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MALTON - ONTARIO

TECHNICAL DEPARTMENT (Aircraft)

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FORM 1316A

The Impulsive Excitation of Nutational Oscillations

INTRODUCTION

Project 'Y' differs fundamentally from other aircraft in that it contains a large gyroscope; thus the associated nutational mode needs detailed examination to establish that,

(a) It is adequately damped and/or
(b) It is not possible to excite an embarrassing amplitude.

The purpose of this report is to examine the amplitudes likely to occur as a result of impulsive control movement.

Since the damping of this mode is almost exclusively accomplished via the derivatives $M_{\dot\theta}$ and $L_{\dot\phi}$ (See Ref. 1), the amplitude of excitation is likely to be of greatest significance when these derivatives are least. Thus equations of motion have been adopted which approximate to the hovering flight condition. i.e. $M_{\dot\theta} = L_{\dot\phi} = 0$*.

The effects of pitching and rolling impulses are so closely analogous to one another that only the former has been considered.

* It should be noted that $M_{\dot\theta}$ and $L_{\dot\phi}$ are not zero in hovering flight as there is an appreciable contribution to these quantities resulting from the gas flow through the aircraft.

Notation

A	Moment of inertia in roll (slugs ft.^{2})
B	Moment of inertia in pitch (slugs ft.^{2})
I_z	Moment of inertia of gyro (slugs ft.^{2})
K	An arbitrary constant defined in text (lb. ft.)
M	Pitching moment (lb. ft.)
M_η	($= \partial M / \partial \eta$) (lb. ft./rad.)
P_M	Pitching moment impulse (lb. ft. sec.)
T	Duration of impulse (sec.)
k	($= \tau / T$) (dimensionless)
t	Time (sec.)
λ	($= d/dt$) (sec.$^{-1}$)
ω	Angular velocity of gyro (rad./sec.)
η	Deflection of elevators (radians)
τ	Period of nutation (sec.)
θ	Angular perturbation in pitch (radians)
ϕ	Angular perturbation in roll (radians)
Am.	The amplitude of an oscillation (e.g. $x = \alpha \sin \beta t + \gamma \cos \beta t$, $\text{Am.}x = \lvert\sqrt{\alpha^2 + \gamma^2}\rvert$)
Δ	Mean displacement (e.g. $x = \alpha \sin \beta t + \delta$ $\quad \Delta x = \delta$)

The Impulsive Excitation of Nutational Oscillations (continued)

CONCLUSIONS

1. That a nutation is difficult to excite by an impulsive moment as it is necessary for the duration of the impulse to be small compared with the period of the nutation.

2. That any response study based on a step function moment is unrealistic and will predict longer oscillations than would occur in practice (See 1 above).

3. That on Project 'Y' in particular in hovering flight it is impossible to induce any appreciable amplitude of oscillation in either θ or ϕ by an impulsive control movement (See Fig. 4).

4. That nutations will never be troublesome in forward flight because;

(a) Damping ($M_{\dot{\theta}}$ and $L_{\dot{\phi}}$) increases rapidly with forward speed.

(b) The amplitudes excited are so small statically that even if they were increased say ten times they would still not be serious.

5. That in hovering flight the application of pitching moment will produce a displacement in ϕ only (See Fig. 5) i.e. the control is perfect, producing no secondary effects.

6. That it is unnecessary to do any further work specifically designed to investigate the nutational mode on Project 'Y'.

References ....

1. The approximate derivation of the stability modes of Project 'Y'. Stability and control report No. 2 by J. Dubbury. (In course of preparation).

