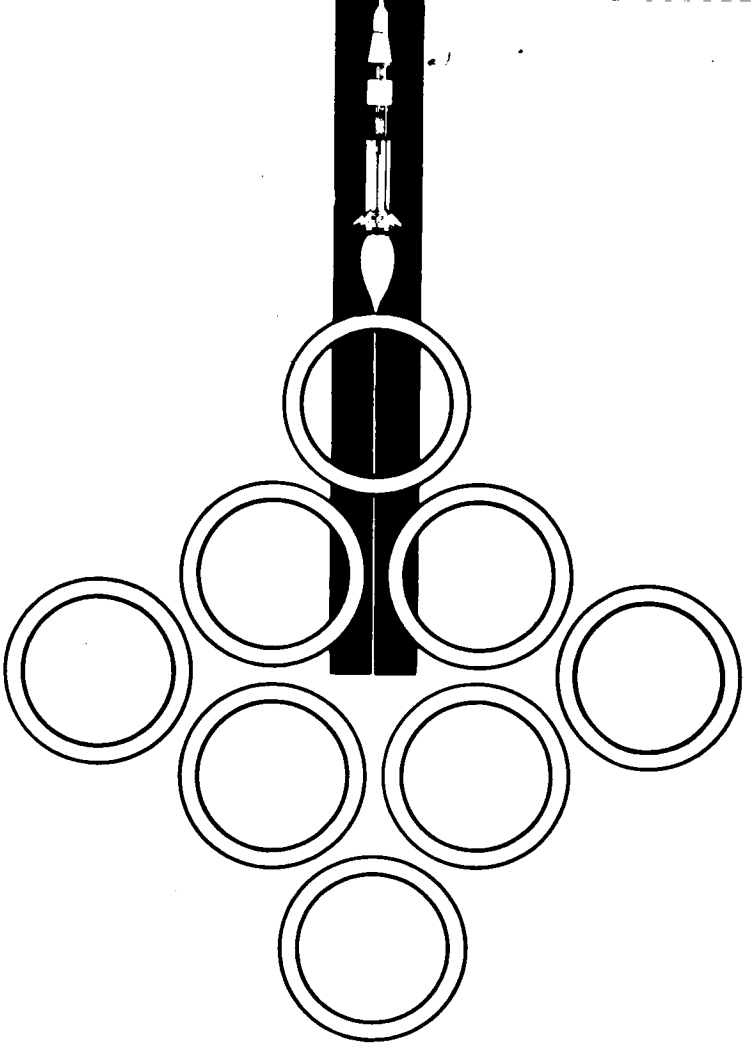

ENGINEERING DEPARTMENT

TECHNICAL NOTE

TN-AP-67-157

AS-206 LAUNCH VEHICLE OPERATIONAL TRAJECTORY RANGE SAFETY ANAYSIS

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AS-206 LAUNCH VEHICLE OPERATIONAL TRAJECTORY RANGE SAFETY ANALYSIS

JANUARY 1967

by

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SUMMARY

This technical note presents data and results of the final Saturn IB range safety analysis for the AS-206 mission. Generalized Saturn IB range safety data are contained in TR-AP-66-1. The analysis documented herein has been scoped to meet the requirements of the range control office and was accomplished under Contract NAS8-4016, Modification MSFC-1, Amendment 19 and 21, BB Item 3.1.3-9.

The lateral impact zone containment area from the intended flight direction (72° east of North) is determined, for AS-206, to reach a maximum of approximately ± 135 km throughout powered flight. For the overflight of Africa, an extreme lateral crossrange deviation, related to the AS-206 mission, is determined to be ± 224 km.

Since the continent of Africa and Malagasy Republic are encompassed within the range safety corridor, a study of the impact and casualty probability related to the overflight of these land masses is conducted.

Under normal operation S-IB stage impact for the AS-206 mission is predicted to occur at 29.89 degrees north geodetic latitude and 75.26 degrees west longitude. S-IVB guidance cutoff signal is predicted to occur at 580.46 ± 22 seconds following first motion at a downrange distance from the launch site of 1773.42 ± 57 km.

Flight azimuth limits to useful mission orbits are 57° east of North for the left and 90° east of North for the right.

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Section 1.0 - INTRODUCTION

This technical note, in conjunction with TR-AP-66-1 (Reference 1), presents range safety data for Saturn IB launch vehicle SA-206 for use by the range safety office as well as an independent analysis of the results. The data and analysis contained herein are oriented around the characteristics of the standard trajectory for AS-206, designated the preliminary operational trajectory which is documented in TN-AP-66-125 (Reference 2).

Contained in Reference 1 are general information and data applicable to Saturn IB launch vehicles SA-205 and subsequent. Included are range safety data requirements; range safety analysis technique; predicted change in total velocity vector orientation and velocity in the lateral direction for the Apollo payload configuration; summary description of the flight termination system; expected effects of destruct action as well as drag coefficients of resulting pieces; stage, subsystem, and component reliability predictions; pad area clearance data; cape magnetic tape information; etc.

Reference 2 presents detailed data pertinent to launch vehicle SA-206 including mission and vehicle configuration description; vehicle environmental data; L/V test objectives and constraints; etc.

Contained herein are the maximum expected trajectory deviations from the intended flight path; expected impact of staging reentry bodies; predicted change in total velocity vector orientation and velocity in the lateral direction for a non-Apollo payload configuration (aerodynamic fairing); range safety associated corridors; downrange land impact and casualty probabilities; etc. In addition an outboard profile of the Apollo Saturn IB AS-206 configuration and April wind profile envelopes for a 72° flight azimuth are presented in Figures 1 and 2, respectively.

Section 2.0 - RANGE SAFETY DATA REQUIREMENTS - TRAJECTORY

Formal range safety data requirements are defined for the launch agency by the Deputy Commander of tests (Reference 1) and in general, pertain to vehicle subsystems descriptions and performance predictions, and trajectory characteristics, for various flight modes. The following sections present the required trajectory data associated with the standard, dispersed, and engine malfunction flight conditions for the Saturn IB launch vehicle SA-206.

2.1 Standard Trajectory

The standard trajectory for the AS-206 mission corresponds to the preliminary operational trajectory which is presented in Reference 2. The range safety required data related to the standard trajectory are contained on the cape magnetic tape in Record 12, Files 2 through 5.

2.2 Dispersed Trajectories

Listed below are the combined off nominal parameter variations about the standard trajectory which define the respective dispersed trajectories:

3σ Maximum	S-IB Stage:	+1.7% Thrust, +1.7% Flow Rate, -5000 lb NPM.
	S-IVB Stage:	+3.0% Thrust, +3.0% Flow Rate.
3σ Minimum	S-IB Stage:	-2.6% Thrust, -2.6% Flow Rate, April HW, +1500 lb NPM.
	S-IVB Stage:	-3.0% Thrust, -3.0% Flow Rate, April HW.
3σ Right Lateral	S-IB Stage:	-0.62° Yaw Thrust Misal., April LCW, +0.05 m YCG Offset.
	S-IVB Stage:	+3.0% Thrust, +3.0% Flow Rate, April LCW.
3σ Left Lateral	S-IB Stage:	+0.62° Yaw Thrust Misal., April RCW, -0.05 m YCG Offset.
	S-IVB Stage:	-3.0% Thrust, -3.0% Flow Rate, April RCW.
Right Flt. Az. Limit	S-IB Stage:	90° Flight Azimuth.
Left Flt. Az. Limit	S-IB Stage:	57° Flight Azimuth.

Steepest	S-IB Stage:	+1.5% Thrust, +1.5% Flow Rate, -0.62° Pitch Thrust Misal., -0.05 m XCG Offset, April HW.
	S-IVB Stage:	+3.0% Thrust, +3.0% Flow Rate, April HW.
Engine Out	S-IB Stage:	Eng. 3 out at L.O., 22 sec. CHIP Freeze starting at L.O. + 30 sec.

The range safety data requirements prescribed by the range control office, in connection with the above trajectories, are contained in Record 12, Files 6 through 29 on the cape magnetic tape at one second time intervals.

2.3 Impact of Staging Reentry Bodies

S-IB Stage Impact

Trajectory	Latitude (deg N)	Longitude (deg W)	Time Remaining (sec)	Range (km)	Range (n mi)
Standard	29.8911	75.2572	406.1	537.6	290.3
3σ Maximum	29.9710	74.9015	415.9	573.1	309.4
3σ Minimum	29.8297	75.5171	391.3	511.6	276.2
3σ Right Lateral	29.5662	75.1161	407.6	542.9	293.1
3σ Left Lateral	30.1772	75.3128	407.3	541.6	292.4
Right Flt. Az. Limit	28.3739	74.9814	408.1	547.1	295.4
Left Flt. Az. Limit	31.0937	75.7510	406.4	545.1	294.3
Steepest	29.9279	75.0821	428.3	555.0	299.7
Engine Out	29.6327	76.0530	388.2	456.0	246.2

The S-IB stage impact data requirements prescribed by the range safety office to be included on the cape magnetic tape correspond to the standard trajectory related data only. These data are contained in Record 12, File 5 on the cape magnetic tape at two second intervals and includes both retro-rocket simulation and the ballistic trajectory to S-IB stage impact.

Ullage-Rocket Cases Impact

Trajectory	Latitude (deg N)	Longitude (deg W)	Time Remaining (sec)	Range (km)	Range (n mi)
Standard	29.9484	75.0234	610.6	561.1	302.9
3σ Maximum	30.0146	74.7256	625.0	590.7	319.0
3σ Minimum	29.8447	75.4562	595.4	517.7	279.5
3σ Right Lateral	29.5417	74.9704	609.9	556.2	300.4
3σ Left Lateral	30.2329	75.2116	609.7	552.8	298.5
Steepest	29.9584	74.9516	631.2	568.0	306.7
Engine Out	29.6670	75.9466	589.3	466.9	252.1
Right Flt. Az. Limit	28.3769	74.8354	611.2	561.4	303.1
Left Flt. Az. Limit	31.1555	75.6221	609.3	559.1	301.9

A plot of the impact dispersion for staging reentry bodies associated with the primary mission is presented in Figure 3.

2.4 Velocity Vector Turning Capability

It is necessary to ascertain how fast the missile IIP trace can leave the range or an unstable condition, i.e. tumbling, can occur. The data presented herein relates to a type of malfunction which may occur such that thrust is not terminated and the controllable outboard thrust chamber nozzles seek an abnormal steady-state deflection angle, hardover or otherwise. Only yaw plane movement of the vehicle for discrete thrust chamber deflection angles in the lateral plane are considered. Each deflection angle is introduced during S-IB stage flight at 4 second time intervals, starting at t_o + 12 seconds. Similarly, each deflection angle related to S-IVB stage flight is introduced at 4 second intervals between S-IVB ignition and t_o + 158 seconds, and at 16 second intervals during the remainder of S-IVB stage flight. The initial conditions (vehicle position, velocity, atmospheric density, etc.) for each case are obtained from the standard trajectory. Turning data are terminated when angle of attack (α_y) corresponds to 180°. The lateral turning rates are considered symmetrical, hence the vehicle is yawed only in the right lateral direction.

The data requirements associated with these conditions, prescribed by the range control office, in connection with velocity vector turning capability are presented in Figures 4 through 123. Figures 4 through 63 present the change in the corresponding total velocity vector orientation referenced to the standard trajectory, while Figures 64 through 123 present the magnitude of the relative velocity vector.

To apply these results to other than the standard trajectory, the proper time differential, reflecting the effects of off-nominal characteristics, must be considered.

The following presents the proper time differentials between the AS-206 standard and the maximum (+ 3σ) and minimum (- 3σ) trajectories.

Time of Yaw Turn Initiation - Seconds

Standard Trajectory	3σ Maximum Trajectory	3σ Minimum Trajectory
30	28	32
80	78	84
130	127	134
200	191	213
300	289	316
400	386	418
500	482	522
575	556	597

Section 3.0 - RESULTS

This section contains an independent analysis of the pertinent range safety related data.

3.1 3σ Flight Corridor

The pitch plane corridor limits are defined by the 3σ maximum vehicle profile and the 3σ minimum vehicle profile. The yaw plane corridor limits are defined by the 3σ left lateral and the 3σ right lateral deviating vehicle.

At S-IB/S-IVB separation the 3σ maximum vehicle profile produces an increase from that of the standard in velocity and altitude of 27 m/sec and 2308 m, respectively. The 3σ minimum vehicle profile produces a decrease, relative to the standard, in velocity of 28 m/sec and in altitude of 2392 m. The 3σ left and right lateral trajectories deviate from the standard in crossrange at S-IB/S-IVB stage separation by 4.20 km and 5.30 km, respectively.

The 3σ maximum vehicle profile increases the downrange impact point of the standard trajectory S-IB stage by 35.5 km while the 3σ minimum vehicle profile causes the S-IB stage to impact 26.0 km short of the standard impact point. Lateral crossrange deviations of the S-IB stage impact point of 38.3 km and 32.0 km from the standard result from the 3σ right lateral and 3σ left lateral trajectories, respectively.

S-IVB stage guidance target conditions: velocity (V), radius (R), flight path angle (γ), inclination angle (i), and descending node (θ_N) for a $\pm 3\sigma$ vehicle profile are virtually unchanged from those of the standard. For normal operation S-IVB guidance cutoff signal is predicted to occur at 580.46 $\pm$ 22.19 seconds following first motion, at a downrange distance from the launch site of 1773.42 $\pm$ 56.44 km.

Figure 124 presents altitude versus range for the 3σ pitch plane flight profile.

3.2 Range Safety Crossrange Corridors

The range safety lateral corridor is established by combining the effects of the major contributing conditions that produced a significant crossrange deviation from the standard trajectory. In chronological order, these major contributing conditions are: 1) maximum 3σ out-of-plane trajectory, 2) turning the vehicle in the yaw plane at the maximum turning rate maneuver considered (β_y = 11.3° for S-IB stage, β_y = 10° for S-IVB stage) until the vehicle has turned through 180°, and 3) assuming range safety destruct action occurrence and flying the maximum distance structural piece on a ballistic path to impact under the influence of an explosion and complimenting crosswind.

The maximum lateral crossrange deviation from the standard trajectory impact trace is approximately 135 km during powered flight. Due to convergence of the lateral corridor, crossrange deviation is approximately 96 km at Bermuda, which does not encompass any land mass, and approximately 88 km over Africa. The lateral crossrange deviation is assumed symmetrical about the standard trajectory impact trace. The vehicle yaw maneuver caused an insignificant deviation of itself, but created the flight condition which allowed the structural piece to travel a maximum distance to impact. The left and right sections of the range safety lateral corridor for AS-206 are shown in Figures 125 and 126 and are identified as Sectors 1 and 2, respectively.

The range safety extreme lateral corridor is established to denote the absolute impact limits of a malfunctioning vehicle that is allowed to continue on a deviated trajectory until propellant depletion before range safety destruct command is activated. The malfunction is assumed to occur at the "Gate", that is, when the standard IIP reaches the Western coast of Africa. The flight events employed to establish the extreme lateral corridor are: 1) maximum 3σ out-of-plane trajectory 2) a combined pitch (θ_p) and yaw (θ_y) maneuver at the "Gate" calculated to produce a maximum crossrange deviation of the vehicle at propellant depletion, 3) vehicle powered flight continuance on the deviated trajectory until propellant depletion, and 4) ballistic path to impact of the maximum distance piece under the influence of a pressure vessel explosion and complimenting crosswinds.

The extreme lateral crossrange deviation from the standard trajectory impact trace over the continent of Africa is approximately 224 km. This deviation is assumed symmetrical about the standard trajectory impact trace. The pitch and yaw maneuver at the "Gate" caused an insignificant deviation of itself, but created the flight condition which allowed the structural piece to travel a maximum distance to impact. The left and right sections of the extreme lateral corridor are shown in Figures 125 and 126 and are designated as Sectors 3 and 4, respectively.

The maximum distance piece resulting from a destruct explosion of the S-IVB stage, as utilized in establishing each corridor, is a fragment of the cylindrical section of the fuel container. The minimum distance piece is the J-2 engine.

Flight azimuth limits to non-primary (useful) mission orbits are determined in order to contain as much of the continent of Africa as possible between the IIP traces associated with these limits. Useful mission flight azimuth limits are 57° east of North for the left and 90° east of North for the right.

3.3 Downrange Impact and Casualty Probability

The probability of impacting on land is calculated as:

$$P_I = P(S)_1 \cdot P(F)_2 \cdot P(F)_x \cdot P(F)_y$$

where: $P(S)_1$ = Probability of successful first stage operation.
$P(F)_2$ = Probability of second stage failure.
$P(F)_x$ = Probability of failure in the downrange (x) direction.
$P(F)_y$ = Probability of failure in the crossrange (y) direction.

The probability of injuring a person downrange is calculated as:

$$P_{IP} = P_I \cdot \frac{N}{A} \cdot L_A$$

where: P_I = Probability of impact.
N/A = Population density.
L_A = Lethal area of impacting vehicle.

The probability of impact within the established range safety lateral corridor (sectors 1 and 2) for the continent of Africa is:

$$P_{I_A} = .957 \cdot .030 \cdot \frac{8.35}{432.40} \cdot 1 = 5.54 \times 10^{-4}$$

The probability of impact for individual countries within sectors 1 and 2 is:

COUNTRY	Δt	P_I
Spanish Sahara	1.18	7.82×10^{-5}
Mauritania	2.09	1.38×10^{-4}
Mali	2.01	1.34×10^{-4}
Niger	0.85	5.64×10^{-5}
Nigeria	0.46	3.03×10^{-5}
Cameroun	0.15	9.63×10^{-6}
Chad	0.27	1.82×10^{-5}
Central African Republic	0.47	3.09×10^{-5}
Republic of Congo (Leopoldville)	0.44	2.89×10^{-5}
Uganda	0.11	7.10×10^{-6}
Tanzania	0.34	2.21×10^{-5}
Zanzibar	0.02	8.79×10^{-7}
Malagasy Republic	0.04	1.16×10^{-6}

The probability of injuring a person as a result of debris impact within the confines of the range safety lateral corridor (sectors 1 and 2) for the continent of Africa is:

$$P_{IP_A} = 5.54 \times 10^{-4} \cdot 52 \cdot \frac{19,400}{27,878,400} = 2.00 \times 10^{-5}$$

The probability of injuring a person for individual countries within sectors 1 and 2 is:

COUNTRY	$\frac{N}{A}$	P_{IP}
Spanish Sahara	0.27	1.48×10^{-8}
Mauritania	1.98	1.91×10^{-7}
Mali	9.98	9.28×10^{-7}
Niger	7.51	2.95×10^{-7}
Nigeria	163.11	3.44×10^{-6}
Cameroun	23.09	1.55×10^{-7}
Chad	5.87	7.43×10^{-8}
Central African Republic	5.56	1.19×10^{-7}
Republic of Congo (Leopoldville)	17.60	3.55×10^{-7}
Uganda	82.32	4.07×10^{-7}
Tanzania	26.63	4.10×10^{-7}
Zanzibar	304.50	1.86×10^{-7}
Malagasy Republic	27.60	2.23×10^{-8}

The probability of impact within the established range safety extreme lateral corridor (sectors 3 and 4) for the continent of Africa is:

$$P_{I_A} = .957 \cdot .00237 \cdot \frac{11.59}{432.40} \cdot 1 = 6.08 \times 10^{-5}$$

The probability of impact for individual countries within sectors 3 and 4 is:

COUNTRY	Δt	P_I
Spanish Sahara	11.59	6.08×10^{-5}
Mauritania	6.65	3.49×10^{-5}
Mali	4.09	2.15×10^{-5}
Niger	1.57	8.23×10^{-6}
Nigeria	0.87	4.56×10^{-6}
Cameroun	0.25	1.31×10^{-6}
Chad	0.57	2.97×10^{-6}
Central African Republic	0.90	4.72×10^{-6}
Republic of Congo (Leopoldville)	0.97	5.08×10^{-6}
Uganda	0.25	1.29×10^{-6}
Rwanda	0.19	1.42×10^{-7}
Tanzania	0.84	4.36×10^{-6}
Kenya	0.61	1.31×10^{-7}
Pemba	0.04	2.75×10^{-8}
Zanzibar	0.03	4.90×10^{-8}
Malagasy Republic	0.10	2.62×10^{-7}

The probability of injuring a person as a result of debris impact within the confines of the range safety extreme corridor (sectors 3 and 4) for the continent of Africa is:

$$P_{IP_A} = 6.08 \times 10^{-5} \cdot 52 \cdot \frac{19,400}{27,878,400} = 2.20 \times 10^{-6}$$

The probability of injuring a person for individual countries within sectors 3 and 4 is:

COUNTRY	$\frac{N}{A}$	P_{IP}
Spanish Sahara	0.27	1.14×10^{-8}
Mauritania	1.98	4.81×10^{-8}
Mali	9.98	1.49×10^{-7}
Niger	7.51	4.30×10^{-8}
Nigeria	163.11	5.17×10^{-7}
Cameroun	23.09	2.11×10^{-8}
Chad	5.87	1.21×10^{-8}
Central African Republic	5.56	1.82×10^{-8}
Republic of Congo (Leopoldville)	17.60	6.22×10^{-8}
Uganda	82.32	7.37×10^{-8}
Rwanda	251.70	2.48×10^{-8}
Tanzania	26.63	8.08×10^{-8}
Kenya	41.66	3.79×10^{-9}
Pemba	304.50	5.83×10^{-9}
Zanzibar	304.50	1.04×10^{-8}
Malagasy Republic	27.60	5.03×10^{-9}

Section 4.0 - CONCLUSIONS

Final range safety data and associated analyses for the Saturn IB SA-206 launch vehicle denote the following conclusions.

1) From the standpoint of the launch vehicle, a flight related to the primary mission presents a minimum range safety hazard;
2) Normal flight, in tolerance, should occur within minimum pitch and yaw plane corridors;
3) Areas requiring special studies to determine impact and casualty probabilities are the launch pad area, Africa, and Malagasy Republic;
4) Flight azimuth limits, within specified constraints, relating to useful missions are established;
5) An engine out condition, without other malfunctions, discloses a minimum range safety hazard.

Section 5.0 - REFERENCES

1) CCSD TR-AP-66-1, Saturn IB Boost Vehicle Range Safety Analysis SA-205 and Subsequent, dated July 1966.

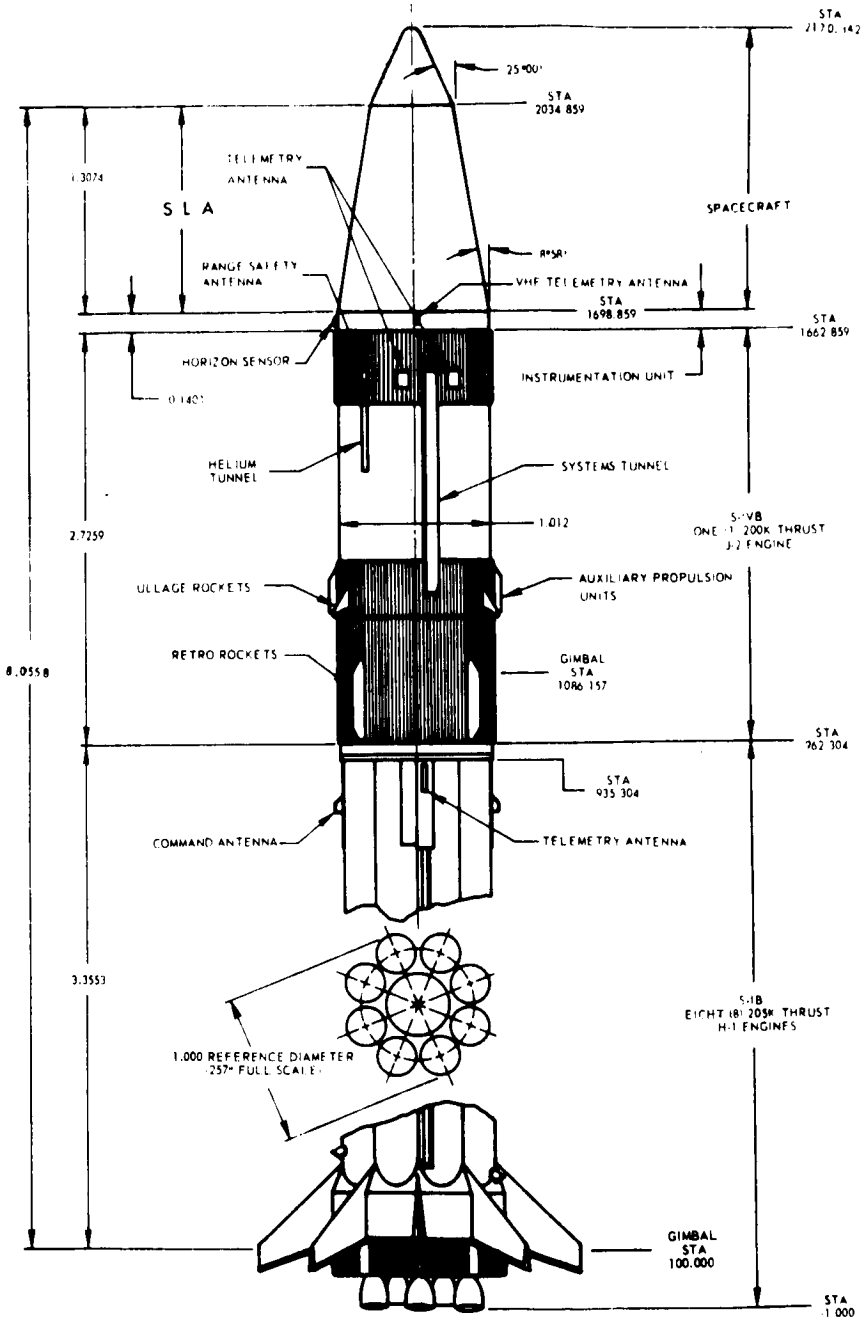
2) CCSD TN-AP-66-125, AS-206A Preliminary L/V Operational Trajectory and Guidance Presettings, dated November 7, 1966.

3) CCSD TN-AP-66-150 Volume I, Summary of Saturn IB/LEM, AS-206 Static Aerodynamics, dated December 20, 1966.

Section 6.0 - DISTRIBUTION

R. C. Callaway	I-1/1B-E	(1)
O. M. Hardage	R-AERO-FM	(5 copies and 2 Magnetic Tapes)
L. L. McNair	R-AERO-P	(55 copies and 1 reproducible)

Figure 1



APOLLO SATURN IB AS-206
CONFIGURATION

Figure 2

APRIL WIND PROFILE ENVELOPES
FOR 72° FLIGHT AZIMUTH

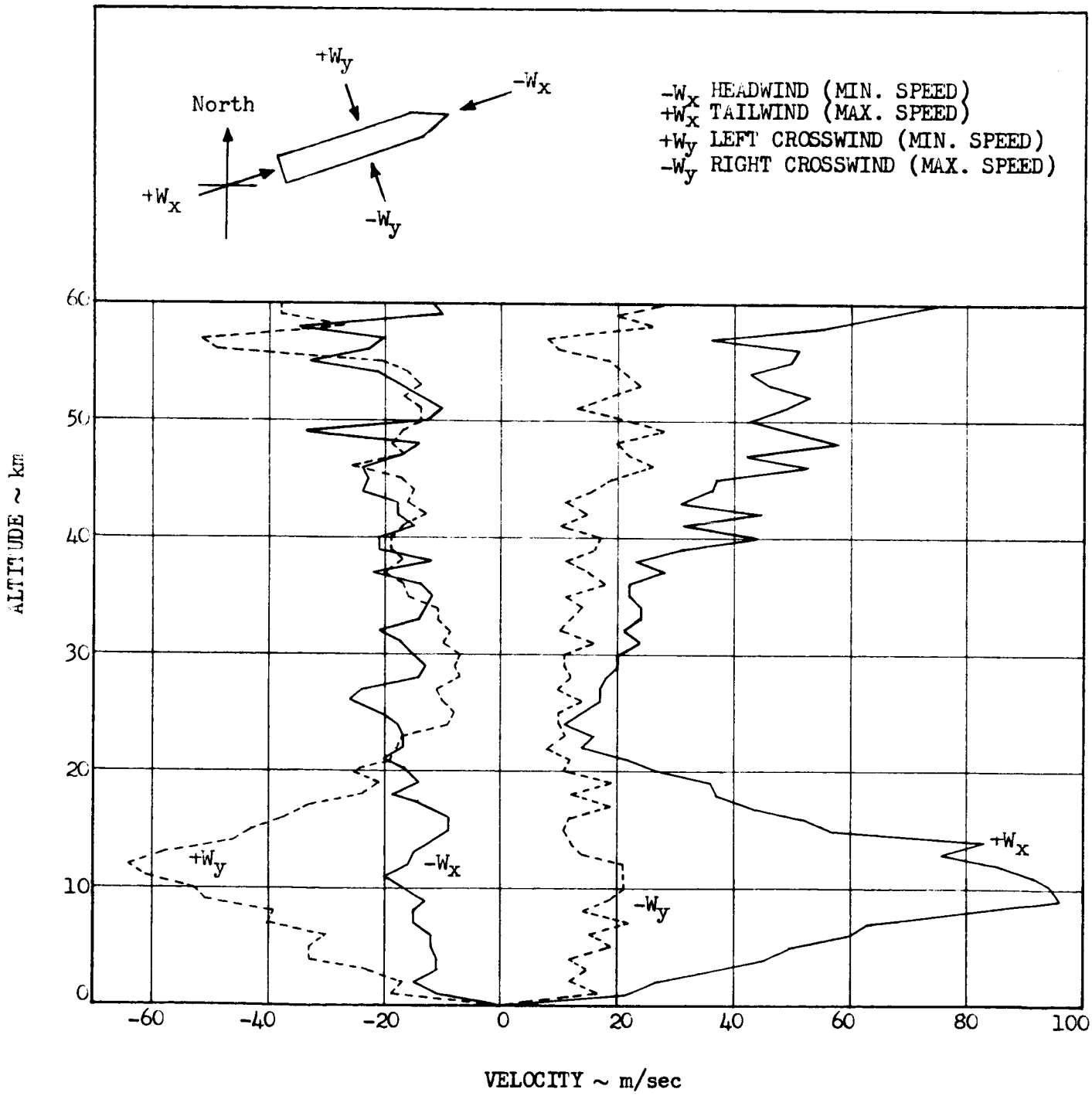


Figure 3

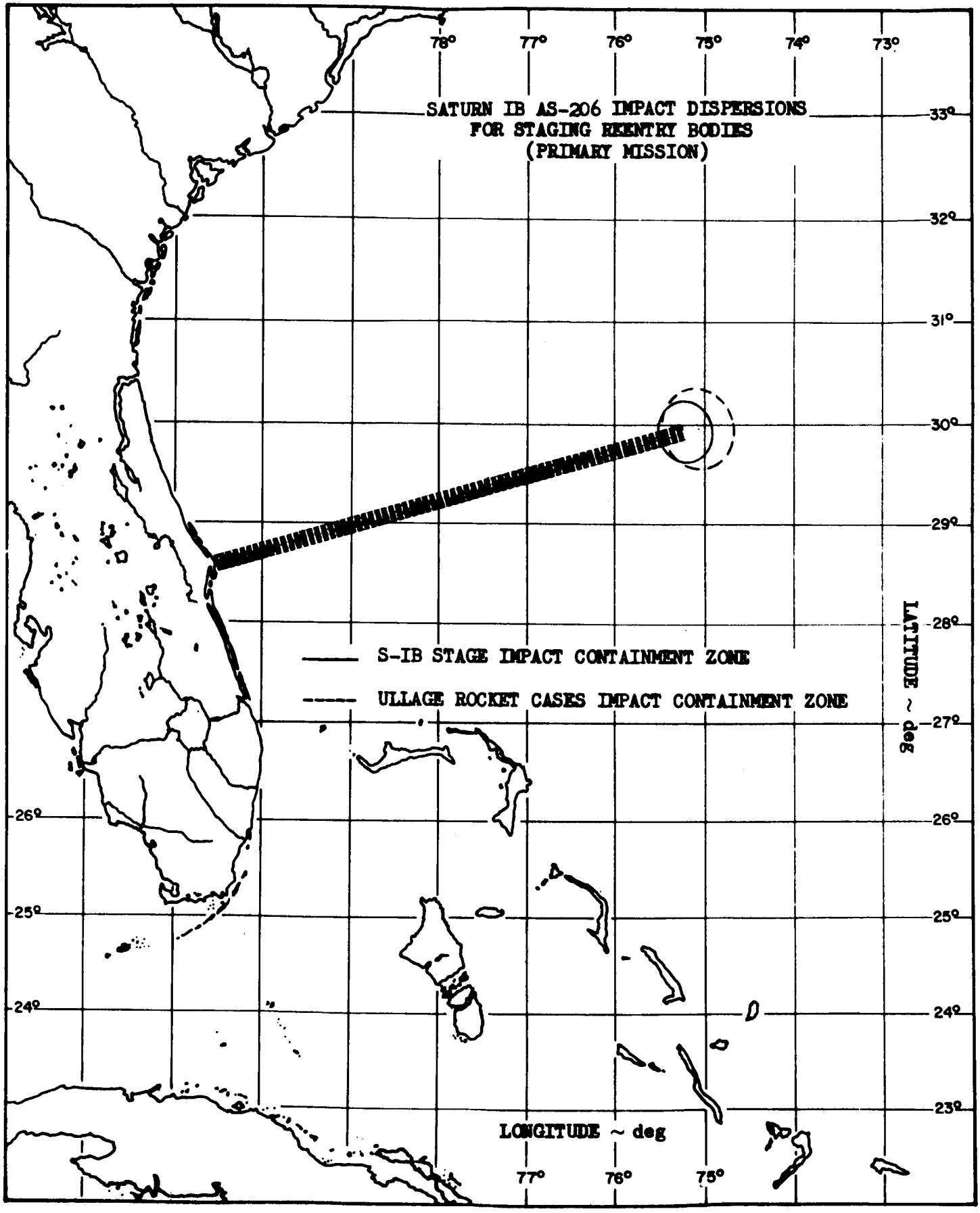

SATURN IB AS-206 IMPACT DISPERSIONS
FOR STAGING REENTRY BODIES
(PRIMARY MISSION)
78°
77°
76°
75°
74°
73°
33°
32°
31°
30°
29°
28°
27°
26°
25°
24°
23°
LATITUDE ~ deg
S-IB STAGE IMPACT CONTAINMENT ZONE
ULLAGE ROCKET CASES IMPACT CONTAINMENT ZONE
LONGITUDE ~ deg
77°
76°
75°

Figure 4

CHANGE IN TOTAL VELOCITY VECTOR ORIENTATION IN THE LATERAL DIRECTION VERSUS TIME FOR MALFUNCTION AT $t_i = 12$ sec

(β_y = 11.3, 8.0, 5.0, 3.0, 1.0, 0.1 deg)

β_y is the thrust vector deflection angle in the yaw plane

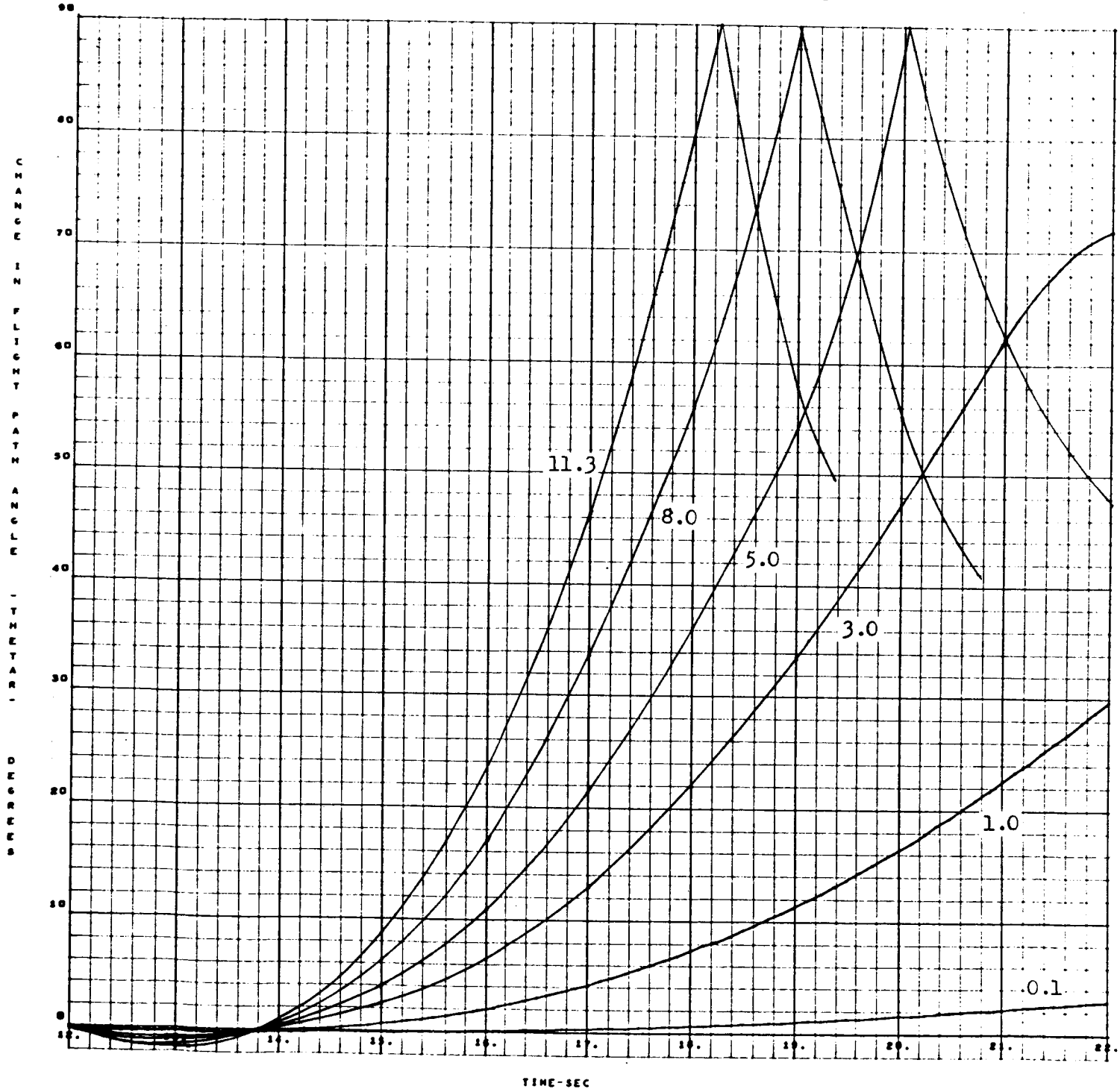


Figure 5

CHANGE IN TOTAL VELOCITY VECTOR ORIENTATION IN THE LATERAL DIRECTION VERSUS TIME FOR MALFUNCTION AT t_i = 16 sec

(β_y = 11.3, 8.0, 5.0, 3.0, 1.0, 0.1 deg)

β_y is the thrust vector deflection angle in the yaw plane

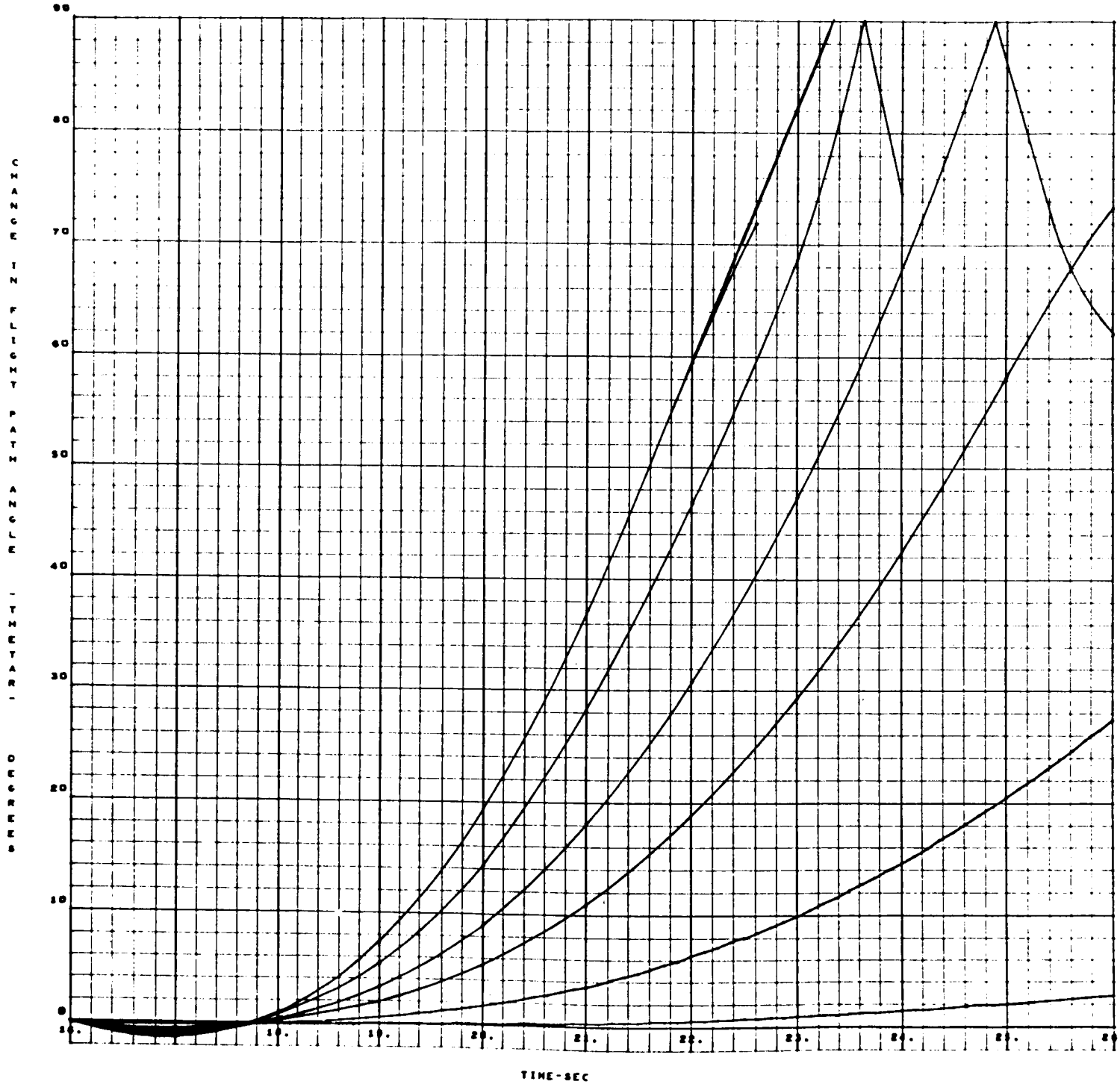


Figure 6

CHANGE IN TOTAL VELOCITY VECTOR ORIENTATION IN THE LATERAL DIRECTION VERSUS TIME FOR MALFUNCTION AT t_i = 20 sec

(β_y = 11.3, 8.0, 5.0, 3.0, 1.0, 0.1 deg)

β_y is the thrust vector deflection angle in the yaw plane

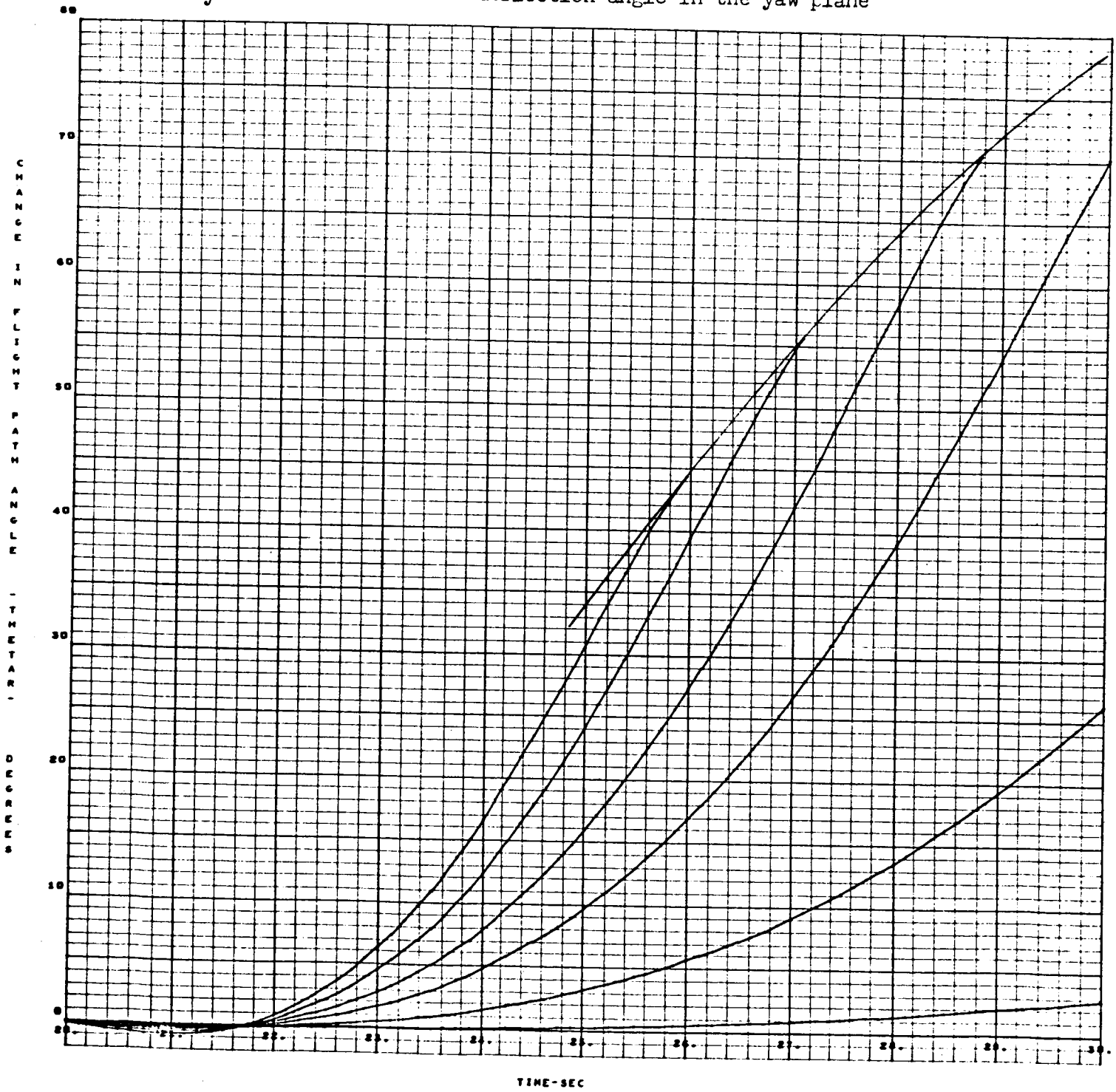


Figure 7

CHANGE IN TOTAL VELOCITY VECTOR ORIENTATION IN THE LATERAL DIRECTION VERSUS TIME FOR MALFUNCTION AT t_i = 24 sec

(β_y = 11.3, 8.0, 5.0, 3.0, 1.0, 0.1 deg)

β_y is the thrust vector deflection angle in the yaw plane

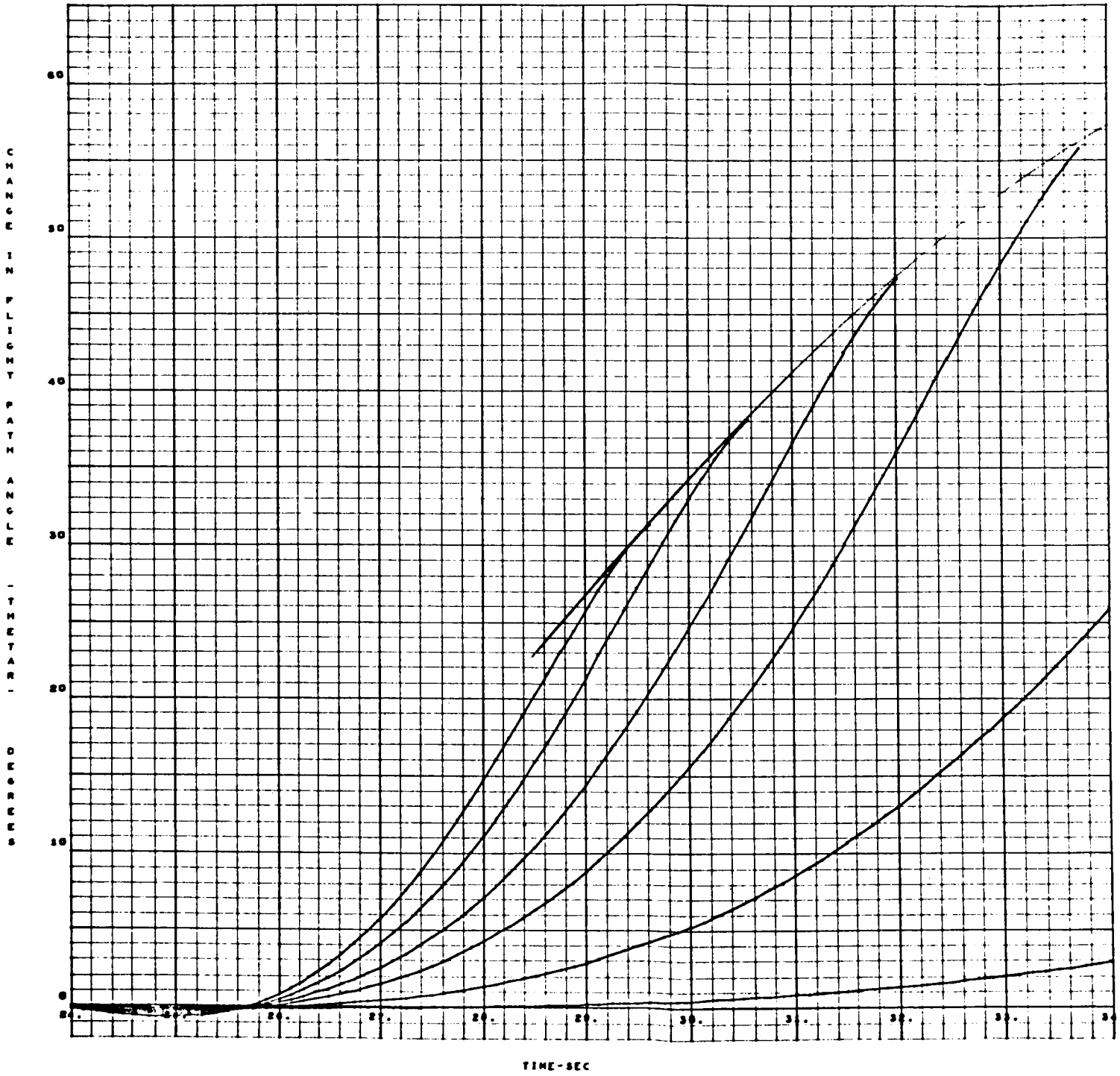


Figure 8

CHANGE IN TOTAL VELOCITY VECTOR ORIENTATION IN THE LATERAL DIRECTION VERSUS TIME FOR MALFUNCTION AT t_i = 28 sec

(β_y = 11.3, 8.0, 5.0, 3.0, 1.0, 0.1 deg)

β_y is the thrust vector deflection angle in the yaw plane

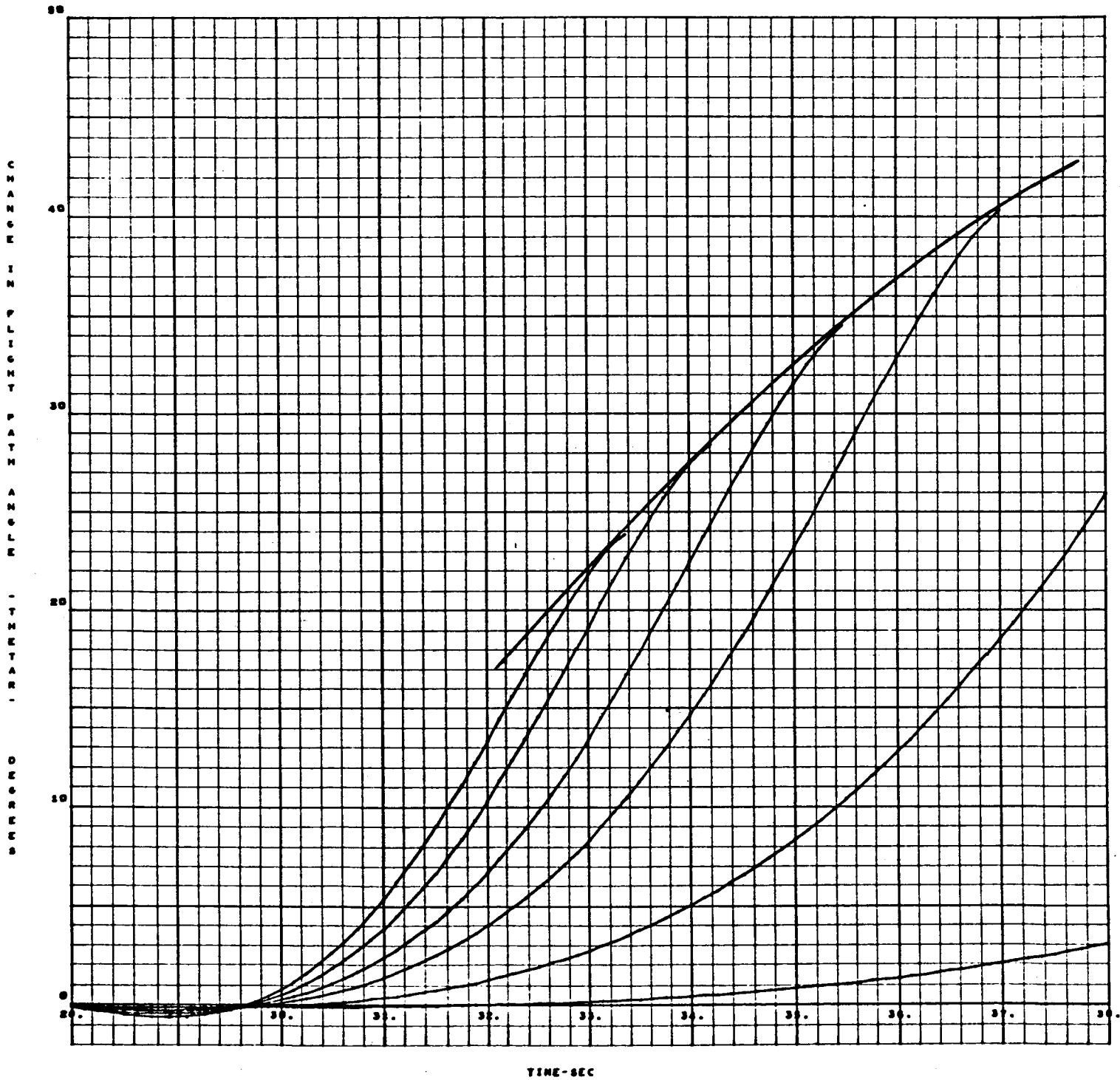


Figure 9

CHANGE IN TOTAL VELOCITY VECTOR ORIENTATION IN THE LATERAL DIRECTION VERSUS TIME FOR MALFUNCTION AT t_i = 32 sec

(β_y = 11.3, 8.0, 5.0, 3.0, 1.0, 0.1 deg)

β_y is the thrust vector deflection angle in the yaw plane

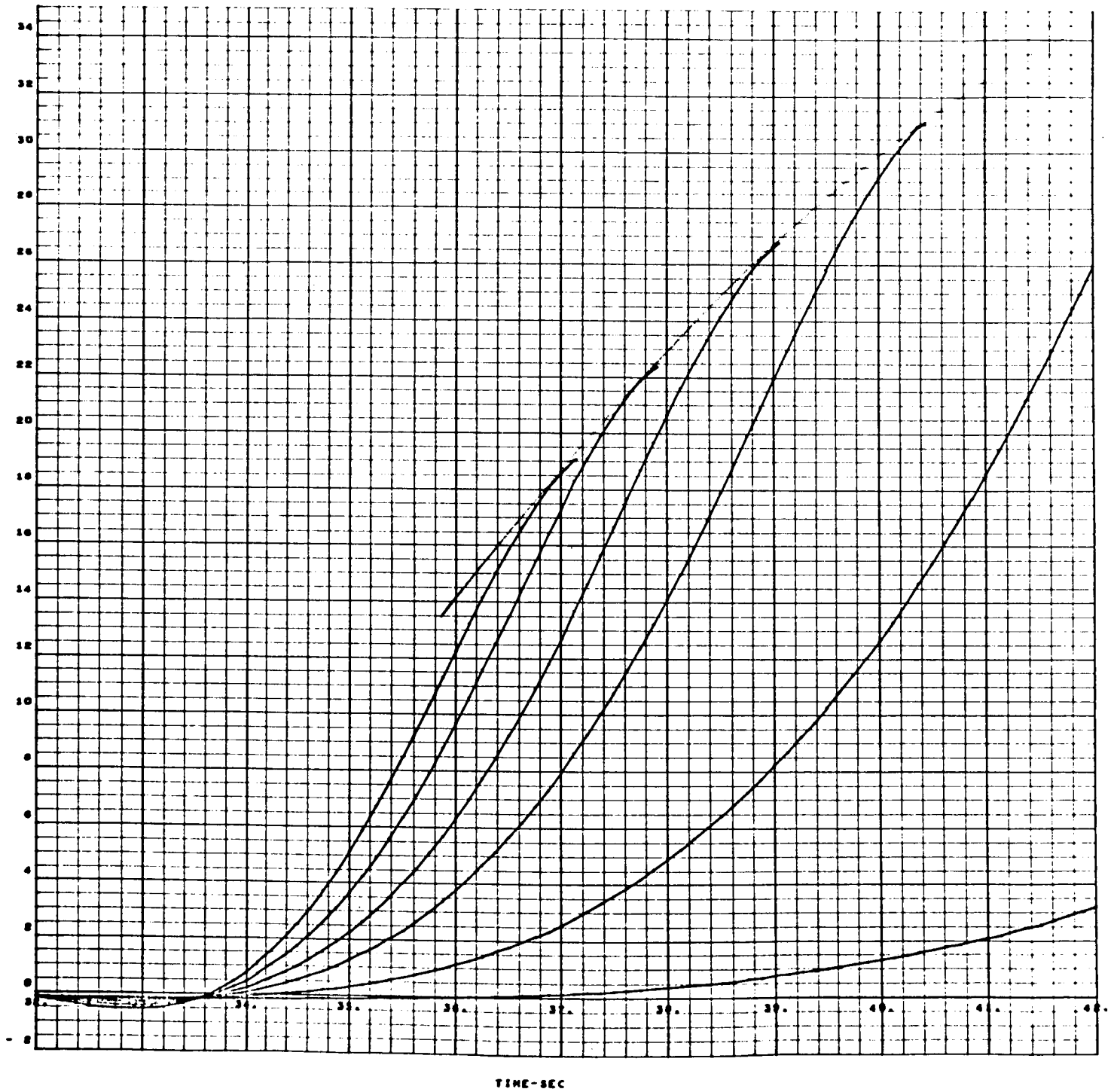


Figure 10

CHANGE IN TOTAL VELOCITY VECTOR ORIENTATION IN THE LATERAL DIRECTION VERSUS TIME FOR MALFUNCTION AT t_i = 36 sec

(β_y = 11.3, 8.0, 5.0, 3.0, 1.0, 0.1 deg)

β_y is the thrust vector deflection angle in the yaw plane

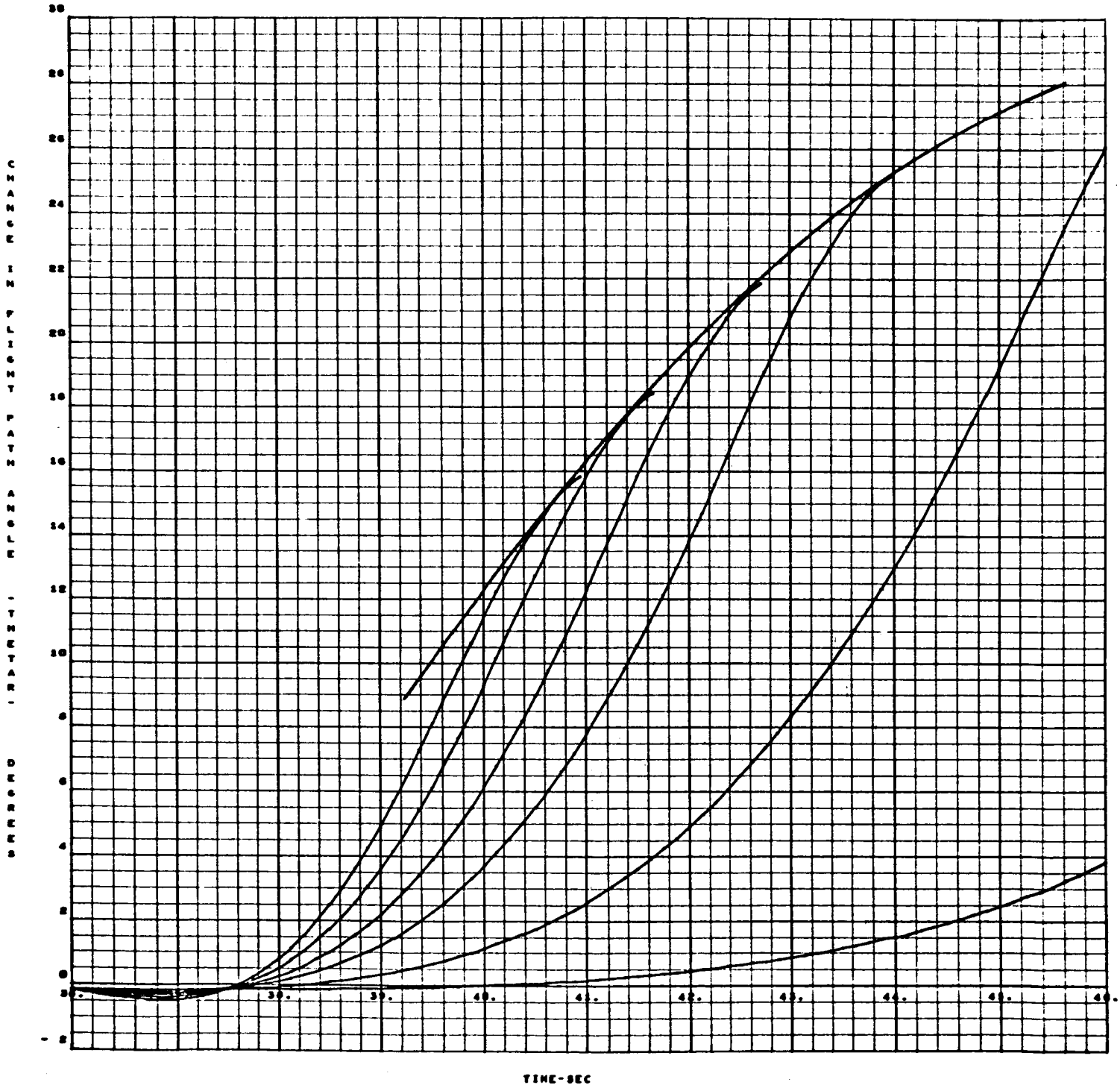


Figure 11

CHANGE IN TOTAL VELOCITY VECTOR ORIENTATION IN THE LATERAL DIRECTION VERSUS TIME FOR MALFUNCTION AT $t_i = 40$ sec

(β_y = 10.0, 7.0, 5.0, 3.0, 1.0, 0.1 deg)

β_y is the thrust vector deflection angle in the yaw plane

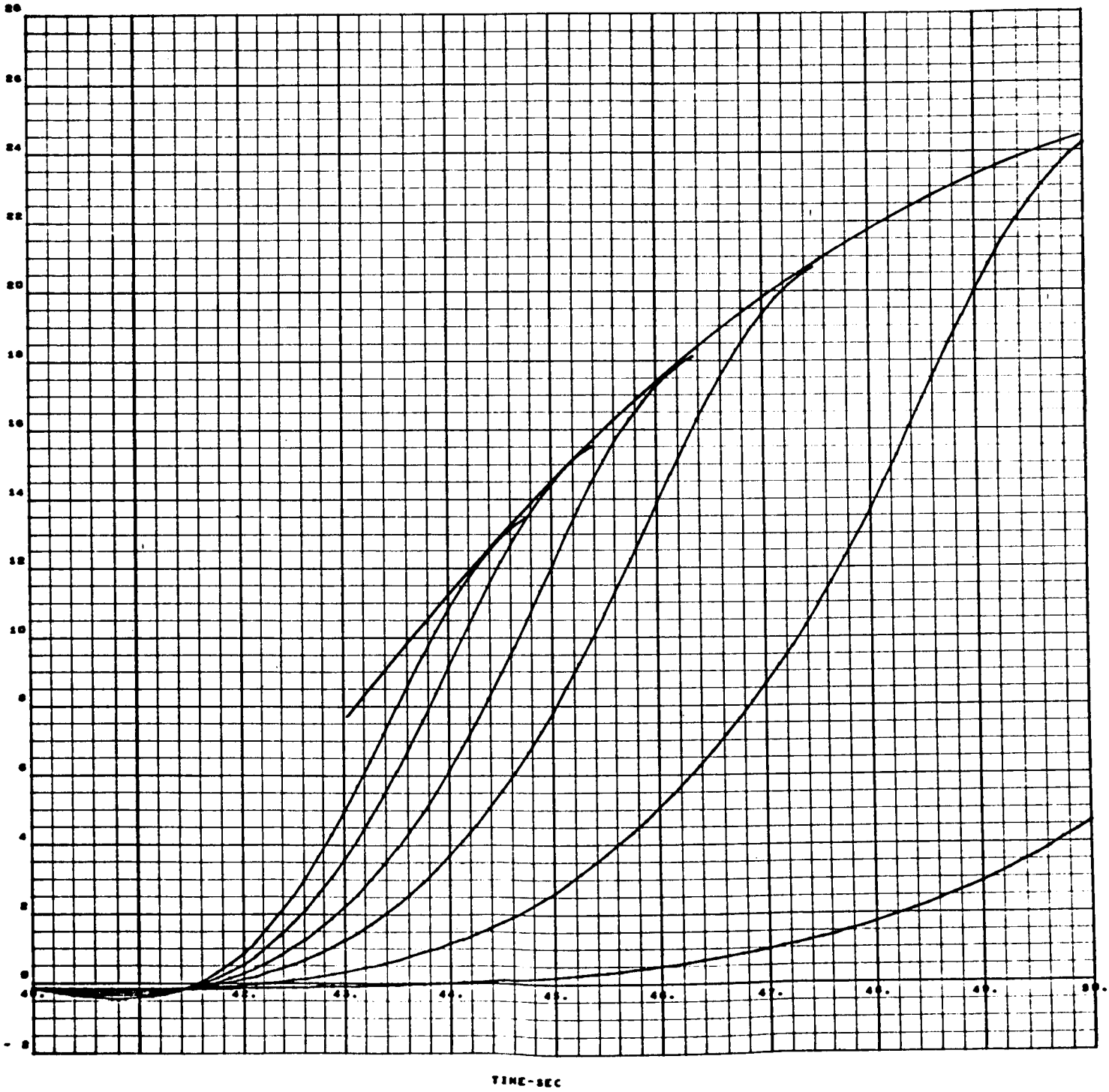


Figure 12

CHANGE IN TOTAL VELOCITY VECTOR ORIENTATION IN THE LATERAL DIRECTION VERSUS TIME FOR MALFUNCTION AT t_i = 44 sec

(β_y = 11.3, 8.0, 5.0, 3.0, 1.0, 0.1 deg)

