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Kellett KD-1

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

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MEMORANDUM REPORT

BLADE MOTION AND BOUNCING TESTS OF KD-1 AUTOGIRO

By JOHN B. WHEATLEY

June 13, 1935

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[redacted] MEMORANDUM REPORT

BLADE MOTION AND BOUNCING TESTS OF KD-1 AUTOGIRO

BY JOHN B. WHEATLEY

There are forwarded herewith the results of blade motion and bouncing tests on the Kellett KD-1 three-bladed autogiro. Motion picture records and two-component accelerometer records were taken in flight during glides at air speeds from 30 miles per hour to 100 miles per hour indicator readings. Calibration curves of correct indicated air speed and rotor speed as functions of air speed meter reading were established with a trailing pitot-static head and a rotoscope, at 2,000 ft. altitude and an air density of 0.00231 slug/cu.ft., all tests being made at approximately that density.

The test results are given in figures 1 to 14 and tables I to III. Rotor speed and $\frac{V}{\Omega R}\left(= \frac{\mu}{\cos \alpha}\right)$ are shown as functions of indicated air speed in figure 1. A typical curve of flapping angle β and of the angular motion λ about the vertical pin as functions of azimuth angle ψ are given in figure 2, showing the relative dispersion of the experimental data. All curves of this type have been analyzed on the assumption that they are expressible in the forms

$$\beta = a_0 - a_1 \cos \psi - b_1 \sin \psi - a_2 \cos 2\psi - b_2 \sin 2\psi$$

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and

$$\lambda = -a_1 \cos \psi - b_1 \sin \psi - a_2 \cos 2\psi - b_2 \sin 2\psi$$

and the results of this analysis are shown in figures 3 and 4 and tables I and II as functions of the speed ratio $\frac{V}{\Omega R}$. The twist of the blade at the fifteen foot radius has been plotted in figures 5 to 12, the dynamic twist θ' being the difference between the zero reading, which varies for different runs because of the camera position, and the curve of pitch angle θ as a function of ψ. This twist angle has been assumed expressible in the form

$$\theta' = \epsilon_0 + \epsilon_1 \cos \psi + \eta_1 \sin \psi + \epsilon_2 \cos 2\psi + \eta_2 \sin 2\psi + \epsilon_3 \cos 3\psi + \eta_3 \sin 3\psi$$

and the resultant data is shown in figure 13 and in table III. Figure 14 shows a typical accelerometer record obtained simultaneously with the blade motion data.

Much of the test data is self-explanatory, so only items of particular interest will be discussed. In figure 3 it will be seen that a_1 differs from its usual form in that it does not increase steadily with $\frac{V}{\Omega R}$. This can be adequately explained by reference to the curves of pitch angle θ against ψ, which show a variation in blade pitch angle which would replace part of the flapping motion represented by a_1. The

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curves of θ against ψ are consistent with the fact that the c.g. position of the rotor blade along the chord is at 22.5 percent c, which is always forward of the c.p., giving a washed-out blade when the rotor develops thrust. The amount of washout varies with the thrust and the c.p. position of the thrust, and consequently with ψ. The thrust is a maximum and the c.p. position farthest aft between $\psi = 0$ and $\psi = 90^\circ$, and this is reflected in the marked decrease in θ in that range. Figure 10 is particularly noteworthy because of the high-frequency vibration of the blade manifested in part of the range. It is thought that at this particular rotor speed the natural frequency of the blade in torsion is an integral multiple of the rate of rotation of the rotor, which results in a repeated oscillation in phase with itself during successive rotor revolutions. At a different rotor speed the phase relation would change and merely result in dispersing the data. Figure 14 shows that in the strictest sense there is no bouncing in this rotor, bouncing being a vibration with a frequency of three times the rotor speed. The vibration in the normal acceleration at 34 miles per hour occurs at twice rotor speed, or approximately at 6 cycles/sec.; as the air speed increases, there is superposed on this vibration another one of the same frequency as the rotor speed, giving an

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acceleration record resembling a cycloid curve. The vibration of the same frequency as the rotor can be ascribed to a slight difference in the pitch angle of the individual blades, which would result in a slightly uneven distribution of the thrust load. No explanation has been found for the presence of a vibration at twice rotor speed. The scale on the normal component of the accelerometer is 1 inch of ordinate equals 2.33 g.

Langley Memorial Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., June 13, 1935.

John B. Wheatley
John B. Wheatley,
Junior Aeronautical Engineer.

Approved:
Elton W. Miller
Elton W. Miller,
Principal Mechanical Engineer.

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TABLE I

KD-1 TEST

SUMMARY β

$\frac{V}{\Omega R}$	a_0	a_1	b_1	a_2	b_2
0.125	8.44	0.94	1.86	0.09	-0.15
.158	8.14	1.53	1.86	.15	-.17
.188	7.79	1.62	1.93	.11	-.15
.217	7.72	1.50	1.99	.16	-.18
.246	7.52	1.79	2.00	.18	-.20
.273	6.50	1.24	2.04	.28	-.16
.298	6.97	1.40	2.11	.31	-.25
.317	6.26	1.37	2.15	.38	-.28

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TABLE II

KD-1 TEST

SUMMARY λ

$\frac{V}{\Omega R}$	a_1	b_1	a_2	b_2
0.125	-0.55	0.08	0.01	0.01
.158	-.60	.23	.01	.01
.188	-.54	.20	.01	.02
.217	-.53	.13	.02	.04
.246	-.56	.20	.03	.04
.273	-.47	0	.01	.06
.298	-.55	.08	0	.03
.317	-.52	0	0	.04

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TABLE III

KD-1 TEST

SUMMARY θ'

$\frac{V}{\Omega R}$	ϵ_0	ϵ_1	η_1	ϵ_2	η_2	ϵ_3	η_3
0.125	-1.13	0.12	-0.51	0.01	0.02	0.13	-0.14
.158	-.57	-.20	-.69	.10	-.14	.06	-.06
.188	-1.16	.01	-.77	.08	-.15	.11	-.05
.217	-.90	-.13	-1.05	.17	-.15	.12	-.08
.246	-1.38	.12	-1.27	.20	-.14	.18	-.13
.273	-1.11	-.09	-1.46	.71	-.42	-.06	.16
.298	-1.51	.31	-1.61	.48	-.35	.21	.21
.317	-1.63	.52	-2.13	.74	-.19	.34	-.12

