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Wind Tunnel Tests on a Griffith Meteor Model (without suction)

By

D. A. Clarke, B.sc.(Eng.), A.C.G.I.

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Wind tunnel tests on a Griffith Meteor Model (without suction)

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D.A. Clarke, B.Sc. (Eng.) A.C.G.I.

SUMMARY

Tests were made on a $^1/_{7.5}$ scale model of the Meteor with Griffith wing without suction in the High Speed Wind Tunnel. Lift, pitching moment, rolling moment were measured at incidences up to the stall, at aileron angles up to 14°. A Reynolds number range of 1.2×10^6 to 4.6×10^6 was covered at Mach numbers not greater than 0.2.

The maximum lift coefficient was 1.08 at $R = 4.4 \times 10^6$. This is nearly 0.2 higher than the value measured on the Meteor I.[1] Aileron control was good, $\left(-\frac{\partial C_\ell}{\partial \xi}\right)_{C_L}$ being about 0.005 at low incidences and falling to about 0.004 at $C_L = 0.8$. No bad trim or stability changes were found.

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1 Introduction

The Griffith Meteor differs from the Meteor I in having suction on the wings outboard of the nacelles, the wing section of this part being of 16% Griffith section (Table II). Information was required on the control characteristics in the event of failure of the suction, and measurements of $C_{L_{max}}$ and aileron power were therefore made on a $^1/7.5$ scale model in the R.A.E. High Speed Tunnel in November 1945 and May 1946.

2 Details of tests

2.1 Model and Rig

The $^1/7.5$ scale wooden model was tested with W2B nacelles faired at entry and exit. It was supported by two struts just outboard of the nacelles and a rear strut which entered the fuselage from below. Neither bracing wires nor strut guards were used.

2.2 Range of tests

In the first tests lift and pitching moment were measured at incidences up to the stall, at low Mach numbers, at Reynolds numbers of 1.2×10^6, 2.5×10^6, 4.4×10^6. The model was tested in the following conditions:-

(a) Complete model, $\eta_T = -1^\circ$, $\eta = +1^\circ$

(b) Complete model, without tailplane.

Ailerons were fitted for the second tests and rolling moments were measured for the following cases:-

(c) Complete model, without tailplane, $\xi = 0^\circ$

(d) Complete model, without tailplane, $\xi = 5^\circ$

(e) Complete model, without tailplane, $\xi = 10^\circ$

(f) Complete model, without tailplane, $\xi = 14^\circ$.

2.3 Corrections

The usual corrections have been applied for strut interference. The struts came directly in front of the ailerons, but at low speeds strut interferences are known to be small so that their effect on rolling moment is probably negligible. Therefore no strut correction was applied to rolling moment.

The usual corrections for tunnel constraint were made to the incidence, pitching moment and speed, but the rolling moment was left uncorrected. This correction to rolling moment would probably amount to less than 3% in the worst case. Values of rolling moments have not been corrected for asymmetry in the model or tunnel flow.

Pitching moments were transferred from the strut centres to the Meteor I CG position at 0.310 $\bar{c}$.

In order to make these results directly comparable with those for the Meteor I, the values given in Reference 1 have been corrected for blockage[5], and strut interference by the present methods. This accounts for certain small discrepancies in the curves.

3 Results and Discussion

3.1 $C_{L_{max}}$

The Griffith Meteor has a $C_{L_{max}}$ of about 1.08 at $R = 4.4 \times 10^6$, as compared with 0.92 for the Meteor I. This difference may be attributed mainly to the greater thickness of the Griffith section. The Griffith Meteor nacelles were faired whereas those of the Meteor I were open, but this is expected to have little effect on the result. It may also be noted that the surface of the Griffith wing model was much smoother than that of the Meteor I.

3.2 $\frac{dC_L}{d\alpha}$

A change in the slope of the lift curve occurs at about $C_L = 0.6$ (Fig.3). This agrees with results obtained[3] at the N.P.L. on a 16% Griffith wing of infinite aspect ratio, at a Reynolds number of 0.47×10^6. The effect is not so noticeable in the present tests, as the section was conventional inboard of the nacelles. The reduction in slope can be seen from the following table:-

$R \times 10^{-6}$	$\left(\frac{dC_L}{d\alpha}\right)$ per degree	
	$C_L < 0.6$	$C_L > 0.6$
1.2	0.072	0.060
2.6	0.077	0.065
4.4	0.075	0.067

This effect is explained in Reference 2 as a forward movement of the transition point.

3.3 $\frac{dC_m}{dC_L}$

The pitching moment curves in Figs.5, 6, 7 show similar changes of slope at $C_L = 0.6$, both with and without the tailplane. Values for $R = 4.4 \times 10^6$ are summarised below:-

	$\left(\frac{dC_m}{dC_L}\right)$	
	$C_L < 0.6$	$C_L > 0.6$
With tailplane	$\bar{0}.055$	$\bar{0}.028$
Without tailplane	0.122	0.163
Difference	$\bar{0}.177$	$\bar{0}.191$

The increase in tailplane effectiveness is produced directly by the change in mainplane lift curve slope. Changes at $C_L = 0.6$ of $\left(\frac{\partial\varepsilon}{\partial\alpha}\right)$ are inappreciable as the tailplane is not behind the Griffith portion of the wing.

No serious trim or stability changes arise from these effects.

3.4 C_{M_0}

The value of C_{M_0} is between $\bar{0}.028$ and $\bar{0}.032$ (Figs.5,6,7) over the range of Reynolds numbers used, which is about the same as for the Meteor I.

3.5 Aileron power

Fig.8 gives the values of rolling moment for various aileron angles, for lift coefficients up to the stall, at the highest Reynolds number used. Table III gives the values for all Reynolds numbers. Fig.9 shows the aileron power for lift coefficients up to $C_L = 0.8$. The values are given as mean slopes for the range $\xi = 0^\circ$ to 14°, as the C_ℓ v. ξ curves were almost linear.

Up to $C_L = 0.3$, $-\left(\frac{\partial C_\ell}{\partial\xi}\right)_{C_L}$ increases slightly. This is followed by a reduction with increasing lift coefficient but even at $C_L = 0.8$, it has not fallen below 0.0038 per degree. The possibility of a reduction in aileron power at high C_L is referred to in Reference 2, but the measured effects are not large enough to be serious. From an examination of C_L values it appears that the aileron is equally effective up or down.

The aileron power was considerably greater than that of the Meteor I, for which the estimate of 0.0028 has been given[4].

4 Conclusions

Between $R = 1.2 \times 10^6$ and 4.6×10^6 the maximum lift coefficient and aileron power are greater with the Griffith wing than for the standard Meteor I.

