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REPORT

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1415.

Life of Stainless Steel Retorts: A Survey of Records up to May 12th, 1943.

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(Copy No. 10.)

TABLE OF CONTENTS

Abstract.

Undesirable variation in retort life is encountered in the reduction of magnesium. Neither furnace nor furnace position affects retort life. Operating technique has lengthened average life. Wall thickness does not correlate very closely, indicating variations in metal soundness. Chemical analysis is a minor factor in reducing variation.

Melting practice and casting practice are suspected to be the main causes for variation in retorts. Short-time creep tests should be run on every heat in order to observe the variations due to melting practice. Testing instruments should be used to measure the properties of foundry materials so that foundry variations can be reduced.

Scientific methods of recording and analysing data should be employed so that no valuable information will be lost because of lack of proper interpretation.

Three appendices to the report deal respectively with (A) testing foundry materials, (B) tentative creep test, and (C) the statistical method of analysis of observations.

(Report of Investigation)
(No. 1415, May 26th, 1943.)

Bureau of Mines
Division of Metallic
Minerals
-
Ore Dressing
and Metallurgical
Laboratories

CANADA

DEPARTMENT
OF
MINES AND RESOURCES

Mines and Geology Branch

OTTAWA   May 26th, 1943.

REPORT

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ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1415.

Life of Stainless Steel Retorts: A Survey of Records up to May 12th, 1943.

[redacted]

Origin of Request and Purpose of Survey:

The following survey was made at the request of Mr. J. Barrington, Superintendent, DOMINION MAGNESIUM LIMITED, Haley Station, Ontario. All data used were obtained from the Retort Record Book of the Stainless Steel and Alloy Division of SHAWINIGAN CHEMICALS LIMITED, Shawinigan Falls, Quebec, supplied by Mr. C. M. Carmichael, General Manager, and Mr. C. K. Lockwood, Asst. Sales Manager.

The survey was undertaken with the object of discovering which variables had significant effect on retort performance. Begun on May 13th, it covers the period from the beginning of operations to May 12th, 1943.

It was agreed that distribution of information should be restricted to the companies concerned.

Distribution of Failures:

Figure 1 shows the percentage of the retorts failing at various ages. Figure 2 records the same data in the regular frequency distribution form. These graphs demonstrate that some retorts last four times longer than others. A considerable saving could be effected if the short-life retorts could be eliminated.

Relationship of Analysis to Retort Life:

Retorts were divided into analysis classifications and the average life of the retorts in each class is shown on Figure 3. It is evident that with higher carbon, slightly longer life occurs. Higher carbon content would be expected to adversely affect creep properties at the high operating temperatures. An explanation of the better results with higher carbon alloy may be that this metal is more easily cast. The optimum analysis range appears to be 15-17 per cent chromium, 33-35 per cent nickel, 0.29-0.38 per cent carbon, 0.30-0.69 per cent silicon.

Silicon classification was made as follows:

Silicon range, per cent		Average retort life, days
0.30-0.69	-	129
0.70-0.89	-	127.8
0.90-1.69	-	123.3

Since chemical analysis has only a slight correlation with retort life it must be considered as a minor factor.

Relationship of Wall Thickness to Retort Life:

If the failure of retorts were of a mechanical nature, it should correlate closely with wall thickness. Figure 4 shows that, within the limits reported, retort life

(Relationship of Wall Thickness to Retort Life, cont'd) -

is only slightly dependent upon wall thickness. Tabulation of these data was done as follows:

Wall thickness, inch		Average life, in days	Standard deviation,	Percentage of retorts over 110 days' life
8/16-11/16	-	127.6	48.9	56
12/16-13/16	-	133.8	38.4	69
14/16-16/16	-	135.4	38.6	65

While wall thickness does increase life slightly, the improvement is not as much as mechanical equations would predict. There must be variation in the retort other than in analysis or thickness which accounts for the extreme variation in retort life.

Effect of Furnace:

Retort life was taken in samples of four in the order in which the data appear in the records. This allows a comparison of furnaces to be made. Points outside the control limits indicate assignable causes of variation. Figure 5 shows that retort life is under statistical control when sampled by furnaces. This means that no differences between Furnaces 5, 7, 8, and 9 are evident from the data available to date.

Furnace Position:

Grouping the retort lives according to position in the furnace resulted in groups of from 2 to 6. When placed in quality control chart form, varying control limits were required because of the variation in group number. As Figure 6 shows, no furnace position is significantly different from the general average. As yet, therefore, no evidence is available to prove that furnace position has any effect on retort life.

Date of Failure:

Retort lives were arranged in order of date of failure and groups of four were plotted on the statistical quality control system. Figure 7 shows that gradual improvement has been made over the period from November 1942 to April 1943. This trend indicates that assignable causes have been operating. In starting up a new process, gradual improvement is expected as operations settle down to normal and difficulties are eliminated. While the average life has increased there has been no reduction in the variation in retorts.

From this it is concluded that improvement in operating technique is responsible for increasing average life. Variation in retorts is not due to the operating technique.

History of Casting Practice:

Test results were arranged in order of heat number and plotted in groups of four, using the quality control chart method (see Figure 8).

Retort Life -

Retort life is not under statistical control when sampled in casting order. Long runs above and below average indicate that casting practice could be divided into four periods.

Period		Groups Nos.	Heats Nos.
1	-	4- 9	2578 - 2748
2	-	10-14	2749 - 2776
3	-	16-20	2776 - 2799
4	-	21-25	2799 - 2836

Casting practice had more effect on retort life

(History of Casting Practice, cont'd) -

than any of the variables previously studied (analysis, wall thickness, furnace, position in furnace).

While process operation has improved the life of the retorts (Figure 7), casting practice has shown no improvement. Indications are that cycles of good retorts and poor retorts can be expected, due to changes occurring in the foundry.

The reason advanced for assuming that casting practice, and not melting practice, is the main factor affecting retort life is that the runs above and below average in retort life are not paralleled by runs in analysis. Since retort life and analysis do not fluctuate together, a logical alternative is that casting technique is the most potent variable.

