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HW-66284 RD

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STATISTICAL ANALYSIS OF DATA FROM PT-IP-250A-FP [redacted]

by

K. B. Stewart

Reference: HW-61619 C, Secret, "Irradiation of Alloyed Dingot Uranium Fuel Elements," R. E. Hall.

PURPOSE

The objective of this production test is to compare the dimensional stability characteristics of fuel elements with alloyed low hydrogen dingot cores and standard fuel elements with ingot cores. The basic measurements of dimensional stability are the average warp(1) and the tube-filling capacity(2) (TFC) values of the fuel elements.

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SUMMARY

The results of this production test indicate that under normal exposure conditions the ingot and dingot fuel elements exhibit similar dimensional distortion characteristics. The average warp for dingot fuel elements in this test is slightly smaller (1.3 mils) than the average warp of the ingot fuel elements, but this result is only of borderline statistical significance and most of this difference is introduced at the low exposure levels. At the higher exposure levels the difference between the average warps is small. There is no significant difference between the average TFC values for the two fuel element types.

The average profile measurements are small and except for OD_2, there is no statistically significant difference between the fuel element types. The OD variance may be of more interest here.

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(1) The average warp is the average of the convex and concave warps of a fuel element.
(2) The tube-filling capacity (TFC) statistic was designed to estimate the maximum incremental diameter of the irradiated fuel element.

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The results in this production test are based on 11 charges, 4 at low exposure (361-389 MWD/ton) and 7 at high exposure (761-826 MWD/ton). The sensitivity and validity of the TFC value as a measure of dimensional stability is indicated by the clear-cut way the average TFC value for a tube classifies the tube as being from either the low- or high-exposure category. All of the tubes in the high exposure group exhibit much larger average TFC values. The same tendency is here for average warp although the division between high and low exposure tubes is not nearly as clear-cut.

PROCEDURE

In most production tests the tube differences and position differences introduce large sources of variation. When two types of fuel elements are being compared, the effects of these sources of variation can be eliminated by the simple expedient of alternating the two fuel element types in a tube. Thus, any fuel element and the adjacent fuel element are exposed to relatively the same environmental effects, so that differences beyond those expected, due to random variation, must be attributable to the differences in fuel element types. In this test, for instance, the ingot and dingot fuel elements are alternated in a tube. The differences Δ_1 between a dingot and ingot fuel elements are used as the basic statistic. If there are no differences between the two fuel element types with respect to the dimensional distortion characteristic under study, average $\Delta_1 = \bar{\Delta}$ should be close to 0. If $\bar{\Delta}$ is a significantly large positive number, the dingot fuel elements are significantly larger. If $\bar{\Delta}$ is negative and of sufficient magnitude, then we can infer that the ingot fuel elements are larger.

The distribution characteristics of the profile measurements OD_1, OD_2, and OD_3 are also described.

RESULTS

TFC

The over-all averages for TFC values are:

MATERIAL	AVERAGE TFC
Dingot	14.8 mils
Ingot	14.1 mils

The difference of 0.7 mils is not statistically significant. This is determined in the following way. Let

$$\Delta_1 = \text{dingot TFC} - \text{ingot TFC}$$

for two adjacent fuel elements, where each fuel element is used in only one Δ_1 value. Here

$$\bar{\Delta} = 0.7 = \text{dingot TFC average minus ingot TFC average}$$

$$s_{\Delta_1} = 10.7$$

so that

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$$t = \frac{0.7}{10.7}\sqrt{180} = 0.9$$

which is not statistically significant. The frequency distributions of the dingot and ingot TFC values are given in the appendix. The following table gives the tube averages.

Table I

AVERAGE TFC BY TUBE (mils)

	Tube No.	Dingot Average	Ingot Average	Difference	Tube Average
Low Exposure	2679	7.1	7.1	0.0	7.1
	2774	7.3	8.0	-0.7	7.7
	2680	7.8	7.8	0.0	7.8
	2667	4.3	7.2	-2.9	5.7
High Exposure	2874	21.0	18.1	2.9	19.6
	2881	19.6	18.0	1.6	18.8
	2870	20.3	22.1	-1.8	20.7
	2776	15.3	15.8	-0.5	15.5
	2668	19.8	13.0	6.8	16.4
	2673	20.4	17.2	3.2	18.8
	2664	17.8	18.6	-0.8	18.2
Low Exposure		6.6	7.5	-0.9	7.1
High Exposure		19.1	17.5	1.6	18.3
Over-all Averages		14.6	13.9	0.7	14.2

The most interesting feature of this table is the clear-cut division between the TFC values for the low- and high-exposure tubes. Tube 2668 is the only high exposure tube where the dingot TFC average is appreciably higher, and this seems to be due more to a rather low TFC average for the ingot fuel elements than to a high dingot average.

