RESTRICTED

Report No. 710/496

ARMOR PLATE

Metallurgical Examination of Laminated Aluminum Alloy German Aircraft Armor from a Messerschmitt ME-109 Plane

by

P. V. Riffin
Assistant Metallurgist

April 15, 1943

WATERTOWN ARSENAL
WATERTOWN, MASS.

Report No. 710/496
Watertown Arsenal
Problem B-40

April 15, 1943

ARMOR PLATE

Metallurgical Examination of Laminated Aluminum Alloy
German Aircraft Armor from a Messerschmitt ME-109 Plane

The object of this 1943 report

OBJECT

To make a metallurgical examination of the subject armor including a chemical analysis, hardness determination, physical tests, and microscopic examination.

SUMMARY OF RESULTS

1. The armor section consisted of a lamination of thirty (30) sheets of a high strength aluminum alloy held together by bolts. The individual sheets were of .025 inches thickness, equivalent solid thickness of the section being .735 inches.

2. The material is similar in analysis to high strength alloys used for aircraft skin coverings in this country. The ductility of the material appears to be inferior to that of the domestic product.

P. V. Riffin
Assistant Metallurgist

APPROVED:

H. H. ZORNIG
Colonel, Ordnance Dept.
Director of Laboratory

INTRODUCTION

Upon request[1] of the Office, Chief of Ordnance, an armor section from a German Messerschmitt ME-109 fighter airplane was forwarded to this arsenal from Aberdeen Proving Ground for metallurgical examination.

The armor section consisted of numerous, thin sheets of aluminum alloy bolted together to form a section approximately three quarters of an inch (3/4") in thickness. The section had been subjected to ballistic tests at The Proving Center with calibers .30 and .50 and 20 MM armor piercing projectiles. The results of ballistic tests have not been forwarded to this arsenal.

TEST PROCEDURE

Thickness measurements were made on each lamination. Sections were cut from two of the sheets in both the longitudinal and transverse directions for physical tests. Chemical analysis was also determined on the same two sheets together with a microscopic examination.

RESULTS AND DISCUSSION

1. Visual Examination

The section was composed of thirty (30) sheets of aluminum alloy, each sheet being .024-.025 inches in thickness. The average overall thickness was .813 inches. The equivalent solid thickness (based upon a calculation .0245 x 30) would be .735 inches. The section was held together by a series of steel bolts around its circumference.

No markings were stamped on the section. Photographs of the front, rear, and a side view showing the laminations appear as Figures 1, 2, and 3 respectively. The individual sheets were obviously blanked out of an aluminum alloy sheet of a type probably used as a skin covering in German aircraft construction.

2. Chemical Analysis

Results of the chemical analysis are as follows:

	Sheet 1	Sheet 2
Mn	.49%	.59%
Fe	.51	.40
Si	.51	.30
Cu	3.44	3.53
Mg	.72	.72
Al (by difference)	94.33	94.51

1. O.O. 350.05/2378, see Appendix A.

The analyses are quite comparable to those of high strength aluminum alloy sheet materials used in this country such as the 17ST and 24ST types. The analysis most resembles that of the 17ST alloy. The iron content is probably an impurity.

3. Hardness Tests

The average Superficial Rockwell hardness using a 30 N load is 64. This value converts to a Brinell hardness of 112, which is comparable to the usual hardness values of 17ST or 24ST alloys.

4. Physical Tests

Physical test values on sheets 1 and 2 were determined in both the longitudinal and transverse directions as follows:

(Specimen Size - 1" wide x 2" gauge.)

