A. V. ROE CANADA LIMITED
MALTON, ONTARIO

TECHNICAL DEPARTMENT (Aircraft)

AIRCRAFT: C - 105

REPORT NO. 71/Comp ε/8

FILE NO.

NO. OF SHEETS:

TITLE:

EVALUATION OF DAMPER PERFORMANCE DURING FLIGHT TEST

PREPARED BY S. Galezowski DATE Oct. 1957

Extract A117/Damper Flight Test/1 CHECKED BY DATE Nov. 1957

SUPERVISED BY DATE

APPROVED BY DATE

ISSUE No.	REVISION No.	REVISED BY	APPROVED BY	DATE	REMARKS

FORM 1316A

AIRCRAFT		PREPARED BY	DATE
C-105	Damper, Flight Test	S. Galezowski	Nov. 1957
		CHECKED BY	DATE
		R. Carley	Nov. 1957

TABLE OF CONTENTS

AILERON, ELEVATOR AND RUDDER SERVO POSITIONS

FOR ALL FLIGHT CONDITIONS

NOTATION

$\delta a_{D_{pos}}$ AILERON DIFFERENTIAL SERVO POSITION

$\delta a_{P_{pos}}$ AILERON PARALLEL SERVO POSITION

$\delta e_{D_{pos}}$ ELEVATOR DIFFERENTIAL SERVO POSITION

$\delta e_{P_{pos}}$ ELEVATOR PARALLEL SERVO POSITION

$\delta_{R_{pos}}$ RUDDER SERVO POSITION

p ROLL RATE

p_c COMMAND ROLL RATE

q PITCH RATE

r YAW RATE

n NORMAL LOAD FACTOR

n_c COMMAND NORMAL LOAD FACTOR

δ_a AILERON ANGLE

$F_{C_{lateral}}$ LATERAL STICK FORCE

A_y, $\ddot{y}$ LATERAL ACCELERATION

NOTATION CONT:

$\delta_{R_{AY}}$
$\delta_{R_{\delta a}}$
$\delta_{R_{\delta aq}}$
δ_{R_r}
δ_{a_p}
$\delta_{a_{p_1}}$
δ_q
δ_n
δ/n

} DAMPER GAIN SCHEDULES

$\delta_{e_{LANDING}}$
$\delta_{a_{LANDING}}$

} CONSTANTS FOR ANY GIVEN FLIGHT

B_T OUTPUT OF AILERON TRIM MOTOR

C_T OUTPUT OF PITCH INTEGRATOR

η_T OUTPUT OF TRIM MOTOR IN PITCH

$F_{C_{LONGITUDINAL}}$ LONGITUDAL STICK FORCE

AIRCRAFT: C-105		REPORT NO	SHEET NO 5
		PREPARED BY: GALEZOWSKI	DATE: NOV '57
		CHECKED BY	DATE

NOTATION CONT:

K_1 CONSTANT FOR ANY GIVEN FLIGHT

q_c COMPRESSIBLE DYNAMIC PRESSURE

Δn, $n-1$, A_z, $\ddot{z}$ — SYNONYMOUS NOTATION FOR NORMAL ACCELERATION

h PRESSURE HEIGHT (AE[illegible] DA[illegible])

INTRODUCTION

The purpose of this report is to prepare a method for evaluating the performance of the damper system during flight test.

The performance of the damper can be divided into three parts as follows:-

(a) Damper sensor outputs

(b) Commands to Differential and Parallel Servos

(c) Motion of control surfaces

The method of evaluating each of these parts is presented in the following paragraphs.

A. Sensor Outputs

The perfomance of the sensors can be evaluated by comparing the calcuated sensor output obtained from flight test instrumentation raw data with the measured sensor output presented on the same graph.

B. Commands to Differential and Parallel Servos

The performance of the damper can be evaluated by computing the servo commands based on the measured sensor outputs and then comparing these computed commands with the measured commands.

The measured sensor outputs and the measured servo commands will be recorded on the data tape.

Damper computations can be broken into two sets of equations, corresponding to two separate parts of the damper, that is, normal damper operation and emergency damper operation. Both normal and emergency damper operation are subdivided into two subsectionscalled the gear up and the gear down modes.

I	Normal Damper		
	Pitch	gear up	1
		gear down	2
	Roll	gear up	3
		gear down	4
	Yaw	gear up	5
		gear down	6
II	Emergency Damper		
	Yaw	gear up	7
		gear down	8

When the gear is up, the equations for modes 1, 3, 5, and 7 should be solved and plotted. When the gear is down, the equations for modes 2, 4, 6 and 8 should be solved and plotted.

C. Motion of Control Surfaces

The performace of the parallel and differential servos can be evaluated by comparing the commanded servo positions with the measured servo positions. The comparison is accomplished by graphical methods as shown in the section "Presentation of Data".

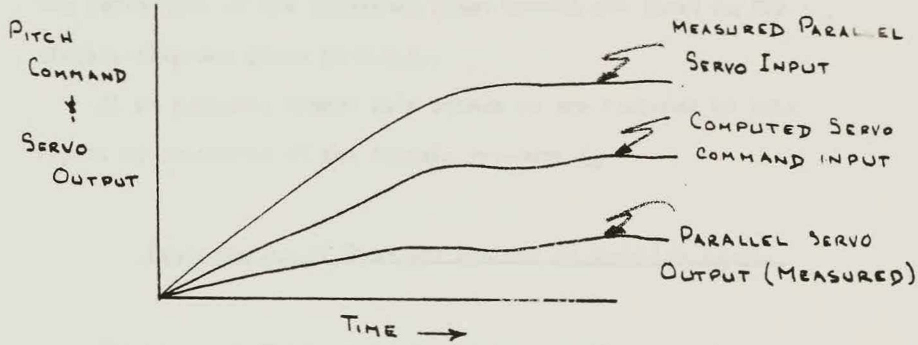
The use of this method of evaluating damper performance provides a method of evaluating some aspects of the damper performance even when the damper modes are not engaged. The engage or disengage of any mode is accomplished by controlling the supply of hydraulics to the parallel or differential servos associated with the mode. This means that the operation of the sensors and the computations for the differential and parallel servo commands can be assessed when the modes are not engaged.

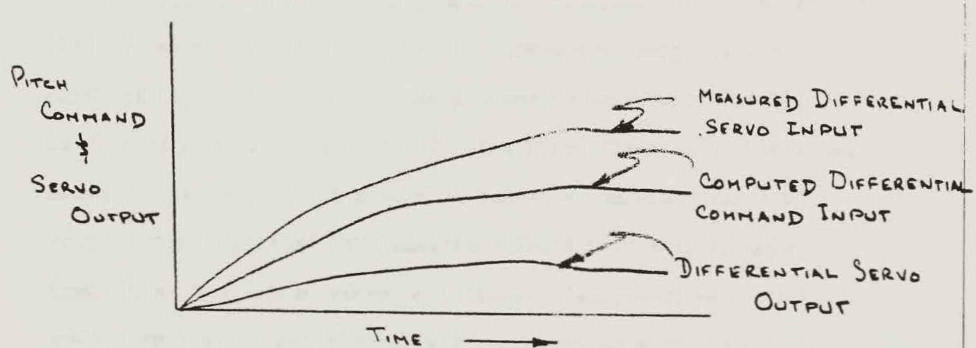
It is desirable that these equations be programmed for all Mach numbers and altitudes. Flight test data should be taken at the rate of 20 readings per second where the flight test schedule so states; otherwise a lesser rate will be accepted. The values of S used in the equations for any given flight condition are determined from the period of aircraft motion in that particular flight condition.

