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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

MEMORANDUM REPORT

for

Army Air Corps

A FLIGHT DETERMINATION OF THE MOMENTS OF THE YG-1B TAPERED BLADE ROTOR ABOUT THE HUB TRUNNIONS

By F. J. BAILEY, JR.

November 15, 1939

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CONFIDENTIAL MEMORANDUM REPORT

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INTRODUCTION

At the request of the Materiel Division, Wright Field, the National Advisory Committee for Aeronautics is conducting a program of flight tests on a Kellett YG-1B autogiro equipped with a new type of rotor blade. The new blades are tapered in both plan form and thickness and are designed to avoid periodic blade twist. One phase of the investigation, involving determination of the moments of the resultant rotor force about the trunnions on which the hub is pivoted for control, has been completed. The results obtained are reported herein.

APPARATUS AND METHODS

The new blades were tested on a standard YG-1B rotor hub. The lateral and longitudinal trunnions about which this hub is pivoted for control intersect in a point 7/16 inch to the left and 1-5/8 inches ahead of the rotor axis,

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and lie in a plane 2-3/4 inches below the plane of the flapping hinges.

Ordinarily the moments of the resultant rotor force vector about the trunnions are counteracted by the moments applied by the pilot through the control system, plus the moments applied to the hub by the bungee spring. In the present tests the bungee spring was wedged open until, with the bungee lever full forward, the bungee cable became slack as soon as the stick was moved approximately an inch back from its full forward position. All records were taken with the bungee lever full forward and the stick more than an inch aft of its full forward position. Hence the moments contributed by the bungee spring were zero in every case.

The lateral and longitudinal moments applied to the control system by the pilot were recorded simultaneously on an N. A. C. A. stick type control force recorder. Multiplication of these moments by the lateral and longitudinal mechanical advantages of the control system established the moments of the rotor vector about the trunnion axes.

In addition to records of control force, records of control position and air speed were obtained during each run. Pressure altitude and rotor speed were noted by the pilot.

Records were taken in steady level flight and in steady glides at indicated air speeds ranging from zero to 110 miles per hour.

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Two flights were made. In the first flight the air-speed recorder was connected to the same service head to which the pilot's meter is attached; in the second it was connected to a swiveling head mounted on a boom extending to a point several feet outboard of the service head. Comparison of recorded air speed with readings of the pilot's air-speed meter for the two flights indicated that the accuracy of air speeds recorded with the service head was satisfactory.

The air-speed recorder installation was also checked to insure that no appreciable error resulted from rates of change of static pressure comparable to those encountered in glides.

The gross weight of the autogiro at take-off was 1,960 pounds.

RESULTS AND DISCUSSION

Data obtained during each run are tabulated in table I.

The lateral and longitudinal trunnion moments are plotted against one another in figure 1 for the level-flight condition and in figure 2 for the glide condition. Average values of the tip-speed ratio corresponding to several values of longitudinal trunnion moment are indicated on figures 1 and 2. These tip-speed ratios were determined from the faired curves of longitudinal trunnion moment versus tip-speed ratio shown in figure 3.

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The actual stick force applied by the pilot can be obtained by dividing the corresponding trunnion moment by the product of the stick length, 1.906 feet, and the mechanical advantage of the control system, 3.86 longitudinally and 5.27 laterally. The figures given for the mechanical advantages were obtained from simultaneous measurements of hub and stick angles made previously on an autogiro of the YG-1B type.

The magnitude of the accidental errors is indicated by the scatter of the experimental points on figures 1 and 2. In interpreting this scatter it must be remembered that a lateral trunnion moment of 20 foot-pounds corresponds to a lateral stick force of only 2 pounds. Most of the test records showed third harmonic variations of stick force having an amplitude of several pounds, and many also showed non-periodic variations of stick force probably traceable to gusts. The pilot commented particularly on the difficulty of holding the autogiro steady in the low-speed glides, where the most serious discrepancies occur.

The consistent differences shown between moments in glides and in level flight on figure 3 are believed to be indicative of the effect of the propeller slipstream on the rotor.

