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OTTAWA December 12th, 1944.

REPORT

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1756.

Effect of Risers on Magnesium
(ASTM-4) Test Bar Properties.

(This is P.M.R.L.)
(Foundry Research)
(Report No. 1.)

(Copy No. 10.)

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

CANADA,
DEPARTMENT
OF
MINES AND RESOURCES
Mines and Geology Branch

O T T A W A December 12th, 1944.

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Effect of Risers on Magnesium (ASTM-4) Test Bar Properties.

Abstract

ASTM-4 magnesium alloy was cast into test bars. The risers at each end of the bar were varied in size and the effects on strength were noted.

Introduction:

Cast magnesium alloys are susceptible to a phenomenon called microshrinkage which is not usually found in ferrous metals. Shrinkage in cast ferrous metals leaves a void or a number of voids which are due to the liquid shrinkage as the metal solidifies in the mould. Shrinkage areas in the magnesium are porous and spongy in nature, and are identified as cloudy areas on the X-ray. It is generally believed that microshrinkage of magnesium alloys is partly due to inherent characteristics of the metal, partly induced

(Introduction, cont'd) -

in melting, and partly due to the liquid shrinkage during solidification.

The object of this investigation was to determine the effect of risers on the soundness of magnesium test bars. Risers were designed to eliminate liquid shrinkage during solidification. By varying the size of risers, their effects were observed.

Pattern:

Figure 1 shows the pattern used.

Figure 1.

TWO VIEWS OF CASTING FROM EXPERIMENT NO. 9.

The area at bottom of sprue is 1.77 sq. in. Total area of gates is 0.39 sq. in. This provides a "choke" to keep the sprue full.

The overall length of test bars is 6¼ inches. The large ends are 0.75 inch in diameter. The part of the bar that is gauge-marked is 4 inches long and 0.500 inch in diameter.

Method:

The size of the risers was changed by cutting off the tops of the pattern as shown in Figure 2.

Figure 2.

Experiment No.:- 1 2 3 4 5 6 7

Risers used on left side of pattern.

The risers on the right side of the pattern remained unchanged. The risers on the left side were altered as follows:

Experiment No.	Weight of riser, ounces	Height of riser, inches	Remarks
1	$18\frac{3}{4}$	5	Left and right sides identical.
2	16	$3\frac{1}{8}$	Right side unchanged.
3	$13\frac{1}{2}$	$2\frac{1}{8}$	" " "
4	$10\frac{1}{2}$	$1\frac{1}{8}$	" " "
5	7	$\frac{3}{4}$	" " "
6	$4\frac{1}{2}$	7/16	" " "
7	3 1/3	7/16	" " "
8	0	0	" " "
9	0	0	Gate on left side reduced 50% in area.
10	$18\frac{3}{4}$	5	Right side unchanged, riser on left side placed at end of bars opposite gate (see Figure 5).

Melting Procedure:

A typical log of furnace operations is as follows:

Elapsed time, minutes	Operation	Remarks
0	40 pounds magnesium charged. 20 pounds new, 20 pounds scrap.	Furnace hot; crucible at red heat; layer of flux on bottom of crucible.
25	Charge melted down, scale cleaned off pot, slag removed. New flux.	
65	One minute stirring at 1350° F.	
85	Heat to 1650° F.	
100	Remove from furnace; pour at 1400° F.	

Dow 310 flux was used. Melting was carried out in a gas-fired Fisher crucible furnace.

Typical Analysis of Metal:

Chemical Analysis of 4X Alloy -

		Per Cent
Aluminium	-	5.00
Zinc	-	2.30
Manganese	-	0.18
Copper	-	0.004
Sulphur	-	0.03
Iron	-	0.012

Moulding Sand:

Moisture	-	5.0 per cent.
Permeability	-	60.
Bond	-	5.0-6.0 pounds (per sq. in.).
Resilience	-	0.020 inch.
Sulphur	-	3.30 per cent.
Boric acid	-	0.60 "
Sulphite and sulphide		0.30 "
Diethylene glycol		0.60 "

—

Mechanical Properties:

Each mould contained two test bars for controls and two test bars with experimental risers or gating. In each experimental heat five or more moulds were poured. No test bar was scrapped for foundry defects, such as blows, dirt, oxide, etc., as it was felt that if the effects of risers were to be studied all of the test bars should be included. The inclusion of foundry scrap, of course, lowers the average mechanical properties. The average ultimate strength and elongation of all of the test bars are shown in Figures 3 and 4.