It is possible that other factors are responsible. Deoxidation practice, inclusion types in metal, pouring temperature, and pouring speed may have influenced the cycles of retort life.

Carbon -

The carbon range was deliberately shifted at Group No. 18 (Heat No. 2793) and again at Group No. 41 (Heat No. 2920). No change in ability to control carbon is evident. Successive groups of four carbons are expected to vary as much as 0.20 per cent. The black dots indicate the groups out of control.

Silicon -

Silicon remained at the same level throughout the period studied. Lack of control is shown by the black dots.

(Continued on next page)

(History of Casting Practice, cont'd) -

Nickel -

Nickel was deliberately shifted upwards at Group No. 28 (Heat No. 2846) and at Group No. 46 (Heat No. 3057).

Nickel is not under statistical control, as the black dots show.

Chromium -

At Group No. 46 (Heat No. 3058), chromium was shifted upwards. Lack of statistical control is evident from the black dots.

Casting Method:

No comments on the present casting method can be made, due to the lack of any first-hand information. It is understood that centrifugal casting is being considered, and that sand casting is done at present.

Both processes require close control over all variables in order to produce high-quality pressure vessels. In both processes, instruments should be used to measure the quality of mould materials.

Design:

It is understood that changes in design are under consideration.

CONCLUSIONS:

The following conclusions are based upon the limited amount of information in the retort records. These conclusions may be disproved when more information becomes available:

1. The differences in length of service observed in the alloy steel retorts are greater than would be normally expected from uniform and sound castings which were all treated alike.

2. Within the limits used, analysis has but slight effect on retort life. The analysis which can be cast the easiest results in the longest life.

3. Wall thickness does not correlate with retort life in the way that mechanical formulas would predict. One-inch walls apparently last only slightly longer than half-inch walls. This means that the quality of the metal has a greater effect than the thickness of the wall. Mechanical calculation, then, cannot be used to accurately predict the improvement that would result from a thickening of the wall, as this thickening may have a direct effect on metal soundness.

4. The effect of Furnaces 5, 7, 8, and 9 upon the retorts is identical. Each furnace must have been designed, built, and operated in an identical manner.

5. From two to six retorts have been used in each furnace position. To date there is no evidence that any furnace position differs from any other furnace position in its effect on retort life.

6. The method of handling retorts and operating the magnesium reduction process has resulted in a gradual increase of the average retort life. It has not affected the variation in retort life, however.

7. Retort life when plotted in order of heat number

(Conclusions, cont'd) -

does not fluctuate with chemical analysis. Casting practice is therefore assumed to be the cause of retort life variation.

8. Casting practice can be divided into four periods. Each period represents a different way of making retorts.

Period		Groups Nos.	Heats Nos.
1	-	4- 9	2578 - 2748
2	-	10-14	2749 - 2776
3	-	16-20	2776 - 2799
4	-	21-25	2799 - 2836

9. The main cause for variation in retort life is variation in casting practice.

Recommendations:

A. Close attention should be paid to the control of foundry operations. Properties of cores and of the mould should be measured and recorded for comparison with casting quality (see Appendix A). Other foundry variables, such as pouring temperature, pouring time, shake-out time, gating method, etc., should be measured and recorded, so that control over all variables can be established.

B. Test pieces from each heat should be obtained for creep testing. This will provide immediate knowledge of the creep properties of the metal being used.

C. Records kept on cards for each retort will enable data to be studied by statistical methods. The Quality Control Chart method is recommended as the best way to present process data so that variation can be studied.

These recommendations are discussed more fully in Appendices A, B, and C in this report.

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(Pages 9 to 16 comprise Figures 1 to 8.
(Pages 17 to 20 contain Appendices A, B, and C.)