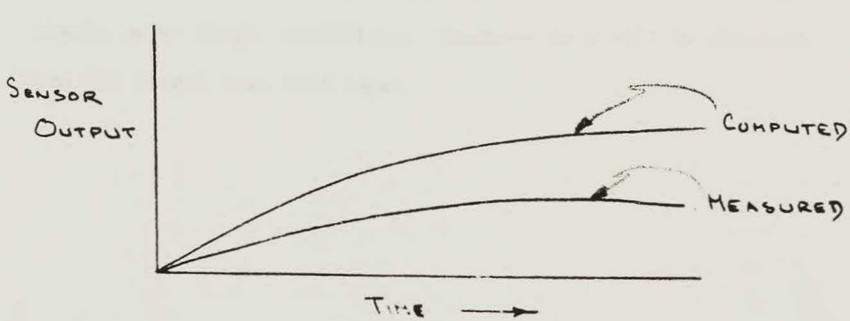
AVRO AIRCRAFT LIMITED
MALTON - ONTARIO
TECHNICAL DEPARTMENT

AIRCRAFT:		REPORT NO.	
C-105	DAMPER FLIGHT TEST	SHEET NO.	
		PREPARED BY: GALEZOWSKI	DATE: NOV '57
		CHECKED BY: [signature]	DATE:

GRAPHICAL PRESENTATION OF DATA.







NOTE: THE ABOVE CURVES SHOULD BE PRESENTED FOR BOTH THE U/C EXTENDED AND RETRACTED CASES IN THE NORMAL MODE.

The derivation of the equations given herein are based on the circuit diagrams given in C.E.L.,

As an appendix damper gain schedules are included in this report as functions of the dynamic pressure q_c.

Presentation of Data and Sources of Equation Inputs

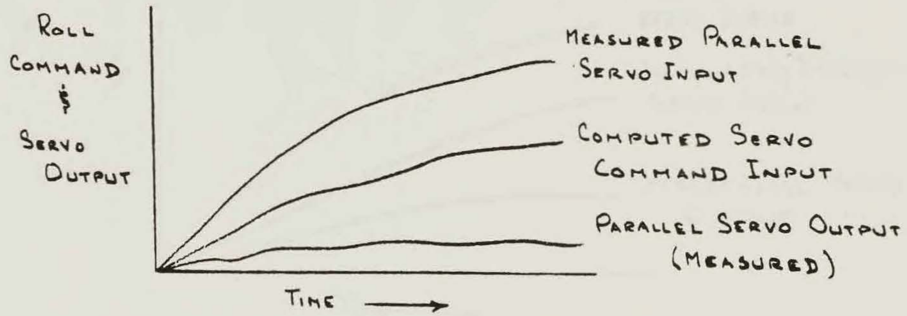
The measured flight data should be presented as a time history plot of servo input and output. For comparison purposes the computed inputs from the equations given in this report should be plotted on the same graph. For the first flight the calculated values of the servo input should be based on computed values of sensor output obtained from equations found in P/Aero Data/92, Issue 2, or the latest subsequent issue. Calculated values of servo input in further flights will be based on measured sensor outputs under flight conditions. Measured data will be obtained from the flight test data tape.

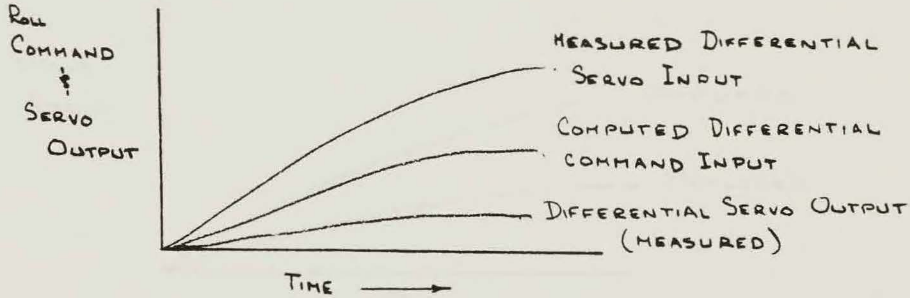
	COMPUTED SENSOR OUTPUTS (FIRST FLIGHT)	DATA OBTAINED FROM FLIGHT TEST TAPE
ROLL	P (P/AERO DATA 92, EQ^N 2.5) δ_a (" , EQ^N 1.14)	P_c B_T $F_{C_{LATERAL}}$ (U/C DOWN ONLY) PARALLEL AND DIFFERENTIAL SERVO INPUT AND OUTPUT
PITCH	q (" , EQ^N 2.4) η (" , EQ^N 2.7)	C_T n_c n_T $F_{C_{LONGITUDINAL}}$ (U/C DOWN ONLY) PARALLEL AND DIFFERENTIAL SERVO INPUT AND OUTPUT
YAW	r (" , EQ^N 2.6) A_y (" , EQ^N 2.15)	DIFFERENTIAL SERVO (2) INPUT AND OUTPUT.
GENERAL	h (" , EQ^N 1.5) M (" , EQ^N 1.6) q_c (" , EQ^N 1.7)	U/C POSITION NORMAL OR EMERGENCY MODE S

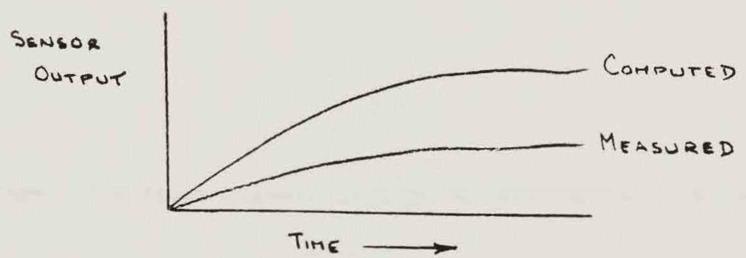
QUANITIES THAT ARE CONSTANT FOR ANY GIVEN FLIGHT
K_1 $\delta_{e_{LANDING}}$ $\delta_{a_{LANDING}}$

AVRO AIRCRAFT LIMITED
MALTON - ONTARIO
TECHNICAL DEPARTMENT

AIRCRAFT:		REPORT NO	
		SHEET NO	
		PREPARED BY	DATE
C-105	DAMPER FLIGHT TEST	GALEZOWSKI	NOV '57
		CHECKED BY	DATE
		[signature]	





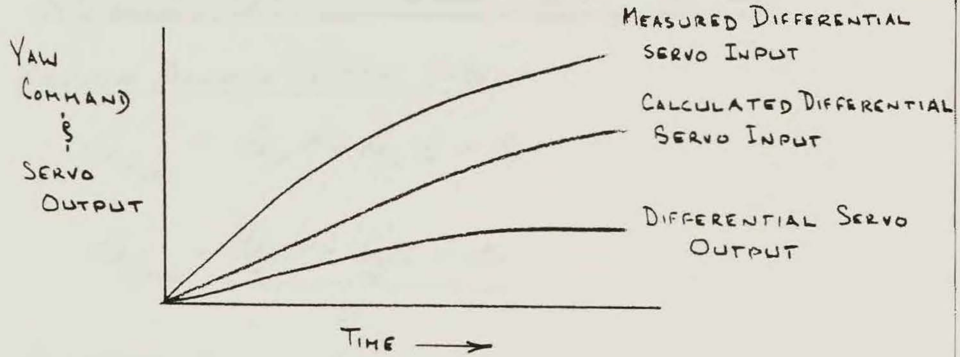


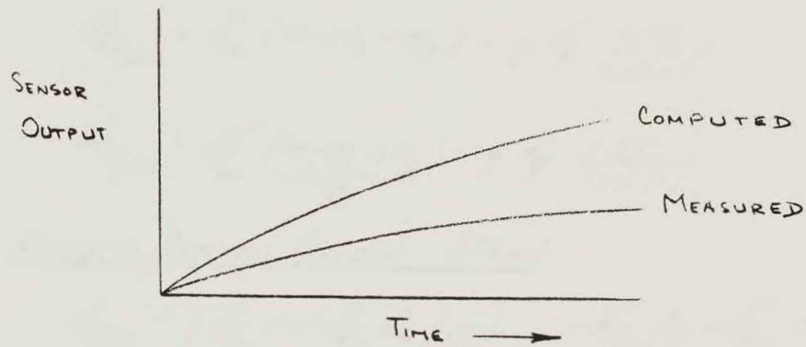
NOTE: THE ABOVE CURVES SHOULD BE PRESENTED FOR BOTH THE U/C EXTENDED AND RETRACTED CASES IN THE NORMAL MODE.

FORM 1319A

AVRO AIRCRAFT LIMITED
MALTON - ONTARIO
TECHNICAL DEPARTMENT

AIRCRAFT:		REPORT NO	
		SHEET NO	
		PREPARED BY	DATE
C-105	DAMPER, FLIGHT TEST	GALEZOWSKI	Nov '57
		CHECKED BY	DATE
		[signature]	





NOTE: THE ABOVE CURVES SHOULD BE PRESENTED FOR BOTH THE U/C EXTENDED AND RETRACTED CASES IN THE NORMAL AND THE EMERGENCY MODES.