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Control positions, expressed in terms of the tilt angles of the hub relative to the fuselage reference axes are shown in figures 4 and 5.

Langley Memorial Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., November 15, 1939.

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Approved:

Elton W. Miller,
Principal Mechanical Engineer.

HE

L.F. 1003

Test No. ....

Job No. ....

Date 11/8/39

Observer ....

SUMMARY OF DATA ON TRUNNION MOMENTS

Flight	Condition	Run	Line	V_i M.P.H.	R.P.M.	Pres. Alt., Ft.	μ	Hub Angle, Deg. Lat. (+ = Rt.)	Hub Angle, Deg. Long. (+ = Back)	Trunnion Moments, Ft. Lbs. Lat.	Trunnion Moments, Ft. Lbs. Long.
			0								
Flight 1	Level	1	1	72.3	210	1000	.245	-.36	1.39	31	98
Flight 1	Level	2	2	77.5	211	"	.260	-.41	1.17	21	85
Flight 1	Level	3	3	83.0	212	"	.277	-.47	0.98	18	82
Flight 1	Level	4	4	65.4	209	"	.222	-.31	1.90	21	124
Flight 1	Level	5	5	60.0	209	"	.204	-.31	2.26	18	144
Flight 1	Level	6	6	57.2	206	"	.197	-.24	2.48	12	151
Flight 1	Level	7	7	51.2	206	"	.176	-.18	2.78	25	168
Flight 1	Level	8	8	48.4	206	"	.167	-.24	3.35	31	185
Flight 1	Level	9	9	43.3	202	"	.150	-.13	3.14	9	178
Flight 1	Glides	10	10	36.5	202	2500	—	-.59	4.77	25	199
Flight 1	Glides	11	11	42.4	206	↓	.149	-.64	4.42	29	198
Flight 1	Glides	12	12	55.2	206	↓	.193	-.59	4.14	6	180
Flight 1	Glides	13	13	58.0	206	↓	.202	-.70	3.50	2	155
Flight 1	Glides	14	14	69.2	210	↓	.236	-.77	2.70	15	130
Flight 1	Glides	15	15	78.0	210	1500	.266	-1.00	2.04	18	109
			16								
			17								
Flight 2	Level	1	18	43.4	200	3500	.160	-.10	3.13	26	172
Flight 2	Level	2	19	38.5	200	3700	.142	0	3.20	31	181
Flight 2	Level	3	20	31.2	200	4300	—	0	3.79	20	206
Flight 2	Level	4	21	25.9	197	4300	—	.10	4.07	20	206
Flight 2	Level	5	22	22.5	196	4200	—	.25	4.75	8	233
Flight 2	Level	6	23	18.0	195	4100	—	.30	5.41	13	233
Flight 2	Level	7	24	11.0	193	4100	—	.40	6.20	13	233
Flight 2	Level	8	25	81.8	216	4700	.284	-.23	1.03	13	72
Flight 2	Level	9	26	92.1	224	4800	.309	-.40	.56	20	64
Flight 2	Level	10	27	98.2	226	5000	.328	-.48	.34	13	55
Flight 2	Level	11	28	110.8	231	5000	.362	-.60	-.13	-4	22
Flight 2	Glides	12	29	109.4	225	4300	.363	-1.28	.55	2	46
Flight 2	Glides	13	30	88.8	215	3500	.304	-1.19	1.17	13	80
Flight 2	Glides	14	31	97.6	220	2500	.322	-1.26	.69	13	72
Flight 2	Glides	15	32	39.8	210	5000	.143	-0.70	5.09	13	199
Flight 2	Glides	16	33	33.1	200	4500		-0.76	5.35	13	199
Flight 2	Glides	17	34	27.8	198	4000		-0.76	6.00	13	215
Flight 2	Glides	18	35	25.9	195	3500		-0.70	6.32	31	233
Flight 2	Glides	19	36	17.5	193	3000		-0.76	6.72	56	224
Flight 2	Glides	20	37	0	190	2500		-0.60	7.06	-22	206
			38								
			39								
			40								

NOTE: TRUNNION MOMENTS ARE SHOWN AS POSITIVE WHEN THE AIR FORCES TEND TO TILT THE ROTOR FORWARD AND TO THE RIGHT.