FIG. 1

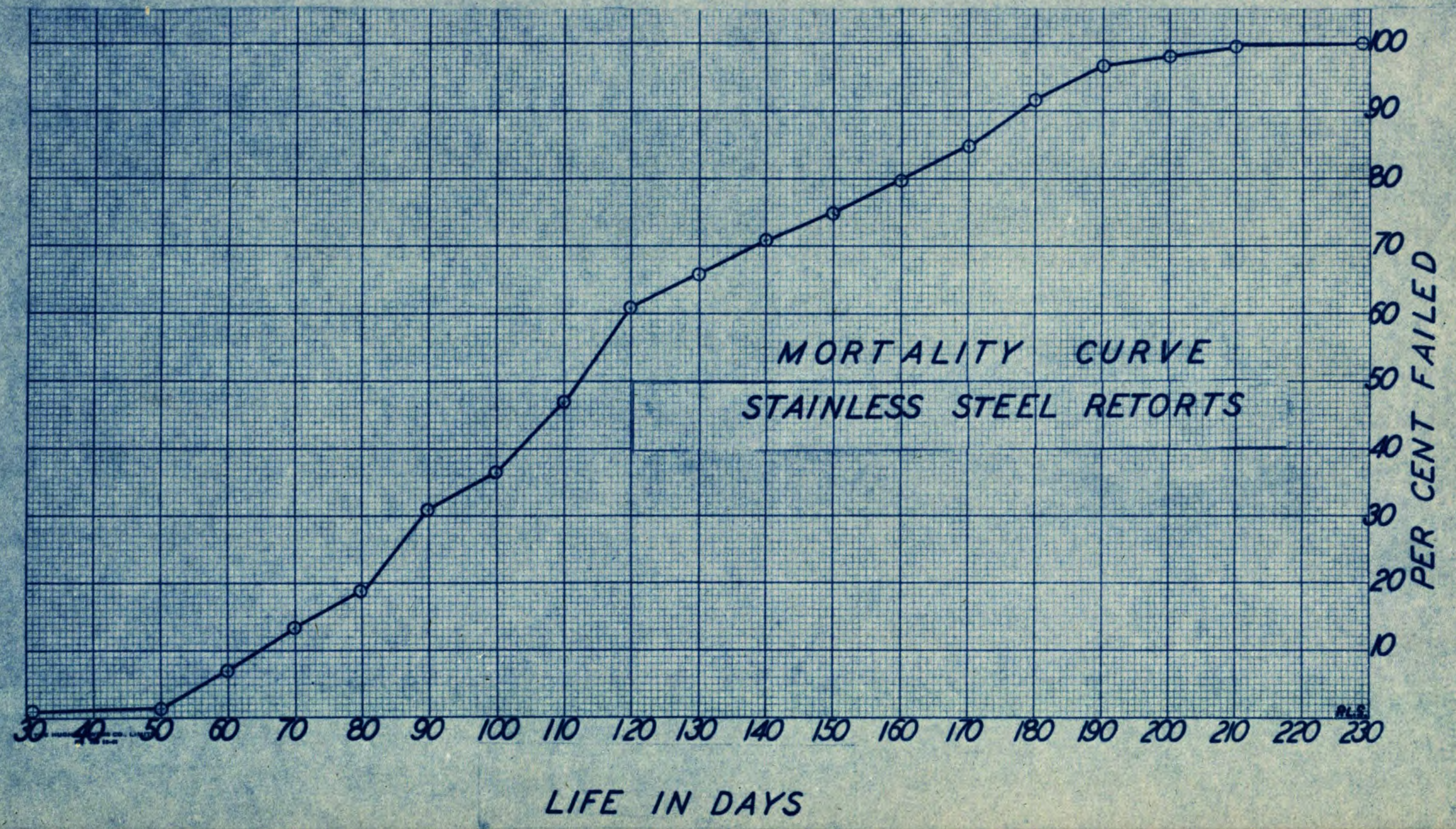

MORTALITY CURVE
STAINLESS STEEL RETORTS
PER CENT FAILED
10
20
30
40
50
60
70
80
90
100
