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TITLE

FLIGHT TEST RESULTS OF BLACK BRANT IIA \(CC -II-29 AND 30\), FIRED AT CHURCHILL RESEARCH RANGE, JAN., 1964

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FLIGHT TEST RESULTS OF BLACK BRANT IIA (CC II-29 AND 30) FIRED AT CHURCHILL RESEARCH RANGE, JANUARY 1964

F/L B.R. Waters

CANADIAN ARMAMENT RESEARCH AND DEVELOPMENT ESTABLISHMENT

CENTRE CANADIEN DE RECHERCHES ET PERFECTIONNEMENT DES ARMES

DEFENCE RESEARCH BOARD

CONSEIL DES RECHERCHES POUR LA DEFENSE

Valcartier, Quebec

February 1965

CARDE TECHNICAL NOTE 1661
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ABSTRACT

Two Black Brant IIA rocket vehicles,(CC-II-29 and 30) were successfully flight tested at Churchill Research Range, Fort Churchill Manitoba, on January 20th 1964. Performance calculations, launch and radar data and telemetered information for these vehicles are presented. The radar information is compared with the calculated performance data.

The rocket vehicles (CC-II-29 and 30) were launched at elevation angles of 81 and 81.5 degrees respectively. The vehicles carried a 197 pound payload to a recorded peak altitude of 667,000 ft. and 671,000 ft. respectively.

TABLE OF CONTENTS

LIST OF SYMBOLS

A_b - Body cross-sectional area, ft^2.

A_e - Nozzle exhaust plane area, ft^2.

a - Acceleration, g's.

C_{Db} - Base drag coefficient.

C_{Do} - Zero lift drag coefficient.

C_{Dw} - Wave drag coefficient.

C_{Df} - Skin friction drag coefficient.

$C_{L\alpha o}$ - Vehicle, zero lift curve slope.

D - Drag, lb.

H - Altitude, ft.

I_z - Pitch moments of inertia, slugs ft^2.

I_x - Roll moments of inertia, slugs ft^2.

M - Mach No.

P - Engine pressure, lb/ft^2.

P_i - Ambient pressure, lb/ft^2.

R - Range, ft.

T_s - Temperature, ^oC.

T - Thrust, lb.

t - Time, sec.

tb - Burning time, sec.

V - Velocity, ft/sec.

vw - Wind velocity, ft/sec.

W - Weight, lb.

Xcg - Distance from the apex of the nose cone to the vehicle center of gravity, inches.

LIST OF SYMBOLS (cont'd)

X_{cp} - Distance from the apex of the nose cone to the vehicle center of pressure, inches.

$\ddot{X}$ - Longitudinal acceleration, g's.

$\ddot{Y}$ - Yaw acceleration, g's.

$\ddot{Z}$ - Pitch acceleration, g's.

θ - Launch or position angle, degrees.

θ_w - Wind direction, degrees.

ψ - Yaw position angle, degrees.

ϕ - Roll position angle, degrees.

δ_{xoy} - Yaw angle of attack, degrees.

δ_{xoz} - Pitch angle of attack, degrees.

w_o - Pitching frequency, cps.

LIST OF FIGURES

LIST OF FIGURES (cont'd)

INTRODUCTION

Two Black Brant IIA rocket vehicles (CC-II-29 and 30) were flight-tested in January 1964 at the Churchill Research Range, Fort Churchill, Manitoba. The vehicles were flown with a new 3-fin stabilizer assembly, designed and manufactured by Bristol Aero-Industries Ltd.

This Technical Note presents the aerodynamic characteristics, the performance calculations and the flight test results of these vehicle tests. The flight objectives were as follows:-

1) To flight test the new BAIL fin design.

2) To record propellant ballistic data by means of telemetered information.

3) To obtain trajectory and dispersion data.

4) To measure vehicle dynamic motions.

ROCKET VEHICLE

General

The Black Brant IIA rocket vehicles in this test series used the original Canadair designed nose cone, the CARDE 15KS25000 rocket engine and the new BAIL design three fin stabilizer assembly.

The vehicles used in these tests were aerodynamically stabilized by three large fixed fins and were uncontrolled in flight. The basic vehicle is 17.20 inches in diameter, 27.3 feet long and has a fin-span of 59.2 inches. The weights of these vehicles (CC-II-29 and 30) at launch were 2684 pounds and 2684.5 pounds respectively. The estimated rigid static stability margin was 2.0 calibers (body diameter) at burnout and the effect of fin flexibility was negligible.

A photograph of the rocket vehicle is shown in Figure 1 and the outline of the vehicle configuration is given in Figure 2.

Nose Cone

The nose cone consisted of a standard Black Brant II cone-cylinder housing 120 pounds of instrumentation cantilevered forward from a mounting ring located at station 87.50 in the cylindrical section. The total weight of the instrumented nose cone was 297 pounds and its center of gravity was located at station 68.21 (with the zero reference station at the apex of the nose cone) see Figure 2. A photograph of the nose cone and instrumentation is shown in Figure 3.

Rocket Motor

The CARDE 15KS25000 propulsion unit is used to power these Black Brant IIA rocket vehicles. The total impulse at sea-level is 380,000 lb-sec. with a nominal burning time of 15.5 sec. Tabulated engine performance data is presented in Table III.

Rocket Motor (cont'd)

In the performance calculations, the sea-level thrust was corrected for an increase in thrust at altitude by the term:

$$T = (2116.8 - P_i)\ A_e$$

where P_i is the instantaneous ambient pressure during the rocket powered flight, lb/ft^2.

A_e is the exit area of the nozzle, ft^2.

T Thrust, lb.

The unburnt and burnt weights and the center of gravity locations of CC-II-29 and 30 rocket engines are given in Table I. A photograph of the rocket engine and nozzle assembly is shown in Figure 4.

Igniter

The igniter assembly consisted of a flame tube and the main igniter charge attached to the head end enclosure of the engine. A photograph of the igniter assembly is shown in Figure 5. The McCormick Selph M56 squib is illustrated in detail in Figure 6.

Fin Assembly

The fins flown on vehicles CC-II-29 and 30 were designed and manufactured by Bristol Aero-Industries Ltd. This fin assembly is a three-fin configuration with the fins mounted on a cast magnesium support structure. An outline of the fin configuration is shown in Figure 9.

The fin is made up of a truss grid core bonded to a .063 in. thick aluminum skin covered with a .06 in. thick ablative coating. A titanium cuff (.06 in.) is used to cap the aluminum leading edge block and the (.26 in.) trailing edge is filled with a polyester high temperature resin. Two photographs of the fin assembly are shown in Figures 7 and 8.

Launcher

Black Brant II rocket vehicles are fired underslung from zero-tip-off launcher. The rail system consists of a single forward rail and two rear rails 15 feet in length. A layout of the launcher lugs and a layout of the rails and alignment data are shown in Figures 10 and 11.

INSTRUMENTATION

The telemetry system consisted of a 10 channel FM/FM unit operating at a transmitting frequency of 225.7 Kc and had a radiative power output of 5 to 6 watts. The transmitter, subcarrier oscillators, commutators, keyer and converter were packaged as a complete unit in a sealed container. In the event of a component failure the complete package could have been replaced to avoid delaying a firing. A photograph of the telemetry package is shown in Figure 3.

INSTRUMENTATION (cont'd)

A list of the measured functions, ranges, frequency of response and channel allocations of the instrumentation is given in Table II. A range supplied DPN 41 radar beacon was flown on CC-II-29 and 30 with a set of S-Band quadraloop antennas from New Mexico State University.

VEHICLE DATA

General vehicle information is given in Table I. The vehicle time-dependent parameters during the boost phase of the rocket are presented in Figures 12 to 18 and Table IV.

STABILITY

The stability derivatives have been determined using References 2, 3 and 4. The center of gravity of the various components was obtained from the vehicle check out data. The basic lift-curve slope is referred to the body cross-sectional area A_B. The slope of the coefficient of lift at zero angle of attack and the center of pressure versus Mach No. for:-

a) The nose and afterbody is shown in Figure 19.

b) The fins in the presence of the body in Figure 20.

c) The complete vehicle in Figure 21.

The static stability margin (rigid structure) versus Mach No. is presented in Figure 22.

DRAG

The calculated wave and base drag coefficients were prepared using References 3 and 4 as functions of Mach No. and are presented in Figure 23. The skin friction drag was computed along with the flight history of the rocket. Figure 25 presents the variation of the skin friction coefficient as a function of Reynolds No. and Mach No. The total zero lift drag coefficient versus Mach No. is given in Figure 26. The total drag versus time is given in Figure 24 and in Table IV.

PERFORMANCE

Predicted performance data were calculated for a vehicle launch weight of 2675 pounds and a zero wind launch elevation angle of 80 degrees. Calculated performance information and radar flight data are compared in Figures 29 to 33 for CC-II-29 and in Figures 34 to 38 for CC-II-30.

FLIGHT-TESTING

General

Black Brant IIA (CC-II-29 and 30) rocket vehicles were flight-tested at Churchill Research Range, Fort Churchill, Manitoba on January 20th, 1964. A summary of the launch conditions for the vehicles is given in Table V.

Telemetry Results

Excellent telemetry results were obtained on both flights from launch to impact. The flight time of CC-II-29 was 433 seconds and that of CC-II-30 was 424 seconds. The rocket vehicles carried the instrumentation outlined in Table II. The telemetry quick look recordings for the first 25 seconds of flight time for CC-II-29 and 30 are reproduced in Figures 32A and 32B, 37A and 37B respectively. The telemetry recordings of the reentry phase of the vehicles' flights are presented in Figures 32C and 32D, 37C and 37D respectively. In Figures 32A, 32C, 37A and 37C the following telemetered functions are shown:-

$\ddot{X}$ - Longitudinal acceleration.

$\ddot{Y}$ - Yaw acceleration.

$\ddot{Z}$ - Pitch acceleration

δ_{xoz} - Pitch angle of attack.

δ_{xoy} - Yaw angle of attack.

P_e - Engine pressure #1 (Stathem gauge).

- Ground Station timing.

In Figures 32B, 32D, 37B and 37D the following telemetered functions are shown:-

θ_p - Roll position angle (pitch)

ϕ - Roll position angle (yaw)

- X axis magnetometer.
- Y axis magnetometer.
- Z axis magnetometer.
- Engine pressure #2 (Bourns gauge)
- Ground Station timing.

A study of the telemetry flight recordings indicated the following results:-

1) Longitudinal Accelerometers

The longitudinal accelerometer output was normal on both vehicles with no evidence of unusual accelerations.

2) Pitch and Yaw Accelerometers

These accelerometers indicated that both vehicles experienced slight oscillatory motions during the tail off of the boost phase. The maximum lateral acceleration recorded on both flights was approximately 1/4 g.

3) Pitch and Yaw Angle of Attack

The pitch and yaw angle of attack outputs indicated oscillatory motions with increasing amplitude and period starting after burnout on both vehicles. Both vehicles were subjected to very small angles of attack in the denser portion of the atmosphere.

4) Engine Pressure Transducers

Two engine pressure transducers were mounted on the head end of each of the engines. The engine pressure was normal on both flights. The reduced engine pressure data will be reported on separately.

5) Roll Position Gyros

These indicated that vehicle CC-II-29 had a maximum spin rate of .36 rps at 16 seconds which decreased to .15 rps for the remainder of the flight. Vehicle CC-II-30 had a maximum spin of .14 rps at 16 sec. which decreased to .05 rps for the remainder of the flight.

6) X-Axis Magnetometer

The X-axis magnetometer on vehicle CC-II-30 indicated that the axis of the vehicle moved through 140° from T + 80 seconds to T + 360 seconds at which time re-entry into the denser atmosphere took place. Vehicle CC-II-29 started a similar movement at T + 70 seconds, moved through 125° by T + 260 seconds and back to 58.5° at T + 370 when it re-entered the denser portion of the atmosphere.

7) Y and Z Axis Magnetometers

These magnetometers confirmed the spin data provided by the gyros. They also indicated a rapid rise in spin rate to 2 rps in the last five seconds before impact.

8) Skin Temperatures

The maximum skin temperature recorded during the flights was 228°C at T + 30 seconds on the conical section (station 36) and 135°C at T + 40 seconds on the cylindrical section (station 94). Plots of reduced temperatures are presented in Figures 33 and 38.

Radar Data

Two AN/MPS-19 radars were used to track the vehicles in skin and beacon modes using the DPN41 radar beacon. Reduction of radar data has not been possible, however some useful data was obtained from the analog plots of test vehicle position versus time plotted as X versus Y and H versus R.

CC-II-29

This vehicle was skin tracked to T + 61 seconds and an altitude of 314,900 feet. In the beacon mode the radar tracked the vehicle from T + 68 seconds through to impact at T + 433 seconds at a range of 424,500 feet. A peak altitude of 667,000 feet was attained after 220 seconds of flight time. A maximum velocity of 6,450 ft/sec at T + 17.5 seconds was obtained at an altitude of 73,600 feet.

CC-II-30

This vehicle was skin tracked to T + 59 seconds and an altitude of 294,250 feet. In the beacon mode the radar tracked the vehicle from T + 64 seconds through to impact at T + 424 seconds at a range of 385,680 feet. A peak altitude of 671,000 feet was attained after 215 seconds of flight time. A maximum velocity of 6,365 ft/sec at T + 17.5 seconds was obtained at an altitude of 72,300 feet.

Radar data for CC-II-29 and 30 vehicles are presented in the following form and compared with the calculated performance of a 2675 lb vehicle fired into a cold atmosphere with an 83.5 degree launch.

a) Measured and calculated altitudes versus total flight time, Figures 29 and 34.

b) Measured and calculated trajectories, Figures 30 and 35.

DISCUSSION OF RESULTS

The flight tests of both these vehicles were very successful. The telemetry functioned faultlessly throughout both flights. The DPN 41 radar beacons with the University of New Mexico antennas worked well and both vehicles were radar tracked to impact. As only two antennas were used and the vehicles had a very slow spin rate, nuls were experienced in the radar tracking.

The new Bristol Aero Industries three fin system was flown successfully on both vehicles. The weight, drag and flexibility characteristics of these fins are very good. It appears that the use of Avcoat as a ablative coating on the fins affects the flight characteristics of the fin in two ways. It reduces the accuracy of spin prediction, and also reduces the accuracy of the prediction of unbalanced lateral forces on the fins due to misalignment. For accurate prediction of the spin rate and unbalanced lateral forces it is necessary to know the misalignment of the fin surfaces due to manufacturing and assembly errors. The ablation of the Avcoat in flight must change the surface contours of the fin. Both these vehicles experienced tumbling motions in flight as recorded by the X-axis magnetometers. These motions were probably caused by unbalanced lateral fin forces with spin yaw resonance and trim magnification effects.

REFERENCES

1. Delisle, J.R.: "Flight Test Results of Black Brant IIA (CC-II-54 and 55) Fired at Wallops Island, Va., August 1962". CARDE TN 1547/63 (Unclassified).

2. Syvertson, Clarence A. and Deniss, David H.: "A Second-Order Shock Expansion Method Applicable to Bodies of Revolution Near Zero Lift". NACA TN 3527 January 1958. (Unclassified)

3. Royal Aeronautical Society, Royal Aeronautical Society Data Sheets. Volumes 1-3, Twelfth Issue, 1961. (Unclassified)

4. Hoerner, Sighard, F.: "Fluid Dynamic Drag" Published by the Author, 1958. (Unclassified)

TABLE I

Vehicle Data CC-II-29 and 30

Weights and Centers of Gravity

Items	CC-II 29 Vehicle Weight lb.	CC-II 29 Vehicle C. of G. Sta. in.	CC-II 30 Vehicle Weight lb.	CC-II 30 Vehicle C. of G. Sta. in.
Nose Cone and payload	297	69.9	300	70.6
Motor (unburnt)	2268.5	204.3	2266	204.3
Motor (burnt estimated)	494.0	214.0	488.5	211.5
Fin assembly	118	306.5	114.5	306.3
Complete vehicle (unburnt)	2684	193.7	2684.5	193.6
Complete vehicle (burnt)	909.5	178.0	907.0	175.0

Vehicle Parameters

Over-all length, inches	334.6
Body diameter, inches	17.20
Body area, ft^2	1.614
Length of conical section, inches	86.0
Length of cylindrical section, inches	24.0
Cone semi-apex angle, degrees	5.73
Gross payload volume, ft^3	6.0
Parallel length of casing, inches	184.0
Fin semi-span, inches	29.6
Fin root chord, inches	48.25
Fin tip chord, inches	24.0
Fin sweepback angle leading edge, degrees	60.0
Fin sweepback angle trailing edge, degrees	10.0
Fin planform area (each) ft	5.25
Nozzle length, inches	21.0
Nozzle throat diameter, inches	5.25
Nozzle exit diameter, inches	13.46
Nozzle exit area, ft^2	.988
Pitch moments of inertia (unburnt) slugs ft^2	2,906.8
Pitch moments of inertia (burnt) slugs ft^2	1,751.8
Roll moments of inertia (unburnt) slugs ft^2	31.3
Roll moments of inertia (burnt) slugs ft^2	14.3

TABLE II

Telemetry Range and Channel Allocation

CC-II 29 and 30

Instrument or Reading	Range	Channel	Freq. Response	30x30 PDM Channel #	30x5 PAM Channel #
Yaw angle of attack	± 5°	7	35 cps		
Pitch angle of attack	± 5°	8	45 cps		
Roll attitude, pitch	± 180°	9	59 cps		
Roll attitude, yaw	± 180°	10	80 cps		
Acceleration yaw	± 5g	11	110 cps		
Acceleration pitch	± 5g	12	160 cps		
Acceleration longitudinal	- 5 to +25g	13	220 cps		
Pressure #1, engine	0-1500 psi	C	1200 cps		
MASTER PULSE	-	E	30 sps	29-30	
Voltage Reference	0 & 5v	E	30 sps	14-15	
X axis attitude Magnetometer	0-5v	E	60 sps	1-16	
Y axis attitude Magnetometer	0-5v	E	60 sps	17	
Z axis attitude Magnetometer	0-5v	E	60 sps	3-18	
Spare		E	60 sps	4-19	
Pitch attitude	± 15°	E	60 sps	5-20	
Yaw attitude	± 15°	E	60 sps	6-21	
Pressure #2, engine	0-2000 psi	E	30 sps	9-	
X axis bias	+ 2.5v	E	30 sps	10-	
Y axis bias	+ 2.5v	E	30 sps	25	
Z axis bias	+ 2.5v	E	30 sps	11-	
Forw. R.F. Power	0-5v	E	30 sps	26	
Backw. R.F. Power	0-5v	E	30 sps	12-	
Ant. Bias Monitor	0-5v	E	30 sps	27	
Battery TM	0-32v	E	30 sps	13-	
Battery Motors	0-32v	E	30 sps	28	
TEMPERATURES				Rdf Type#	
Sta. 36 0 330	0-350°	A	5 sps	200	1
Sta. 36 0 90	0-350°	A	5 sps	"	2
Sta. 36 0 210	0-350°	A	5 sps	"	3
Spare				"	7to9,16to21
Sta. 94 0 30	0-350°	A	5 sps	"	10
Sta. 94 0 150	0-350°	A	5 sps	"	11
Sta. 94 0 270	0-350°	A	5 sps	"	12
Magnetometer Block	0-200°	A	5 sps	400	4
Gyro frame	0-200°	A	5 sps	"	5
Batt. frame	0-200°	A	5 sps	"	6
TM Xmitter	0-200°	A	5 sps	"	13
TM sco's	0-200°	A	5 sps	"	14
TM Commut.	0-200°	A	5 sps	"	15
CALIBRATIONS	100 ohms/step	A	5 sps		22to29
Sync.	1000 ohms	A	5 sps		30

NRC EXPERIMENTS CC-II-29		
Unprocessed output	30 x 30 PDM Channels	7-22, 8-29
Processed output	1.7 Kc s.c.o.	
NRC EXPERIMENTS CC-II-30		
Unprocessed output	1.7 Kc s.c.o.	
Processed output	30 x 30 PDM Channels	7-22, 8-29

TABLE III

Engine Propulsion Data (Temperature 73°F)

Time sec.	Average Thrust Sea Level lb	Average Thrust Altitude Corrected lb	Average Thrust Vacuum lb
0-1	27,800	27,805	29,890
1-2	26,200	26,227	28,290
2-3	26,200	26,270	28,290
3-4	26,100	26,232	28,190
4-5	25,900	26,118	27,990
5-6	25,600	25,917	27,690
6-7	25,500	25,933	27,590
7-8	25,300	25,863	27,390
8-9	25,000	25,724	27,090
9-10	24,400	25,236	26,490
10-11	24,200	25,181	26,290
11-12	23,800	24,930	25,890
12-13	22,300	23,579	24,390
13-14	21,200	22,621	23,250
14-15	14,900	15,985	16,370
15-16	7,700	8,283	8,450
16-17	3,800	4,116	4,160
17-18	1,800	1,928	1,970
18-19	300	319	330
19-20	0	0	0

Propellant weight, lb.	1,760
Propellant discharge, lb.	1,780
Total Impulse (S.L.), lb-sec.	378,000
Total Impulse (Vacuum), lb-sec.	410,000
Nozzle exit area, ft^2.	.988
Nominal burning time, sec.	15.5

TABLE IV

Time Dependent Data CC-II-29 and 30

Time sec.	Weight lb	Pitch Inertia Slugs ft^2	Roll Inertia Slugs ft^2	Xcg in.	Total Drag lb	q lb.	M No
0	2675	2907	31.3	193.7	0	0	0
1	2550	2826	30.2	193.3	110	91	.27
2	2425	2745	29.1	192.8	350	441	.57
3	2300	2664	27.9	192.3	780	1063	.90
4	2180	2587	26.9	191.8	1410	1880	1.20
5	2060	2509	25.8	191.2	1930	2870	1.51
6	1950	2438	24.8	190.6	2370	3975	1.85
7	1830	2360	23.7	189.9	2760	5220	2.25
8	1720	2289	22.6	189.1	3070	6440	2.6
9	1600	2211	21.6	188.1	3280	7770	3.02
10	1485	2137	20.6	187.1	3430	8920	3.50
11	1375	2066	19.6	185.9	3500	9810	3.93
12	1270	1998	18.7	184.5	3470	10570	4.47
13	1165	1930	17.8	182.9	3360	10860	5.07
14	1060	1862	16.8	181.1	3150	10880	5.75
15	980	1810	16.1	179.3	2730	9960	6.27
16	925	1775	15.6	178.0	2160	8110	6.57
17	900	1759	15.4	177.3	1650	6000	6.65
18	890	1752	15.3	177.1	1270	4340	6.60
19	890	1752	15.3	177.1	990	3111	6.55
20	890	1752	15.3	177.1	750	2340	6.50

TABLE V

Launch Data CC-II-29 and 30

	CC-II-29	CC-II-30
Firing Date	20 January, 1964	20 January, 1964
Time of Firing	15:15 CST	12:00 CST
Launch Site	CRR Manitoba	CRR Manitoba
Instrumented by	CARDE	CARDE
Launcher, Elevation Angle	77° 48'	79° 12'
Launcher, Azimuth Angle	129° 06'	141° 18'
Motor Temperature (approx)	62°F	57°F
Time on Pad	12:30 CST	09:30 CST
Air temperature at time of firing	+ 5°F	0°F
Launch weight	2684 lb.	2684.5 lb.
Payload and Ballast	180 lb.	183 lb.
Zero wind elevation angle	83.5°	83.5°

TABLE VI

Wind Component Calculation

Vehicle CC-II 29 Launch Winds predicted from Aerovane, Pibal and Rawin Data

Altitude Meters	Direction	γ	Speed Meters/sec	N-S Component	E-W Component
SFC	003	3	7.2	+ 7.2	+ 0.4
59	010	10	5.6	+ 5.5	+ 0.5
117	006	6	6.7	+ 6.6	+ 0.7
234	360	0	8.8	+ 8.8	+ 0.0
350	003	3	10.7	+10.7	+ 0.6
457	017	17	12.1	+11.6	+ 3.5
563	022	22	13.7	+12.7	+ 5.1
670	025	25	12.0	+10.9	+ 5.1
774	023	23	10.8	+ 9.9	+ 4.2
877	022	22	11.2	+10.4	+ 4.2
980	025	25	11.1	+10.1	+ 4.7
1082	025	25	11.6	+10.5	+ 4.9
1390	058	58	8.0	+ 4.2	+ 6.8
2050	059	59	8.5	+ 4.4	+ 7.3
2370	056	56	8.4	+ 4.7	+ 6.9
3190	068	68	4.0	+ 1.5	+ 3.7
3910	035	35	2.5	+ 2.0	+ 1.5
4610	036	36	3.4	+ 2.7	+ 2.0
5620	218	38	2.4	- 1.9	- 1.5
7000	274	86	3.8	+ 0.3	- 3.8
9500	276	84	10.2	+ 1.1	-10.1
11800	264	84	15.6	- 1.6	-15.5
13200	255	75	22	- 5.7	-21.3

TABLE VI cont'd

Calculation of Ballistic Wind

Vehicle CC-II 29 T = 0 15:15 CST 20 January, 1964

Layer Number	Altitude Meters	Weighting Factor	N-S	N-S Weighted	E-W	E-W Weighted
1	15.0	1	+ 7.3	+ 7.3	+ 0.3	+ 0.3
2	22.5	1	+ 7.3	+ 7.3	+ 0.3	+ 0.3
3	35.0	1	+ 7.4	+ 7.4	+ 0.3	+ 0.3
4	52.5	1	+ 7.4	+ 7.4	+ 0.4	+ 0.4
5	77.5	1	+ 7.5	+ 7.5	+ 0.5	+ 0.5
6	120.0	1	+ 7.8	+ 7.8	+ 0.6	+ 0.6
7	197.5	1	+ 8.4	+ 8.4	+ 0.5	+ 0.5
8	377.5	1	+ 9.9	+ 9.9	+ 0.1	+ 0.1
9	1070	1	+10.7	+10.7	+ 3.0	+ 3.0
10-i	2600	.5	+ 8.6	+ 4.3	- 1.5	+ 3.3
10-ii	4400	.2	+ 2.2	+ 0.44	+ 3.0	+ 0.6
10-iii	7600	.2	+ 0.4	+ 0.08	- 1.5	- 0.3
10-iv	12800	.1	- 0.4	- 0.04	-12.0	- 1.2
Sum	-	10		+78.48		+ 8.40
Ballistic Wind Components				+ 7.85		+ 0.84

$$\frac{(de)}{(dw)t} = 1.20^\circ \text{ per meter/sec.}$$

TABLE VI cont'd

Prediction of Wind Effect

Vehicle CC-II 29

	Elevation	Azimuth
Desired no wind launcher settings.	080°	095°
Actual launcher settings-wind weighted.	077.8°	129.1°
Effective launcher setting obtained.	083°	099.5°

The variation between the desired launcher settings and the effective launcher settings was partially due to an error in the selsyn control from the launcher to the block house as well as the normal inaccuracy due to pre-flight wind prediction. From wind information gathered before and after the flight the true launcher settings would have been 77° elevation and 140° azimuth in order to obtain the desired trajectory.