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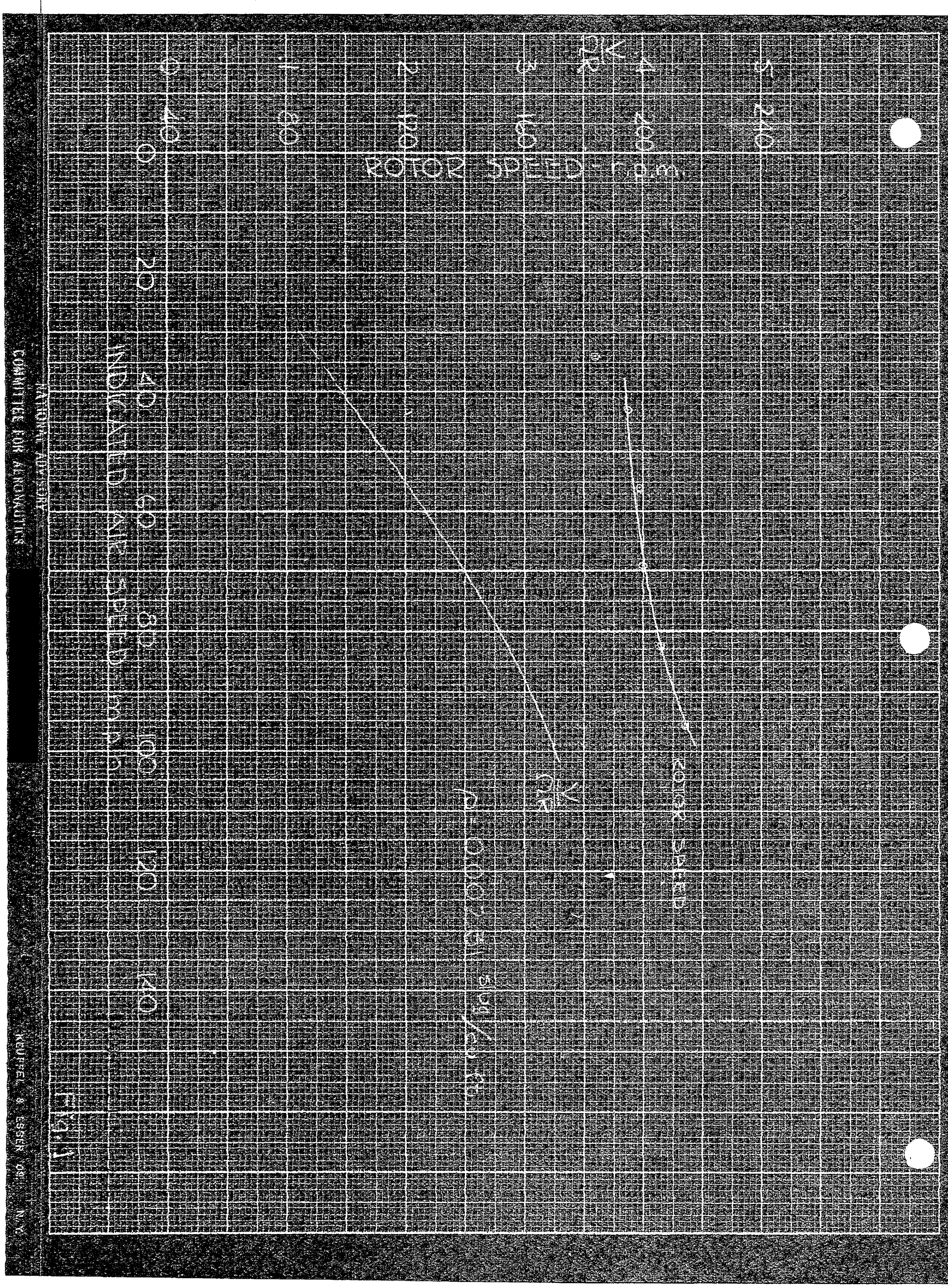

Fig. 1

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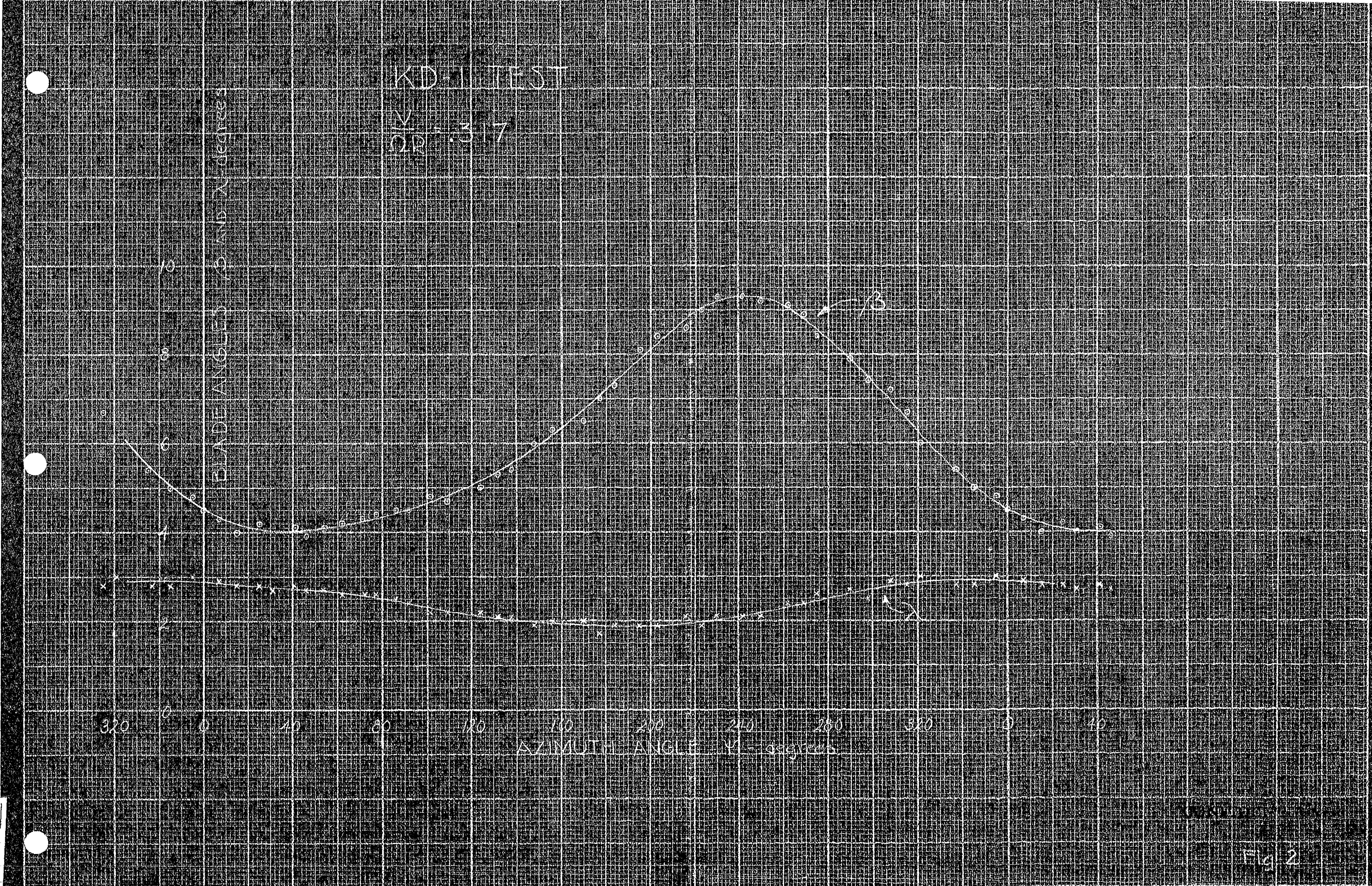