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
210
220
230
LIFE IN DAYS
R.L.S.

FIG. 2

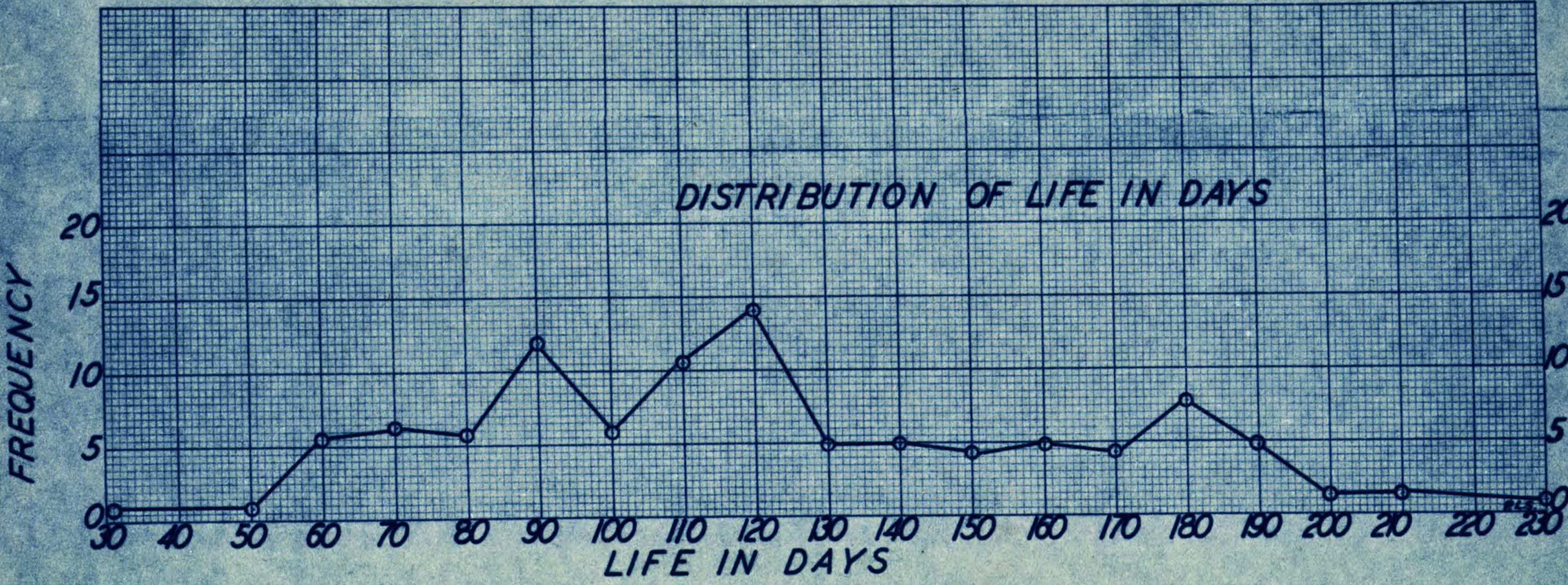
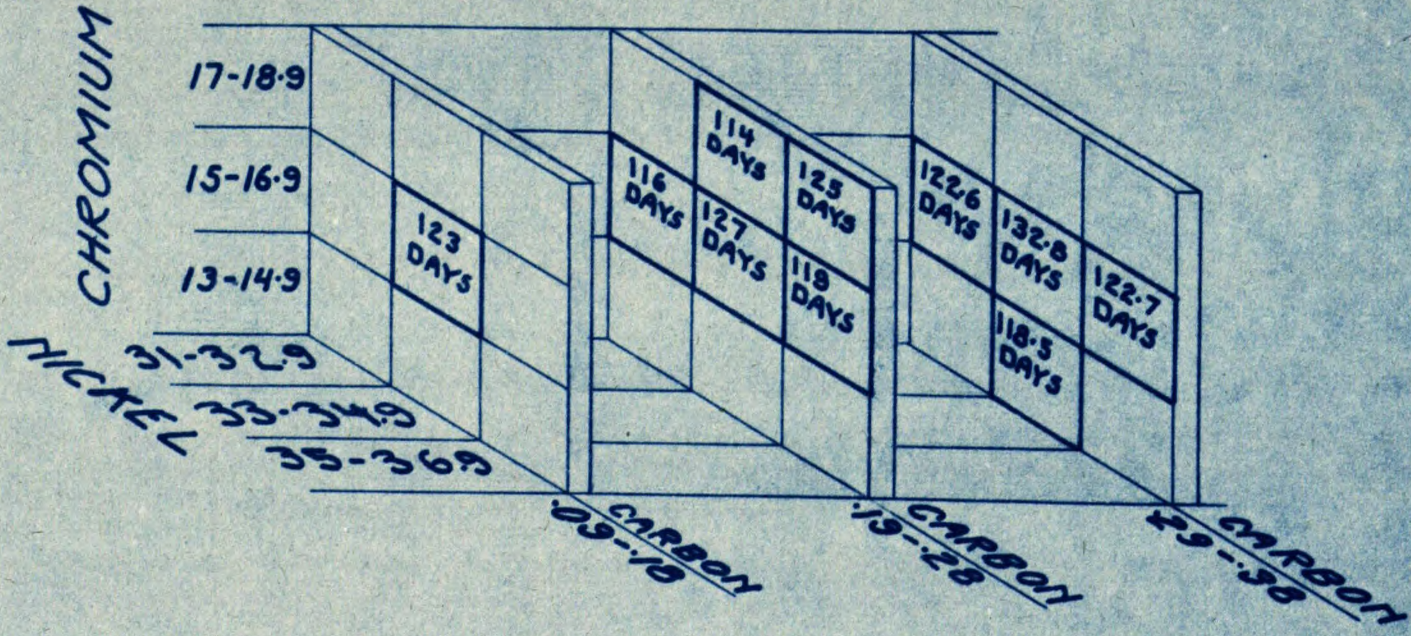