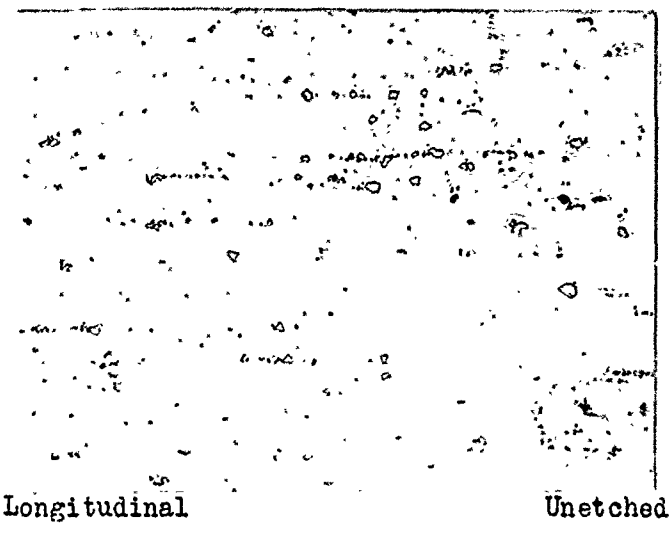
	Sheet 1		Sheet 2	
	Tensile Strength Pounds/Sq. In.	% Elong.	Tensile Strength Pounds/Sq. In.	% Elong.
Longitudinal	55,200	8.5*	55,500	12.0*
Transverse	38,000	1.5*	48,000	4.5*

*Broke outside gage markers.

The tensile test values are essentially equivalent to those obtained on the 17ST type of alloy, but, on the other hand, the ductility characteristics appear to be inferior, especially in the transverse direction. These elongation results must not be considered an accurate measure of the ductility, since the specimens fractured at the end of the gauge length in every case.

5. Microstructure

A typical field showing the microstructure at X100 appears below:



Longitudinal Unetched

The intermetallic compounds visible are of two types and have a slightly bluish tint. According to the procedure of Dix and Keller,[2] these compounds are identified as follows:

[redacted]
Phase - Al-Cu-Fe-Mn
Phase - $CuAl_2$

Microscopic examination revealed a uniform structure with small amounts of impurities present.

High physical properties are obtained in such alloys by a precipitation hardening process. The material is heated after final rolling to a temperature of approximately 925°F and then quenched in water. This constitutes the solution heat treatment. Subsequently the material will harden with time by the precipitation of intermetallic compounds. In these samples the size of the intermetallic compounds is comparatively large, indicating that the material was probably artificially aged at some temperature such as 225°F.

6. General Considerations

From the shape of the armor section, it is concluded that the material as installed in the aircraft was used for the purpose of protecting the instrument panel and pilot and was mounted forward and above the back side of the instrument panel (notice the numerous cutouts as shown in Figure 1).

Such a material would have poor ballistic properties at near-normal impact. Under high obliquity impact or under impact of yawed projectiles, however, its performance would probably be equivalent or better than steel of comparable weight. The reason for using the great number of thin sheets is not known, but it is felt that this was probably an expediency. It is probable that this section was added to the original design as additional protection and the simple solution consisted of forming the section from multiple sheets of an aluminum alloy available in the aircraft factory.

