AFFDL - TR - 70 - 1
PART II, VOLUME I

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STUDY AND DESIGN OF AN EJECTION SYSTEM FOR VTOL AIRCRAFT

PART II, VOLUME I

ESCAPE SEAT SYSTEM CONCEPT ANALYSIS

E. O. CARTWRIGHT, Jr.
I. L. CLINKENBEARD

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Vought Aeronautics Division
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Technical Report AFFDL - TR - 70 - 1, PART II, VOLUME I

JUNE 1970

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The distribution of this report is limited because it describes the capabilities and limitations of crew escape concepts for aerospace vehicles in VTOL and conventional take off and landing situations.

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FOREWORD

This report was prepared by the Vought Aeronautics Division of the LTV Aerospace Corporation, a subsidiary of Ling-Temco-Vought, Inc., under Air Force Contract F33615-69-C-1692. This contract was initiated under Project 1362, "Crew Escape for Flight Vehicles", Task No. 136203, "Crew Escape Techniques Research". The program is administered under the direction of the Recovery and Crew Station Branch, Vehicle Equipment Division, Air Force Flight Dynamics Laboratory, Air Force Systems Command, Wright-Patterson Air Force Base, Ohio. Mr. B. J. White (FDFR) was the Air Force Project Engineer.

This report covers work conducted during the period April 1969 to April 1970. It was submitted by the authors in April 1970.

The documentation of this project necessitates publication in several parts. The total documentation includes:

Part I
- Volume 1 - VTOL Aircraft Equations and Failure Mode Analysis
- Volume 2 - Escape System Parameters Analysis
- Volume 3 - Computer Program User's Manual for VTOL Escape System Simulation

Part II
- Volume 1 - Escape Seat Systems Concept Analysis
- Volume 2 - Escape Seat Subsystems and Detail Drawings

The authors wish to express their thanks to the following LTV Crew Systems Design Engineers who contributed to the system design and to this report; Mr. W. T. Timmons, Mr. James Harding, Mr. Tom Harper, Mr. Ray Parrish, and Mr. Richard McClung.

This technical report has been reviewed and is approved.

George A. Solt, Jr.

GEORGE A. SOLT, JR.
Chief, Recovery and Crew Station Branch
Vehicle Equipment Division
Air Force Flight Dynamics Laboratory

ABSTRACT

An ejection seat escape system is described for a hypothetical two-place fighter-attack VTOL aircraft. The system includes an emergency detection and escape initiation subsystem which functions independently of the crew. The performance required of the system is developed by an analysis of the parent aircraft modes of failure. The trajectory behavior of each of the seats in VTOL and conventional flight failures is presented in the form of time history plots generated by a six degree-of-freedom digital computer simulation.

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LIST OF TABLES

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1.0 INTRODUCTION AND SUMMARY

The basic objective of this study was to design an ejection seat escape system that is able to provide safe crew escape from fighter/attack VTOL aircraft during emergencies in the VTOL and high speed, low altitude flight regimes. It was stipulated at the outset that the design must be built on a totally analytical foundation employing a computer simulation to account for all system interactions from aircraft failure occurrence to crew recovery.

To fulfill the overall program objective, a logical sequence of intermediate objectives was planned. In Part I, Volume 1 of this five volume report, the first series of objectives are discussed. They are:

- Select a hypothetical aircraft as a basis for escape system design.
- Establish the failure modes which influence the escape system design.
- Provide an aircraft dynamic analysis to define the post-failure behavior of the aircraft.

In Part I, Volume 2 another set of interim objectives is accomplished. They are:

- An analytical study to arrive at approximations of the performance of drag parachute stabilizers while operating behind an ejection seat in flight.
- An analysis that constitutes a detailed study of the separation dynamics of the ejection seat as it moves along and separates from the guide rails.
- An evaluation of ejection propulsion techniques through a comparative analysis of rocket/catapult designs and a determination of the consequences on performance and trajectory.

This volume, Part II, Volume 1, is devoted to the establishment of the escape system performance required to meet the program objective, a description of a suitable system, and the results of the computer simulation of the system which substantiates the fact that the system described does in fact provide safe escape from the critical failure modes that may be experienced in VTOL or conventional flight.

The escape system described in this report has sufficient performance to insure recovery of both crew members above the ejection altitude following the critical failures in the VTOL and transition flight regimes.

The salient system features which help to provide this performance are:

- Timely ejection initiation by means of an automatic system which senses an emergency situation and responds by firing the seat catapult more rapidly than is humanly possible.
- Sequencing of post ejection events based on conditions of aircraft attitude, attitude rate and speed.
- A drogue parachute system suitable for subsonic and supersonic speeds.
- A personnel parachute system configured to provide line stretch in less than 300 milliseconds in hover flight.
- An ejection propulsion system which provides tailoring of the trajectory based on aircraft attitude and attitude rate.

During this design activity the primary criteria in the selection or configuration of subsystems were to obtain sufficient performance to enable the total system to meet the program objectives. Of almost equal importance was the question of feasibility and simplicity of design. In the cases where qualified items were not satisfactory, the units recommended are only slightly different in design or make use of a different arrangement of existing components.

2.0 SYSTEM PERFORMANCE REQUIREMENTS

a. Program Objective

The objective of this program was to derive the design of an ejection seat escape system that will provide safe emergency crew escape under the extreme conditions encountered during emergencies in the VTOL and high speed, low altitude flight regimes.

The extreme conditions created by emergencies in VTOL and conventional flight have been defined and quantified by completing the following studies and analyses:

(1) The selection of a hypothetical aircraft representative of a second generation fighter-attack VTOL aircraft.

(2) The establishment of the failure modes characteristic of this aircraft which require crew escape.

(3) The determination of the dynamic behavior of the hypothetical aircraft subsequent to the failure modes in VTOL, transition and conventional flight regimes.

These activities are dealt with in detail in Part I, Volume 1 and the discussion herein will be brief.

b. Description of the Study Model Aircraft

It was the objective of the study model aircraft selection process to define a two-place configuration which would provide the most difficult escape environment.

After screening the propulsion systems potentially suitable for a high performance VTOL aircraft, the four aircraft listed below were selected as candidates for evaluation to select the study model.

- XV-5A (Fan in Wing)
- XV-4B (Direct Lift Engines)
- AV-6 (Deflected Thrust)
- ADAM III (Propulsive Wing)

Vehicle excursions following propulsion failure and full hardover control failures were computed to enable the selection of the most critical propulsion/control system arrangement.

From this analysis, it was concluded that the XV-5A propulsion/control configuration has the worst failure characteristics. It was selected as the simulator model for a detailed six-degree-of-freedom study with adjustments in data to permit the airplane to attain a 600 KEAS and 50,000 feet flight envelope.

The XV-5A aircraft, shown in Figures 1 and 2, is a twin engine, tri-fan (two wing fans and one nose fan), midwing, turbojet powered aircraft. The hover lift is produced by diverting engine exhaust gas through crossover ducts to drive the wing and nose fans. Pitch trim and control is provided by deflection of the nose fan jet by means of adjustable exit doors. Wing fan louvers are deflected in various combinations to produce height control, yaw and roll control and forward translation.

c. Description of Critical Failure Modes

A six degree-of-freedom computer simulation was constructed to perform a detailed analysis of the dynamic behavior of the study model aircraft. Time histories of acceleration, rate and position of the airplane, and of the crew station reactions to a variety of aircraft failure modes were generated and plotted. A detailed discussion of these modes of failure as well as the complete history of the study model aircraft response may be seen in the Part I, Volume 1 of this report.

The most critical failures in terms of aircraft excursions and sink rate are found to result from:

(1) Hard-over roll control failure during transition at 46 knots equivalent airspeed.

(2) Hard-over pitch control failure during transition at 46 knots equivalent airspeed.

(3) Complete propulsion failure during hover flight.

Time histories of the aircraft behavior subsequent to these failures are shown in Figures 3 through 31.

These three critical failures then are considered to constitute the most unfavorable VTOL conditions for crew escape and therefore become part of the escape system performance requirements in that the system must provide safe crew escape from these initial conditions.

Additional performance requirements for the VTOL escape system are those contained in MIL-S-9479A, "Seat System - Upward Ejection Aircraft, General Specification for" dated 16 June 1967. These requirements are listed in Table I.

TABLE I MIL-S-9479A REQUIREMENTS

	ATTITUDE				ALTITUDE AVAILABLE
CASE	PITCH	ROLL	SINK	VELOCITY	FOR RECOVERY
1	0	0	0	0	0
2	0	0	0	600 K	0
3	0	0	0	MN 2.0	Safe escape
4	0	60°	0	120 K	0
5	0	180°	0	150 K	200 Ft.
6	0	0	-10,000 FPM	150 K	300 Ft.
7	-60°	0	-17,500 FPM	200 K	500 Ft.
8	-60°	60°	-17,500 FPM	200 K	550 Ft.
9	-45°	180°	-18,000 FPM	250 K	600 Ft.

Case 4. Impact occurs at instant of seat/aircraft separation.
In all other cases, conditions are at initiation of escape sequence.

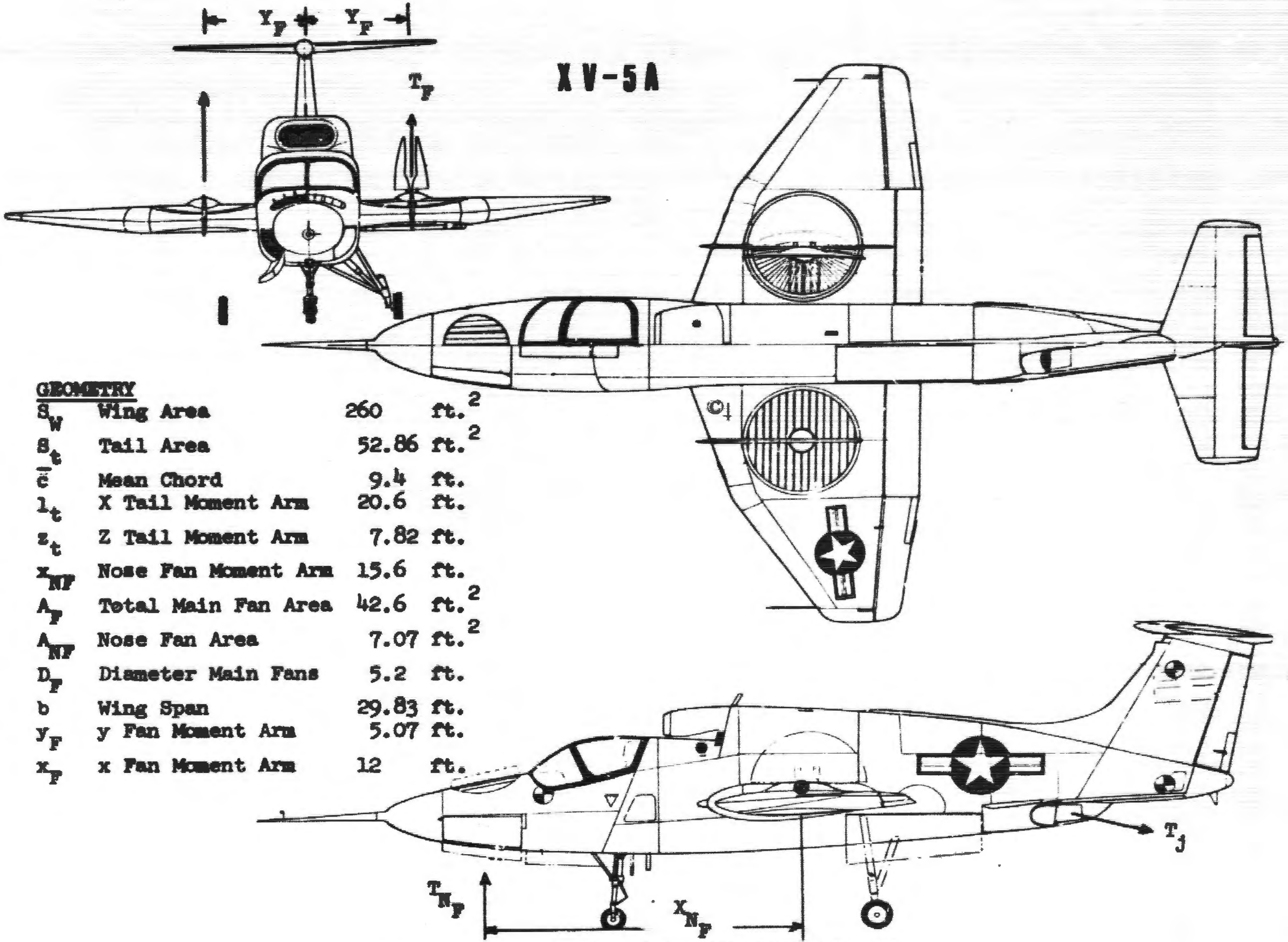
d. Summary of VTOL Escape System Performance Requirements

In order to meet the program objective of providing safe emergency crew escape from VTOL and high speed, low altitude emergencies, the ejection seat escape system must be capable of providing safe crew escape from the study model aircraft under the conditions existing:

(1) After the most critical aircraft malfunctions in the VTOL and transition flight regime as defined in Figures 3 through 31.

(2) Under the initial conditions specified in MIL-S-9479A shown in Table I.

Conditions (1) and (2) above therefore, constitute the top level performance requirements which any escape system must meet in order to attain the objectives of this program.



GEOMETRY

S_W	Wing Area	260	ft.^{2}
S_t	Tail Area	52.86	ft.^{2}
$\bar{c}$	Mean Chord	9.4	ft.
l_t	X Tail Moment Arm	20.6	ft.
z_t	Z Tail Moment Arm	7.82	ft.
x_{NF}	Nose Fan Moment Arm	15.6	ft.
A_F	Total Main Fan Area	42.6	ft.^{2}
A_{NF}	Nose Fan Area	7.07	ft.^{2}
D_F	Diameter Main Fans	5.2	ft.
b	Wing Span	29.83	ft.
y_F	y Fan Moment Arm	5.07	ft.
x_F	x Fan Moment Arm	12	ft.

FIGURE 1 XV-5A (RYAN FAN-IN-WING) DRAWING

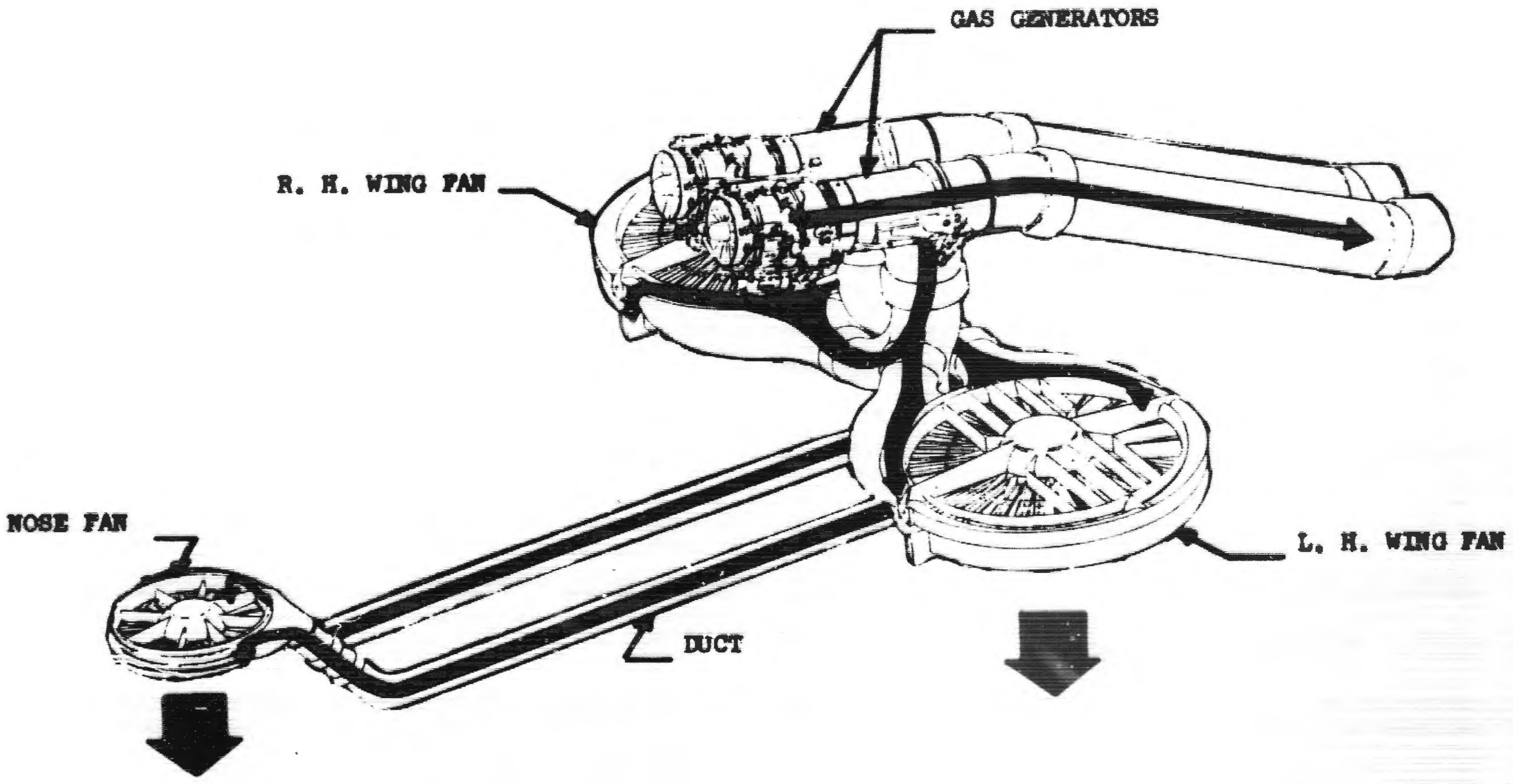


FIGURE 2 XV-5A PROPULSION SYSTEM

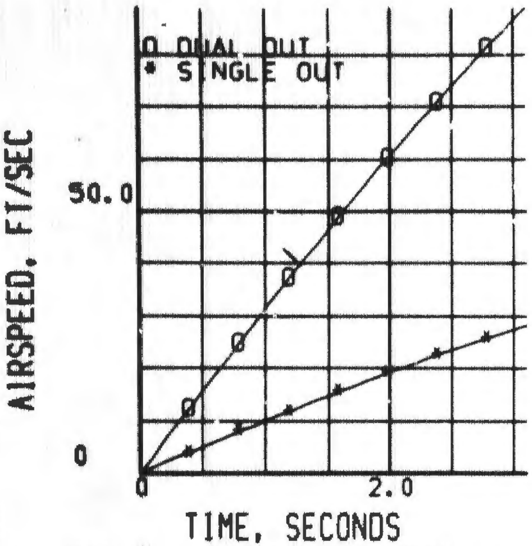


FIG 3 ENGINE FAILURES, HOVER AIRPLANE AIRSPEED

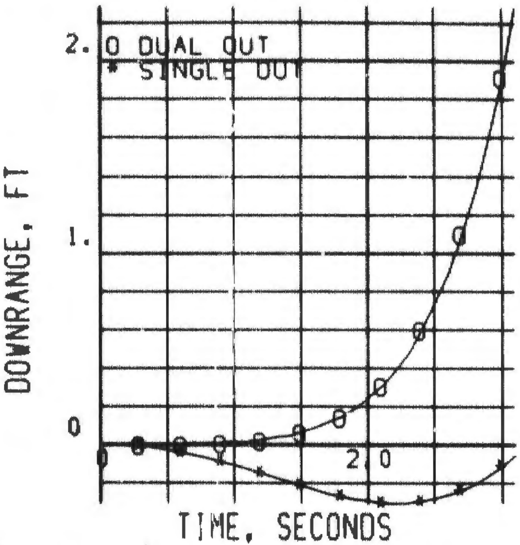


FIG 4 ENGINE FAILURES, HOVER AIRPLANE DOWNRANGE DISTANCE

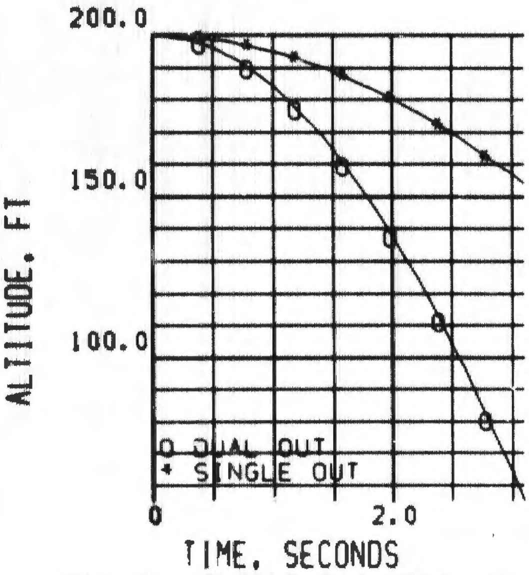


FIG 5 ENGINE FAILURES, HOVER AIRPLANE ALTITUDE

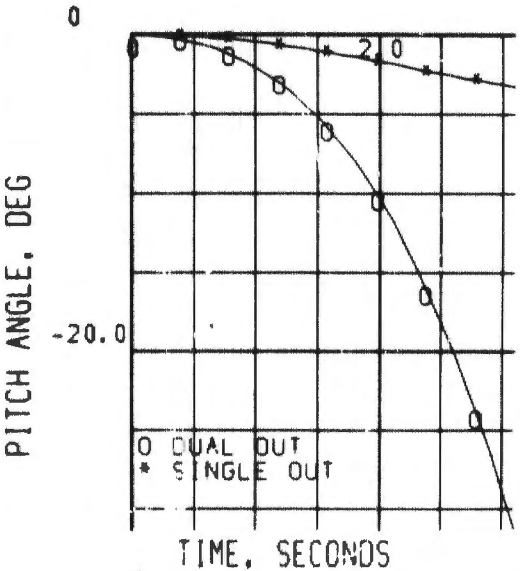


FIG 6 ENGINE FAILURES, HOVER AIRPLANE PITCH ANGLE

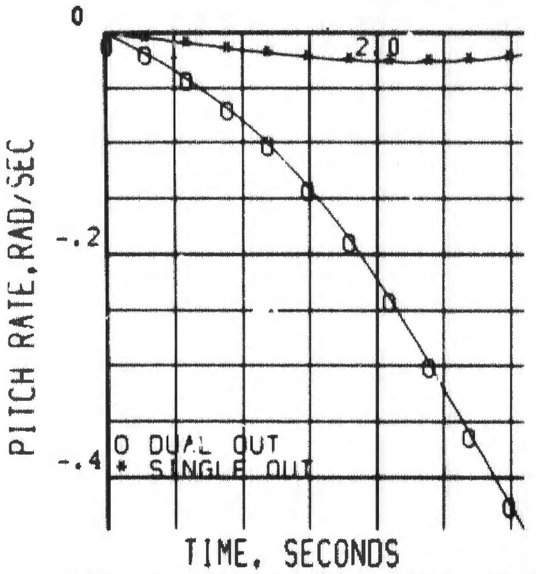


FIG 7 ENGINE FAILURES, HOVER AIRPLANE PITCH RATE

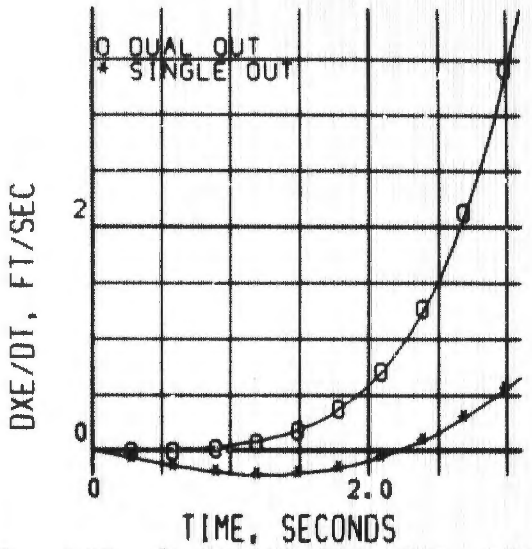


FIG 8 ENGINE FAILURES, HOVER AIRPLANE DOWNRANGE SPEED

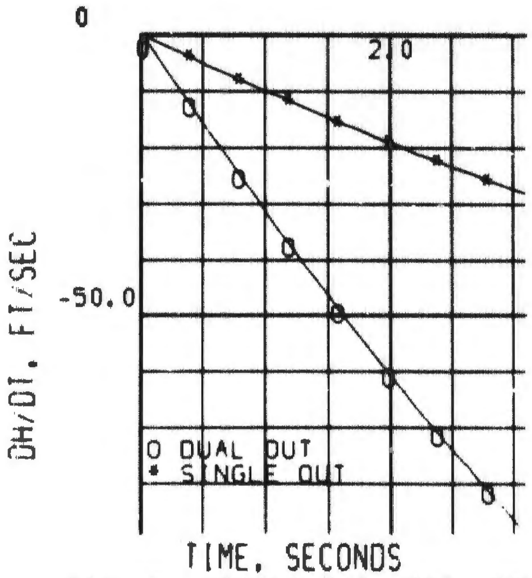


FIG 9 ENGINE FAILURES, HOVER AIRPLANE CLIMB RATE

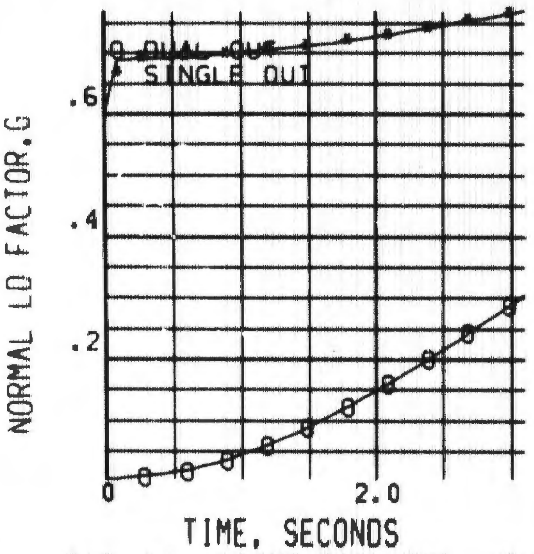


FIG 10 ENGINE FAILURES, HOVER AIRPLANE NORMAL LOAD FACTOR

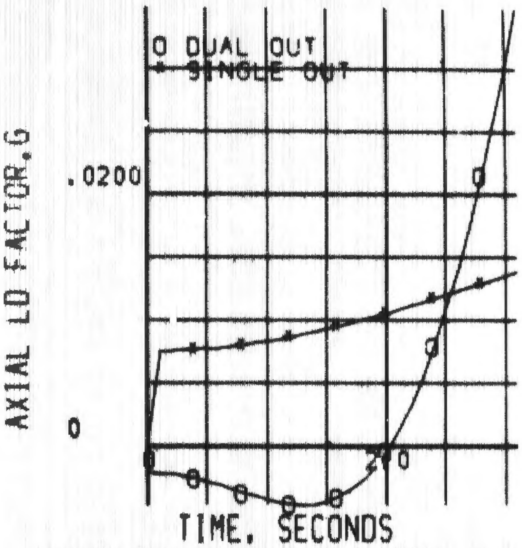


FIG 11 ENGINE FAILURES, HOVER
COCKPIT AXIAL LOAD FACTOR

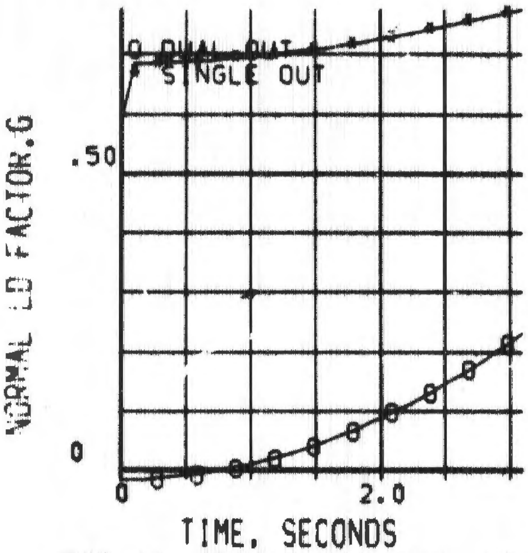


FIG 12 ENGINE FAILURES, HOVER
COCKPIT NORMAL LOAD FACTOR

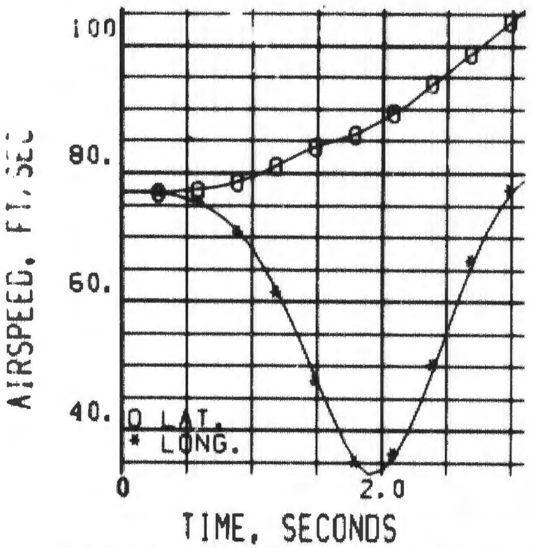


FIG 13 CONTROL FAILURES, 46 KT
AIRPLANE AIRSPEED

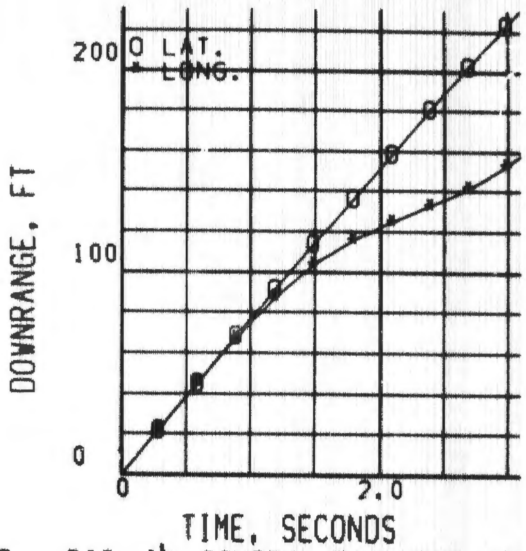


FIG 14 CONTROL FAILURES, 46 KT
AIRPLANE DOWNRANGE DISTANCE

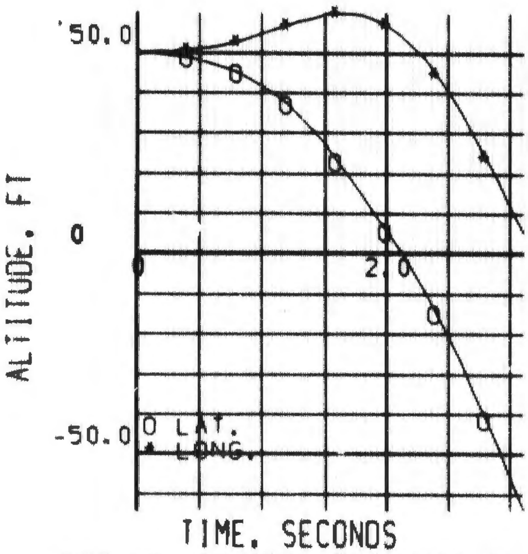


FIG 15 CONTROL FAILURES, 46 KT
AIRPLANE ALTITUDE

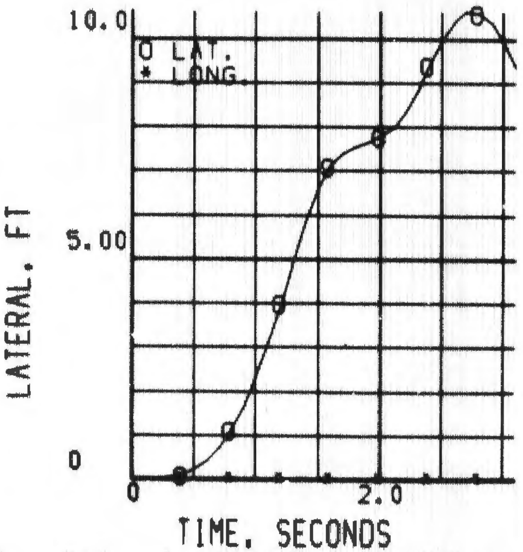


FIG 16 CONTROL FAILURES, 46 KT
AIRPLANE LATERAL DISTANCE

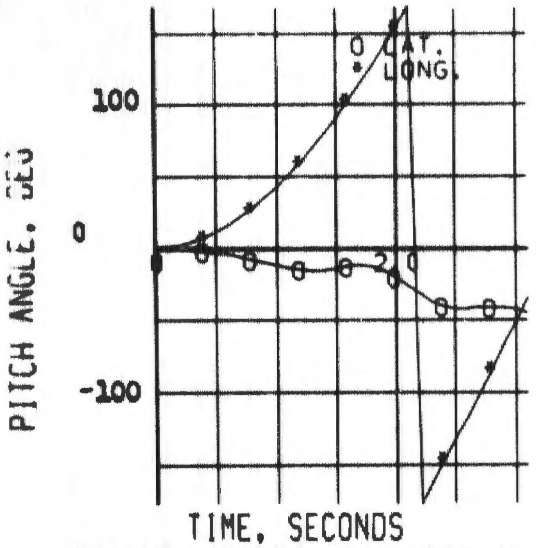


FIG 17 CONTROL FAILURES, 46 KT
AIRPLANE PITCH ANGLE

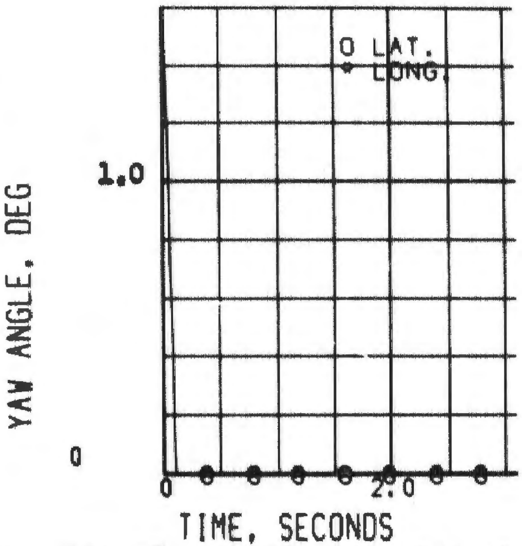


FIG 18 CONTROL FAILURES, 46 KT
AIRPLANE YAW ANGLE

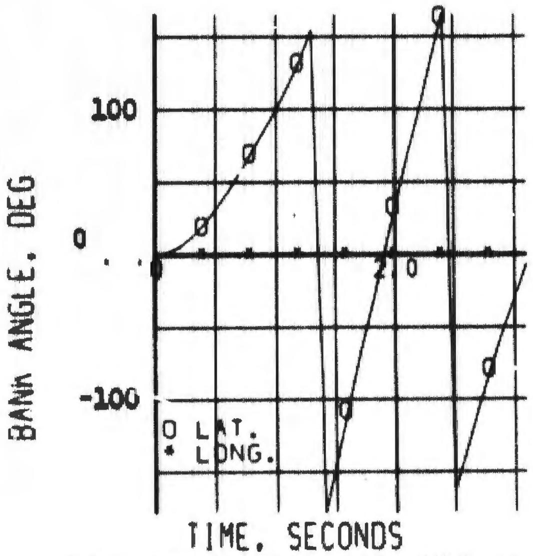


FIG 19 CONTROL FAILURES, 46 KT
AIRPLANE BANK ANGLE

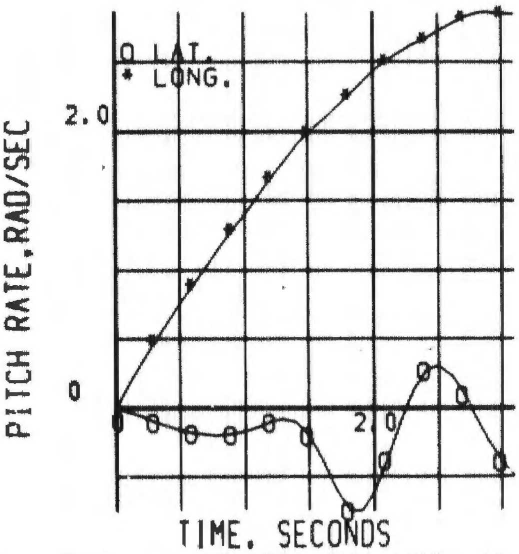


FIG 20 CONTROL FAILURES, 46 KT
AIRPLANE PITCH RATE

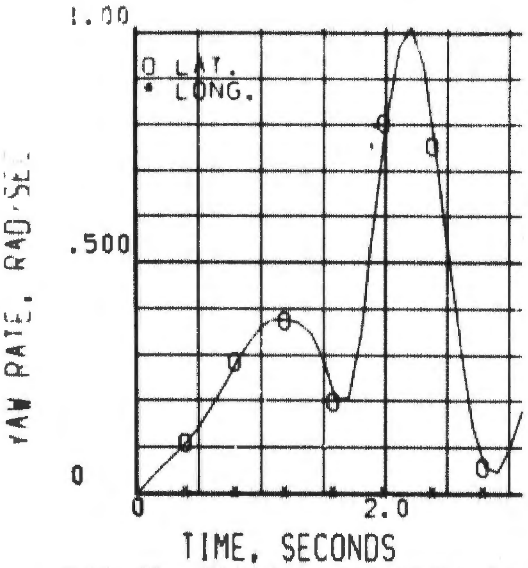


FIG 21 CONTROL FAILURES, 46 KT
AIRPLANE YAW RATE

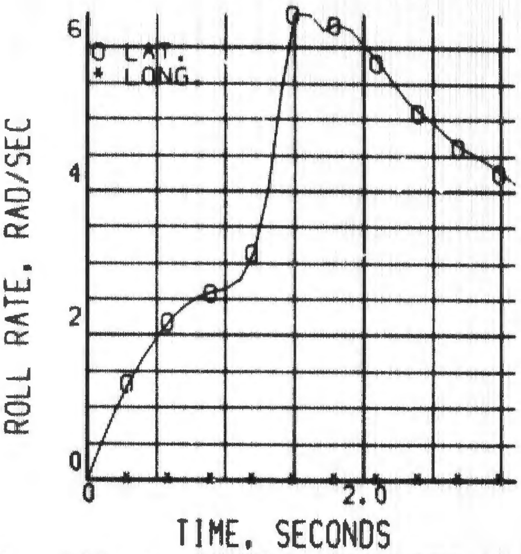


FIG 22 CONTROL FAILURES, 46 KT
AIRPLANE ROLL RATE

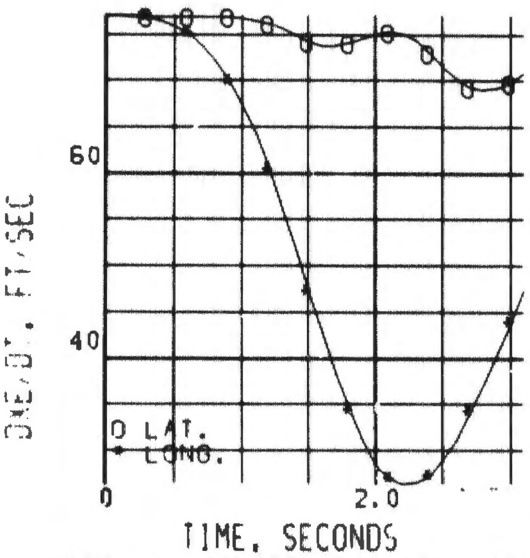


FIG 23 CONTROL FAILURES, 46 KT
AIRPLANE DOWNRANGE SPEED

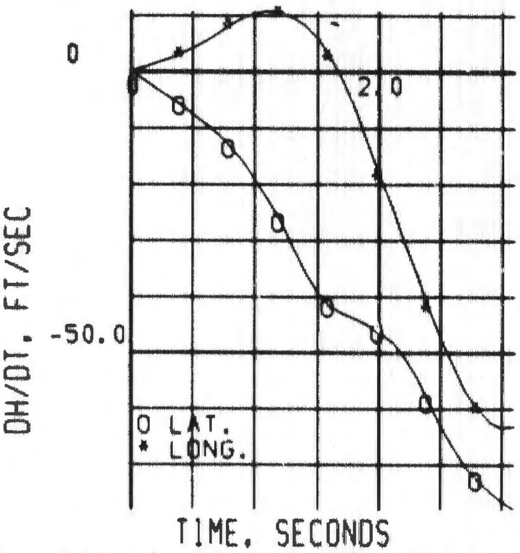


FIG 24 CONTROL FAILURES, 46 KT
AIRPLANE CLIMB RATE

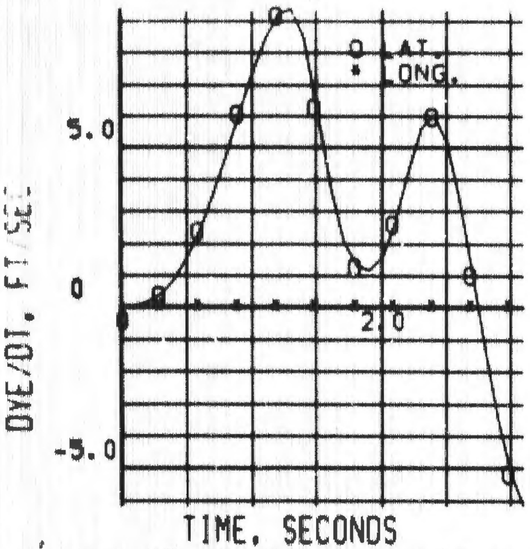


FIG 25 CONTROL FAILURES,46 KT
AIRPLANE LATERAL SPEED

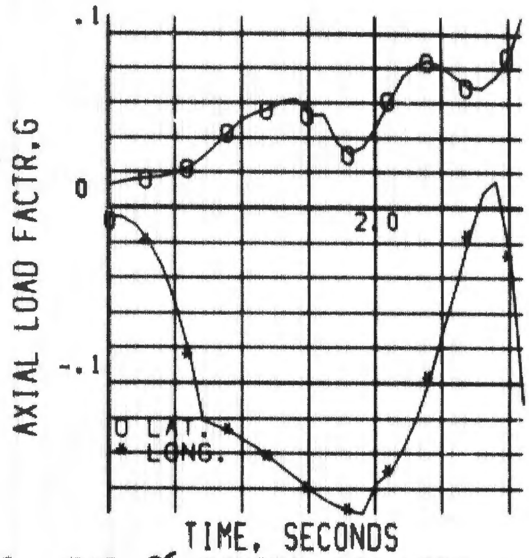


FIG 26 CONTROL FAILURES,46 KT
AIRPLANE AXIAL LOAD FACTOR

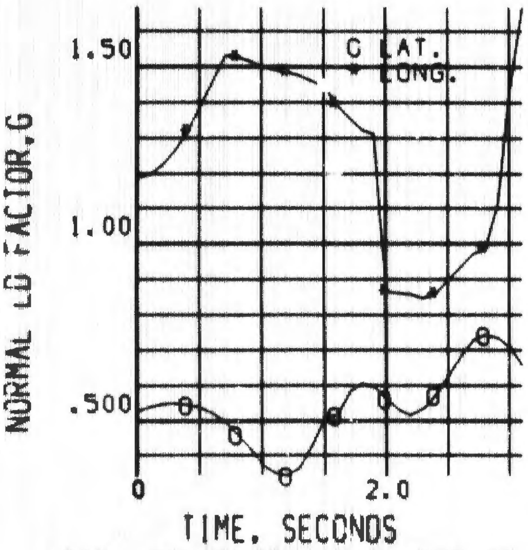


FIG 27 CONTROL FAILURES,46 KT
AIRPLANE NORMAL LOAD FACTOR

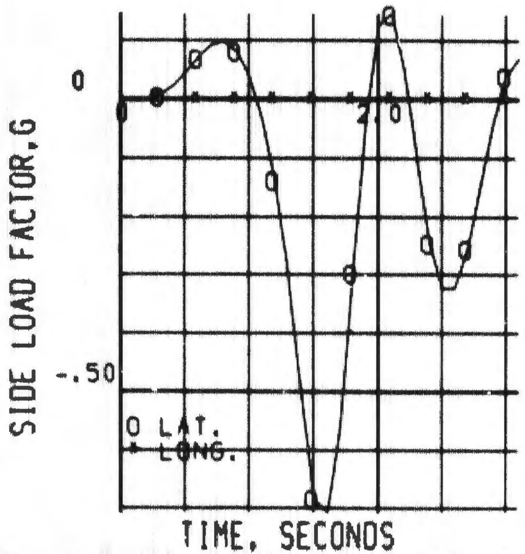


FIG 28 CONTROL FAILURES,46 KT
AIRPLANE SIDE LOAD FACTOR

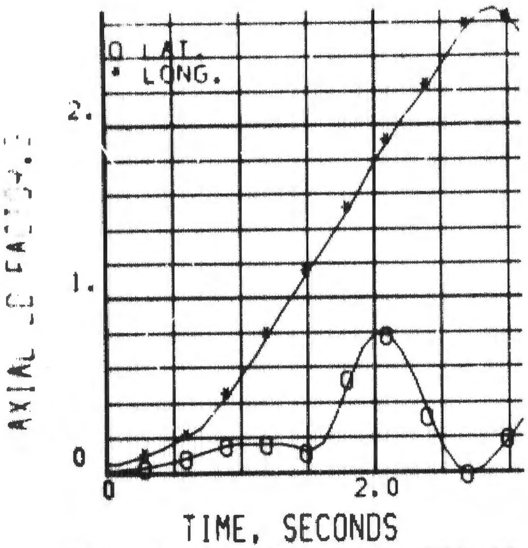


FIG 29 CONTROL FAILURES, 46 KT
COCKPIT AXIAL LOAD FACTOR

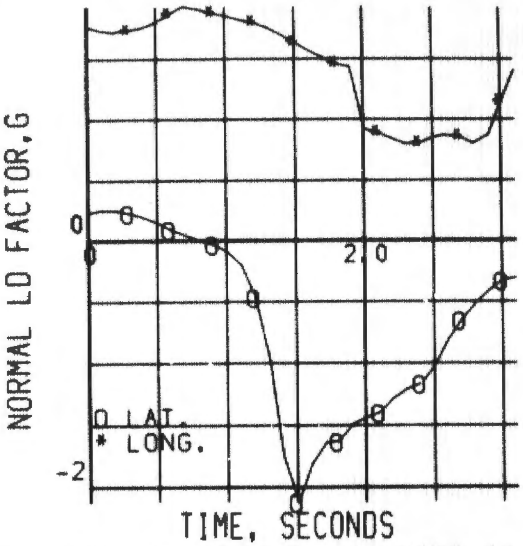


FIG 30 CONTROL FAILURES, 46 KT
COCKPIT NORMAL LOAD FACTOR

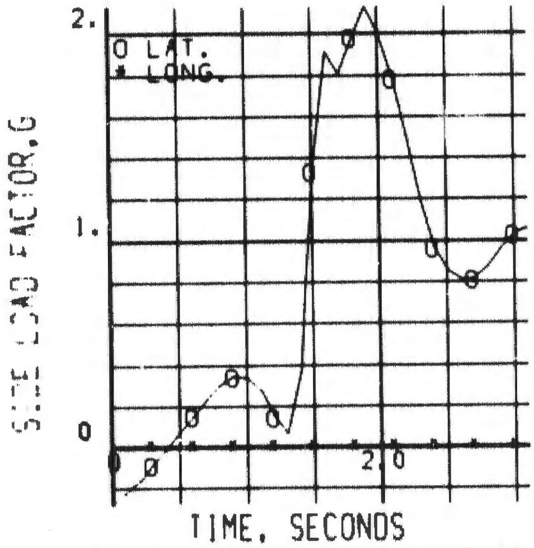


FIG 31 CONTROL FAILURES, 46 KT
COCKPIT SIDE LOAD FACTOR

3.0 SYSTEM DESCRIPTION

a. General Description

The ejection seat escape system described here is designed for a two place, side-by-side cockpit configuration. The complete system consists of the following:

- An aircraft mounted avionics subsystem which will detect an emergency condition and provide a signal to initiate escape.
- A seat mounted programmer to provide ejection and post-ejection event initiation and sequencing.
- A left hand and a right hand ejection seat assembly which includes crew restraint, ejection propulsion, drag parachute and personnel parachute subsystems.

