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Wind Tunnel Model tests on the German Flying Bomb

- by -

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SUMMARY.

Wind tunnel tests were made on a 1/2.5 scale model of the German Flying Bomb to assist in an analysis of its stability. The lateral and directional derivatives due to sideslip were measured for a range of rudder angles. Engine nacelle drag and effect of spoilers on longitudinal trim were also measured.

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1. Reasons for enquiry

Various measurements were required to assist in an analysis of the stability in yaw.

2. Model and test details

Dimensions were taken from the latest available material, and a model of 1/2.5 scale was tested in the No. 1 $11\frac{1}{2}$ ft. x $8\frac{1}{2}$ ft. wind tunnel at the R.A.E. in July, 1944. The wind speed was 120 ft./sec. Table 1 gives relevant dimensions and Fig. 1 an illustration of the model.

The wing-body angle was not known, and the majority of the tests were made with an angle of 3°, some check tests being made at 6°. A body centre-line incidence to wind of −1° was used for the majority of the tests; with a wing-body angle of 3° this corresponded to a C_L of 0.17 (the condition for top-speed flight, 390 m.p.h. at 2,000 ft.). Some measurements were repeated at a body-line incidence of 2.6°. By fitting a baffle plate in the engine duct, an entry velocity of 0.22 x the flight speed was obtained (corresponding roughly to top-speed flight conditions); in addition, the effect of a higher flow, 0.63 x the flight speed, was tried.

The C.G. position to which the results have been referred was estimated for the condition with half fuel and air, from data supplied.

3. Results

3.1 Lateral and directional stability in sideslip

The measurements are given in Table 2 and Figs 2, 3 and 4.

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The following table summarises the derivatives with rudder at 0°, for the duct velocity of 0.22 x the flight speed. The effect of change of flow was very small. The angles quoted refer to the mean range of β for which the results are given.

Condition	Body incidence (deg.)	Wing-body angle (deg.)	$10^3 n_v$		$10^3 \ell_v$		$10^3 y_v$	
			0° to 5°	0° to 15°	0° to 5°	0° to 15°	0° to 5°	0° to 15°
Complete model	-1.0	3	94	149	-21	-23	-315	-332
Fin off	-1.0	3	56	68	-11	-19	-287	-273
Fin and engine nacelle off	-1.0	3	-95	- 73	- 5	- 3	- 57	- 90
Complete model	-1.0	6	119	156	-21	-32	-320	-350
Complete model	2.6	3	71	132	-29	-28	-286	-320

It will be seen that the uncertainties in wing-body angle and body-incidence introduce some uncertainty in the value of the derivatives for angles of sideslip up to 5°.

The derivatives are very similar with rudder angles up to 20°. The rudder on the actual bomb has a maximum deflection of 16°.

The values of the derivatives due to rudder are:-

$10^3\, n_\zeta = -55, \quad 10^3 \ell_\zeta = 4.5, \quad 10^3\, y_\zeta = 35.$

For the fin and rudder, these give, for β + 5° to -5°,

$$a_1\left(1 - \frac{d\sigma}{d\beta}\right) = 0.84 \quad \text{and} \quad a_2 = 1.04$$

where σ = sidewash at the fin.

This shows that there is a very large sidewash at the fin, probably due to the strut fairing ahead of it. The centres of pressure of the loads on the fin and the rudder are, to the accuracy of the results, at the fin quarter chord and at the rudder hinge respectively. The side-load on the engine nacelle and front strut fairing, which provides the main stabilising force, acts $6\frac{1}{2}$ ft. behind the C.G., that is, just behind the leading edge of the engine duct.

3.2 Drag

The following table gives the increase of drag with sideslip, as a percentage increase in the overall drag.

β°	0	2.5	5	10	15
Δ D, %	0	2.6	10.6	66.6	157

The internal drag of the duct on the model is here assumed to remain constant with β ; its value has been estimated from measurements of the flow at the duct exit, and was equivalent to 3.2 lb. at 100 ft./sec. Taking this figure from the measured values, the model had the following external drag (converted to lb. full scale at 100 ft./sec.):-

Complete model	18.8 lb.
Complete model less fin	18.5 lb.
Model less fin and engine	13.7 lb.