Although the lift curve slope changes at $C_L = 0.6$ no serious stability or trim changes are produced.

LIST OF REFERENCES

No.	Author	Title, etc.
1	Mair, Hutton and Gamble	High speed wind tunnel tests on the Meteor I. R & M 2504. October, 1945.
2	Richards and Walker	13' x 9' wind tunnel tests on a Griffith aerofoil. Part IV. Lift, drag, pitching moments and velocity distributions. R & M 2148. March, 1944.
3	Burge	Lift and pitching moment on a model Griffiths aerofoil with flap. ARC.7178. Nov., 1943. (Unpublished)
4	Husk	Aileron performance tests carried out on Gloster F9/40 aircraft No. DG 208. ARC.8675. Feb., 1945. (Unpublished)
5	-	Addendum to R.A.E. Report No. Aero.1833. R.A.E. Report No. Aero.1833a. Dec., 1943. ARC.7679.

TABLE I

Model Particulars

Griffith Meteor ($^1/_{7.5}$ scale model)

	Full Scale	Model Scale
Wing		
Gross area	376.3 sq.ft.	6.69 sq.ft.
Span	43.1 ft.	5.750 ft.
Standard mean chord	8.73 ft.	1.16 ft.
Section inboard of nacelles	EC 1240/0640	
Section outboard of nacelles	Griffith 16% (t/c)	
Dihedral inboard of nacelles	+1°	
Dihedral outboard of nacelles	+6°	
Angle of chord to fuselage datum inboard of nacelles	+3° 50'	
Angle of chord to fuselage datum outboard of nacelles	+3° 28'	
Tail		
Tail volume coefficient	0.45	
Aileron		
Distance of hinge behind L.E.	0.745c	
Distance of hinge above chord line	0.009c	
Distance of gap behind L.E.	0.750c	
Area of one aileron behind hinge line	19.8 sq.ft.	0.35 sq.ft.
C.G. Position		
Height above wing root chord (Measured $\perp^{r}$ to W.R.C.)	1.03 ft.	0.14 ft.
Distance behind L.E. of W.R.C. (Measured // to W.R.C.)	3.66 ft.	0.49 ft.
Distance behind L.E. of mean chord	$0.310\bar{c}$	

METEOR I ($^1/_{7.5}$ scale model)

	Full Scale	Model Scale
Wing		
Gross area	374.6 sq.ft.	6.66 sq.ft.
Span	43.0 ft.	5.735 ft.
Standard mean chord	8.71 ft.	1.16 ft.
Section at tip	EC 1040/0640	
Angle of chord to fuselage datum	+3° 50'	

TABLE II

Details of Griffith Section

$\left(\frac{x}{c}\right)$	$\left(\frac{y_1}{c}\right)$	$\left(\frac{y_2}{c}\right)$
0.0050	0.01162	0.01006
0.0075	0.01436	0.01218
0.0125	0.01877	0.01543
0.0250	0.02703	0.02117
0.0500	0.03887	0.02881
0.0750	0.04791	0.03431
0.1000	0.05541	0.03872
0.1500	0.06750	0.04557
0.2000	0.07692	0.05076
0.2500	0.08433	0.05477
0.3000	0.09005	0.05781
0.3500	0.09424	0.06000
0.4000	0.09693	0.06135
0.4500	0.09811	0.06185
0.5000	0.09768	0.06143
0.5500	0.09546	0.06000
0.6000	0.09111	0.05734
0.6500	0.08427	0.05310
0.7000	0.07305	0.04653
0.7100	0.07012	0.04478
0.7200	0.06631	0.04282
0.7300	0.06301	0.04057
0.7400	0.05846	0.03788
0.7450	0.05569	0.03624
0.7500	0.05132	0.03402
0.7550	0.04816	0.03180
0.7600	0.04568	0.03016
0.7700	0.04080	0.02745
0.7800	0.03696	0.02517
0.7900	0.03361	0.02316
0.8000	0.03060	0.02135
0.8200	0.02538	0.01820
0.8500	0.01900	0.01427
0.8800	0.01387	0.01103
0.9000	0.01099	0.00915
0.9200	0.00846	0.00743
0.9300	0.00732	0.00662
0.9500	0.00524	0.00508
0.9750	0.00295	0.00316

(See Fig. 2)

TABLE III

Values of Rolling Moment

(Both Ailerons)

	$\xi = \pm 0.1^\circ$		$\xi = \pm 4.9^\circ$		$\xi = \pm 9.8^\circ$		$\xi = \pm 14.1^\circ$	
	C_L	C_ℓ	C_L	C_ℓ	C_L	C_ℓ	C_L	C_ℓ
$R=4.6\times10^6$ $M=0.15$	-0.094	0.0048	-0.089	0.0299	-0.084	0.0519	-0.083	0.0743
	0.133	0.0038	0.129	0.0303	0.144	0.0518	0.135	0.0745
	0.368	0.0022	0.370	0.0289	0.364	0.0510	0.339	0.0725
	0.583	0.0026	0.578	0.0251	0.567	0.0440	0.543	0.0623
	0.778	0.0029	0.778	0.0231	0.773	0.0410	0.750	0.0592
	0.910	0.0027	0.914	0.0234	0.911	0.0402	0.886	0.0575
	0.974	0.0021	0.977	0.0230	0.971	0.0392	0.951	0.0561
	1.031	0.0019	1.033	0.0227	1.026	0.0387	1.022	0.0551
	1.052	0.0012	1.059	0.0202	1.056	0.0374	1.037	0.0522
	1.039	0.0035	1.044	0.0232	1.041	0.0379	1.018	0.0563
$R=3.8\times10^6$ $M=0.20$	-0.089	0.0037	-0.093	0.0298	-0.085	0.0511	-0.077	0.0695
	0.135	0.0034	0.140	0.0290	0.144	0.0550	0.138	0.0752
	0.364	0.0026	0.372	0.0300	0.367	0.0537	0.350	0.0743
	0.580	0.0039	0.583	0.0257	0.564	0.0449	0.540	0.0618
	0.773	0.0029	0.775	0.0238	0.767	0.0418	0.749	0.0584
	0.905	0.0035	0.906	0.0232	0.901	0.0404	0.882	0.0559
	0.962	0.0020	0.964	0.0221	0.958	0.0394	0.941	0.0557
	1.014	0.0024	1.014	0.0219	1.008	0.0390	0.965	0.0546
	1.013	0.0016	1.024	0.0209	1.015	0.0371	0.994	0.0538
	1.012	0.0025	1.012	0.0218	1.019	0.0232	0.987	0.0536
$R=2.9\times10^6$ $M=0.15$	-0.089	0.0042	-0.091	0.0292	-0.086	0.0516	-0.073	0.0694
	0.318	0.0043	0.139	0.0304	0.133	0.0543	0.134	0.0764
	0.367	0.0033	0.362	0.0308	0.366	0.0531	0.356	0.0771
	0.578	0.0034	0.565	0.0265	0.557	0.0451	0.539	0.0641
	0.719	0.0034	0.765	0.0237	0.764	0.0406	0.741	0.0596
	0.897	0.0038	0.899	0.0248	0.891	0.0403	0.872	0.0572
	0.972	0.0036	0.956	0.0239	0.948	0.0406	0.927	0.0555
	1.012	0.0031	1.011	0.0226	1.000	0.0390	0.984	0.0512
	1.022	0.0020	1.025	0.0204	1.016	0.0360	1.002	0.0615
	1.010	0.0036	1.009	0.0177	1.006	0.0342	0.984	0.0508
$R=1.2\times10^6$ $M=0.15$	-0.092	0.0051	-0.082	0.0289	-0.079	0.0476	-0.082	0.0624
	0.124	0.0053	0.133	0.0307	0.131	0.0512	0.124	0.0688
	0.351	0.0053	0.357	0.0308	0.357	0.0541	0.355	0.0703
	0.564	0.0034	0.563	0.0281	0.544	0.0486	0.533	0.0636
	0.735	0.0032	0.743	0.0253	0.736	0.0426	0.727	0.0562
	0.852	0.0050	0.855	0.0241	0.852	0.0400	0.840	0.0542
	0.894	0.0039	0.884	0.0217	0.879	0.0384	0.860	0.0525
	0.852	-0.0008	0.886	0.0180	0.890	0.0338	0.875	0.0495
	0.830	0.0022	0.836	0.0220	0.842	0.0367	0.829	0.0510
	0.846	0.0027	0.857	0.0206	0.852	0.0371	0.844	0.0515