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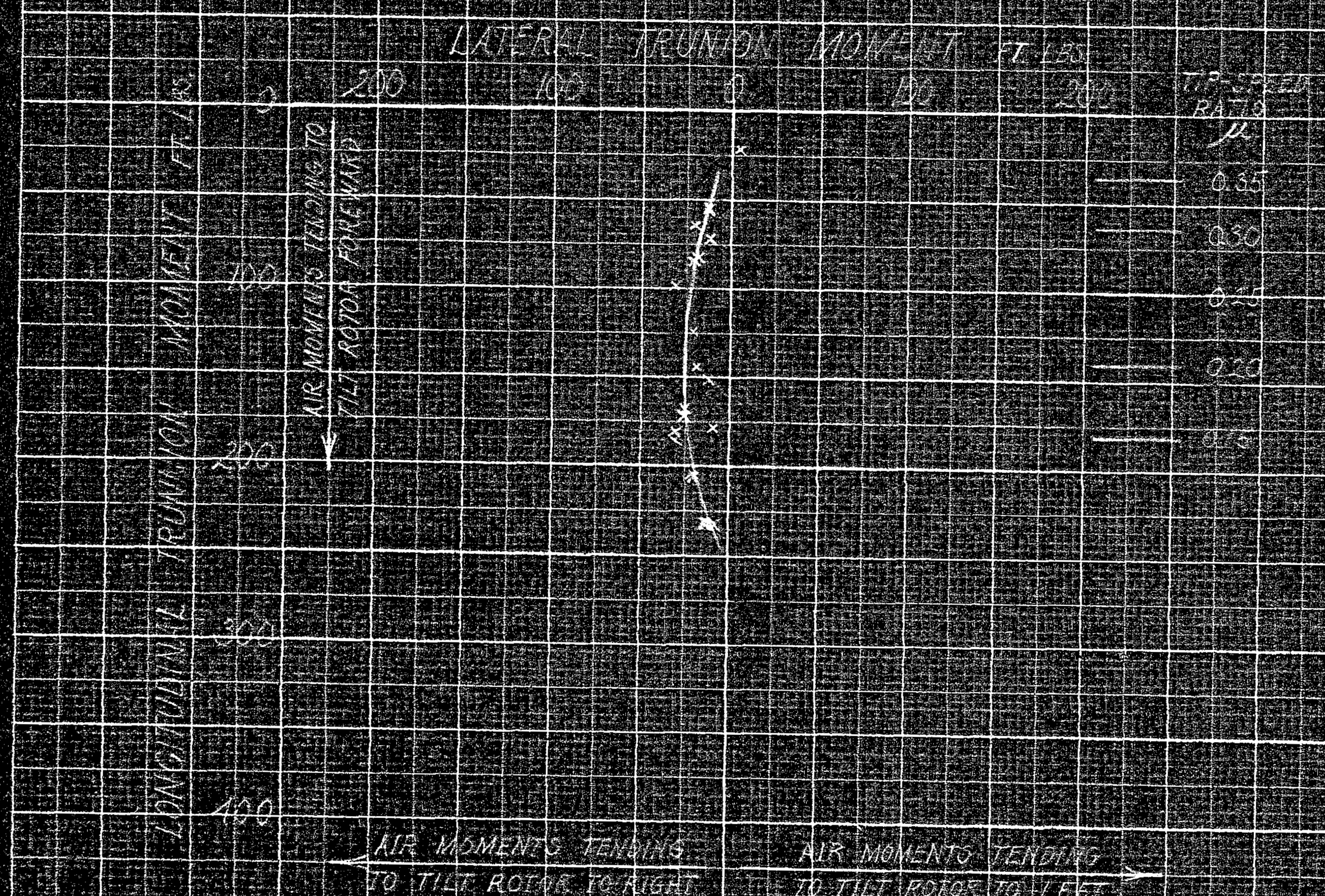