AVRO AIRCRAFT LIMITED
MALTON - ONTARIO
TECHNICAL DEPARTMENT

AIRCRAFT:		REPORT NO	
C-105		SHEET NO 6	
		PREPARED BY: GALEZOWSKI	DATE: Oct '57
		CHECKED BY: [signature]	DATE

SERVO POSITIONS NORMAL MODE U/C UP

AILERON DAMPER SYSTEM (ROLL)

$$\delta a_{D_{pos}} = \delta a_p P - \delta a_{p_1} P_c + B_T$$

$$\delta a_{P_{pos}} = \frac{\delta a_p P - \delta a_{p_1} P_c + B_T}{S}$$

ELEVATOR DAMPER SYSTEM (PITCH)

$$\delta e_{D_{pos}} = \delta_n (n - n_c + n_T) + q\, \delta_q \frac{1.5S}{1.5S+1}$$

$$\delta e_{P_{pos}} = \delta_n^I \frac{(n - n_c + n_T)}{S} + q\, \delta_q \frac{2.25}{1.5S+1}$$

RUDDER DAMPER SYSTEM (YAW)

$$\delta_{R_{pos}} = \left\{ \delta_{R_r} r + \delta_{R_{\delta a}} \delta a \right\} \frac{2S}{2S+1} + \delta_{R_{AY}} A_y + \delta_{R_{\delta a \cdot q}} \delta a \cdot q$$

SERVO POSITIONS NORMAL MODE U/C DOWN

AILERON DAMPER SYSTEM

$$\delta a_{D_{pos}} = P\delta a_p - P_c \delta a_{p_1} + B_T$$

$$\delta a_{P_{pos}} = \delta a_{LANDING} F_{C_{LATERAL}}$$

ELEVATOR DAMPER SYSTEM

$$\delta e_{D_{pos}} = q \, \delta_q$$

$$\delta e_{P_{pos}} = F_{C_{LONGITUDINAL}} \delta e_{LANDING} + C_T$$

RUDDER DAMPER SYSTEM

$$\delta_{R_{pos}} = \left\{ \delta_{R_r} \cdot r + \delta_{R_{\delta a}} \delta a + \delta_{R_{AY}} A_Y K_1 \right\} \frac{2S}{2S+1}$$