TABLE VI cont'd

Wind Component Calculation

Vehicle CC-II 30   Launch Winds predicted from Aerovane Pibal and Rawin Data

Altitude Meters	Direction	γ	Speed Meters/sec	N-S Component	E-W Component
SFC	018	18	4.6	+4.4	+1.4
59	027	27	7.2	+6.4	+3.3
117	029	29	7.6	+6.6	+3.7
234	027	27	9.0	+8.0	+4.1
350	022	22	9.1	+8.4	+3.4
457	033	33	11.0	+9.2	+6.0
563	042	42	13.9	+10.3	+9.3
670	042	42	12.4	+9.2	+8.3
774	052	52	11.1	+6.8	+8.7
877	057	57	11.4	+6.2	+9.6
980	058	58	12.0	+6.4	+10.2
1082	061	61	10.9	+5.3	+9.5
1460	069	69	5.8	+2.1	+5.4
2100	055	55	8.3	+4.8	+6.8
2730	068	68	9.5	+3.6	+8.8
3690	075	75	6.2	+1.6	+6.0
4700	085	85	4.2	+0.4	+4.2
6000	148	32	4.3	-3.6	+2.3
7640	275	85	1.0	+0.1	-1.0
9550	335	25	1.0	+0.9	-0.4
10200	262	82	19.0	-3.3	-14.3
11530	257	77	14.7	-2.6	-18.8

TABLE VI cont'd

Calculation of Ballistic Wind

Vehicle CC-II-30 T = 0 12:00 CST 20 January, 1964

Layer Number	Altitude Meters	Weighting Factor	N-S	N-S Weighted	E-W	E-W Weighted
1	15.0	1	+ 5.2	+ 5.2	+ 1.8	+ 1.8
2	22.5	1	+ 5.4	+ 5.4	+ 2.0	+ 2.0
3	35.0	1	+ 5.7	+ 5.7	+ 2.3	+ 2.3
4	52.5	1	+ 6.1	+ 6.1	+ 2.7	+ 2.7
5	77.5	1	+ 6.4	+ 6.4	+ 3.1	+ 3.1
6	120.0	1	+ 6.5	+ 6.5	+ 3.6	+ 3.6
7	197.5	1	+ 7.2	+ 7.2	+ 3.9	+ 3.9
8	377.5	1	+ 8.2	+ 8.2	+ 3.8	+ 3.8
9	1070.0	1	+ 8.0	+ 8.0	+ 8.0	+ 8.0
10-i	2600	.5	+ 3.8	+ 1.9	+ 7.5	+ 3.75
10-ii	4400	.2	+ 2.2	+ 0.44	+ 6.5	+ 1.30
10-iii	7600	.2	- 1.0	- 0.20	+ 2.5	+ .50
10-iv	12800	.1	- 1.0	- 0.10	- 8.0	- .80
Sum	-	10	-	+60.74		+35.95
Ballistic Wind Components			-	+ 6.07		+ 3.60

$$\frac{(de)}{(dw)t} = 1.20^{\circ} \text{ per meter/sec.}$$

TABLE VI cont'd

Prediction of Wind Effect

Vehicle CC-II 30

	Elevation	Azimuth
Desired no wind launcher settings.	080°	095°
Actual Launcher settings-wind weighted.	079.2°	141.3°
Effective launcher setting obtained.	083°	113°

The variation between the desired launcher settings and the effective launcher settings was partially due to an error in the selsyn control from the launcher to the block house as well as the normal inaccuracy due to pre-flight wind prediction. From wind information gathered before and after the flight the true launcher settings would have been 80.7° elevation and 130° azimuth in order to obtain the desired trajectory.

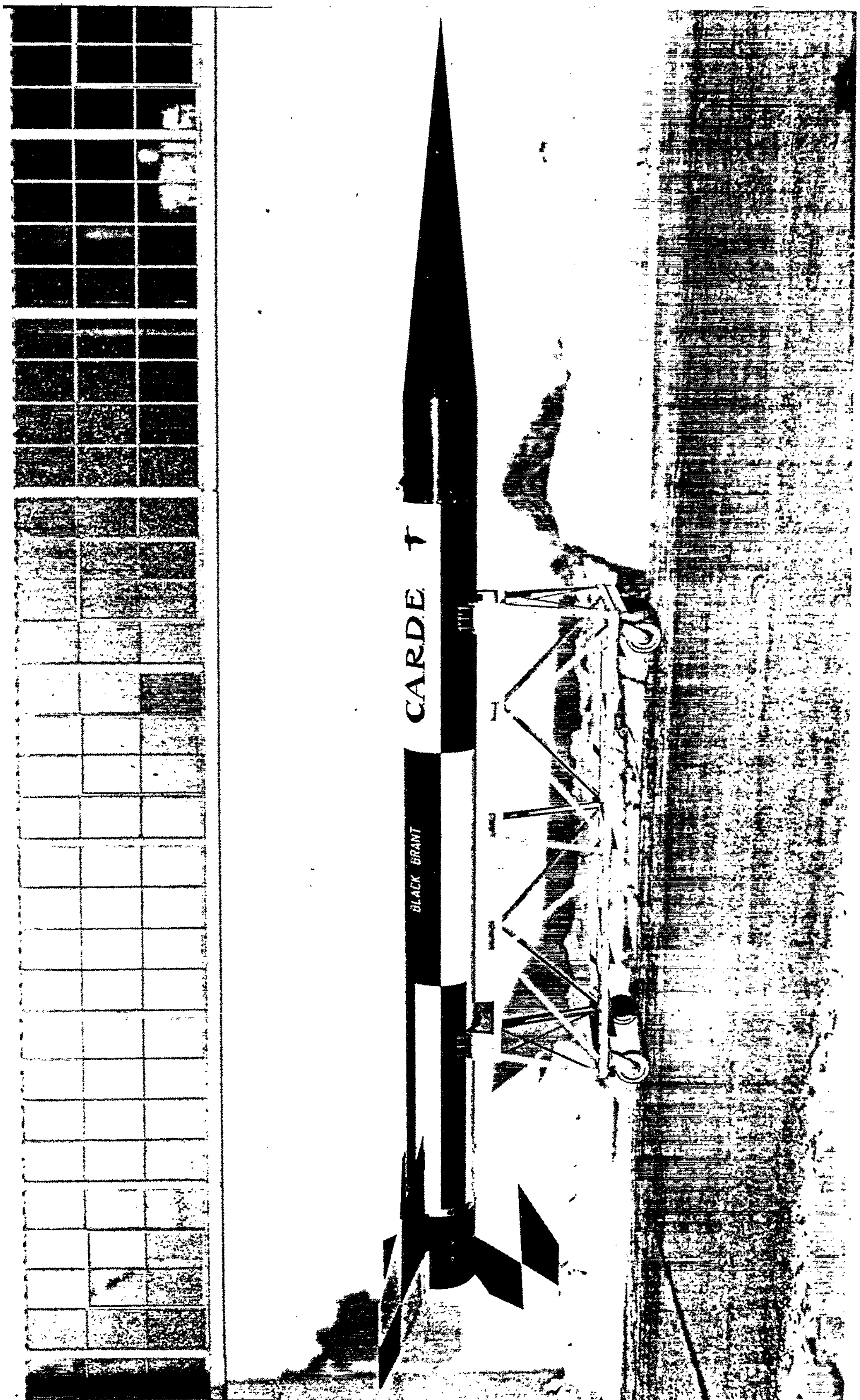


FIGURE 1 - Black Brant IIA Rocket Vehicle

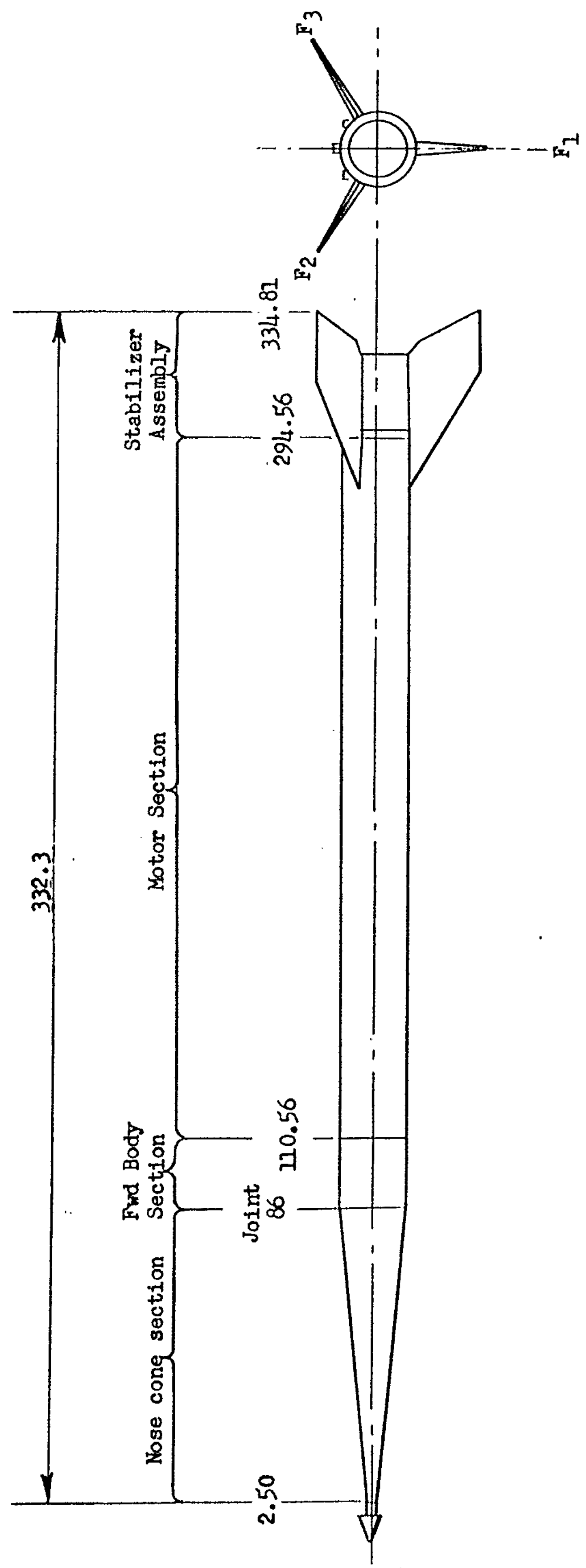


FIGURE 2 - Vehicle Configuration for CC-II-29 and 30

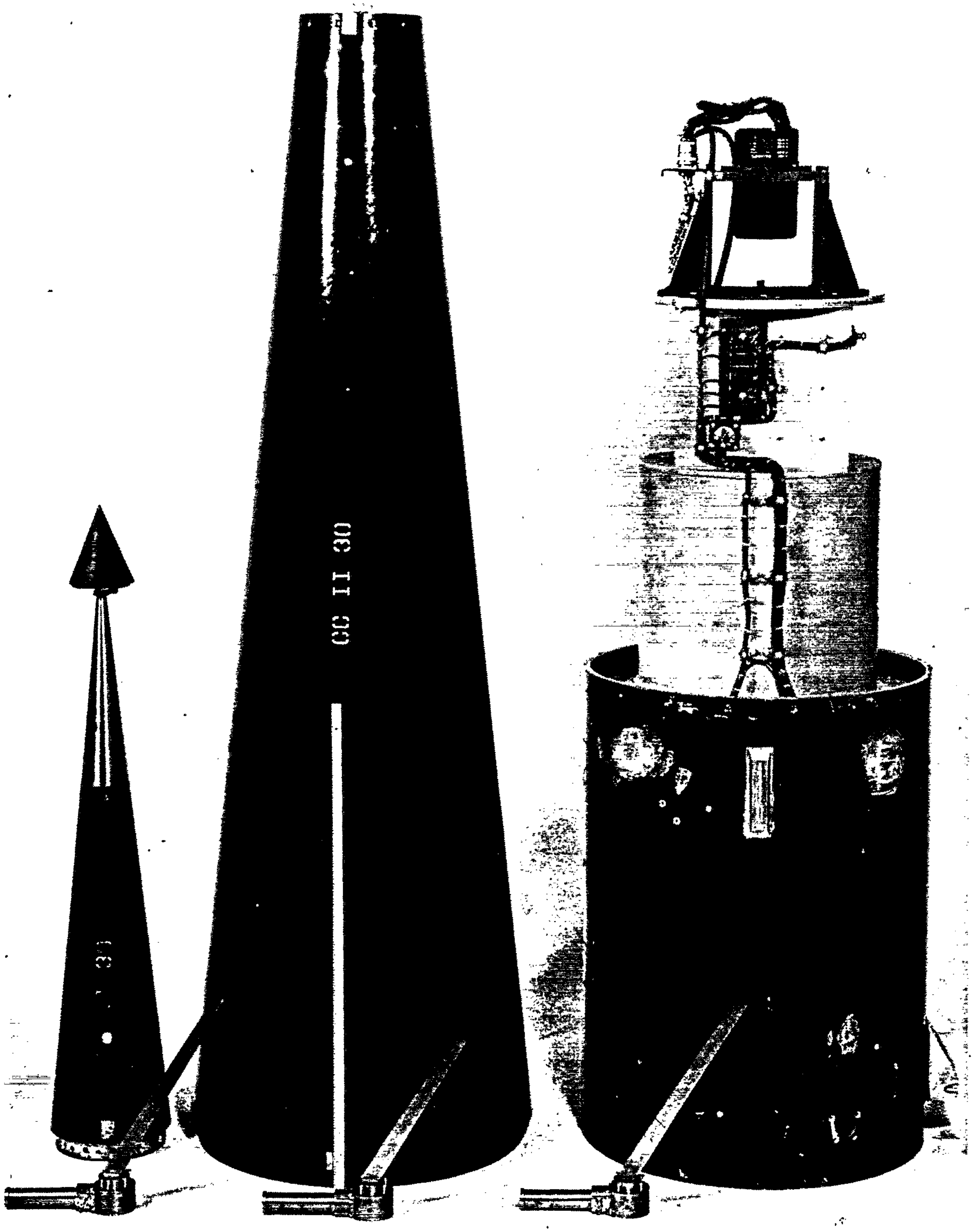


FIGURE 3 - Nose Cone and Instrumentation

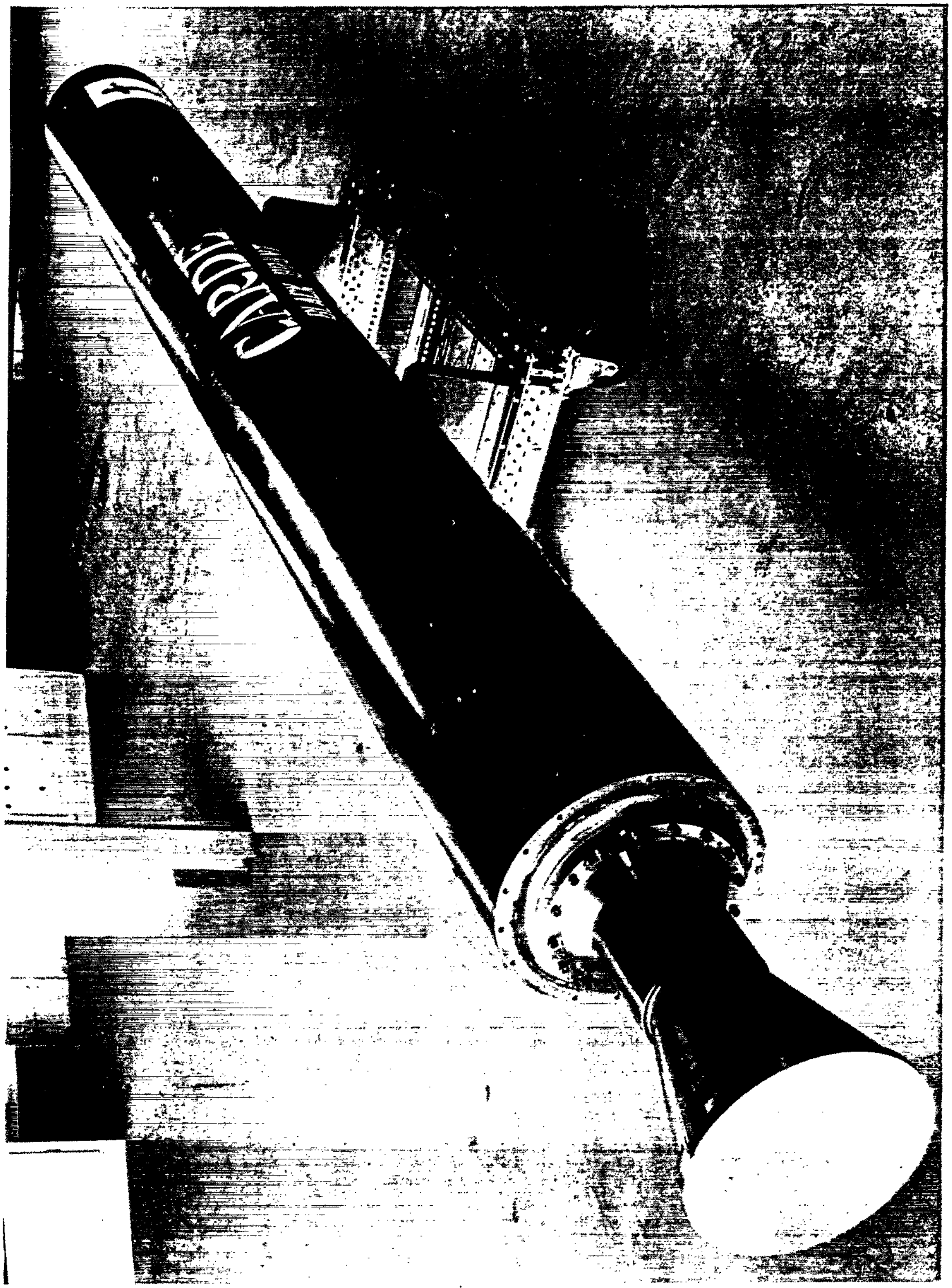


FIGURE 4 - Rocket Engine and Nozzle

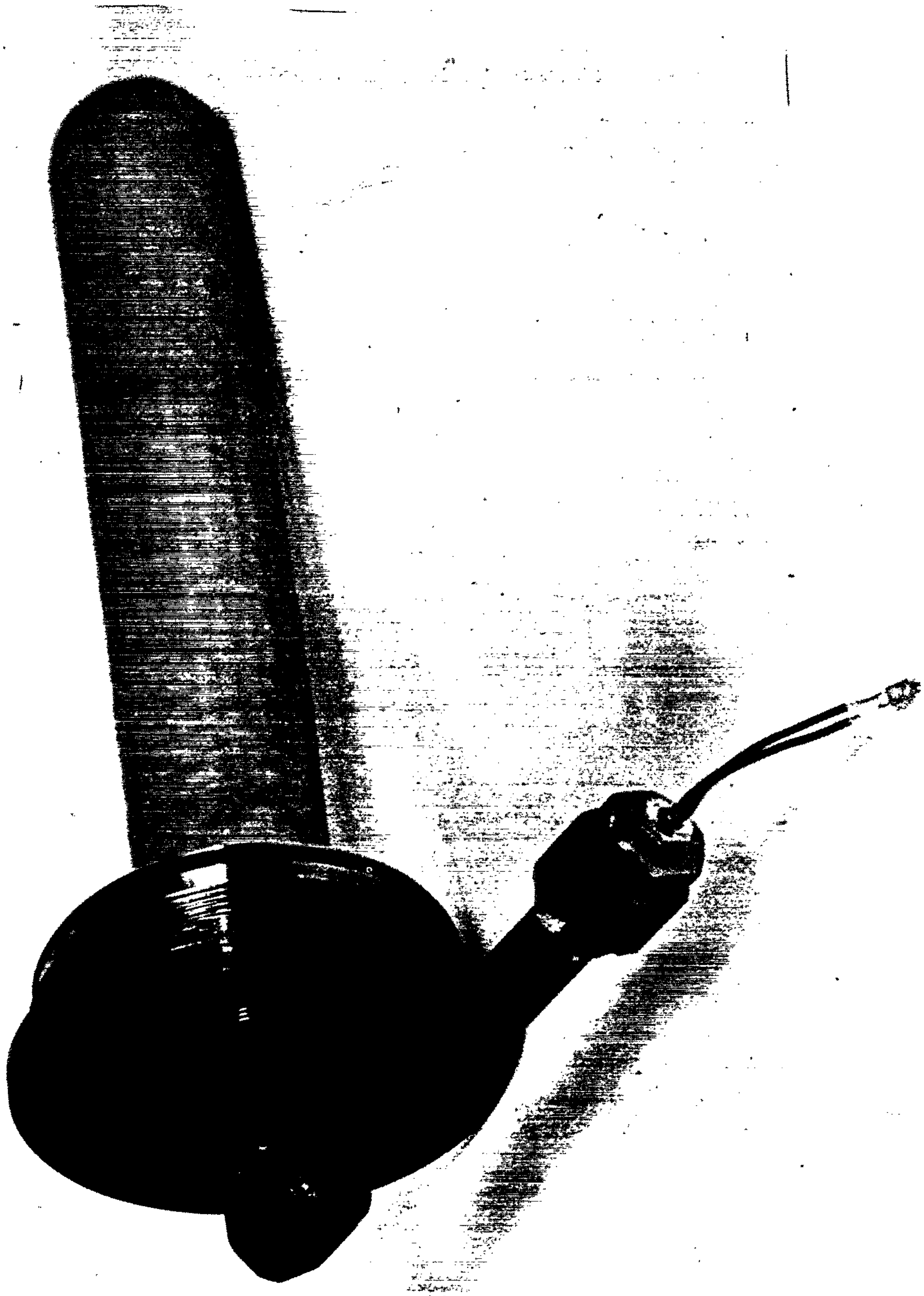
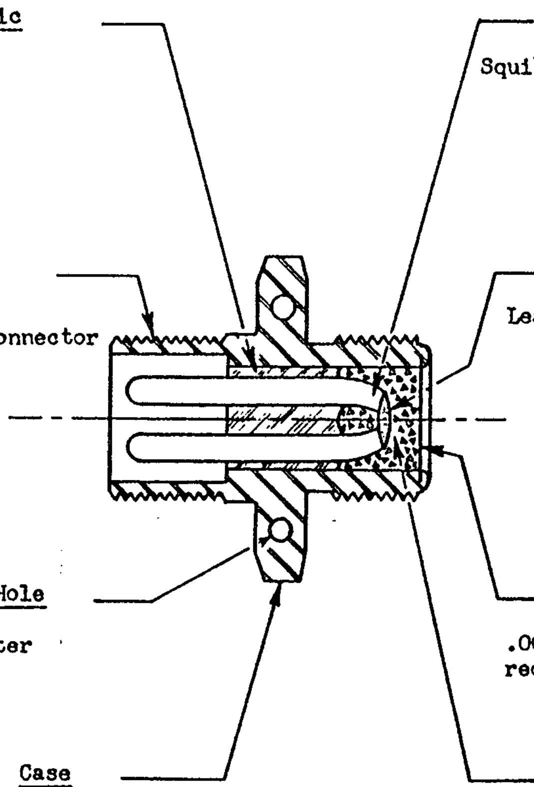