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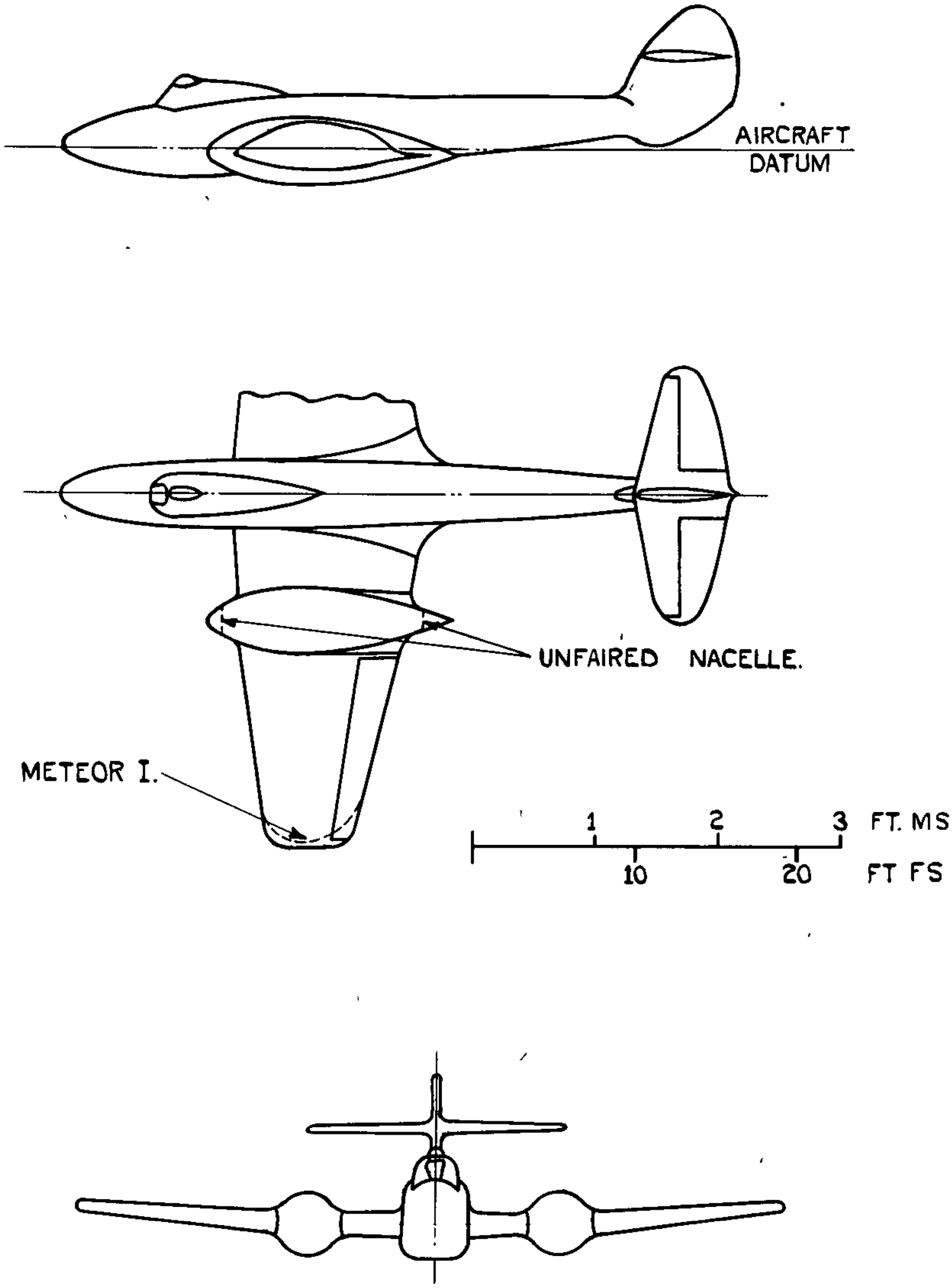
FIG. 1.



GRIFFITH METEOR

G.A. OF MODEL.

FIG. 2 (a) & 2 (b).