TRUNNION MOMENTS IN LEVEL FLIGHT
YG-1B AUTOGIRO WITH TAPERED BLADES

Fig. 1

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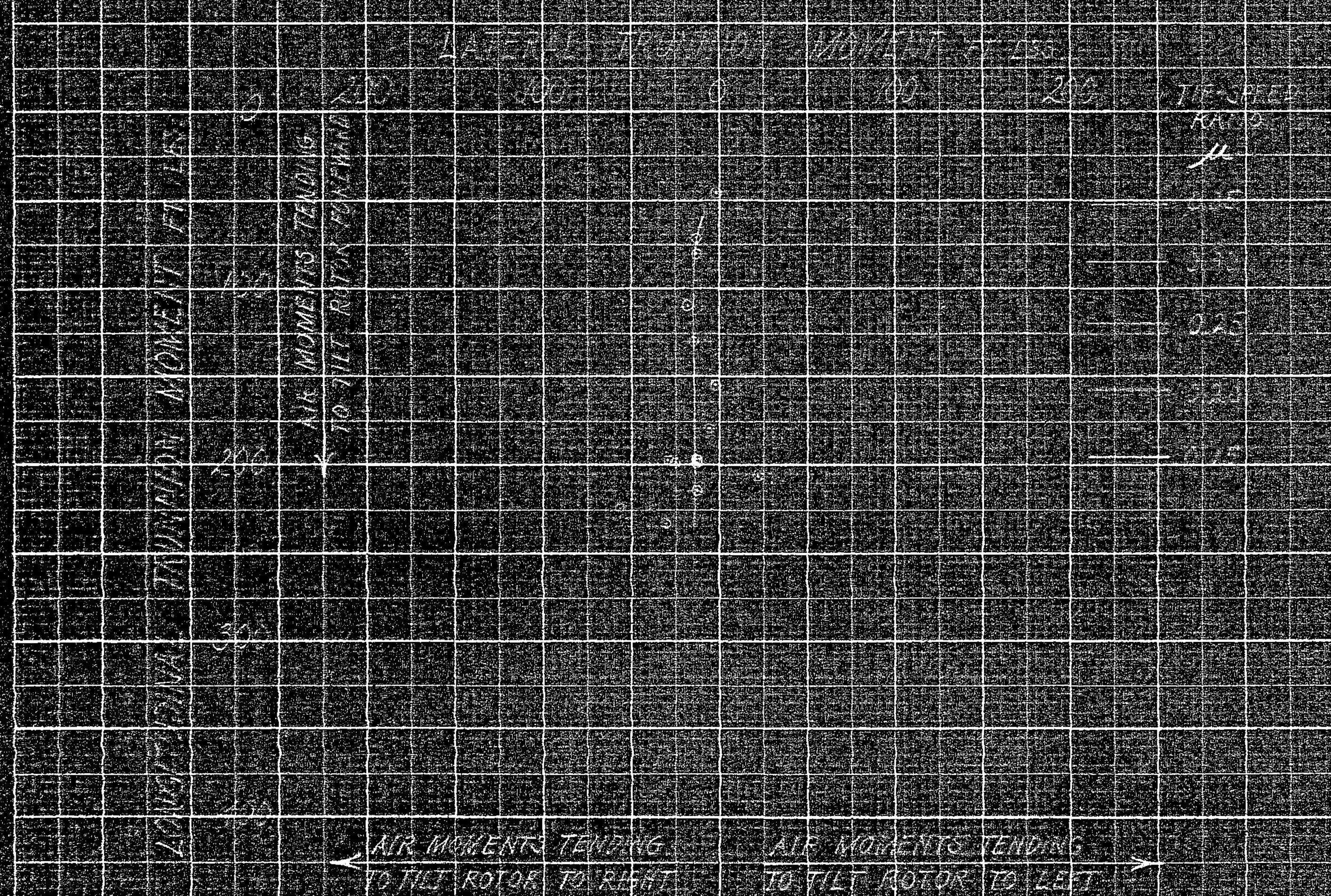

TRUNNION MOMENTS IN GLIDES
YG-1B AUTOGIRO WITH TAPERED BLADES

Fig.