Fig 2

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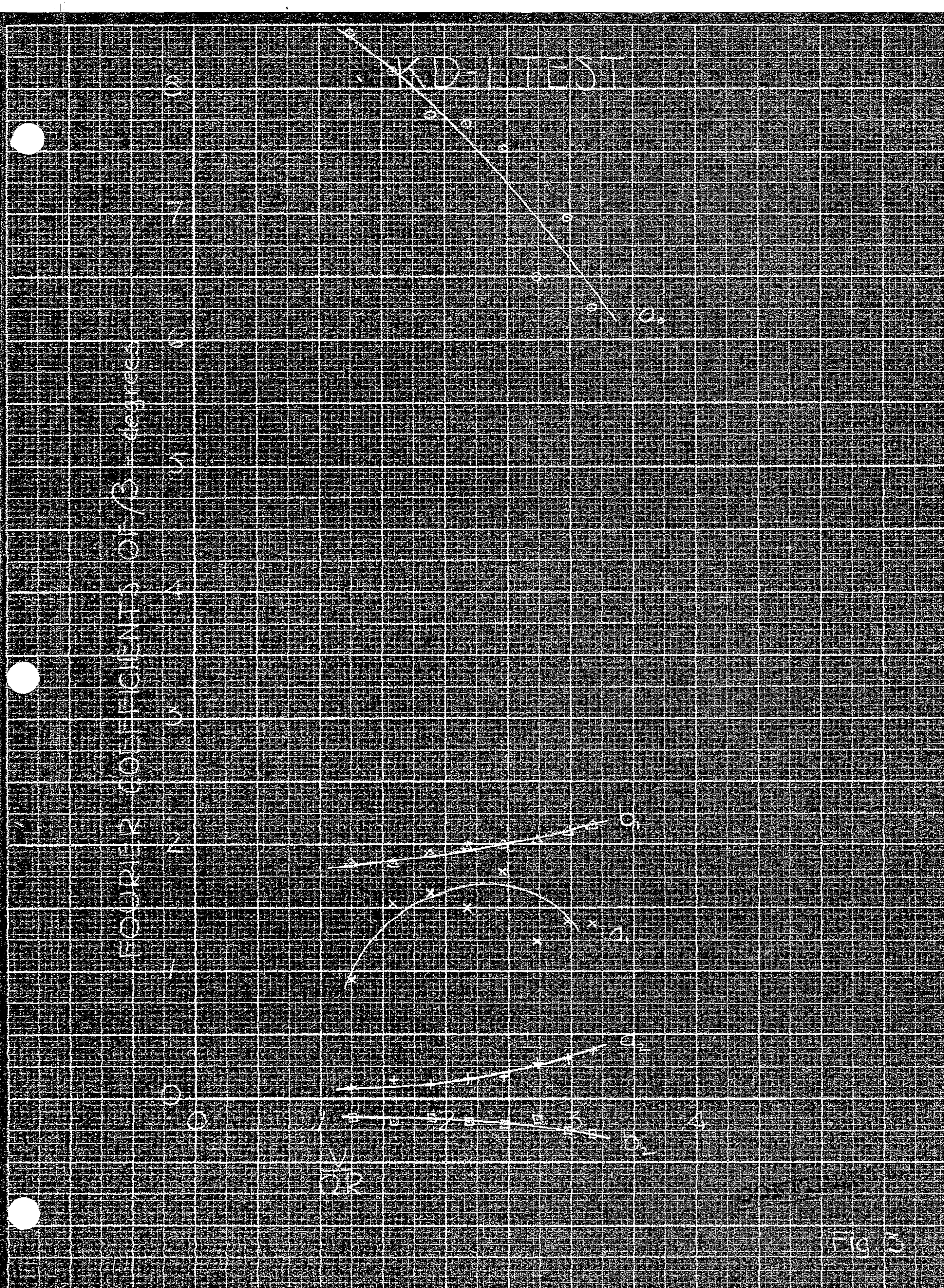