FIGURE 5 - Igniter Assembly

Electric Squib McCormick Selph No. M-56



Firing Current 5 amps recommended
0.9 amps minimum
No Fire Current 0.4 amps

FIGURE 6 - Outline of M-56 Igniter Squib

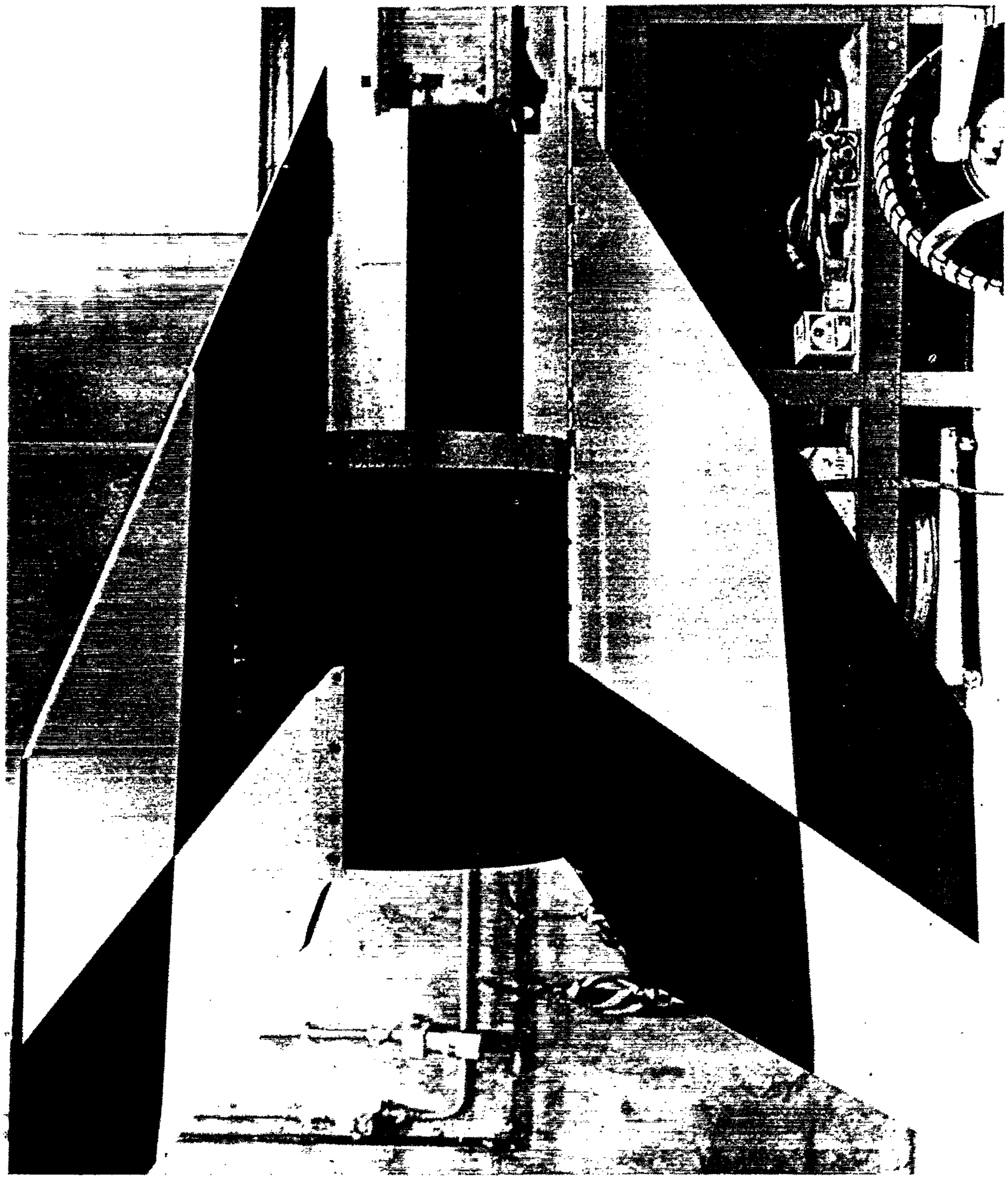


FIGURE 7 - Bristol Aero Industries Three-Fin System - CRR Photograph

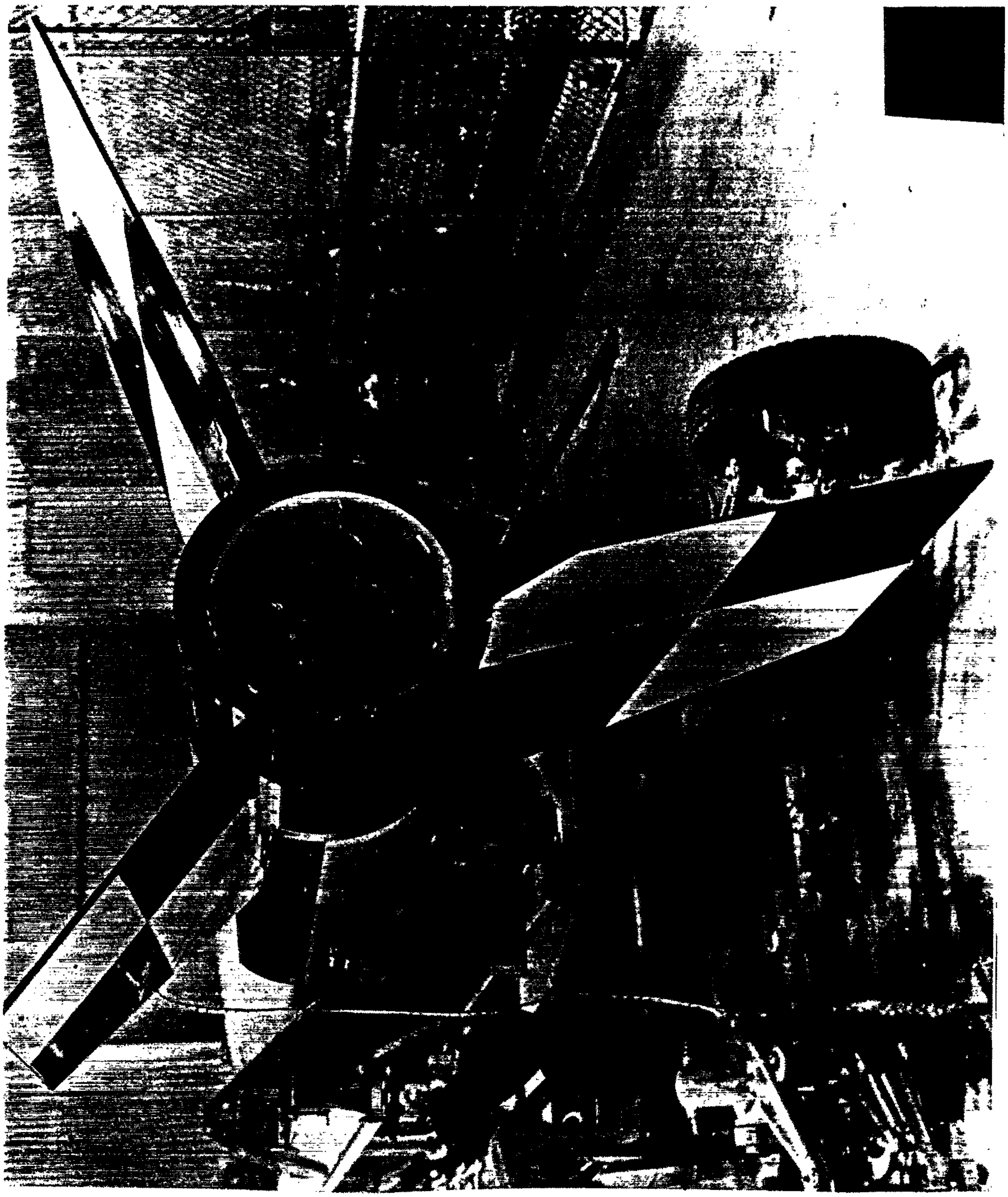
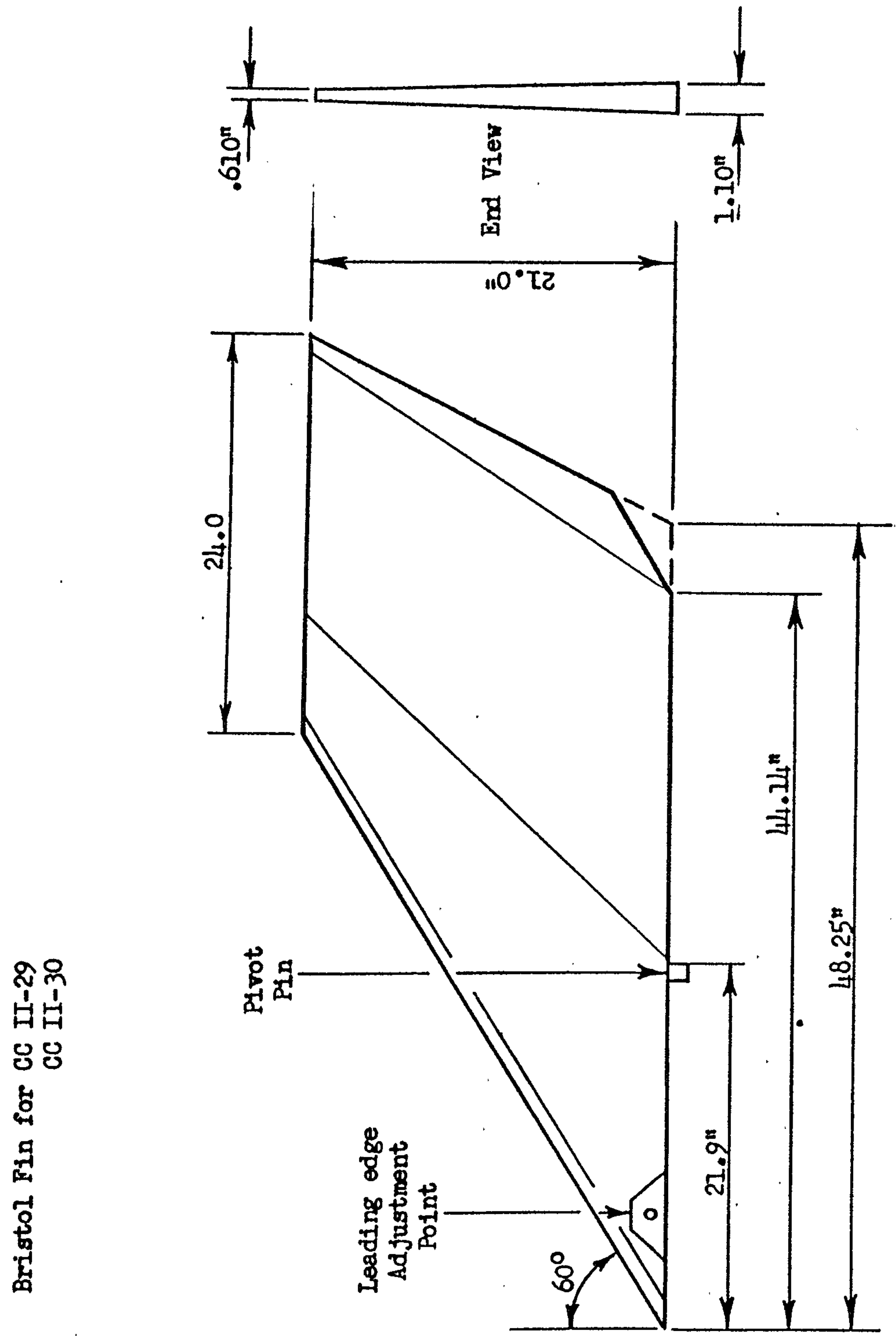