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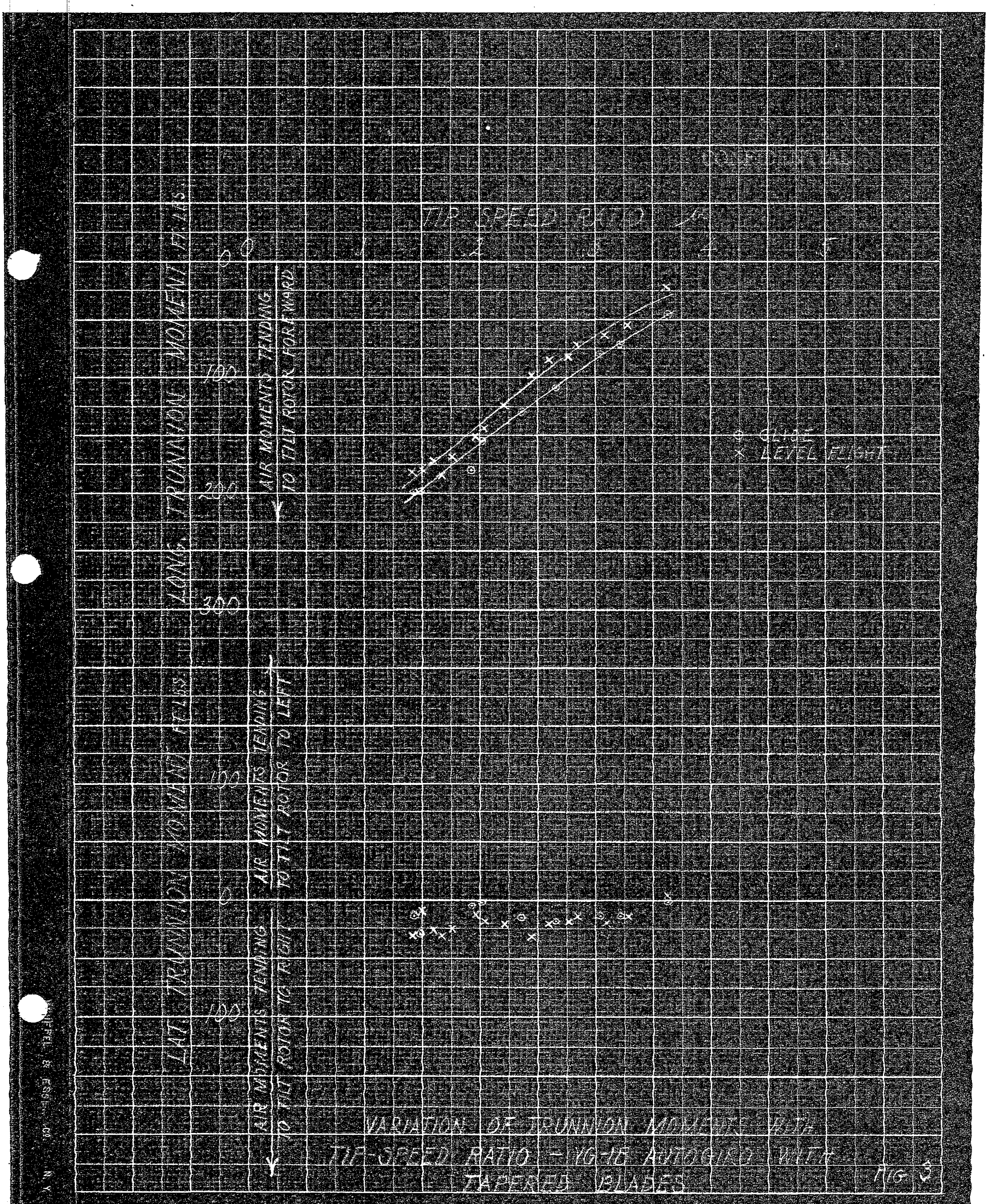