$$+ \delta_{R_{AY}} A_Y (1 - K_1) + \delta_{R_{\delta a q}} \delta a \cdot q$$

AIRCRAFT:		PREPARED BY	DATE
C-105		GMEZOWSKI	Oct '57
		CHECKED BY	DATE
		R. R. Carley	

SERVO POSITIONS EMERGENCY MODE

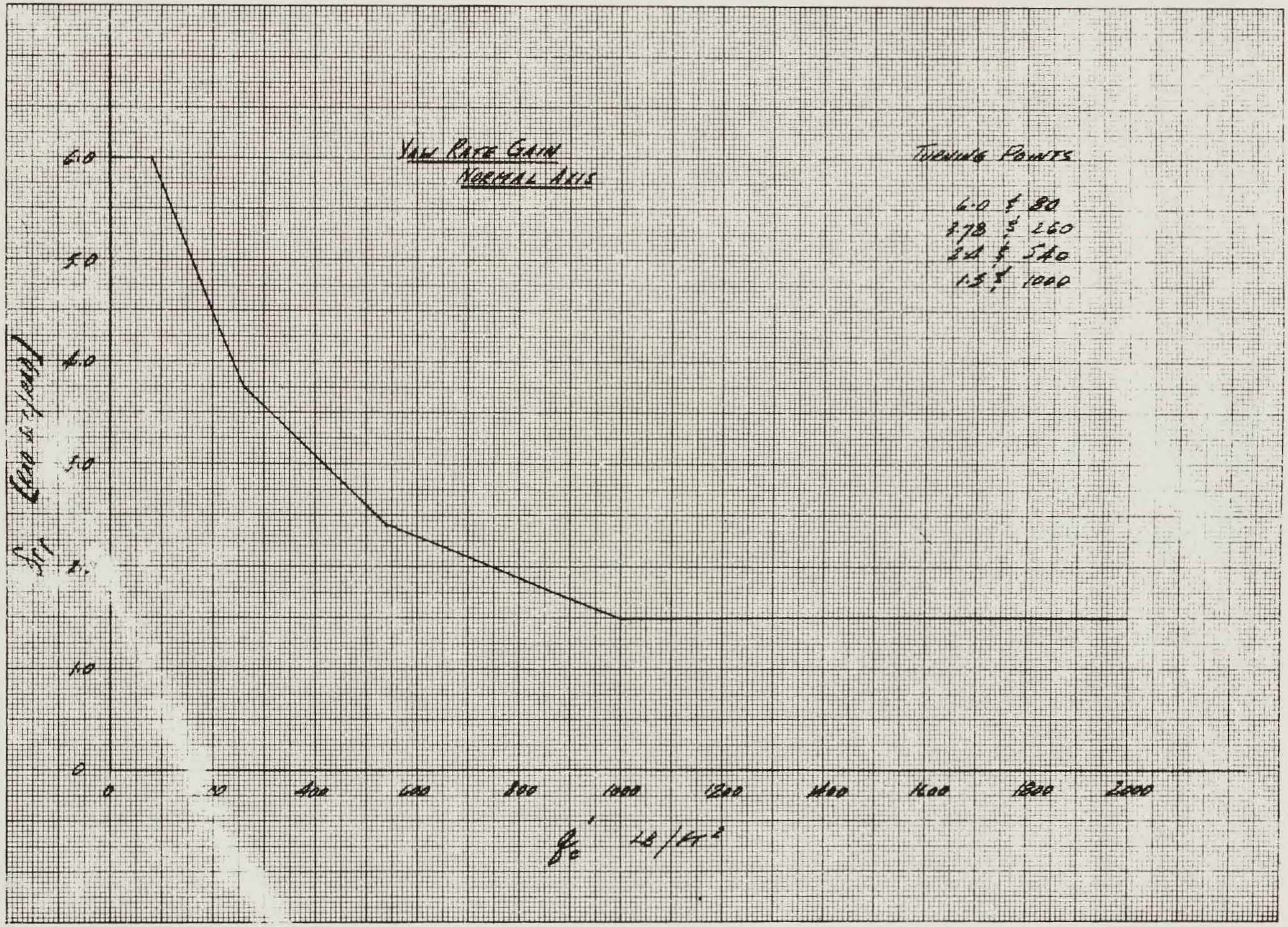
U/C UP

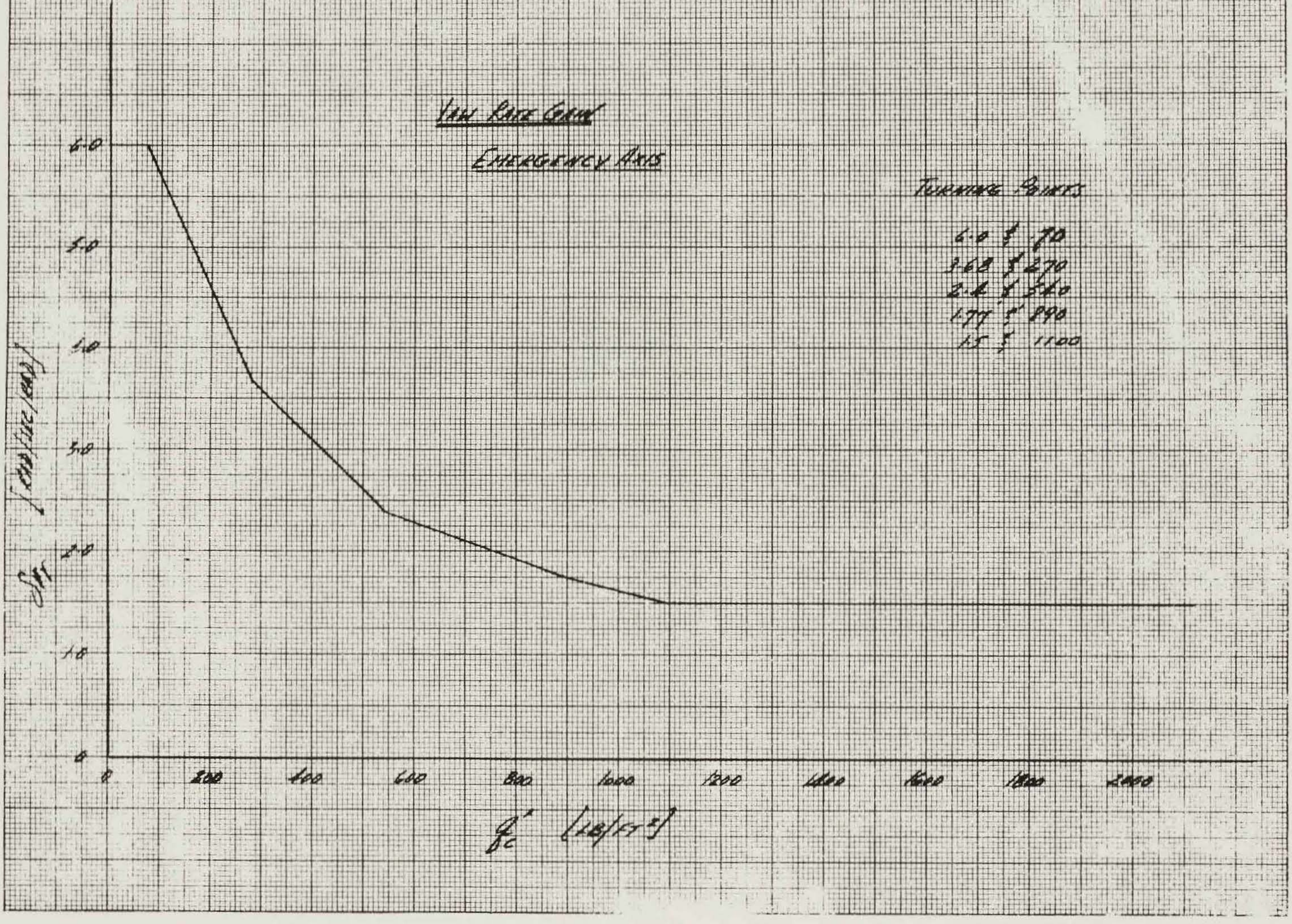
$$\delta_{R_{pos}} = \left\{ \delta_{R_r} \cdot r + \delta_{R_{\delta_a}} \cdot \delta_a \right\} \frac{2S}{2S+1} + A_y \, \delta_{RAY}$$

U/C DOWN

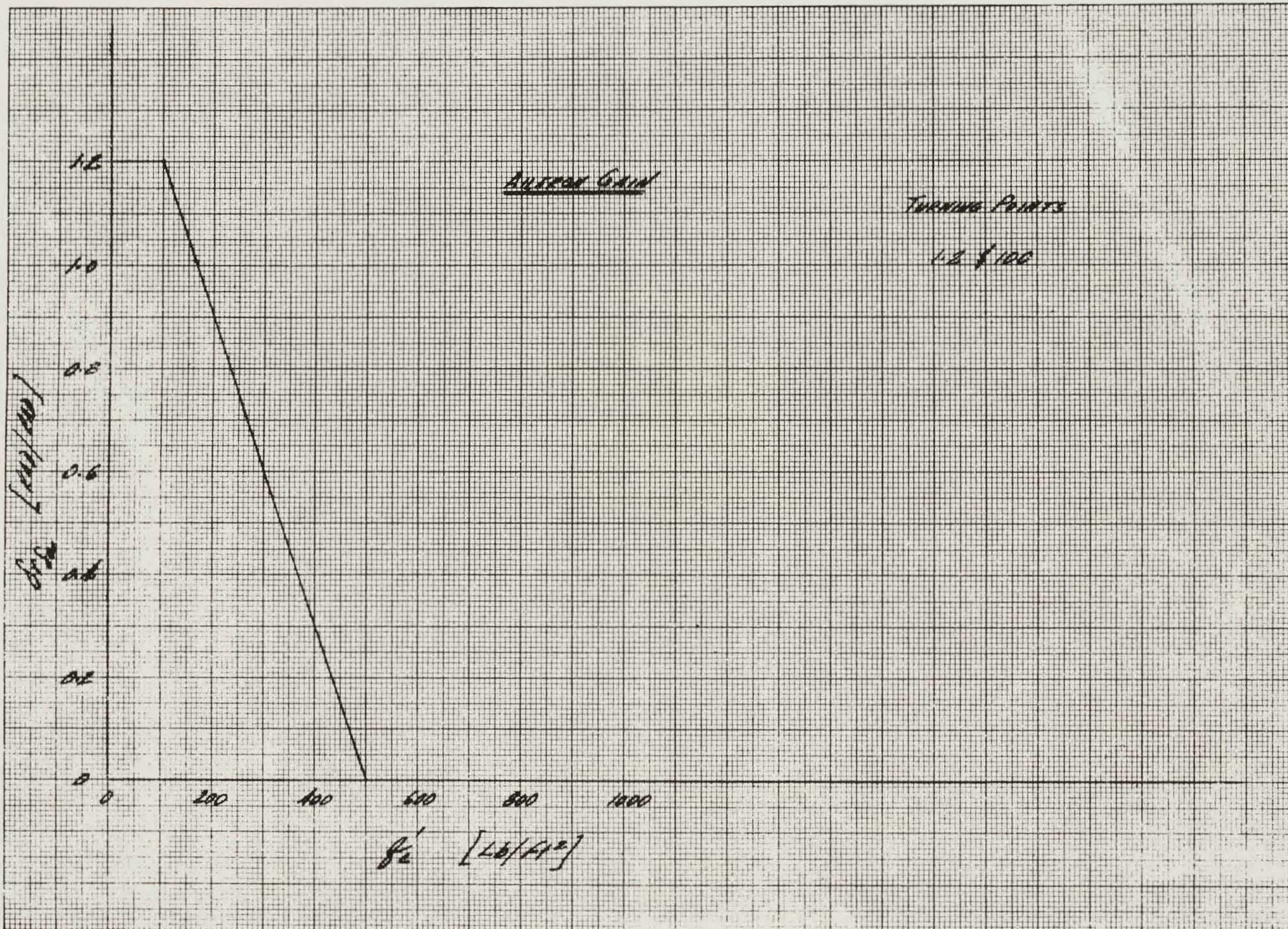
$$\delta_{R_{pos}} = \left\{ \delta_{R_r} \cdot r + \delta_a \cdot \delta_{R_{\delta_a}} + K_1 A_y \, \delta_{RAY} \right\} \frac{2S}{2S+1}$$

$$+ A_y (1 - K_1) \, \delta_{RAY}.$$


YAW RATE GAIN
NORMAL AXIS
TURNING POINTS
6.0 & 80
3.78 & 260
2.4 & 540
1.5 & 1000
0
1.0
3.0
4.0
5.0
6.0
0
400
600
800
1000
1200
1400
1600
1800
2000
LB/FT²