FIGURE 8 - Bristol Aero Industries Three-Fin System - CRR Photograph



Outline of fin
FIGURE 9 - Fin Dimensions

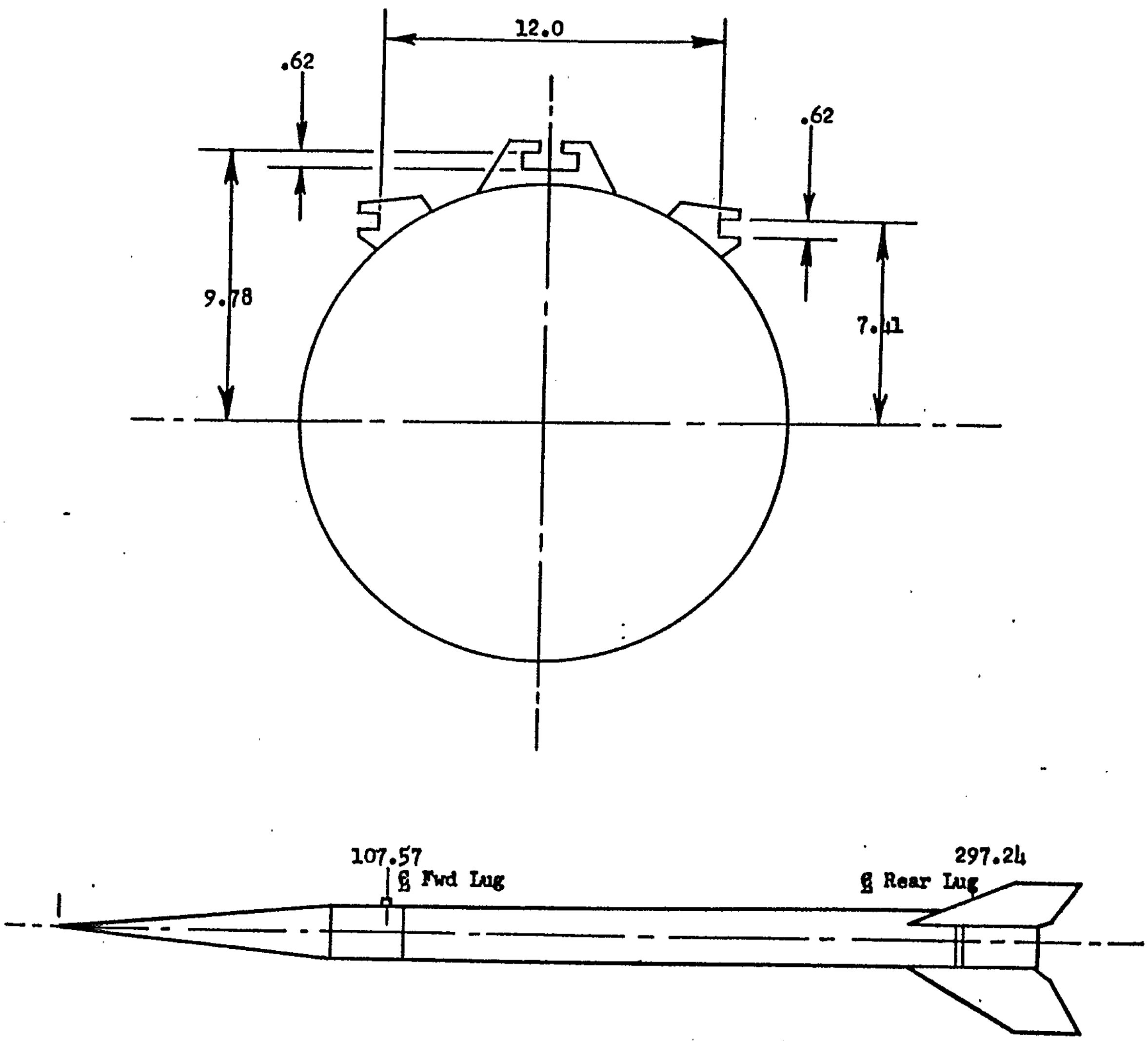


FIGURE 10 - Layout of Launcher Lugs

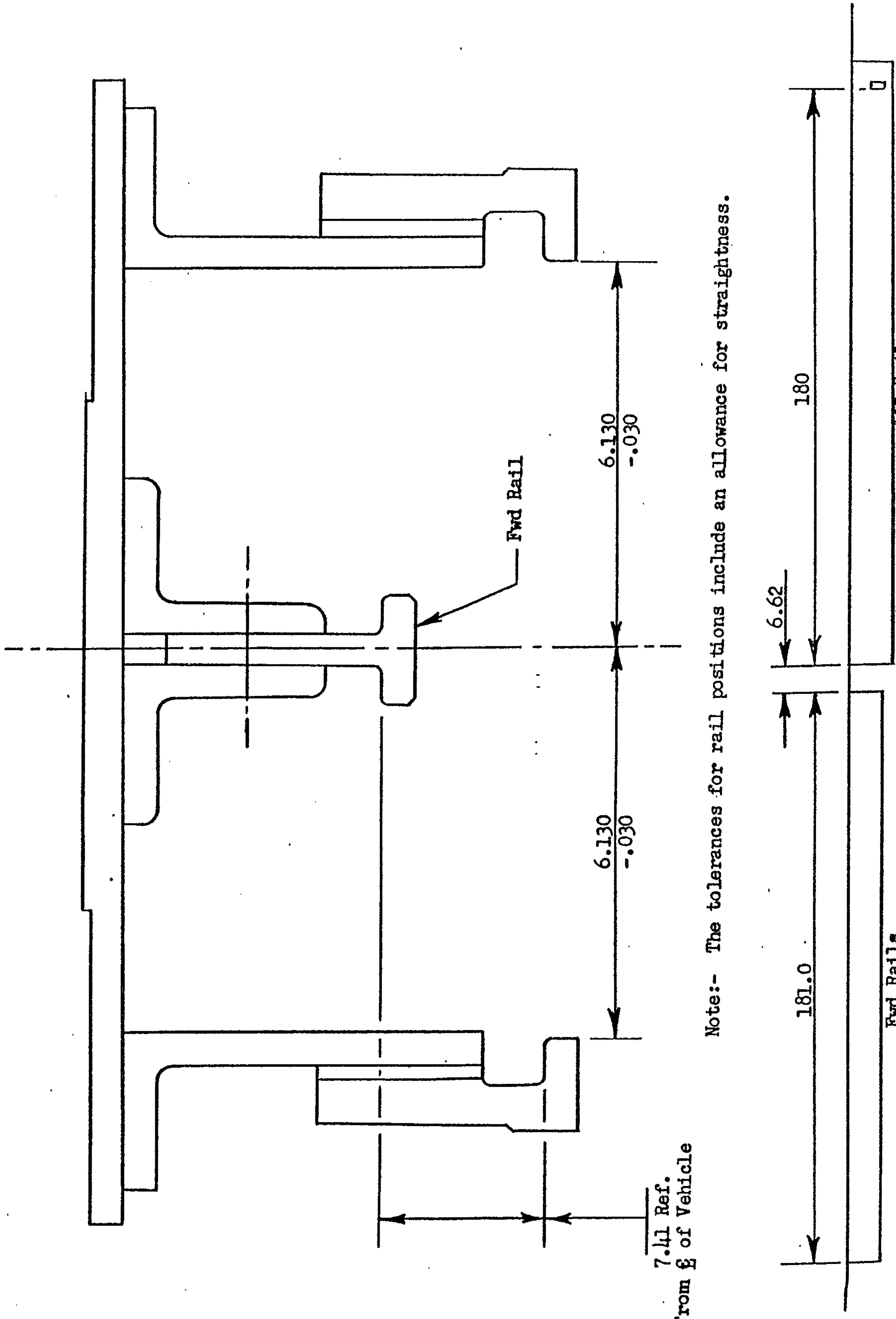


FIGURE 11 - Launcher Rail Layout and Alignment

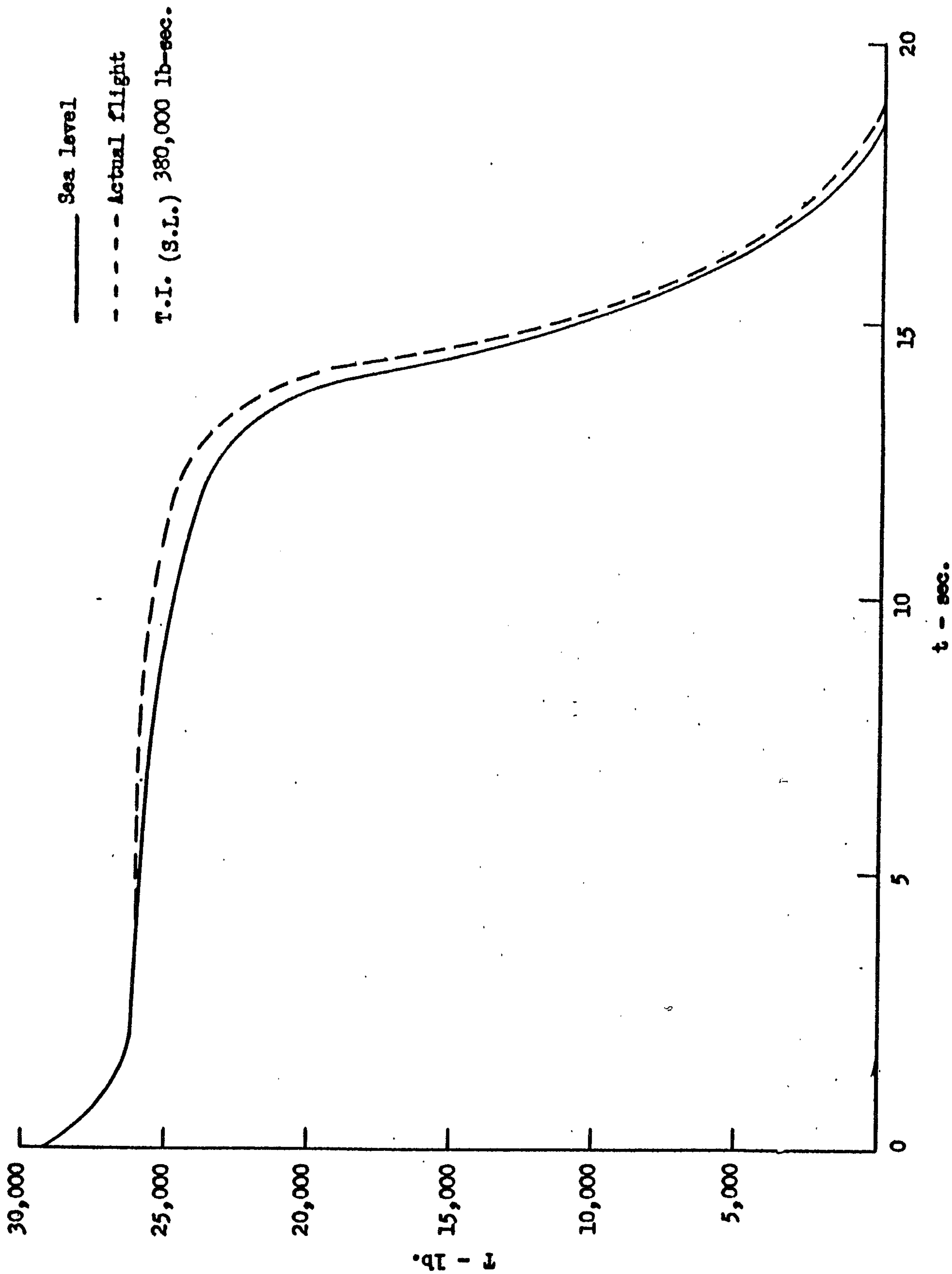


FIGURE 12 - Thrust versus Time

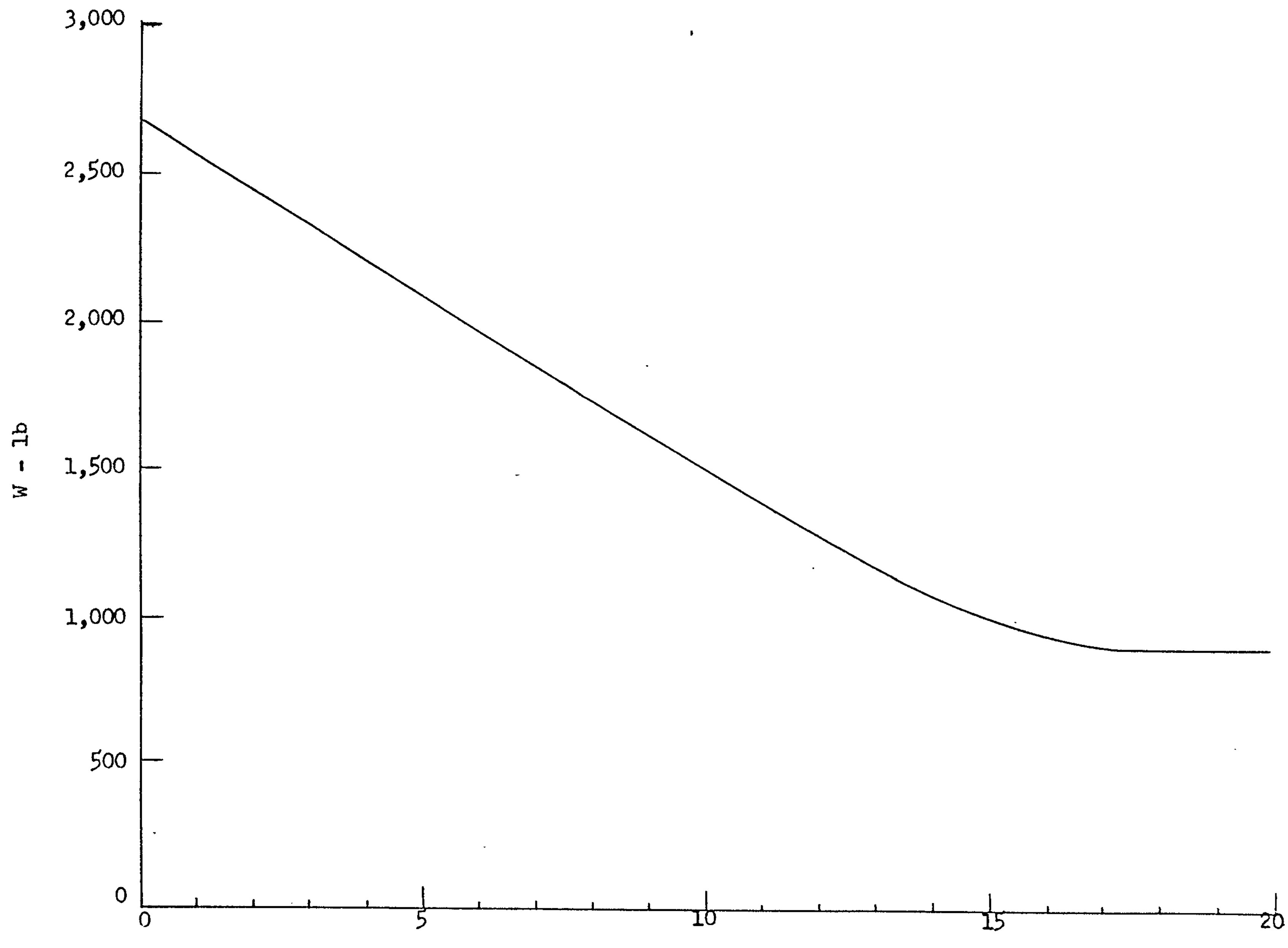


FIGURE 13 - Weight versus Time

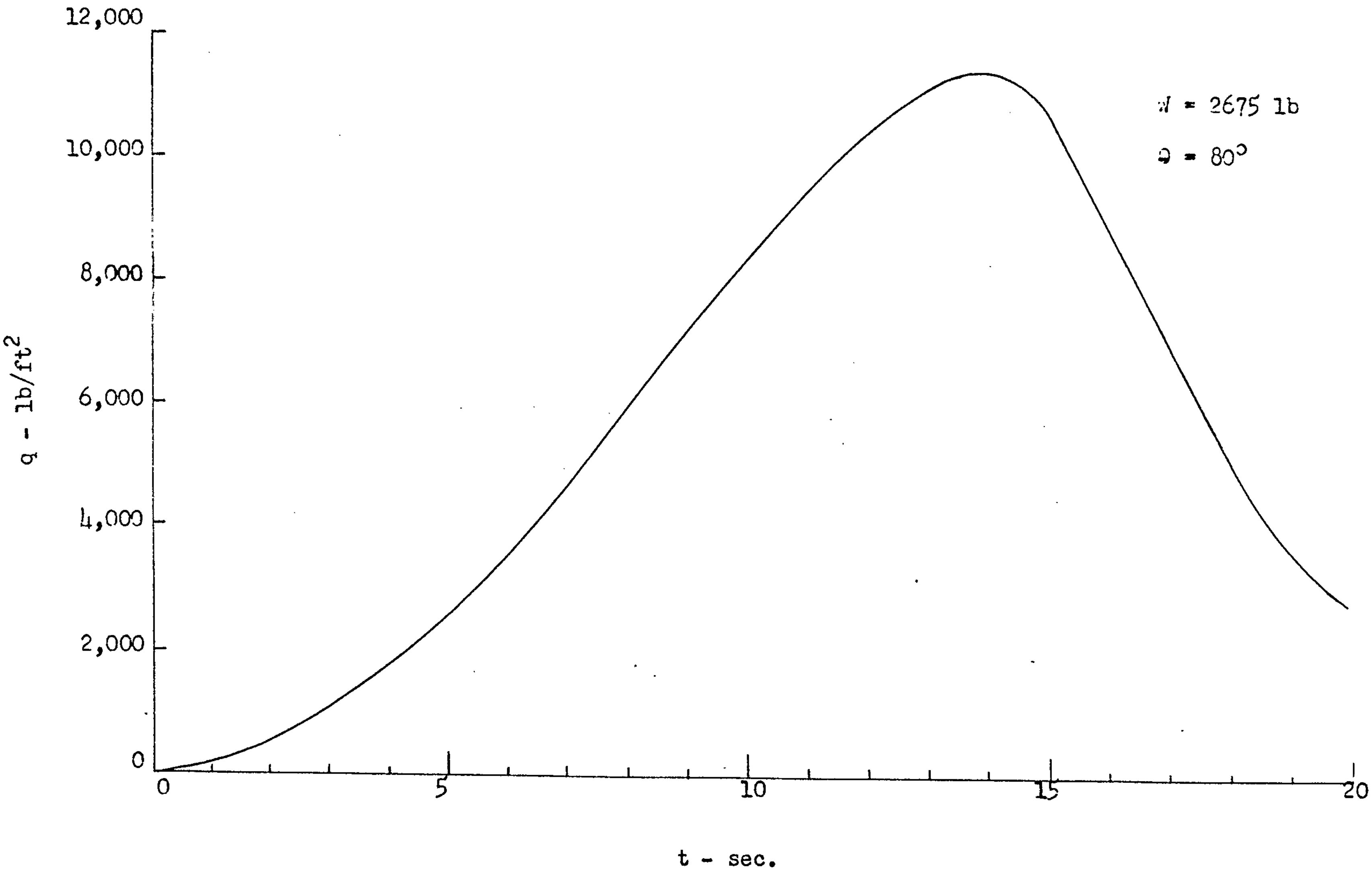


FIGURE 14 - Dynamic Pressure versus Time

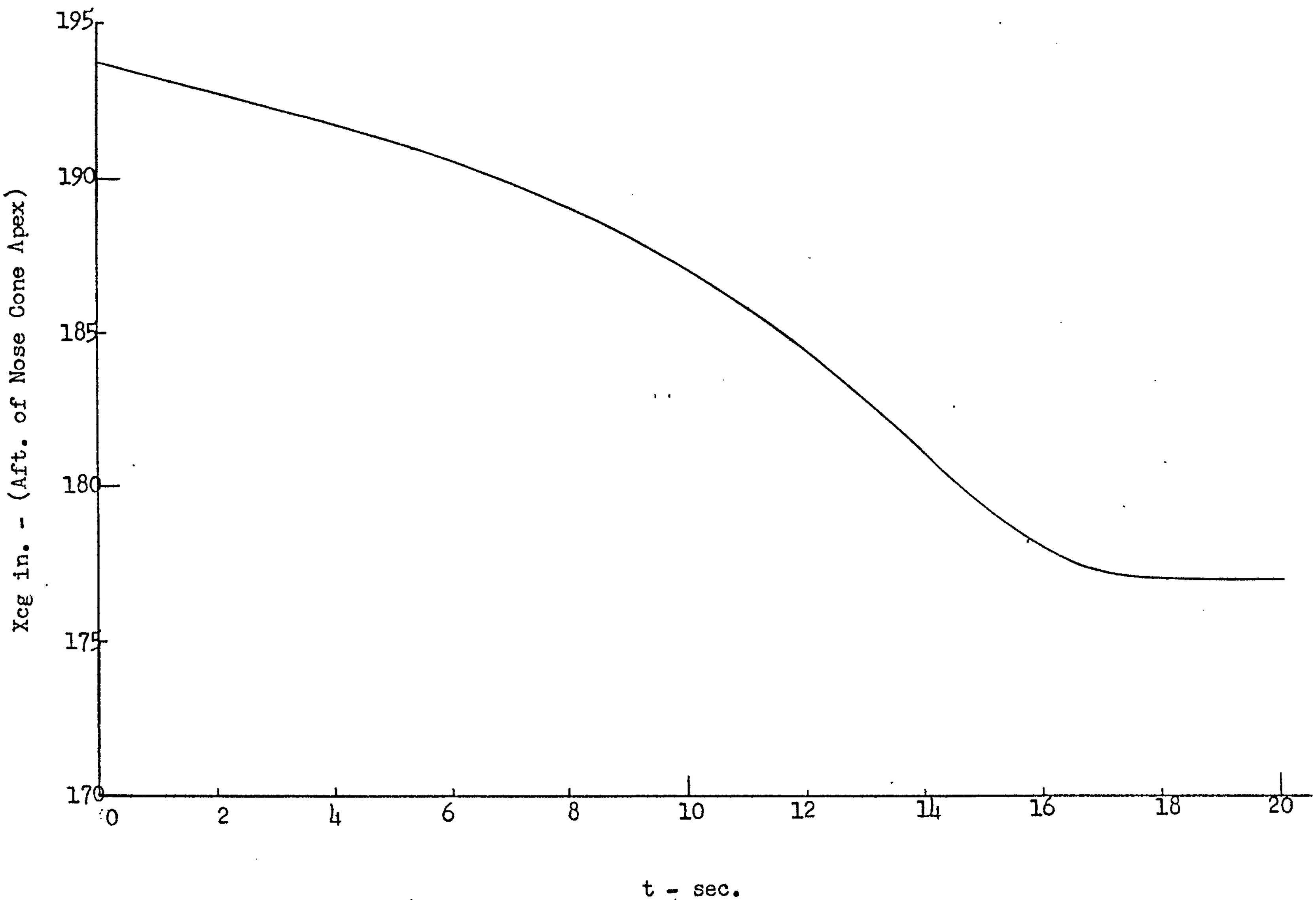
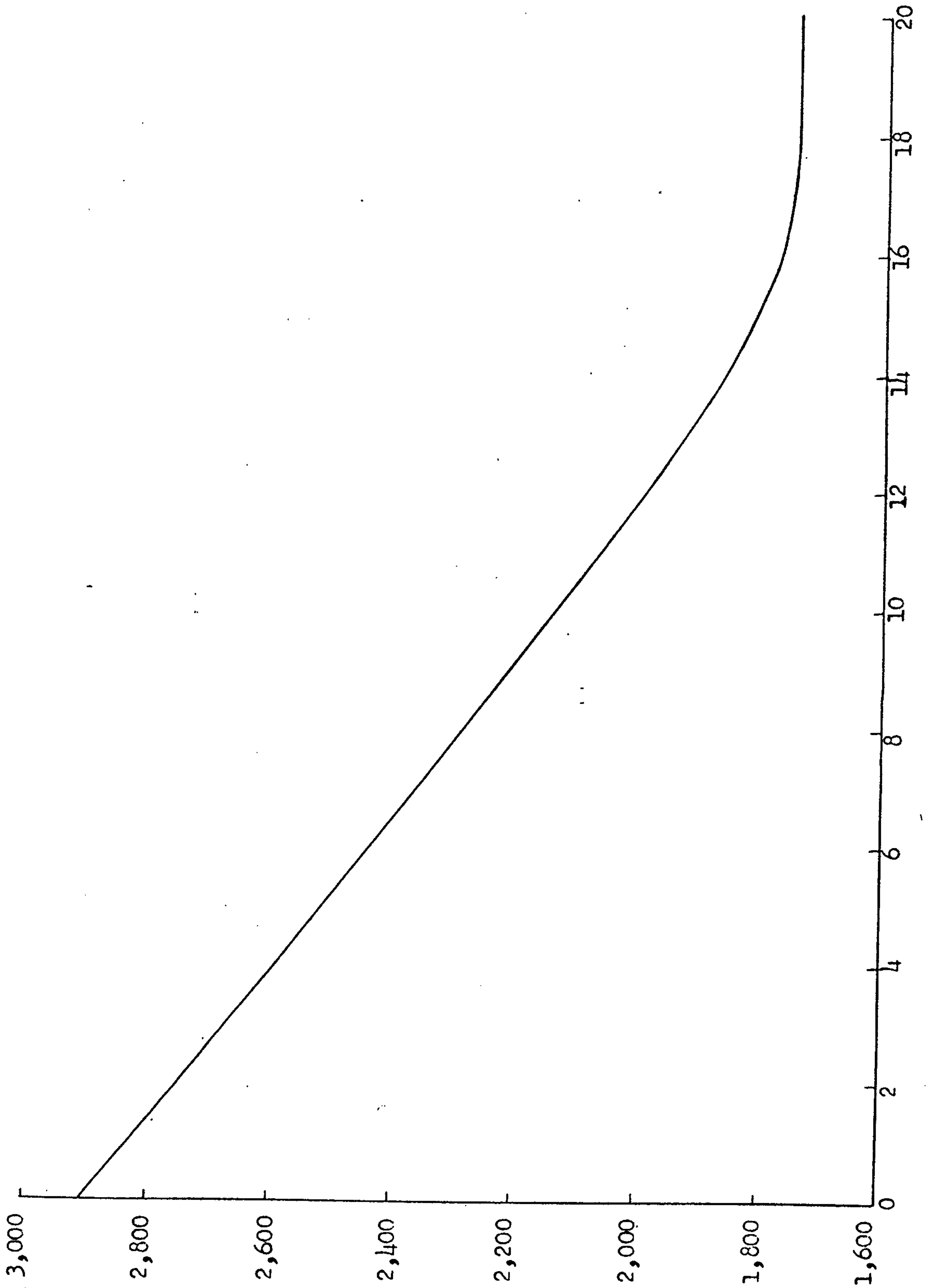


FIGURE 15 - Centre of Gravity versus Time



t - sec.

FIGURE 16 - Pitch Moments of Inertia versus Time

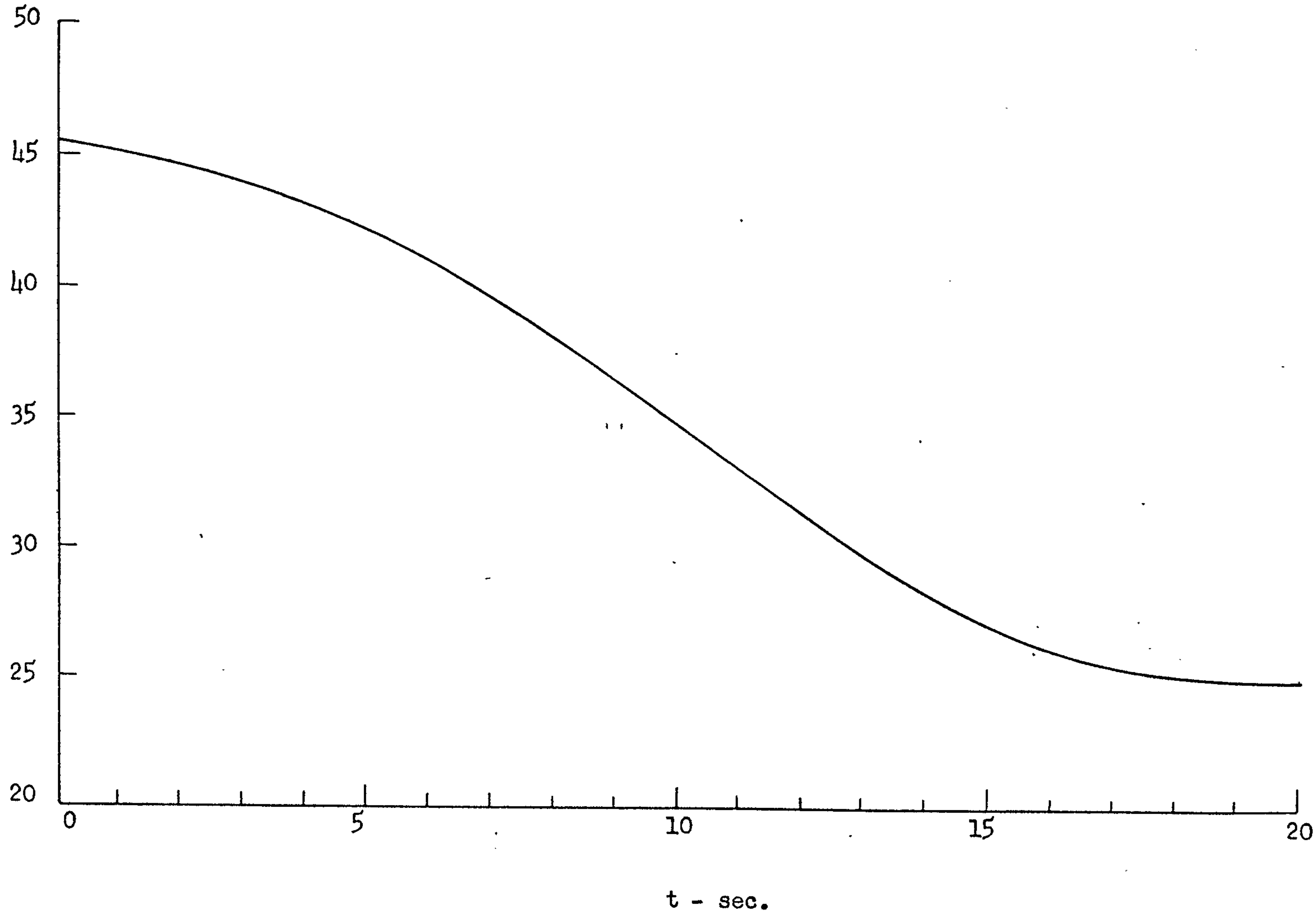


FIGURE 17 - Roll Moments of Inertia versus Time

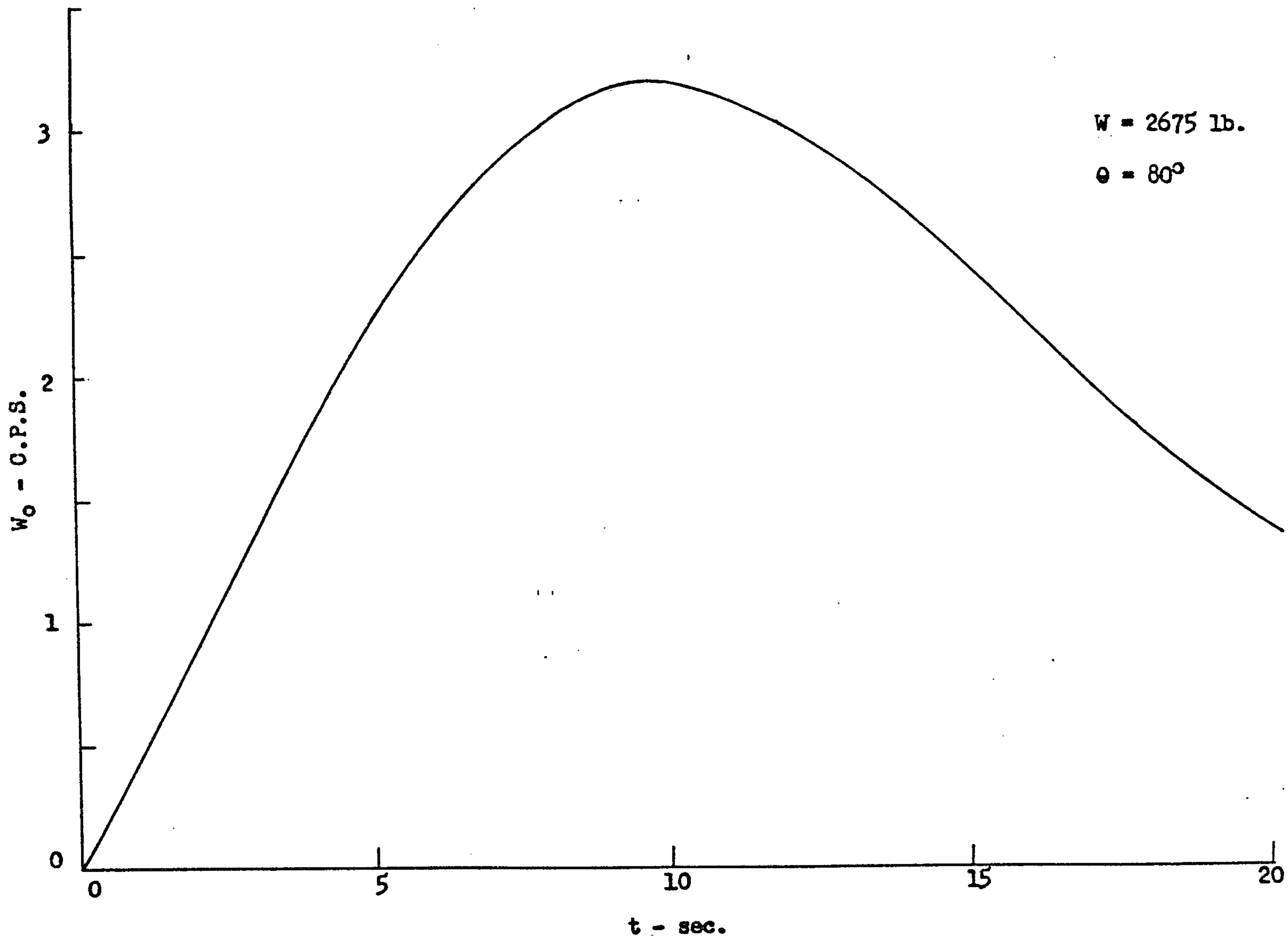
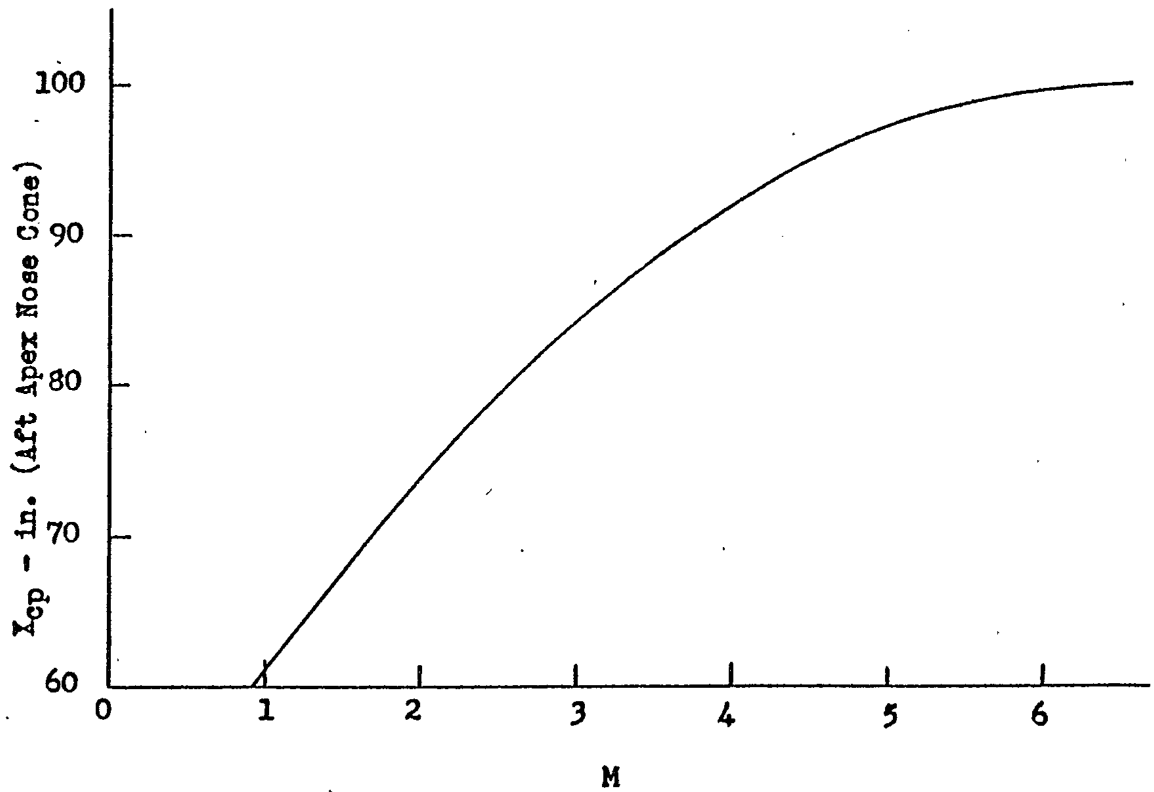


FIGURE 18 - Undamped Pitching Frequency versus Time



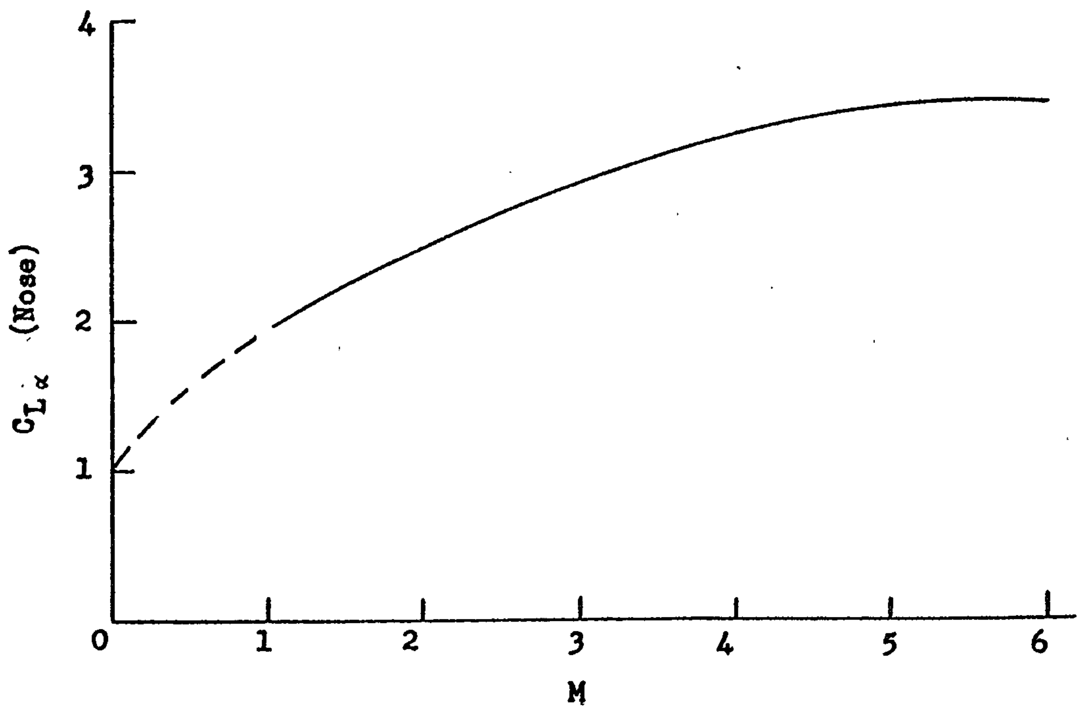


FIGURE 19 - Nose and Body Zero Lift Curve Slope and Centre of Pressure versus Mach Number

