A. V. ROE CANADA LIMITED

MALTON - ONTARIO

TECHNICAL DEPARTMENT (Aircraft)

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REPORT NO. 71/Stab/17

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ARROW I

DIGITAL COMPUTATION AND ANALYSIS OF ARROW LONGITUDINAL RESPONSE IN EMERGENCY MODE

PREPARED BY M.V. Jenkins DATE Jan. 1958.

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AVRO AIRCRAFT LIMITED
MALTON - ONTARIO
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INTRODUCTION AND SUMMARY

In the knowledge that the bare essentials are required at the present time and that a more comprehensive presentation will be required at a later stage, this report is simply a record of the longitudinal equations which may be used relevant to longitudinal response in the Emergency Mode with negligible speed and height variation.

The equations may be used in two ways;-

1) The calculation of aircraft longitudinal response assuming the aerodynamic derivatives are known, for any given variation in longitudinal stick force or thrust.

2) Analysis of longitudinal response records to determine the derivatives which generated the response.

Only normal aerodynamic derivatives are involved but transient motion with a varying forcing function is involved and hence the analysis method of reference 3 cannot be applied in these circumstances.

The principles of the method of evaluation of longitudinal derivatives from longitudinal response records are given in reference 1. The application in the Emergency Mode is obvious and it is thought that a description is not necessary in this presentation of this report.

Use of this method as applied to the equations in this report will greatly increase the scope of longitudinal flight analysis as the boundary conditions for analysis are less stringent than in the method of reference 3.

However it is considered that experimental evaluation of derivatives by the method of reference 3 is possibly more reliable because of the averaging process and the self-checking nature of the inter-dependent functions.

The principles of the step by step time solution of response are given in reference 2.

Records of response solutions to various test cases will be included in a more comprehensive presentation of this report.

References

1. Digital Computation Of Response Using An Approximation To Pitch Damper System.

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2. Digital Computation Of Response Using An Approximation To Lateral Damper System.

   71/Stab/9 M.V. Jenkins

3. Digital Computer Determination Of Longitudinal Derivatives From Oscillatory Flight Tests.

   71/Stab/6 M.V. Jenkins

4. Dynamic Equations Relative To Body Axes.

   P/Stab/132 M.V. Jenkins

Notation

Relevant to a body axes system is given in reference 4.

EMERGENCY MODE OZ EQUATION OF MOTION

$$-\alpha \frac{C_{z_\alpha}}{2\tau} - \dot{\alpha}\frac{C_{z_{\dot{\alpha}}}}{4\mu_1} - q\frac{C_{z_q}}{4\mu_1} - \alpha\frac{\sin i}{mV_1}\cdot\frac{\partial T}{\partial \alpha}$$

$$+\alpha\, q_1 \sin\alpha_1 + \dot{\alpha}\cos\alpha_1 - q\cos\alpha_1$$

$$+\theta\frac{g}{V_1}\cdot\sin\Theta\cos\phi_1 = \frac{C_{z_\delta}}{2\tau}\cdot K_E\cdot F_E + \frac{\sin i}{mV_1}\cdot T_i$$

EMERGENCY MODE PITCHING EQUATION

$$-\alpha\cdot\frac{C_{m_\alpha}}{\tau^2 h} - \dot{\alpha}\cdot\frac{C_{m_{\dot{\alpha}}}\cdot\bar{c}^2}{4K_y^2\tau} - q\cdot\frac{C_{m_q}\cdot\bar{c}^2}{4K_y^2\tau}$$

$$-\frac{e}{I_y}\cdot\frac{\partial T}{\partial\alpha}\cdot\alpha + q = \frac{C_{m_\delta}}{\tau^2 h}\cdot K_E\cdot F_E + \frac{e}{I_y}\cdot T$$

$$\ddot{z} = V_1\left[\left(q_1\cdot\sin\alpha_1\right)\alpha + \left(\cos\alpha_1\right)\dot{\alpha} - q\cos\alpha_1 + \theta\frac{g}{V_1}\cdot\sin\Theta\cos\phi_1\right]$$

WHERE $\ddot{z}$ IS THE ACCELERATION MEASURED IN FEET/SEC^2 BY AN ACCELEROMETER ALIGNED IN THE OZ DIRECTION.

$$K_E = \left[\frac{\delta e}{F_E}\right]$$ INCREMENTAL FROM TRIMMED STEADY STATE CONDITION

F_E – INCREMENTAL STICK FORCE POSITIVE PRODUCING NEGATIVE INCREMENTAL VALUES OF ELEVATOR DEFLECTION

Conclusions

If in the equations of motion contained in reference 1 with the normal mode pitch damper engaged, the following values are put to zero, K_o, K_1, K_1', K_2, K_2', K_3 and $F_E K_E$ is substituted for

$$\left[\int (K_1 n - K_1' N)\, dt - K_2' N + K_o \int q . dt\right]$$

the equations become relevant to the Emergency Mode where the normal aerodynamic derivatives only are involved.