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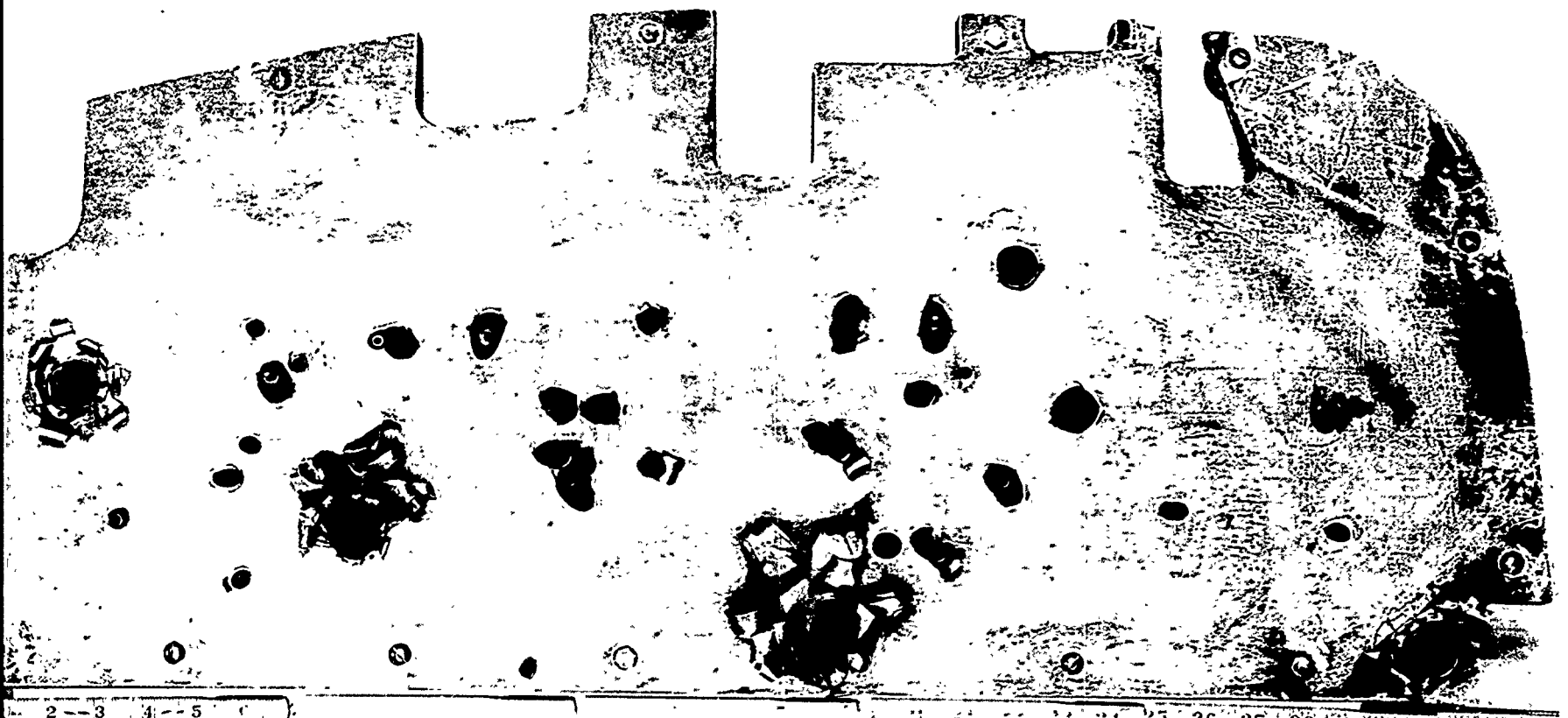
2. E. H. Dix and F. Keller, "Etching Aluminum for Metallographic Examination", Metals Handbook, 1939 Edition, Pages 1290-1294.