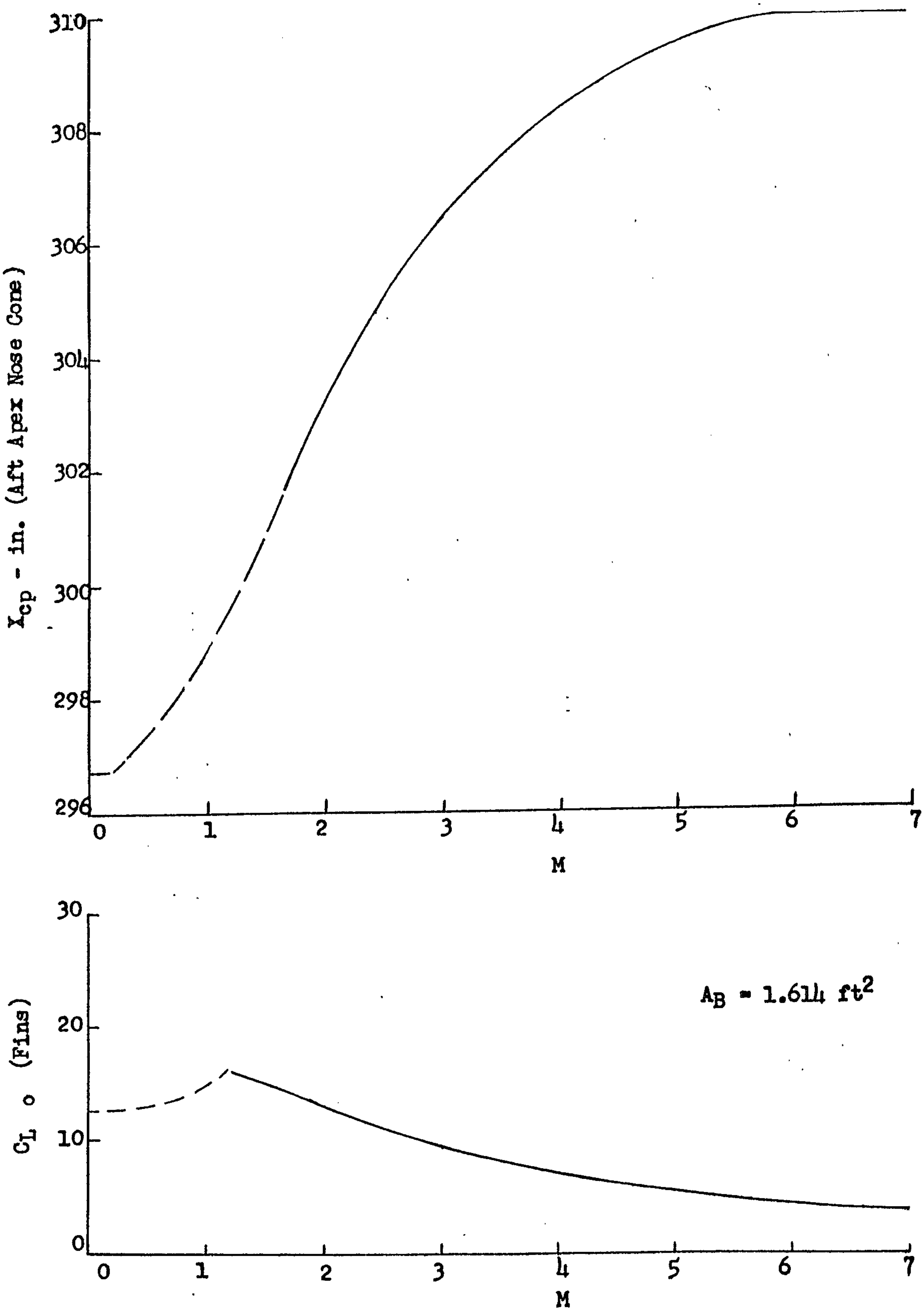


FIGURE 20 - Fins Zero Lift Curve Slope for the Complete Vehicle versus Mach Number

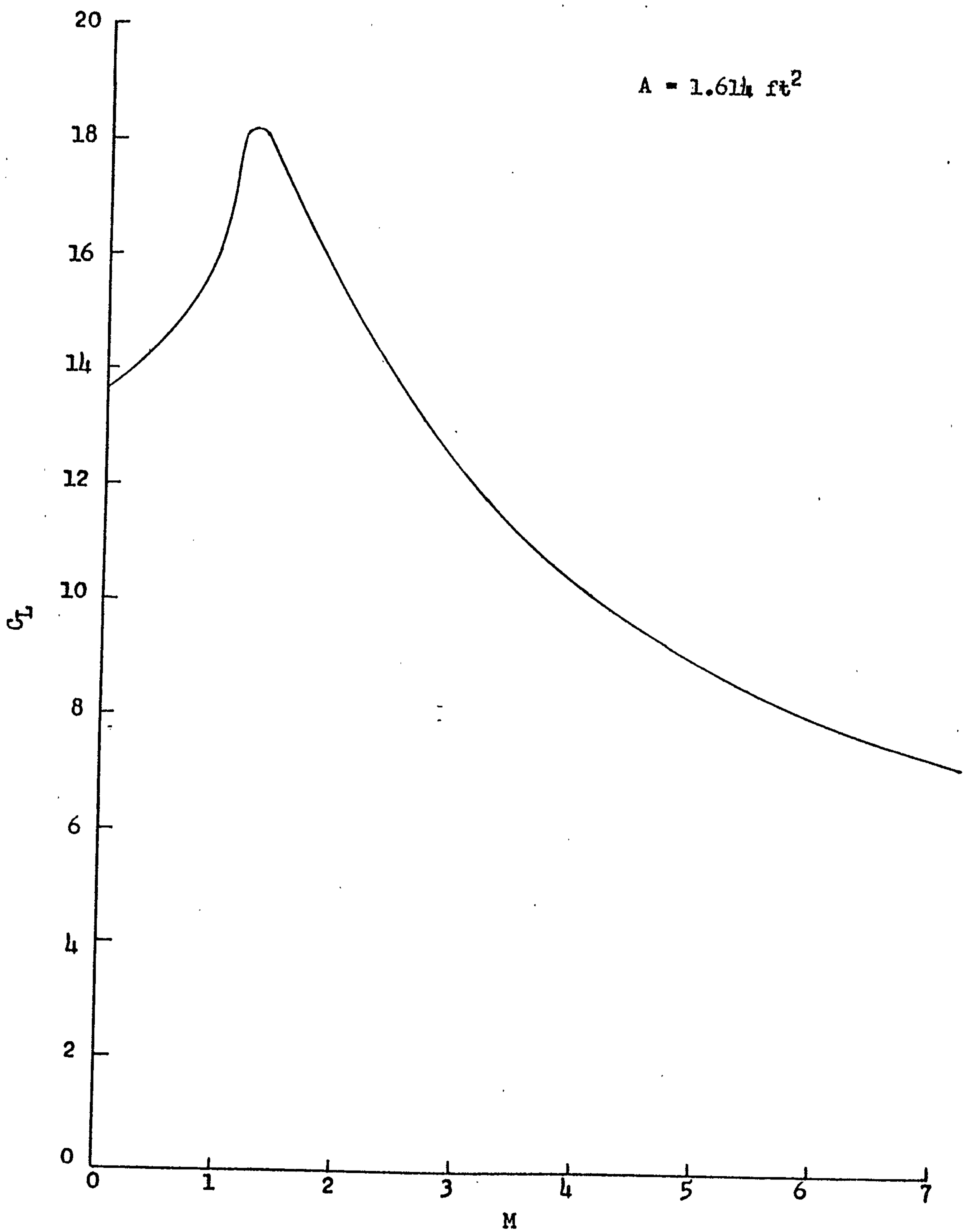


FIGURE 21 - Zero Lift Curve Slope for the Complete Vehicle versus Mach Number

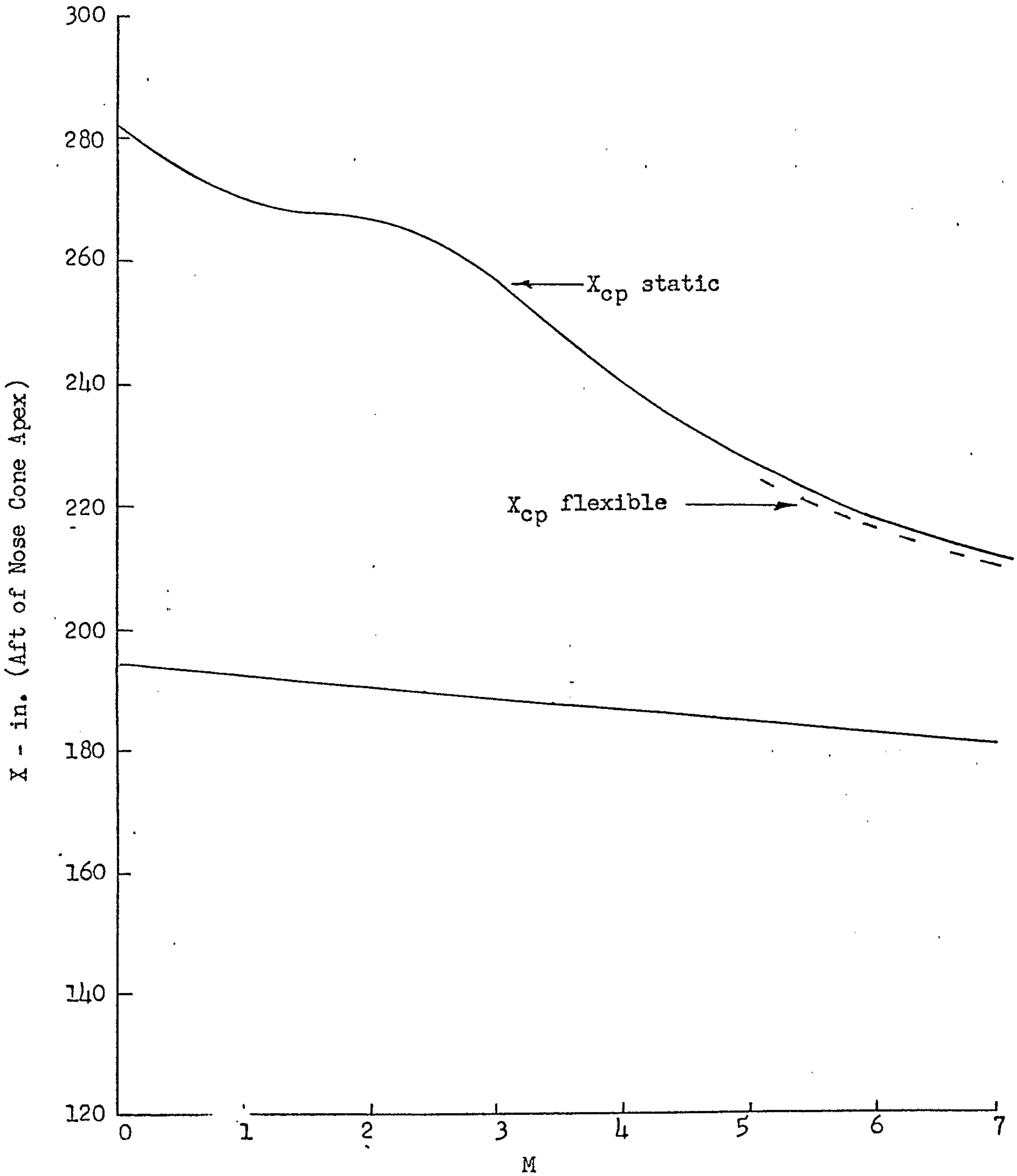


FIGURE 22 - Static and Flexible Stability Margin versus Mach Number

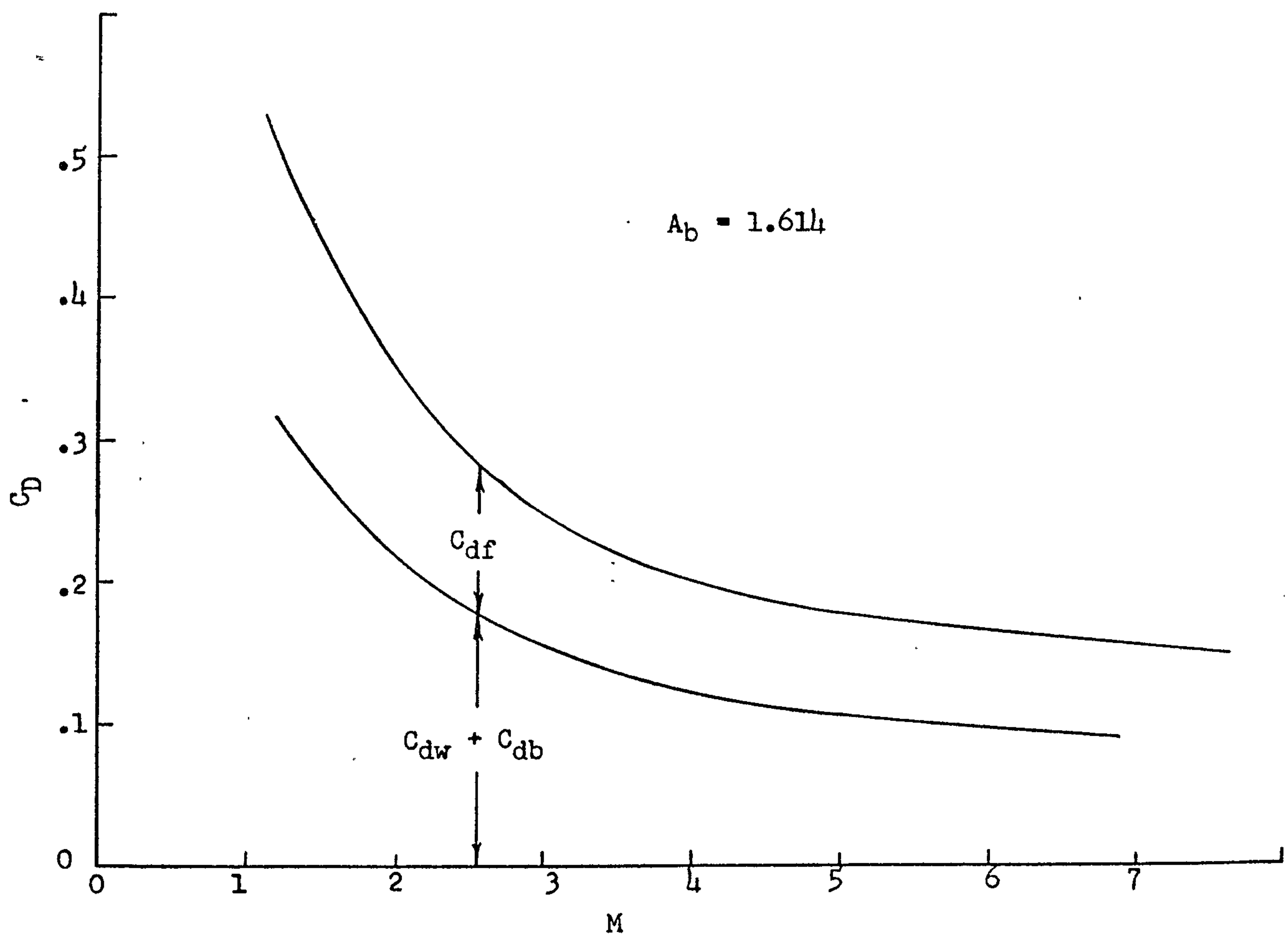


FIGURE 23 - Wave, Base and Skin Friction Drag Coefficients versus Mach Number

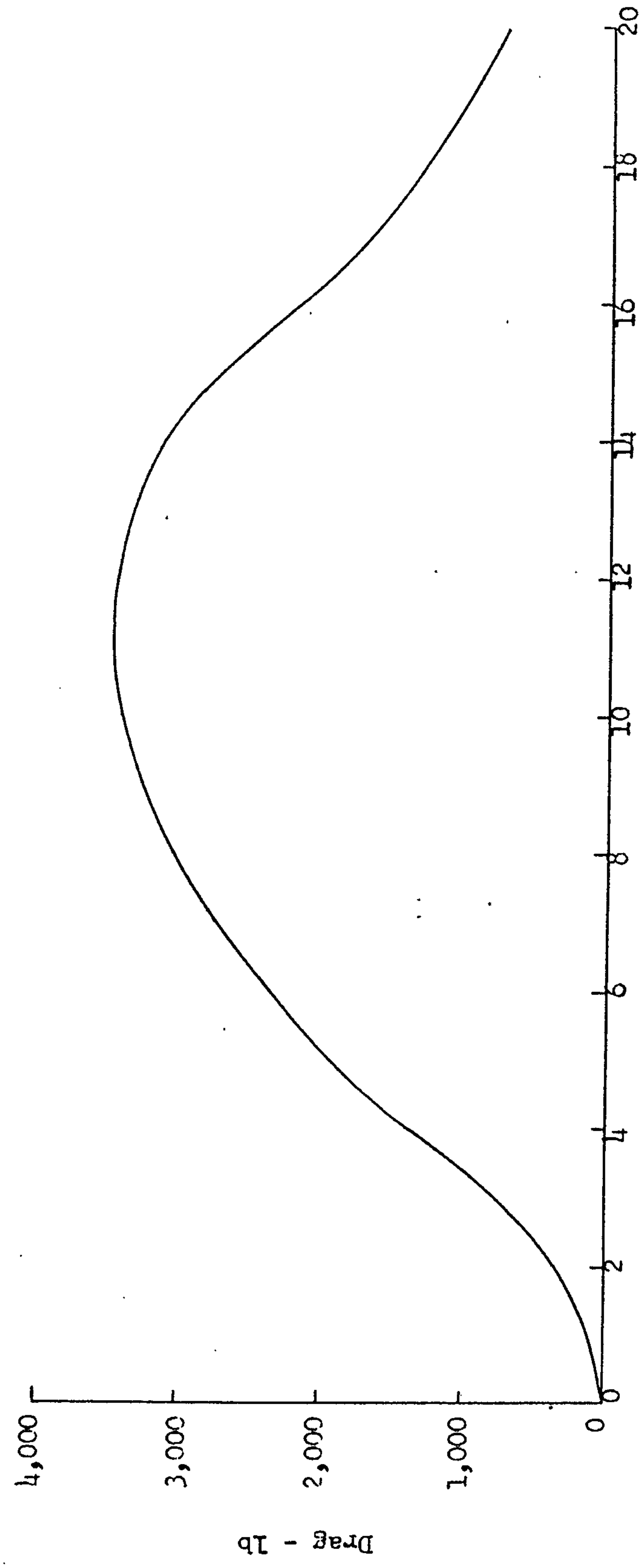


FIGURE 24 - Drag versus Time

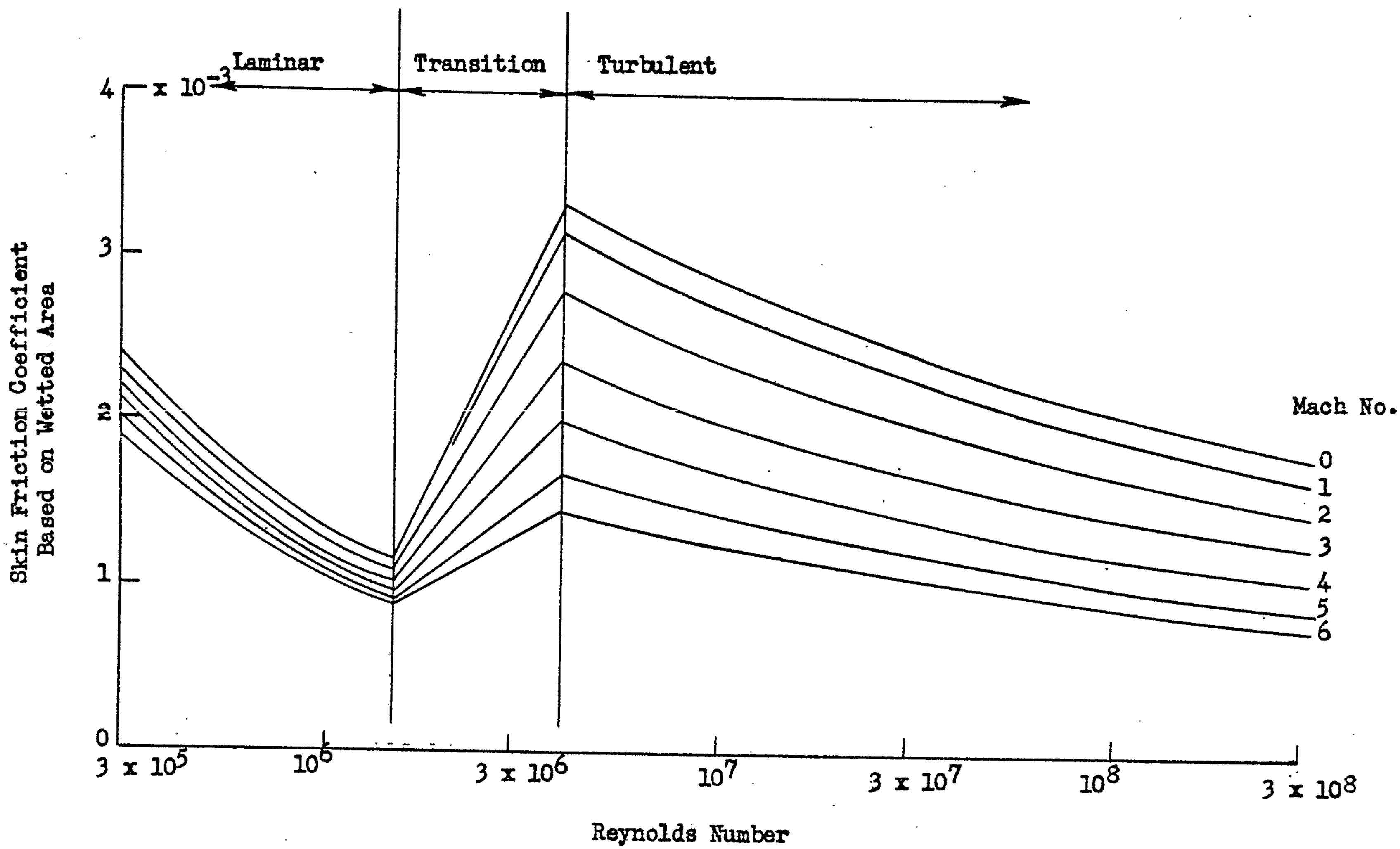


FIGURE 25 - Skin Friction Coefficient as a Function of Mach Number and Reynold's Number