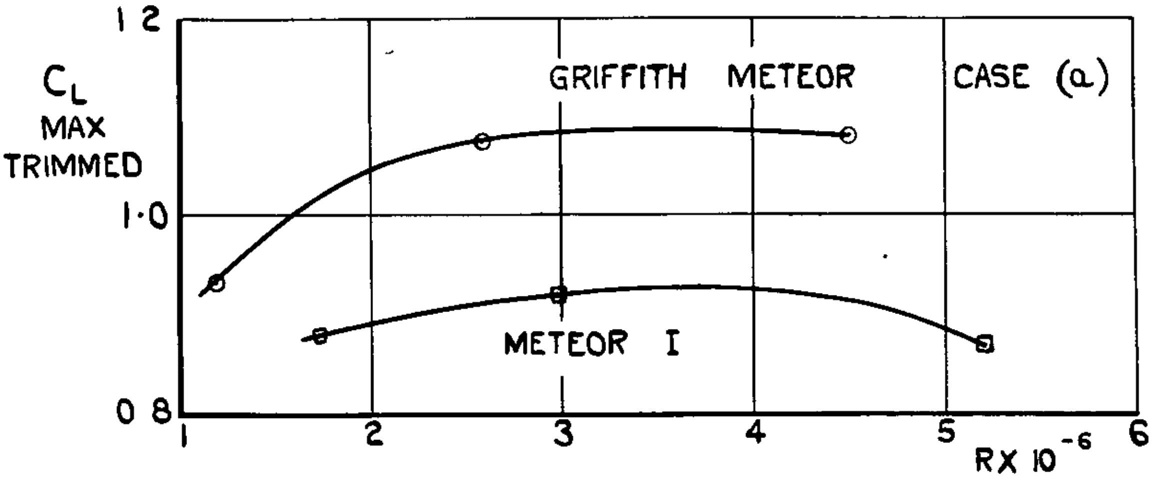


FIG. 2 (a) EFFECT OF REYNOLDS NUMBER ON MAXIMUM LIFT COEFFICIENT.

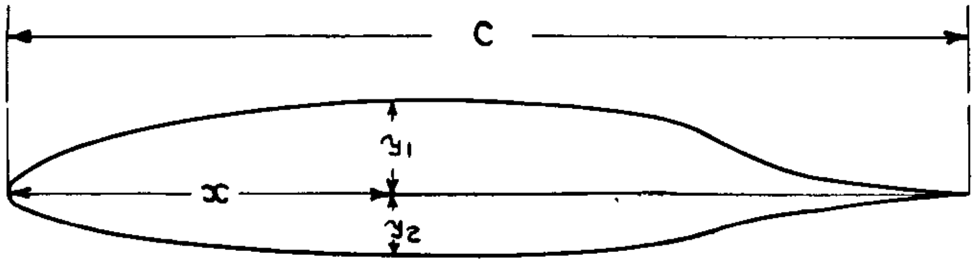
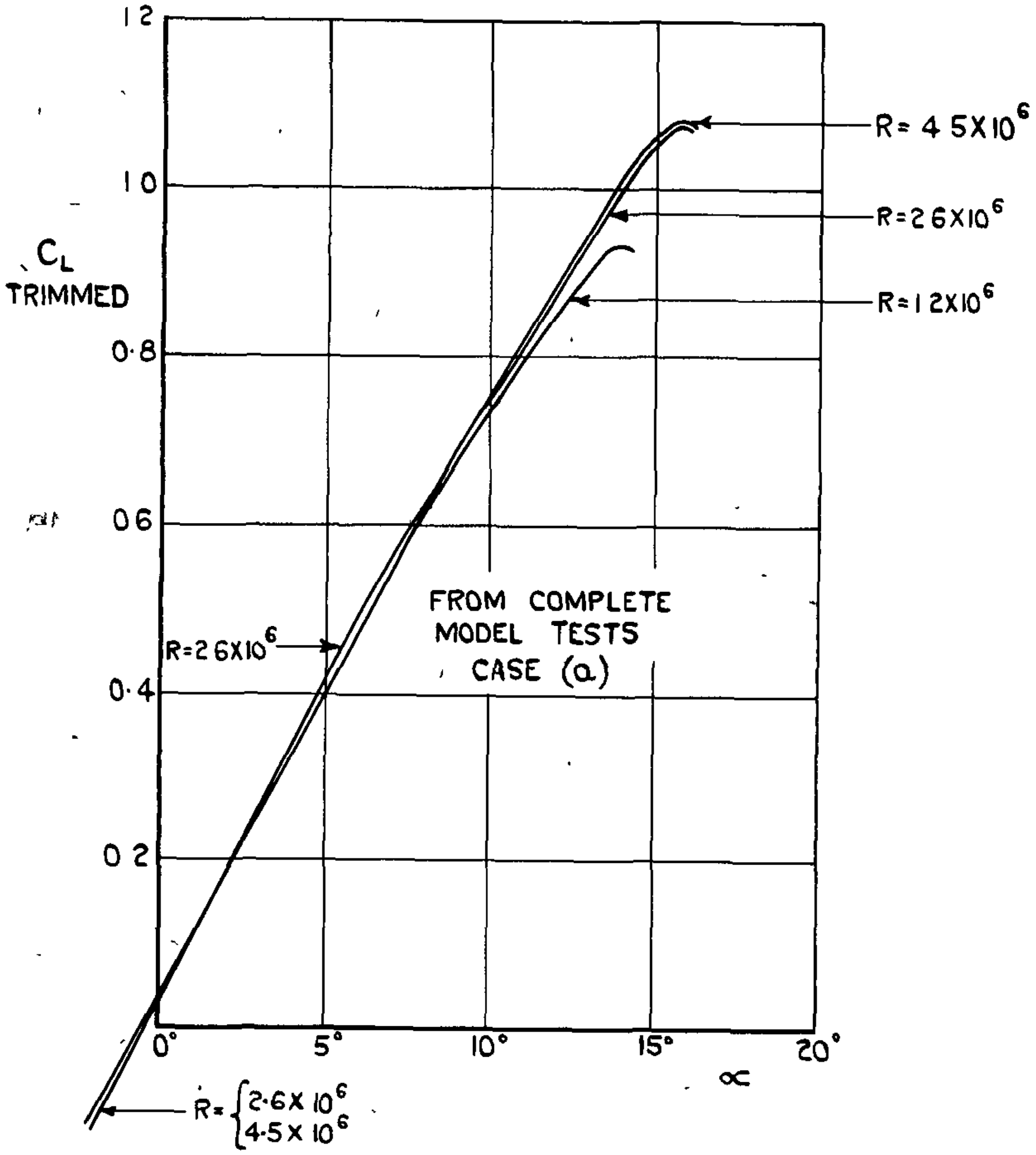


FIG. 2 (b) GRIFFITH SECTION.