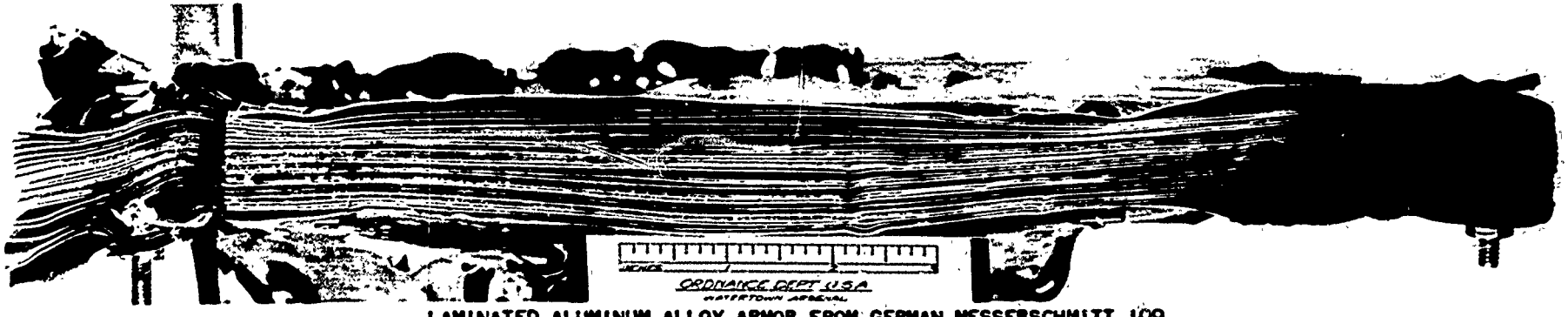


WATERTOWN ARSENAL

LAMINATED ALUMINUM ALLOY ARMOR FROM GERMAN MESSERSCHMITT 109
MARCH 25 1943 FRONT VIEW WTN.710-2054

WATERTOWN ARSENAL

LAMINATED ALUMINUM ALLOY ARMOR FROM GERMAN MESSERSCHMITT 109
MARCH 25 1943 BACK VIEW WTN.710-2055



LAMINATED ALUMINUM ALLOY ARMOR FROM GERMAN MESSERSCHMITT 109
MARCH 25 1943 SIDE VIEW WTN.710-2056

FIGURE 3

APPENDIX A

COPY

WAR DEPARTMENT
OFFICE OF THE CHIEF OF ORDNANCE
WASHINGTON

Peterson/mks

December 10, 1942

O.O. 350.05/2378
SPOTB - Intel.

386.3/150

Subject: Transfer of Foreign Ordnance Materiél

To: The Director
The Proving Center
Aberdeen Proving Ground, Md.

Attn.: Major C. B. Speir
Foreign Materiél Section

1. It is requested that item FMPL-12, Plate, Armor, head piece from back of seat in Macchi-202 Plane be subjected to standard ballistic tests and when this is completed the armor should be sent to Watertown Arsenal for complete metallurgical analysis. This has been requested by the Aircraft Armament Development Branch.

2. It is also requested that photographs be taken of items FMMISC-29 Vision block for tank and item FMMISC-30 Vision glass from Mk. IV Tank. It is also requested that dimensional drawings be made of these two items.

3. This will confirm order given over the telephone to ship one piece of the armor plate from the Mk III Tank to Battelle Institute, Columbus, Ohio, for metallurgical examination.

By Order of the Chief of Ordnance:

/S/ K. E. Peterson
for E. S. Davis
Capt., Ord. Dept.
Assistant

COPY

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Behrens/msc

December 17, 1942

Major G. B. Speir, Foreign Materiel Branch

Mr. Harry J. Rouse, Armor Plate Section thru Colonel G. G. Eddy

Test of Foreign Armor Plate

1. In accordance with the attached letter, it is requested that item FMPL-12 mentioned therein be subjected to standard ballistic tests and that twenty copies of the report on such tests be submitted to the Foreign Materiel Branch.

2. Preceding the ballistic tests, it is requested that a general photograph of the plate be taken.

3. Following these tests and as soon as sufficient data has been accumulated to complete the report, it is requested that the plate be shipped, as quickly as possible, to Watertown Arsenal for metallurgical analysis and that this analysis be included with the report.

4. Work Order No. 327-3 may be used in connection with the test on this item.

5. The plate is at present in the possession of the Foreign Materiel Branch and is immediately available.

C. B. SPEIR
Major, Ord. Dept.
OC Foreign Materiel Branch

COPY

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WAR DEPARTMENT
The Proving Center
ABERDEEN PROVING GROUND

Armor Plate Branch
Fisher/mhc
January 13, 1943

386.3/172

Subject: Foreign Materials

To: The Commanding Officer
Watertown Arsenal
Watertown, Massachusetts

Attention: Capt. N. A. Matthews

1. A section of Italian armor plate and a section of German armor upon which have been conducted firing tests by the Armor Plate Branch of this office are being forwarded to you under separate cover, shipping order 9660.

2. In accordance with the attached letters, it is requested that a metallurgical analysis be made of these plates and that information so obtained be furnished to this office.

For the Commanding General:

/S/ M. J. Zweig
Capt., Ord. Dept.

(G. G. EDDY
for (Col., Ord. Dept.
(Assistant

2 Inclosures
Copy of Memo., Dec. 17, 1942
Copy of Ltr., O.O., Dec. 10, 1942

COPY