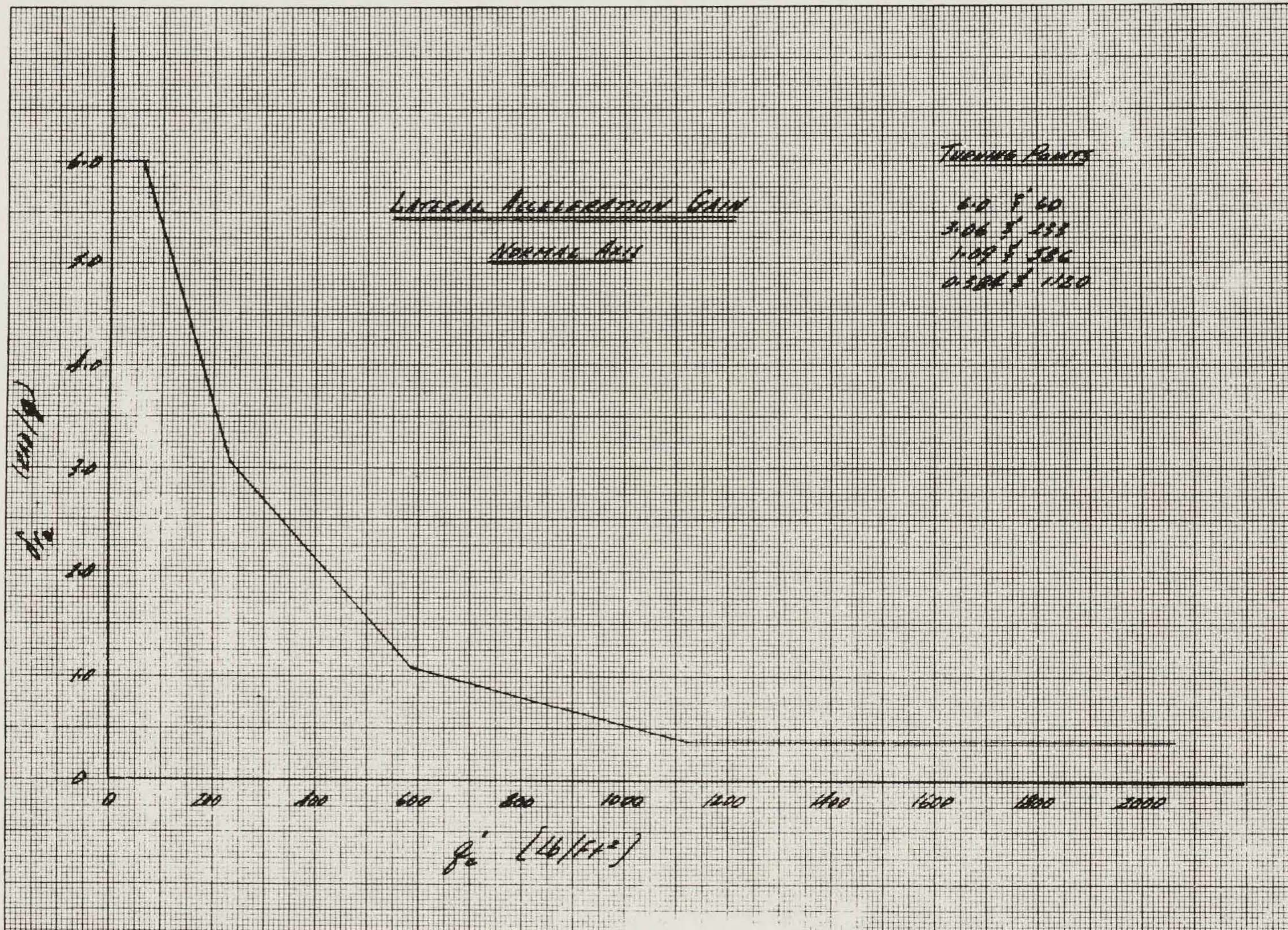

YAW RATE GAIN
EMERGENCY AXIS
TURNING POINTS
6.0 & 70
3.68 & 270
2.4 & 540
1.77 & 890
1.5 & 1100
6.0
5.0
4.0
3.0
2.0
1.0
0
0
200
400
600
800
1000
1200
1400
1600
1800
2000
[DEG/SEC/RAD]
[LB/FT²]

Gr #3 CEL #161



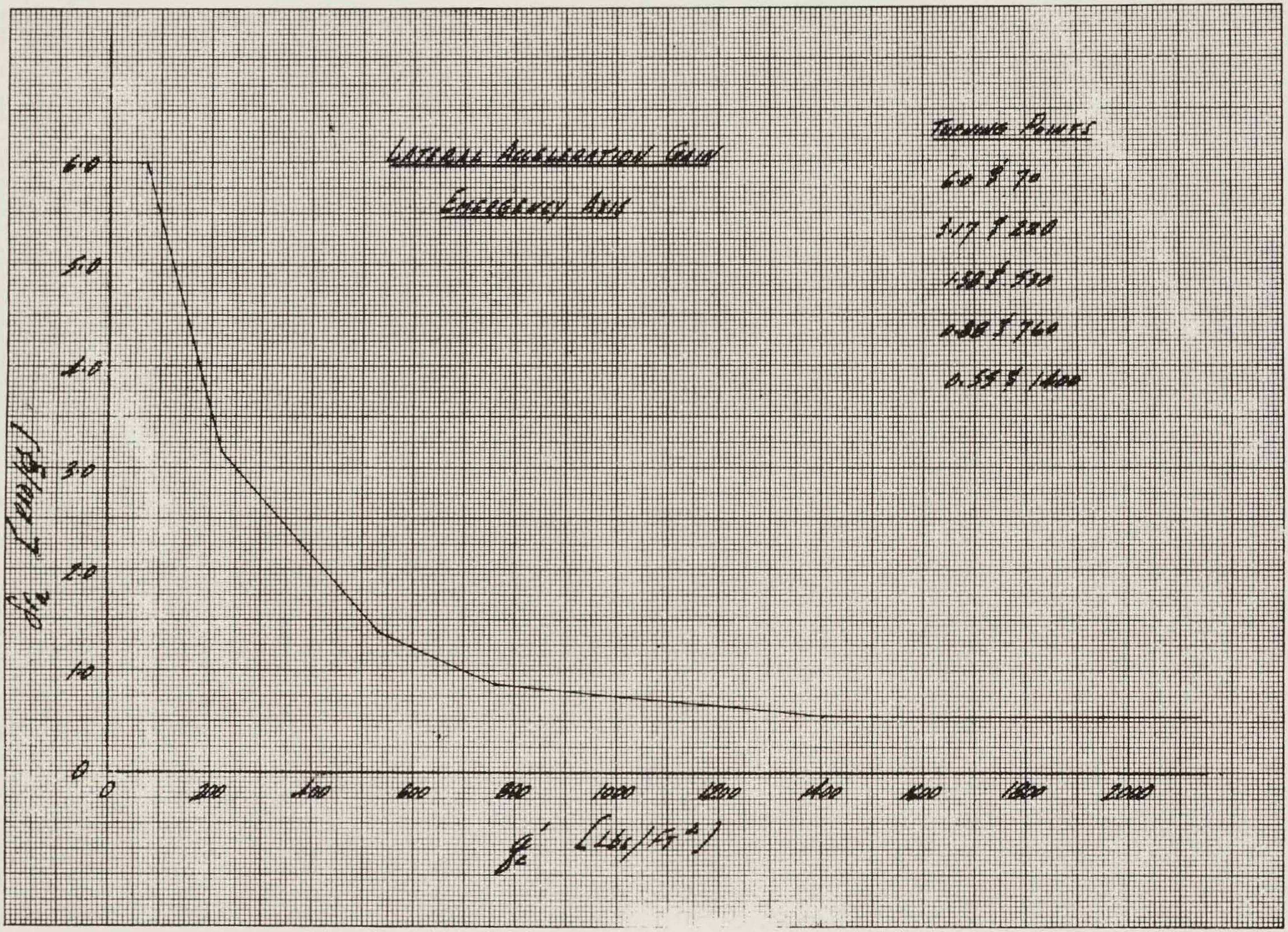
AILERON GAIN
TURNING POINTS
1.2 & 100
1.2
1.0
0.8
0.6
0.4
0.2
0
0
200
400
600
800
1000
[LB/FT²]