AVERAGE WARP

The over-all averages for average warps are:

Material	Average Warp
Dingot	7.4 mils
Ingot	8.7 mils
Difference	-1.3 mils

This result, indicating a slightly higher average warp for ingot fuel elements, is of borderline statistical significance. Most of the difference is in the fuel elements of low exposure. For fuel elements at higher exposures, there is only a difference of -0.8 mils between the average warps for dingot and ingot fuel elements.

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Let

$$\bar{\delta} = -1.3 \text{ mils}$$

$$s_{\delta_1} = 9.1$$

$$|t| = \frac{1.3}{9.1}\sqrt{180} = 1.9$$

which is between the critical t values of t 0.10 (179) = 1.7 and t 0.05 (179) = 2.0. From a practical standpoint, the difference in average warps of the two fuel elements is small particularly at the higher exposure levels. The large amount of data involved makes the statistical test of significance sensitive to small differences between fuel element types, and again even with a large amount of data, the difference is only of borderline statistical significance.

The following table gives the tube averages.

Table II

WARP VALUES BY TUBE (mils)

	Tube No.	Dingot Average	Ingot Average	Difference	Tube Average
Low Exposure	2679	7.0	6.8	0.2	6.9
	2774	3.7	7.8	-4.1	5.7
	2680	6.4	7.4	-1.0	6.9
	2667	4.7	8.1	-3.4	6.4
High Exposure	2874	12.4	11.2	1.2	11.8
	2881	9.2	12.5	-3.3	10.8
	2870	10.0	10.3	-0.3	10.1
	2776	7.0	9.9	-2.9	8.4
	2668	8.2	4.9	3.3	6.5
	2673	8.7	7.8	0.9	8.2
	2664	4.8	9.5	-4.7	7.1
Low Exposure		5.4	7.5	-2.1	6.5
High Exposure		8.6	9.4	-0.8	9.0
Over-all Average		7.4	8.7	-1.3	8.1

THE PROFILE MEASUREMENTS OD_1, OD_2, AND OD_3

The following table gives the results of the profile measurements OD_1, OD_2 and OD_3.

Table III

AVERAGE PROFILE MEASUREMENTS IN MILS

Measurements	Dingot	Ingot	Difference	Remarks
OD_1	-3.2	-3.2	0.0	----
OD_2	3.0	0.5	2.5	Statistically Significant
OD_3	2.0	2.0	0.0	----

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Except for the OD_2 measurements there is a good deal of agreement between the ingot and dingot fuel element types. This is also borne out by the frequency distributions as shown in the appendix.

K. B. Stewart

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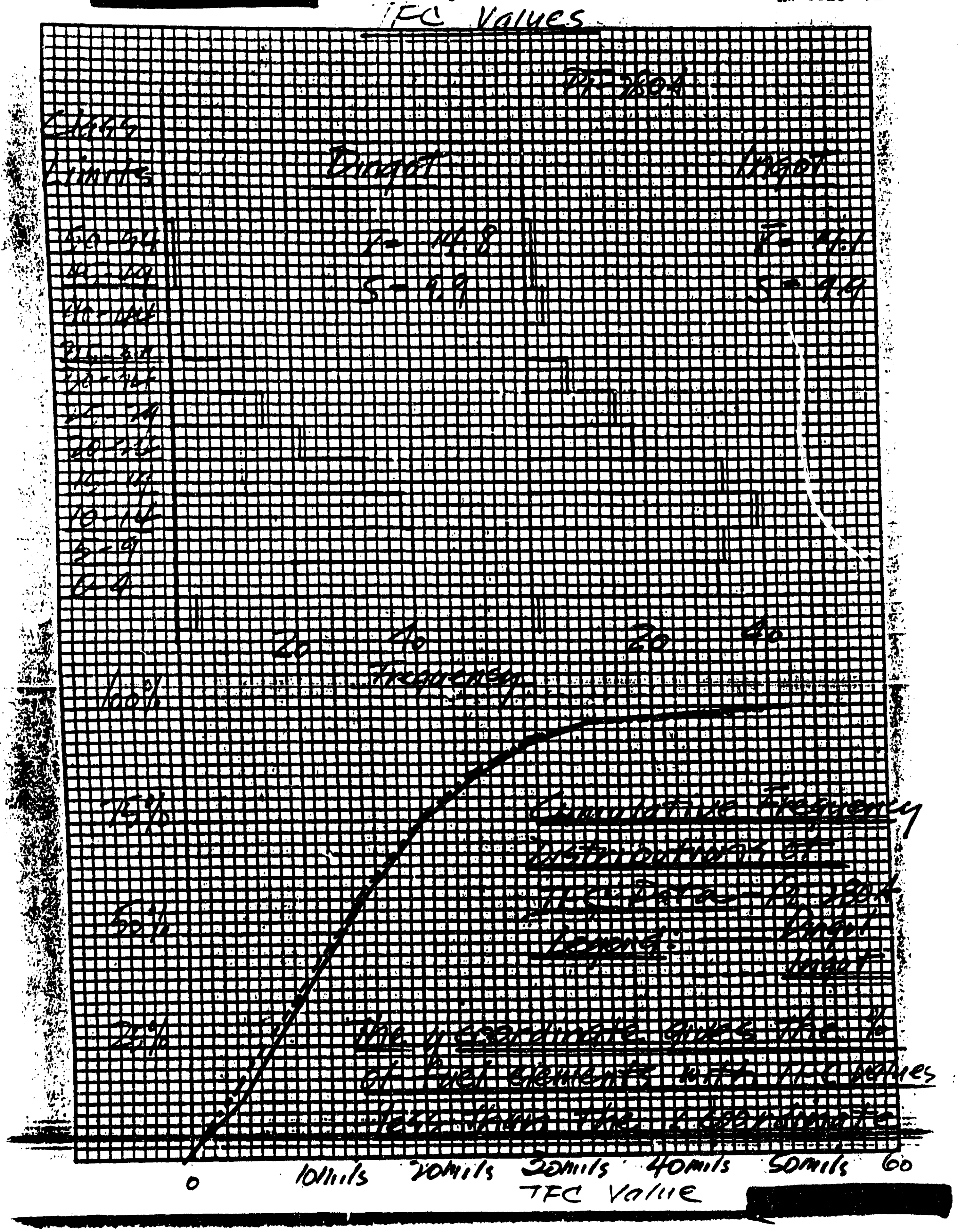

