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Preliminary Measurements of the Aerodynamic Damping in Pitch of a 12 ft Diameter Helicopter Rotor

By

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LONDON: HIS MAJESTY'S STATIONERY OFFICE

1950

Price 1s. 0d. net.

C.P. No. 22

Technical Note No. Aero 2049

May, 1950

ROYAL AIRCRAFT ESTABLISHMENT

Preliminary Measurements of the Aerodynamic Damping in Pitch of a 12 ft diameter Helicopter Rotor

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SUMMARY

Brief measurements of the damping characteristics of a rotor in pitching oscillation were made, primarily to verify the simple technique proposed for a full research programme on this subject. The results obtained have not been fully analysed or compared with theory, but the technique employed appears to be satisfactory.

LIST OF CONTENTS

LIST OF TABLES

LIST OF ILLUSTRATIONS

1 Introduction

In continuation of the research programme on a 12 ft diameter helicopter rotor, the design and operation of which is described in Ref. 1, it was proposed to investigate the damping characteristics of the rotor in pitching oscillations. This note places on record the few preliminary measurements which were made, primarily to verify the technique. No analysis of the results or comparison with available theory has been made.

2 Description of Tests

The tests were carried out in the 24 ft wind tunnel during June and July, 1949. The 12 ft diameter rotor and driving motor have been fully described in Ref. 1. Principal data are given in Table 1 and Fig. 1 For most of the oscillation tests the rear sting was supported by a cable and coil spring attached to a point above the open test section of the tunnel A tensioning weight of 56 lb also hung from the rear sting, (See fig. 2a).

In order to investigate the effect of frequency ratio on the rotor damping, a few data were obtained with the modified rig shown in Fig. 2b, which had a natural period about four times greater.

The oscillations of the model were initiated by hand and then left to damp out. A ciné-camera, running at approximately 22 frames/sec., recorded the movements over a scale of a pointer attached to one of the cables, and a timing clock was placed in the field of view. Damping measurements were made over a range of rotor r.p.m. in still air, and at various tunnel speeds for a rotor speed of 600 r.p.m. The effect of inclining the rotor axis was also investigated. In order to show the degree of accuracy of the technique, repeat runs were made for several cases. Finally a rough check of rotor lag was made by aligning the ciné-camera in the plane of the rotor disk and recording the oscillations of the disk and the sting simultaneously, while maintaining approximately constant amplitude by hand.

3 Results

The film records have been reduced to plots of amplitude against time, from which have been obtained values of 'k', the damping coefficient in the amplitude equation:-

$$a_t = a_o e^{-kt}$$

A typical plot of amplitude against time is shown in Fig. 3. The damping coefficient k_R of the rotor alone was obtained by subtracting the damping coefficient with rotor stationary from the measured damping coefficient k for the whole rig. Table 2 gives the values of k & k_R found for various tunnel speeds, rotor speeds, and shaft inclinations. These results are plotted in Figs. 4 and 5. Fig. 6 records the result of the test on the lag of the rotor disk behind the sting and the shaft.

The apparently irregular effects of forward speed, as shown in Fig. 5, were unexpected and no explanation can be offered at present.

It will be seen in Table 2 that all but one of the repeat tests gave values of 'k' agreeing within 5% with the previous result. With rotor running and wind on, the period of oscillation decreases a few per cent, in accord with the degree of damping. Within the accuracy of these experiments it is not possible to compare these small variations with the theoretical values.

4 Conclusions

The simple technique employed proved adequate for the investigation of rotor damping characteristics in pitch over a wide range of conditions. The experimental data obtained were insufficient to justify detailed analysis.

LIST OF SYMBOLS

R	Radius of rotor
V	tunnel velocity (ft/sec.)
Ω	angular velocity of rotor (rads/sec.)
i_s	shaft inclination (degrees) positive when shaft is tilted forward.
μ_N	tip speed ratio $\frac{V}{\Omega R}$
a_t	amplitude of pitching oscillation at time 't'.
k	damping coefficient of whole system
k_R	damping coefficient of rotor

REFERENCES

No.	Author	Title, etc.
1	Squire, Fail and Eyre	Wind Tunnel Tests on a 12 ft Diameter Helicopter Rotor RAE Report No. Aero 2324, April, 1949 ARC 12,524 (To be published.)