Figure 32 shows the cockpit geometry. Each subsystem is described in detail in this section.

b. Emergency Detection and Ejection Initiation System (EDEIS)

An analysis of all pertinent factors regarding the vertical takeoff, hover, and vertical landing portions of a VTOL flight have resulted in the following preliminary design objectives for the Emergency Detection and Ejection Initiation System, hereafter referred to as EDEIS:

- The system will be designed on the Fail Operational philosophy such that the remainder of the system remains active after failure of any system element.
- Accuracy of decision and reliability of action will be designed into the system so that the probability of erroneous escape is negligible, but the probability of correct escape is very high.
- The system will be active between the altitudes of 10 feet above terrain and 500 feet above terrain providing the pilot has selected the "Automatic Initiation" mode.
- The system will have built-in test equipment which will monitor its operation, deactivate a failed portion, and provide information to the pilot on the portion that has failed.
- The only equipment failure which will render the automatic initiation system inoperative is the complete failure of all electrical power. Such a failure will not affect the manual initiation system

The system will be designed primarily to sense, identify and react to emergency conditions which result from an out-of-control, unrecoverable flight condition. The decision process to automatically initiate escape will require a finite time after the aircraft has entered the out-of-control regime.

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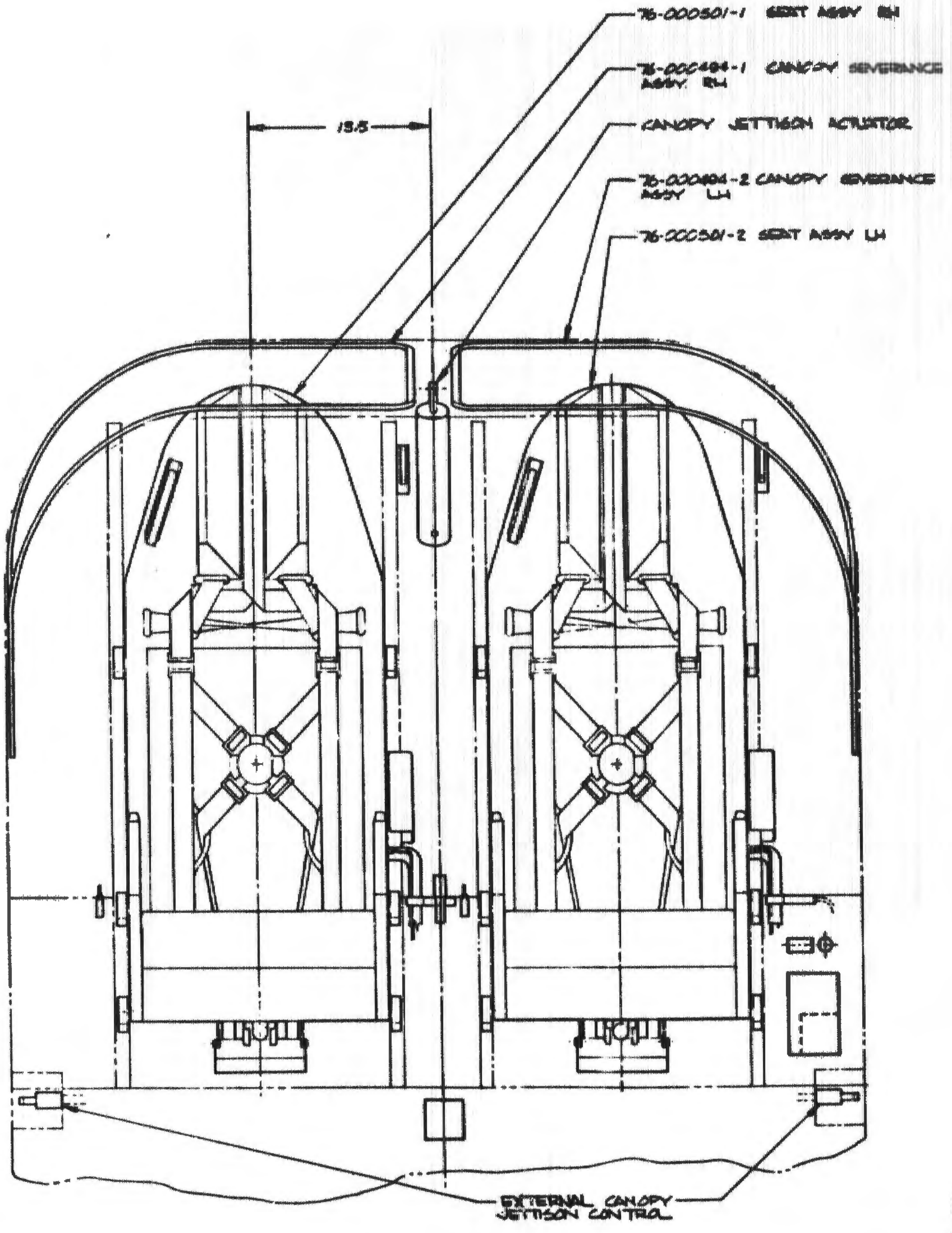
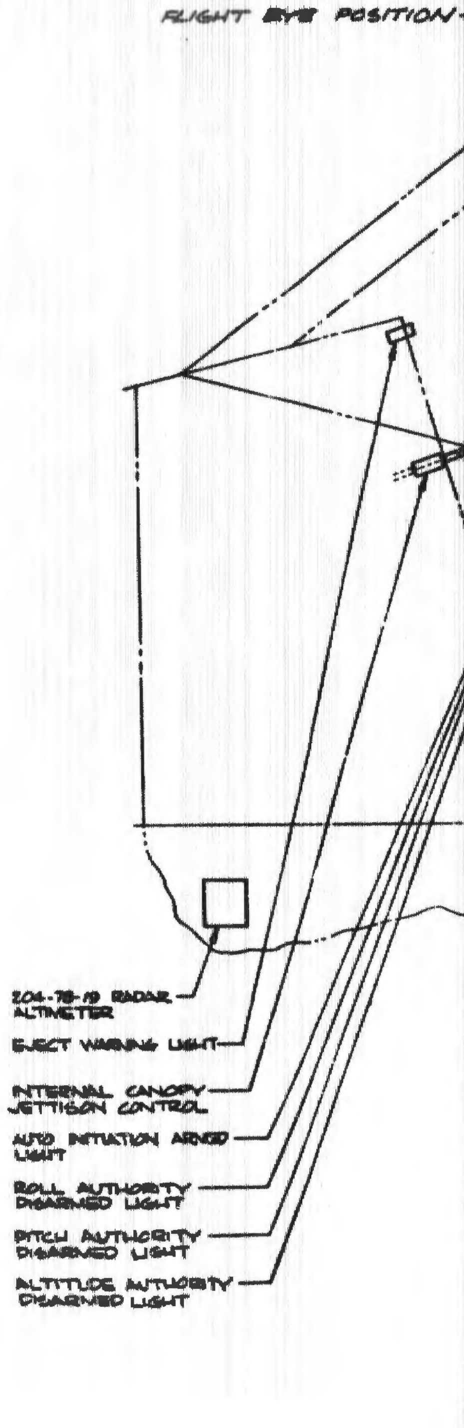

76-000501-1 SEAT ASSY RH
76-000494-1 CANOPY SEVERANCE ASSY RH
CANOPY JETTISON ACTUATOR
76-000494-2 CANOPY SEVERANCE ASSY LH
76-000501-2 SEAT ASSY LH
15.5
EXTERNAL CANOPY JETTISON CONTROL

SECTION A-A


FLIGHT EYE POSITION
204-78-19 RADAR ALTIMETER
EJECT WARNING LIGHT
INTERNAL CANOPY JETTISON CONTROL
AUTO INITIATION ARMED LIGHT
ROLL AUTHORITY DISARMED LIGHT
PITCH AUTHORITY DISARMED LIGHT
ALTITUDE AUTHORITY DISARMED LIGHT

A.

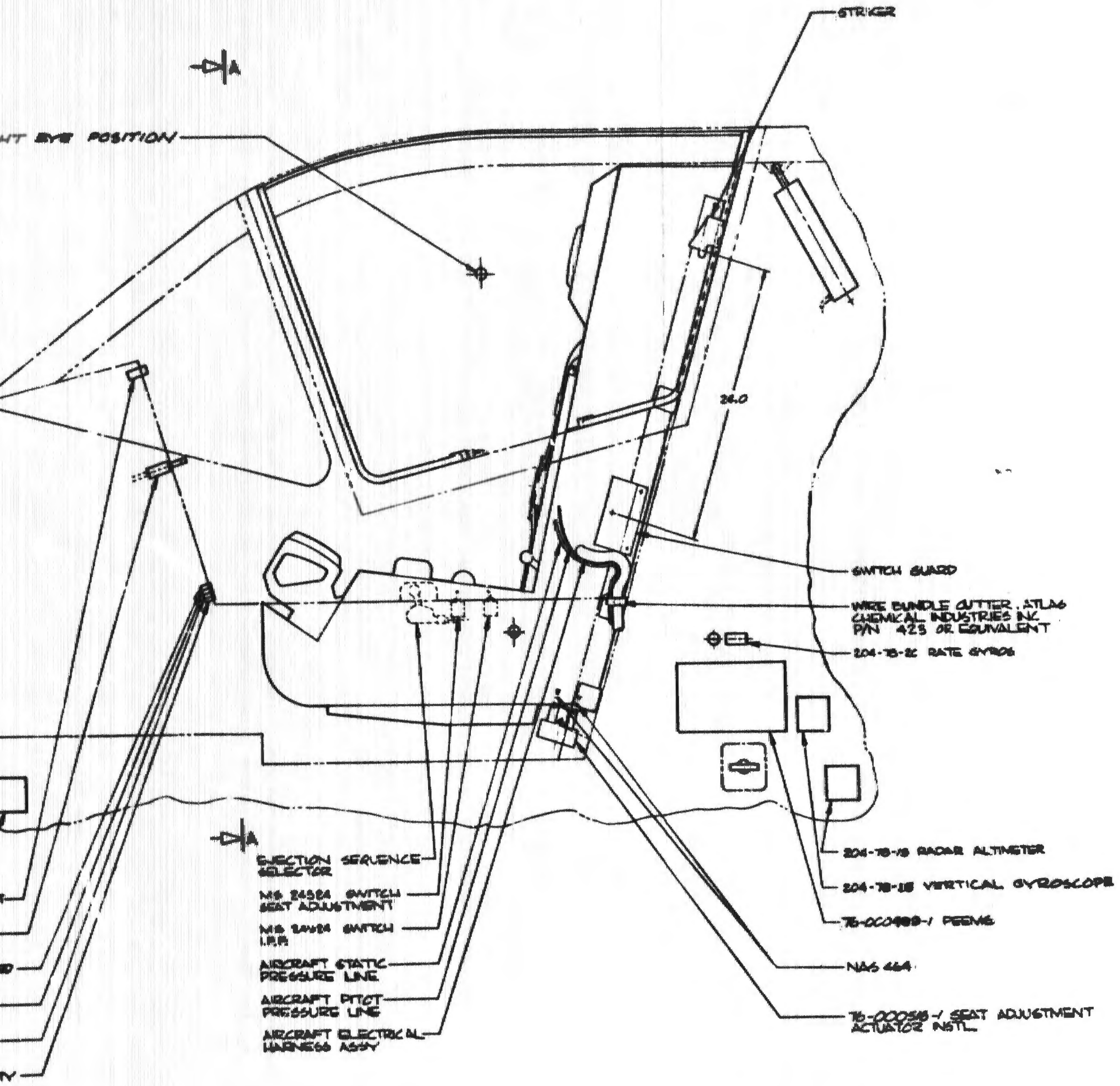


FIGURE 32
COCKPIT GEOMETRY

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R.

In all cases, the system will decide and initiate automatic escape in time for the seat functions to provide safe recovery for both crew members.

The system will be designed and packaged with safe-guards to prevent erroneous decisioning and inadvertent initiation.

The system will be designed to achieve high reliability through simplicity of design.

The decision to initiate escape from an aircraft has traditionally been a personal decision of the aircraft commander; however, in a VTOL aircraft in the hover mode, the emergency conditions necessitating escape have moved out of the time frame of human reaction time and into a time regime where only automatic decisions may be effective. Therefore, as a very important part of this program, emergencies requiring automatic escape have been defined.

At the outset it was apparent that the number of parameters used in the decision for automatic escape must be kept to an absolute minimum consistent with the requirement for a successful escape. In addition, it is extremely difficult to predict all possible failure modes and to provide methods of detecting these failures. Thus, the emphasis has been placed on detecting the results of the failures rather than the failures themselves.

The number of parameter families necessary to define out-of-control emergencies requiring escape has been reduced to three. These three families are:

- Roll parameters
- Pitch parameters
- Vertical parameters

The elimination of other parameter families in the definition of emergencies requiring escape was accomplished primarily by a judgment as to the time required for accurate decisioning and the time available for successful manually-initiated escape. For example, the detection of fire is not difficult; but assessing precisely the extent of any resulting emergency is difficult and best left to the judgment of the pilot. If the fire should cause unrecoverable, out-of-control flight conditions, the three parameter families chosen will initiate a successful automatic escape.

Similarly, a complete failure of all aircraft electrical power may be detected readily, but this in itself may not constitute an emergency requiring escape. The pilot may land the aircraft, take corrective action such as activating a back-up electrical system, or manually initiate escape.

Each of the three parameter families has been given parallel authority to initiate automatic escape in the design philosophy.

(1) Fail Operational Design

In the preliminary design studies of the EDEIS, the problem of reliability of sensors was of prime concern. It was apparent that single channel, non-redundant systems would not be satisfactory. Studies indicated that typical VTOL vehicles would use at least dual redundant sensors in the flight control systems and the output of these sensors may be utilized as the basis of the detection system.

The two sensors may be used in parallel, with either sensor capable of indicating an emergency. In this case the reliability of detecting an actual emergency would be increased but the chance of a false ejection signal due to sensor failure would be doubled. This is unacceptable. A monitor circuit could be added which would deactivate a particular channel if the two sensors in this channel do not agree. In this case the chance of a false ejection signal would be considerably reduced, but the chance of failure to detect an actual emergency condition would be doubled. This also is unacceptable.

The only acceptable solution is to add a third sensor in each channel and to use a majority voting concept. In the concept used, the outputs of the three sensors are sent to a comparator which will pass a signal to the gate if the outputs of any two of the three sensors agree. This results in a Fail Operational System in that the system will still operate after any single failure.

After a sensor has failed, it is removed from the circuit and the two remaining sensors provide the signal for that channel. If a second sensor fails, then the remaining two sensor outputs will not agree and that channel is deactivated. That is, the system is Fail Safe for a dual failure in a single channel.

(2) EDEIS Activation/Deactivation Philosophy

The EDEIS is necessary only during the vertical takeoff and landing portions of a typical aircraft mission. For other segments of the flight, manual escape initiation is desirable; therefore, provision for the activation/deactivation of the EDEIS has been made under the following pattern of reasoning.

The EDEIS must be absolutely deactivated while the aircraft is sitting on the ground; therefore, when weight is on the gear, the EDEIS will be off. When the aircraft actually contacts the ground on landing, the EDEIS sensors will be subjected to large transient shocks and may produce erroneous outputs; therefore, it is desirable that the EDEIS be deactivated just prior to touchdown.

The above reasons have set the requirements for a series arrangement of switches for activation/deactivation of the EDEIS. First, the navigation system mode of "VTOL Takeoff and Landing" is to be selected by the pilot to activate the necessary systems. Then the Weight-on-Gear (Off-Gear) Switch will be activated automatically on lift-off or touchdown of the aircraft. Then the Altitude Switch will be operated by radar altimeters at 10 feet above terrain and 500 feet above terrain. Between these altitudes EDEIS is activated.

The radar altimeters chosen have an accuracy of ± 5 feet at ground level; therefore, the choice of 10 feet activation/deactivation level will insure that the EDEIS will not be active at touchdown. It is felt that a free fall of the aircraft from 10 feet altitude above the terrain would be survivable by the crew, with the collapsing gear absorbing most of the impact momentum.

Another switch is necessary in the activation/deactivation sequence since the pilot conceivably could leave the VTOL Takeoff and Land Switch on after converting to forward flight at less than 500 feet altitude; therefore, a forward velocity switch set at the aircraft transition speed will be needed. The overall EDEIS activation/deactivation then can be considered semi-automatic.

(3) Built-in Test Equipment

Because of the critical nature of the EDEIS; it is essential that its operational capability be continuously evaluated; therefore, a continuously sampling built-in test circuit will be incorporated in each major section of the EDEIS. Each of these circuits will have the authority to deactivate that section of the EDEIS for which it is responsible if that section has lost the capability to reliably detect an emergency condition. For example, such capability would be lost if two of the three roll rate gyros failed. In such a case, the roll authority channel of the EDEIS would be deactivated by the roll built-in test circuit.

An indicator system will be provided so that the built-in test equipment can keep the pilot informed of the operational status of the EDEIS.

One important function of the built-in test equipment is to determine the operational capability of the EDEIS before it is activated. In particular, the test equipment will prevent the system from being activated if an automatic ejection signal exists at the time the pilot selects the automatic mode. Note that when the system is activated, the triple redundant channel concept protects the system from any dual failure, except for the extremely unlikely possibility of two identical failures occurring simultaneously; however, with the system deactivated there is a finite possibility that two identical failures could have occurred at different times in the past. If these two failures would result in an automatic ejection signal, the built-in test equipment will prevent the EDEIS from being activated.

(4) Automatic Escape by Roll Authority

Specific envelopes of in-control, out-of-control flight have been determined for both roll and pitch axes during VTOL and hover flight. It has been determined that if the aircraft rolls past 50 degrees, it is out of control and the crew should be automatically ejected. In addition, because of limited control moments available, at lesser roll angles, there are values of roll rate which cannot be arrested before the aircraft reaches 50 degree roll angle. The limit boundaries shown in Figures 33 and 34 are based on the maximum control power characteristics of the XV-5A airplane and two assumptions. Assumption I for the roll axis condition states that the maximum allowable roll rate at $\phi = 0^\circ$ would be the value which full lateral control power would generate if an instantaneous recovery step input was initiated with the airplane in a 45 degree bank angle with zero

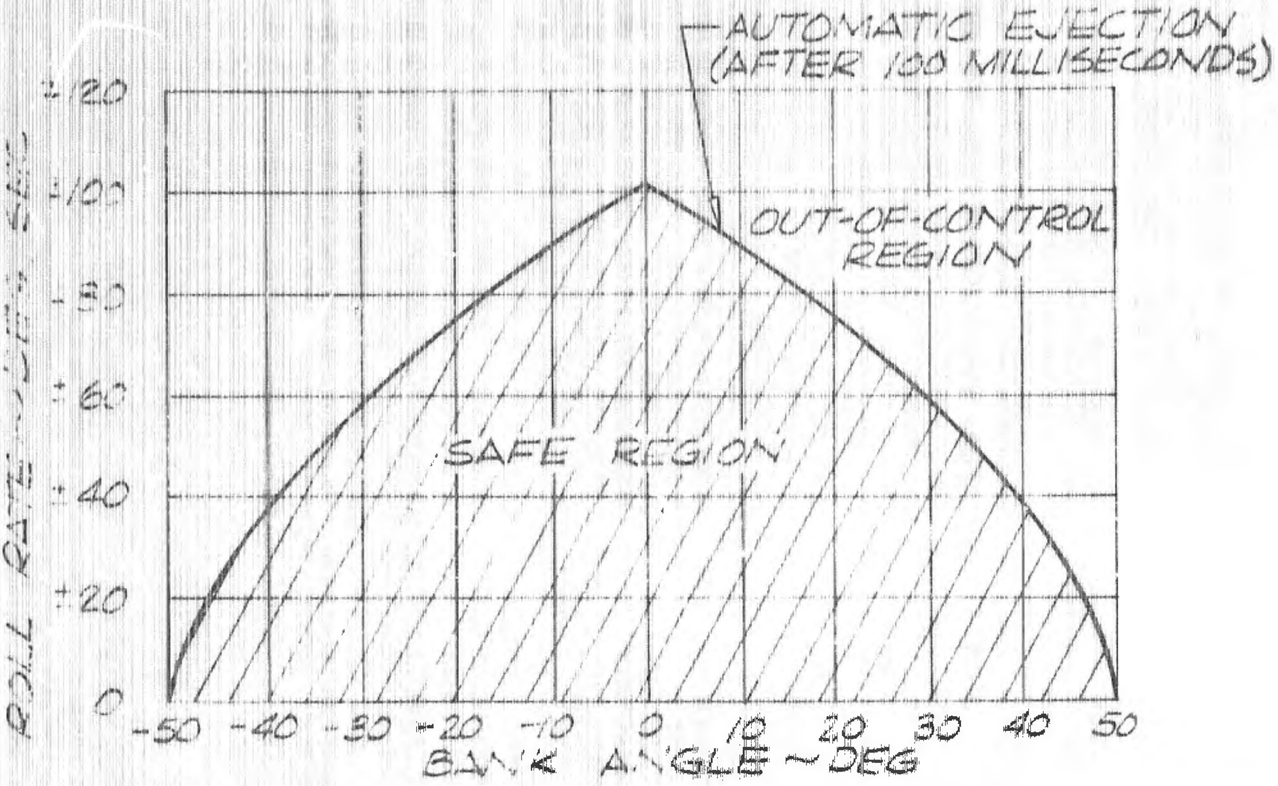


FIGURE 33
BANK ANGLE PLUS ROLL RATE
AUTOMATIC SEAT EJECTION ENVELOPE

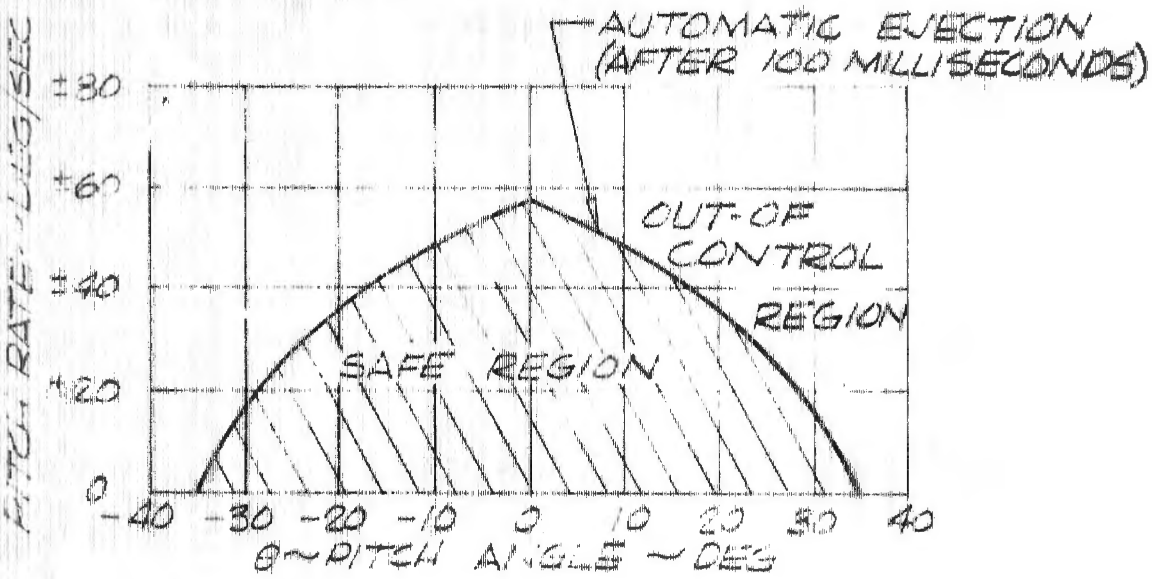


FIGURE 34
PITCH ANGLE PLUS PITCH RATE
AUTOMATIC SEAT EJECTION ENVELOPE

roll rate. It is felt that the 45 degree bank angle assumption is a realistic limit based on normal airplane lateral translation bank angle requirements and thrust/weight (1.41) requirements to maintain altitude with the airplane at a 45 degree bank angle. Assumption II is based on the theory that the limit roll rates the pilot would tolerate as a function of bank angles would be what full normal control power against the roll rate could arrest to zero at a bank angle of 50 degrees. The calculations to define this limit boundary include a time delay of 0.125 second prior to the step lateral input and no angular rate damping. These considerations result in an in-control/out-of-control boundary as shown in Figure 33. From this figure, the requirements for automatic escape have been determined as primarily a function of actual roll angle.

Three sources of roll angle have been chosen to provide inputs to a Roll Comparator. These sources are the Inertial Measurement Set, the Standby Attitude Indicating system, and an additional attitude indicating system not ordinarily included in the aircraft. These three roll angle values are fed to the Roll Comparator. Figure 35 is the EDEIS block diagram showing the Roll Axis Emergency Detection Circuit. If one of the roll angle values is radically different from the other two because of a failed configuration, it is voted out and the detection circuit remains operable. If one of the roll angle sources is determined by the built-in test equipment to be in a failed condition and is removed as a source, the detection circuit remains operable. But if no two roll angle values agree within a predetermined tolerance, or if two of the roll angle sources are deemed failed by the built-in test equipment, the entire Roll Axis Emergency Detection Circuit is disabled and the pilot is alerted to this failure. However, the remainder of the Emergency Detection System remains operable and capable of automatic escape initiation.

In addition to roll angle value, it is necessary to determine roll rate in order to make the proper decision for automatic escape. Three separate sources of roll rate were chosen. Two sources are roll rate gyros which supply roll rate to the Automatic Flight Control System. The third source is a similar roll rate gyro which is not normally included in the aircraft. The three roll rate values are processed in the Roll Rate Comparator in a similar manner to that described for roll angle. Two of the roll rate values must always agree within a predetermined tolerance for the Roll Axis Emergency Detection Circuit to remain operable.

When the combination of roll angle and roll rate exceeds the limits shown on Figure 33, an output signal is generated by the roll gate. If the output of the gate is continuous for 100 milliseconds, the decision to initiate automatic escape is complete and final. The 100 milliseconds is a compromise between obtaining a maximum sampling time to maximize the accuracy of the decision and obtaining a minimum sampling time to minimize the time required to complete ejection. If the Roll Arming Circuit has not been disarmed by the built-in test equipment, the Automatic Escape Signal is channeled to the OR circuit which is the parallel authority previously discussed. Thus, it is seen that if the aircraft is out of control in only the roll axis, this is sufficient to initiate automatic escape.

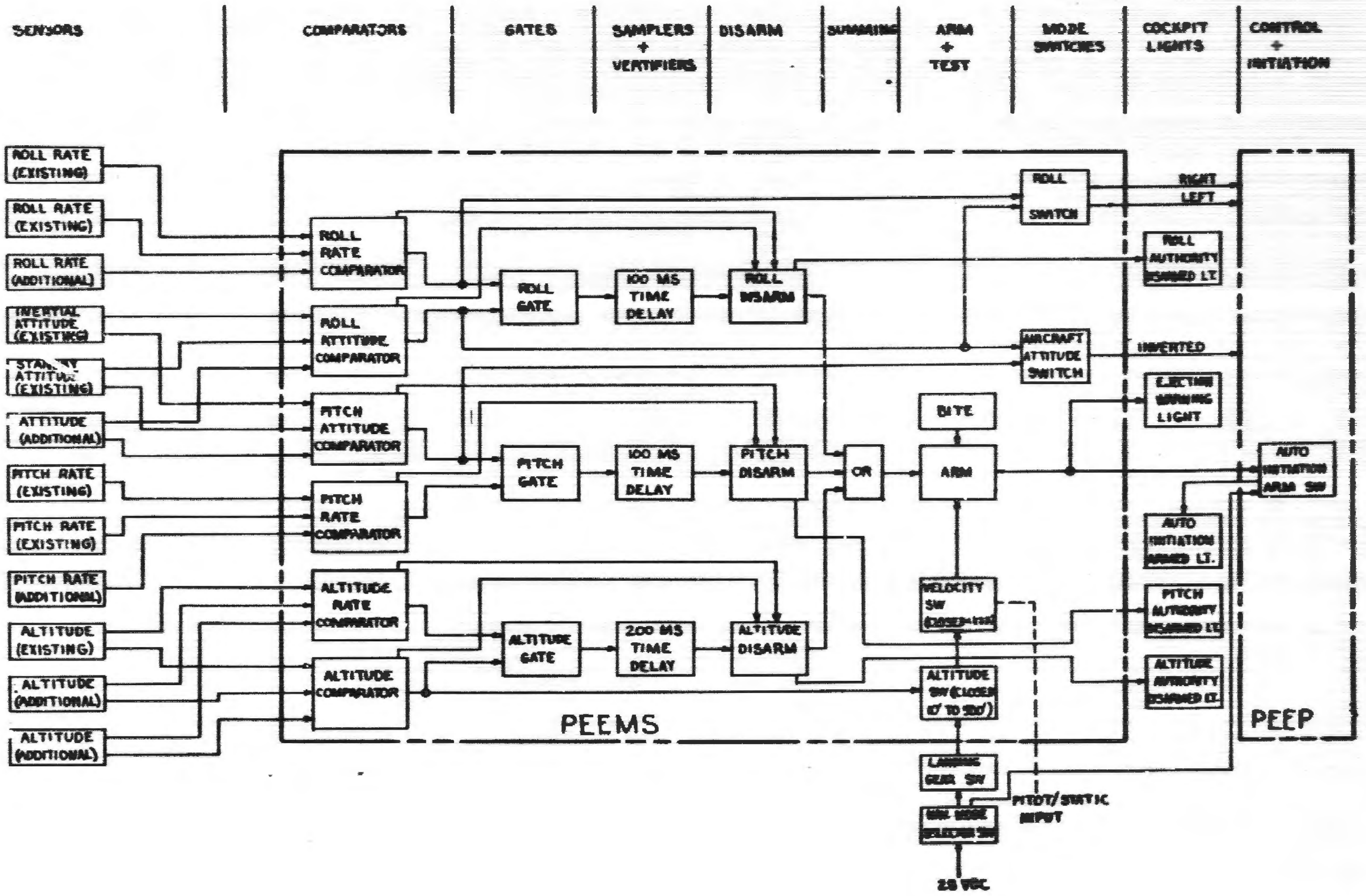


FIGURE 35
EMERGENCY DETECTION AND EJECTION INITIATION SYSTEM
BLOCK DIAGRAM

(5) Automatic Escape by Pitch Authority

Figure 34 is the in-control/out-of-control envelope for the aircraft pitch axis in the VTOL takeoff, landing, and hover flight modes. The considerations previously detailed in roll apply to the pitch axis, and the only difference is the values of angle and rates defining the automatic escape region. Automatic escape may be achieved from an aircraft out-of-control in the pitch axis only. Figure 35 shows the pitch axis emergency detection circuit.

Assumptions I and II for the pitch axis are the same as the roll axis as described in paragraph (4) except the limit pitch attitudes are reduced. The rationale for this reduction is based on the manner in which thrust vectoring is accomplished in the respective axes. Thrust vectoring in the lateral axis is accomplished only by banking the airplane while thrust vectoring in the longitudinal axis can be performed either by wing fan symmetrical louver deflections or by fuselage pitch attitudes. Therefore, it can be expected that fuselage pitch attitude changes would be considerably less than bank angle changes under normal hover operating conditions. Relative to Assumption I, the initial pitch attitude was assumed to be 30 degrees and relative to Assumption II, it is assumed the pilot would tolerate pitch rates which could be arrested to zero at a pitch attitude of 35 degrees.

(6) Automatic Escape by Vertical Authority

In the VTOL mode, the aircraft is vulnerable to high descent rates from various causes which may constitute out-of-control flight even with wings-level attitude. The envelope for such in-control/out-of-control vertical flight is shown in Figure 36. The value of descent rate which is deemed an out-of-control condition is seen to be a function of actual altitude above the terrain. For this reason, three radar altimeters have been chosen to provide three sources of altitude and altitude rate. The two additional radar altimeters added to the aircraft for this purpose are small, lightweight, and inexpensive, being limited to 500 feet altitude range.

The three altitude signals are sent to the Altitude Comparator and the three altitude rate signals are sent to the Altitude Rate Comparator as shown in Figure 35. The output of these comparators are sent to the altitude gate. When the combination of altitude and altitude rate exceeds the limits of Figure 36, an output signal is generated by the altitude gate. If the output of the rate gate representing an out-of-control condition exists continuously for 200 milliseconds, the decision to initiate automatic escape is complete and final. If the Vertical Arming Circuit has not been disarmed by the built-in test equipment, the Automatic Escape Signal is channeled to the OR circuit which is the parallel authority previously discussed. Thus, if the aircraft is out of control due to excessive descent rate only, ejection will be initiated automatically.

c. Post Ejection Event Mode Selector (PEEMS)

In addition to monitoring the outputs of the sensors and generating an initiation signal, the PEEMS will also perform the function of providing ejection mode signals based upon flight parameters of the aircraft. An

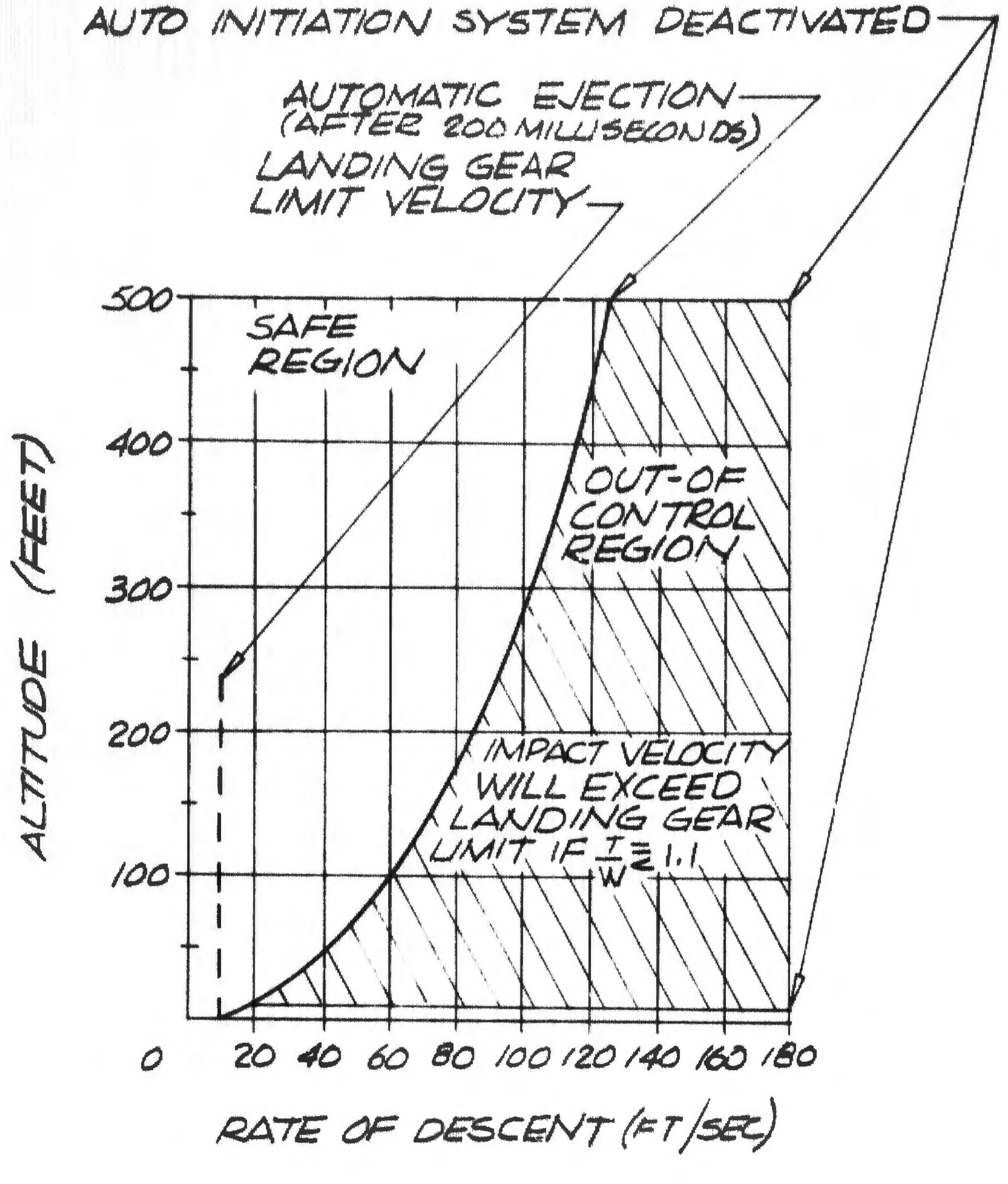


FIGURE 36
EMERGENCY DETECTION AND AUTOMATIC SYSTEM VERTICAL AUTHORITY

"aircraft inverted" signal and an "aircraft rolled" signal is generated by the PEEMS as shown in Figure 35. These mode signals are sent to the Post Ejection Event Programmer (PEEP) for use in selecting the sequence of events to be followed during ejection.

d. Post Ejection Event Programmer (PEEP)

The PEEP is a package mounted on the ejection seat to sequence the events of ejection and post ejection depending upon the aircraft operating mode at ejection time. A functional block diagram of the programmer is shown in Figure 37. The PEEP installation is shown in Figure 38.

