O T T A W A May 1st, 1942.

R E P O R T

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1166.

A Statistical Analysis of 60 mm. Armour Plate from the Dominion Foundries and Steel Limited.

(This is Report No. 4 of the Canadian Bureau of Mines 1942 Armour Plate Statistics Series.)

(Copy No. 37.)

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BUREAU OF MINES
DIVISION OF METALLIC MINERALS
—
ORE DRESSING AND
METALLURGICAL LABORATORIES

CANADA
DEPARTMENT
OF
MINES AND RESOURCES
MINES AND GEOLOGY BRANCH

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Introduction.

The quality of armour plate is one of the deciding factors in the outcome of mechanized battle. Any improvement in armour, or any additional information on its properties and manufacture, therefore, is a contribution to the war effort.

The Metallurgical Laboratories of the Canadian Bureau of Mines at Ottawa, assisted by Lt.-Col. L. E. Simon, of the United States Ordnance, have attempted to show the

(Introduction, cont'd) -

value of statistical analysis of operating data. Previous reports on this subject are:

No. 1144: Armour Plate Improvement As Related To Statistical Analysis of Manufacturing Data. (January 9th, 1942).

No. 1157: Armour Plate Quality and its Relation to Chemical and Physical Tests. (February 12th, 1942).

No. 1163: Statistical Analysis of Armour Data, Applied to the General Steel Castings Corporation. (February 14th, 1942).

These reports (designated Nos. 1, 2, and 3 of the Canadian Bureau of Mines 1942 Armour Plate Statistics Series) show that chemical and physical tests have some relationship to ballistic limit.

In order to show how and where statistical analysis can serve a useful purpose in the armour field, a discussion of the basic principles involved has been included in this report.

Part I deals with the logic of the method and Part II contains the graphic and mathematical digest of data from the Dominion Foundries and Steel Limited. Part III, Appendix, contains detailed records of correlation and distribution.

PART I. - LOGIC OF METHOD.

Why Test Armour?

Armour is tested to assure that is is battle-worthy. Minimum performance standards have been established for ballistic limit, shock, and overmatching performance. So far as inspection is concerned, if these minimum tests are passed and other conditions, such as uniformity, weldability, etc., are met, the plate is acceptable. Is there any reason, then, for further testing or for further analysis of test results?

Control Tests.

The manufacturer has found it necessary to make certain tests to ensure that the quality of the steel is controlled and does not deviate too far from the arbitrary standards. Among control tests may be included the following:

Slag fluidity,
Melting history,
Pouring temperature,
Mould properties,
Chemical analysis of steel,
Physical tests on steel,
Homogenizing time and temperature,
Heat-treating times and temperatures,
and others.

Ordinarily such tests are taken and used as a guide for applying corrective action if and when necessary for the maintenance of the process in such a way that ballistic qualities will pass the minimum standards.

As only a small fraction of the product is ballistically tested, uniform conditions are the only guarantee that the untested plate did not deviate from the tested plate.

Why Analyse Past Records?

Past records are analysed so that information may be obtained and presented in a way that will make the nature of the process clearer. From a better understanding of the

scientific laws which are in operation, those in control of these processes may bring about desirable changes which will result in some improvement in armour plate.

Exact Laws and Statistical Laws.

Although it is generally assumed that exact laws are always operating, these are obscured behind an infinite variation in the environment in which they operate. Laboratory experiments stabilize the environment and allow us to study such laws very precisely (for example, drawing temperature versus hardness). However, the effect of fluctuating environment on this exact law can only be determined by studying results in actual production conditions. In the absence of any information which can be called truly exact, statistical analysis is essential and information revealed by this method comes as close to exact scientific laws as is possible in an industrial environment.

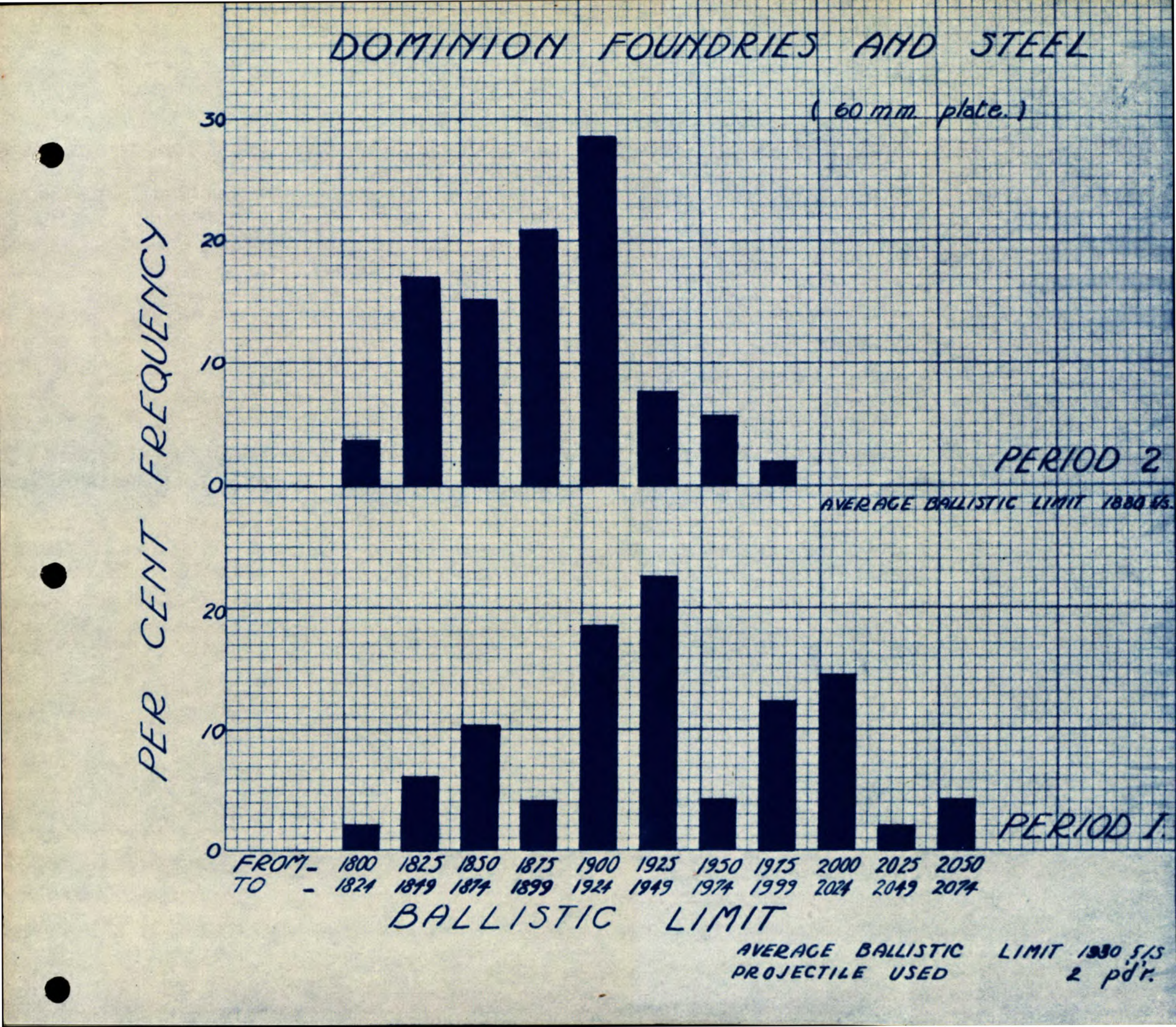
Variation.

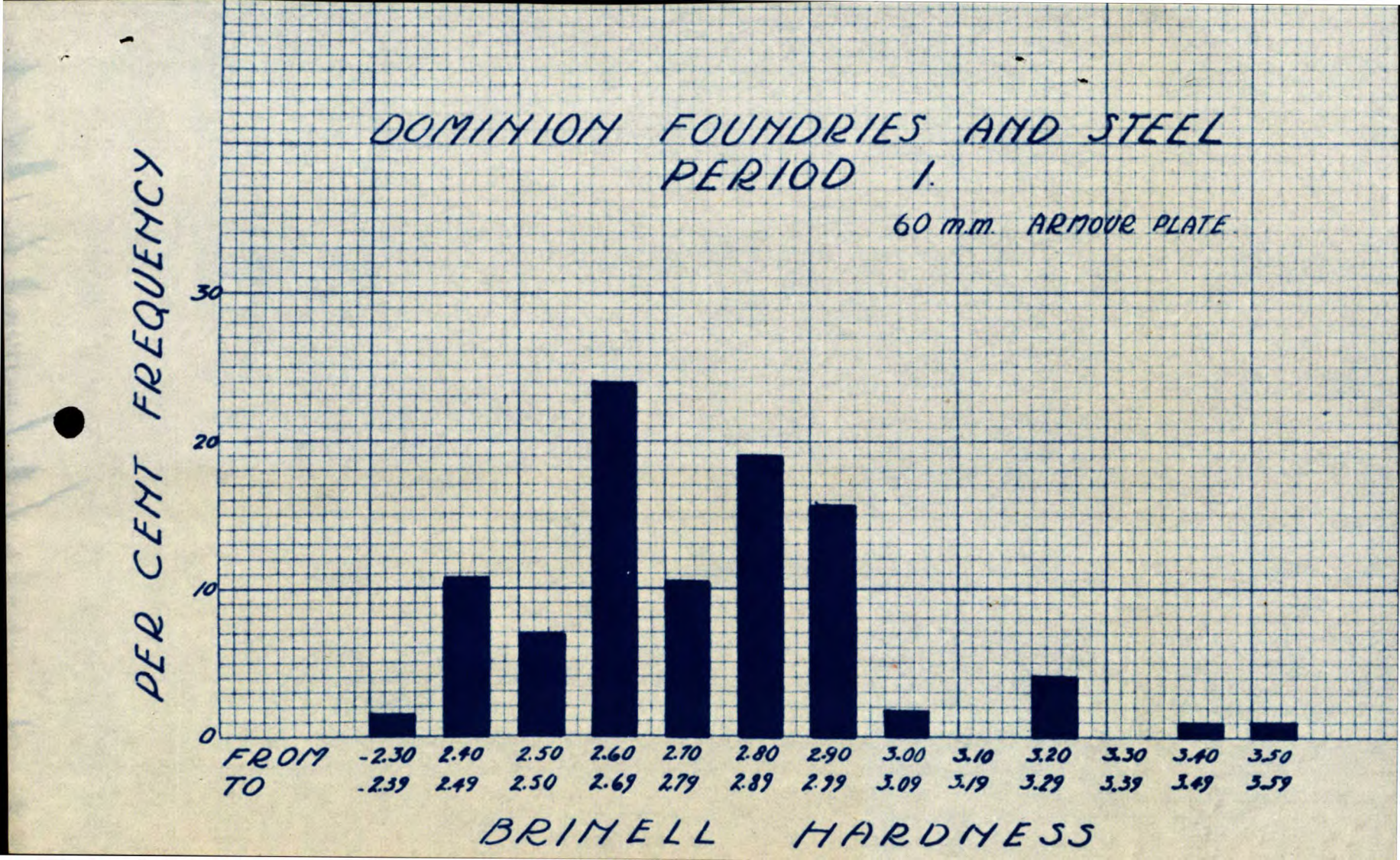
"No two things are alike."

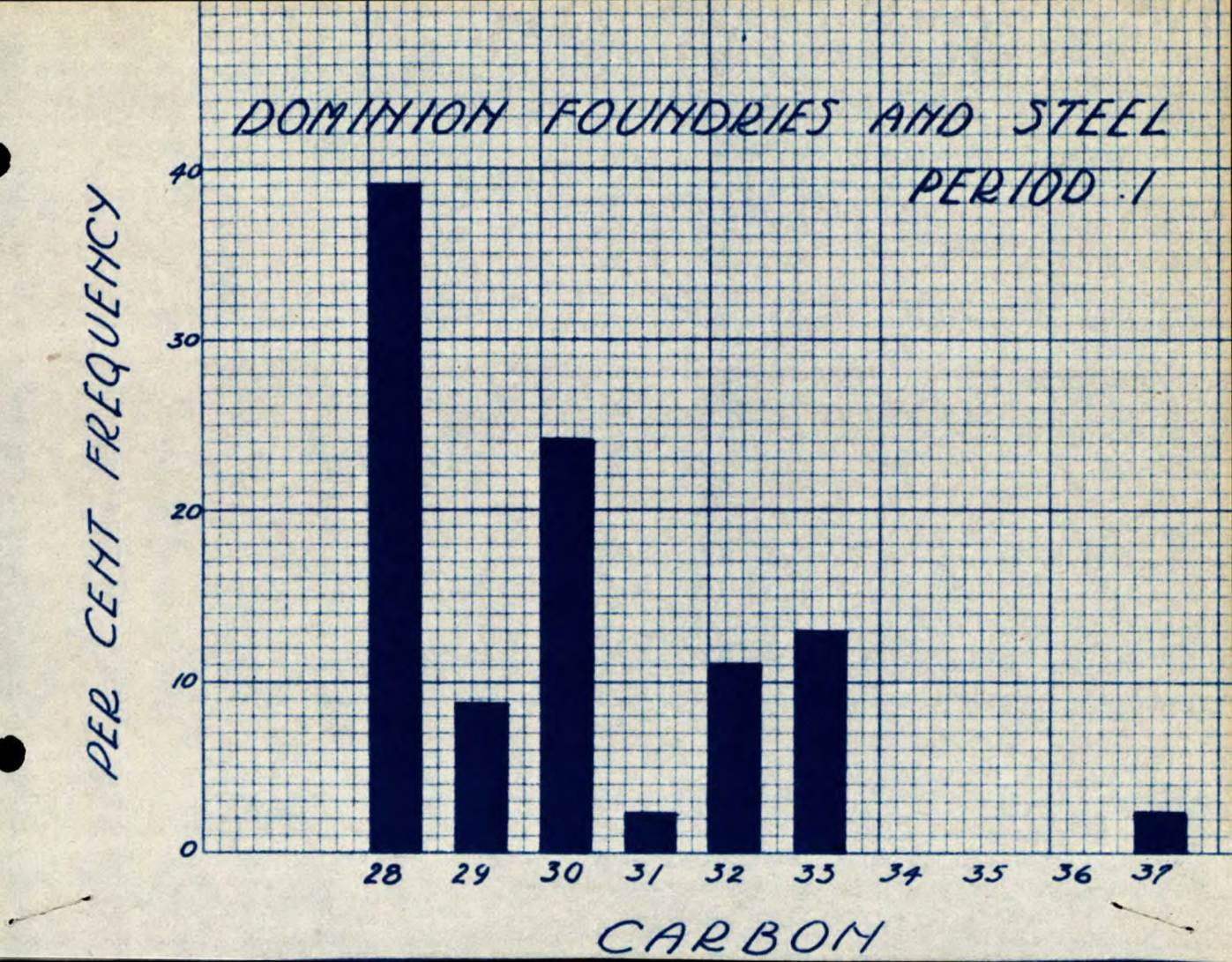
The above statement illustrates the popular conception of variation. The following charts show how ballistic limit, carbon, and Brinell hardness vary over a considerable range:

(These charts are shown on Pages 5 and 6.)

(Continued on Page 7)


DOMINION FOUNDRIES AND STEEL
(60 mm plate.)
PER CENT FREQUENCY
30
20
10
0
PERIOD 2
AVERAGE BALLISTIC LIMIT 1880 f/s.
20
10
0
PERIOD I.
FROM- 1800 1825 1850 1875 1900 1925 1950 1975 2000 2025 2050
TO - 1824 1849 1874 1899 1924 1949 1974 1999 2024 2049 2074
BALLISTIC LIMIT
AVERAGE BALLISTIC LIMIT 1930 f/s
PROJECTILE USED 2 pdr.


DOMINION FOUNDRIES AND STEEL
PERIOD 1.
60 m.m. ARMOUR PLATE.
PER CENT FREQUENCY
30
20
10
0
FROM -2.30 2.40 2.50 2.60 2.70 2.80 2.90 3.00 3.10 3.20 3.30 3.40 3.50
TO .2.39 2.49 2.50 2.69 2.79 2.89 2.99 3.09 3.19 3.29 3.39 3.49 3.59
BRINELL HARDNESS


DOMINION FOUNDRIES AND STEEL
PERIOD 1
PER CENT FREQUENCY
40
30
20
10
0
28
29
30
31
32
33
34
35
36
37
CARBON

Any test measurement is subject to fluctuation as illustrated above. Although engineers and metallurgists are prone to believe that their product is "rigidly controlled" and that chance plays no part in establishing the quality of their product, this phenomenon of variation cannot be eliminated in a commercial process.

Statistical Quality Control Chart.

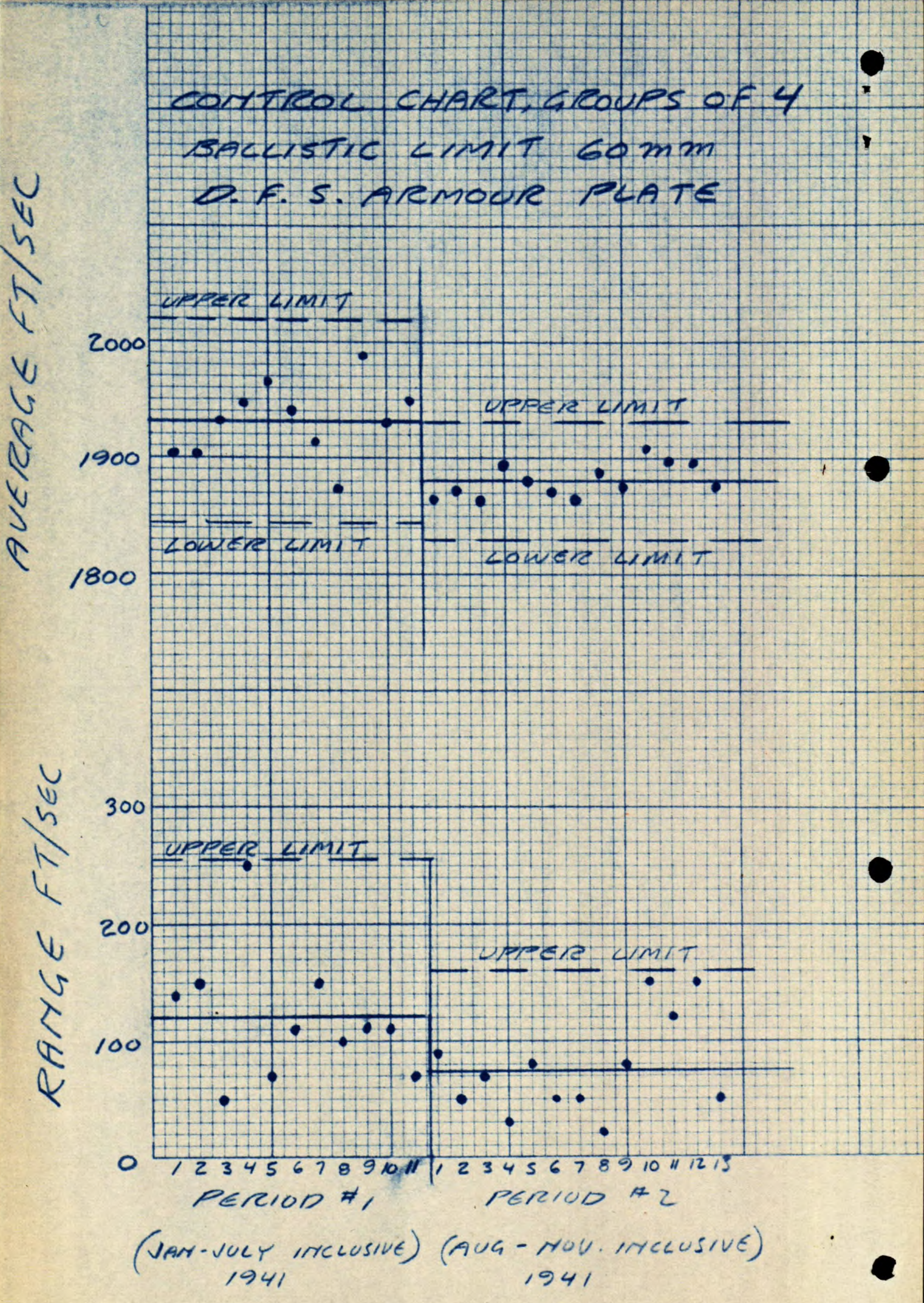
The "Control Chart" method (described in the A.S.T.M. Manual on Presentation of Data and in many other publications), by means of a quite simple technique, classifies variation into two groups: (a) normal variation, and (b) extreme results.

Normal variation may be described as that range over which a property varies due to a system of chance causes inherent in the process and which cannot be removed. Extreme results are due to the presence of definite assignable causes which can be traced down and eliminated. Page 8 shows the ballistic limit values plotted according to the control chart system. Average and range of successive groups of four test values were plotted. Note that all values fell within the control limits (limits of normal variation), indicating that the process is in statistical control. A constant quality of armour is being produced. Note that a change in the process on or about August 1941 reduced the normal variation considerably. Since the process is in control, a test falling between control limits indicates no change in the process. A test falling outside control limits would indicate some definite change in the process or testing method, or a definite assignable cause.

