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ESTABLISHMENT OF RELEASE LIMITATIONS OF MK 5 AND MK 6 FROM B-47B AIRCRAFT

... B. Stephenson

SANDIA SYSTEMATIC DECLASSIFICATION REVIEW
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ABSTRACT

The present memo indicates that release pitching oscillations of the Mk 5 and Mk 6 weapons from the B-47B aircraft are repeatable (within 10%) with the factor $q/I\sqrt{1 - M^2}$. Mk 6 repeatability is well established for altitudes above 15,000' and only one bomb drop is required to confirm predictions. Three Mk 5 practice bomb drops are required to confirm the empirical curve. If the data presented prove correct, it will be possible to accurately state release limitations as determined by acceleration tolerance based on dynamic pressure ($\frac{\gamma}{2} p M^2$) alone. The enclosed curves present sufficient data to make range corrections in bombing tables. If these corrections are made, the absolute value of the range error will be small, and in many cases the probable error will be within the desired 3 mil trajectory repeatability characteristic.

Case No. 409.0

June 15, 1953

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INTRODUCTION

Discussions evolving as a result of Reference 1 indicated that further investigations into the Mk 5 and Mk 6 release problems from the B-47B should seek to answer three questions:

1. How repeatable are the release pitching phenomena?

2. What release condition limitations should be established for delivery of both weapons?

3. What bombing table corrections are necessary and/or desirable?

The present memo attempts to answer these questions, using the best available data.

DISCUSSION OF RESULTS:

Table I is a compilation of the drop test data for both the Mk 5 and the Mk 6. It should be noted that Mk 5 drop ST 635 differs in initial pitch angle from the figure given in Reference 1. The new figure is established from the telemetered pitch record, rather than from film analysis.

The effect of the initial damped oscillation on bomb range has been computed* for a nose-down pitch of α_0 degrees at release. Figures 1 and 2 show the effects of altitude and Mach number of release for the two bombs. They were computed for pitch angles of ± 20°. The computations are somewhat conservative for larger amplitudes as indicated in Figure 1, where the point for 40,000' at M = .8 has been calculated by using drag data for pitch angles between ± 30°.

Following the reasoning used in Reference 2 for the determination of pitch amplitude from wind tunnel test results, a correlation factor for the available drop data was derived. The total nose-down pitch in the bomb bay is expected to be proportional to the aerodynamic pitching moment and inversely to the moment of inertia of the bomb. This can be shown by the following consideration:

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* The computation method will be described in a forthcoming report.

$$\frac{\text{Pitching Moment}}{I} = \frac{C_{m_o}\, q\, d^3}{I} = (C_{m_o} d^3)\ \frac{q/I}{\sqrt{1 - M^2}}$$

where

d - Diameter

C_{m_o} - Moment coefficient for incompressible flow

q - Dynamic pressure, $\frac{\gamma}{2}\ p_a\ M^2$

M - Mach number: ($\sqrt{1 - M^2}$ - Prandtl - Glauert compressibility correction factor)

p_a - Ambient pressure

When the maximum nose-down pitch angle is plotted against this factor, a straight line through the origin may be drawn within the limits of accuracy of the data. Figures 3 and 4 illustrate the relationship for the Mk 5 and Mk 6 bombs. It is thus believed that release phenomena are reasonably repeatable.

Figures 5 and 6 present the data of Figures 1 - 4 in a form for easy computation of the pitch angles and range reduction for specified drop conditions. The upper left-hand quadrant duplicates Figure 1 and may be used to determine range reduction for amplitudes less than about 30°. When higher amplitudes occur, the right side of the upper right quadrant is used.

The lower part of Figure 5 presents the pitch angle to be anticipated for a given release. The right side is the same as the line in Figure 3. The left side is used to determine the correlating factor $q/I\ \sqrt{1 - M^2}$ for a bomb having the standard stockpile moment of inertia of 348 slug-ft^2. To use the chart, enter with Mach number on the left-hand axis, go down to altitude, across into the lower right-quadrant to find pitch-down angle. If the angle is less than 30°, use the two upper left-hand charts to determine range reduction. If greater than 30°, enter the upper right-hand chart with altitude. Figure 6 presents similar data for the Mk 6 for a moment of inertia of 1190* slug-ft^2.

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* Mk 6 stockpile moment of inertia will be measured in the near future. If the true value differs significantly from 1190 slug-ft^2, new curves will be submitted.

Figure 7 presents the limit lines for 10 g acceleration on a critical component of the Mk 5 weapon. Amplitudes of pitch, α_o to the left of the constant Mach number lines are permissible. The significant data from this figure are reproduced on Figure 5 (lower left-hand quadrant) as the 10 g limit line. This line determines a realistic Mach number-altitude combination to be used as a bomb structural limit.

Figure 8 presents the component load limit of 10 g for the Mk 6 weapon. The significant data from this figure are reproduced on Figure 6 (lower left-hand quadrant).

In view of the great success of drop tests conducted from a B-47 equipped with the WADC spoilers (5-70, 5-71, 5-72, Ref. 1), it is believed that the wind tunnel method of studying anticipated release characteristics is valid. If the installation used in these drops is not deemed practicable, it is believed that further wind tunnel testing might lead to a more suitable fix from the standpoint of aircraft retrofit.

SUMMARY

1. Table II gives release limitations deduced from the above information for weapons having the nominal stockpile moment of inertia of 348 slug-ft^2 for the Mk 5 and a moment of inertia of 1190 slug-ft^2 for the Mk 6.

2. Tables III (Mk 5) and IV (Mk 6) summarize the expected values of range reduction for allowable release conditions. If these corrections are made to the bombing tables, it is believed that the probable range errors will be within 3 to 5 mils.

3. The present data are applicable only to presently stockpiled Mk 5 and Mk 6 weapons. Future versions of these weapons will have lower moments of inertia. Thus, release limitations and range reduction figures will have to be revised as newer weapons are stockpiled.