Table I

Leading Particulars of Model Rotor

Diameter	12 ft
No. of blades	3
Blade chord	0.5 ft
Blade section	NACA 0012
Disk area	113.1 sq ft
Solidity	0.0796
Flapping hinge offset	0.1876 ft
Height of rotor centre above pitching axis	1.475 ft
Weight of each blade	10.52 lb
Distance of blade C.G. from flapping hinge	1.828 ft
Moment of inertia of blade about flapping hinge	2.25 slugs ft^2
Lock's inertia number (about flapping hinge)	3.52

Table II

Damping Coefficients

Rig A Period (rotor static) = 0.97 secs

θ_o	is	V ft/sec	RPM	μ_N	k_1	k_2 (check tests)	k_{Mean}	k_R
8°	0°	0	0	0	0.017	-	0.017	0
			200		0.038	-	0.038	0.021
			300		0.079	-	0.079	0.062
			400		0.149	-	0.149	0.132
			500		0.228	-	0.228	0.211
			600		0.326	-	0.326	0.309
8°	0°	12.8	600	0.034	0.445	-	0.445	0.428
		37.5		0.099	0.370	0.360	0.365	0.348
		58.3		0.155	0.433	-	0.433	0.416
		76.0		0.202	0.399	0.399	0.399	0.382
8°	15°	37.5	600	0.099	0.372	0.364	0.368	0.351
		76.0		0.202	0.342	0.344	0.343	0.326
		113.0		0.300	0.407	0.426	0.417	0.400
8°	30°	37.5	600	0.099	0.396	-	0.396	0.379
		76.0		0.202	0.417	-	0.417	0.400
4°	0°	37.5	600	0.099	0.386	-	0.386	0.369
		76.0		0.202	0.354	-	0.354	0.337
4°	15°	0	600	0	0.405	0.450	0.427	0.410
		37.5		0.099	0.370	0.386	0.378	0.361
		76.0		0.202	0.336	0.344	0.340	0.323
		95.0		0.252	0.342	0.354	0.348	0.331

Rig B Period (rotor static) = 4.00 secs

θ_o	is	V ft/sec	RPM	k	k_R
8°	0°	0	200	0.046	0.029
			300	0.071	0.054
			400	0.096	0.079
			500	0.132	0.115
			600	0.182	0.165