These figures are only of relative value, and the model measurements cannot be taken as giving a reliable estimate of the drag of the actual bomb.

The transition point was fixed on the model body at 6% of its length from the nose, and on the nacelle at 4% of its length from the leading edge.

3.3 Longitudinal stability and effect of spoilers

Table 3 gives the measured values of pitching moment about the C.G. position. The static stick-fixed margin on the model was 9% of the wing mean chord. Small spoilers on the tailplane lower surface, which operate when the bomb starts to dive, were represented on the model. They induced a nose-down pitching moment equivalent to a change in C_M of nearly 0.06.

Attached:- Tables 1 - 3.
Drg. No. 14999S Fig. 1.
" No. 15000S " 2.
" No. 15001S " 3 & 4.

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TABLE 1.

Relevant Model and Full Scale Data

Model Scale 1 : $2\frac{1}{2}$.

	Model Scale.		Full Scale.
Wing.			
Span - b - ft.	7.067		17.67
Mean chord - $\bar{c}$ - ft.	1.351		3.38
Area - S - sq.ft.	9.55		59.7
Tail and elevator.			
Span - ft.	2.70		6.75
Area - S_t - sq.ft.	1.92		11.98
Tail arm - (C.G. to $\frac{1}{4}$ chord pt.) - ℓ_t - ft.	4.37		10.90
Tail volume - $\frac{S_t \ell_t}{S \bar{c}}$		0.650	
Fin and Rudder.			
Area (above surface of body) - Sf - sq.ft.	0.639		4.00
Chord - Cf - ft.	0.984		2.46
Aspect Ratio		0.67	
Thickness/Chord Ratio		10.2%	
Rudder Area aft of Hinge Line - sq.ft.	0.149		0.932
Rudder Chord aft of Hinge Line - ft.	0.227		0.567
Fin Arm (C.G. to Rudder Hinge Line) - ℓ_f - ft.	5.58		13.95
Fin Volume $\left(\frac{S_f \ell_f}{S\, b}\right)$		0.0529	
Rudder Set Back		44%	
C.G. Position. (With half fuel and air supply)			
Above Body Centre Line - ins.	0.64		1.6
Aft of L.E. of Wing - ins.	4.2		10.5
- in terms of Mean Chord		0.256$\bar{c}$	
Reynold's No. of Tests (based on Mean Chord)	1×10^6		

Wing-Body angle of 3^o and Body Centre Line incidence of -1.0^o, corresponding to C_L = 0.17 (assumed top speed of 390 m.p.h., at 2,000 ft.) and Body Centre Line incidence of 2.6^o corresponding to C_L = 0.44.

TABLE 2.

Rolling and Yawing Moment and Side Force Coefficients.

$$\frac{v}{V} = \frac{\text{Duct entry velocity}}{\text{Duct exit velocity}}$$

i^o = wing-body setting. $\alpha_B{}^o$ = body centre-line incidence.

Condition	$\frac{v}{V}$	i^o	$\alpha_B{}^o$	ξ^o	β^o	10^3C_n	10^3C_ℓ	10^3C_Y
Complete model	0.22	3	-1.0	0	0	0	0	0
					2.5	3.8	- 0.6	- 26
					5	8.2	- 1.8	- 55
					10	20.5	- 4.7	-111
					15	38.9	- 6.1	-174
					20	60.2	- 9.1	-246
				- 5	-20	-55.5	9.1	242
					-15	-27.6	5.9	172
					-10	-15.3	4.2	102
					- 5	- 4.3	2.0	41
					- 2.5	0.6	1.1	22
					0	4.9	- 0.9	- 6
					2.5	8.5	- 0.3	- 32
					5	12.8	- 1.7	- 70
					10	25.9	- 3.9	-120
					15	43.9	- 5.6	-188
					19	61.6	- 7.8	-251
				-10	-20	-50.1	10.0	232
					-15	-28.7	6.2	159
					-10	-12.0	3.7	97
					- 5	0.5	1.5	36
					0	9.9	- 0.5	- 13
					5	17.9	- 1.9	- 77
					10	31.1	- 4.9	-127
					15	49.5	- 6.1	-194
					19	66.4	- 7.7	-259
				-20	-20	-42.9	8.6	224
					-15	-22.3	6.3	151
					-10	- 3.2	3.0	85
					- 5	9.2	0.3	24
					0	19.0	- 1.4	- 24
					5	27.6	- 5.2	- 87
					10	41.9	- 5.4	-141
					15	60.4	- 7.3	-206
					19	77.8	- 8.3	-271
Fin off Engine on.	0.22	3	-1.0	-	0	0	0	0
					5	4.9	- 0.9	- 49
					10	10.1	- 2.5	- 96
					15	17.8	- 5.2	-143
					19	27.9	- 7.2	-192

(continued overleaf.)