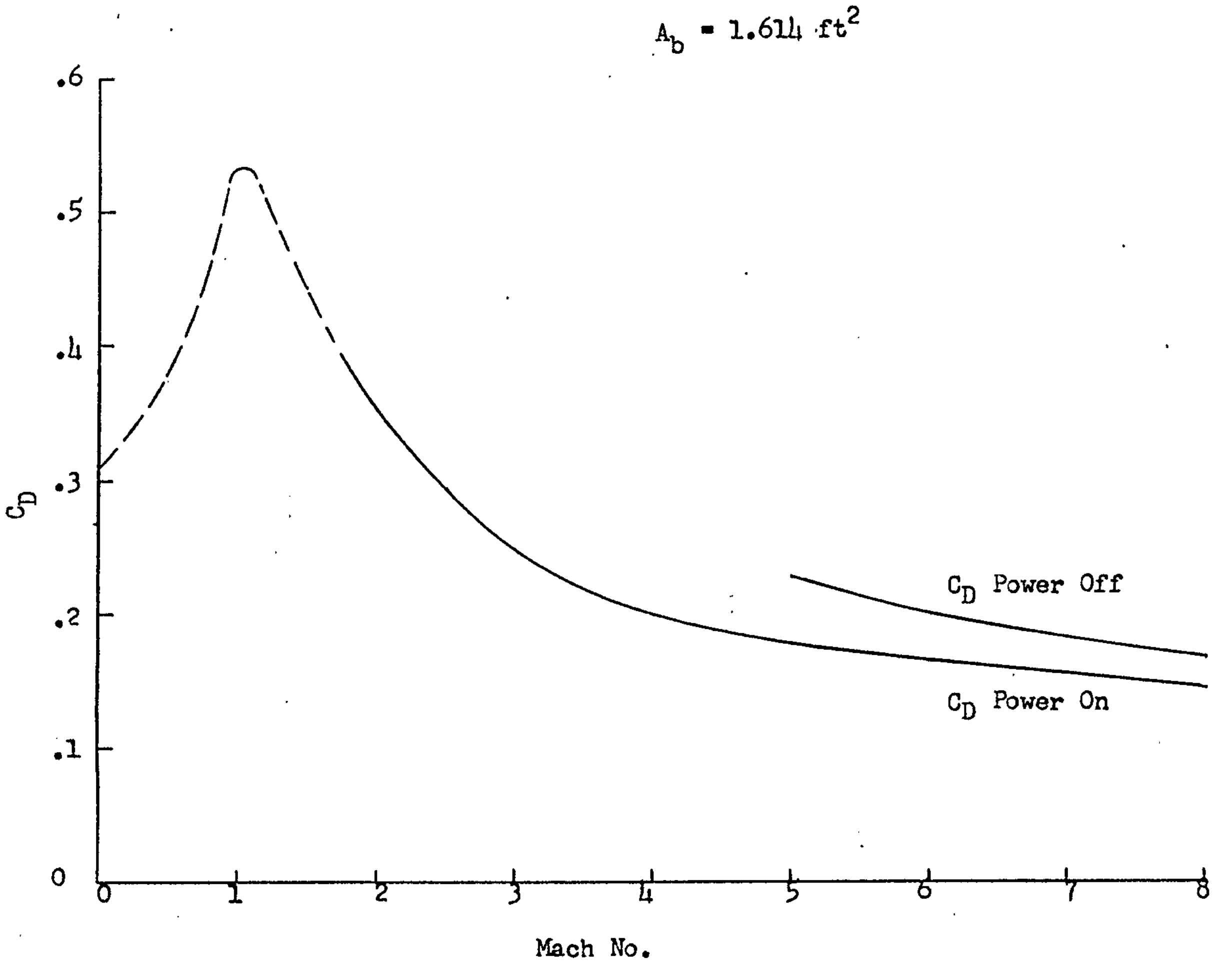


FIGURE 26 - Zero Lift Drag Coefficient versus Mach Number

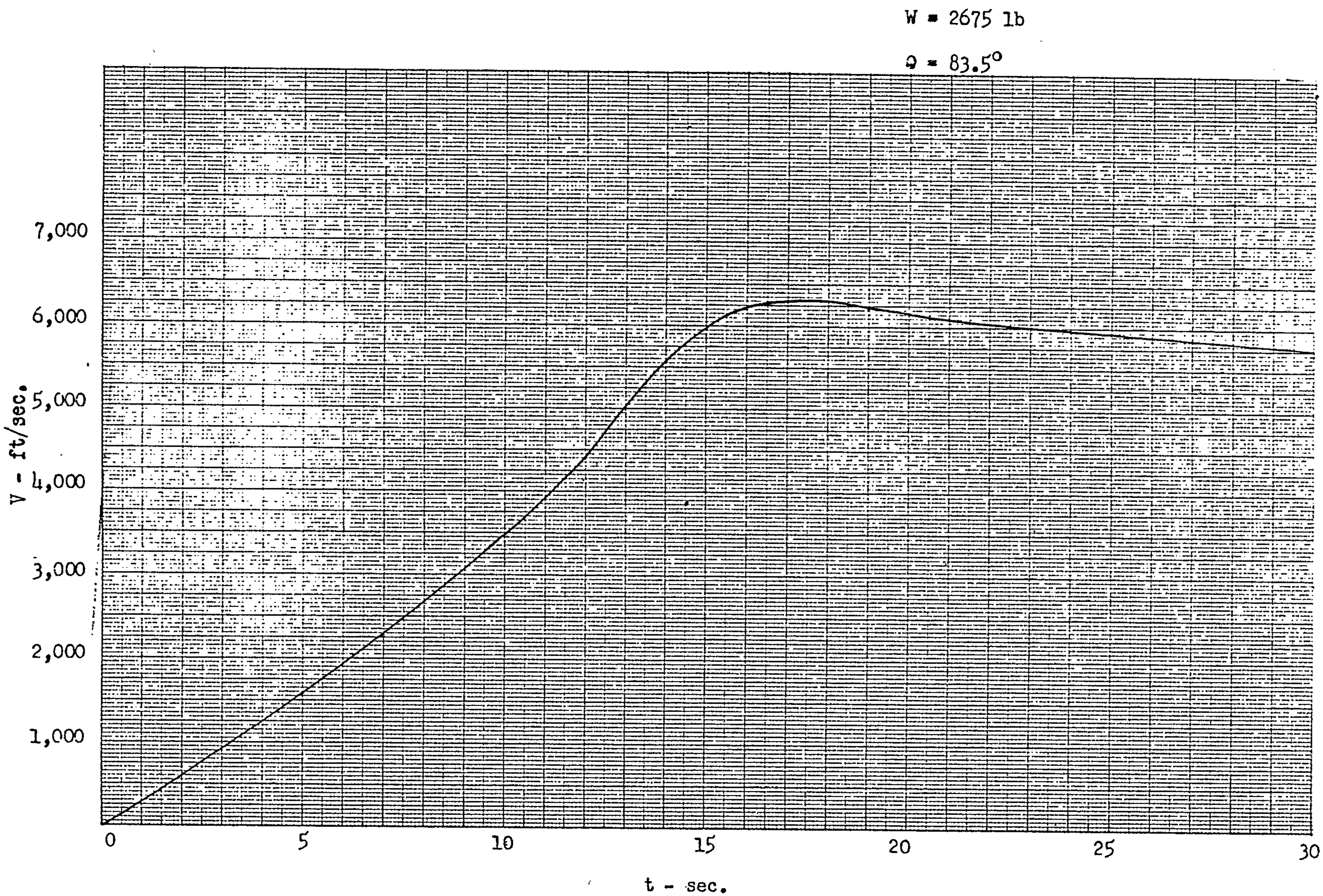


FIGURE 27 - Velocity versus Time

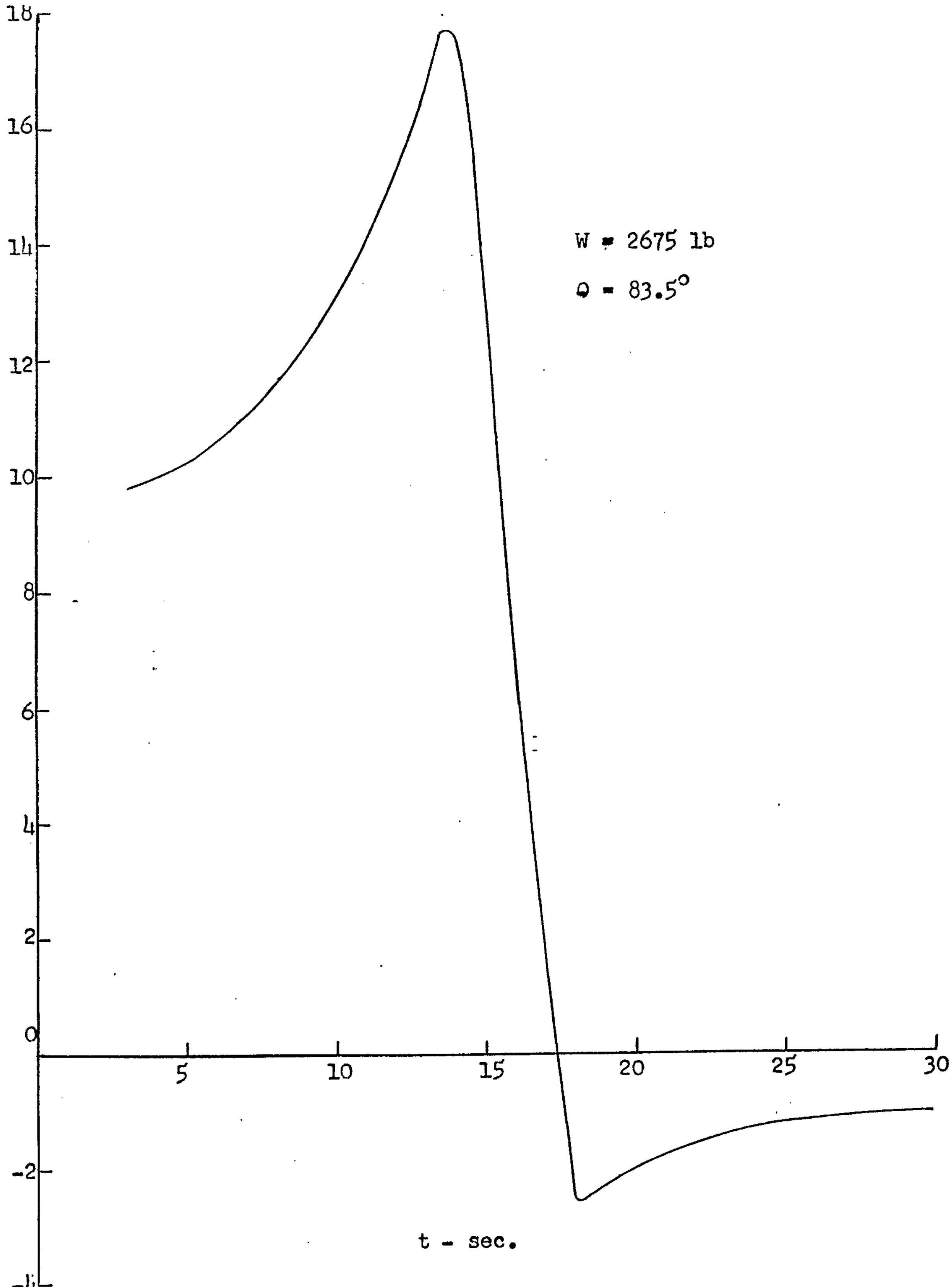


FIGURE 28 - Acceleration versus Time

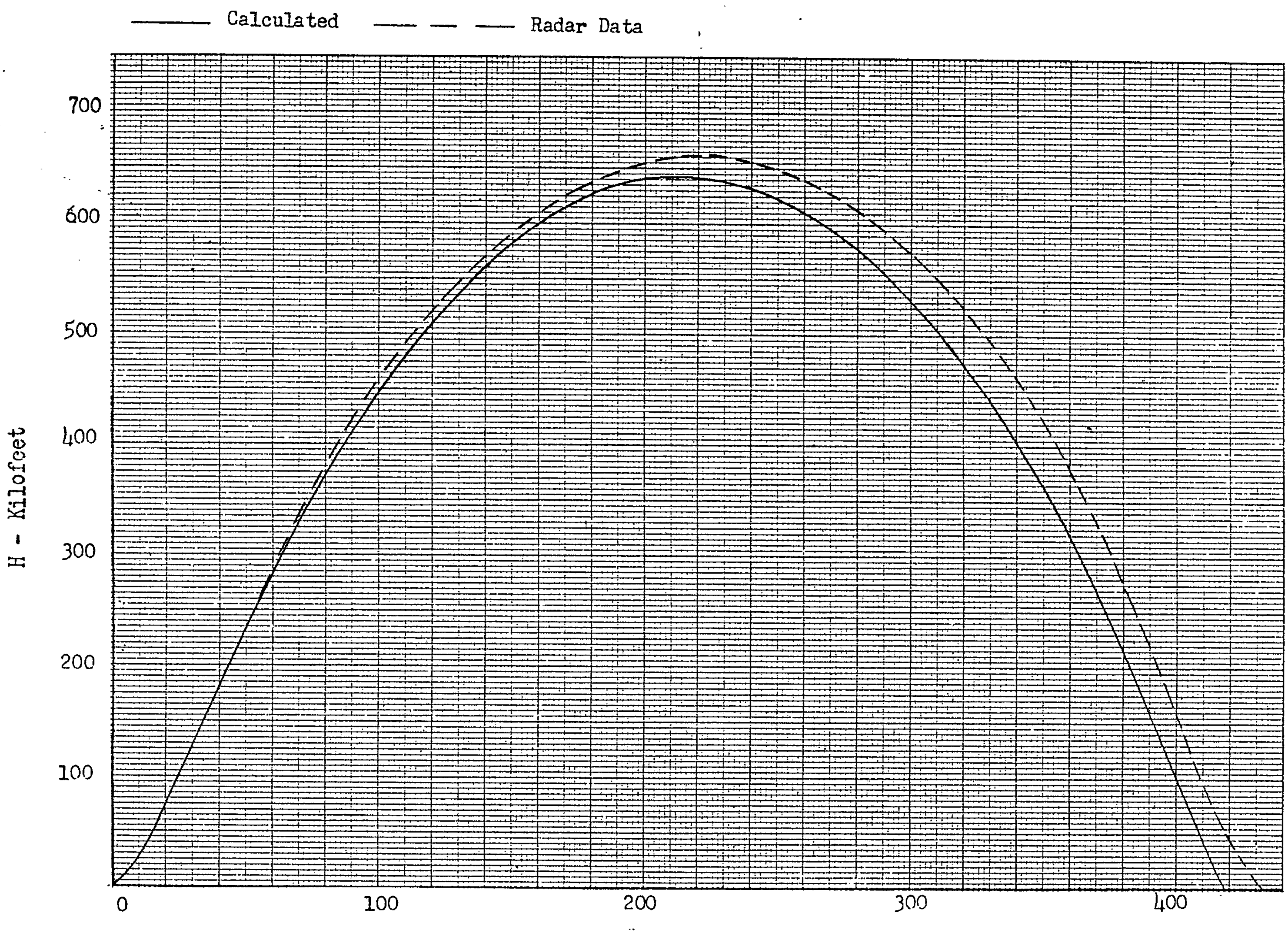


FIGURE 29 - Altitude versus Total Flight Time CC-II-29

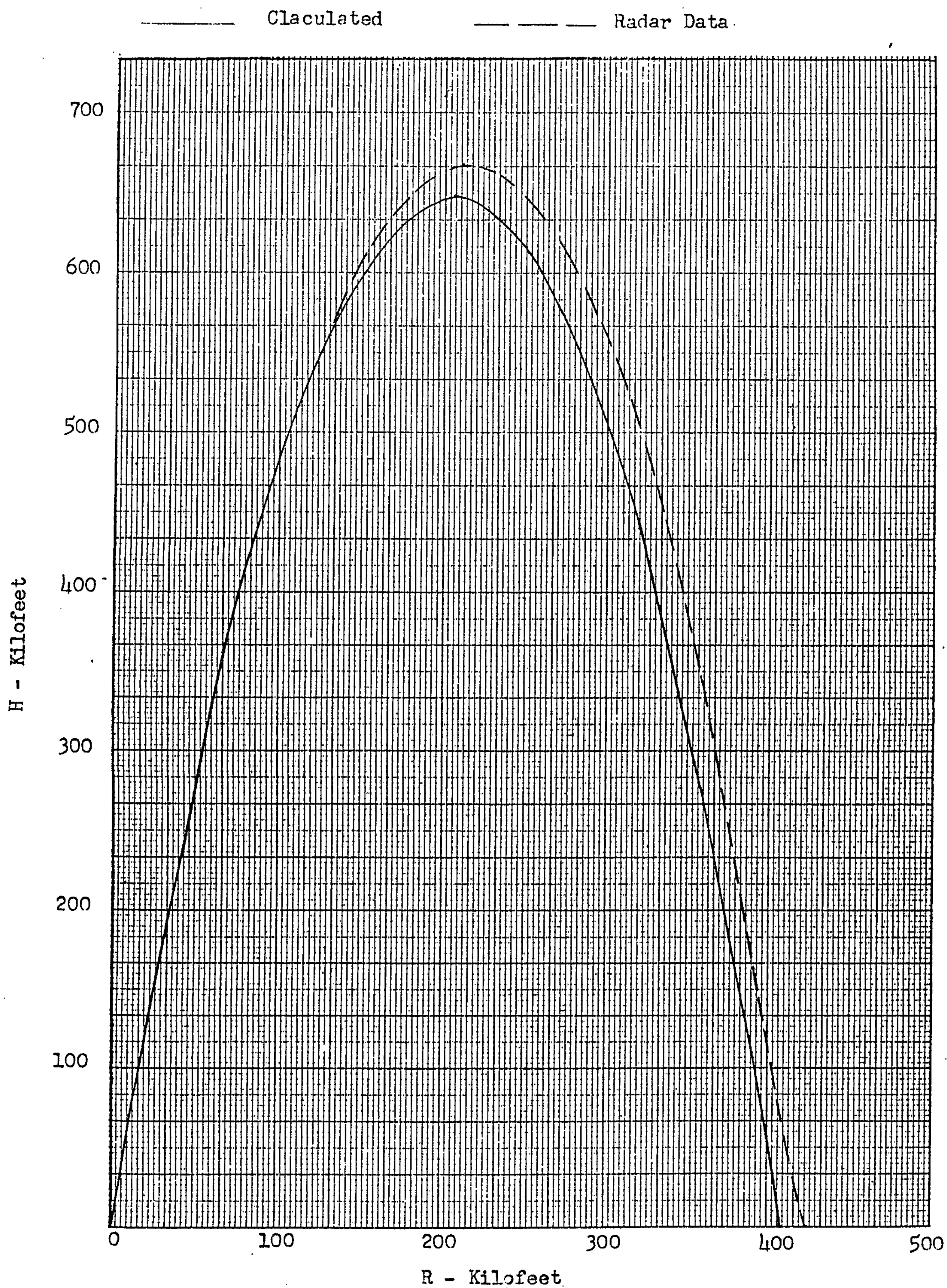


FIGURE 30 - Trajectory for CC-II-29

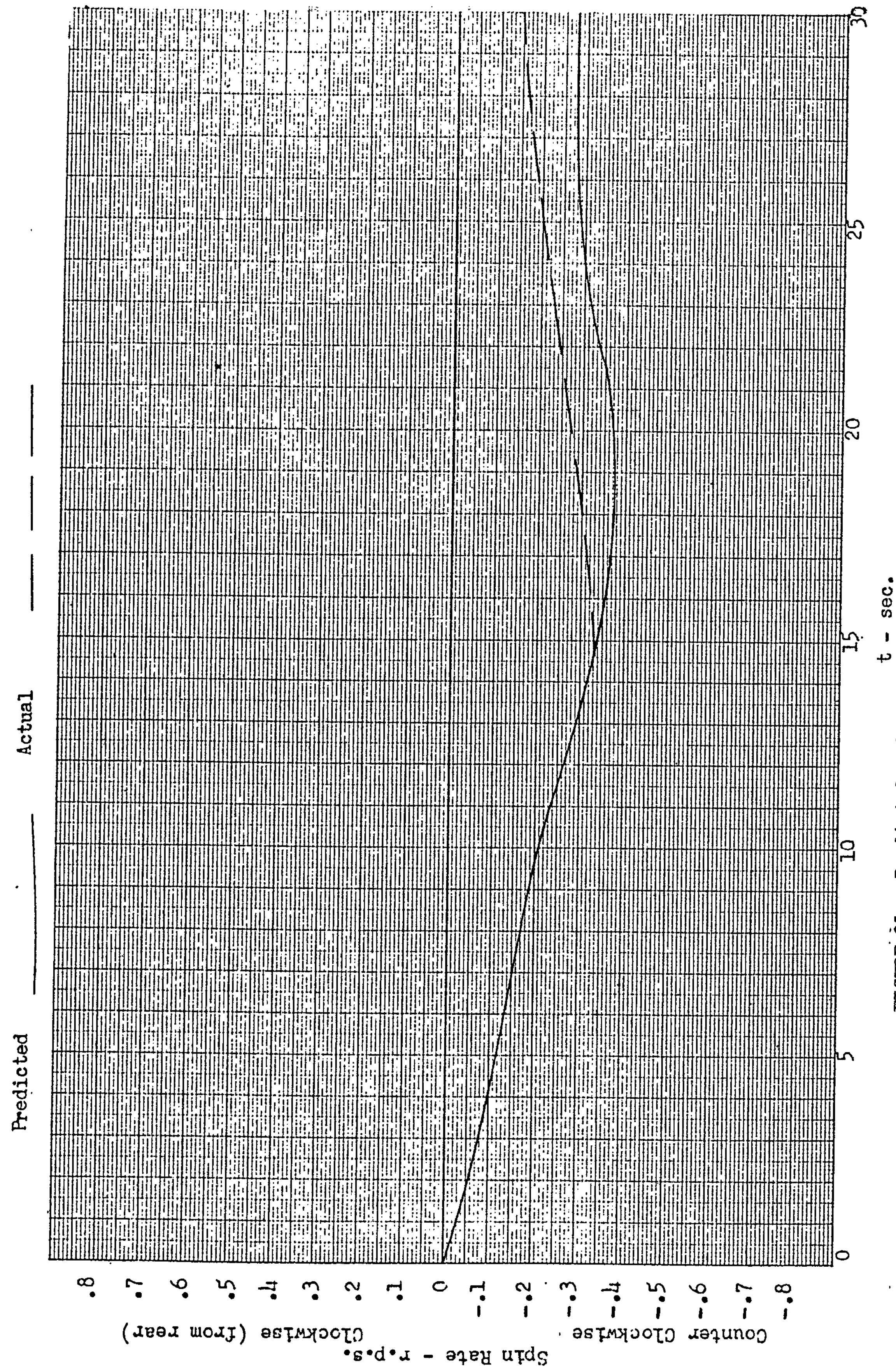


FIGURE 31 - Predicted and Actual Spin Rate versus Time CC-II-29

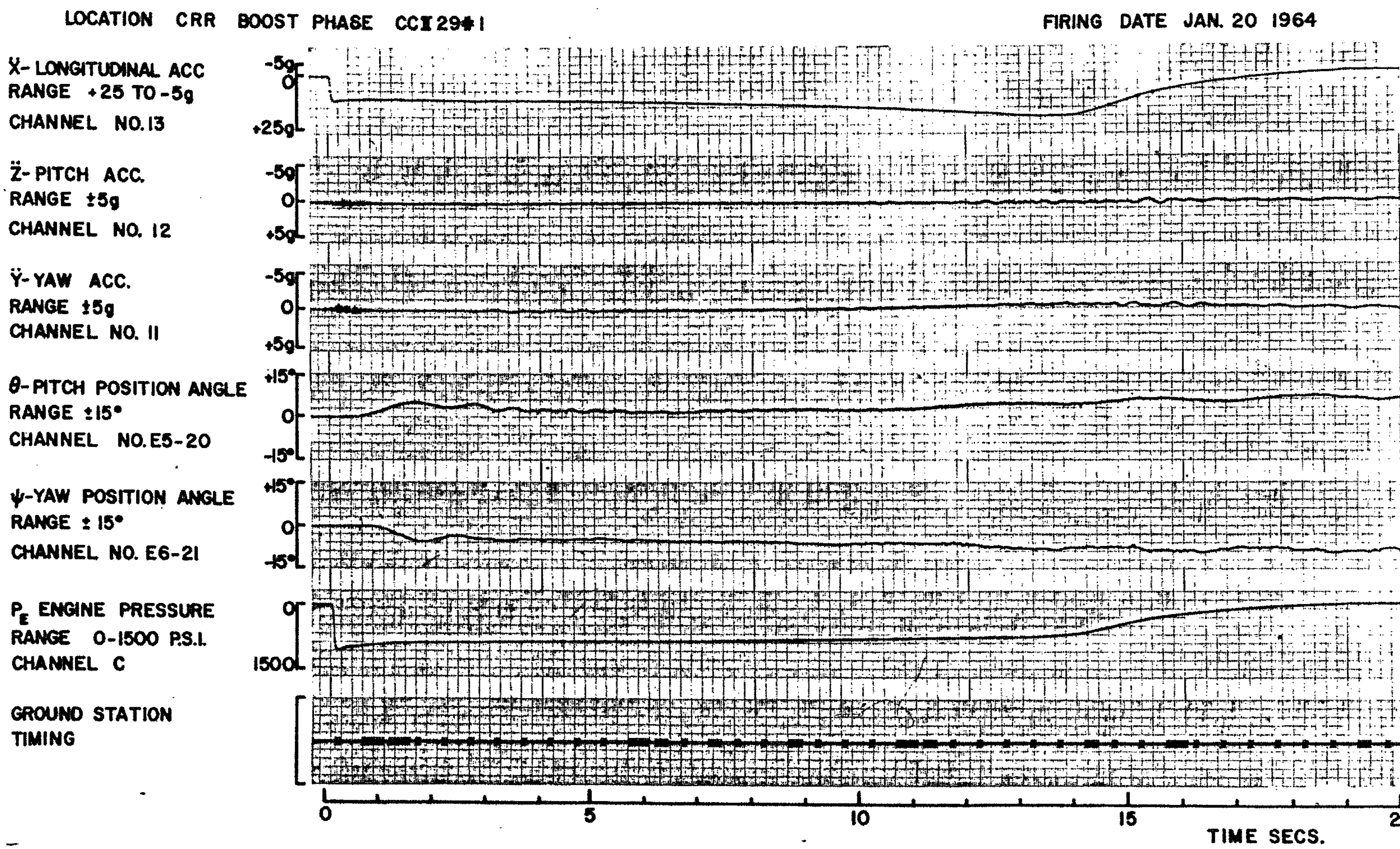


FIGURE 32A - Telemetry Test Flight Records CC-II-29

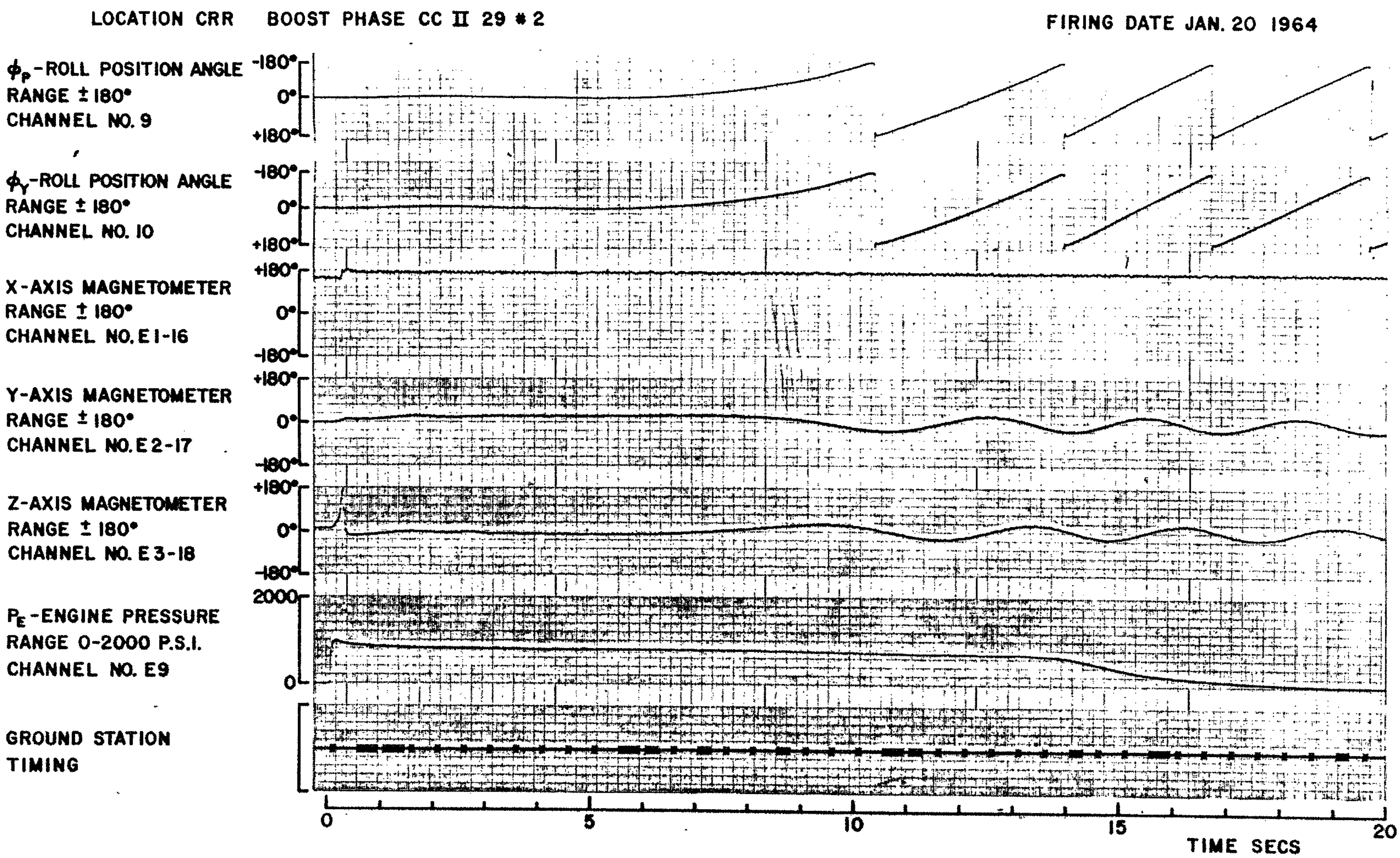