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FIG. 1

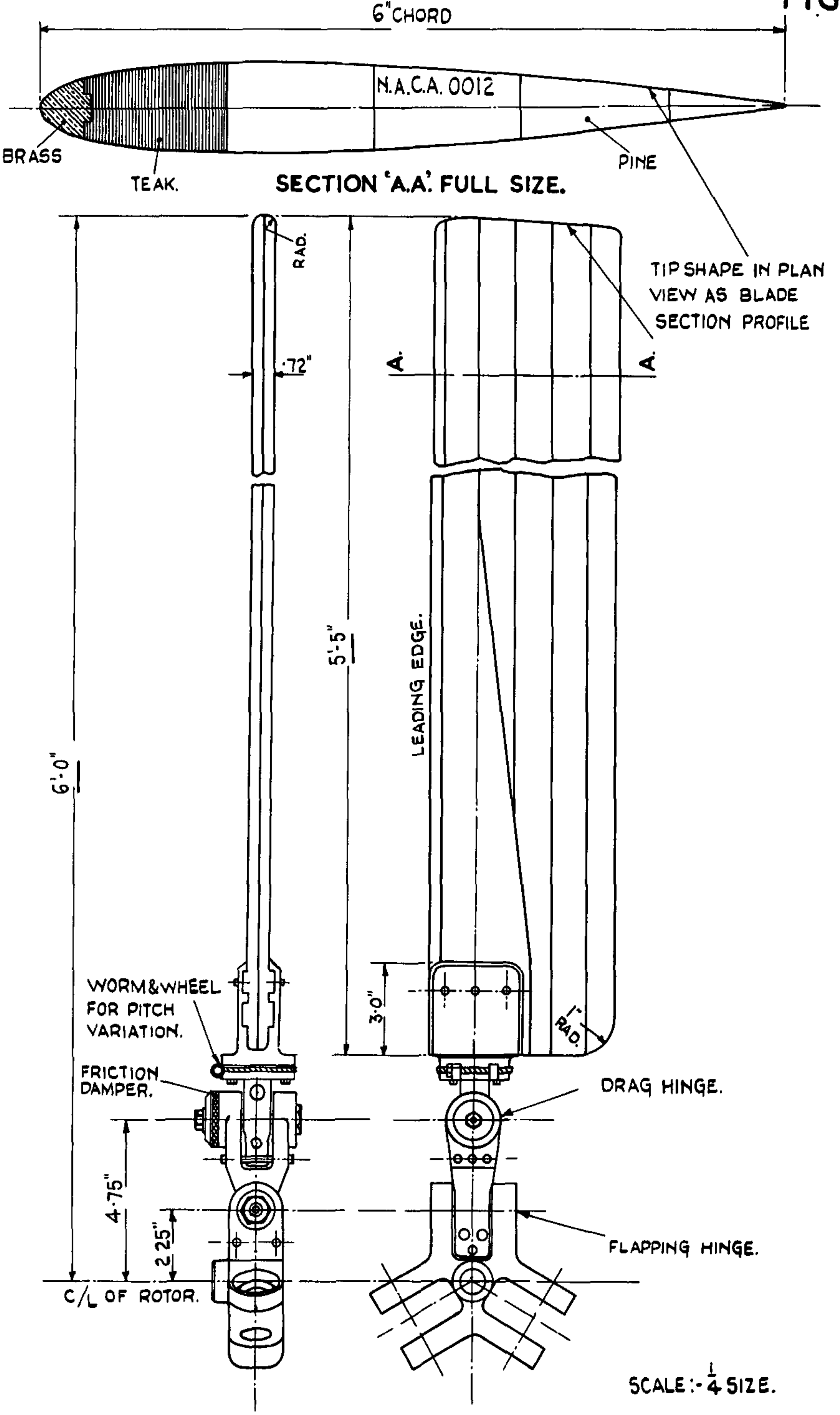
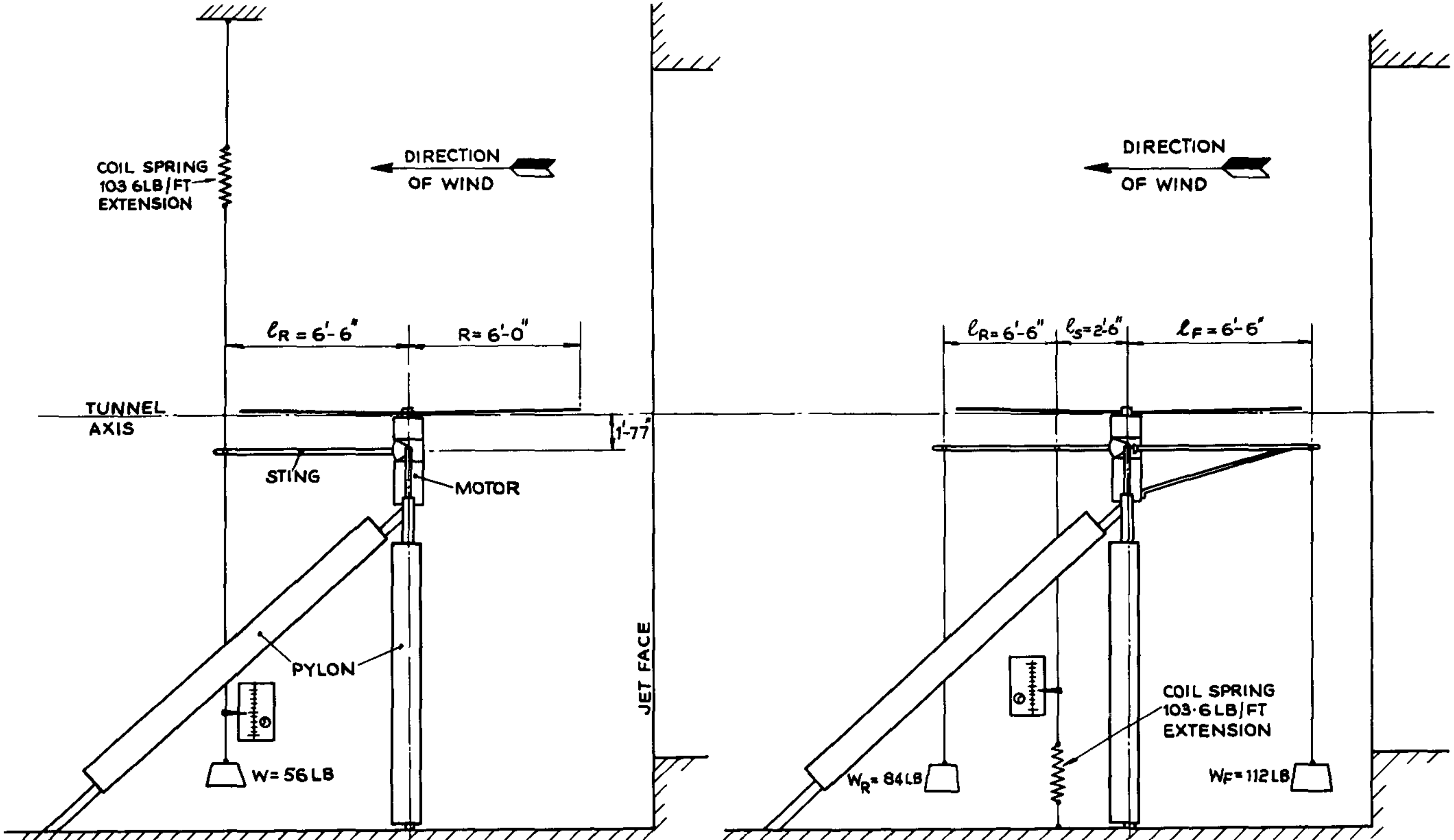