Now, if we assume that variation in ballistic limit

(Continued on Page 9)

CONTROL CHART, GROUPS OF 4
BALLISTIC LIMIT 60 mm
D. F. S. ARMOUR PLATE



is due to variation in the environment producing the plate, then a comparison of various metallurgical tests with ballistic limit might throw some light on the pattern of relationships which exists.

Proving Ground Tests.

Field tests, or proving ground tests, give the actual serviceability of the product under conditions approximating actual service. Many field tests are expensive and take a long time to complete. Some field tests destroy the product tested. Additional subsidiary tests of the product are therefore desirable.

Subsidiary Tests.

The purpose of subsidiary tests is to get a cheaper and quicker indication of serviceability. It is therefore essential that the subsidiary test bear some relation to the serviceability test. Chemical analysis, physical tests, and processing history of armour plate are subsidiary tests which are assumed to give some indication of armour serviceability, which is measured by ballistic limit, shock resistance, and overmatching performance. If the subsidiary tests do not indicate anything about ballistic behaviour what benefit is obtained from making the test?

Correlation.

It seems logical that, instead of taking the relationship for granted, the exact correlation between, say, sulphur and ballistic limit should be determined. This can be done quite easily by statistical methods of long standing. From such analysis, ideal ranges for each variable may be indicated and thus improvement in armour may be brought about. Also, the most important variables can be determined. Up to

the present time only a few of the many variables have been studied.

Statistical treatment of data puts them in a concentrated form so that engineers can interpret their meaning more easily. Many valuable data are never interpreted because they are spread out through so many pages that their true significance is never realized.

Chemical analysis and physical tests have been used to show correlations. Slag properties, melting history, rolling details, ingot practice, heat treatment variations, and many other phases of armour production all have some degree of correlation with the final properties. Unfortunately, data on the operating methods are not available at present. Collection and analysis of such data is carried out in many steel plants, including the following:

American Rolling Mills Company

Edgewater Steel

National Tube

Youngstown Sheet and Tube

Wheeling

Carnegie Illinois

End of Part I.

PART II. - ANALYSIS OF DOMINION FOUNDRIES AND STEEL TEST RESULTS.

Quality Control Chart.

As Page 8 shows, the 1941 ballistic limit tests fall naturally into two periods:

Period 1, covering January to July, inclusive, and

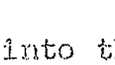
Period 2, covering August to November, inclusive.

Trends.

Graphic presentation of the trends shows:

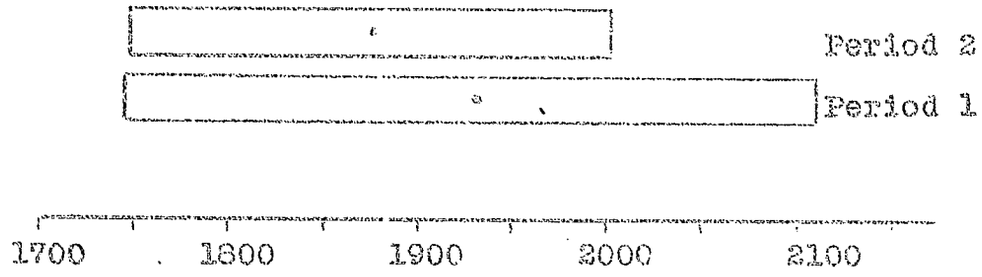
(a) Spread, or range of results based on average ± 3 standard deviations except where noted.

(b) ⊗ Average.

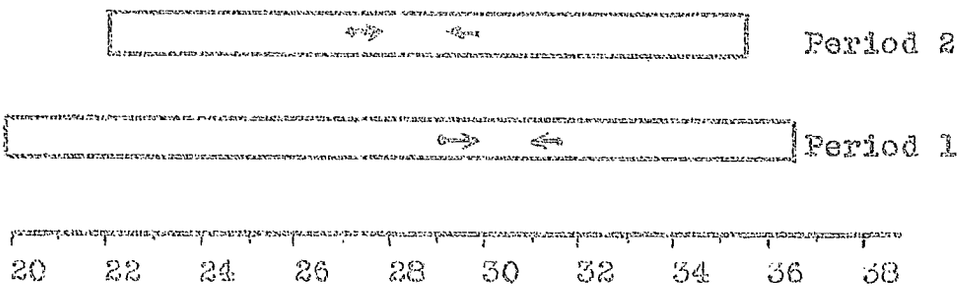
(c)  Direction in which the best plate occurs, according to correlation analysis described in Report of Investigation No. 1144 (Report No. 1 of this series).

(NOTE: Where more than one dot occurs, the data were divided into three groups, each containing about the same number of test values.)

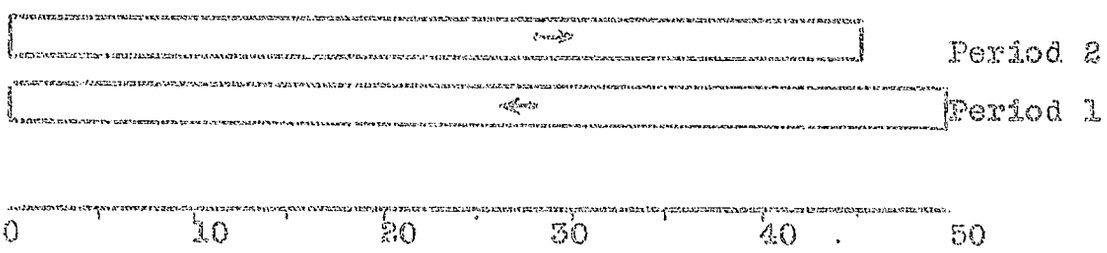
(Trends, cont'd) -
(Graphic Presentation of Trends)



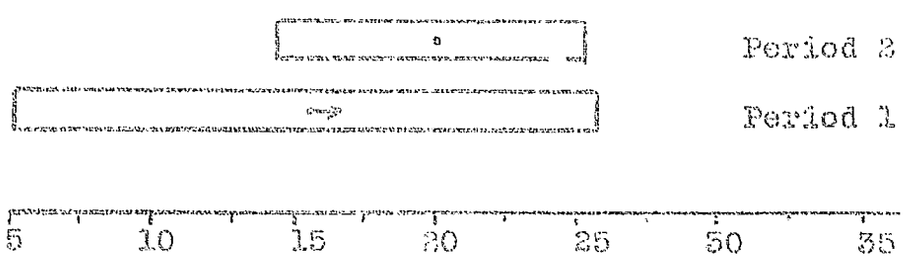
(Graphic Presentation of Trends, cont'd) -



CARBON

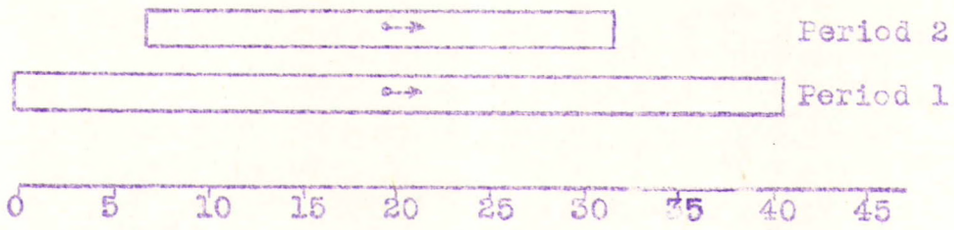


SILICON



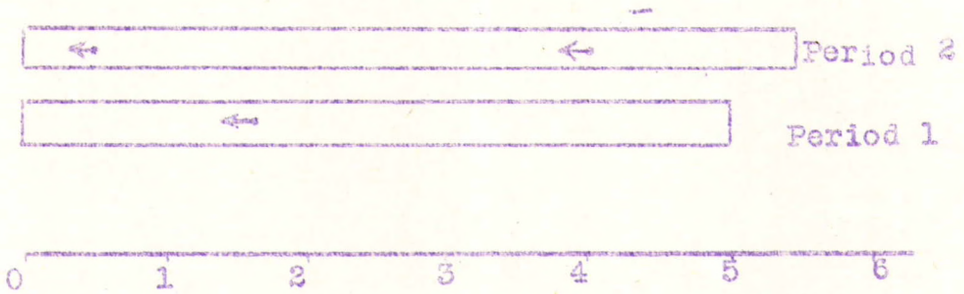
SULPHUR

(Graphic Presentation of Trends, cont'd) -



PHOSPHORUS

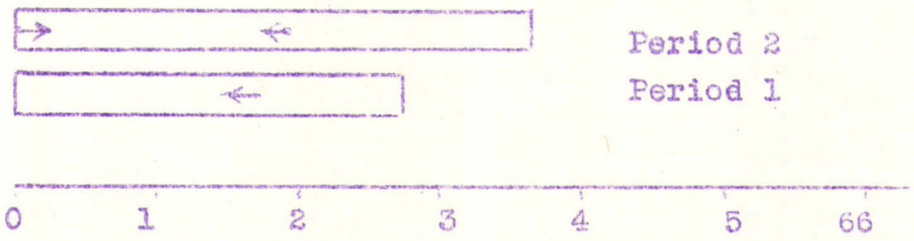
MANGANESE



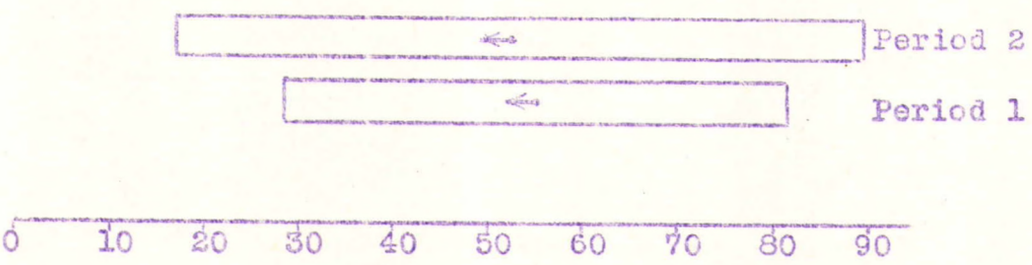
NICKEL

(Actual Spread)

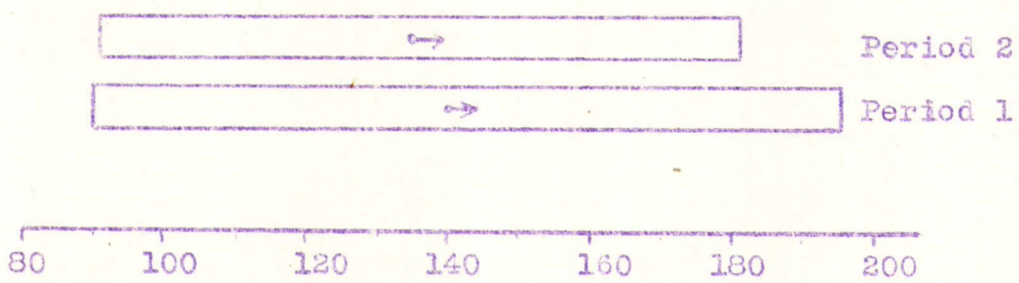
(Graphic Presentation of Trends, cont'd) -



CHROMIUM
(Actual Spread)

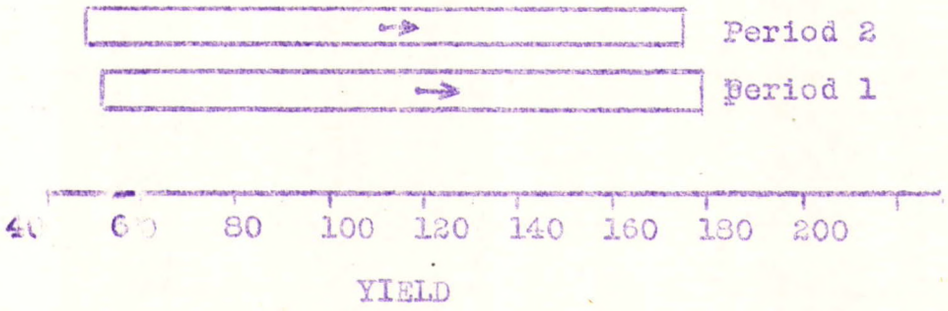


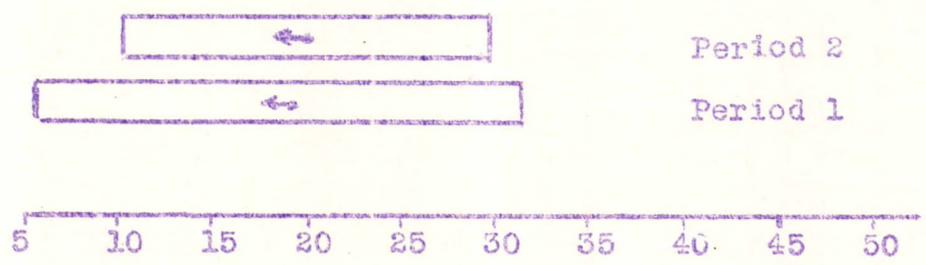
MOLYBDENUM

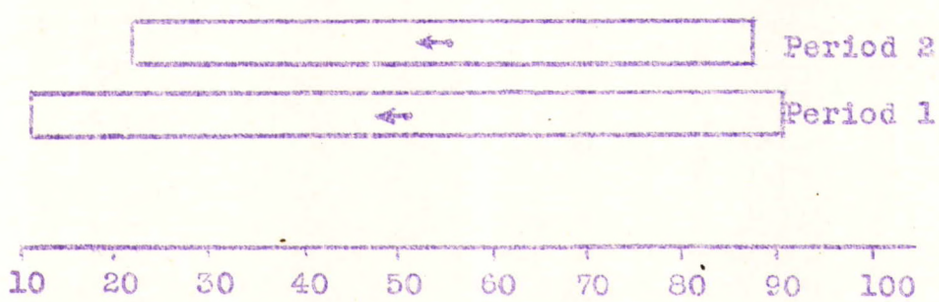


TENSILE

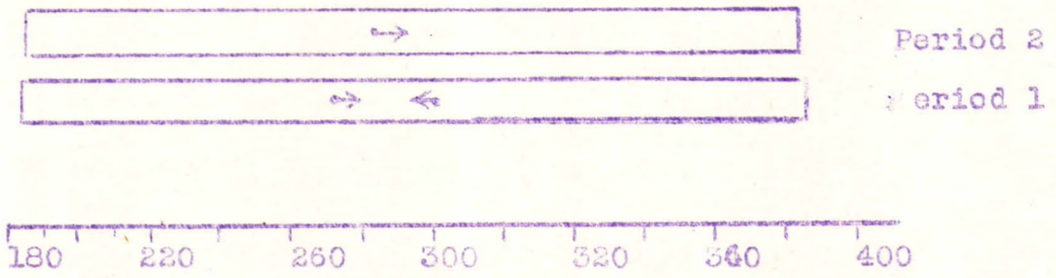
(Graphic Presentation of Trends, cont'd) -

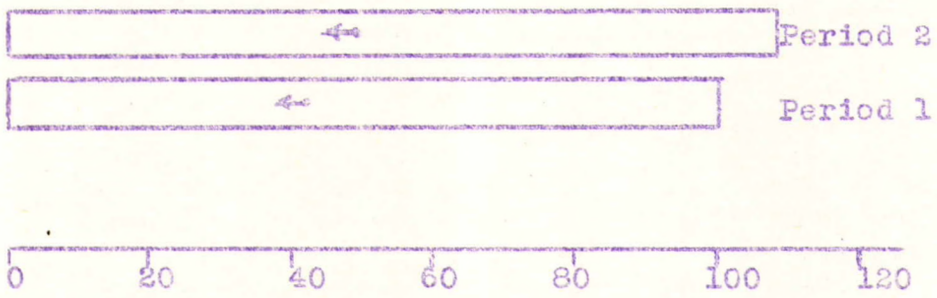






(Graphic Presentation of Trends, cont'd) -





Discussion.

The following trends are evident in the data examined;

BELOW AVERAGE BALLISTIC LIMIT RESULTS OCCURRED WHEN -

Carbon is below 0.27 per cent;

Sulphur is below 0.015 per cent;

Phosphorus is below 0.020 per cent;

Chromium is above 2.00 per cent;

Molybdenum is above 0.55 per cent;

Tensile strength is below 140,000 p.s.i.;

Yield strength is below 120,000 p.s.i.;

Elongation is above 20 per cent;

Reduction of area is above 5.5 per cent;

Brinell hardness is below 270;

Izod impact value is above 50 foot pounds;

also -

when nickel is below 2.00 per cent, better results are obtained.

INTERPRETATION.

The above statistical treatment is merely a condensed presentation of the test results reported by Dominion Foundries and Steel. This is as far as the statistician goes. The meaning of these apparent relationships can only be interpreted by the engineers and metallurgists in charge of the process. Interpretations of these data by those unfamiliar with operations in the place from which the data originated would be dangerous and unpractical. For example, note that better armour resulted

(Interpretation, cont'd) -

when phosphorus was above 0.02 per cent than when it was below 0.02 per cent. This may be stated in another way: --"conditions coinciding with phosphorus below 0.02 per cent produced below average armour"--(obviously, half the plate is below average and half is above average). What were the conditions that produced phosphorus below 0.02 per cent? Only the men familiar with this particular source know the answer to this.

Note that high alloys coincided with below average plate. Was this due to the fact that heat treatment was not designed for the stable high alloy structures? Evidence from other sources shows that increasing alloys results in improved plate. It is apparent that FOR THE PROCESSES EMPLOYED, LOWER ALLOYS WERE MORE SUCCESSFUL IN THIS CASE. Obviously such data are limited in their application by the conditions under which they were collected. What holds true in one plant does not necessarily hold true under the different environment of another plant.

In collecting, classifying, correlating, and graphically presenting data it is true that errors can be made. In this case all data were collected by Dominion Foundries and Steel. The effect of a wrongly classified value would be small if the total amount of data were great. The greatest source of error in this type of work is in drawing conclusions from the final result. The figures are "as found" and their validity is based on

(1) the reliability of the test method, and

(2) the personal element in testing.

The facts which these figures represent are a

(Interpretation, cont'd) -

problem of interpretation for the experts. The practical man acts upon empirical judgment, because "experience is the best guide." All that statistical methods do is to present past experience in such a form that it can be clearly interpreted and the system or natural law involved can be visualized. -

> "An empirical acquaintance with facts rises to a scientific knowledge of facts as soon as the mind discovers beneath the multiplicity of single events the unity of a system."
>
> - MÜLLER, 1871.

End of Part II.

(Part III, following, shows detailed records of correlation.)

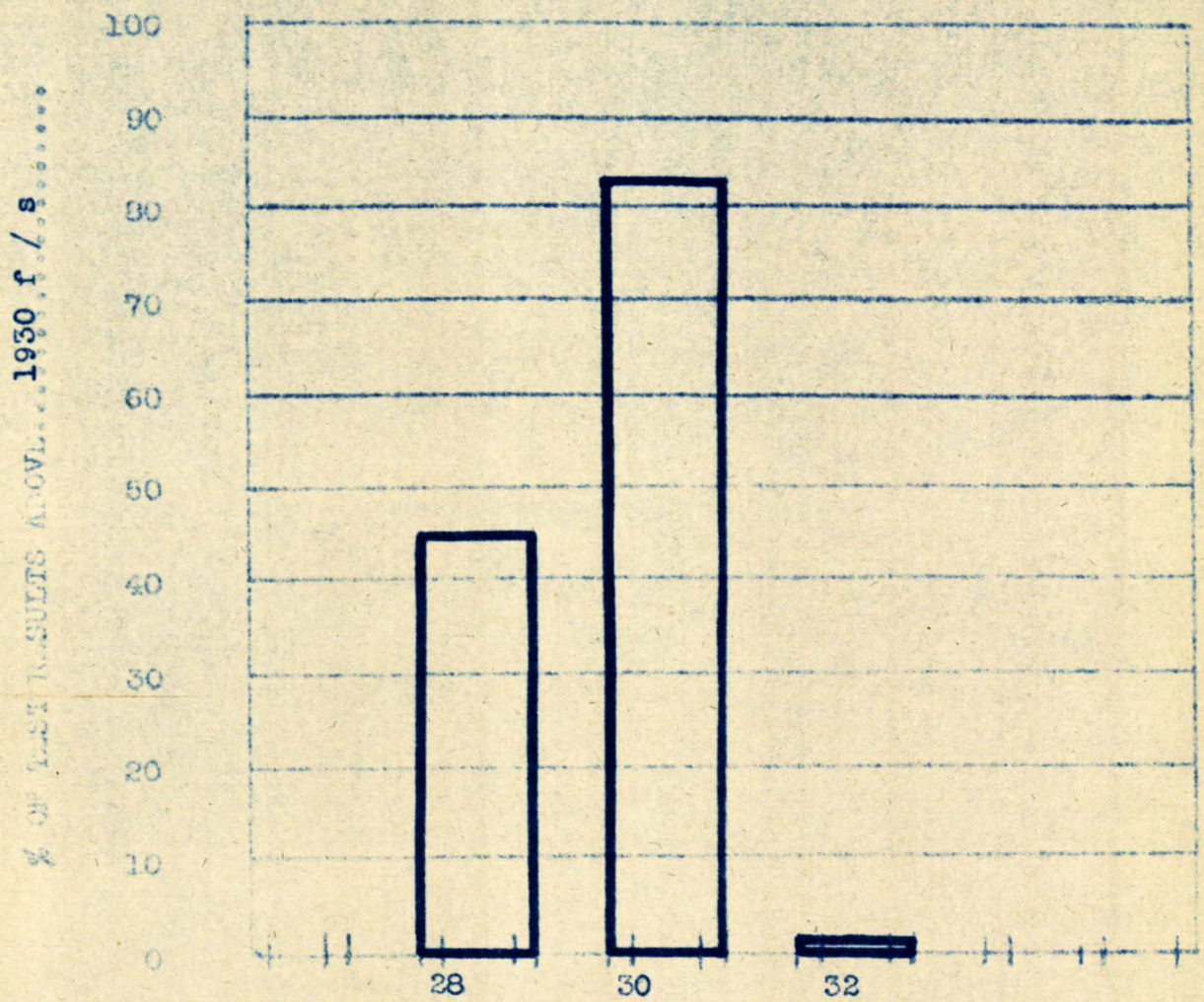
PART III. - APPENDIX.