GR #4 CEL #161

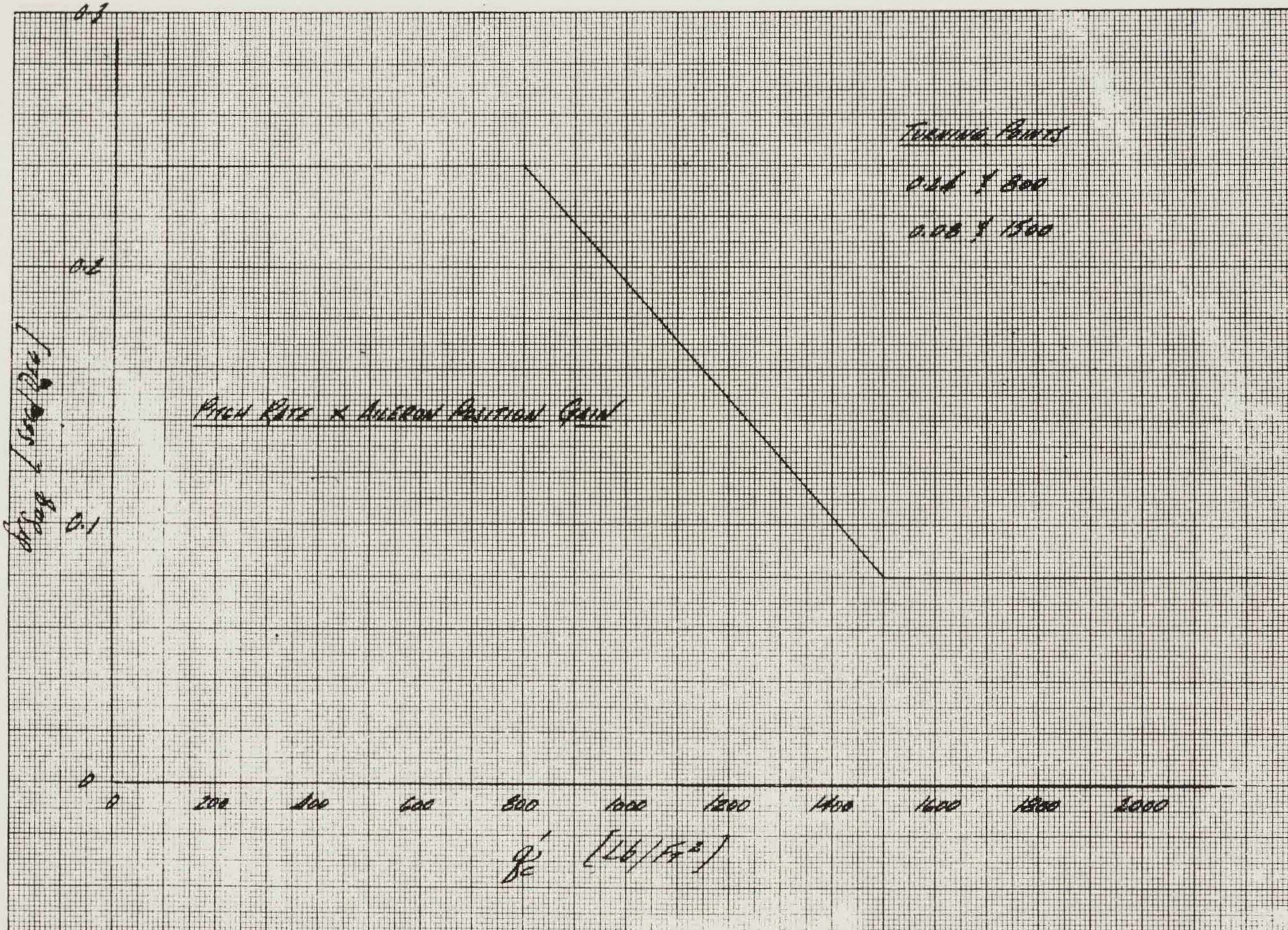


LATERAL ACCELERATION GAIN
NORMAL AXIS
TURNING POINTS
6.0 q' 60
3.06 q' 233
1.09 q' 586
0.384 q' 1120
6.0
5.0
4.0
3.0
2.0
1.0
0
0
200
400
600
800
1000
1200
1400
1600
1800
2000
(lb/ft²)

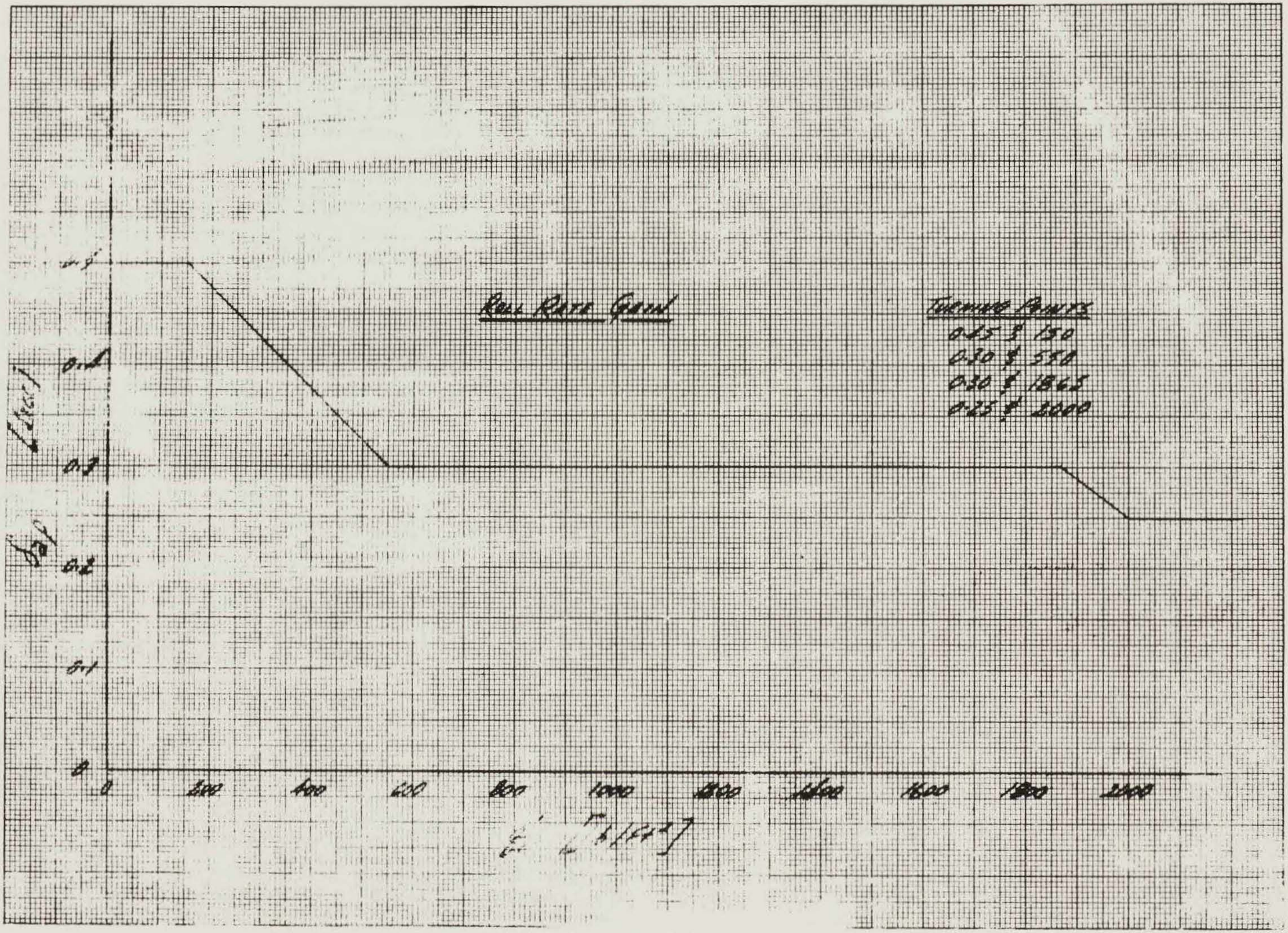
GR#5 CEL #161


LATERAL ACCELERATION GAIN
EMERGENCY AXIS
TURNING POINTS
6.0 & 70
3.17 & 220
1.38 & 530
0.80 & 760
0.55 & 1400
6.0
5.0
4.0
3.0
2.0
1.0
0
0
200
400
600
800
1000
1200
1400
1600
1800
2000
f_a [Deg/g]
f_a' [Lbs/Ft²]