(Figures 3 and 4 appear on Page 6.)

After Experiment No. 3 the "left" bars seem to be definitely lower in strength and elongation than the "control" bars.

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Reducing Gate Area:

In Experiment No. 9 the area of the gate was reduced to 50 per cent of its former cross-section, that is, from 0.195 to 0.100 sq. in. This had the effect of further lowering the mechanical properties.

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Effect of Volume of Metal Flowing Through:

In Experiment No. 10 a riser of the same size as that used on the control bars was placed at the end of the experimental bars opposite the gate (see Figure 5, on Page 7). No riser was placed at the end of the bars next to the gate. These experimental bars all broke at the end next to the gate, and had low mechanical properties. The volume of metal flowing

(Text continues on Page 7)

A.S.T.M. 4 MAGNESIUM - AVERAGE PHYSICAL PROPERTIES

FIG. 3

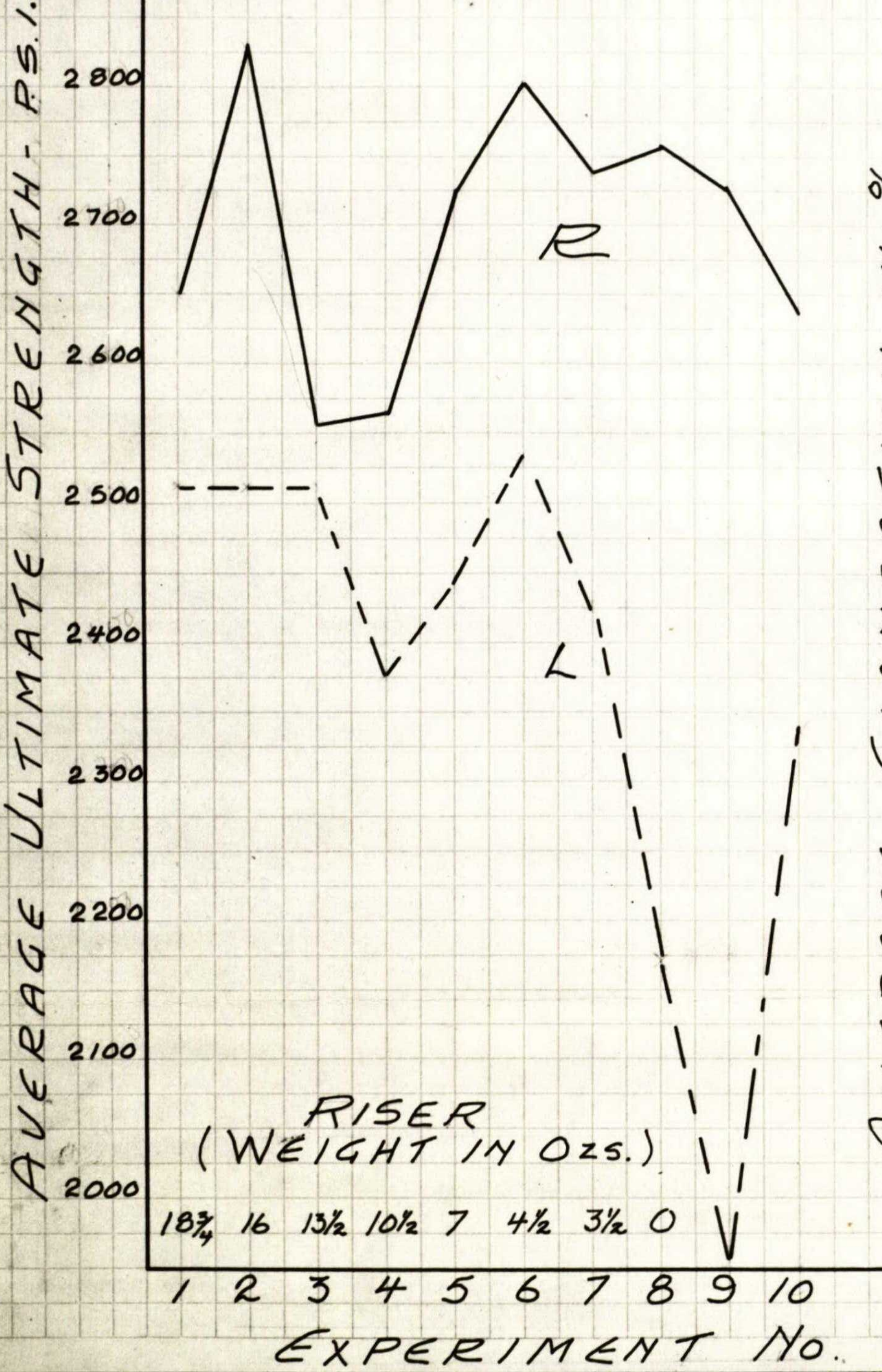
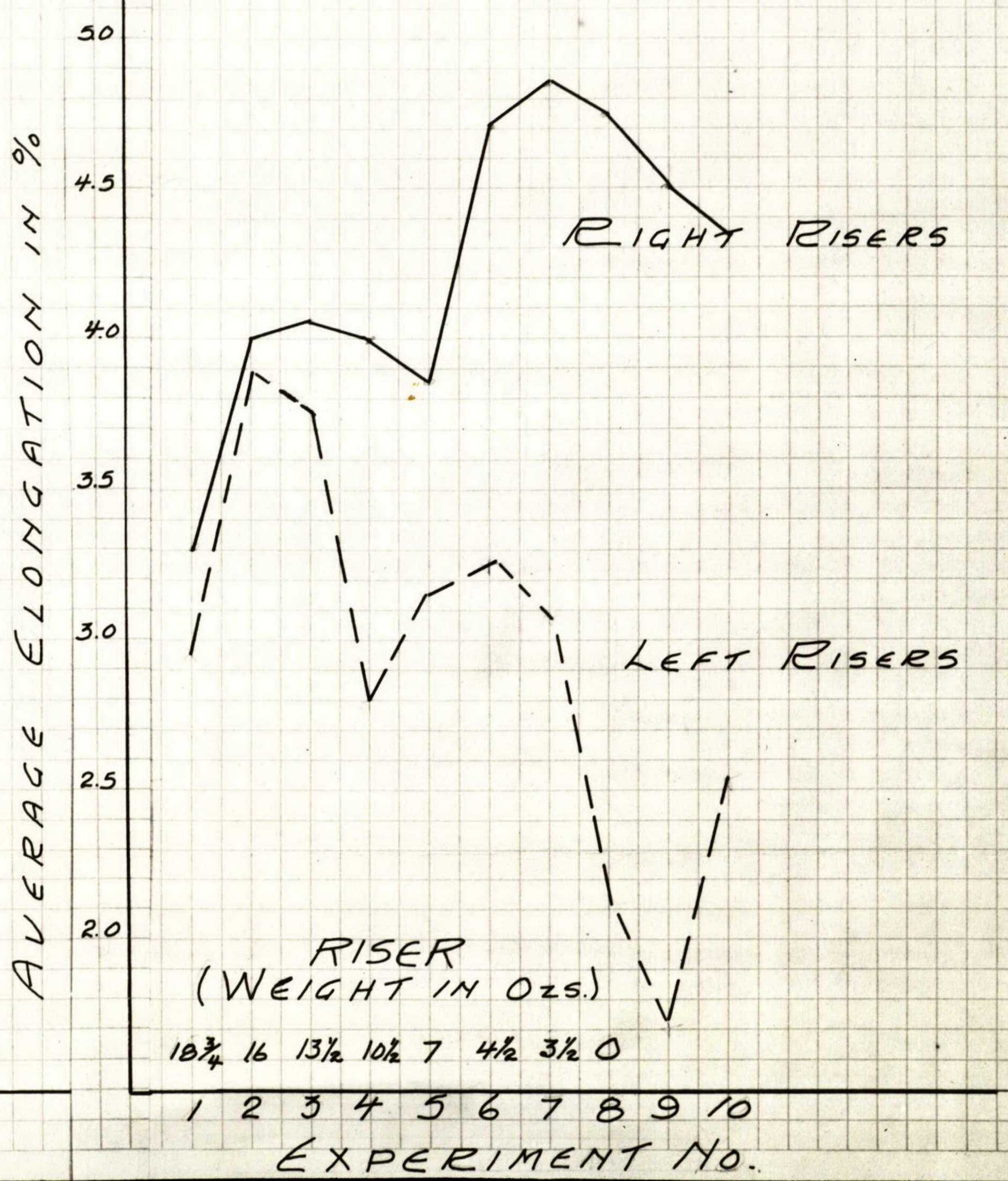