Following are the summary sheets showing the correlation between chemical and physical tests and ballistic limit:

(The next thirty pages, Pages 22 to 51 inclusive, are photostated charts. Page 52 shows the distribution characteristics for the test values studied.)

CORRELATION BETWEEN ...CARBON.....&...BALLISTIC LIMIT.

IN.....60 mm. ... FROM DOMINION FOUNDRIES & STEEL #1



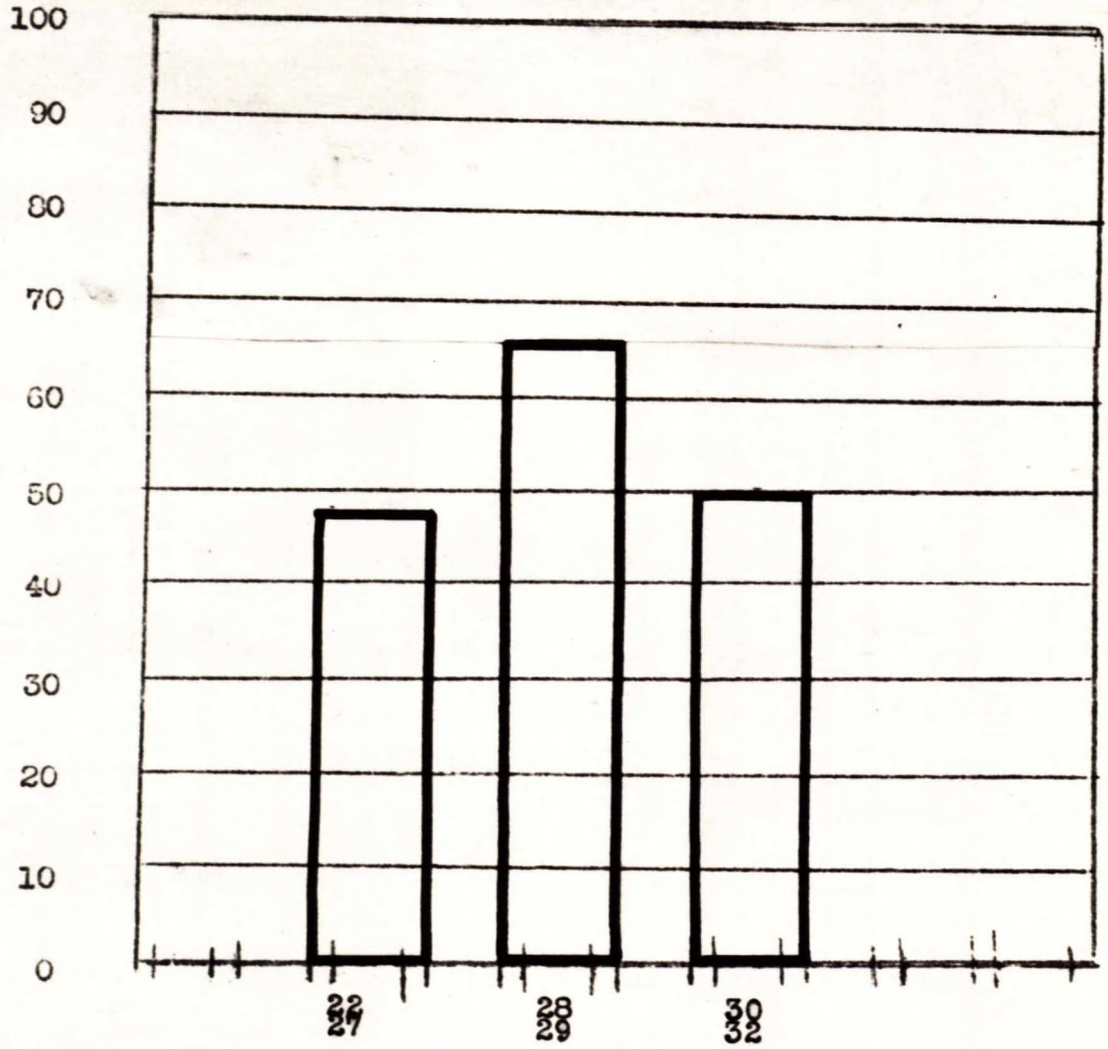
RANGE	28 29	30 31	32 33
No. above: 2550 f/s 1930 f/s	10	10	1
Total number of test results:	22	12	11
Percentage above:	45.5	83.3	.09
Ratio difference:	37.8	83.21	
Number effect:	.0454 .0833=.128	.0833	.0909= .1742
Significance*	94.5		

(*Note: This means that [illegible] equals the percentage of the time the above ratio difference would occur due to chance.)

Armour Statistics
Data Sheet No. 5.

CORRELATION BETWEEN .CARBON..... and BALLISTIC.LIMIT.....

IN....60.mm..... FROM DOMINION.FOUNDRIES & STEEL # 2



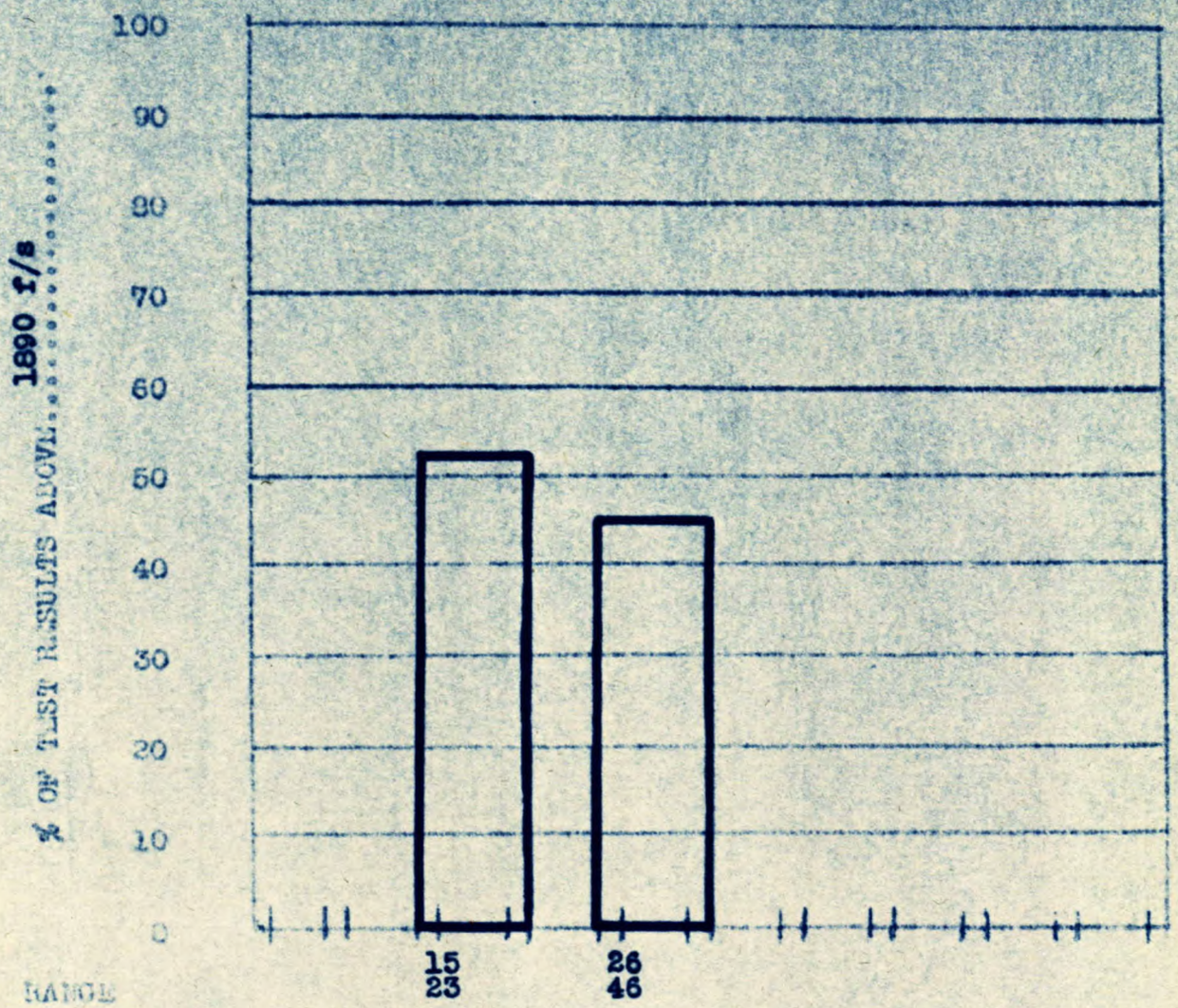
RANGE			
No. above: ~~2550 f/s~~ 1890 f/s	7	11	6
Total number of test results:	15	17	12
Percentage above:	47	65	50
Ratio difference:	.18	.15	
Number effect:	.067 .059	.126 .059	.083 .142
Significance:*	60 %		48 %

(NOTE: THIS MEANS THAT (100-....%) equals the percentage of the time the above ratio difference would occur due to chance.)

Armour Statistics
Data Sheet No. 5.

CORRELATION BETWEEN ...SILICON....&..BALLISTIC LIMIT.

IN.....60 mm.....FROM. DOMINION FOUNDRIES & STEEL #1

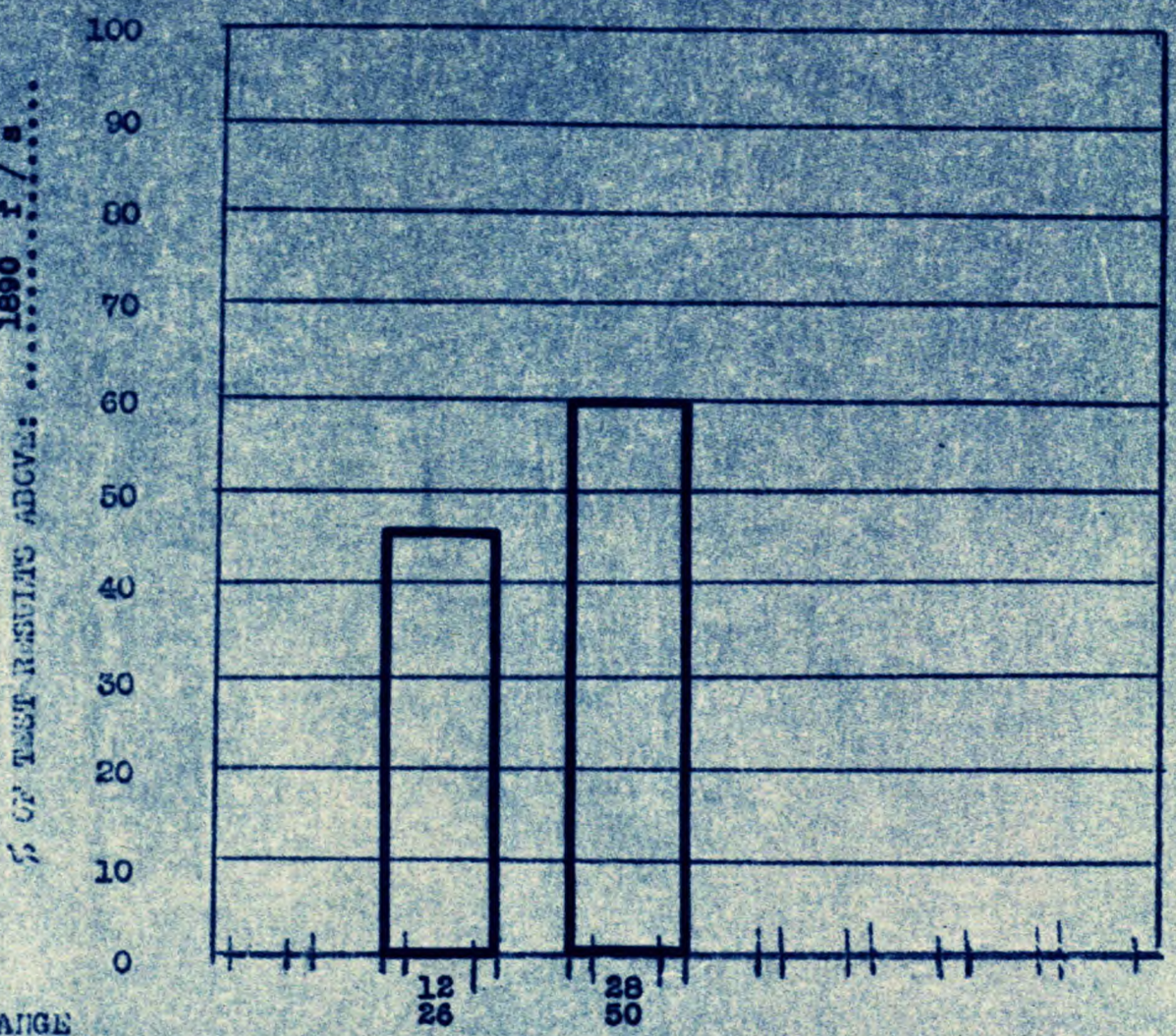


RANGE	15 23	26 46
No. above: 2550 f/s 1890 f/s :	12	11
Total number of test results:	23	24
Percentage above:	52.2	45.8
Ratio difference:	6.4	
Number effect:	.0435 + .0417 = .0852	
Significance:*	33	

(NOTE: This means that (100-.....%) equals the percentage of the time the above ratio difference would occur due to chance.)

CORRELATION BETWEEN ..SILICON..... and ..BALLISTIC LIMIT....

IN....60.##:..... FROM..DOMINION FOUNDRIES & STEEL # 2



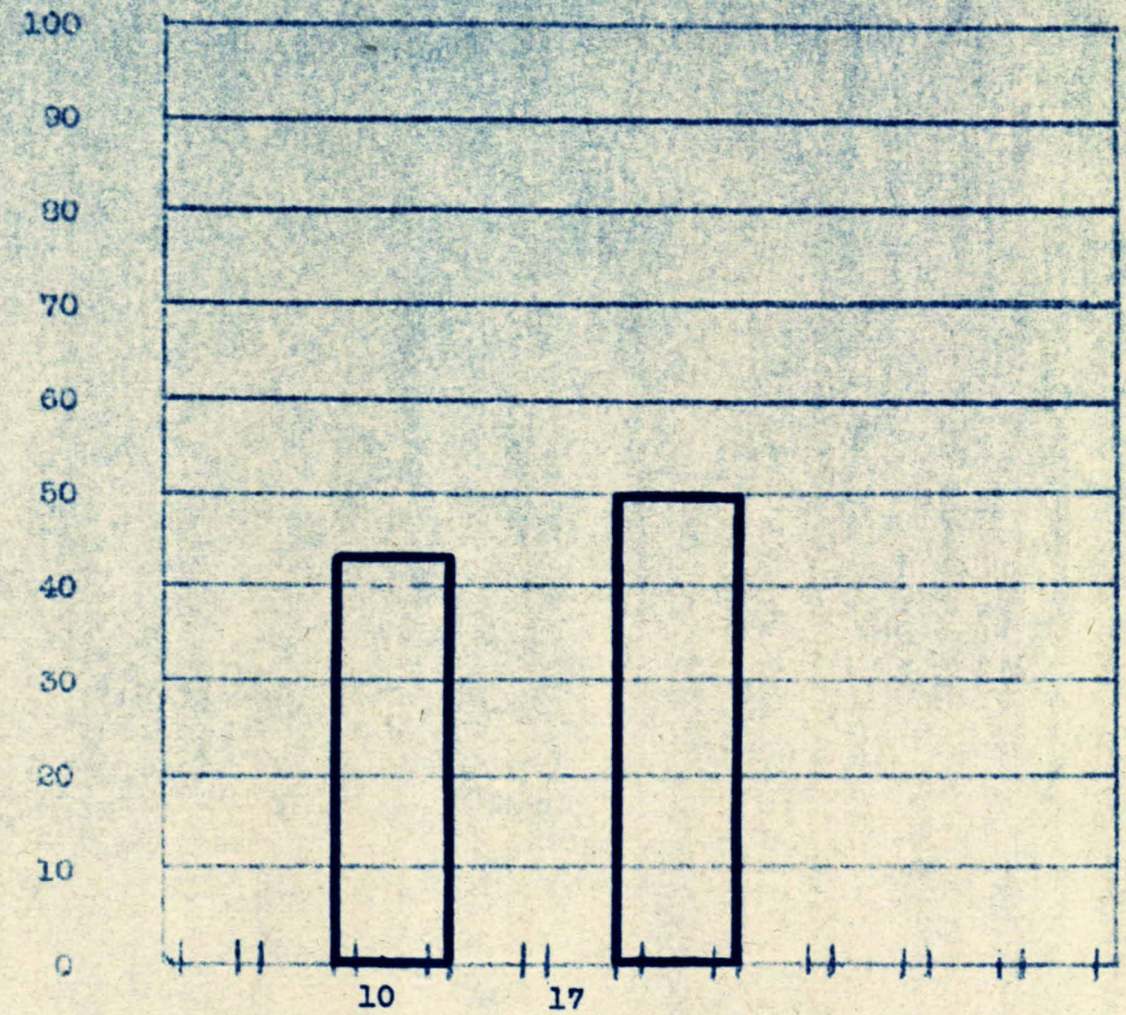
RANGE		
No. above: 2550 f/s: 1890 f/s:	11	12
Total number of test results:	24	20
Percentage above:	45.8	60
Ratio difference:	.142	
Number effect:	.042 + .05 = .092	
Significance:*	60 %	

(NOTE: THIS MEANS THAT (100-....%) equals the percentage of the time the above ratio difference would occur due to chance.)

Armour Statistics
Data Sheet No. 5.

CORRELATION BETWEEN ...SULPHUR.....&...BALLISTIC LIMIT.

IN.....60 mm..... FROM DOMINION FOUNDRIES & STEEL #1



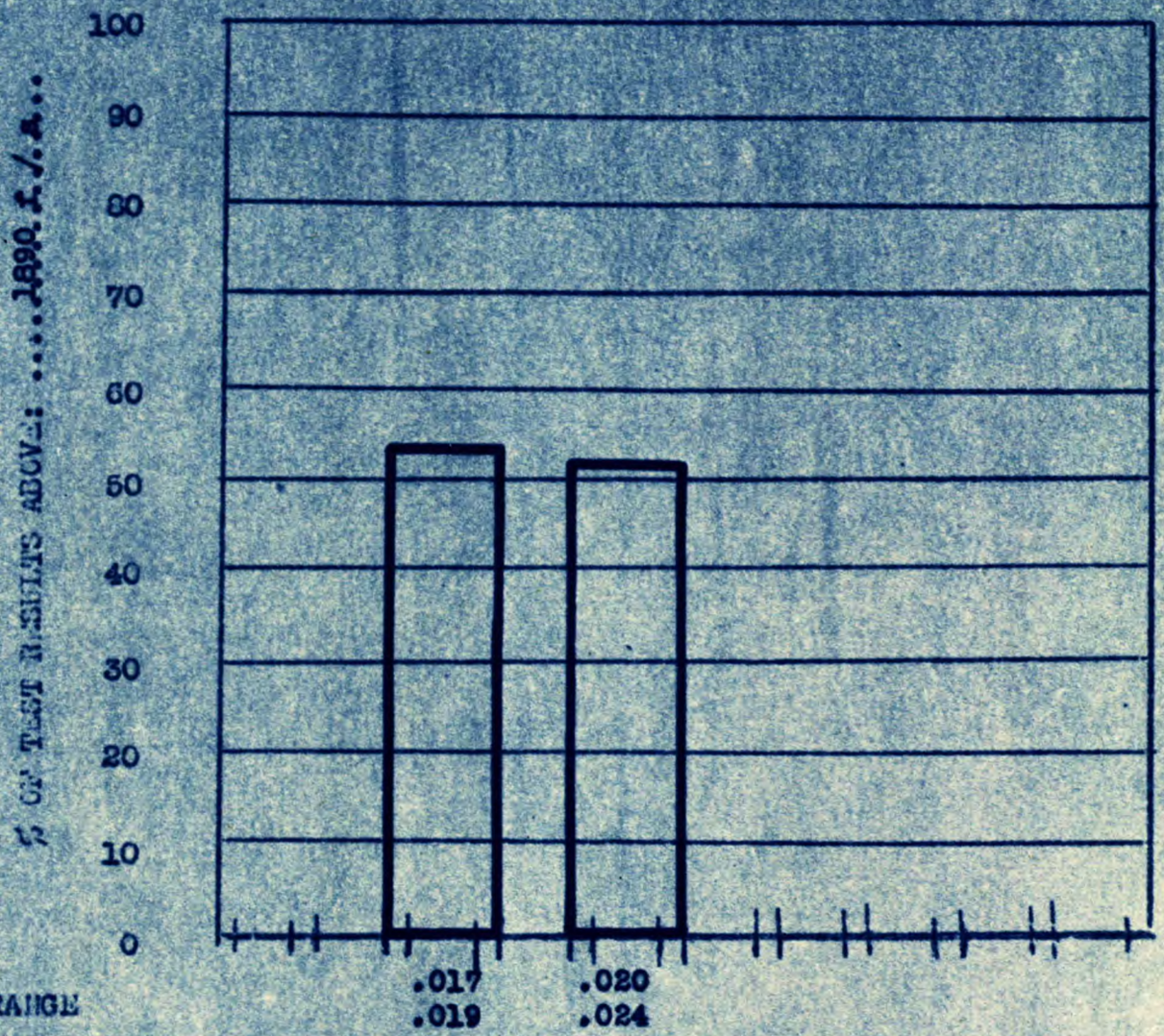
RANGE	10 16	17 22
No. above: 2550 f/s: 1930 f/s	10.	12.
Total number of test results:	23.	24.
Percentage above:	43,5	50.
Ratio difference:	6.5	
Number effect:	..0435. +	.0417. = .0852
Significance:	33	

NOTE: This means that (100-.....%) equals the percentage of the time the above ratio difference would occur due to chance.