The determination of the actual sequence of events to follow during ejection is made by the PEEP upon receipt of an electrical initiation signal from the PEEMS or upon receipt of a crew-initiated explosive stimulus via shielded mild detonating cord. At this time the mode signals from the PEEMS are used to energize latching relays and aircraft pitot and static inputs are used to set the altitude switch, air speed switch, and variable time delay. Thus, when an actual ejection occurs, the events after initiation occur in a sequence tailored to the conditions that exist at ejection initiation.

e. Manual Ejection Firing Control and Signal Transmission

Manual ejection initiation will be accomplished by actuation of either or both of two handles, one located on the forward edge of each seat side as shown in Figure 41. Actuation of the handles requires a squeeze and pull motion and a pull force of 20 ± 3 pounds. The handle meets the requirements of MIL-STD-9479 and is fully qualified and used for ejection initiation of the F-111 escape module. Actuation of the handle causes dual mechanical firing pins to be cocked and released. The firing pins strike and initiate dual percussion primers which detonate dual booster charges. The booster charges incorporate a cross over such that detonation of one charge will cause detonation of the other. These booster charges initiate dual shielded mild detonation cord (SMDC) assemblies which are routed beneath the seat to the post ejection event programmer (PEEP). The SMDC assemblies initiate the PEEP's redundant electrical power supply. These SMDC assemblies are also fully qualified and used for signal transmission throughout the F-111 escape system. The SMDC installation is shown in Figure 39.

f. Ejection Propulsion Unit

Ejection propulsion is provided by a catapult-rocket (reference Figure 40). The catapult is ignited by dual SMDC lines which are connected to and are initiated by the PEEP. Each SMDC will actuate one of two mechanical firing pins which, through percussion primers, will initiate the catapult ballistic charge. This charge will be sufficient to give the ejected mass a velocity of fifty feet per second at the end of its thirty-four inch stroke.

As the catapult nears the end of its stroke, dual SMDC lines initiated by the PEEP will ignite the rocket motor in the same manner as the catapult was initiated. The initiation signal from the PEEP will not ignite the rocket until the seat has moved a precise distance up the

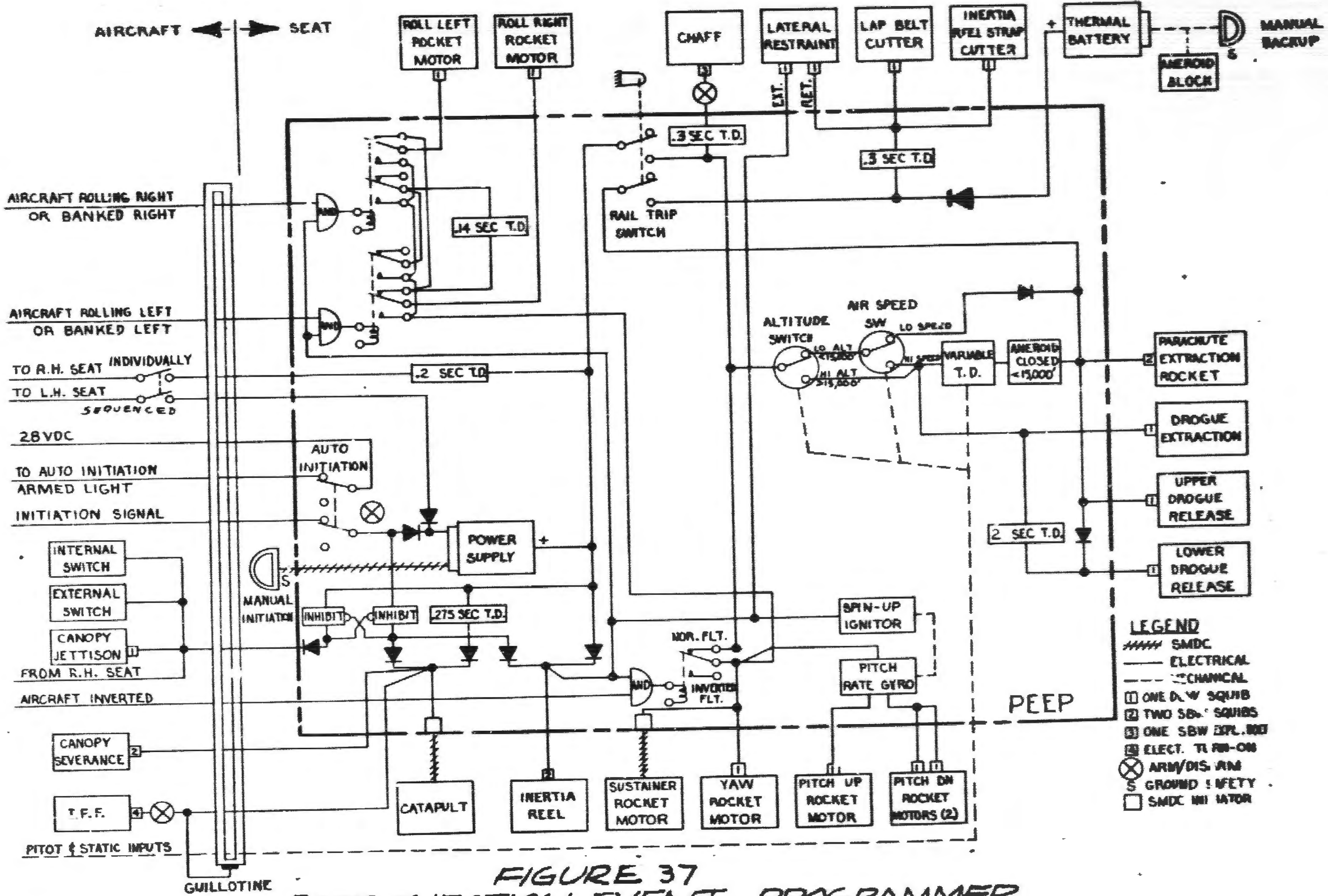
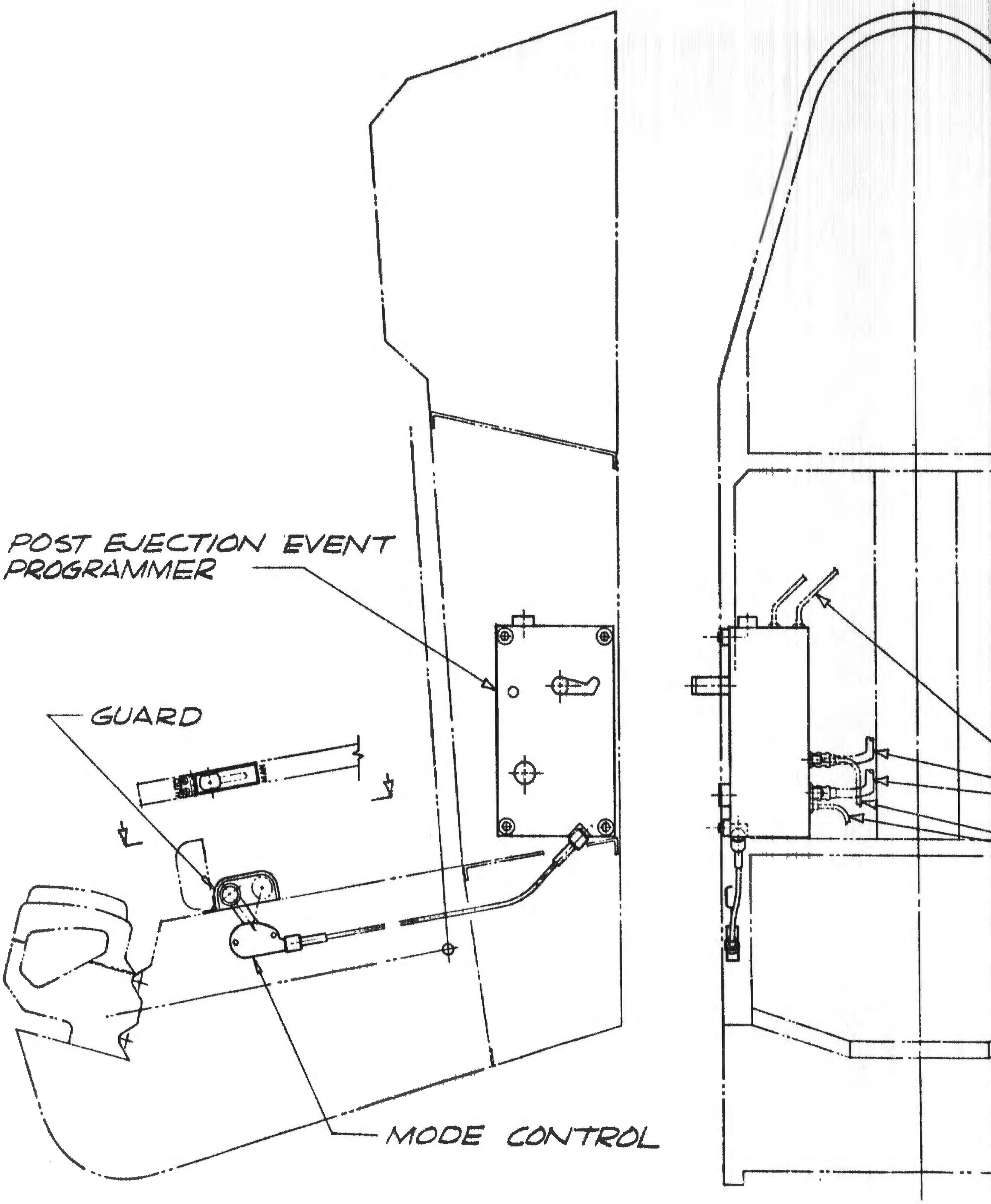


FIGURE 37
POST EJECTION EVENT PROGRAMMER
BLOCK DIAGRAM



A.

CONTROL

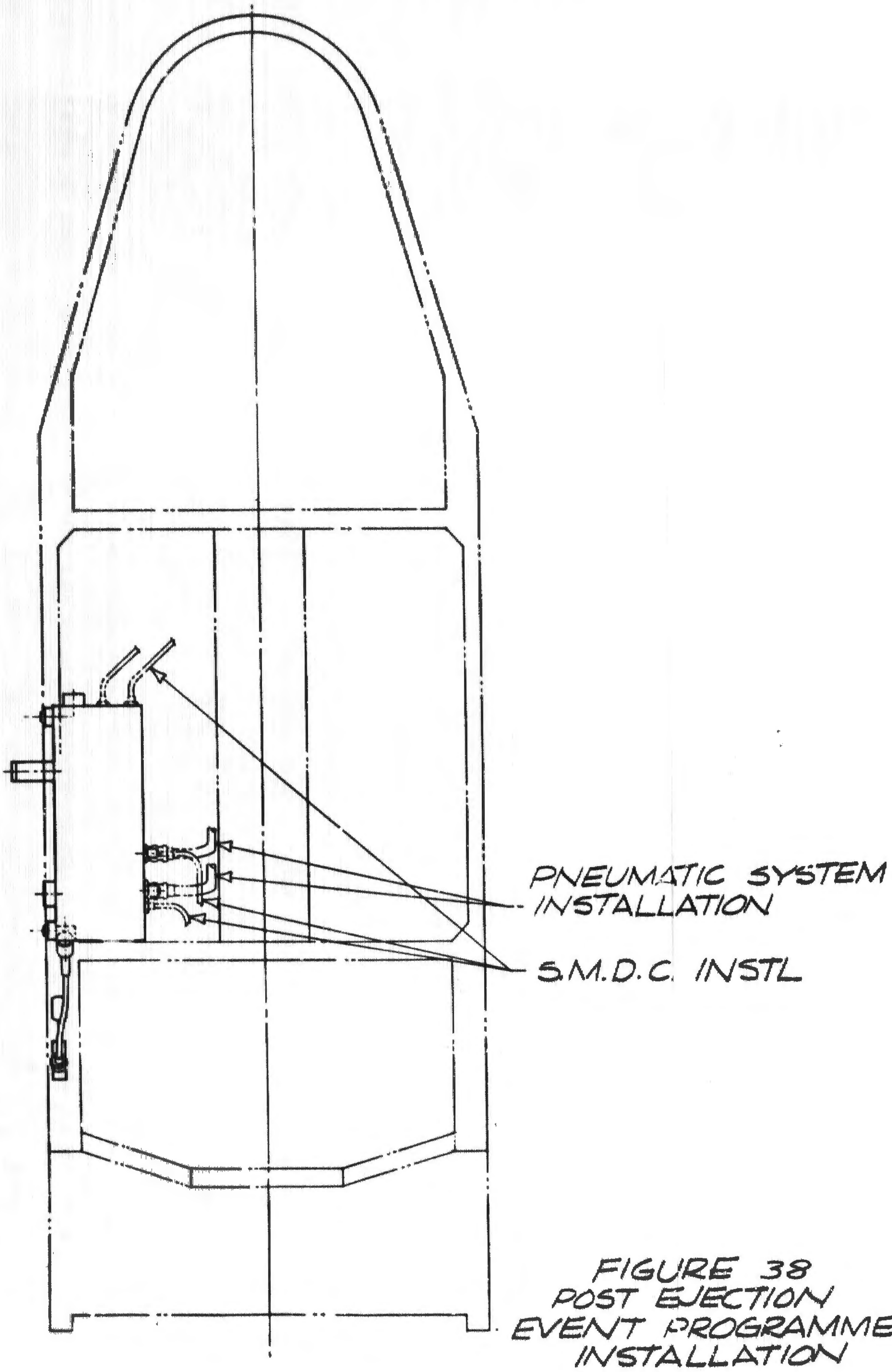


FIGURE 38
POST EJECTION
EVENT PROGRAMMER
INSTALLATION

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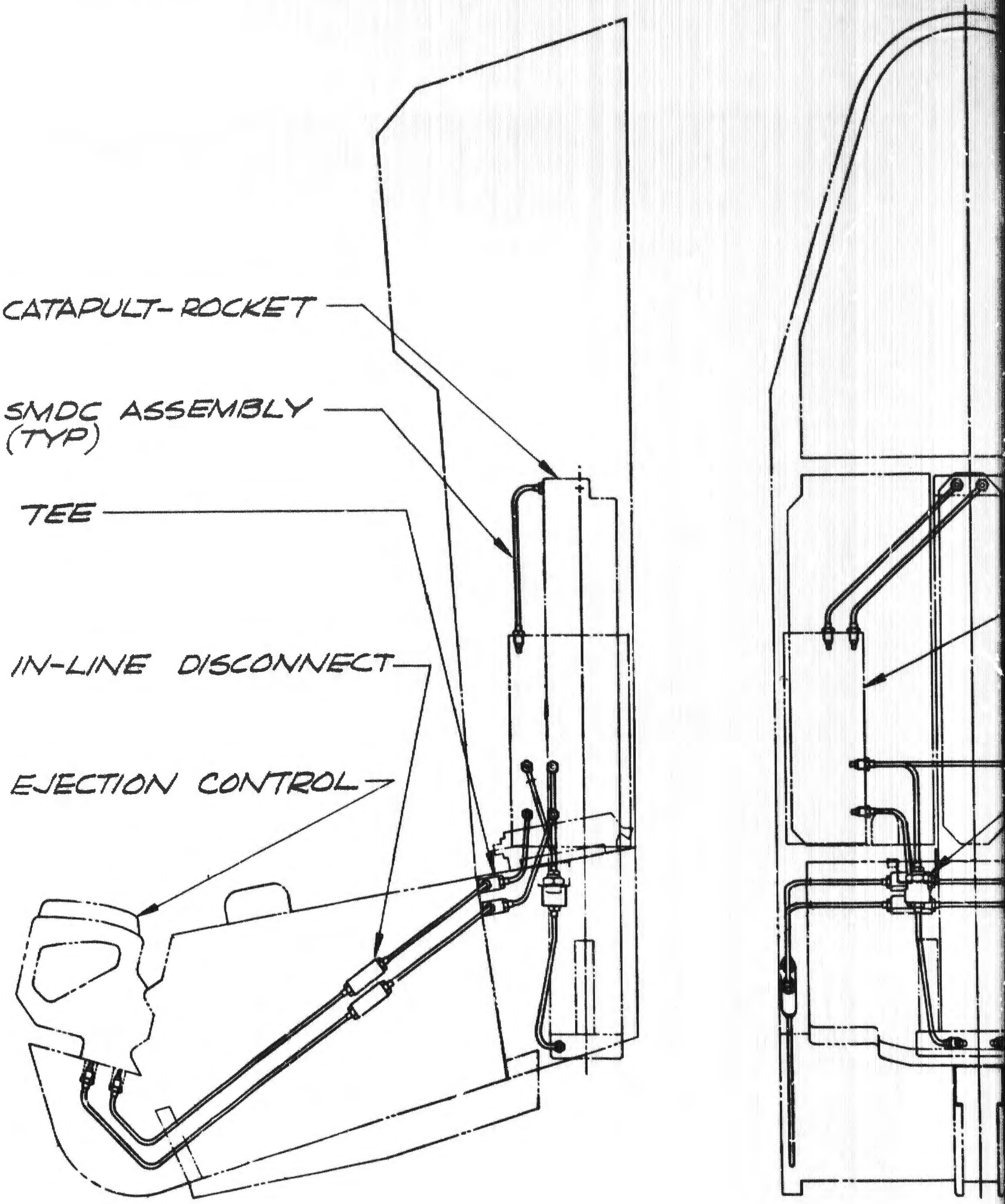
B.


CATAPULT-ROCKET
SMDC ASSEMBLY (TYP)
TEE
IN-LINE DISCONNECT
EJECTION CONTROL

A.

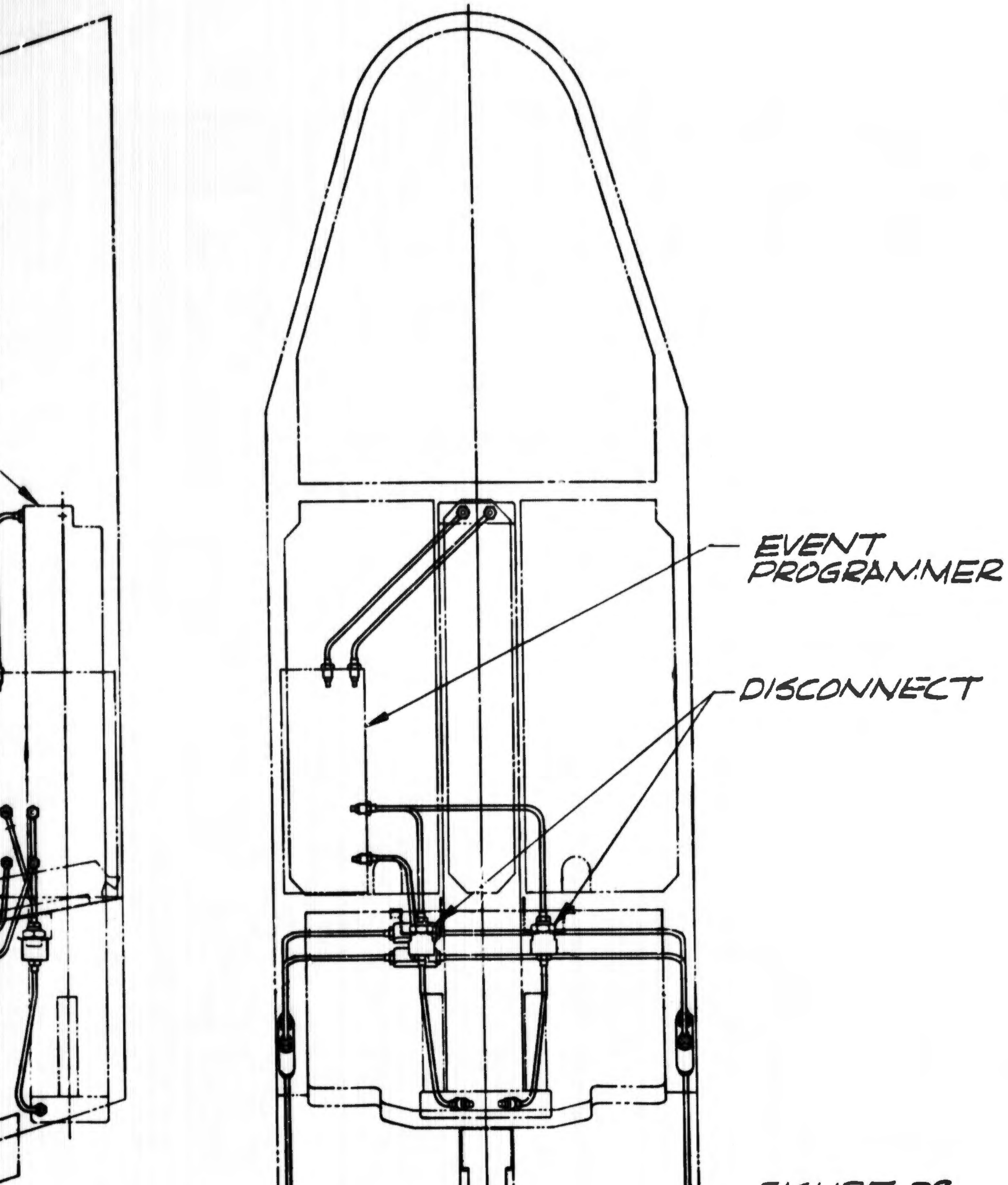


FIGURE 39
S.M.D.C. INSTL.

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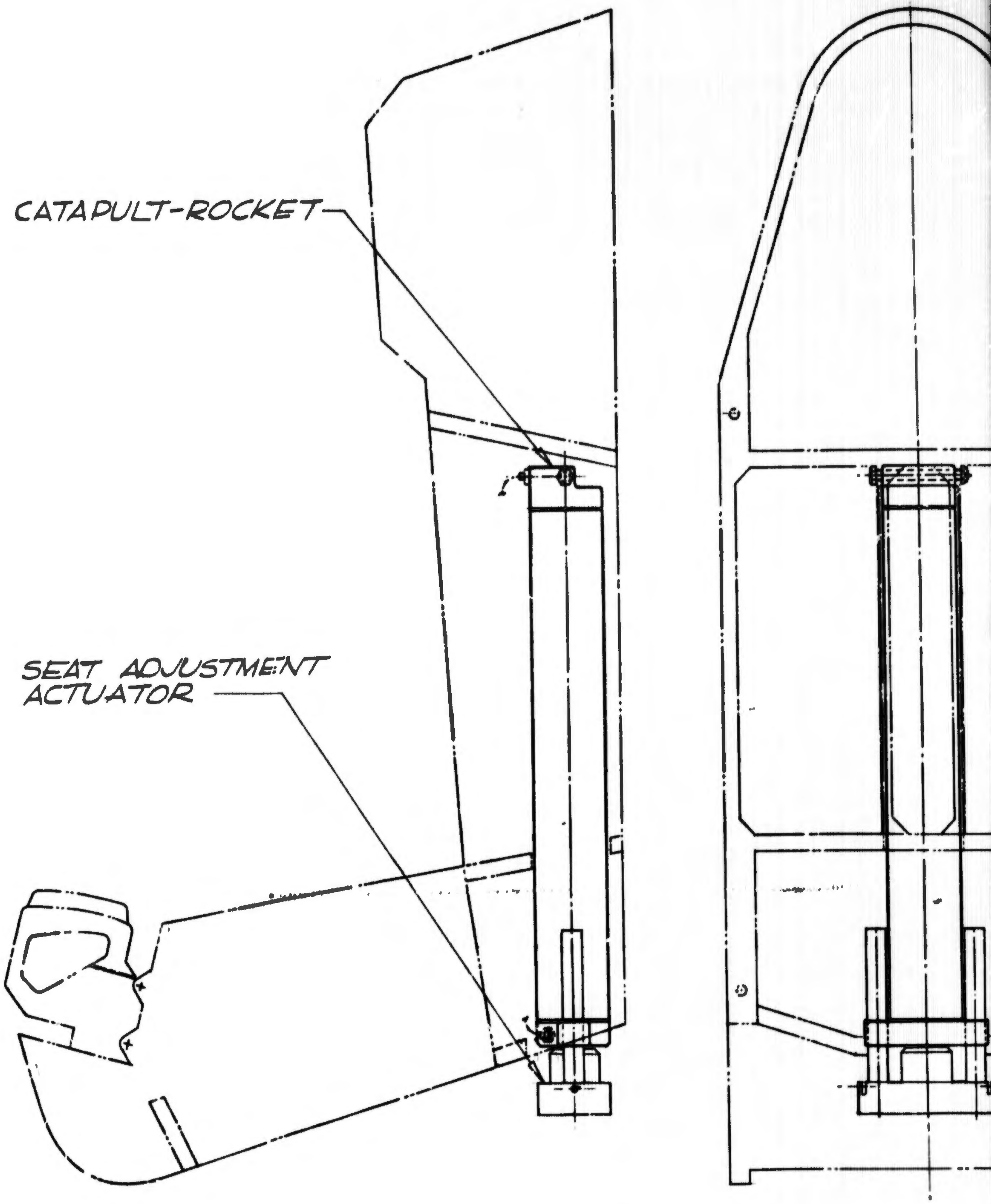
Q.



A.

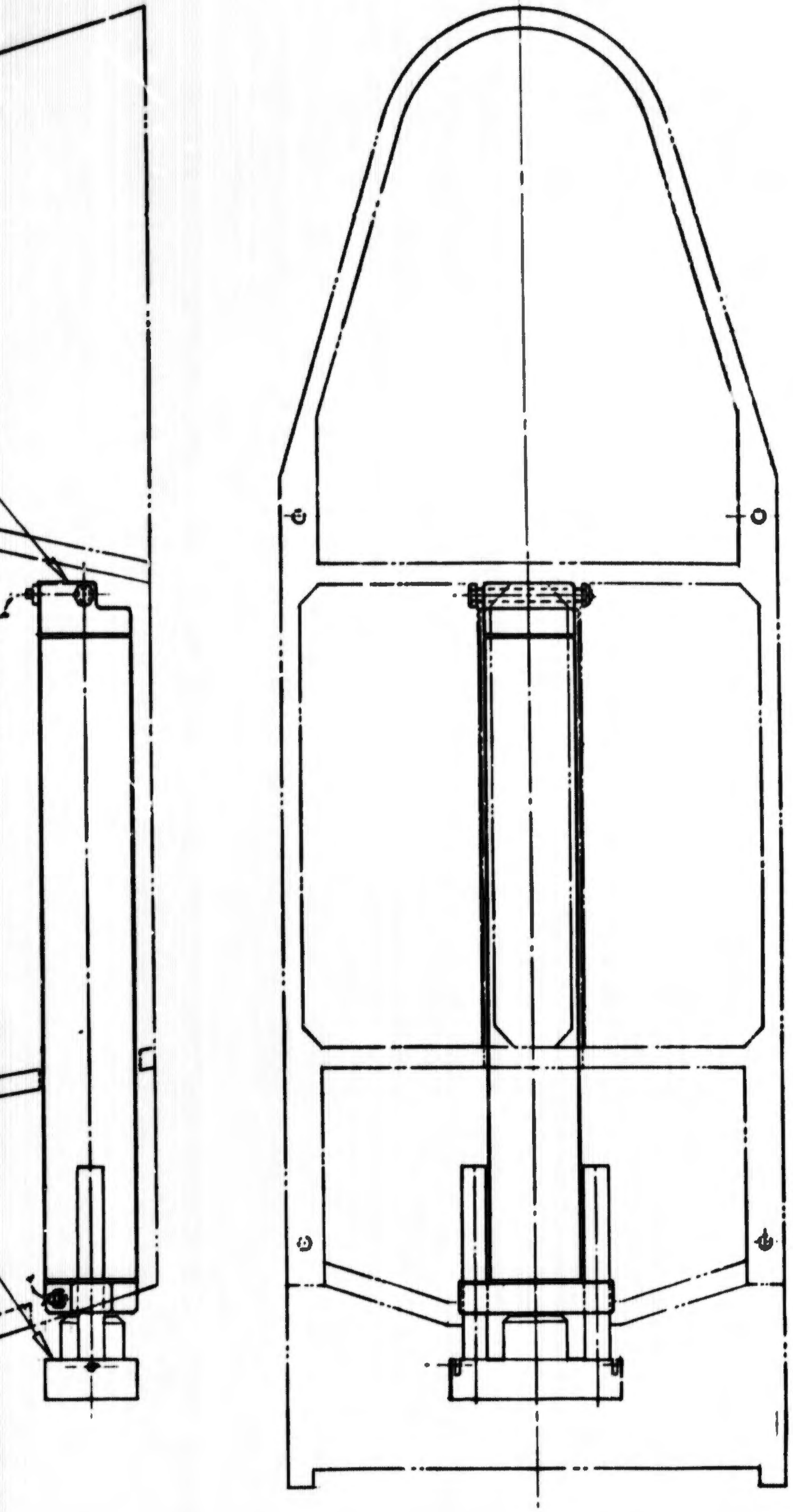


FIGURE 40
CATAPULT–ROCKET INSTALLATION

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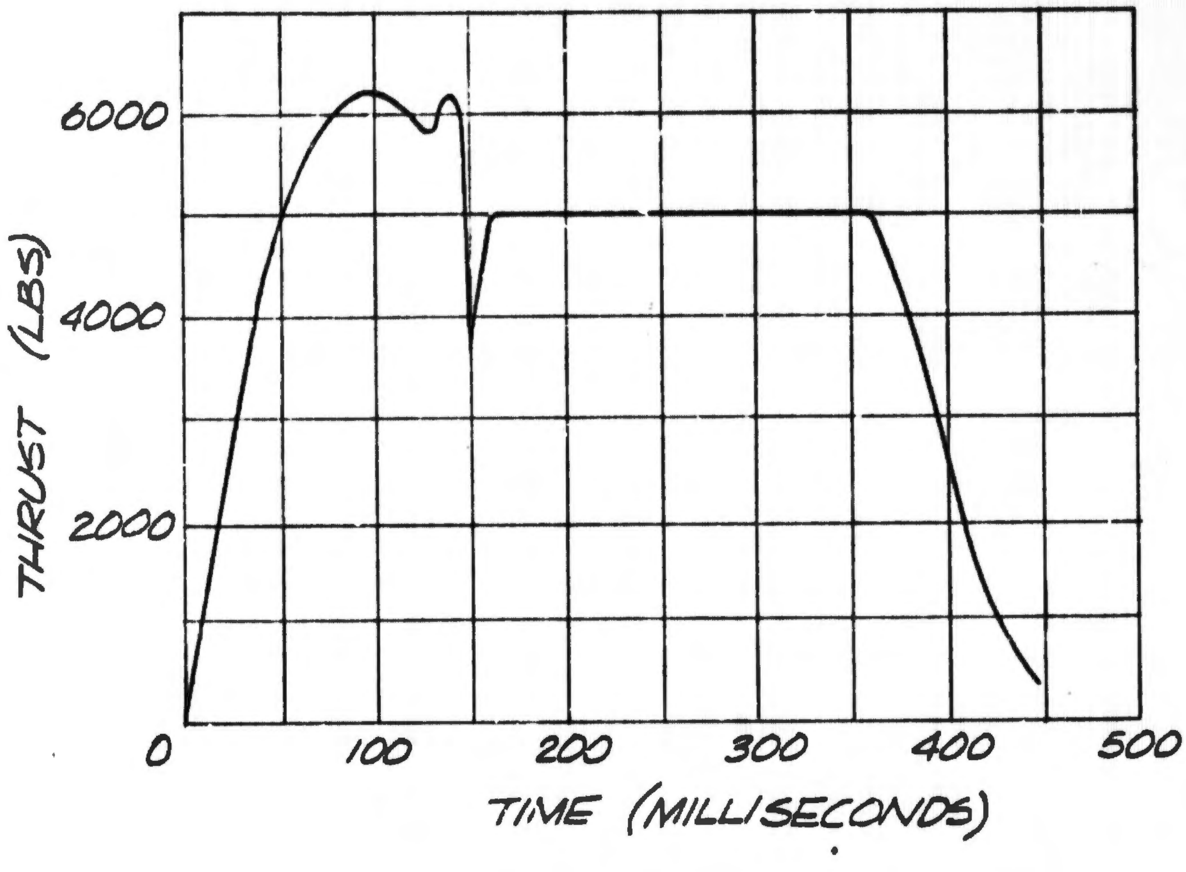

FIGURE 41
THRUST-TIME CURVE

rails. At this point, a rail trip switch will close and allow the PEEP signal to pass through and initiate the SMDC lines. In this manner, the rocket ignition can be controlled such that it occurs at the time the catapult stroke has reached a precise distance. Rocket ignition by rail trip allows the catapult and rocket thrust overlap to be precisely controlled regardless of variation in catapult stroke times. The catapult-rocket thrust vs time curve is shown in Figure 41.

Should ejection occur while the aircraft is inverted, a normally closed latching relay, located inside the PEEP, will be opened by electrical power from an aircraft mounted attitude sensor. Opening of this relay will preclude rocket ignition. Withholding the rocket burn will vastly improve the systems inverted escape capability. The system block diagram is shown in Figure 37.

An electrical powered seat adjustment actuator, Figure 40 will connect the rocket catapult to the aircraft floor structure. A seat adjustment switch located on the aircraft console will control the actuator which has a five inch adjustment stroke.

g. Vernier Rocket Installation

The six fixed impulse, fixed thrust vector solid propellant rocket motors are mounted as described below. Figure 42 is typical of these motors.

Roll Motor Installation

Two solid propellant fixed impulse rocket motors are mounted on the seat as shown in Figure 43. These motors are located to produce left and right rolling motion about the seat principal X-axis. The firing signal and sequence is provided by the Post Ejection Event Programmer. Each motor has a total impulse of 90 pound-seconds and a burn time of 0.18 seconds.

Pitch Motor Installation

Three solid propellant, fixed impulse rocket motors are installed as shown in Figure 43 to produce a pitching acceleration. Two 90 pound-second impulse motors are mounted on either side of the seat sustainer to provide negative pitching acceleration. One 36 pound-second motor is located on the seat centerline to produce a positive pitching acceleration. All three motors have a 0.18 second burn time.

A gas operated rate gyro and the power supply located in the post ejection event programmer provide a firing signal when the seat attains a pitching rate of +2.0 or -1.0 radians per second. These motors are sized to counteract a sustainer thrust and seat center of gravity offset ranging from 3.0 inches below to 1.0 inch above the c.g.

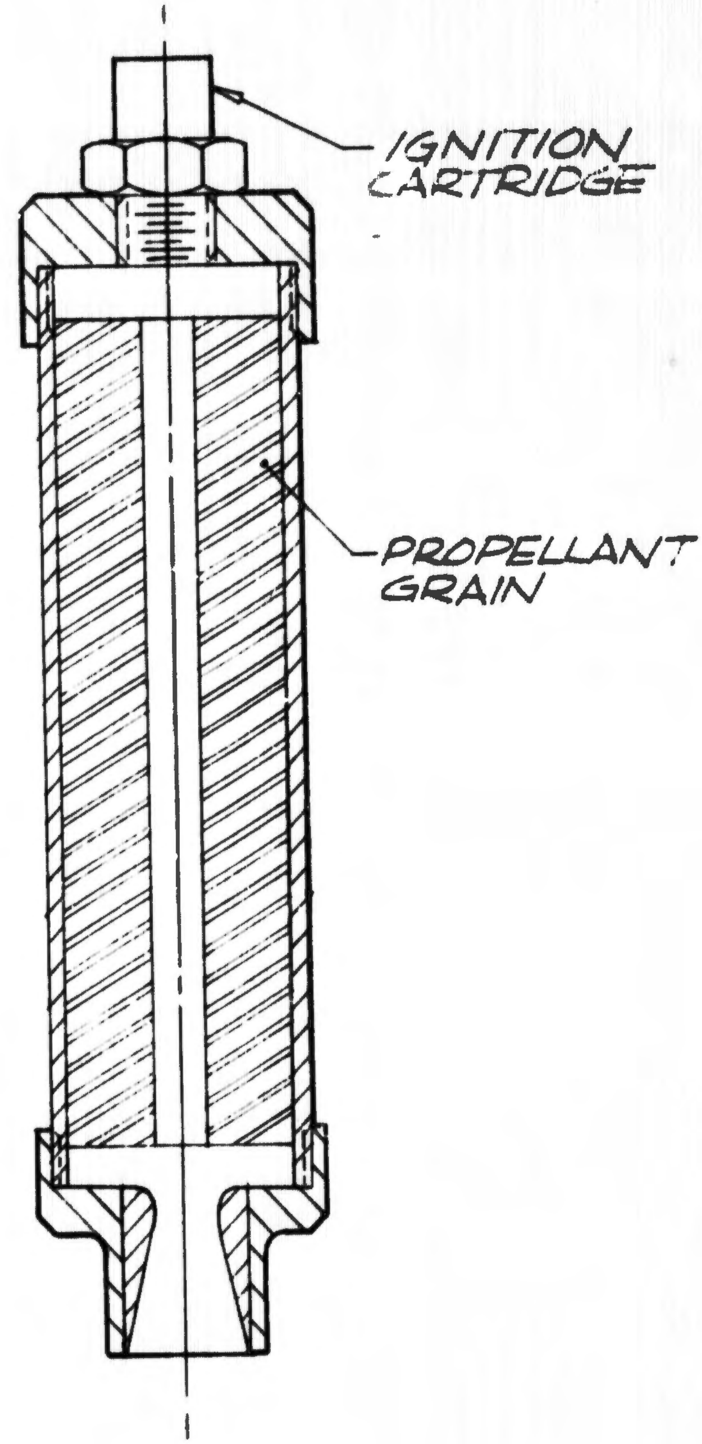

FIGURE 42
TYPICAL VERNIER ROCKET MOTOR

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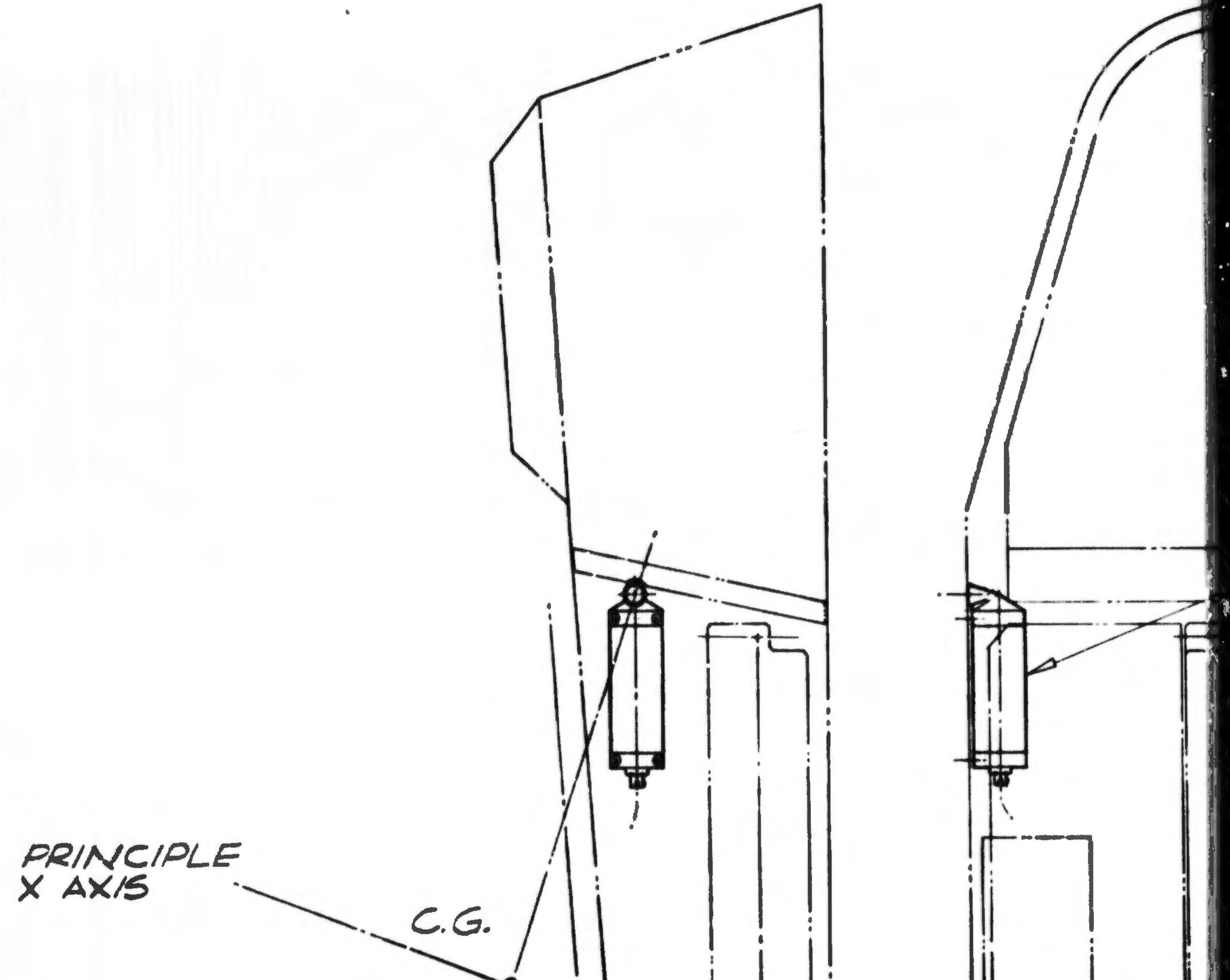

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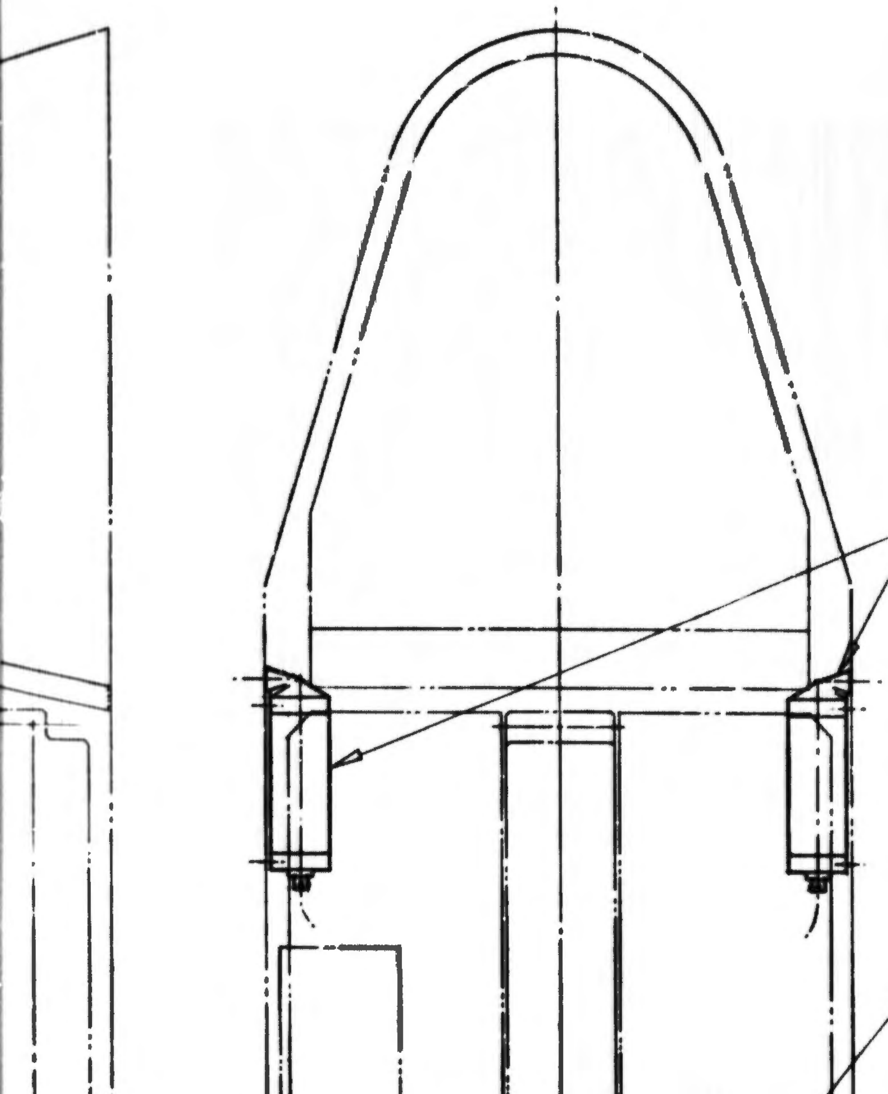

FIGURE 43
VERNIER ROCKETS

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B.