RECOMMENDATIONS:

1. In view of the information contained in this report, it is recommended that a Mk 5 - B47 release limitation of 25,000' (pressure altitude), Mach .75 be established on a preliminary basis*. Such a restriction

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* It is believed that this restriction is in line with AFSWC recommendations.

should limit initial pitching amplitudes to ~ 60° and will allow a reasonable margin of safety on component loading. Similarly, a Mk 6 release limitation of 12,000', Mach .75 should be adopted until recommendation 4 is carried out. Upon completion of recommendations 2, 3 and 4, final release limitations should be established.

2. It is recommended that three Sandia instrumented Mk 5 practice bombs (5-74, 5-79, 5-81) be dropped to establish conclusively the curves of Figures 1 and 3. The following drop conditions are recommended:*

   a. One T-62 bomb (5-74 - high moment of inertia) at M = .65 and 40,000' to provide a lower limit value of $q/I \sqrt{I - M^2}$.

   b. One PT-5 (5-79) weighted to I = 348 slug-ft^2 at M = .72 and 15,000' for the high extreme of $q/I \sqrt{I - M^2}$. Range reduction will also be measured.

   c. One PT-5 (5-81) weighted to I = 348 slug-ft^2 at M = .8 and 40,000' to further check the large range reduction.

3. Assuming that the above drops confirm the trends of Figure 3, it is recommended that two Mk 5 fusing and firing tests (5-80, 5-83) be conducted as a final check on the release limitations. The purpose of these drops will be to test at a release condition yielding maximum "g" loading. The release conditions for these drops cannot be specified until their moments of inertia are known. An attempt to measure range reduction should be made, if the moments of inertia of these bombs are reasonably close to the nominal stockpile value.

4. It is felt that the Mk 6 curve (Figure 4) is established to a sufficient degree such that only one instrumented practice bomb need be dropped. The purpose of this drop would be to confirm initial pitching oscillation amplitude predictions for 10,000' maximum velocity release. A waiver to exceed aircraft red-line Mach number at 10,000' should be requested for this test.

5. Because of the large absolute magnitude of range reduction, it is recommended that bombing table corrections be made for all B-47B releases of the Mk 5 weapon. Table III may be used to determine such corrections quantitatively.

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* All release condition altitudes specified are pressure (altimeter) altitudes.

6. The matter of the necessity and desirability of correcting Mk 6 bombing table is one for military decision. If corrections are not made, the 3 mil requirement will not be met. However, except for low (12,000') releases, the absolute values of range reductions are believed to be so small as to be negligible in comparison to normal bombing system error. For low releases, where bombing system errors may be reduced, corrections may be desirable.

7. It is believed that a satisfactory fix for the B-47 can be obtained by further wind tunnel testing. A modification which is more practical mechanically though somewhat less effective would be acceptable if it would eliminate the present release restrictions. It is recommended that such tests be conducted as soon as practicable.

W. B. Stephenson
W. B. STEPHENSON - 5141

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REFERENCES

1. Confidential Memo, Poole to Commanding General, AFSWC, dtd. 3/27/53, Ref. Sym: 1000 (1275), "Summary of TX-5 Separation Characteristics From the B-47 Aircraft".

2. Confidential Memo, W. B. Stephenson to G. E. Hansche, dtd. 3/27/53, Ref. Sym: 5141 (373), "Release Pitching of Mk 5 Bomb in B-47 Bomb Bay".

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TABLE I

Summary of Pitch Angle at Release from B-47B Airplane

	Test	Altitude Ft.	Mach No.	Dyn. Press (psf) q	Mom. of Inertia (Slug-Ft.^{2}) I	Initial Pitch α_o	$\frac{q/I}{\sqrt{1-M^2}}$
Mk 5	ST-634	40,900	.841	207	432	37°	.835
	ST-635	20,000	.755	400	439	69°	1.386
	ST-636 m	10,000	.790	650	428	* 70° 1	2.475
	ST-637	10,000	.661	451	430	62°	1.398
	5-77	44,000	.728	126	391	* 28°	.456
	PT-5-6	19,730	.81	455	312	* 83°	2.485
	T-62-41	30,130	.83	305	534	* 48°	1.024
	T-62-37	25,000	.83	379	557	* 50°	1.223
		Nominal Stockpile I = 348 Slug-Ft.^{2}					
Mk 6	ST-740 m	34,700	.77	224	1509	13°	.2475
	ST-742 m	42,900	.78	153	1450	8°	.1722
	ST-808 m	35,100	.76	228	1482	11°	.2433
	ST-467	35,000	.80	225	1219	16°	.3080
	ST-469 m	35,000	.82	240	1212	17°	.3455
	ST-470 m	35,000	.82	222	1216	14°	.320
	ST-478	15,000	.74	460	1195	28°	.570
	ST-479	15,000	.69	400	1159	18° 2	.476
	ST-472 m	25,000	.76	320	1206	21°	.408
	6-112 m	42,000	.798	168	1490	11° 3	.1865
	6-115 m	45,100	.737	132	1412	11° 3	.1384
		I = 1190 Slug-Ft.^{2}					

1 Very improbable: - High q and pull-out cable damage

2 Pitch gyro data doubtful

3 Early estimate, data not fully reduced

* Pitch angle from photo, accuracy, ± 4°

m Meteorological Data for Alt., Mach No., and Dynamic Pressure (Std. Atmos. used in others; accuracy ± 8% in $\sqrt{1-M^2}$)

I: ± 5% measured accuracy

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TABLE II

B-47 Release Limitations
(10 g Component Acceleration)

Altitude	Mach Number Mk 5	Mk 6
10,000'	.57	.75
20,000'	.71	-
30,000'	.81	-
40,000'	-	-

TABLE III

Mk 5 Range Reduction for B-47 Releases

Altitude	M .5	.6	.7	.8
10,000'	840'	-	- *	- *
20,000'	470'	920'	1000'	- *
30,000'	100'	680'	1130'	1870'
40,000	60'	290'	550'	1240'