Armour Statistics
Data Sheet No. 5.

CORRELATION BETWEEN ..SULPHUR..... and .BALLISTIC LIMIT....

IN....90 mm..... FROM..DOMINION FOUNDRIES & STEEL #2



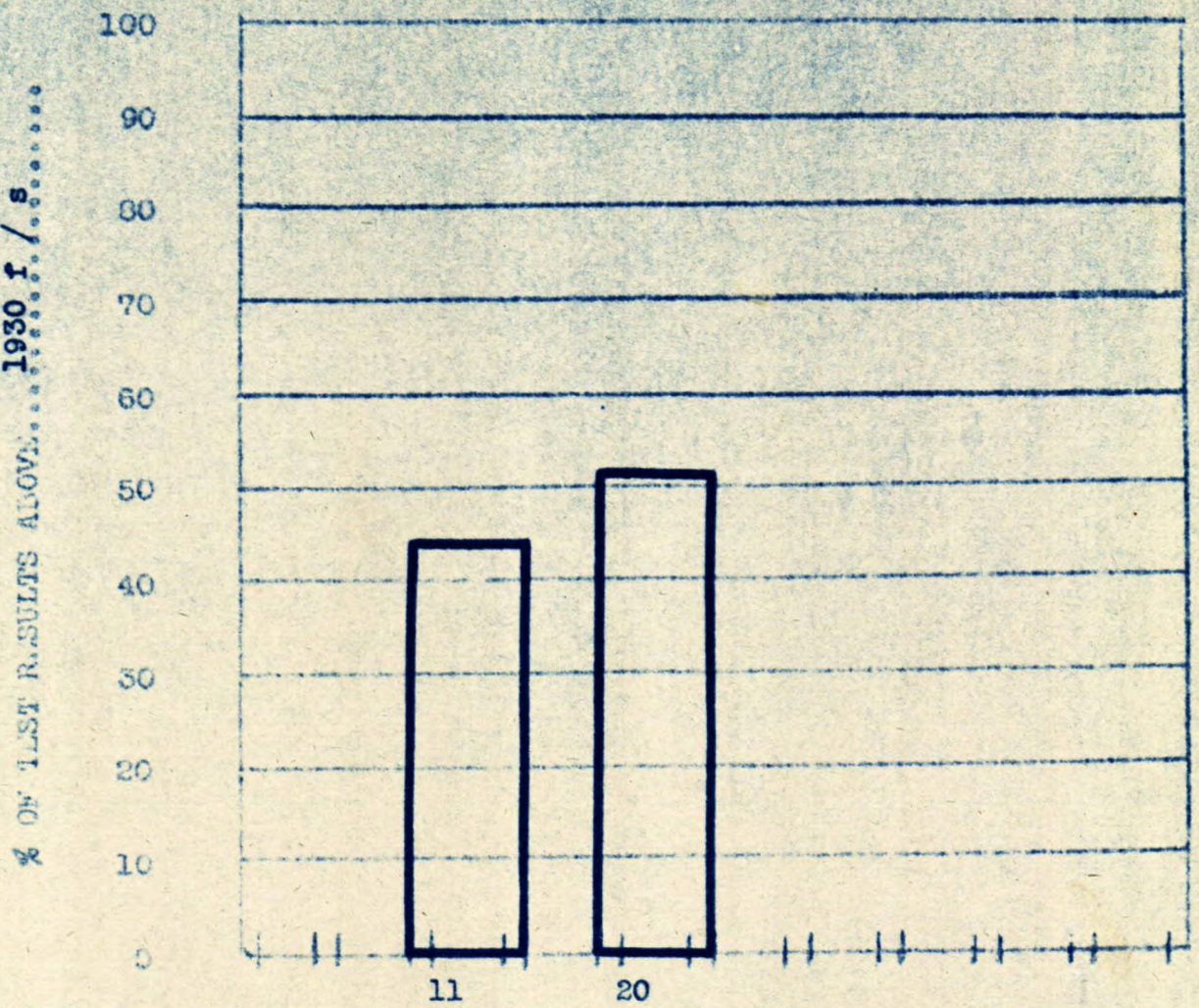
RANGE	.017 .019	.020 .024
No. above: 2550 f/s: 1890 f /s	10	13
Total number of test results:	19	25
Percentage above:	53	52
Ratio difference:	.01	
Number effect:	.053 + .04 = .093	
Significance:*	....4.....%	

(NOTE: THIS MEANS THAT (100-....%) equals the percentage of the time the above ratio difference would occur due to chance.)

Armour Statistics
Data Sheet No. 5.

CORRELATION BETWEEN . PHOSPHORUS ...&... BALLISTIC LIMIT

IN... 60 mm. ..... FROM DOMINION FOUNDRIES & STEEL #1



RATIO:	11 19	20 30
No. above: 2550 f/s 1930 f/s	11	12
Total number of test results:	25	23
Percentage above:	44	52

Ratio difference: 8

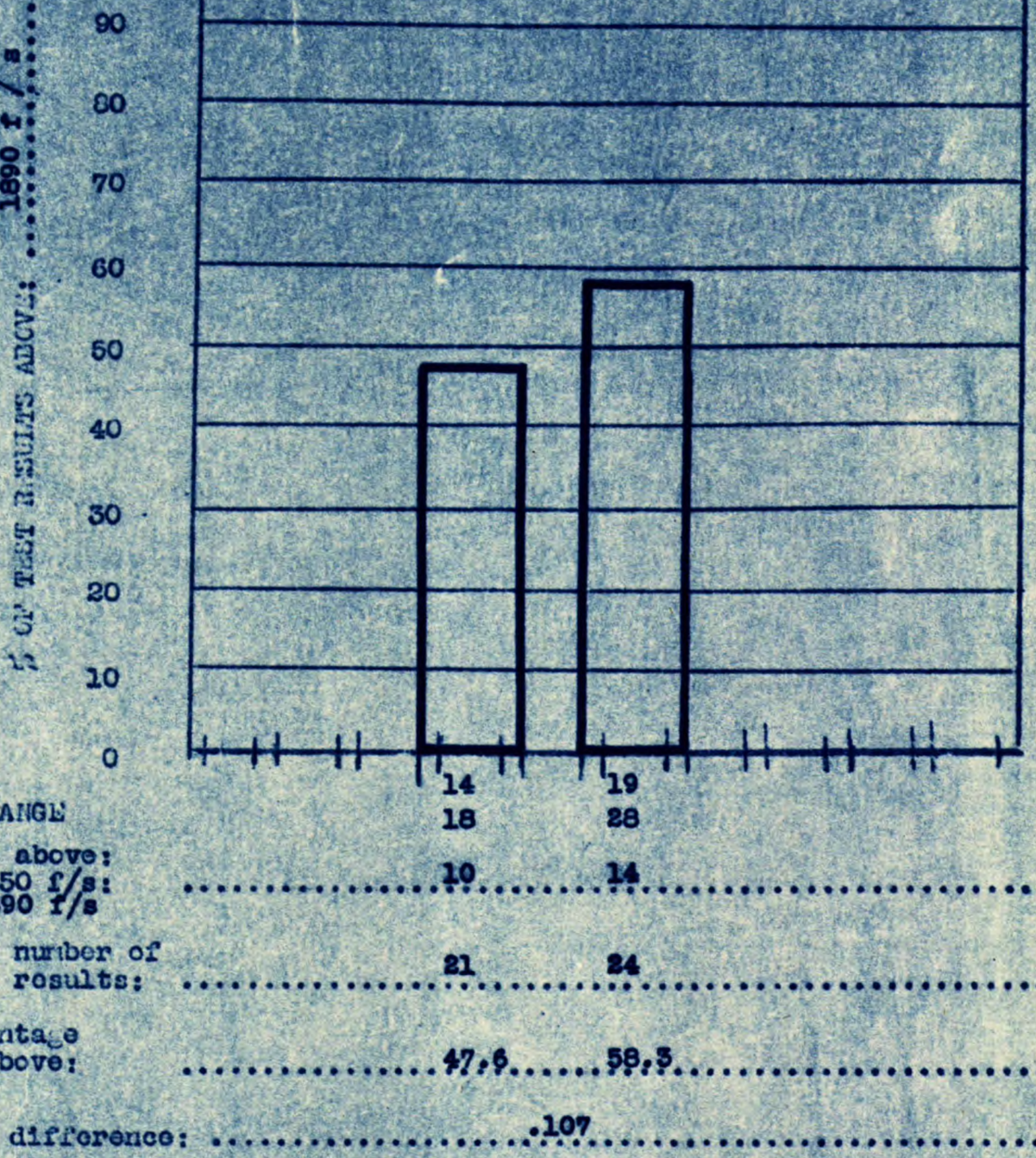
Number effect: .04 + .0435 = .0835

Significance:* 40

(*NOTE: This means that (10-.....%) equals the percentage of the time the above ratio difference would occur due to chance.)

CORRELATION BETWEEN ...PHOSPHORUS.. and BALLISTIC LIMIT.....

IN.....60 mm..... FROM DOMINION FOUNDRIES & STEEL # 2



RANGE	18	28
No. above: 2550 f/s: 1890 f/s	10	14
Total number of test results:	21	24
Percentage above:	47.6	58.3

Ratio difference: .107

Number effect: .0476 + .0417 = .0893

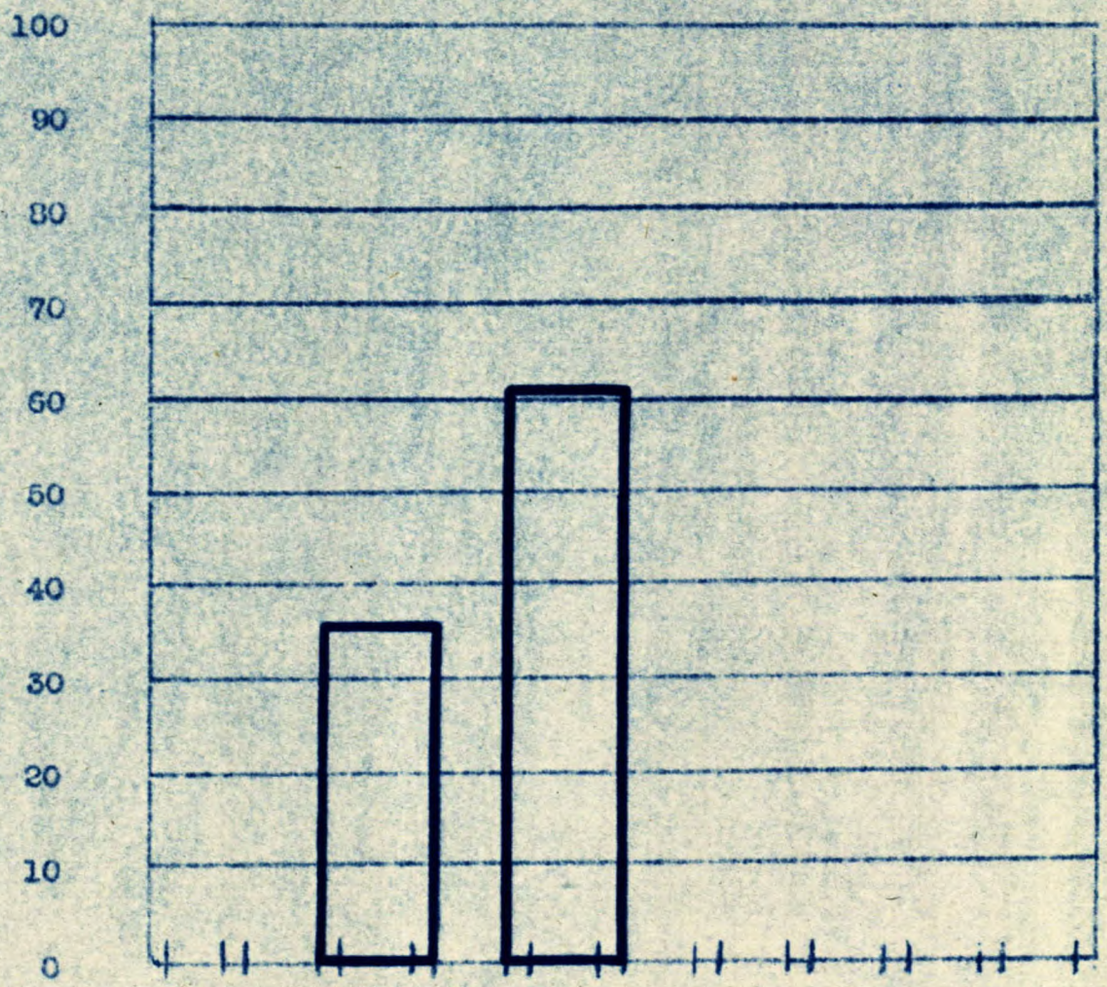
Significance:* 50 %.

(NOTE: THIS MEANS THAT (100-....%) equals the percentage of the time the above ratio difference would occur due to chance.)

Armour Statistics
Data Sheet No. 5.

CORRELATION BETWEEN MANGANESE ..... & ..... BALLISTIC LIMIT

IN ....60.mm..... FROM DOMINION FOUNDRIES & STEEL #1



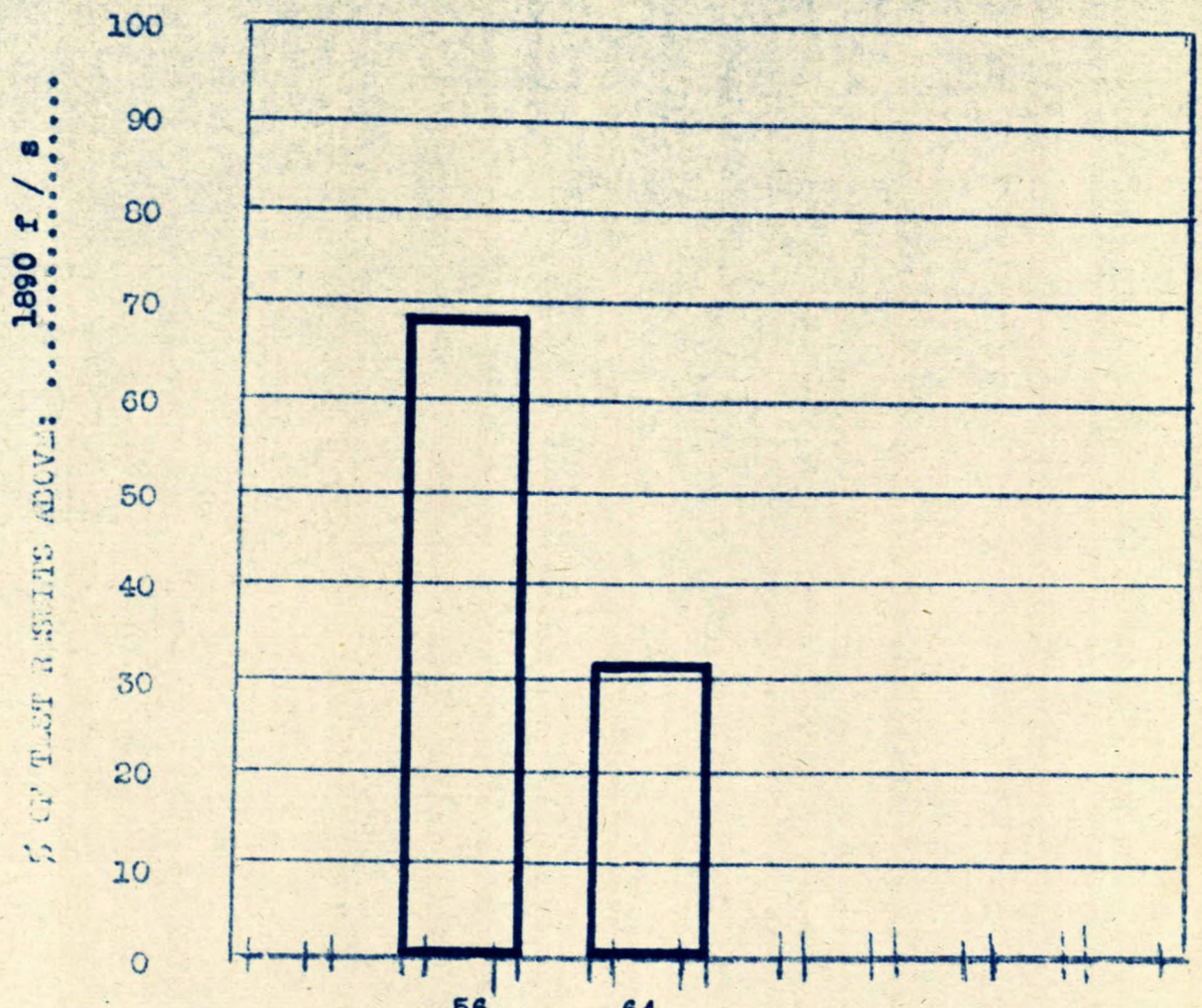
RANGE	33 61	62 75
No. above: 2550 f/s: 1930 f/s	9	14
Total number of test results:	25	23
Percentage above:	36.	61.
Ratio difference:	25.	
Number effect:	.04 + .0435	= .0835
Significance:*	91 ..... %	

(NOTE: This means that (100-.....%) equals the percentage of the time the above ratio difference would occur due to chance.)

Armour Statistics
Data Sheet No. 5.

CORRELATION BETWEEN ..MANGANESE.... and BALLISTIC LIMIT.....

IN....60.mm..... FROM.DOMINION.FOUNDRIES & STEEL #2



RANGE	56 63	64 72
No. above: 2550 f/s: 1890 f/s	15	7
Total number of test results:	22	22
Percentage above:	68.2	31.8

Ratio difference: .364

Number effect: .046 + .046 = .091

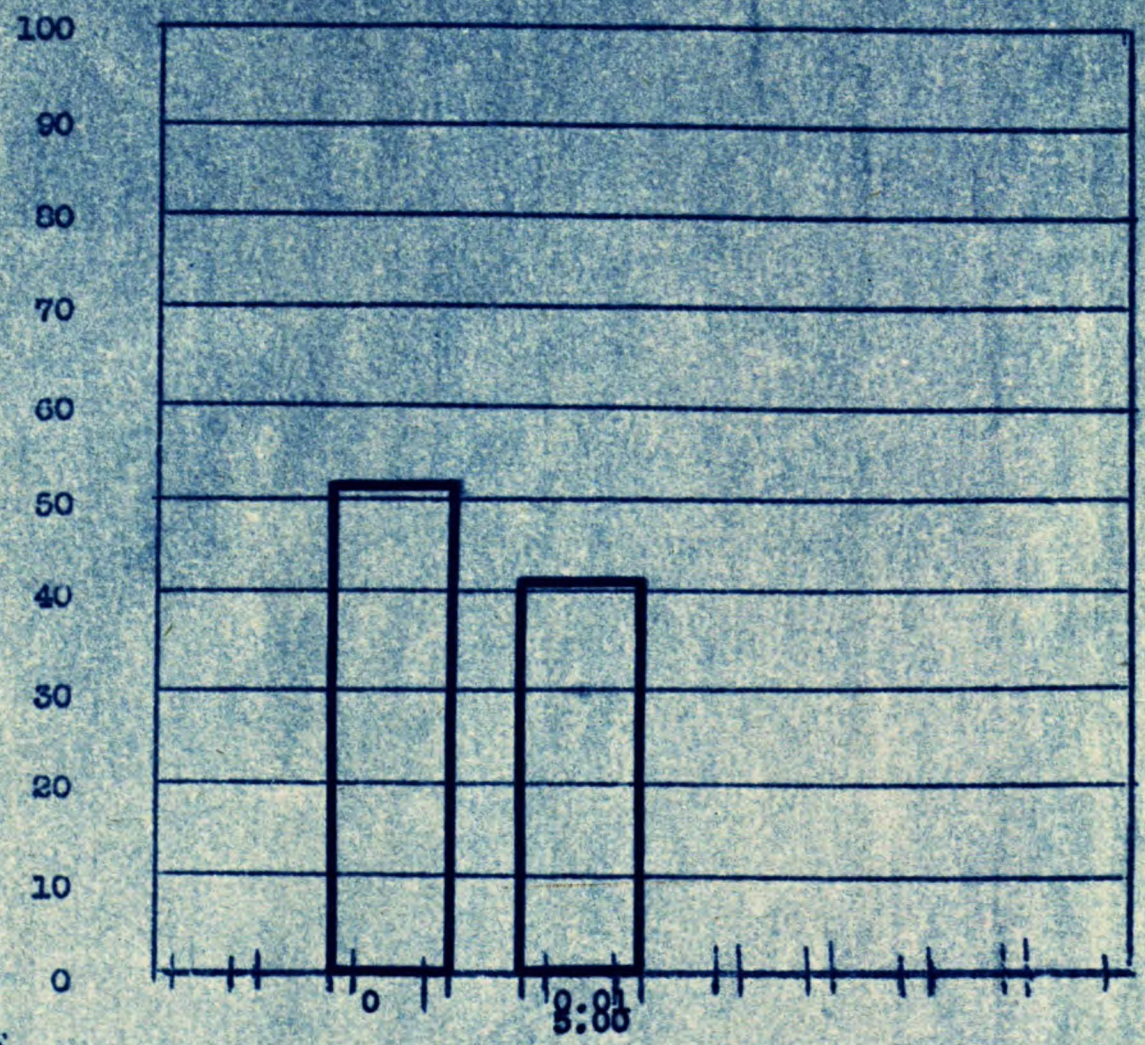
Significance:* 98 %.