DISTRIBUTION OF LIFE IN DAYS
FREQUENCY
LIFE IN DAYS
0
5
10
15
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
210
220
230

FIG. 3



AVERAGE LIFE AND ANALYSIS CLASSIFICATION

STAINLESS STEEL RETORTS

H.H.F.

FIG. 4
THICKNESS AND LIFE OF
STAINLESS STEEL RETORTS

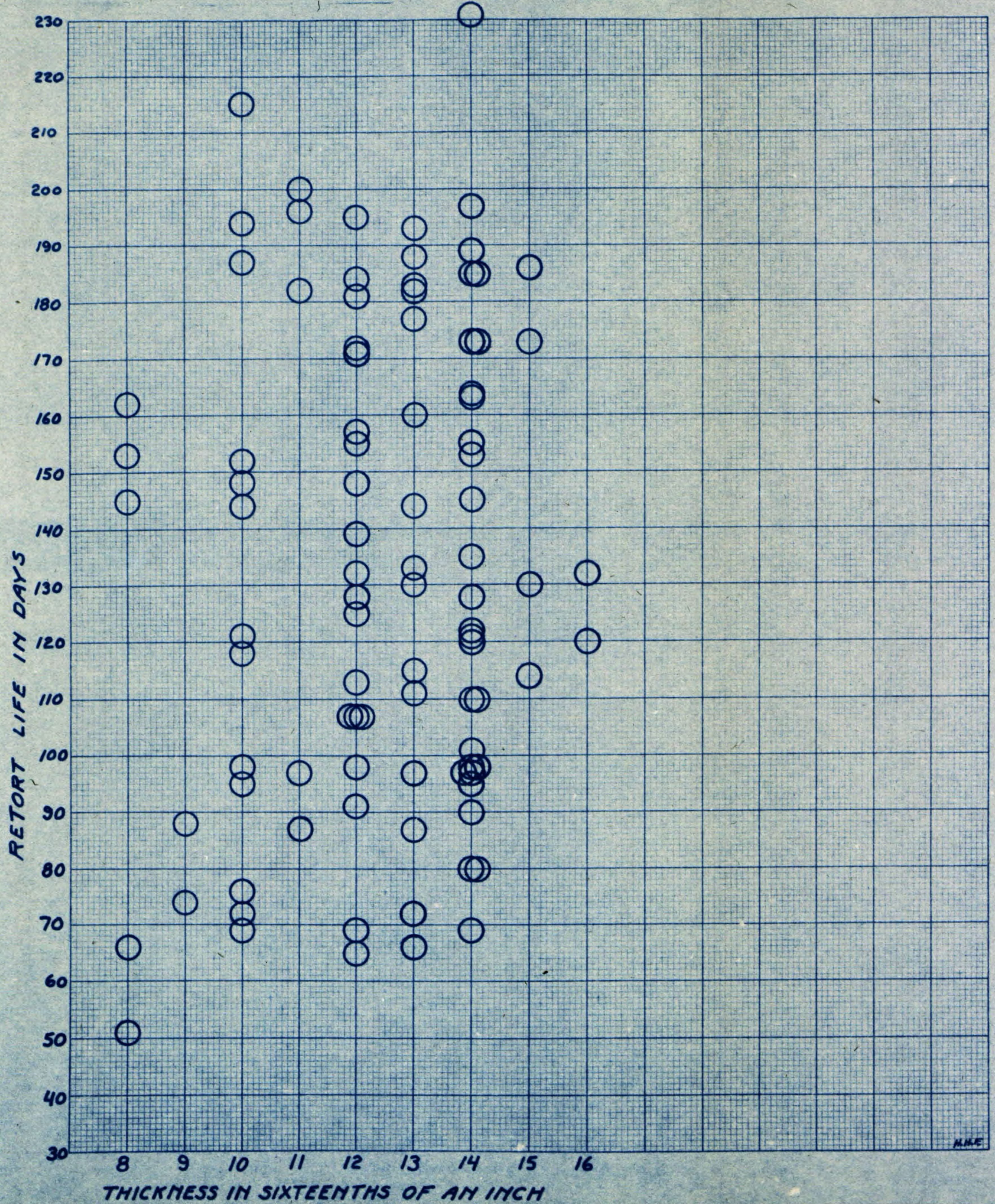
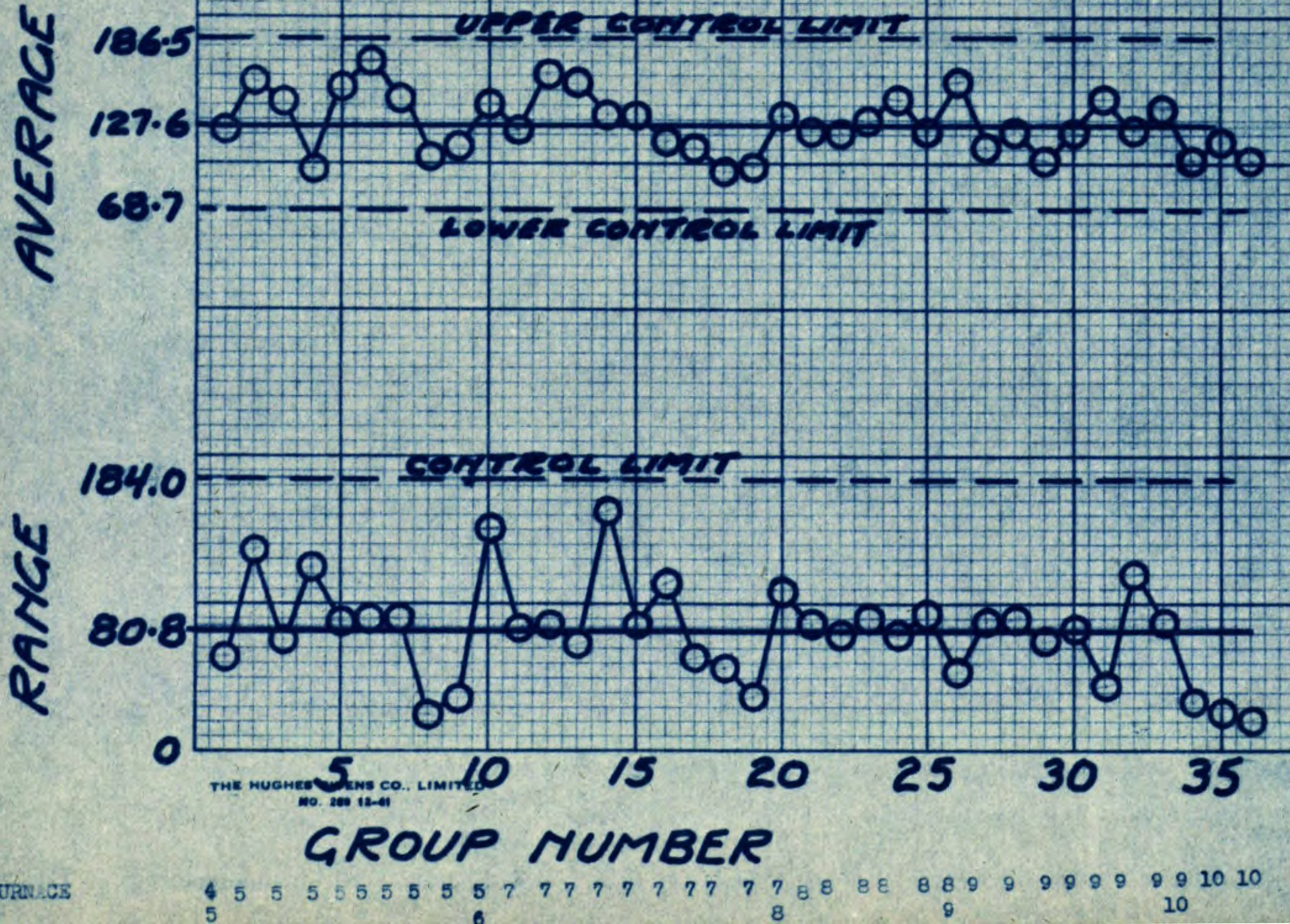