Yaw Rocket Installation

One 36 pound-second solid propellant rocket motor is installed on each seat to produce an acceleration about the principal Z-axis. The motor is installed to yaw the seats away from each other to provide diverging trajectories. The motor burn time is 0.18 seconds. Electrical power for motor ignition is provided by the post ejection event programmer. Figure 43 shows the yaw motor location.

h. Drogue Parachute System

The drogue system consists of a rocket deployed, 4.66 foot projected diameter hemisflo parachute attached to the seat back by a four point bridle as shown in Figure 44. The drogue system is initiated prior to seat tip-off to provide the earliest possible stabilization and deceleration of the ejected mass. Deployment is accomplished by an electrical signal from the PEEP at rail trip switch actuation initiating the dual bridgewire extractor rocket base charge. This base charge catapults the rocket out of its tube and ignites the rocket propellant at the end of a three inch stroke. The Rocket is shown in Figure 45. An extraction lanyard connects the rocket to the apex of the parachute canopy. First movement of the extraction rocket releases the drogue container lid allowing extraction of the canopy, suspension lines, riser and bridle assembly. After an appropriate time delay, which varies with aircraft speed, an electrical signal from the PEEP initiates two guillotines to sever the upper and lower bridles which releases the drogue from the seat. The drogue is released simultaneously with recovery parachute projection. For high altitude, high speed ejections, a time delay allows the lower bridle to be released after two seconds. An aneroid prevents the upper bridle from being released until the seat-man combination has descended in a head-up attitude to 15,000 feet. The upper bridle is then released and the recovery parachute deployed by an electrical signal from the PEEP. Refer to the block diagram Figure 37.

i. Recovery Parachute System

The recovery parachute system consists of a personnel parachute (A.F. drawing 50C7024-10) modified to incorporate a ballistic spreading gun, packed in a rigid container located in the seat headrest and deployed by an extraction rocket. The parachute risers are routed over the top of the head rest and down between the head rest pads. Adequate riser length is provided for the 5th through 95th percentile USAF pilots as defined by WADC TR 52-321. The parachute installation is shown in Figure 46.

Deployment of the parachute is accomplished by an electrical signal from the PEEP which initiates the extraction rocket.

Initiation of the rockets base charge catapults the rocket out at an angle of 20° as shown in Figure 47. At the end of a four and one-half inch stroke the motor propellant is ignited to the catapult ignition cartridge gases. A lanyard with the rocket release mechanism connects the rocket to the apex of the parachute canopy. Action of the rocket pulling this lanyard releases the container cover and withdraws the parachute, apex first. The rocket will continue to burn until complete parachute line stretch has been achieved. At parachute line stretch, a snubbing lanyard initiates the ballistic spreading gun and causes release of the extraction

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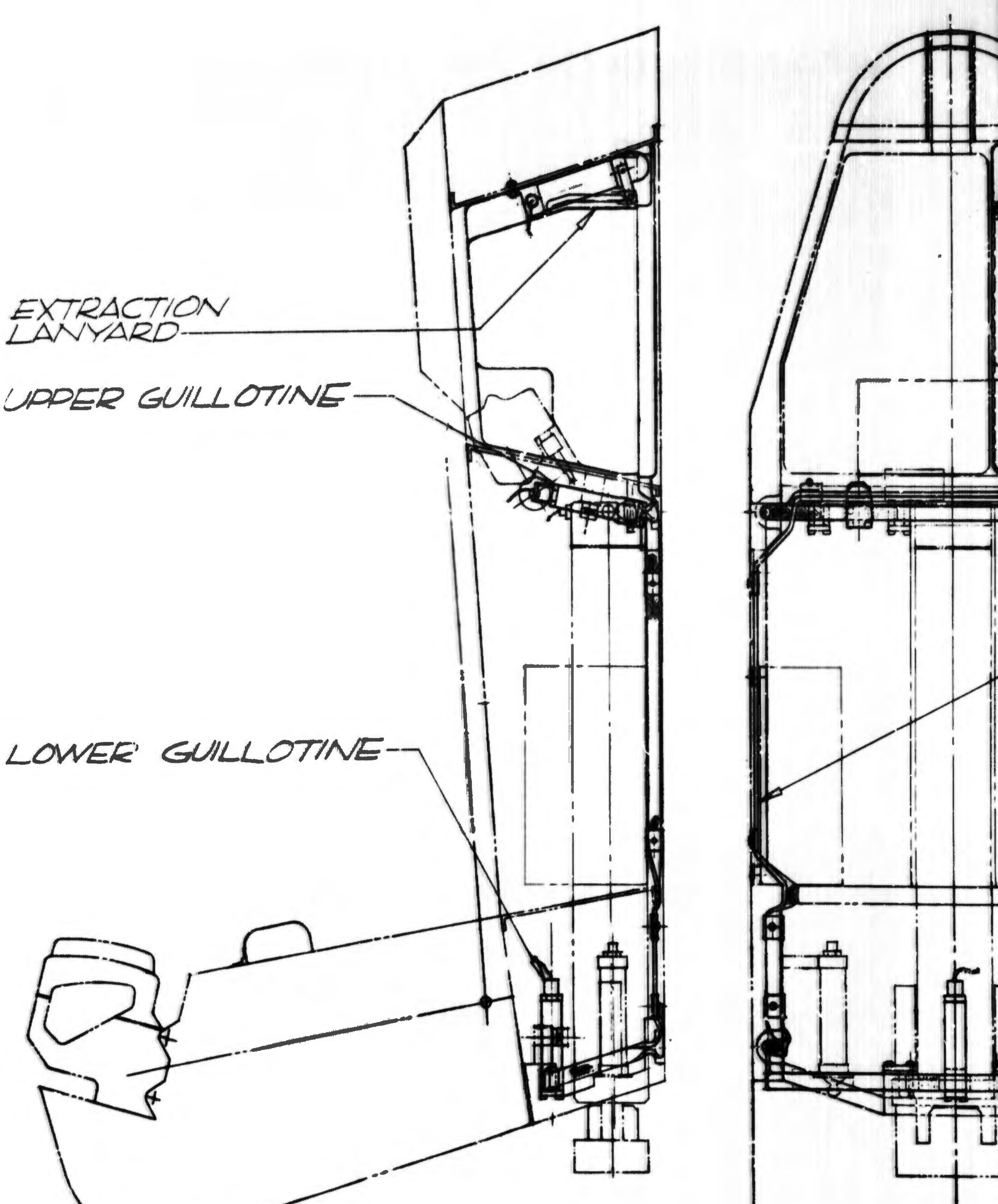

A.

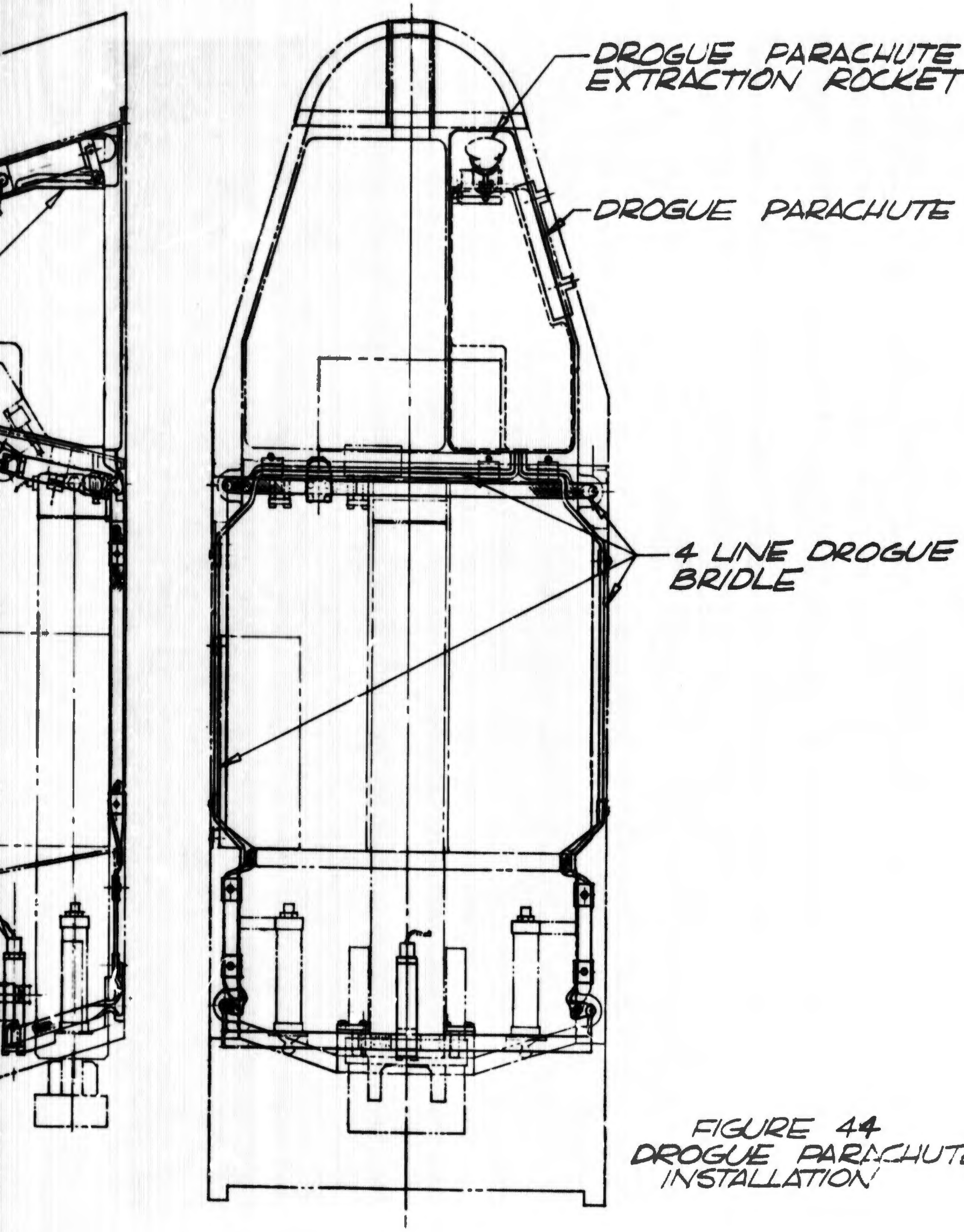

FIGURE 44
DROGUE PARACHUTE
INSTALLATION

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B.

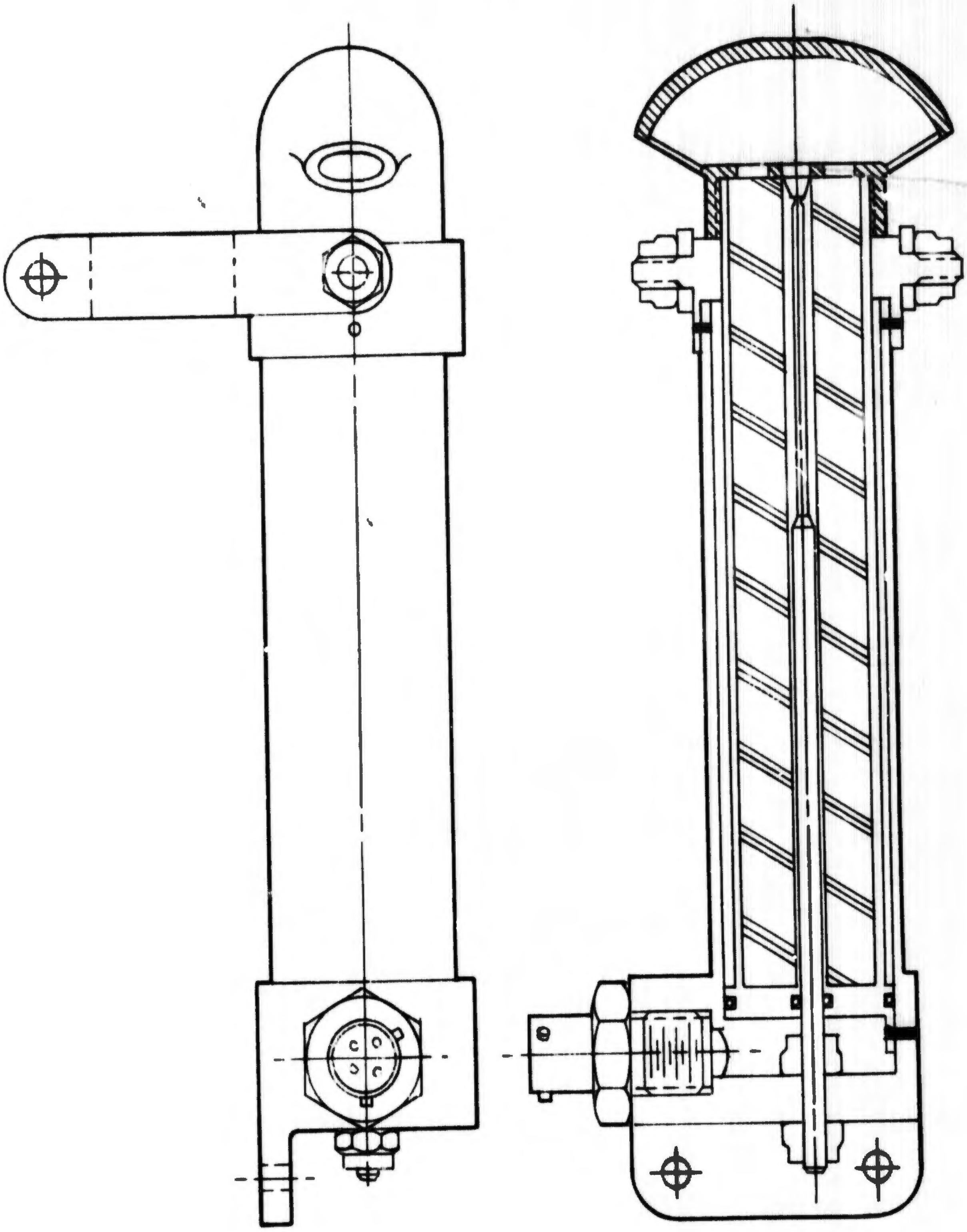

FIGURE 45
DROGUE PARACHUTE
EXTRACTION ROCKET CATAPULT

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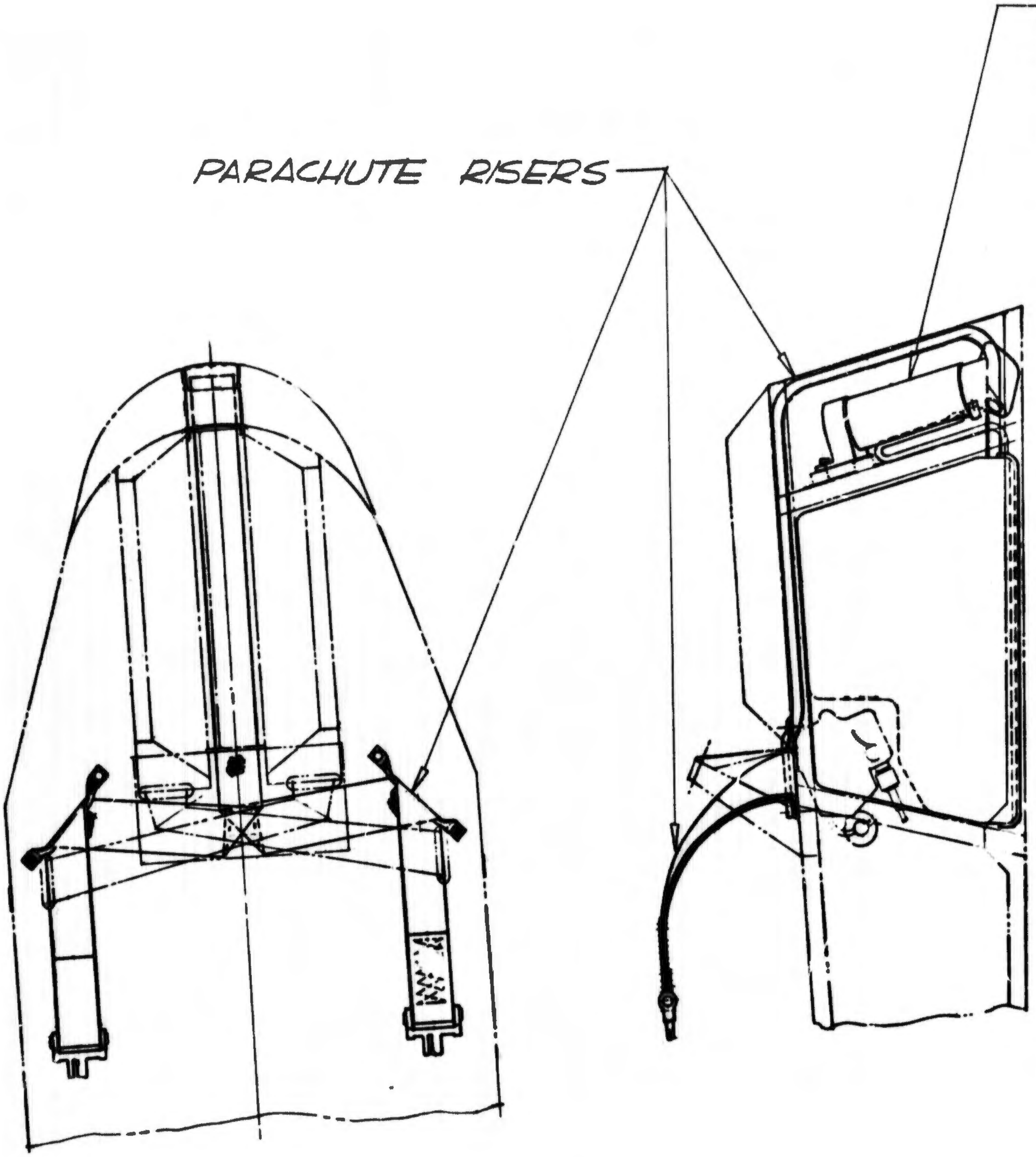

A1

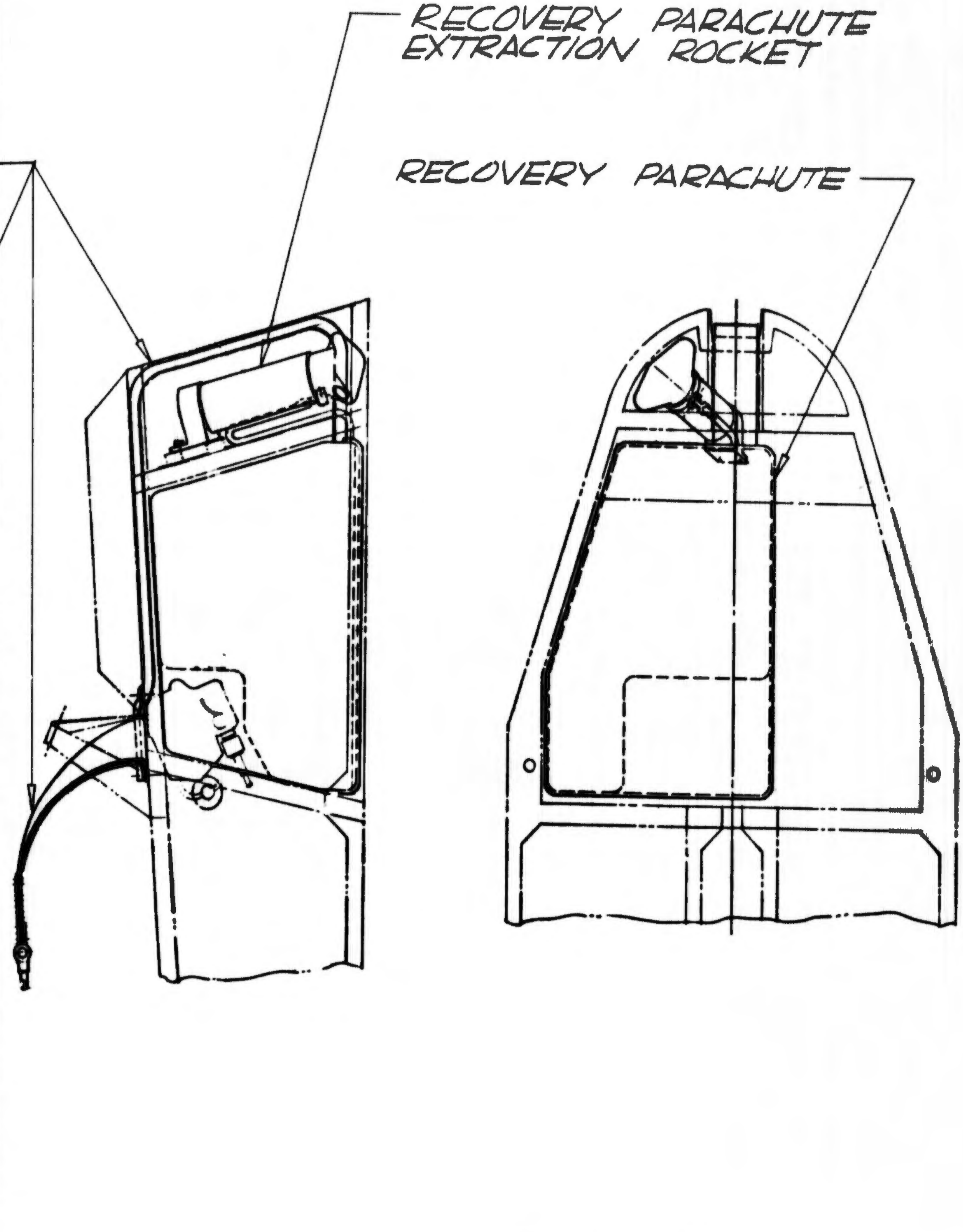

FIGURE 46
RECOVERY PARACHUTE
INSTALLATION

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R.

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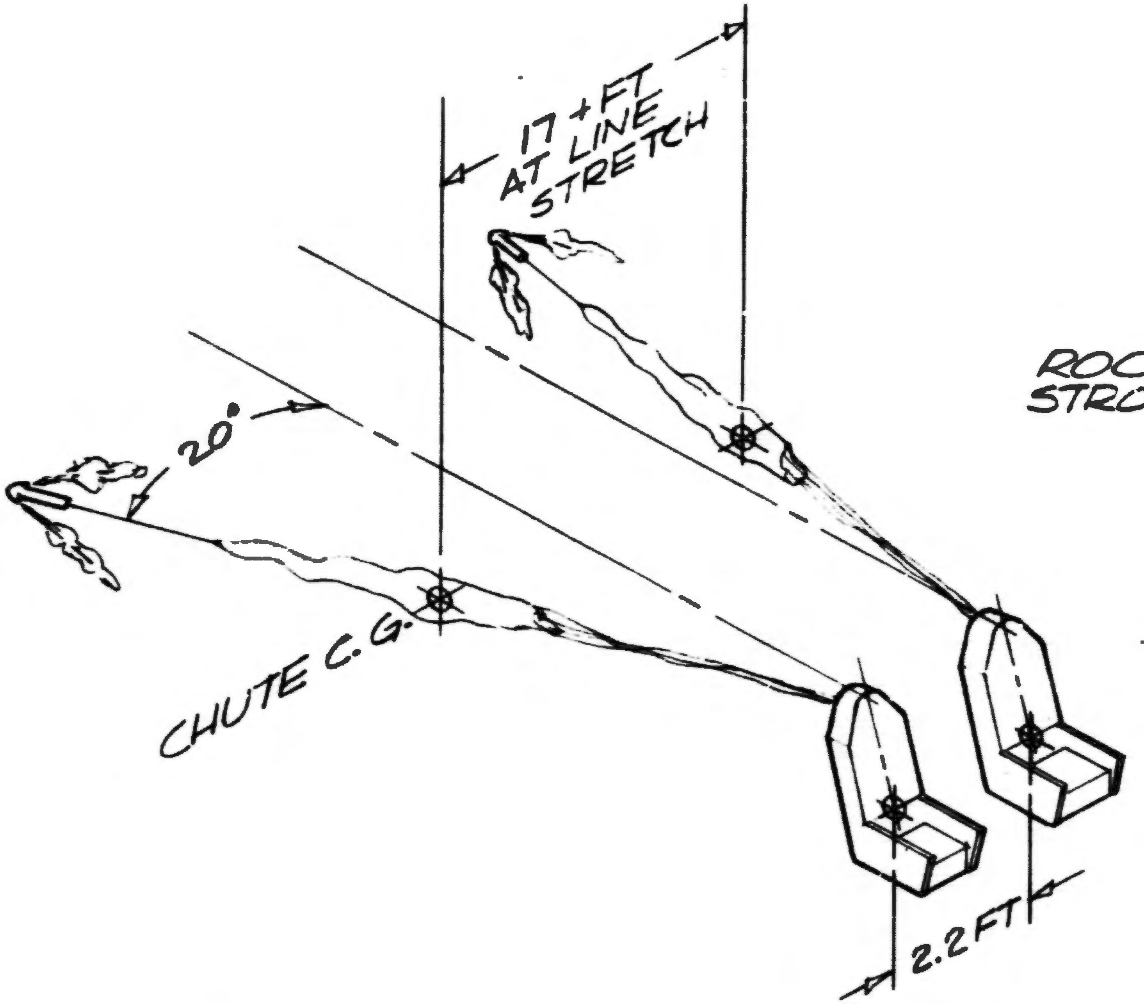


ROCKET FIRED WHILE SEAT
STROKE STILL RAIL GUIDED

EVENT	TIME
CAT. IGN.	0
CHUTE ROCKET EJECTED	.11
TIP-OFF	.14
LINE STRETCH	.39

FIGURE 47
PERSONNEL PARACHUTE PERFORMANCE

rocket from the parachute. Spreading gun action is shown in Figure 48. Harness release is initiated at the time of parachute spreading and the subsequent parachute inflation affects seat-man separation. Figures 49 and 50 show the rocket and its release mechanism.

j. Restraint System

The crew restraint system is a system of webbing straps, with fittings for the attachment of the parachute risers, inertia reel straps, survival kit retention straps, and lap belt, which is fastened to a one inch thick foam back pad. The harness straps encircle the crewman's torso and terminate at a single point release mechanism. The system consists of the following items:

- An adjustable single point release restraint/parachute harness
- An adjustable lap belt
- A powered retraction inertia reel
- Three webbing strap cutters
- Manual back-up handle

Lower torso restraint is provided by the lap belt. Each lap belt half integrates into the harness, connecting with the harness leg straps at the single point release mechanism. Adjusters are incorporated in the belt for length adjustment.

Upper torso restraint is provided by the webbing straps from the inertia reel. These straps encircle the roller fittings provided on the shoulder straps of the restraint harness, and cross for attachment to the ejection seat providing lateral restraint. Figures 51 and 52 illustrate the restraint system.

Adjusters are incorporated into the harness straps to allow the harness to be adjusted to the proper fit for the 5th through 95th percentile crewman. With this adjustment capability and the incorporation of the foam back pad, the harness becomes a part of the ejection seat and is not removed from the aircraft for normal egress/ingress.

The reel is a dual strap ballistic haul back reel with a self-contained gas generator. Two electrical initiators provide redundant initiation of the gas generator. Manual control is provided by a lever mounted on the lower left edge of the seat backrest. Manual movement of the lever to the locked position locks the reel and restrains the crew member. Under sever accelerations, the reel will automatically lock on sudden strap play out or "g" loading. Any strap slack which might occur after the reel has locked will be automatically taken up by the reel. After the reel has automatically locked, cycling of the manual control lever will return it to normal operation. The inertia reel conforms to MIL-R-8236.

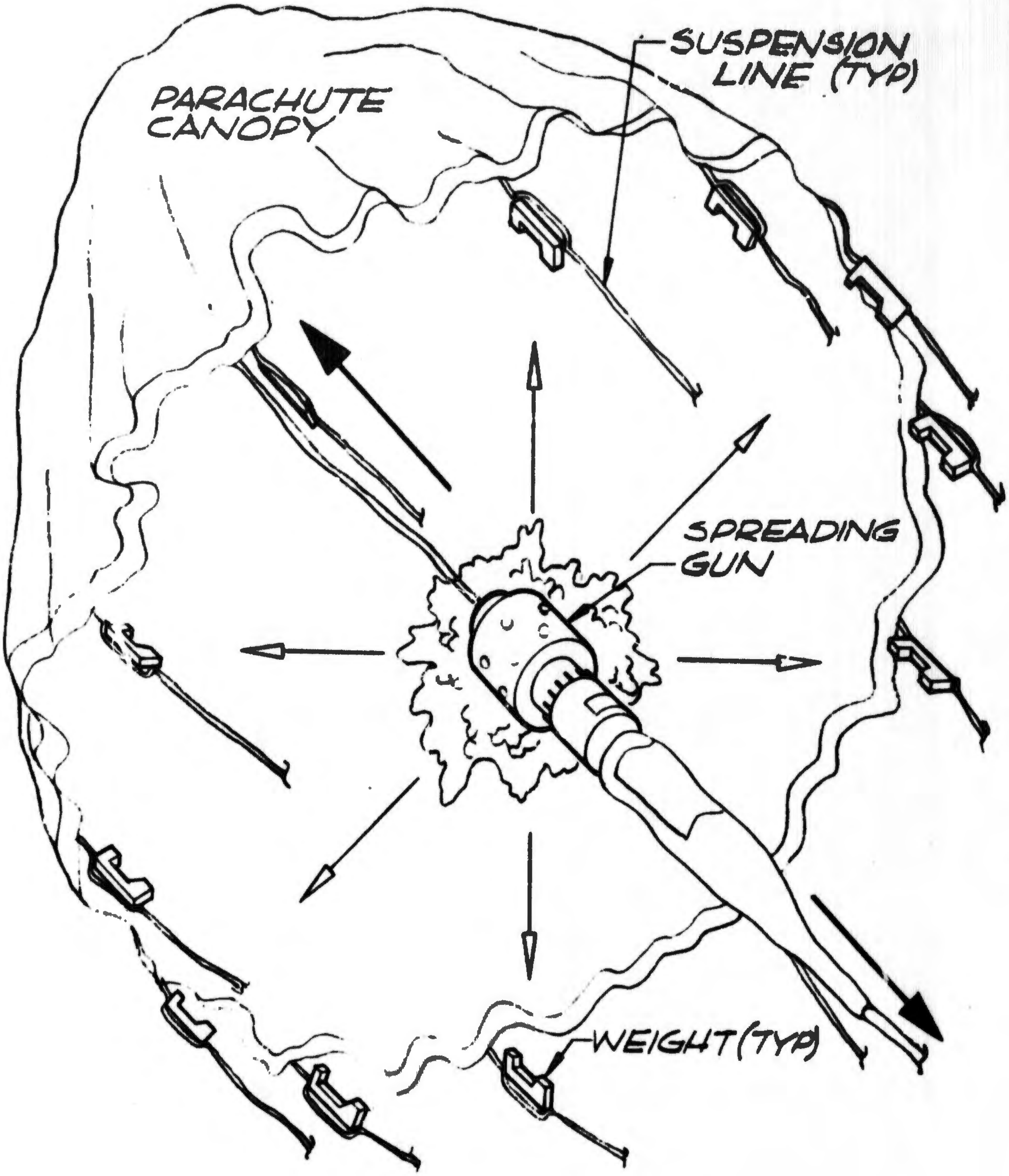


FIGURE 48
PARACHUTE SPREADING GUN

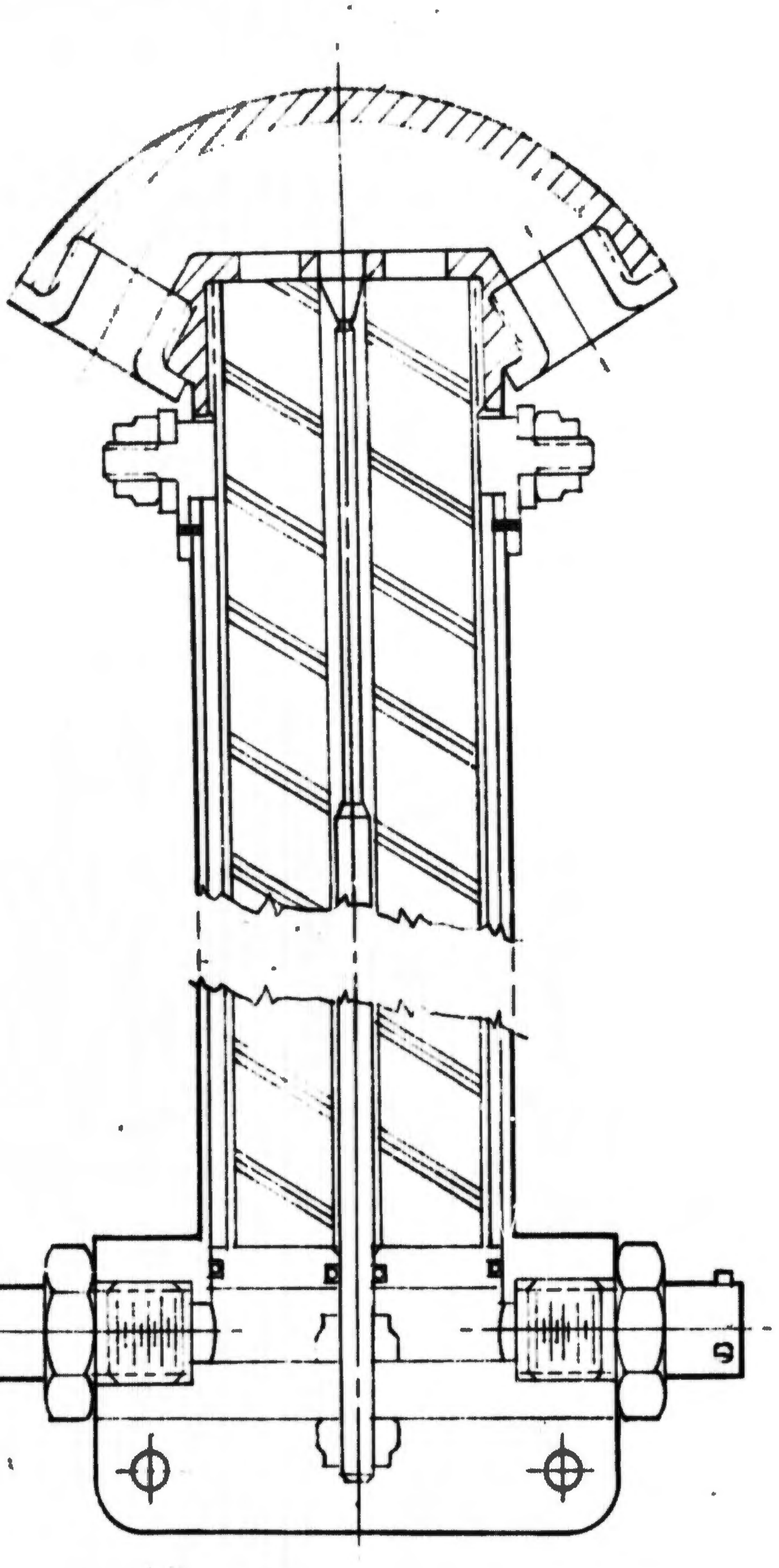


FIGURE 49
RECOVERY PARACHUTE
EXTRACTION ROCKET CATAPULT

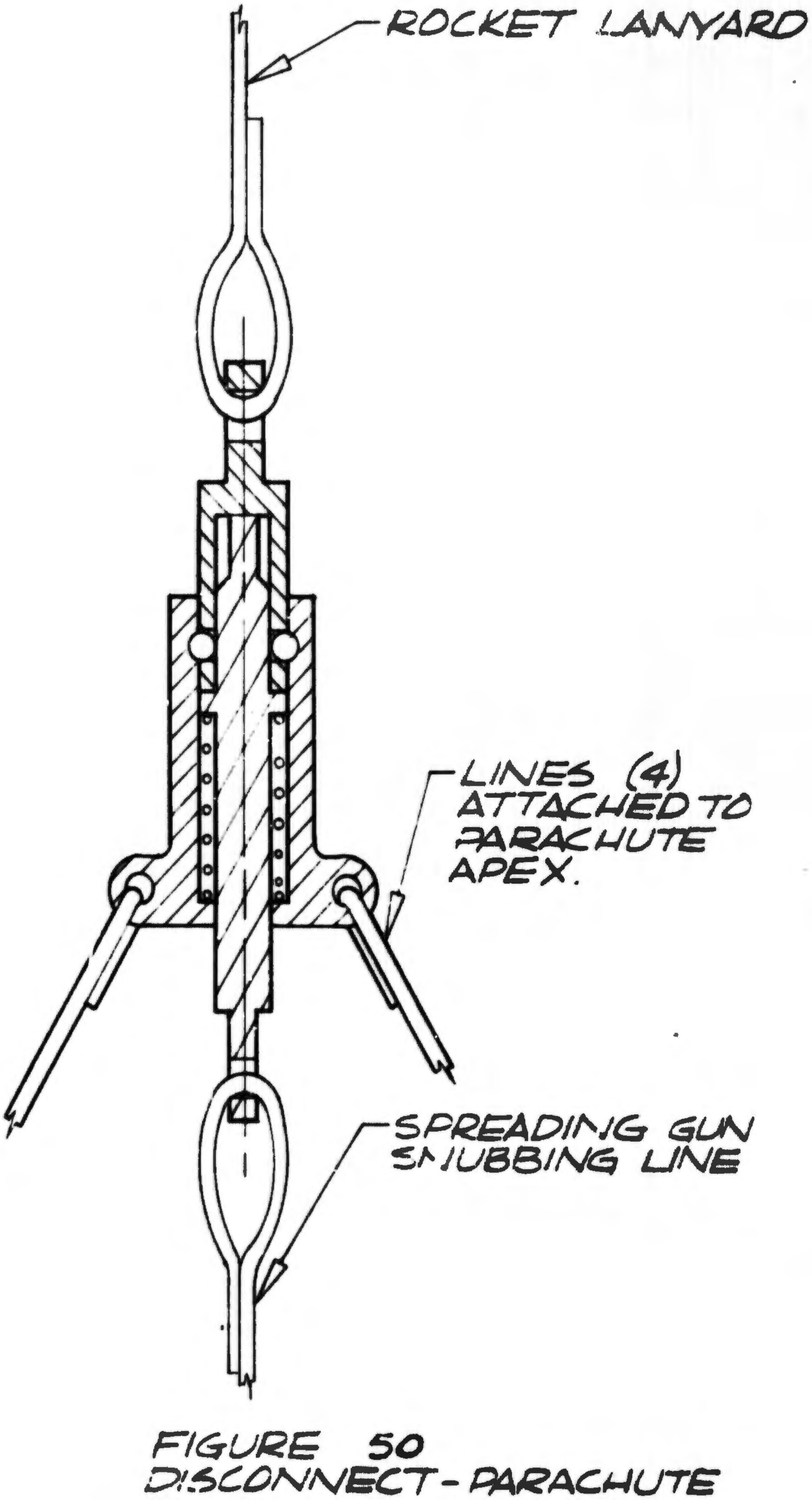


FIGURE 50
DISCONNECT - PARACHUTE
EXTRACTION ROCKET

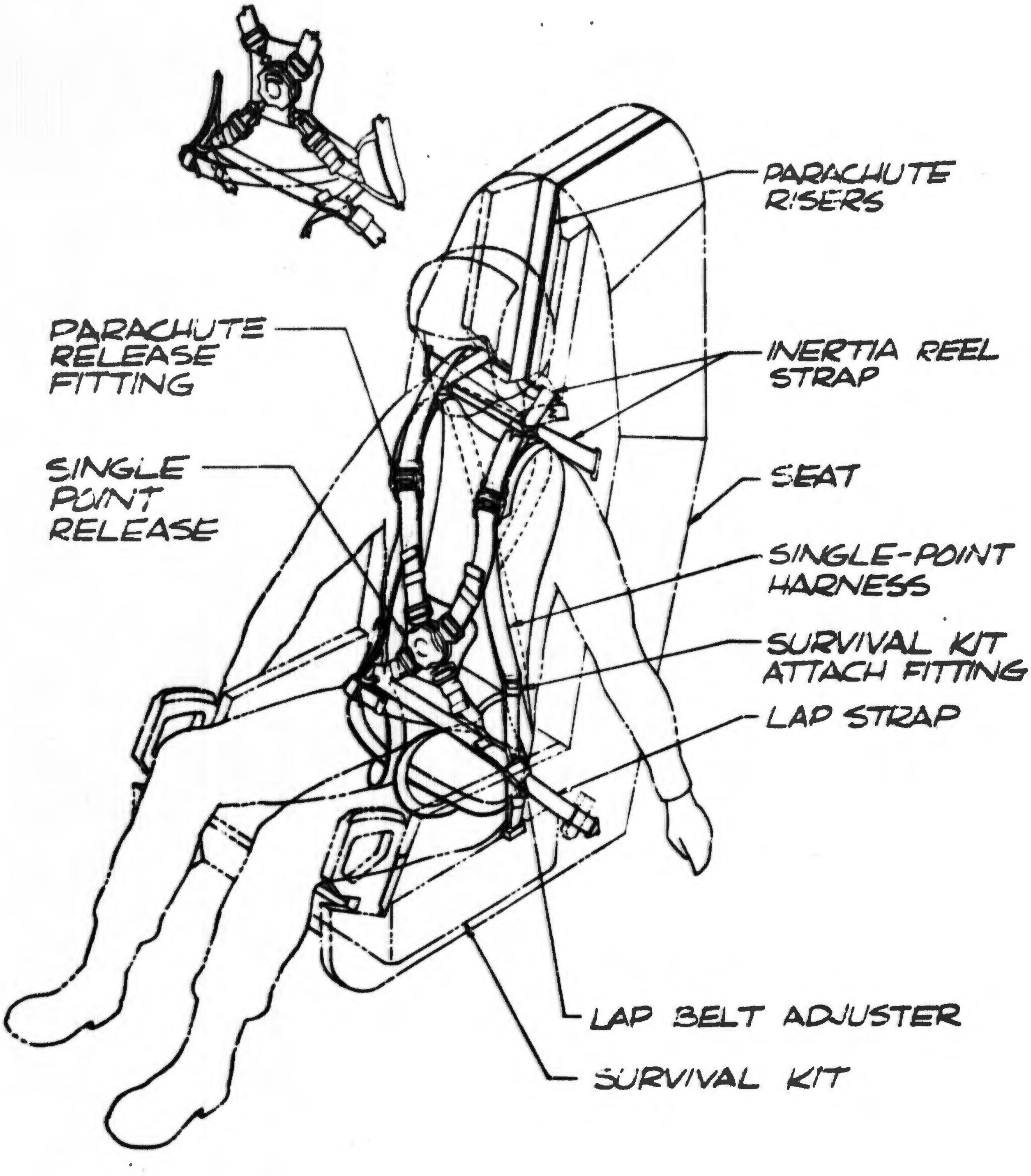


FIGURE 51
RESTRAINT HARNESS

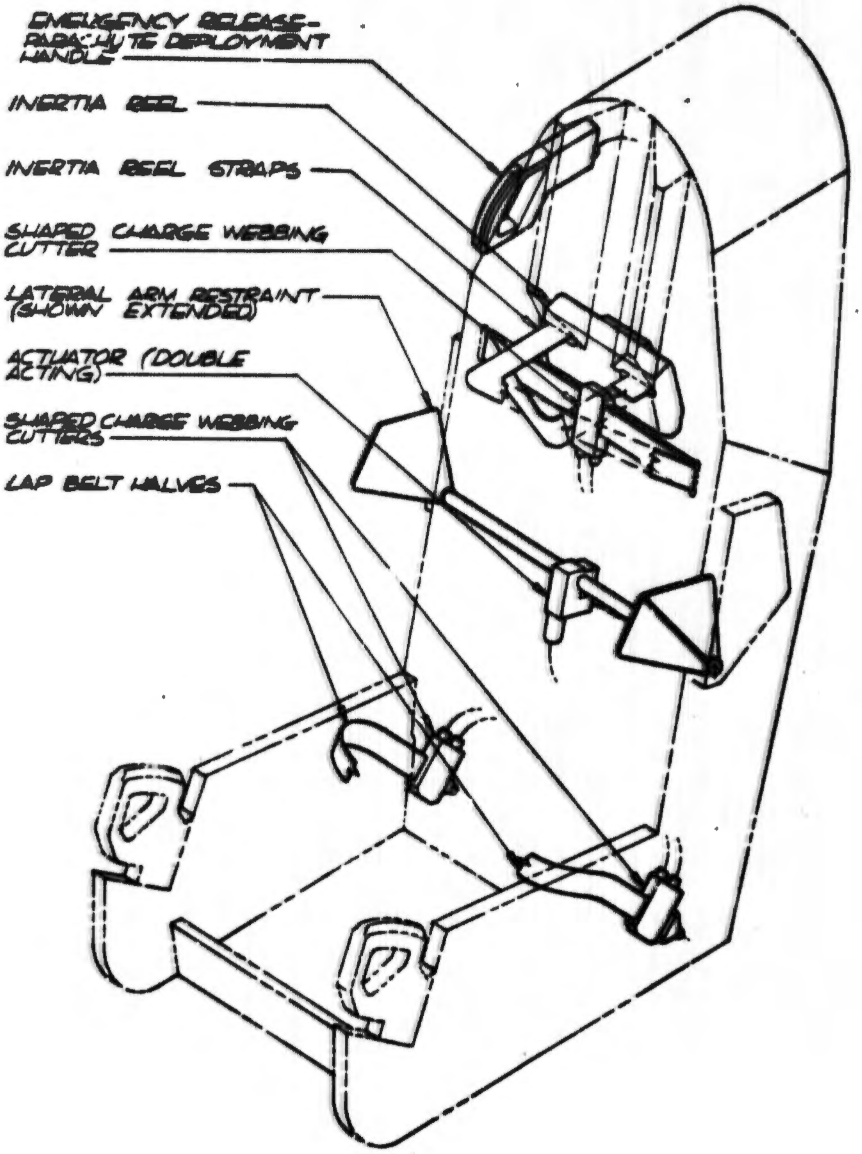


FIGURE 52
LATERAL RESTRAINT INSTALLATION

(1) Ejection Operation

In an ejection sequence, the restraint system functions as follows: On electrical signal from the PEEP, the dual ballistic inertia reels are initiated to restrain the crewman against the backrest of the seat and lock in this position. Throughout catapult stroke, rocket burn, and seat deceleration, the crewman is restrained in a safe posture. The shaped charge webbing cutters (Figure 53) are electrically initiated by the PEEP through a 0.3 second time delay. This delay allows the lap belt and inertia reel straps to be explosively cut freeing the crewman from the seat 20 to 50 milliseconds after parachute line stretch occurs. The harness distributes the parachute snatch load into the seat structure. An aneroid in the PEEP prevents harness release and parachute deployment above 15,000 feet.