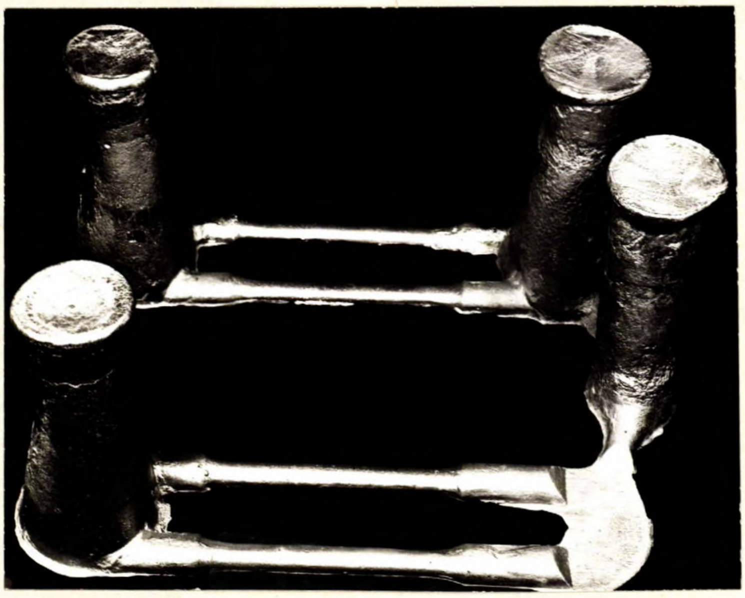
FIG. 4



(Effect of Volume of Metal Flowing Through, cont'd) -

through would therefore seem to be of little importance if adequate feeding is not supplied.

Figure 5.



A CASTING FROM EXPERIMENT NO. 10.

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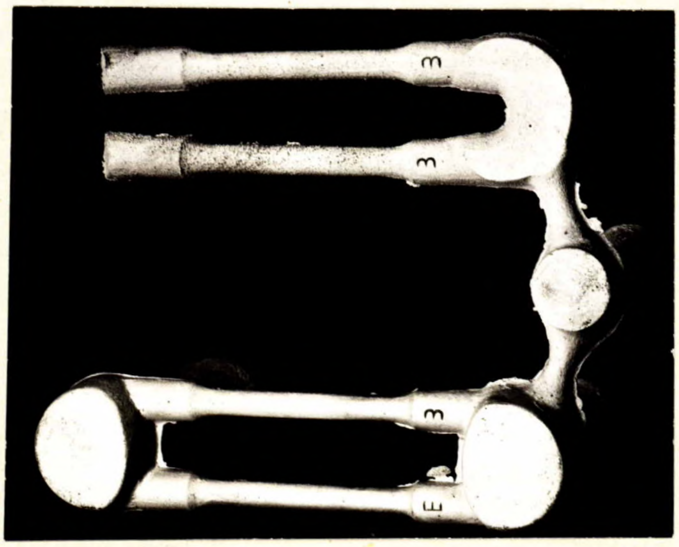
As Figure 6 shows, volume of metal flowing through affects surface finish. The more metal flowing through, the better is the finish on the casting.

Figure 6.



EFFECT OF VOLUME FLOWING THROUGH
ON SURFACE OF CASTING.

Note that the side without risers is very rough.
Where risers are used the bar is much smoother.

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DISCUSSION:

From the tests carried out it would seem evident that the soundness of Magnesium Alloy 4X castings was dependent in part upon proper gating and risering. A riser of a certain size is necessary for a sound casting.

Since the "controls" varied from heat to heat it would appear that other variables, unaccounted for, also affected the soundness of test bars.

The control bars contained very few defects such as slag, oxide, blow-holes, shrinkage. In the experimental bars, however, these defects were very frequent.