VARIATION OF TRUNNION MOMENTS WITH TIP-SPEED RATIO - YG-1B AUTOGIRO WITH TAPERED BLADES

FIG 3

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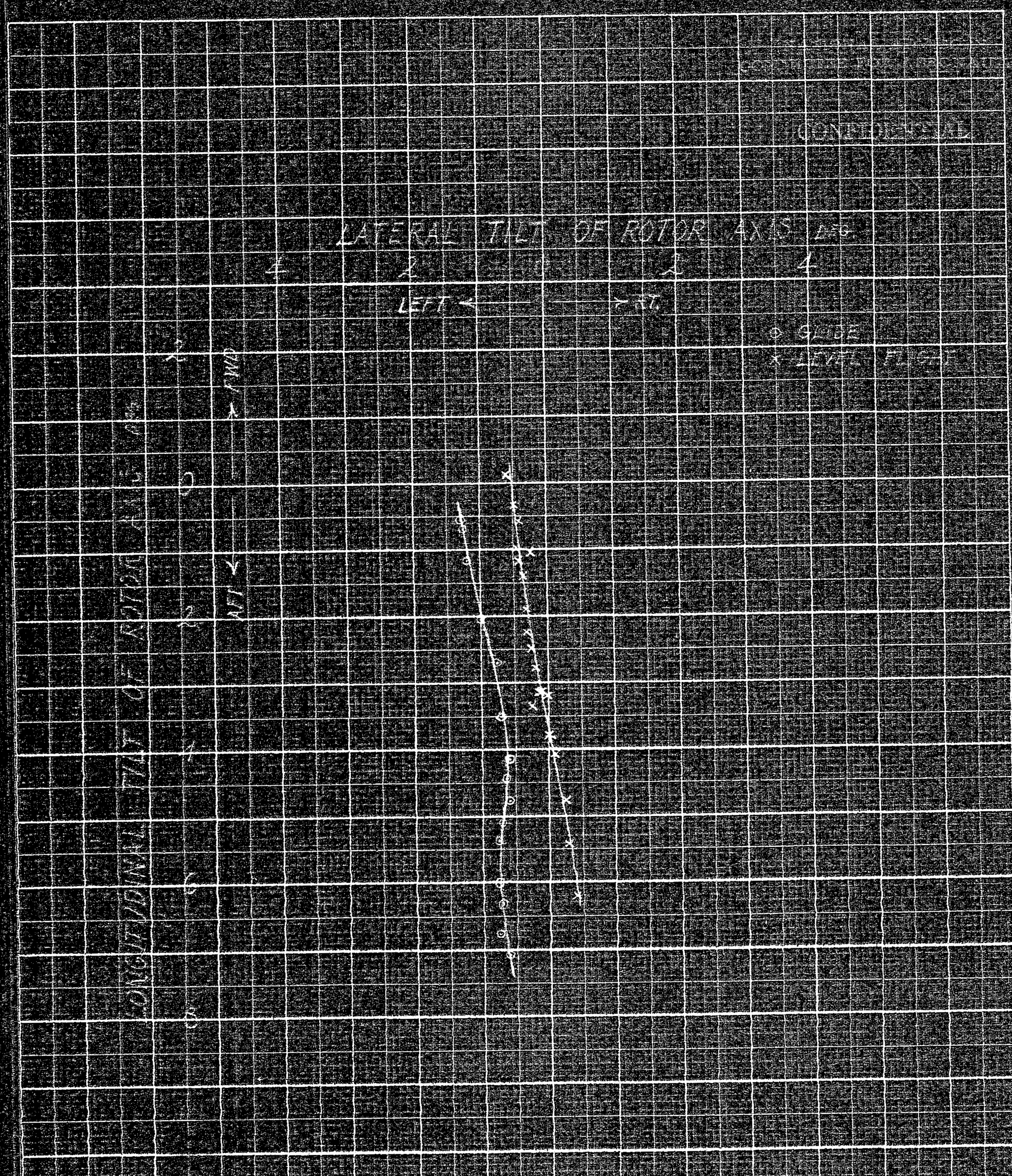