GR #6 CEL #161

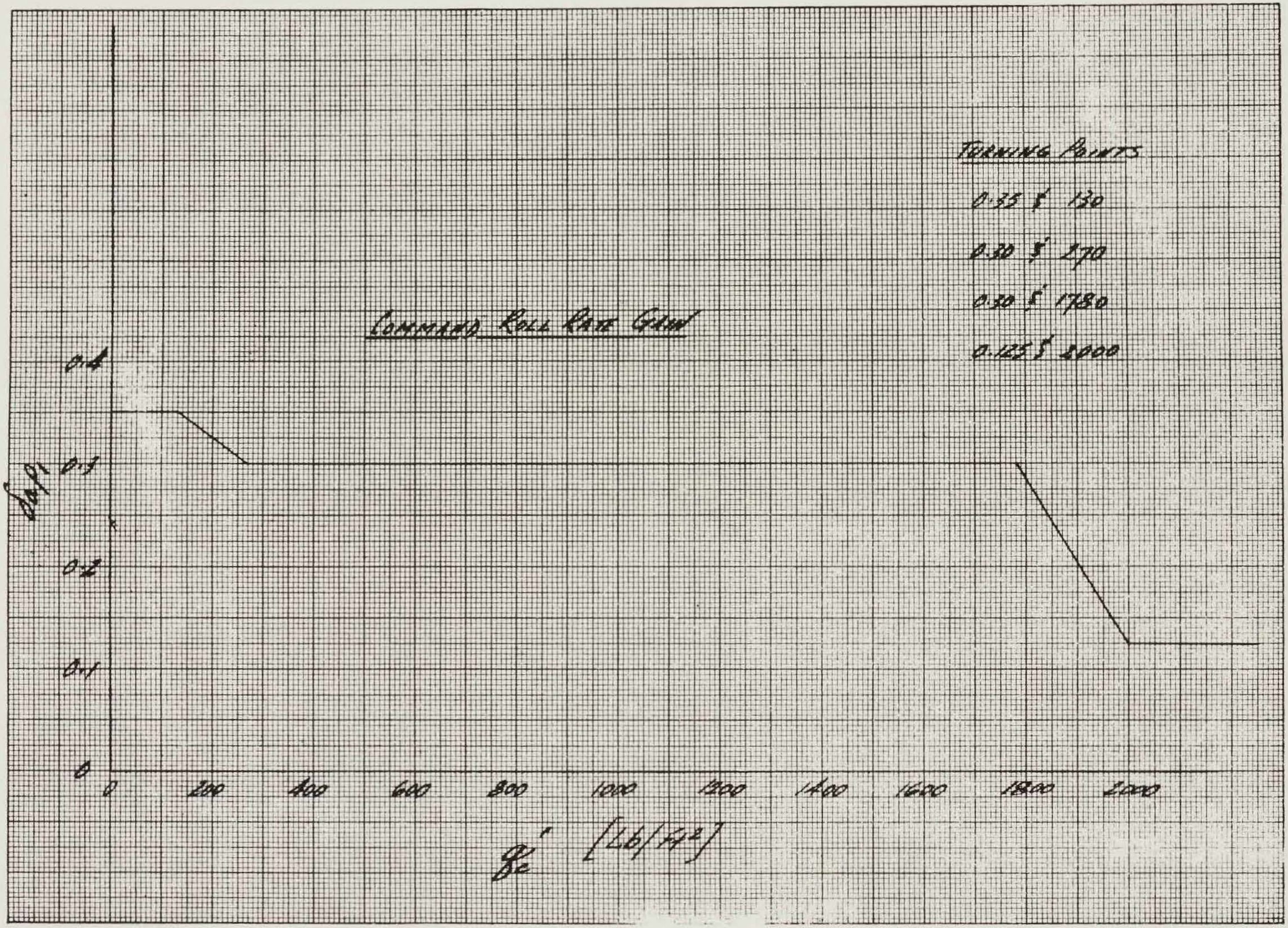

PITCH RATE × AILERON POSITION GAIN
TURNING POINTS
0.24 $ 800
0.08 $ 1500
0
0.1
0.2
0.3
0
200
400
600
800
1000
1200
1400
1600
1800
2000
[LB/FT²]