Figure 7 shows the relationship between tensile strength and elongation in the test bars made in this investigation. When low tensile corresponds to low elongation, it is assumed that the low mechanical results are due to unsound metal. When low tensile corresponds to high elongation, the variations in physicals are attributed to structural changes in the metal. A better feeding action could have been obtained if the test bar section had been less than 4 in. in length. This long cylindrical shape probably solidifies before proper feeding can occur, even when large risers are used.

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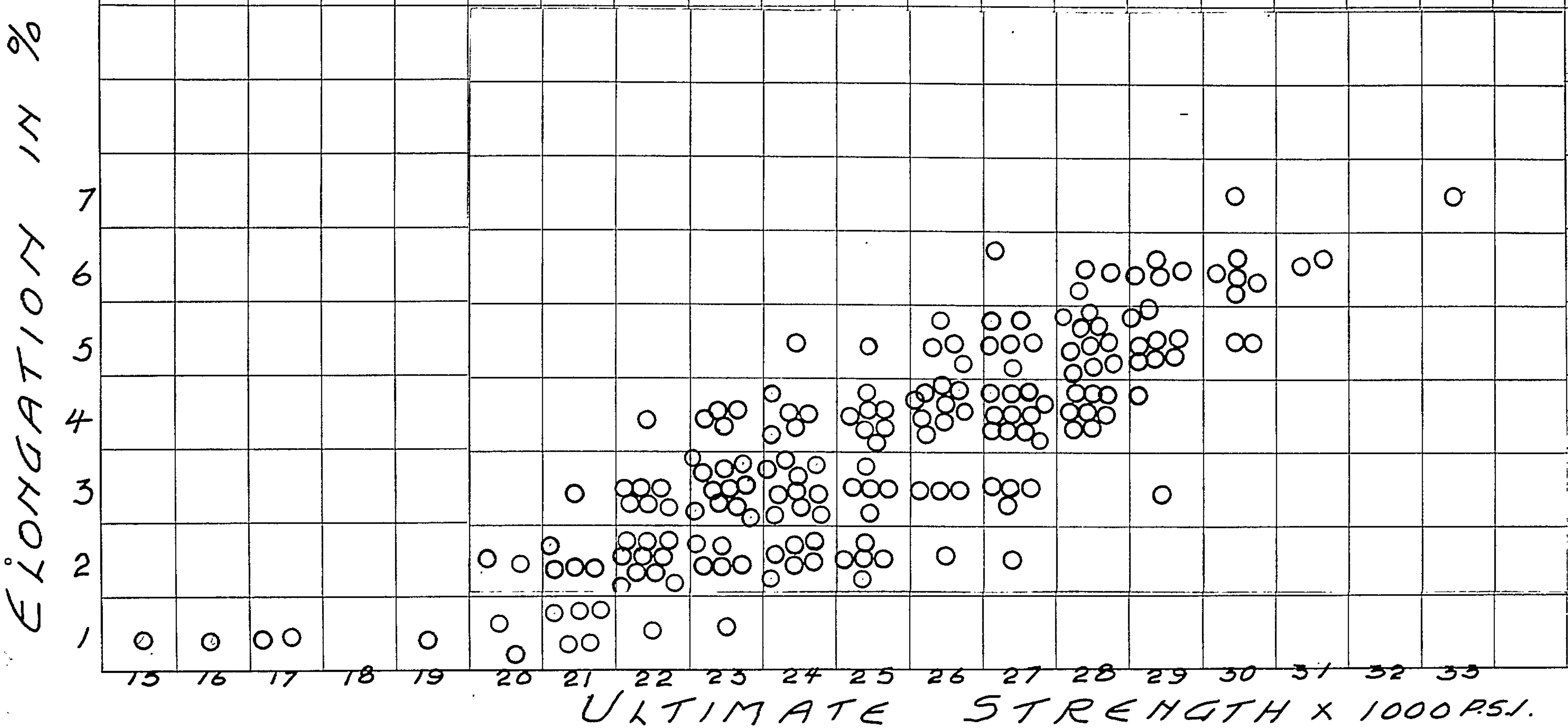
(Figure 7 appears on Page 9.)
(Pages 10 to 14 comprise an appendix containing further statistical data.)