FIG. 1 DETAILS OF 12 FT. DIA. ROTOR.

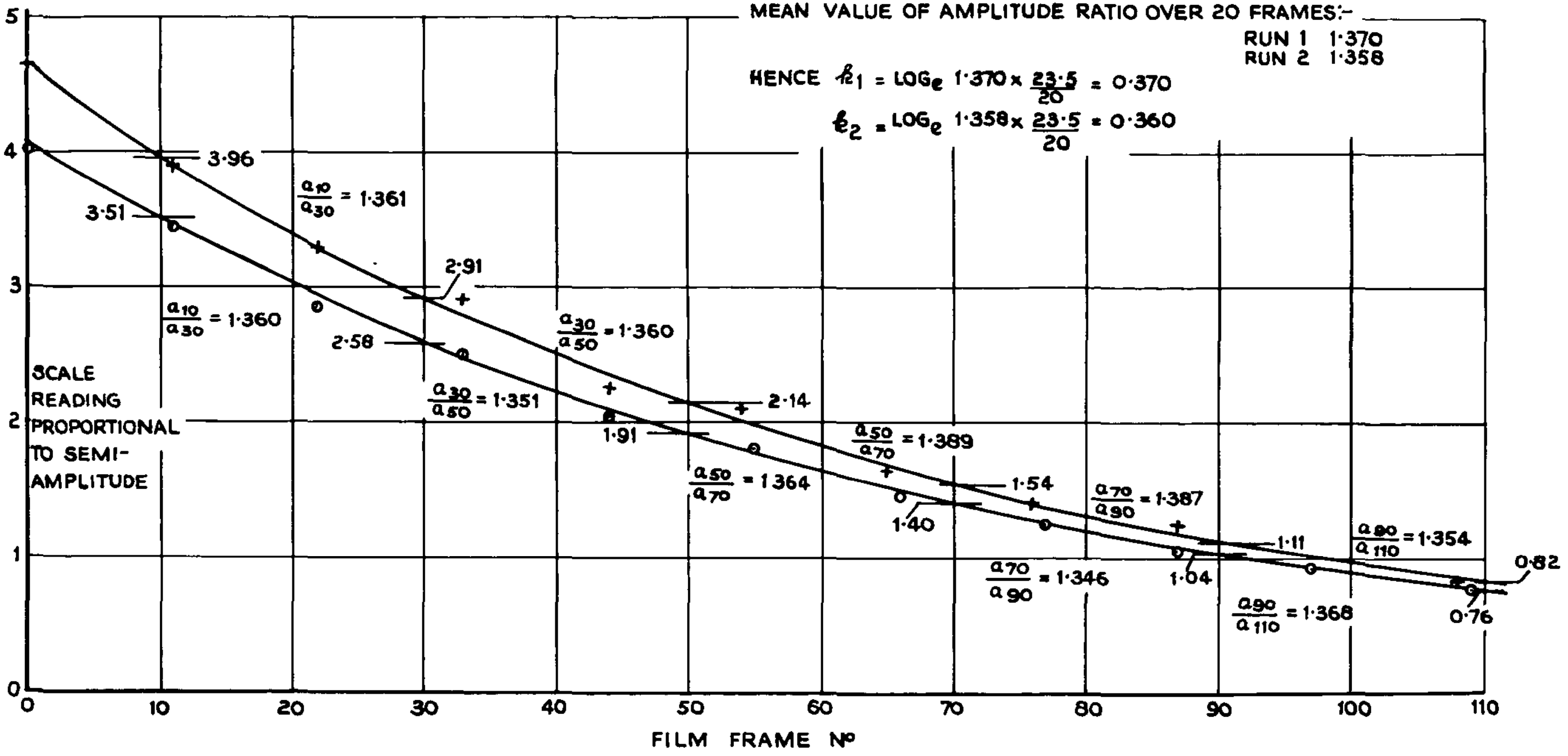
FIG.2 (a&b)



(a) RIG 'A' WITH NATURAL PERIOD OF 0·97 SECS.

(b) RIG 'B' WITH NATURAL PERIOD OF 4·00 SECS.

FIG.2 (a & b) GENERAL ARRANGEMENT OF 12 FT ROTOR IN 24 FT TUNNEL FOR DAMPING TESTS



$\theta_0 = 8°$ MEAN $i_S = 0°$ V = 37 5 FT/SEC RPM = 600 $\mu_N = 0\ 099$
FILM SPEED = 23·5 FRAMES/SEC.
MEAN VALUE OF AMPLITUDE RATIO OVER 20 FRAMES:–

RUN 1 1·370
RUN 2 1·358

HENCE $k_1 = \log_e 1{\cdot}370 \times \frac{23{\cdot}5}{20} = 0{\cdot}370$

$k_2 = \log_e 1{\cdot}358 \times \frac{23{\cdot}5}{20} = 0{\cdot}360$

FIG. 3 TYPICAL PLOT OF AMPLITUDE DECAY WITH TIME.