Fig 3

NATIONAL ADVISORY
COMMITTEE FOR AERONAUTICS

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KD-1 TEST

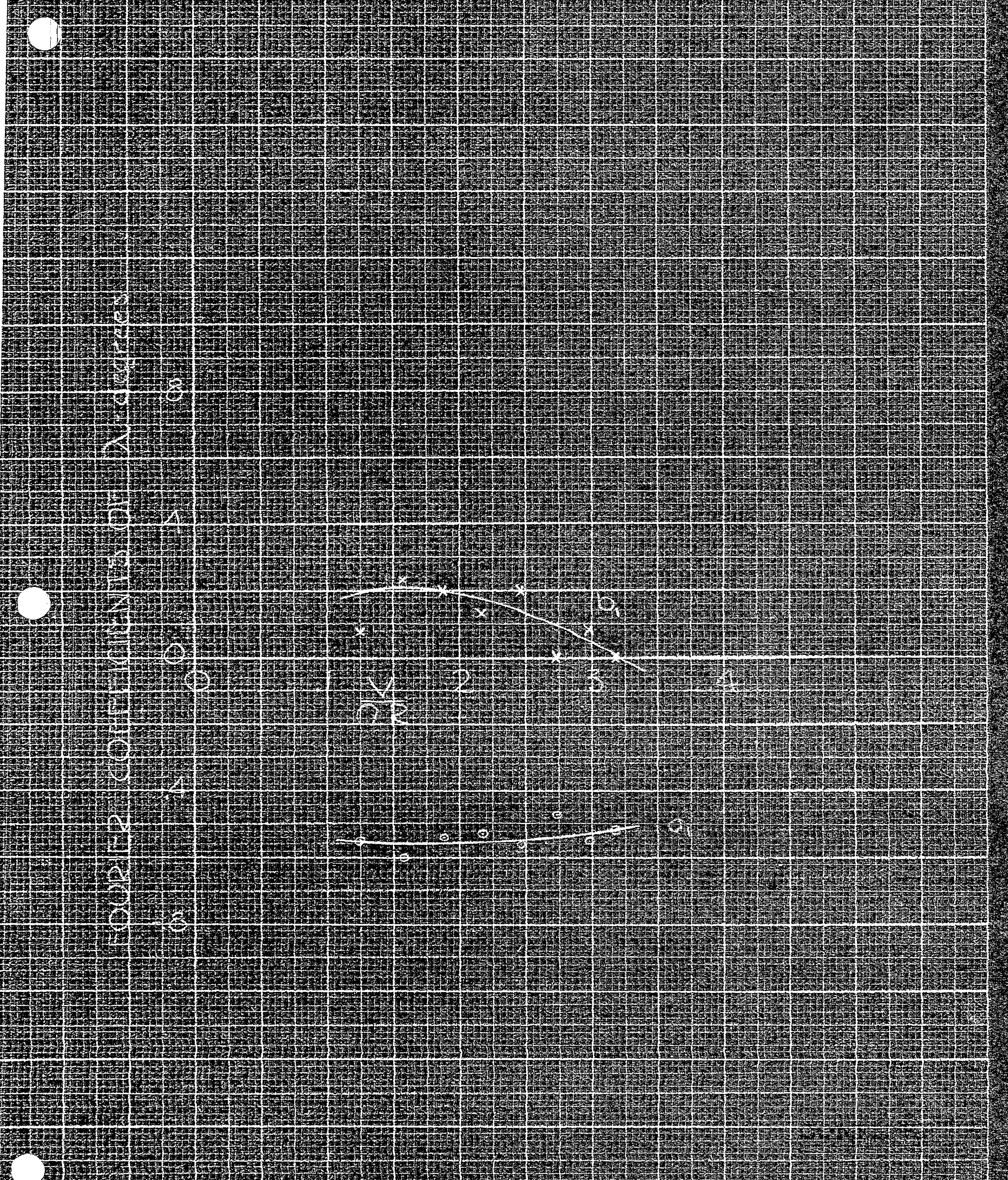

Fig. 4

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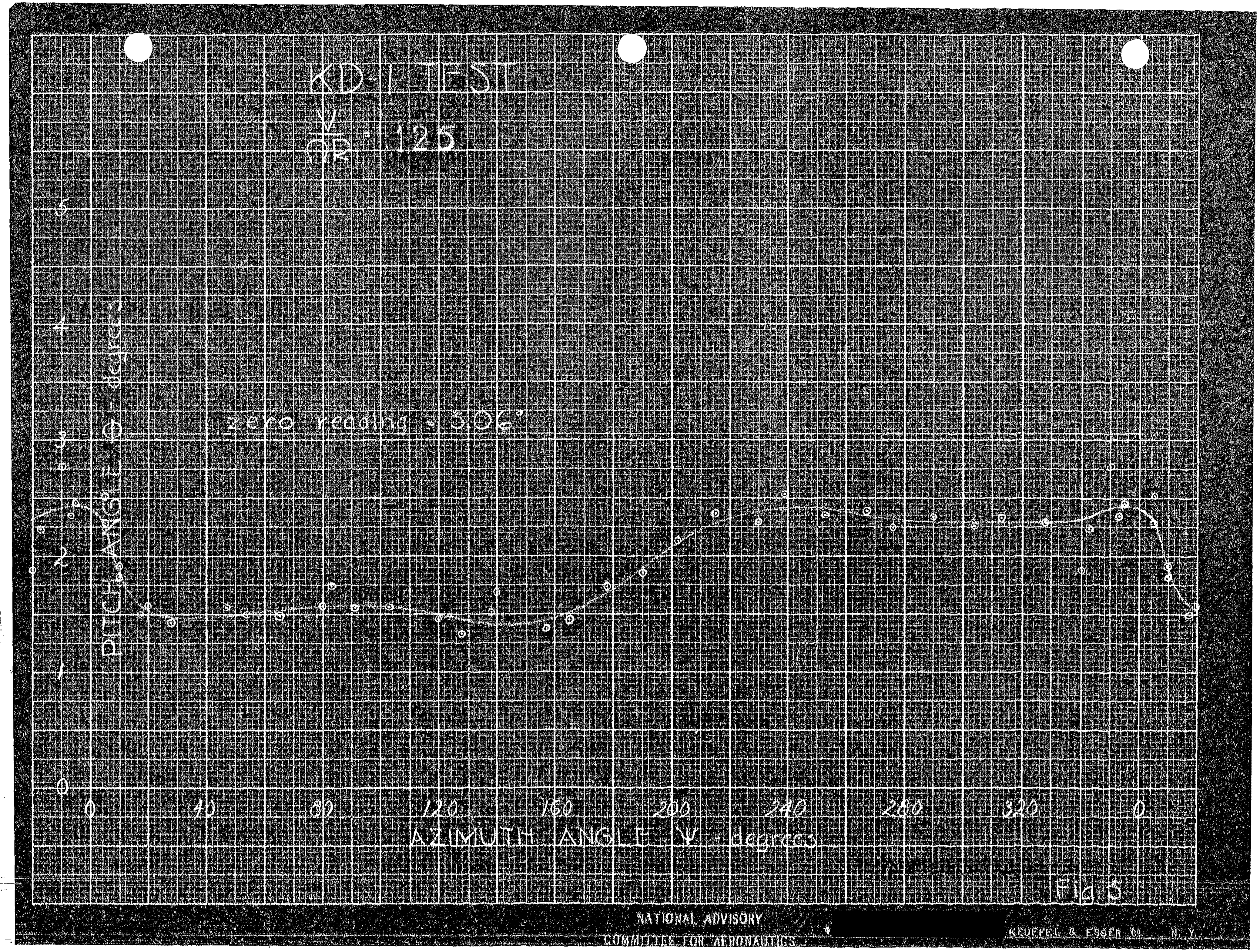

Fig 5

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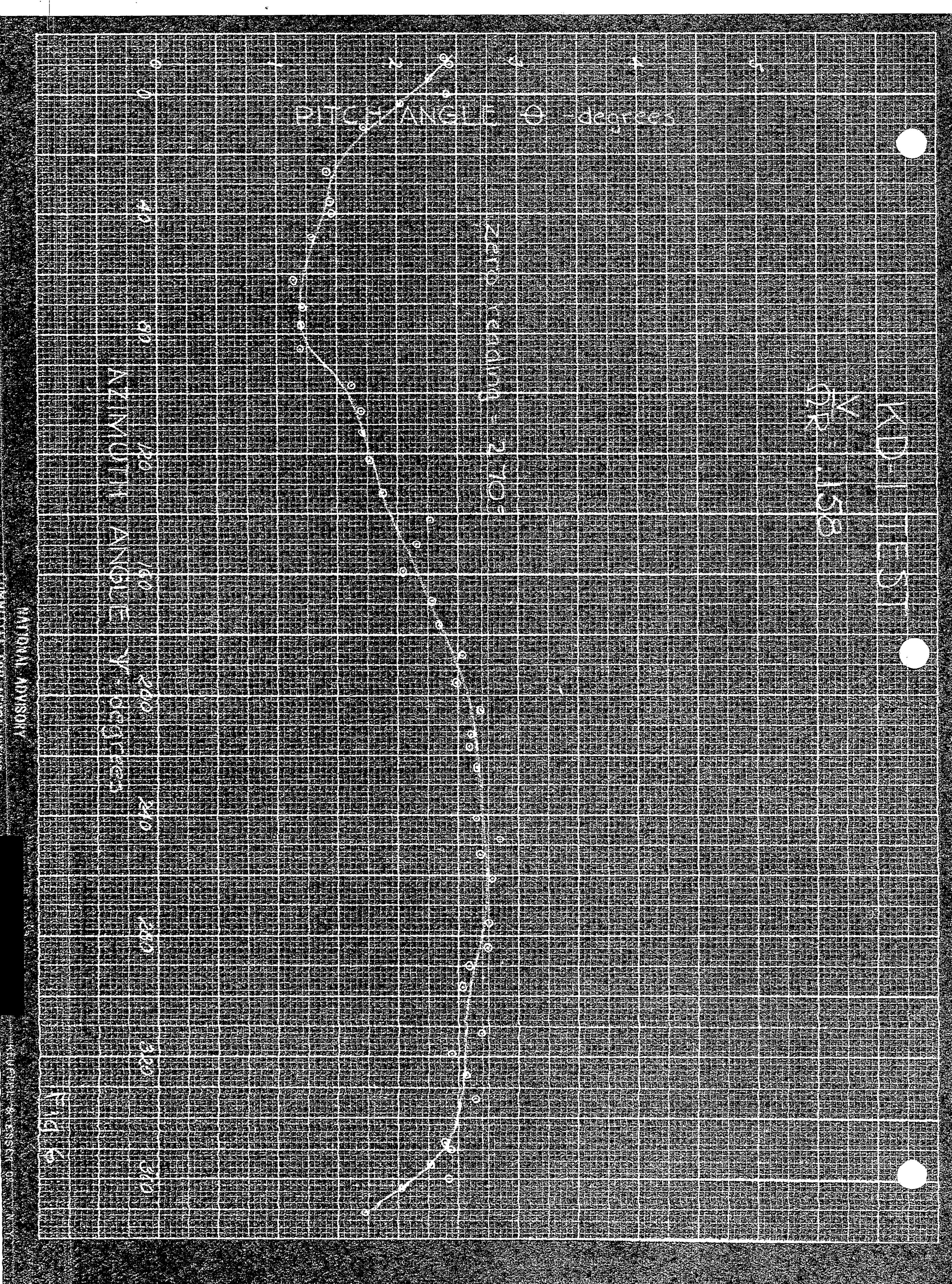