FIG. 5

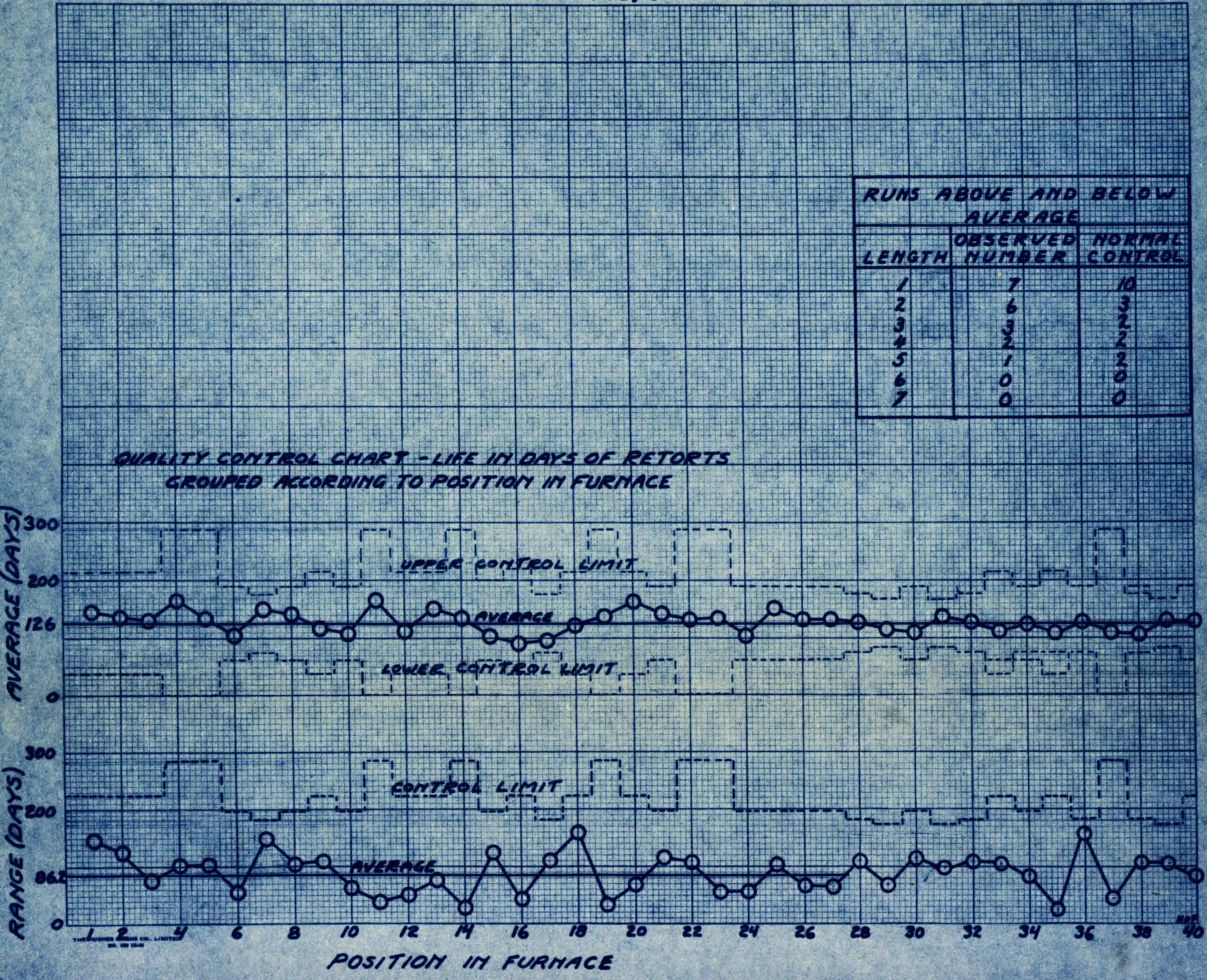
QUALITY CONTROL CHART
FOR RETORT LIFE IN DAYS
GROUPS OF 4 ACCORDING TO FURNACES



RUNS ABOVE AND BELOW AV'GE		
LENGTH	OBSERVED NUMBER	NORMAL CONTROL
1	10	10
2	4	4
3	2	2
4	3	3
5	0	0
6	0	0
7	0	0

H.E.F.