(NOTE: THIS MEANS THAT (100-....%) equals the percentage of the time the above ratio difference would occur due to chance.)

Armour Statistics
Data Sheet No. 5.

CORRELATION BETWEEN ..NICKEL..... and .BALLISTIC LIMIT....

IN....60 mm..... FROM DOMINION FOUNDRIES & STEEL #1



RANGE

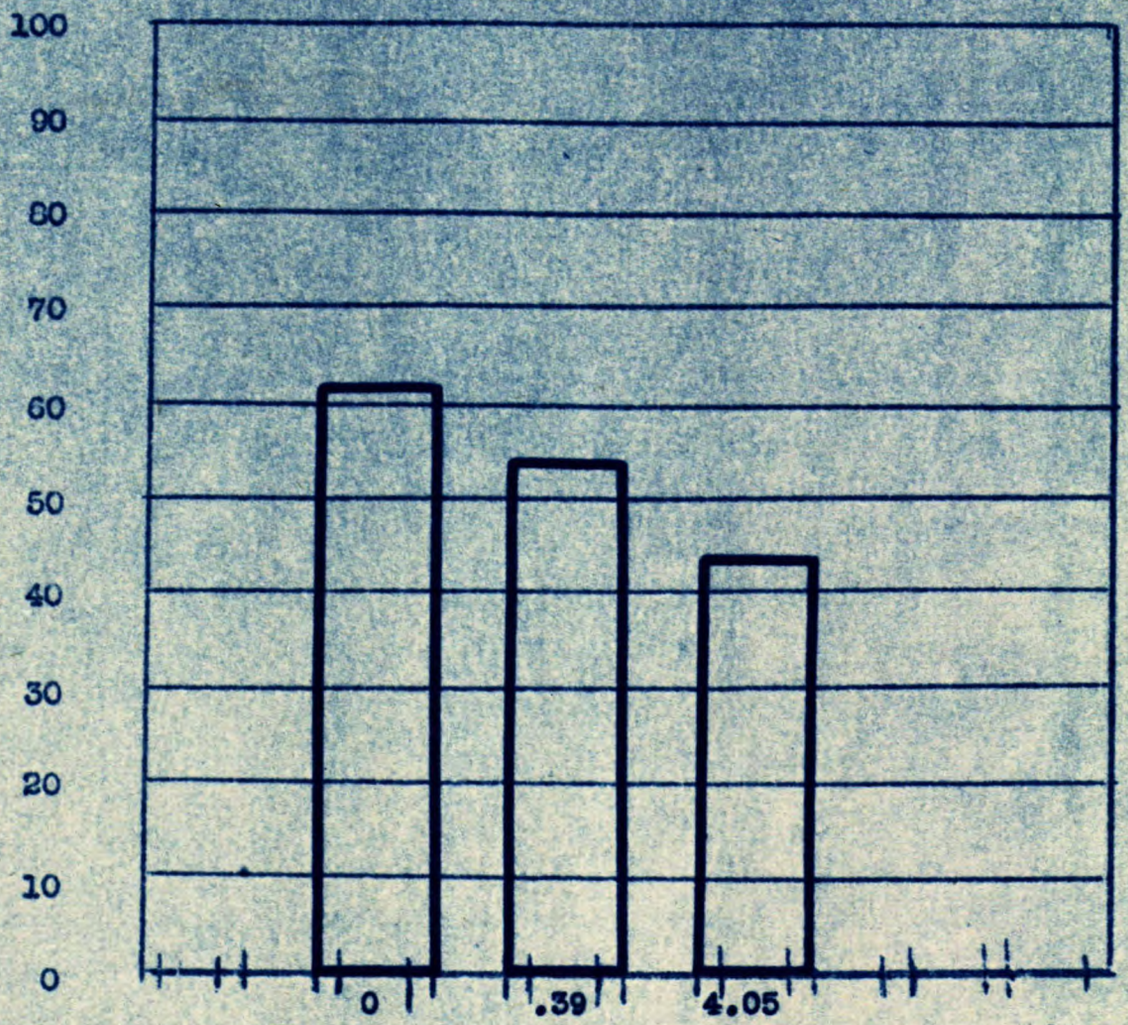
No. above: 2550 f/s:	12
1930 f/s	10
Total number of test results:	23 / 24
Percentage above:	52 / 41.7
Ratio difference:	.103
Number effect:	.0435 + .0417 = .0852
Significance:*	80%

(NOTE: THIS MEANS THAT (100-....%) equals the percentage of the time the above ratio difference would occur due to chance.)

Armour Statistics
Data Sheet No. 5.

CORRELATION BETWEEN ...NICKEL..... and .BALLISTIC LIMIT....

IN.....60 mm..... FROM..DOMINION FOUNDRIES & STEEL # 2



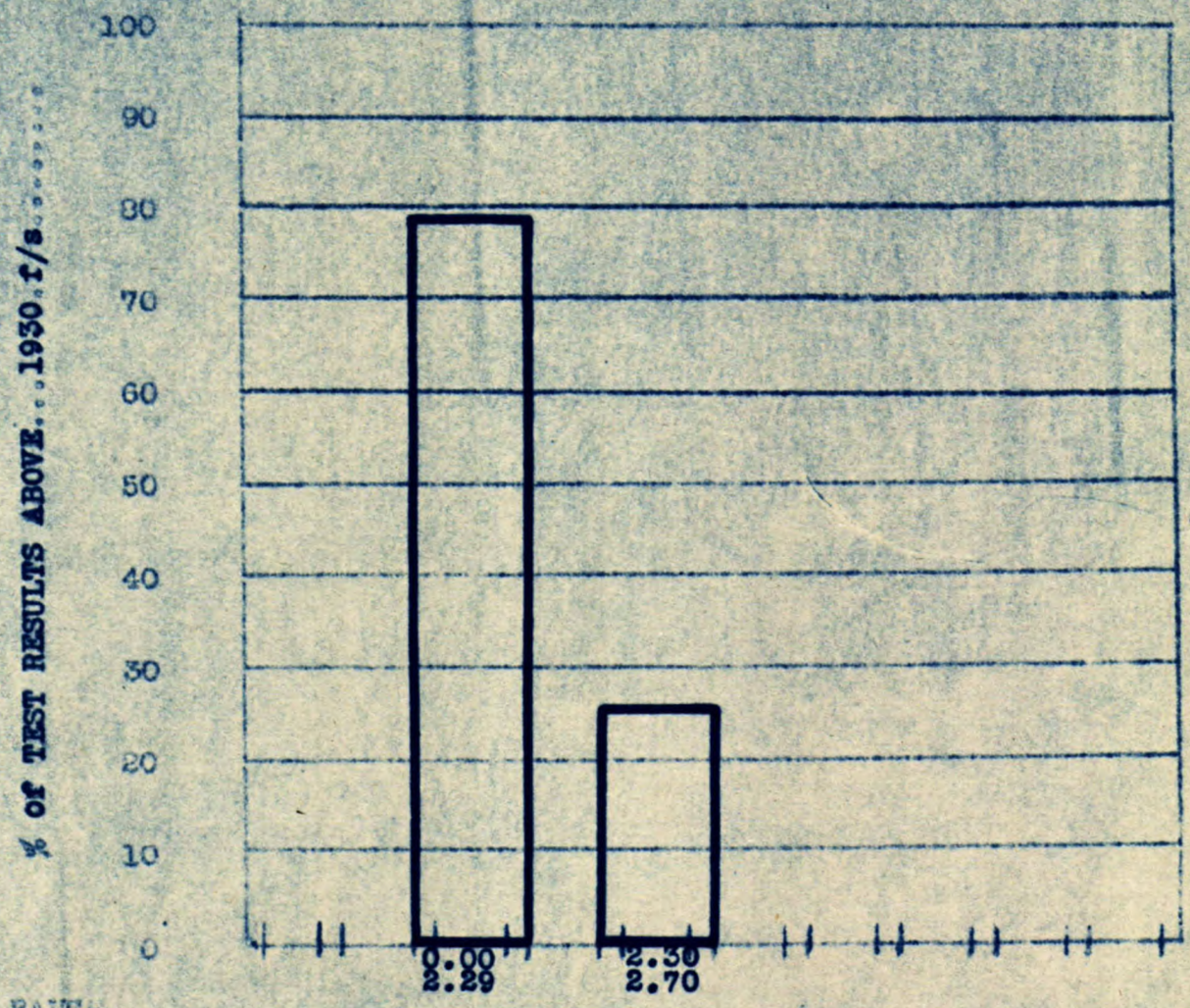
RANGE	0	.39 .87	4.05 5.40
No. above: 2550 f/s: 1890 f/s:	5	12.	6.
Total number of test results:	8	22	14.
Percentage above:	62.5	54.5	43
Ratio difference:		.08	.12
Number effect:	.125 + .046 = .171		.046 + .072 = .118
Significance:*	81 %		42 %

(NOTE: THIS MEANS THAT (100-....%) equals the percentage of the time the above ratio difference would occur due to chance.)

Armour Statistics
Data Sheet No. 5.

CORRELATION BETWEEN ..CHROMIUM.....&...BALLISTIC LIMIT.

IN....60 mm..... FROM DOMINION FOUNDRIES & STEEL #1



RANGE	0.00 2.29	2.30 2.70
No. above: 1930 f/s:	15.	7.
Total number of test results:	19	27.
Percentage above:	79	26

Ratio difference: .53

Number effect: .0526 + .0370 = .0896

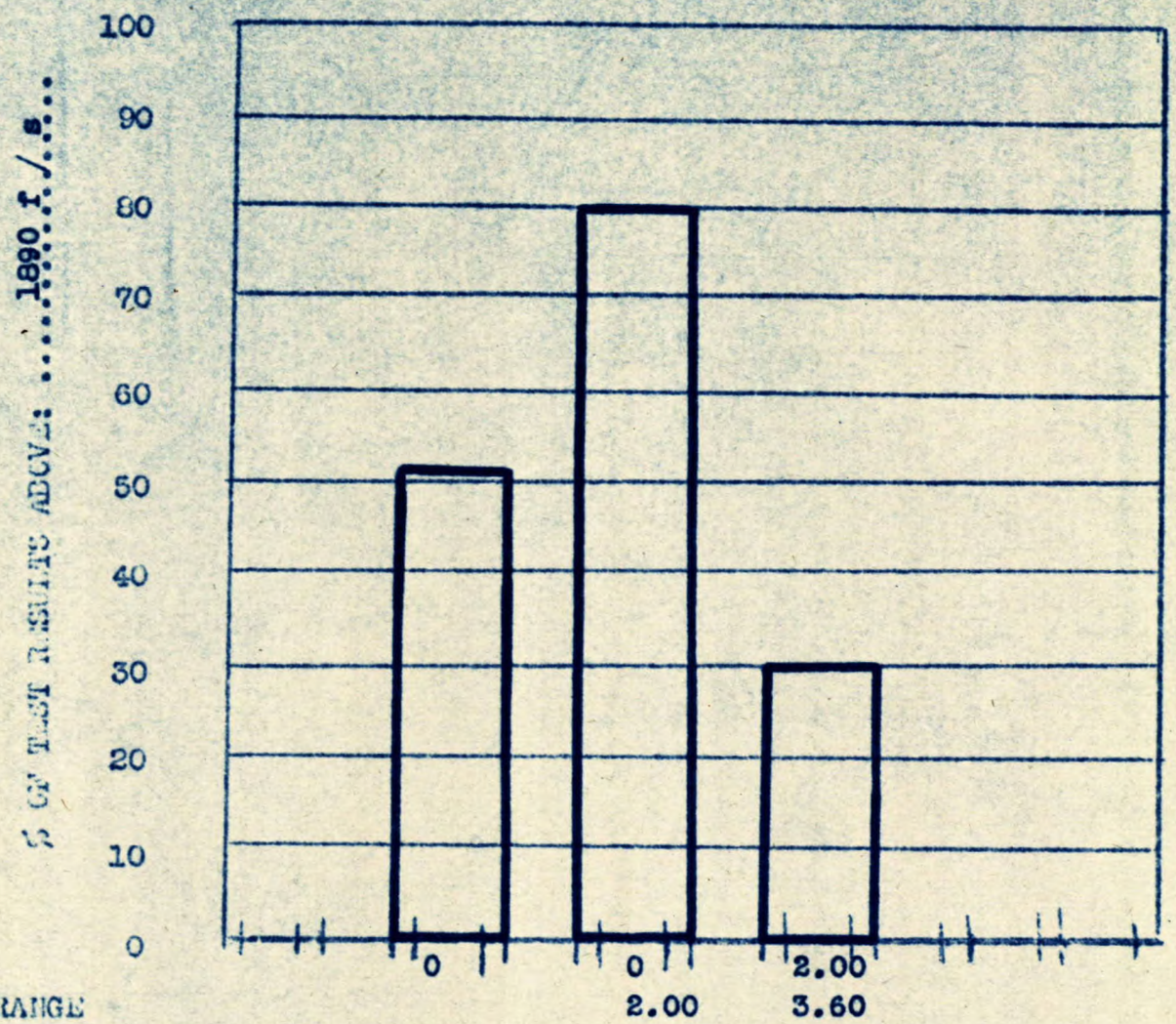
Significance:* 99.99 %.

(NOTE: This means that (100-.....%) equals the percentage of the time the above ratio difference would occur due to chance.)

Armour Statistics
Data Sheet No. 5.

CORRELATION BETWEEN ....CHROMIUM... and .BALLISTIC LIMIT...

IN....60 mm..... FROM.DOMINION FOUNDRIES & STEEL #2



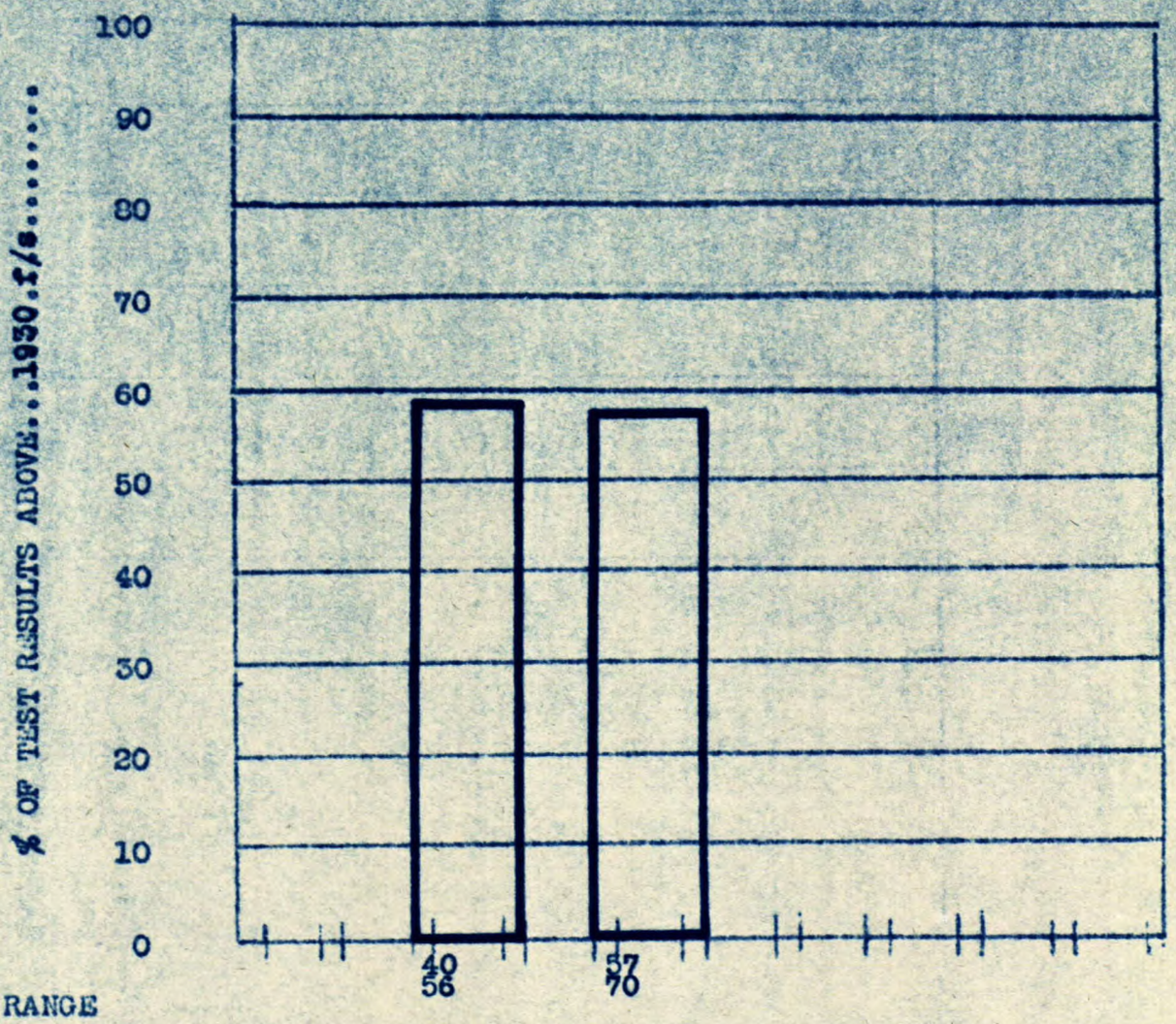
RANGE		2.00	3.60
No. above: 2550 f/s: 1890 f/s:	11	4	9
Total number of test results:	21	5	30.
Percentage above:	52	80	30
Ratio difference:		.28	.50
Number effect:	.476 + .2 = .676		.2 + .333 = .533
Significance:*	....97.....%		99.99

(NOTE: THIS MEANS THAT (100-....%) equals the percentage of the time the above ratio difference would occur due to chance.)

Armour Statistics
Data Sheet No. 5.

CORRELATION BETWEEN .MOLYBDENUM....&...BALLISTIC .LIMIT.