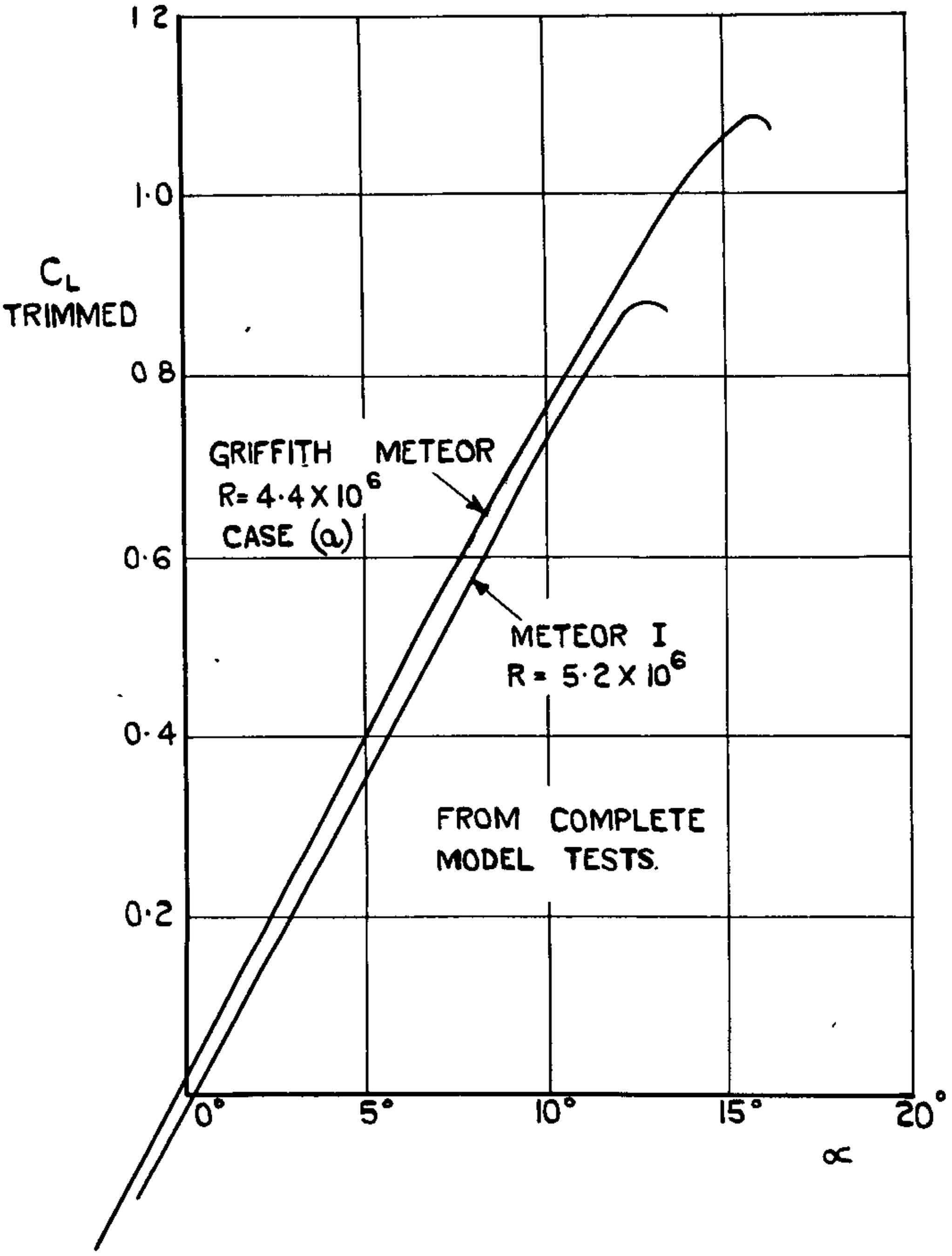
MAX. $\left(\frac{t}{c}\right)$ = 0·16 AT 0·45 C.

FIG. 3.



EFFECT OF REYNOLDS NUMBER ON LIFT. GRIFFITH METEOR.

FIG. 4.



COMPARISON OF LIFT CURVES OF GRIFFITH METEOR AND METEOR I.

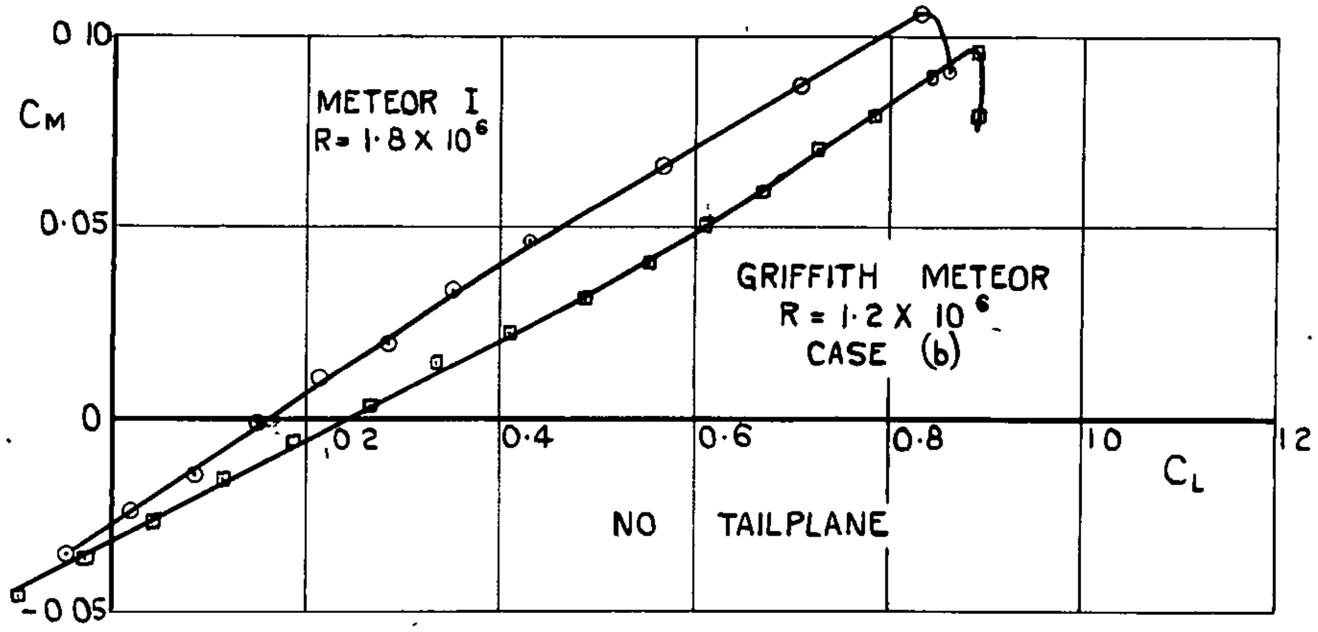


FIG. 5(a).

