WATERTOWN ARSENAL LABORATORY

MEMORANDUM REPORT

NO. WAL 710/731

Metallurgical Evaluation of a Method of Anti-Personnel Defense for the Medium Tank M4A1

BY

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Final Report on Problem B-4.72

21 March 1945

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ABSTRACT

An anti-personnel device consisting of explosive-laden pipes attached to the side of the tank hull was found to damage the hull upon detonation. Cracks on the inside surface of the hull extending to a maximum depth of 0.4" and length of 6" were found directly behind and parallel to the anti-personnel device mountings. It is believed that these cracks will lower the resistance to subsequent impacts of armor piercing and high explosive projectiles. Damage to the armored vehicle may possibly be prevented by modifying the device by using a smaller charge or by changing to an explosive of lower brisance.

1. Reference basic communication - APG 451.21/374-2083(r), Wtn 451.25/191(r), 3 February 1945, metallurgical examination of a section cut from the cast armor hull of a Medium Tank M4A1, No. 3070871, has been completed.

2. According to the basic letter, the tank was used in conjunction with the development of a method of anti-personnel defense for combat vehicles. Lengths of 3/4" diameter pipe were welded to the sides of the hull and turret, loaded with explosives, and detonated. Photographs of the tank showing the details of attaching the pipe are shown in Figure 1. A strip of angle iron was welded into position between the two pipes attached to the hull presumably to prevent fragments resulting from the detonation of one pipe from perforating the other. "The first explosive loaded pipe detonated from this mounting created a definite concave niche in the tank armor. The second pipe detonated in the same location increased the concavity to a depth of approximately 1/16"."

3. A section was flame cut from the hull after the testing was completed and was submitted to this arsenal for examination to determine whether or not the ballistic qualities of the armor had been affected by either the welding of the angle iron to the hull or the explosions.

[redacted]

4. Examination of the submitted sample leads to the following conclusions and observations:

a. The ballistic qualities of the armor have been seriously affected by the detonations of the pipes. The inside surfaces of the hull immediately in back of the pipes were cracked to a maximum depth of 0.4", the cracks extending for a length of 6" under the upper pipe and 3" under the lower pipe.

b. It is not believed that the welding of the angle iron to the hull produced any deleterious effect upon the ballistic properties of the hull. The shallow penetration welds showed no cracking whatsoever in the armor base metal.

c. A fibre fracture test resulted in a completely fibrous fracture, indicating that the hull had been satisfactorily heat treated. The hardness of the hull was 248-255 Brinell. Radiographic examination, fracture testing, and macroetching all revealed the existence of a considerable amount of centerline shrinkage. (3B3 - Type B, Radiographic Spec. AXS-476 Appendix 2, Rev. 1).

5. The submitted section was approximately 10"x16" in size, varying in thickness from 2" at the lower end to 1½" at the upper end. The location of the section is shown in Figure 1 and a drawing showing its details is contained in Figure 2.

6. Tests conducted upon the submitted sample include the following:

a. Magnaflux.

b. Radiography.

c. Macroetch.

d. Fracture and hardness survey.

7. Details of the tests follow:

a. Visual Examination.

The appearance of the surface of the casting after two successive detonations of explosive laden pipes is shown in Figure 3. This region is in the vicinity of the upper pipe shown in Figure 1. The concave depression is approximately 1/16" deep. A photograph of the inside surface of the hull directly in back of the area contained in Figure 3 is presented in Figure 4. A crack approximately 1" in length is visible in the as-received condition. A considerable amount of the white paint covering the interior of the hull has been flaked off in the vicinity of the exploded pipes.

It is presumed that only one pipe was detonated in the lower position. The surface of the casting has been but slightly affected and no cracking of the back surface was visible in the as-received condition.

b. Magnaflux Inspection.

The area on the back of the casting behind the upper pipe was lightly sandpapered to remove the paint and scale after which the casting was magnafluxed using the dry powder method. Heavy indications developed over a total length of 6", see Figure 5. The region behind the lower pipe was similarly magnafluxed, exept that the surface received no prior sandpapering. Magnaflux indications covering a length of 3" developed in this region, see Figure 6. In both cases the magnaflux indications were directly behind and parallel to the explosive laden pipes.

c. Radiographic Examination.

The areas in back of both the upper and lower pipes were radiographed. Fairly extensive shrinkage (3B3 - Type B, Spec. AXS-476, Appendix 2, Rev. 1) was found throughout the submitted sample. The crack in the upper section of the casting was detectable on the X-Ray negative, but the cracks corresponding to the magnaflux indications on the lower portion of the sample could not be detected.

d. Macroetch Tests.