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THE IMPULSIVE EXCITATION
OF NUTATIONAL OSCILLATIONS

J. Dubbury
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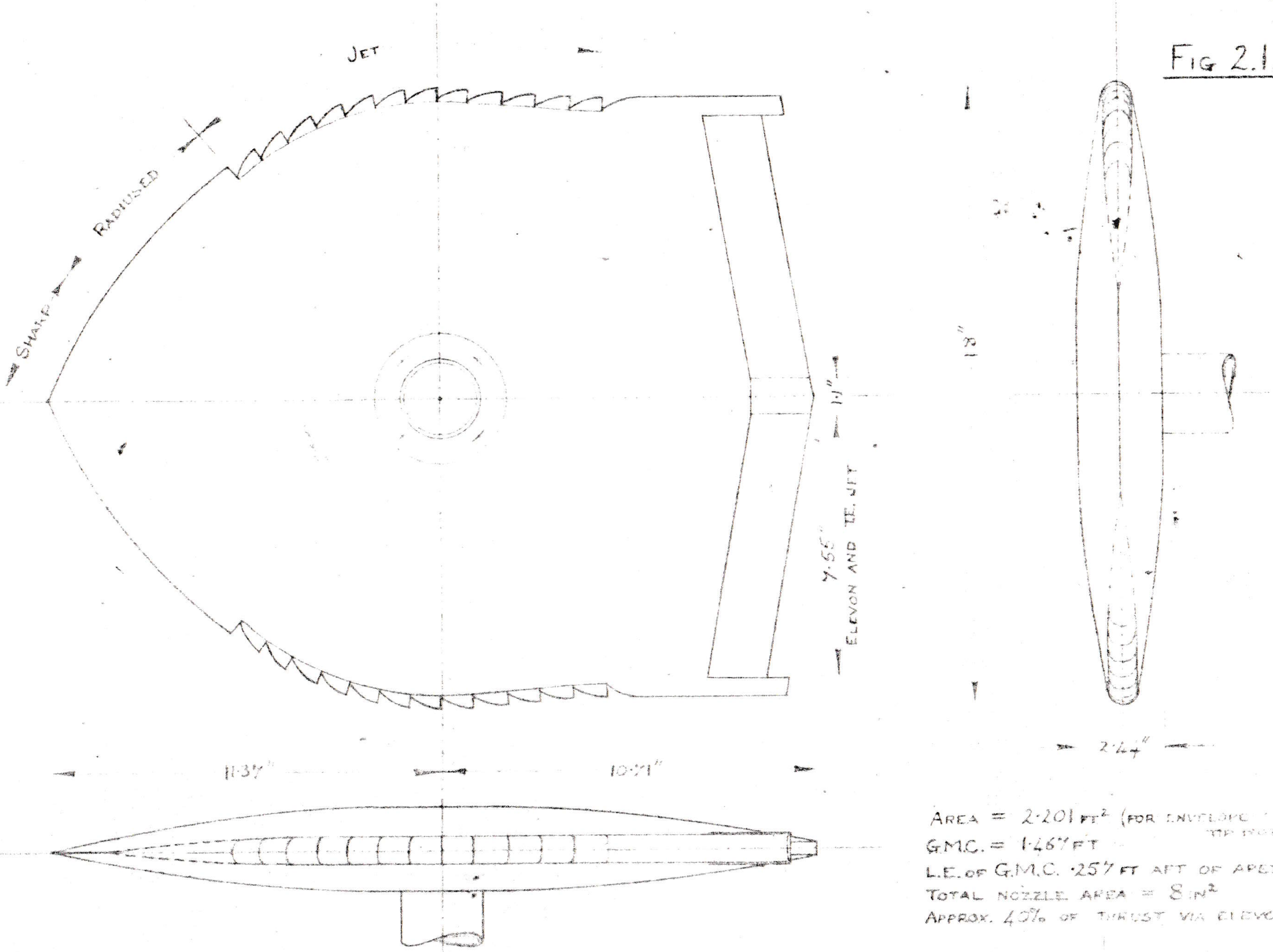
Fig 2.1.