β_y is the thrust vector deflection angle in the yaw plane

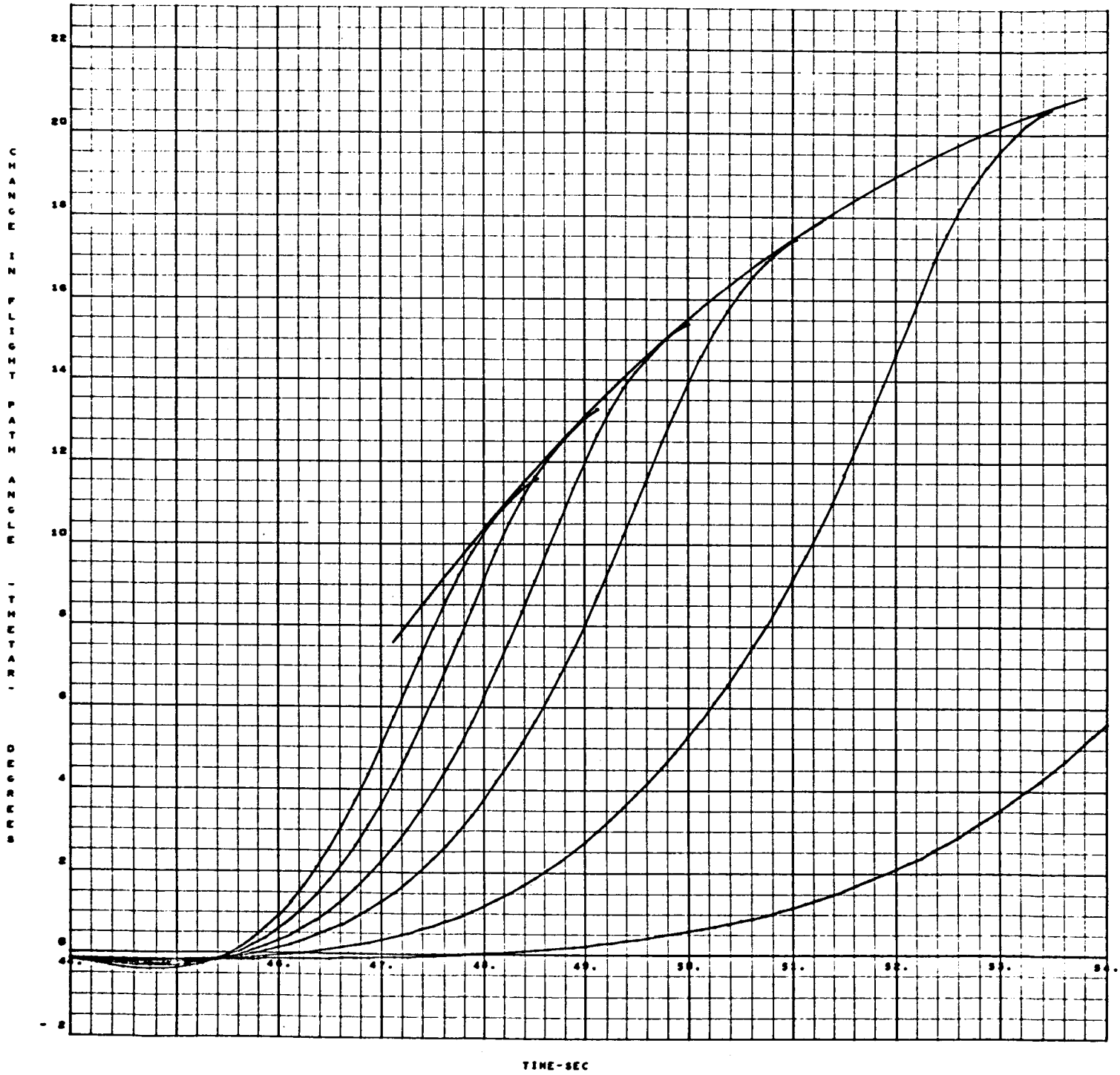


Figure 13

CHANGE IN TOTAL VELOCITY VECTOR ORIENTATION IN THE LATERAL DIRECTION VERSUS TIME FOR MALFUNCTION AT t_i = 48 sec

(β_y = 11.3, 8.0, 5.0, 3.0, 1.0, 0.1 deg)

β_y is the thrust vector deflection angle in the yaw plane

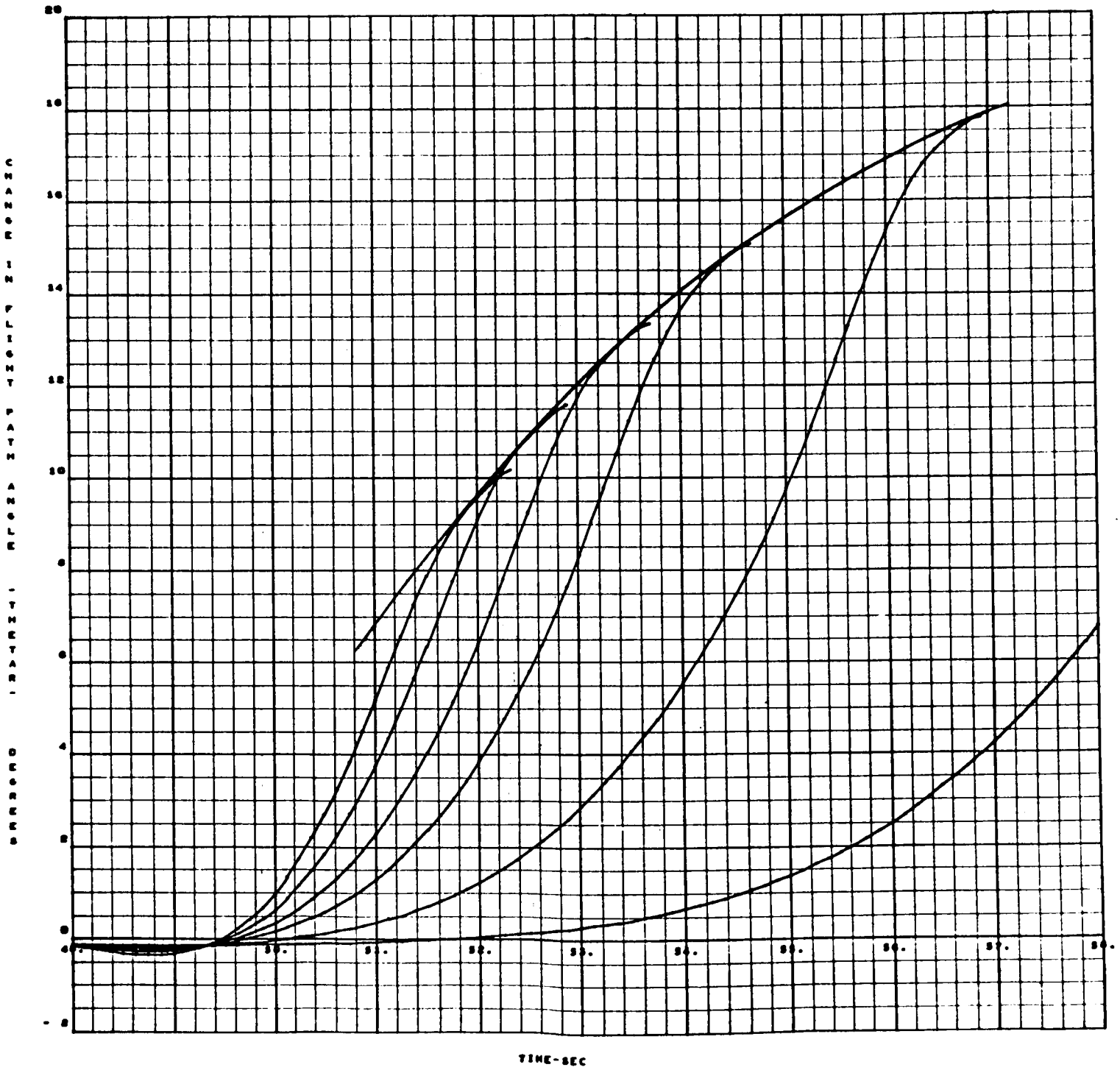


Figure 14

CHANGE IN TOTAL VELOCITY VECTOR ORIENTATION IN THE LATERAL DIRECTION VERSUS TIME FOR MALFUNCTION AT t_i = 52 sec

(β_y = 11.3, 8.0, 5.0, 3.0, 1.0, 0.1 deg)

β_y is the thrust vector deflection angle in the yaw plane

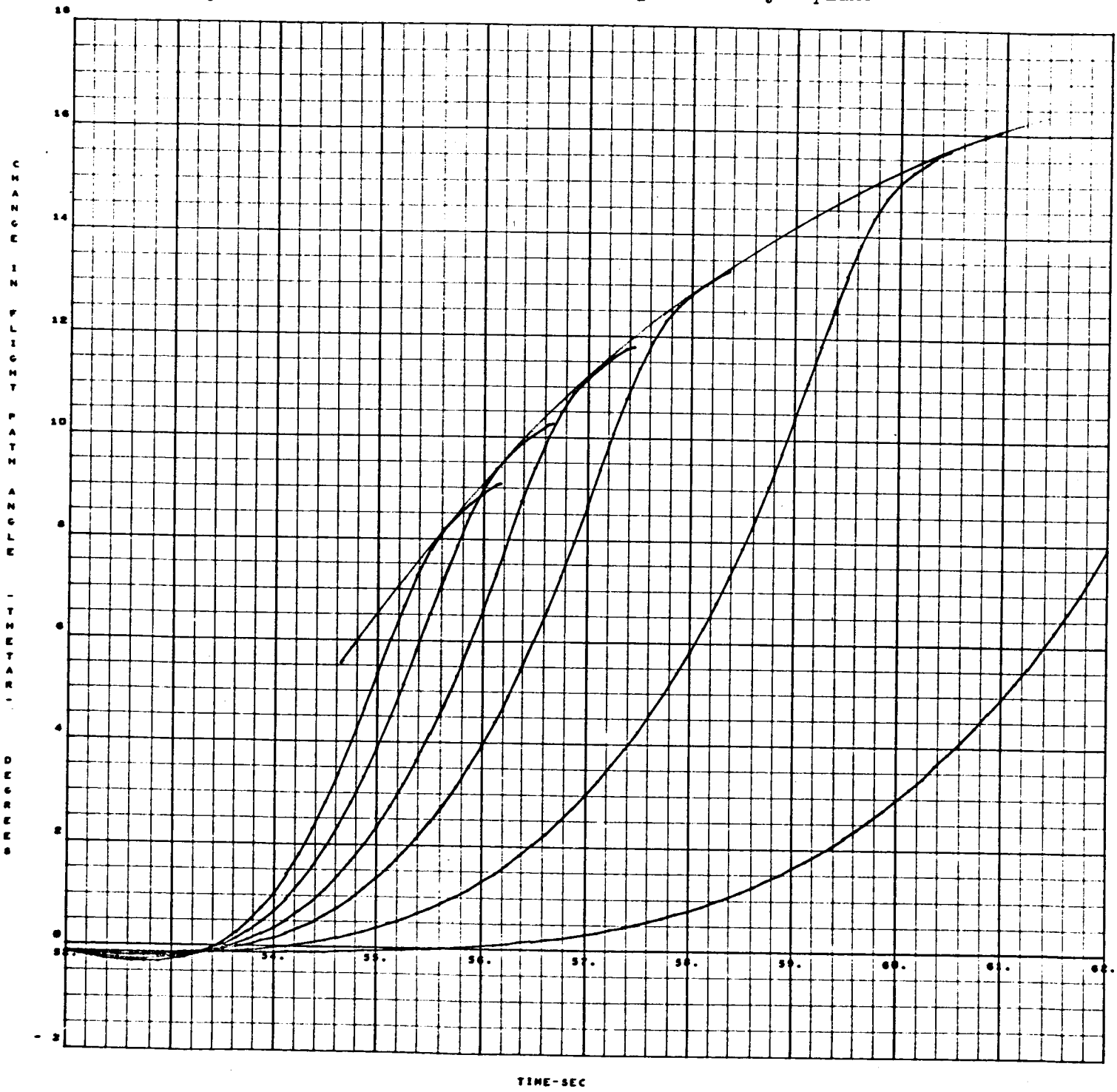


Figure 15

CHANGE IN TOTAL VELOCITY VECTOR ORIENTATION IN THE LATERAL DIRECTION VERSUS TIME FOR MALFUNCTION AT t_i = 56 sec

(β_y = 11.3, 8.0, 5.0, 3.0, 1.0, 0.1 deg)

β_y is the thrust vector deflection angle in the yaw plane

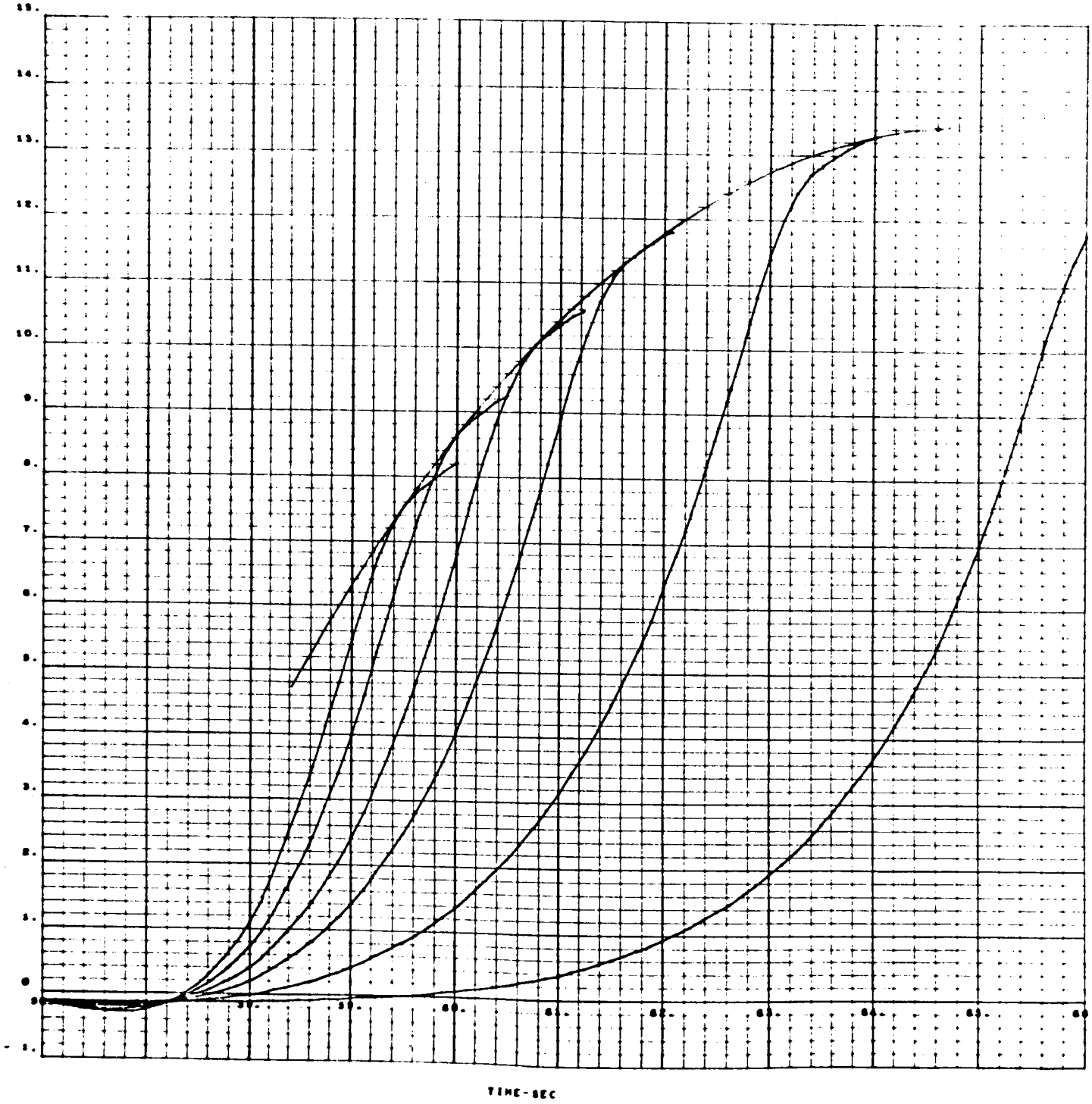


Figure 16

CHANGE IN TOTAL VELOCITY VECTOR ORIENTATION IN THE LATERAL DIRECTION VERSUS TIME FOR MALFUNCTION AT t_i = 60 sec

(β_y = 11.3, 8.0, 5.0, 3.0, 1.0, 0.1 deg)

β_y is the thrust vector deflection angle in the yaw plane

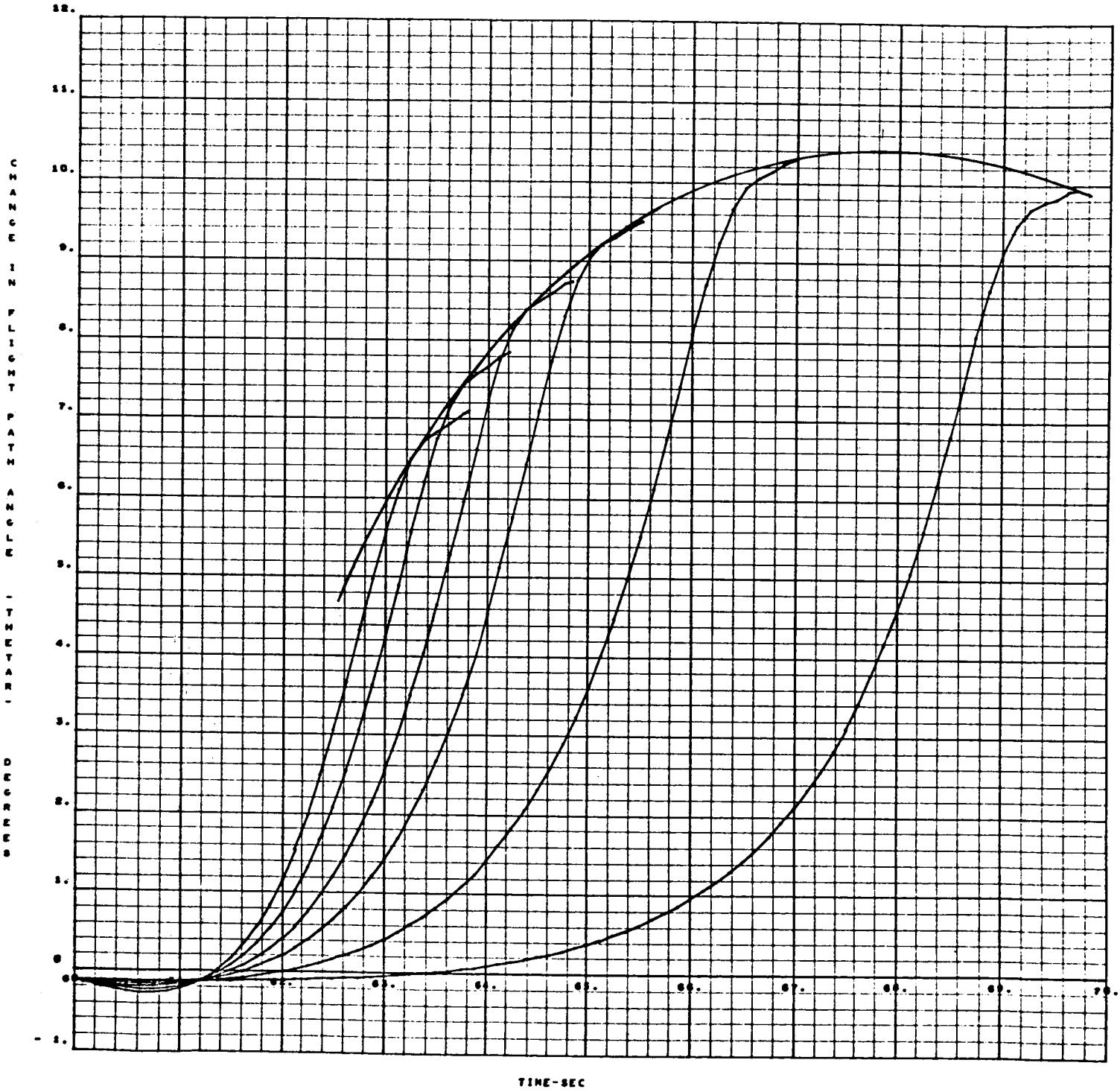


Figure 17

CHANGE IN TOTAL VELOCITY VECTOR ORIENTATION IN THE LATERAL DIRECTION VERSUS TIME FOR MALFUNCTION AT t_i = 64 sec

(β_y = 11.3, 8.0, 5.0, 3.0, 1.0, 0.1 deg)

β_y is the thrust vector deflection angle in the yaw plane

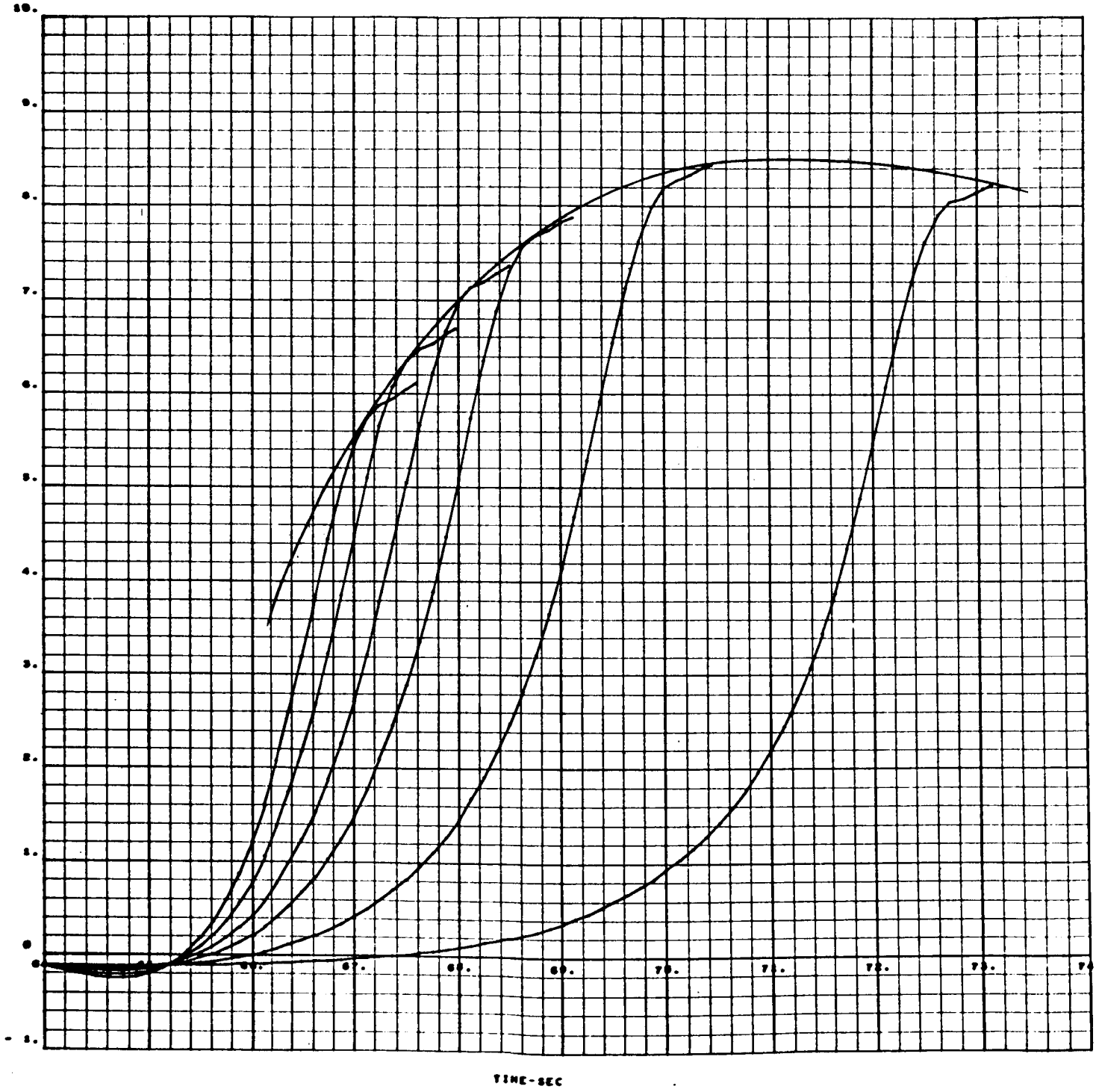


Figure 18

CHANGE IN TOTAL VELOCITY VECTOR ORIENTATION IN THE LATERAL DIRECTION VERSUS TIME FOR MALFUNCTION AT t_i = 68 sec

(β_y = 11.3, 8.0, 5.0, 3.0, 1.0, 0.1 deg)

β_y is the thrust vector deflection angle in the yaw plane

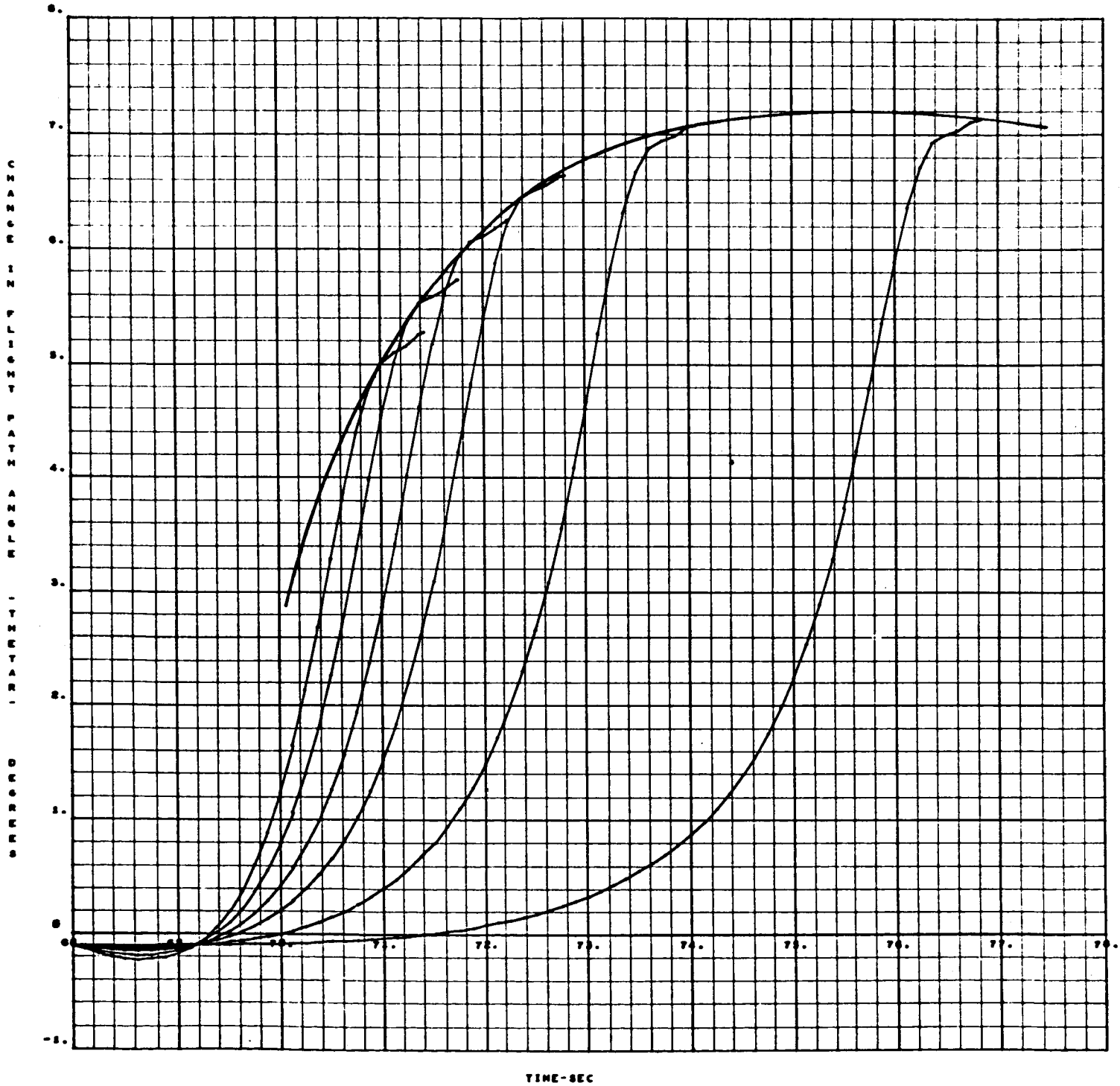


Figure 19

CHANGE IN TOTAL VELOCITY VECTOR ORIENTATION IN THE LATERAL DIRECTION VERSUS TIME FOR MALFUNCTION AT t_i = 72 sec

(β_y = 11.3, 8.0, 5.0, 3.0, 1.0, 0.1 deg)

β_y is the thrust vector deflection angle in the yaw plane

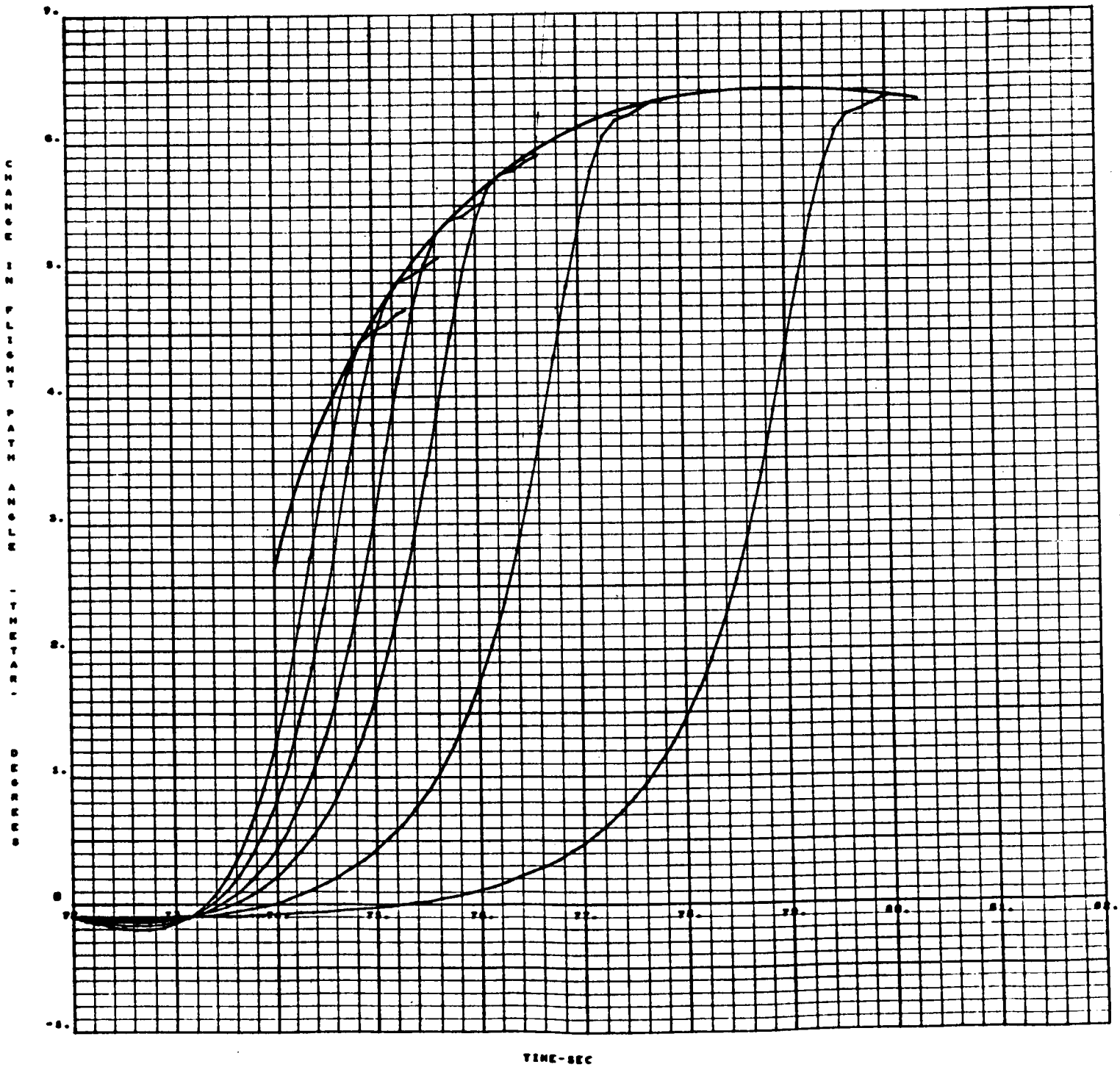


Figure 20

CHANGE IN TOTAL VELOCITY VECTOR ORIENTATION IN THE LATERAL DIRECTION VERSUS TIME FOR MALFUNCTION AT t_i = 76 sec

(β_y = 11.3, 8.0, 5.0, 3.0, 1.0, 0.1 deg)

β_y is the thrust vector deflection angle in the yaw plane

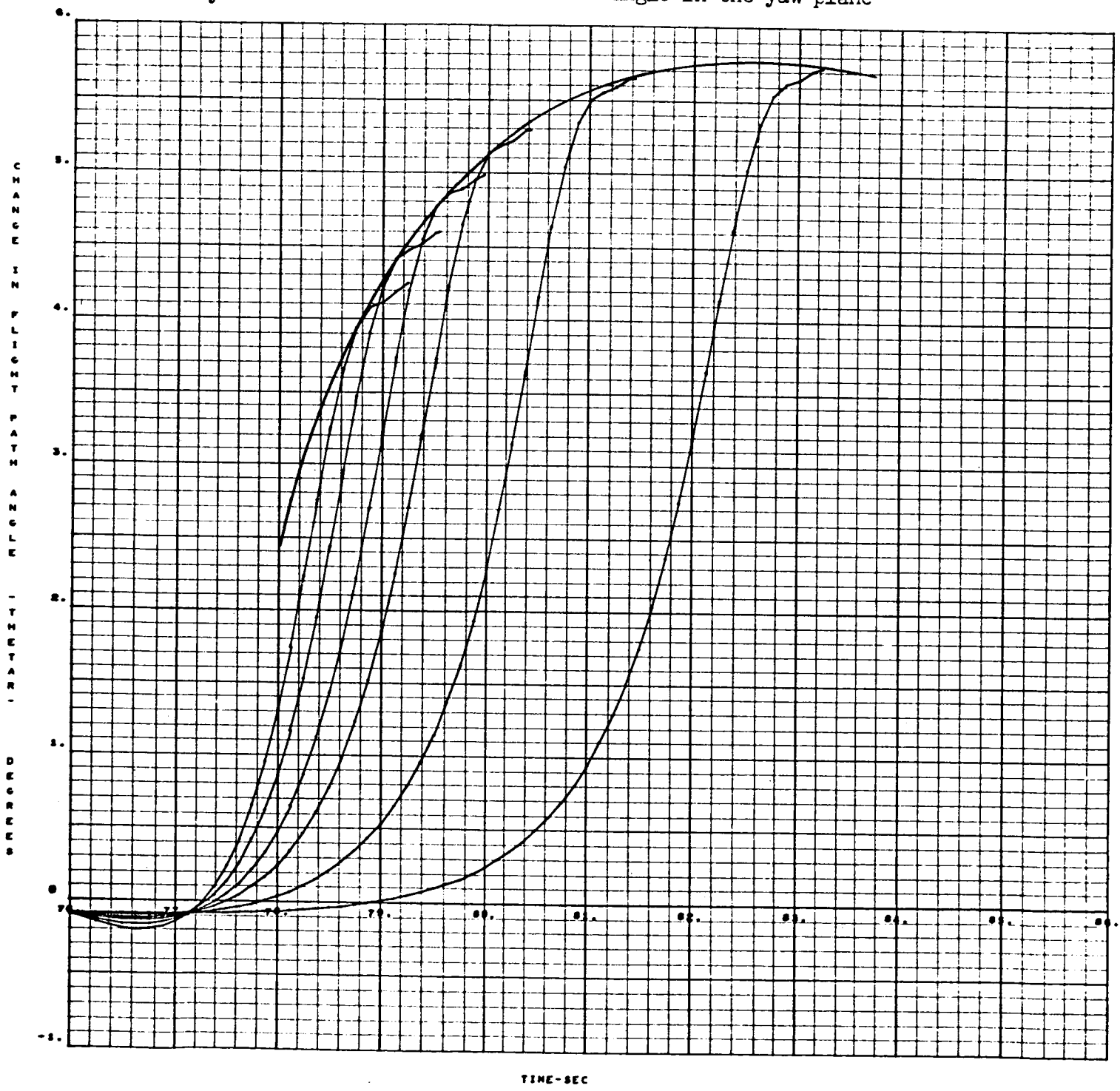


Figure 21

CHANGE IN TOTAL VELOCITY VECTOR ORIENTATION IN THE LATERAL DIRECTION VERSUS TIME FOR MALFUNCTION AT t_i = 80 sec

(β_y = 11.3, 8.0, 5.0, 3.0, 1.0, 0.1 deg)

β_y is the thrust vector deflection angle in the yaw plane

Figure 22

CHANGE IN TOTAL VELOCITY VECTOR ORIENTATION IN THE LATERAL DIRECTION VERSUS TIME FOR MALFUNCTION AT $t_i = 84$ sec

(β_y = 11.3, 8.0, 5.0, 3.0, 1.0, 0.1 deg)

β_y is the thrust vector deflection angle in the yaw plane

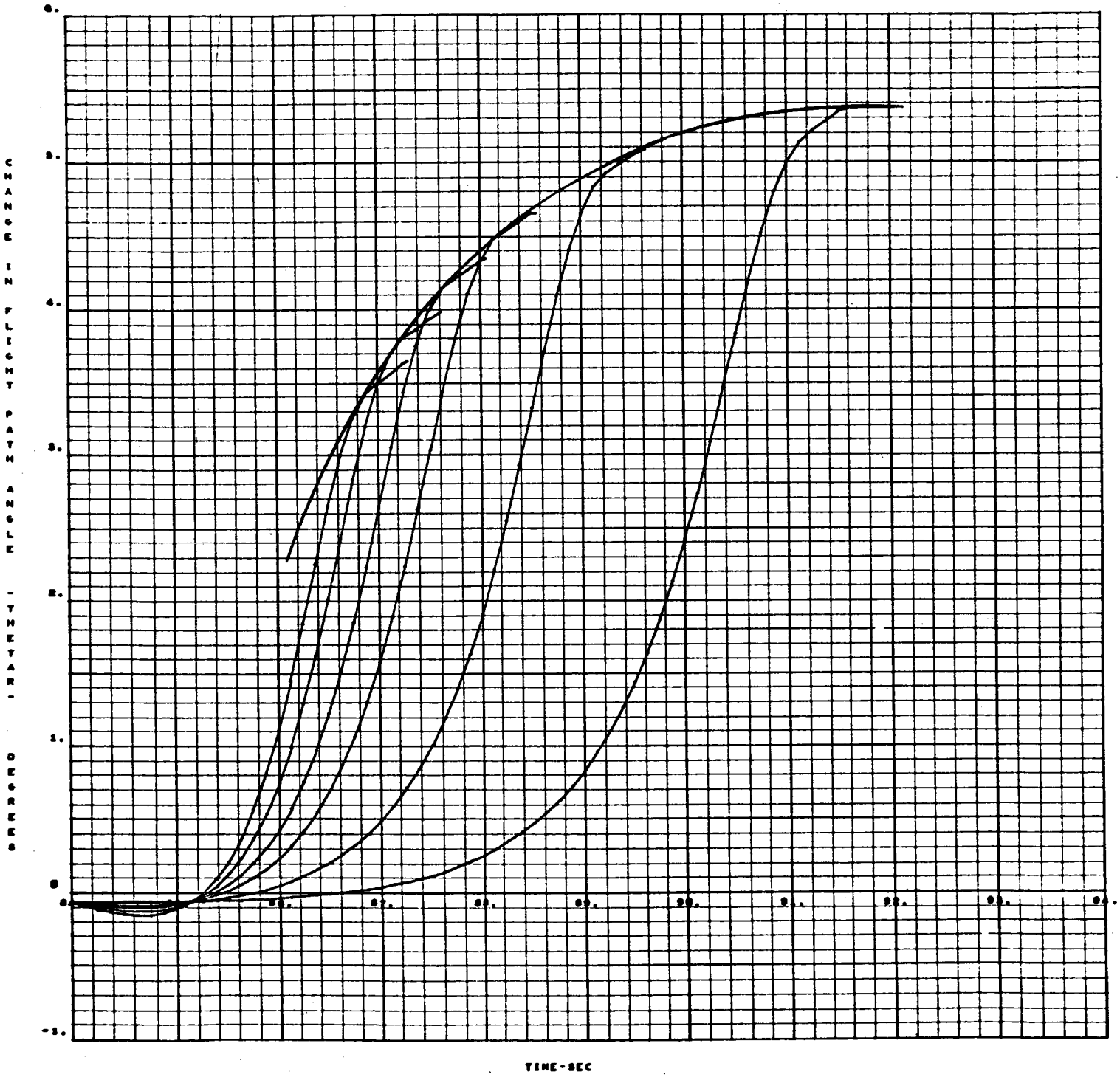


Figure 23

CHANGE IN TOTAL VELOCITY VECTOR ORIENTATION IN THE LATERAL DIRECTION VERSUS TIME FOR MALFUNCTION AT t_i = 88 sec

(β_y = 11.3, 8.0, 5.0, 3.0, 1.0, 0.1 deg)

β_y is the thrust vector deflection angle in the yaw plane

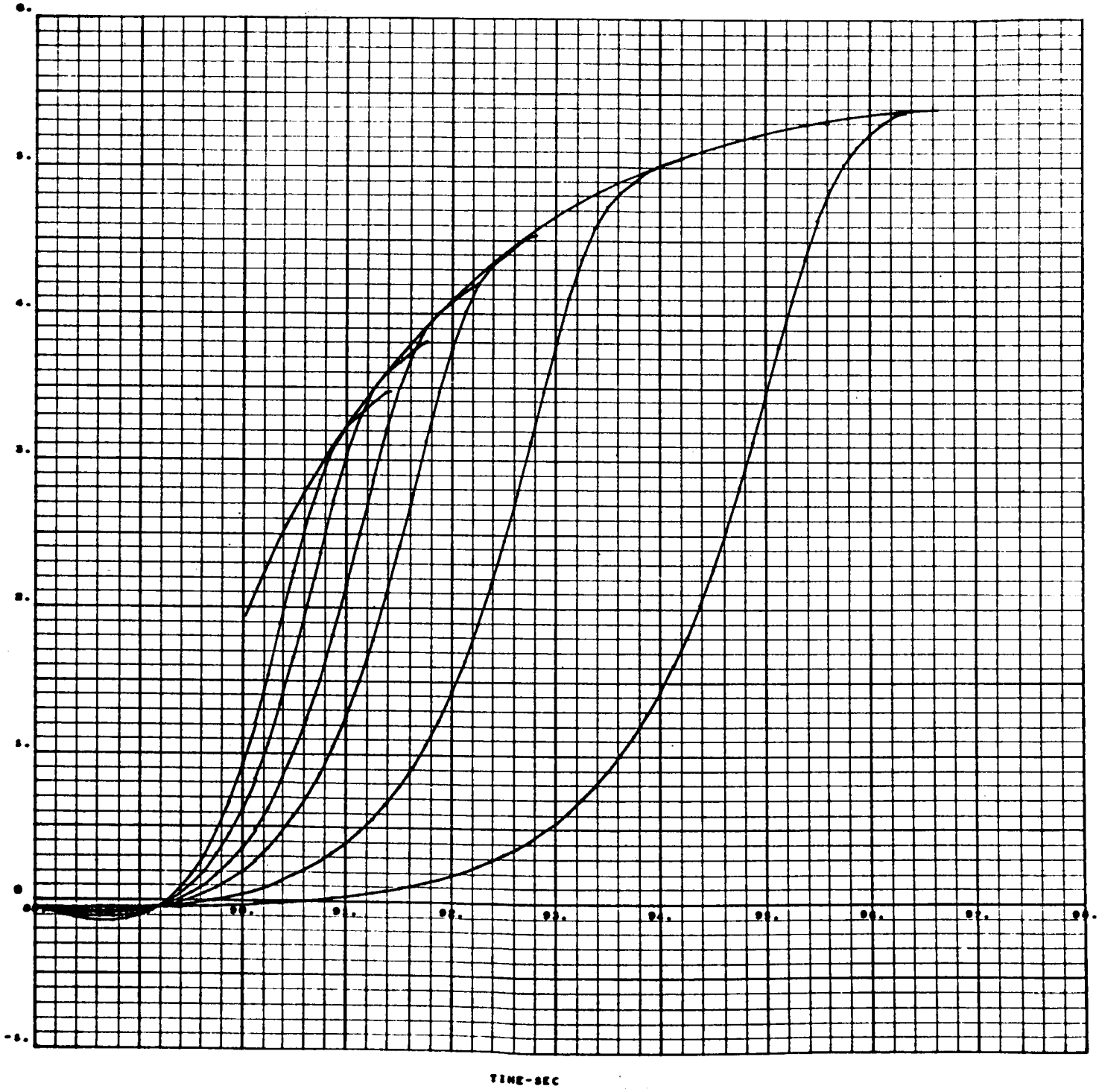


Figure 24

CHANGE IN TOTAL VELOCITY VECTOR ORIENTATION IN THE LATERAL DIRECTION VERSUS TIME FOR MALFUNCTION AT t_i = 92 sec

(β_y = 11.3, 8.0, 5.0, 3.0, 1.0, 0.1 deg)

β_y is the thrust vector deflection angle in the yaw plane

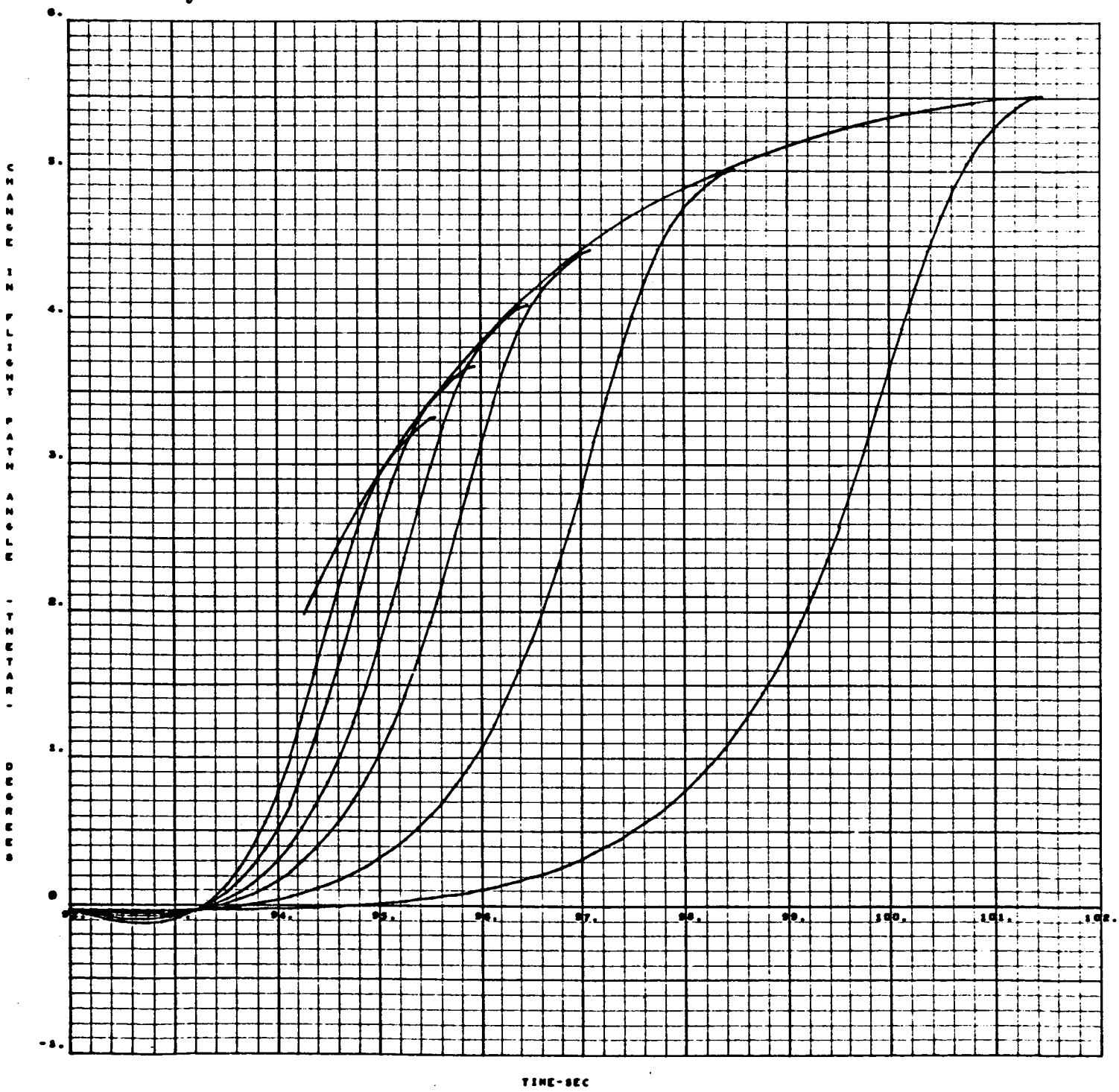


Figure 25

CHANGE IN TOTAL VELOCITY VECTOR ORIENTATION IN THE LATERAL DIRECTION VERSUS TIME FOR MALFUNCTION AT t_i = 96 sec

(β_y = 11.3, 8.0, 5.0, 3.0, 1.0, 0.1 deg)

β_y is the thrust vector deflection angle in the yaw plane

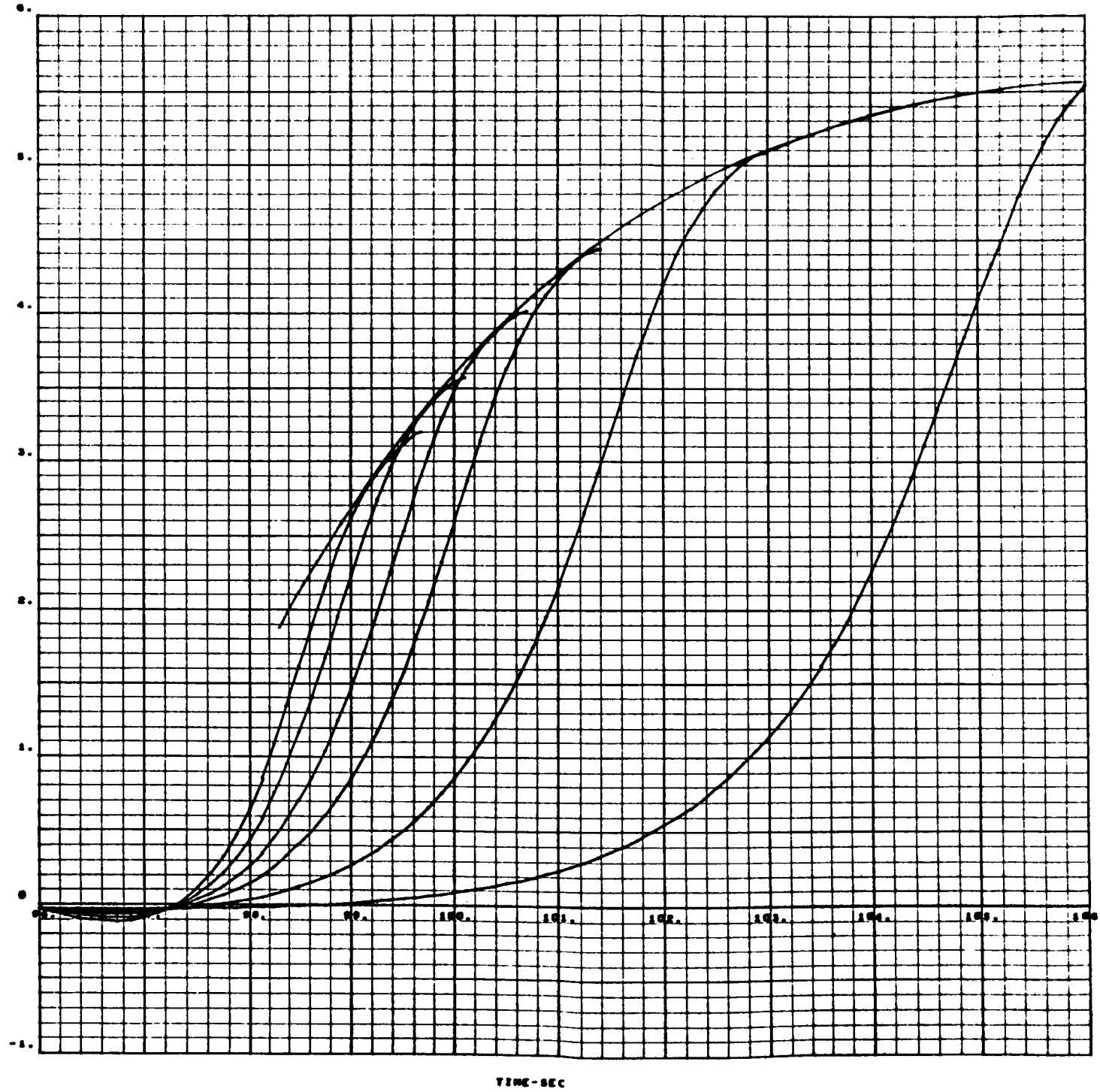


Figure 26

CHANGE IN TOTAL VELOCITY VECTOR ORIENTATION IN THE LATERAL DIRECTION VERSUS TIME FOR MALFUNCTION AT t_i = 100 sec

(β_y = 11.3, 8.0, 5.0, 3.0, 1.0, 0.1 deg)

β_y is the thrust vector deflection angle in the yaw plane

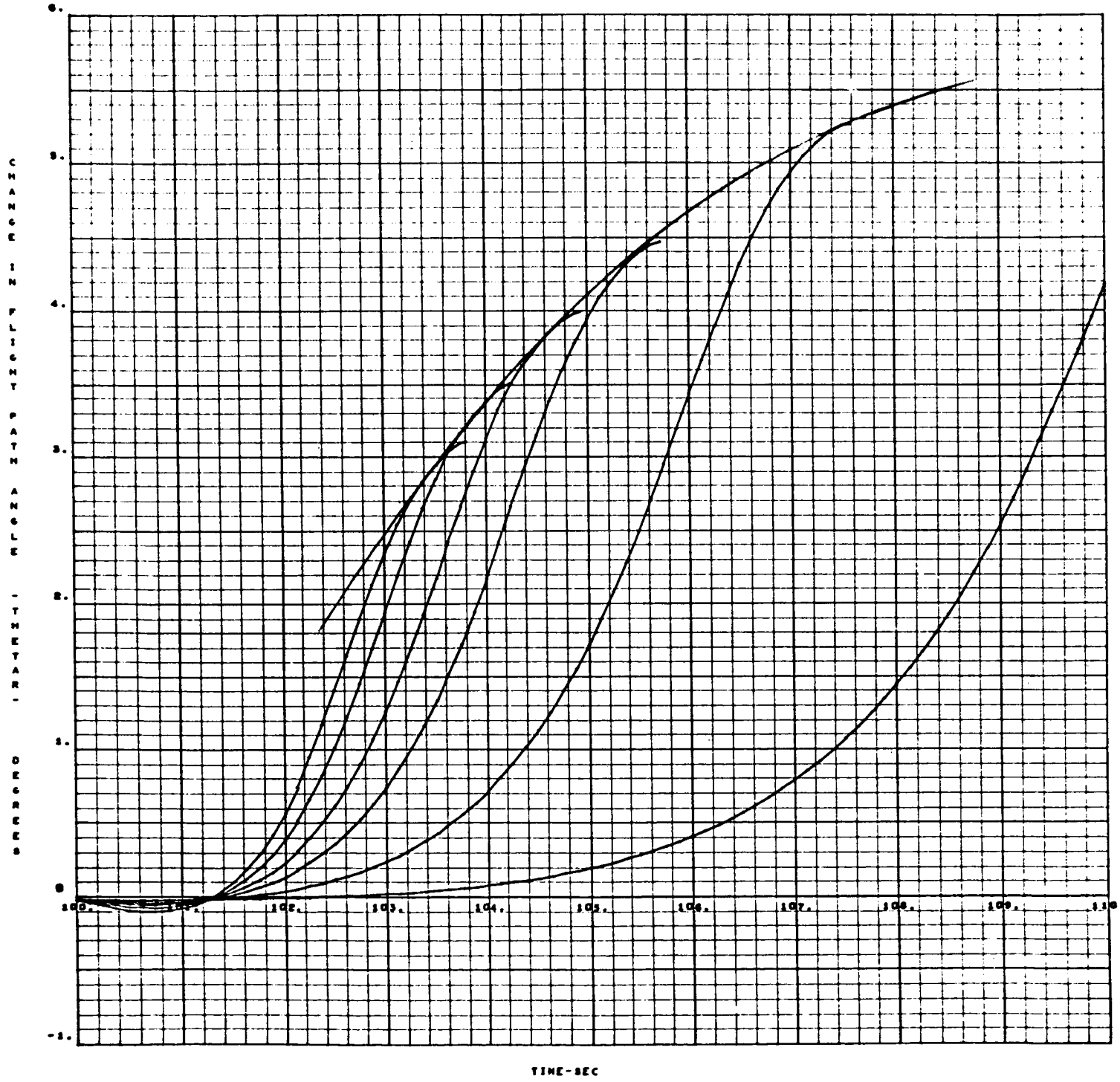


Figure 27

CHANGE IN TOTAL VELOCITY VECTOR ORIENTATION IN THE LATERAL DIRECTION VERSUS TIME FOR MALFUNCTION AT t_i = 104 sec

(β_y = 11.3, 8.0, 5.0, 3.0, 1.0, 0.1 deg)

β_y is the thrust vector deflection angle in the yaw plane

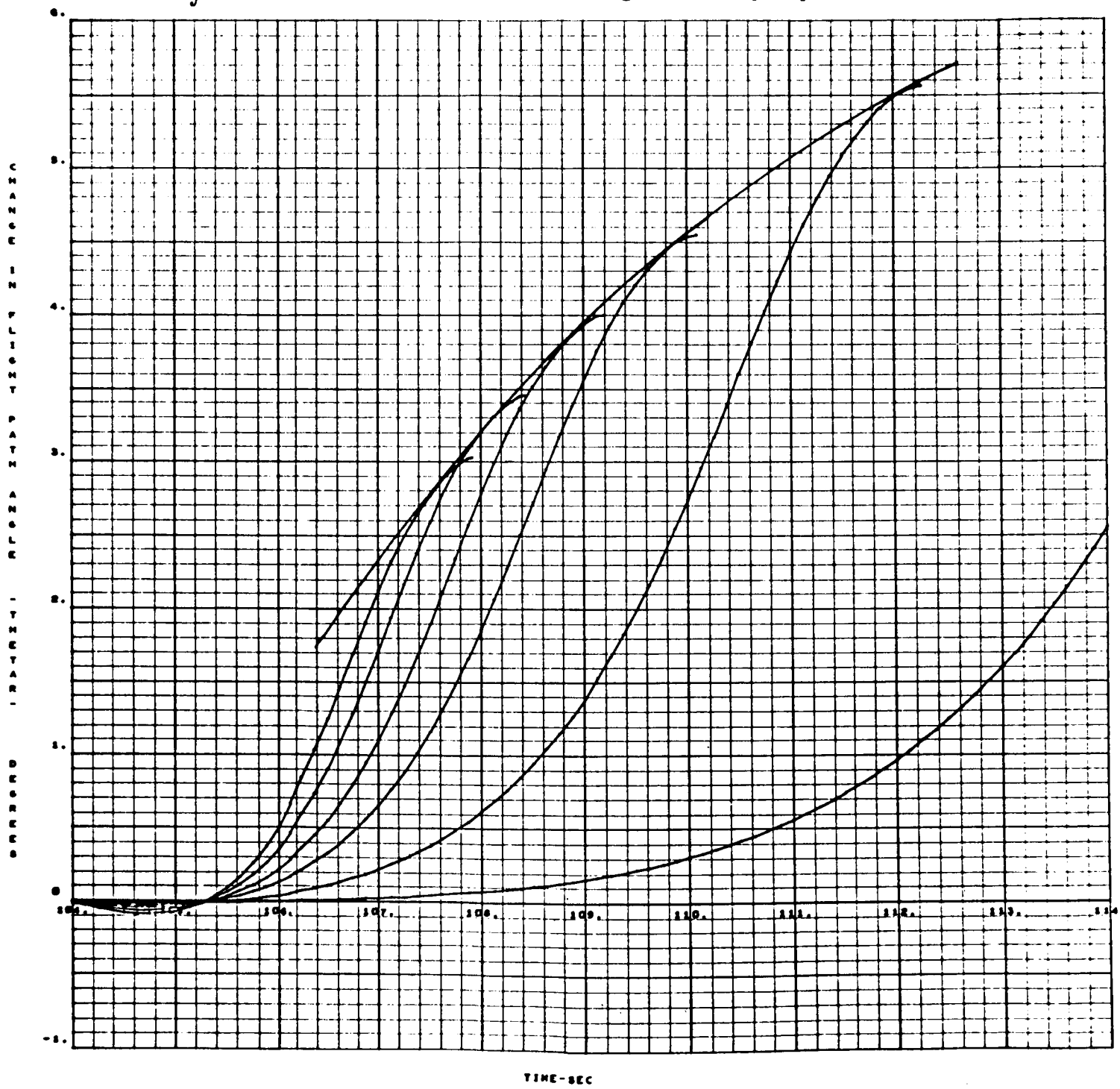


Figure 28

CHANGE IN TOTAL VELOCITY VECTOR ORIENTATION IN THE LATERAL DIRECTION VERSUS TIME FOR MALFUNCTION AT t_i = 108 sec

(β_y = 11.3, 8.0, 5.0, 3.0, 1.0, 0.1 deg)

β_y is the thrust vector deflection angle in the yaw plane

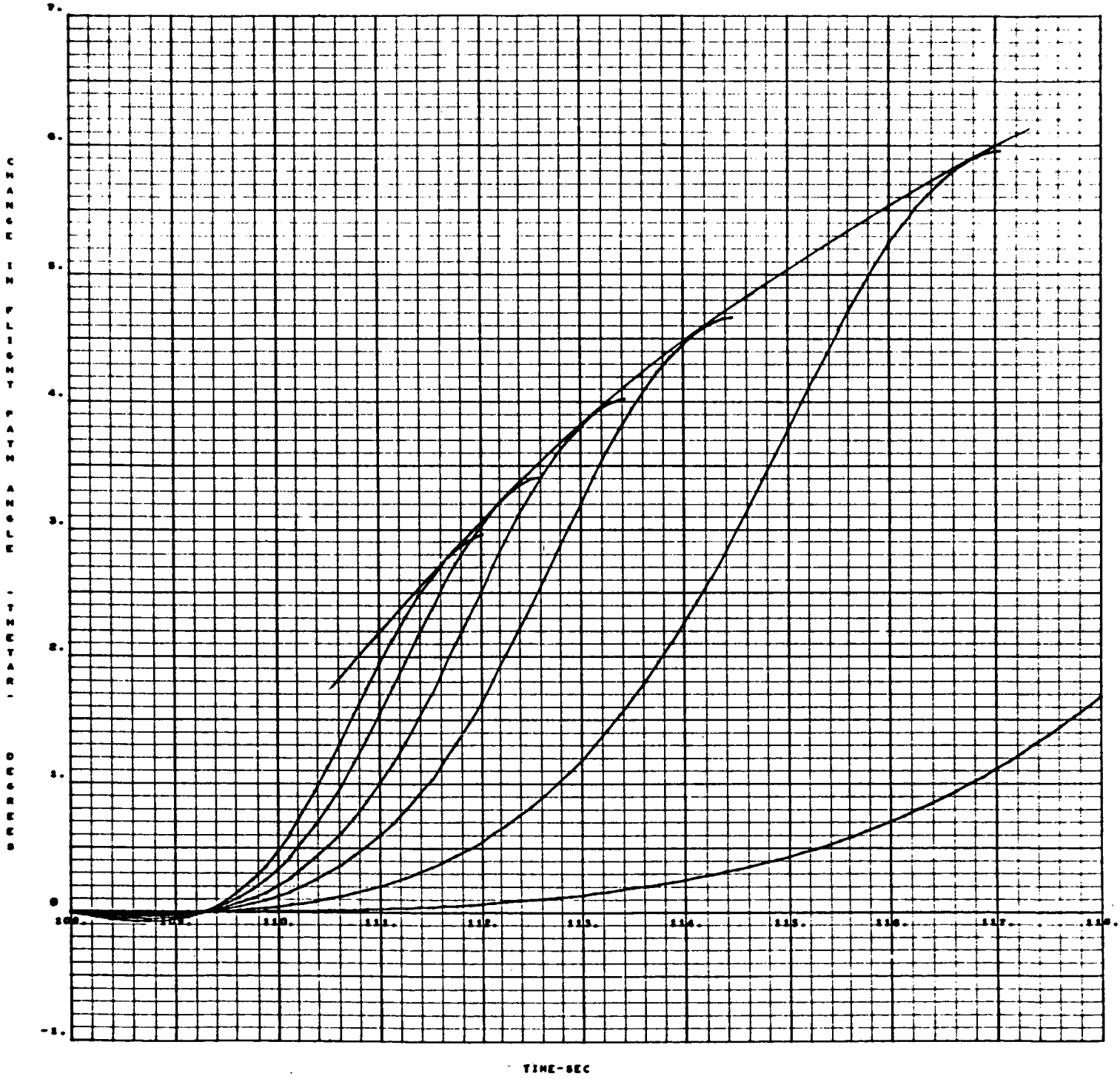


Figure 29

CHANGE IN TOTAL VELOCITY VECTOR ORIENTATION IN THE LATERAL DIRECTION VERSUS TIME FOR MALFUNCTION AT t_i = 112 sec

(β_y = 11.3, 8.0, 5.0, 3.0, 1.0, 0.1 deg)