Eight sections approximately ½" wide and 8" long were machined from the casting in the areas containing the magnaflux indications, see Figure 2. After surface grinding, the eight sections were macroetched in a hot 50% hydrochloric acid solution for approximately 20 minutes. The appearance of the macroetched sections taken from the vicinity of the upper pipe is shown in Figure 7. Figure 8 contains photographs of the macroetched sections cut from the vicinity of the lower pipe. All of the macroetched sections reveal a considerable amount of centerline shrinkage. The white arrows in Figures 7 and 8 point to the cracks on the inside surface of the hull casting. These cracks are directly behind the area impacted by the force of the exploding pipes. The cracks behind the upper pipe are from 0.2" to 0.4" deep while those behind the lower pipe are from 0.2" to 0.3" deep.

Since the armor in the vicinity of the upper pipe is 1½" thick whereas in the vicinity of the lower pipe it is 2" thick, it is indicated that the upper portion of the hull would be more vulnerable to damage by the explosion of the anti-personnel device.

The photographs in Figure 8 show the details of the welds attaching the angle iron to the side of the hull. The welds consist of shallow penetration beads. In one case the weld bead is cracked, but no cracks were found in either the heat affected zone or the base metal of the armor. It is not believed that the welds, as made on the submitted sample, exert any deleterious effect upon the ballistic properties of the armor.

e. Fracture and Hardness Survey.

An 8"x6" section was cut from the sample, see Figure 2, and was notched and fractured by impact. The fracture was completely fibrous, with some centerline shrinkage visible on the fractured surface. It is concluded

that the subject casting was satisfactorily heat treated and possessed optimum resistance to shock.

A Brinell hardness survey conducted upon a section cut from the casting showed hardnesses of 248-255 BHN. This hardness range is considered representative of production armor of the thicknesses involved.

8. The tests described in paragraph 7 demonstrate that the hull has been damaged by the explosion of the anti-personnel device employed. Cracks of the type initiated would be expected to lower the resistance of the hull to subsequent impacts of armor piercing or high explosive projectiles. For safe performance, the anti-personnel device must consequently be modified to prevent damage to the vehicle upon which it is mounted. This may be accomplished either by reducing the amount of explosive charged into the pipes or by replacing the explosive by one of lower brisance.