TILT OF ROTOR AXIS - YG-1B AUTOGIRO
WITH TAPERED BLADES

FIG. 4

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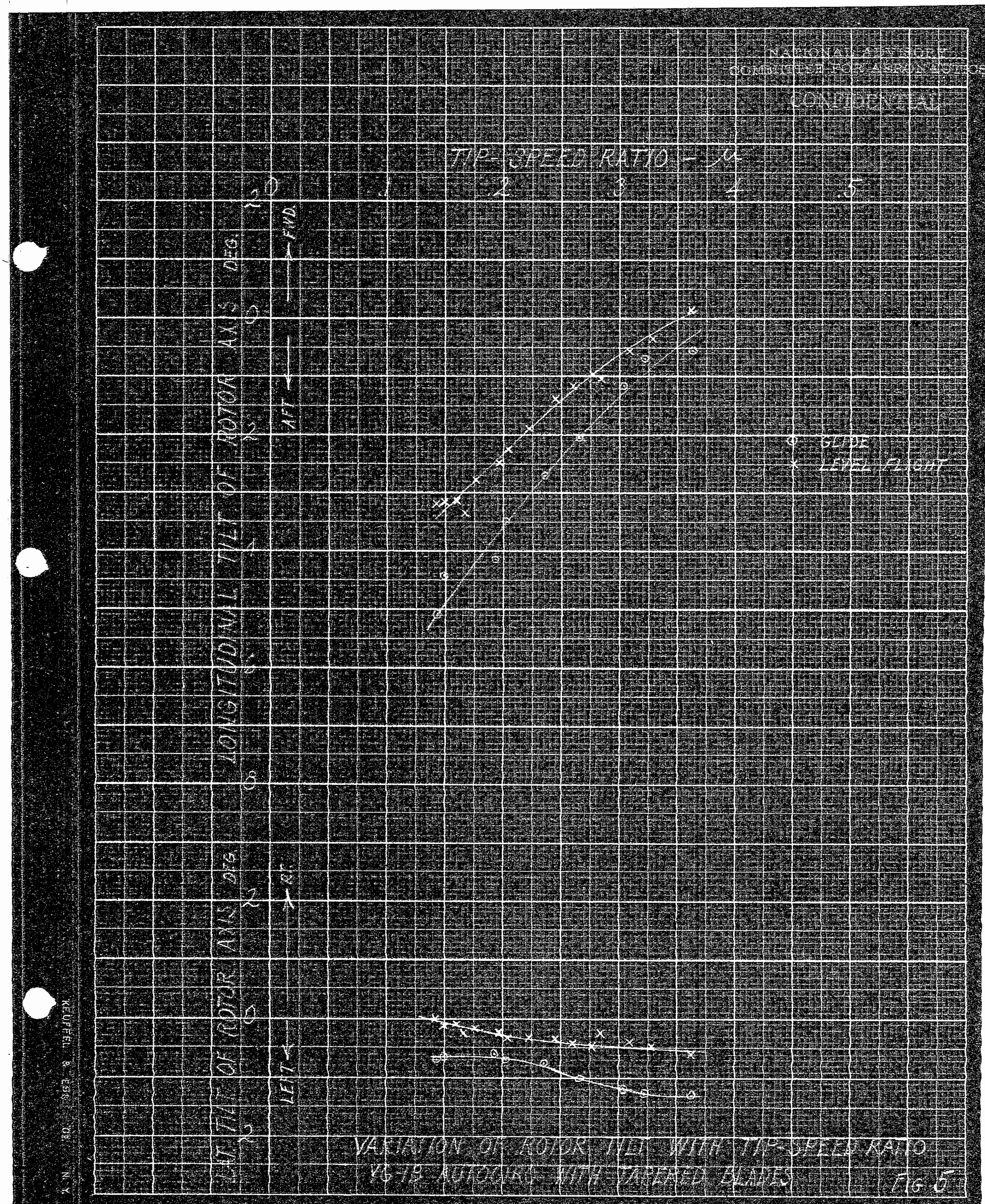

VARIATION OF ROTOR TILT WITH TIP-SPEED RATIO
YG-1B AUTOGIRO WITH TAPERED BLADES

FIG. 5