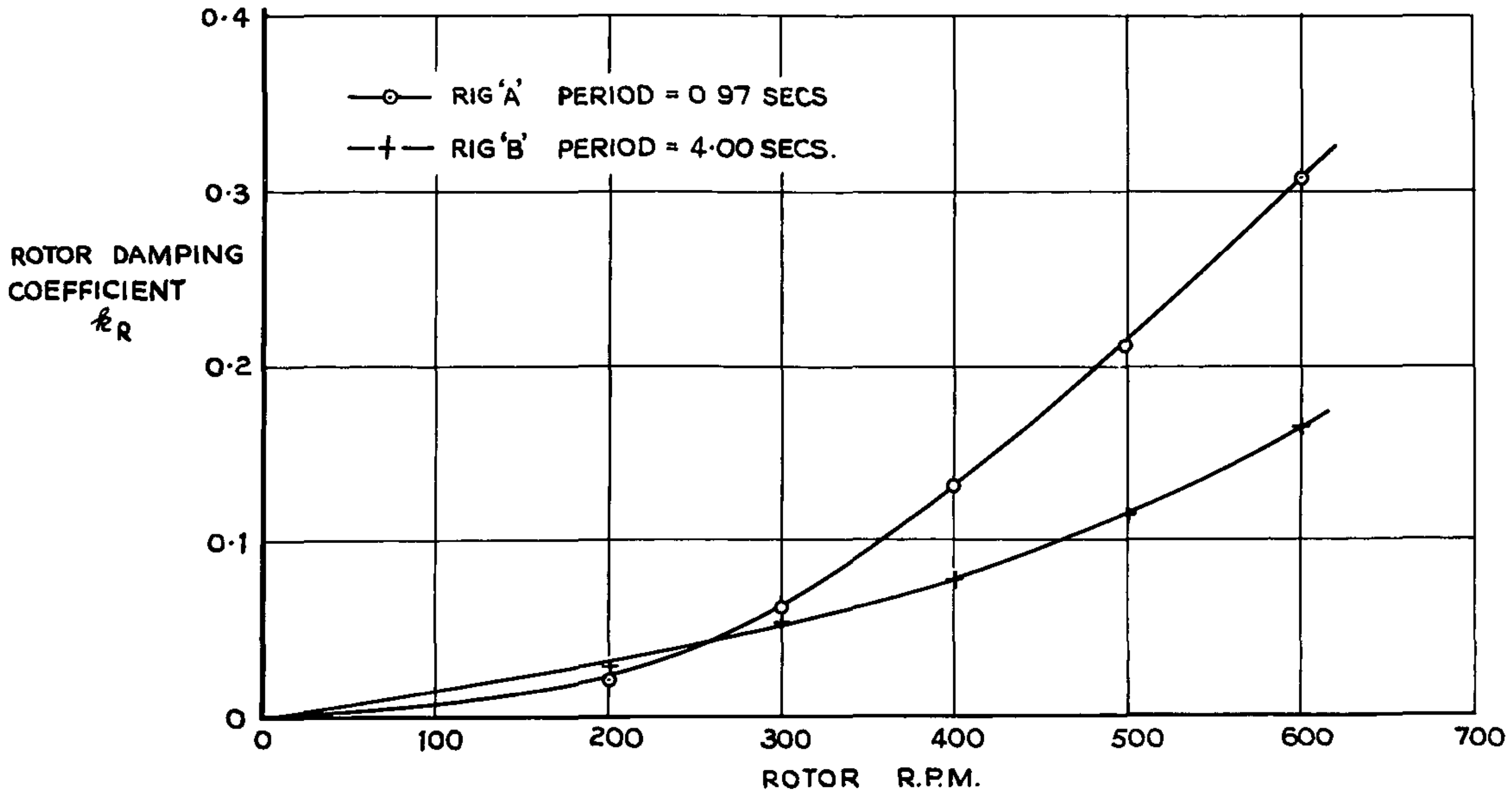


FIG.4 VARIATION OF ROTOR DAMPING WITH ROTOR SPEED ($\mu_N = 0$)