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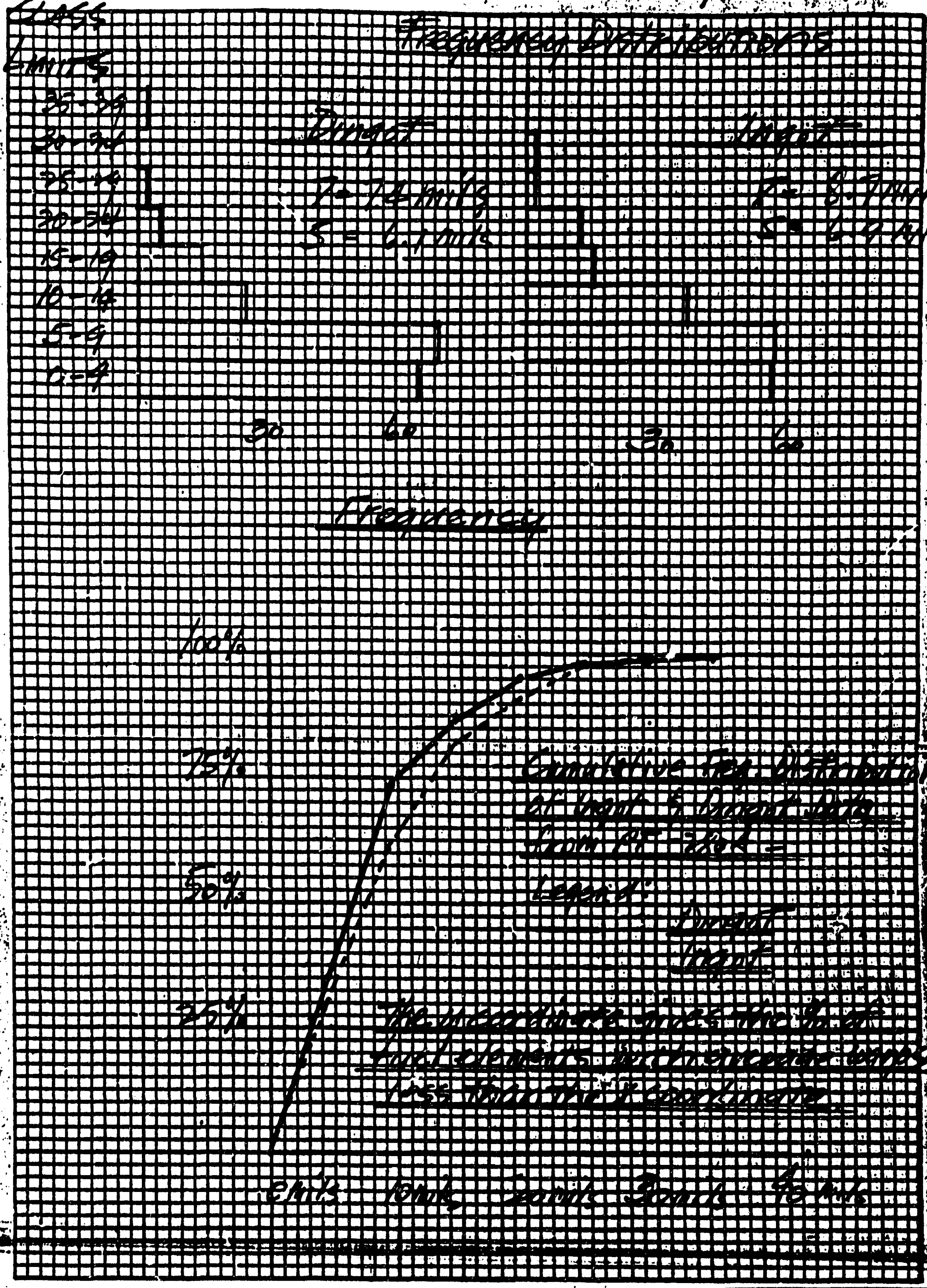