TABLE IV

Mk 6 Range Reduction

Altitude	M = .5	.6	.7	.8
10,000'	60'	220'	550'	(1130')*
20,000'	30'	95'	240'	600'
30,000'	Negl.	50'	120'	310'
40,000'	"	Negl.	50'	120'

* Release condition not permissible, see Table II

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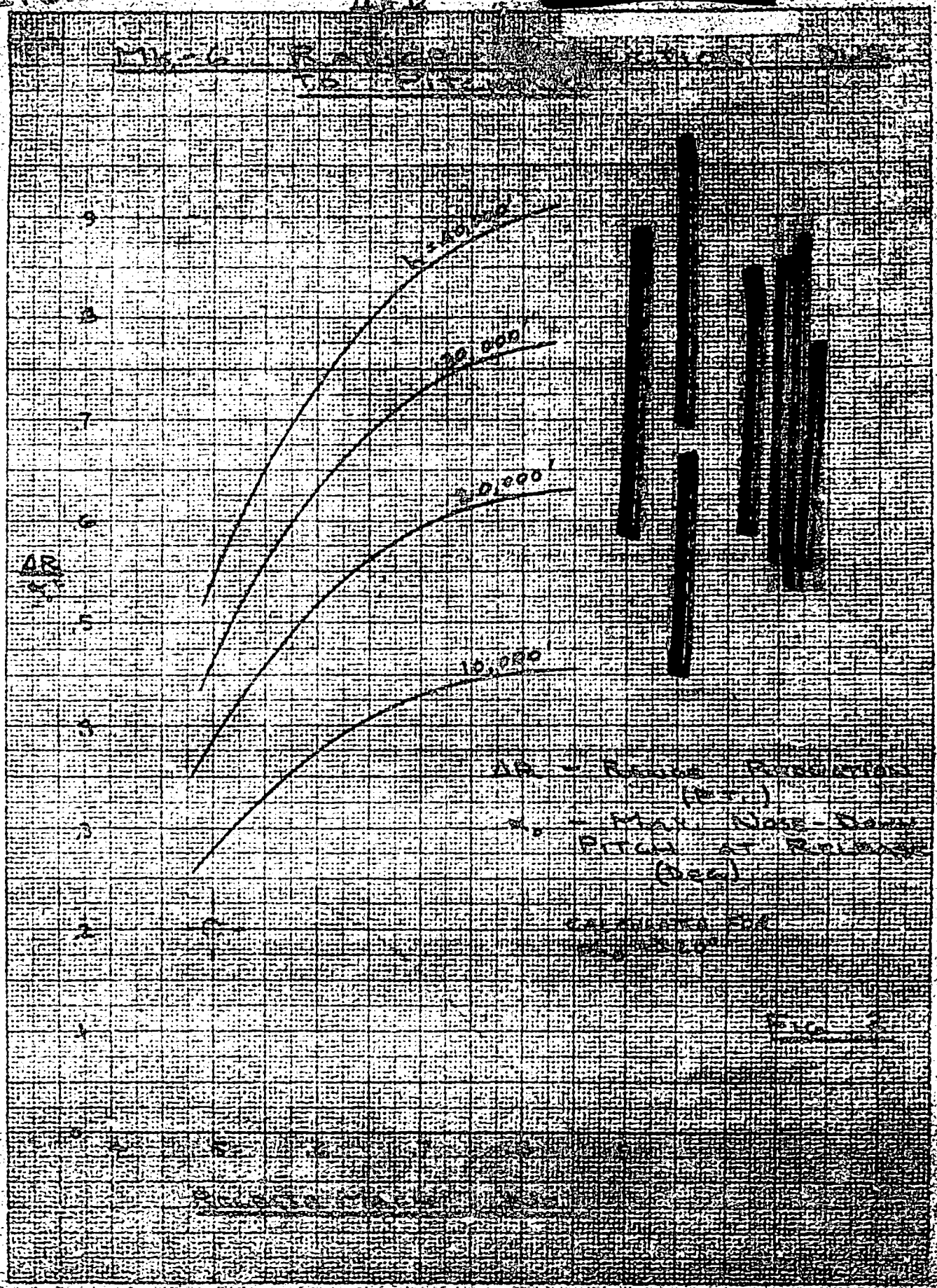