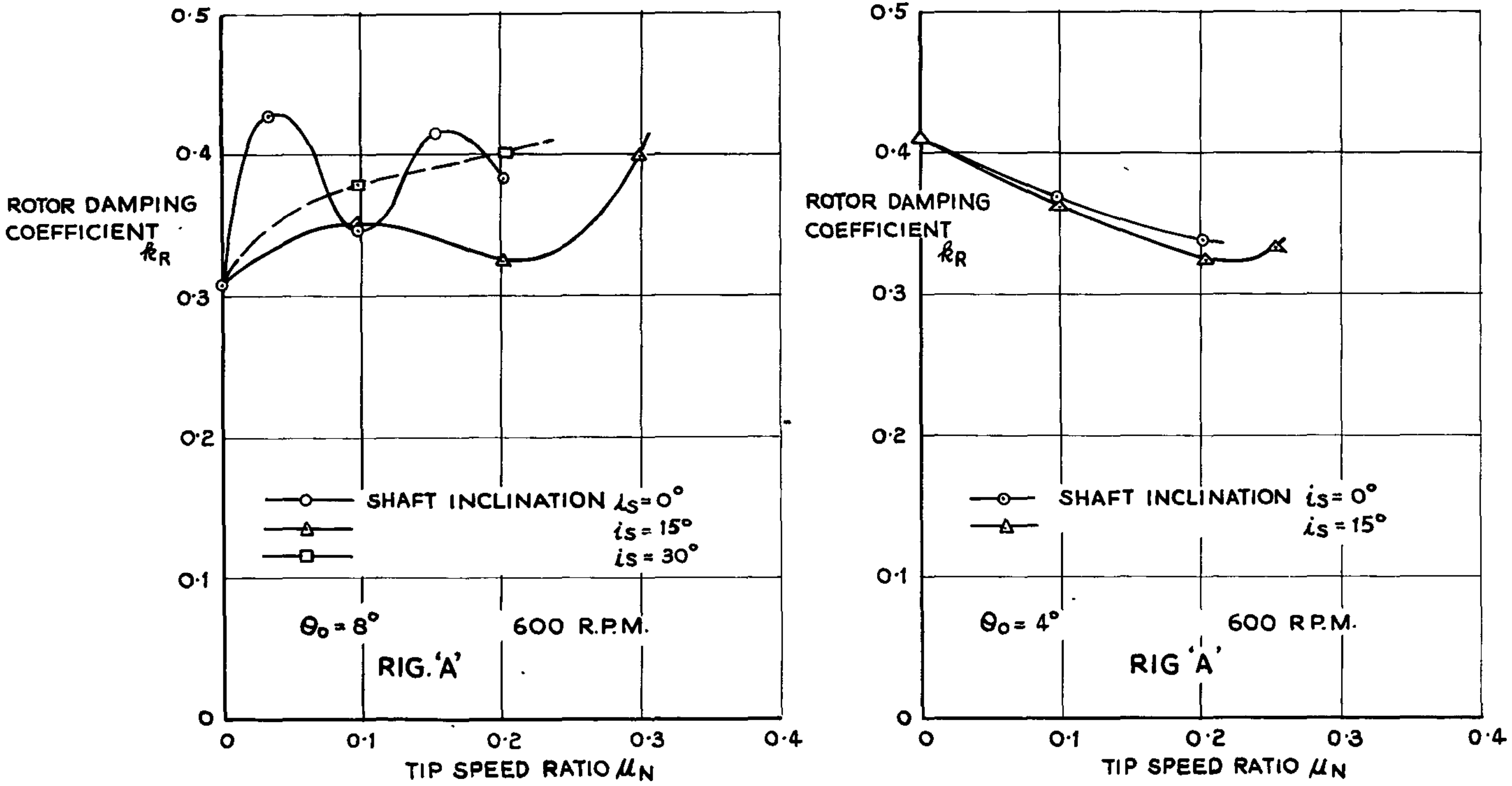
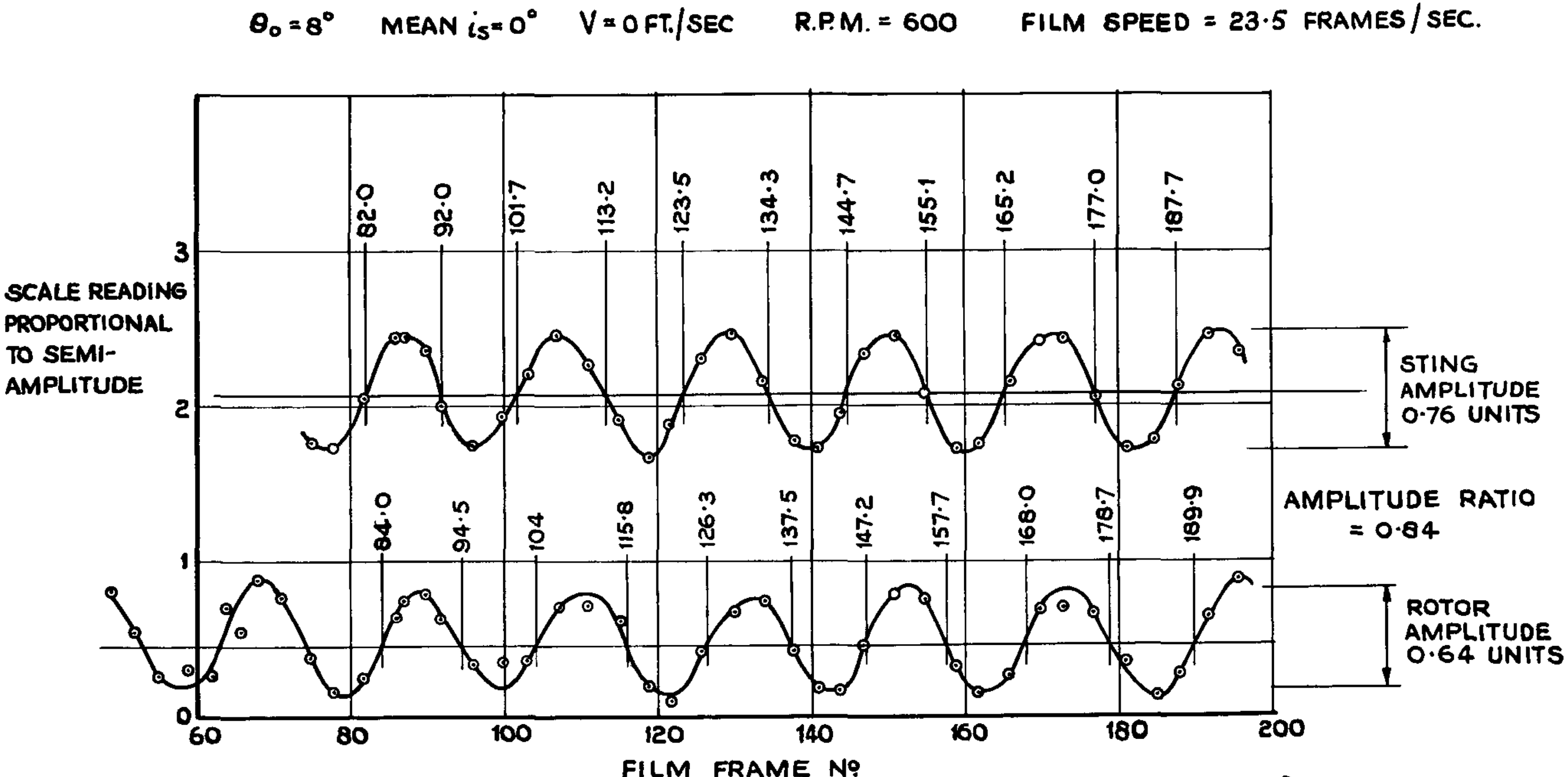


FIG.5 A

FIG.5B

FIG.5 a & 5 b VARIATION OF ROTOR DAMPING WITH TIP SPEED RATIO.

FIG.5a & b



AVERAGE LAG OF ROTOR RELATIVE TO STING = 2·47 FRAMES ≡ 0·105 SECS. ≡ 42° PHASE LAG.

FIG.6 PHASE LAG BETWEEN ROTOR & STING IN MAINTAINED PITCHING OSCILLATION.

C.P. No. 22
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A.R.C. Technical Report

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