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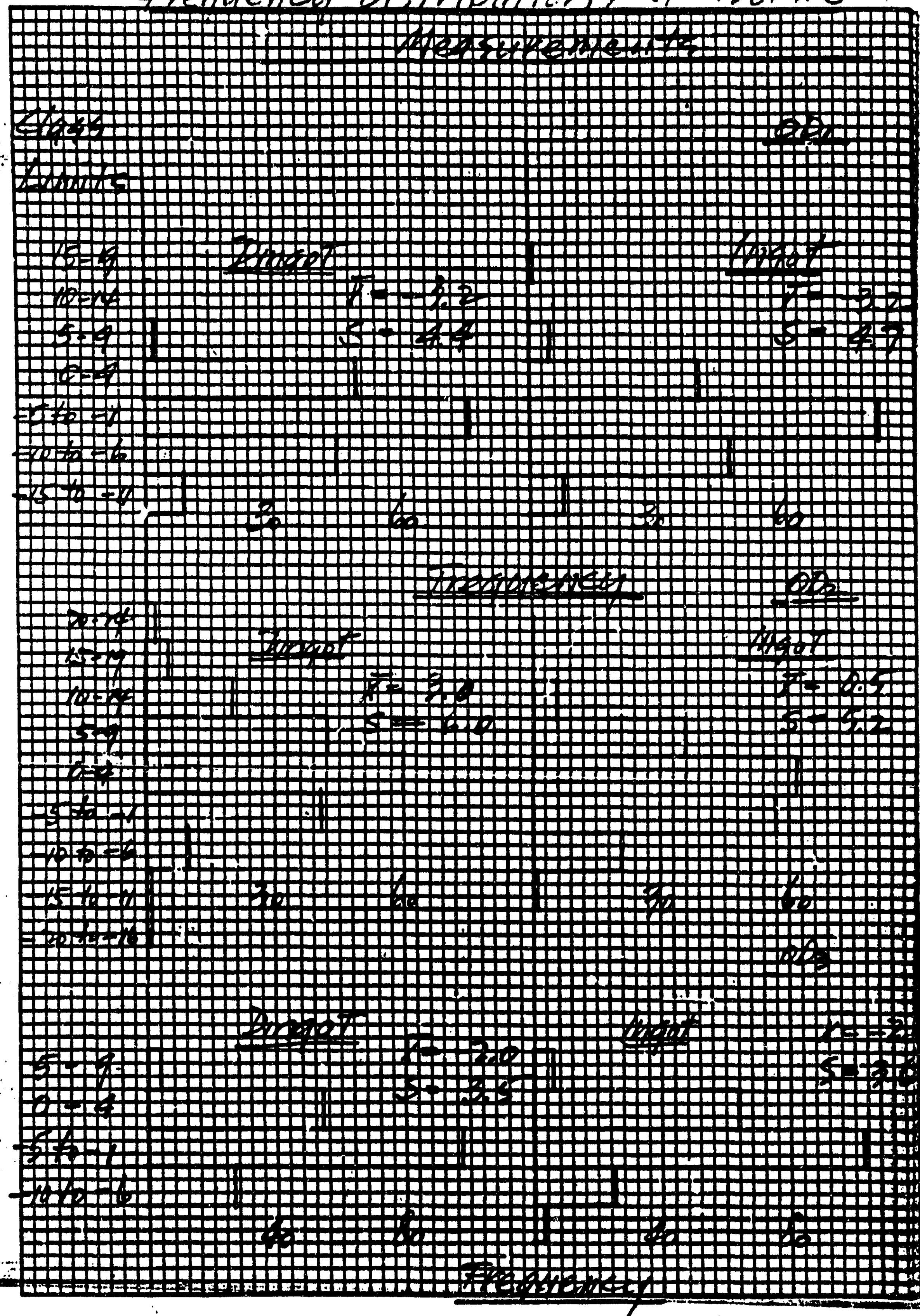
Frequency Distributions of Mottle



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