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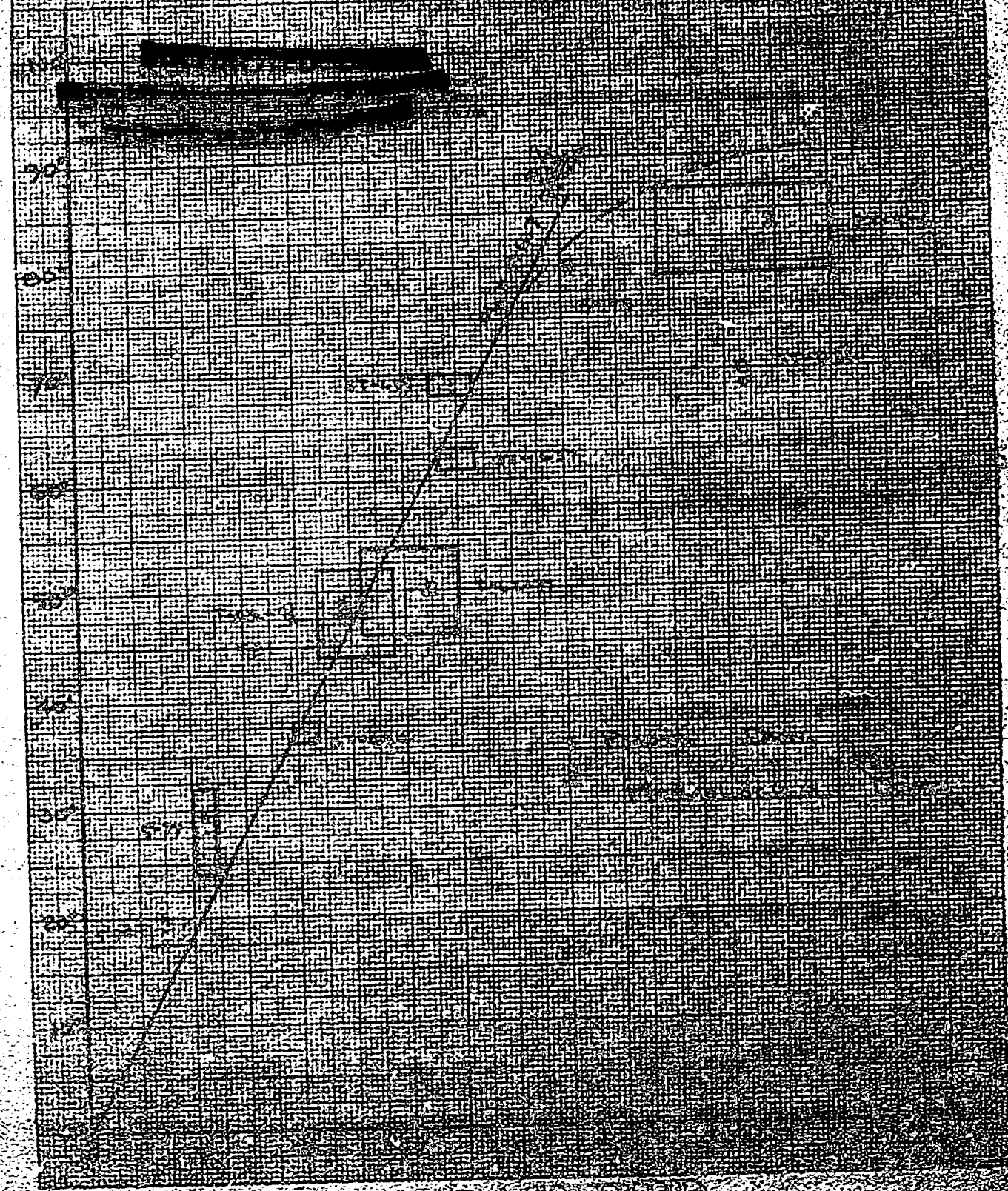

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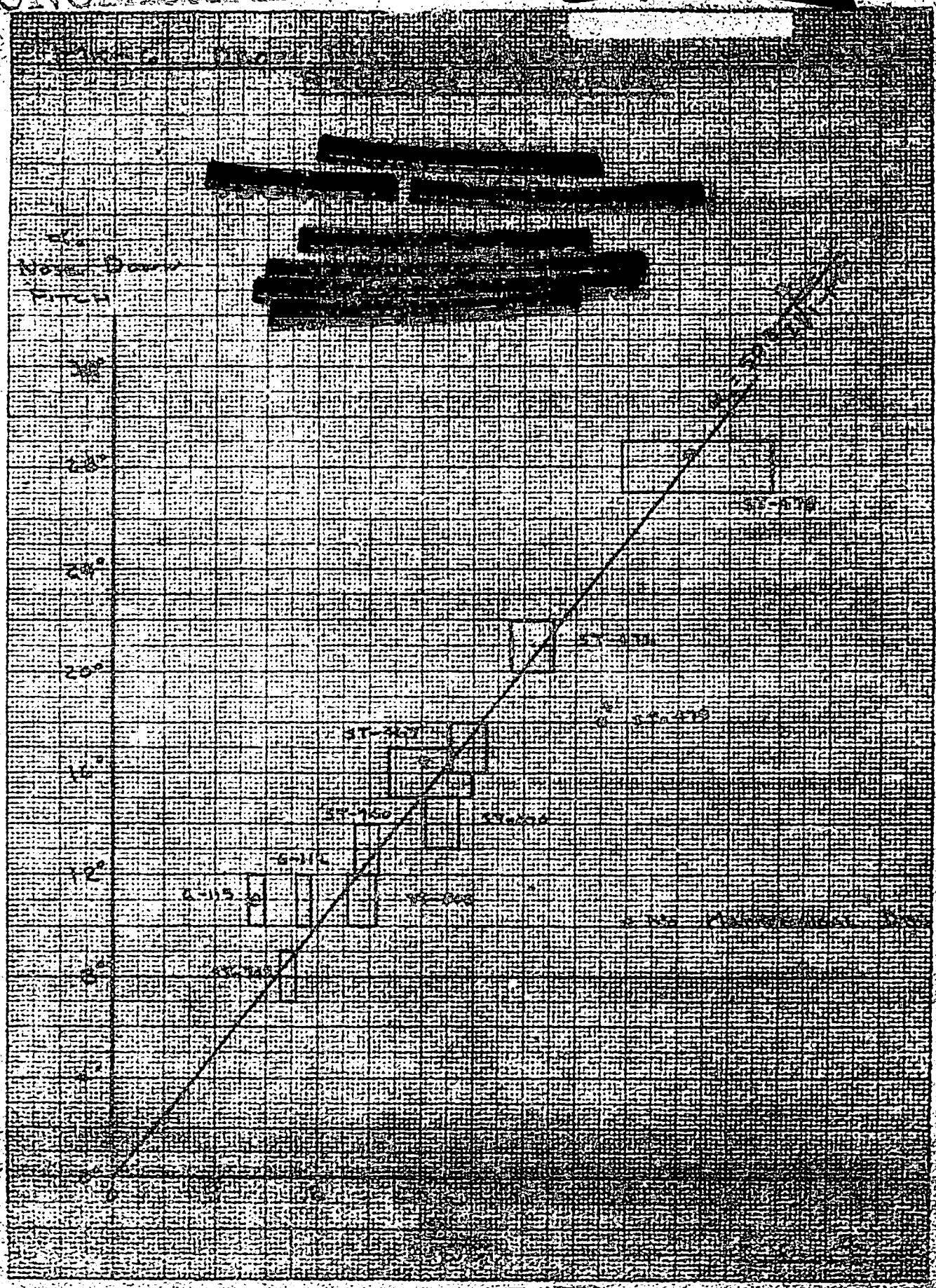