β_y is the thrust vector deflection angle in the yaw plane

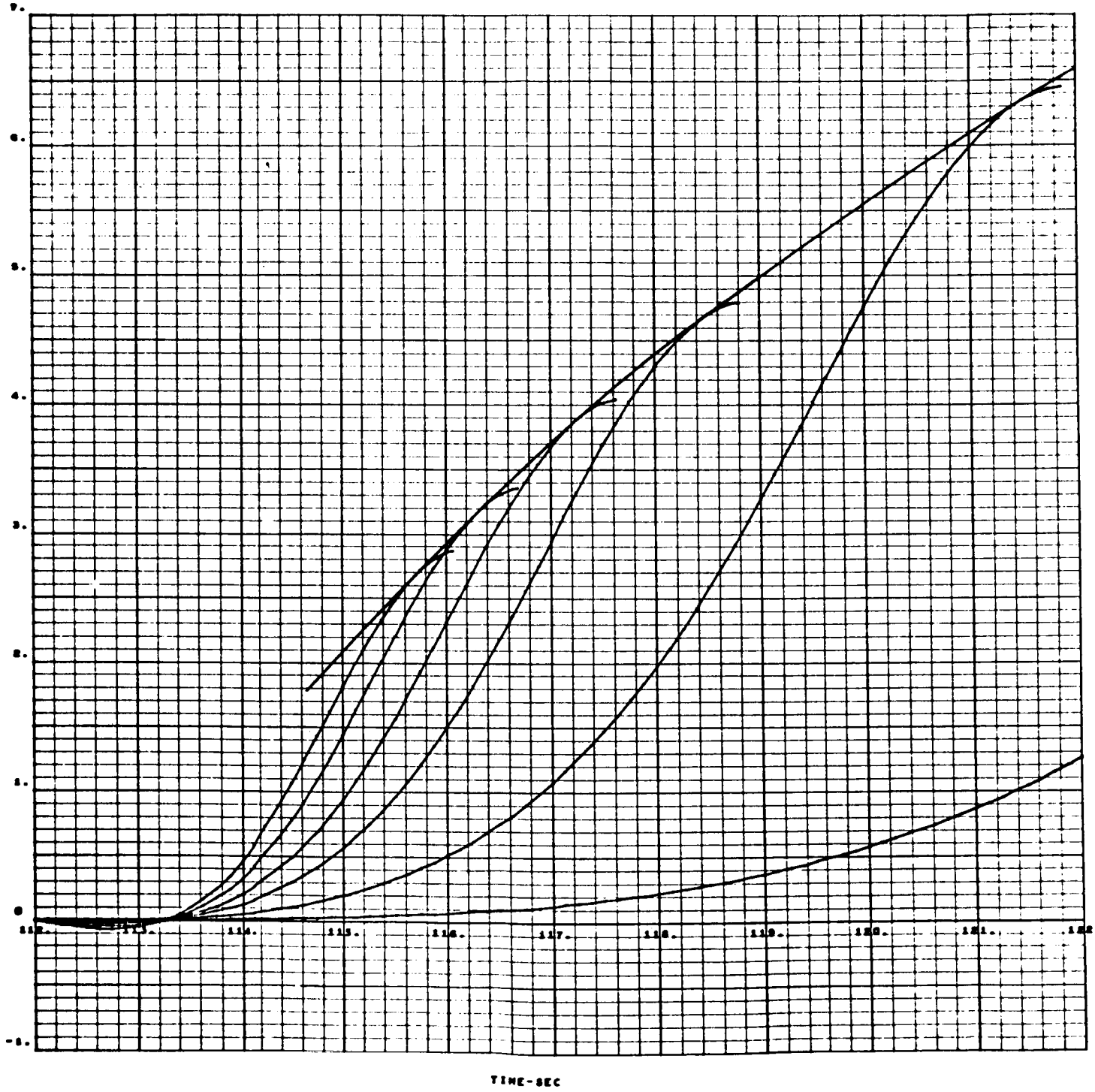


Figure 30

CHANGE IN TOTAL VELOCITY VECTOR ORIENTATION IN THE LATERAL DIRECTION VERSUS TIME FOR MALFUNCTION AT t_i = 116 sec

(β_y = 11.3, 8.0, 5.0, 3.0, 1.0, 0.1 deg)

β_y is the thrust vector deflection angle in the yaw plane

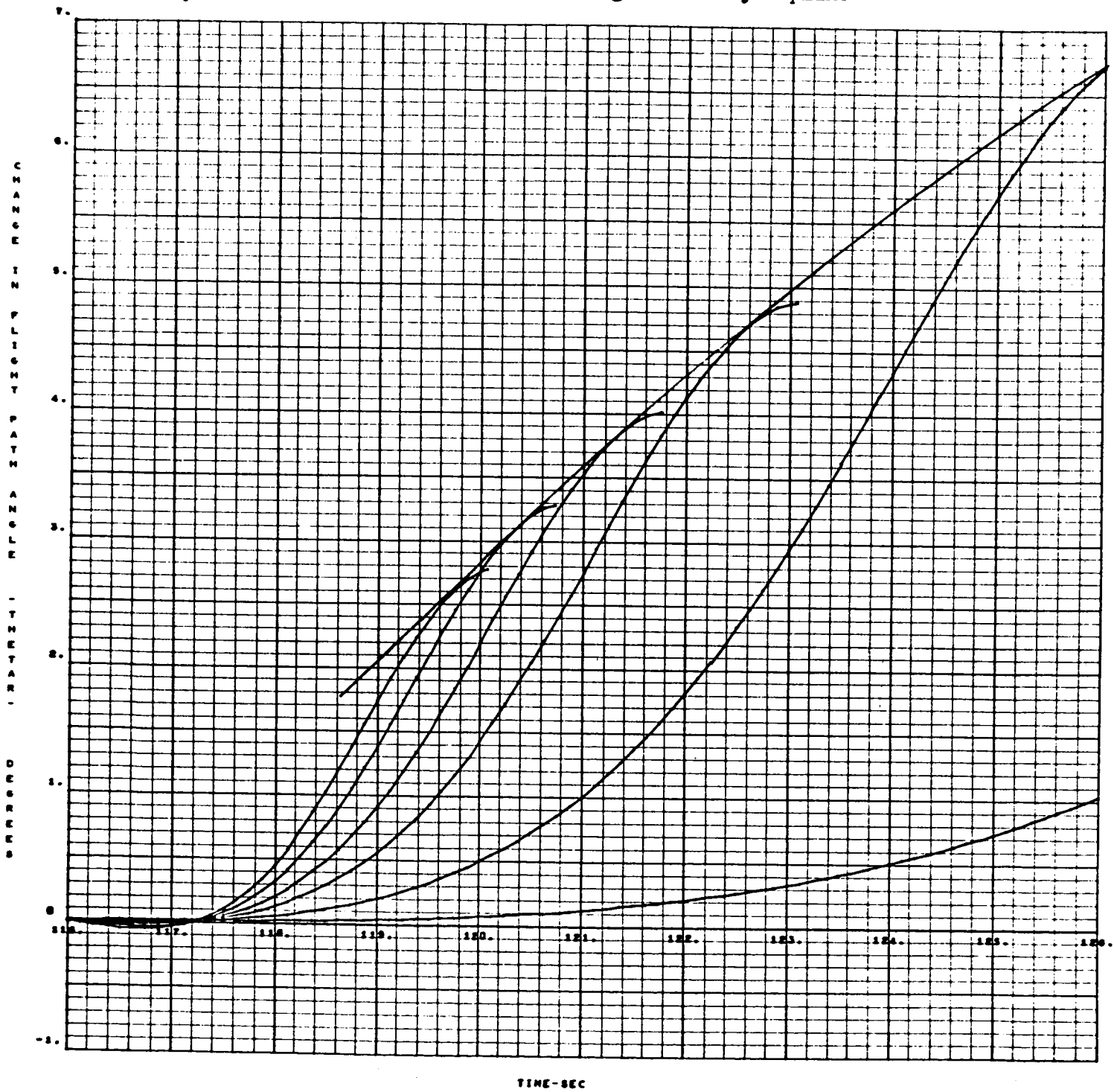


Figure 31

CHANGE IN TOTAL VELOCITY VECTOR ORIENTATION IN THE LATERAL DIRECTION VERSUS TIME FOR MALFUNCTION AT t_i = 120 sec

(β_y = 11.3, 8.0, 5.0, 3.0, 1.0, 0.1 deg)

β_y is the thrust vector deflection angle in the yaw plane

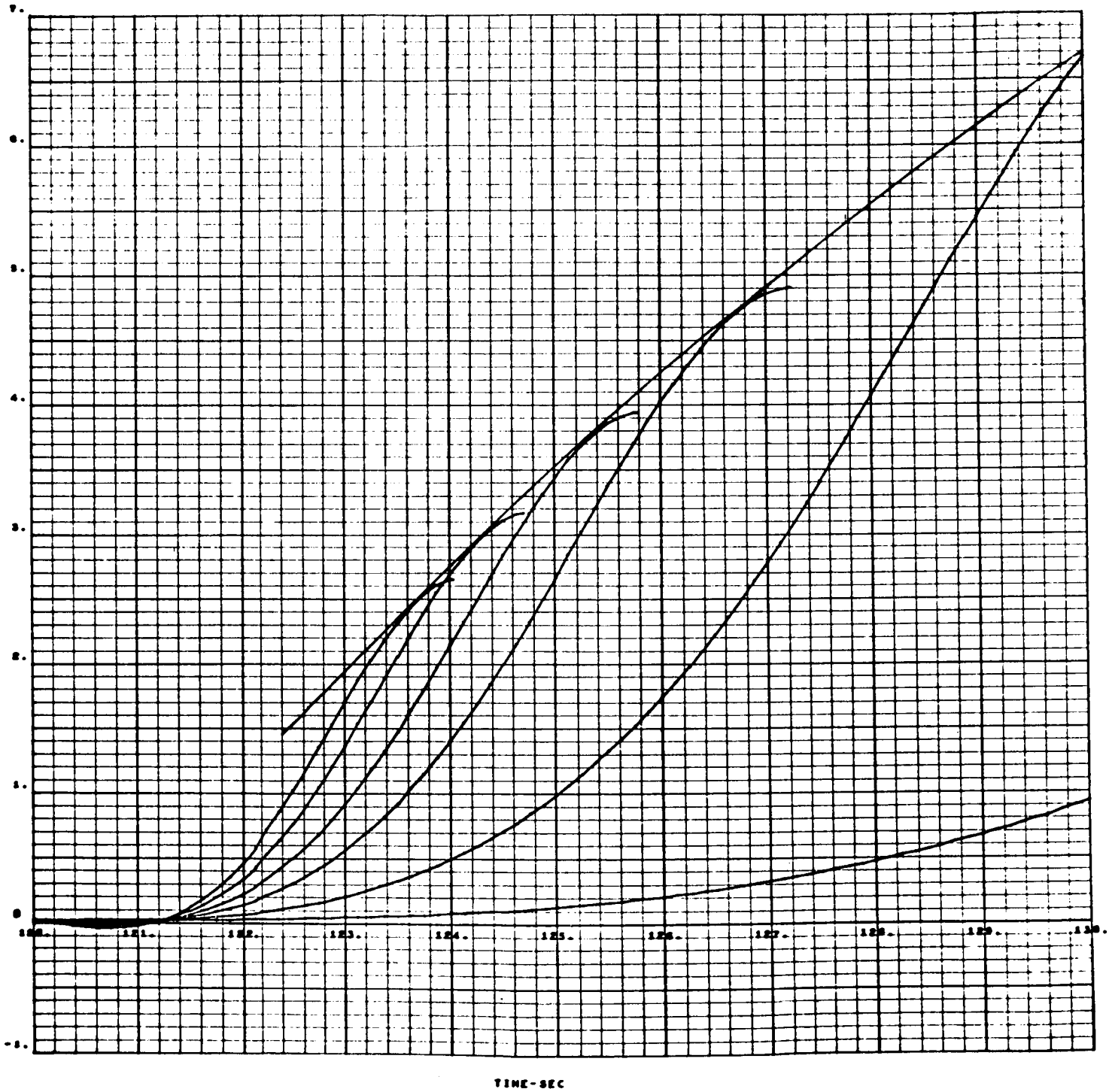


Figure 32

CHANGE IN TOTAL VELOCITY VECTOR ORIENTATION IN THE LATERAL DIRECTION VERSUS TIME FOR MALFUNCTION AT t_i = 124 sec

(β_y = 11.3, 8.0, 5.0, 3.0, 1.0, 0.1 deg)

β_y is the thrust vector deflection angle in the yaw plane

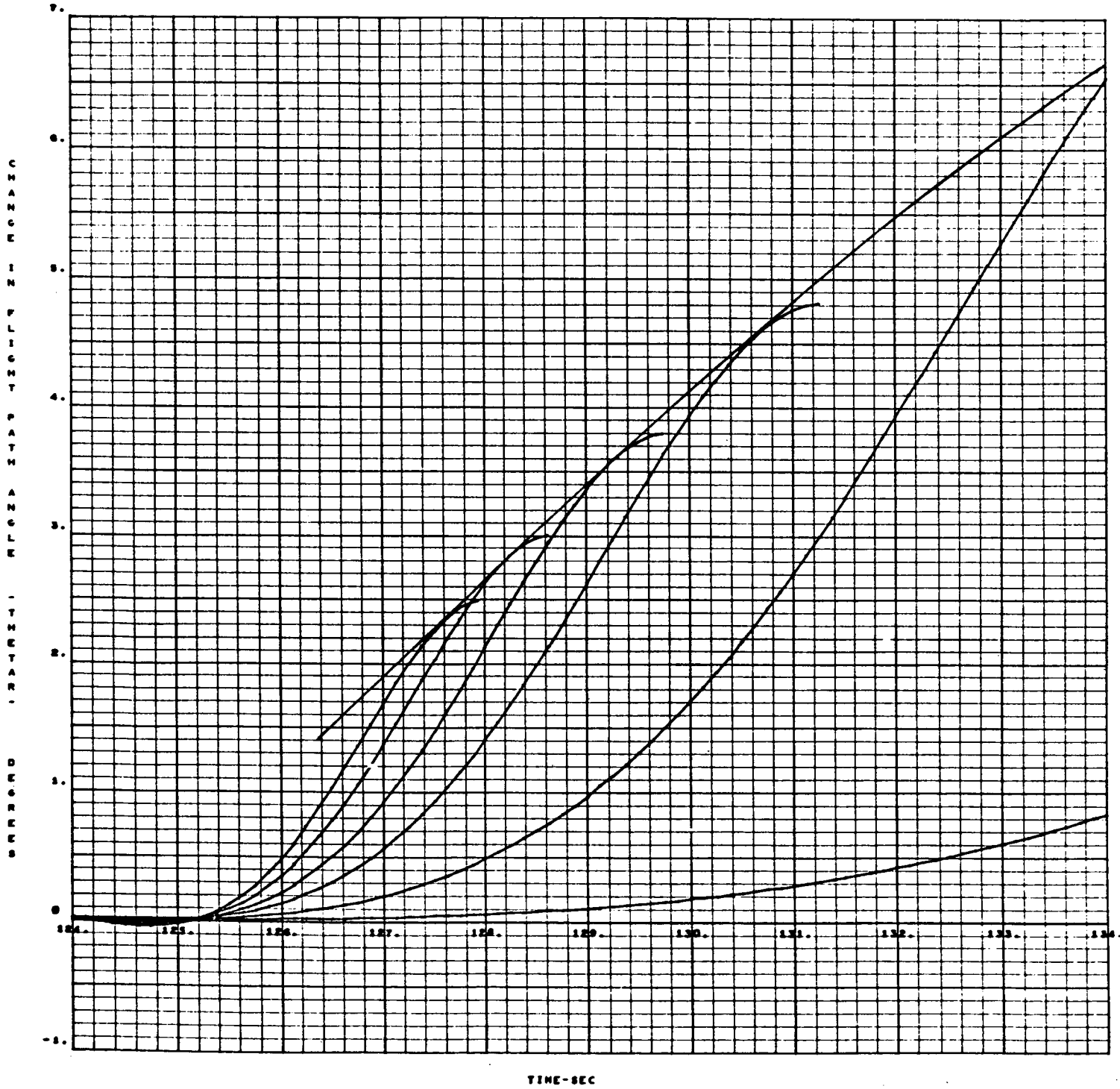


Figure 33

CHANGE IN TOTAL VELOCITY VECTOR ORIENTATION IN THE LATERAL DIRECTION VERSUS TIME FOR MALFUNCTION AT t_i = 128 sec

(β_y = 11.3, 8.0, 5.0, 3.0, 1.0, 0.1 deg)

β_y is the thrust vector deflection angle in the yaw plane

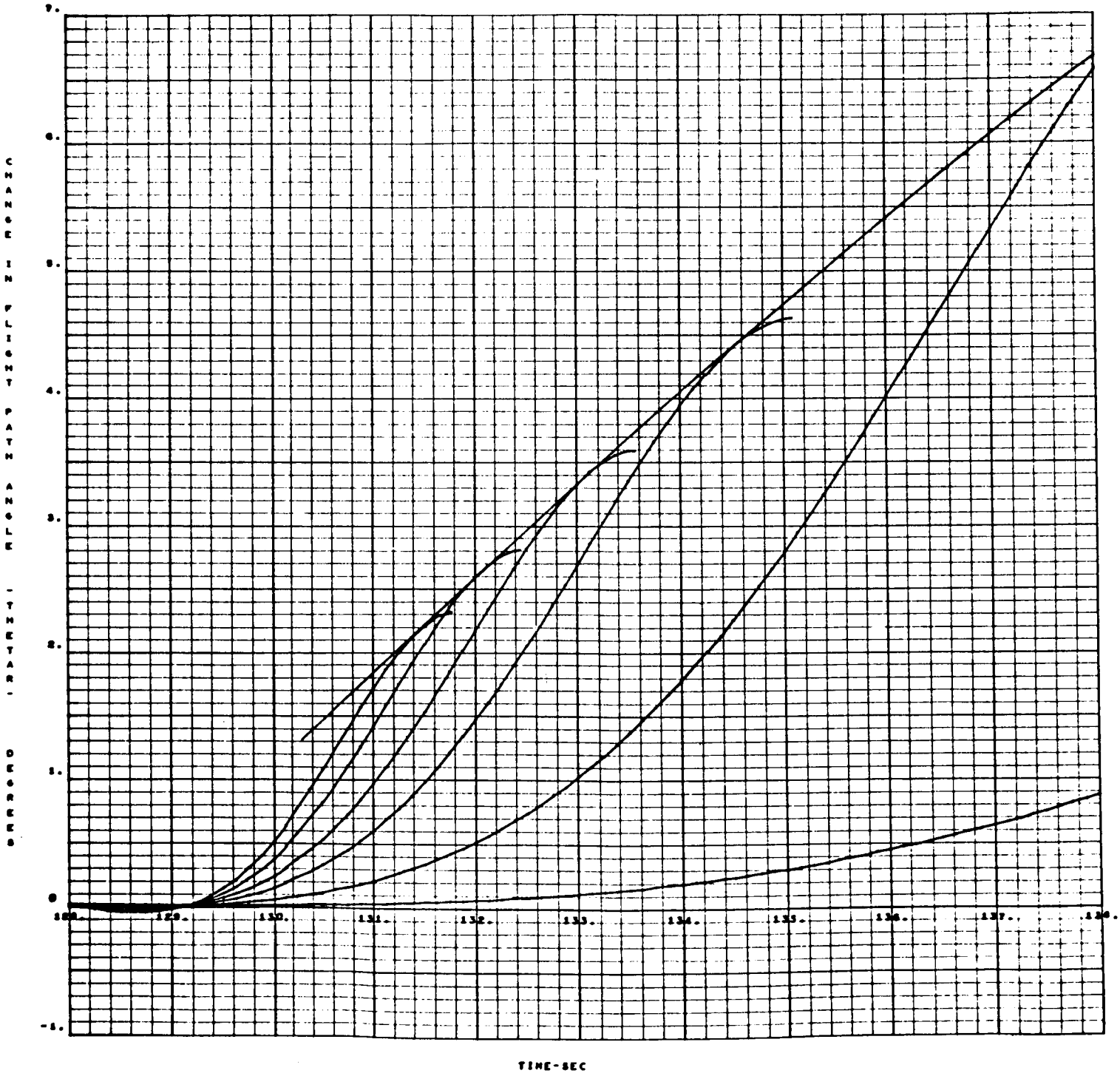


Figure 34

CHANGE IN TOTAL VELOCITY VECTOR ORIENTATION IN THE LATERAL DIRECTION VERSUS TIME FOR MALFUNCTION AT t_i = 132 sec

(β_y = 11.3, 8.0, 5.0, 3.0, 1.0, 0.1 deg)

β_y is the thrust vector deflection angle in the yaw plane

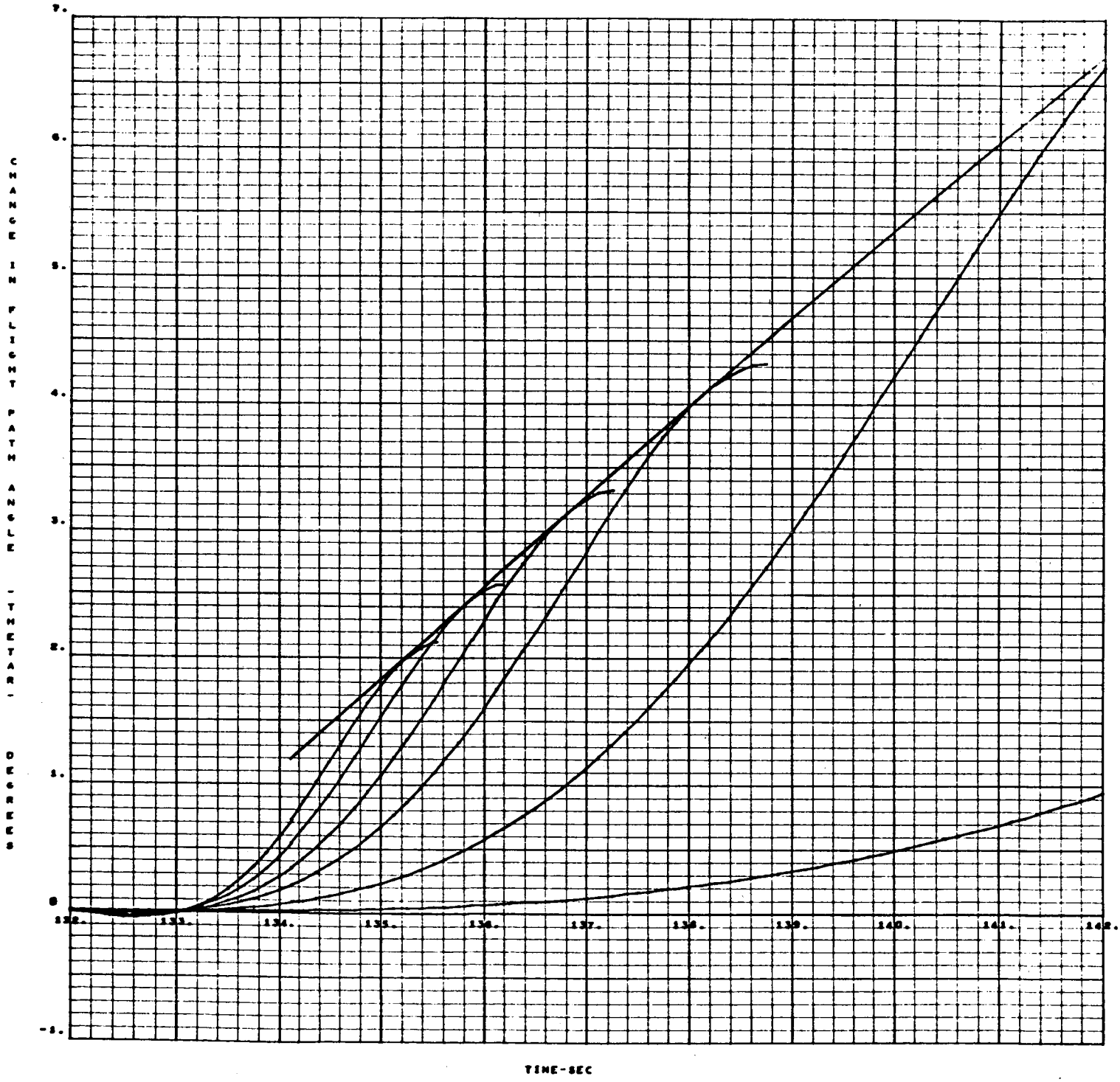


Figure 35

CHANGE IN TOTAL VELOCITY VECTOR ORIENTATION IN THE LATERAL DIRECTION VERSUS TIME FOR MALFUNCTION AT t_i = 150 sec

(β_y = 10.0, 7.0, 5.0, 3.0, 1.0, 0.1 deg)

β_y is the thrust vector deflection angle in the yaw plane

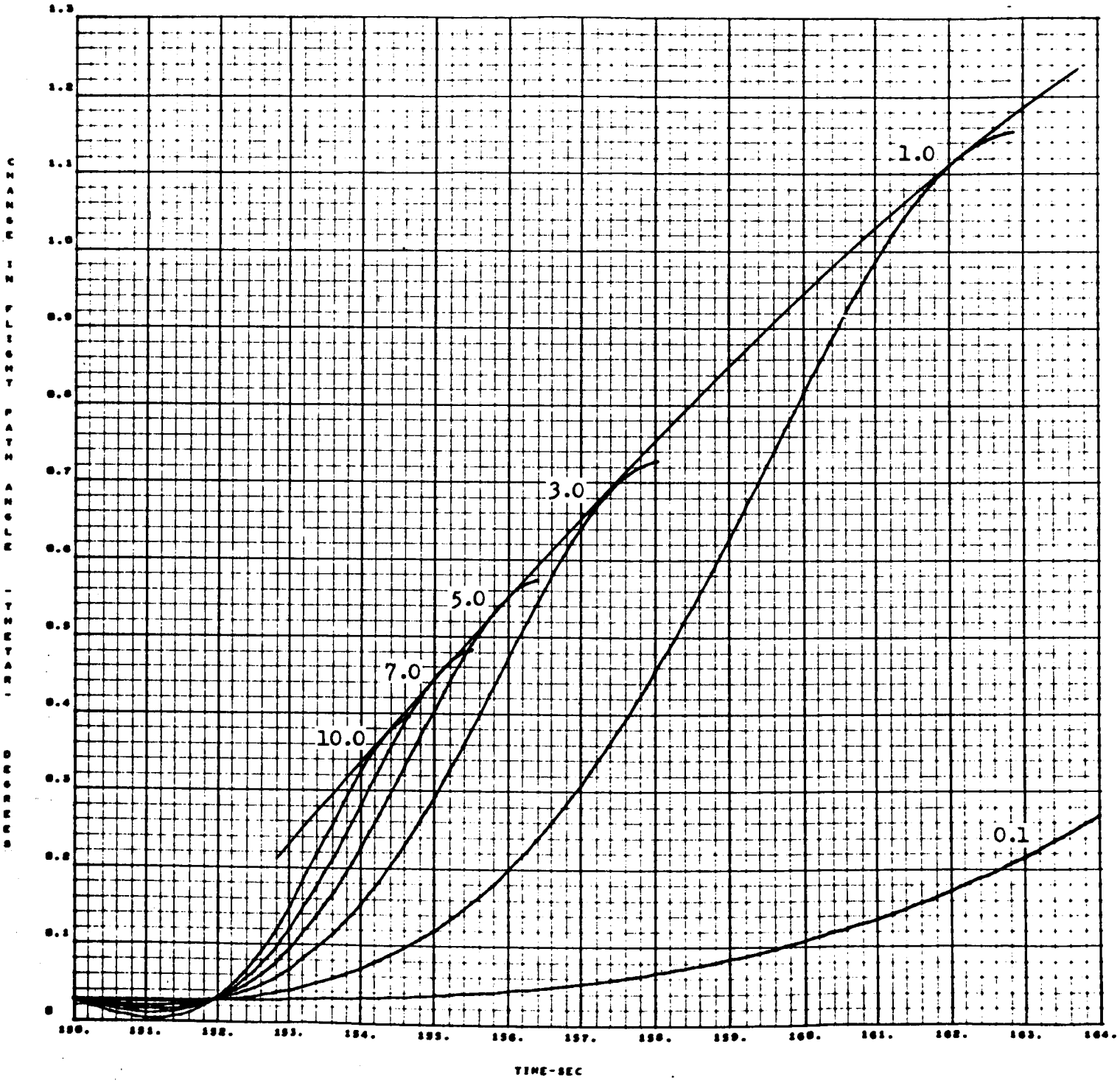


Figure 36

CHANGE IN TOTAL VELOCITY VECTOR ORIENTATION IN THE LATERAL DIRECTION VERSUS TIME FOR MALFUNCTION AT t_i = 154 sec

(β_y = 10.0, 7.0, 5.0, 3.0, 1.0, 0.1 deg)

β_y is the thrust vector deflection angle in the yaw plane

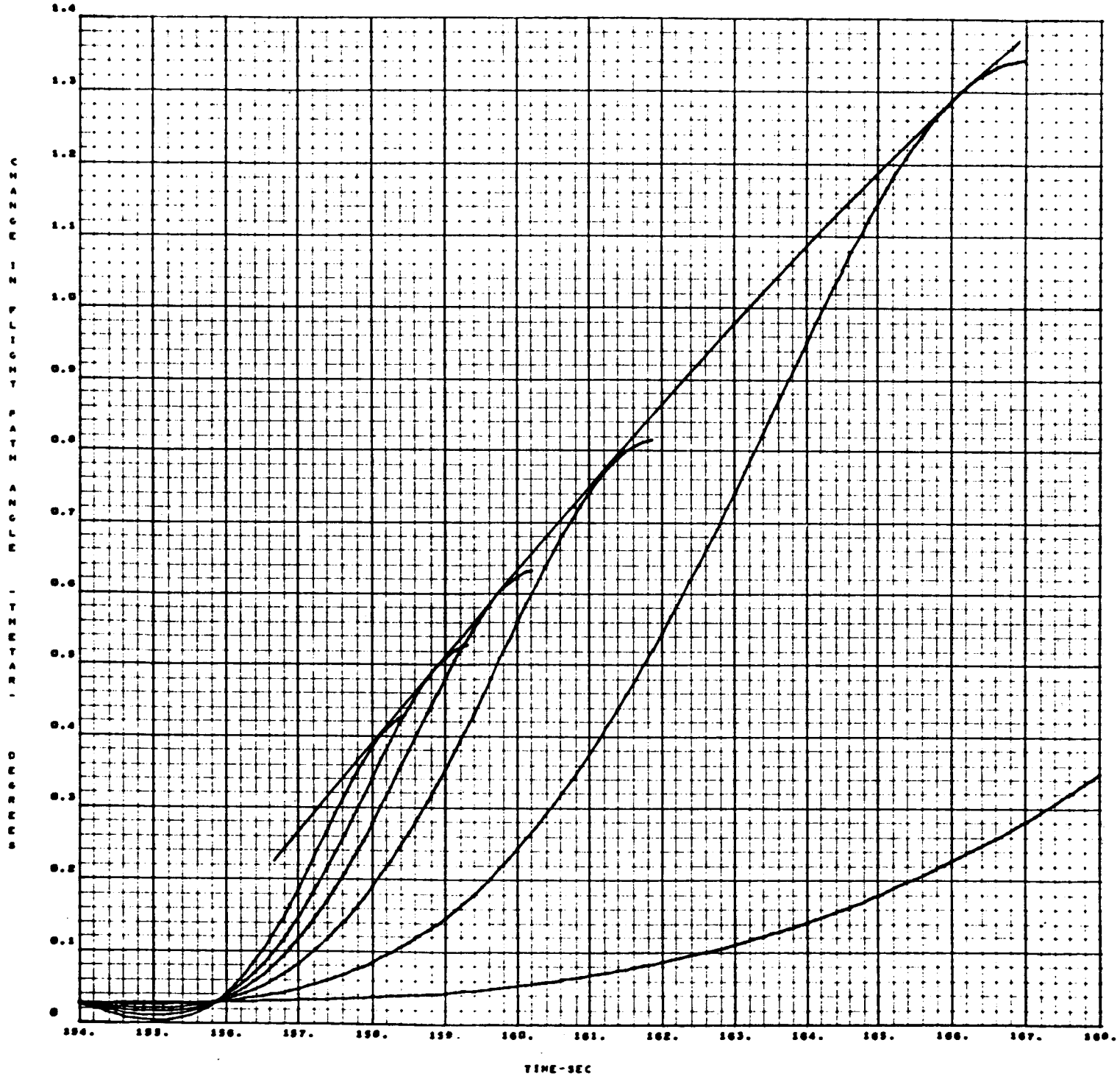


Figure 37

CHANGE IN TOTAL VELOCITY VECTOR ORIENTATION IN THE LATERAL DIRECTION VERSUS TIME FOR MALFUNCTION AT t_i = 158 sec

(β_y = 10.0, 7.0, 5.0, 3.0, 1.0, 0.1 deg)

β_y is the thrust vector deflection angle in the yaw plane

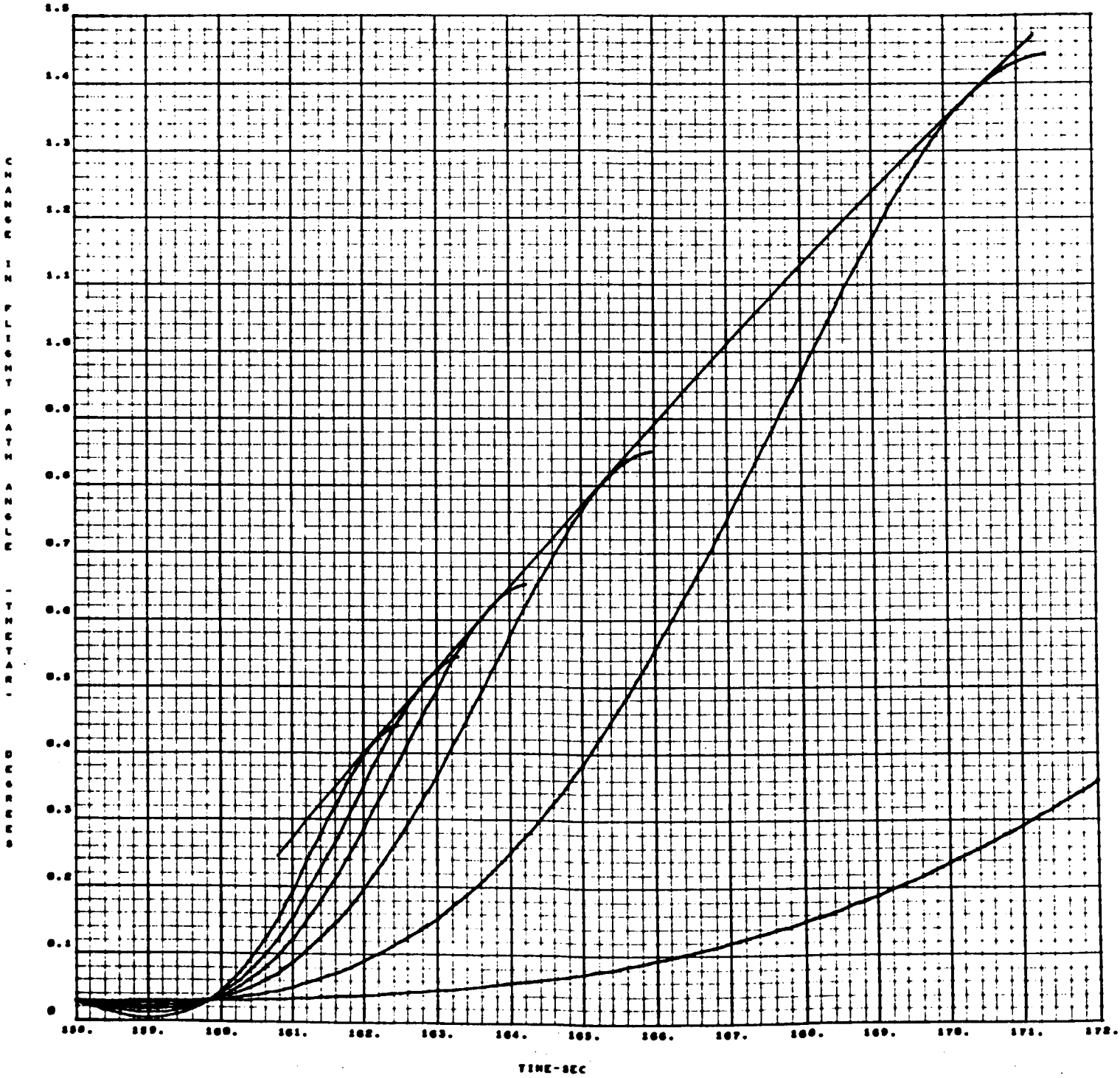


Figure 38

CHANGE IN TOTAL VELOCITY VECTOR ORIENTATION IN THE LATERAL DIRECTION VERSUS TIME FOR MALFUNCTION AT t_i = 174 sec

(β_y = 10.0, 7.0, 5.0, 3.0, 1.0, 0.1 deg)

β_y is the thrust vector deflection angle in the yaw plane

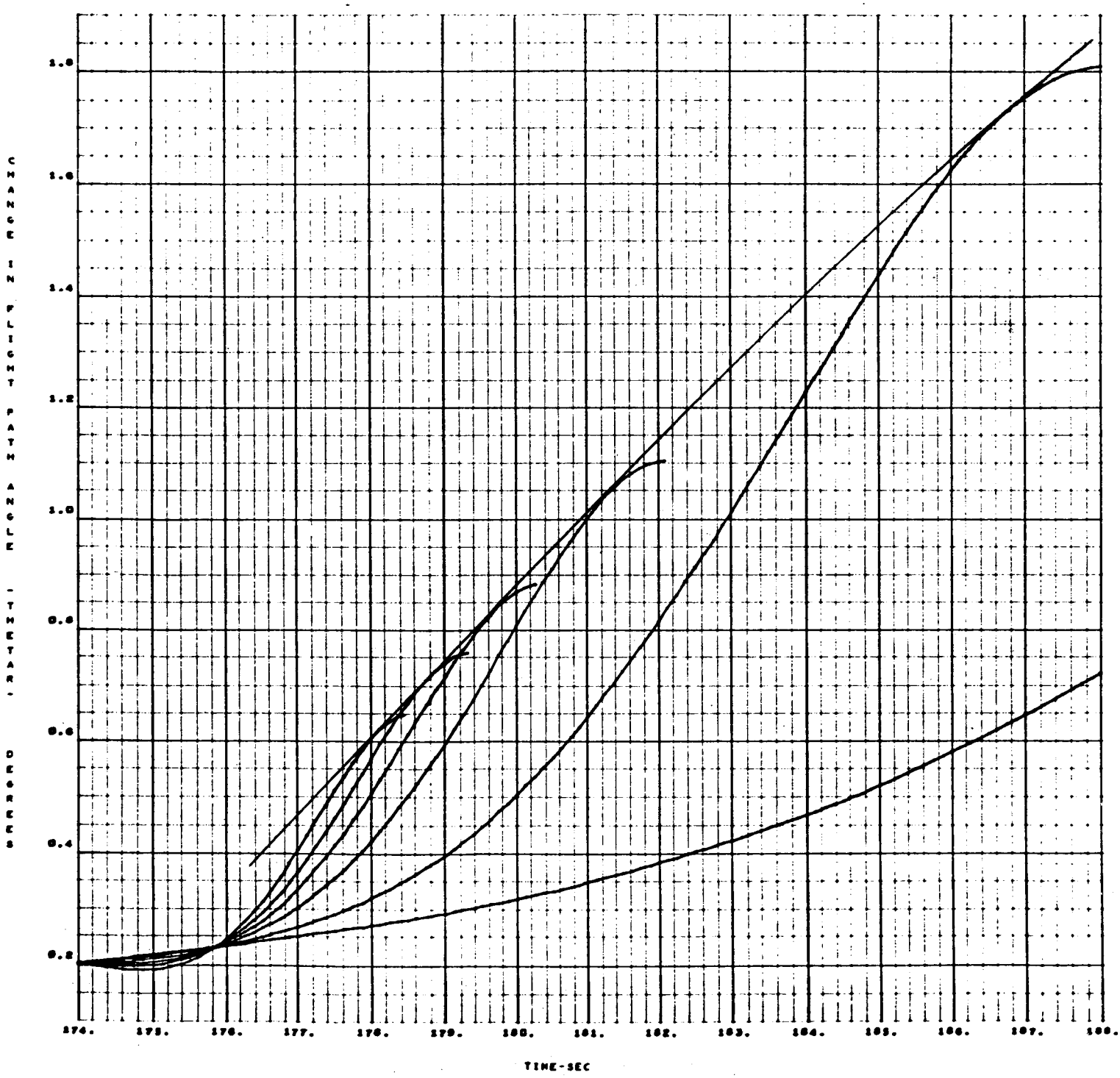


Figure 39

CHANGE IN TOTAL VELOCITY VECTOR ORIENTATION IN THE LATERAL DIRECTION VERSUS TIME FOR MALFUNCTION AT $t_i = 190$ sec

(β_y = 10.0, 7.0, 5.0, 3.0, 1.0, 0.1 deg)

β_y is the thrust vector deflection angle in the yaw plane

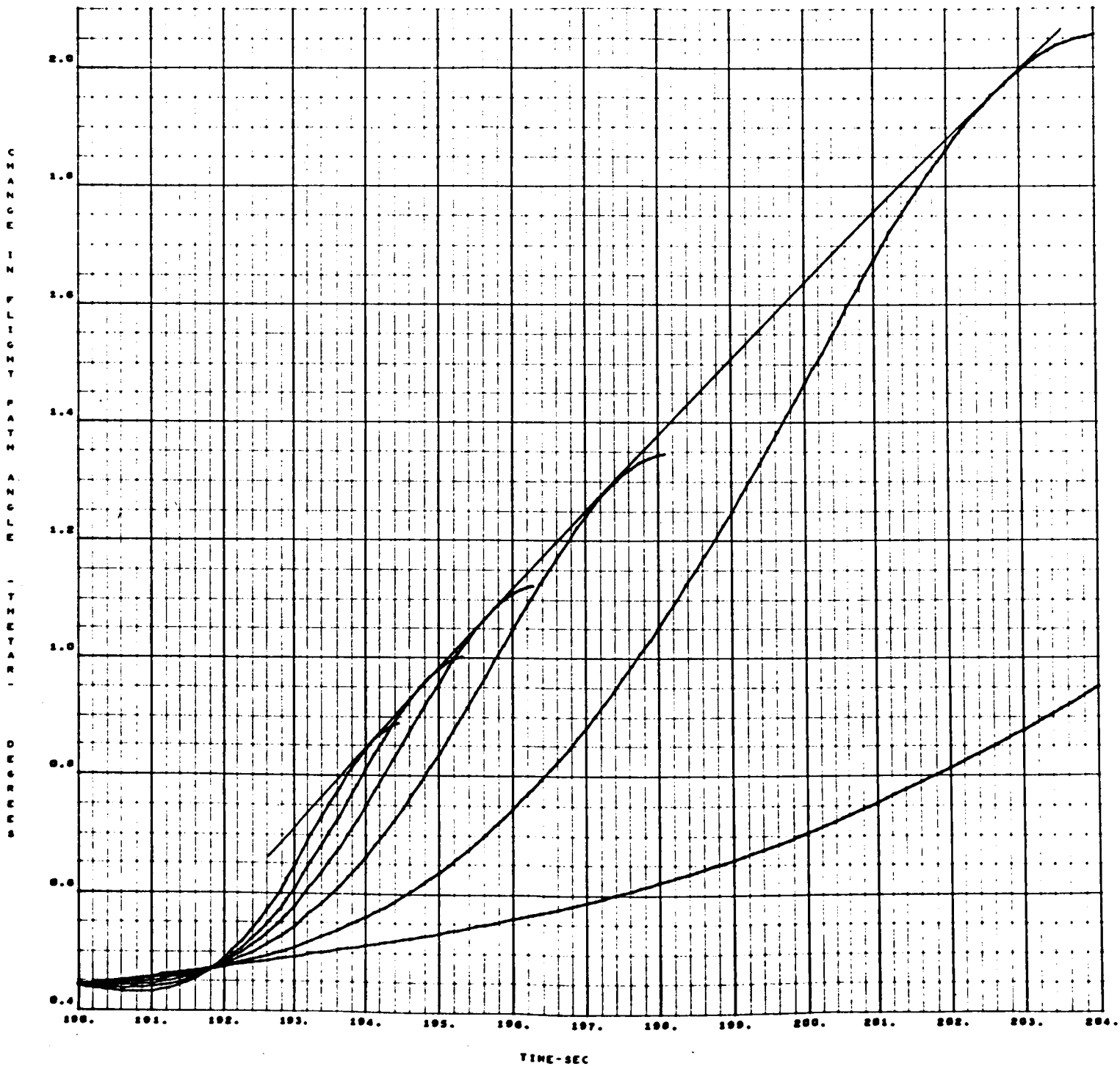


Figure 40

CHANGE IN TOTAL VELOCITY VECTOR ORIENTATION IN THE LATERAL DIRECTION VERSUS TIME FOR MALFUNCTION AT t_i = 206 sec

(β_y = 10.0, 7.0, 5.0, 3.0, 1.0, 0.1 deg)

β_y is the thrust vector deflection angle in the yaw plane

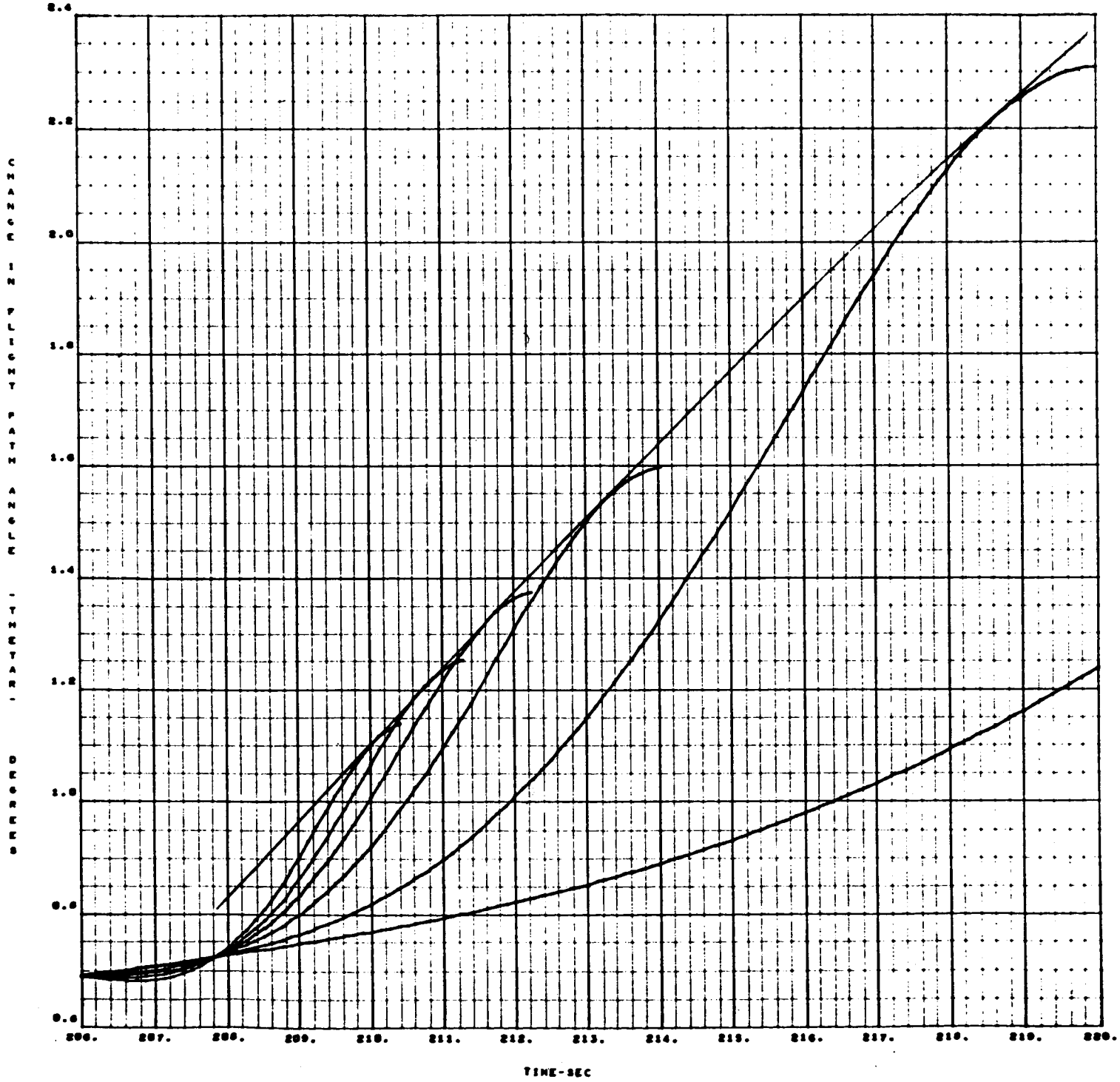


Figure 41

CHANGE IN TOTAL VELOCITY VECTOR ORIENTATION IN THE LATERAL DIRECTION VERSUS TIME FOR MALFUNCTION AT t_i = 222 sec

(β_y = 10.0, 7.0, 5.0, 3.0, 1.0, 0.1 deg)

β_y is the thrust vector deflection angle in the yaw plane

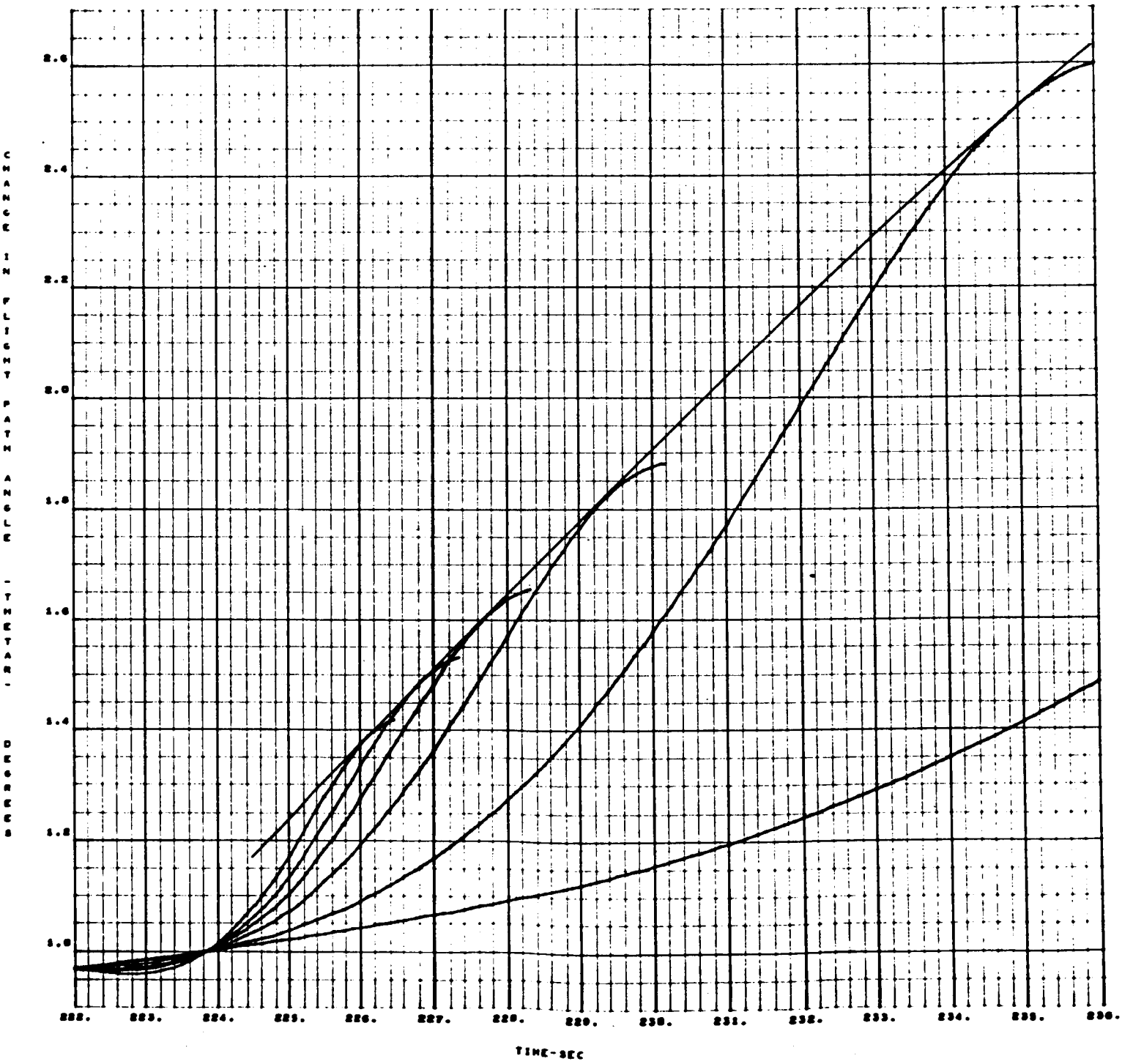


Figure 42

CHANGE IN TOTAL VELOCITY VECTOR ORIENTATION IN THE LATERAL DIRECTION VERSUS TIME FOR MALFUNCTION AT t_i = 238 sec

(β_y = 10.0, 7.0, 5.0, 3.0, 1.0, 0.1 deg)

β_y is the thrust vector deflection angle in the yaw plane

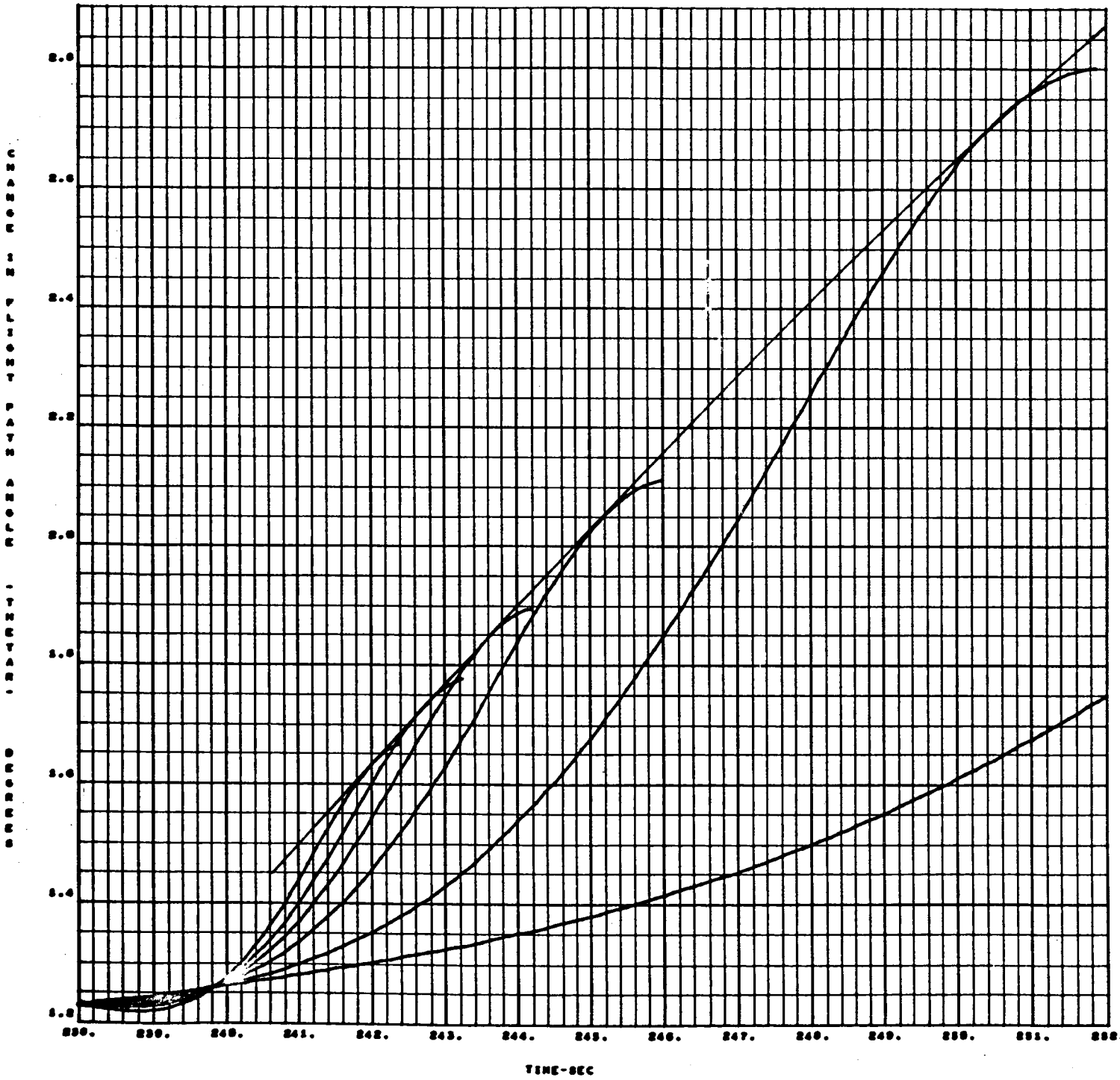


Figure 43

CHANGE IN TOTAL VELOCITY VECTOR ORIENTATION IN THE LATERAL DIRECTION VERSUS TIME FOR MALFUNCTION AT t_i = 254 sec

(β_y = 10.0, 7.0, 5.0, 3.0, 1.0, 0.1 deg)

β_y is the thrust vector deflection angle in the yaw plane

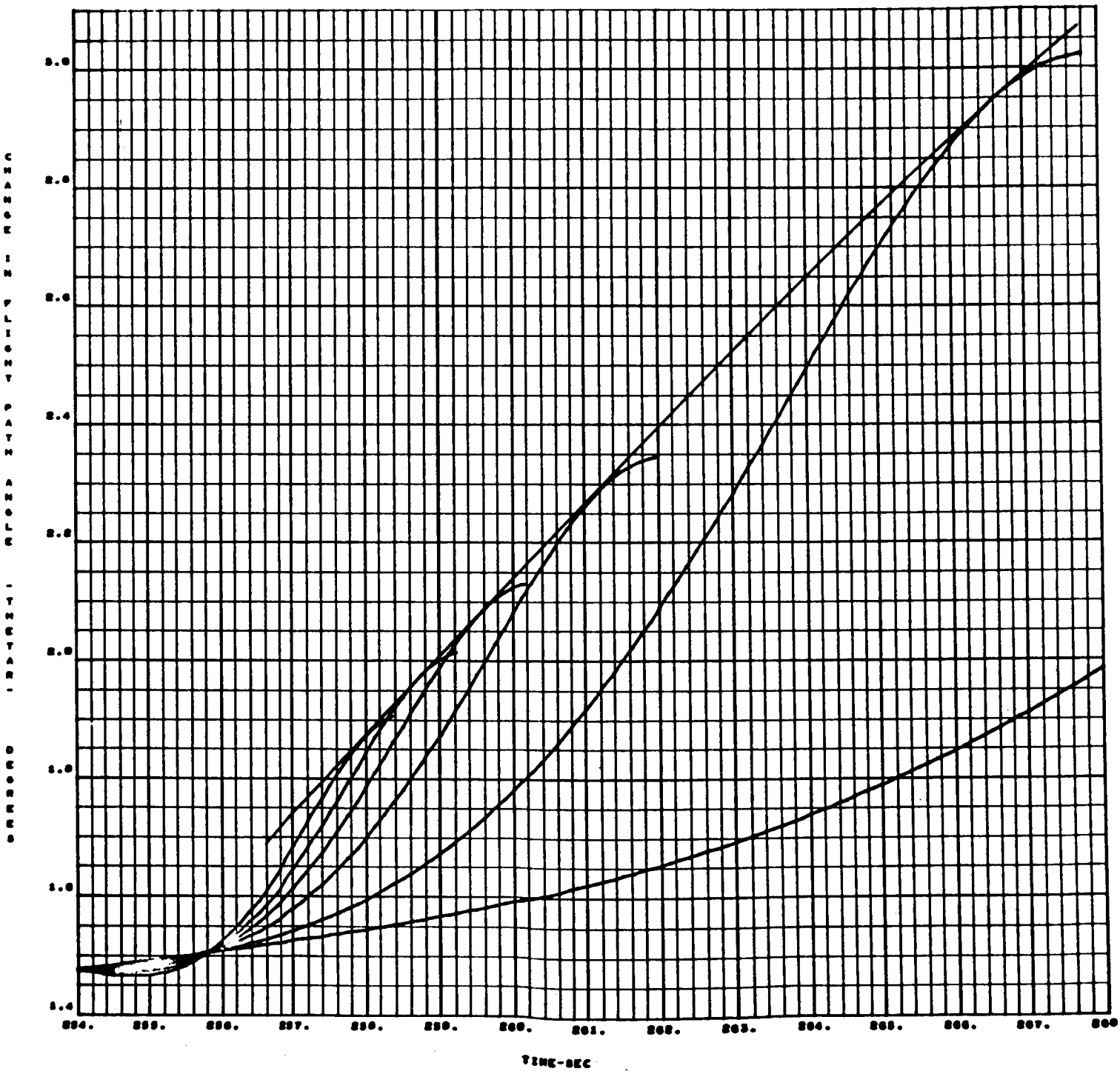


Figure 44

CHANGE IN TOTAL VELOCITY VECTOR ORIENTATION IN THE LATERAL DIRECTION VERSUS TIME FOR MALFUNCTION AT t_i = 270 sec

(β_y = 10.0, 7.0, 5.0, 3.0, 1.0, 0.1 deg)

β_y is the thrust vector deflection angle in the yaw plane

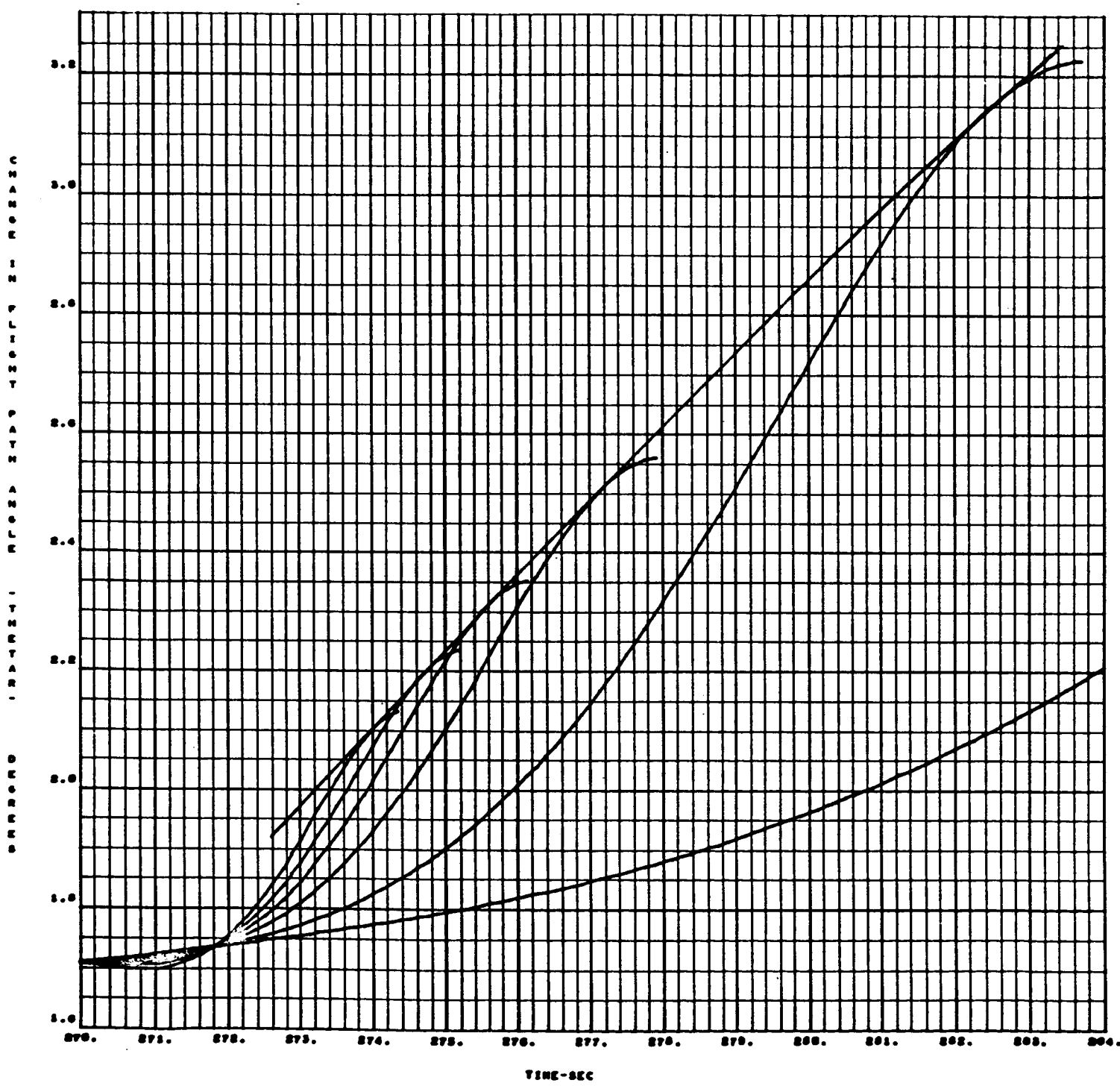


Figure 45

CHANGE IN TOTAL VELOCITY VECTOR ORIENTATION IN THE LATERAL DIRECTION VERSUS TIME FOR MALFUNCTION AT t_i = 286 sec

(β_y = 10.0, 7.0, 5.0, 3.0, 1.0, 0.1 deg)