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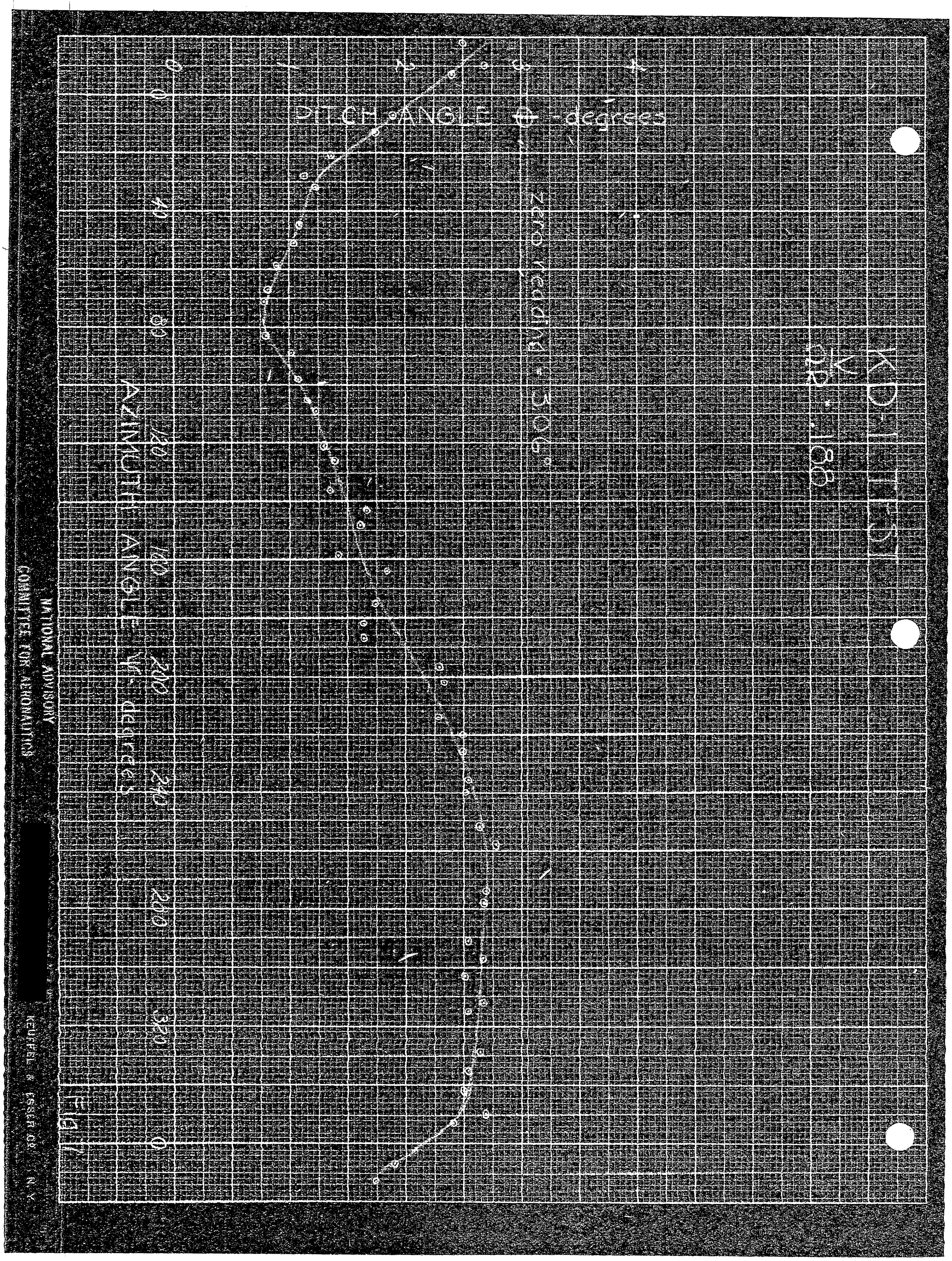

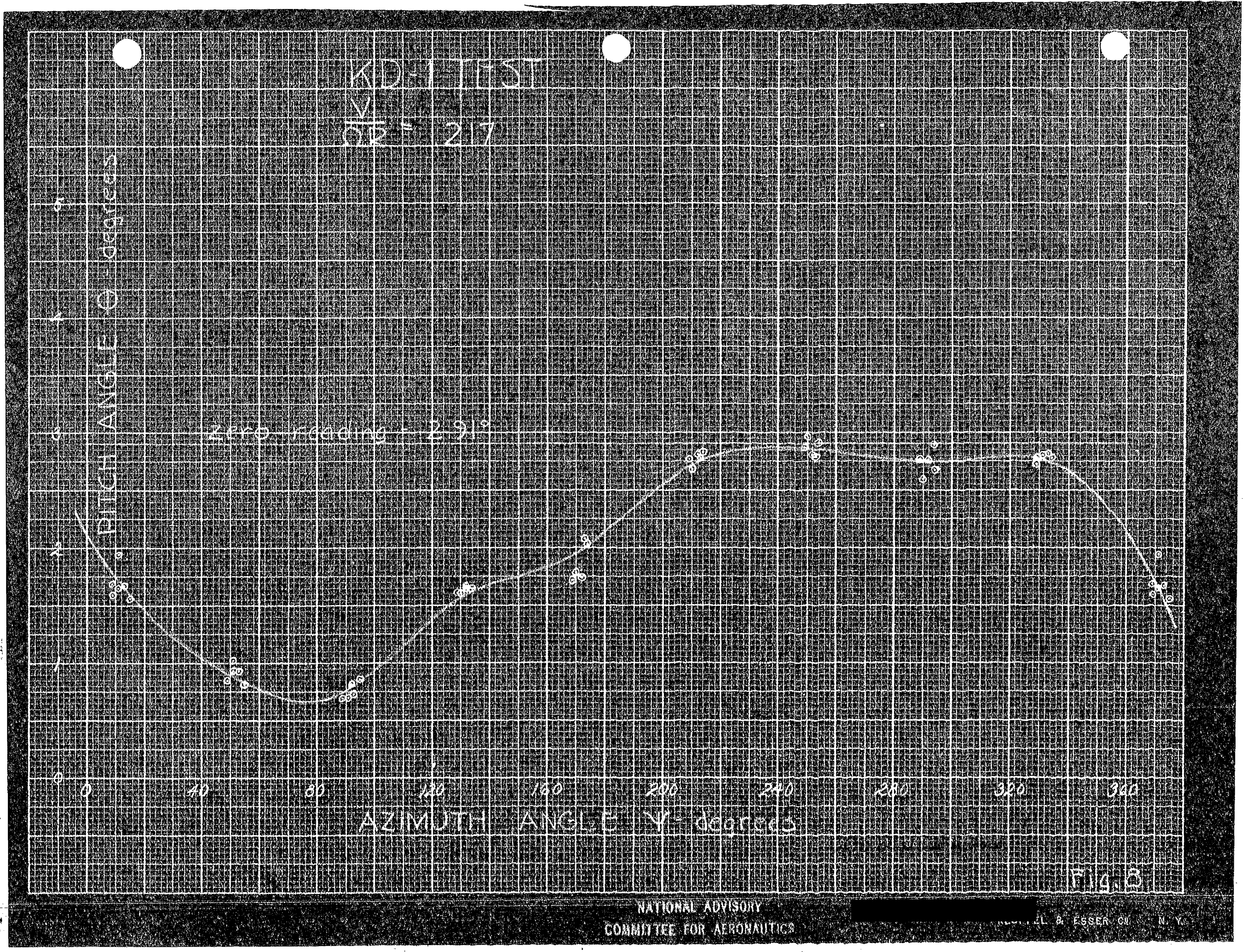
KD-1 TEST
V/ΩR = 217
PITCH ANGLE θ - degrees
Zero reading - 2.91°
0
40
80
120
160
200
240
280
320
360
AZIMUTH ANGLE ψ - degrees
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Fig. 8