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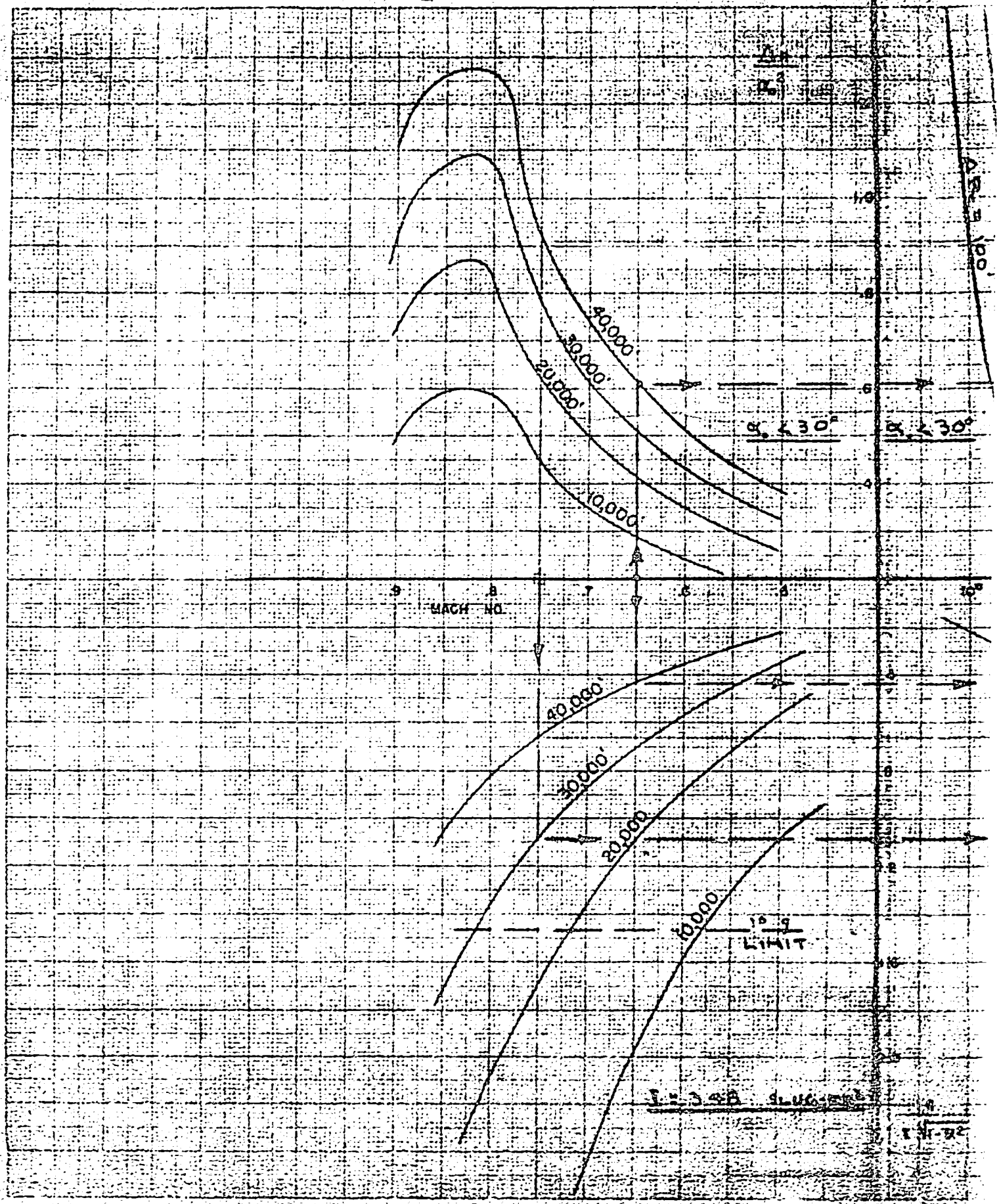