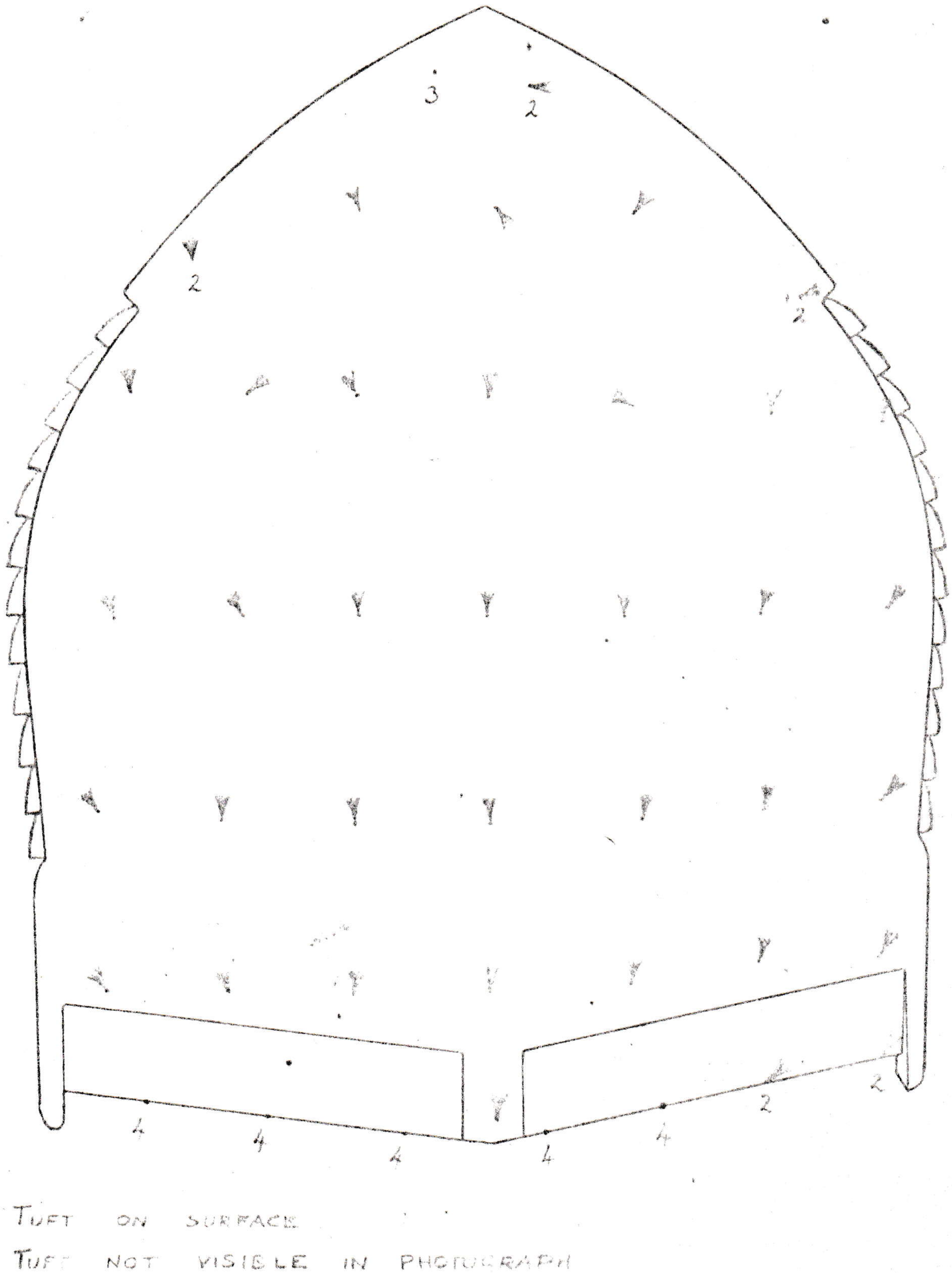


Model G.A.

Area = 2·201 ft² (for envelope enclosing tip nozzles)
G.M.C. = 1·467 ft
L.E. of G.M.C. ·257 ft aft of apex.
Total nozzle area = 8 in²
Approx. 40% of thrust via elevons