At the end of parachute descent, the crewman can free himself from his parachute in one of two ways. Releasing the two parachute riser harness fittings frees him from the parachute canopy, releasing the surge point harness release fitting allows him to become completely free of harness, parachute, and survival kit.

(2) Manual Back-Up

In a normal ejection sequence, restraint release and parachute deployment are automatic with no action required by the crewman. As a back-up system in the ejection sequence, the crewman can manually release his restraint to the seat and deploy his parachute by pulling the emergency release/parachute deployment handle. A squeeze and pull action of 20 pounds force on the handle activates a thermal bettery which electrically initiates the parachute deployment rocket. After a 0.3 second time delay, the thermal battery initiates the harness webbing cutters which sever the lap belt and inertia reel straps. This delay allows the crewman to become free of the seat at the exact time parachute line stretch occurs. An aneroid block is incorporated in the back-up handle to prevent its actuation above 15,000 feet altitude. Location of the handle is shown in Figure 52.

(3) Ground Ingress/Egress

For crew ingress the harness is in the aircraft and all attachments to the ejection seat have previously been made. When seated, the crewman dons the harness and connects the lap belt halves to the lower harness straps. He then connects the two lower straps and the right upper strap to the single point release mechanism which is attached to the upper left harness strap.

For normal egress, the crewman can actuate the single point mechanism and be completely free of his restraint. He can then make a "shirtsleeve" egress with the harness, parachute, and survival kit remaining in the aircraft.

If emergency conditions require the crewman to egress with his survival kit, he must release the fittings that attach the parachute risers to the harness and pull the emergency release/parachute deployment handle. This action causes severance of the lap belt and inertia reel straps and allows egress to be accomplished with the harness and survival kit remaining

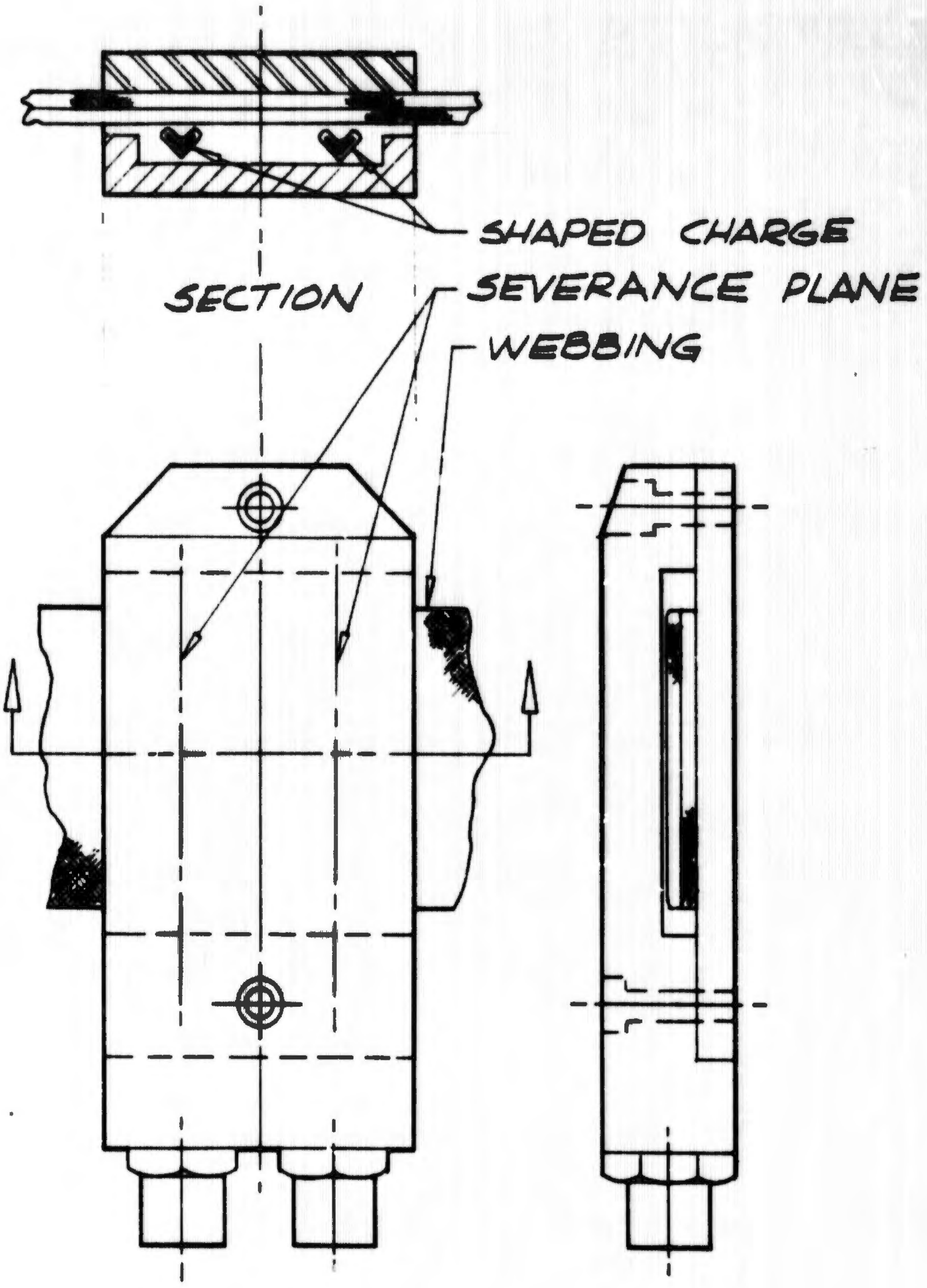


FIGURE 53
SHAPED CHARGE WEBBING CUTTER

attached to the crewman. The rail trip switch, being open while the seat remains in the aircraft, prevents deployment of the recovery parachute during this egress procedure.

k. Seat Structural Arrangement Description

(1) Description of Structure

Functionally speaking, the seat structure must provide a seating surface for the occupant, attachment for the occupant restraint system, mounting provisions the occupant restraint system, mounting provisions for the ejection and recovery subsystems, and load paths to the parent aircraft.

The seat structural arrangment is shown in Figure 54. The concept utilized is a semimonocoque structure comprised of shear carrying webs of sheet aluminum cap strips to resist axial loads. The seat assembly consists of two sides joined by three bulkheads which carry the slide block loads. The seat bucket is comprised of two sides which mount the ejection controls, a beaded and stiffened bottom on a foreward bulkhead to close the bucket.

(2) Introduction of Loads into Structure

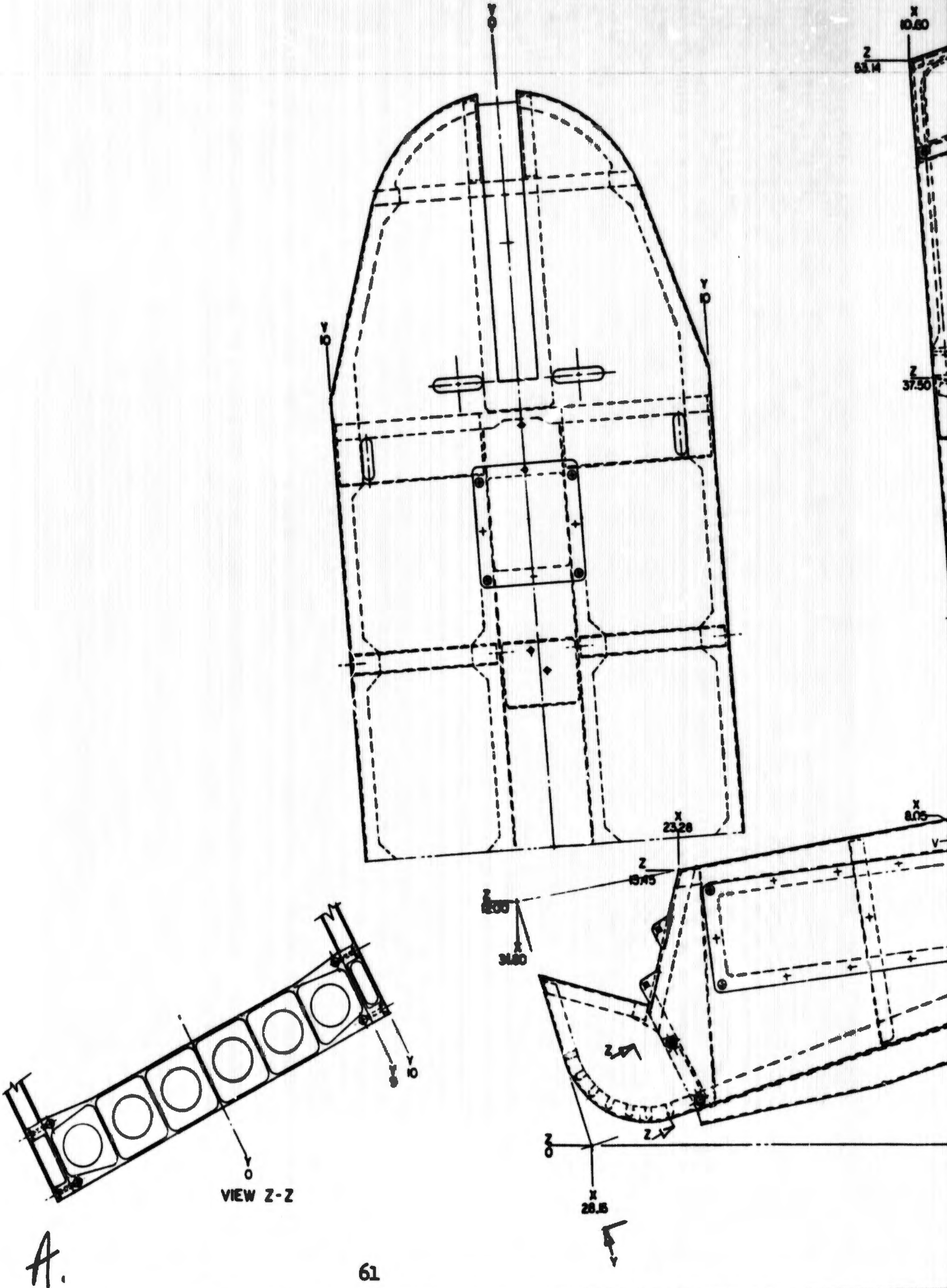
Major bulkhead loads derive from the slide block reactions. In addition the upper and lower bulkheads serve as attachment points for the occupant restraint harness. The upper and mid bulkheads are also loaded by the catapult mounting frames.

- Restraint Harness - All harness loads are reacted at the upper and lower seat bulkheads. The shoulder harness is grounded to the inertia locking reel installed on the upper bulkhead. The lap straps pass through the back closure of the bucket and attach to the lower seat bulkhead.

- Ejection Catapult - The catapult thrust is introduced into seat structure at the upper ends of the catapult beams located at $Y = \pm 4.0$. These beams are placed in equilibrium by shear load applied by the upper and mid block which are more highly loaded by the condition existing during ejection.

- Vernier Motors - Two of the three pitch motors are installed up the lower seat bulkhead and this member furnishes the reactions to the motor thrust forces. The motor inertia and thrust forces are out of the bulkhead plane and subject it to flexural loading. The pitch up vernier motor and the roll motors are installed on the seat bucket bottom surface.

- Drogue and Recovery Parachute Assemblies - These items including their respective deployment rockets are located in the seat headrest area. The reaction loads from the catapult portion of the chute deployment rockets is resisted through headrest structure to the mid and lower slide blocks. In the high speed mode seat pitching inertia is opposing the personnel chute rocket-catapult.


Y
0
Y
10
Y
10
X
10.60
Z
53.14
Z
37.50
X
8.05
V-
X
23.28
Z
19.45
Z
12.00
X
31.80
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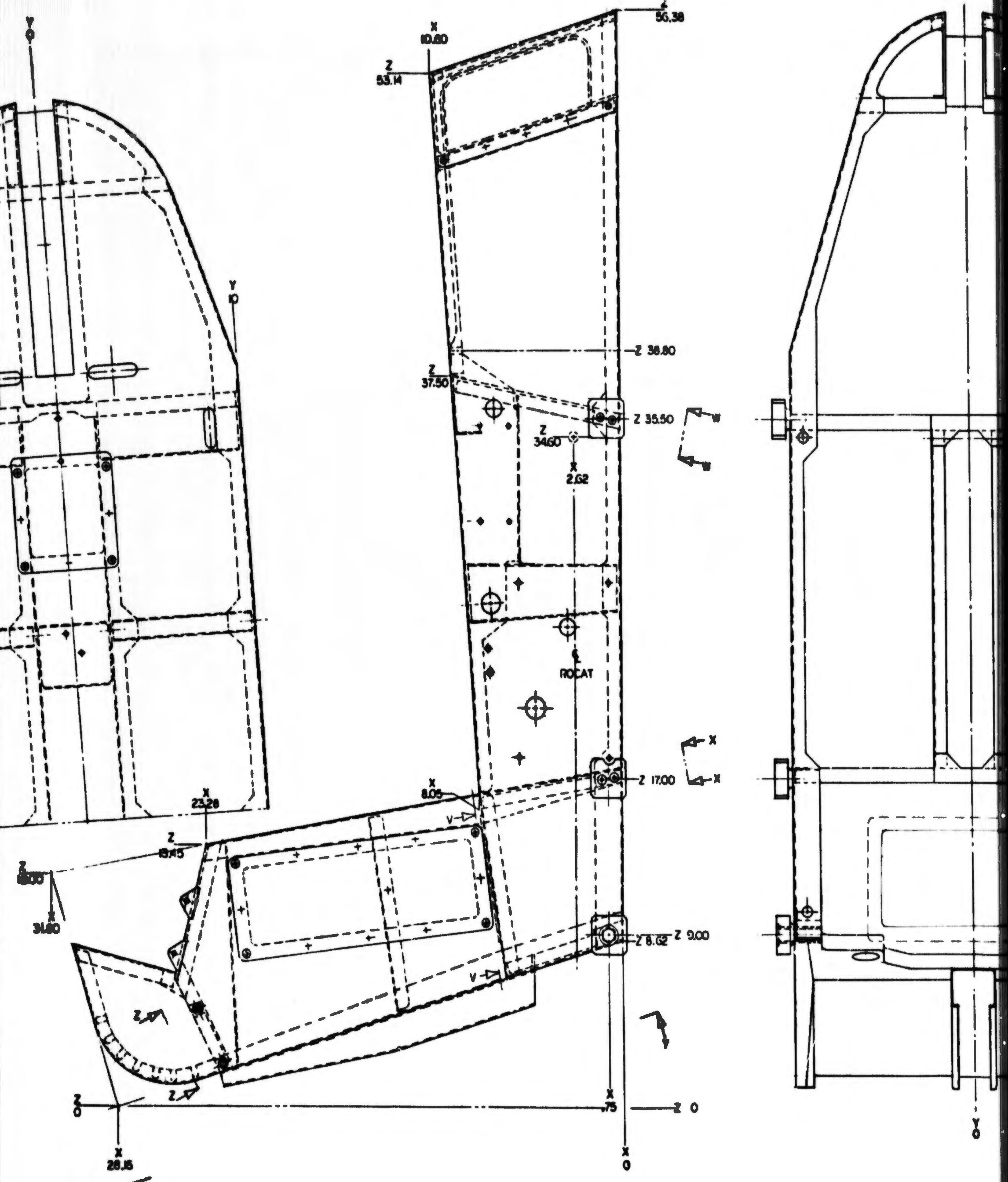
0
X
28.16
Y
10
Y
0
Y
0
VIEW Z-Z

A.


Y
0
Y
10
X
10.80
Z
56.38
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53.14
Z 38.80
Z
37.50
Z 35.50
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Z
34.60
X
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ROCAT
X
X
Z 17.00
X
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X
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B.

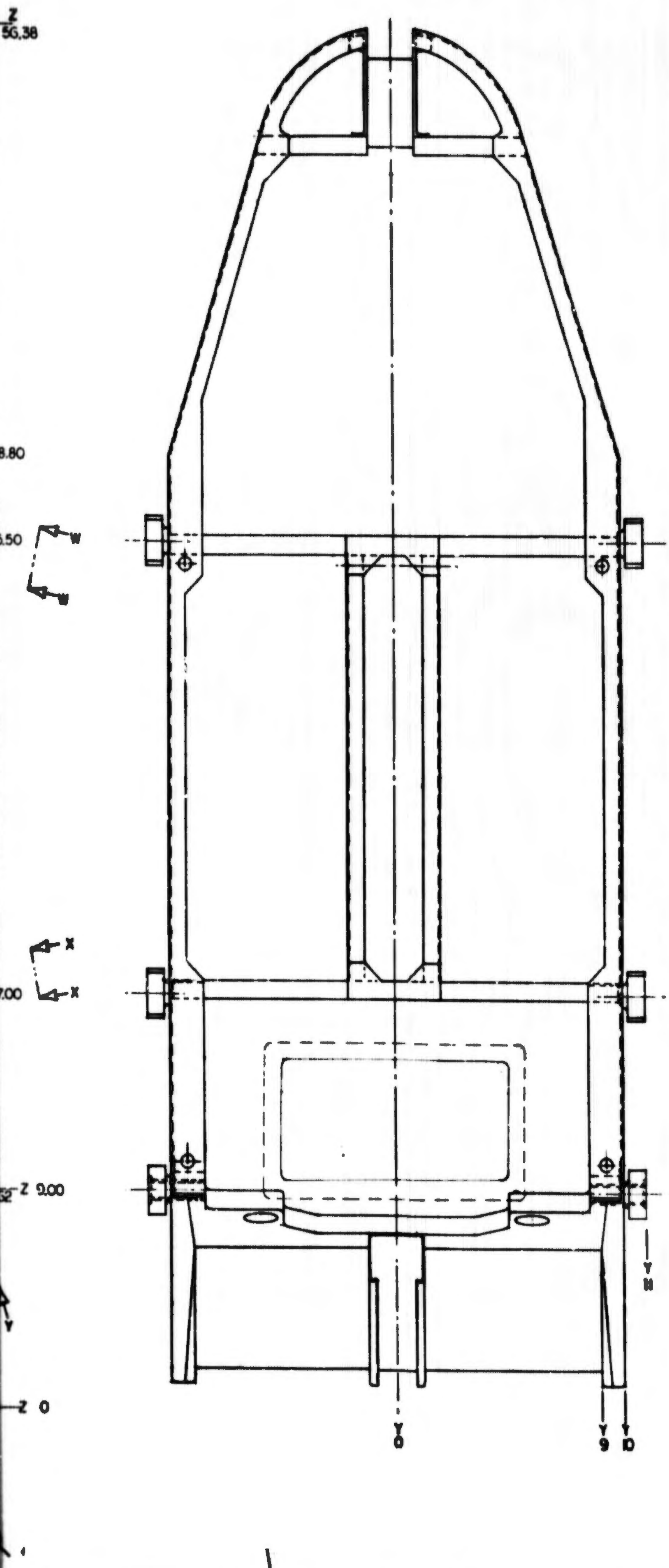

FIGURE 54
STRUCTURAL
ARRANGEMENT

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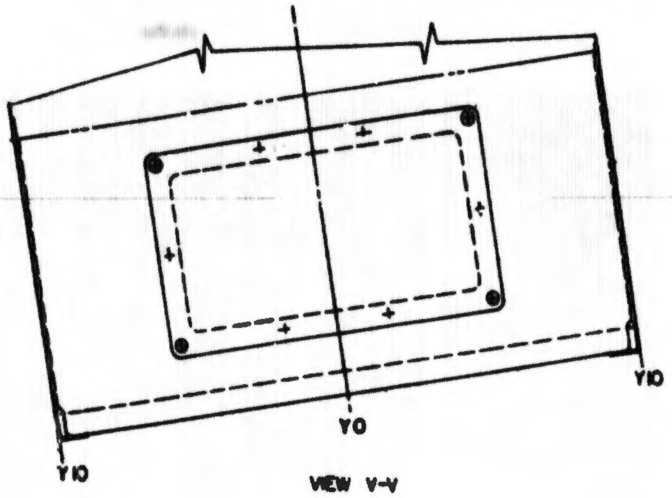
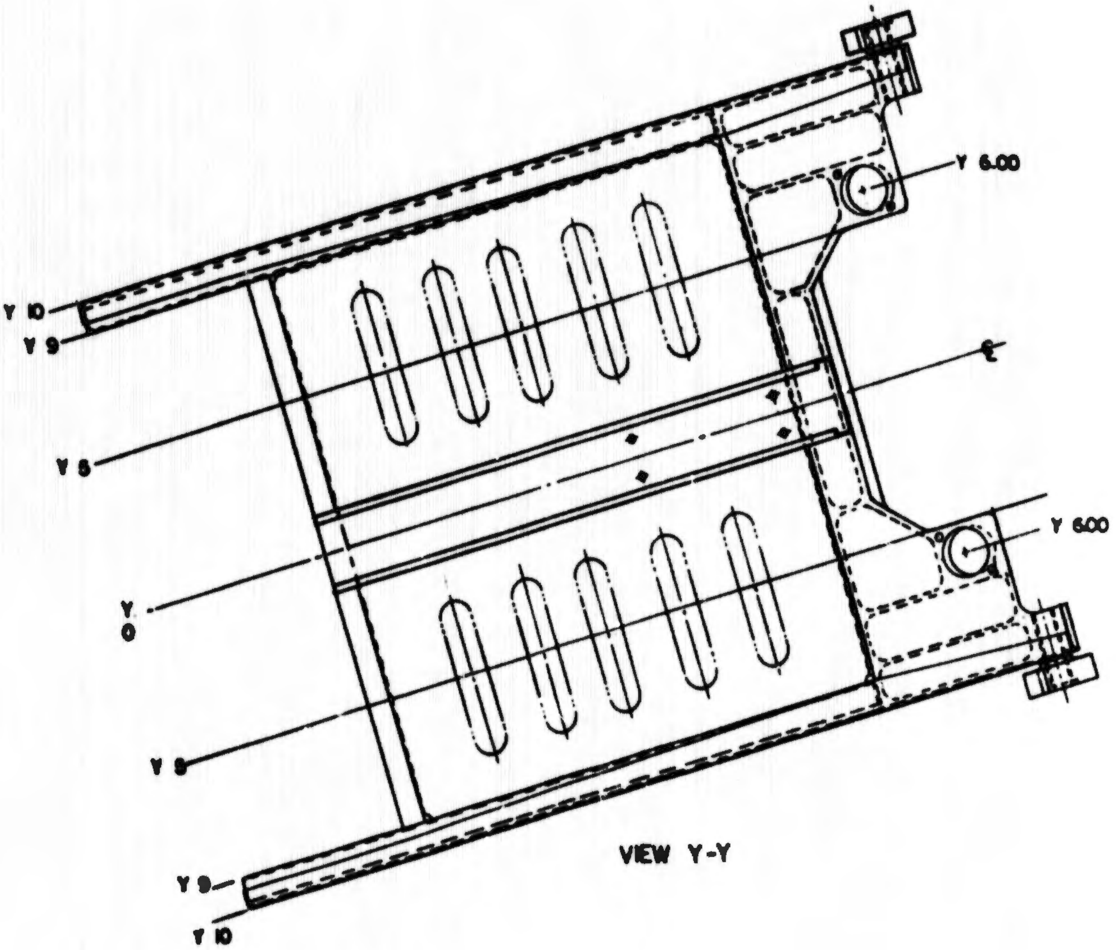


VIEW V-V



VIEW Y-Y

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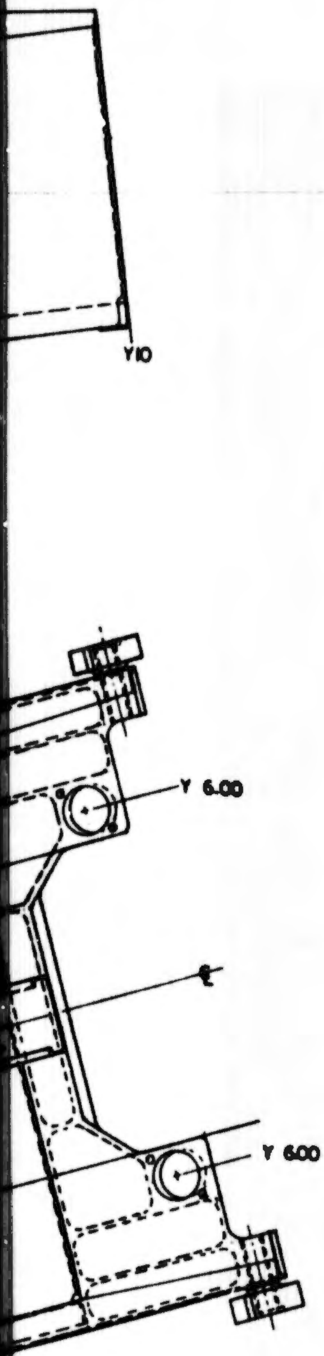
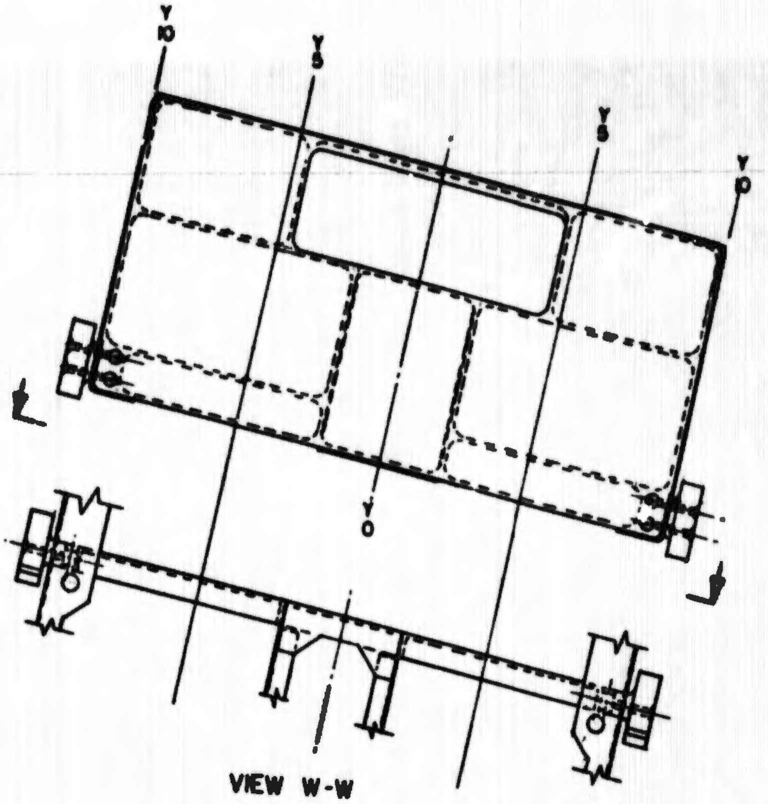
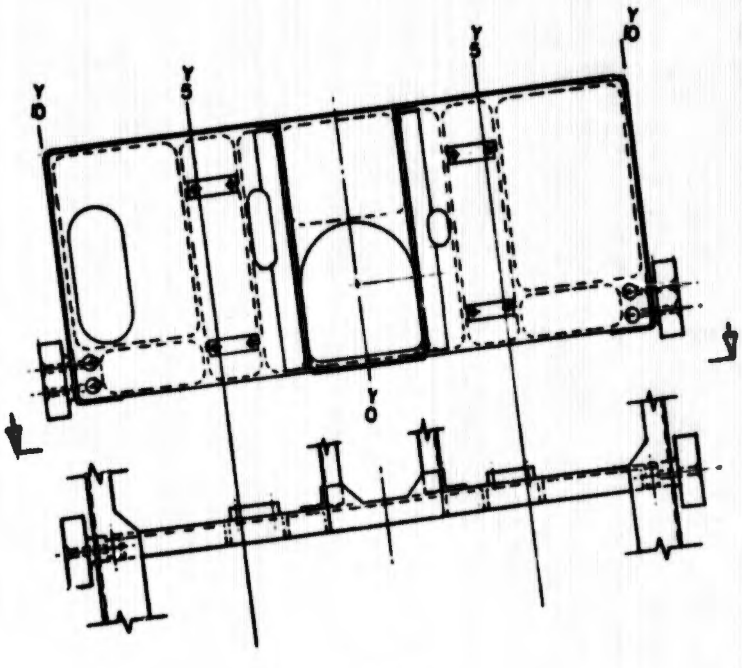




VIEW W-W



VIEW X-X

FIGURE 54 (COMPLETE)
STRUCTURAL ARRANGEMENT

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l. Canopy Severance and Jettison System

In order to take full advantage of the very fast escape allowed by the automatic ejection mode, the system employs canopy severance simultaneously with ejection initiation. Canopy severance is accomplished by a flexible linear shaped charge (FLSC) installed around the periphery of the canopy glass as shown in Figure 55. A signal from the automatic ejection system allows aircraft power to simultaneously initiate two single bridge wire detonators. One detonator initiates each end of the FLSC to provide canopy severance redundancy. The glass will be completely severed except for a twelve inch segment along the lower edge. This segment, by remaining intact, will act as a hinge and allow the ejection seat, as it moves up the rails, to push the canopy glass outboard and clear of the ejection path. The canopy severance system is described in specification number 204-78-16.

When ejection is initiated manually, the electrical power supply in the PEEP immediately initiates a ballistic canopy release and jettison thruster and the canopy is jettisoned in the conventional manner. A delay is provided to allow the canopy to clear the ejection path before the catapult is ignited. Should the canopy fail to be jettisoned, the catapult ignition signal also will initiate canopy severance. In this manner, canopy severance provides a backup for canopy jettison and no interlock is needed.

Should canopy jettisoning without ejection be desired, jettisoning can be accomplished both internally and externally. Internal canopy jettisoning is accomplished by pulling a handle located on the aircraft instrument panel. Pulling this handle activates a thermal battery which in turn initiates the canopy jettison thruster. Two of these handles are provided so that each crewman can jettison his individual canopy section at any time.

External canopy jettisoning is accomplished in the same manner except that jettison handles are provided on each side of the aircraft. These handles are accessible from outside the aircraft by opening an access panel. An extension cable will be provided to allow personnel to stand well clear of the aircraft while actuating these handles.

Detail design and location of both the internal and external canopy jettison handles will depend upon using the aircraft's structural arrangement. Electrical wiring being the only connection between these handles and the canopy jettison thruster makes their location extremely flexible.

m. Chaff Installation

During the ejection sequence, chaff dispensing is initiated by an electrical signal from the PEEP. A 0.3 second time delay prevents chaff dispensing until the ejected seat is well clear of the aircraft. A seat mounted switch provides pre-ejection arming or disarming of the chaff system. The chaff unit is installed underneath the seat pan and consists of a metal container into which a single RR 70/AL chaff package is installed. The container lid is installed with a single explosive bolt. The electrical signal from the PEEP detonates the explosive bolt and allows a spring to jettison the container lid. The chaff, which is installed by a procedure similar to that required by AF T.O. 12P3-1-8, is then dispersed aerodynamically. Figure 56 shows the chaff dispenser installation.

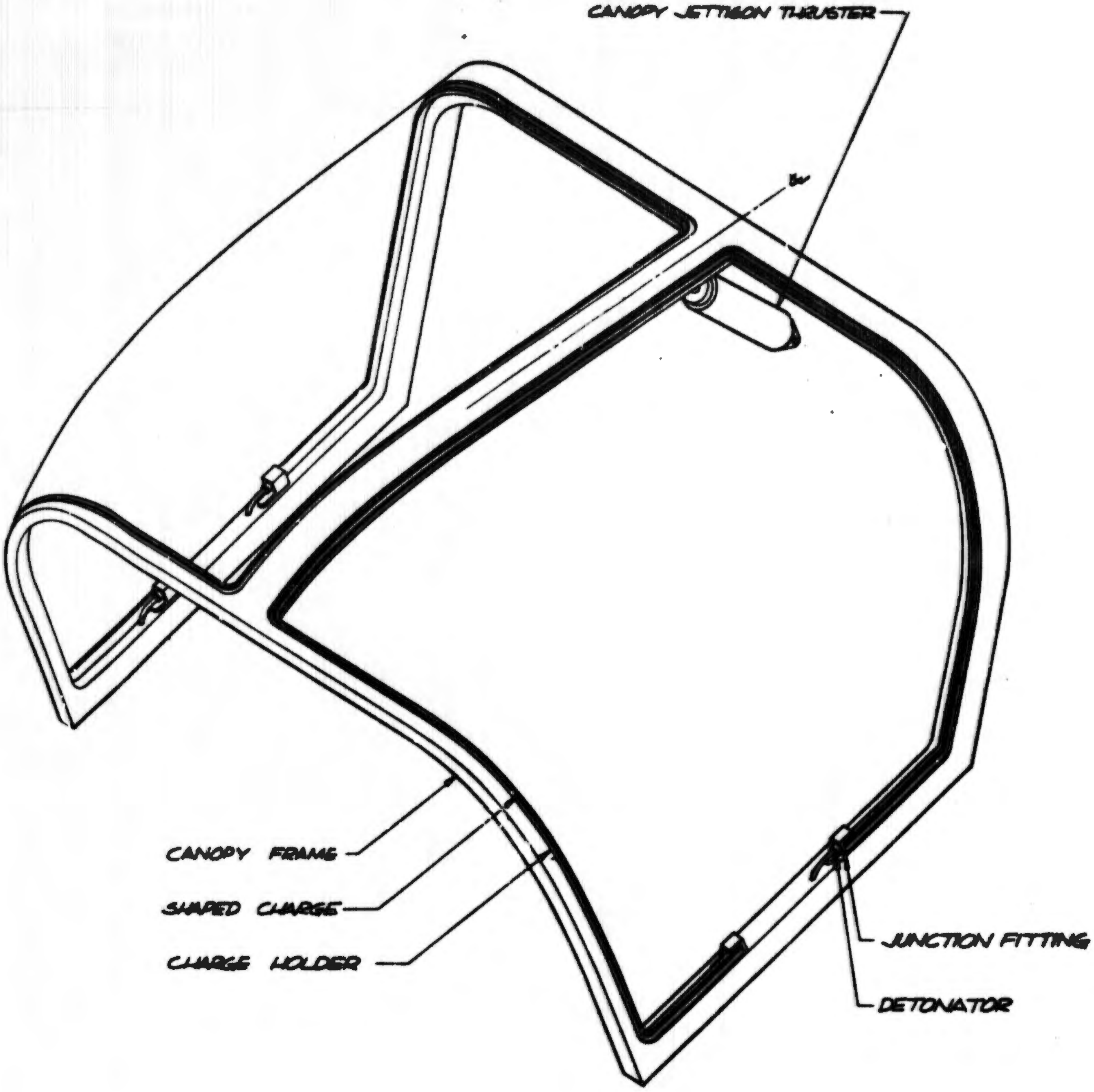


FIGURE 55
CANOPY SEVERANCE AND
JETTISON SYSTEM

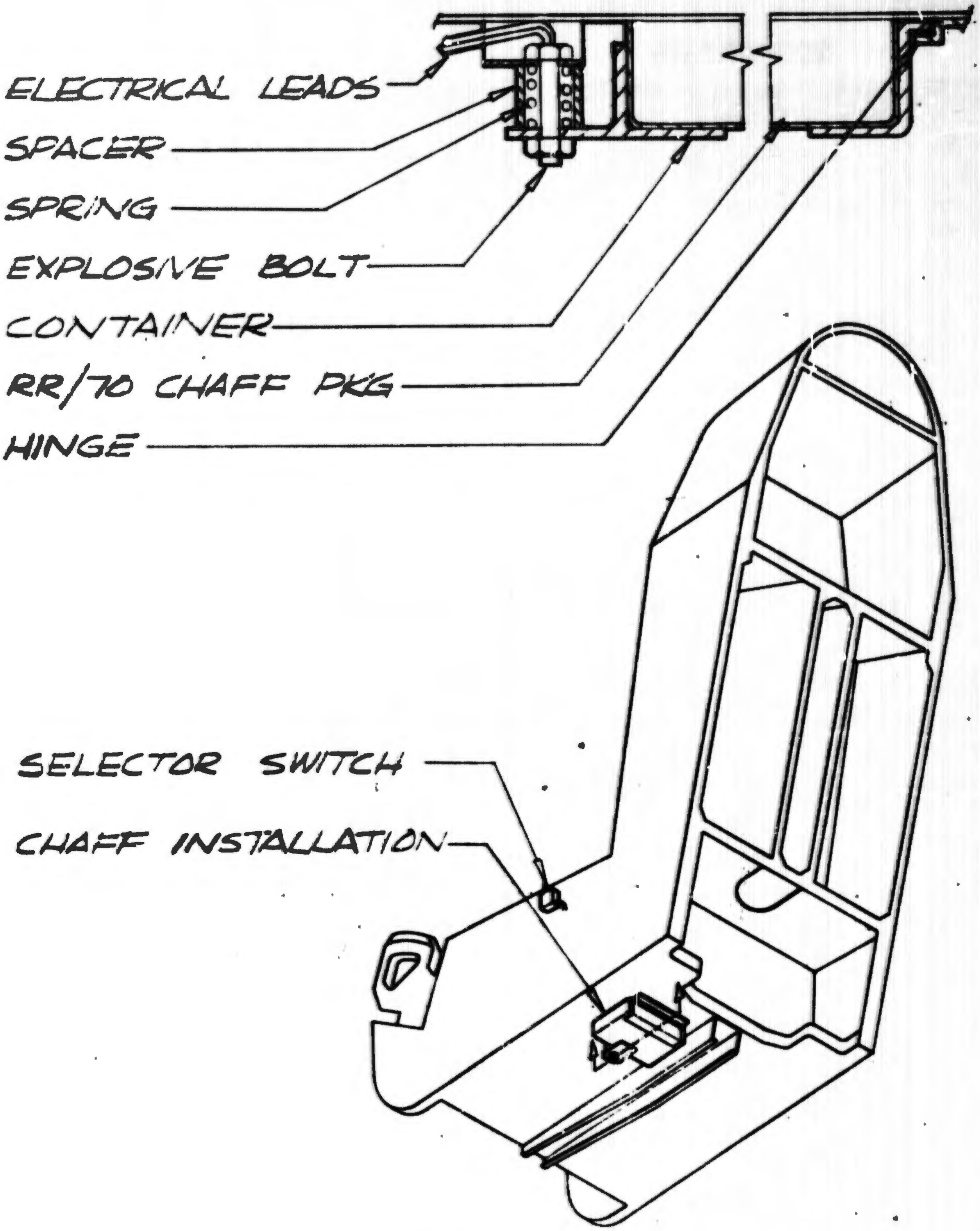


FIGURE 56
CHAFF DISPENSER

n. Maintainability

Ejection Seat

General - The left and right hand seats are identical in operation except for the location of the vernier yaw motors and the angle of recovery parachute deployment. The seats are designed such that they can be removed from the aircraft in their entirety including the catapult-rocket so that all maintenance can be performed in the shop. Seat removal can be accomplished without removing the aircraft canopy. All hardware can be removed and replaced by personnel with ordinary ejection seat skills, without use of special tools. Adjustment is not required for any of the components.