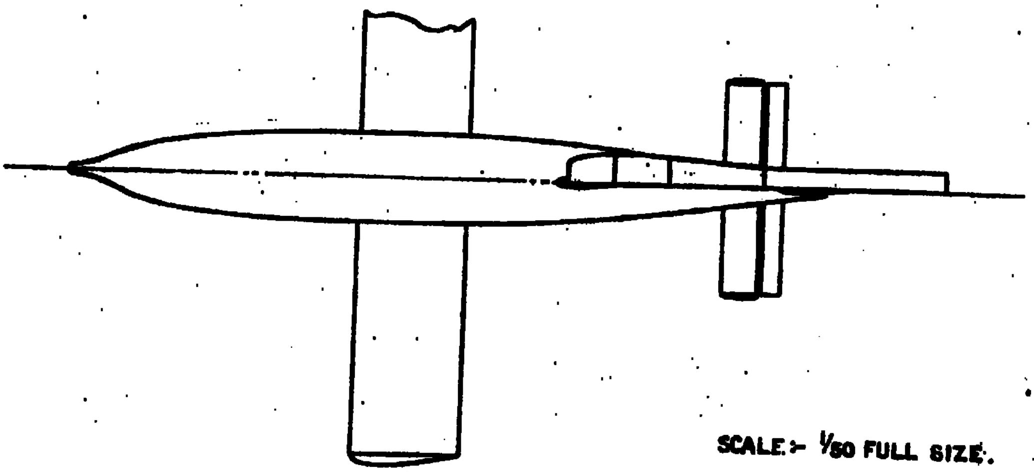
TABLE 2. (continued).

Condition	$\frac{v}{V}$	i°	α_B°	ζ°	β°	$10^3 C_n$	$10^3 C_\ell$	$10^3 C_Y$
Fin off Engine off	0.22	3	-1.0	-	0	0	0	0
					5	- 8.3	- 0.7	- 10
					10	-14.4	- 0.8	- 25
					15	-19.2	- 1.0	- 47
					19	-22.1	- 0.7	- 68
Complete model.	0.22	3	2.6	0	0	0	0	0
					2.5	2.4	- 0.6	- 24
					5	6.2	- 2.5	- 50
					10	16.9	- 4.5	-105
					15	34.4	- 7.3	-167
					20	57.9	- 9.0	-246
Complete model.	0.63	3	2.6	0	0	0	0	0
					5	6.2	- 2.6	- 50
					10	17.5	- 4.8	-107
					15	35.2	- 7.2	-170
					20	60.0	- 9.4	-242
Complete model.	0.22	6	-1.0	0	0	0	0	0
					2.5	4.0	- 1.2	- 27
					5	10.4	- 3.3	- 56
					10	22.3	- 5.7	-116
					15	41.1	- 8.3	-183
					20	66.0	-10.2	-265

TABLE 3.

Lift, drag and pitching moment coefficients on the complete model. $\eta = 0$.

α	C_L	C_D	C_M
Without spoilers on tail.			
-2.7	0.028	0.0306	0.0350
-0.55	0.194	0.0334	0.0195
1.55	0.350	0.0409	0.0063
3.65	0.512	0.0515	-0.0015
With spoilers on tail.			
-2.65	0.041	0.0333	-0.0240
-0.55	0.210	0.0373	-0.0391
1.55	0.363	0.0448	-0.0557
3.65	0.531	0.0563	-0.0647



SCALE:- 1/50 FULL SIZE.

PLAN WITH HALF PROPULSION UNIT REMOVED.