FIG 5.13

THRUST OFF $\alpha = 41.05°$



2/ TUFT ON SURFACE

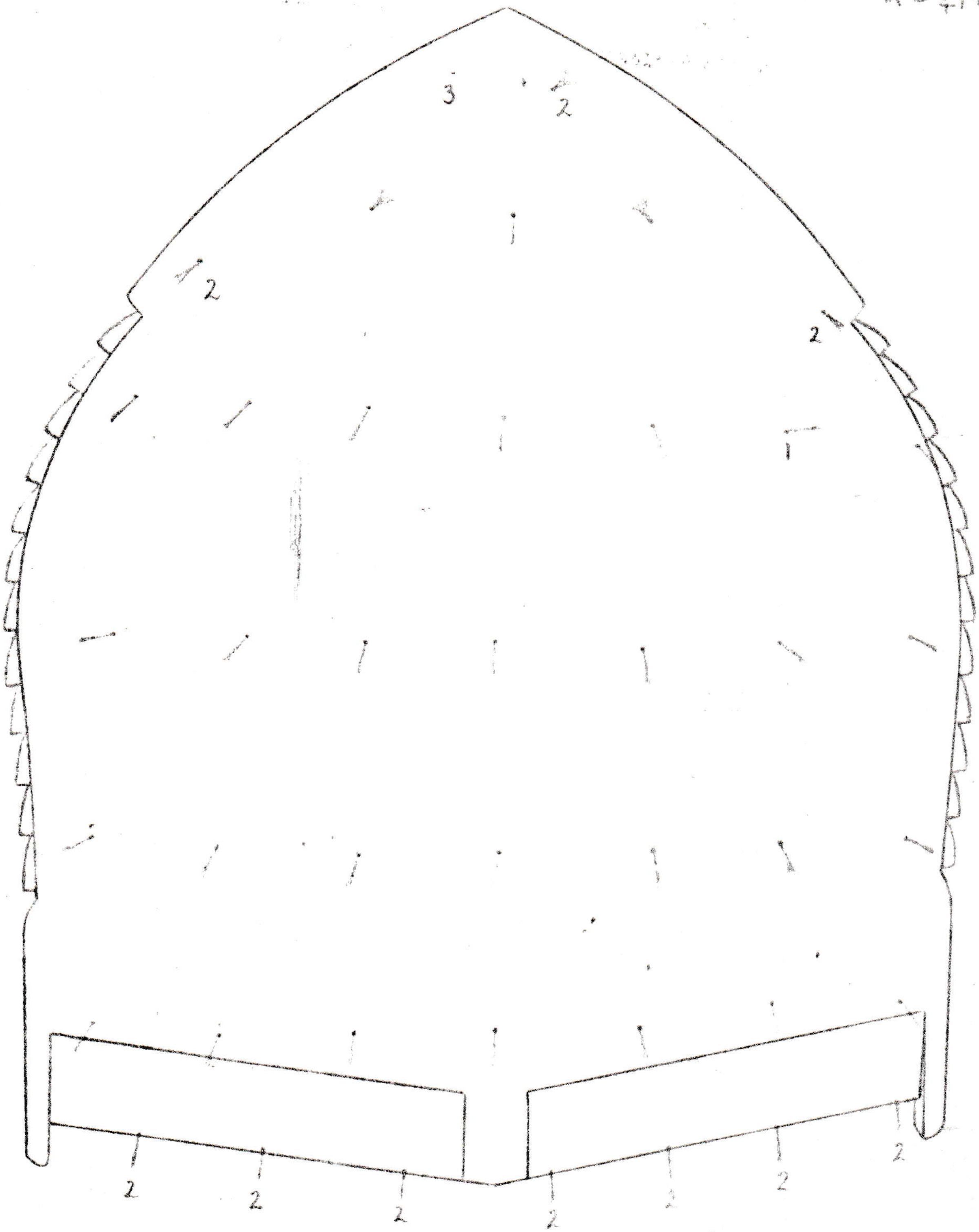
3/ TUFT NOT VISIBLE IN PHOTOGRAPH

4/ TUFT SUCKED IN BETWEEN CONTROL SURFACES

N.B ASYMMETRY OF TRACING DUE TO CAMERA BEING TO PORT OF PLANE OF SYMMETRY OF MODEL.

FIG 5.14

THRUST ON $\alpha = 41.05°$



1, TUFT AT BOTTOM OF PIN ON WING SURFACE.
2, TUFT FASTENED TO WING SURFACE.
3, TUFT NOT VISIBLE IN PHOTOGRAPH.

N.B. ASYMMETRY OF TRACING DUE TO CAMERA BEING TO PORT OF PLANE OF SYMMETRY OF MODEL