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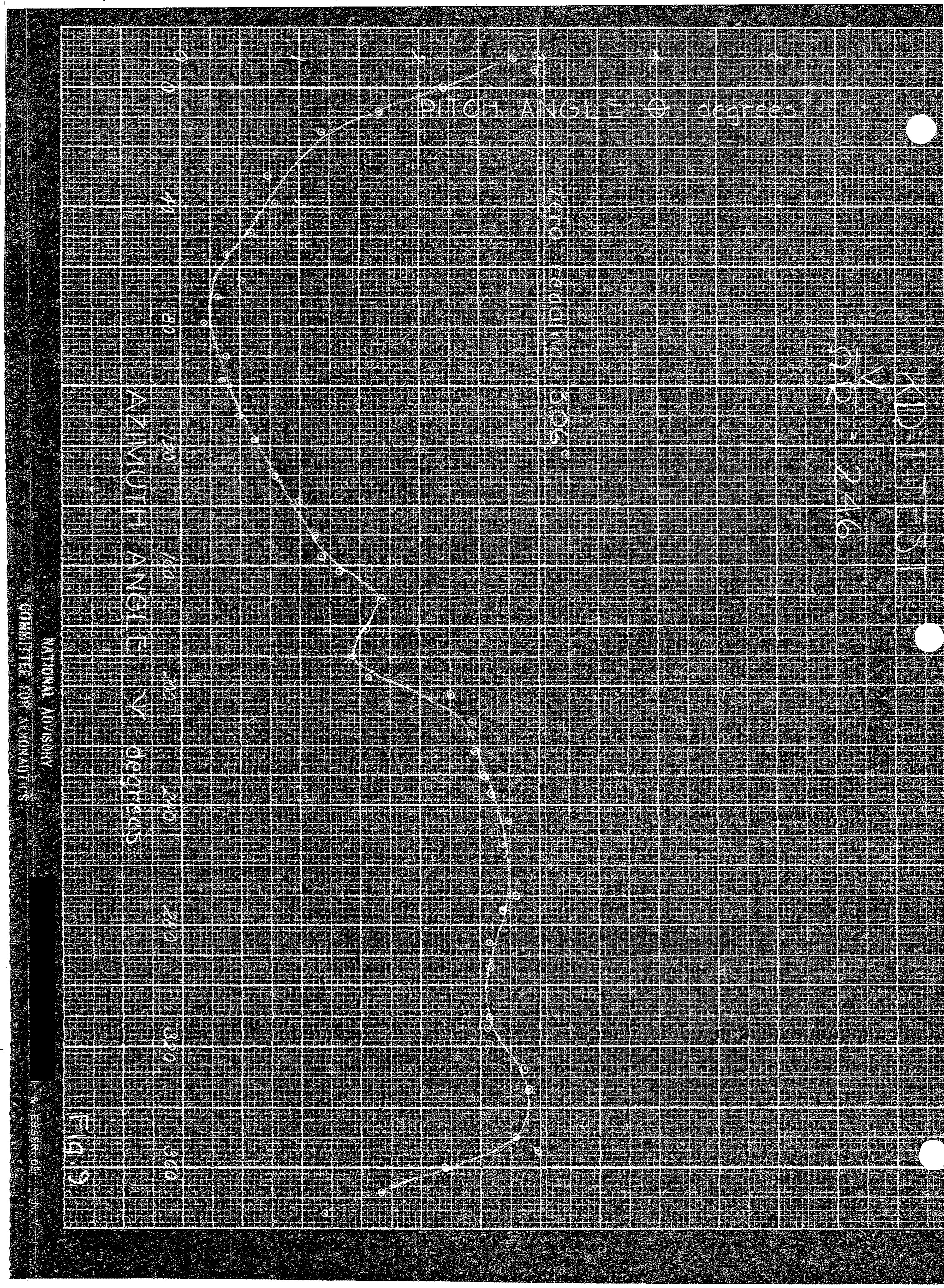

Fig. 9

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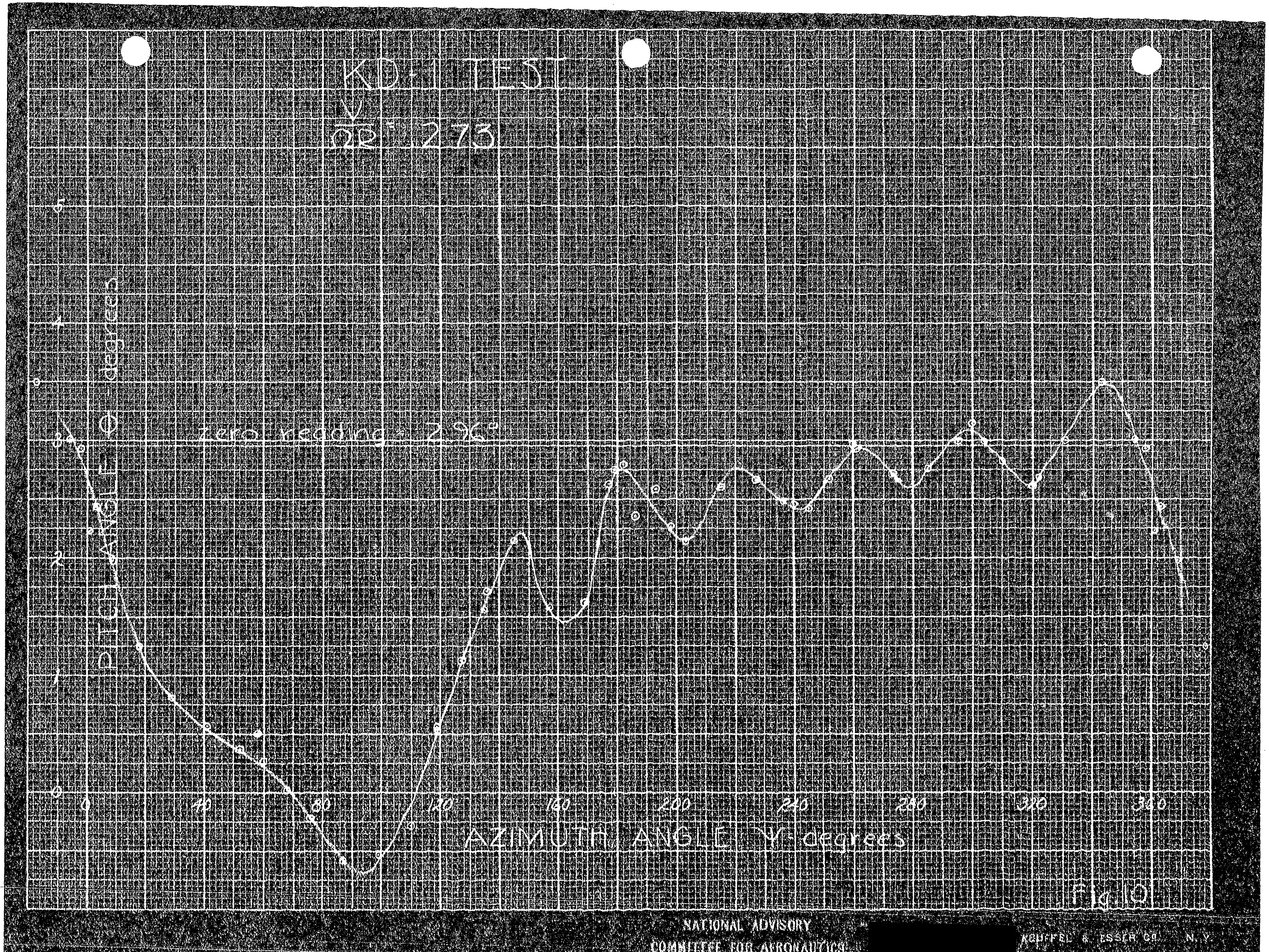