IN.....60 mm.... FROM.DOMINION .FOUNDRIES & STEEL # 1



	RANGE	
No. above: 2550 f/s: 1930 f/s	12	11
Total number of test results:	25	23
Percentage above:	48.	47.8

Ratio difference: .2

Number effect: .04 + .0434 = .0834

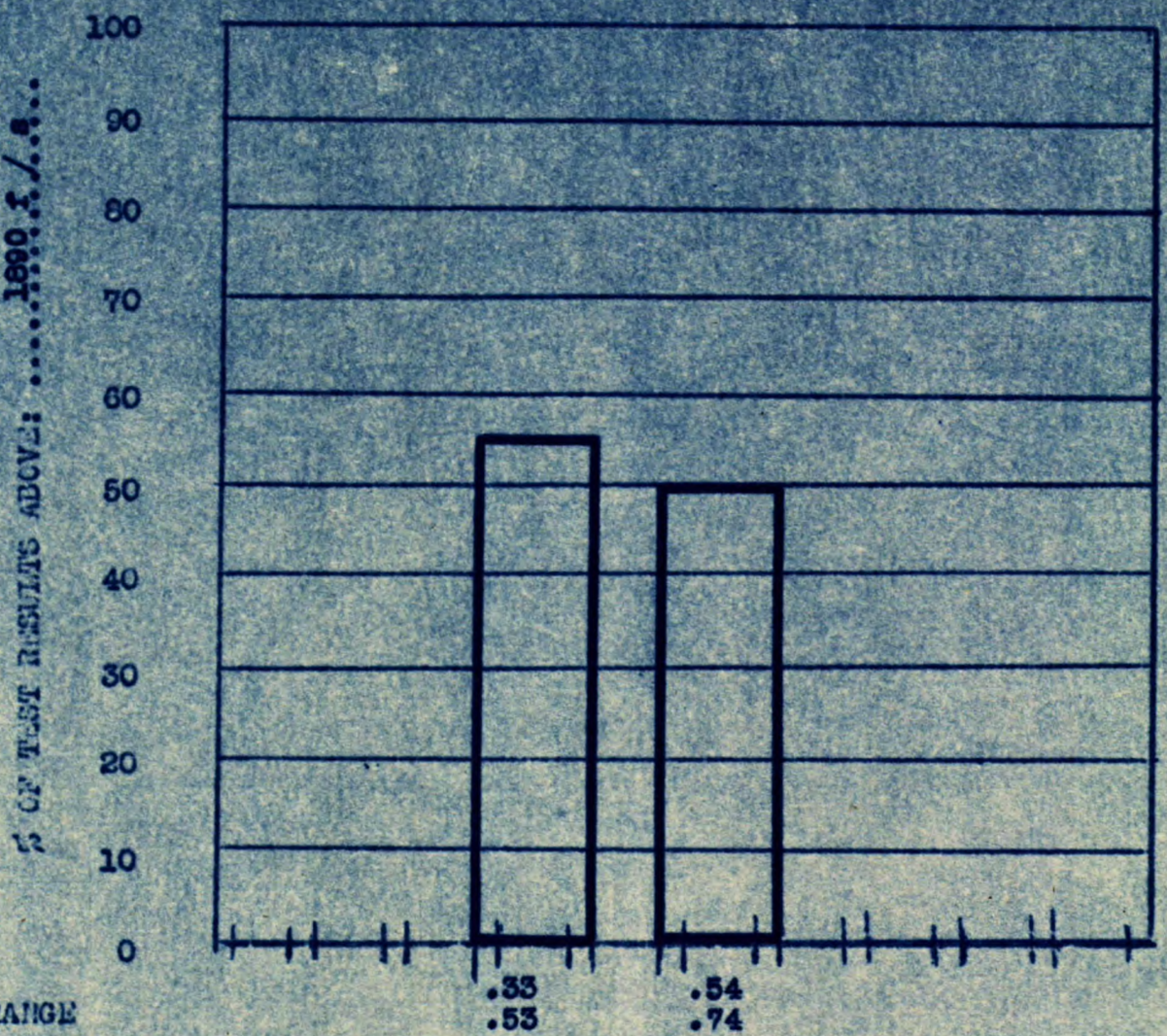
Significance: 10 %.

(NOTE: This means that (100- %) equals the percentage of the time the above ratio difference would occur due to chance.)

Armour Statistics
Data Sheet No. 5.

CORRELATION BETWEEN ..MOLYBDENUM.. and ..BALLISTIC LIMIT..

IN....60 mm..... FROM: DOMINION FOUNDRIES & STEEL # 2



RANGE	.33 / .53	.54 / .74
No. above: 2550 f/s: 1890 f/s	12	12
Total number of test results:	22	24
Percentage above:	55	50

Ratio difference: .05

Number effect: .046 + .042 = .088

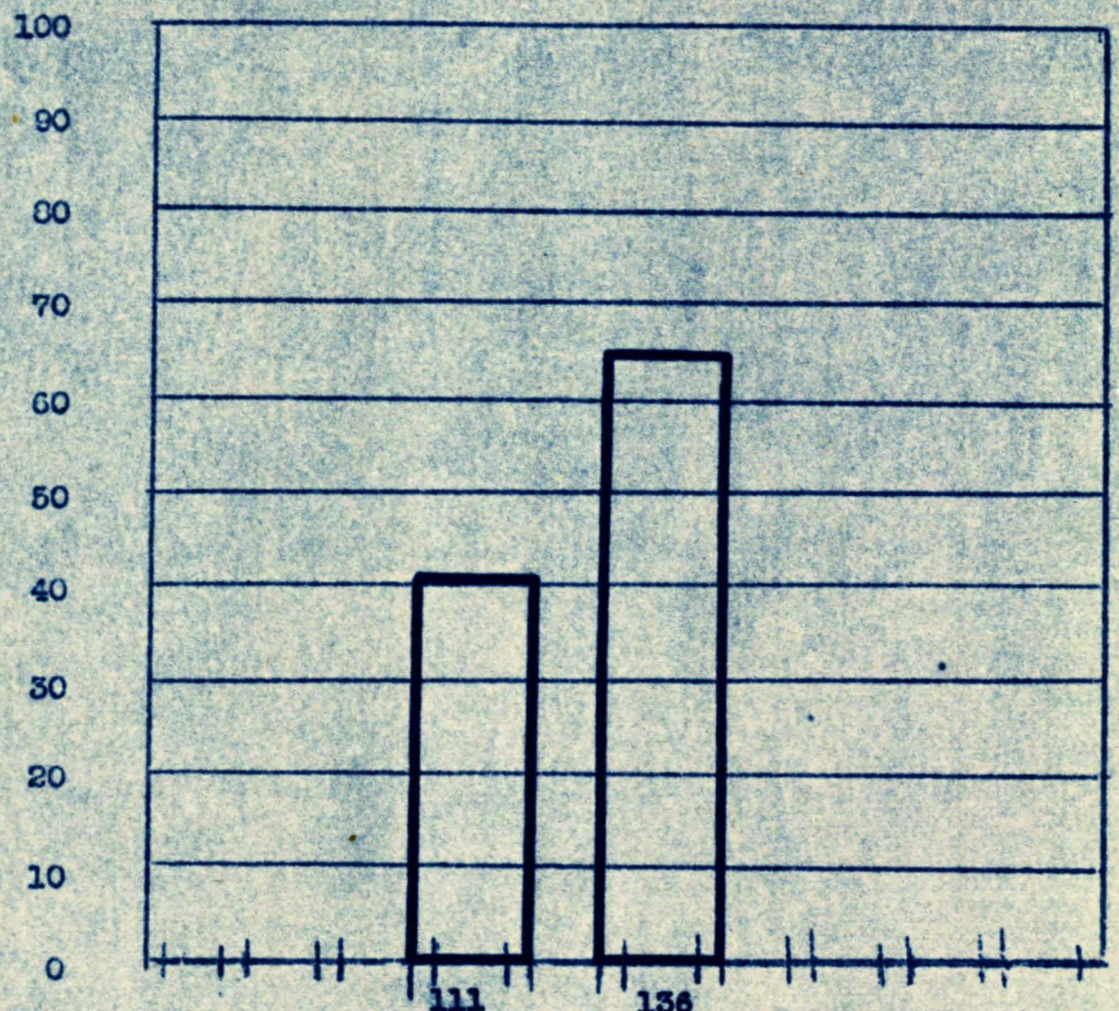
Significance:* 24 %.

(NOTE: THIS MEANS THAT (100-...%) equals the percentage of the time the above ratio difference would occur due to chance.)

Armour Statistics
Data Sheet No. 5.

CORRELATION BETWEEN: TENSILE STRENGTH and BALLISTIC LIMIT....

IN....60 mm..... FROM: DOMINION FOUNDRIES & STEEL #1



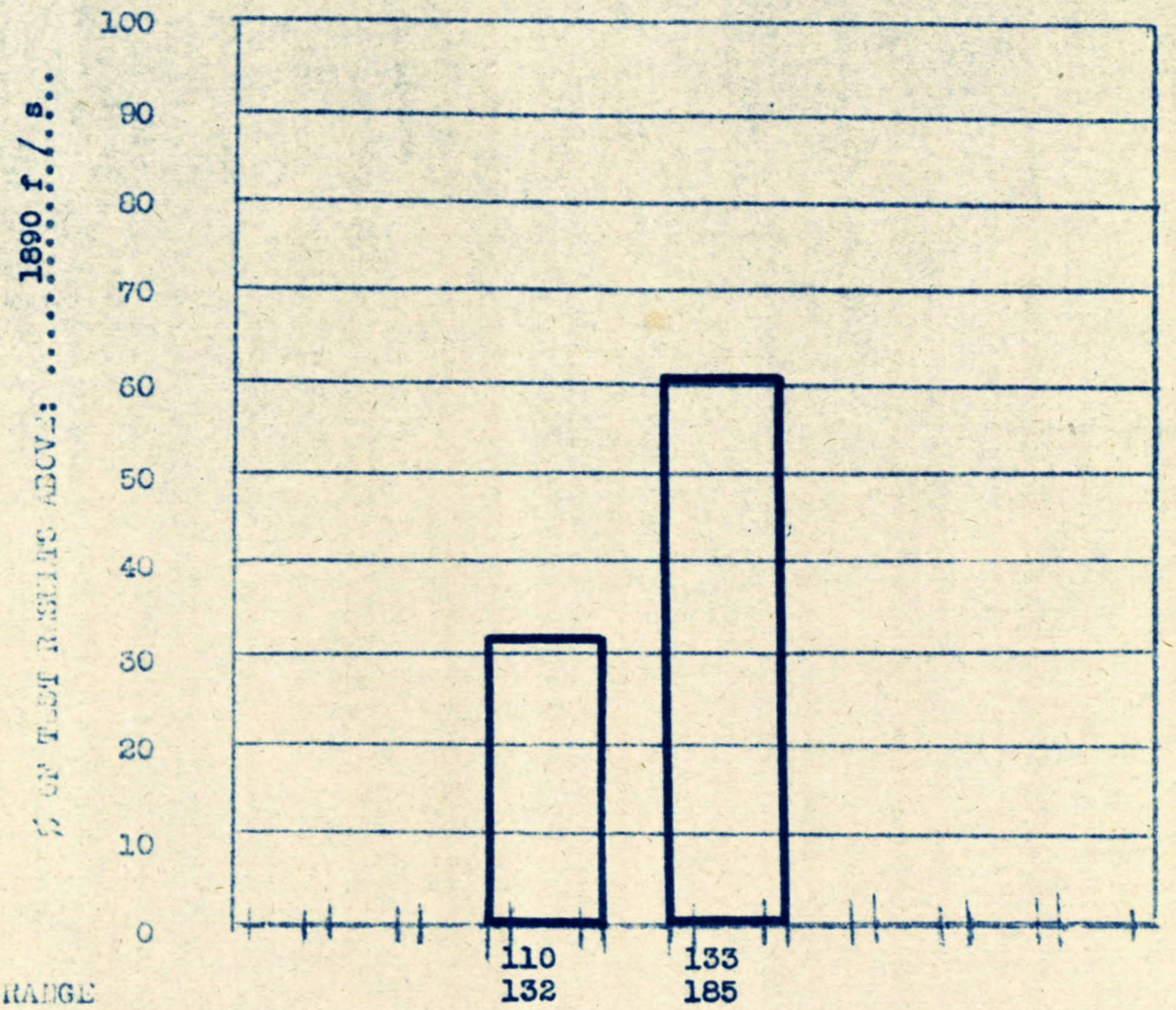
RANGE	111	136
	134	188
No. above: 2550 f/s: 1920 f/s	11	18
Total number of test results:	27	28
Percentage above:	40.7	64.3
Ratio difference:	23.6	
Number effect:	.037 + .036 = .073	
Significance:*	92 %	

(NOTE: THIS MEANS THAT (100-....%) equals the percentage of the time the above ratio difference would occur due to chance.)

Armour Statistics
Data Sheet No. 5.

CORRELATION BETWEEN ..TENSILE..... and BALLISTIC.LIMIT.....

IN.....60.mm..... FROM.DOMINION.FOUNDRIES & STEEL #2



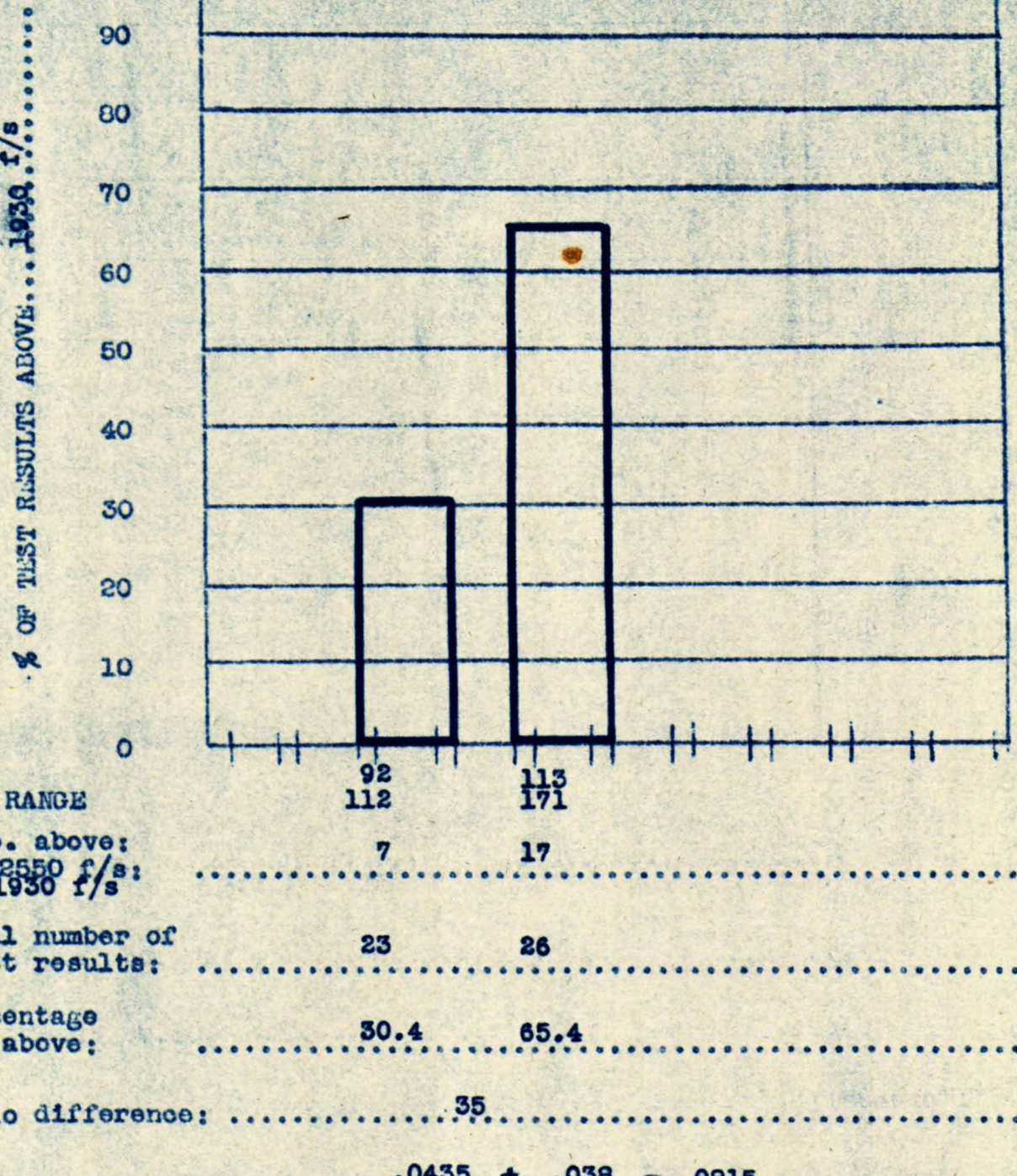
	RANGE	
No. above: 2550 f/s: 1890 f/s	13	25
Total number of test results:	41	41
Percentage above:	31.7	61
Ratio difference:	.293	
Number effect:	.0244 + .0244 = .0488	
Significance:*	99.85 %	

(NOTE: THIS MEANS THAT (100-....%) equals the percentage of the time the above ratio difference would occur due to chance.)

Armour Statistics
Data Sheet No. 5.

CORRELATION BETWEEN ..YIELD.....&..BALLISTIC.LIMIT..

IN....60 mm..... FROM DOMINION FOUNDRIES & STEEL #1



RANGE	92 / 112	113 / 171
No. above: 2550 f/s: 1930 f/s:	7	17
Total number of test results:	23	26
Percentage above:	30.4	65.4

Ratio difference: 35

Number effect: .0435 + .038 = .0815

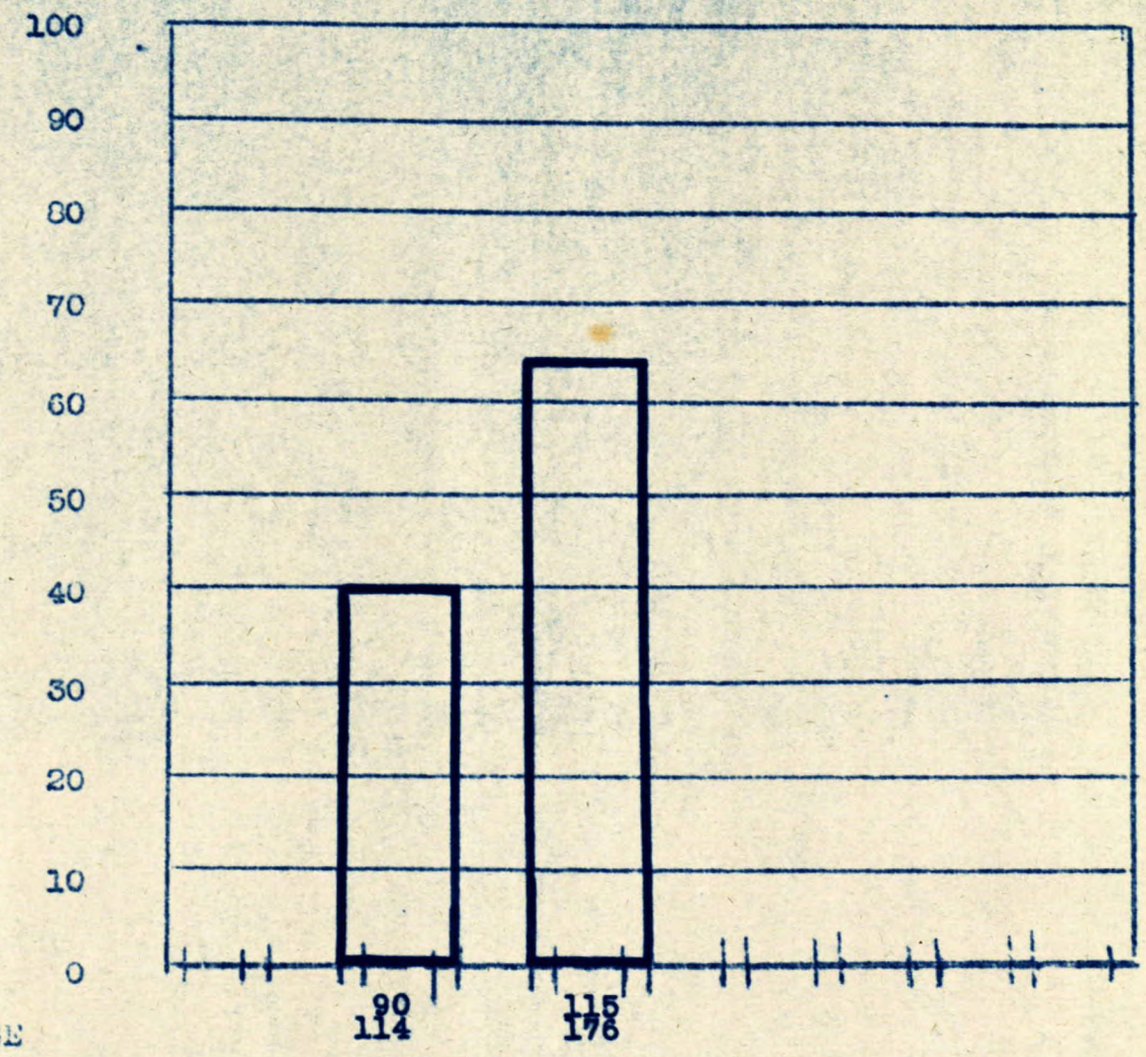
Significance:* 98.5 %.

(NOTE: This means that (100- %) equals the percentage of the time the above ratio difference would occur due to chance.)

Armour Statistics
Data Sheet No. 5.

CORRELATION BETWEEN ..YIELD..... and ..BALLISTIC LIMIT...