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LOCATION OF SPECIMEN

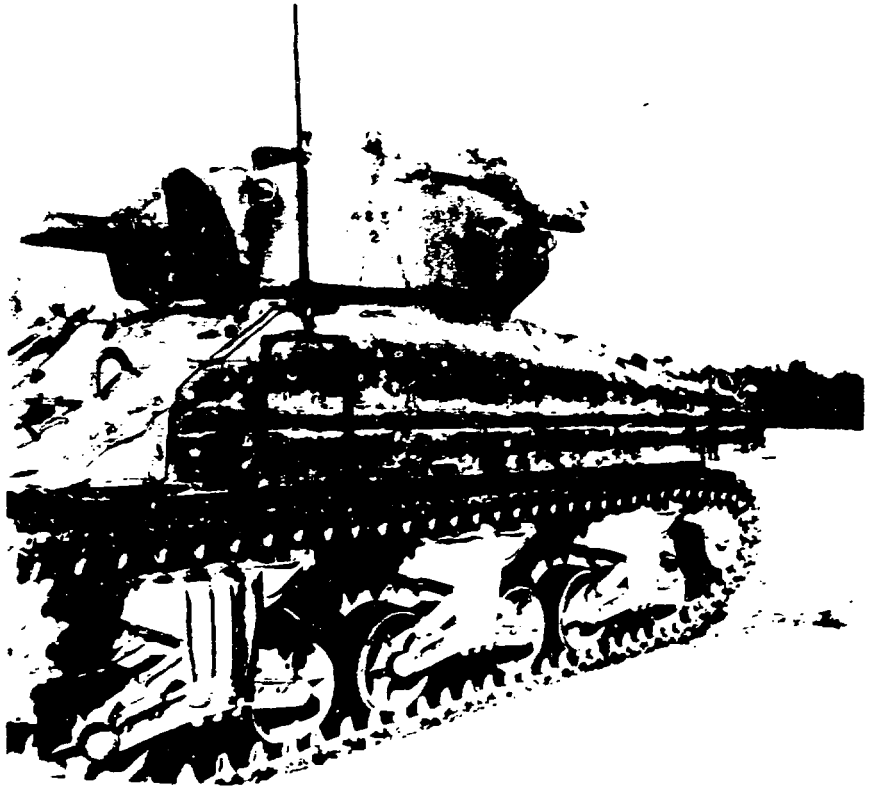
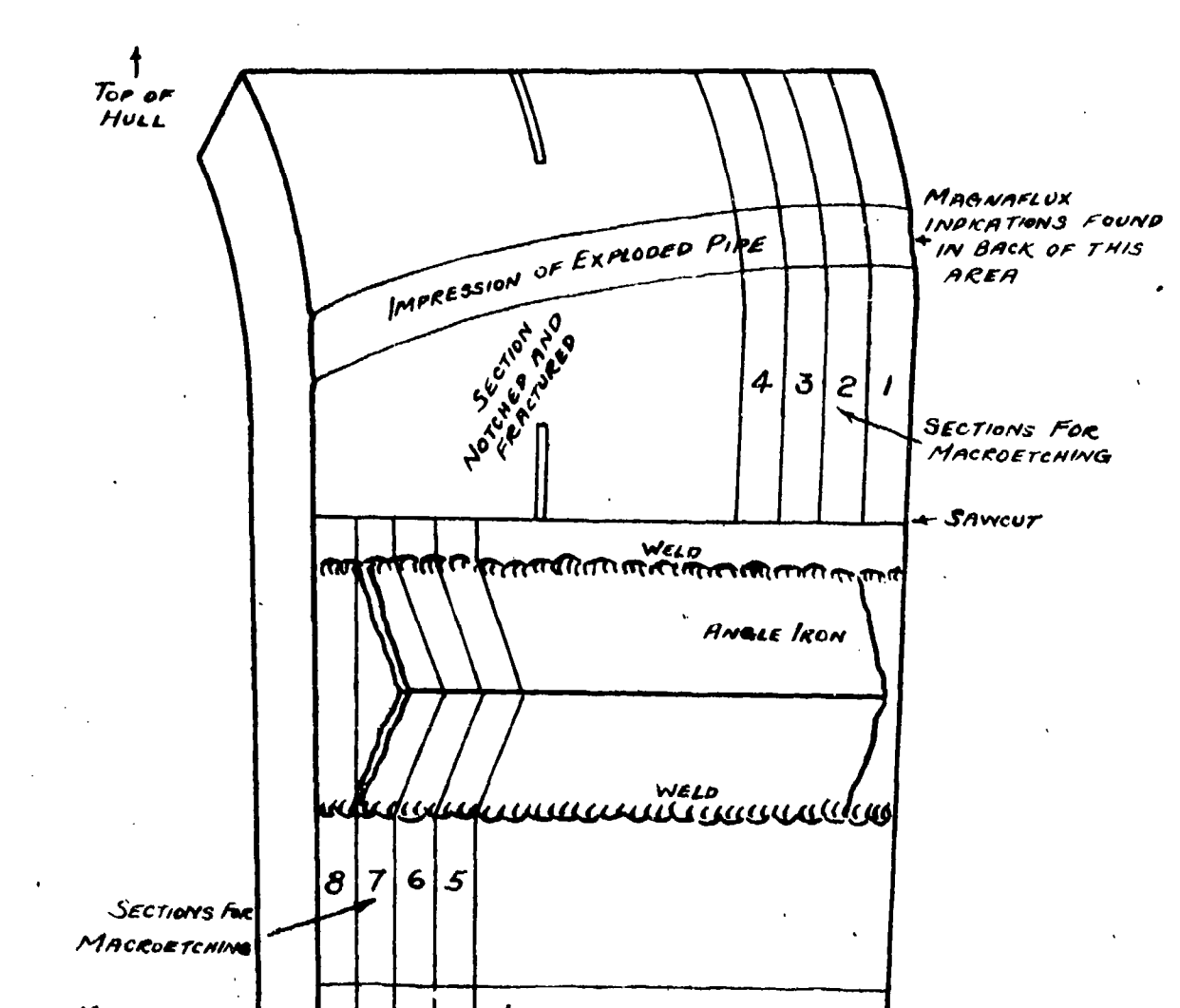