GR #7 CEL #161

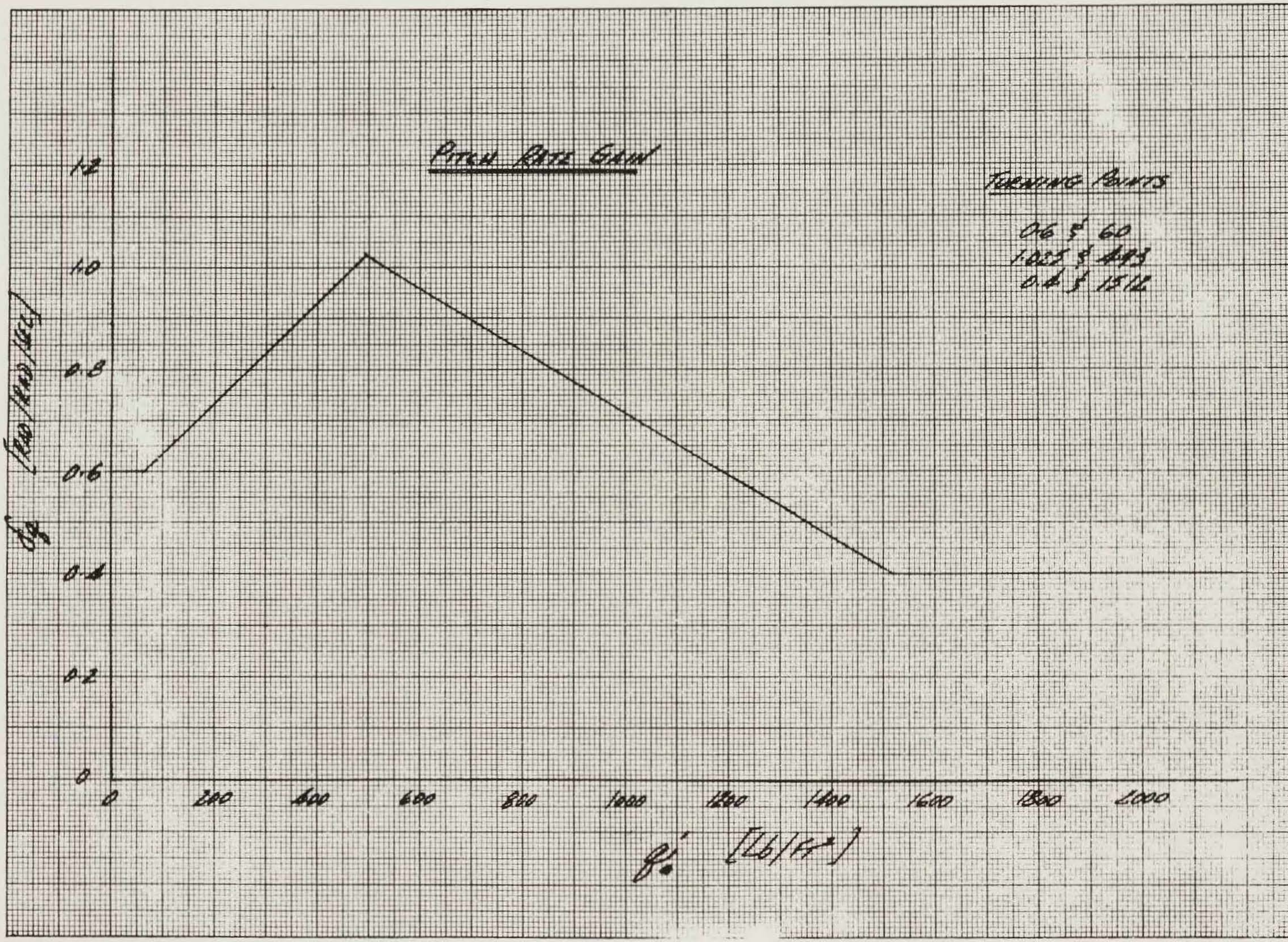


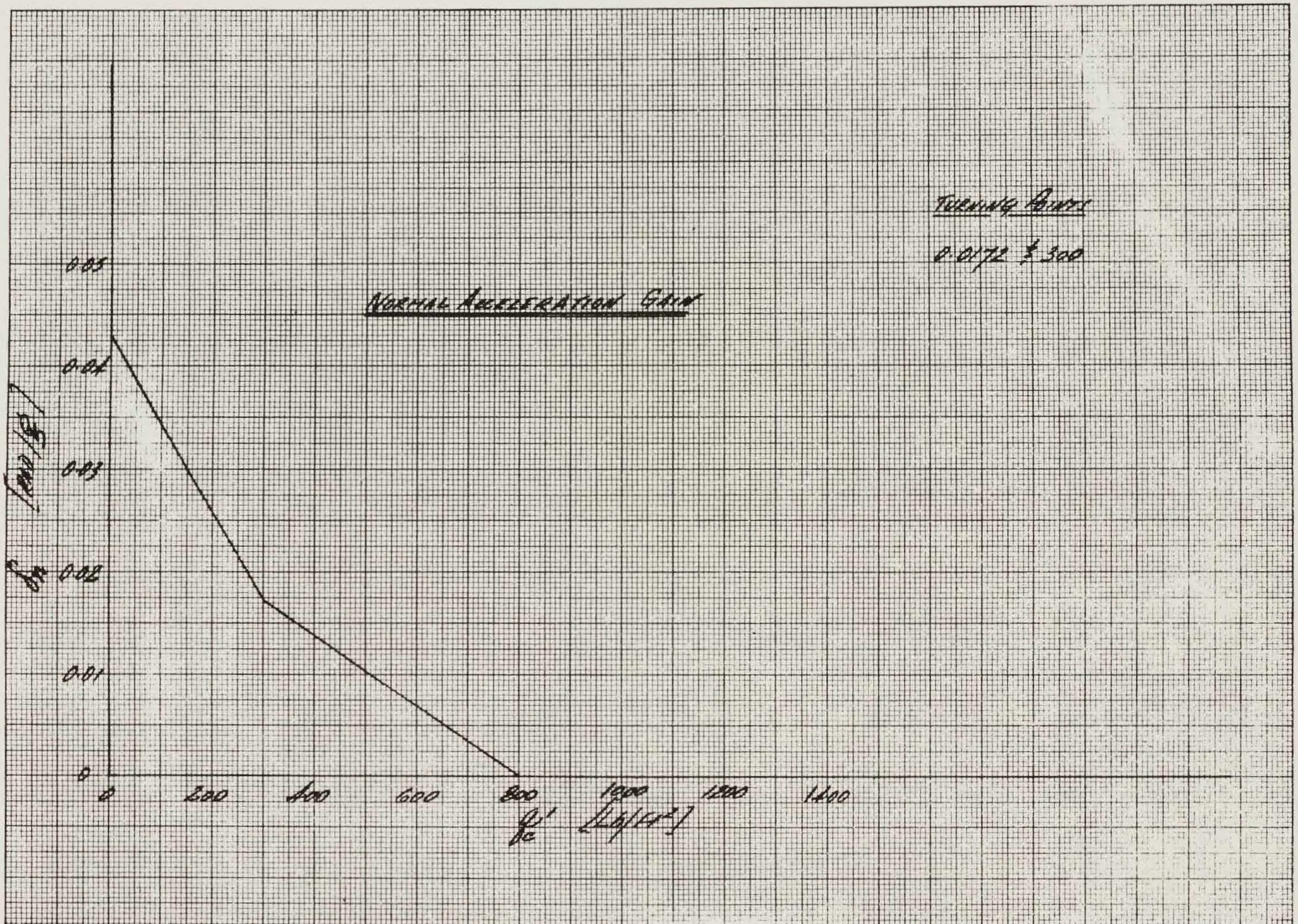
Roll Rate Gain
Turning Points
0.35 & 150
0.30 & 550
0.30 & 1865
0.25 & 2000
0
0.1
0.2
0.3
0.4
200
400
600
800
1000
1200
1400
1600
1800
2000

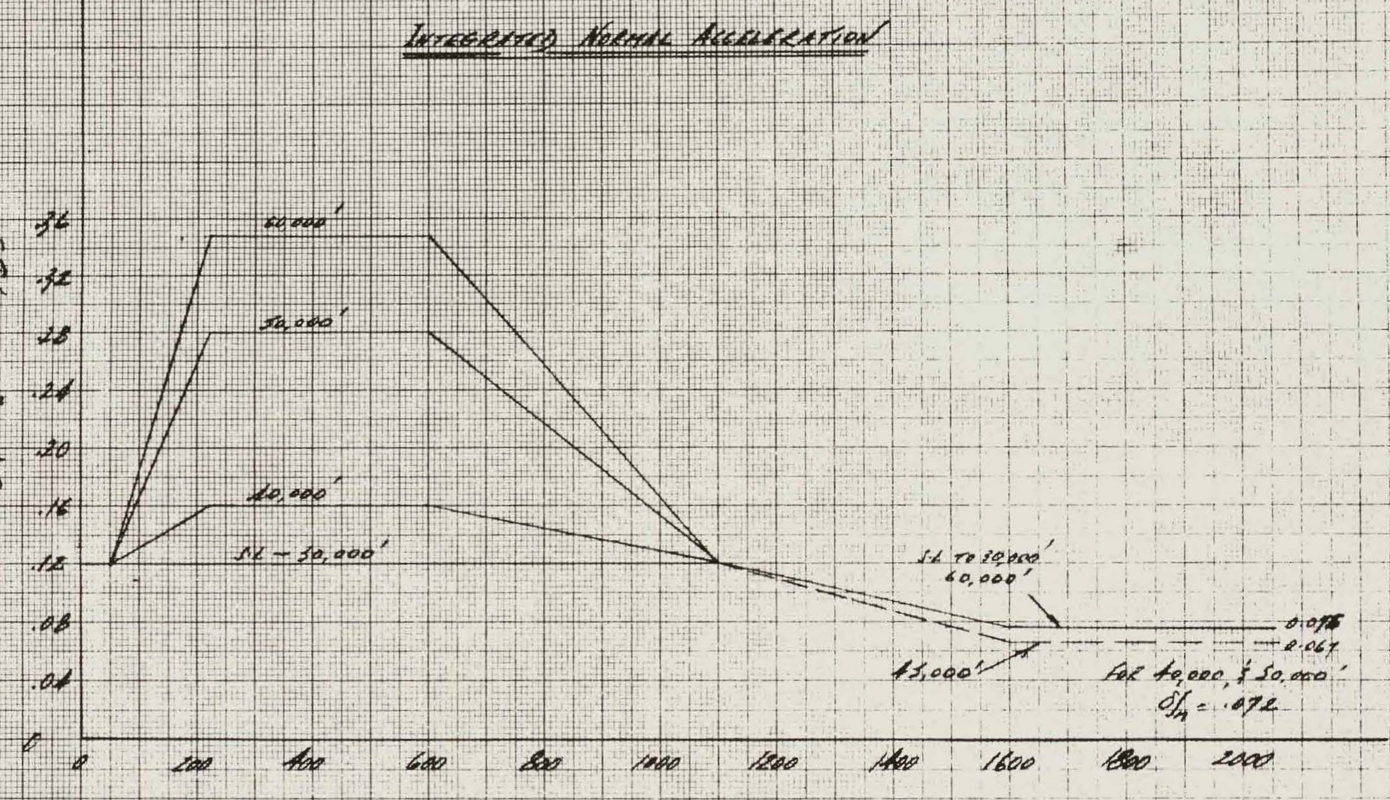
GR #8 CEL #161



COMMAND ROLL RATE GAIN
TURNING POINTS
0.35 $ 130
0.30 $ 270
0.30 $ 1780
0.125 $ 2000
0.4
0.3
0.2
0.1
0
0
200
400
600
800
1000
1200
1400
1600
1800
2000
[Lb/ft²]


PITCH RATE GAIN
TURNING POINTS
0.6 @ 60
1.025 @ 493
0.4 @ 1512
1.2
1.0
0.8
0.6
0.4
0.2
0
[RAD/RAD/SEC]
0
200
400
600
800
1000
1200
1400
1600
1800
2000
[LB/FT²]


NORMAL ACCELERATION GAIN
TURNING POINTS
0.0172 & 300
0.05
0.04
0.03
0.02
0.01
0
0
200
400
600
800
1000
1200
1400


INTEGRATED NORMAL ACCELERATION
60,000'
50,000'
40,000'
SL – 30,000'
SL TO 30,000'
60,000'
45,000'
0.076
0.067
FOR 40,000, & 50,000'
δf_n = .072
.36
.32
.28
.24
.20
.16
.12
.08
.04
0
0
200
400
600
800
1000
1200
1400
1600
1800
2000
δf_n [RAD/SEC/G]
q_c' [LBS/FT²]