PEEP - The PEEP is a self-contained unit, is passive in nature and is designed to require no maintenance. The unit will be removed and replaced only at the expiration of its service life, unless it has been inadvertently activated. A visual indication is provided and can be readily inspected during pre-flight check to determine if the PEEP has been activated.

Pyrotechnics - All pyrotechnic devices, including the vernier rockets, the catapult-rocket, and the parachute spreading gun are designed for no maintenance. They will be removed and replaced only at expiration of their service life.

Parachutes - Both the drogue and recovery parachutes are packaged and installed in individual containers that can be easily removed and replaced. Periodic parachute maintenance can be the simple replacing of the packaged parachutes. The detailed inspection and repacking of the removed units can be accomplished during unscheduled times.

Aircraft Mounted Equipment

Canopy severance and jettison - The canopy severance assembly and the canopy jettison thruster consisting of the following parts are designed to require no maintenance during their service life.

- Severance assembly (2 required)
- Jettison thruster (1 required)
- Manual jettison handle (4 required)

All units will be replaced at the expiration of their service life as s specified in the applicable specifications.

PEMS - The PEMS is designed for no maintenance during its installed life. The unit has its own built-in test equipment that will give a visual indication of the aircraft warning panel when a malfunction occurs. The PEMS will be replaced only at the expiration of its service life unless a malfunction is indicated.

Sensing Devices - The following sensors in addition to those existing on the aircraft have been added to complete the VTOL escape system.

- o Radar altimeter (2 added)
- o Rate gyros (2 added)
- o Attitude reference (1 added)

These units will require the same maintenance procedures and cycles as those existing on the aircraft.

o. Safety

General - A preliminary hazard analysis was conducted early in the design stage in order to assist in the development of the safety criteria imposed upon the final system design.

Inadvertent Actuation - Safety pins with streamers are provided for each of the manually operated controls. The safety pin inserted in the automatic mode selection switch opens all electrical circuits and prevents any stray voltages or electromagnetic radiation from entering the radiation hard PEEP.

The catapult and rocket are ignited by SMDC lines from the PEEP, and this precludes their ignition by inadvertent electrical signals originating outside the PEEP. In addition, the rail trip switch being open prevents rocket ignition and subsequent other events from occuring should any stray electrical signal be applied to the system. To prevent accidental closure of the rail trip switch, the mechanism is designed so that a high force is required to cause switch closure.

For solo flight the manual seat sequencing switch can be placed in the individual ejection position. This will prevent the unoccupied seat from being ejected when the pilot is ejected either automatically or manually.

Canopy Interlock - The system is designed such that canopy severance acts as a backup for canopy jettison in the manual ejection mode, so no canopy/seat interlock is required.

Inadvertent Ejection, Automatic Mode - The automatic ejection system requires signals from any two of three channels which prevents ejection initiation should one channel fail operational.

Visual Indication - The PEEP is provided with a visual indicator to detect if it has been activated. All manual controls are designed so that after actuation they cannot be placed back in the unactuated position. All thermal batteries are provided with a visual indicator to detect when they have been activated.

p. Reliability

General - In order to meet the VTOL escape system's reliability goal of 0.98, an analysis was made of all available published studies regarding the causes of failure encountered in escape from current aircraft. This

Analysis revealed that the major causes of fatalities attributable to hardware failures were:

- Failure of the ejected man/seat to remain stable in pitch and yaw, which prevented proper parachute deployment and subsequent successful recovery.
- Failure of the recovery parachute to inflate and become effective before escapee's impact with ground/water.

To achieve the high reliability necessary in the subsystems involved in the types of failure cited above, and to improve the reliability of all other systems, the following design principles were utilized:

- Simplicity of system, subsystem, and component designs
- Fail-safe designs and manual backups
- Positive, reliable functions in critical phases of escape system operation with traditional passive functions retained as the failsafe design.
- Maximum practicable margin of safety for all functional and environmental stresses.
- During the design phase, every effort was made to employ existing hardware and design concepts which have exhibited mature reliability.

Reliability Features - The following features have been incorporated into the final design to insure the highest possible system reliability.

- Each seat has redundant firing controls; one handle on each seat side.
- All signal transmission, SMDC and electrical are completely redundant
- All initiators are dual bridgewire or dual initiators.
- All channels in the PEEP and PEEMS are redundant.
- Each seat utilizes one simple, highly reliable two-stage catapult-rocket.
- Each seat incorporates positive pitch stabilization which eliminates the man/seat stabilization problem as a major cause of escape system failure.
- The reliability of inflating the recovery parachute is significantly increased by positive stabilization which aids in assuring downwind deployment. The ballistic spreading gun increases inflation reliability at all airspeeds. The

spreading gun is fail-safe in that, should the cartridge fail to fire, the parachute will open and inflate aerodynamically.

- Positive man/seat separation is provided by the parachute opening force which assures positive divergent trajectories of the man and seat.
- The drogue parachute (in Hi-Speed Mode) and the recovery parachute (in Automatic and Lo-Speed Modes) are deployed before the seat leaves the rails. This positively precludes seat/man-parachute interference and entanglement.
- Manual parachute deployment and harness release is provided the crewmen as a backup to the automatic systems.
- All components within the ejection seat are passive in nature and require no routine maintenance.
- All harness release cutters are dual and redundant.
- The PEEP is completely radiation hard which precludes any inadvertent ejection by stray radiation energy including nuclear radiation.
- Should the parachute or drogue extraction rockets fail to ignite, the initial catapult feature of these designs incorporates sufficient energy to cause the parachute and drogue to be withdrawn sufficiently to insure subsequent deployment by aerodynamic forces.
- Redundant SMDC and shielded electrical wires are routed to preclude complete system failure due to battle damage.
- The PEEMS employs three channels in each critical mode of operation. Two of these three channels are required to function before automatic ejection is initiated. This precludes inadvertent ejection should one channel fail operational. Also the two channels required for initiation must agree within a close tolerance before the automatic ejection signal is passed on.

Operational Reliability - The VTOL escape system, while being new in concept, does employ components all of which are either of proven reliability or are similar enough to existing hardware that accurate reliability values can be assessed. The reliability requirements of the component specifications are therefore considered realistic and were used in predicting the following systems reliability for normal operation. (i.e. manual backup and fail-safe features are not included).

EJECTION	INITIATION MODE RELIABILITY		
	AUTOMATIC*	MANUAL (LO-SPEED)	MANUAL (HI-SPEED)
Single	.9868	.9922	.9909
Dual	.9736	.9843	.9817

* Aircraft failure considered to be worst case requiring all roll and pitch vernier motors to function.

The reliability values used in making the above predictions are shown in Table II.

No-Fire reliability - The probability of the PEEMS malfunctioning in a Fail-Operational manner is the same as the probability of it malfunctioning in a Fail-Safe manner. Therefore, the probability of an inadvertent automatic ejection occurring is .005.

TABLE II

RELIABILITY VALUES

ITEM	FAILURE RATE
Catapult - Rocket	.0005
Parachute extraction rocket	.0001
Parachute - Recovery	.001
Drogue parachute	.001
Vernier rocket	.0001
Canopy severance	.0001
Webbing cutter	.0001
Guillotine	.0001
Ejection handle	.0001
SMDC line	.0001
Electrical line	0
Restraint harness	0
Seat structure	0
Guide rails	0
Canopy thruster	.0002
Powered inertia reel	.0001
Rail trip mechanism	0
Crewman services disconnect	0
Parachute spreading gun	.0002
Parachute extraction rocket release	0
PEEP	.005
PEEMS	.005
Rate Gyros	.005
Radar altimeter	.005
Attitude reference	.005
Canopy jettison mechanism	0
Ejection sequencing switch	.0001

q. Mass Properties Summary

VTOL Ejection System Installed Weight

o	Emergency Detection and Ejection Initiation System	17.9
o	Post Ejection Event Mode Selection System	4.0
o	Ejection Command Control Selector	0.4
o	Seat Adjustment Actuator (2)	9.6
o	Seat Assembly LH	179.9
o	Seat Assembly RH	179.9
o	Canopy Glass Severance Instl	2.9
o	Canopy Jettison Controls, Internal & External	3.0
o	Indicator Lights and Misc.	5.8
		403.4

Ejected Weights and Inertias

o	Seat Assembly (less catapult & half motor grain)	164.4
o	Survival Kit	40.0
o	5% tile man and clothing	150.0
	Ejected Weight	354.4
o	95% tile man and clothing	65.0
		419.4

		5% Tile	95% Tile
Seat Body Axes	Ix	11.99 $FT\text{-}LB\text{-}SEC^2$	13.11 $FT\text{-}LB\text{-}SEC^2$
	Iz	10.62	12.25
	Iy	22.61	25.36
	Ixy	3.02	2.98

4.0 SYSTEM OPERATION - GENERAL

a. Pre-ejection and Initiation Period

(1) Automatic Initiation

Electrical power is applied to the EDEIS when the pilot places the navigation mode selector switch (located on the navigation system control panel) in the "VTOL Mode" position. The automatic initiation armed light will then come on when both seat mounted switches are placed in the automatic initiation position. Even though the EDEIS armed light is on, the initiation circuit to the seat is not complete unless the aircraft weight is off the gear, altitude above ground level is between 10 and 500 ft., and airspeed is below conversion airspeed. Thus entering and leaving the automatic ejection mode can be considered semi-automatic.

An additional safety feature incorporated in the activation sequence is the Lockout Circuit. The built-in test equipment (BITE) monitors the output of the OR gate, and if an initiation signal is present when power is applied to the PEEMS arm circuit through the landing gear, altitude, and velocity switches, the arm circuit is locked out and the roll, pitch, and altitude authority disarmed lights are turned on. The rationale is that an initiation signal present during arming is probably erroneous. The escape system retains manual initiation capability.

An aircraft failure may occur during normal vertical takeoff that will produce a rapid, violent roll of the aircraft. As the aircraft begins to roll, the three roll rate sensors feed signals to the roll rate comparator, and the three roll attitude sensors feed signals to the roll attitude comparator. The outputs of these two comparators are sent to the roll gate. When the combination of roll rate and roll attitude exceeds a predetermined amount signifying an out-of-control condition as defined by Figure 33, the roll gate generates an output signal which is sent to the time delay. If the out-of-control signal is continuous for 100 milliseconds, the time delay closes, sending the initiation signal through the arm switches to both seats, igniting canopy severance, catapult, and other devices plus activating the power supply in the PEEP. Thus 100 milliseconds after loss of control, simultaneous crew escape has begun.

(2) Post Ejection Event Mode Selection

The roll mode switch in the PEEMS, shown in Figure 35, monitors the output of the roll rate and roll angle comparators and generates 28 V DC right (rolling or banked) or left (rolling or banked) signals in accordance with the schedule shown in Figure 57. This signal is sent to the PEEP to arm the seat roll motor firing circuit.

The aircraft inverted sensor of the PEEMS monitors the output of the roll attitude and pitch attitude comparators and generates a 28 V DC signal when the aircraft attitude exceeds the roll and pitch values shown in Figure 58. This signal is sent to the PEEP to arm the sustainer, yaw, and roll motors firing circuit. Figure 37 shows a schematic diagram of these circuits.

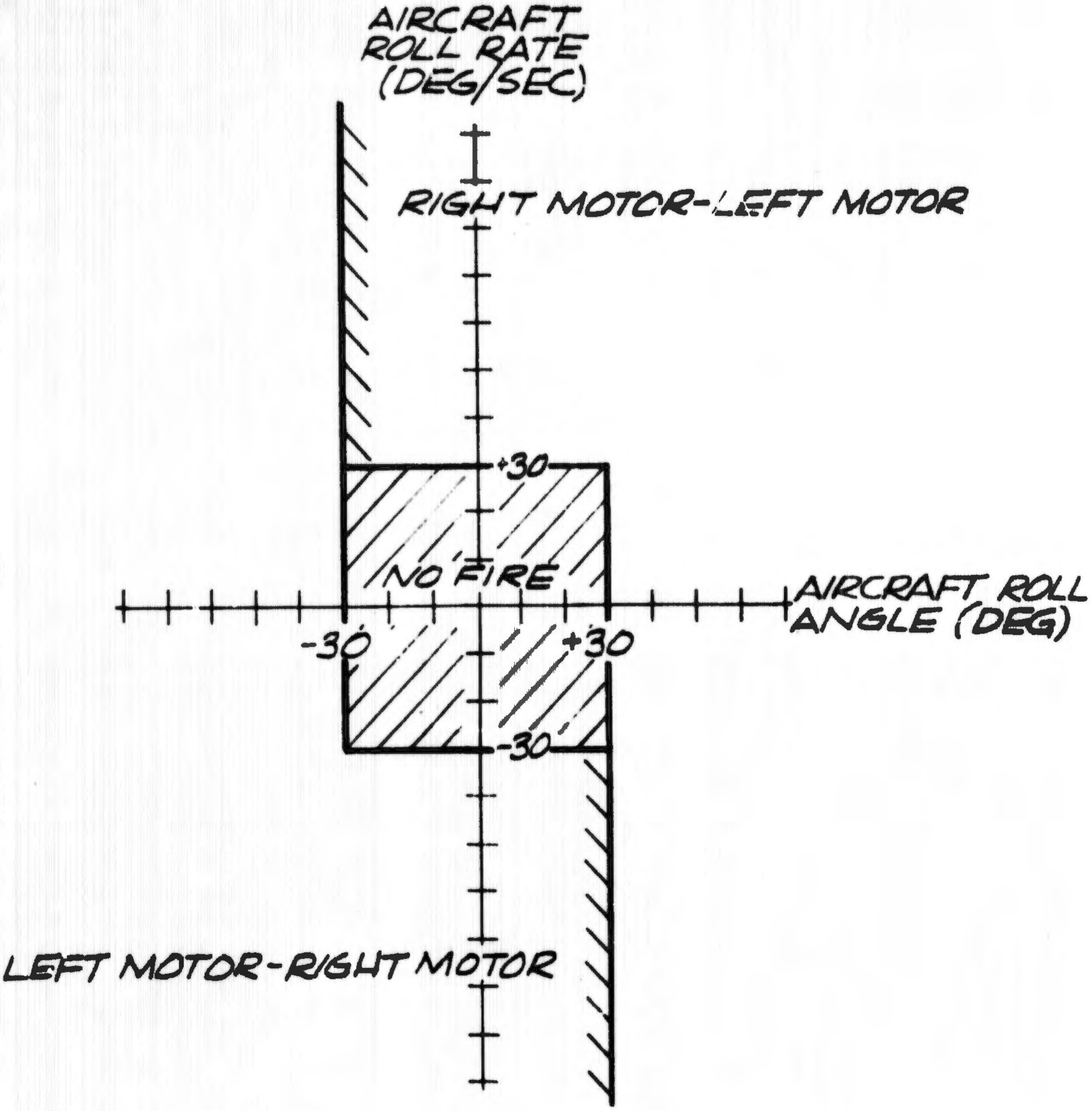


FIGURE 57
EJECTION SEAT
ROLL MOTOR FIRING SCHEDULE

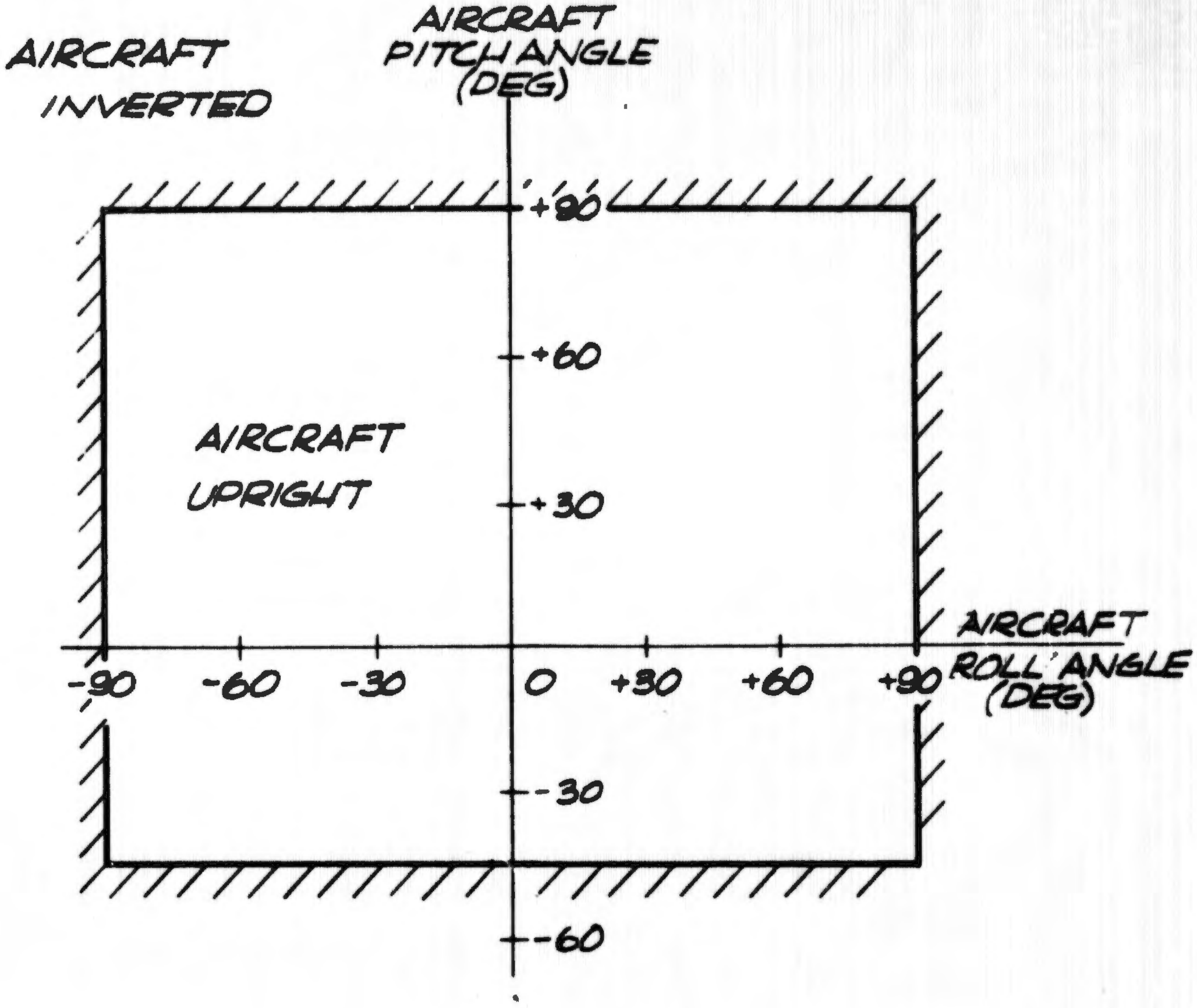


FIGURE 58
AIRCRAFT INVERTED SCHEDULE

(3) Post Ejection Event Programming

The mode selection signals are received continuously by the PEEP; however, they have no effect on the internal program setting until such time as an initiation signal is generated. At this time latching relays are energized if any mode selection signals are present. Thus the sequence of output events from the PEEP is determined and set at the moment of initiation and will be maintained even after all leads between the aircraft and the seat have been severed by the guillotine. A list of the post-ejection events and timing is shown in Table III.

(4) Manual Initiation

Ejection is accomplished by actuating either of the two ejection controls located on the seat bucket sides. This action will mechanically initiate dual SMDC lines by cocking and releasing dual firing pin assemblies. The SMDC output will activate the thermal batteries in the PEEP. Power from the thermal batteries initiates the inertia reel power retraction, the canopy jettison thruster, and the batteries in the other seat if the seat sequence switch is closed.

A 0.275 second time delay will be activated which will allow the thermal batteries to initiate the catapult and IFF. A guillotine will sever all seat/aircraft connections and 0.025 second later the seat will start to move. The time from ejection initiation to seat first movement will be approximately 0.300 second to permit canopy separation. This circuit is shown in Figure 37.

h. Post Ejection Period - Automatic or Manual Initiation

(1) Event Programming

Mode signals from the PEEMS along with aircraft pitot and static inputs were used to set the internal switching of the PEEP at the moment of initiation. Thus the sequence of events to be followed during escape, based on current aircraft condition, was programmed into the PEEP just prior to seat first movement. Refer to Table III, Figures 59 and 60 for mode definition.

(2) Mode Operation

- Low Altitude - Low Speed (below 15000 ft. M.S.L. and 250 K.E.A.S.)

As the seat nears tip-off, a rail trip switch will be closed allowing power from the thermal batteries to ignite the sustainer rocket motor, yaw rocket motor, parachute extraction rocket motor, roll rocket motor and pitch rocket motor (if pitch rate gyro senses seat rate greater than +2.0 or -1.0 radians per second). Within 0.300 seconds after the parachute extraction rocket motor is ignited, the parachute will then be withdrawn from its container. Parachute line stretch will fire the ballistic spreading gun. Closure of the rail trip switch also applies power to two 0.30 second time delays which ignite the chaff dispenser, lateral restraint retract, lap belt cutter, and inertia reel strap cutter.

TABLE III - POST-EJECTION EVENT & EVENT TIMING

SYSTEM MODE / EVENT	LO-SPEED MODE $V_{A/C} < 250$ KEAS				HI SPEED MODE $V_{A/C} > 250$ KEAS		HI ALT. MODE >15000. Ft.	
	AUTOMATIC INITIATION	TIME (SEC.)	MANUAL INITIATION	TIME (SEC.)	MANUAL INITIATION	TIME (SEC.)	MANUAL INITIATION	TIME (SEC.)
Canopy Severance	Yes	0 (14)	No	-	No	-	No	-
Canopy Jettison	No	-	Yes	(7)	Yes	(7)	Yes	(7)
Powered Inertia Reel	Yes	0	Yes	(7)	Yes	(7)	Yes	(7)
Seat Catapult	Yes	0	Yes	(8)	Yes	(8)	Yes	(8)
Seat Sustainer	Yes	(1)	(9)		(9)		(9)	
Yaw Motor	Yes	(1)	Yes	(9)	Yes	(9)	Yes	(9)
Personnel Chute Rocket	Yes	(1)	Yes	(1)	Yes	(11)	Yes	(13)
Roll Motors		(1)(2)	(9)(10) →	→	→	→	→	→
Pitch Motors		(3)(9) →	→	→	→	→	→	→

NOTES:

(1) Fire at rail trip switch.

(2) Fire opposite motor at rail trip switch + .14 sec.

(3) Seat mounted rate gyro fires pitch down motors at $\dot{\theta}_s$ = +2.0 rad. per sec. and pitch up motor at $\dot{\theta}_s$ = -1.0 rad. per sec.

(4) Fire at line stretch

(5) Firing the personnel chute extraction rocket releases drogue bridle.

(6) Chute rocket + .30 sec.

(7) Thermal battery rise time of .05 to .10 sec.

(8) Thermal battery rise time + .275 sec.

TABLE III - POST-EJECTION EVENT & EVENT TIMING (cont.)

SYSTEM MODE / EVENT	LO-SPEED MODE $V_{A/C} < 250$ KEAS				HI SPEED MODE $V_{A/C} > 250$ KEAS		HI ALT. MODE > 15000. Ft.	
	AUTOMATIC INITIATION	TIME (SEC.)	MANUAL INITIATION	TIME (SEC.)	MANUAL INITIATION	TIME (SEC.)	MANUAL INITIATION	TIME (SEC.)
Personnel Chute Spreading Gun	Yes	(4) →						
Drag Chute Projection Rocket	No	-	No	-	Yes	(1)	Yes	(1)
Drogue Bridle Lwr. Release	Yes	(5)	Yes	(5)	Yes	(5)	Yes	(5)
Drogue Bridle Upr. Release	Yes	(5)	Yes	(5)	Yes	(5)	Yes	(5)
Restraint Harness Release	Yes	(6)	Yes	(6)	Yes	(6)	Yes	(6)
Lateral Restraint	Yes	(1)(12) →						
Second Seat	Yes	0	Yes	(15) →				

NOTES:

(9) Fires at rail trip switch if "aircraft inverted" signal does not exist. See Figure 58.

(10) See Figure 57 for roll motor firing schedule.

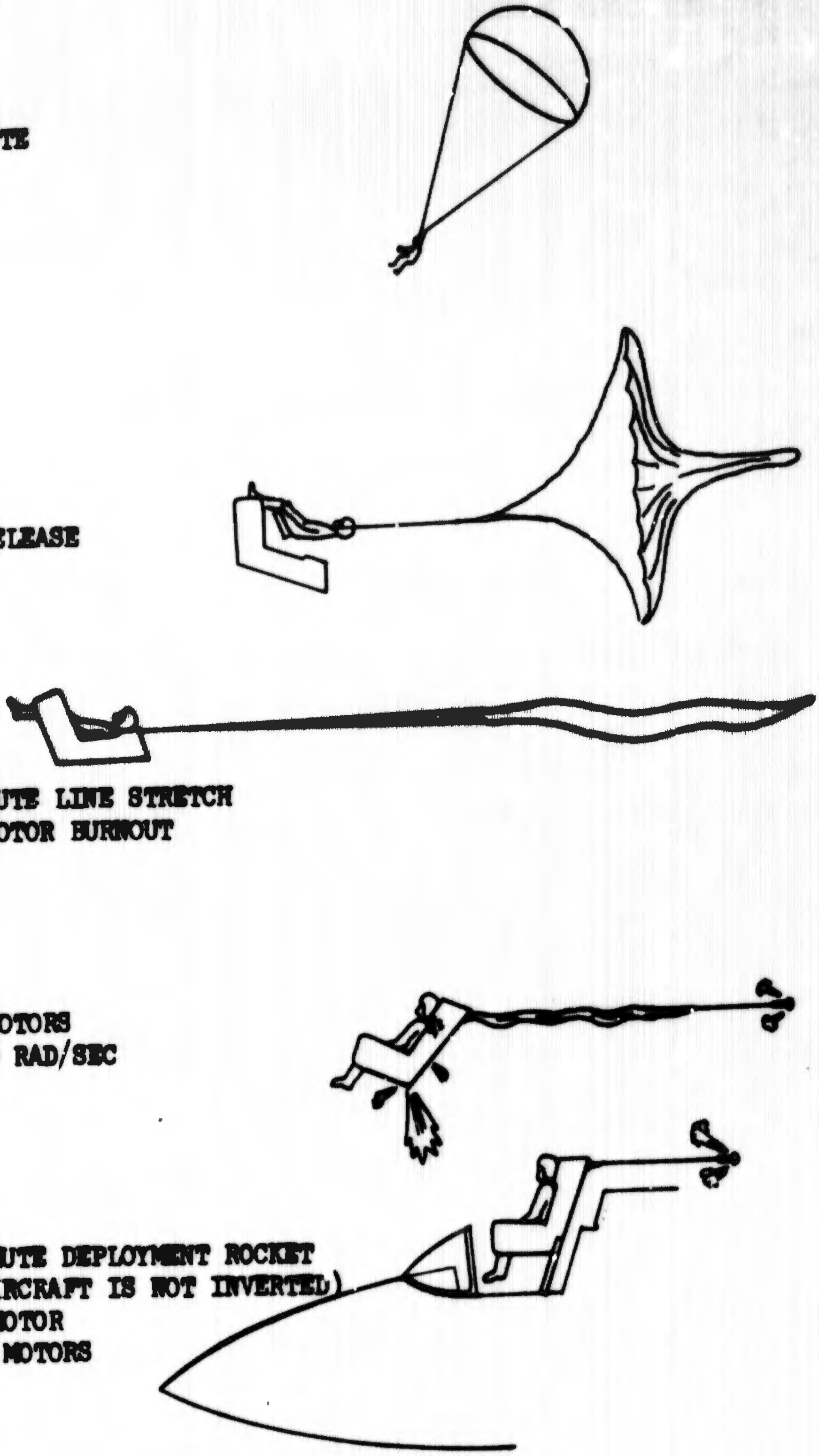
(11) Variable time delay schedule.

(12) Retracts at restraint harness release

(13) Fires at 15000 ft. M.S.L.

(14) Aircraft electrical power is utilized in auto. mode.

(15) Second seat is delayed .20 sec. + its thermal battery rise time of .050 to .10 sec.



t = 1.2 FULL PARACHUTE

t = .42 RESTRAINT RELEASE

t = .40 RECOVERY CHUTE LINE STRETCH
t = .37 SUSTAINER MOTOR BURNOUT

PITCH RATE CONTROL MOTORS
WHEN $-1.0 > \dot{\theta} > +2.0$ RAD/SEC

t = .12
- RECOVERY CHUTE DEPLOYMENT ROCKET
  (AND, IF AIRCRAFT IS NOT INVERTED)
- SUSTAINER MOTOR
- ROLL & YAW MOTORS

t = 0
- AUTO INITIATION - SIMULTANEOUS CATAPULT IGNITION
- MANUAL INITIATION - SECOND SEAT DELAYED .30 SEC.
- CANOPY SEVERANCE INITIATION

FIGURE 59 LOW SPEED MODE

t = RECOVERY CHUTE ROCKET
PLUS 1.2
. FULL PARACHUTE

t = RECOVERY CHUTE ROCKET
PLUS .30
. RESTRAINT RELEASE

ABOVE 15000. FEET
t = VARIABLE DELAY PLUS 2.0
. LOWER DROGUE
BRIDLE RELEASE
(DROGUE RELEASE &
RECOVERY CHUTE
DEPLOYMENT AT
15000. FT.)

BELOW 15000. FEET
t = (VARIABLE TIME DELAY)
. DROGUE RELEASE
. RECOVERY CHUTE DEPLOYMENT

t = .80 DROGUE EFFECTIVE

t = .50 DROGUE CHUTE DEPLOYMENT
(AND, IF AIRCRAFT IS NOT INVERTED)
. SUSTAINER MOTOR
. ROLL & YAW MOTORS

t = .38
. CATAPULT
IGNITION

t = 0
. MANUAL INITIATION
(SECOND SEAT DELAYED .30 SEC.)
. CANOPY JETTISON

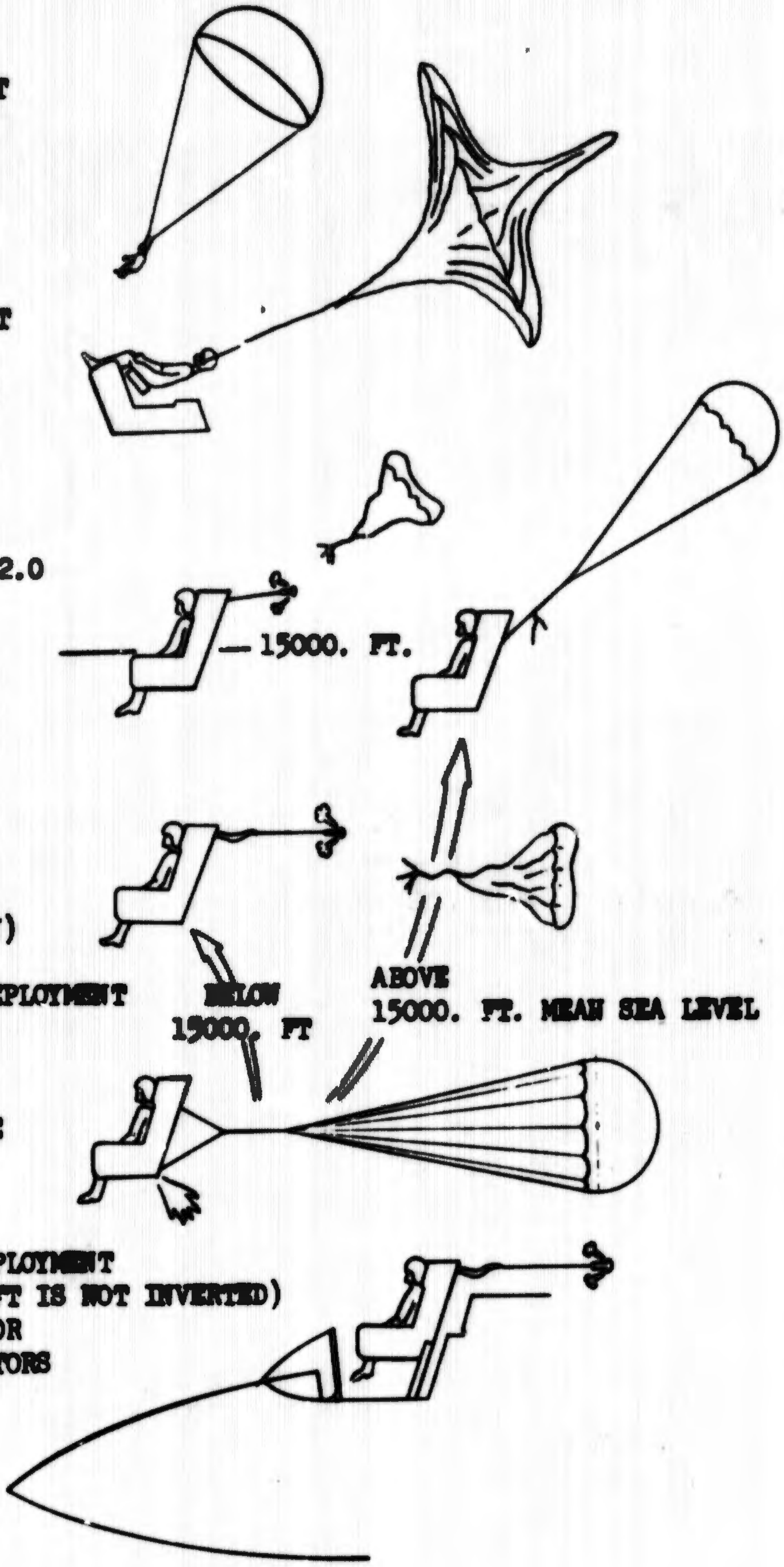


FIGURE 60 HIGH SPEED MODE

The sustainer, roll, pitch, and yaw rocket motors will not be ignited if the aircraft is inverted as defined by Figure 58 at escape initiation

- Low Altitude - High Speed (greater than 250 K.E.A.S.)

The sequence of events after rail trip switch closure is the same as for low altitude - low speed escape, except the drogue parachute is deployed instead of the personnel parachute.

The variable time delay is set by the aircraft speed at initiation to a value which will cause drogue release and personnel parachute extraction to occur at the precise time the seat/man combination has decelerated to a safe parachute deployment speed. Power is applied to the lateral restraint retract, lap belt cutter, and inertia reel strap cutter 0.30 second after the parachute extraction rocket motor is ignited instead of 0.30 second after rail trip switch closure as in the low altitude - low speed mode.

- High Altitude (above 15000 ft. M.S.L.)

The sequence of events is the same as for the low altitude - high speed mode up through drogue parachute deployment.

The 2.0 second time delay will release the drogue lower bridle which allows descent to a lower altitude with the seat/man combination stabilized in the upright position. The aneroid switch closes at 15,000 ft., releasing the drogue parachute, igniting the parachute extraction rocket motor, and 0.30 second later energizes the lateral restraint retract, lap belt cutter, and inertia reel strap cutter.

5.0 SYSTEM PERFORMANCE - SPECIFIC CASES

The system performance under the specific flight conditions shown in this section was generated by the digital computer simulation described in detail in Part I, Volume 3 entitled "Computer Users Manual for VTOL Escape System Simulation". The input data used is shown in Table VII in Appendix I.

Throughout this simulation the right seat is occupied by a 5 percentile man and the sustainer motor thrust vector is located 3.0 inches below the seat-man center of gravity. A 95 percentile man occupies the left seat and the thrust vector is located 1.0 inches above the seat-man center of gravity.

a. VTOL Flight Failures

The performance of the escape system under the VTOL flight critical failure modes is shown in Figures 61, 62 and 63. Figure 64 summarizes the aircraft positions and rates that exist during these ejections.

In each case the recovery altitude is above the ejection altitude.

The computer generated time histories which show the seat and man positions, rates, and accelerations of both seats and from which these data were extracted are presented in Appendix I.

b. Conventional Flight Failures

The VTOL escape system performance for the initial conditions specified in specification MIL-S-9479A "Seat System, Upward Ejection, Aircraft, General Specification For" is presented, in summary, in Table IV.

The detailed computer generated time histories for each case are presented in Appendix II.

Table IV shows that both crew are recovered within the altitude allowed.

c. Conclusions

It may be concluded that the VTOL escape system does meet the program objective of providing safe emergency crew escape from VTOL and conventional flight emergencies because -

- o After the most critical aircraft malfunctions in the VTOL and transition flight regime both crew members are recovered at or above the ejection altitude.
- o Under the flight conditions specified in MIL-S-9479A both crew members are recovered within the allowable altitude.