GERMAN FLYING BOMB

No 15000 S
DR. A.A.
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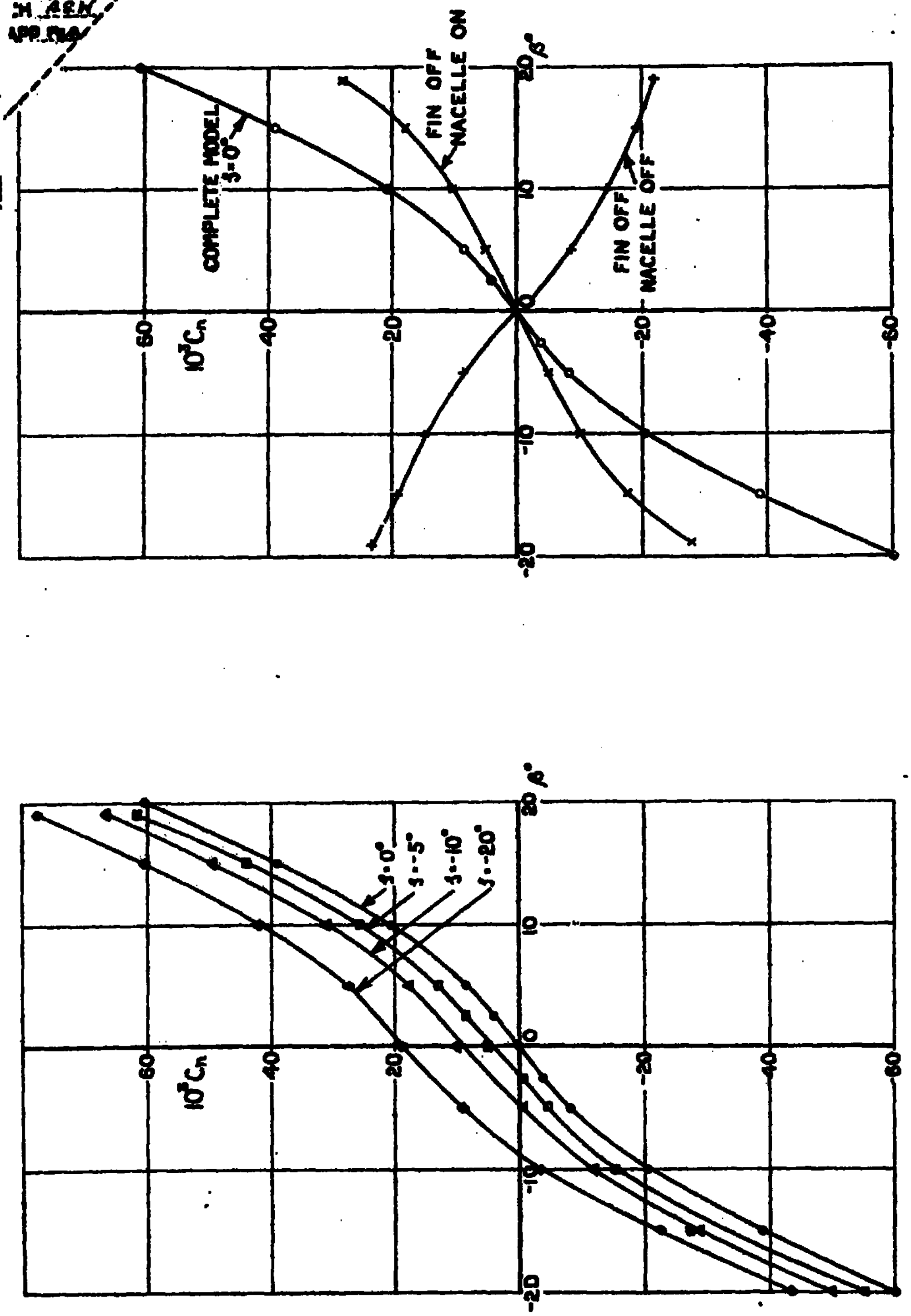
T.N AERO 1489. EA224/8
FIG. 2



VARIOUS MODEL CONDITIONS - RUDDER AT 0°.

COMPLETE MODEL - VARIOUS RUDDER ANGLES.

YAWING MOMENT COEFFICIENTS
DUE TO SIDESLIP.