FIGURE 1

A19899 26 Jan 45	ABERDEEN PROVING GROUND	ORDNANCE DEPT

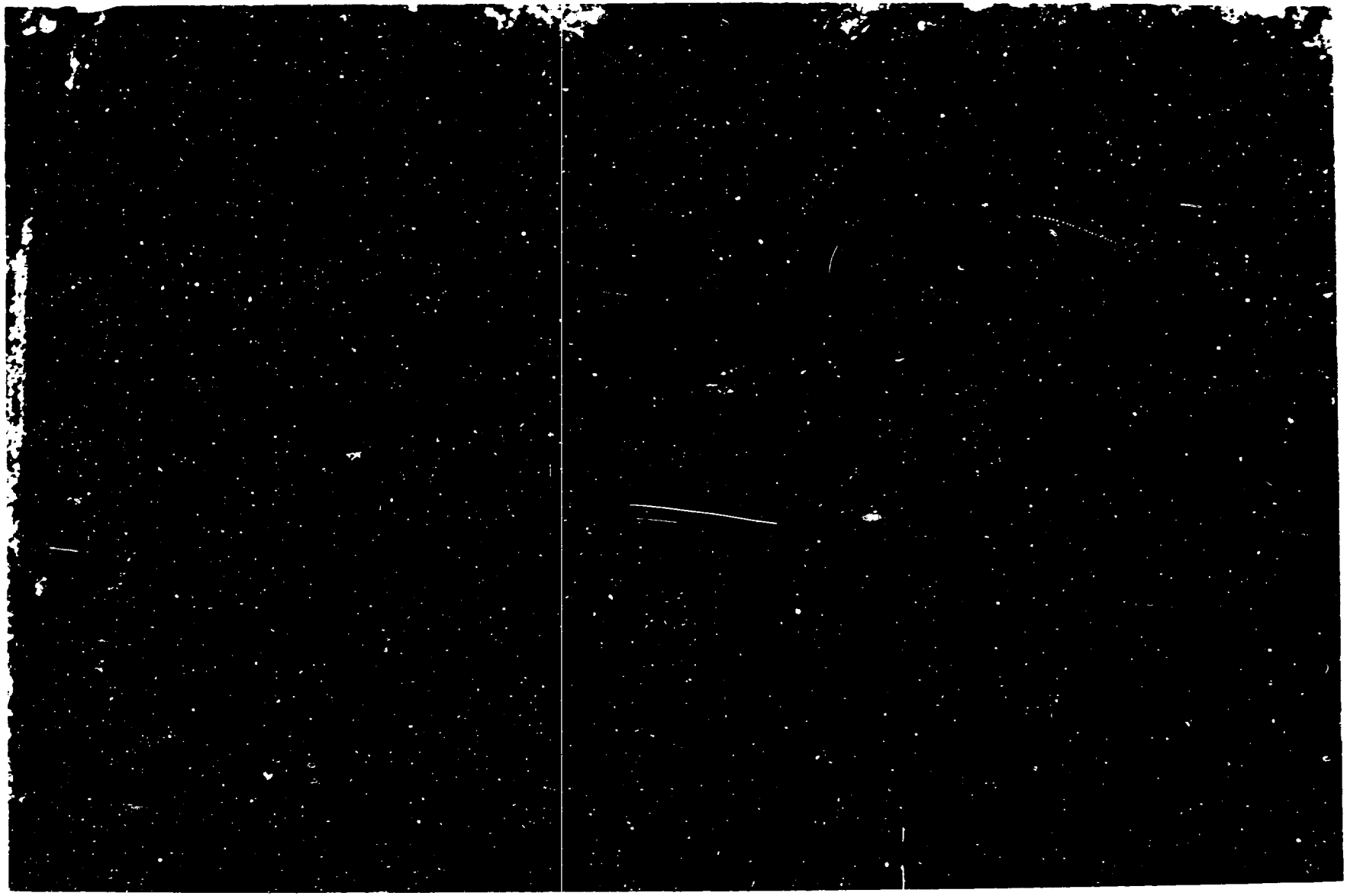
Project No. 5478/3-18-12. Explosive Pipe; Anti-Personnel Defense for Tanks. LEFT: Pipe held by modified triangular blocks and shielded by 3/8" thick angle iron. RIGHT: Close up of mounting.



SCALE: 1/3

SECTION OF CAST ARMOR HULL OF MEDIUM TANK M4A1 SUBMITTED FOR EXAMINATION.

FIGURE 2.