FIG. 7

PHYSICAL PROPERTIES OF A.S.T.M. 4 MAGNESIUM — CAST WITH RISERS OF VARIOUS SIZES.



(Page 9)

APPENDIX.

FURTHER DATA ON PHYSICAL TESTS.

The following is a typical statistical analysis of test data. The data are elongations from Experiment No. 10.

Symbols Used;

$\bar{X}$	=	Average.
Σ	=	The sum of.
σ	=	Standard deviation.
$\sigma_{\bar{x}}$	=	Standard error of average.
t	=	Significance of difference between averages.
N	=	Number of test results.

SINGLE RISER		CONTROL BARS	
Elongation observed	Elongation, squared	Elongation observed	Elongation, squared
1.5	2.25	5	25
2.5	6.25	5	25
2.0	4	3.5	12.25
4.0	16	5	25
2.5	6.25	3.5	12.25
2.0	4	4.5	20.25
4.0	16	5.5	30.25
3.5	12.25	5.0	25
3.5	12.25	5.0	25
2.0	4	1.0	1
1.0	1	3.5	12.25
3.0	9	4.5	20.25
3.0	9	6.0	36
2.0	4		
36.5	106.25	57.0	269.50
N = 14		N = 13	

Single Risers	Control
Average elongation	Average elongation
$\bar{X}$ = 2.6 per cent	$\bar{X}$ = 4.38 per cent

In order to answer the question, Is the above difference significant? the value of t must be found.

(Continued on next page)

(Appendix, cont'd) -

$$t = \frac{\bar{X}_1 - \bar{X}_2}{\sqrt{\sigma_{\bar{x}_1}^2 + \sigma_{\bar{x}_2}^2}} = \frac{1.78}{\sqrt{\sigma_{\bar{x}_1}^2 + \sigma_{\bar{x}_2}^2}}$$

Single Risers

$$\sigma_{\bar{x}} = \frac{\sigma}{\sqrt{N}}$$

$$\sigma = \sqrt{\frac{\Sigma(X^2)}{N} - \bar{X}^2}$$

$$\sigma = \sqrt{\frac{106.25}{14} - 2.6^2}$$

$$\sigma = \sqrt{.845}$$

$$\sigma = .92$$

$$\sigma_{\bar{x}} = \frac{.92}{\sqrt{14}}$$

$$\sigma_{\bar{x}} = .246$$

Control

$$\sigma_{\bar{x}} = \frac{\sigma}{\sqrt{N}}$$

$$\sigma = \sqrt{\frac{\Sigma(X^2)}{N} - \bar{X}^2}$$

$$\sigma = \sqrt{\frac{269.5}{13} - 4.38^2}$$

$$\sigma = \sqrt{1.55}$$

$$\sigma = 1.244$$

$$\sigma_{\bar{x}} = \frac{1.244}{\sqrt{13}}$$

$$\sigma_{\bar{x}} = .345$$

$$t = \frac{\bar{X}_1 - \bar{X}_2}{\sqrt{\sigma_{\bar{x}_1}^2 + \sigma_{\bar{x}_2}^2}} = \frac{4.38 - 2.6}{\sqrt{.246^2 + .357^2}} = \frac{1.78}{\sqrt{.188}}$$

$$t = \frac{1.78}{.434} = \boxed{4.1}$$

Since t is greater than 3,* the difference observed between average elongations in Experiment No. 10 is significant. From this experiment it can be concluded that risers at each end of the bar are definitely better than a riser at one end only.

The following charts show the standard deviations obtained in each experiment:

(Figures 8 and 9 appear on Pages 12 and 13.)

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* APPLIED GENERAL STATISTICS, by F. E. Croxton and D. J. Cowden. Published by Prentice-Hall, Inc., New York, 1940.