FIG. 6



RUNS ABOVE AND BELOW AVERAGE

LENGTH	OBSERVED NUMBER	NORMAL CONTROL
1	7	10
2	6	3
3	3	2
4	2	2
5	1	2
6	0	0
7	0	0

FIG. 7

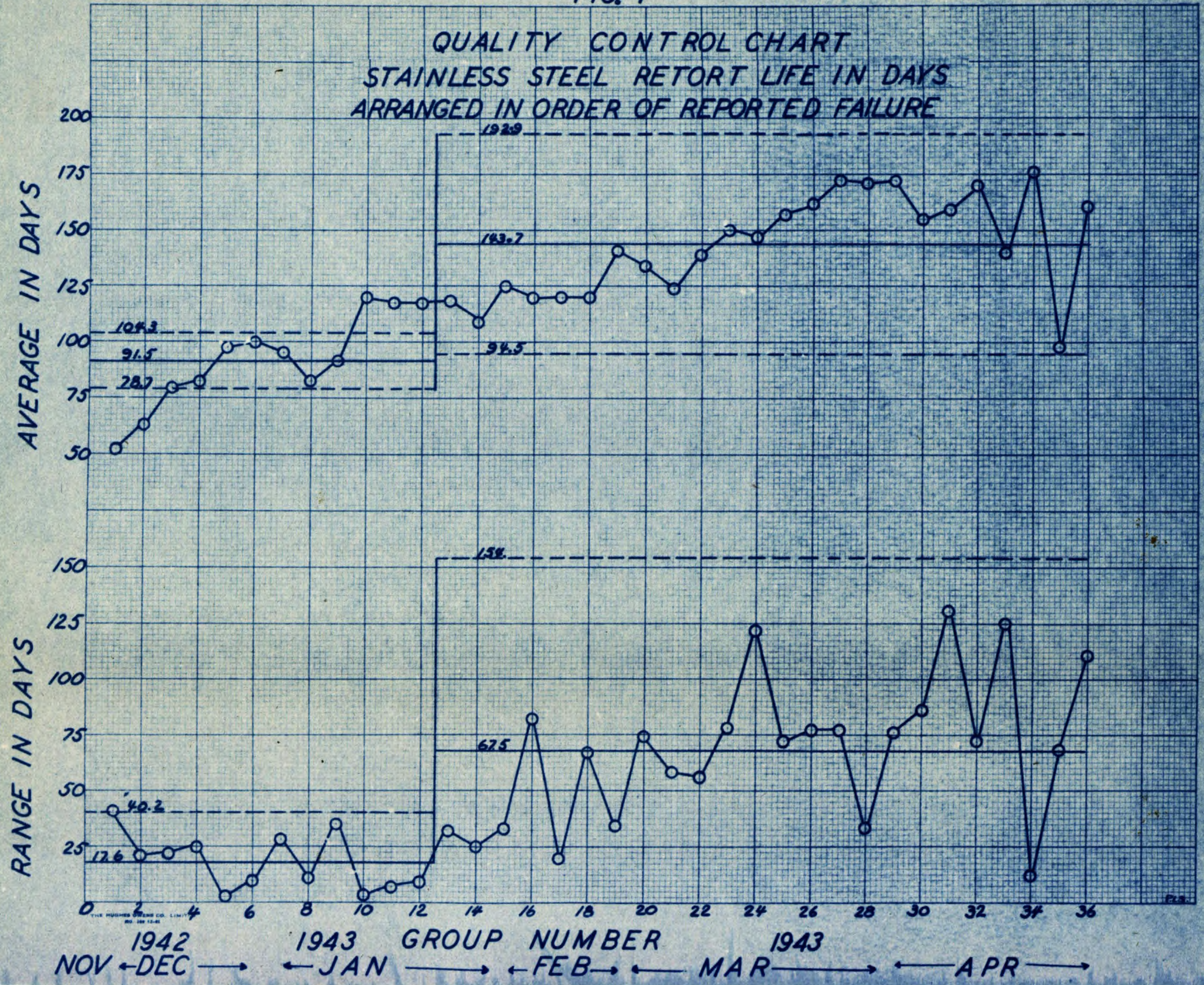
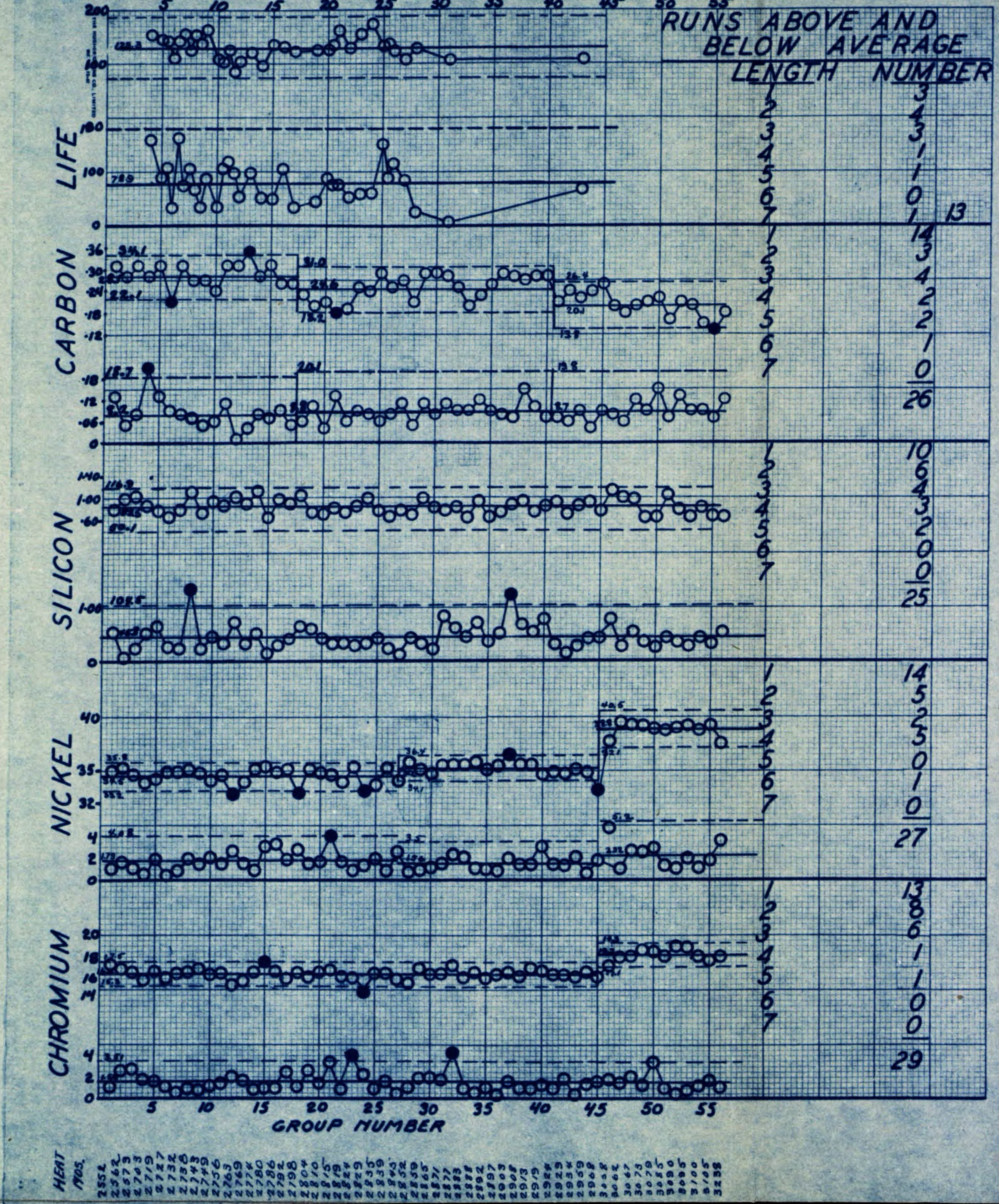

QUALITY CONTROL CHART
STAINLESS STEEL RETORT LIFE IN DAYS
ARRANGED IN ORDER OF REPORTED FAILURE
AVERAGE IN DAYS
RANGE IN DAYS
192.9
143.7
104.3
91.5
78.7
94.5
158
67.5
40.2
12.6
GROUP NUMBER
1942
NOV ←DEC →
1943
← JAN →
←FEB→
← MAR →
1943
← APR →

FIG. 8
HISTORY OF CASTING PRACTICE



APPENDIX A.

TESTING FOUNDRY MATERIALS.

Casting quality is affected by the nature of cores and moulding sand, gating, pouring practice, and melting practice. For complete control of foundry operation these properties of cores and moulding materials should be measured and controlled. The relationship between core collapsibility and other properties and casting quality is found and then these properties are controlled in their optimum range.

If such things as:

CORE

hardness,
permeability,
hot strength,
expansion and contraction,
gas generated per c.c.,
baked strength,

MOULD

hardness,
permeability,
expansion and contraction,
gas per c.c.,
hot strength,
green strength,
green deflection,
moisture content,

are not measured and controlled, the process then must be carried out by "rule of thumb" methods. It is then a matter of skill and good luck. Closely controlled, scientific foundry operation requires laboratory tests in order that variation in foundry conditions can be detected. If variation in retort life is to be reduced, variation in foundry conditions should be reduced also. This requires testing instruments. The following are in general use in the foundry industry:

Moisture tester.
Sand rammer.
Permeability meter.
Sand strength machine.
Green sand strength machine.
Sand washer.
Laboratory sifter.
Test core baking oven.
Core hardness tester.
Laboratory mixer.
Dilatometer.