IN....60 mm..... FROM..DOMINION FOUNDRIES & STEEL #2



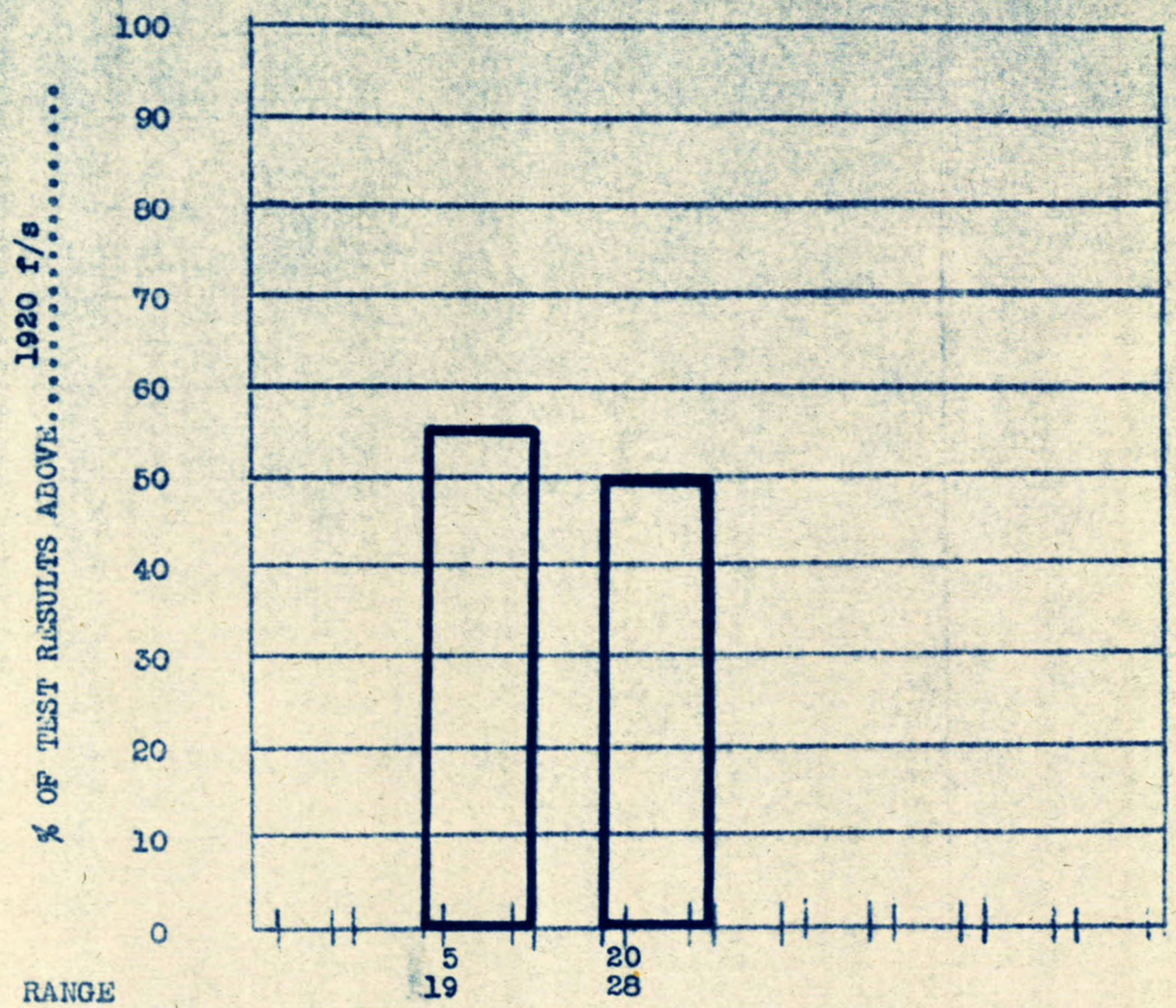
	RANGE	
No. above: 2550 f/s: 1890 f/s	14	25
Total number of test results:	35	39
Percentage above:	40	64
Ratio difference:	.24	
Number effect:	.0286 + 0 .0256 = 0.054	
Significance:*	96 %	

(NOTE: THIS MEANS THAT (100-....%) equals the percentage of the time the above ratio difference would occur due to chance.)

Armour Statistics
Data Sheet No. 5.

CORRELATION BETWEEN ELONGATION ..... & ..... BALLISTIC LIMIT

IN .. 60. mm ..... FROM DOMINION. FOUNDRIES & STEEL # 1



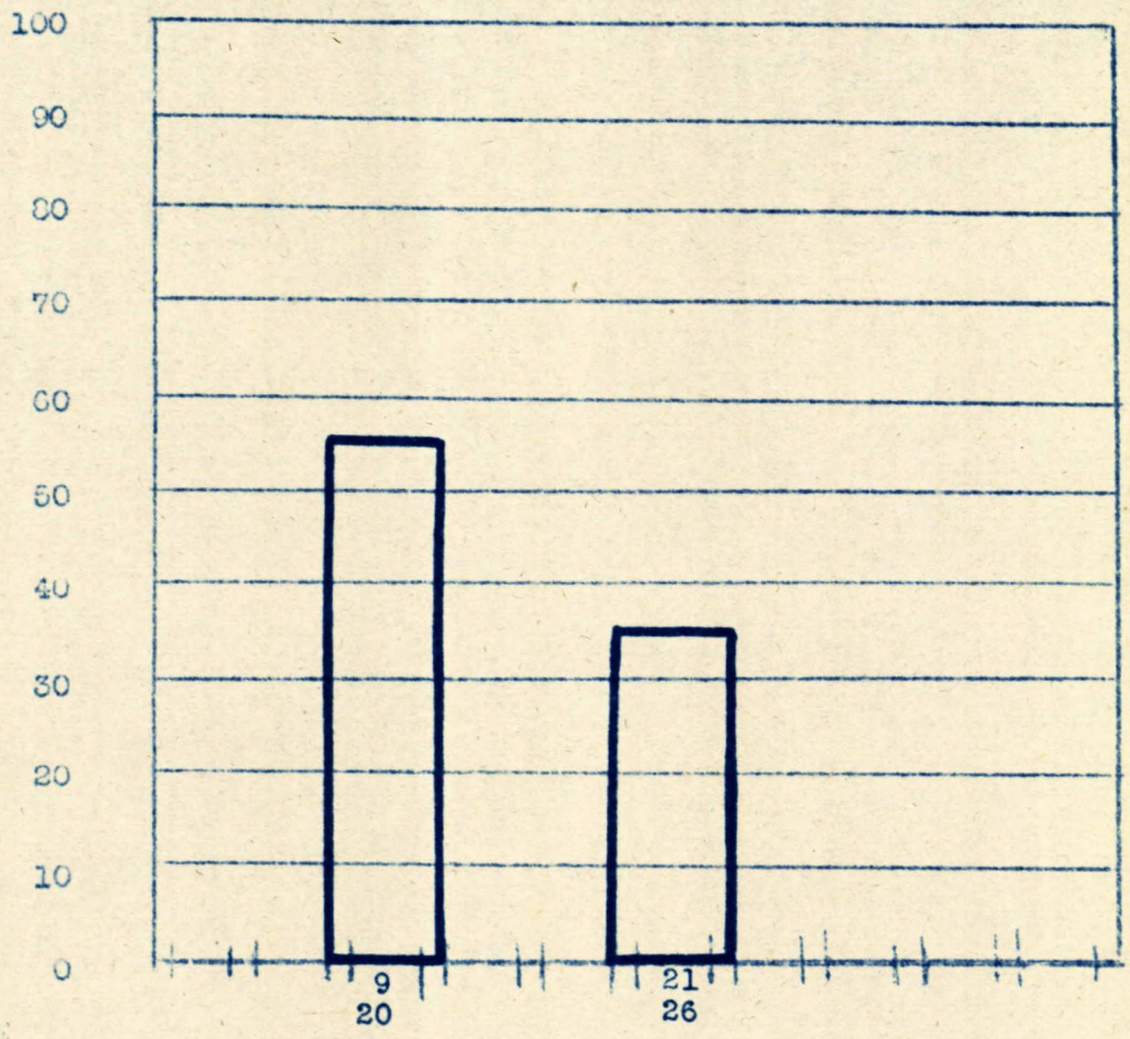
RANGE		
No. above: 2550 f/s: 1920f/s	15	14
Total number of test results:	27	28
Percentage above:	55.5	50.
Ratio difference:	5.5	
Number effect:	.037 + .036 = .073	
Significance:*	34 %	

(NOTE: This means that (100- %) equals the percentage of the time the above ratio difference would occur due to chance.)

Armour Statistics
Data Sheet No. 5.

CORRELATION BETWEEN .ELONGATION... and BALLISTIC LIMIT....

IN....60 mm..... FROM DOMINION FOUNDRIES & STEEL # 2



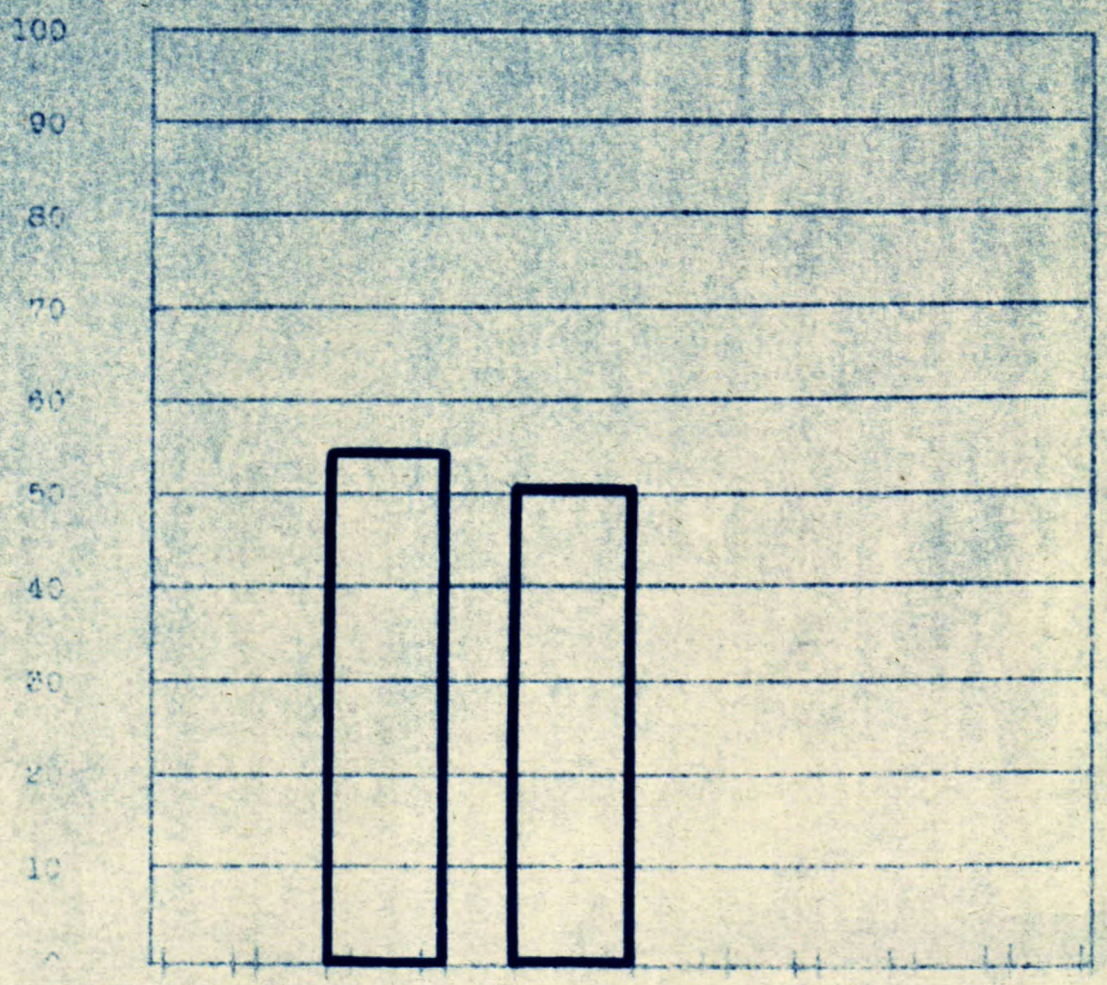
RANGE		
No. above: 2550 f/s: 1890 f/s	.....22.....	.....14.....
Total number of test results:	.....39.....	.....37.....
Percentage above:	.....56.4.....	.....35.9.....
Ratio difference:	.....,205.....	
Number effect:	.....,0256 + ,0270 = ,053.....	
Significance:®	.....93....%.	

(NOTE: THIS MEANS THAT (100-....) equals the percentage of the time the above ratio difference would occur due to chance.)

Armour Statistics
Data Sheet No. 5.

CORRELATION BETWEEN REDUCTION OF AREA & BALLISTIC LIMIT

IN 60 mm FROM DOMINION FOUNDRIES & STEEL #1



RANGE	11 45	46 74
No. above f/s:	13	16
Total number of test results:	24	31
Percentage above:	54.2	51.6

Ratio difference: 2.6

Number effect: .0417 + .0322 = .0739

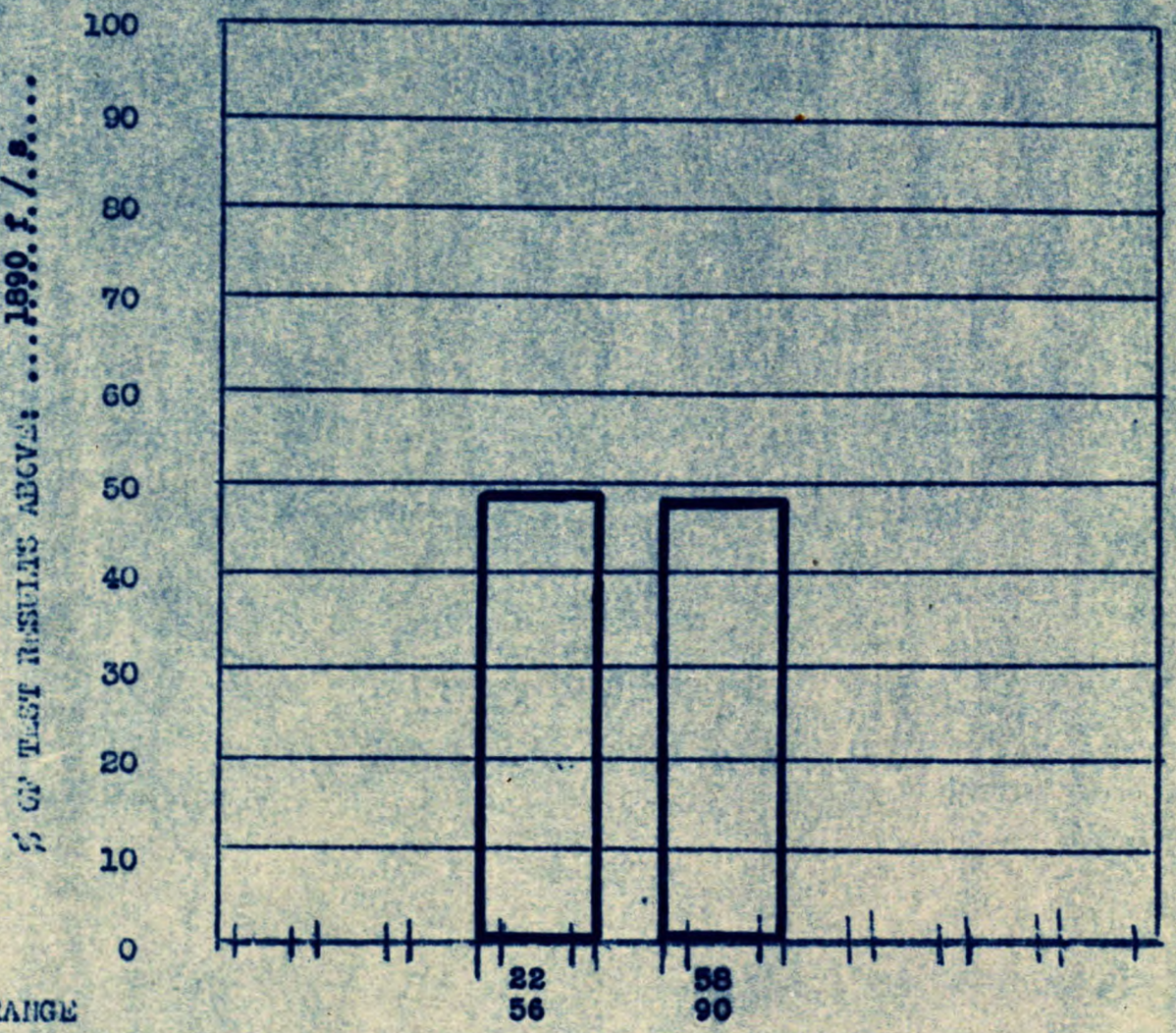
Significance:* 10 %.

*(NOTE: This means that (100-.....%) equals the percentage of the time the above ratio difference would occur due to chance.)

REDUCTION OF

CORRELATION BETWEEN .....AREA..... and ..BALLISTIC LIMIT...

IN....60 mm..... FROM DOMINION FOUNDRIES & STEEL # 2



RANGE	22 56	58 90
No. above: 2550 f/s: 1890 f/s	20	18
Total number of test results:	41	37
Percentage above:	48.8	48.6

Ratio difference: .2

Number effect: .0244 + .0270 = .0514

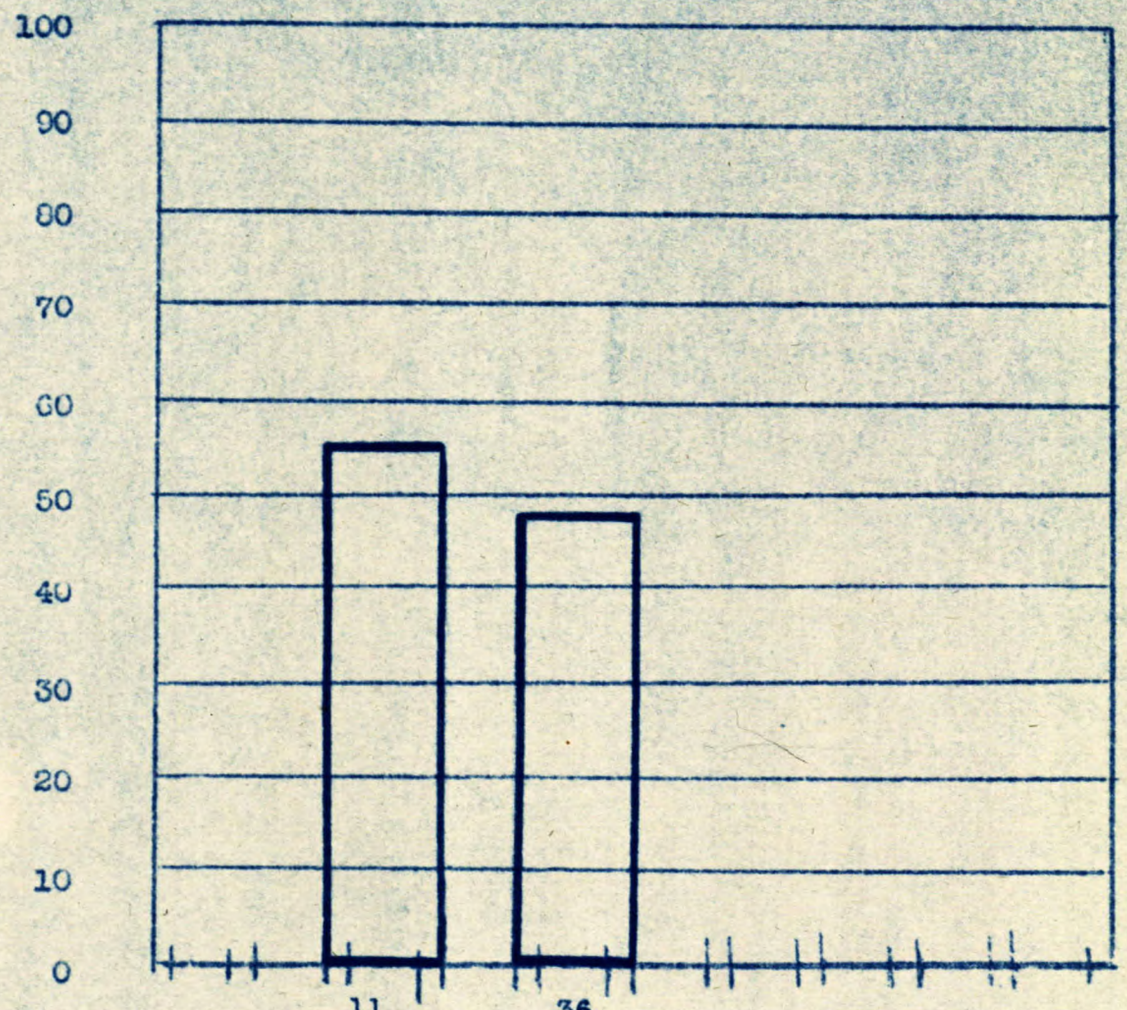
Significance:* 17 %.

(NOTE: THIS MEANS THAT (100-....%) equals the percentage of the time the above ratio difference would occur due to chance.)

Armour Statistics
Data Sheet No. 5.

CORRELATION BETWEEN ..IZOD..... and BALLISTIC LIMIT....