FIG. 8

A.S.T.M. 4 - MAGNESIUM PHYSICAL PROPERTIES
STANDARD DEVIATIONS

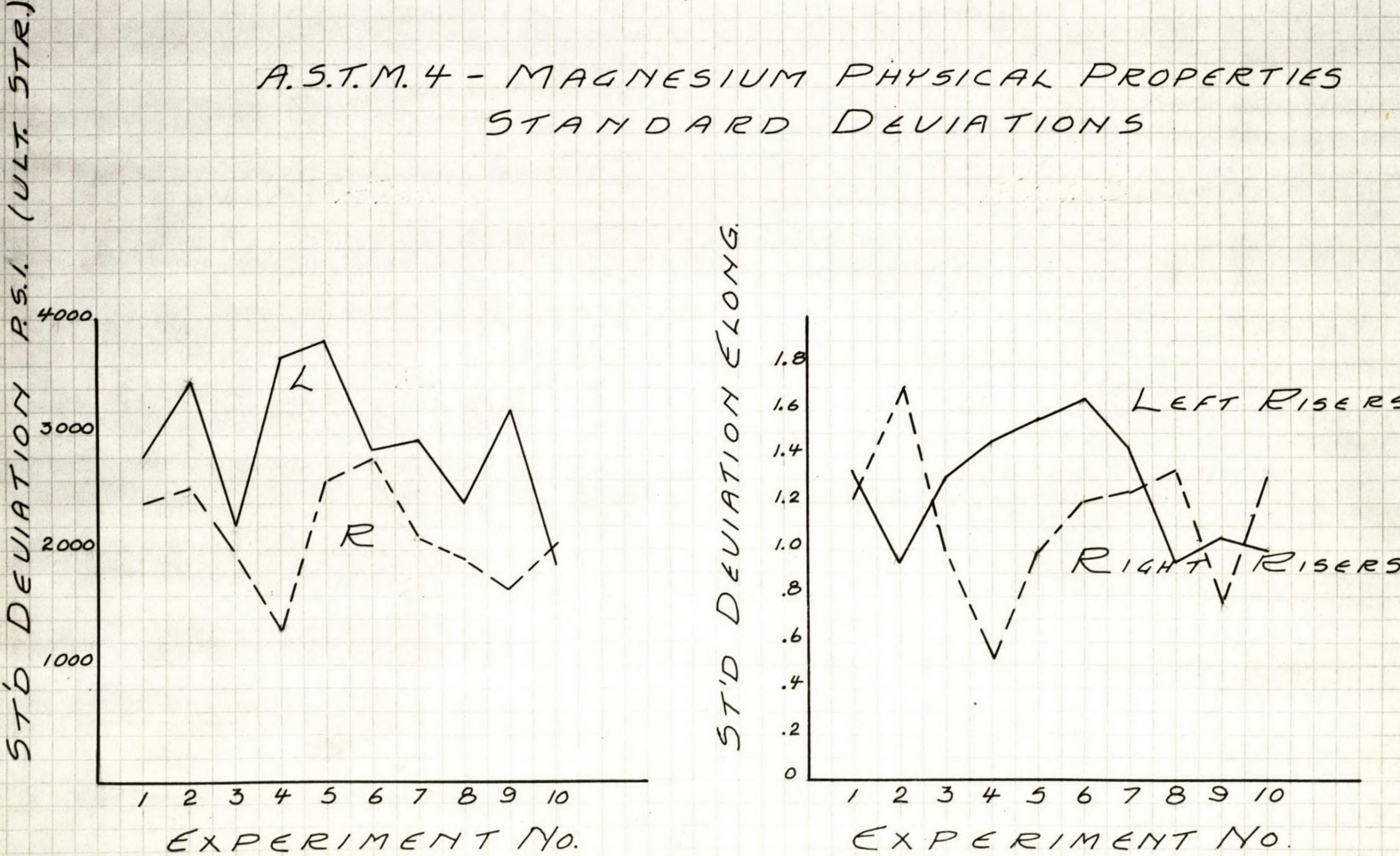
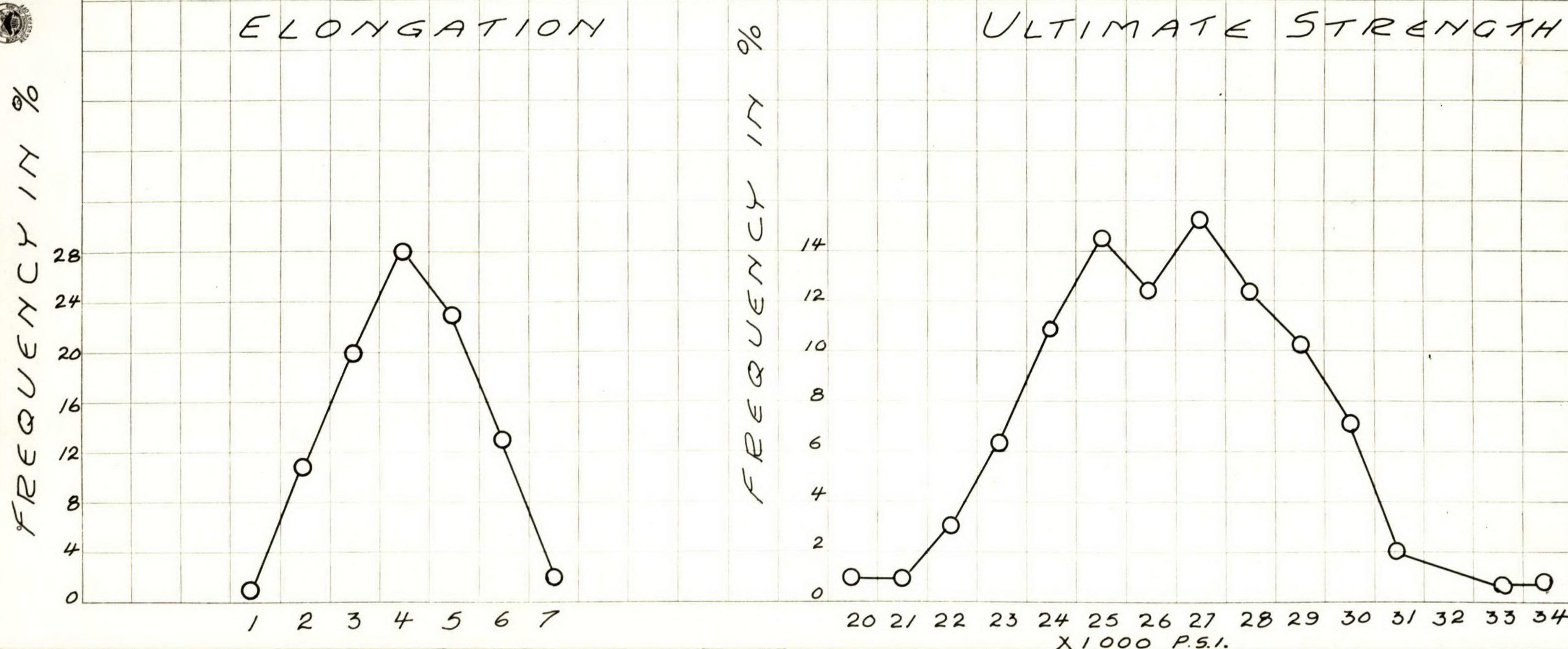