β_y is the thrust vector deflection angle in the yaw plane

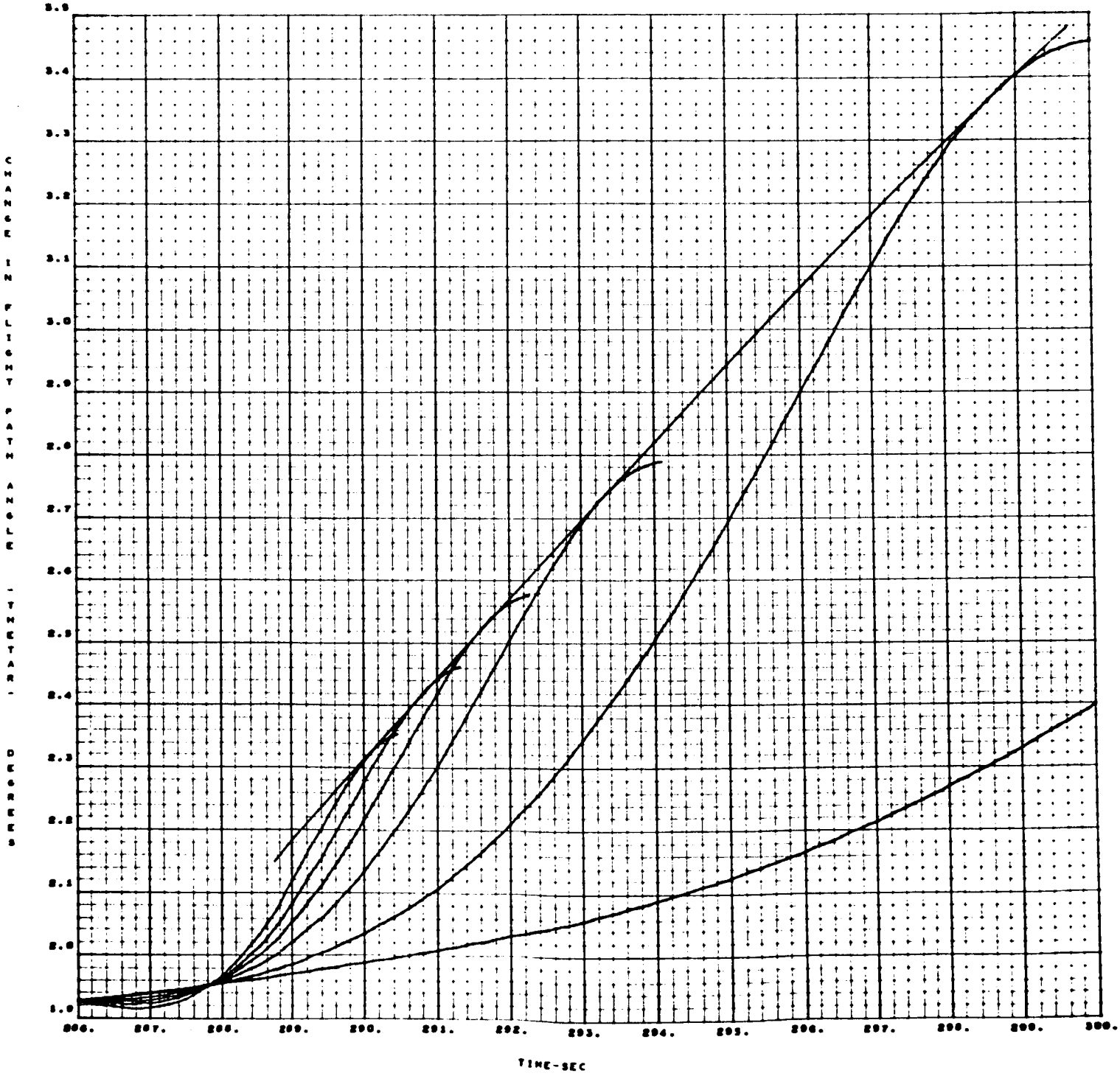


Figure 46

CHANGE IN TOTAL VELOCITY VECTOR ORIENTATION IN THE LATERAL DIRECTION VERSUS TIME FOR MALFUNCTION AT t_i = 302 sec

(β_y = 10.0, 7.0, 5.0, 3.0, 1.0, 0.1 deg)

β_y is the thrust vector deflection angle in the yaw plane

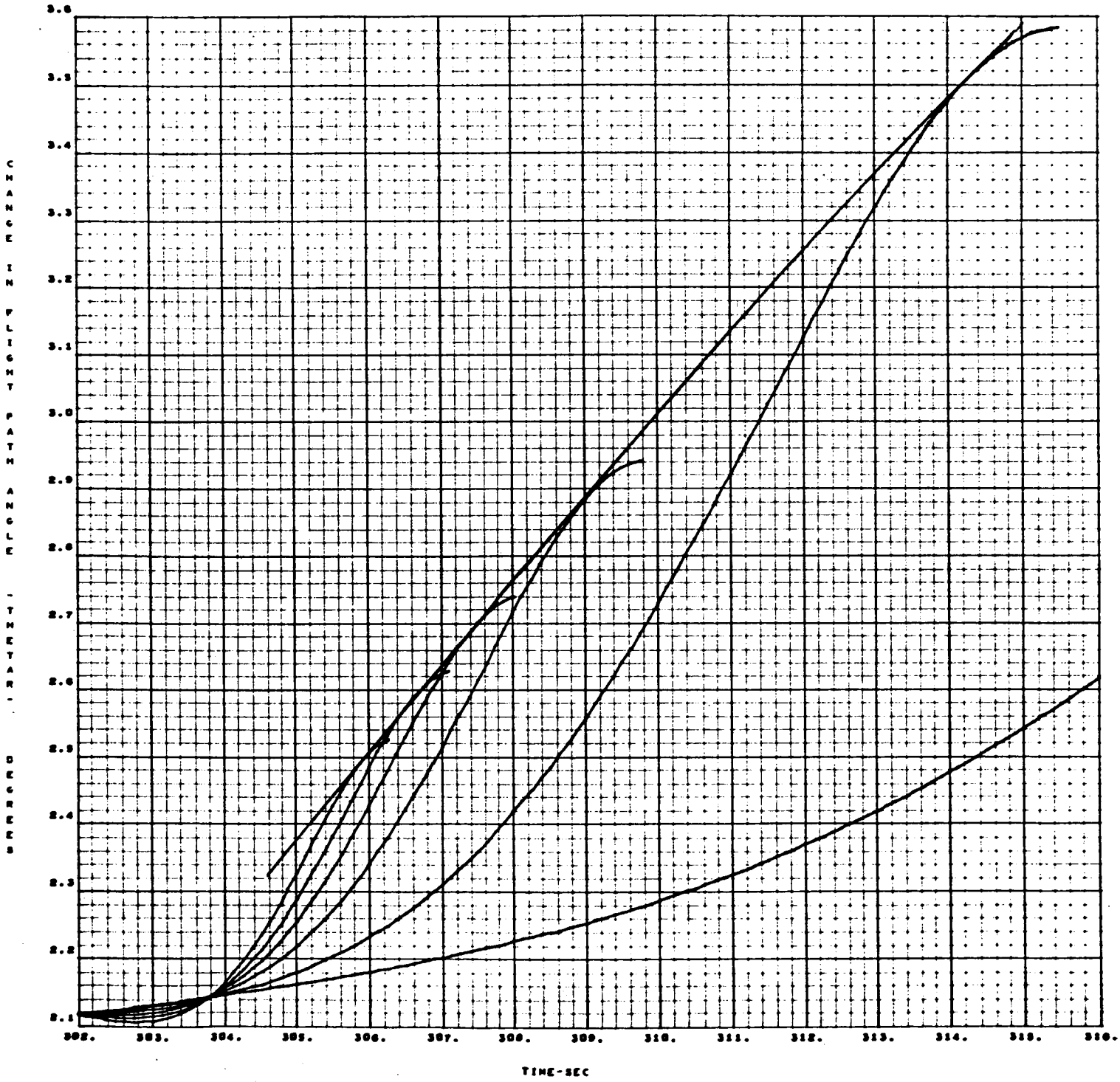


Figure 47

CHANGE IN TOTAL VELOCITY VECTOR ORIENTATION IN THE LATERAL DIRECTION VERSUS TIME FOR MALFUNCTION AT t_i = 318 sec

(β_y = 10.0, 7.0, 5.0, 3.0, 1.0, 0.1 deg)

β_y is the thrust vector deflection angle in the yaw plane

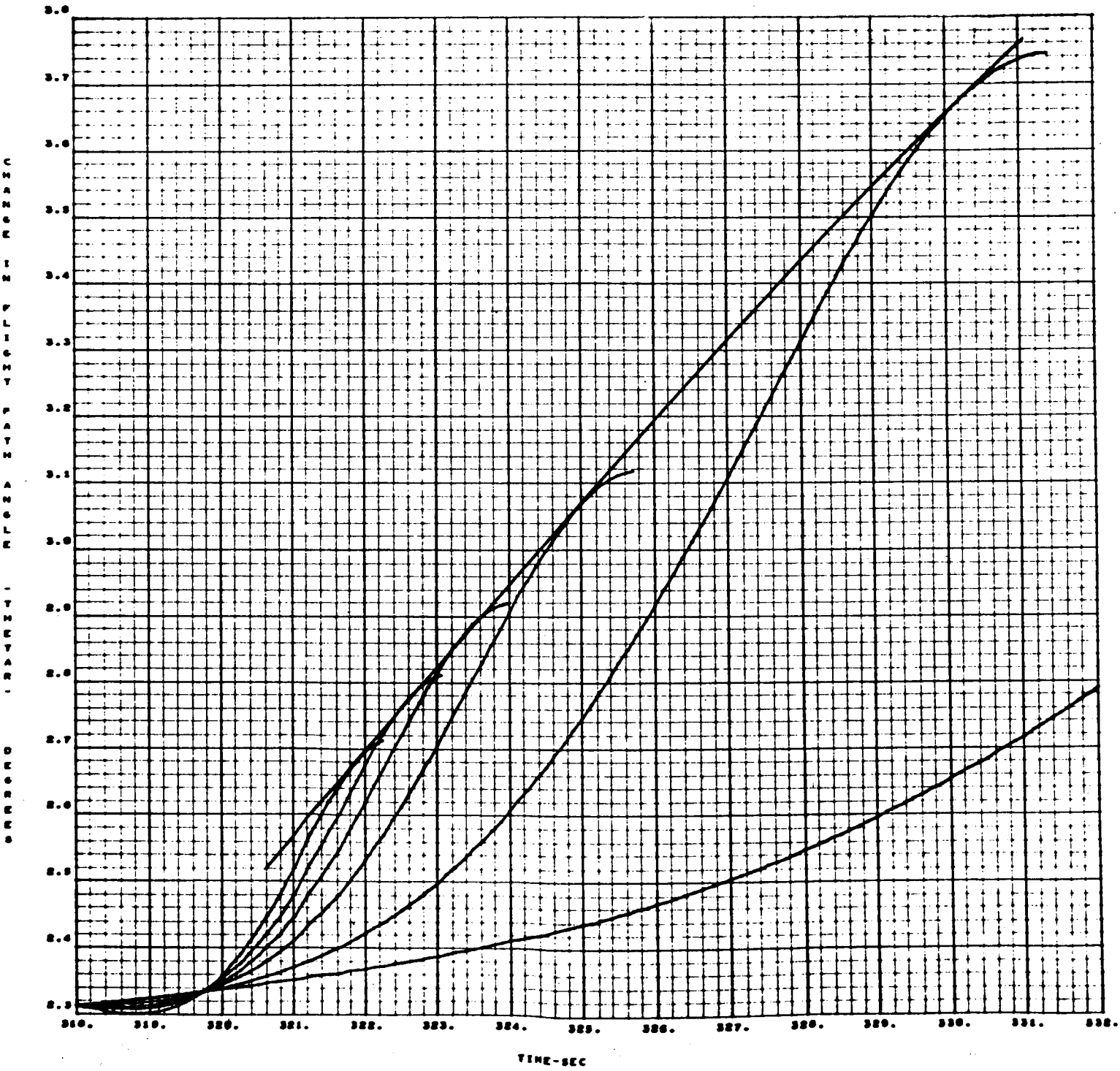


Figure 48

CHANGE IN TOTAL VELOCITY VECTOR ORIENTATION IN THE LATERAL DIRECTION VERSUS TIME FOR MALFUNCTION AT t_i = 334 sec

(β_y = 10.0, 7.0, 5.0, 3.0, 1.0, 0.1 deg)

β_y is the thrust vector deflection angle in the yaw plane

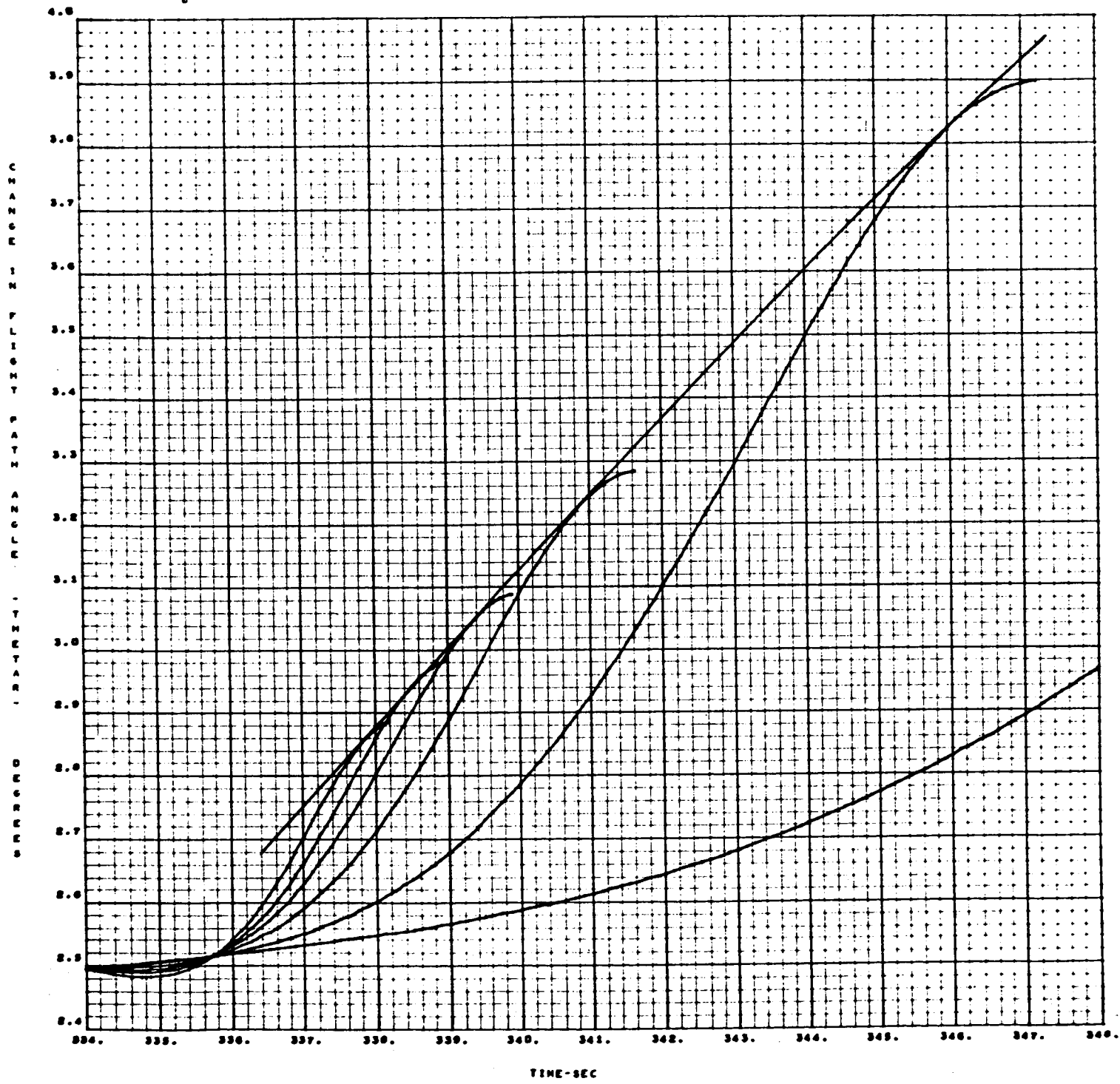


Figure 49

CHANGE IN TOTAL VELOCITY VECTOR ORIENTATION IN THE LATERAL DIRECTION VERSUS TIME FOR MALFUNCTION AT t_i = 350 sec

(β_y = 10.0, 7.0, 5.0, 3.0, 1.0, 0.1 deg)

β_y is the thrust vector deflection angle in the yaw plane

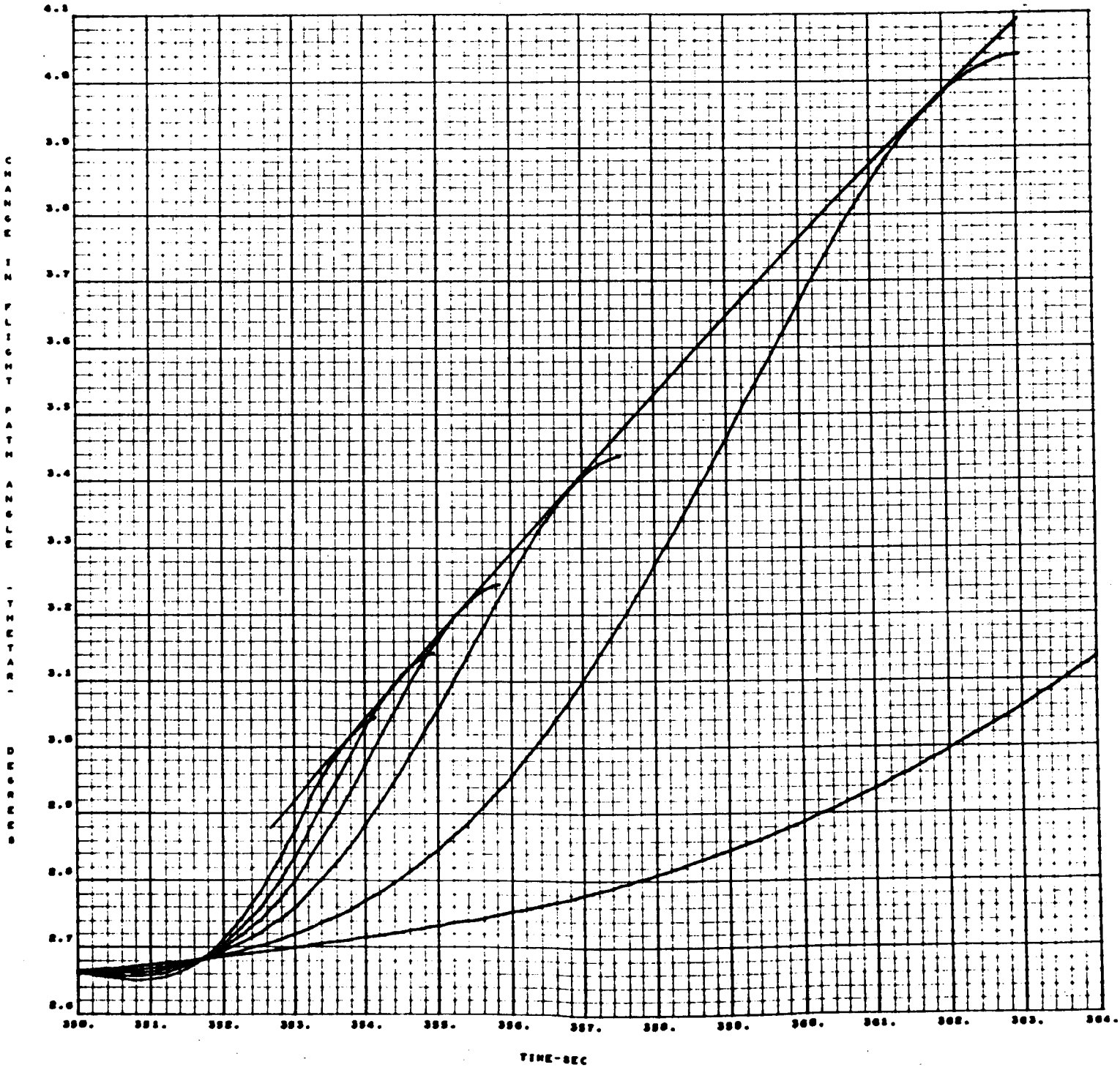


Figure 50

CHANGE IN TOTAL VELOCITY VECTOR ORIENTATION IN THE LATERAL DIRECTION VERSUS TIME FOR MALFUNCTION AT t_i = 366 sec

(β_y = 10.0, 7.0, 5.0, 3.0, 1.0, 0.1 deg)

β_y is the thrust vector deflection angle in the yaw plane

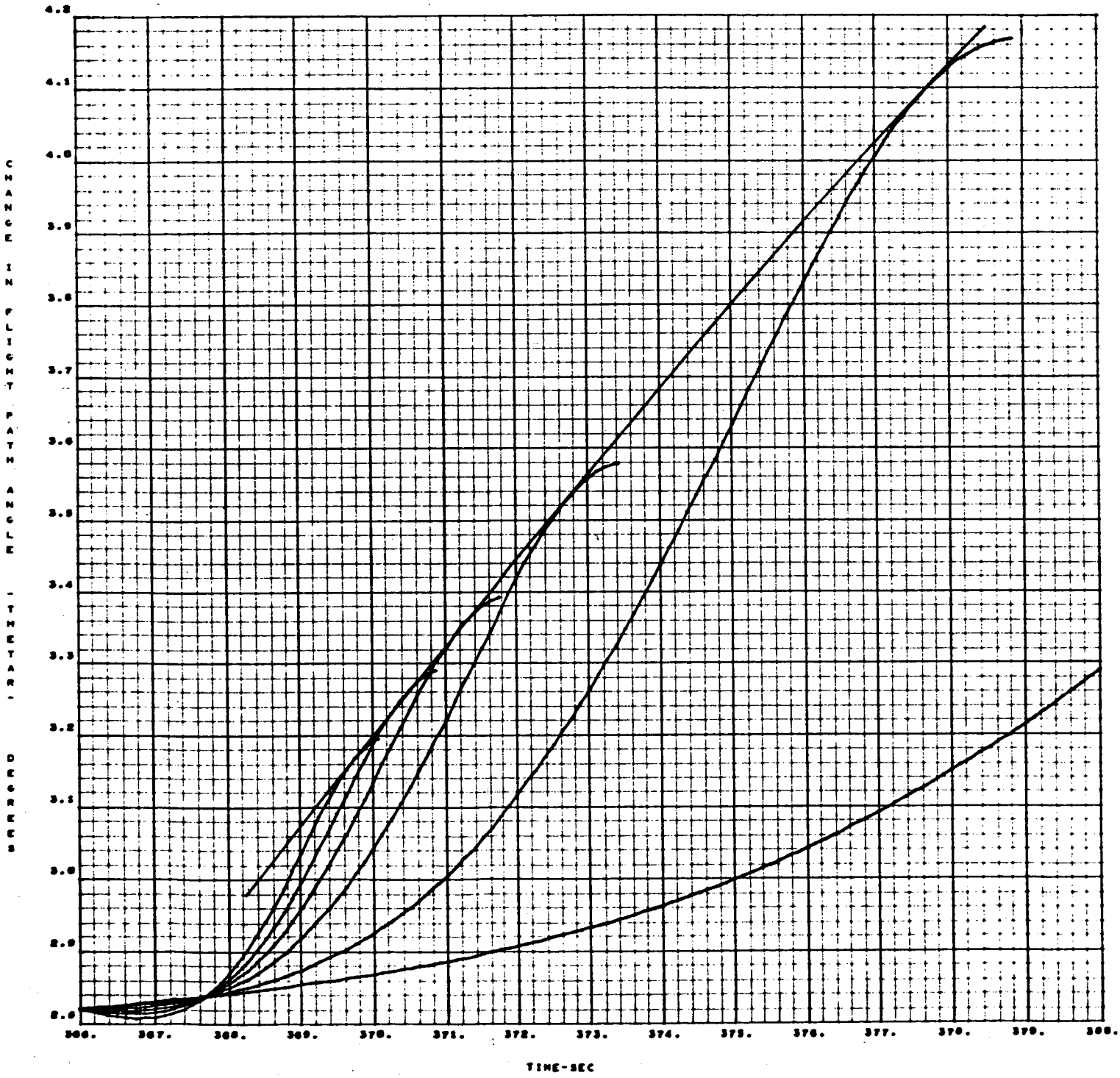


Figure 51

CHANGE IN TOTAL VELOCITY VECTOR ORIENTATION IN THE LATERAL DIRECTION VERSUS TIME FOR MALFUNCTION AT t_i = 382 sec

(β_y = 10.0, 7.0, 5.0, 3.0, 1.0, 0.1 deg)

β_y is the thrust vector deflection angle in the yaw plane

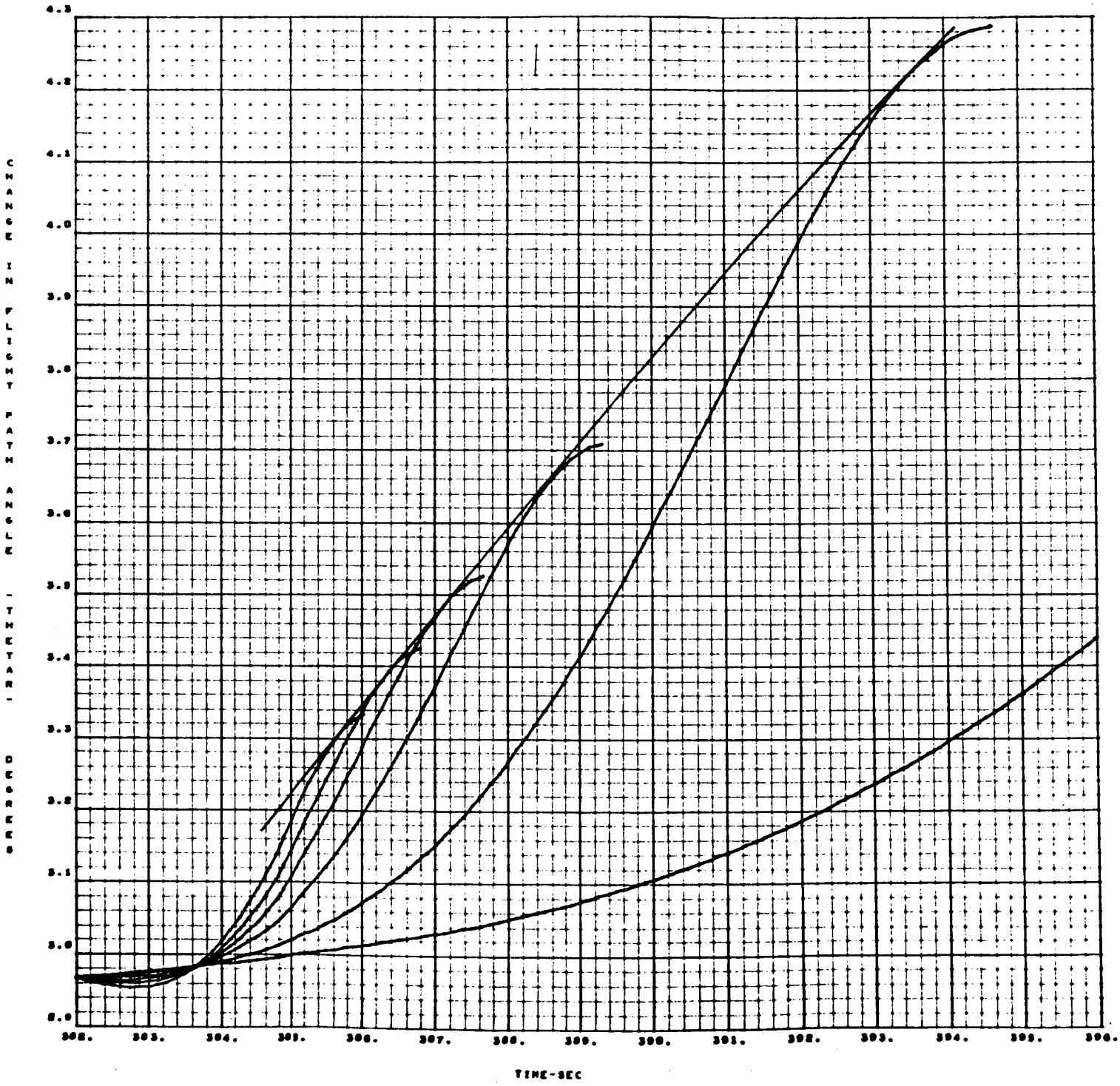


Figure 52

CHANGE IN TOTAL VELOCITY VECTOR ORIENTATION IN THE LATERAL DIRECTION VERSUS TIME FOR MALFUNCTION AT t_i = 398 sec

(β_y = 10.0, 7.0, 5.0, 3.0, 1.0, 0.1 deg)

β_y is the thrust vector deflection angle in the yaw plane

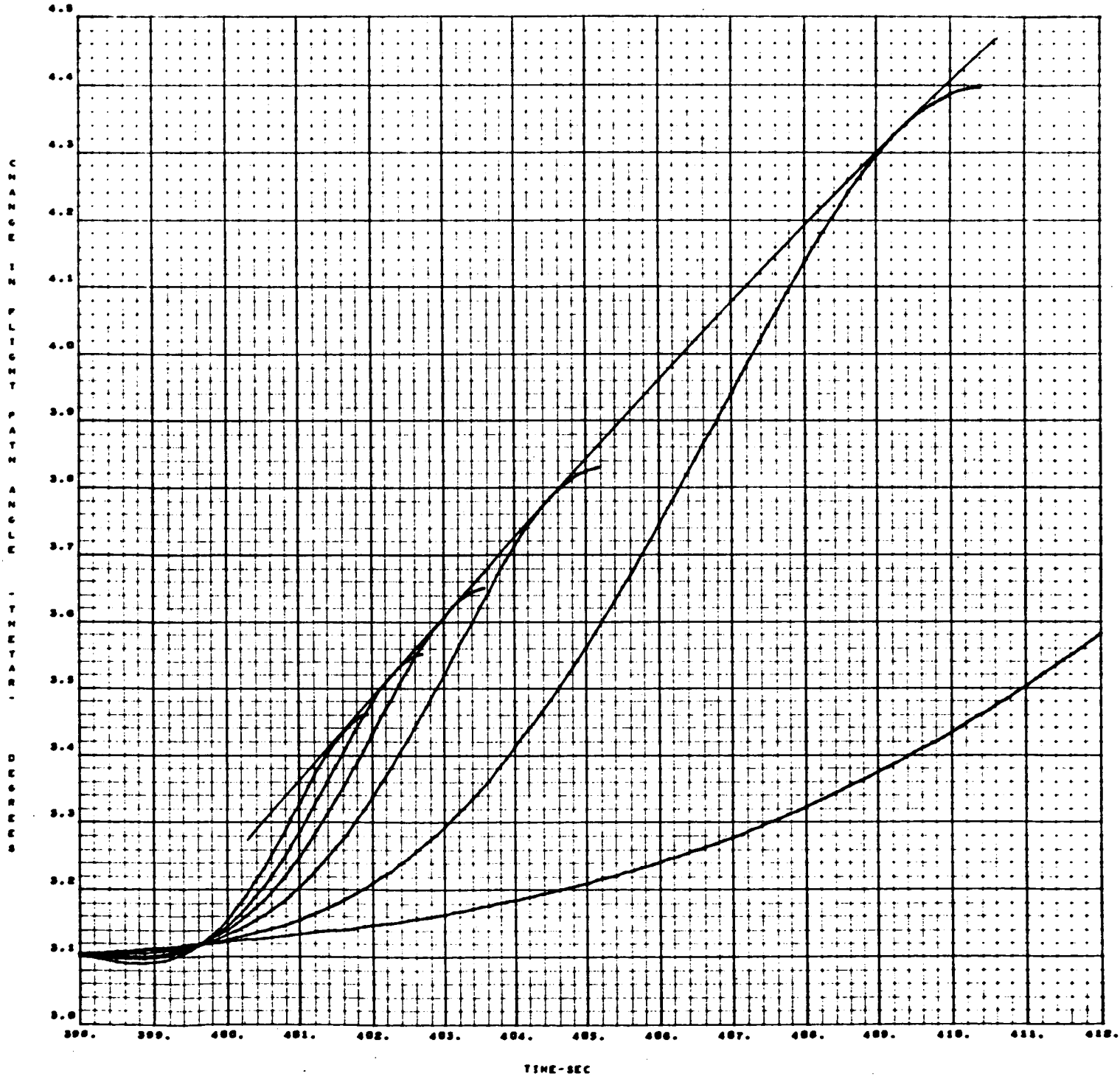


Figure 53

CHANGE IN TOTAL VELOCITY VECTOR ORIENTATION IN THE LATERAL DIRECTION VERSUS TIME FOR MALFUNCTION AT t_i = 414 sec

(β_y = 10.0, 7.0, 5.0, 3.0, 1.0, 0.1 deg)

β_y is the thrust vector deflection angle in the yaw plane

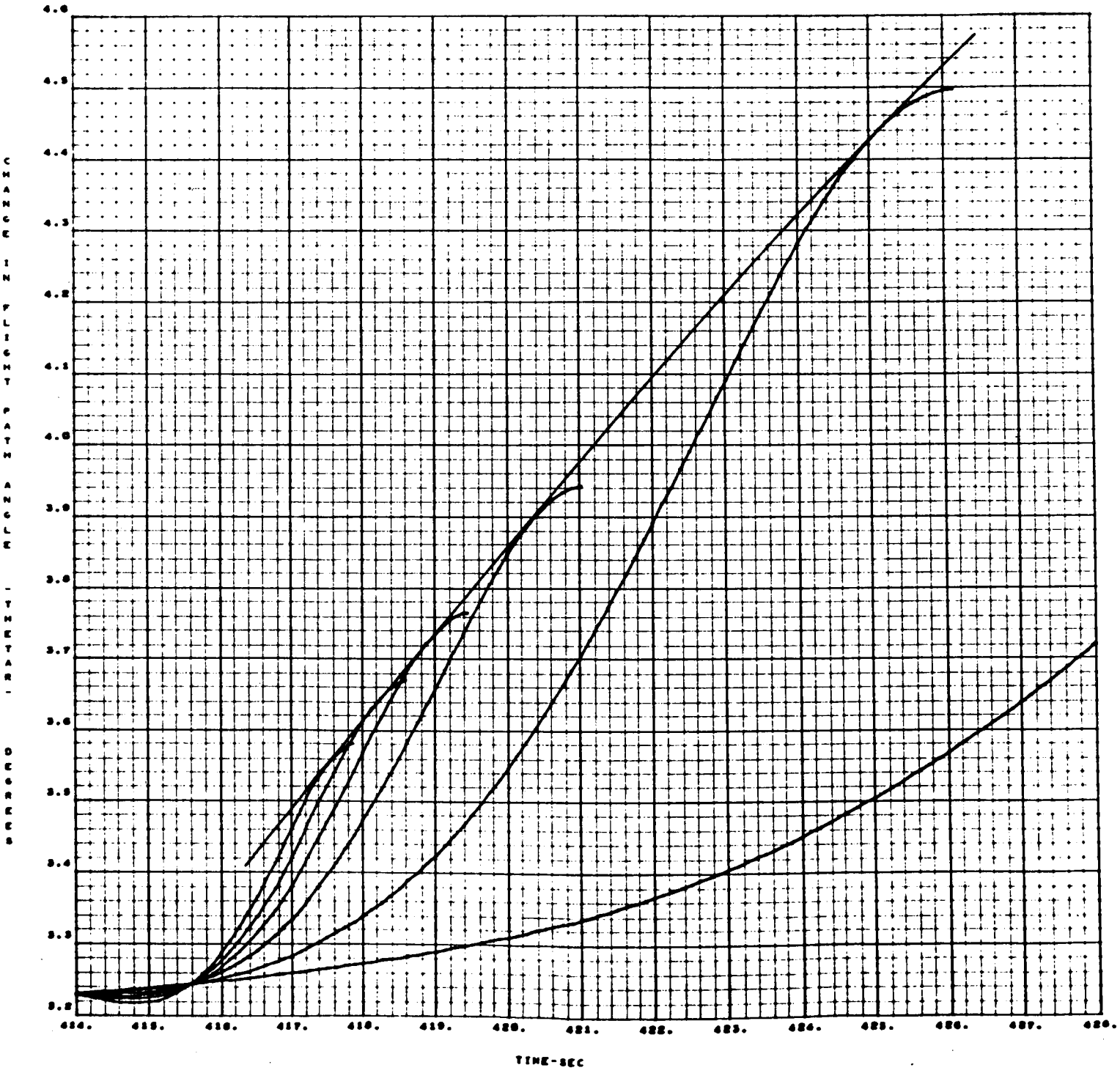


Figure 54

CHANGE IN TOTAL VELOCITY VECTOR ORIENTATION IN THE LATERAL DIRECTION VERSUS TIME FOR MALFUNCTION AT t_i = 430 sec

(β_y = 10.0, 7.0, 5.0, 3.0, 1.0, 0.1 deg)

β_y is the thrust vector deflection angle in the yaw plane

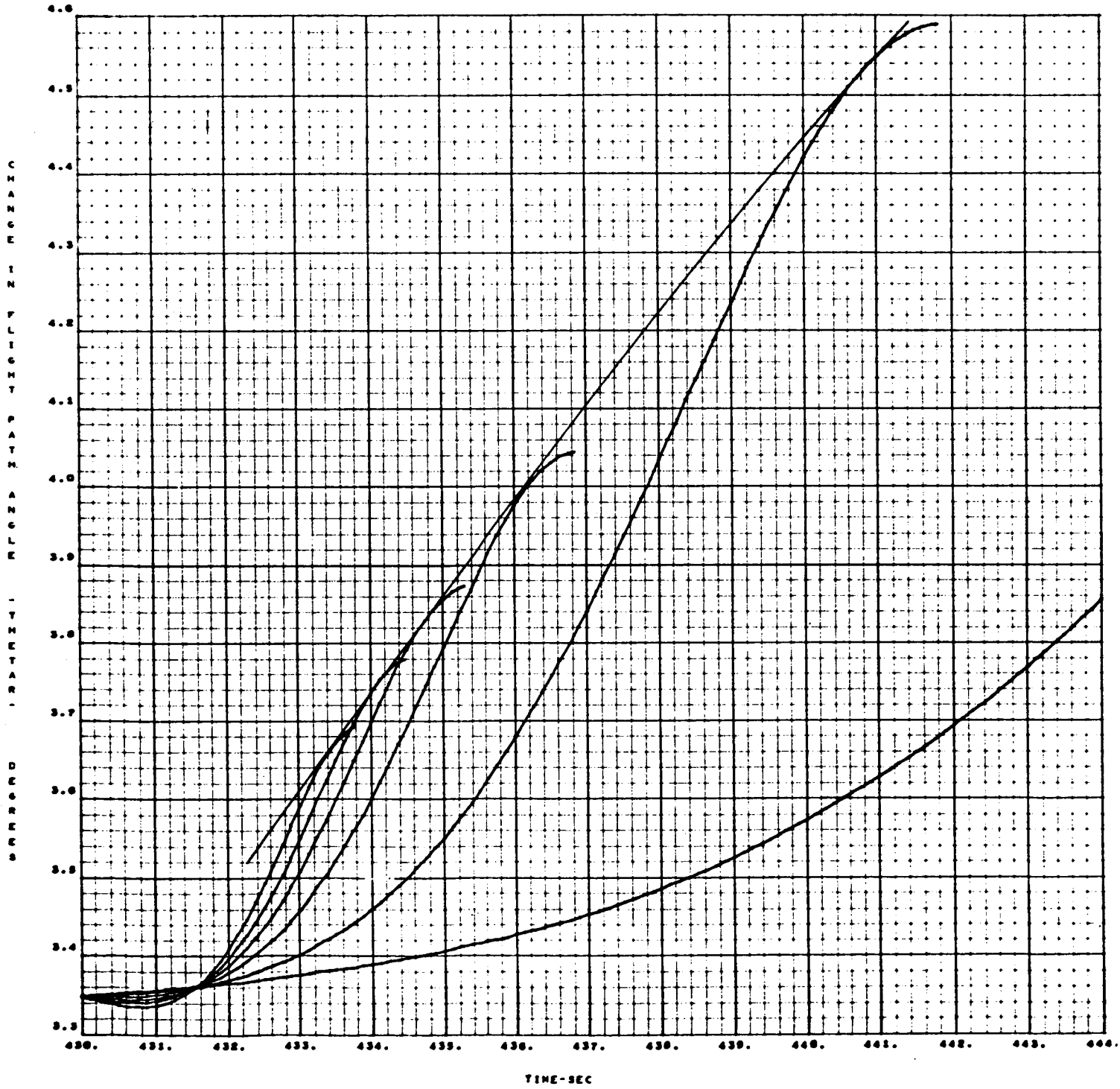


Figure 55

CHANGE IN TOTAL VELOCITY VECTOR ORIENTATION IN THE LATERAL DIRECTION VERSUS TIME FOR MALFUNCTION AT t_i = 446 sec

(β_y = 10.0, 7.0, 5.0, 3.0, 1.0, 0.1 deg)

β_y is the thrust vector deflection angle in the yaw plane

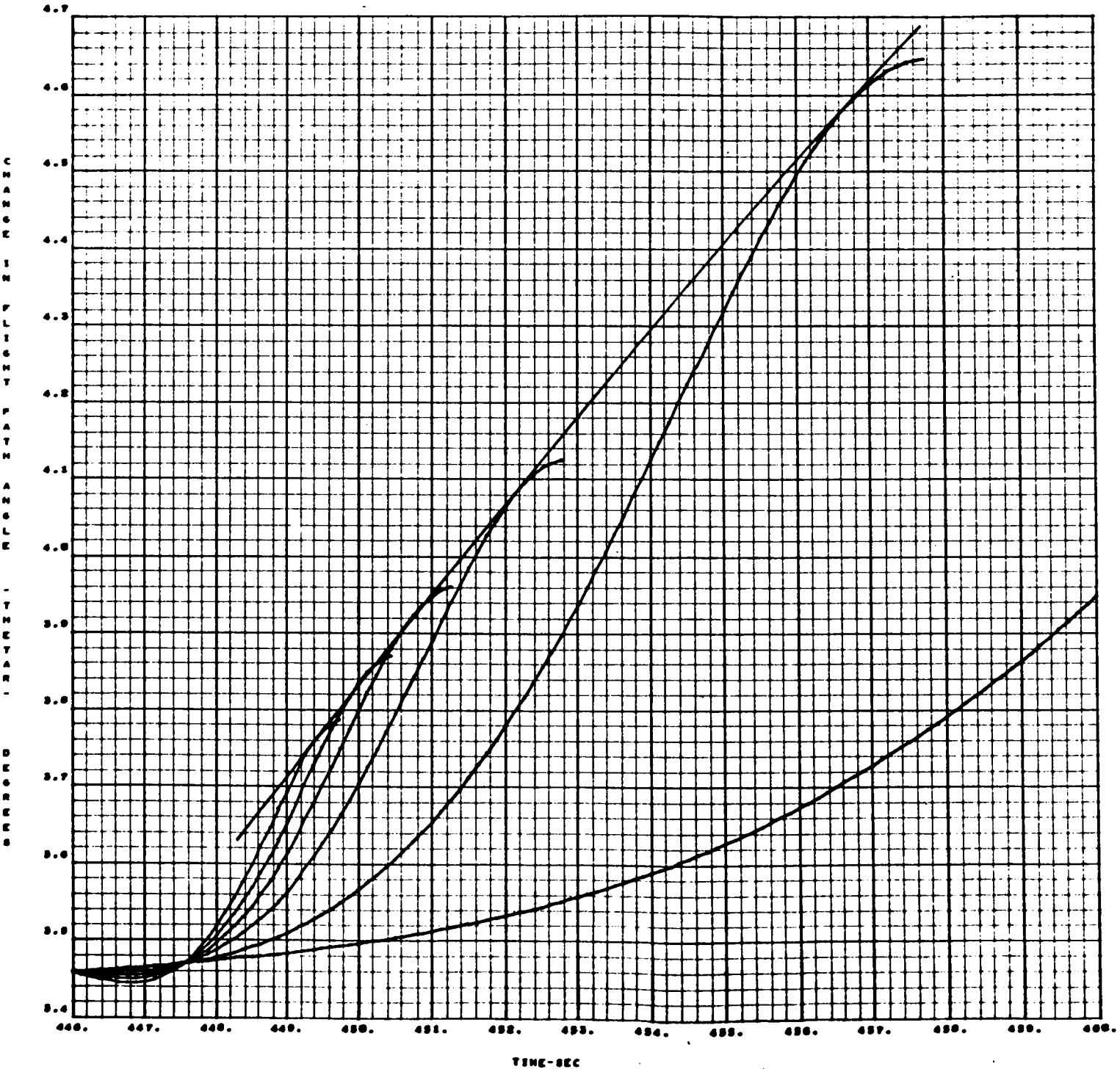


Figure 56

CHANGE IN TOTAL VELOCITY VECTOR ORIENTATION IN THE LATERAL DIRECTION VERSUS TIME FOR MALFUNCTION AT t_1 = 462 sec

(β_y = 10.0, 7.0, 5.0, 3.0, 1.0, 0.1 deg)

β_y is the thrust vector deflection angle in the yaw plane

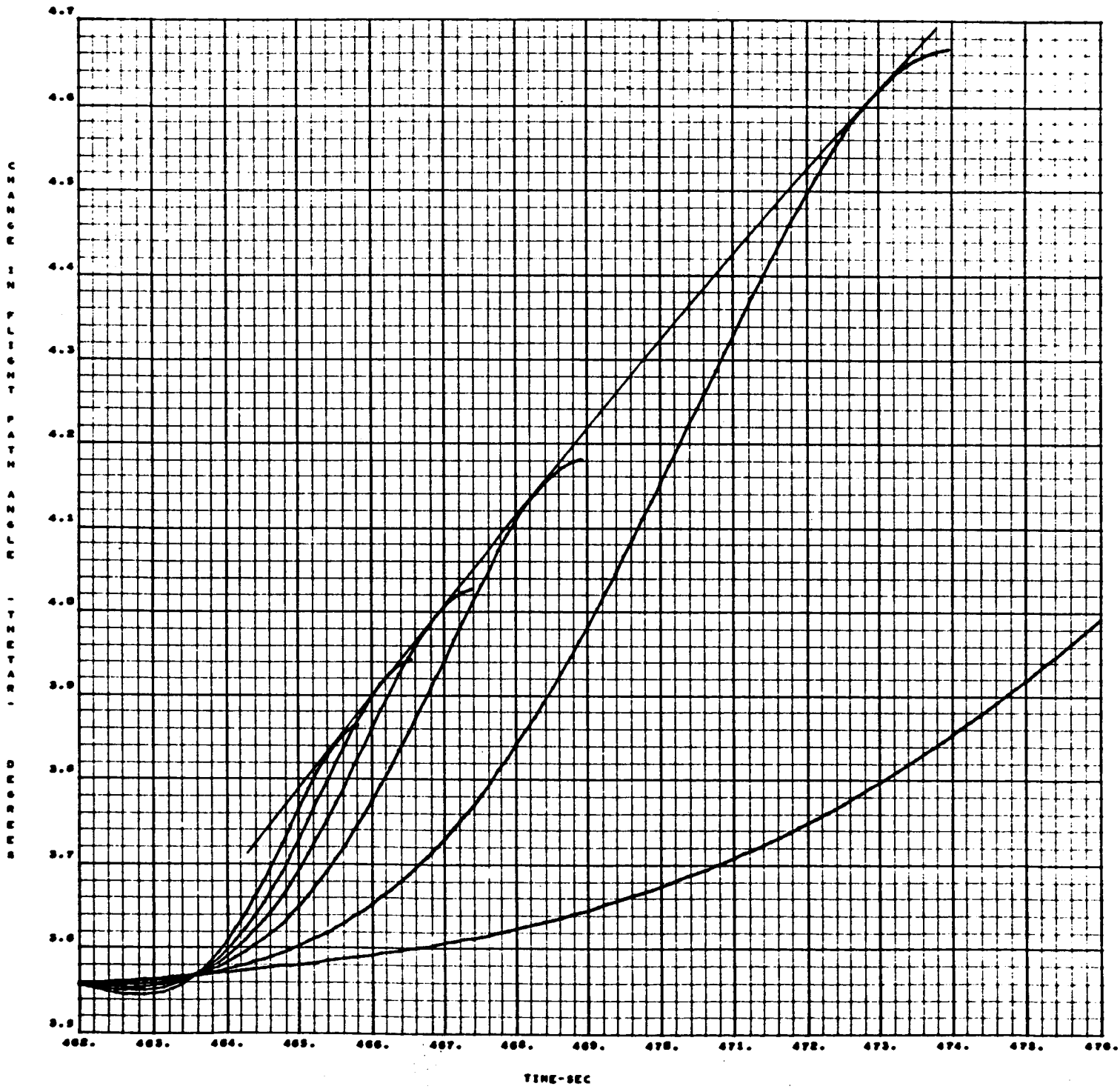


Figure 57

CHANGE IN TOTAL VELOCITY VECTOR ORIENTATION IN THE LATERAL DIRECTION VERSUS TIME FOR MALFUNCTION AT t_i = 478 sec

(β_y = 10.0, 7.0, 5.0, 3.0, 1.0, 0.1 deg)

β_y is the thrust vector deflection angle in the yaw plane

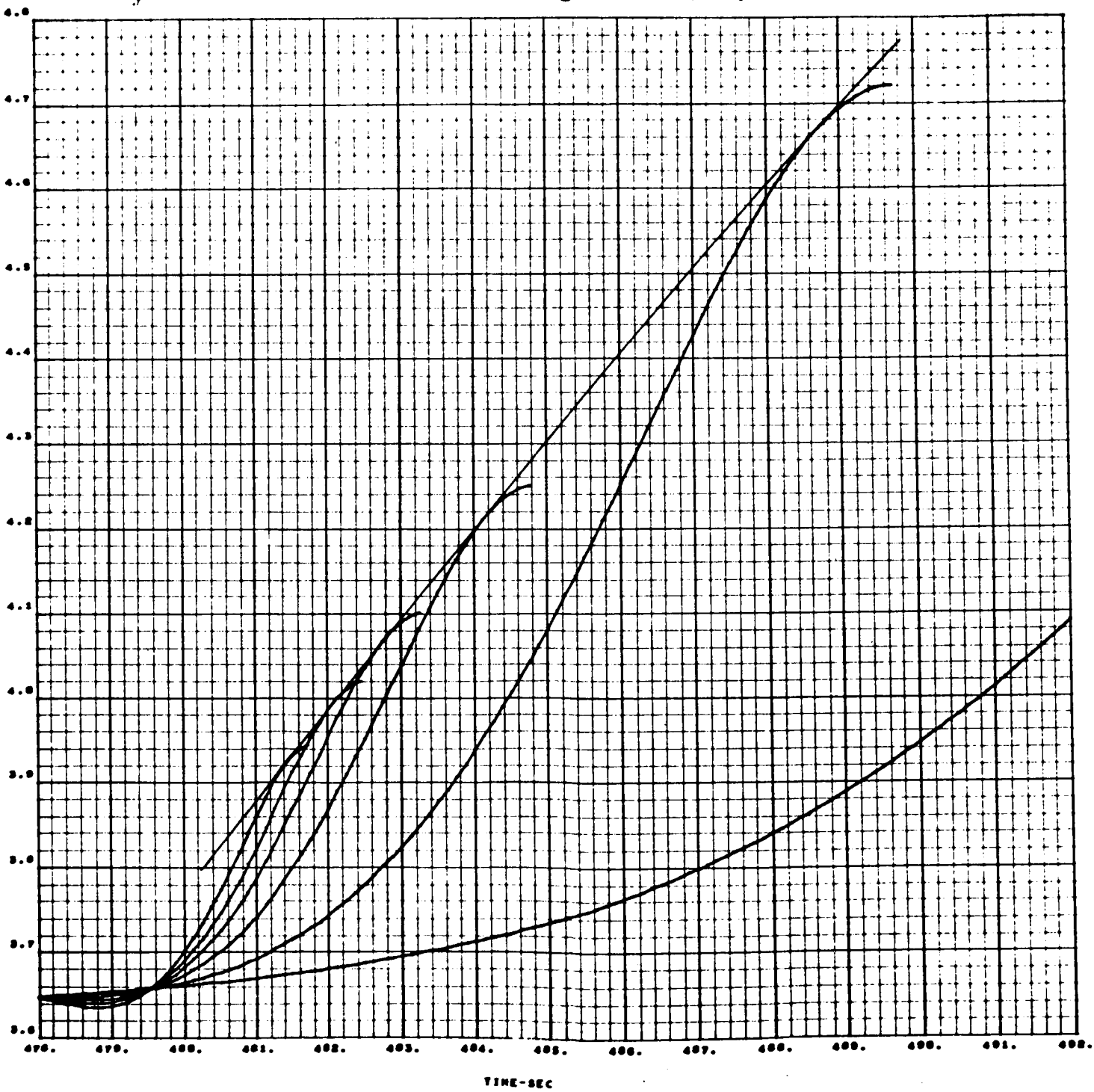


Figure 58

CHANGE IN TOTAL VELOCITY VECTOR ORIENTATION IN THE LATERAL DIRECTION VERSUS TIME FOR MALFUNCTION AT t_i = 494 sec

(β_y = 10.0, 7.0, 5.0, 3.0, 1.0, 0.1 deg)

β_y is the thrust vector deflection angle in the yaw plane

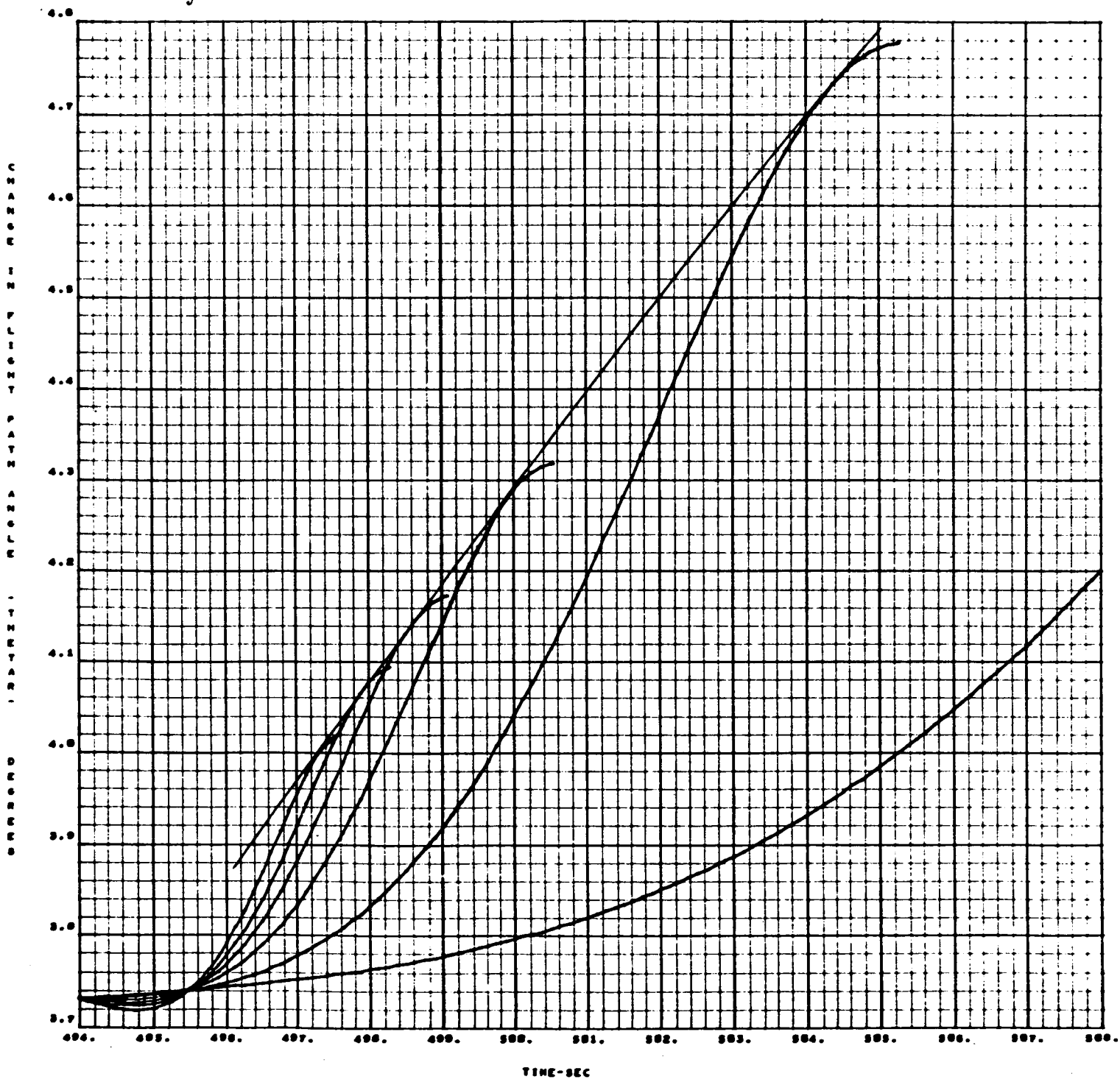


Figure 59

CHANGE IN TOTAL VELOCITY VECTOR ORIENTATION IN THE LATERAL DIRECTION VERSUS TIME FOR MALFUNCTION AT t_i = 510 sec

(β_y = 10.0, 7.0, 5.0, 3.0, 1.0, 0.1 deg)

β_y is the thrust vector deflection angle in the yaw plane

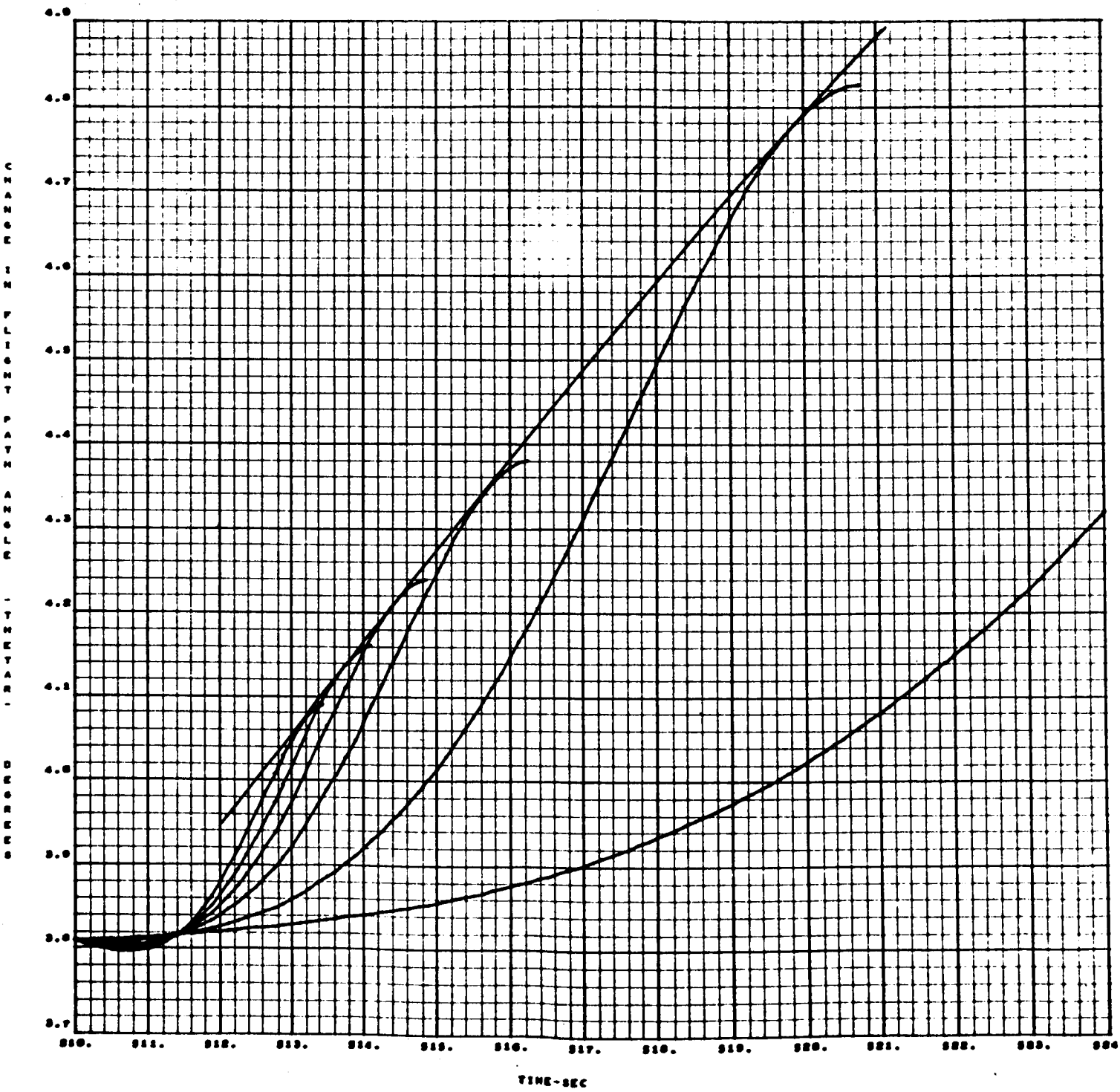


Figure 60

CHANGE IN TOTAL VELOCITY VECTOR ORIENTATION IN THE LATERAL DIRECTION VERSUS TIME FOR MALFUNCTION AT t_i = 526 sec

(β_y = 10.0, 7.0, 5.0, 3.0, 1.0, 0.1 deg)

β_y is the thrust vector deflection angle in the yaw plane

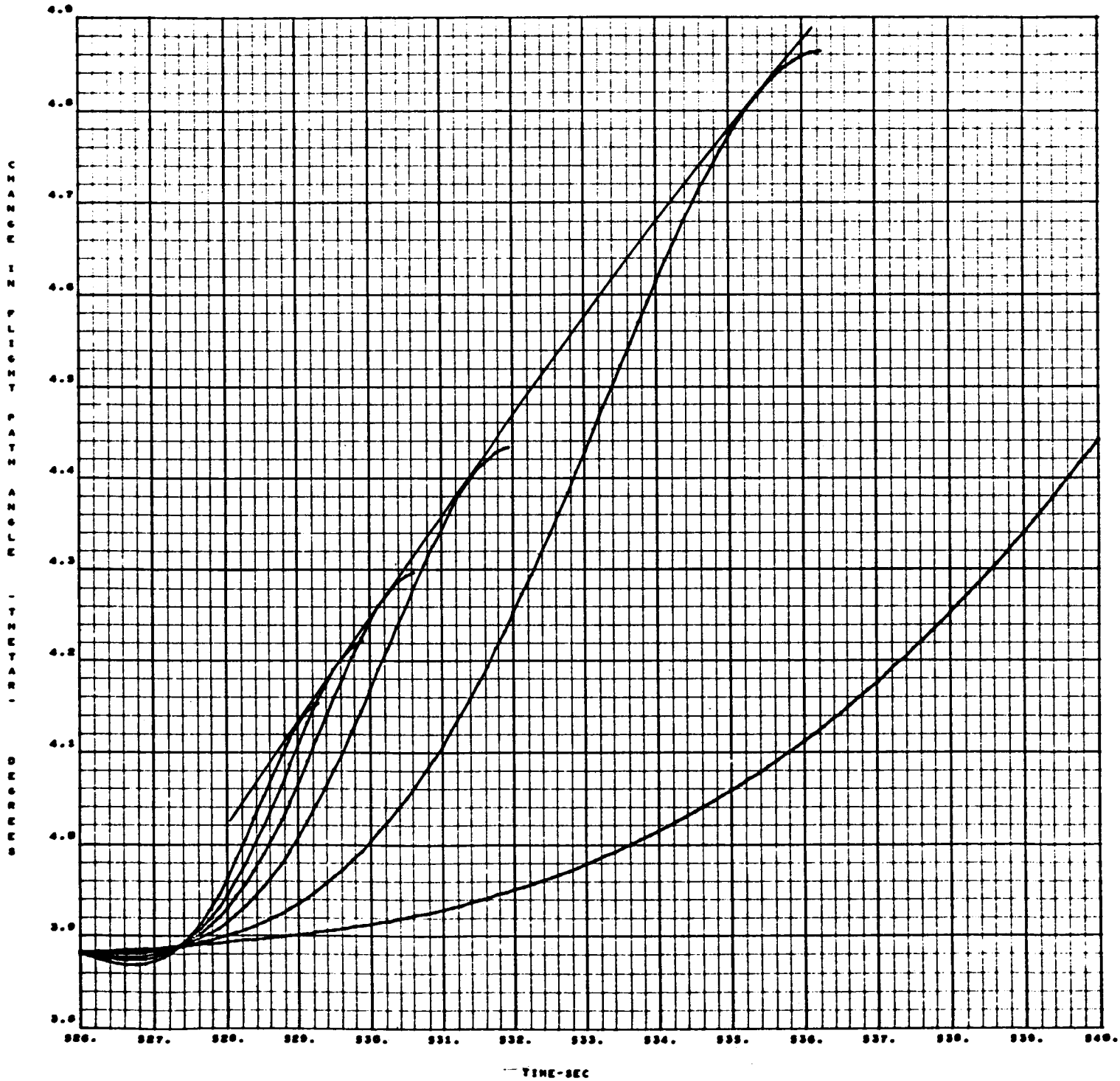


Figure 61

CHANGE IN TOTAL VELOCITY VECTOR ORIENTATION IN THE LATERAL DIRECTION VERSUS TIME FOR MALFUNCTION AT t_i = 542 sec

(β_y = 10.0, 7.0, 5.0, 3.0, 1.0, 0.1 deg)