Fig. 10

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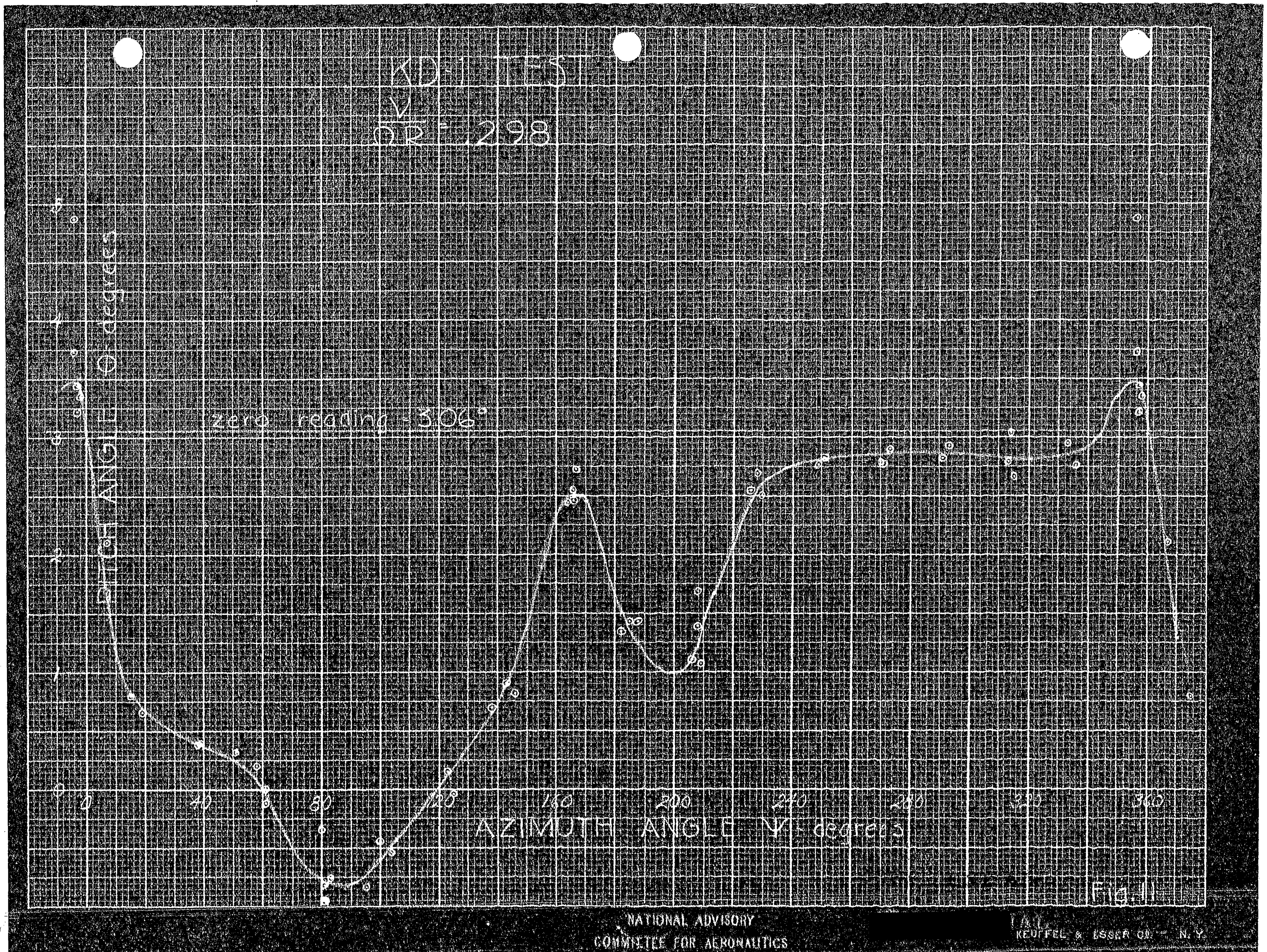

Fig. 11

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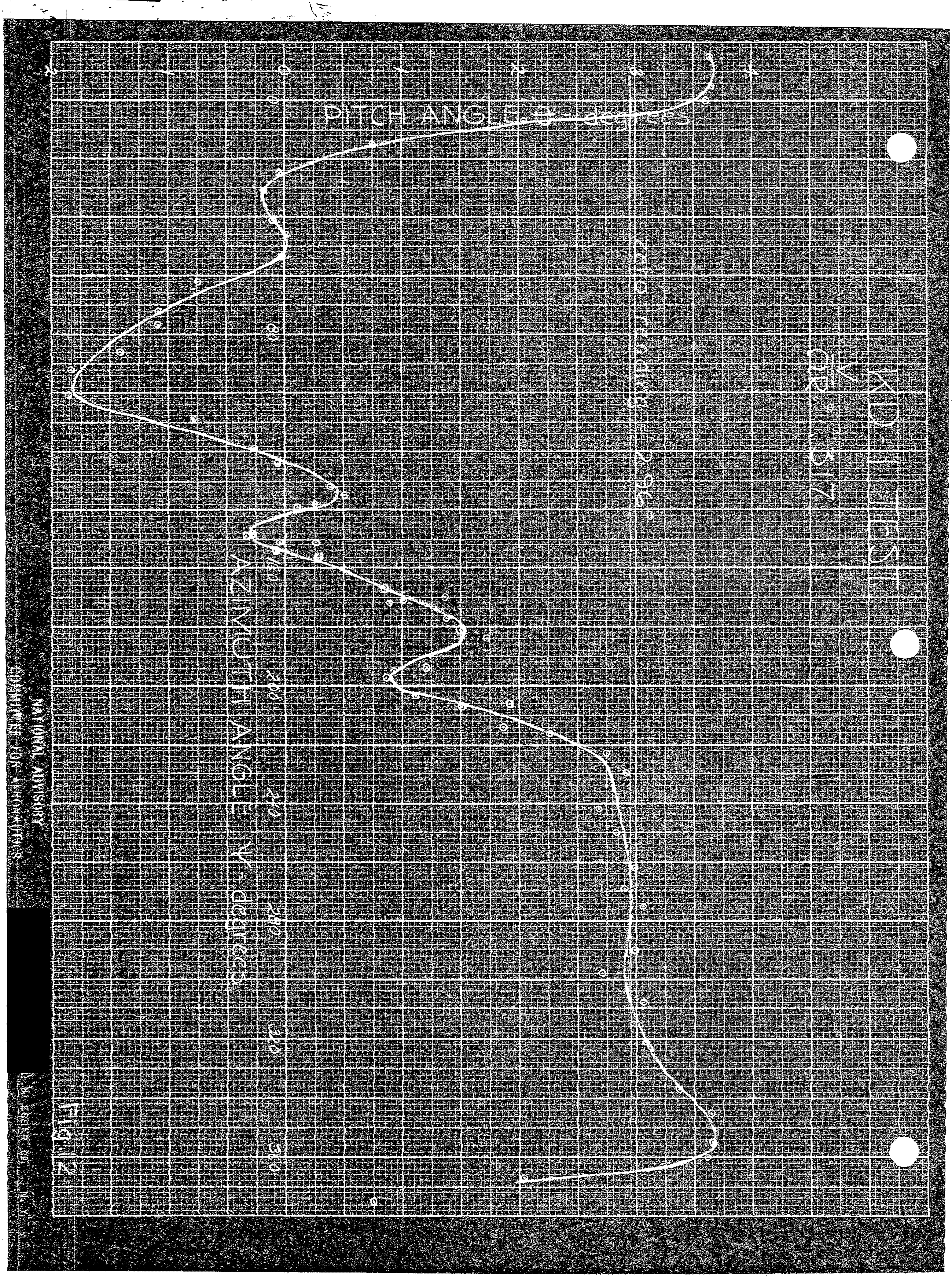