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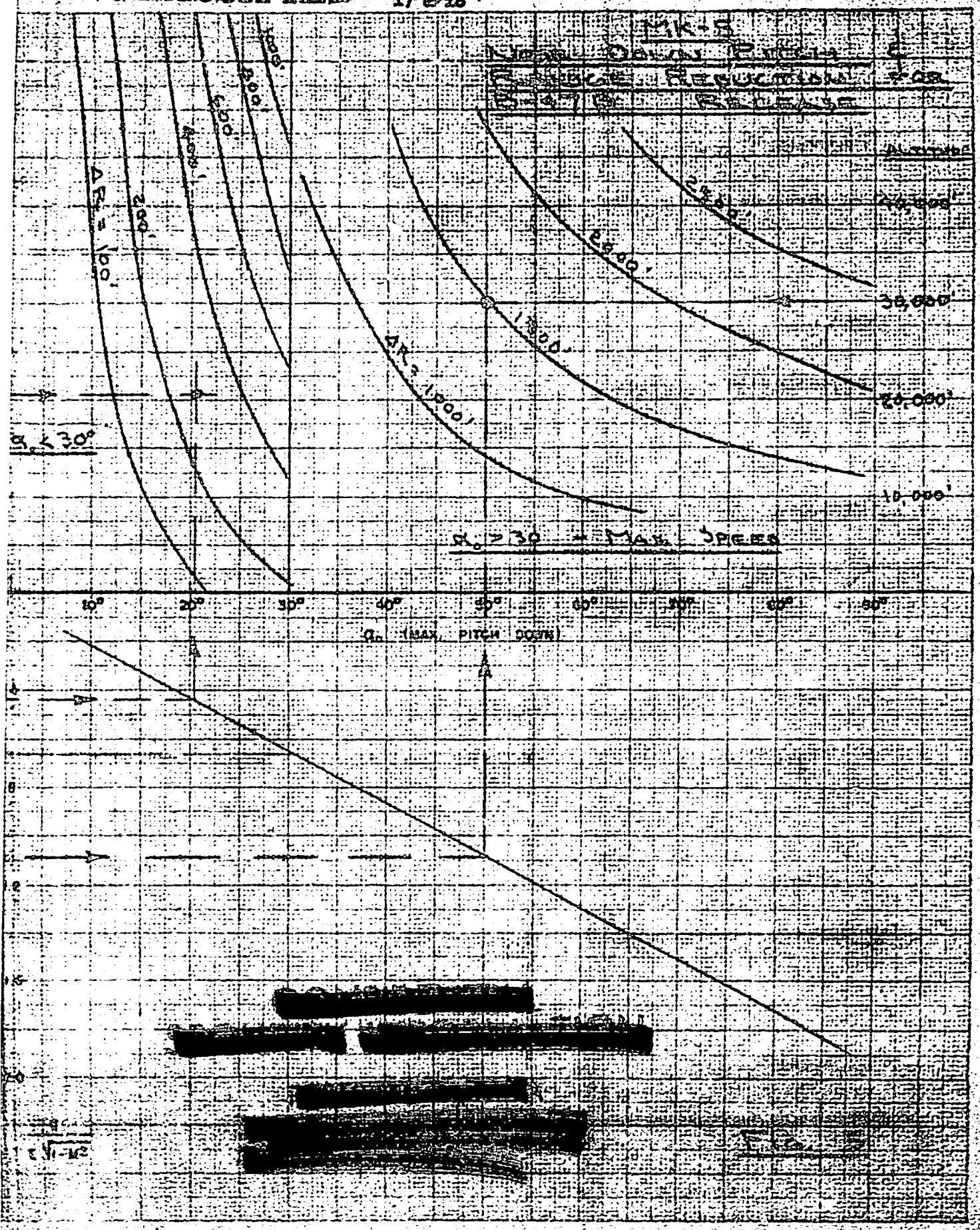

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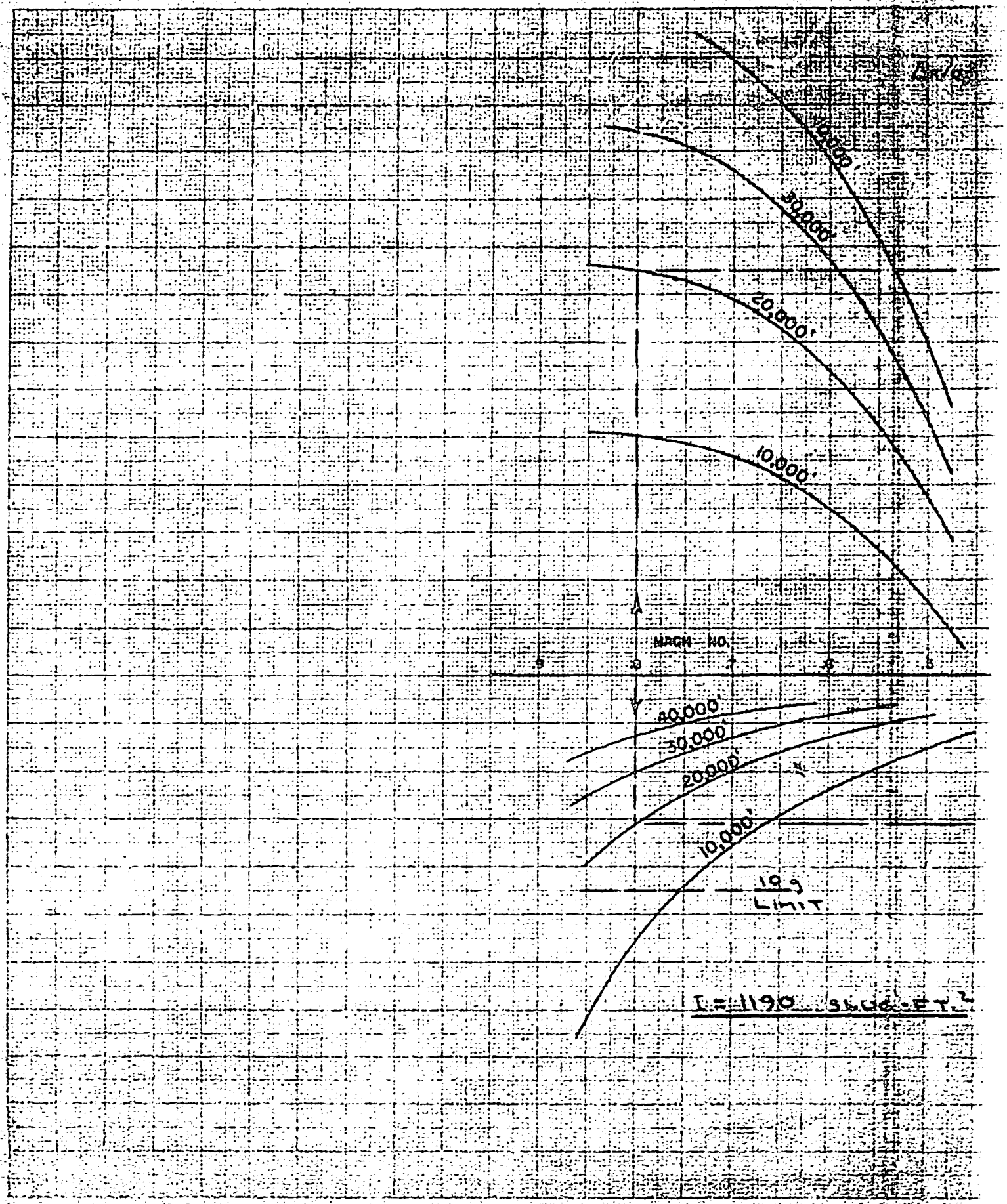