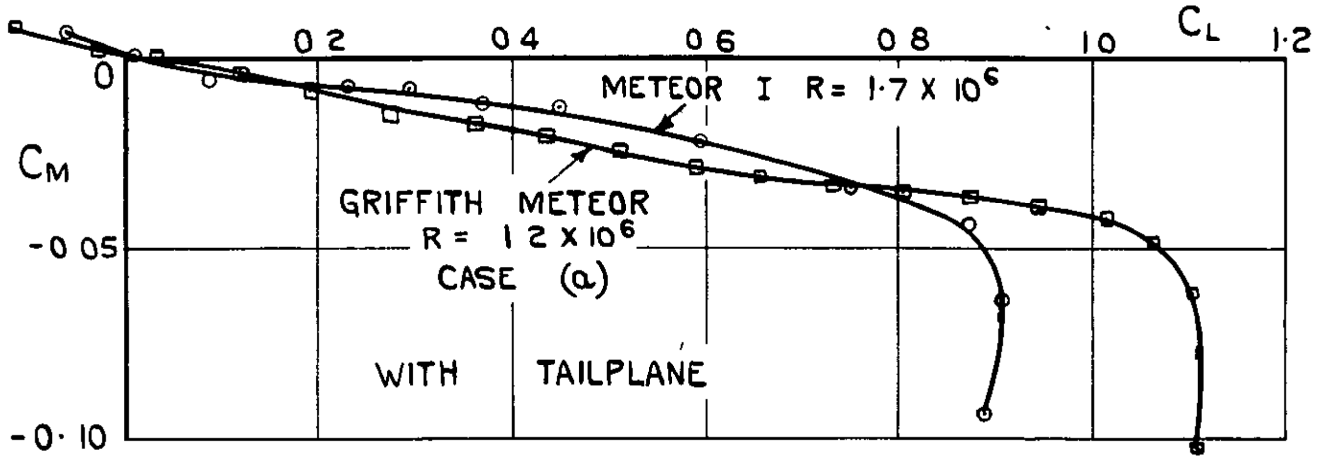


FIG. 5(b).

COMPARISON OF PITCHING MOMENTS ON GRIFFITH METEOR AND METEOR I.

FIG. 6(a) & 6(b).

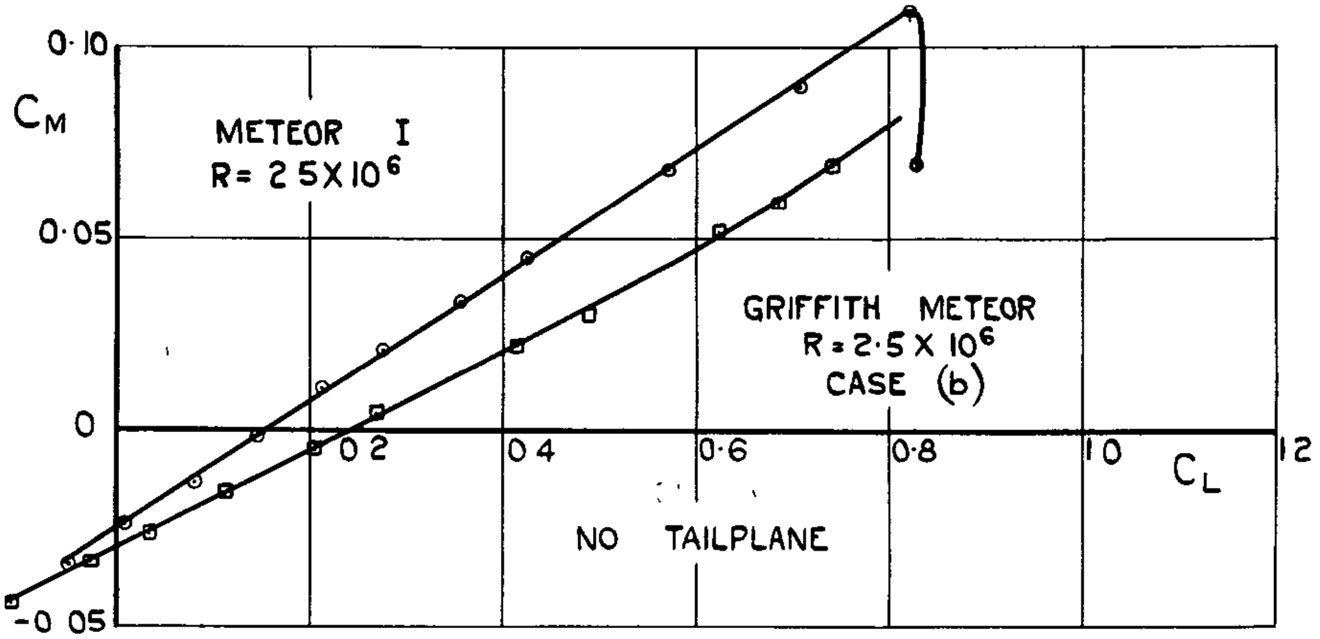


FIG. 6(a).

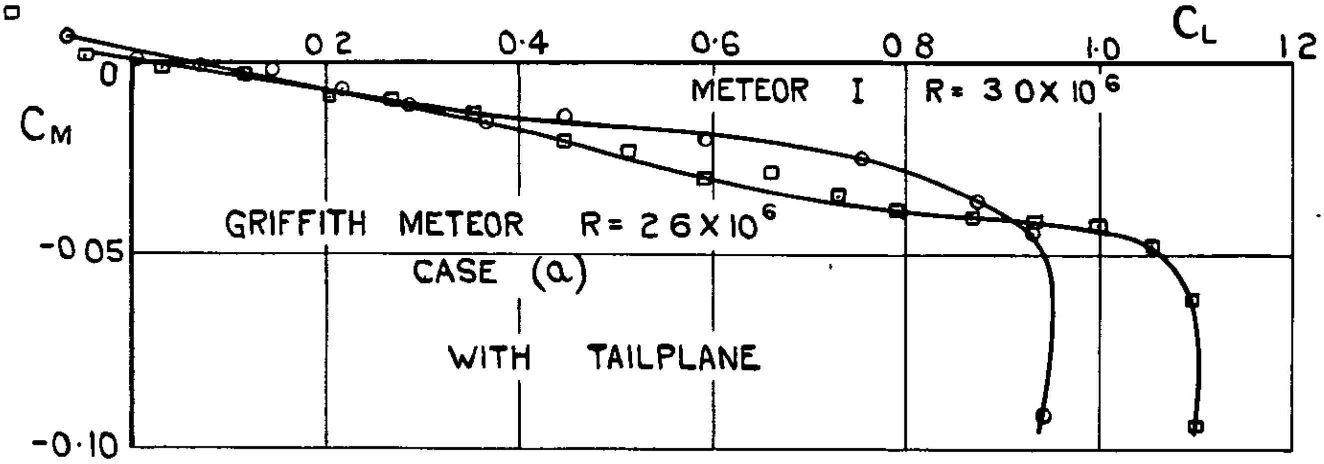


FIG. 6(b).