FIG. 9

FREQUENCY DISTRIBUTION
A.S.T.M. 4 MAGNESIUM PHYSICAL PROPERTIES
(CONTROL BARS ONLY)



(Appendix, cont'd) -

It will be noted, in Figure 8, that the average standard deviation for control bar tensiles is 2,000 p.s.i. This means that 95 per cent of all individual tensile test bars are expected to deviate from the average by ±2x2000, or ±4,000 p.s.i. Note also that 95 per cent of elongation results are expected to be within ±2x1.0 per cent of average.

Distribution of Tensiles and Elongation:

Figure 9 shows the distribution of mechanical properties observed on the control test bars. The properties of as-cast 4X Magnesium Alloy would appear to be as follows:

Elongation, 4 ±2 per cent.

Tensile, 26 ±4 per cent.

The Dow Chemical Company report ASTM 4 Magnesium Alloy to the following properties:

	MINIMUM SPECIFIED	TYPICAL
Tensile, p.s.i. -	24,000	27,000
Elongation, per cent in 2 inches	4	5

Thirty-three (33) per cent of the mechanical test results observed on "control" bars in this series of experiments were below the 4 per cent and 24,000 pounds per square inch specified.

The probable reasons for the low results are:

(a) The design of the test bar, which has a straight cylindrical section 4 inches long. This should be reduced to about 2½ inches in order to get better feeding action.

(b) Blows, slag, oxide, and porous bars were included in this report. Ordinarily, these would be rejected as foundry scrap.

HHF:GHB.
Dec. 12th, 1944.