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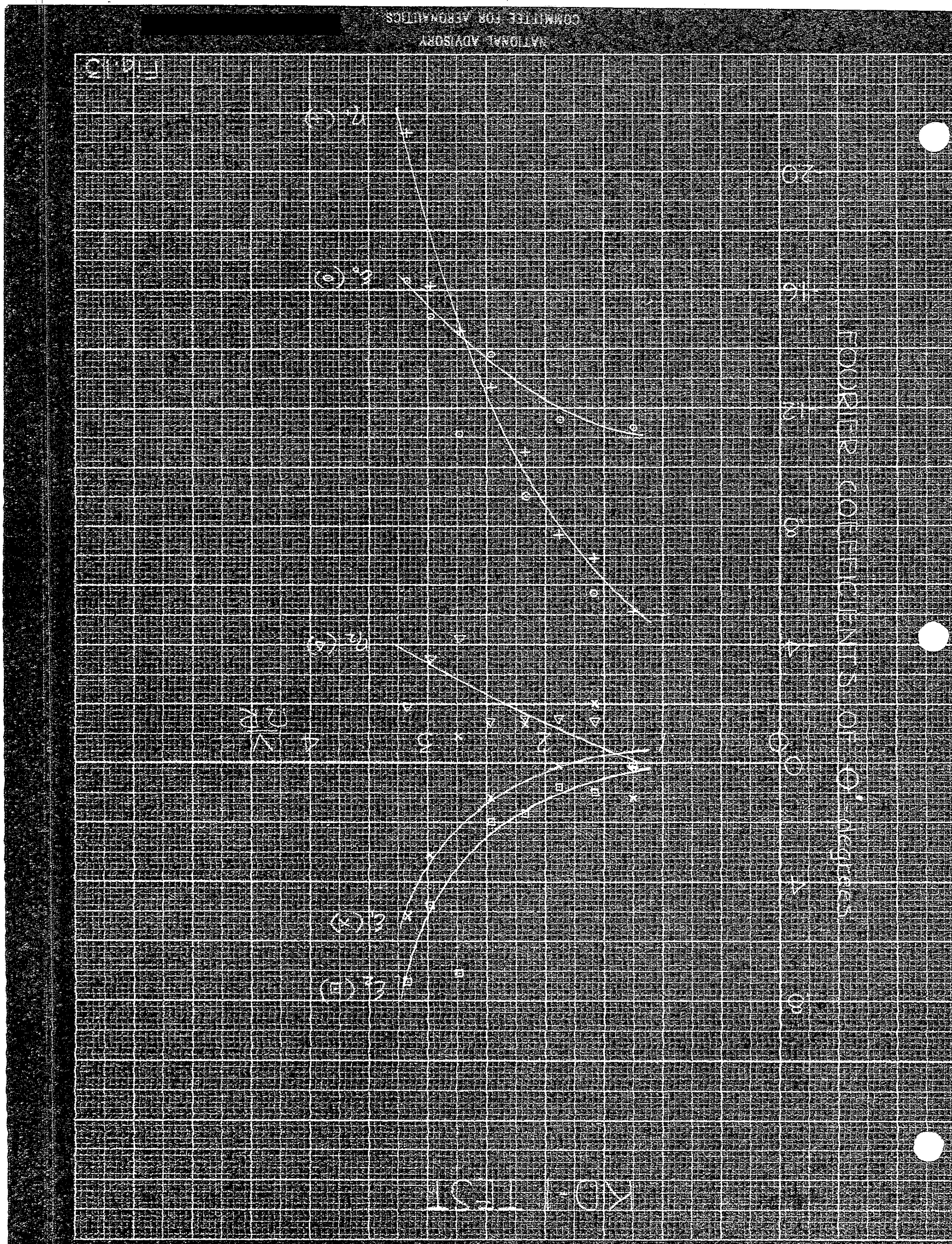

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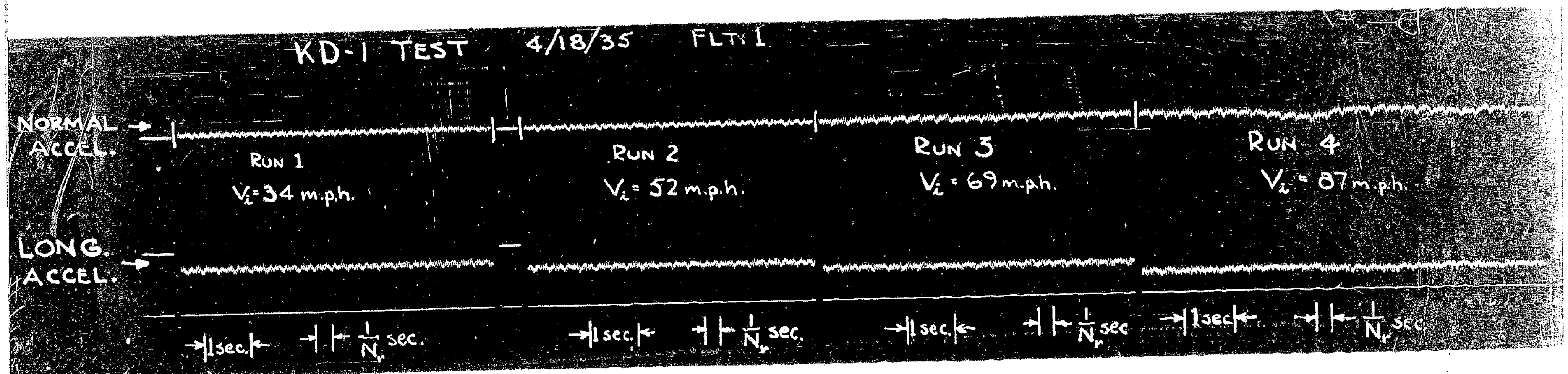

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FIGURE 14.

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