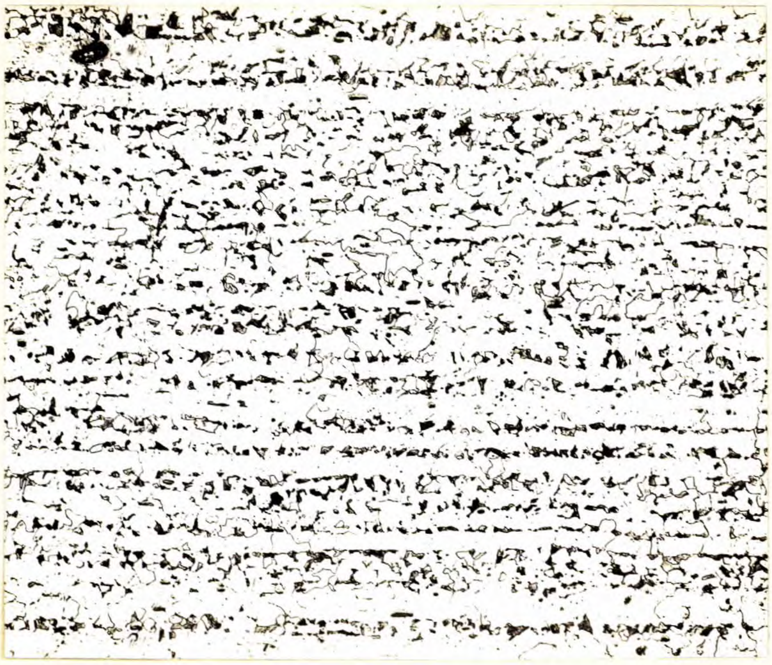
Figure 8.



X100, nital etch.

MICROSTRUCTURE OF CYLINDER BASE PLATE.

Ferrite and pearlite.

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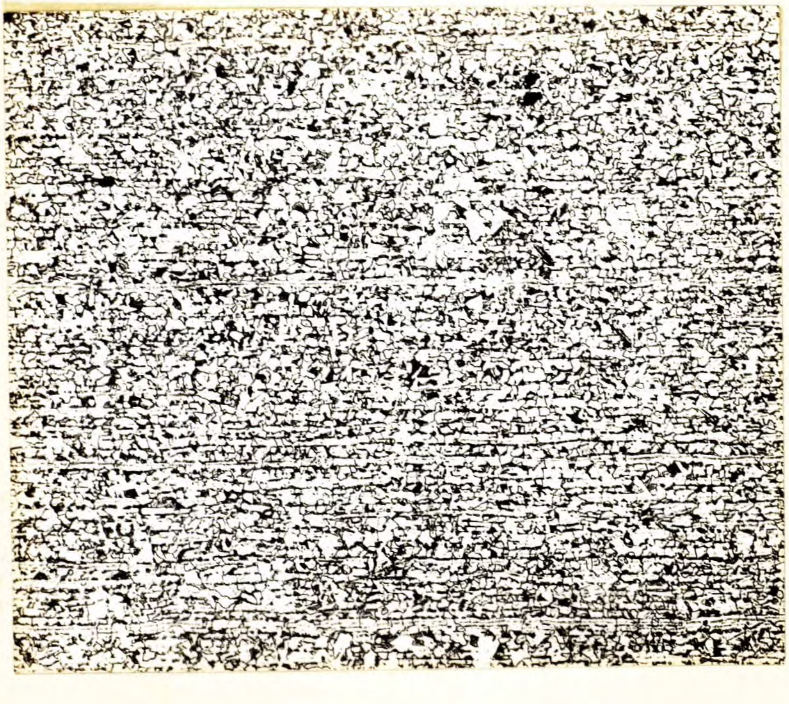
Figure 9.



X100, nital etch.

MICROSTRUCTURE OF CYLINDER WALL.

Ferrite and pearlite.

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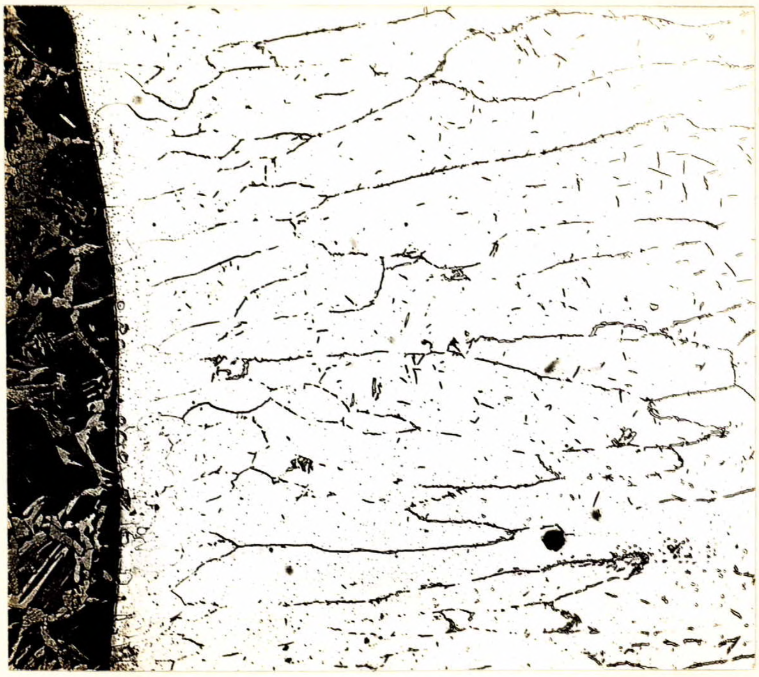
Figure 10.



X100, nital etch.

MICROSTRUCTURE OF THERMITE METAL
ADHERING TO WALL OF CYLINDER.

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