No 15001 S
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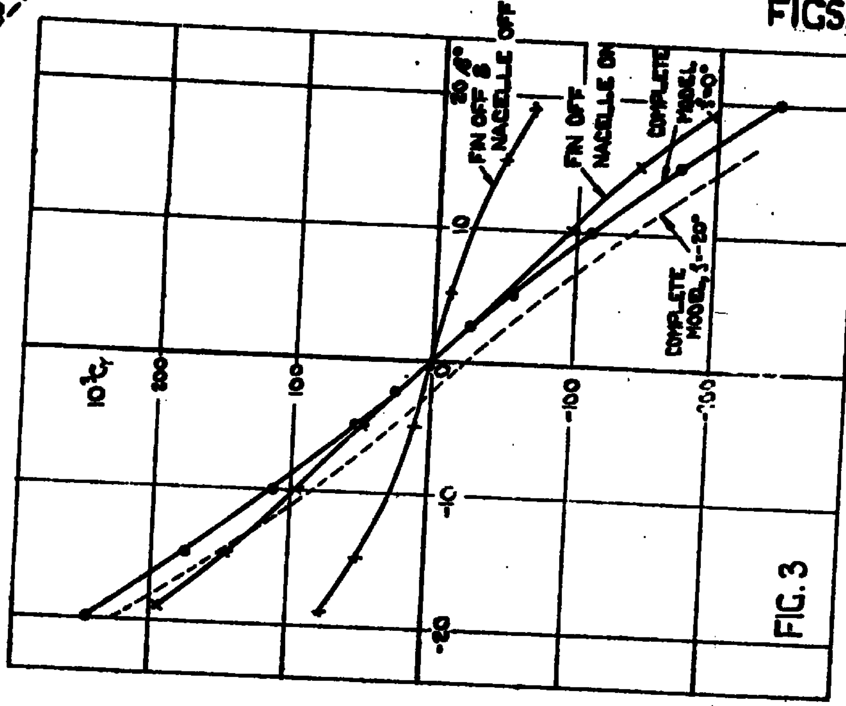

FIG. 3

SIDE FORCE COEFFICIENTS DUE TO SIDESLIP.

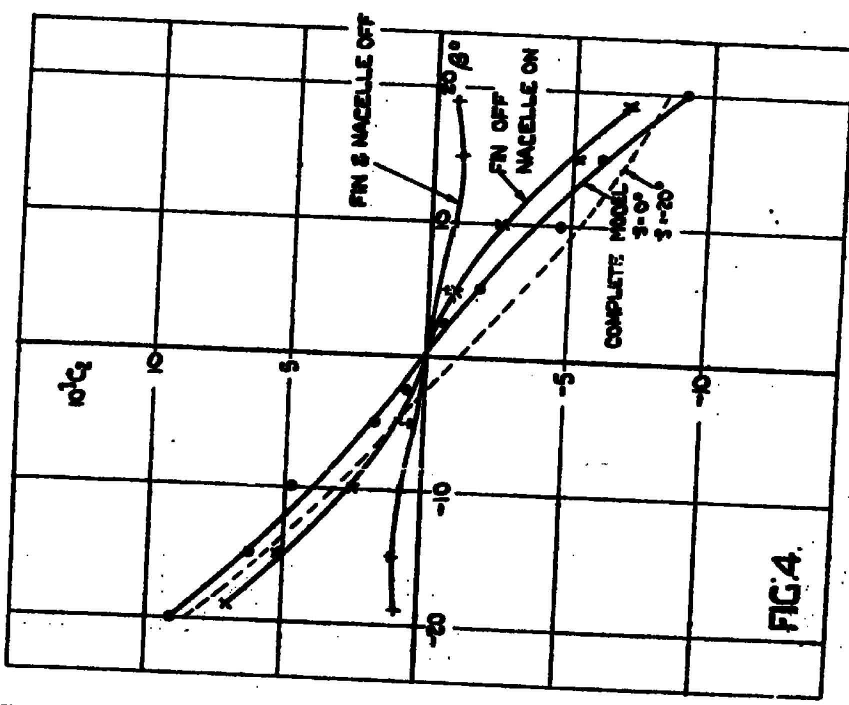

FIG. 4.

ROLLING MOMENT COEFFICIENTS DUE TO SIDESLIP.

ROLLING MOMENTS & SIDEFORCE DUE TO SIDESLIP.

REEL

C37

FRAME

1148

TSDIN FORM 69 A (13 MAR 47)

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