FIGURE 32B - Telemetry Test Flight Records CC-II-29

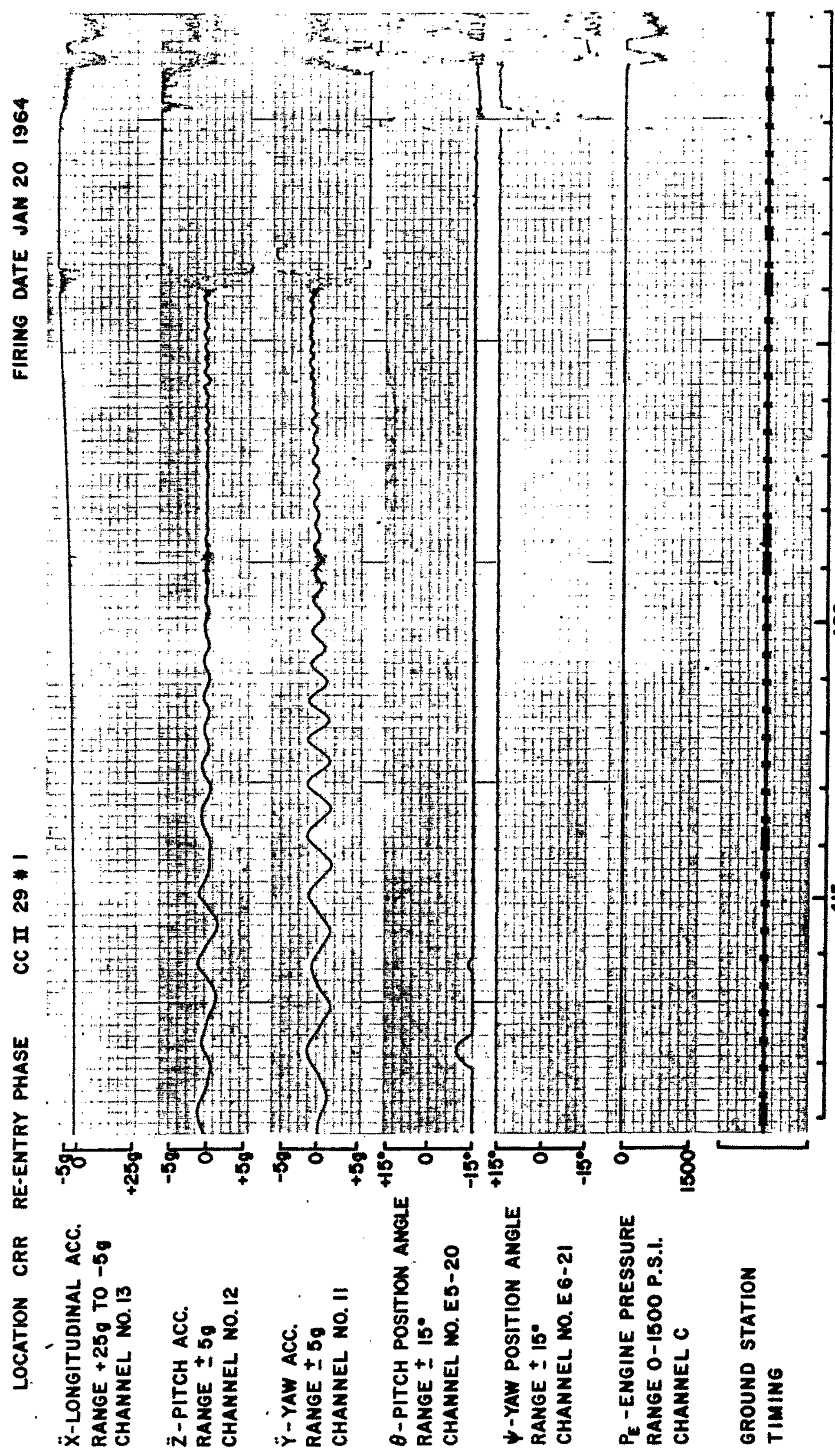


FIGURE 32C - Telemetry Test Flight Records CC-II-29

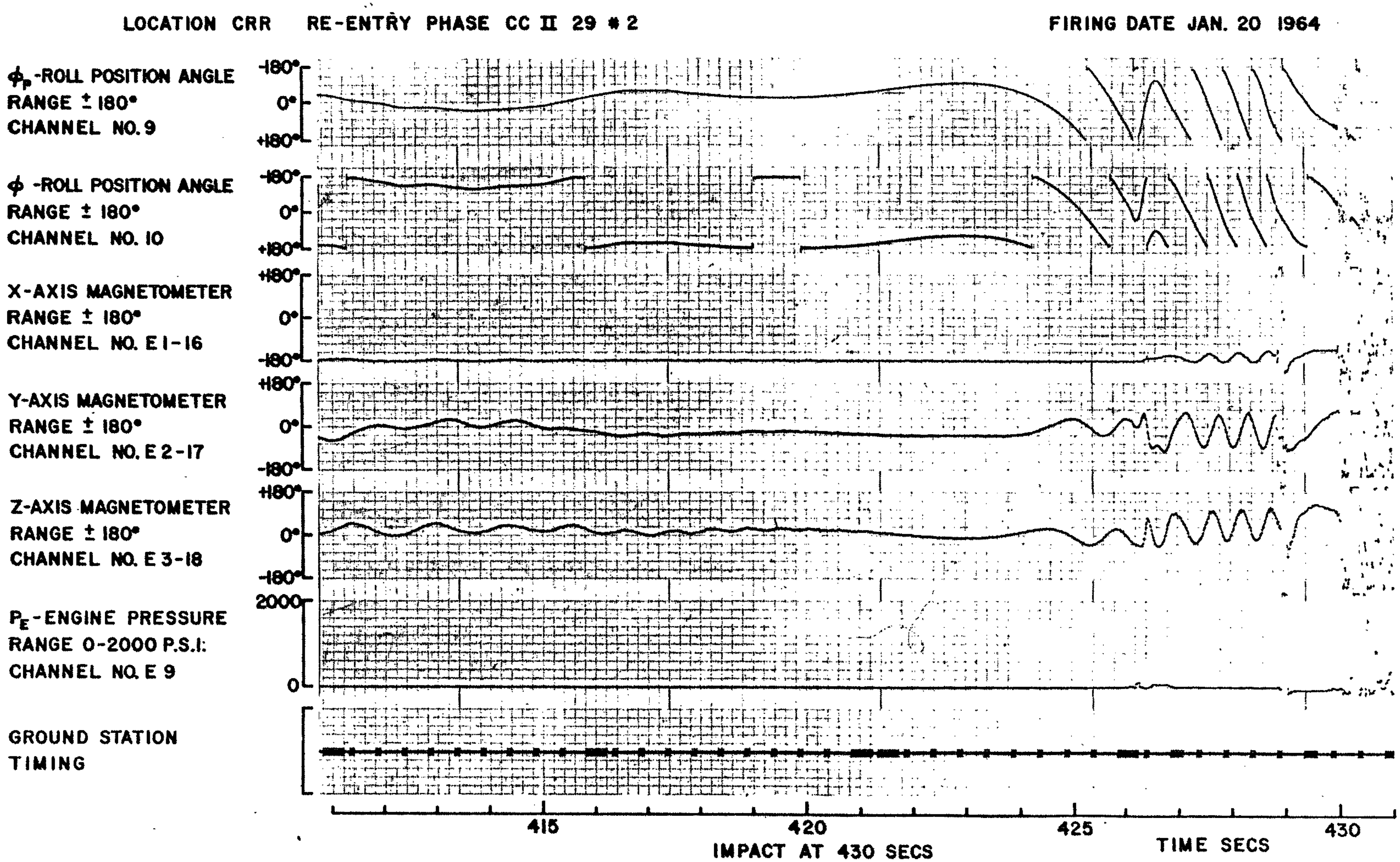


FIGURE 32D - Telemetry Test Flight Records CC-II-29

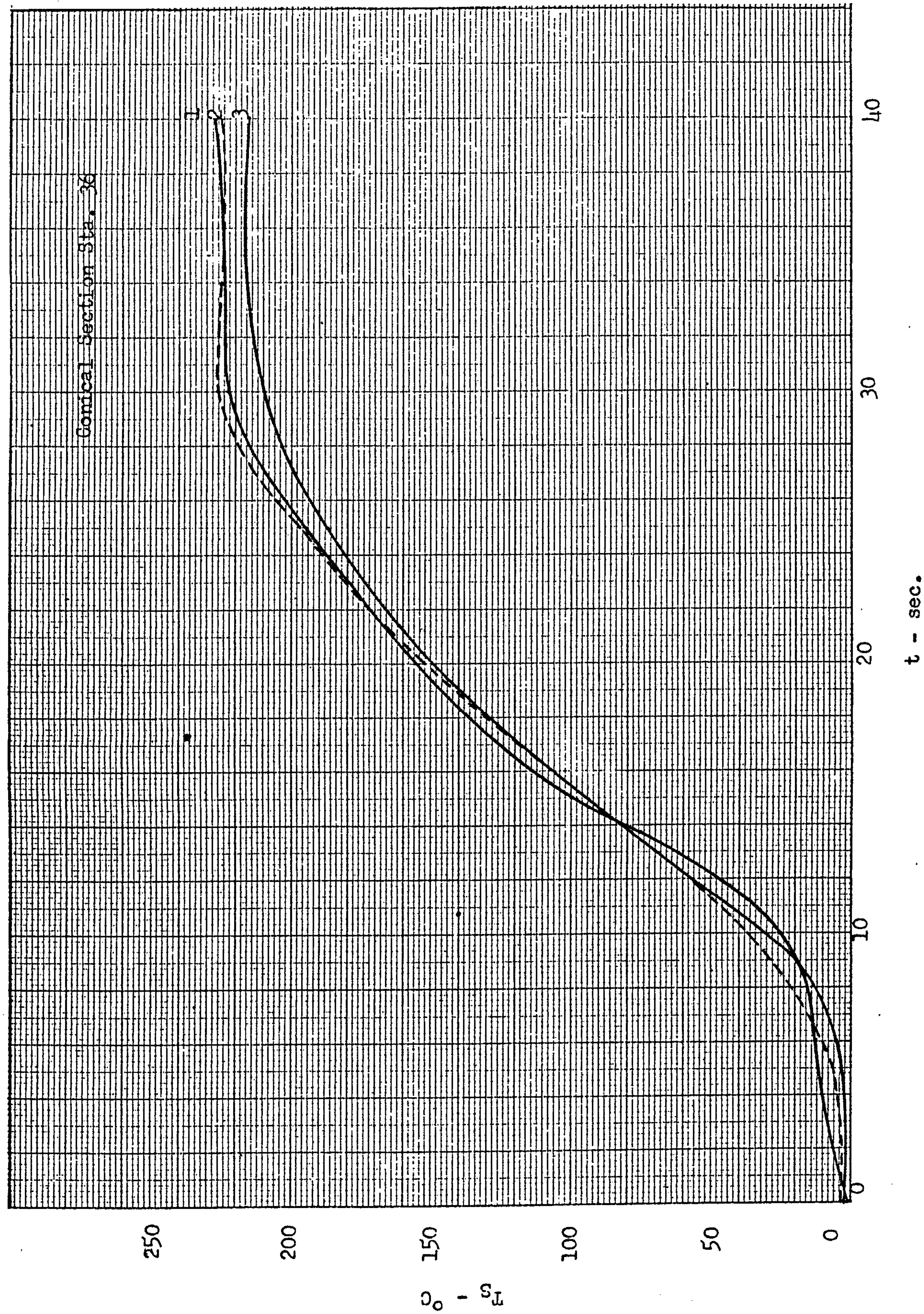


FIGURE 33A - Measured Skin Temperature versus Time CC-II-29

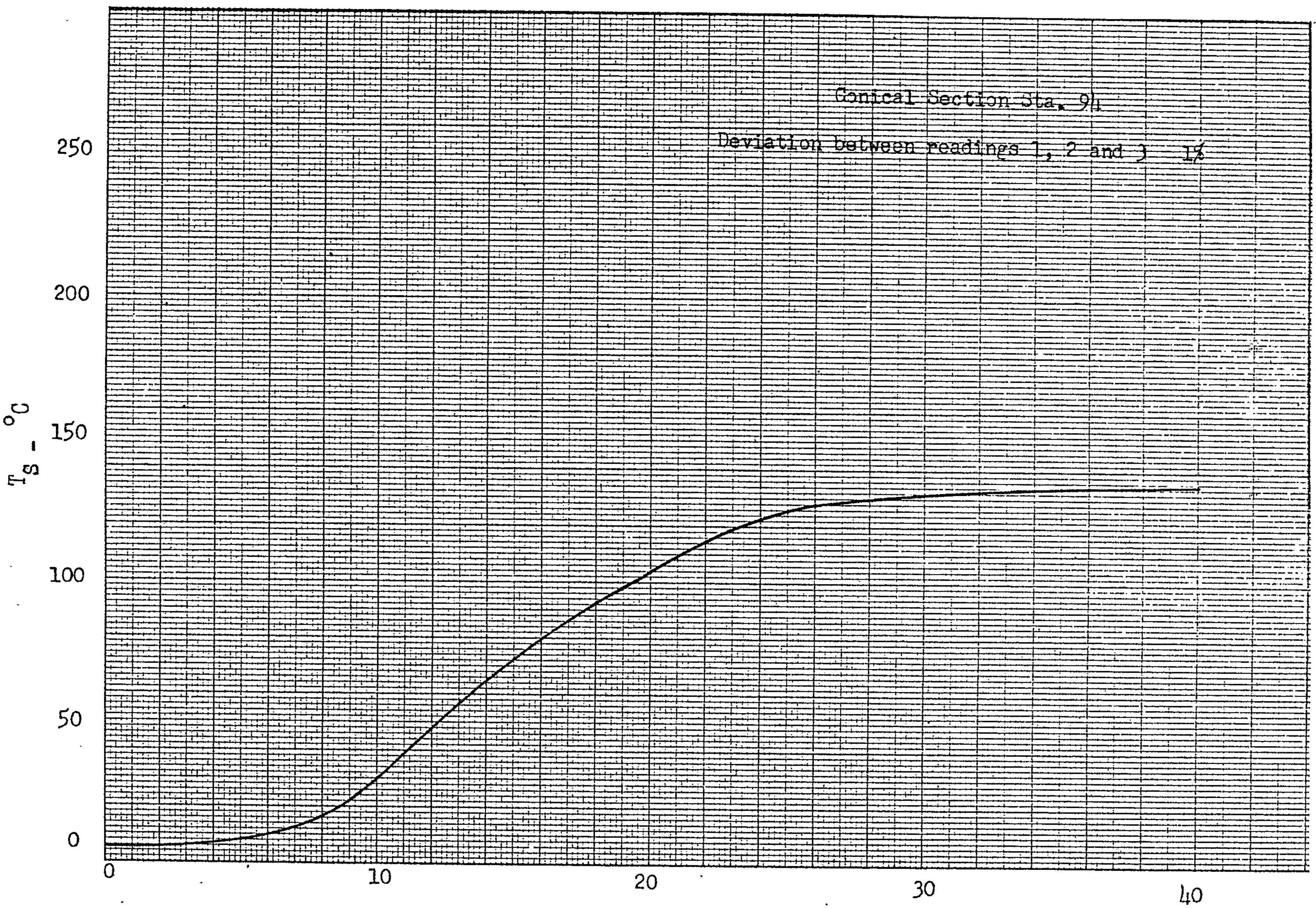


FIGURE 33B - Measured Skin Temperature versus Time CC-II-29

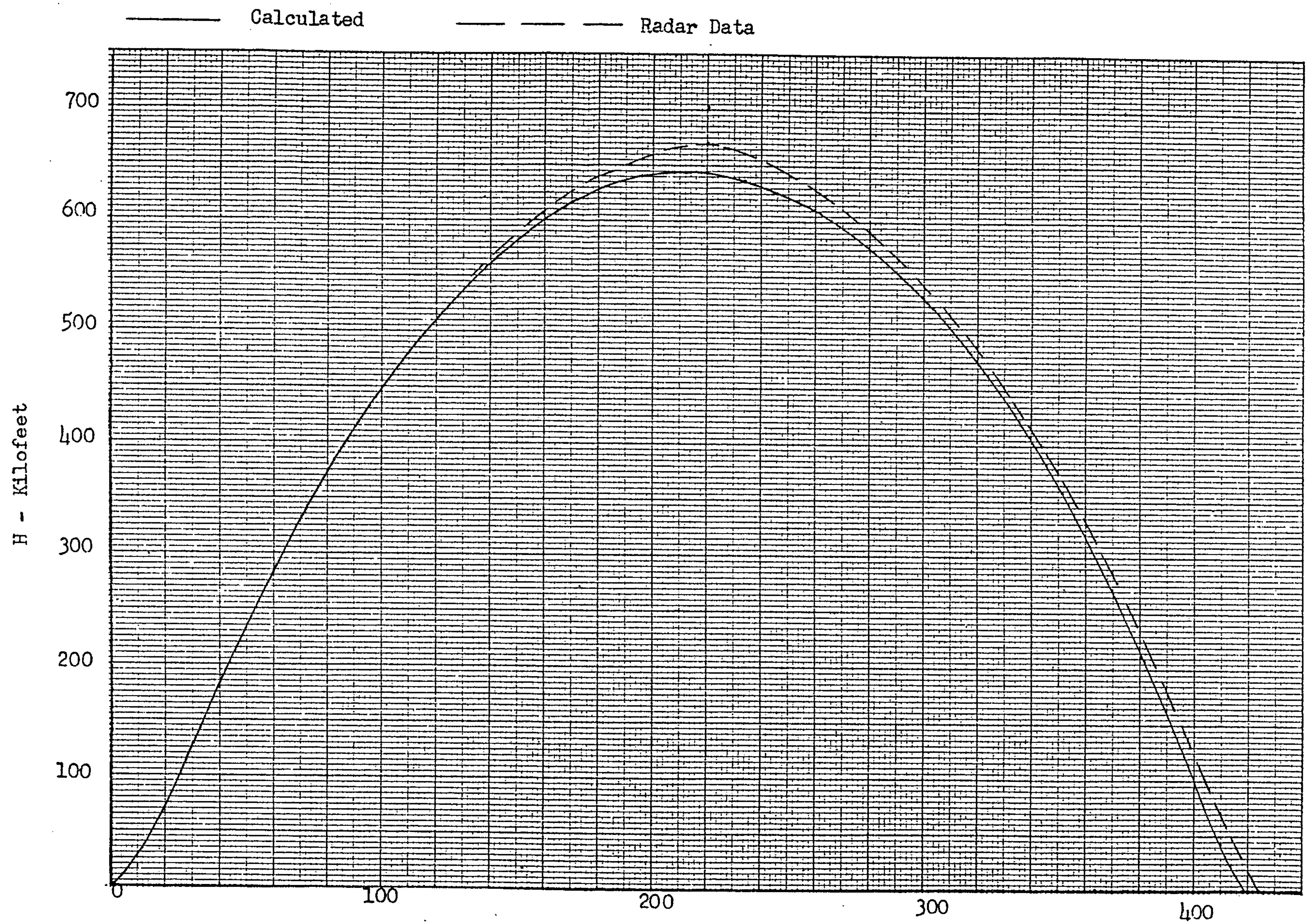


FIGURE 34 - Altitude versus Total Flight Time CC-II-30

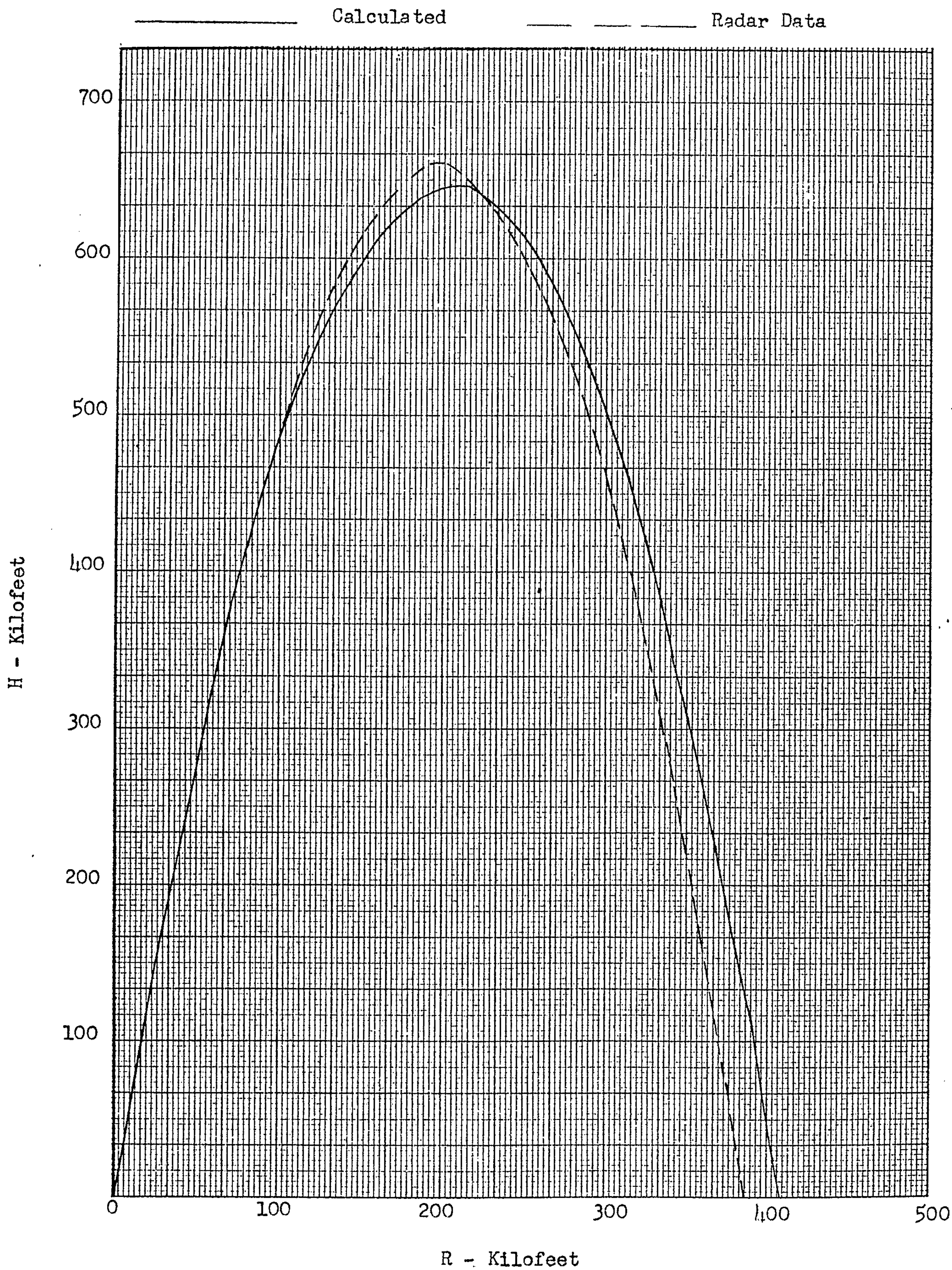


FIGURE 35 - Trajectory for CC-II-30

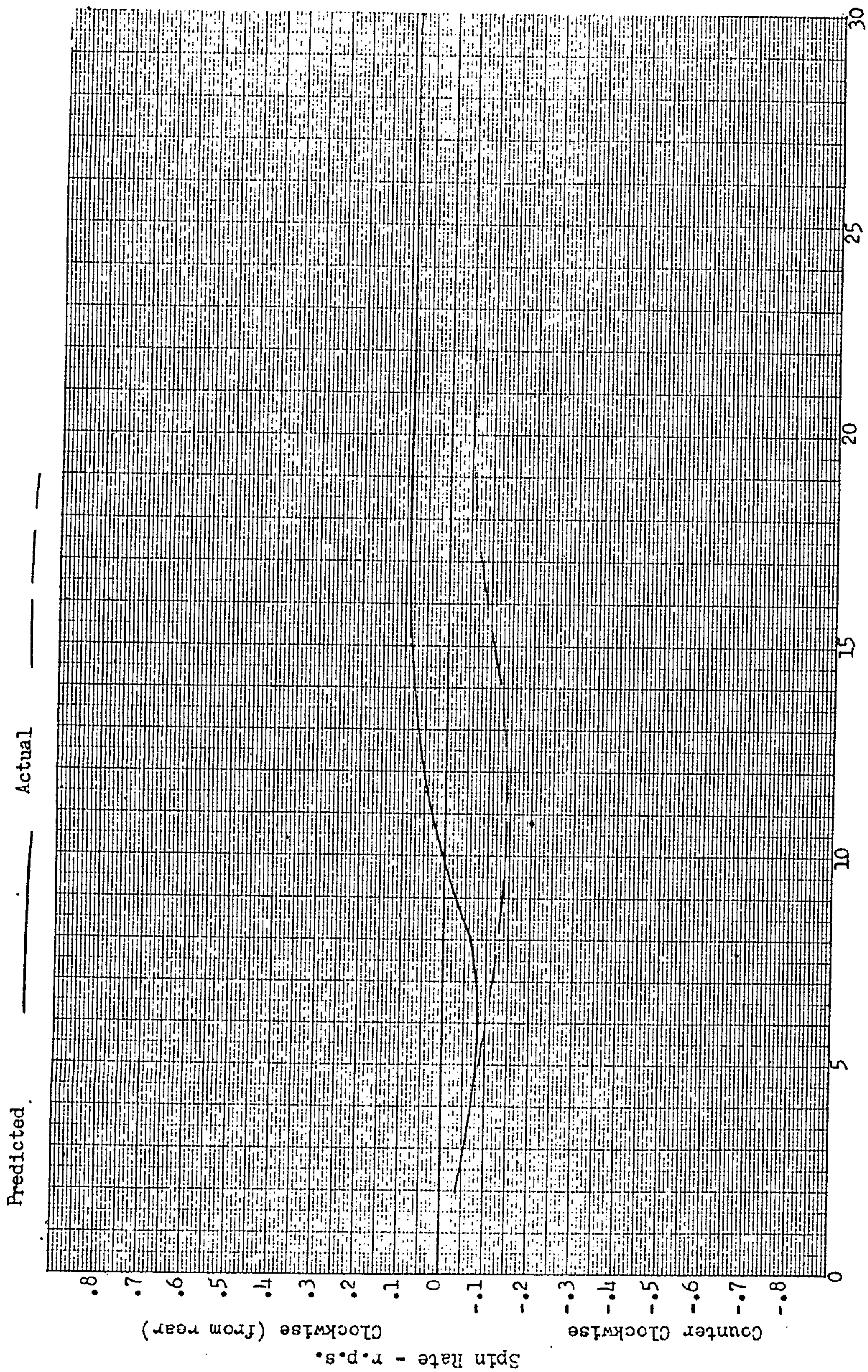