COMPARISON OF PITCHING MOMENTS ON GRIFFITH METEOR AND METEOR I.

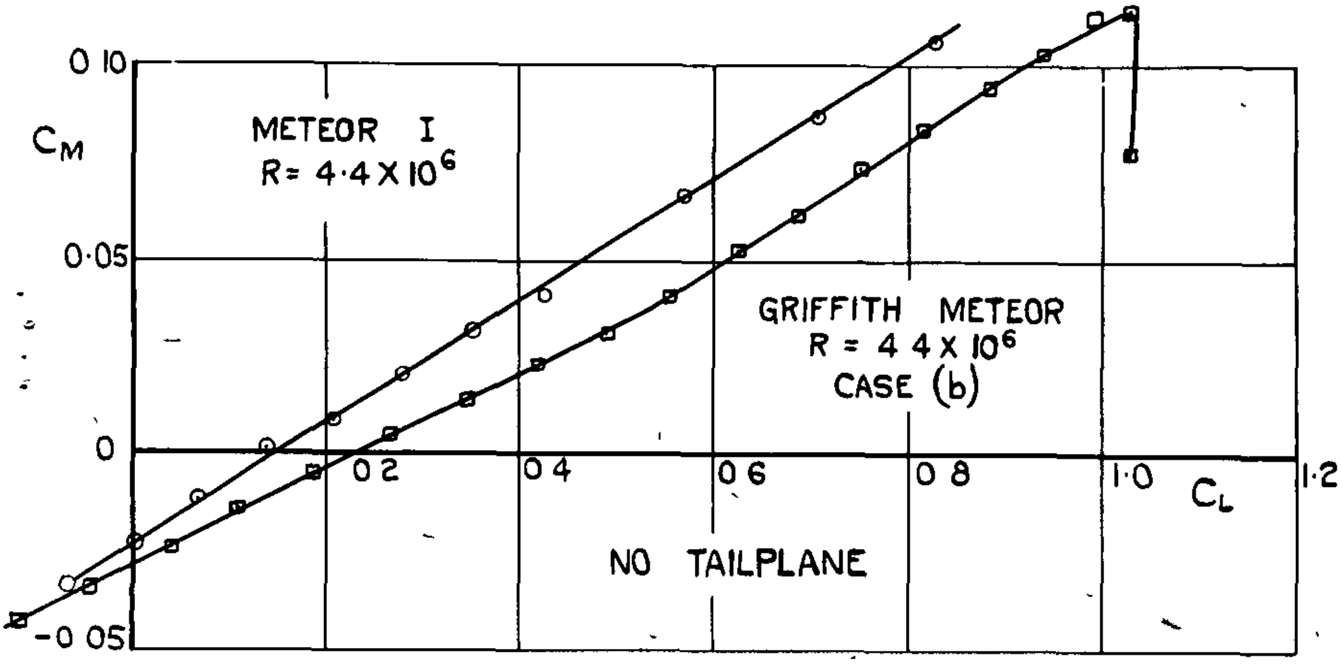


FIG. 7(a).

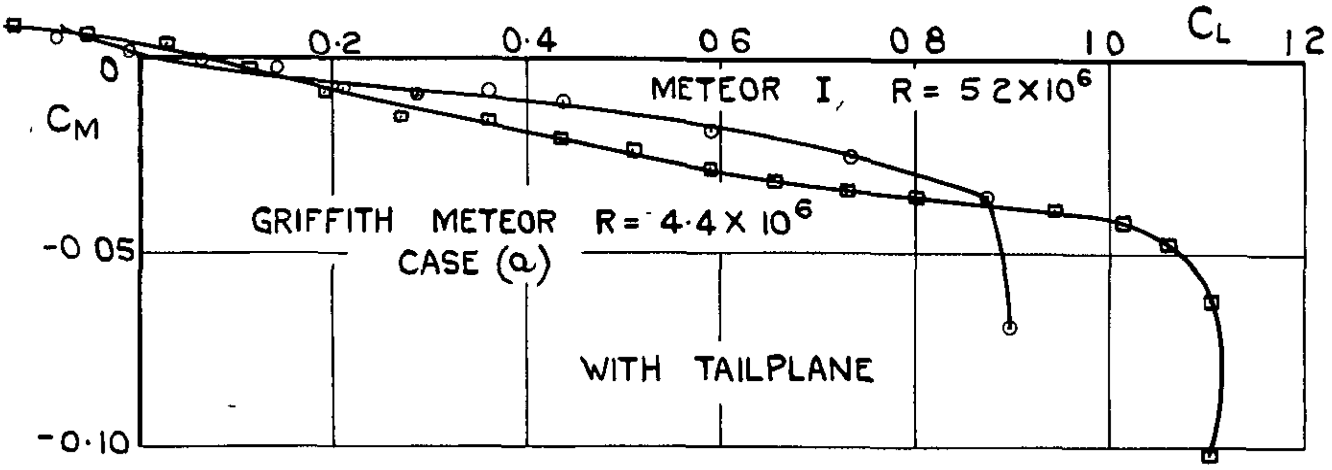
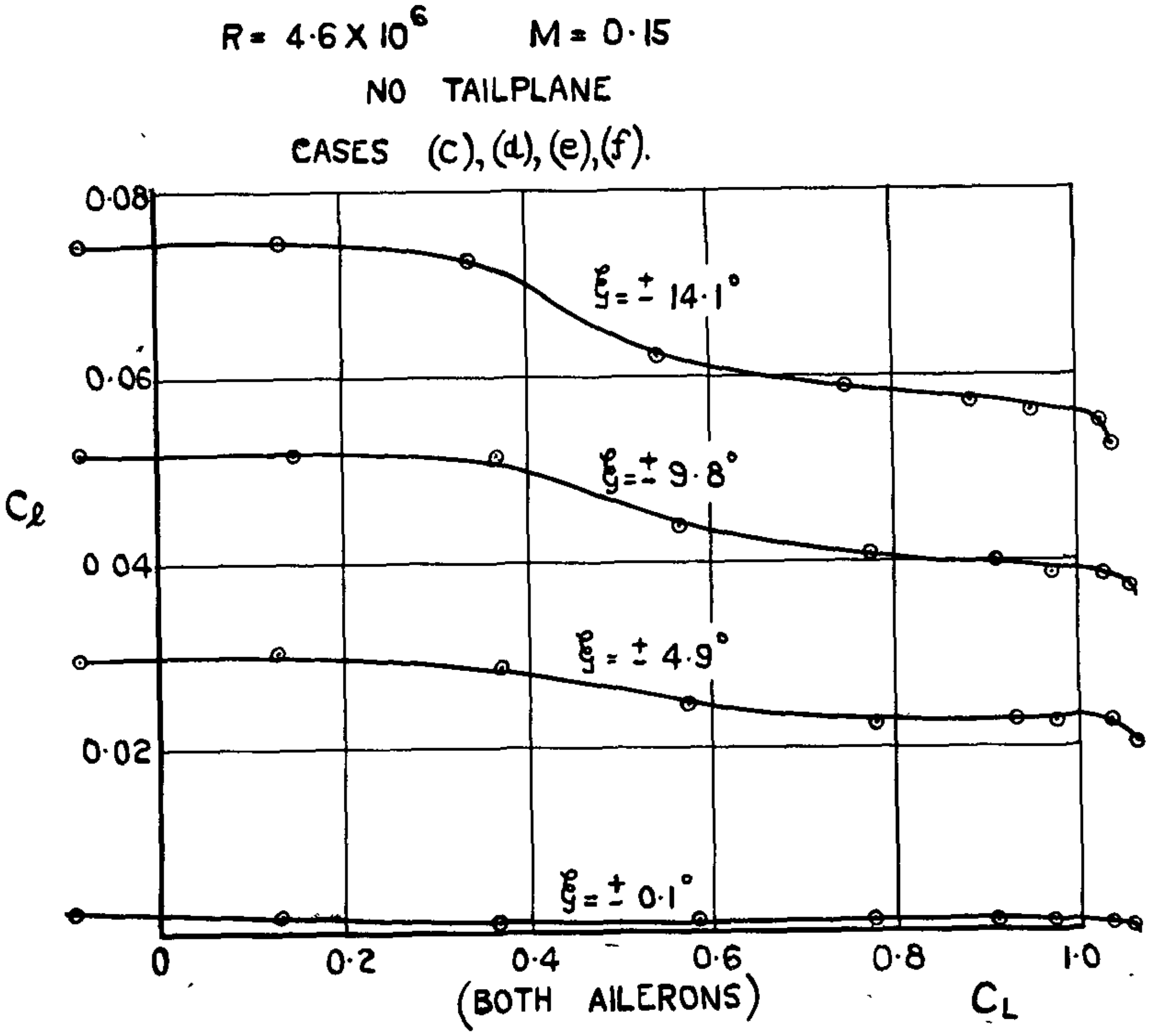