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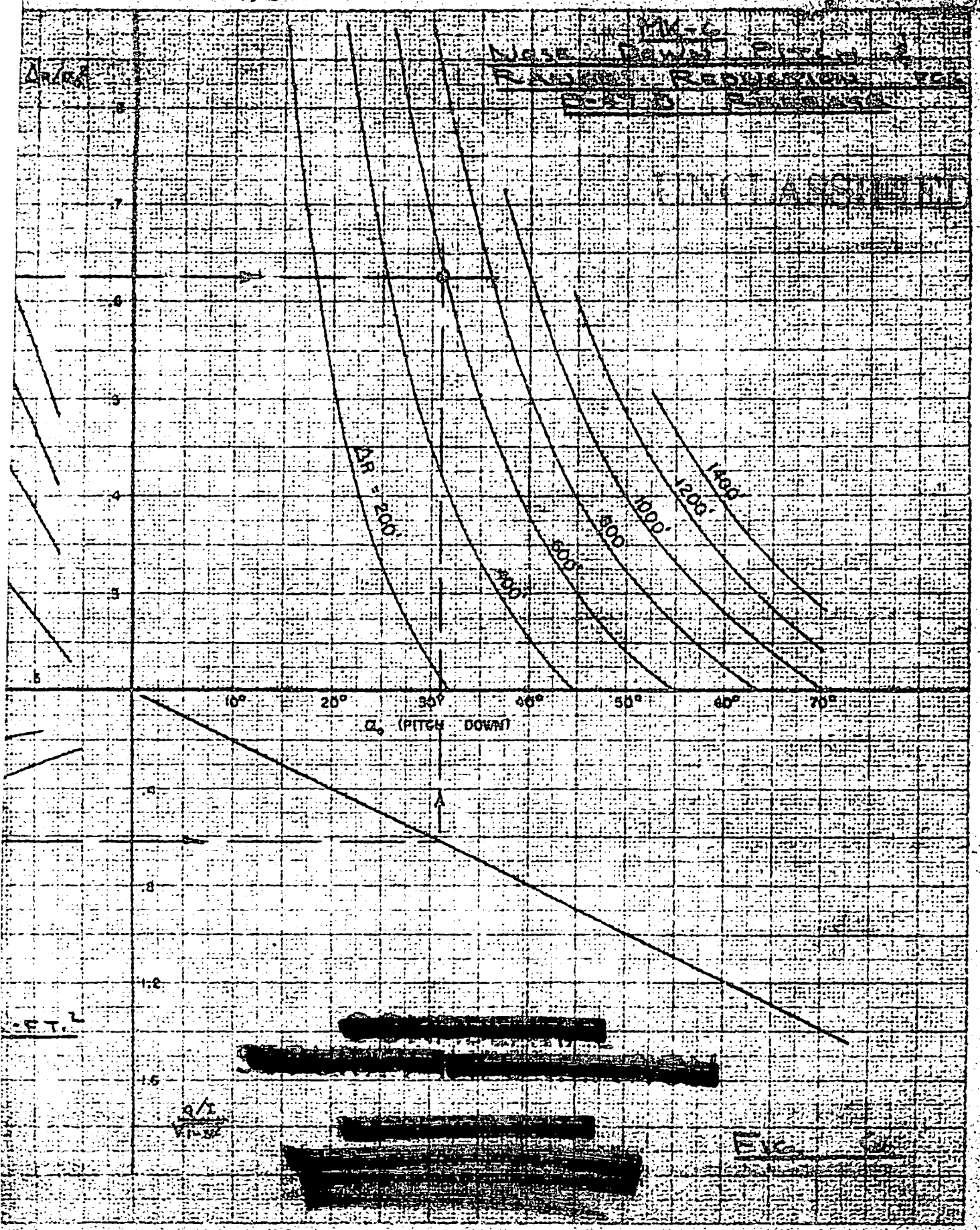