FIGURE 36 - Predicted and Actual Spin Rate versus Time CC-II-30

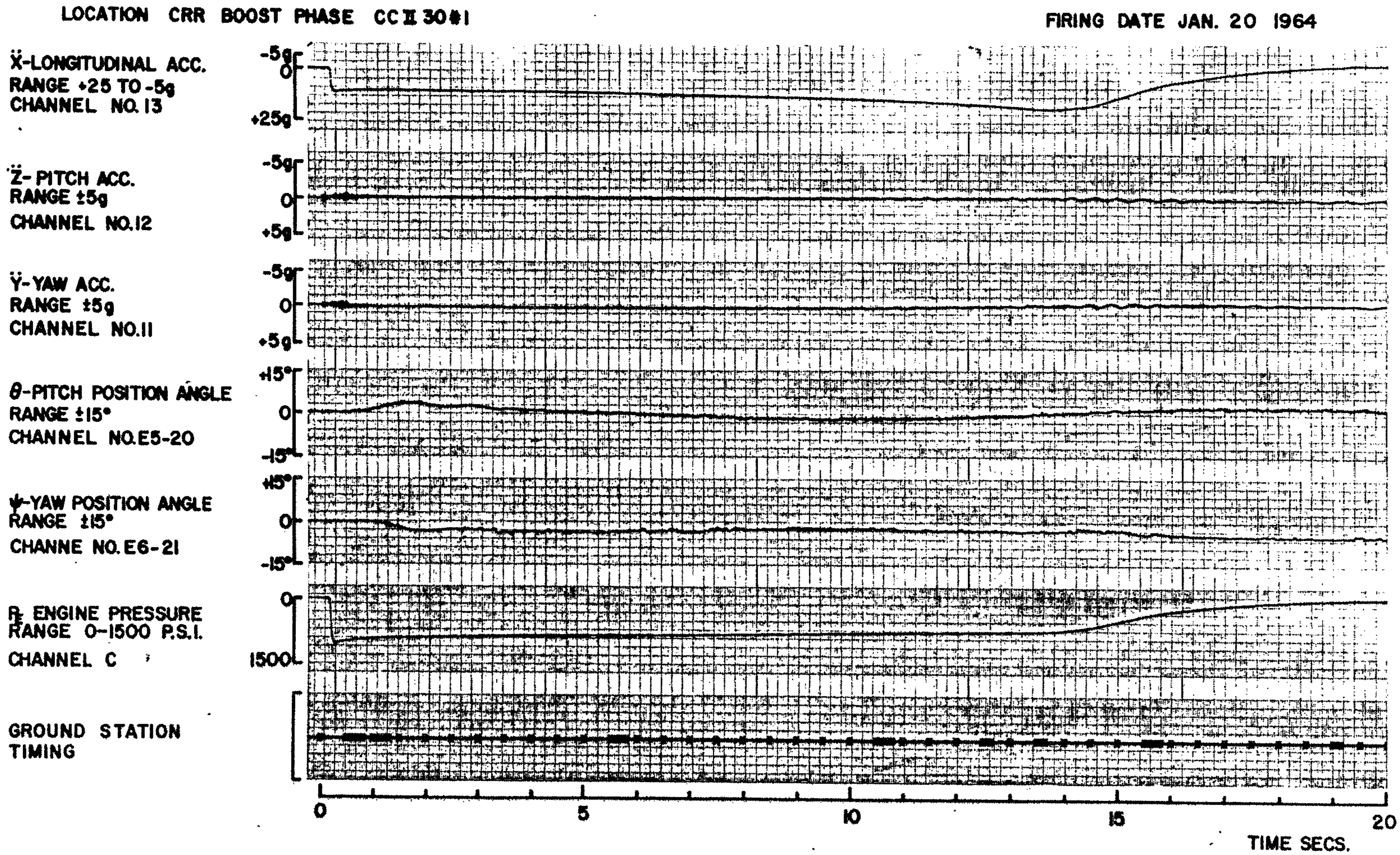


FIGURE 37A - Telemetry Test Flight Records CC-II-30

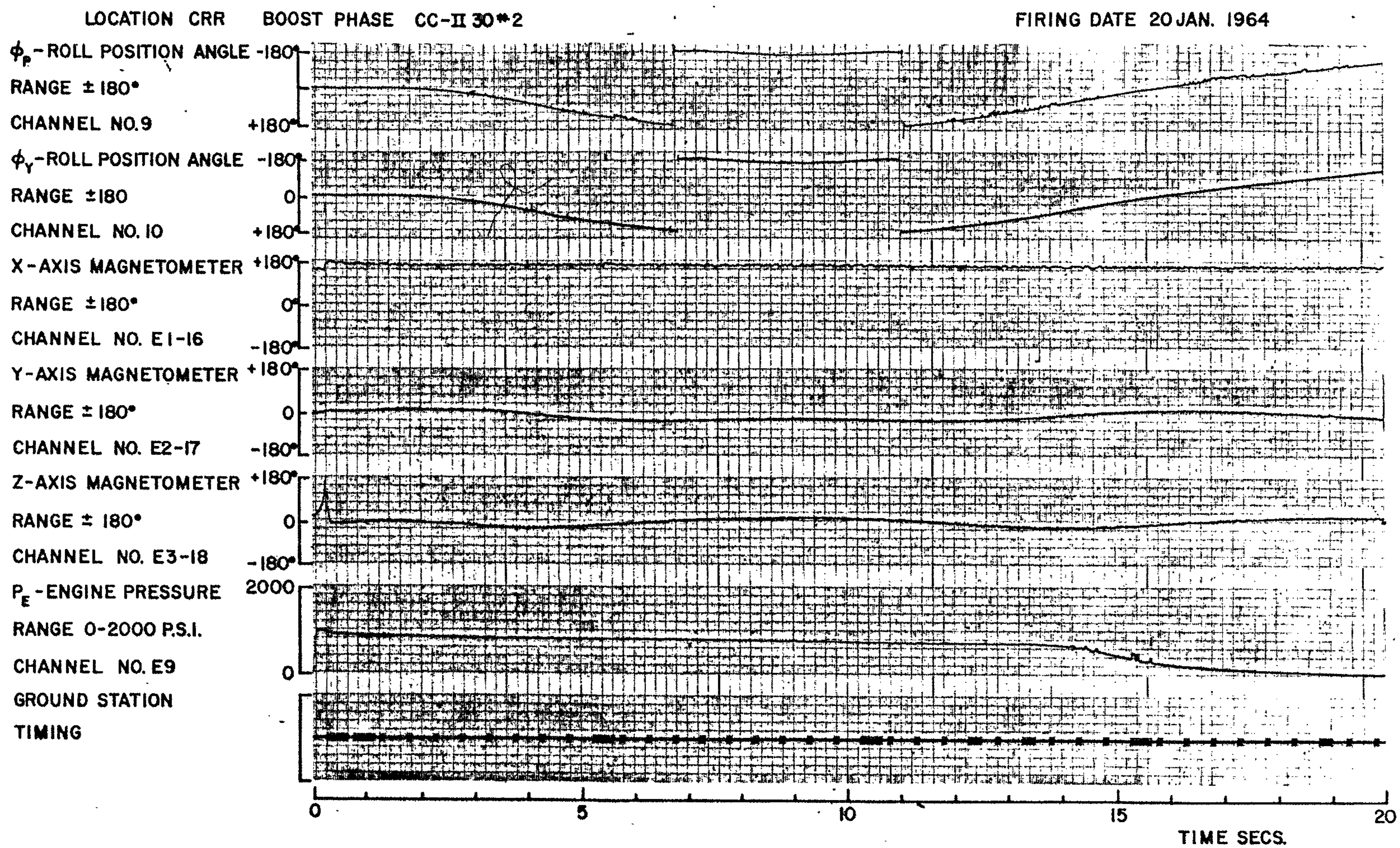


FIGURE 37B - Telemetry Test Flight Records CC-II-30

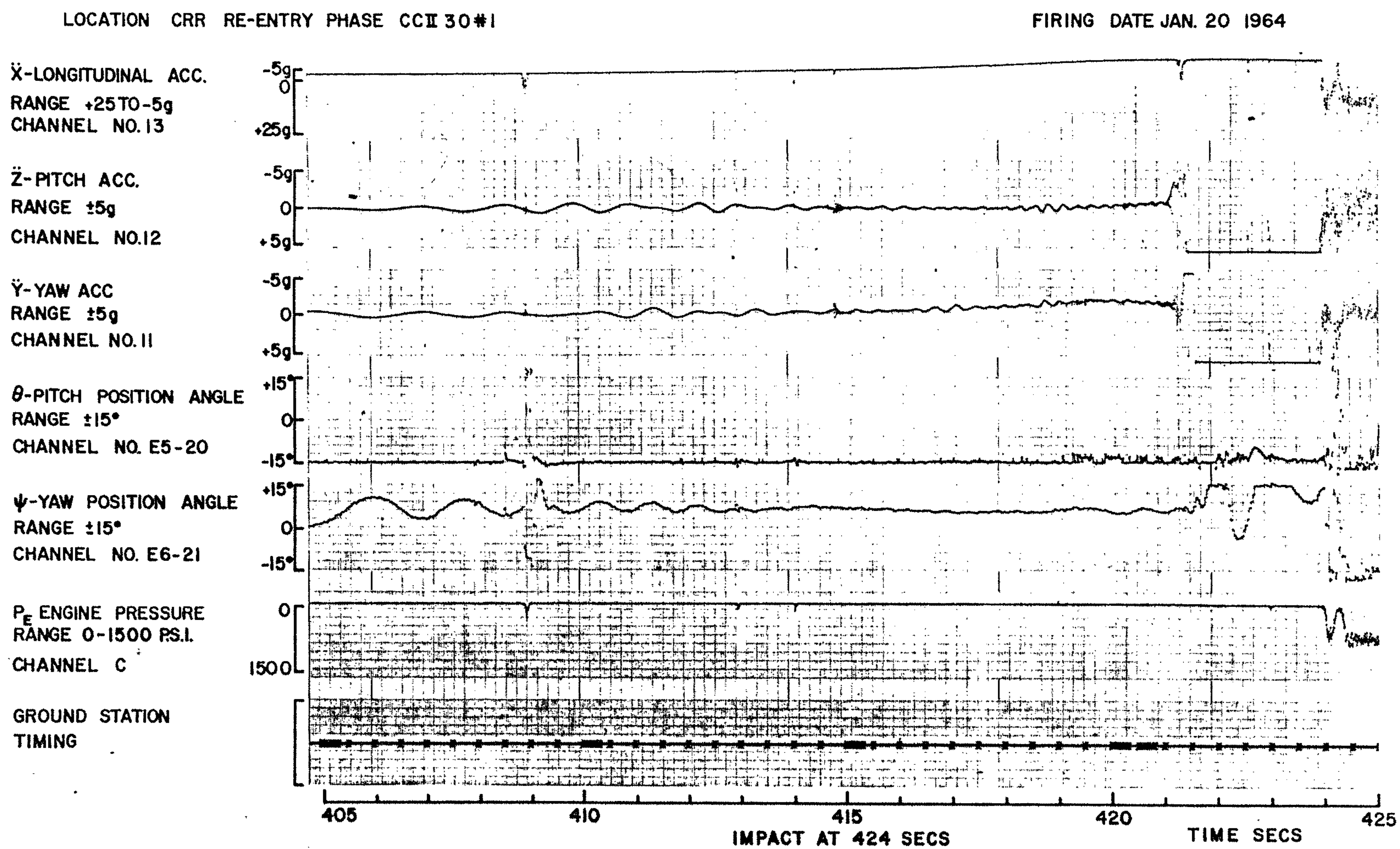


FIGURE 37C - Telemetry Test Flight Records CC-II-30

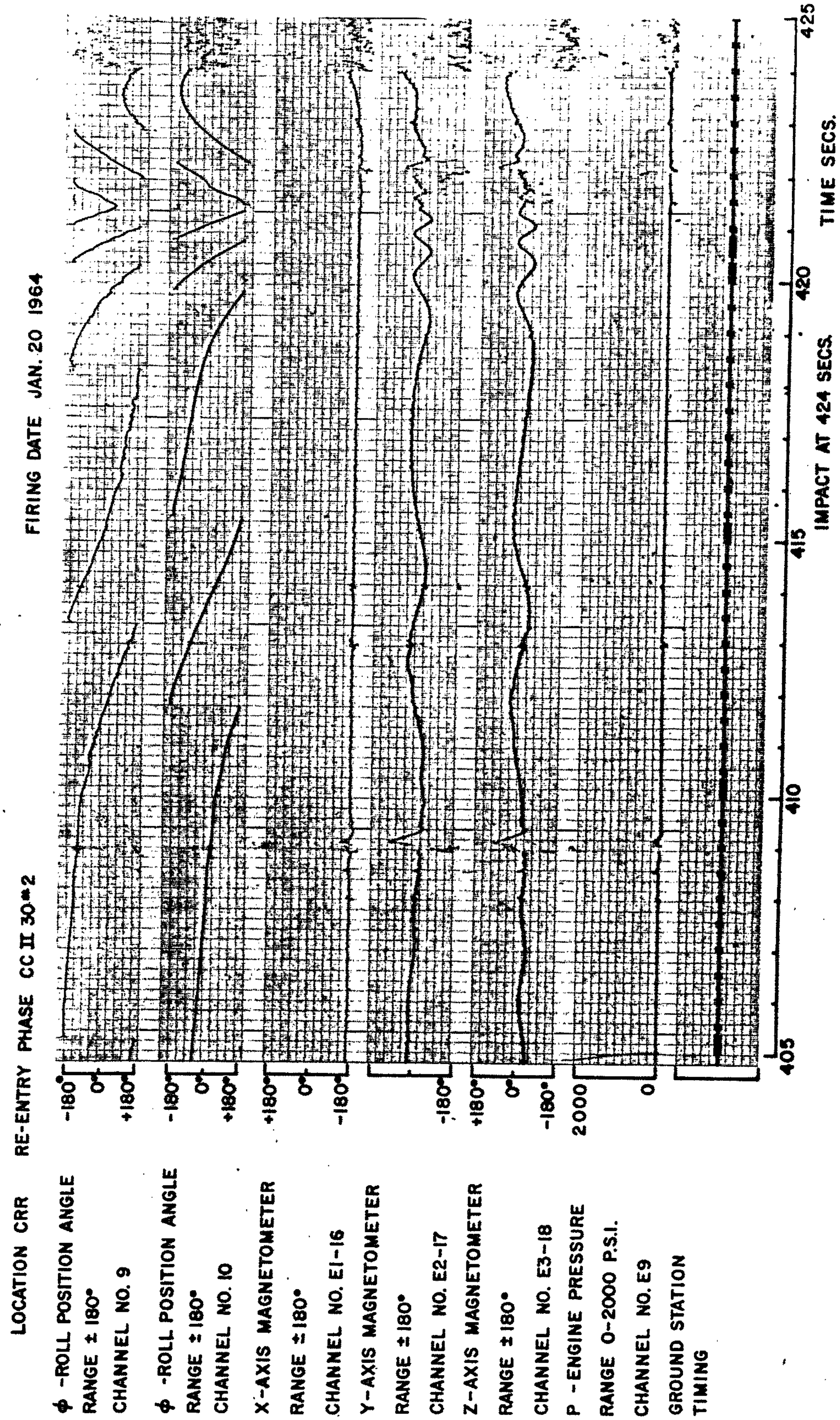


FIGURE 37D - Telemetry Test Flight Records CC-II-30

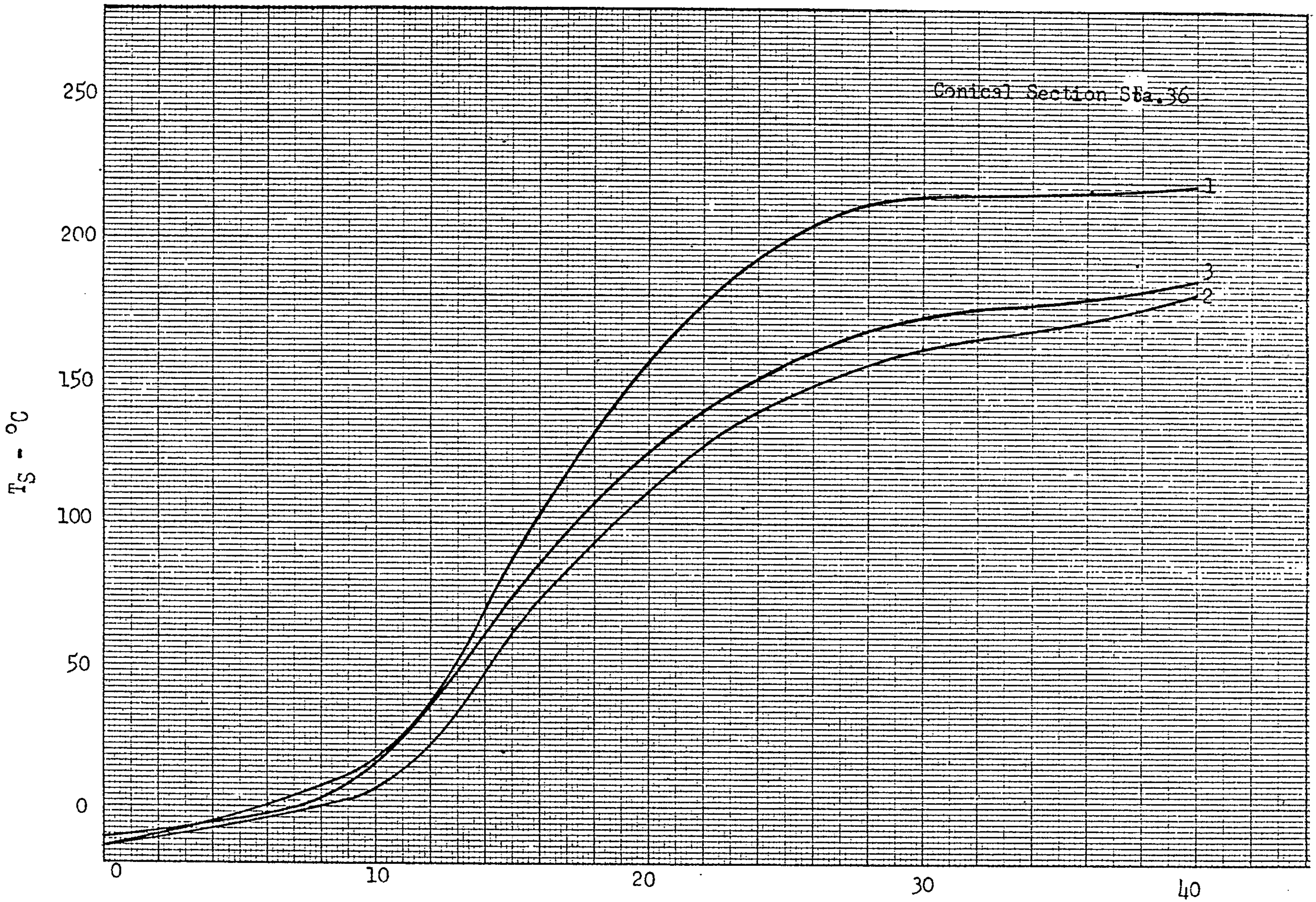


FIGURE 38A - Measured Skin Temperature versus Time CC-II-30

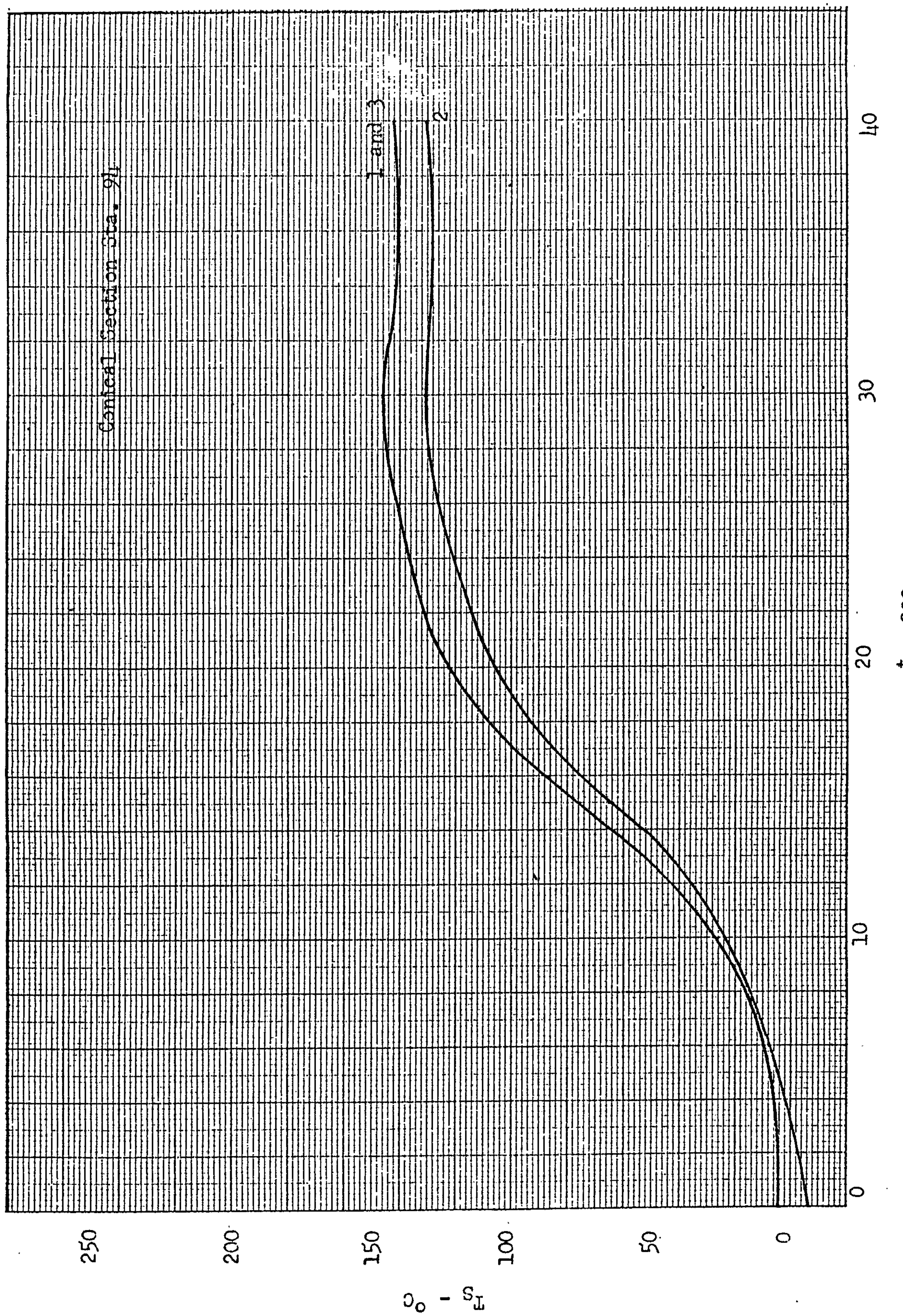


FIGURE 38B - Measured Skin Temperature versus Time CC-II-30

65-6508
441673