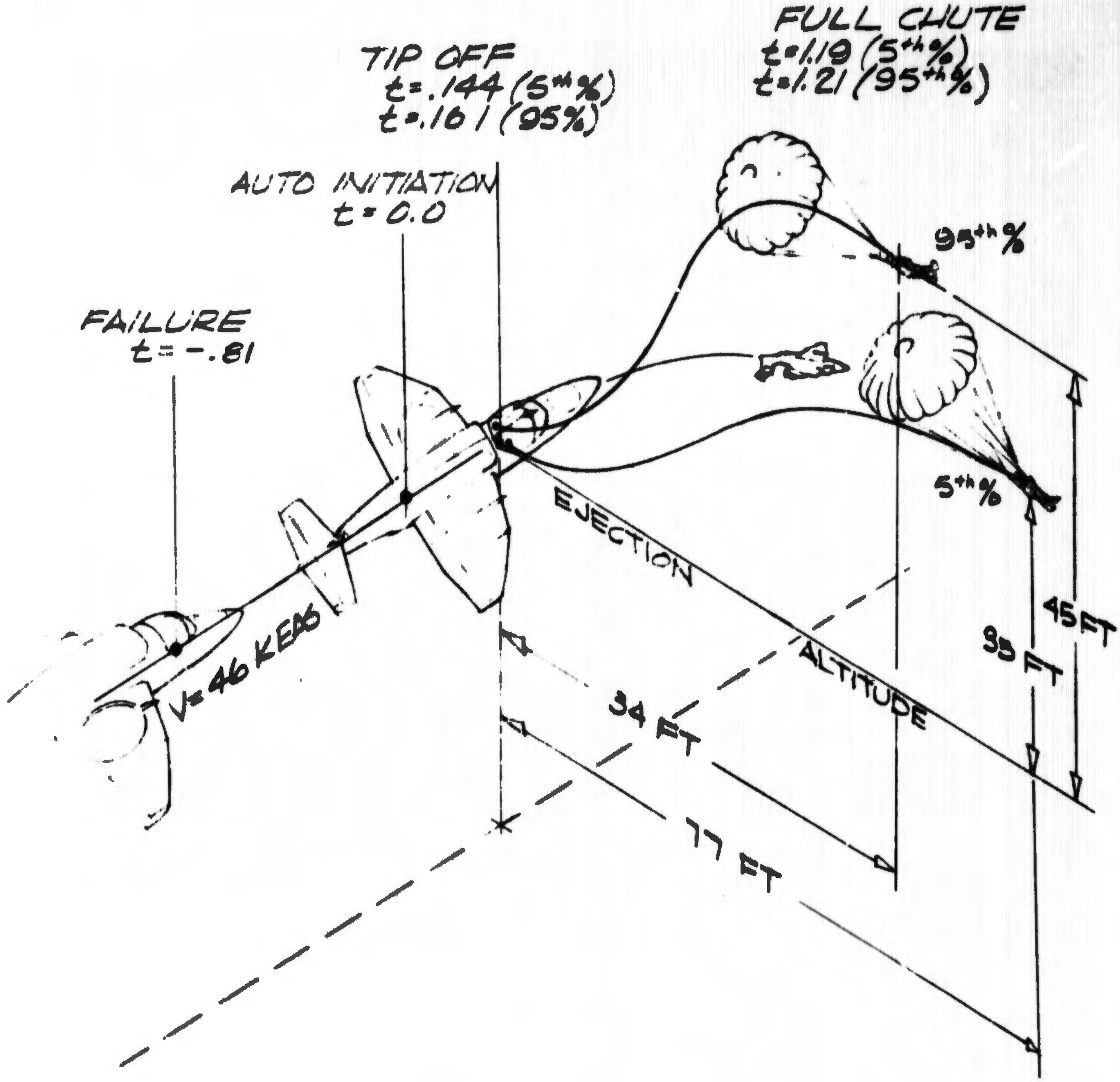


FIGURE 61
CRITICAL FAILURE MODE #1
CONTROL FAILURE-
HARD OVER LATERAL-
TRANSITION FLIGHT

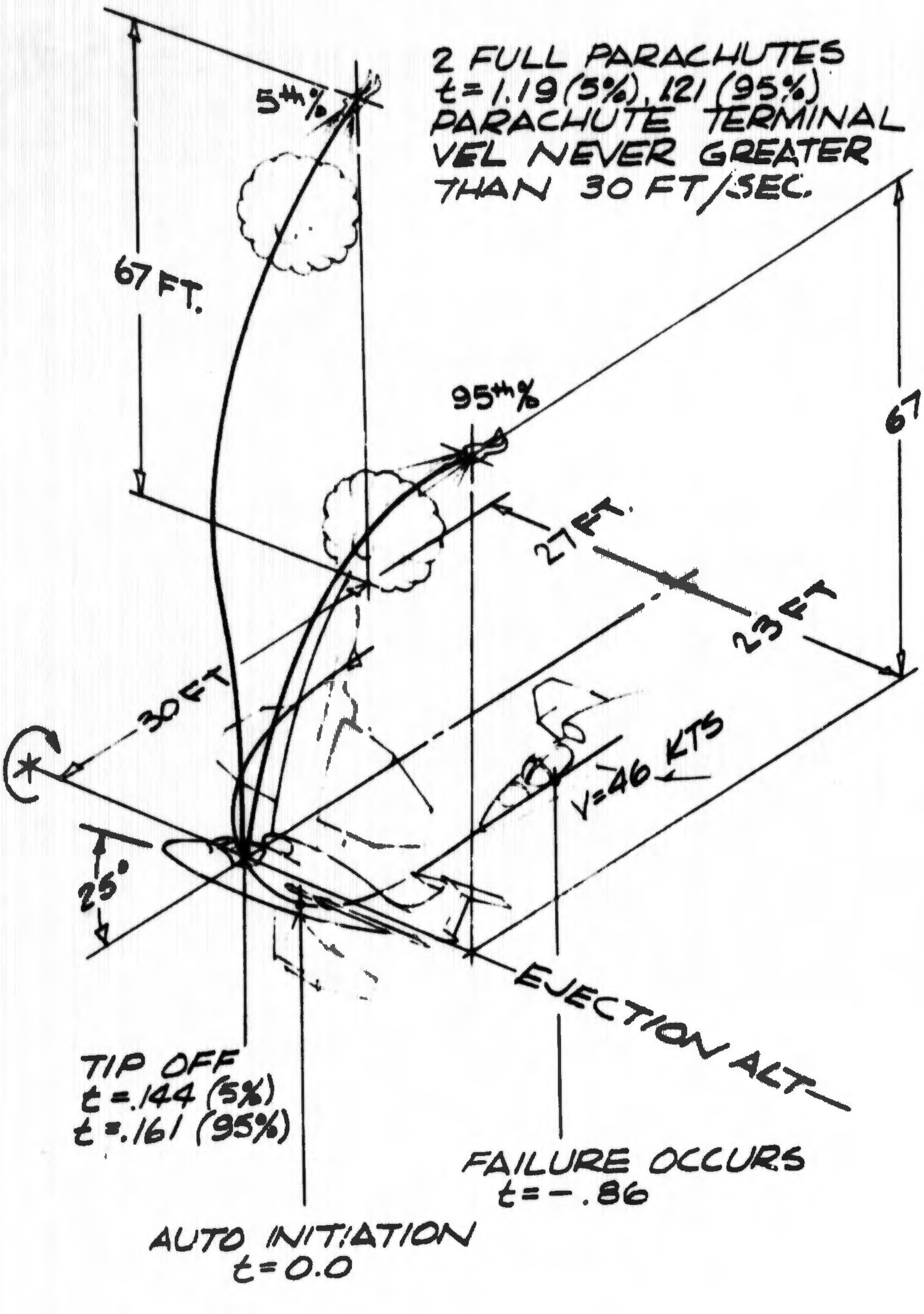


FIGURE 62
CRITICAL FAILURE #2
CONTROL FAILURE
HARD OVER LONGITUDINAL

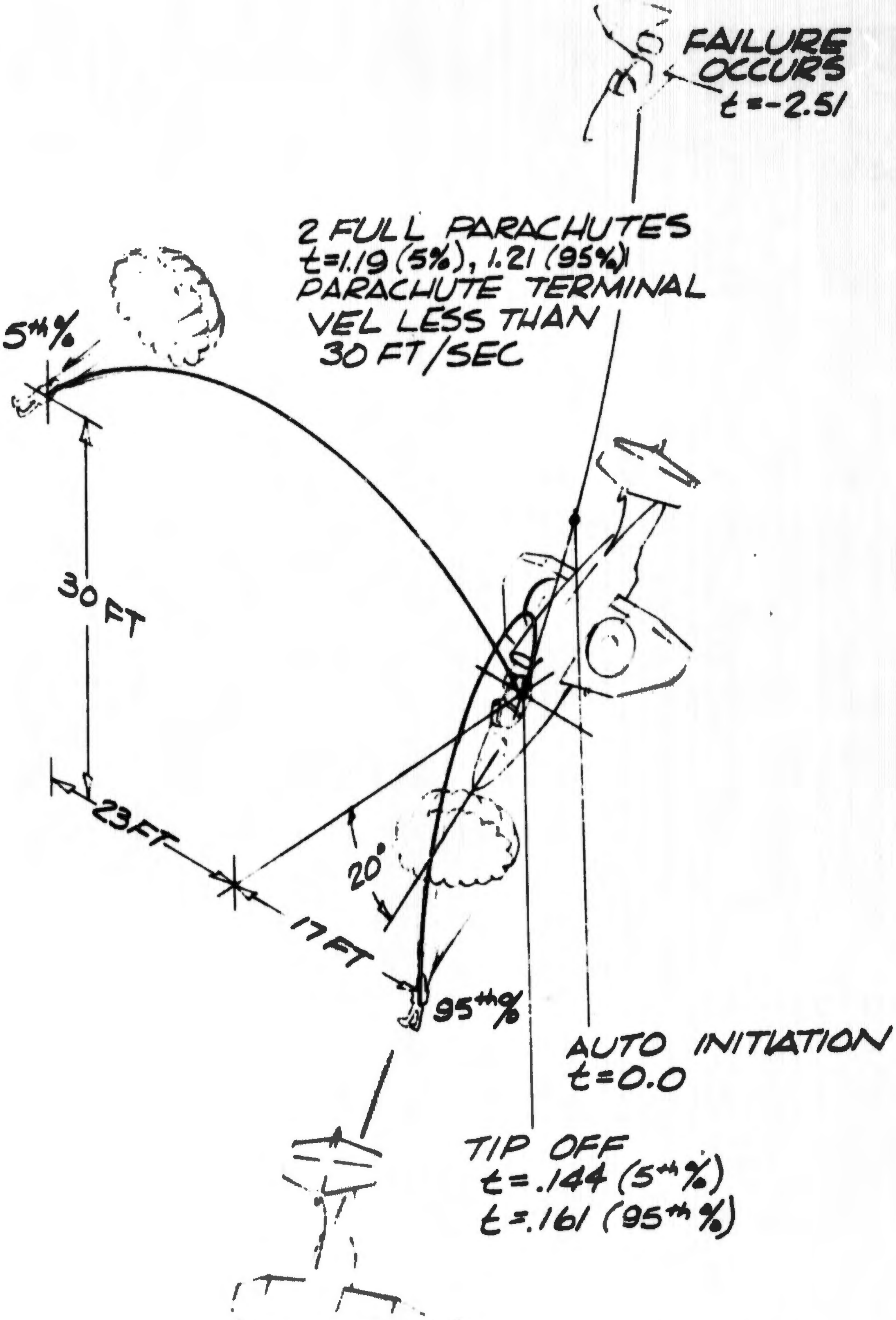
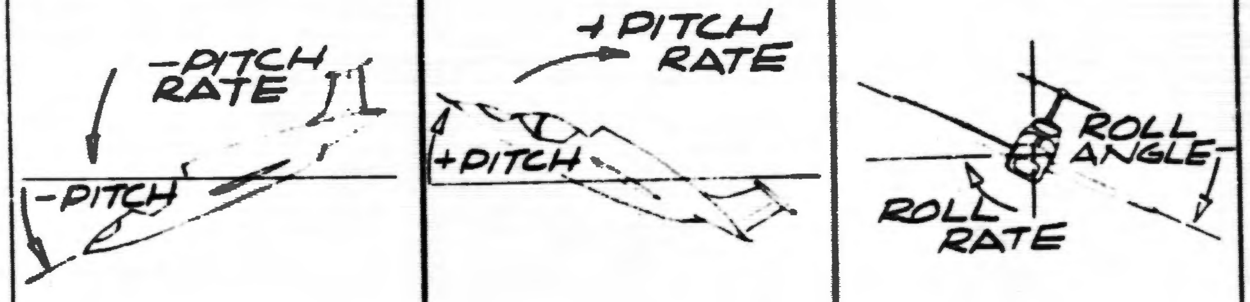


FIGURE 63
CRITICAL FAILURE MODE #3
2-ENGINE FAILURE
HOVER FLIGHT



	DUAL ENGINE FAILURE IN HOVER		CONTROL FAILURE HARD-OVER AT 46 KTS LONGITUDINAL		CONTROL FAILURE HARD-OVER AT 46 KTS LATERAL	
	RATE	ANGLE	RATE	ANGLE	RATE	ANGLE
YAW	0	0	0	0	0	0
PITCH	-20°/SEC	-17°	+40°/SEC	+26°	-30°/SEC	-8°
ROLL	0	0	0	0	50°/SEC	43°
SINK	-80FPS	—	+18FPS	—	-17FPS	—
Δ ALT.	-108 FT.		+10 FT.		-6 FT	

FIGURE 64
AIRCRAFT CONDITIONS AT SEAT TIP-OFF
CRITICAL FAILURE MODE

TABLE IV - MIL-S-9479 PERFORMANCE REQUIREMENTS

CASE	AIRCRAFT CONDITIONS				ALTITUDE ALLOWED (FT.)	VTOL ESCAPE SYSTEM ALTITUDE REQUIRED (FT.)*		
	PITCH	ROLL	SINK	VEL (KEAS)		RH SEAT	LH SEAT	
1	0	0	0	0	0	0	0	
2	0	0	0	600	0	0	0	
3	0	0	0	MN = 2.0	--	Full Chute at 15000 ft. M.S.L.		
4	0	60°	0	120	0	0	0	
5	0	180°	0	150	200	88	92	
6	0	0	-10000	150	300	117	185	
7	-60°	0	-17500	200	500	260	360	
8	-60°	60°	-17500	200	550	270	370	
9	-45°	180°	-18000	250	600	280	390	
10	0	180°	0	600	Not Specified	147.	75.	Other Case
11	0	90°	0	600	Not Specified	85	64	Other Case

* For Fully Inflated Parachute Terminal Velocity

6.0 DISCUSSION OF ALTERNATE CONFIGURATIONS

a. Ejection Propulsion

An investigation of seat propulsion techniques is reported in Part I Volume 2 "Escape System Parameters Analyses". This study included liquid, hybrid, and solid propellant motors. In addition, various propulsion system arrangements were examined. These were:

Rocket Cluster
Up-Down Ejection Propulsion
Dual Rockets, Single Catapult
Single Rocket, Dual Catapults
Single Rocket, Single Catapult
Tractor Rocket
Integral Rocket-Catapult

The effects on the escape system performance of the following propulsion configurations is reported in Part I, Volume 2.

Steerable Tractor Rocket
Withholding Sustainer Motor Ignition
Use of Retrograde Motors
Dual End-Speed Catapult
Up-Down Ejection

The influence of thrust vector stability, accuracy, and repeatability is discussed as are the mounting and installation requirements of the ejection propulsion system.

The conclusions reached from this study resulted in the recommendation that the VTOL ejection seat should utilize an integral unit, solid propellant rocket catapult incorporating the feature of withholding the rocket motor ignition for adverse attitude ejections. The airframe compromise required by incorporation of an "Up-Down" ejection capability is not necessary since the ejection system performance requirements are met with an upward ejection seat.

b. Ejection Initiation Methods

Failure of the crew member to actuate the ejection system in time for successful recovery prior to ground impact is a primary cause of unsuccessful escape. Examination of the escape conditions which exist during VTOL and transition flight reveals that initiation time is very critical if a recovery altitude above the ejection altitude is the objective. Figures 65 through 86 are taken from Part I, Volume 1 of this report for convenience. The cross hatched area on these curves cover the time period of 1.5 seconds to 3.0 seconds following the failure to the aircraft. This time period is representative of an extremely rapid crew reaction to the emergency. The figures show that the altitude lost and the aircraft pitch and roll attitude that might exist within this time frame is not conducive to a successful escape. It follows that if ejection could be accomplished more promptly, the chances of success will be good. Therefore, the Emergency Detection and Ejection Initiation System described in Section 3.0 of this report is recommended to automatically eject the crew when an "out-of-control" condition develops.

An entirely different situation exists in the high speed, low altitude flight condition. Figures 81 through 118 are taken from Part 1 Volume 1 of this report for convenience. These curves show the aircraft behavior following hardover control failures and aircraft structural failures at 600 KEAS and 200 feet above ground. The situation that exists after the lateral control failure and the loss of one wing is very similar as shown on Figures 87 and 106. If ejection is manually accomplished within three seconds, the chances of success are good. Approximately 50 feet of altitude has been lost but reference to Table IV, Section 5.0, Case 10 shows that only about 147 feet is required even if the aircraft is inverted.

For the aircraft failure modes of hardover longitudinal control failure and of loss of horizontal or vertical stabilizers the load factors shown in Figures 95 and 114 exceed human tolerance in less than 200 milliseconds. Therefore, no automatic ejection initiation system is recommended for these aircraft failures.

c. Signal Transmission

Four basic methods are available by which to transfer the primary initiation stimulus to each propellant actuated device in the escape system. These are:

Gas (pneumatics)
Electrical
Explosive (shielded mild detonating cord)
Mechanical

The mechanical system was rejected immediately because of excessive weight plus operational problems associated with misrigging and structural deflections. Of the three remaining the pneumatic method is not considered capable of fulfilling the design requirements. This conclusion is based upon the fact that the various event sequences are electrically programmed and converting these electrical signals to gas pressure will unnecessarily complicate the system.

Both of the two remaining methods, electrical or explosive, are suitable for use in the VTOL escape system. The electrical method is recommended because it occupies a smaller volume than the shielded mild detonating cord.

d. Drogue and Recovery Parachute Deployment

The personnel parachute canopy and suspension lines may be forcibly deployed to line stretch by the following means:

Gun-fired slug
Thruster or catapult
Mortar
Tractor rocket

These methods are depicted in Figures 119 through 122.