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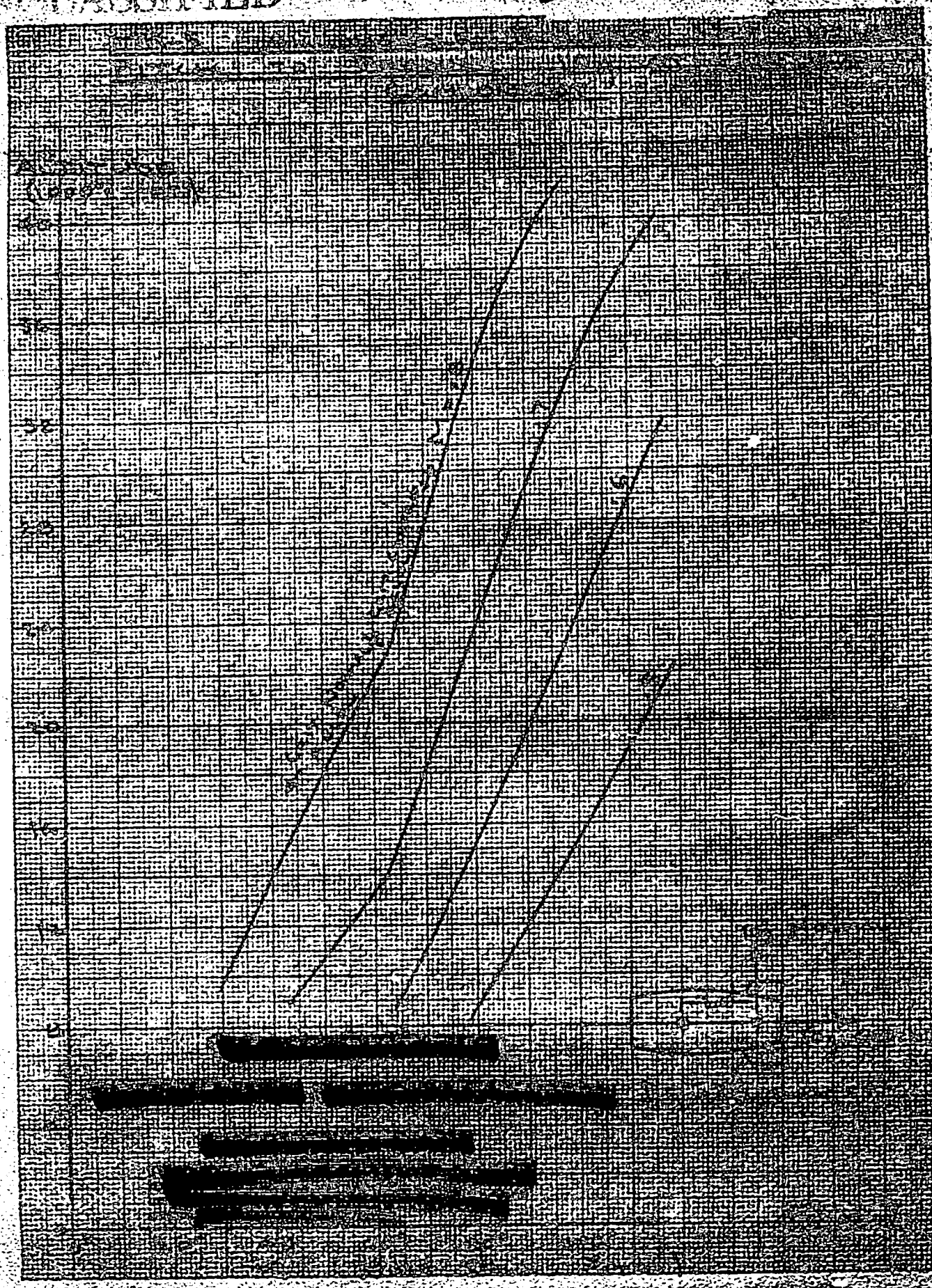

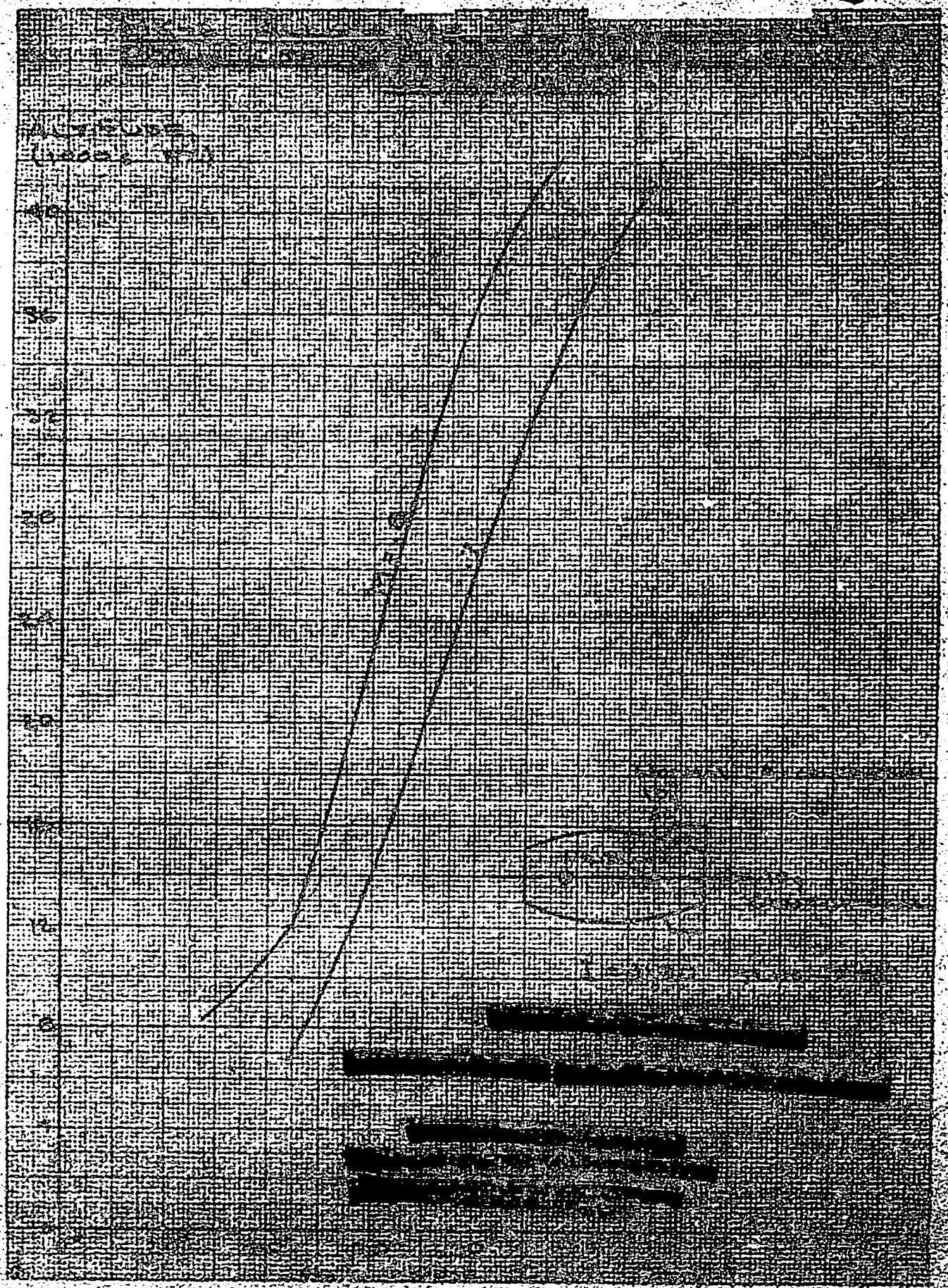
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