WATERTOWN ARSENAL

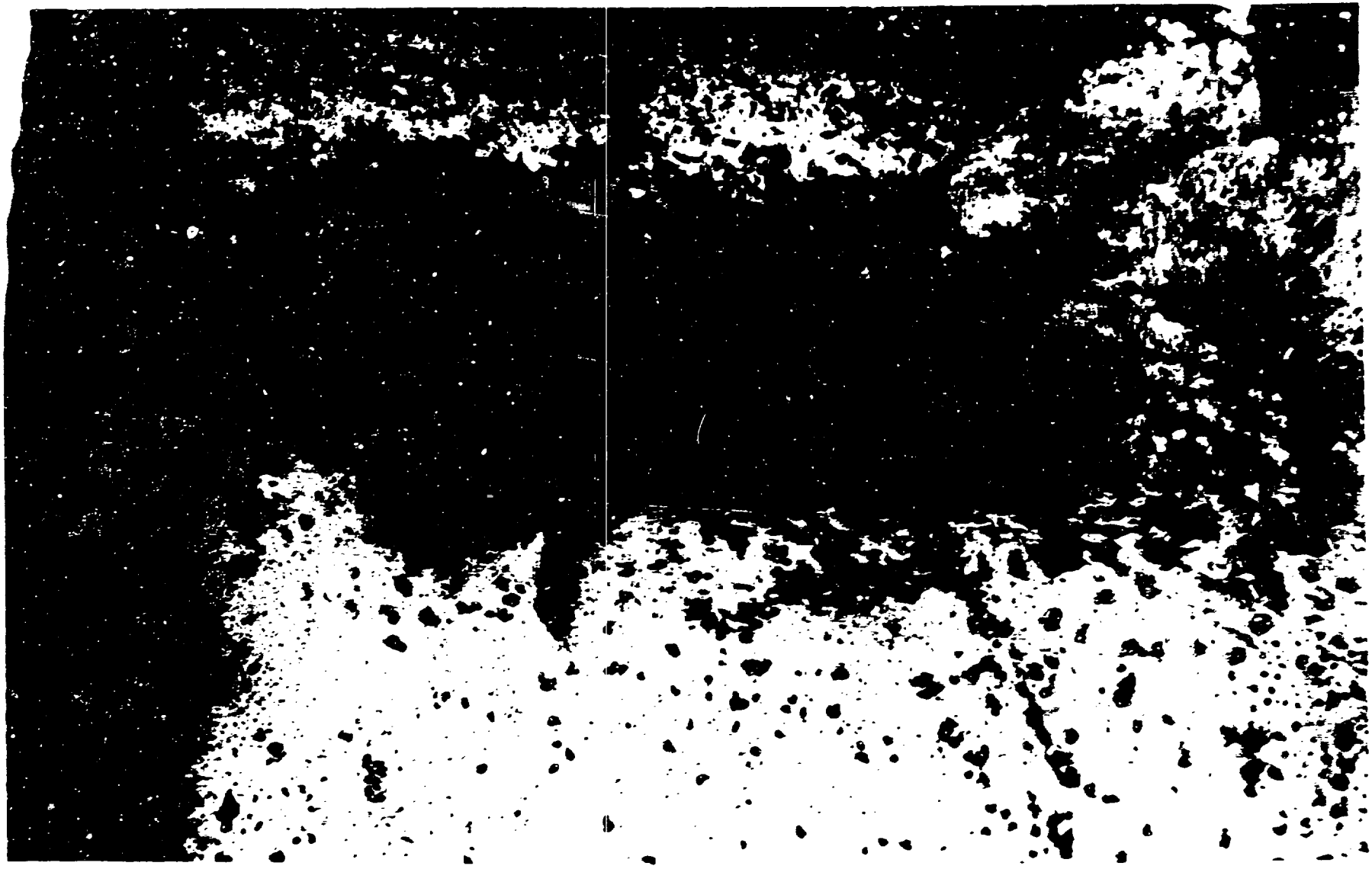
OUTSIDE OF HULL OF M4A1 TANK AFTER DETONATION. MAG. X 1
16 FEB 1945 WTN.710-2358