β_y is the thrust vector deflection angle in the yaw plane

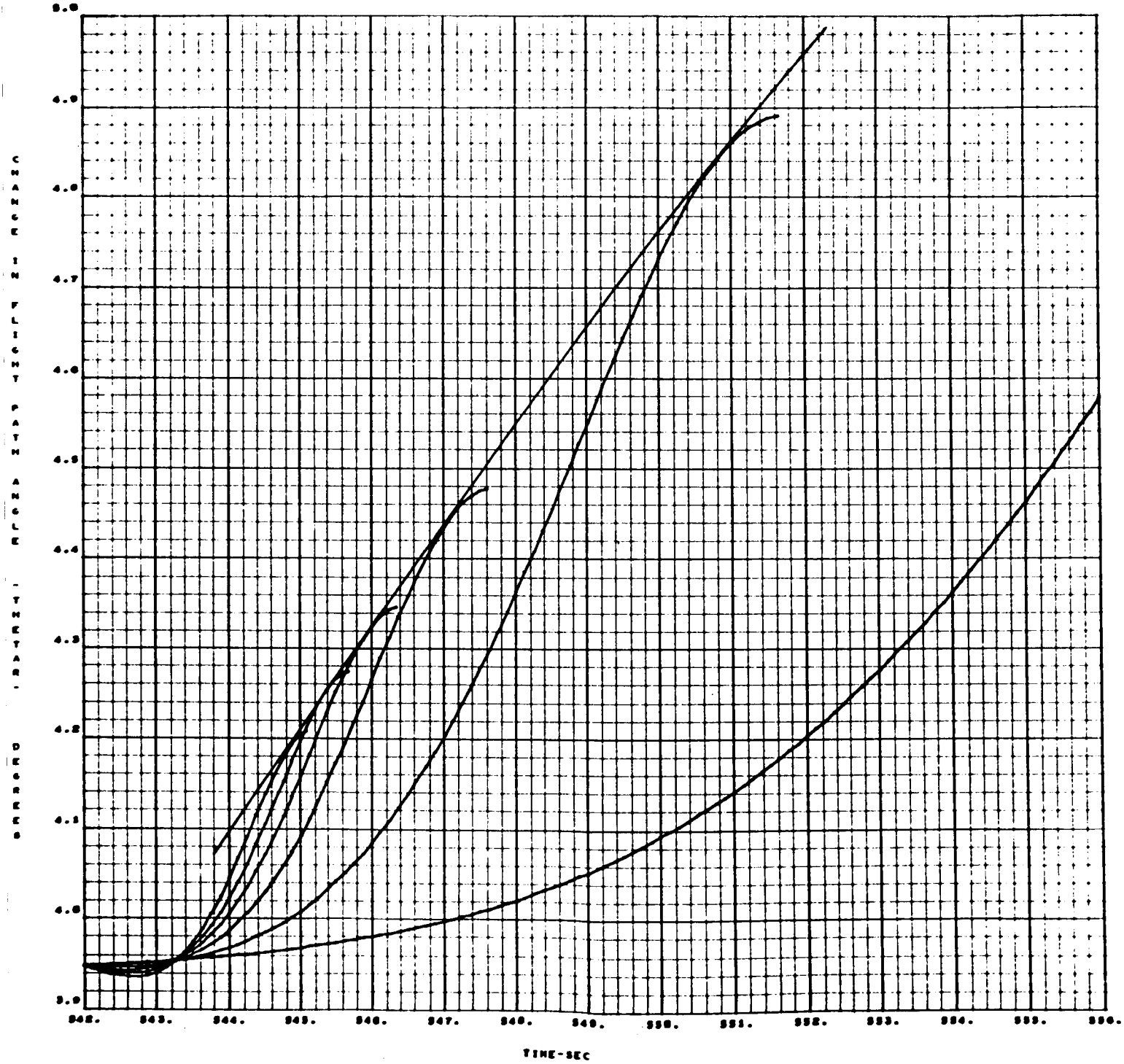


Figure 62

CHANGE IN TOTAL VELOCITY VECTOR ORIENTATION IN THE LATERAL DIRECTION VERSUS TIME FOR MALFUNCTION AT $t_i = 558$ sec

(β_y = 10.0, 7.0, 5.0, 3.0, 1.0, 0.1 deg)

β_y is the thrust vector deflection angle in the yaw plane

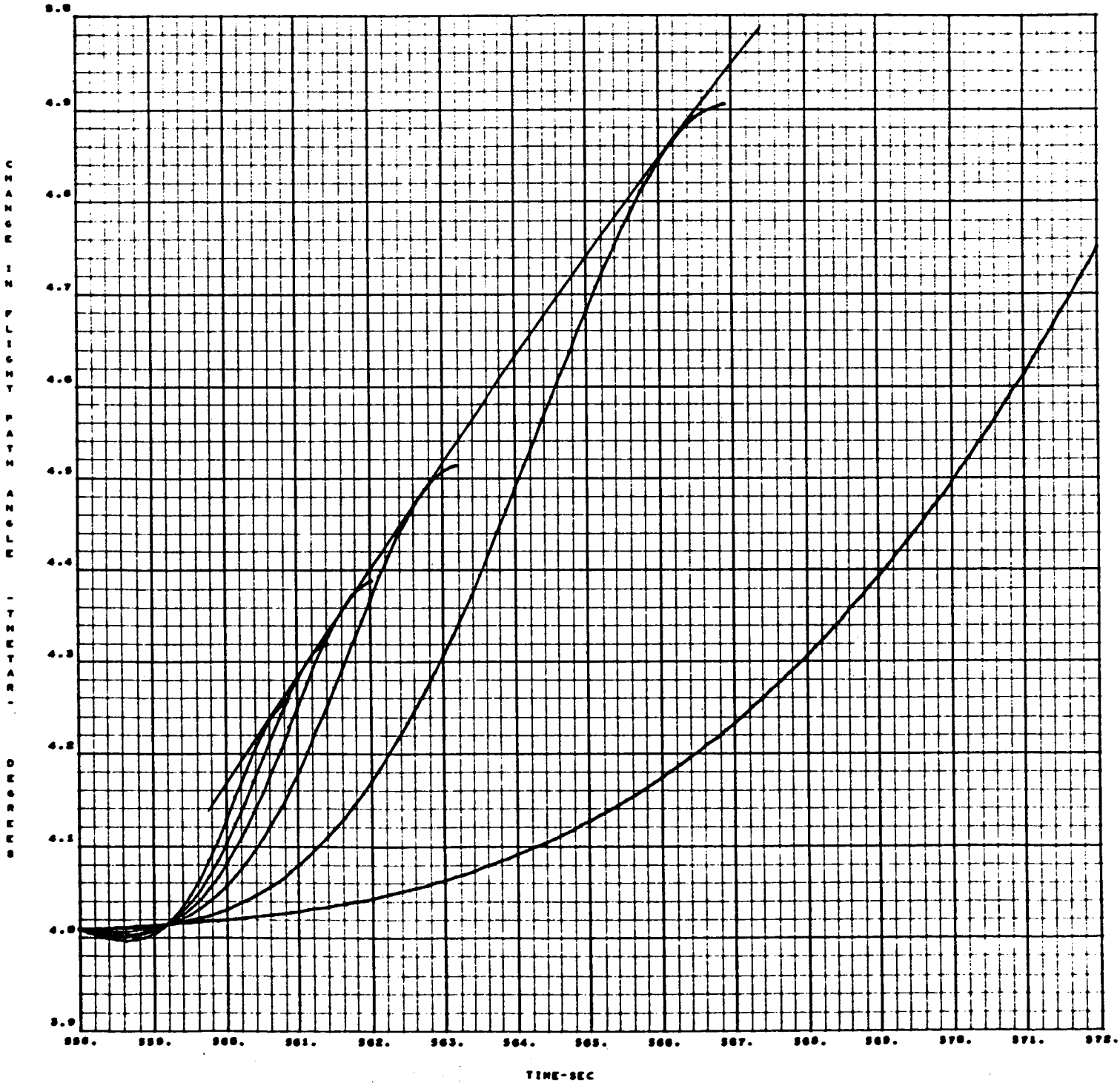


Figure 63

CHANGE IN TOTAL VELOCITY VECTOR ORIENTATION IN THE LATERAL DIRECTION VERSUS TIME FOR MALFUNCTION AT t_i =574 sec

(β_y = 10.0, 7.0, 5.0, 3.0, 1.0, 0.1 deg)

β_y is the thrust vector deflection angle in the yaw plane

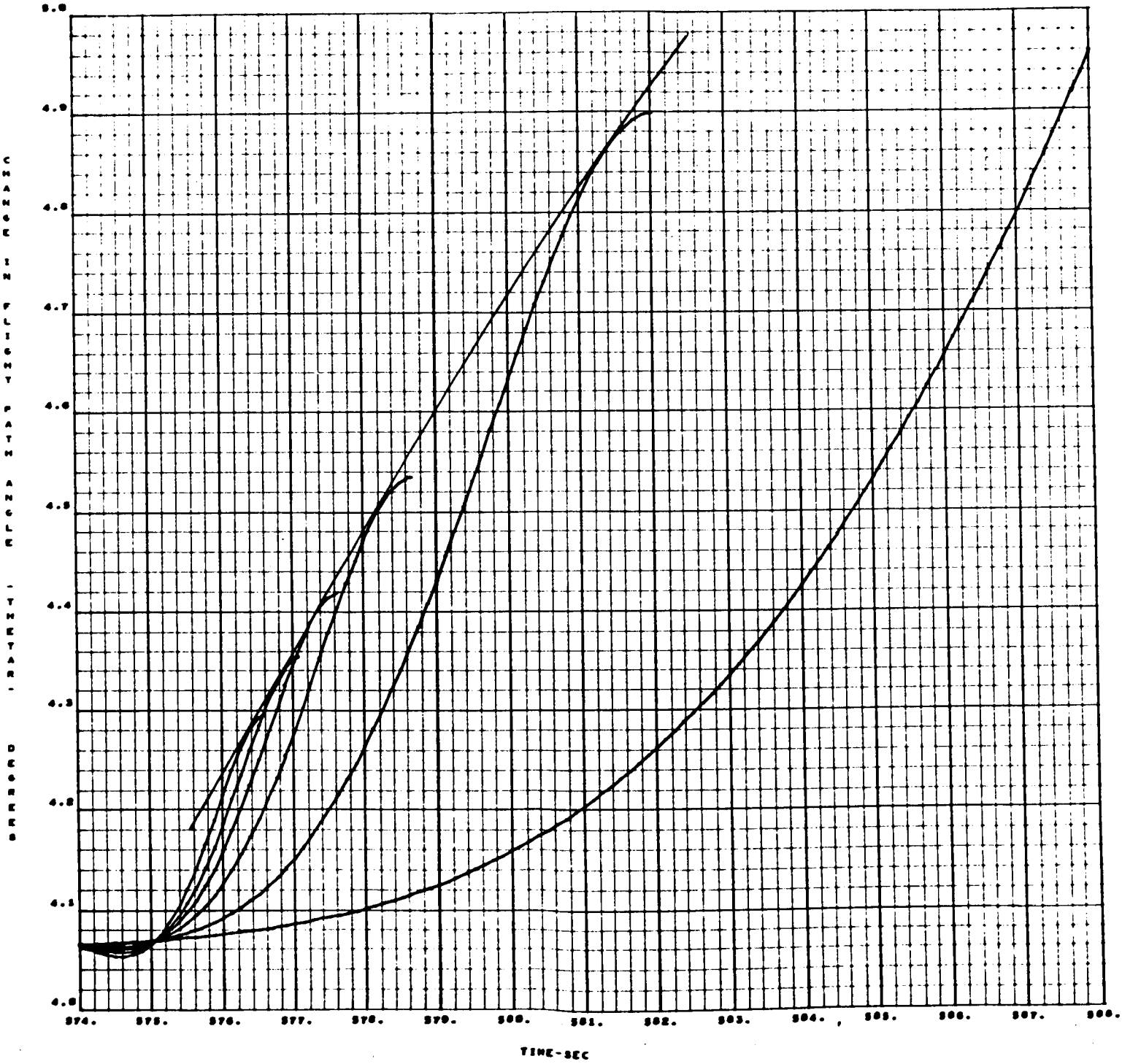


Figure 64

EARTH-FIXED VELOCITY VERSUS TIME
FOR MALFUNCTION AT t_i = 12 sec

(β_y = 11.3, 8.0, 5.0, 3.0, 1.0, 0.1 deg)

β_y is the thrust vector deflection angle in the yaw plane

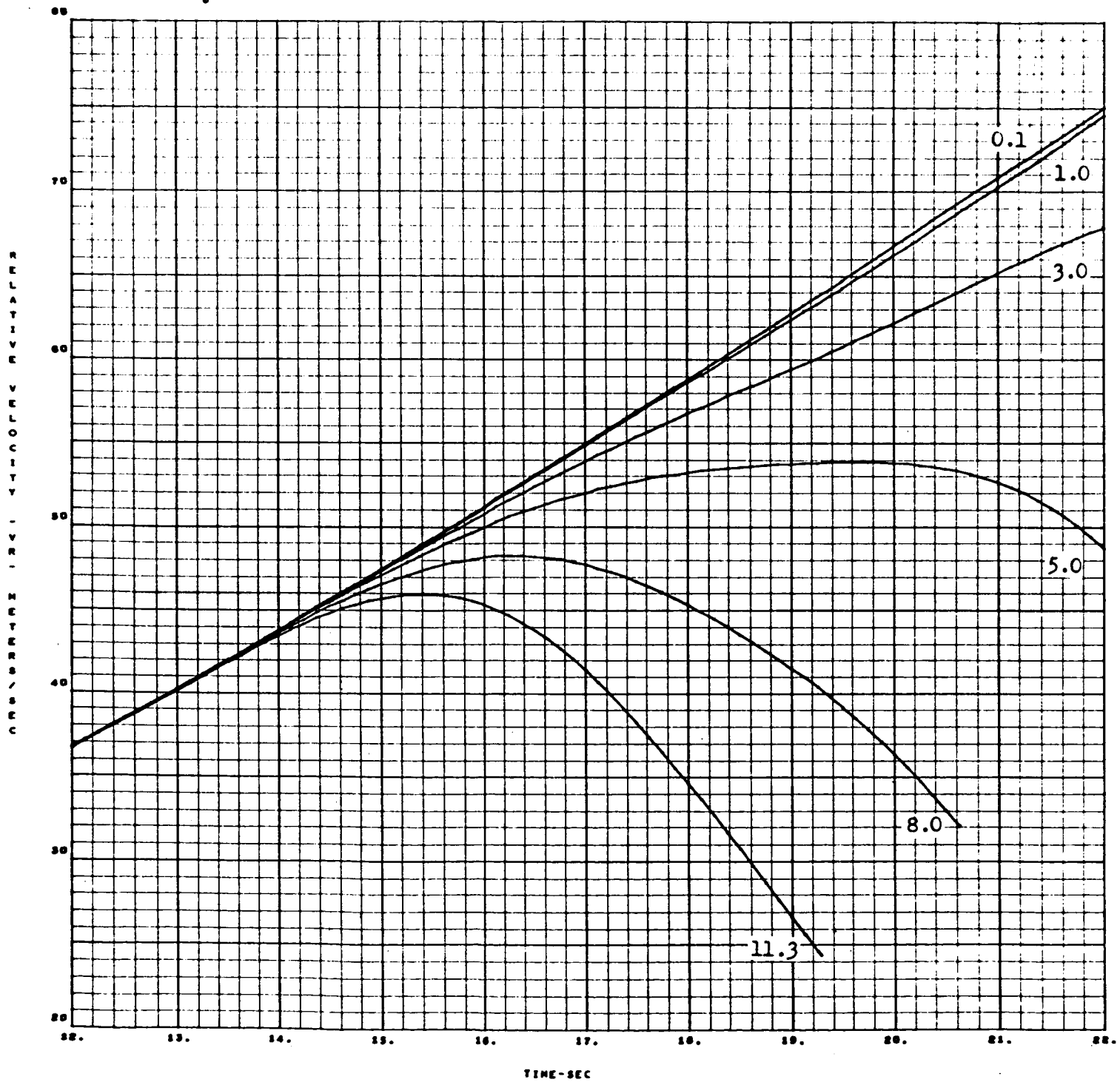


Figure 65

EARTH-FIXED VELOCITY VERSUS TIME
FOR MALFUNCTION AT $t_i = 16$ sec

(β_y = 11.3, 8.0, 5.0, 3.0, 1.0, 0.1 deg)

β_y is the thrust vector deflection angle in the yaw plane

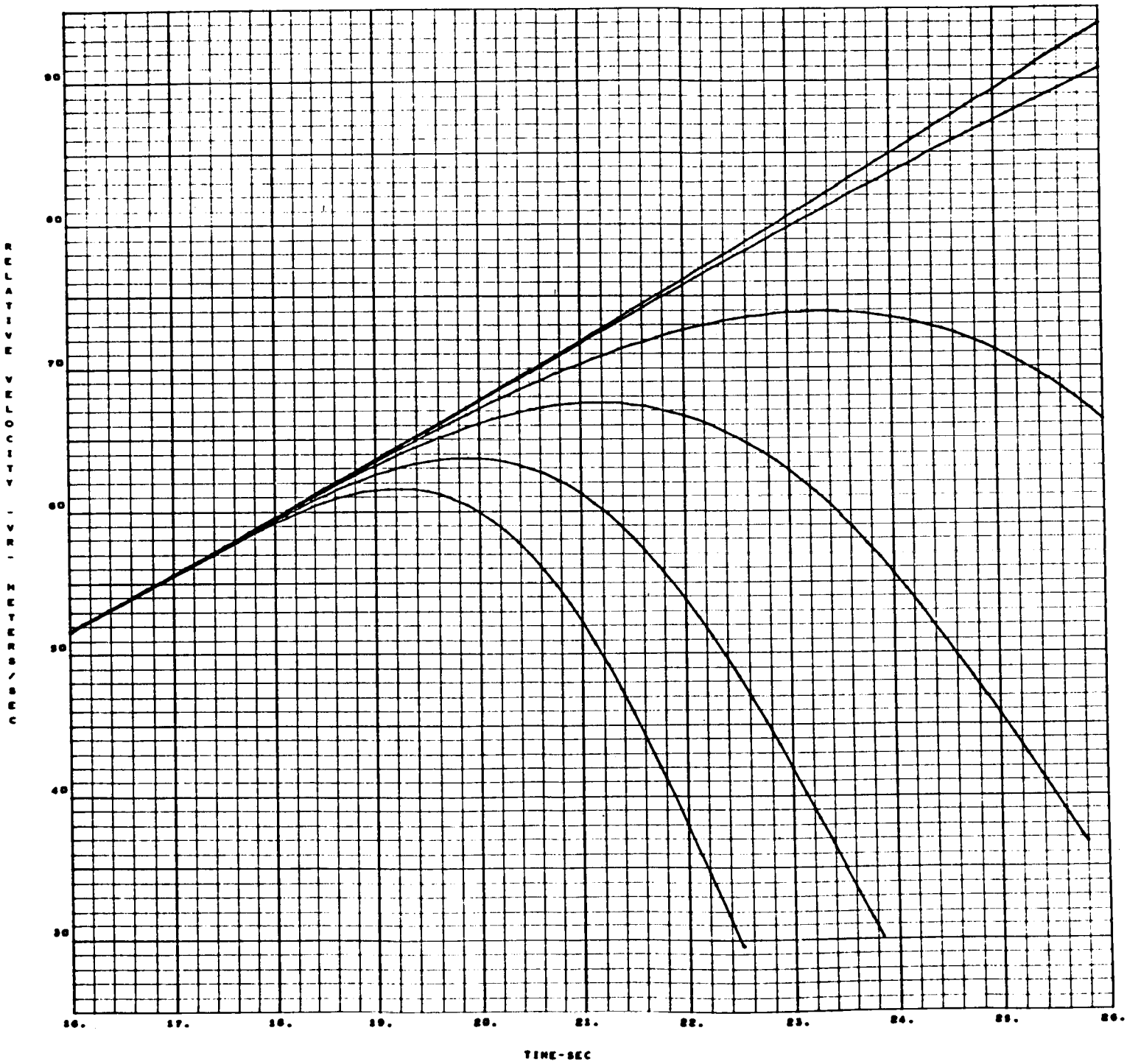


Figure 66

EARTH-FIXED VELOCITY VERSUS TIME
FOR MALFUNCTION AT t_i = 20 sec

(β_y = 11.3, 8.0, 5.0, 3.0, 1.0, 0.1 deg)

β_y is the thrust vector deflection angle in the yaw plane

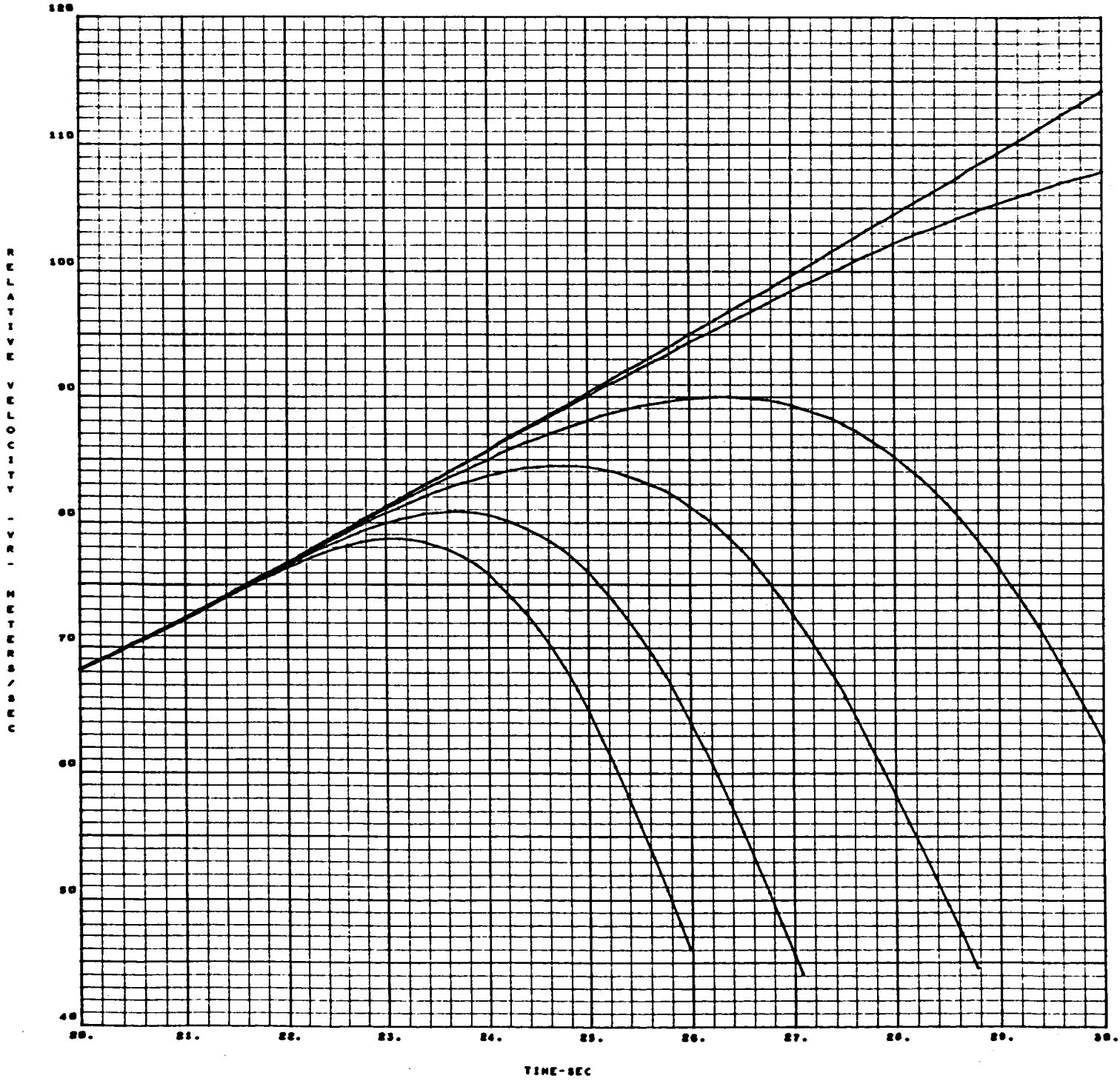


Figure 67

EARTH-FIXED VELOCITY VERSUS TIME
FOR MALFUNCTION AT t_i = 24 sec

(β_y = 11.3, 8.0, 5.0, 3.0, 1.0, 0.1 deg)

β_y is the thrust vector deflection angle in the yaw plane

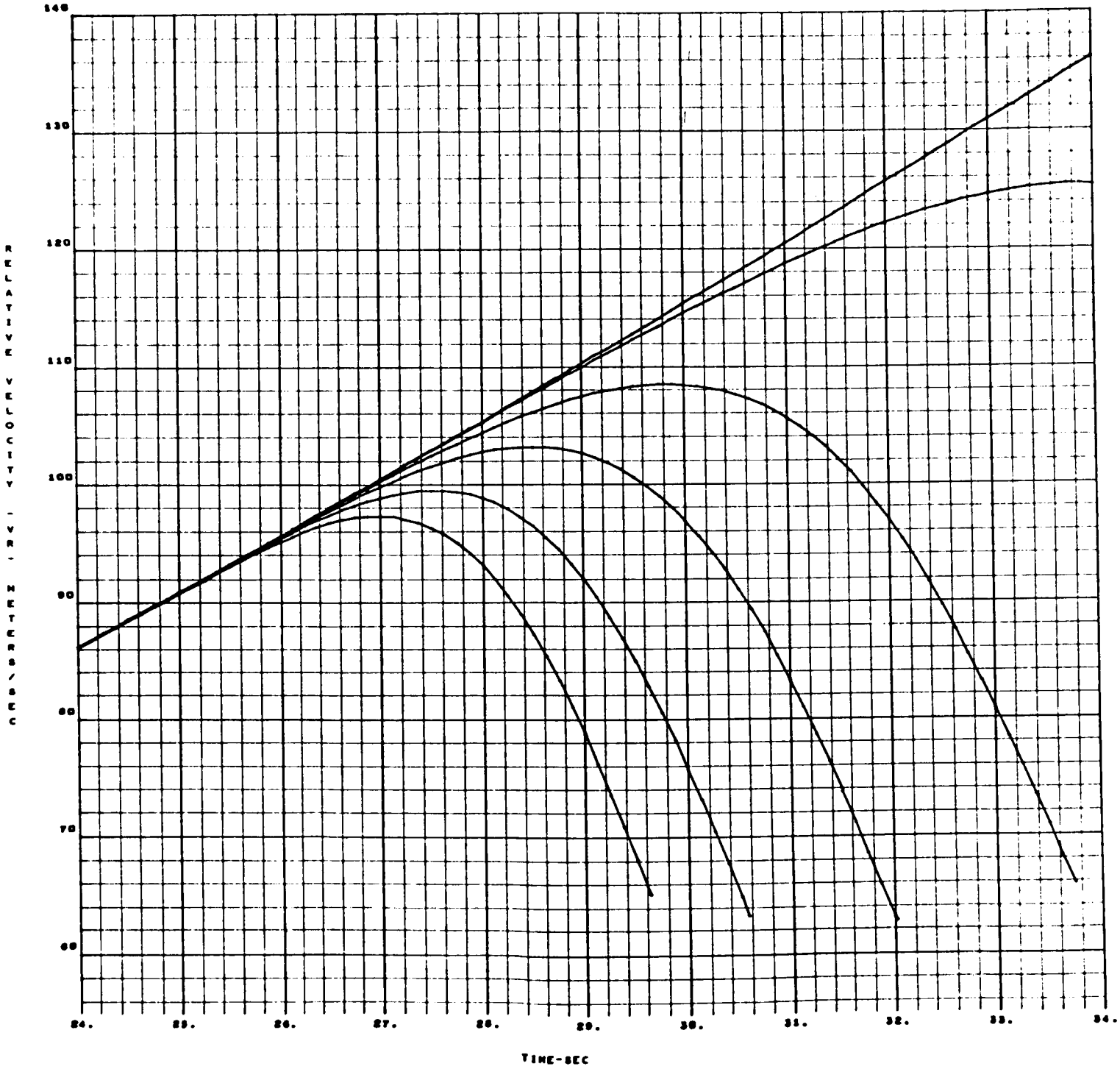


Figure 68

EARTH-FIXED VELOCITY VERSUS TIME
FOR MALFUNCTION AT t_i = 28 sec

(β_y = 11.3, 8.0, 5.0, 3.0, 1.0, 0.1 deg)

β_y is the thrust vector deflection angle in the yaw plane

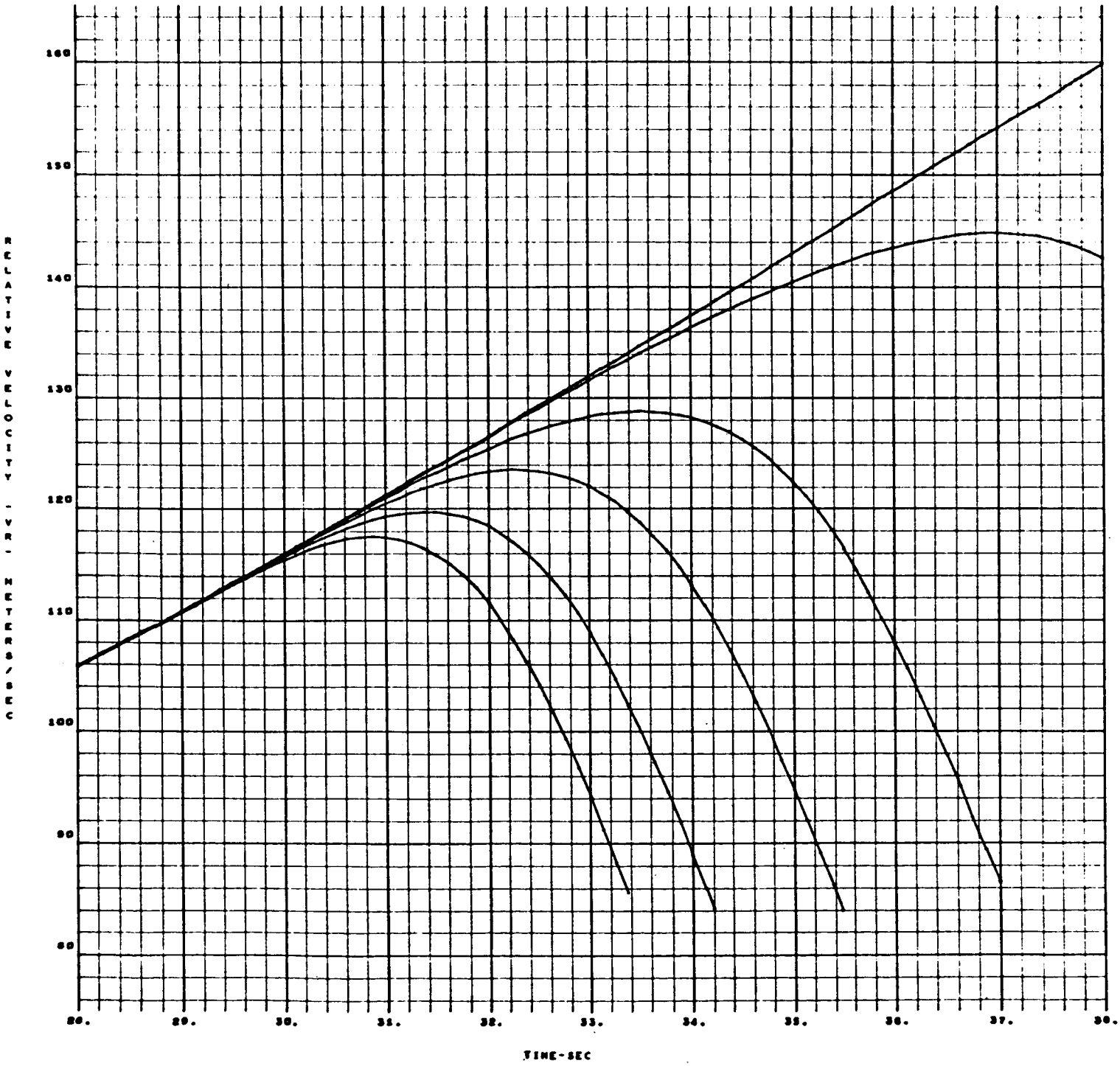


Figure 69

EARTH-FIXED VELOCITY VERSUS TIME
FOR MALFUNCTION AT t_i = 32 sec

(β_y = 11.3, 8.0, 5.0, 3.0, 1.0, 0.1 deg)

β_y is the thrust vector deflection angle in the yaw plane

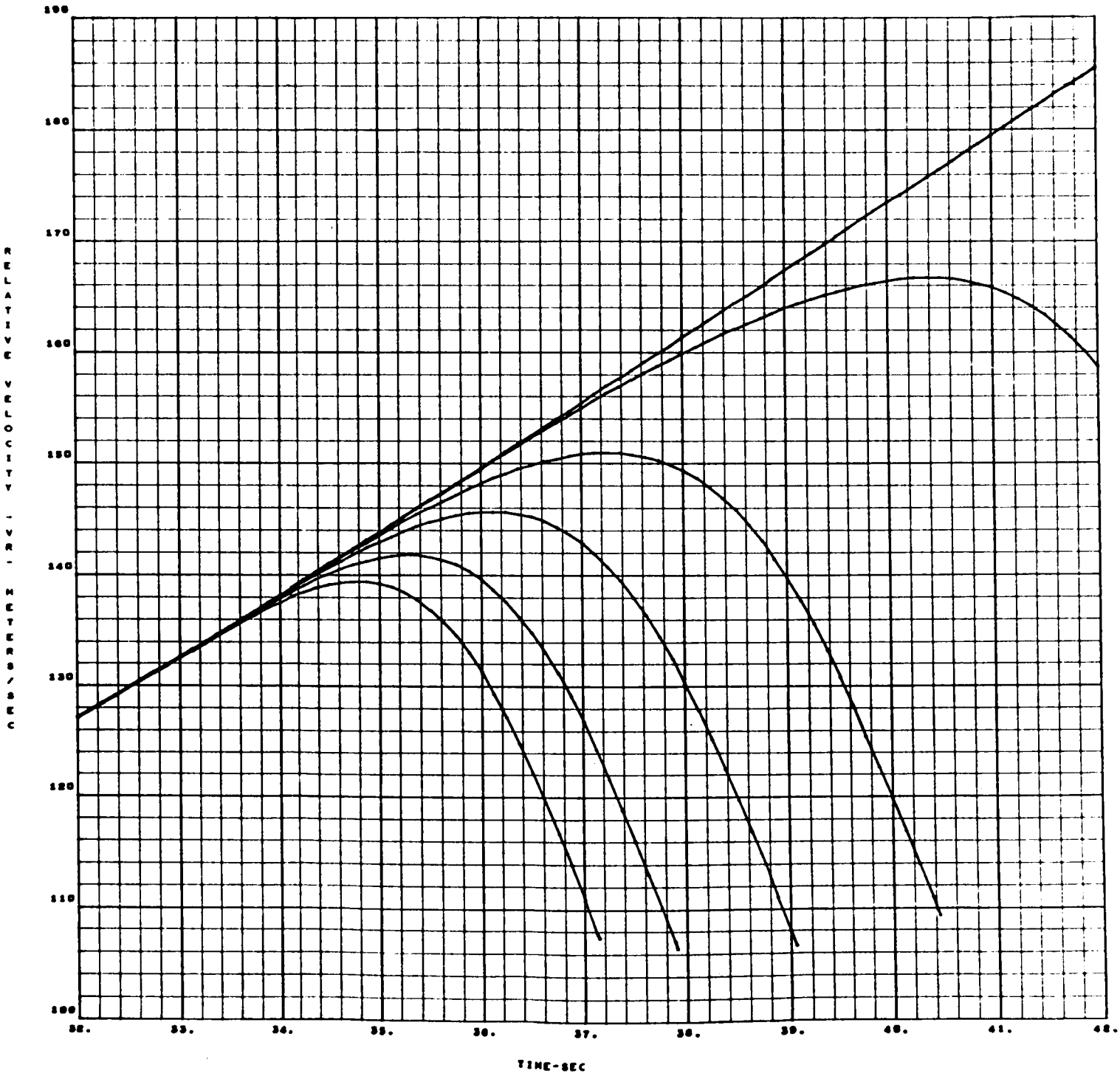


Figure 70

EARTH-FIXED VELOCITY VERSUS TIME
FOR MALFUNCTION AT t_i = 36 sec

(β_y = 11.3, 8.0, 5.0, 3.0, 1.0, 0.1 deg)

β_y is the thrust vector deflection angle in the yaw plane

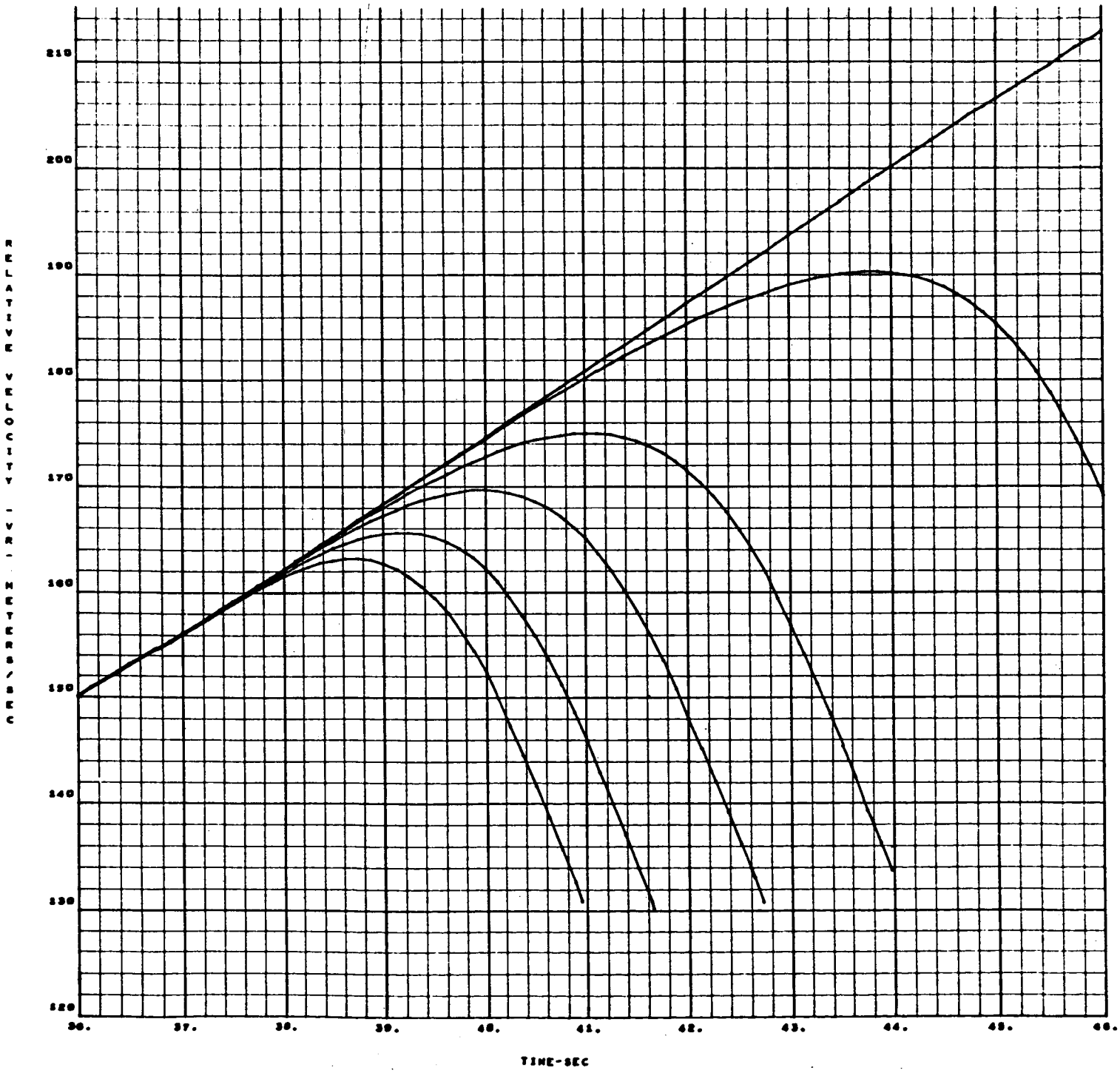


Figure 71

EARTH-FIXED VELOCITY VERSUS TIME
FOR MALFUNCTION AT t_i = 40 sec

(β_y = 11.3, 8.0, 5.0, 3.0, 1.0, 0.1 deg)

β_y is the thrust vector deflection angle in the yaw plane

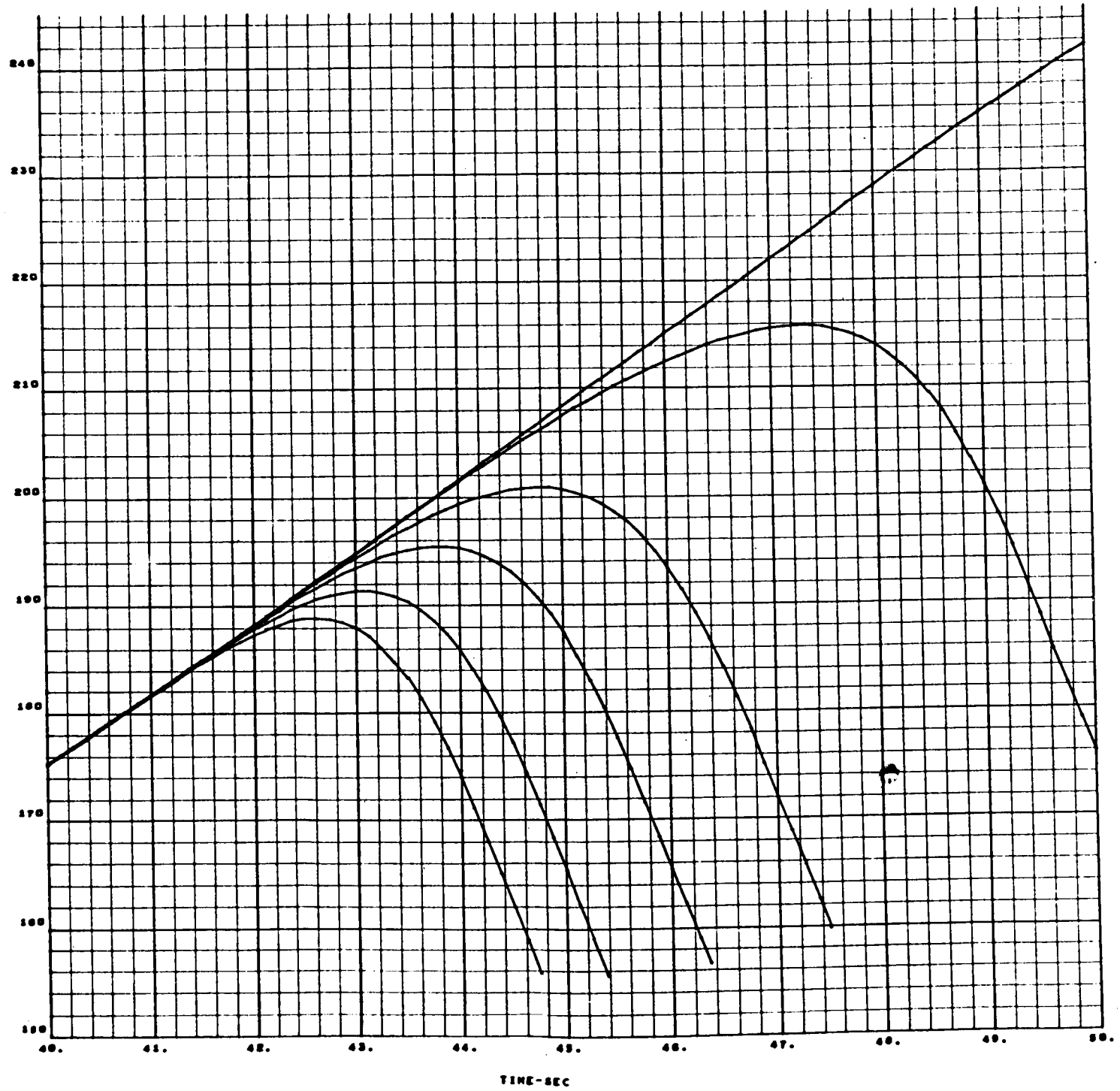


Figure 72

EARTH-FIXED VELOCITY VERSUS TIME
FOR MALFUNCTION AT t_i = 44 sec

(β_y = 11.3, 8.0, 5.0, 3.0, 1.0, 0.1 deg)

β_y is the thrust vector deflection angle in the yaw plane

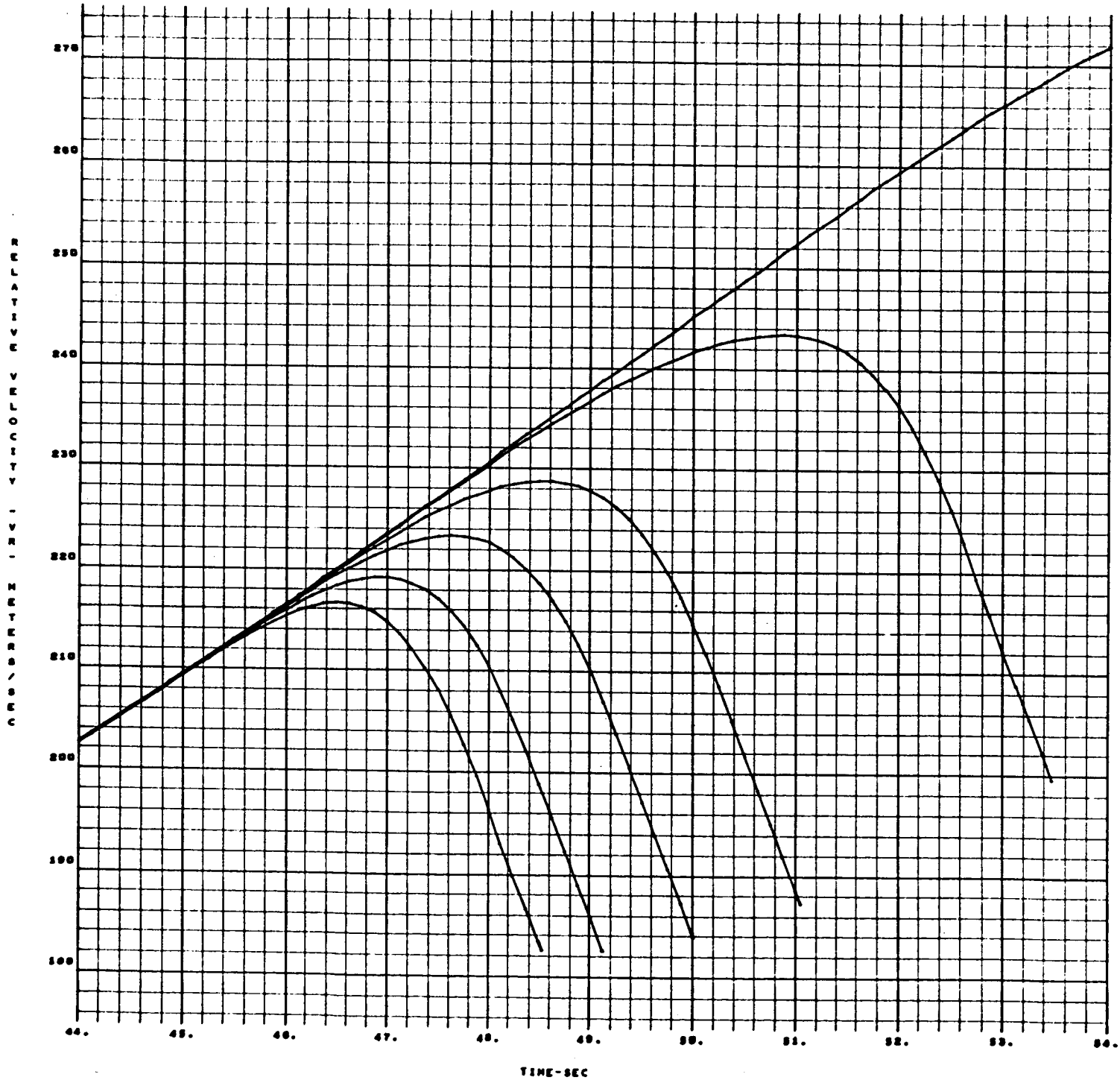


Figure 73

EARTH-FIXED VELOCITY VERSUS TIME
FOR MALFUNCTION AT t_i = 48 sec

(β_y = 11.3, 8.0, 5.0, 3.0, 1.0, 0.1 deg)

β_y is the thrust vector deflection angle in the yaw plane

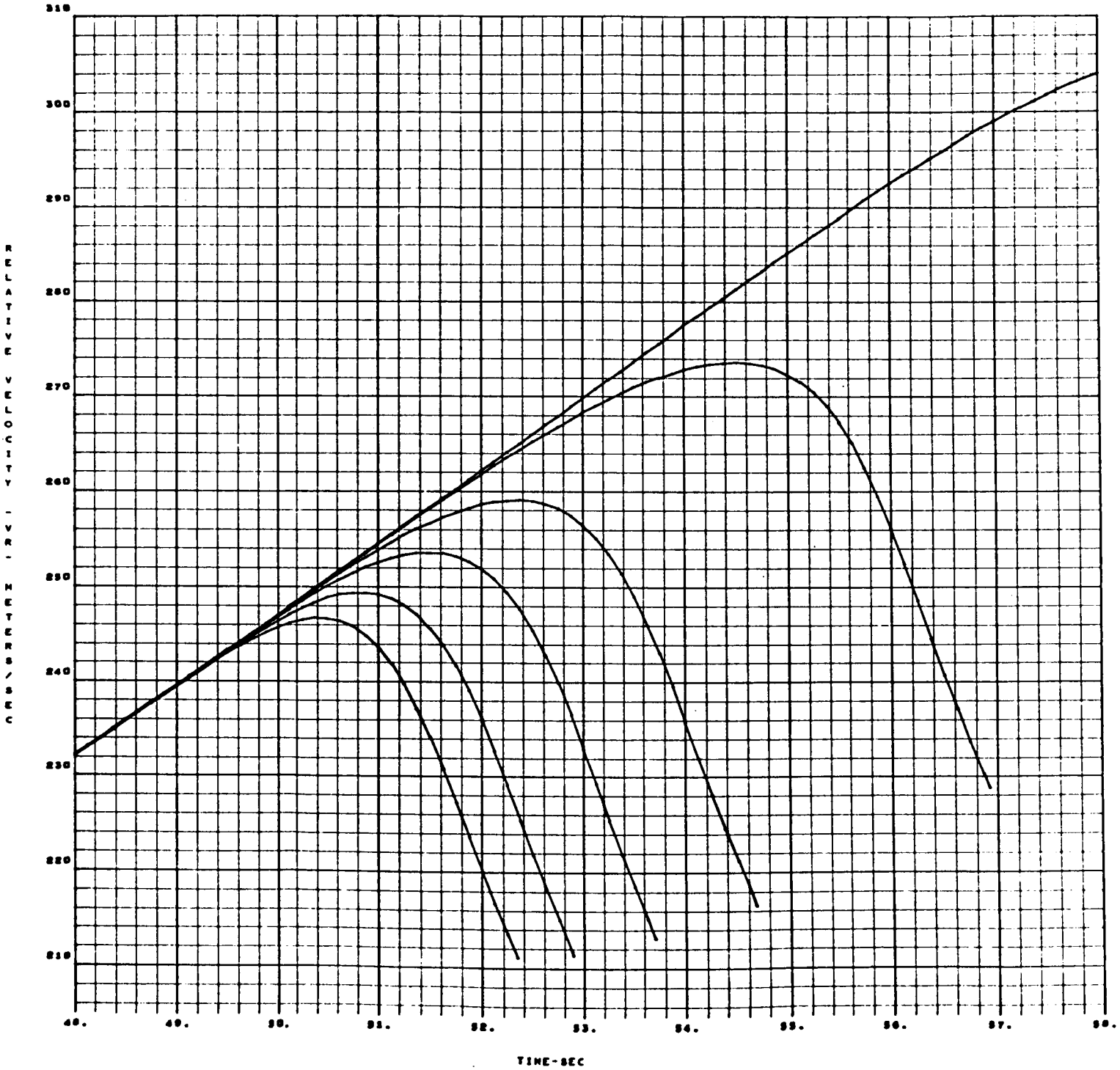


Figure 74

EARTH-FIXED VELOCITY VERSUS TIME
FOR MALFUNCTION AT t_i = 52 sec

(β_y = 11.3, 8.0, 5.0, 3.0, 1.0, 0.1 deg)

β_y is the thrust vector deflection angle in the yaw plane

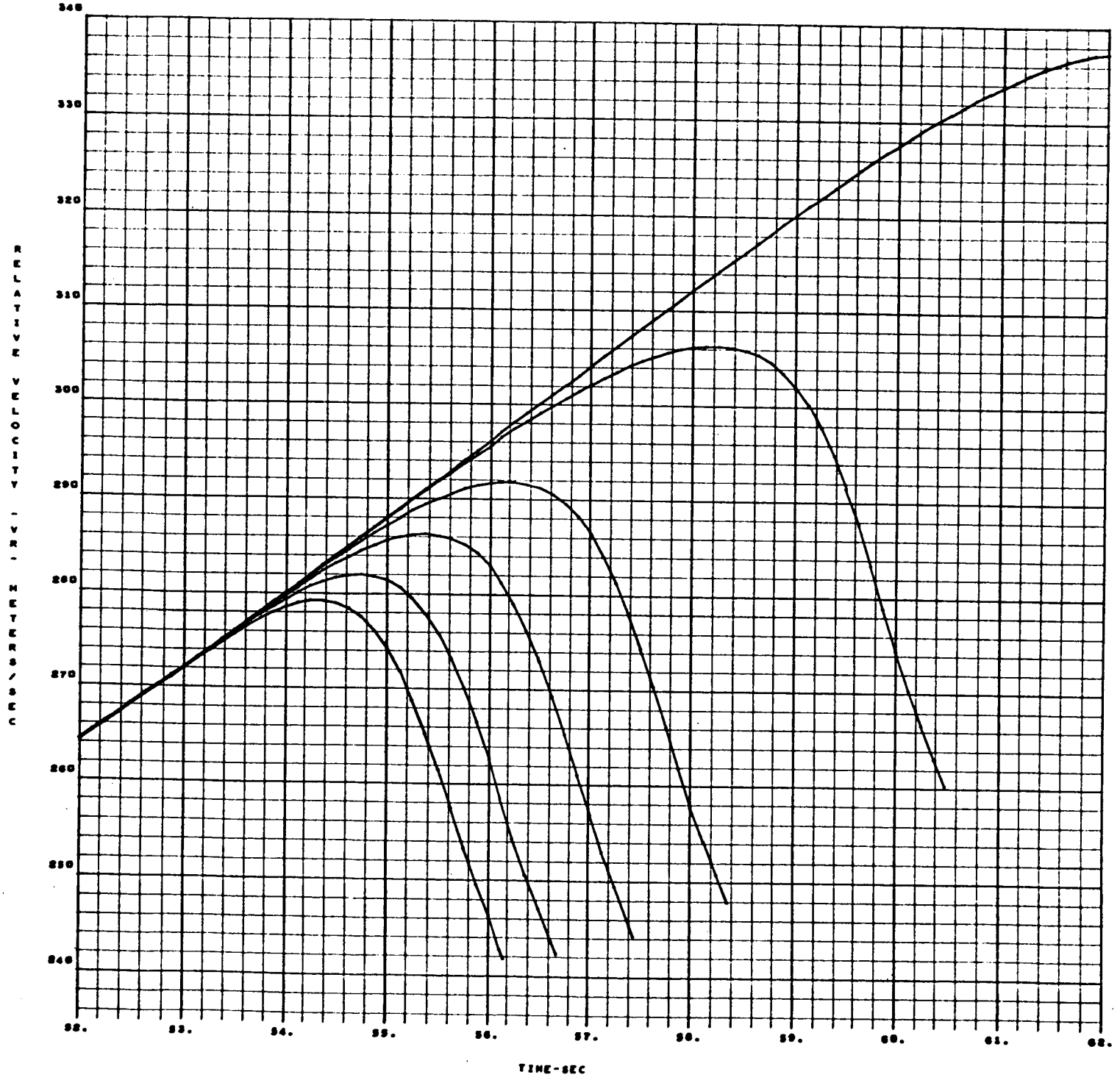


Figure 75

EARTH-FIXED VELOCITY VERSUS TIME
FOR MALFUNCTION AT t_i = 56 sec

(β_y = 11.3, 8.0, 5.0, 3.0, 1.0, 0.1 deg)

β_y is the thrust vector deflection angle in the yaw plane

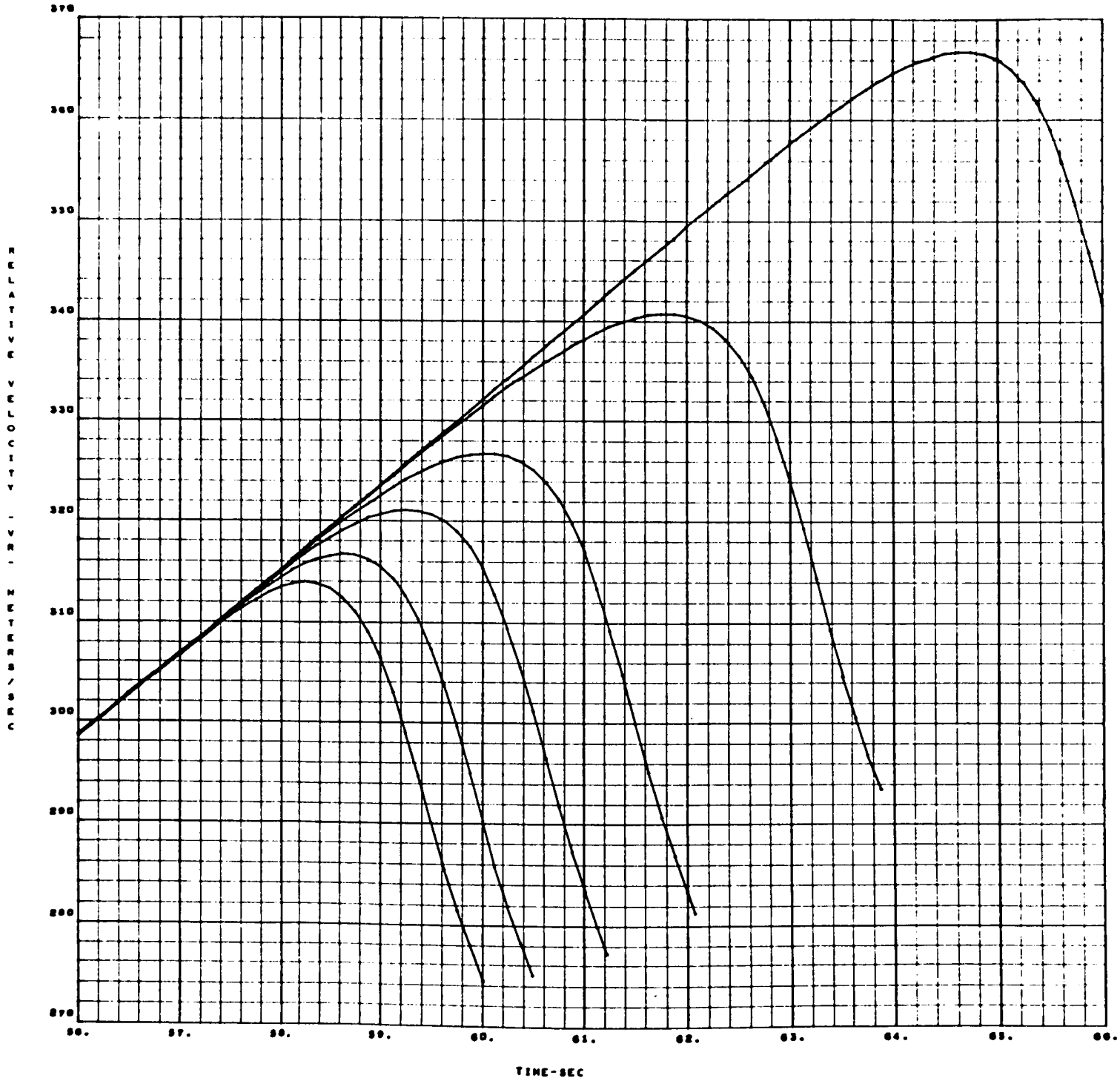


Figure 76

EARTH-FIXED VELOCITY VERSUS TIME
FOR MALFUNCTION AT t_i = 60 sec

(β_y = 11.3, 8.0, 5.0, 3.0, 1.0, 0.1 deg)

β_y is the thrust vector deflection angle in the yaw plane

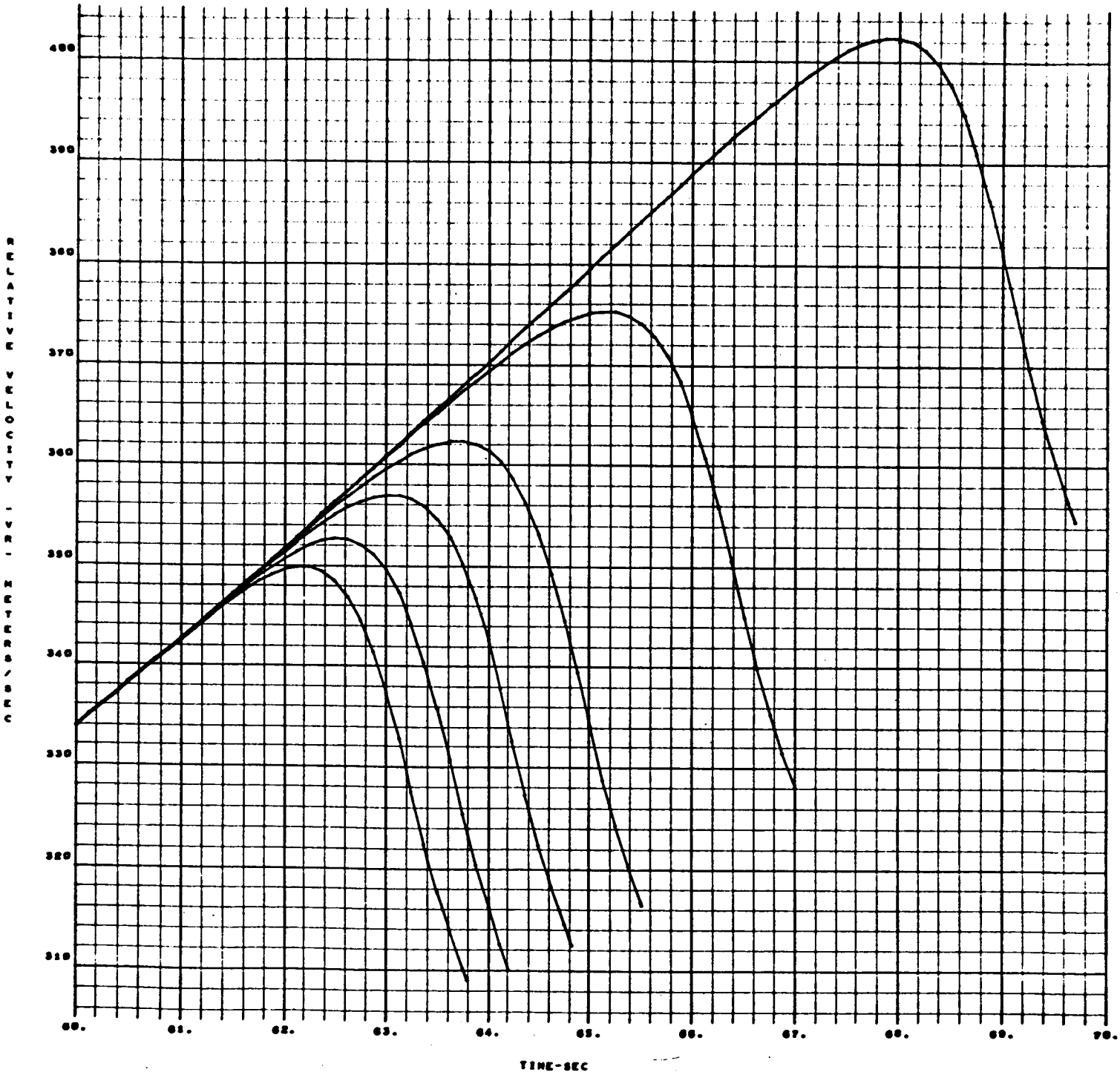


Figure 77

EARTH-FIXED VELOCITY VERSUS TIME
FOR MALFUNCTION AT t_i = 64 sec

(β_y = 11.3, 8.0, 5.0, 3.0, 1.0, 0.1 deg)