APPENDIX B.

TENTATIVE CREEP TEST.

Creep strength is the main property required in the retorts. Therefore, a simple, quick creep test should be made on each heat. This will safeguard retort quality and may make it possible to increase retort life.

A globar-heated furnace operating at the magnesium reduction temperature could be designed to take 12-inch bars held vertically in water-cooled holders. A constant load could be applied by a weighted cantilever. The load would be adjusted so that the average bar would fail by rupture in about 24 hours.

APPENDIX C.

ANALYSIS OF OBSERVATIONS.

The Statistical Quality Control Chart method has been used to analyse the data in this report. The analysis and life data dealt with represent a considerable expenditure of man-hours of labour, strategic alloys, and money. It is important, therefore, that the most scientific method be used to analyse the test results.

The American Society for Testing Materials, the American Standards Association, the United States Ordnance, the Institutions of Mechanical, Electrical and Civil Engineerings (Britain), and many large corporations recommend the Statistical Quality Control Chart method of analysing data.

The technique is described in

A. S. T. M. Manual on Presentation of Data, published by A. S. T. M., 2605 Broad Street, Philadelphia, Pa.,
and
Quality Control Chart Method, published by the American Standards Ass'n., 79 West Thirty-Ninth Street, New York, N.Y.

A publication of the Canadian Bureau of Mines thereon "Quality Control: Engineering Science Applied to Inspection" (Report of Investigation No. 1235, June 1st, 1943), is available.

The basis of the system is a comparison with random numbers. If a succession of test values behaves as do random numbers, then no assignable cause for variation can be found. The variation may then be attributed to the cumulative effect of a constant system of causes inherent in the process. Only a new or changed process could then reduce variation.

Figure 9 shows a quality control chart for 56 groups of four random numbers. The control limits are such that 99.7 per cent of all results would fall within them. It will be

(Appendix C, cont'd) -

noted that there are 29 runs above and below average (a run is one or more results in succession). By comparing the random number chart with the other quality control charts, it can be seen that some of the charts

- Life, in chronological order of reporting failure,
- Life, in order of heats,
- Carbon, silicon, nickel, and chromium,

show variation which cannot be attributed to chance causes. There are, therefore, assignable causes for this variation.

(Figure 9 follows on next page, concluding Appendix C.)

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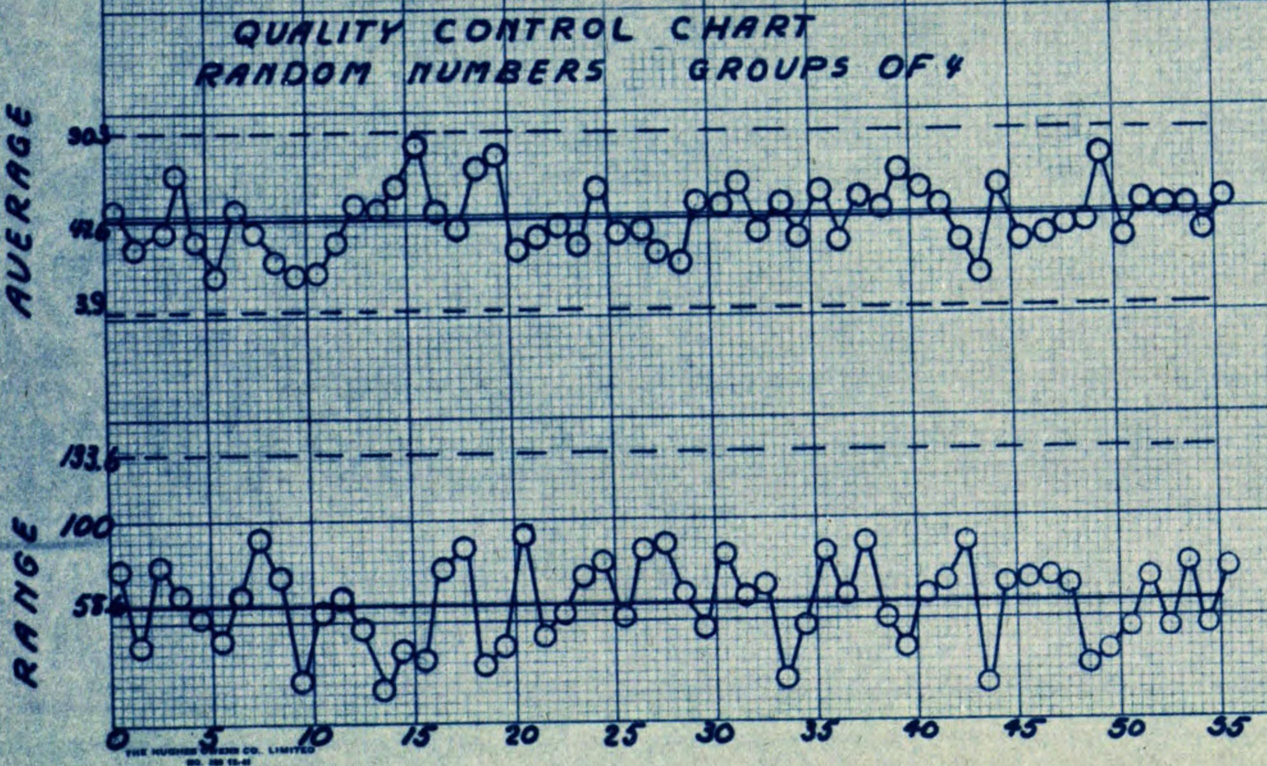
FIG. 9



RUNS ABOVE AND BELOW AV'GE.	
LENGTH	NUMBER
1	15
2	4
3	2
4	3
5	3
6	0
7	0