FIG. 7(b).

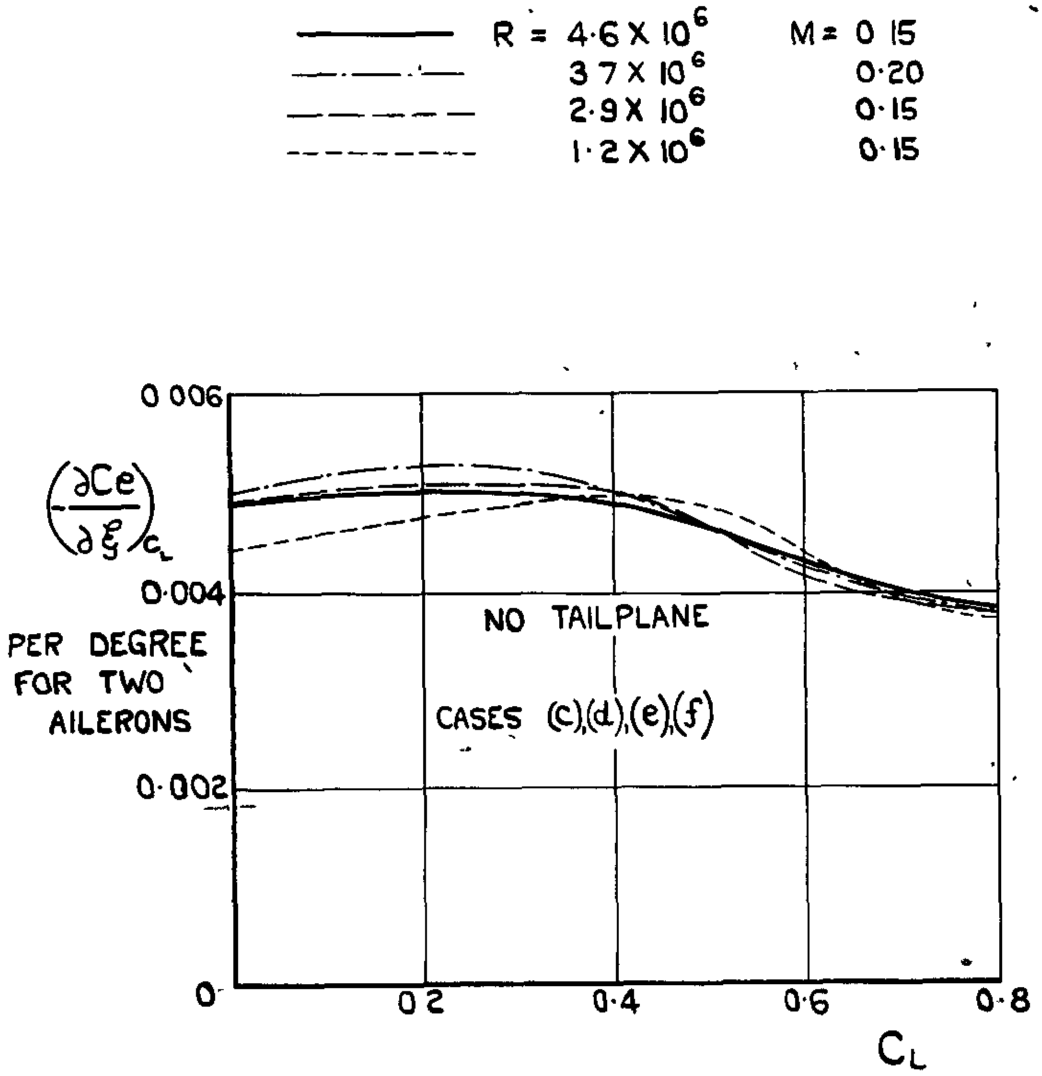
COMPARISON OF PITCHING MOMENTS ON GRIFFITH METEOR AND METEOR I.

FIG. 8



MEASURED ROLLING MOMENTS ON GRIFFITH METEOR.

FIG. 9.



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