β_y is the thrust vector deflection angle in the yaw plane

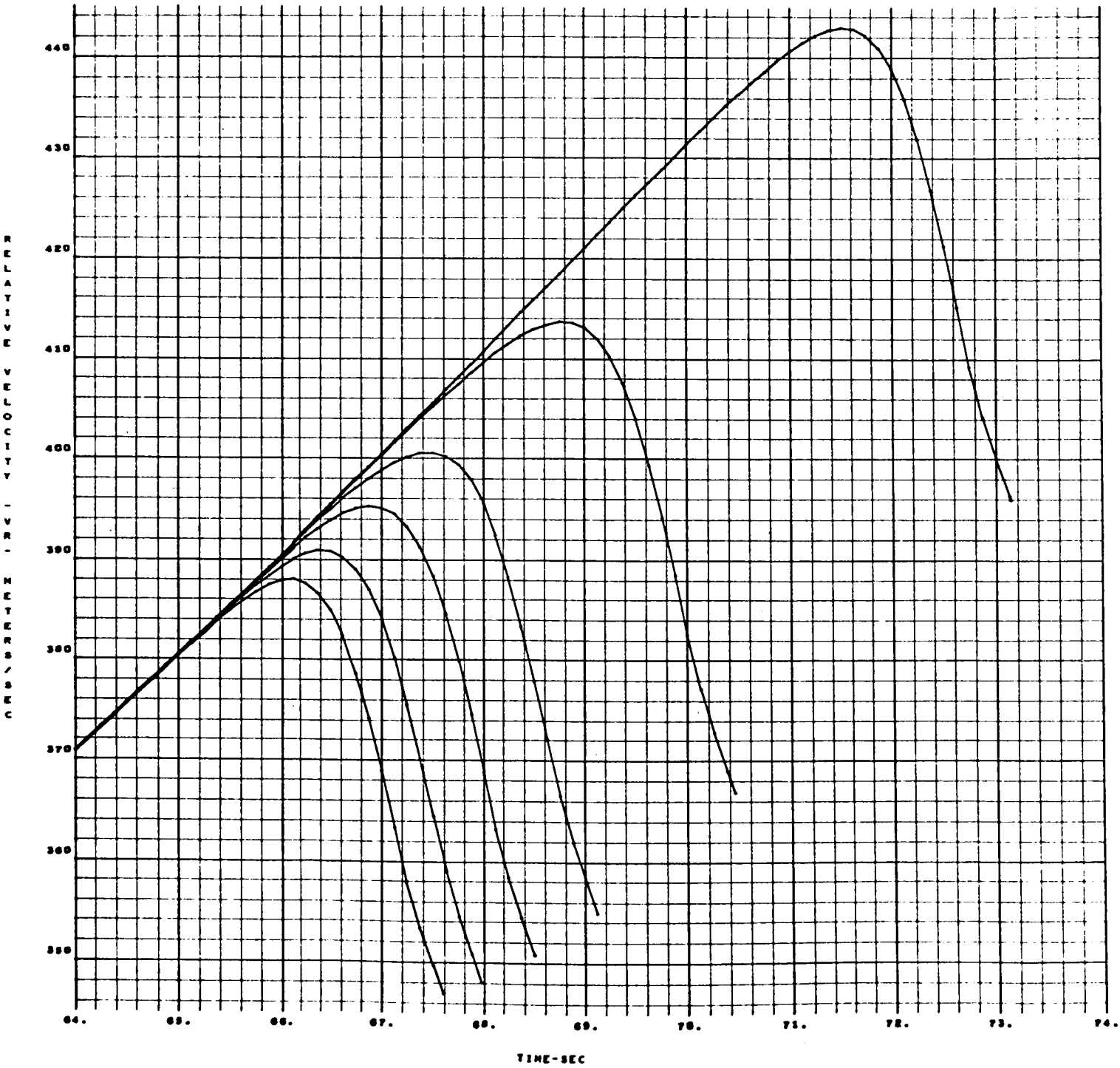


Figure 78

EARTH-FIXED VELOCITY VERSUS TIME
FOR MALFUNCTION AT t_i = 68 sec

(β_y = 11.3, 8.0, 5.0, 3.0, 1.0, 0.1 deg)

β_y is the thrust vector deflection angle in the yaw plane

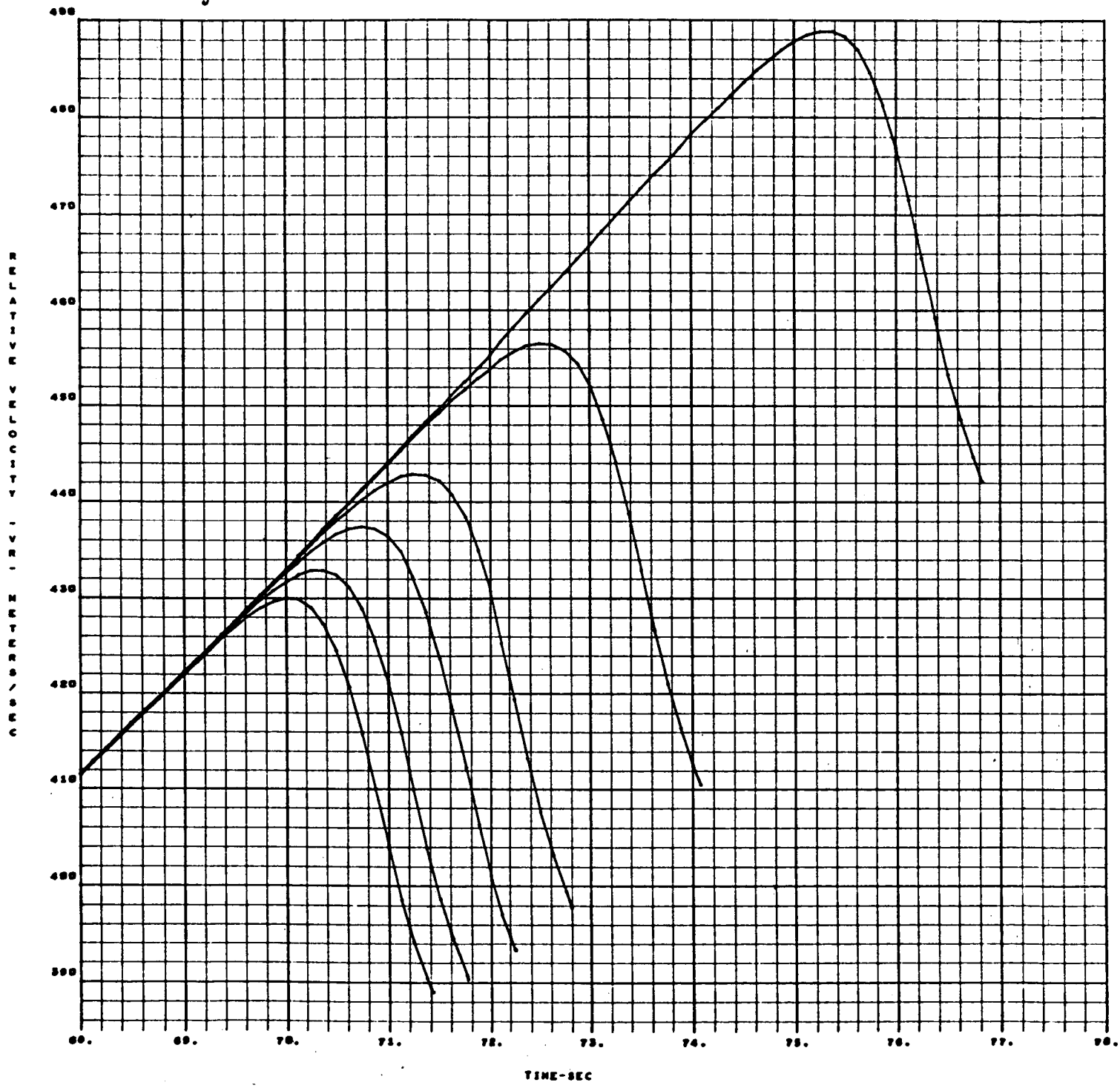


Figure 79

EARTH-FIXED VELOCITY VERSUS TIME
FOR MALFUNCTION AT t_i = 72 sec

(β_y = 11.3, 8.0, 5.0, 3.0, 1.0, 0.1 deg)

β_y is the thrust vector deflection angle in the yaw plane

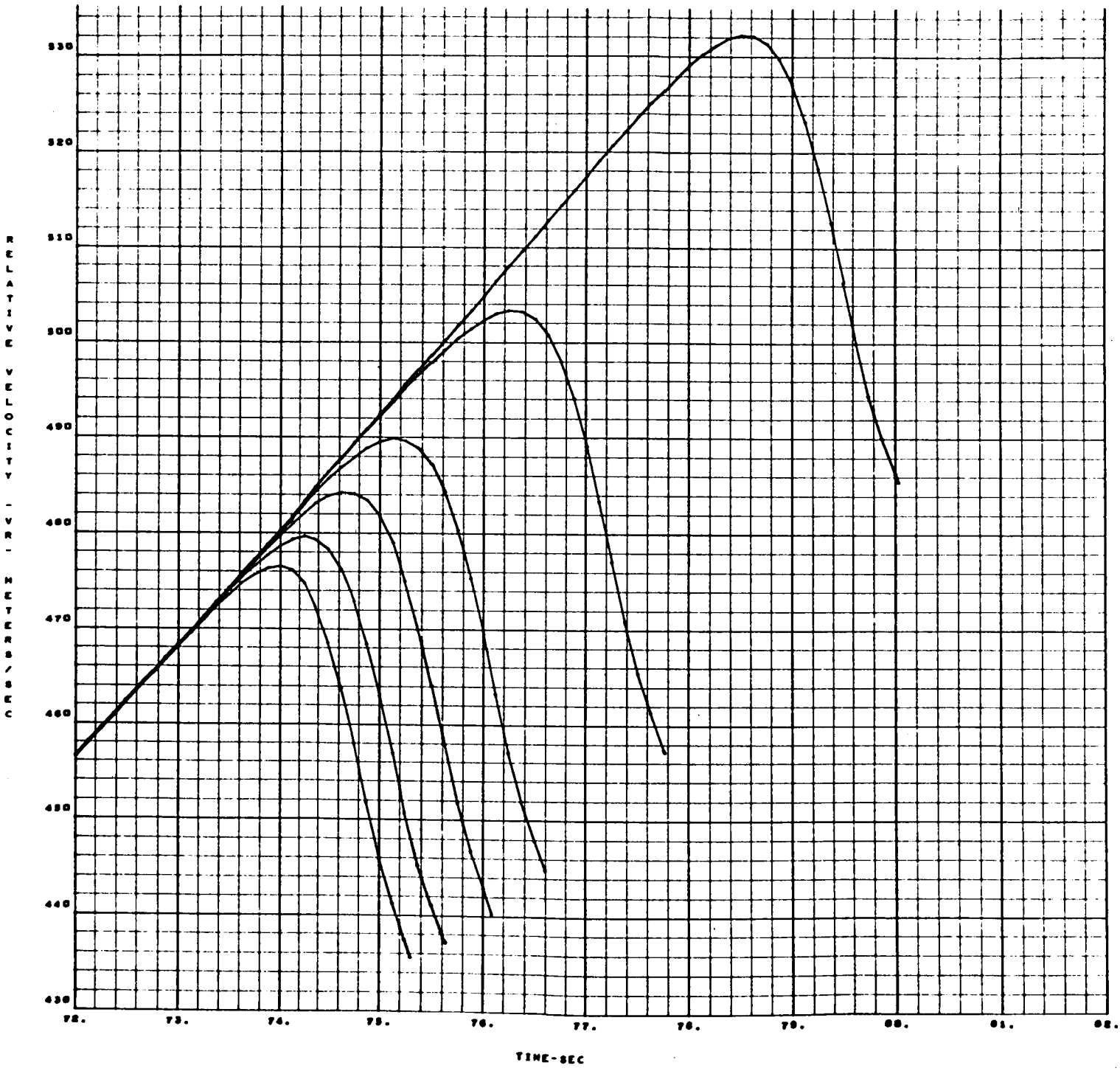


Figure 80

EARTH-FIXED VELOCITY VERSUS TIME
FOR MALFUNCTION AT t_i = 76 sec

(β_y = 11.3, 8.0, 5.0, 3.0, 1.0, 0.1 deg)

β_y is the thrust vector deflection angle in the yaw plane

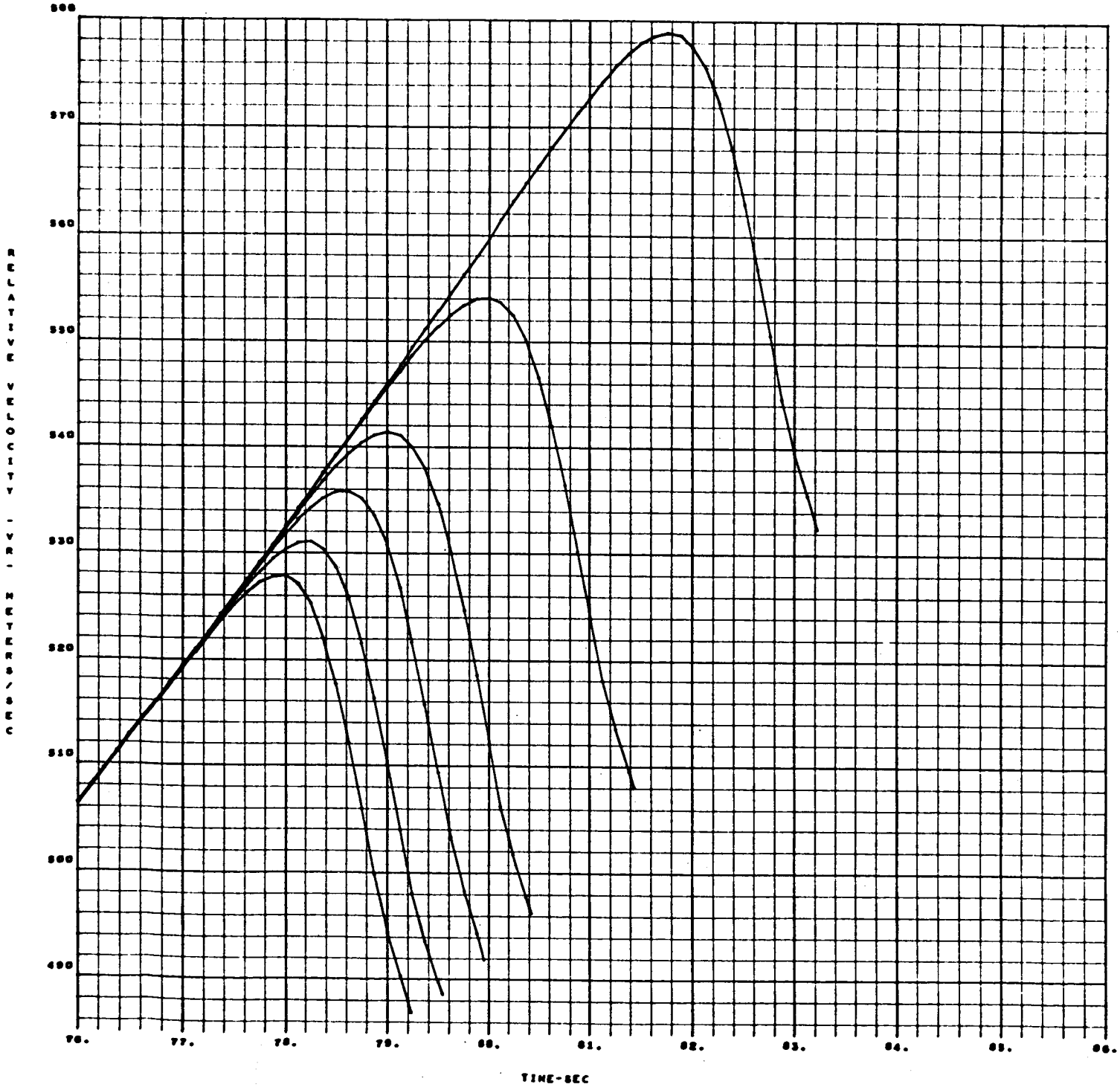


Figure 81

EARTH-FIXED VELOCITY VERSUS TIME
FOR MALFUNCTION AT t_i = 80 sec

(β_y = 11.3, 8.0, 5.0, 3.0, 1.0, 0.1 deg)

β_y is the thrust vector deflection angle in the yaw plane

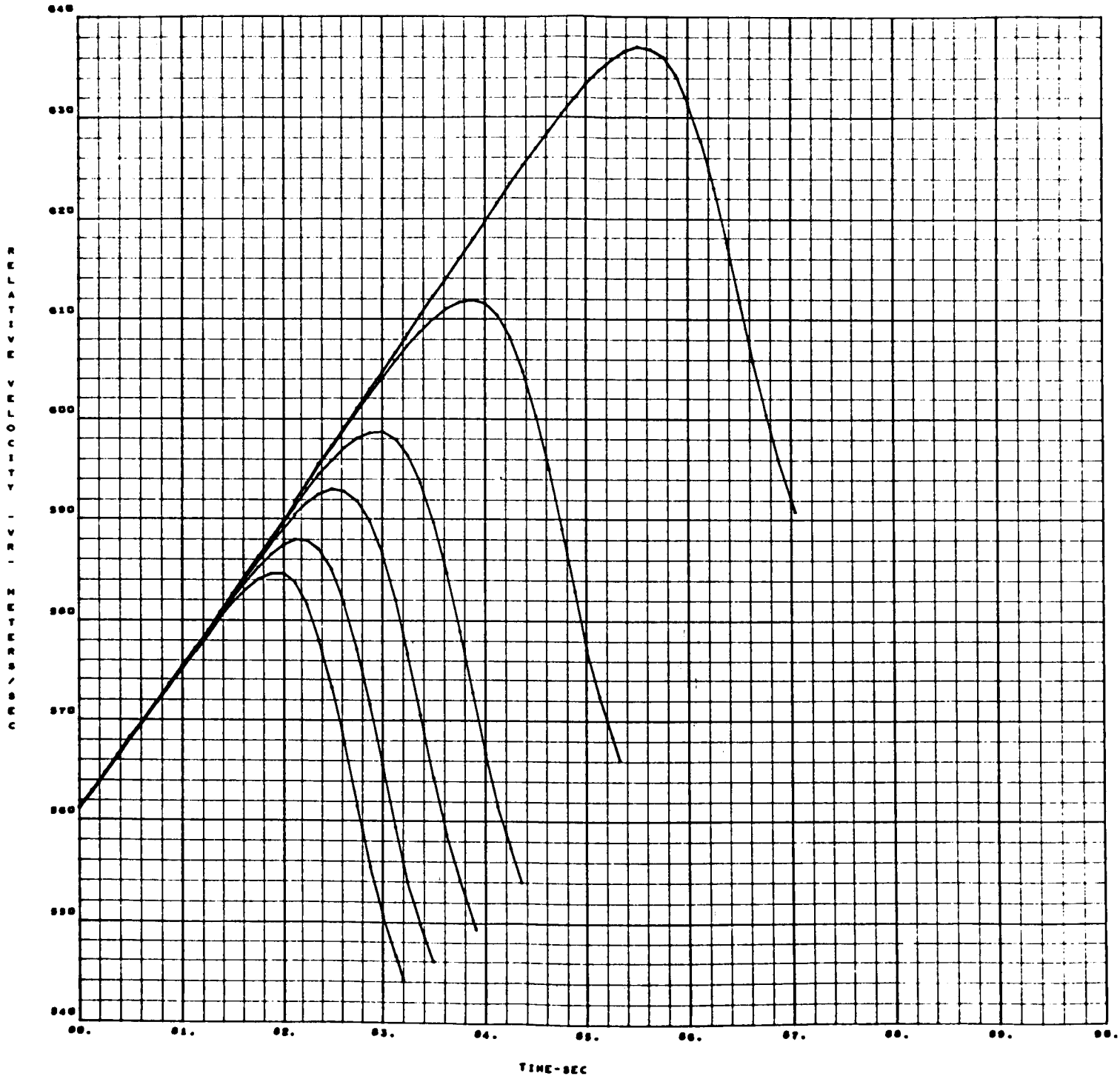


Figure 82

EARTH-FIXED VELOCITY VERSUS TIME
FOR MALFUNCTION AT t_i = 84 sec

(β_y = 11.3, 8.0, 5.0, 3.0, 1.0, 0.1 deg)

β_y is the thrust vector deflection angle in the yaw plane

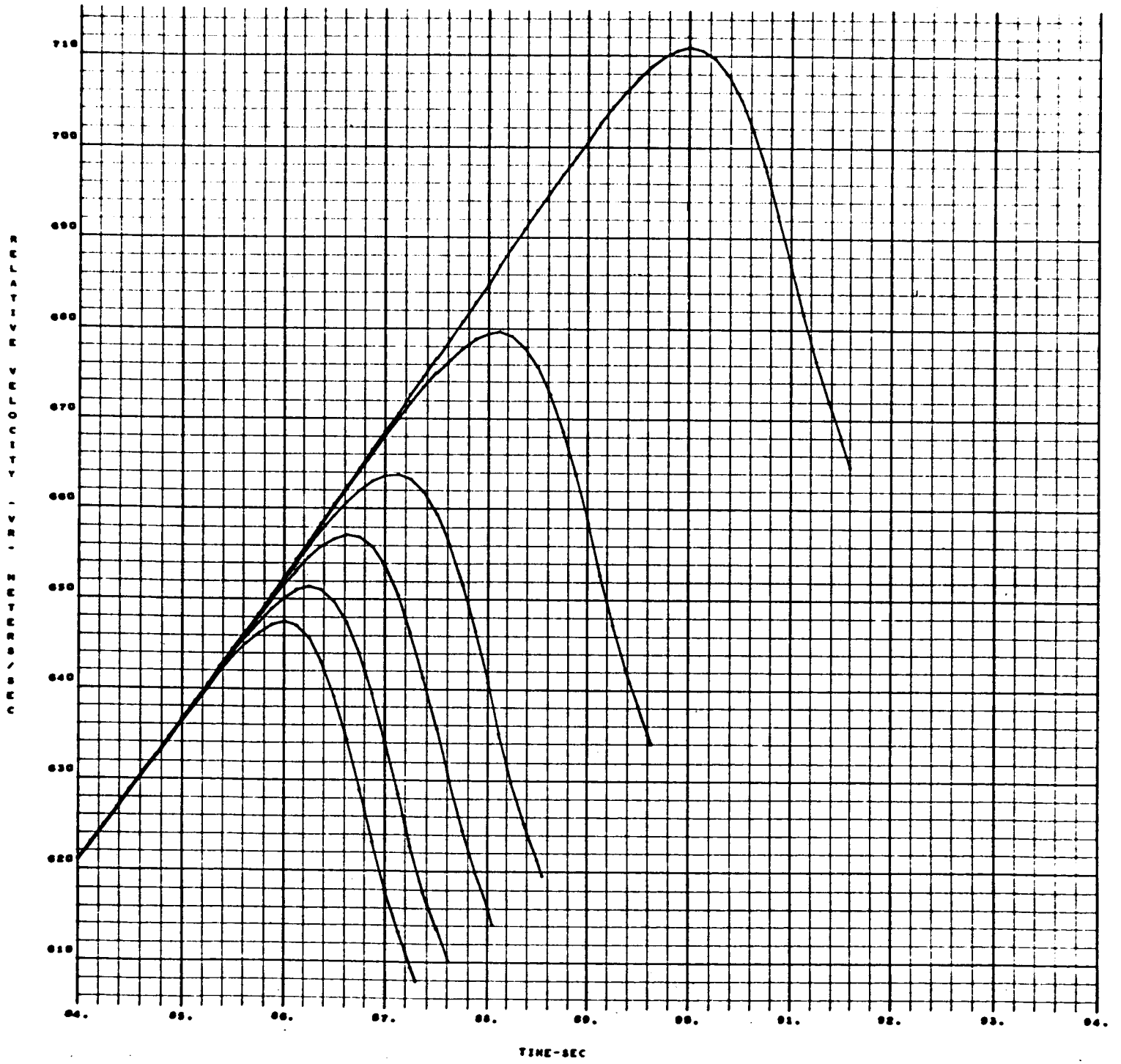


Figure 83

EARTH-FIXED VELOCITY VERSUS TIME
FOR MALFUNCTION AT t_i = 88 sec

(β_y = 11.3, 8.0, 5.0, 3.0, 1.0, 0.1 deg)

β_y is the thrust vector deflection angle in the yaw plane

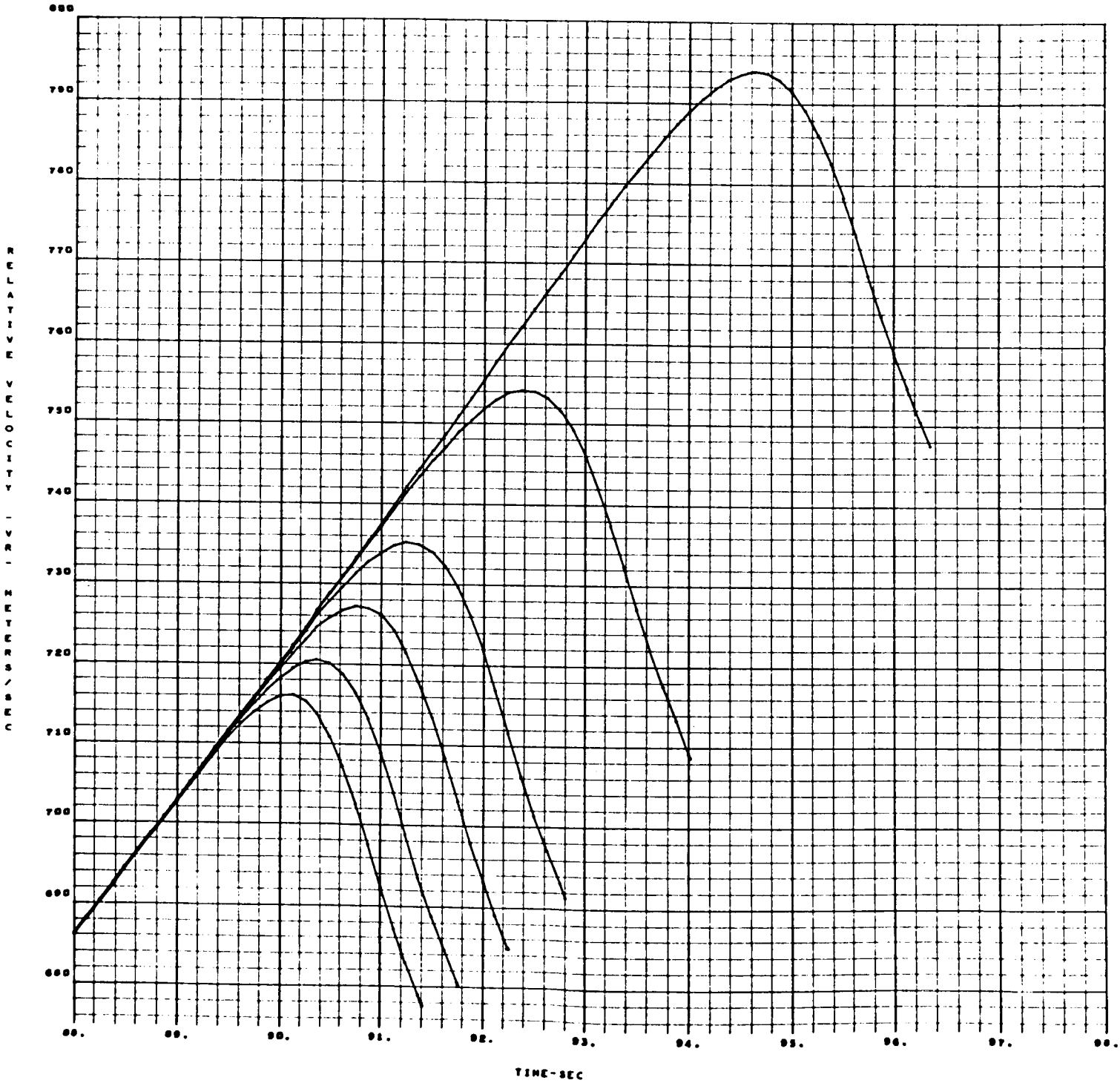


Figure 84

EARTH-FIXED VELOCITY VERSUS TIME
FOR MALFUNCTION AT t_i = 92 sec

(β_y = 11.3, 8.0, 5.0, 3.0, 1.0, 0.1 deg)

β_y is the thrust vector deflection angle in the yaw plane

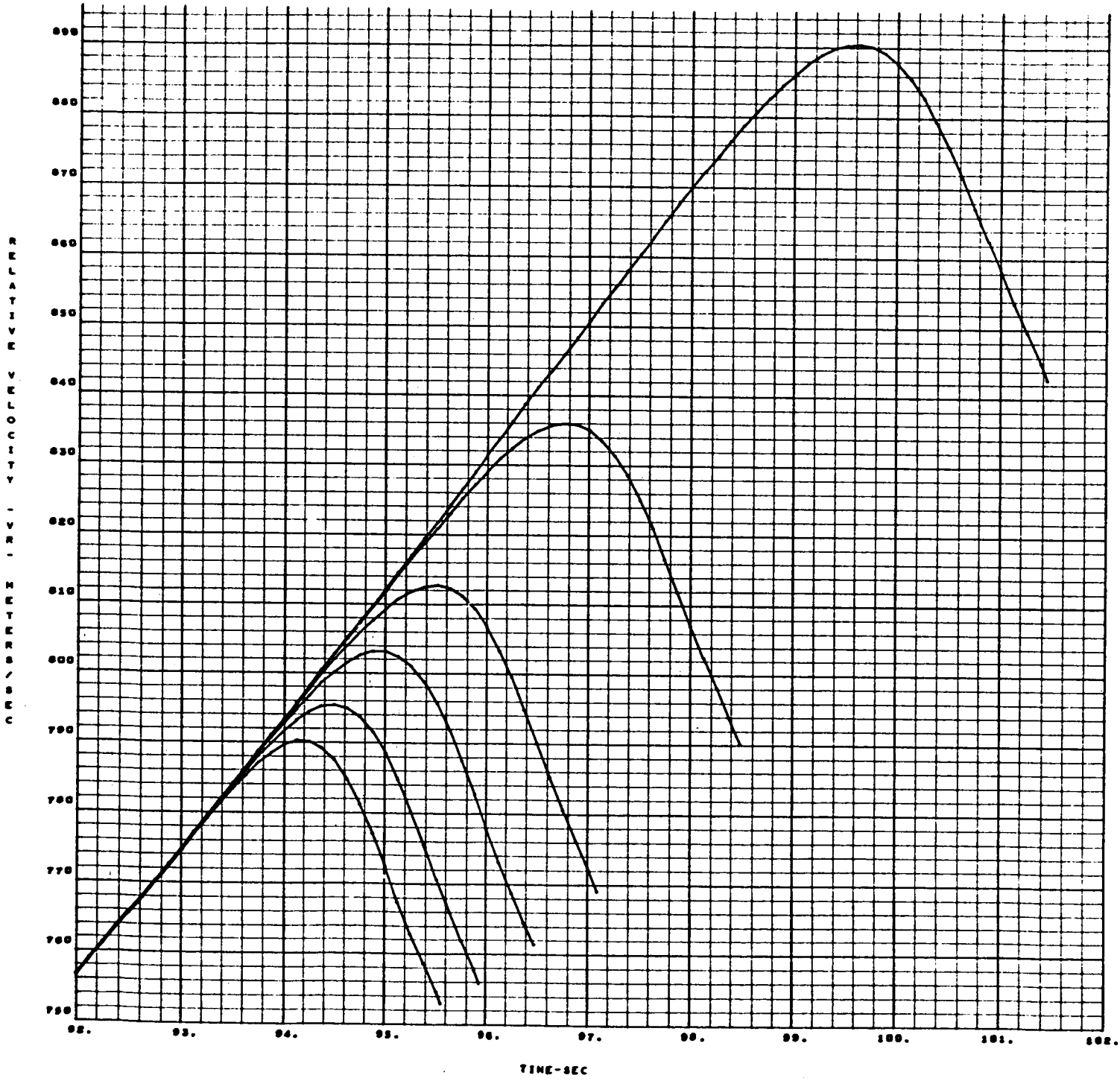


Figure 85

EARTH-FIXED VELOCITY VERSUS TIME
FOR MALFUNCTION AT t_i = 96 sec

(β_y = 11.3, 8.0, 5.0, 3.0, 1.0, 0.1 deg)

β_y is the thrust vector deflection angle in the yaw plane

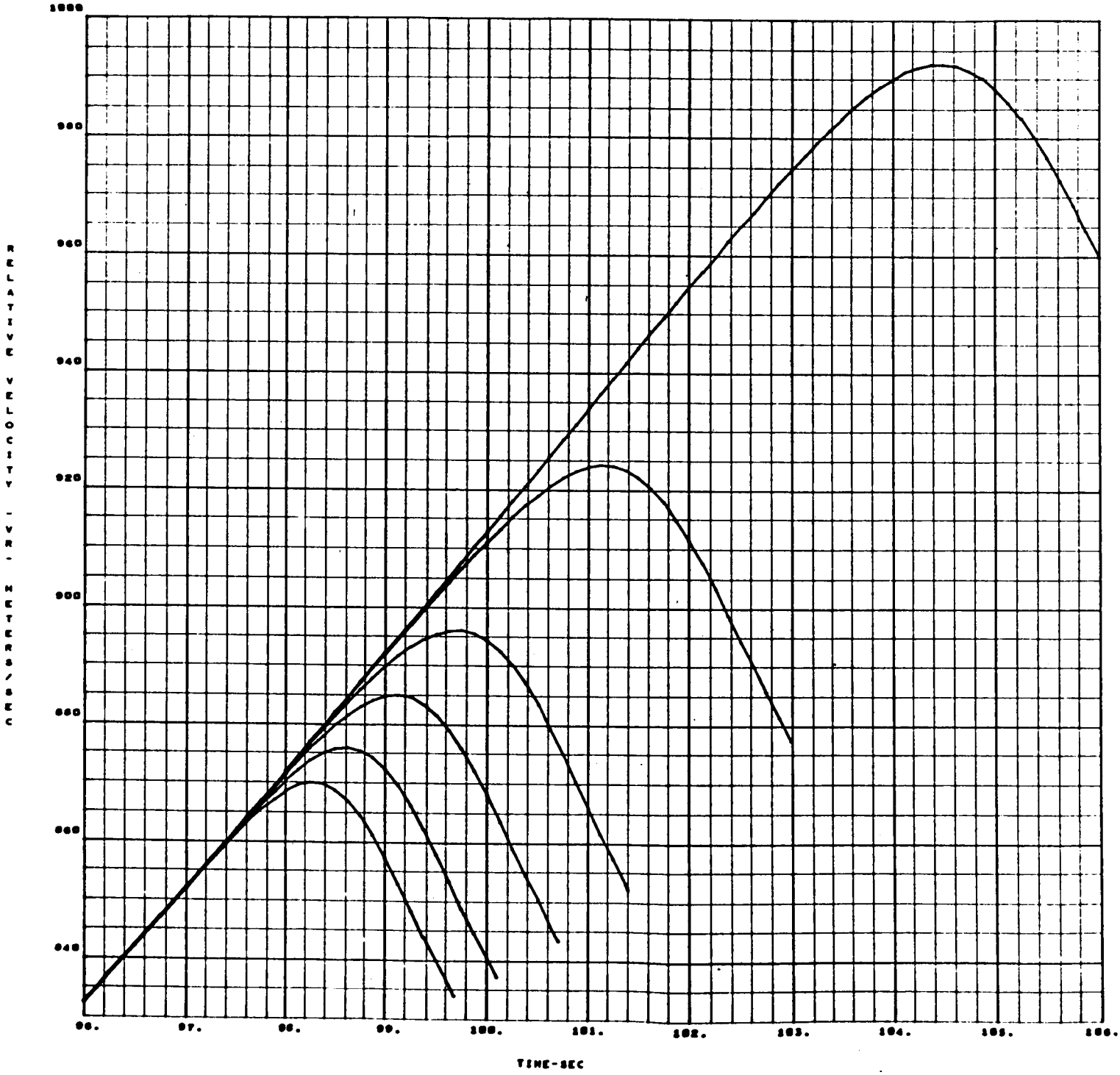


Figure 86

EARTH-FIXED VELOCITY VERSUS TIME
FOR MALFUNCTION AT t_i = 100 sec

(β_y = 11.3, 8.0, 5.0, 3.0, 1.0, 0.1 deg)

β_y is the thrust vector deflection angle in the yaw plane

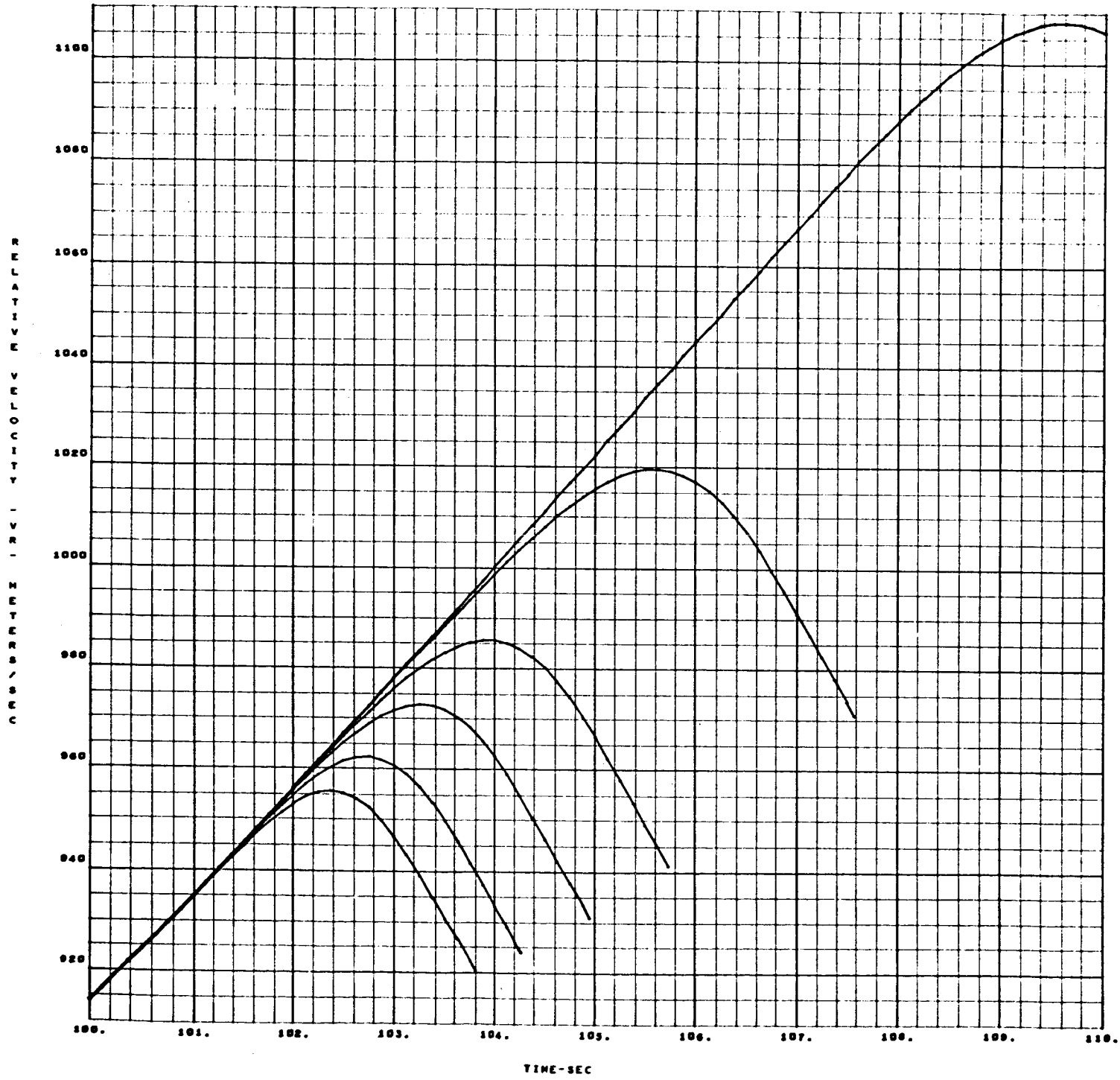


Figure 87

EARTH-FIXED VELOCITY VERSUS TIME
FOR MALFUNCTION AT t_i = 104sec

(β_y = 11.3, 8.0, 5.0, 3.0, 1.0, 0.1 deg)

β_y is the thrust vector deflection angle in the yaw plane

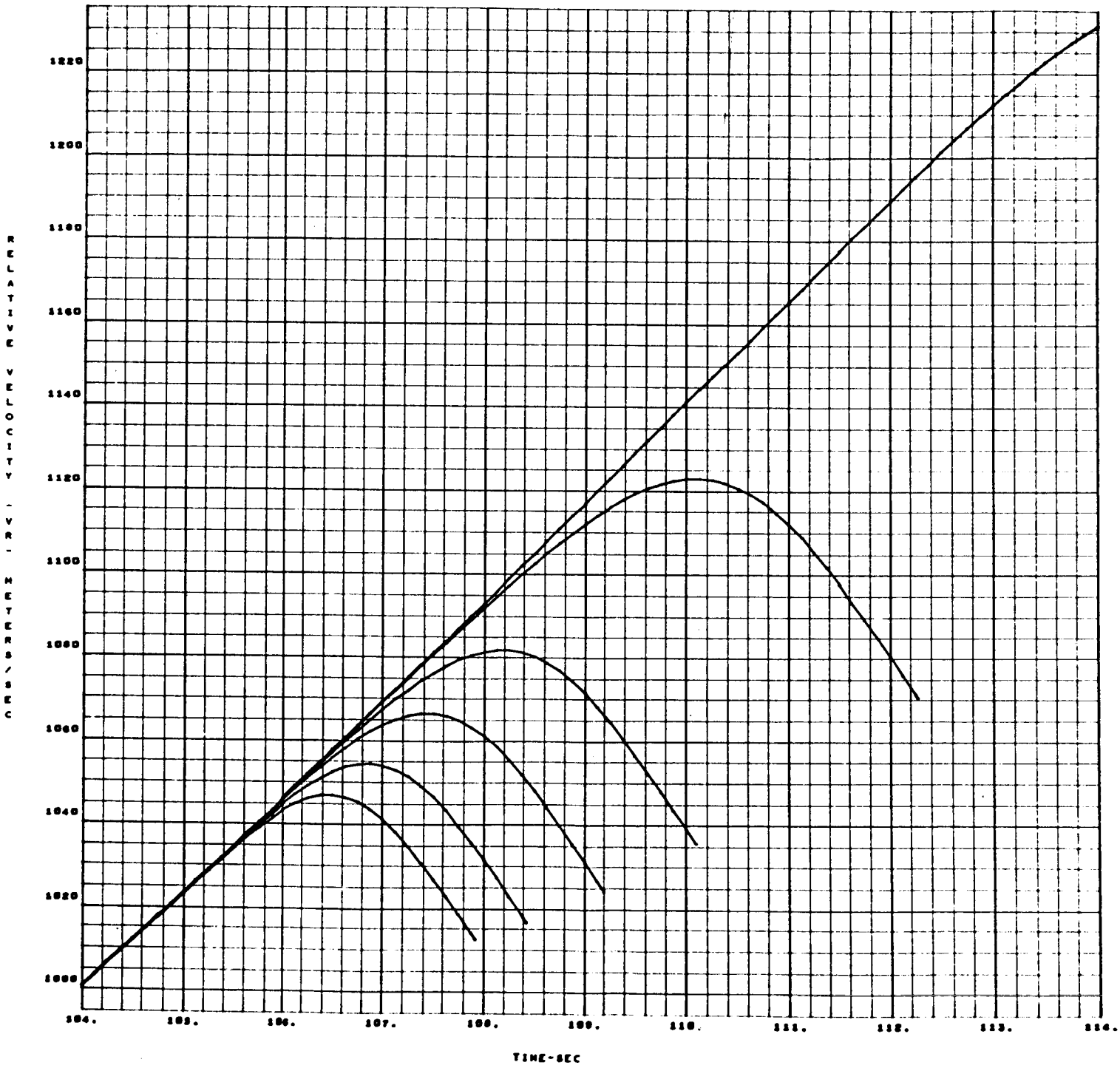


Figure 88

EARTH-FIXED VELOCITY VERSUS TIME
FOR MALFUNCTION AT t_i = 108 sec

(β_y = 11.3, 8.0, 5.0, 3.0, 1.0, 0.1 deg)

β_y is the thrust vector deflection angle in the yaw plane

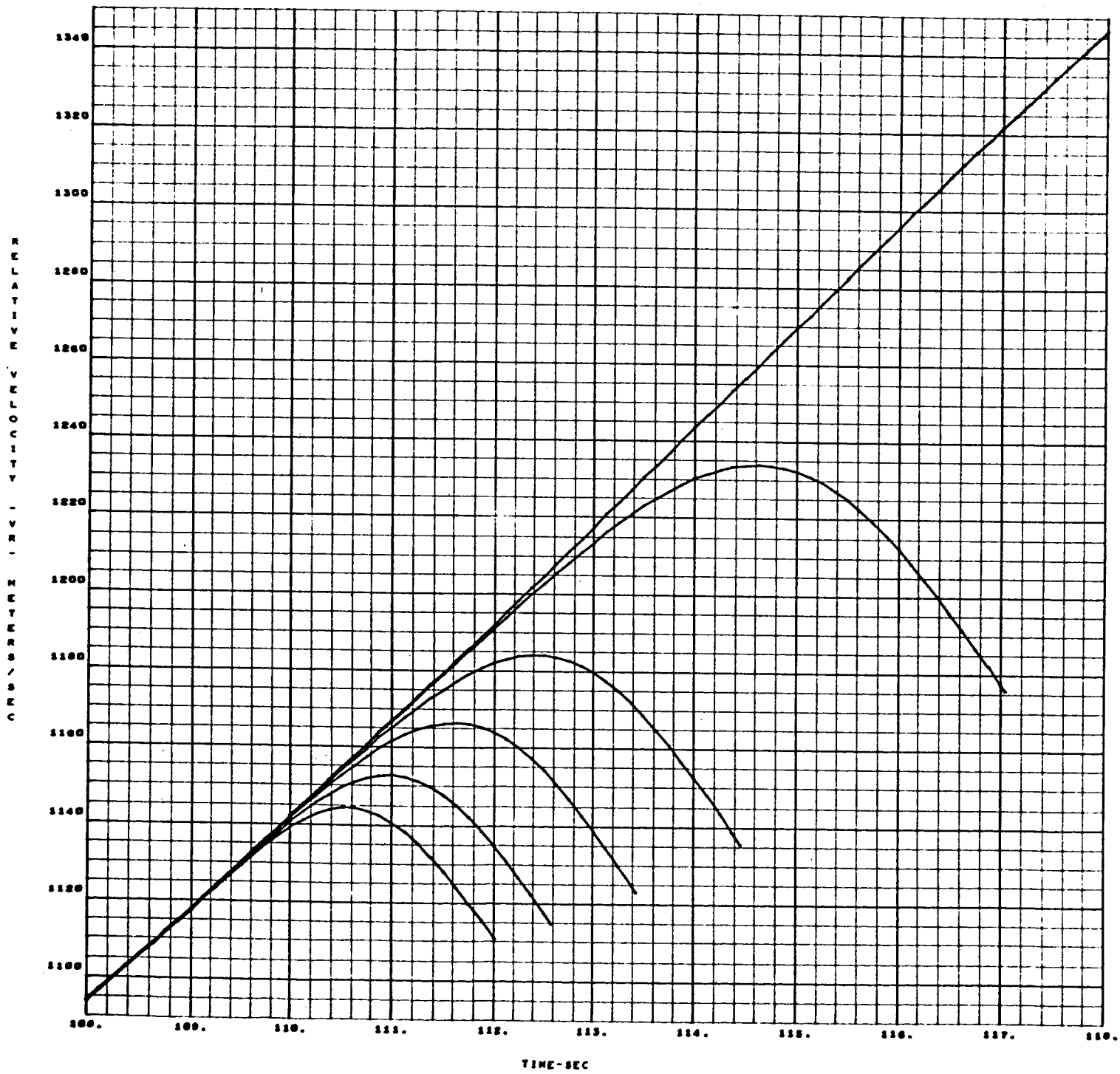


Figure 89

EARTH-FIXED VELOCITY VERSUS TIME
FOR MALFUNCTION AT t_i = 112 sec

(β_y = 11.3, 8.0, 5.0, 3.0, 1.0, 0.1 deg)

β_y is the thrust vector deflection angle in the yaw plane

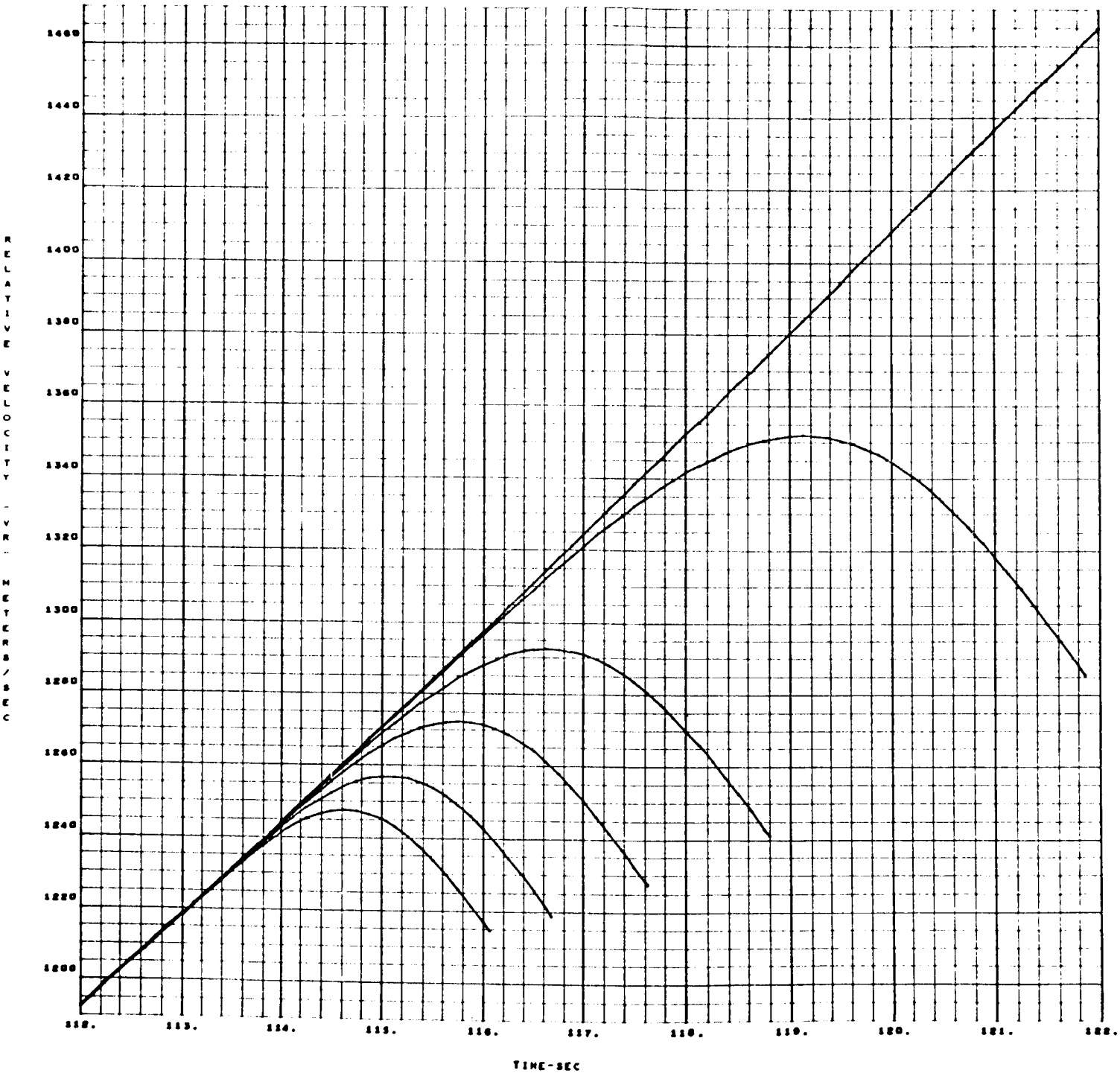


Figure 90

EARTH-FIXED VELOCITY VERSUS TIME
FOR MALFUNCTION AT t_i = 116 sec

(β_y = 11.3, 8.0, 5.0, 3.0, 1.0, 0.1 deg)

β_y is the thrust vector deflection angle in the yaw plane

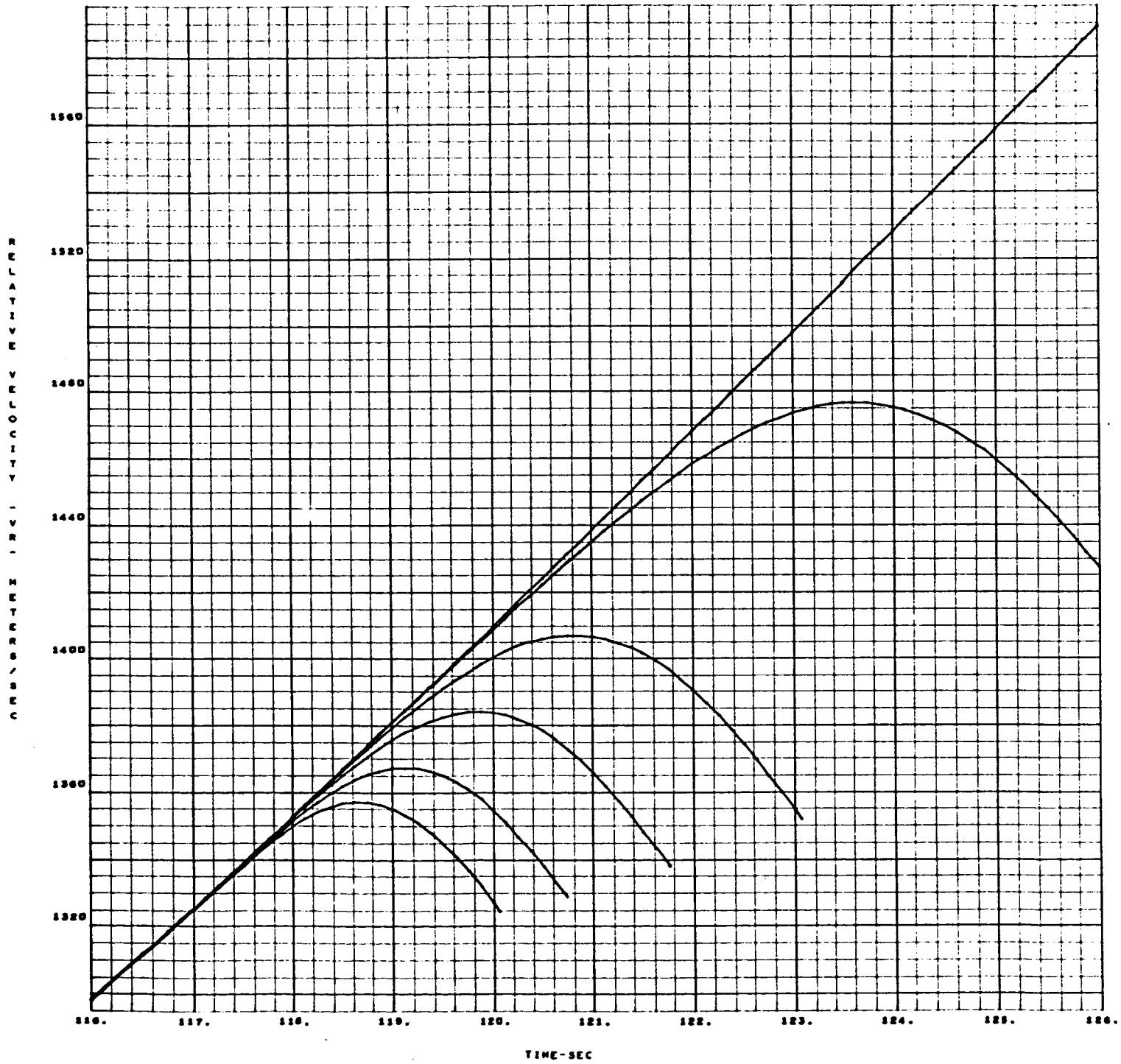


Figure 91

EARTH-FIXED VELOCITY VERSUS TIME
FOR MALFUNCTION AT t_i = 120 sec

(β_y = 11.3, 8.0, 5.0, 3.0, 1.0, 0.1 deg)

β_y is the thrust vector deflection angle in the yaw plane

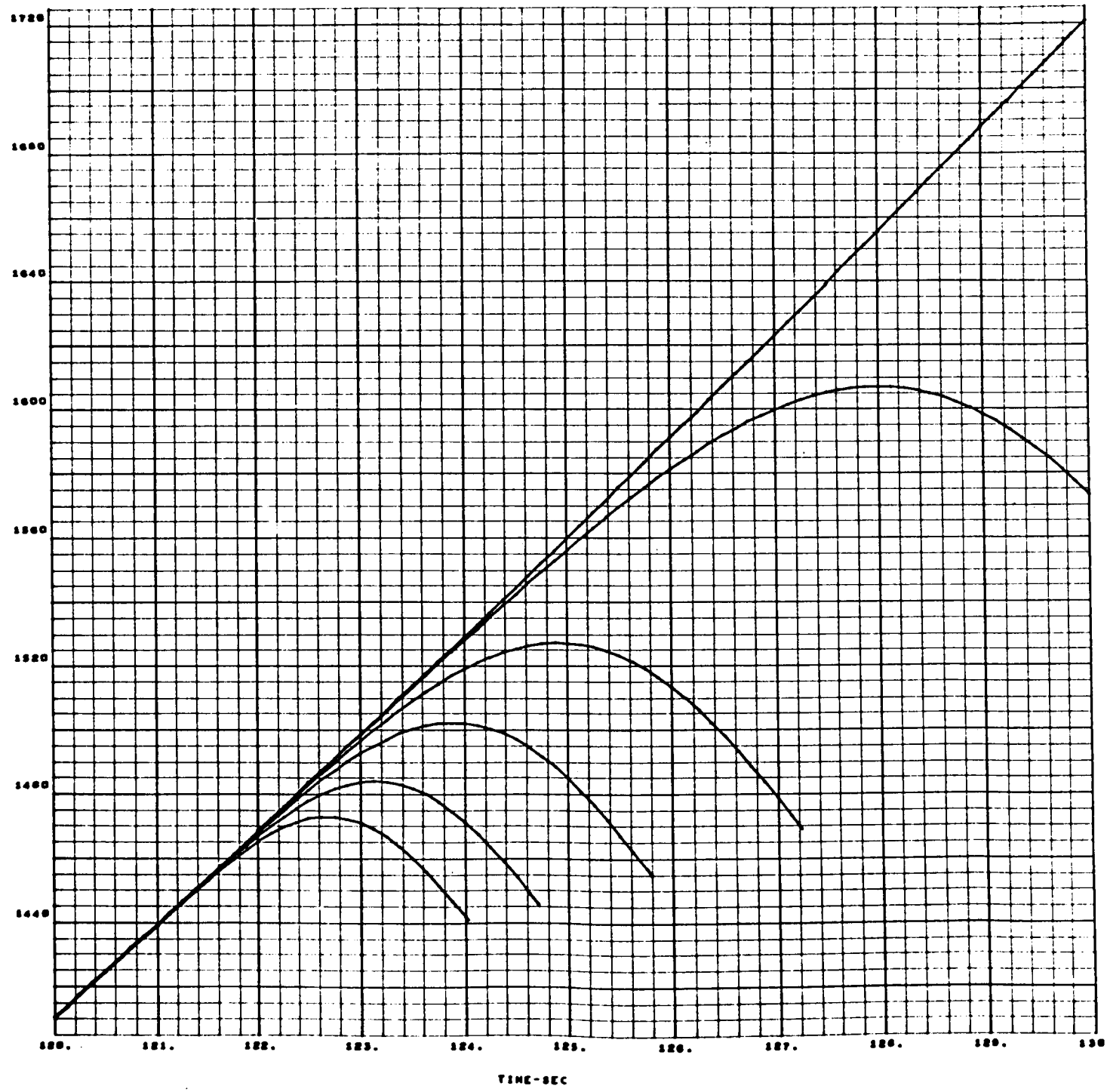


Figure 92

EARTH-FIXED VELOCITY VERSUS TIME
FOR MALFUNCTION AT t_i = 124 sec

(β_y = 11.3, 8.0, 5.0, 3.0, 1.0, 0.1 deg)

β_y is the thrust vector deflection angle in the yaw plane

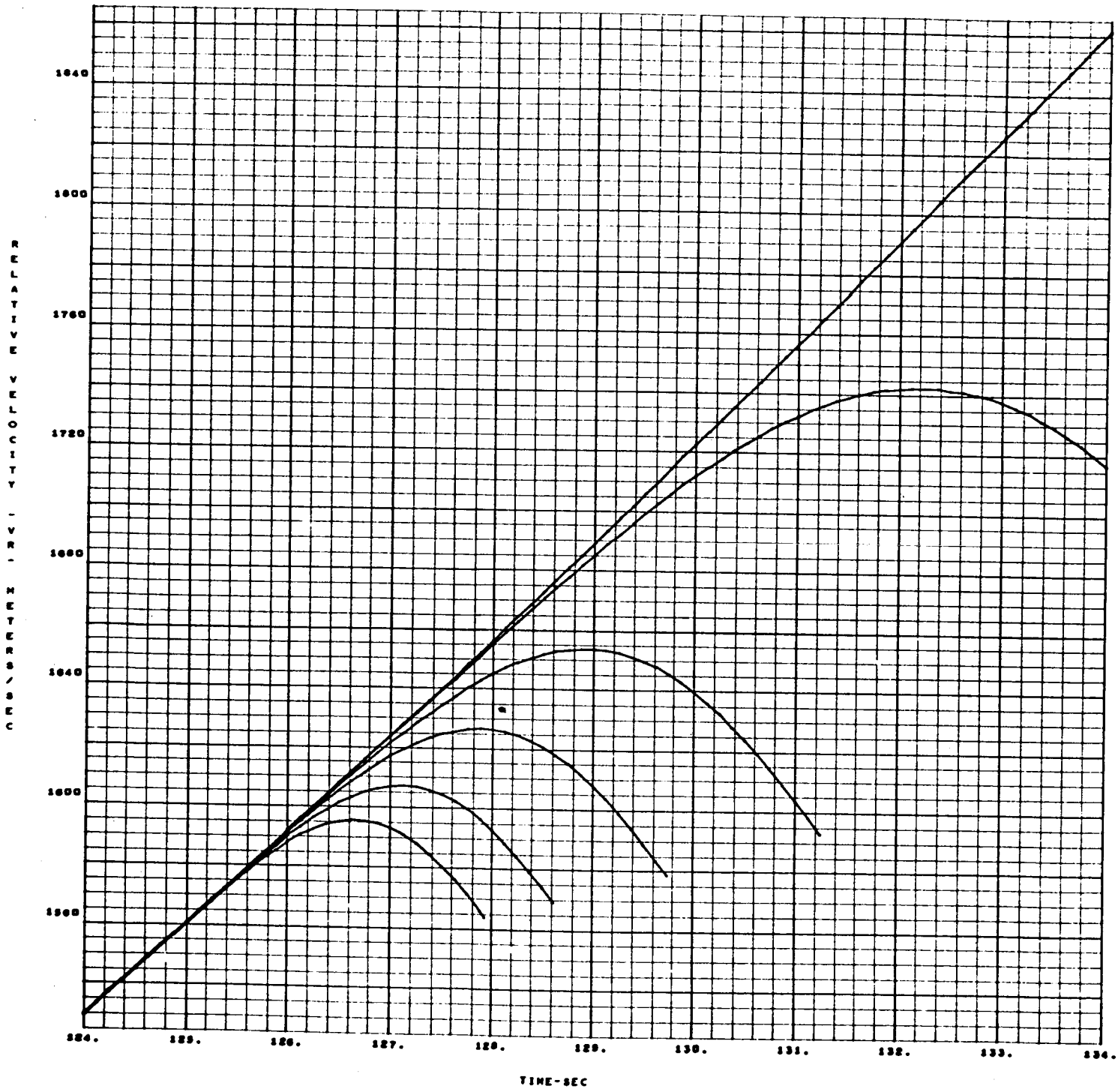


Figure 93

EARTH-FIXED VELOCITY VERSUS TIME
FOR MALFUNCTION AT t_i = 128 sec

(β_y = 11.3, 8.0, 5.0, 3.0, 1.0, 0.1 deg)