FIGURE 8

WATERTOWN ARSENAL

INSIDE OF HULL OF M4A1 TANK AFTER DETONATION. MAG. X 1
16 FEB 1945 WTN. 710-235W

FIGURE 4



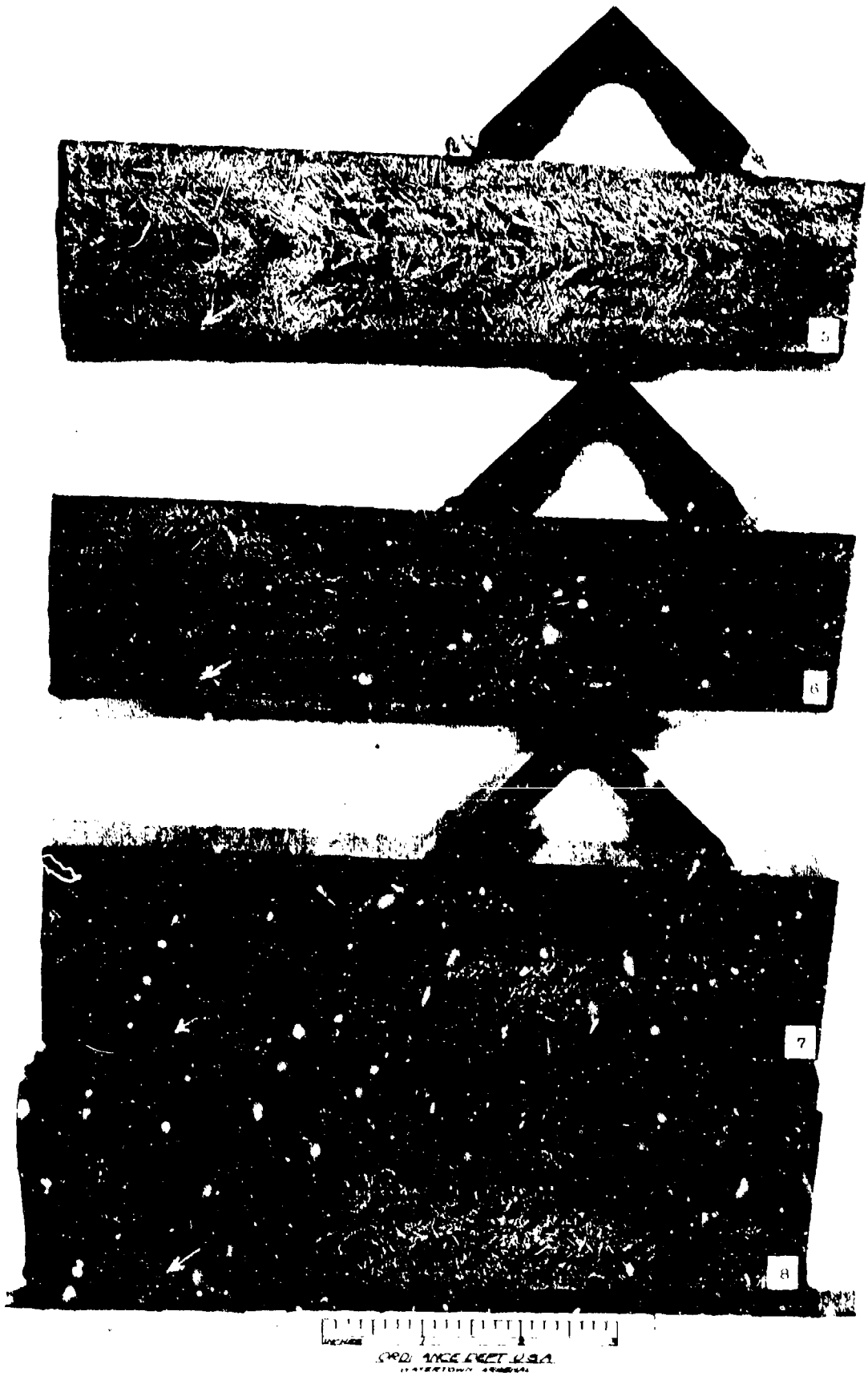
WATERTOWN ARSENAL

INSIDE OF HULL, SANDPAPERED AND MAGNAFLUXED, AREA BACK OF UPPER PIPE AFTER DETONATION
22 FEB 1945 RAB. X 1 WTN. 71C-2360

FIGURE 6

WATERTOWN ARSENAL

INSIDE OF HULL, MAGNAFLUXED, AREA BACK OF LOWER PIPE AFTER DETONATION, MAG. X 1
22 FEB 1945 WTN.710-2361



MACROETCHED SECTIONS OF M4A1 TANK HULL. AREA NEAR LOWEH DETONATED PIPE. ARROWS POINT TO CRACK ON INSIDE OF HULL. 28 FEB 1945 WTN.710-2363

FIGURE 9