IN...60 mm..... FROM DOMINION FOUNDRIES & STEEL #1



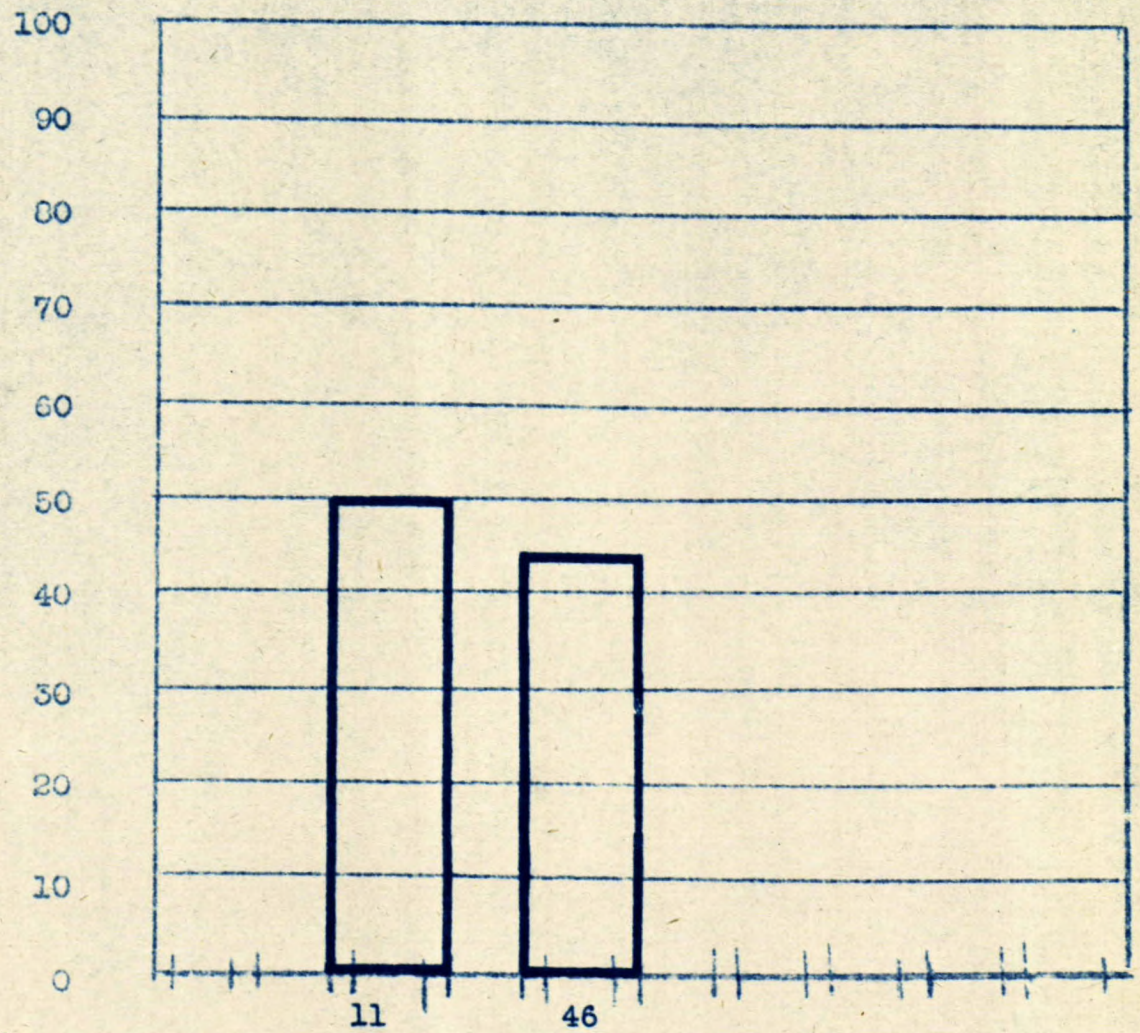
RANGE	11 34	36 82
No. above: 2550 f/s:	16	15
Total number of test results:	29	31
Percentage above:	55.2	48.4
Ratio difference:	6.8	
Number effect:	.0344 + .0322 = .0666	
Significance:	42 %	

(NOTE: THIS MEANS THAT (100-....%) equals the percentage of the time the above ratio difference would occur due to chance.)

Armour Statistics
Data Sheet No. 5.

CORRELATION BETWEEN: IZOD and BALLISTIC LIMIT

IN .60.mm. FROM DOMINION FOUNDRIES & STEEL # 2



RANGE	11 45	46 91
No. above: 2550 f/s: 1890 f/s:	21	19
Total number of test results:	42	43
Percentage above:	50	44

Ratio difference: .06

Number effect: .024 + .023 = .047

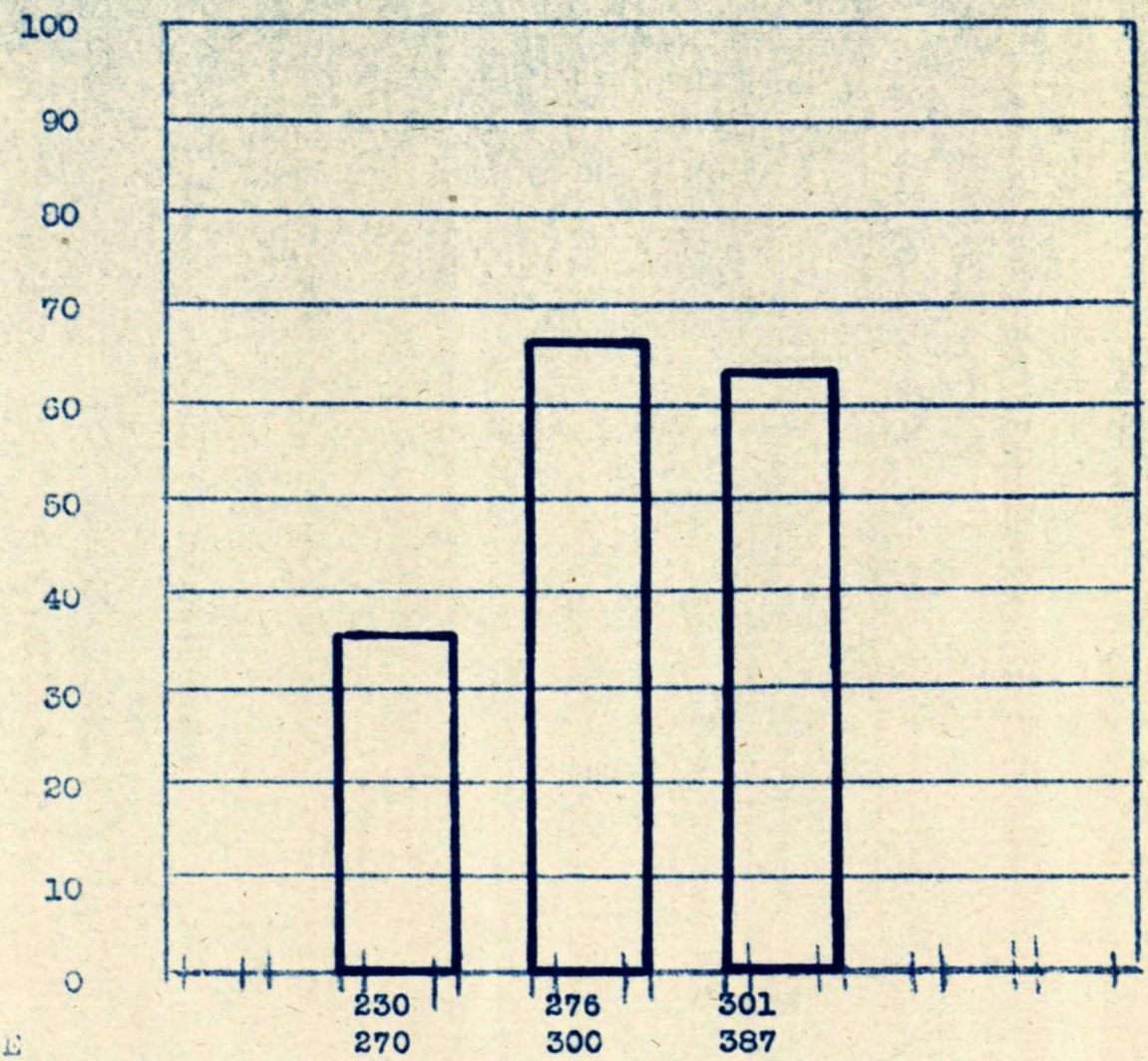
Significance:* 45 %.

(NOTE: THIS MEANS THAT (100-....) equals the percentage of the time the above ratio difference would occur due to chance.)

Armour Statistics
Data Sheet No. 5.

CORRELATION BETWEEN BRINELL HARDNESS and BALLISTIC LIMIT.....

IN...60 mm..... FROM DOMINION FOUNDRIES & STEEL #1



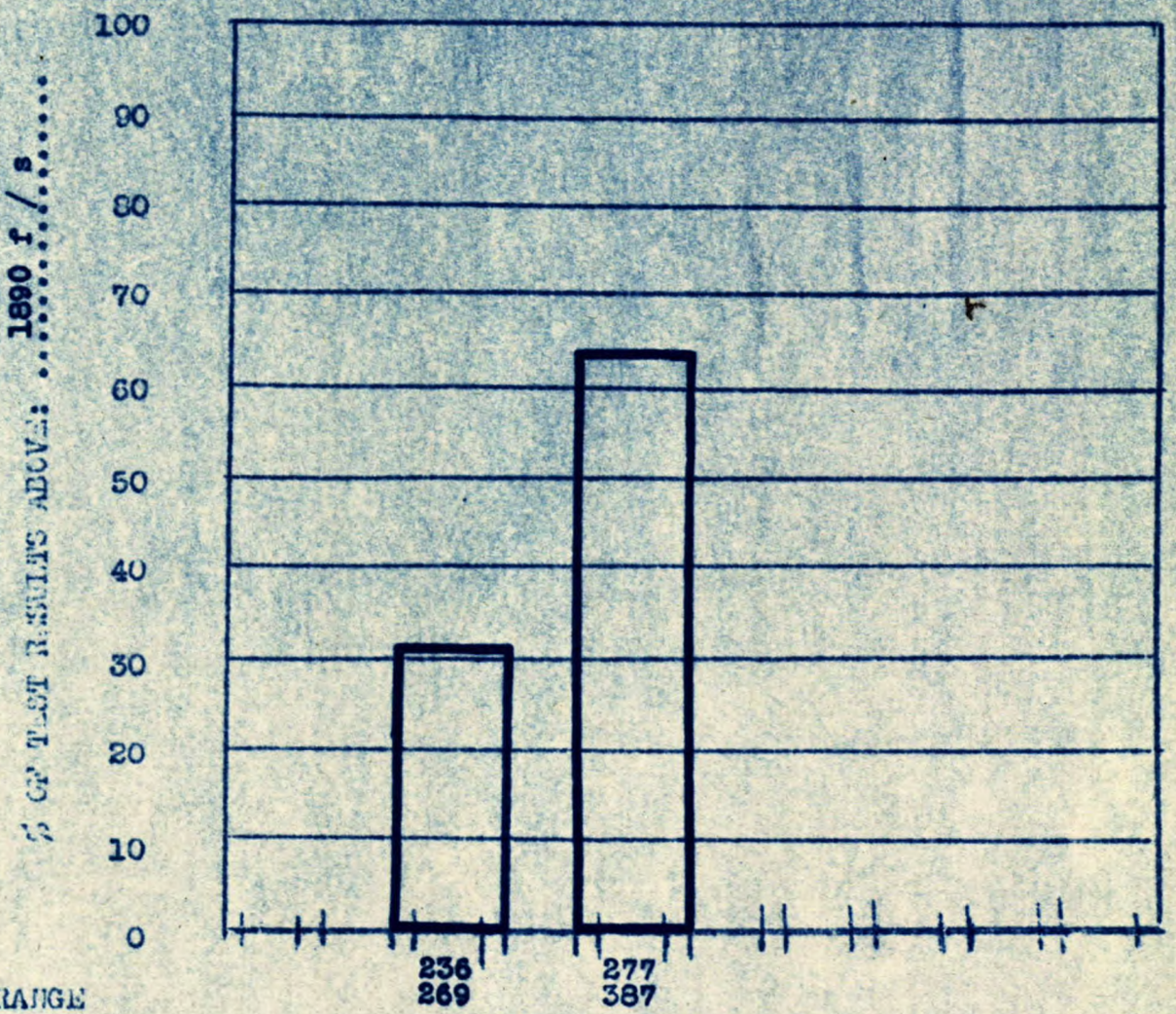
RANGE	230 270	276 300	301 387
No. above: 2550 f/s: 1920 f/s	9	18	7
Total number of test results:	25	27	11
Percentage above:	36	67	63.6
Ratio difference:	31	3.4	
Number effect:	.04 + .037 = .077	.037 + .091 = .128	
Significance:*	(235 - 300 B. H. N. ONLY 97 %)		

(NOTE: THIS MEANS THAT (100-....) equals the percentage of the time the above ratio difference would occur due to chance.)

Armour Statistics
Data Sheet No. 5.

CORRELATION BETWEEN BRINELL HARDNESS and BALLISTIC LIMIT....

IN....60 mm..... FROM DOMINION FOUNDRIES & STEEL #2



RANGE	236 269	277 387
No. above: 2550 f/s: 1890 f/s:	12	27
Total number of test results:	38	42
Percentage above:	32	64

Ratio difference: .32

Number effect: .027 + .024 = .051

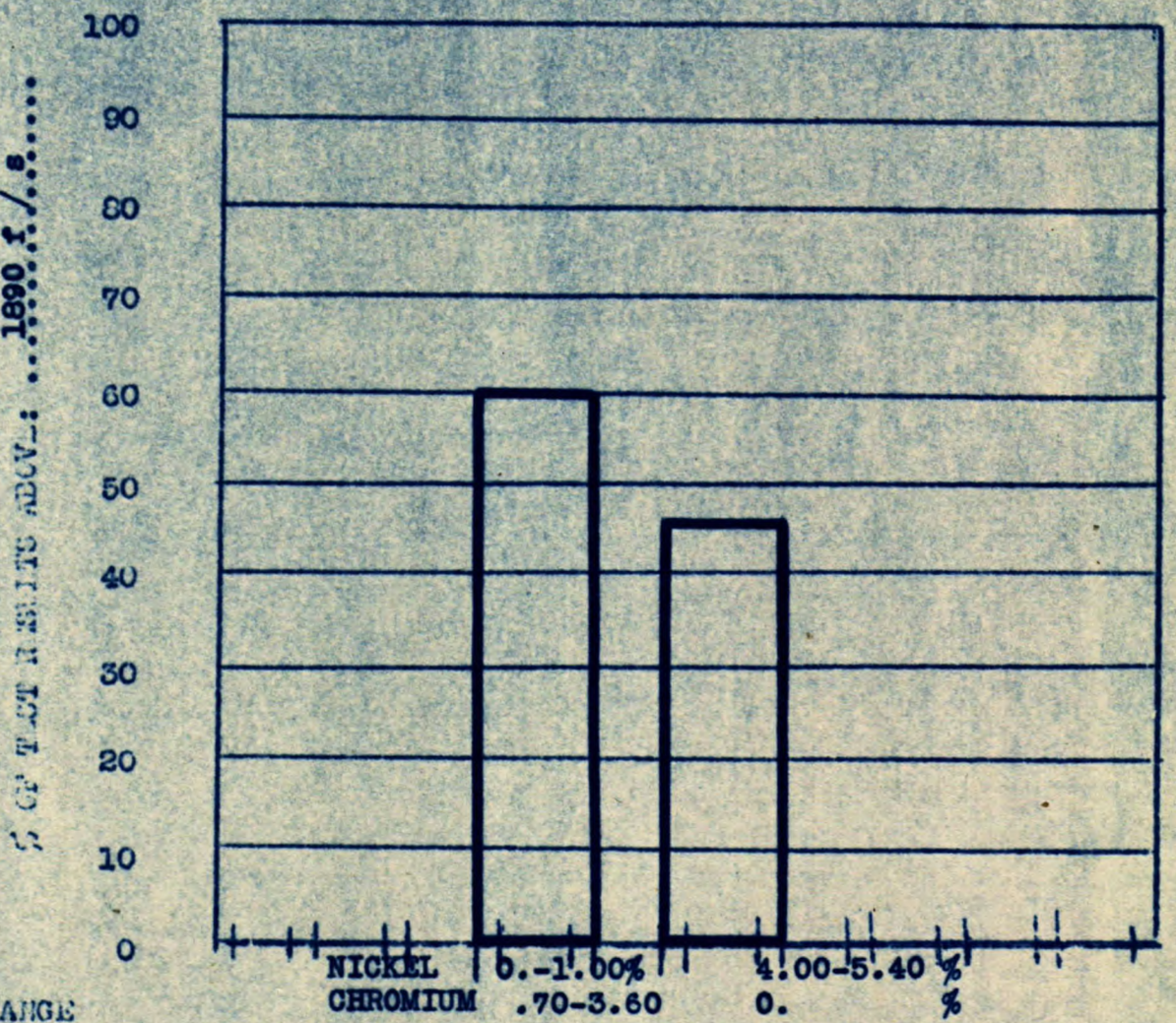
Significance:* ...99.6.....%.

(NOTE: THIS MEANS THAT (100-....%) equals the percentage of the time the above ratio difference would occur due to chance.)

Armour Statistics
Data Sheet No. 5.

CORRELATION BETWEEN CHROMIUM ..... and NICKEL .....

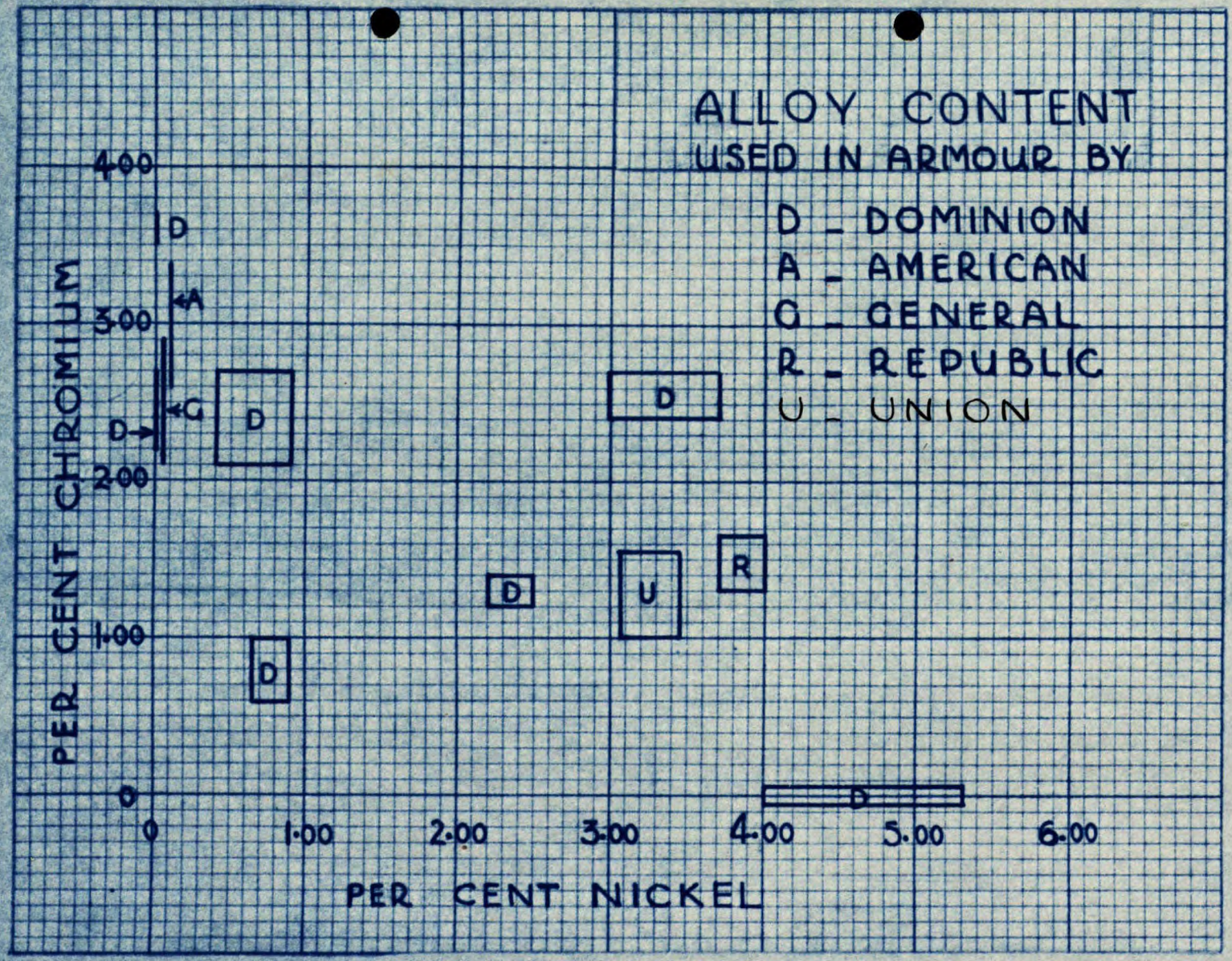
IN 60 mm. ..... FROM DOMINION FOUNDRIES & STEEL #2



RANGE		
No. above: 2550 f/s: 1890 f/s	18	6.
Total number of test results:	30	13.
Percentage above:	60	46.
Ratio difference:	.14	
Number effect:	.0333 +	.0769 = .1102
Significance:*	54	%

(NOTE: THIS MEANS THAT (100-....%) equals the percentage of the time the above ratio difference would occur due to chance.)

Armour Statistics
Data Sheet No. 5.



ALLOY RANGES USED BY ARMOUR MANUFACTURERS.