β_y is the thrust vector deflection angle in the yaw plane

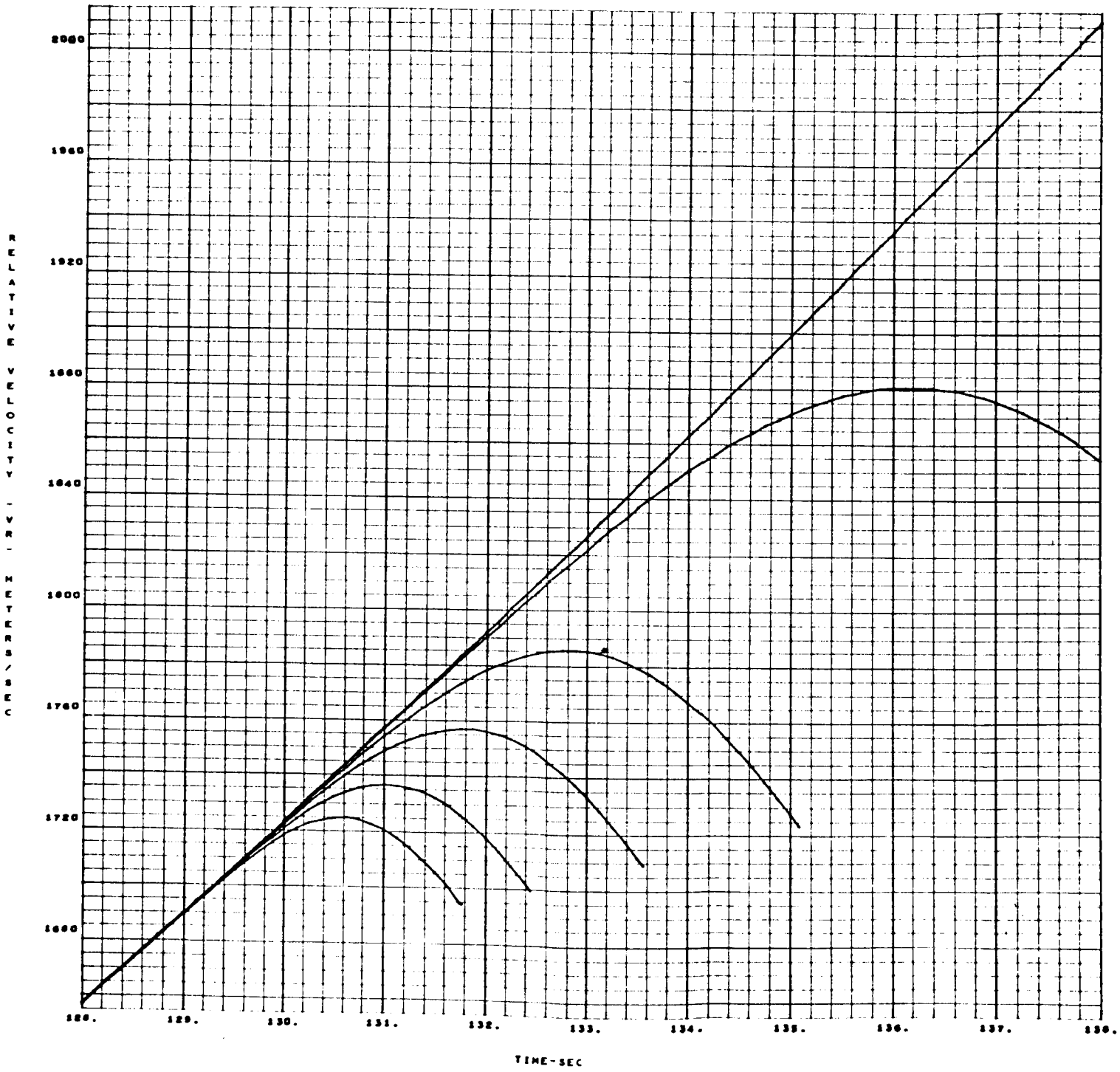


Figure 94

EARTH-FIXED VELOCITY VERSUS TIME
FOR MALFUNCTION AT t_i = 132 sec

(β_y = 11.3, 8.0, 5.0, 3.0, 1.0, 0.1 deg)

β_y is the thrust vector deflection angle in the yaw plane

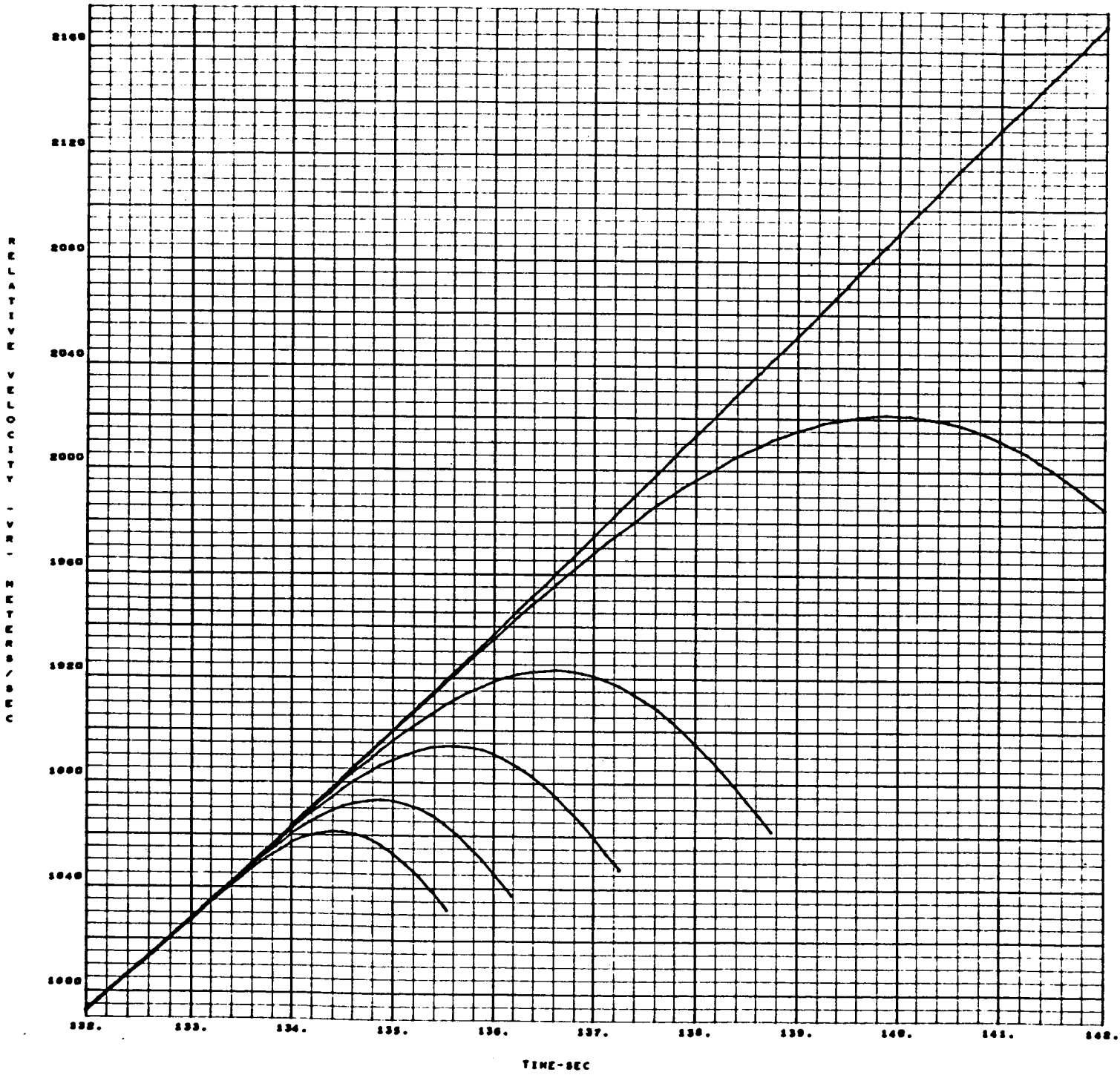


Figure 95

EARTH-FIXED VELOCITY VERSUS TIME
FOR MALFUNCTION AT t_i = 150 sec

(β_y = 10.0, 7.0, 5.0, 3.0, 1.0, 0.1 deg)

β_y is the thrust vector deflection angle in the yaw plane

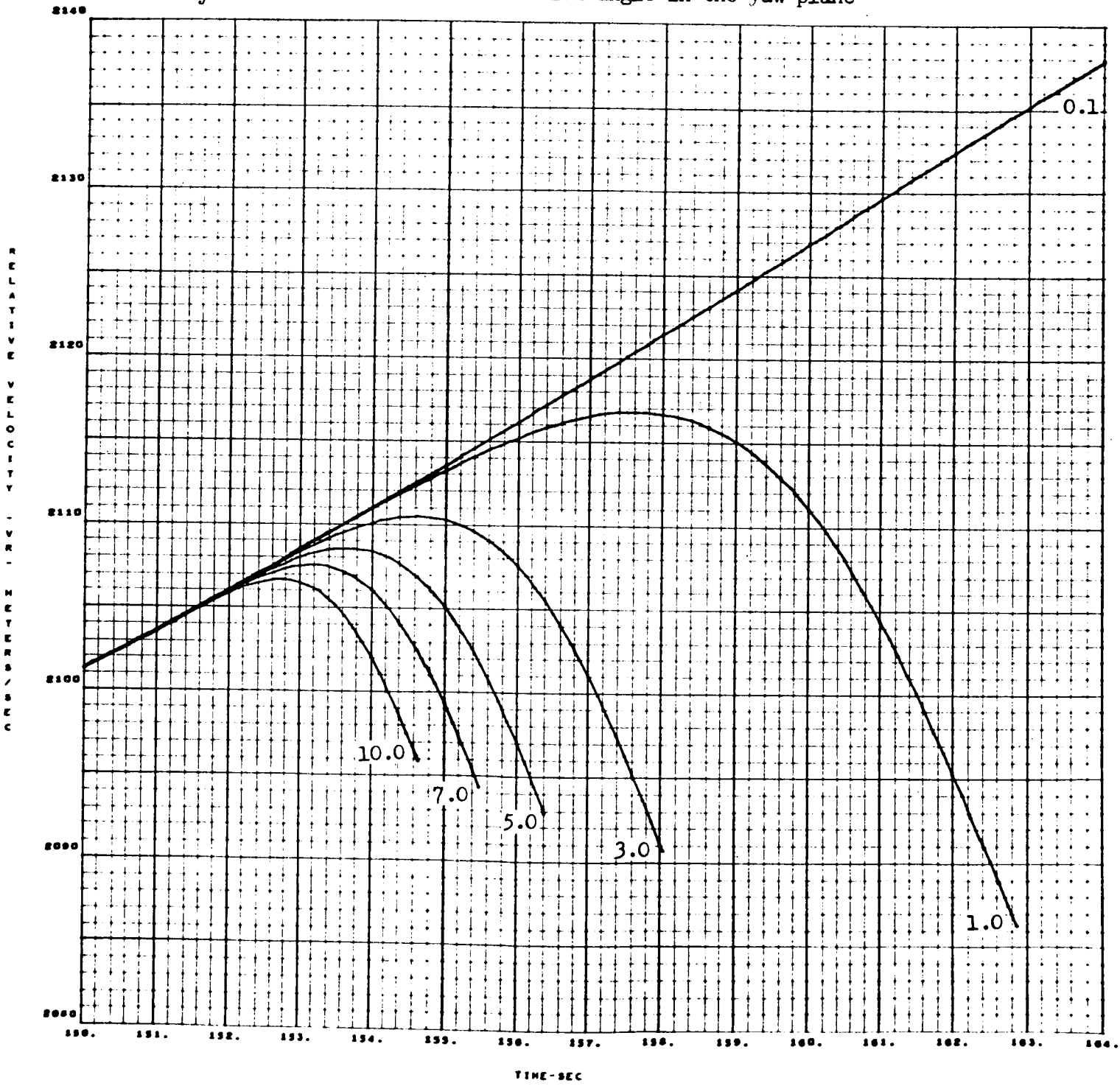


Figure 96

EARTH-FIXED VELOCITY VERSUS TIME
FOR MALFUNCTION AT t_i = 154 sec

(β_y = 10.0, 7.0, 5.0, 3.0, 1.0, 0.1 deg)

β_y is the thrust vector deflection angle in the yaw plane

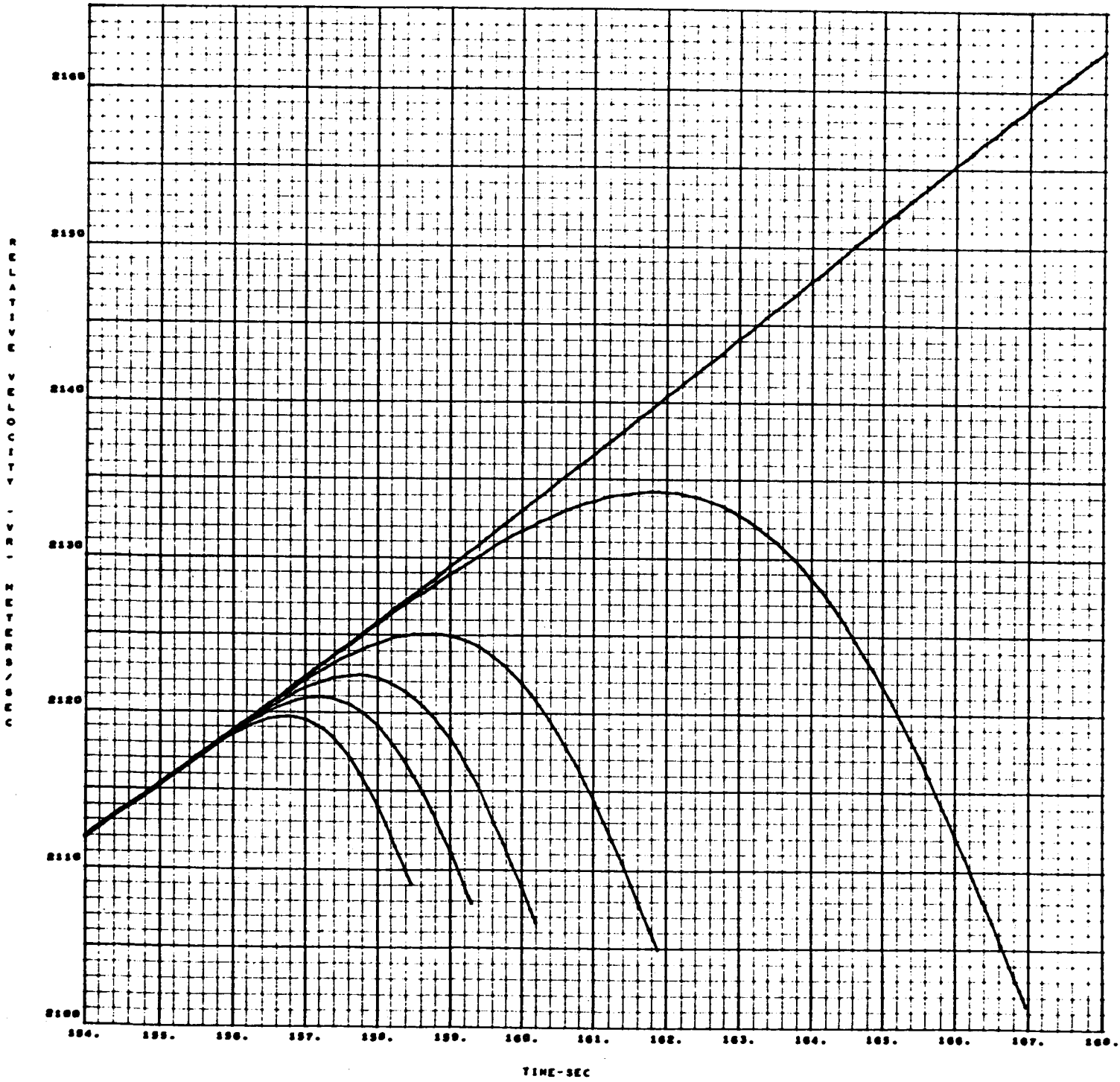


Figure 97

EARTH-FIXED VELOCITY VERSUS TIME
FOR MALFUNCTION AT t_i = 158 sec

(β_y = 10.0, 7.0, 5.0, 3.0, 1.0, 0.1 deg)

β_y is the thrust vector deflection angle in the yaw plane

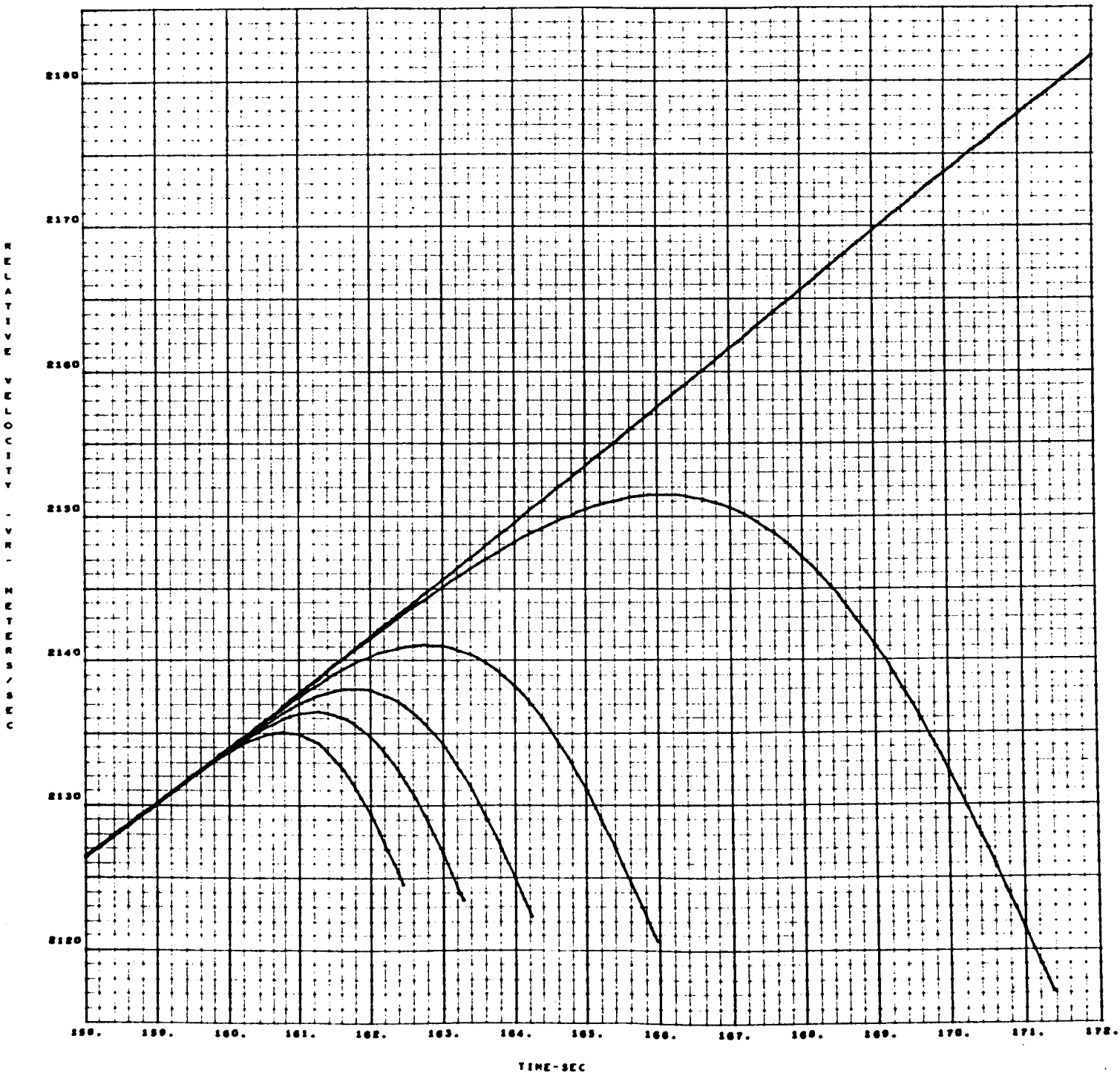


Figure 98

EARTH-FIXED VELOCITY VERSUS TIME
FOR MALFUNCTION AT t_i = 174 sec

(β_y = 10.0, 7.0, 5.0, 3.0, 1.0, 0.1 deg)

β_y is the thrust vector deflection angle in the yaw plane

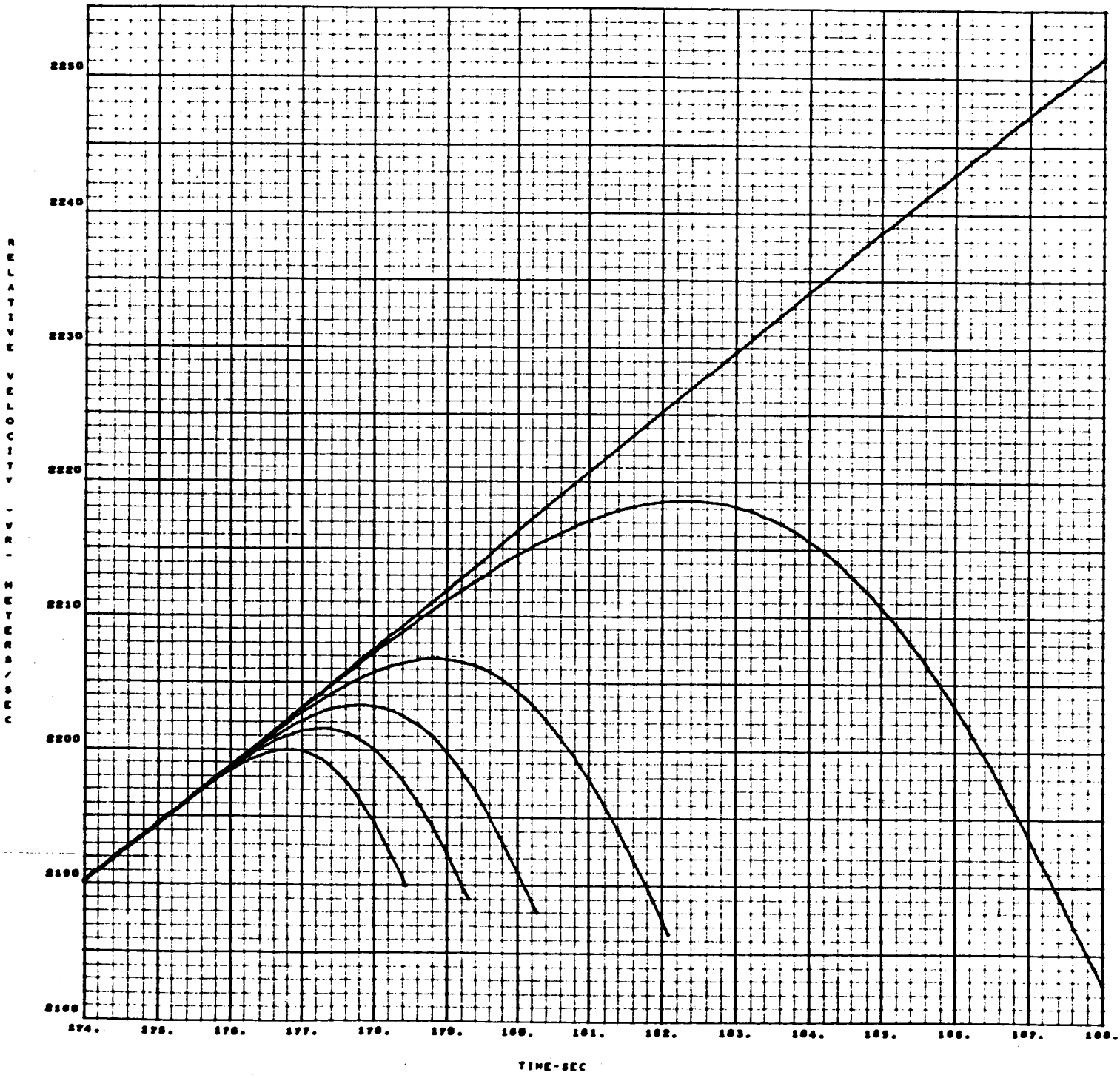


Figure 99

EARTH-FIXED VELOCITY VERSUS TIME
FOR MALFUNCTION AT t_i = 190 sec

(β_y = 10.0, 7.0, 5.0, 3.0, 1.0, 0.1 deg)

β_y is the thrust vector deflection angle in the yaw plane

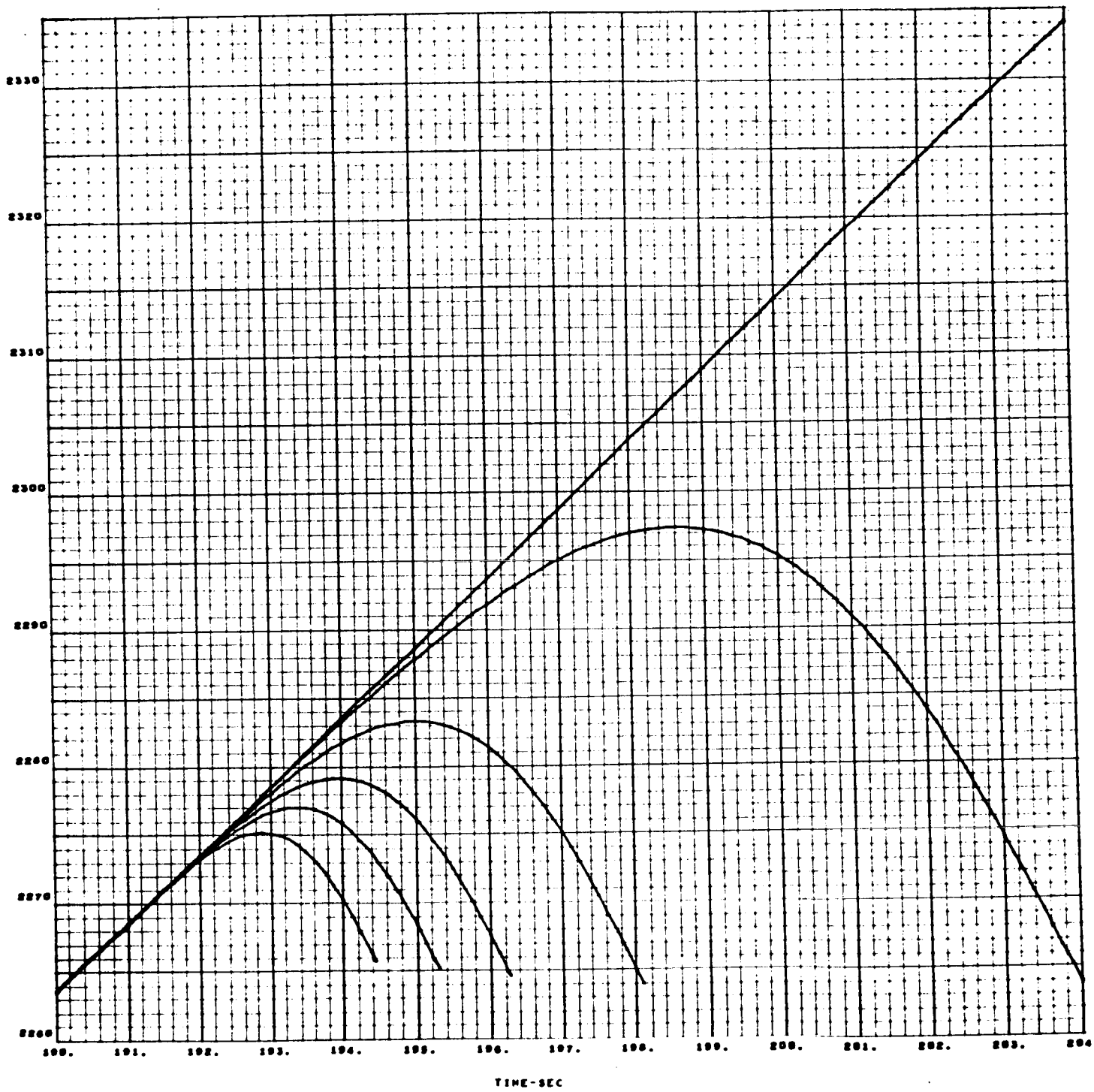


Figure 100

EARTH-FIXED VELOCITY VERSUS TIME
FOR MALFUNCTION AT t_i = 206 sec

(β_y = 10.0, 7.0, 5.0, 3.0, 1.0, 0.1 deg)

β_y is the thrust vector deflection angle in the yaw plane

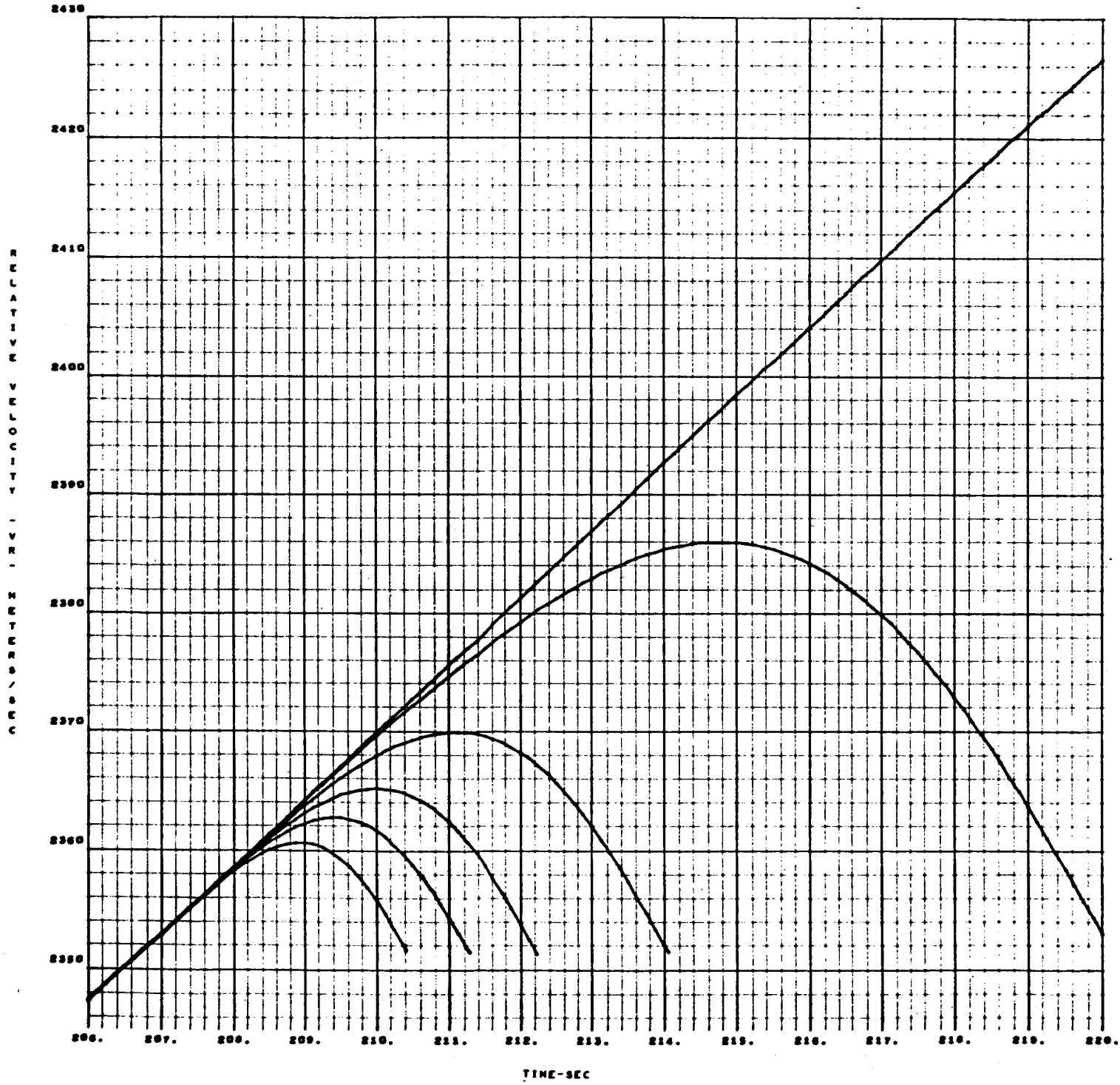


Figure 101

EARTH-FIXED VELOCITY VERSUS TIME
FOR MALFUNCTION AT t_i = 222 sec

(β_y = 10.0, 7.0, 5.0, 3.0, 1.0, 0.1 deg)

β_y is the thrust vector deflection angle in the yaw plane

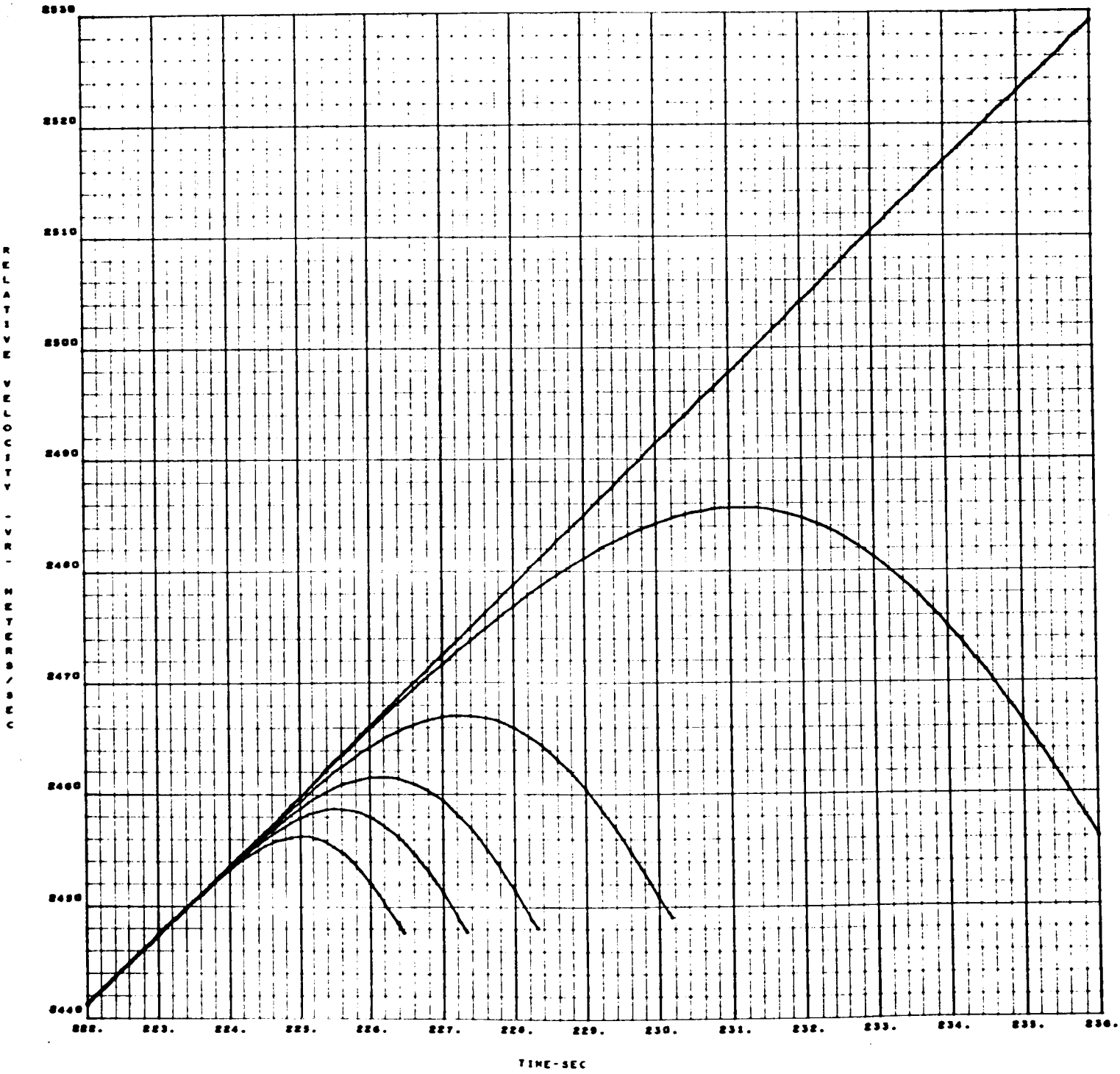


Figure 102

EARTH-FIXED VELOCITY VERSUS TIME
FOR MALFUNCTION AT t_i = 238 sec

(β_y = 10.0, 7.0, 5.0, 3.0, 1.0, 0.1 deg)

β_y is the thrust vector deflection angle in the yaw plane

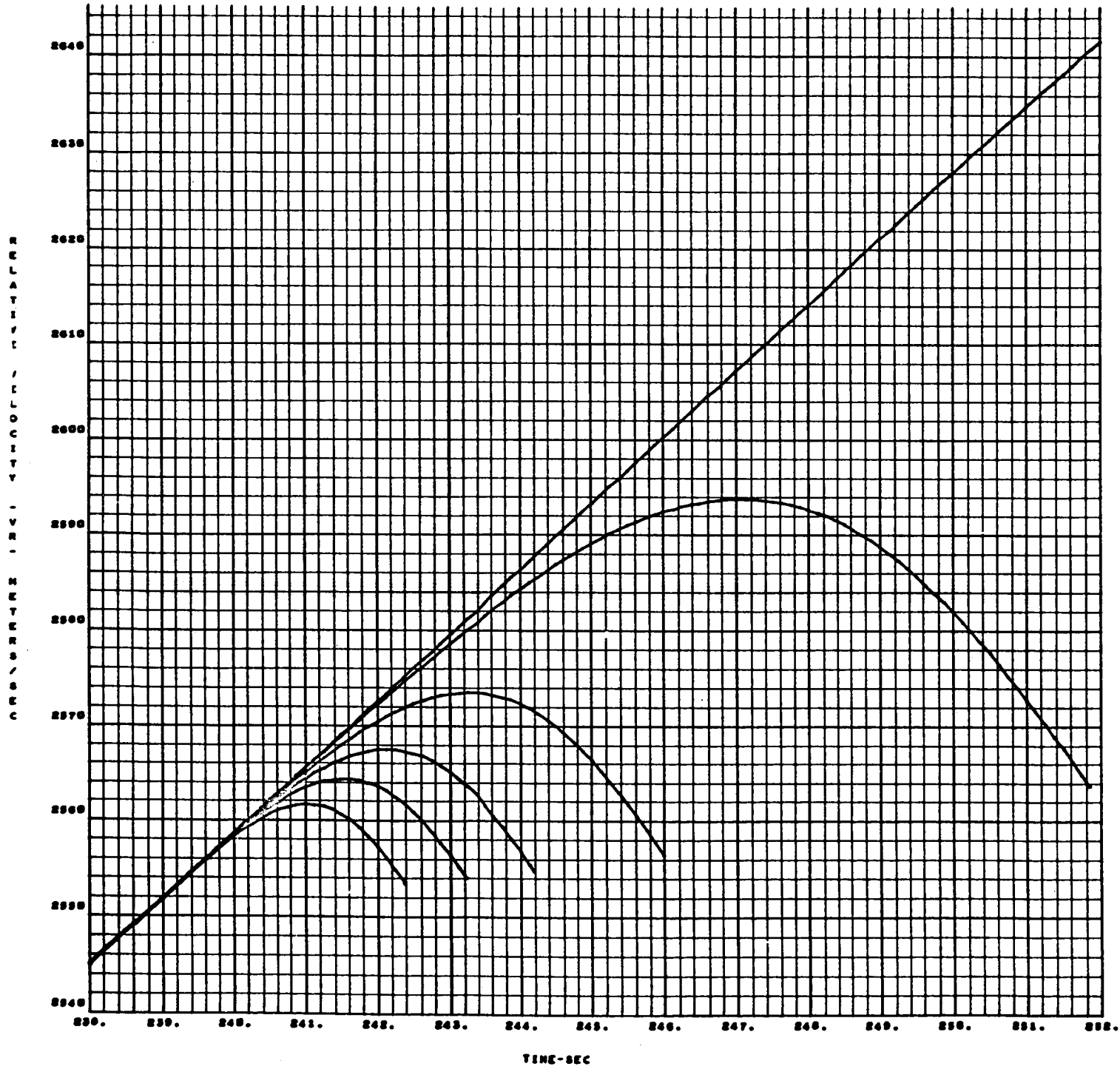


Figure 103

EARTH-FIXED VELOCITY VERSUS TIME
FOR MALFUNCTION AT t_i = 254 sec

(β_y = 10.0, 7.0, 5.0, 3.0, 1.0, 0.1 deg)

β_y is the thrust vector deflection angle in the yaw plane

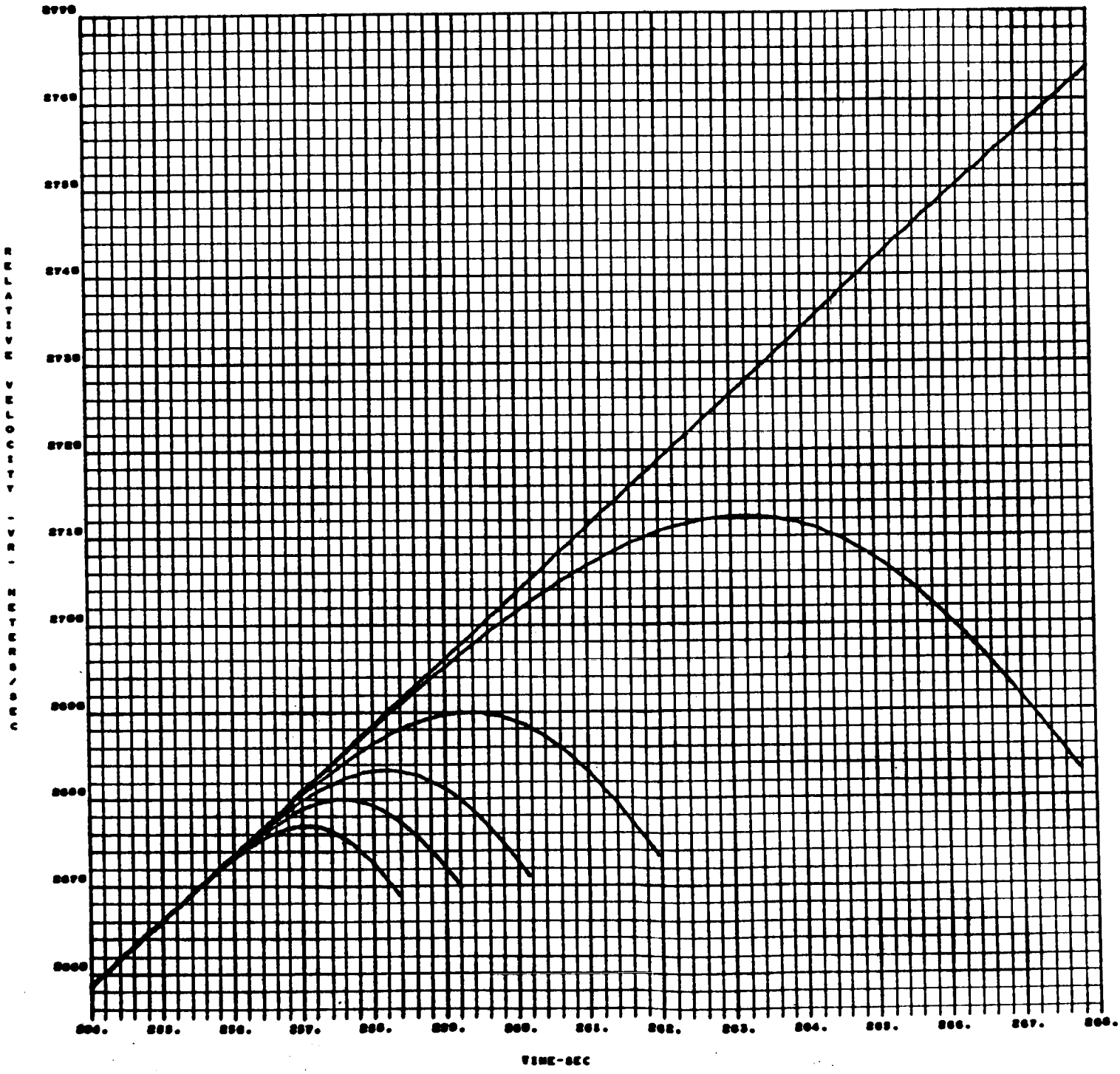


Figure 104

EARTH-FIXED VELOCITY VERSUS TIME
FOR MALFUNCTION AT t_i = 270 sec

(β_y = 10.0, 7.0, 5.0, 3.0, 1.0, 0.1 deg)

β_y is the thrust vector deflection angle in the yaw plane

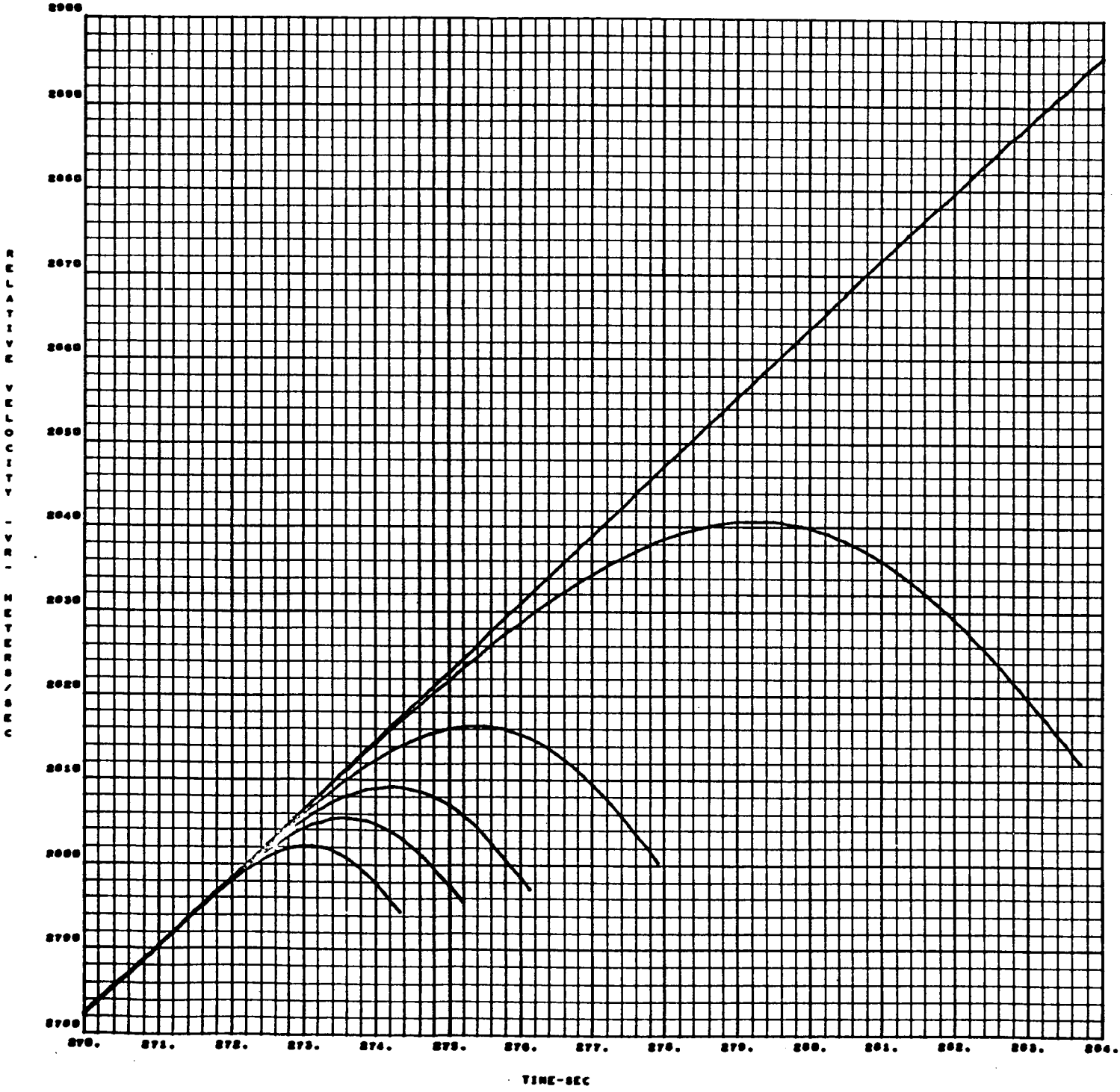


Figure 105

EARTH-FIXED VELOCITY VERSUS TIME
FOR MALFUNCTION AT t_i = 286 sec

(β_y = 10.0, 7.0, 5.0, 3.0, 1.0, 0.1 deg)

β_y is the thrust vector deflection angle in the yaw plane

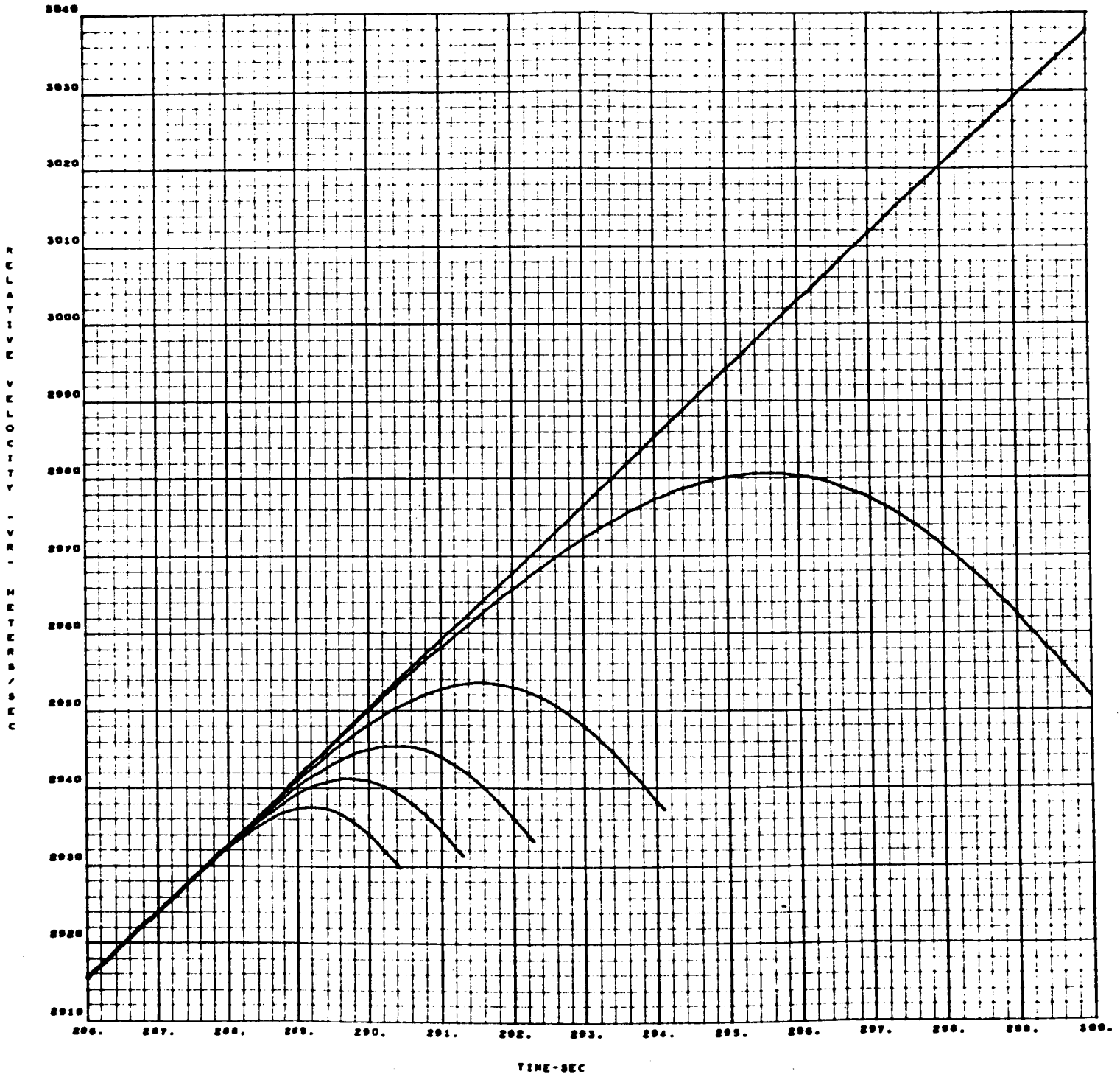


Figure 106

EARTH-FIXED VELOCITY VERSUS TIME
FOR MALFUNCTION AT t_i = 302 sec

(β_y = 10.0, 7.0, 5.0, 3.0, 1.0, 0.1 deg)

β_y is the thrust vector deflection angle in the yaw plane

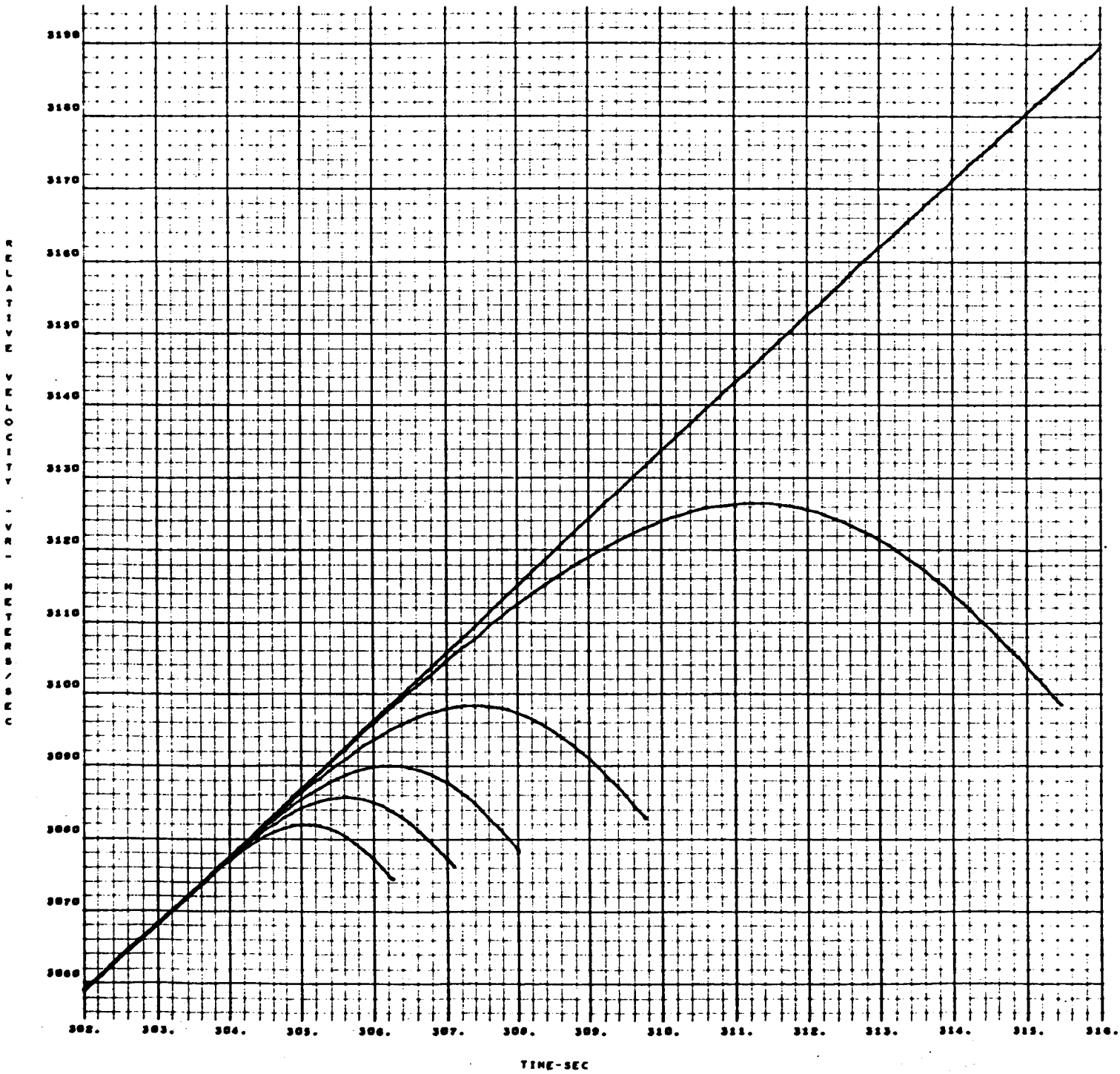


Figure 107

EARTH-FIXED VELOCITY VERSUS TIME
FOR MALFUNCTION AT t_i = 318 sec

(β_y = 10.0, 7.0, 5.0, 3.0, 1.0, 0.1 deg)

β_y is the thrust vector deflection angle in the yaw plane

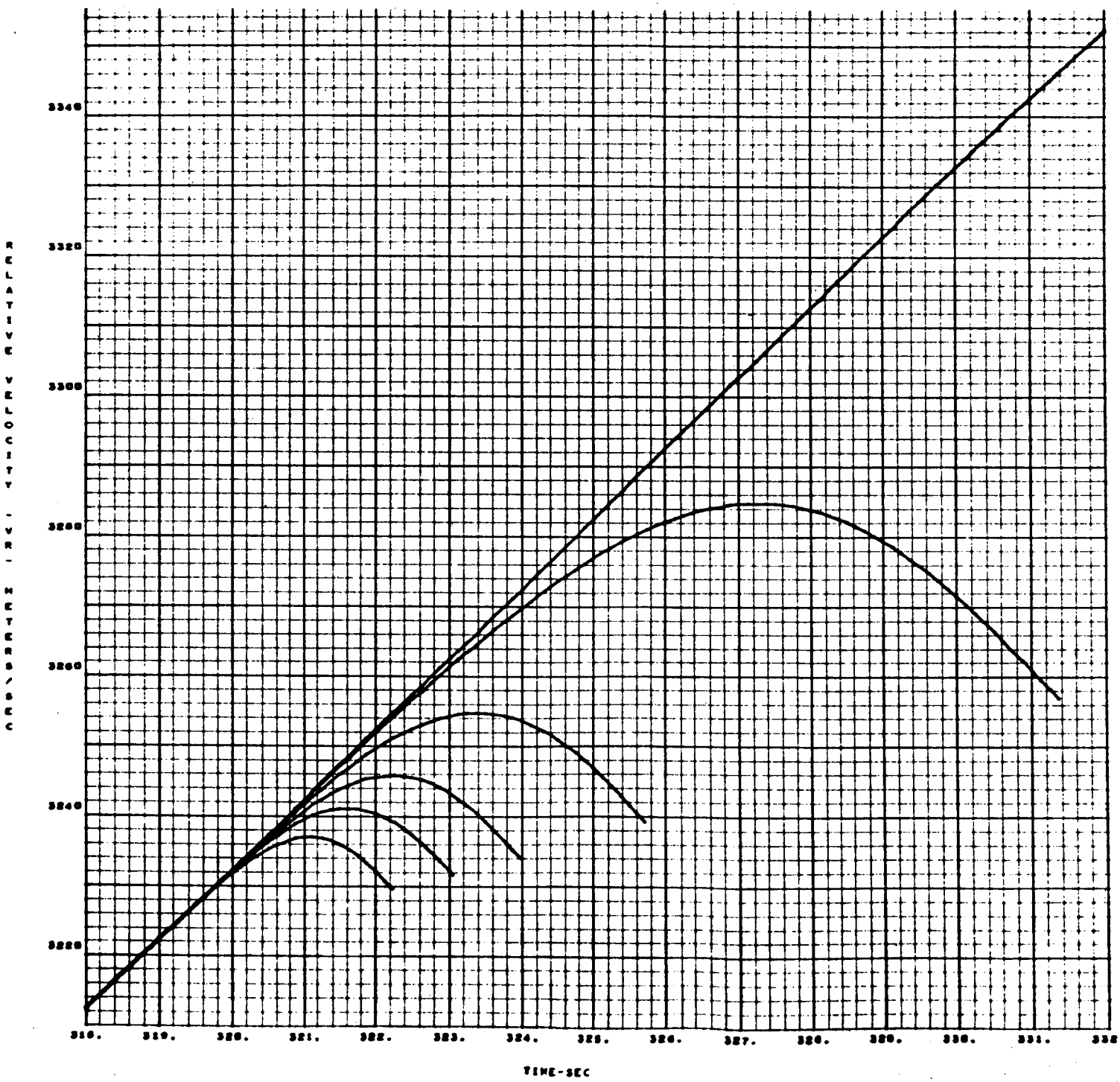


Figure 108

EARTH-FIXED VELOCITY VERSUS TIME
FOR MALFUNCTION AT t_i = 334 sec

(β_y = 10.0, 7.0, 5.0, 3.0, 1.0, 0.1 deg)

β_y is the thrust vector deflection angle in the yaw plane

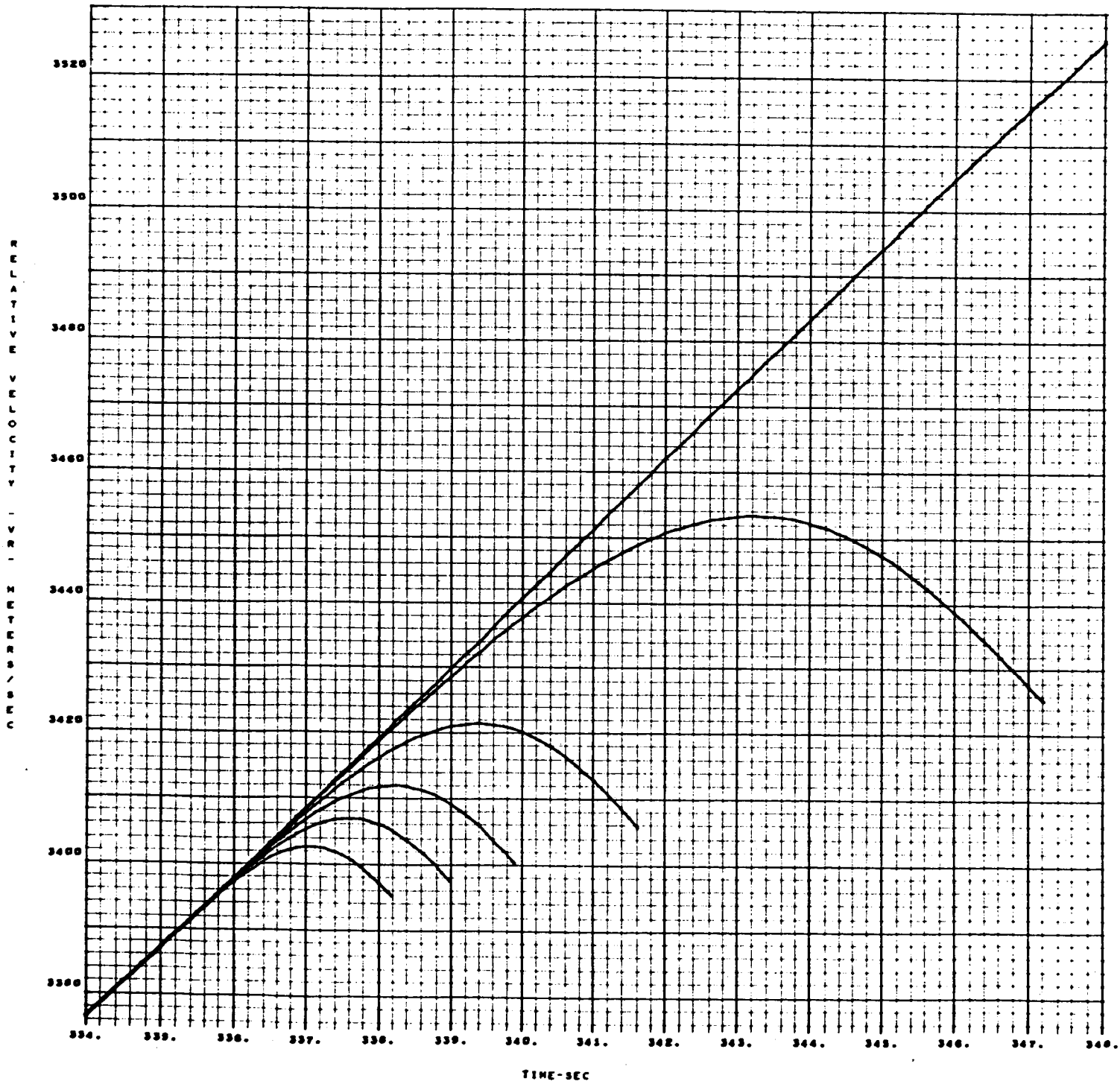


Figure 109

EARTH-FIXED VELOCITY VERSUS TIME
FOR MALFUNCTION AT t_i = 350 sec

(β_y = 10.0, 7.0, 5.0, 3.0, 1.0, 0.1 deg)

β_y is the thrust vector deflection angle in the yaw plane

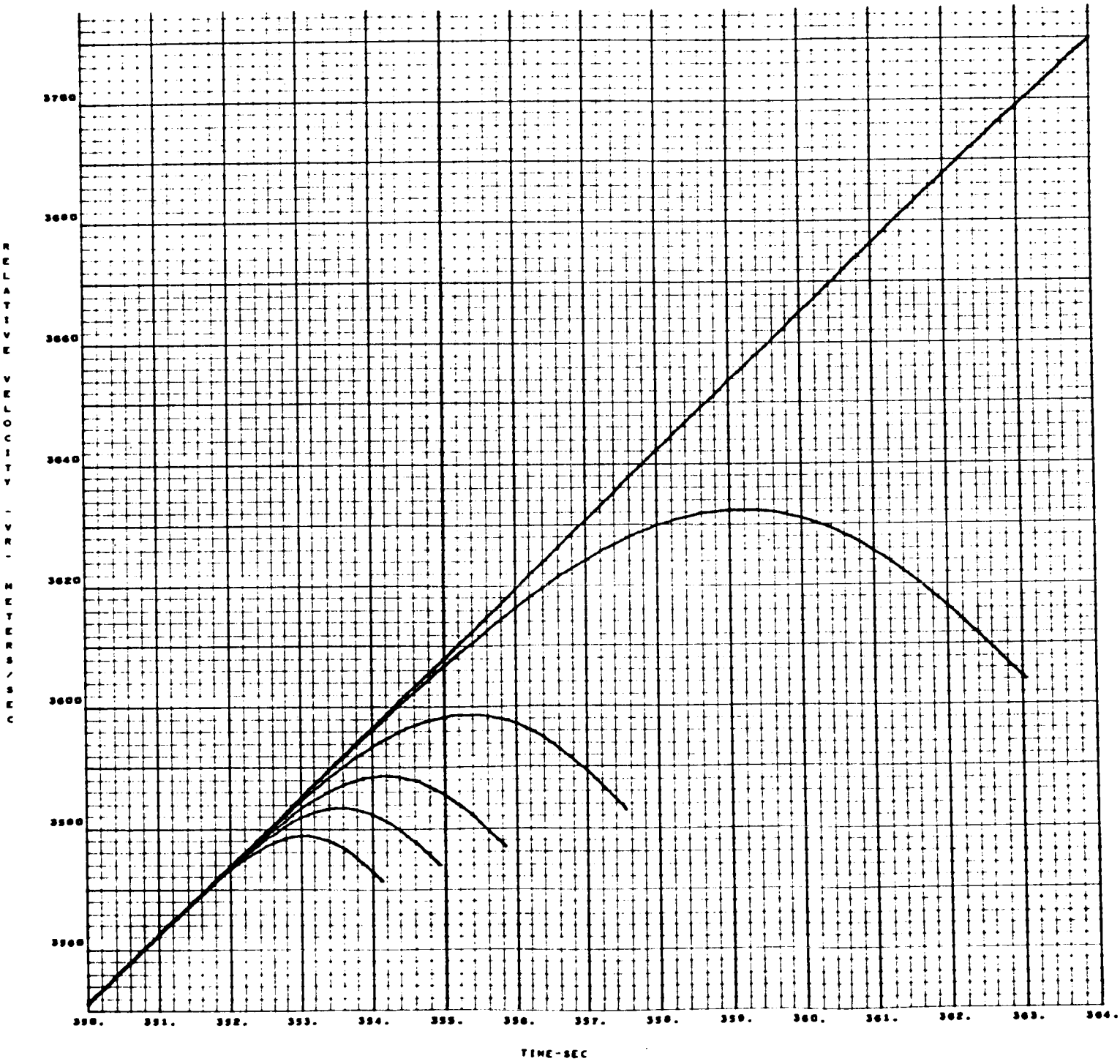


Figure 110

EARTH-FIXED VELOCITY VERSUS TIME
FOR MALFUNCTION AT t_i = 366 sec

(β_y = 10.0, 7.0, 5.0, 3.0, 1.0, 0.1 deg)

β_y is the thrust vector deflection angle in the yaw plane

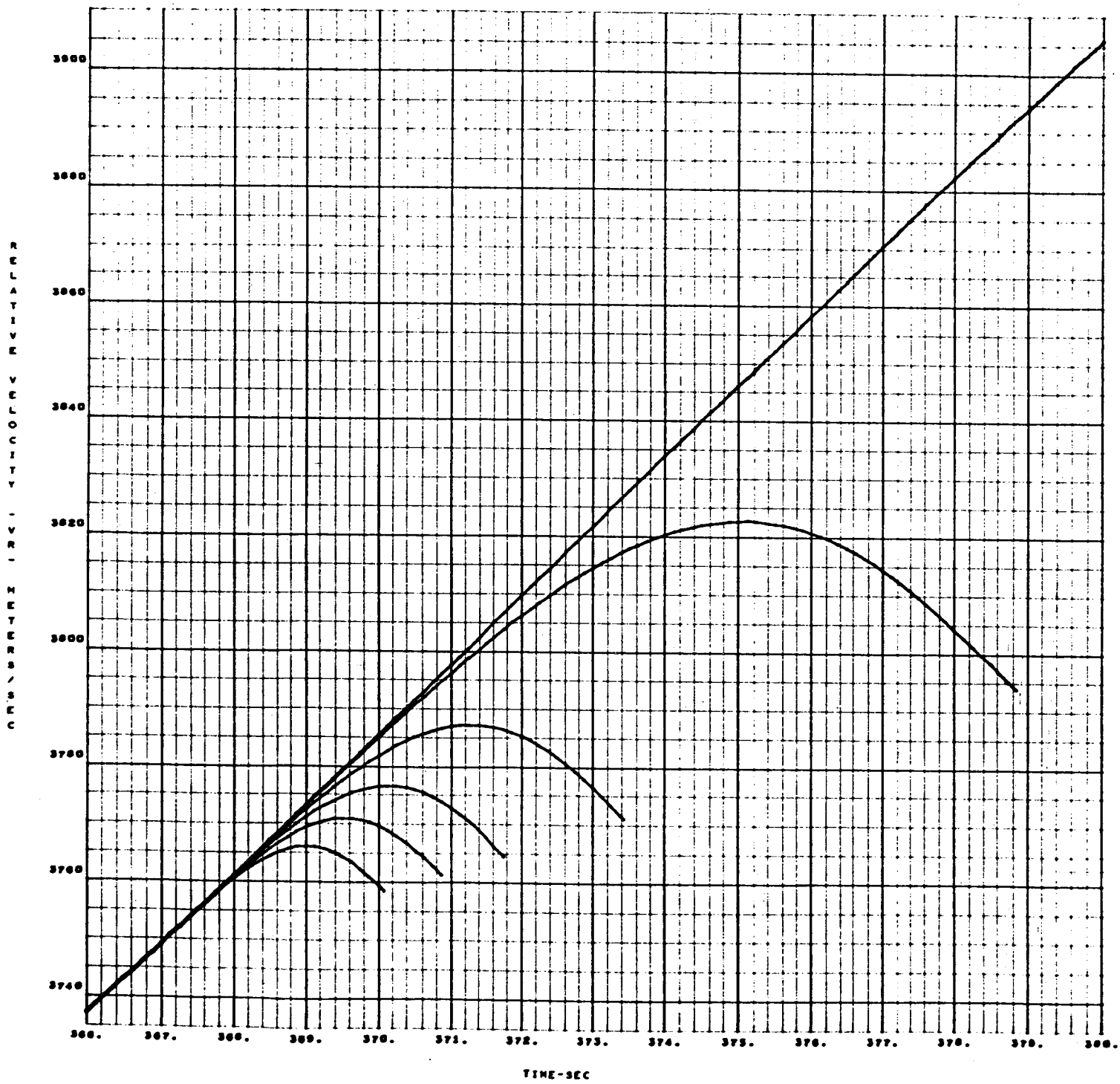


Figure 111

EARTH-FIXED VELOCITY VERSUS TIME
FOR MALFUNCTION AT t_i = 382 sec

(β_y = 10.0, 7.0, 5.0, 3.0, 1.0, 0.1 deg)

β_y is the thrust vector deflection angle in the yaw plane

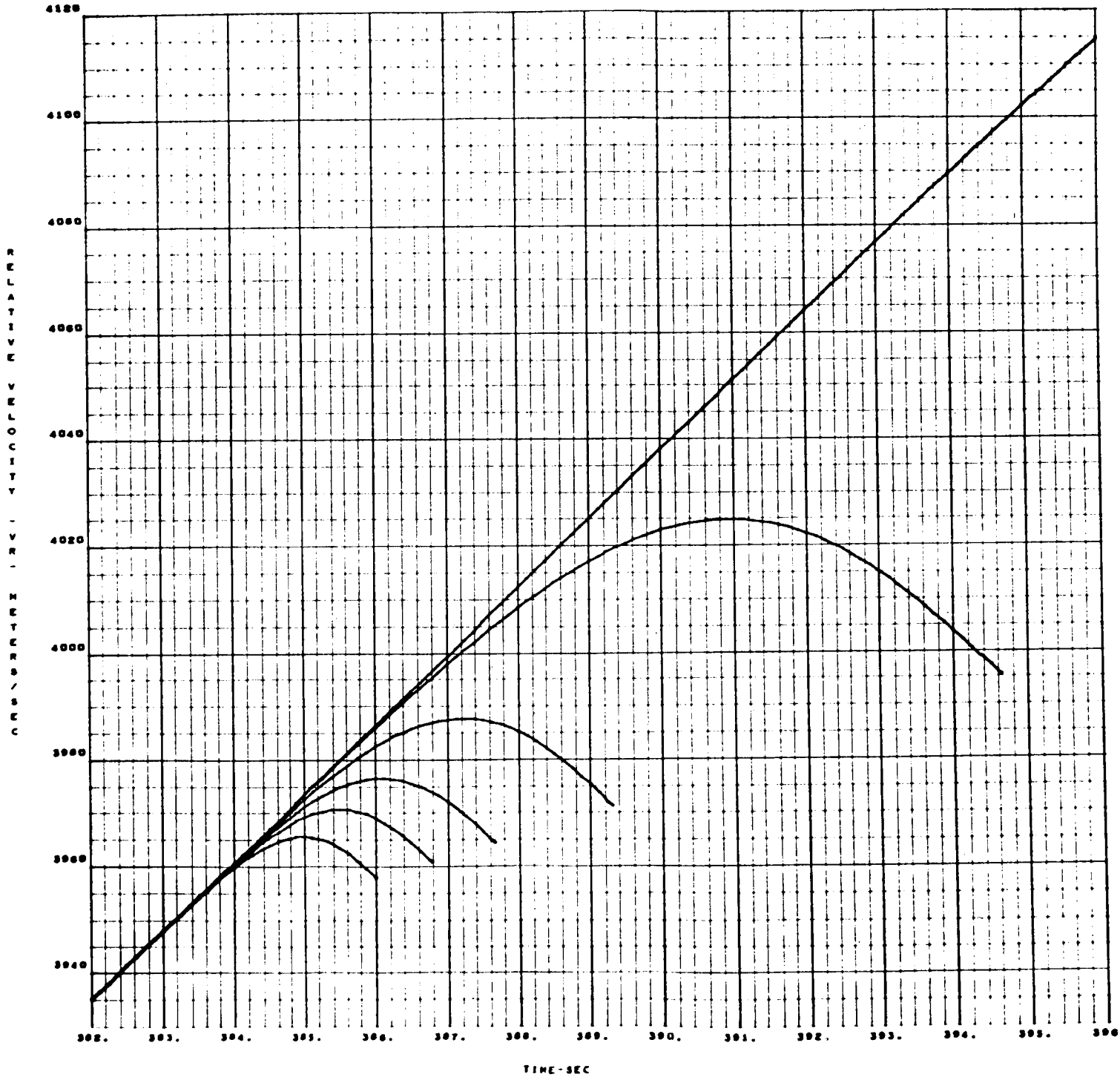


Figure 112

EARTH-FIXED VELOCITY VERSUS TIME
FOR MALFUNCTION AT t_i = 398 sec

(β_y = 10.0, 7.0, 5.0, 3.0, 1.0, 0.1 deg)

β_y is the thrust vector deflection angle in the yaw plane

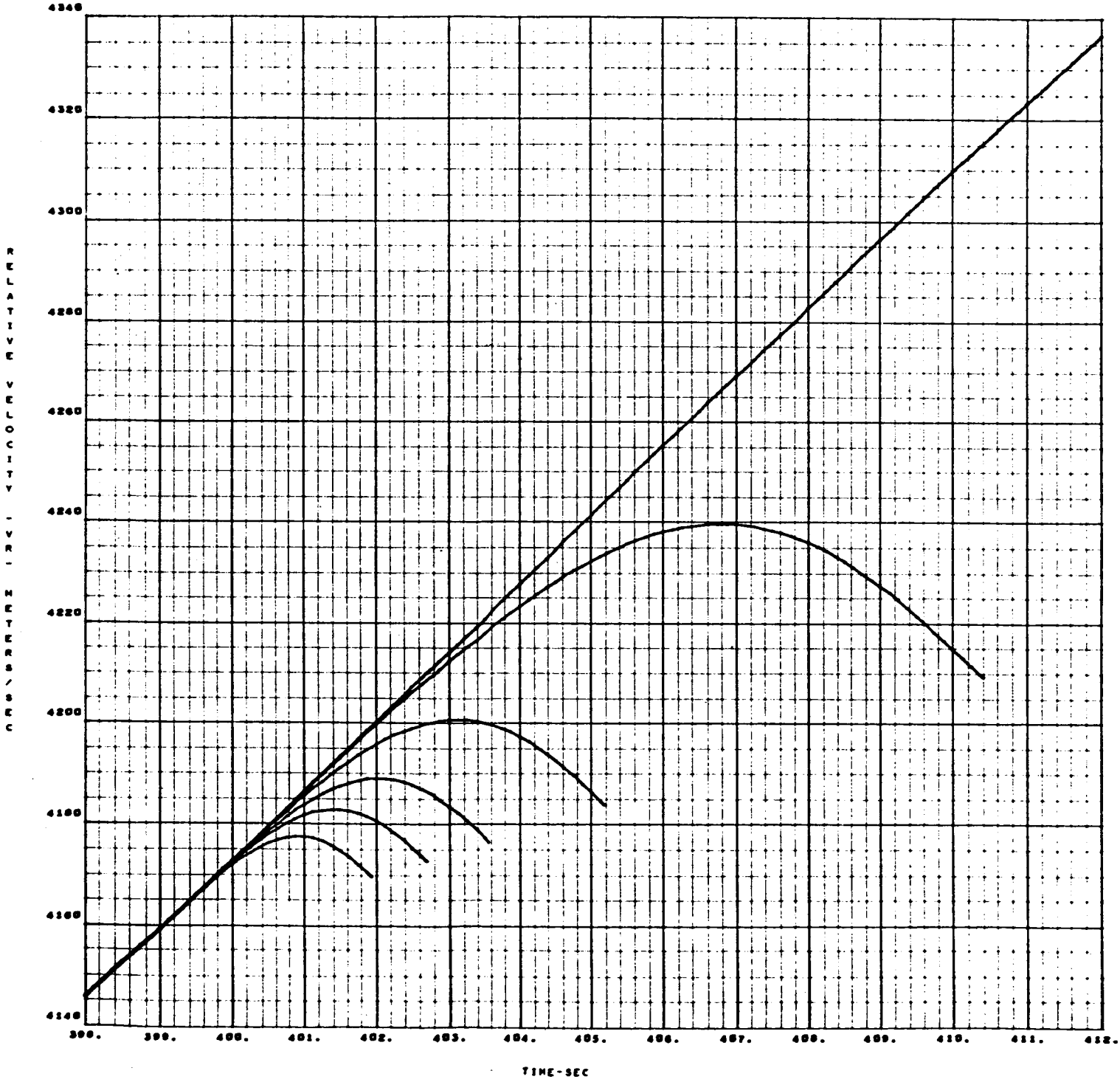


Figure 113

EARTH-FIXED VELOCITY VERSUS TIME
FOR MALFUNCTION AT t_i = 414 sec

(β_y = 10.0, 7.0, 5.0, 3.0, 1.0, 0.1 deg)

β_y is the thrust vector deflection angle in the yaw plane

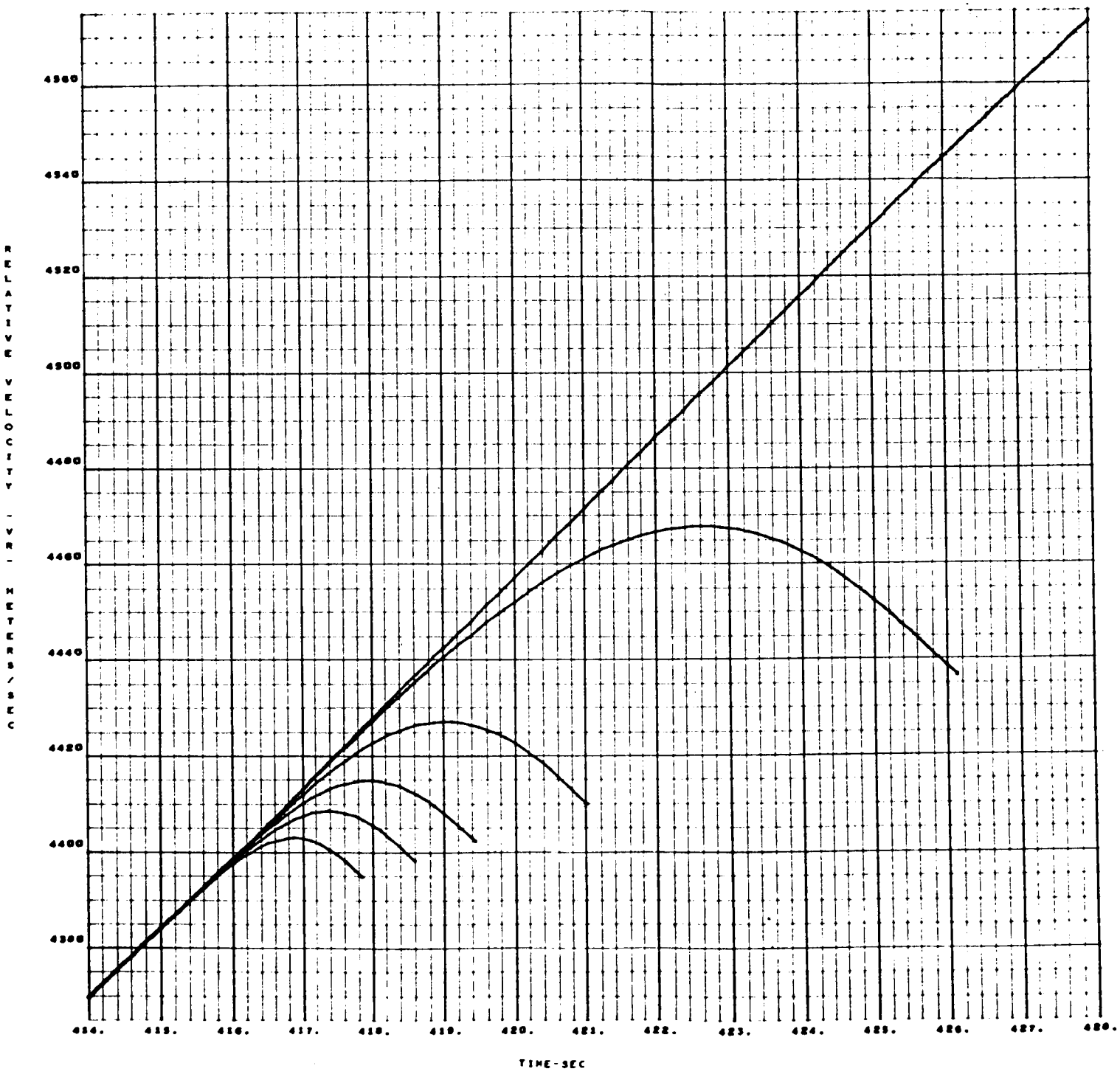


Figure 114

EARTH-FIXED VELOCITY VERSUS TIME
FOR MALFUNCTION AT t_i = 430 sec

(β_y = 10.0, 7.0, 5.0, 3.0, 1.0, 0.1 deg)

β_y is the thrust vector deflection angle in the yaw plane

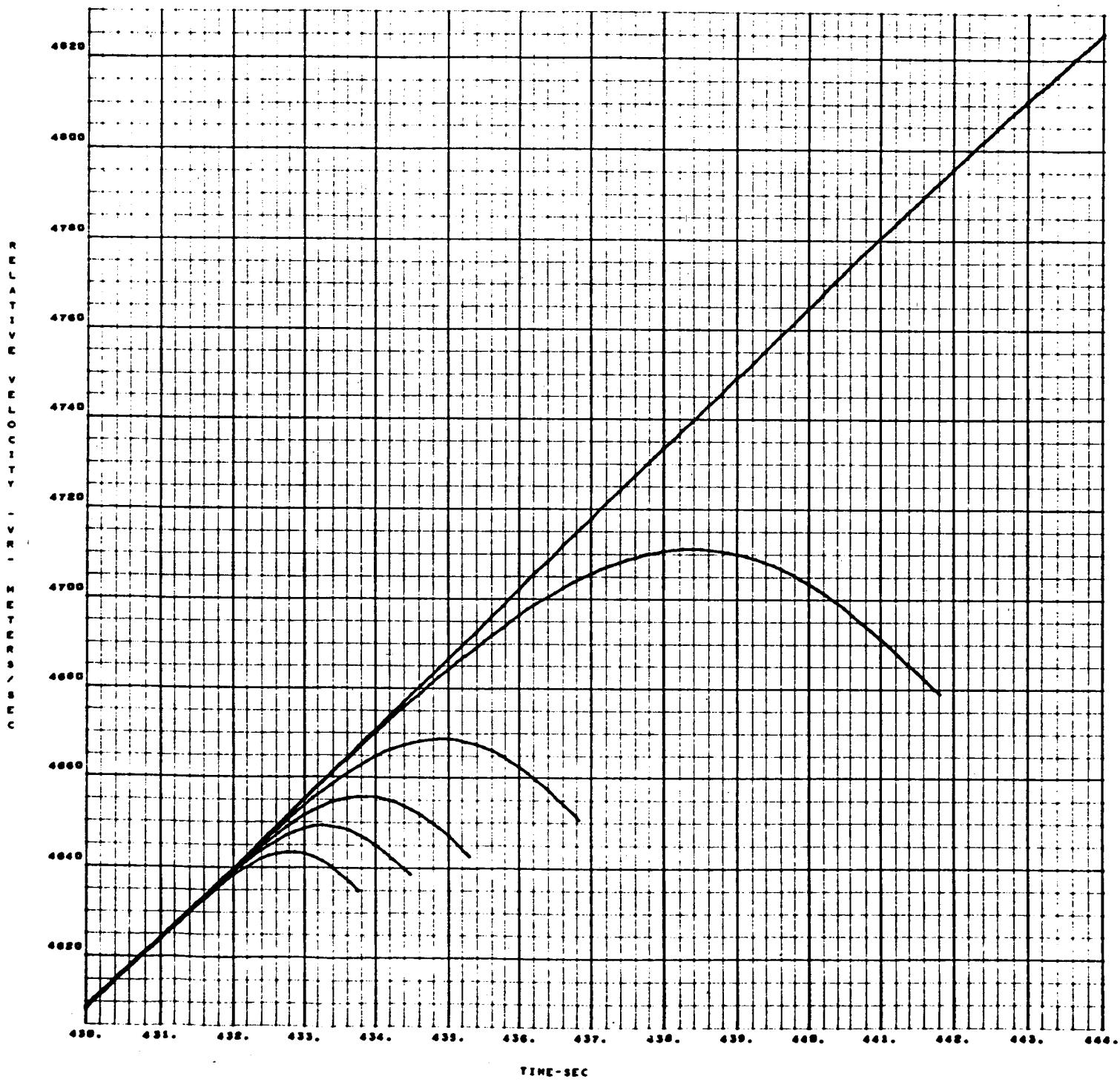


Figure 115

EARTH-FIXED VELOCITY VERSUS TIME
FOR MALFUNCTION AT t_i = 446 sec

(β_y = 10.0, 7.0, 5.0, 3.0, 1.0, 0.1 deg)

β_y is the thrust vector deflection angle in the yaw plane

Figure 116

EARTH-FIXED VELOCITY VERSUS TIME
FOR MALFUNCTION AT t_i = 462 sec

(β_y = 10.0, 7.0, 5.0, 3.0, 1.0, 0.1 deg)

β_y is the thrust vector deflection angle in the yaw plane

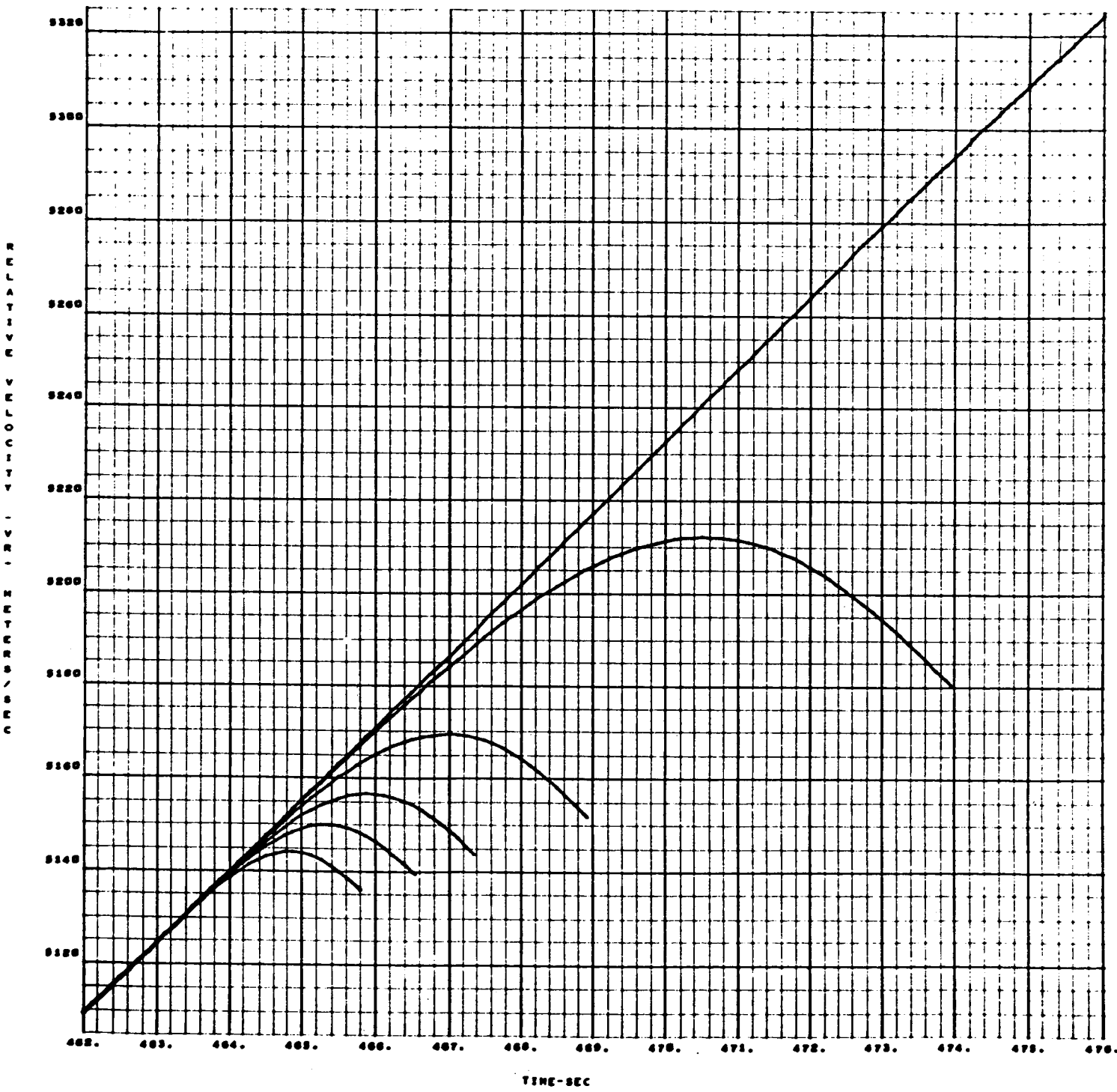


Figure 117

EARTH-FIXED VELOCITY VERSUS TIME
FOR MALFUNCTION AT t_i = 478 sec

(β_y = 10.0, 7.0, 5.0, 3.0, 1.0, 0.1 deg)

β_y is the thrust vector deflection angle in the yaw plane

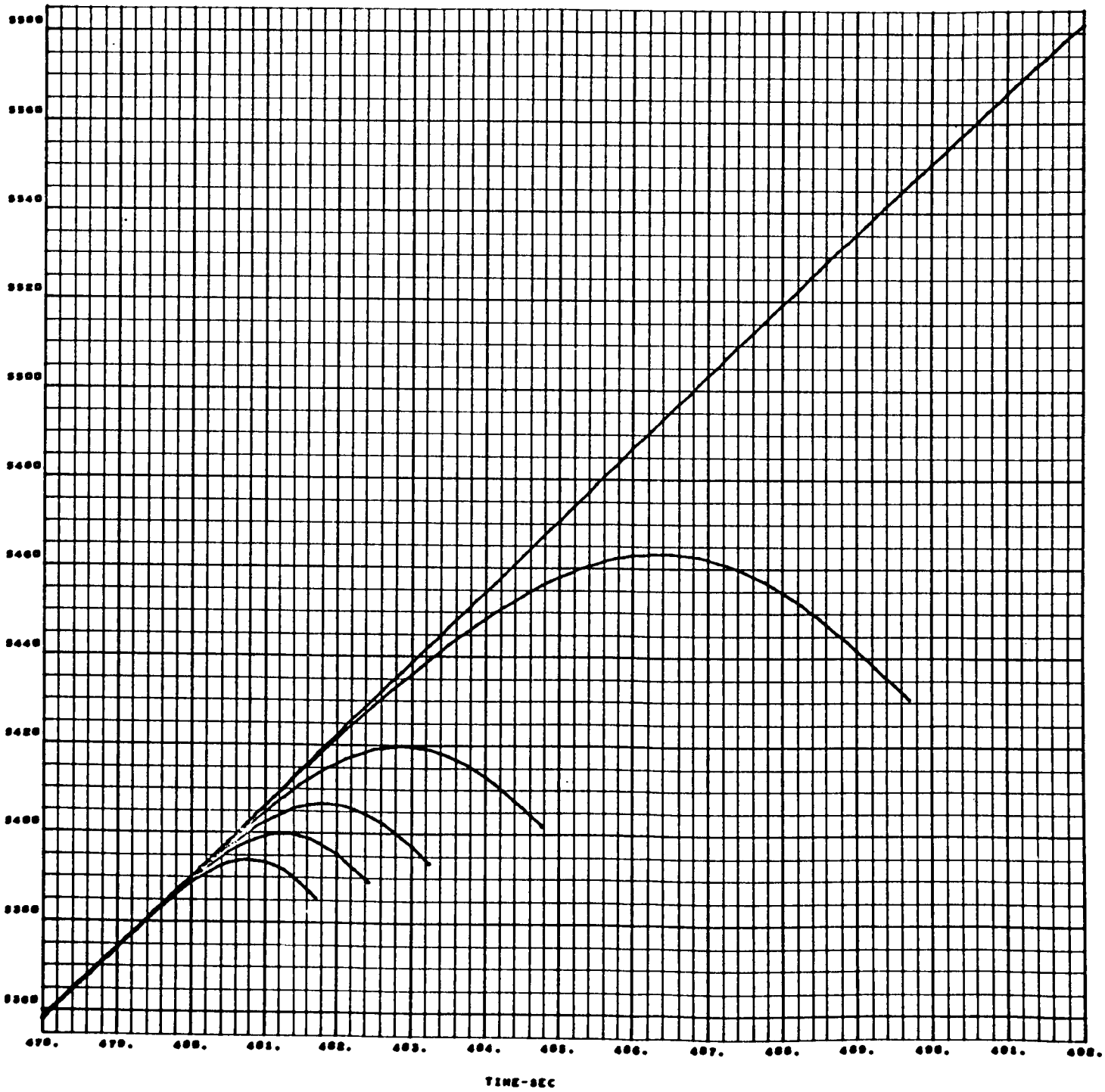


Figure 118

EARTH-FIXED VELOCITY VERSUS TIME
FOR MALFUNCTION AT t_i = 494 sec

(β_y = 10.0, 7.0, 5.0, 3.0, 1.0, 0.1 deg)

β_y is the thrust vector deflection angle in the yaw plane

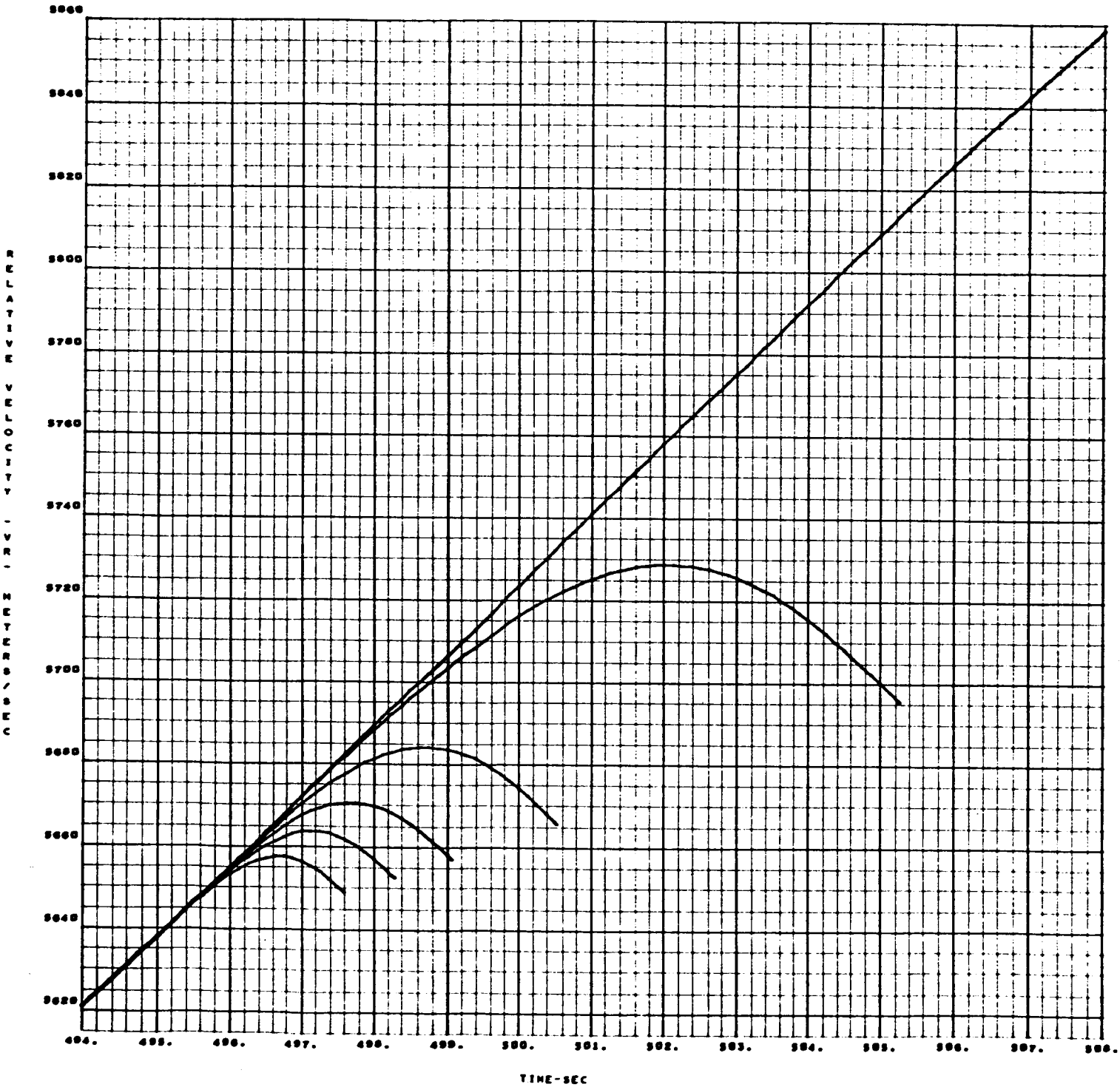


Figure 119

EARTH-FIXED VELOCITY VERSUS TIME
FOR MALFUNCTION AT t_i = 510 sec

(β_y = 10.0, 7.0, 5.0, 3.0, 1.0, 0.1 deg)

β_y is the thrust vector deflection angle in the yaw plane

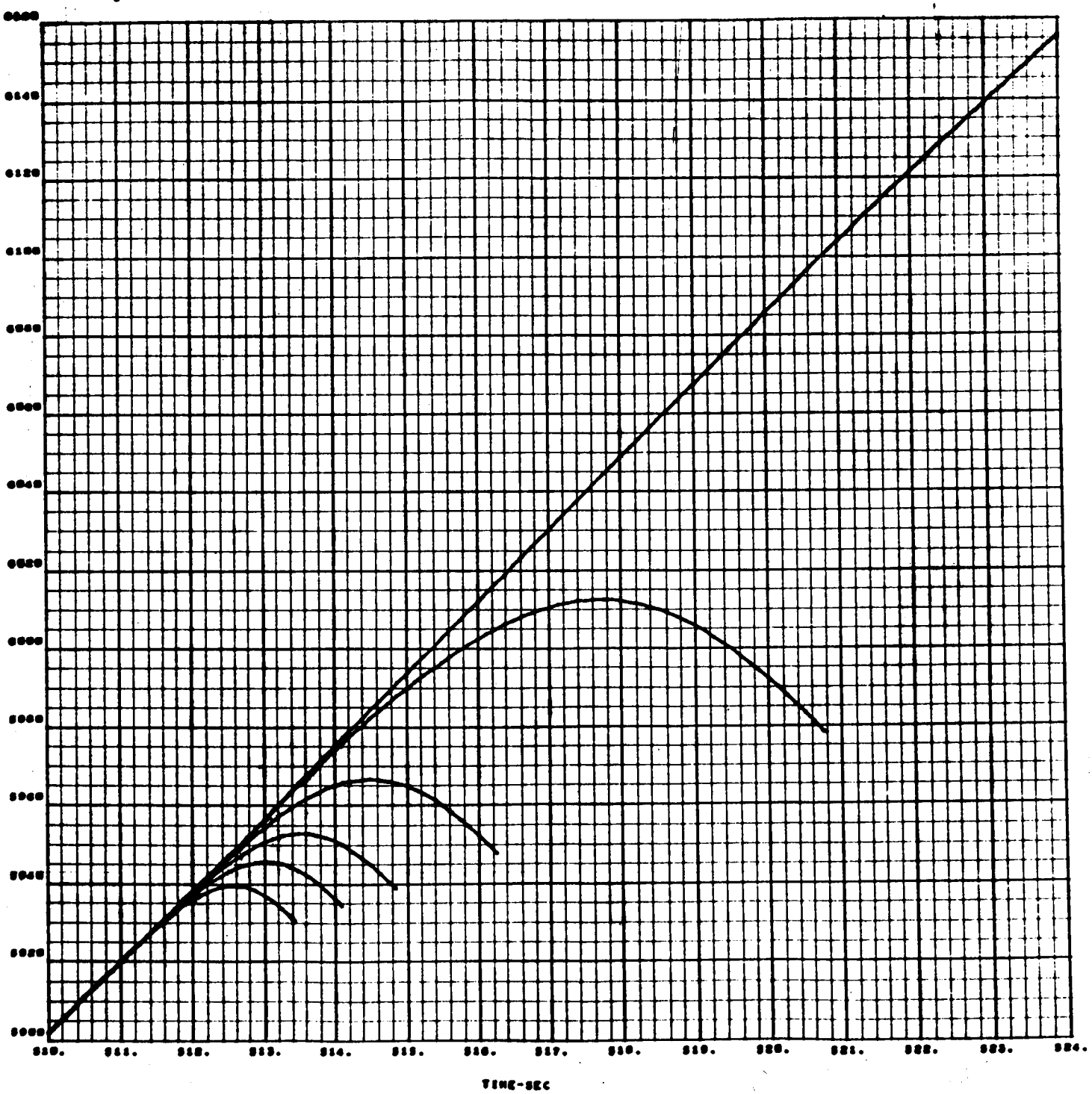


Figure 120

EARTH-FIXED VELOCITY VERSUS TIME
FOR MALFUNCTION AT t_i = 526 sec

(β_y = 10.0, 7.0, 5.0, 3.0, 1.0, 0.1 deg)

β_y is the thrust vector deflection angle in the yaw plane

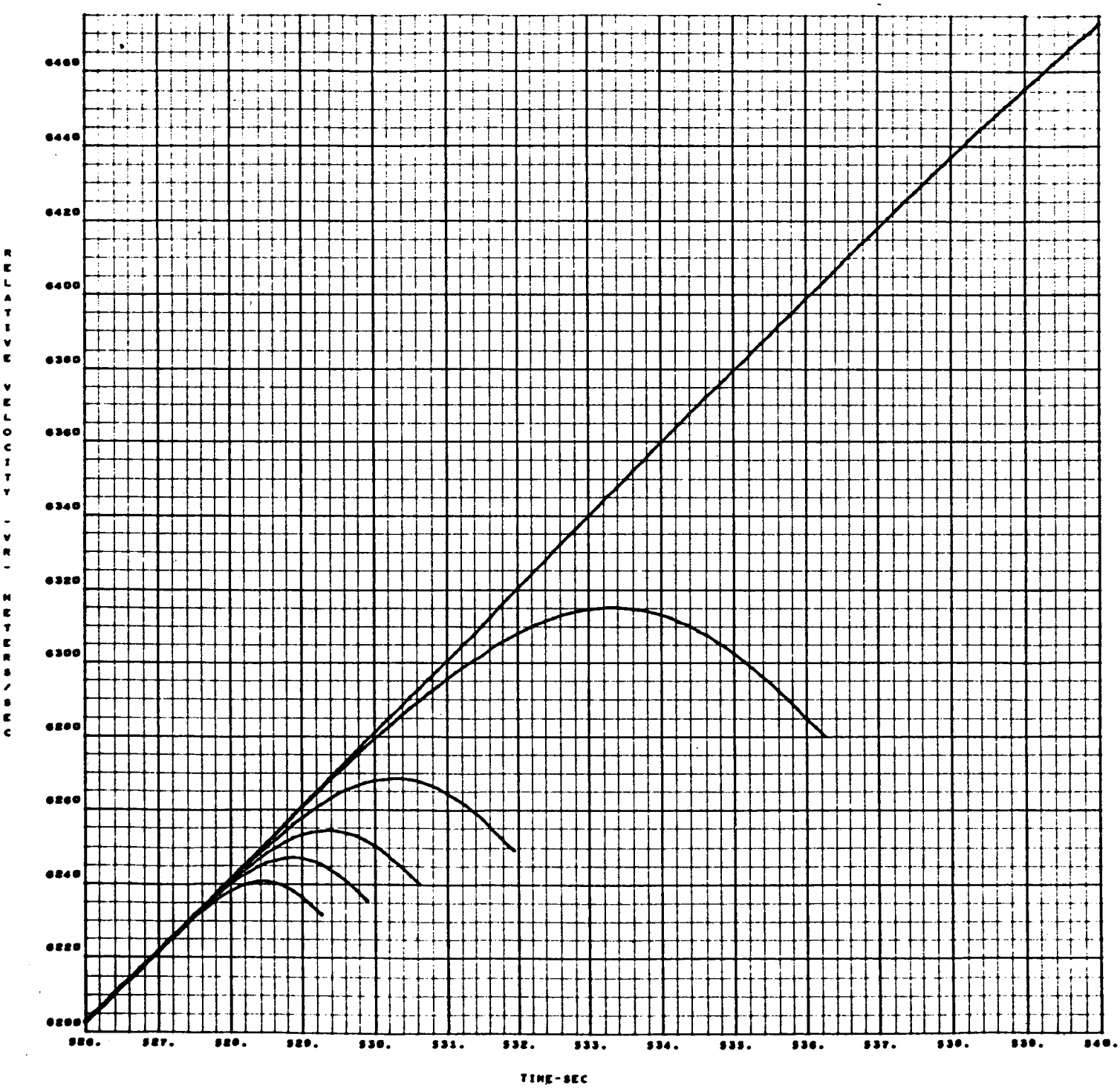


Figure 121

EARTH-FIXED VELOCITY VERSUS TIME
FOR MALFUNCTION AT t_i = 542 sec

(β_y = 10.0, 7.0, 5.0, 3.0, 1.0, 0.1 deg)

β_y is the thrust vector deflection angle in the yaw plane

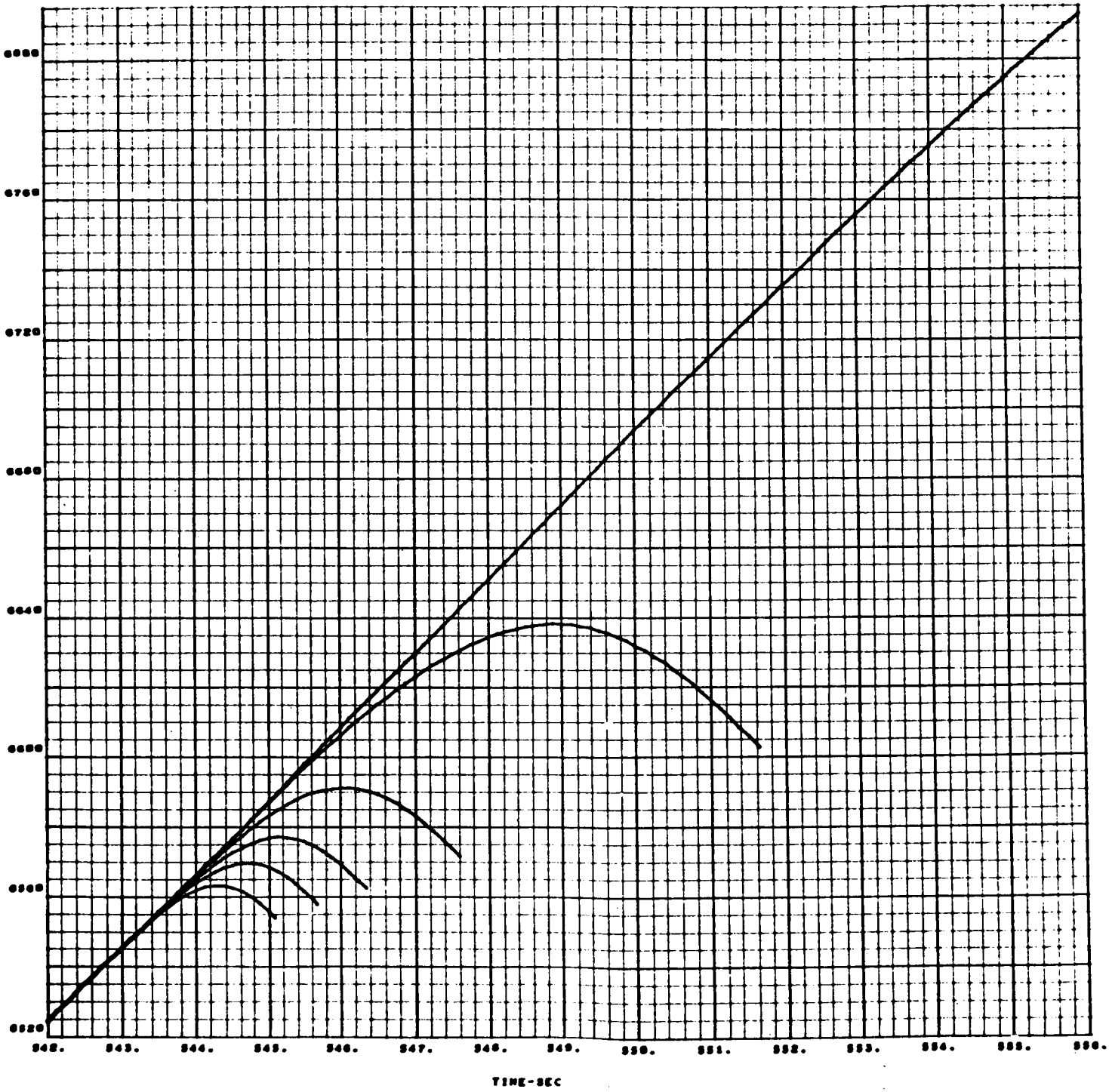


Figure 122

EARTH-FIXED VELOCITY VERSUS TIME
FOR MALFUNCTION AT t_i = 558 sec

(β_y = 10.0, 7.0, 5.0, 3.0, 1.0, 0.1 deg)

β_y is the thrust vector deflection angle in the yaw plane

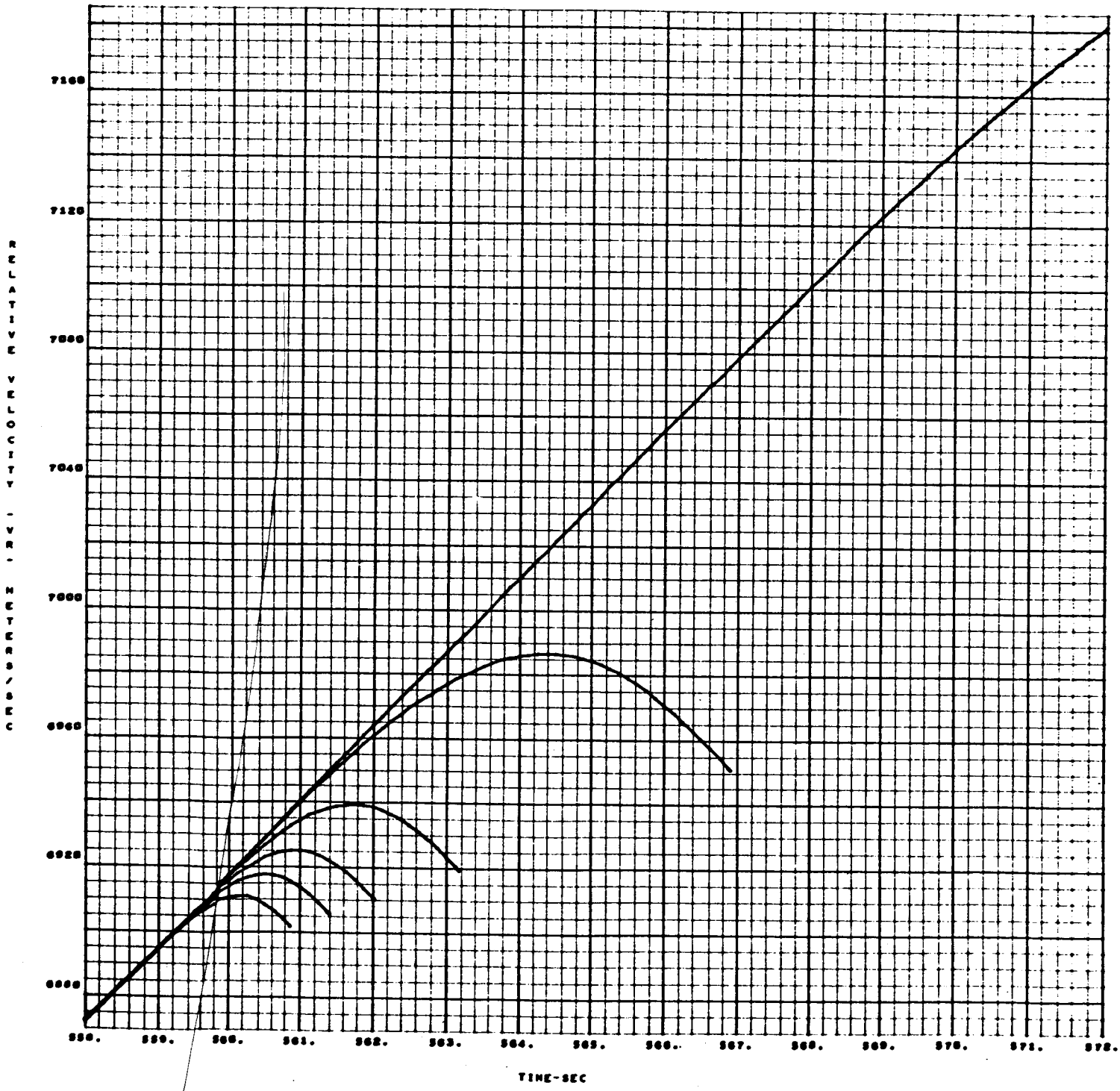


Figure 123

EARTH-FIXED VELOCITY VERSUS TIME
FOR MALFUNCTION AT t_i = 574 sec

(β_y = 10.0, 7.0, 5.0, 3.0, 1.0, 0.1 deg)

β_y is the thrust vector deflection angle in the yaw plane

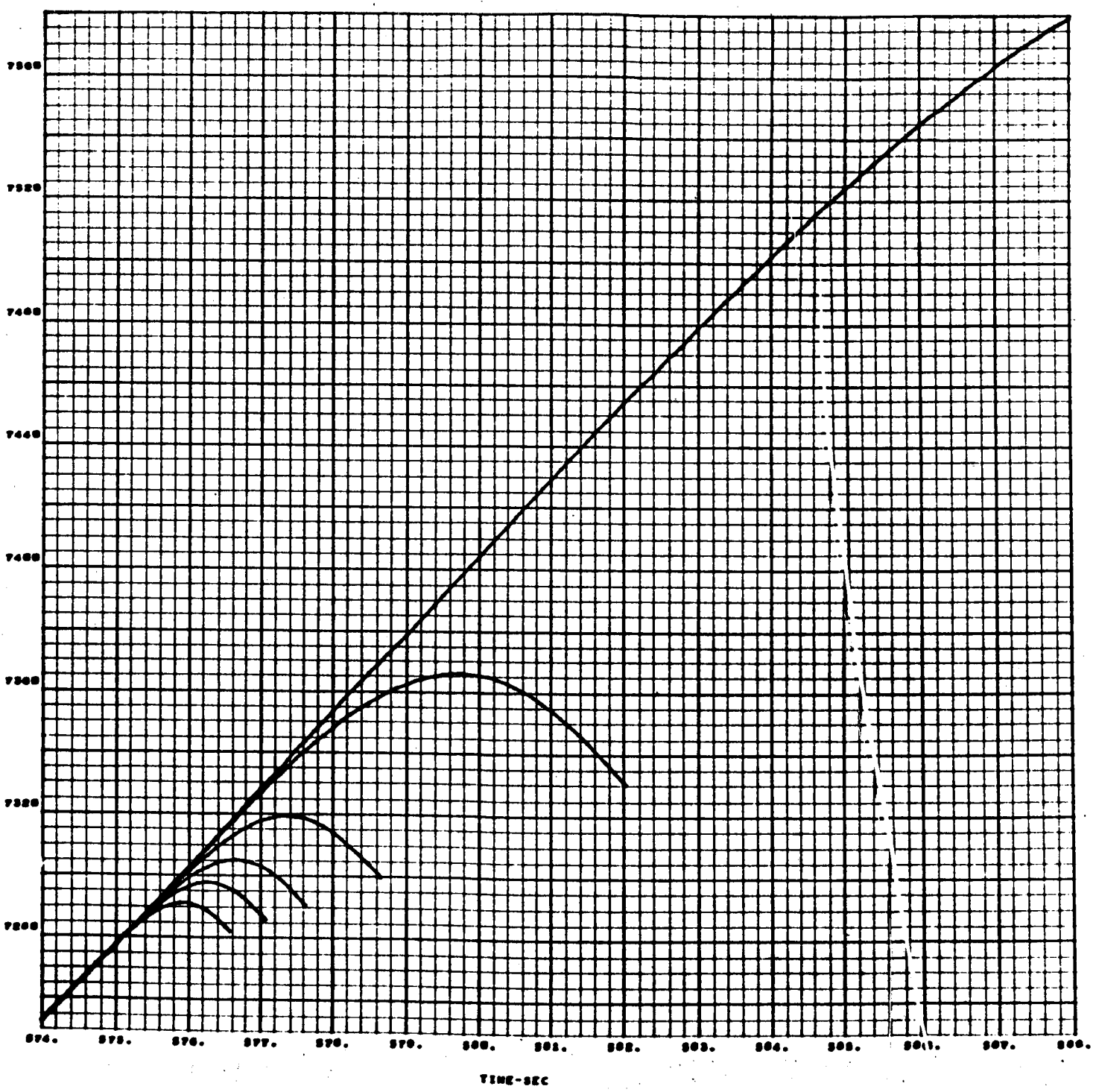


Figure 124

SATURN IB AS-206 LAUNCH VEHICLE
FLIGHT PROFILE (PITCH PLANE)

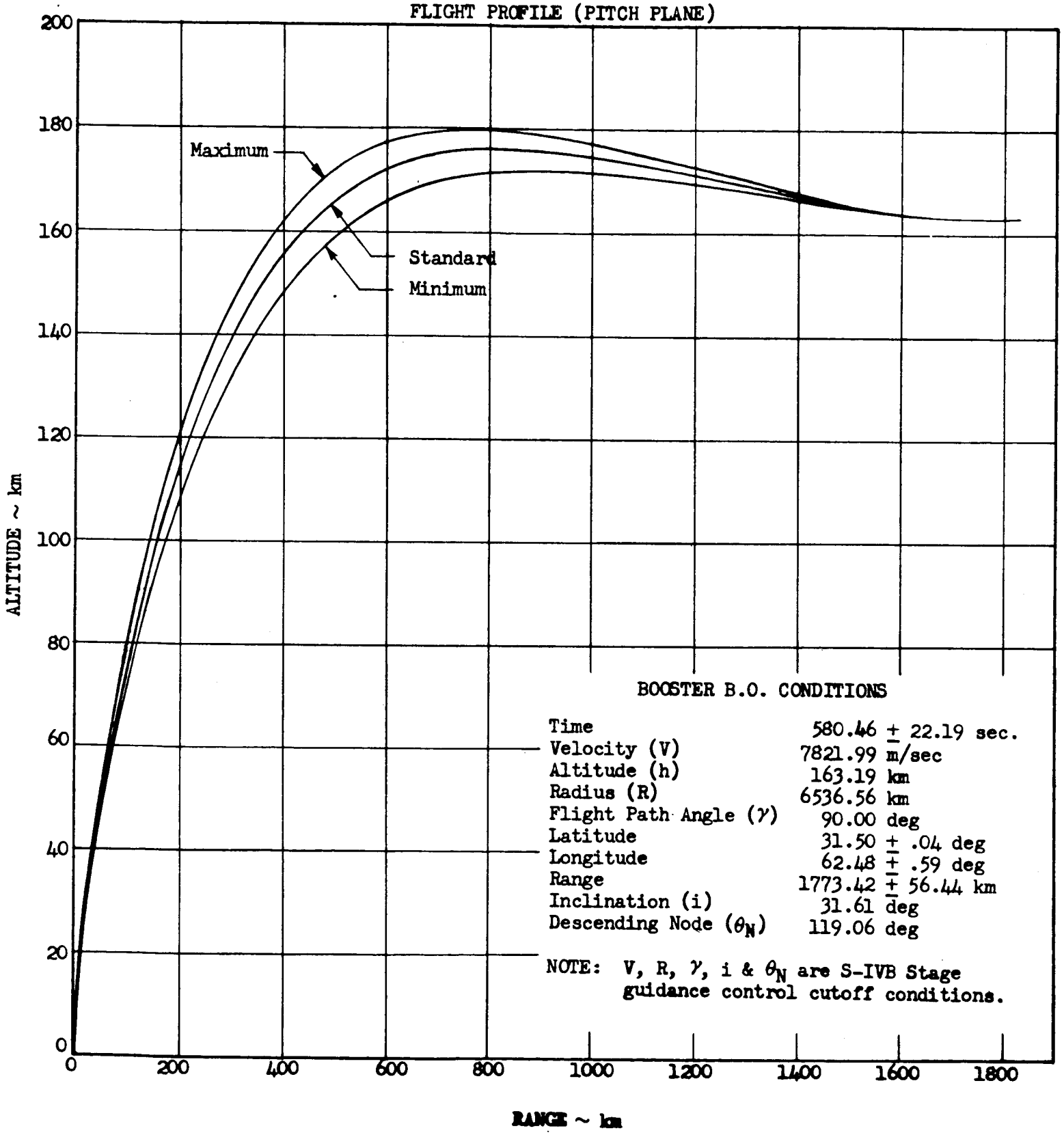
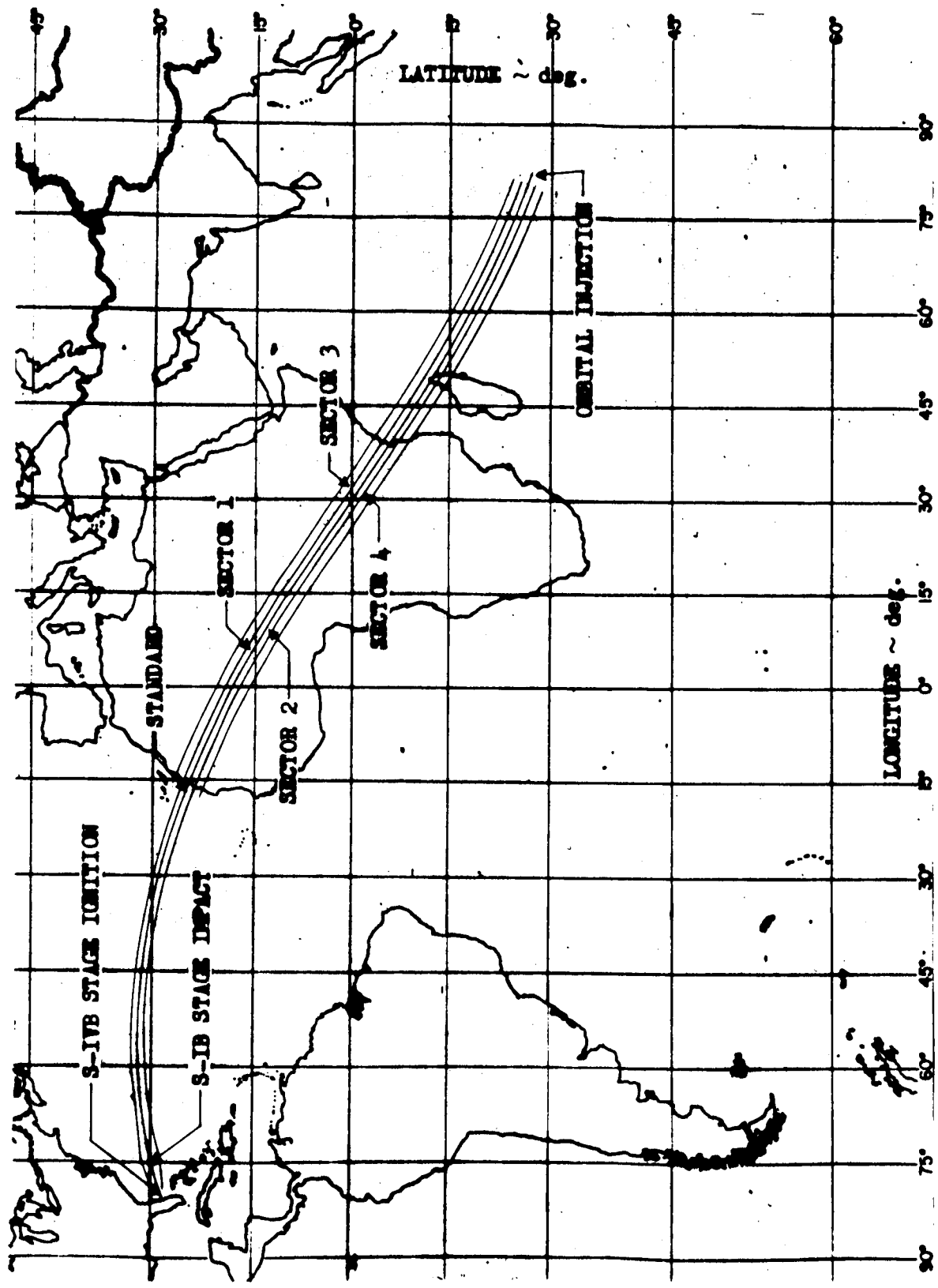
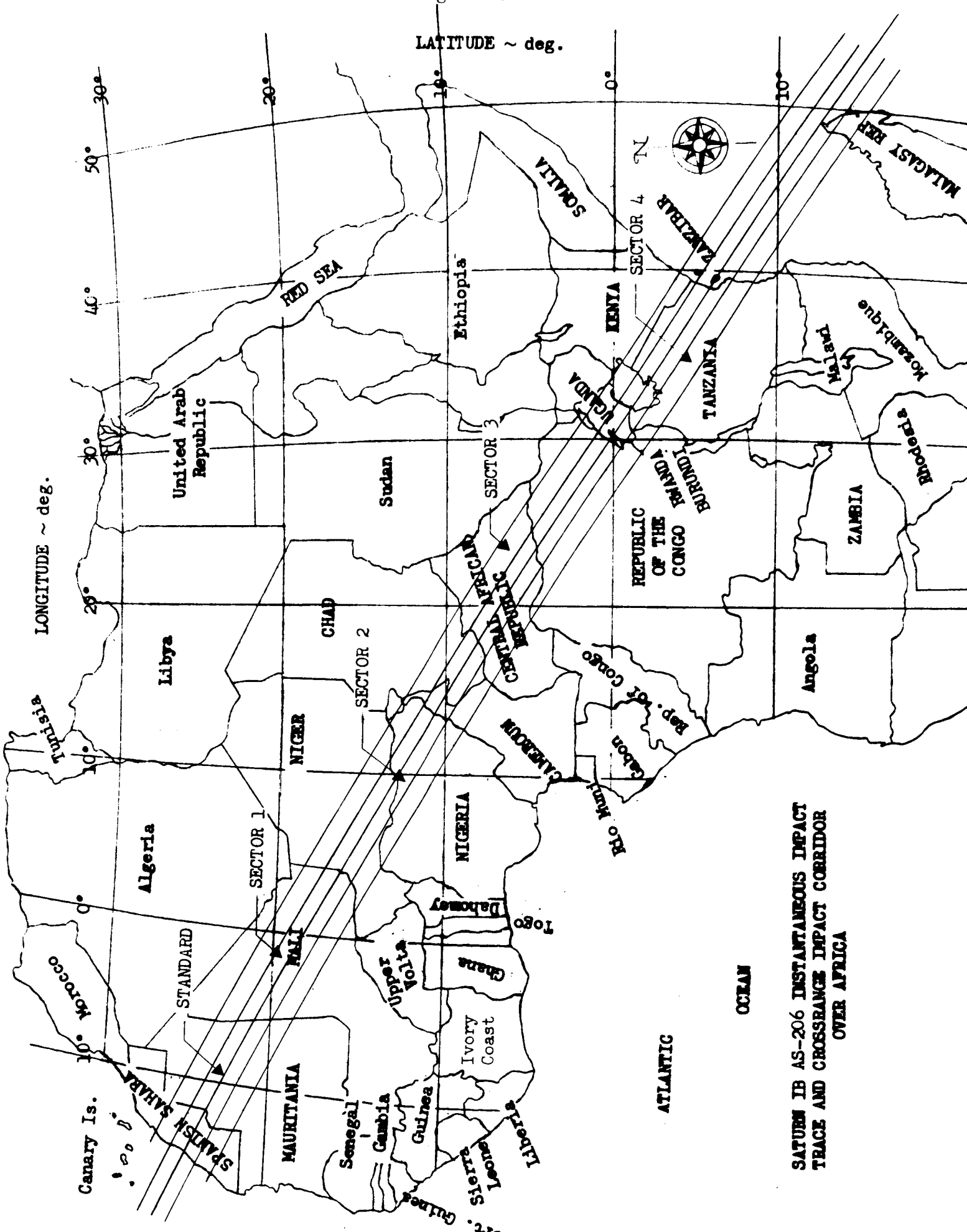


Figure 125



SATURN IB AS-206 INSTANTANEOUS IMPACT
TRACE AND CROSSRANGE IMPACT CORRIDOR

Figure 126



SATURN IB AS-206 INSTANTANEOUS IMPACT TRACE AND CROSSRANGE IMPACT CORRIDOR OVER AFRICA