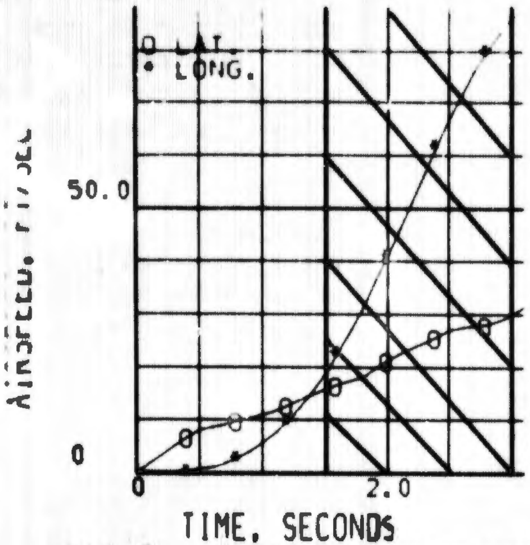


FIG 65 CONTROL FAILURES, HOVER AIRPLANE AIRSPEED

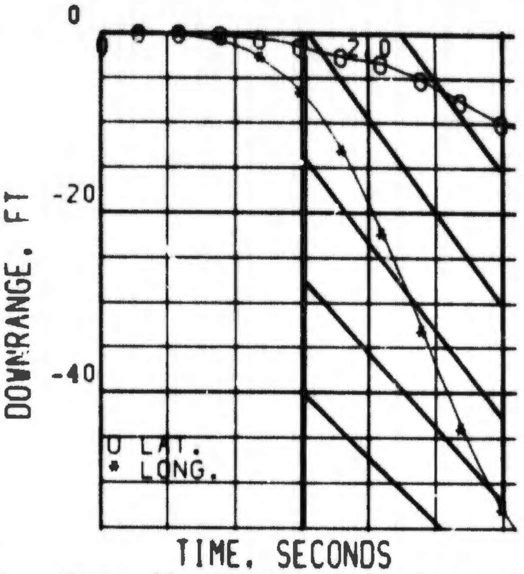


FIG 66 CONTROL FAILURES, HOVER AIRPLANE DOWNRANGE DISTANCE

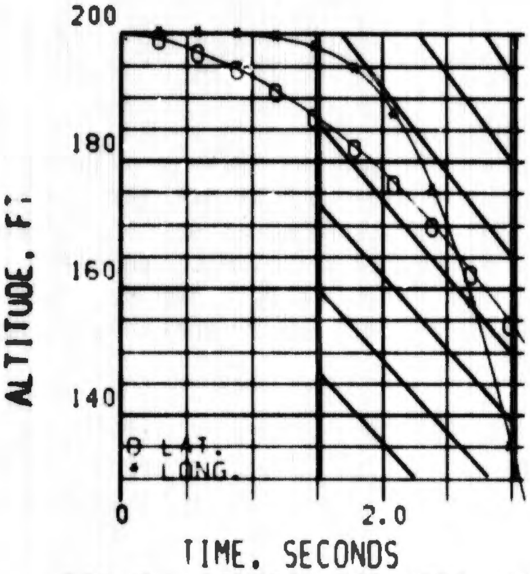


FIG 67 CONTROL FAILURES, HOVER AIRPLANE ALTITUDE

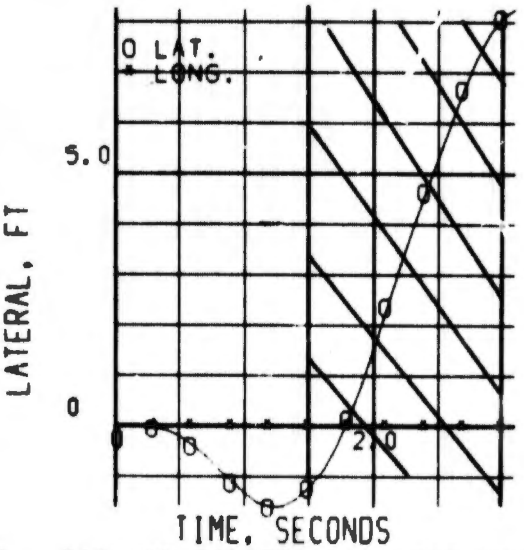


FIG 68 CONTROL FAILURES, HOVER AIRPLANE LATERAL DISTANCE

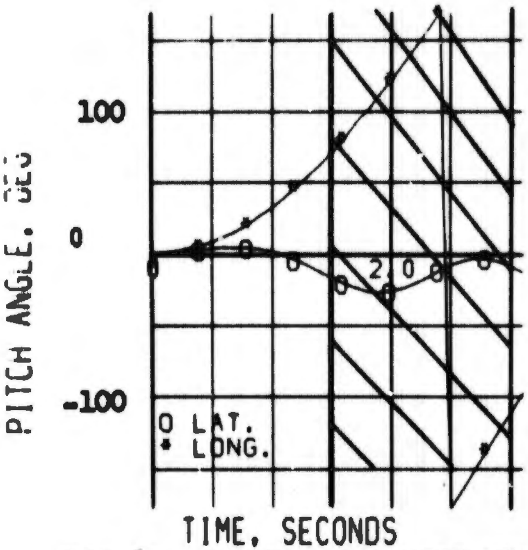


FIG 69 CONTROL FAILURES, HOVER AIRPLANE PITCH ANGLE

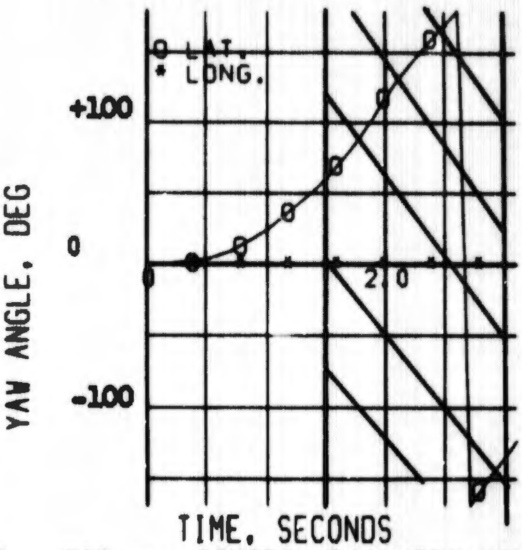


FIG 70 CONTROL FAILURES, HOVER AIRPLANE YAW ANGLE

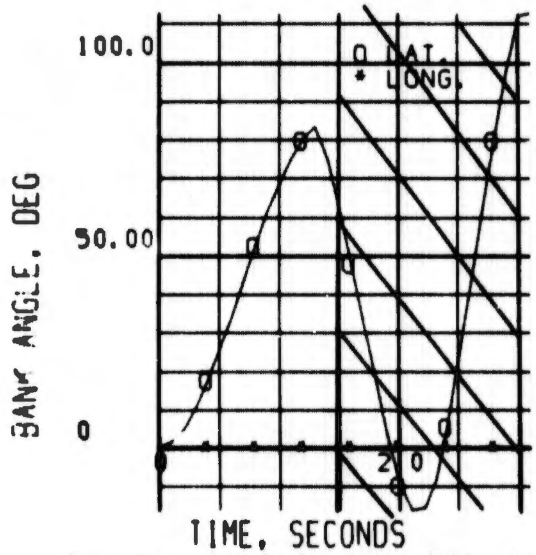


FIG 71 CONTROL FAILURES, HOVER AIRPLANE BANK ANGLE

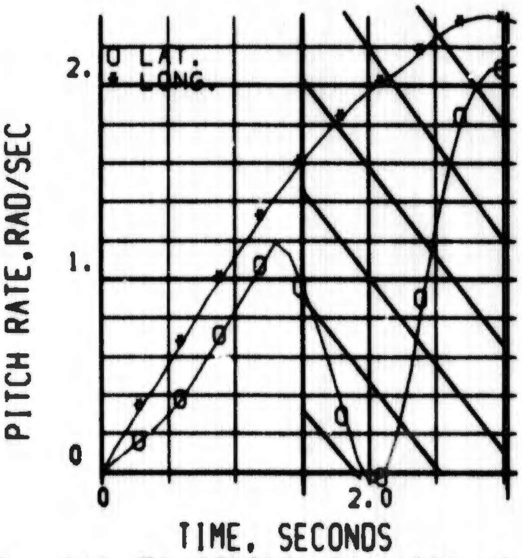


FIG 72 CONTROL FAILURES, HOVER AIRPLANE PITCH RATE

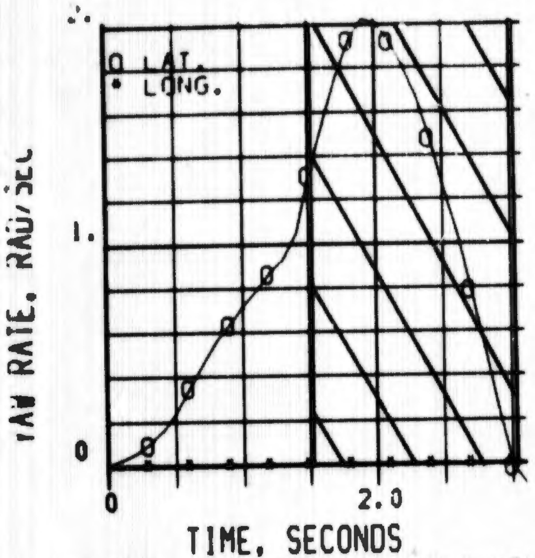


FIG 73 CONTROL FAILURES, HOVER AIRPLANE YAW RATE

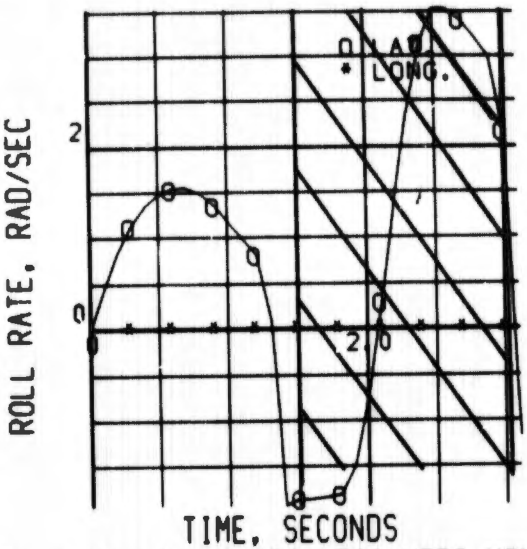


FIG 74 CONTROL FAILURES, HOVER AIRPLANE ROLL RATE

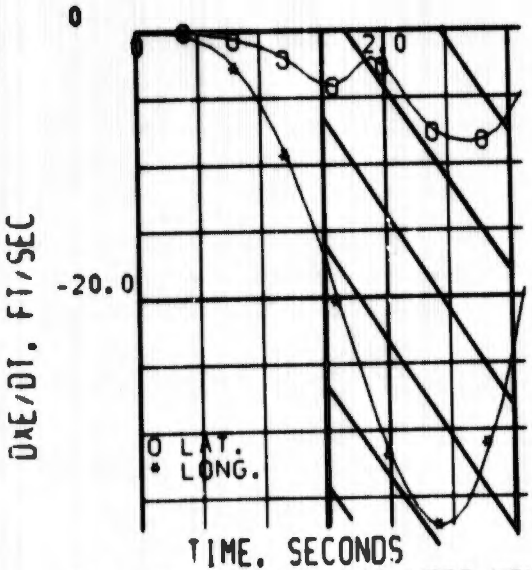


FIG 75 CONTROL FAILURES, HOVER AIRPLANE DOWNRANGE SPEED

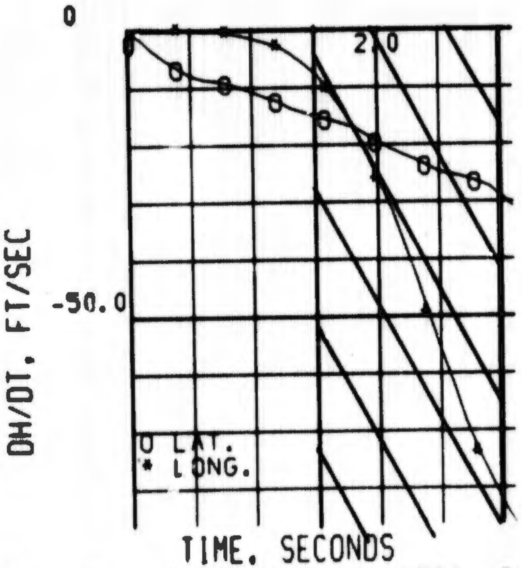


FIG 76 CONTROL FAILURES, HOVER AIRPLANE CLIMB RATE

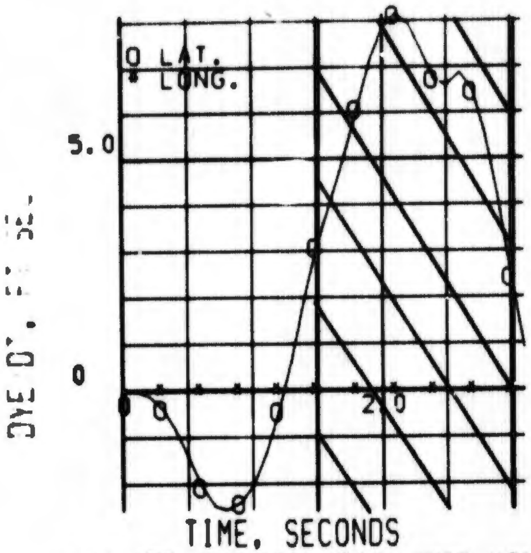


FIG 77 CONTROL FAILURES, HOVER AIRPLANE LATERAL SPEED

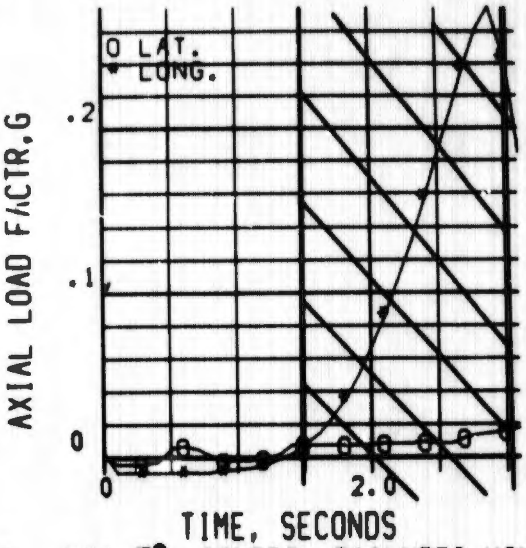


FIG 78 CONTROL FAILURES, HOVER AIRPLANE AXIAL LOAD FACTOR

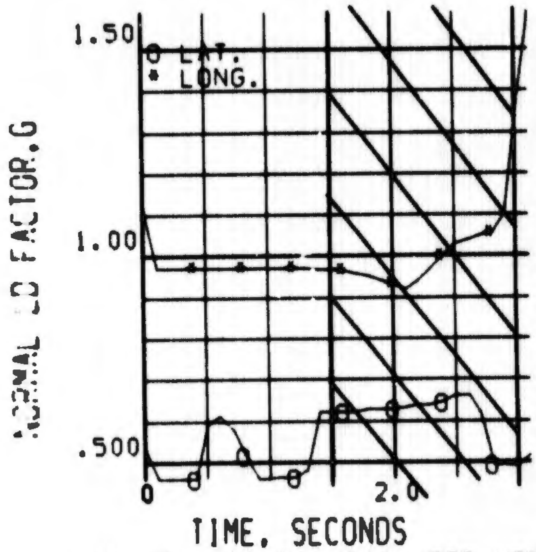


FIG 79 CONTROL FAILURES, HOVER AIRPLANE NORMAL LOAD FACTOR

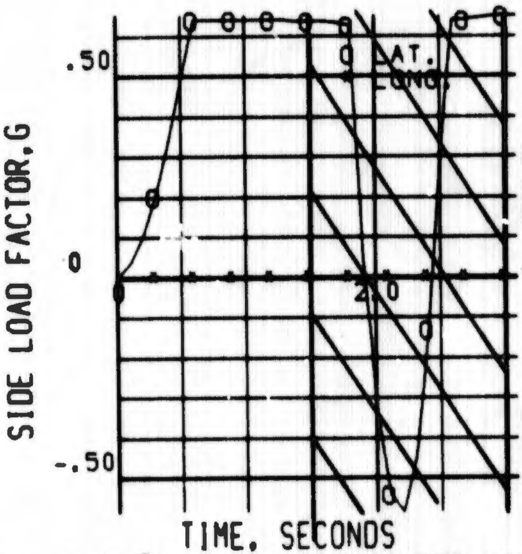


FIG 80 CONTROL FAILURES, HOVER AIRPLANE SIDE LOAD FACTOR

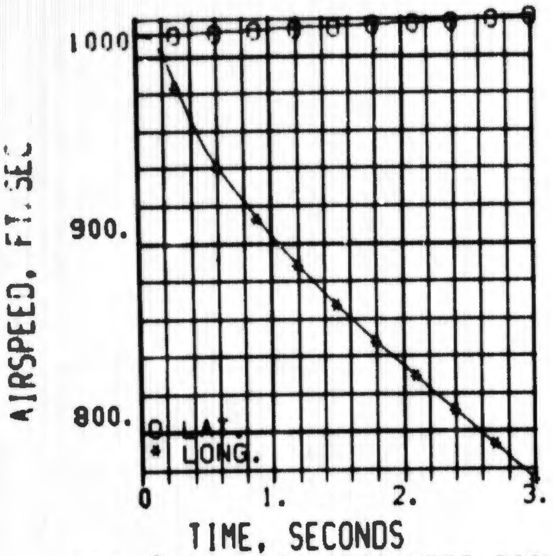


FIG 81 CONTROL FAILURES,600KT
AIRPLANE AIRSPEED

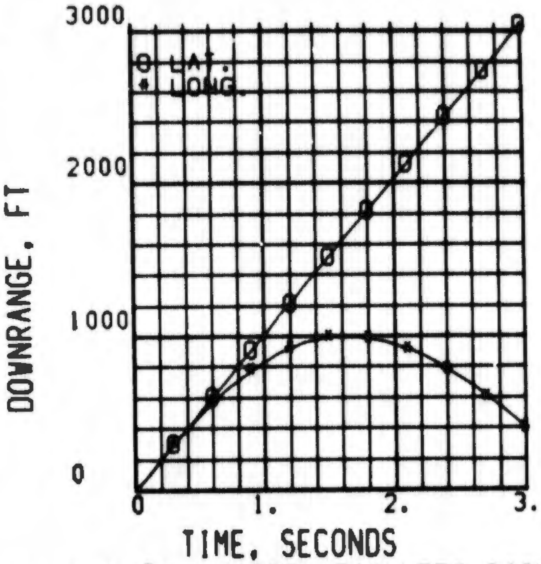


FIG 82 CONTROL FAILURES,600KT
AIRPLANE DOWNRANGE DISTANCE

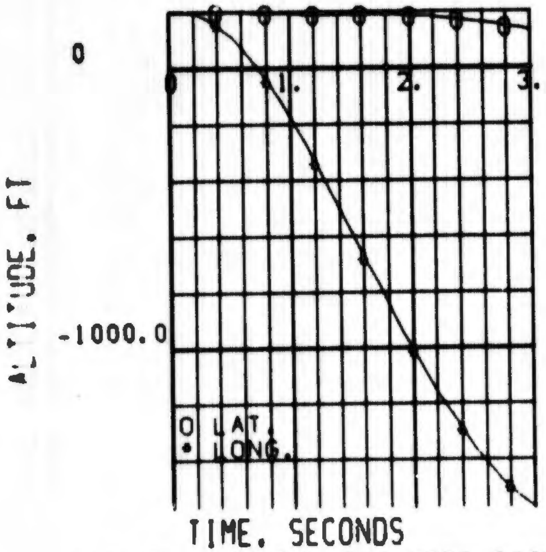


FIG 83 CONTROL FAILURES,600KT
AIRPLANE ALTITUDE

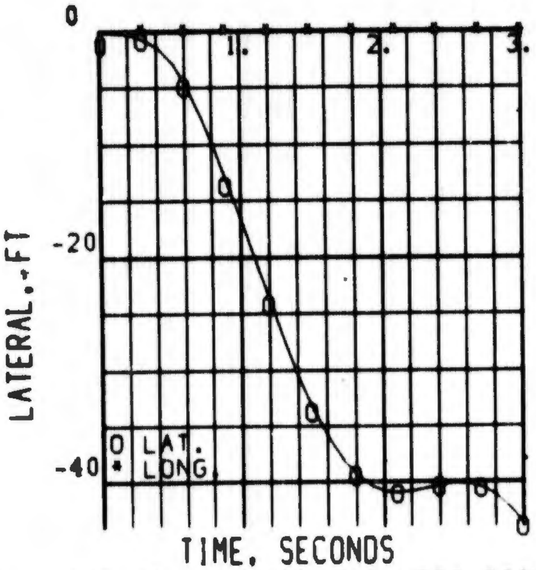


FIG 84 CONTROL FAILURES,600KT
AIRPLANE LATERAL DISTANCE

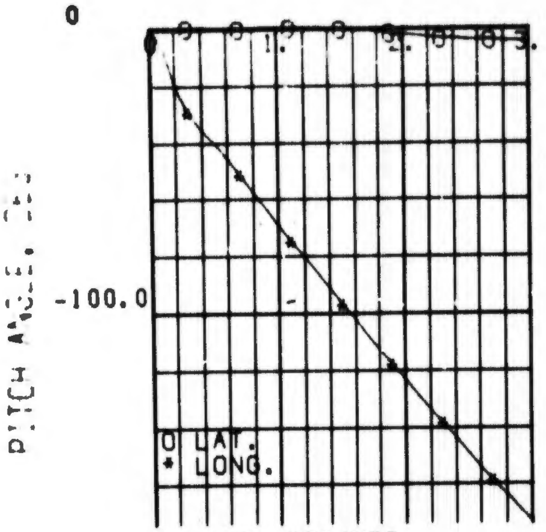


FIG 85 CONTROL FAILURES,600KT
AIRPLANE PITCH ANGLE

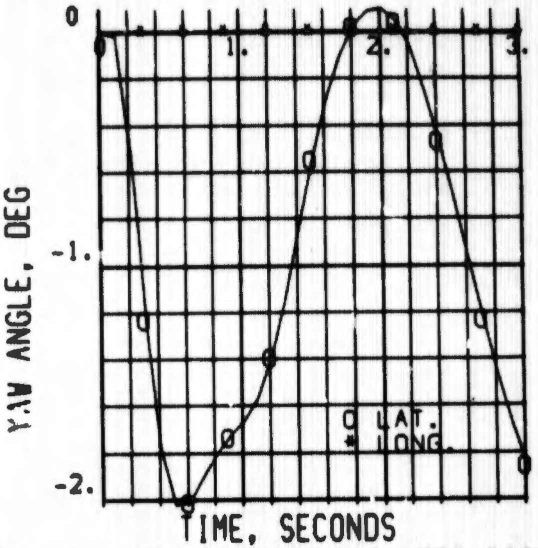


FIG 86 CONTROL FAILURES,600KT
AIRPLANE YAW ANGLE

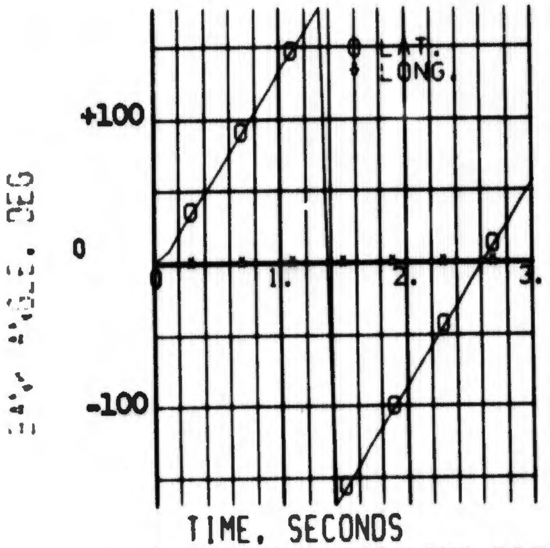


FIG 87 CONTROL FAILURES,600KT
AIRPLANE BANK ANGLE

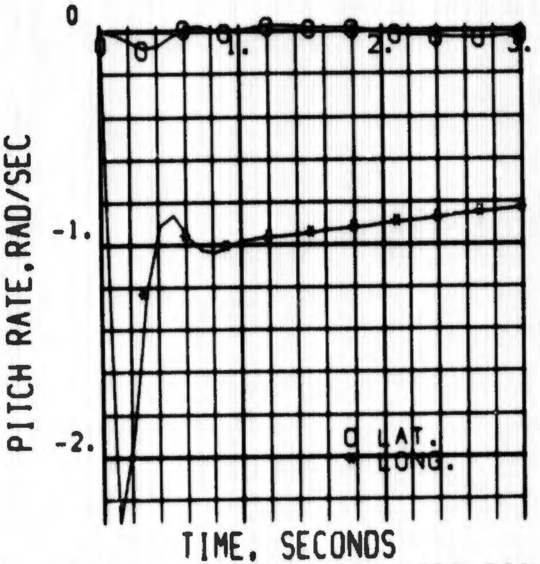


FIG 88 CONTROL FAILURES,600KT
AIRPLANE PITCH RATE

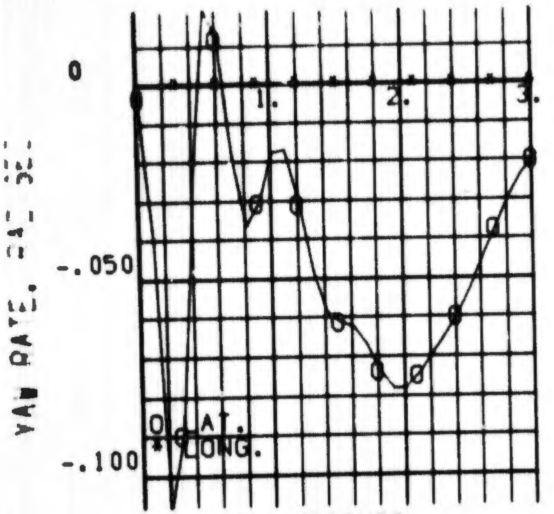


FIG 89 CONTROL FAILURES,600KT AIRPLANE YAW RATE

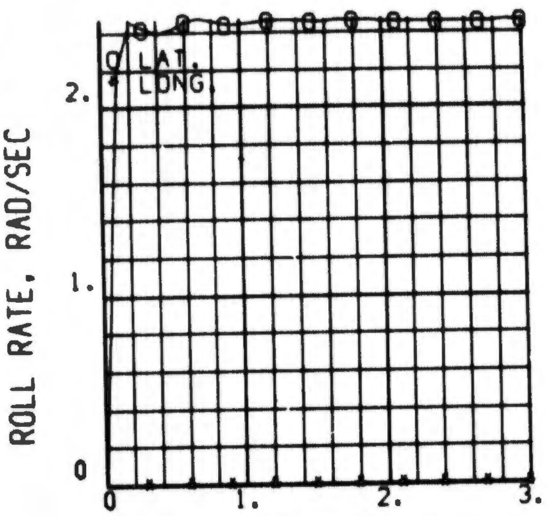


FIG 90 CONTROL FAILURES,600KT AIRPLANE ROLL RATE

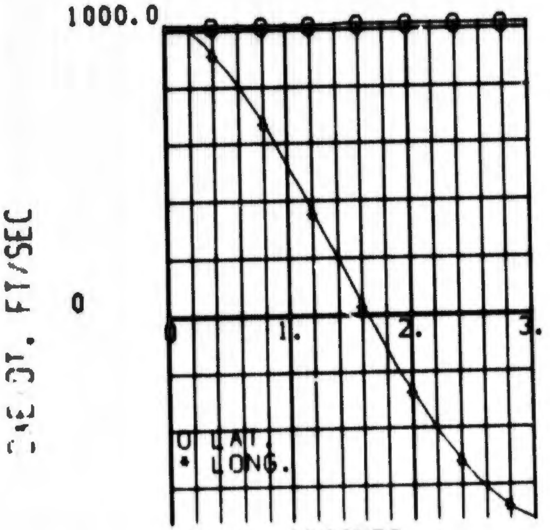


FIG 91 CONTROL FAILURES,600KT AIRPLANE DOWNRANGE SPEED

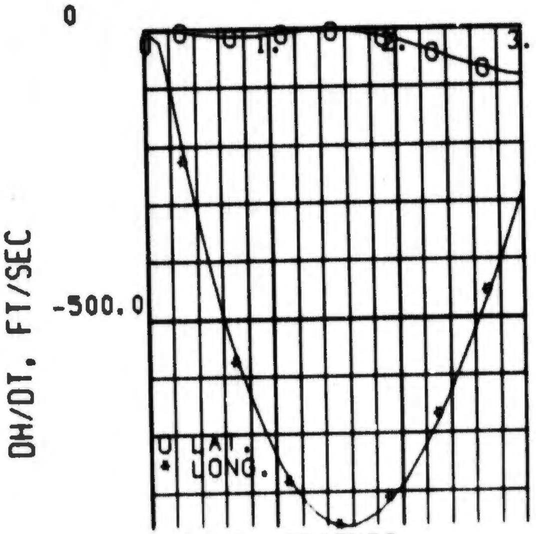


FIG 92 CONTROL FAILURES,600KT AIRPLANE CLIMB RATE

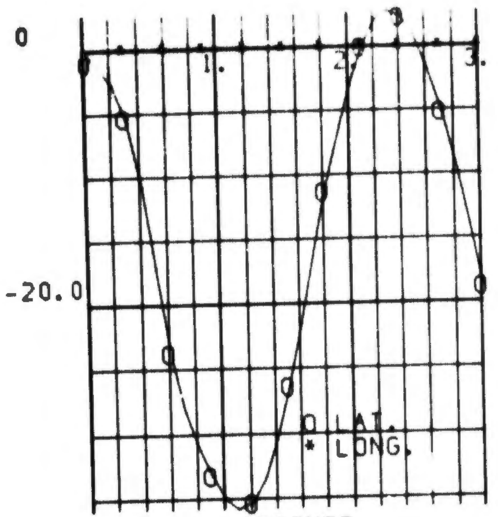


FIG 93 CONTROL FAILURES,600KT
AIRPLANE LATERAL SPEED

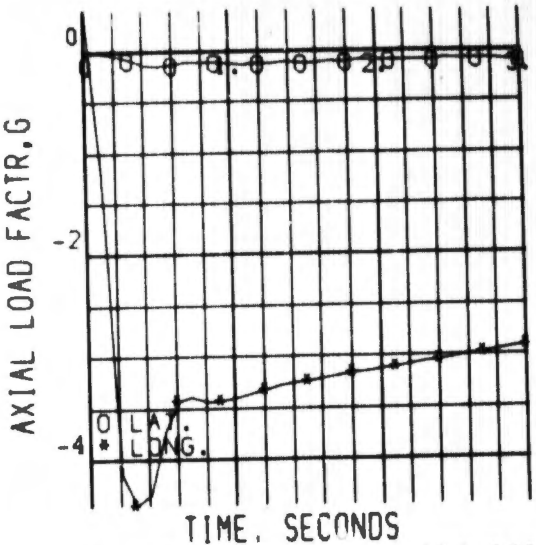


FIG 94 CONTROL FAILURES,600KT
AIRPLANE AXIAL LOAD FACTOR

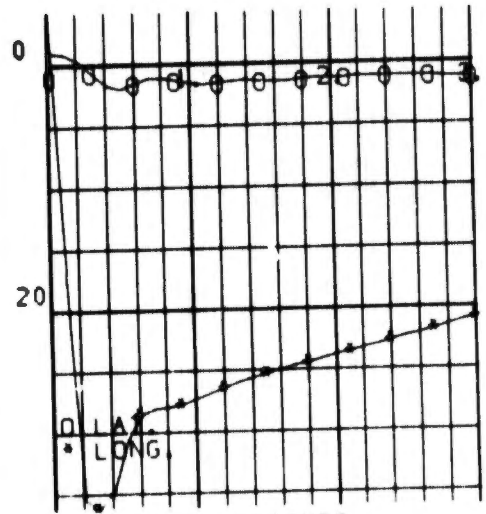


FIG 95 CONTROL FAILURES,600KT
AIRPLANE NORMAL LOAD FACTOR

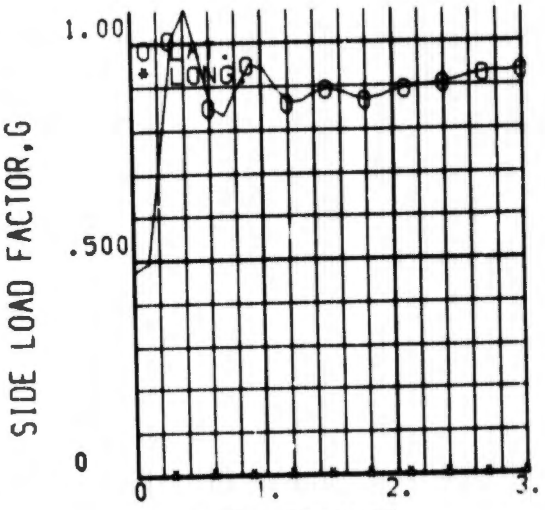


FIG 96 CONTROL FAILURES,600KT
AIRPLANE SIDE LOAD FACTOR

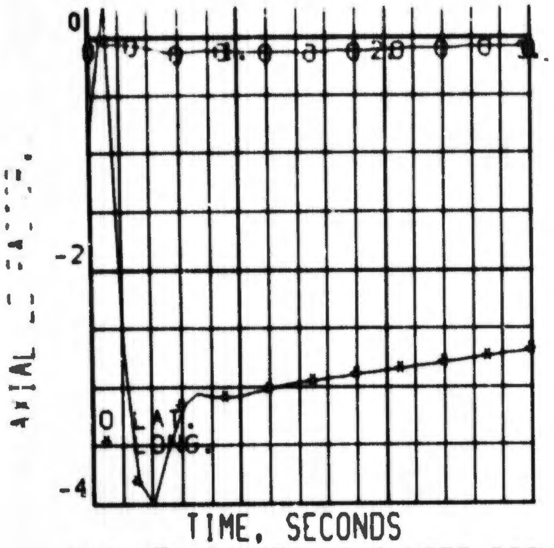


FIG 97 CONTROL FAILURES,600KT
COCKPIT AXIAL LOAD FACTOR

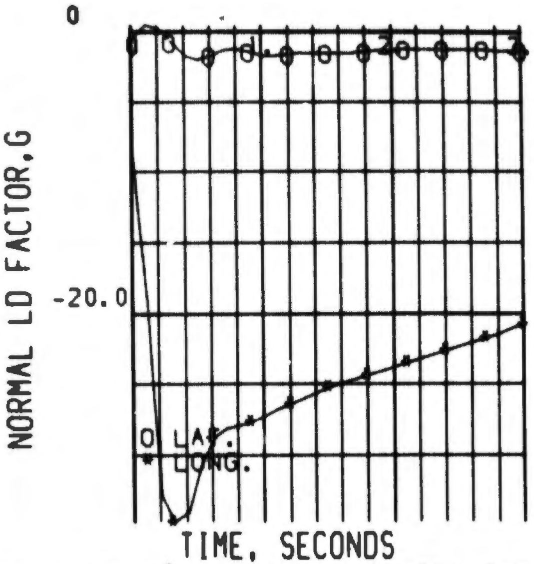


FIG 98 CONTROL FAILURES,600KT
COCKPIT NORMAL LOAD FACTOR

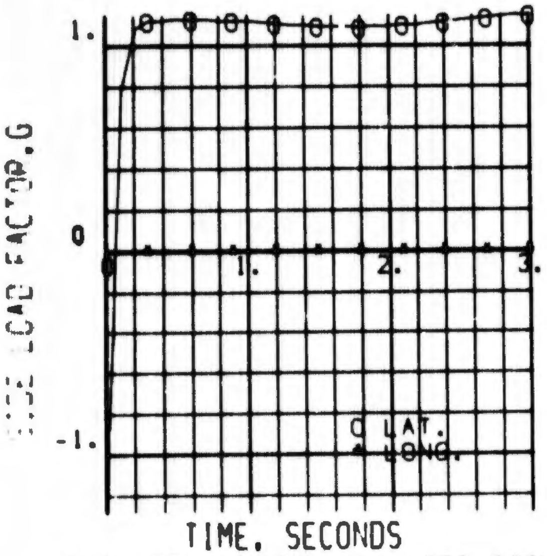


FIG 99 CONTROL FAILURES,600KT
COCKPIT SIDE LOAD FACTOR

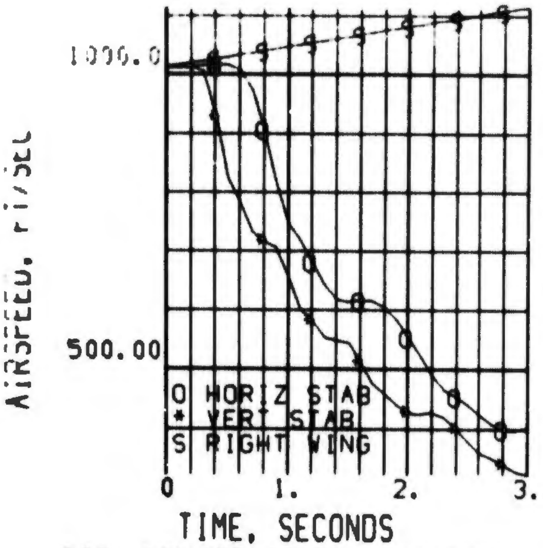


FIG 100 STRUCTURAL FAILURES
600 KT, AIRPLANE AIRSPEED

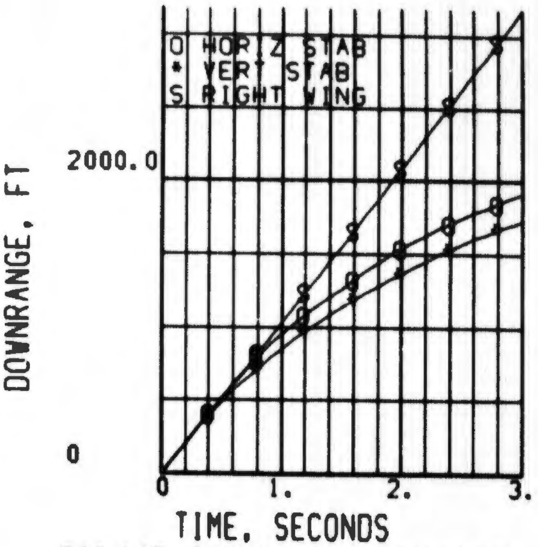


FIG 101 STRUCTURAL FAILURES
600 KT, AIRPLANE DOWNRANGE DIST

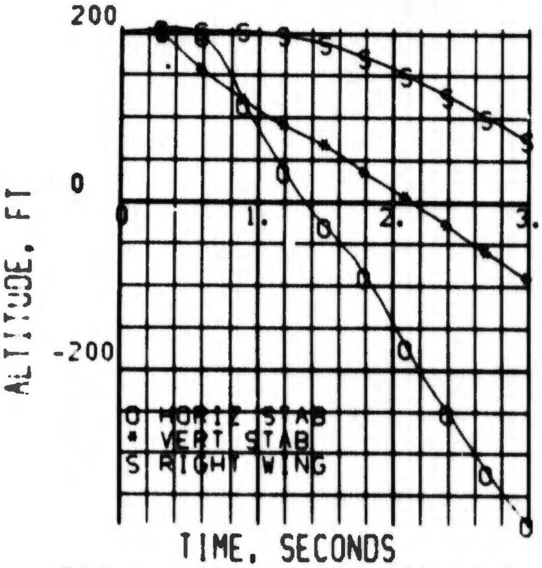


FIG 102 STRUCTURAL FAILURES
600 KT, AIRPLANE ALTITUDE

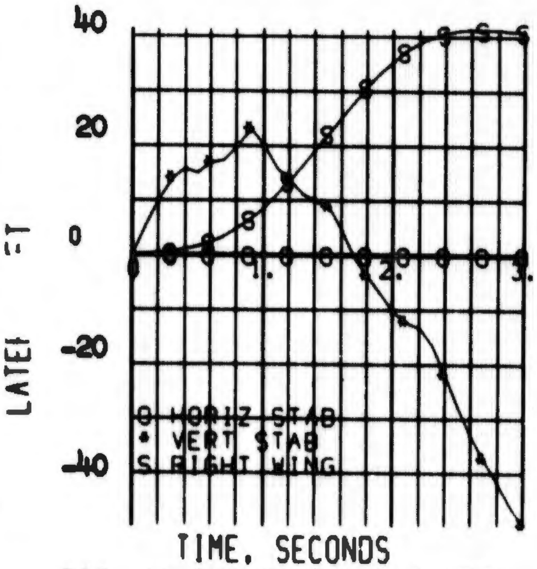


FIG 103 STRUCTURAL FAILURES
600 KT, AIRPLANE LATERAL DIST

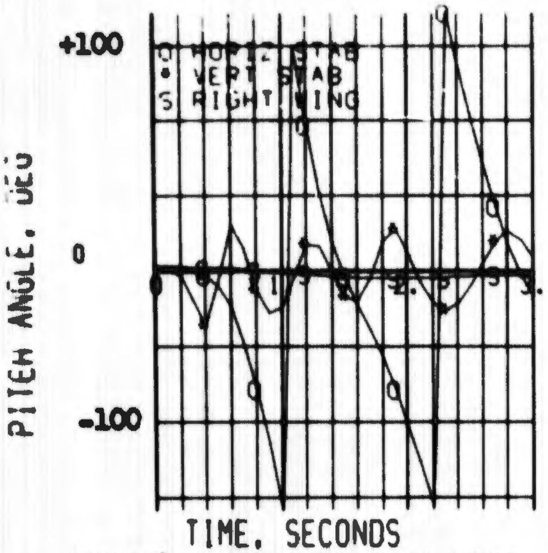


FIG 104 STRUCTURAL FAILURES
600 KT, AIRPLANE PITCH ANGLE

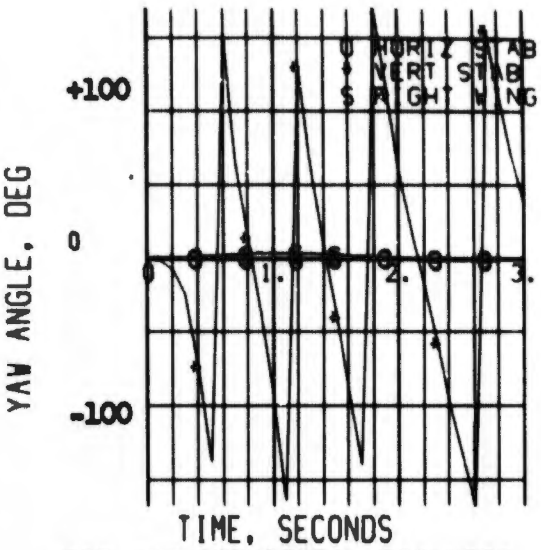


FIG 105 STRUCTURAL FAILURES
600 KT, AIRPLANE YAW ANGLE

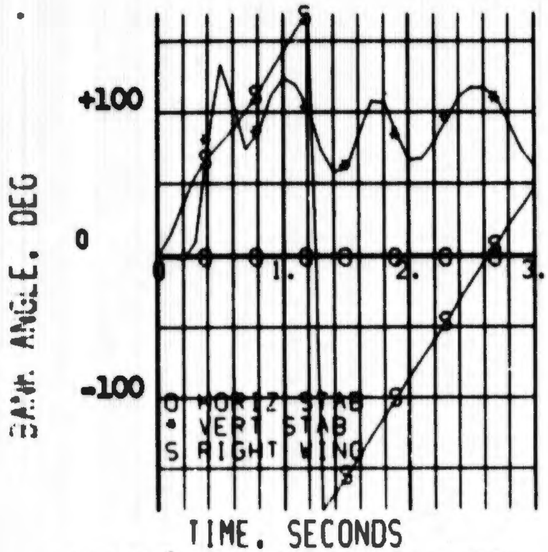


FIG 106 STRUCTURAL FAILURES
600 KT, AIRPLANE BANK ANGLE

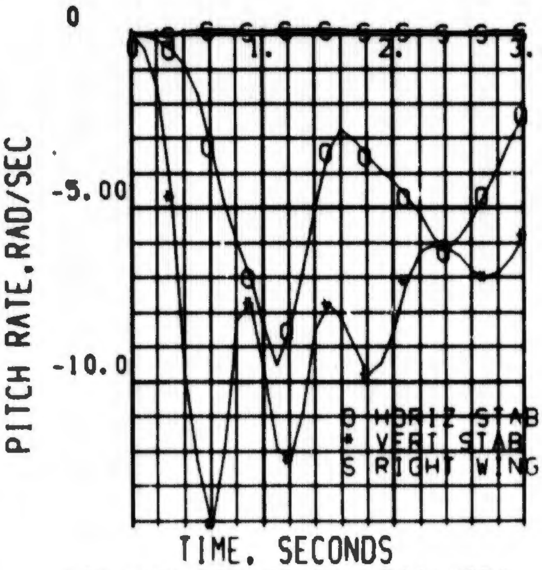


FIG 107 STRUCTURAL FAILURES
600 KT, AIRPLANE PITCH RATE

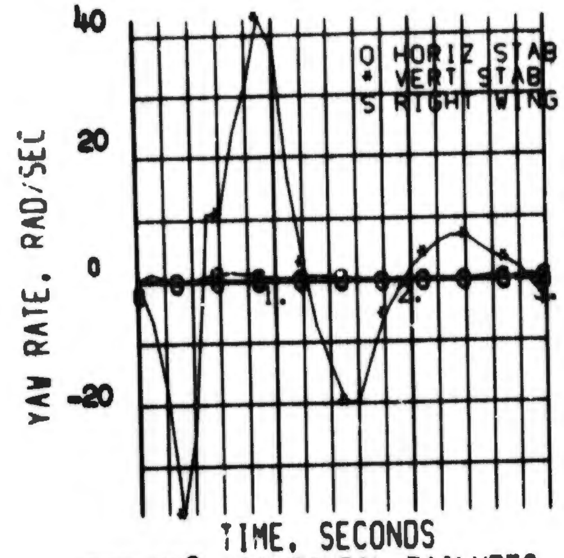


FIG 108 STRUCTURAL FAILURES
600 KT, AIRPLANE YAW RATE

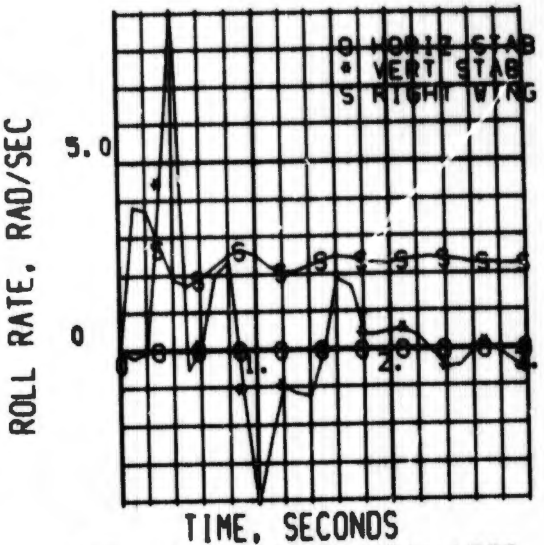


FIG 109 STRUCTURAL FAILURES
600 KT, AIRPLANE ROLL RATE

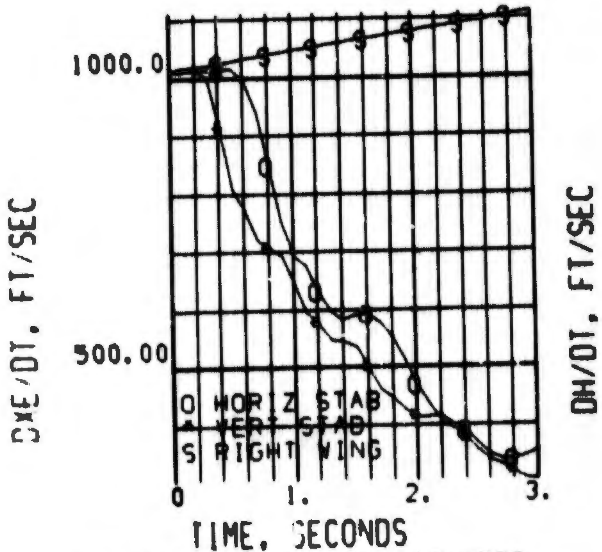


FIG 110 STRUCTURAL FAILURES
600 KT, AIRPLANE DOWNRNGE SPEED

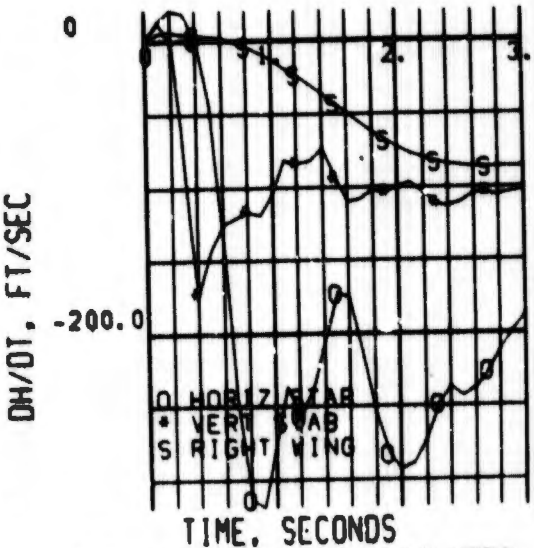


FIG 111 STRUCTURAL FAILURES
600 KT, AIRPLANE CLIMB RATE

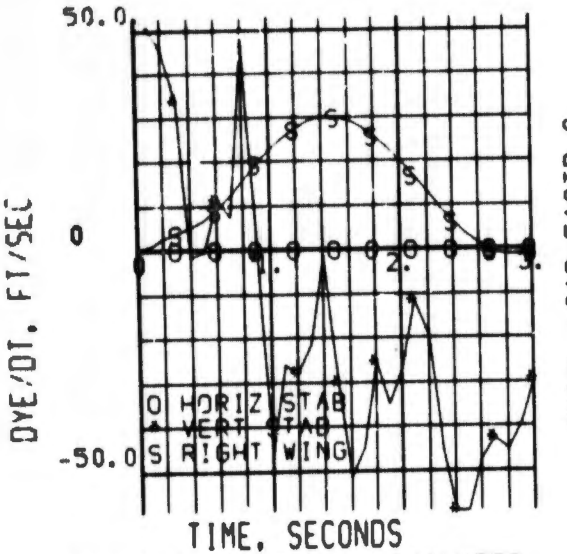


FIG 112 STRUCTURAL FAILURES
600 KT, AIRPLANE LATERAL SPEED

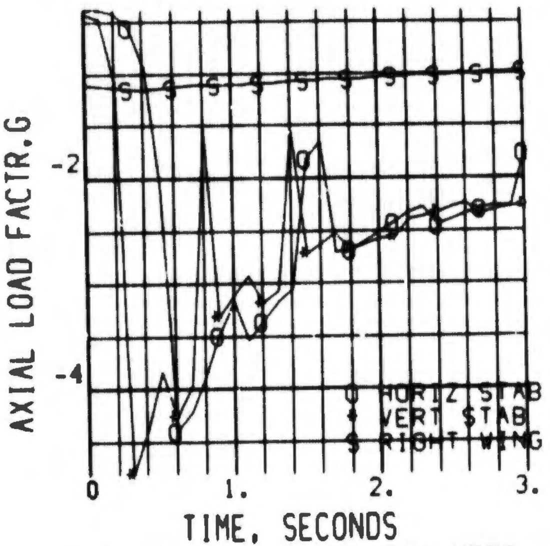


FIG 113 STRUCTURAL FAILURES
600 KT, AIRPLANE LOAD FACTOR

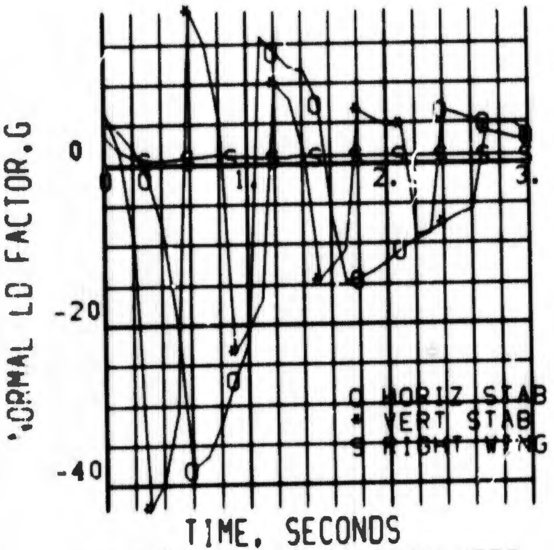


FIG 114 STRUCTURAL FAILURES
600 KT, AIRPLANE LOAD FACTOR

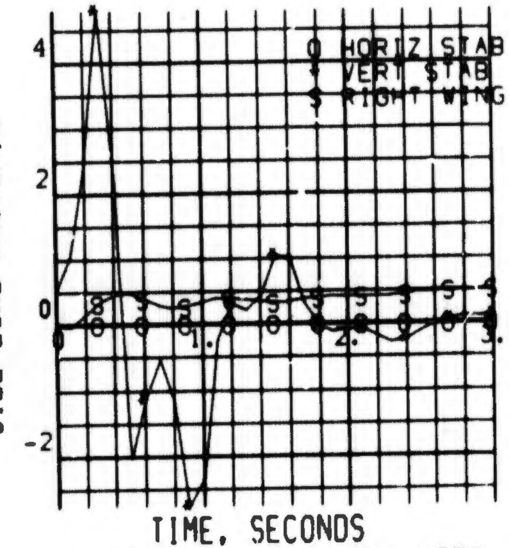


FIG 115 STRUCTURAL FAILURES
600 KT, AIRPLANE LOAD FACTOR

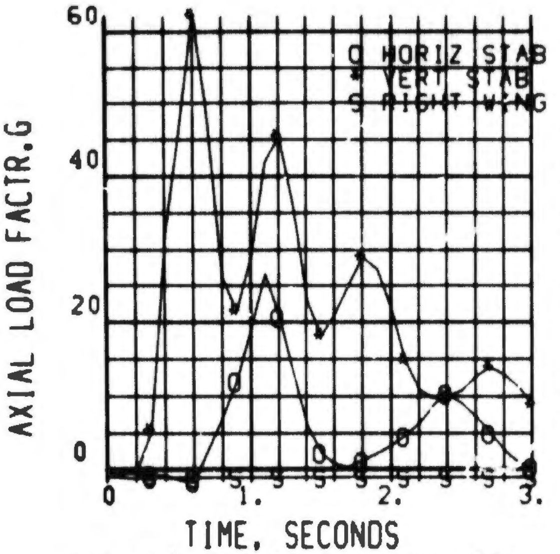


FIG 116 STRUCTURAL FAILURES
600 KT, COCKPIT LOAD FACTOR

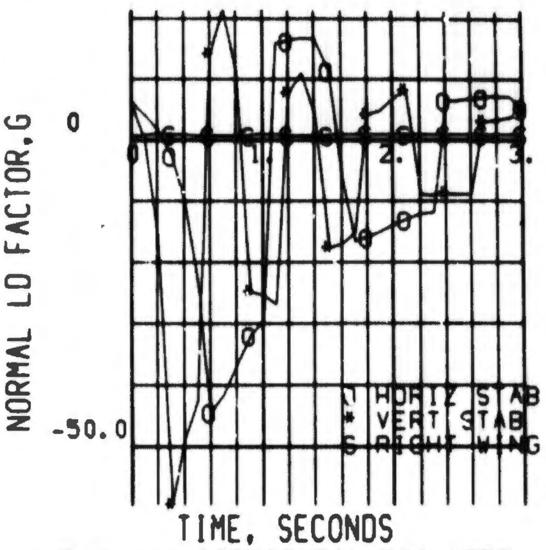


FIG 117 STRUCTURAL FAILURES
600 KT, COCKPIT LOAD FACTOR

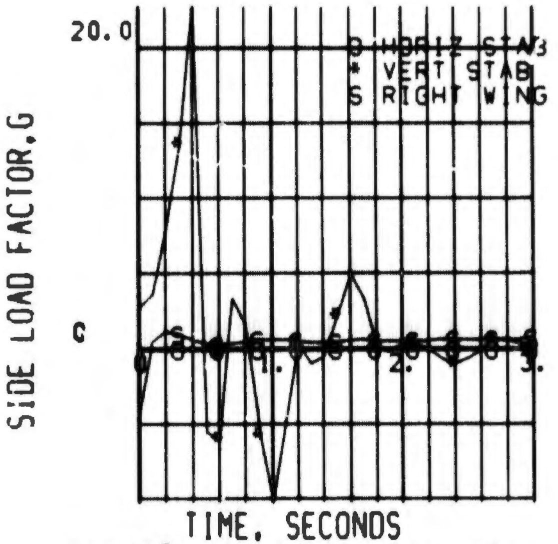


FIG 118 STRUCTURAL FAILURES
600 KT, COCKPIT LOAD FACTOR

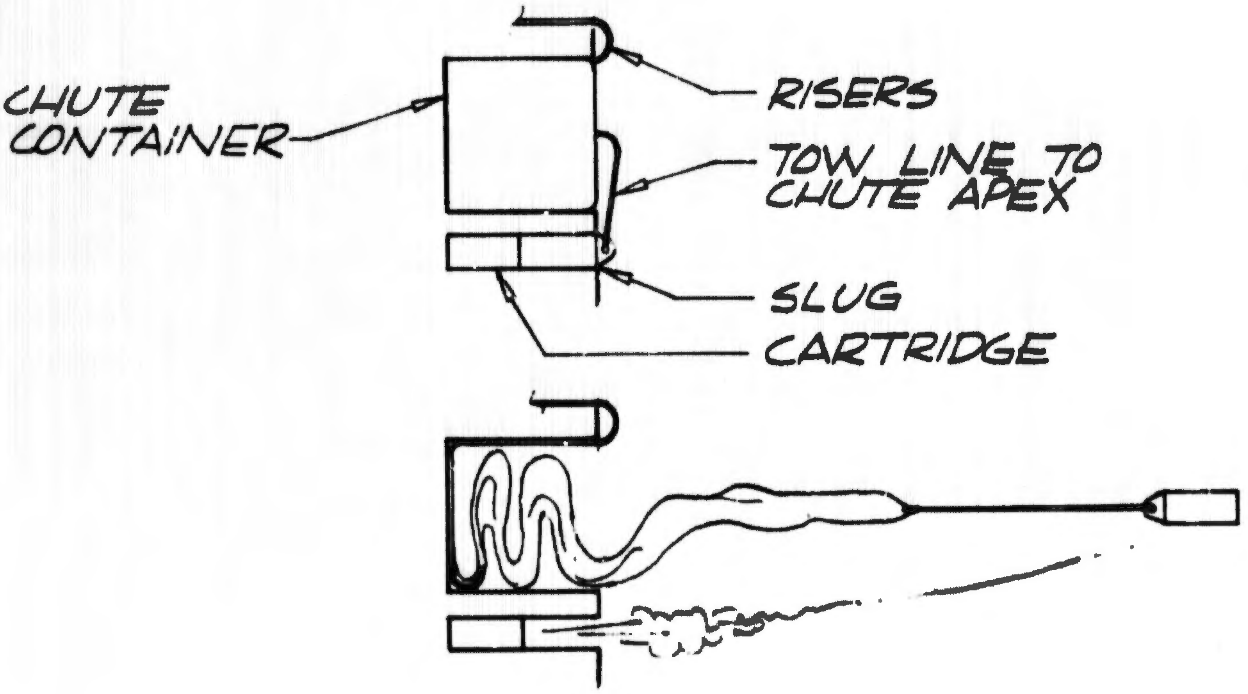


FIGURE 119
SLUG DEPLOYED CANOPY

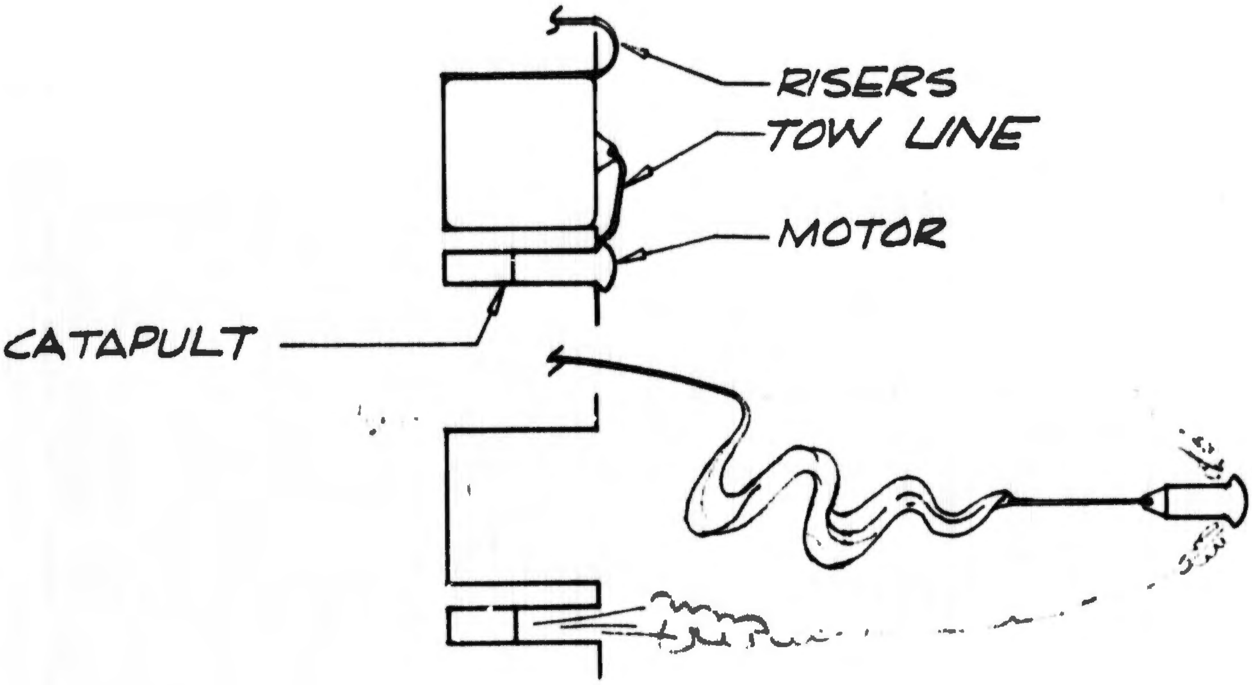


FIGURE 120
TRACTOR ROCKET DEPLOYED CANOPY

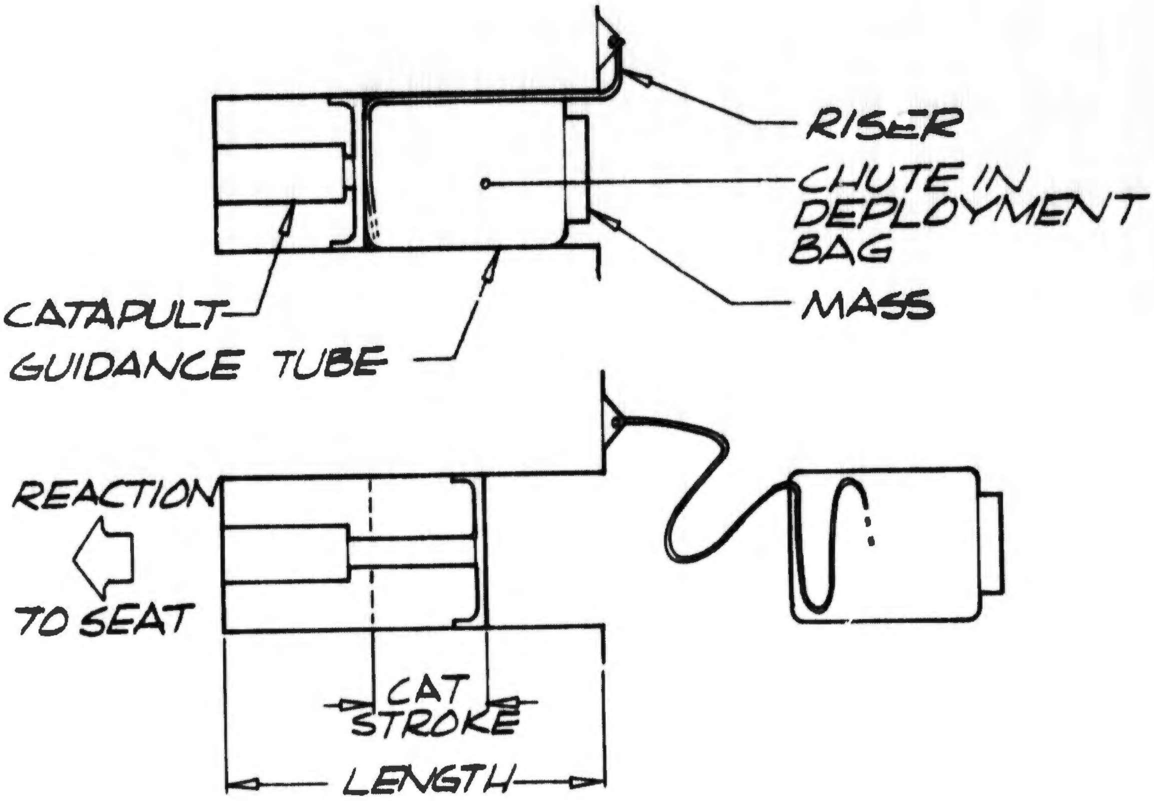


FIGURE 121
CATAPULT DEPLOYED CANOPY

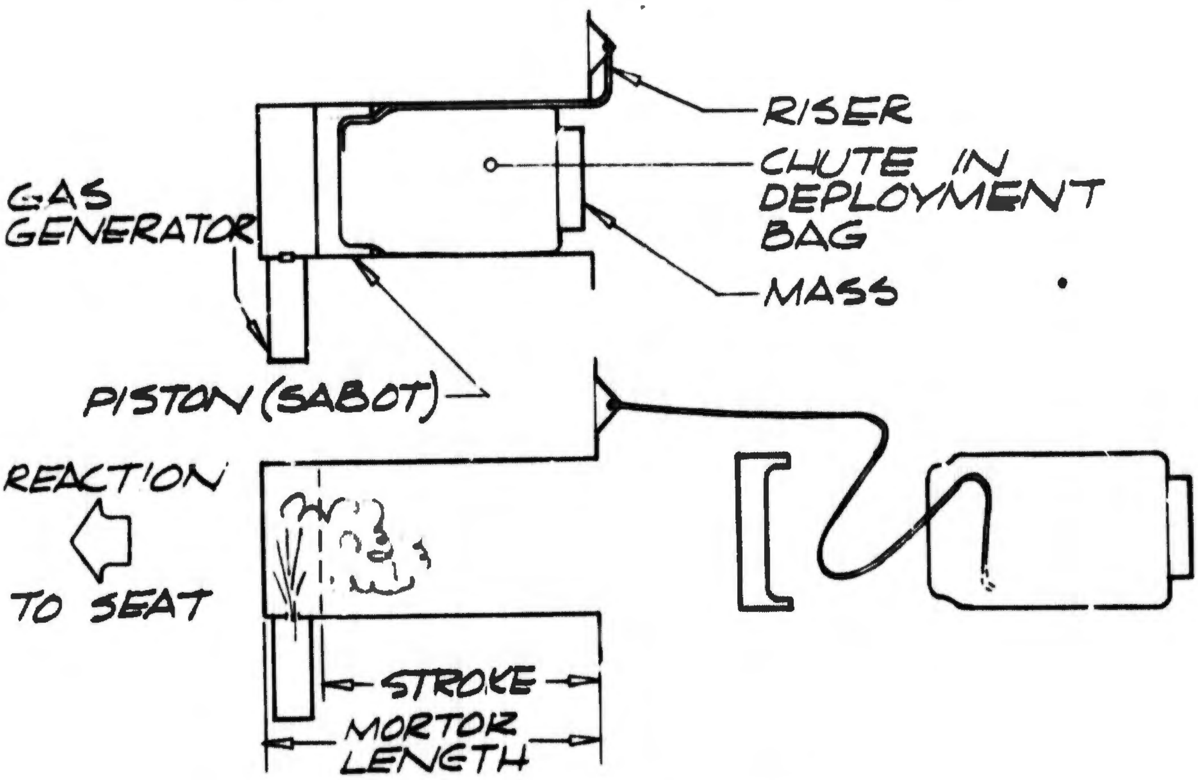


FIGURE 122
MORTOR DEPLOYED CANOPY

Since the C-9 canopy equipped with spreading gun has a weight of approximately 17.0 pounds and the 4.66 foot drogue a weight of about 6.0 pounds, the use of the gun fired slug would impose severe structural loads on the canopies from the heavy, high velocity slug which would be required.

The catapult or mortar deployment methods are suitable except for the large reaction force applied to the seat. If the seat is restrained by the ejection rails then very high loads are applied to the lower slider blocks. If the seat is unrestrained a pitching velocity of as much as -50 RPM may result.

A tractor rocket motor attached to the apex of the canopy, or to a deployment bag, has the advantage of pulling the canopy to the point of suspension line stretch with a constant force. At this point it may be conveniently released to avoid canopy damage from the attached motor. The rockrt may be catapult-deployed to avoid blast impingement on the seat assembly. This system is described in Section 3.0.

e. Drogue Parachute Selection

A detailed drag parachute study is reported in Part I, Volume 2, "Escape System Parameters Analysis". This analysis included:

Solid and ribbon type canopies
Projected diameters from 2.0 to 6.0
Attitude from S.L. to 50000 Ft.
Mach Numbers of 0.10 to 2.0
Dynamic Pressure from 15.0 to
  1220.0 lbs per sq. ft.
Sustainer motor burning and not burning
Seat wake effects

The drag parachute performance was computed by a digital computer simulation which allows evaluation of parachute stability, opening reliability, time to open, accelerations imparted to the seat and drag producing capability.

The following conclusions were drawn from the drag parachute analysis:

(1) Solid Canopies

- The ribless guide surface is superior to the flat circular for subsonic high dynamic pressure environments.

- Neither type stabilizes the seat satisfactorily in a supersonic environment.

(2) Ribbon Canopies

- All three ribbon parachutes; flat circular, equiflo, and hemisflo, are equally acceptable as stabilization, deceleration devices for subsonic, high dynamic pressure conditions.

(3) Solid versus Ribbon Canopies

- The hemisflo parachute demonstrates a marked stabilizing superiority over the ribless guide surface type at supersonic conditions with about the same subsonic deceleration characteristics.

Therefore, the hemisflo type is selected for the VTOL escape system drogue parachute. Figure 147 through 170 are taken from Part I, Volume 2 to show the hemisflo performance at Mach numbers of 0.9, 1.5 and 2.0.

The drag parachute diameter effects are shown in Figures 123 through 146 from Part I, Volume 2. Figure 152 shows the 4.66 ft. (projected diameter) produces about 35. g axial deceleration at 1220 pounds per square foot dynamic pressure. This condition corresponds to Mach number .9 at sea level (600 KEAS). At higher Mach numbers the drag efficiency is slightly reduced; therefore, this size canopy will be suitable throughout a 600 KEAS and 50000 ft. altitude envelope.

Table V defines the cases shown in Figures 123 through 170.

f. Ejection Guide Rails and Slider Block Dimensions

A study of ejection seat tip-off effects was conducted and is reported in detail in Part I, Volume 2 of this report entitled "Escape System Parameters Analysis". A six degree-of-freedom digital computer simulation was conducted of a basic seat as it moved along and separated from the guide rails. The effect of varying the following parameters was analyzed.

Slider block location
Catapult stroke length
Sustainer thrust level
Catapult thrust level
Weight and Inertia

This study confirmed that seat perturbations at tip-off are minimized if slider block location provides complete mechanically guided stroke for the ejection catapult.

TABLE V - DROGUE PARACHUTE PARAMETERS

CASE	DYNAMIC PRESSURE	MACH NO.	CANOPY DIAM. (PROJ.)
1	1220. #/ft^2	0.9	3.18 ft.
4	1220.	0.9	3.18
5	1220.	2.0	3.18
10	1220.	0.9	4.66
11	1220.	0.9	6.60
12	1220.	1.5	3.18

NOTE: Table I referenced in title of Figures 123 through 170 is shown in Part I, Volume 2 "Escape System Parameters Analysis"

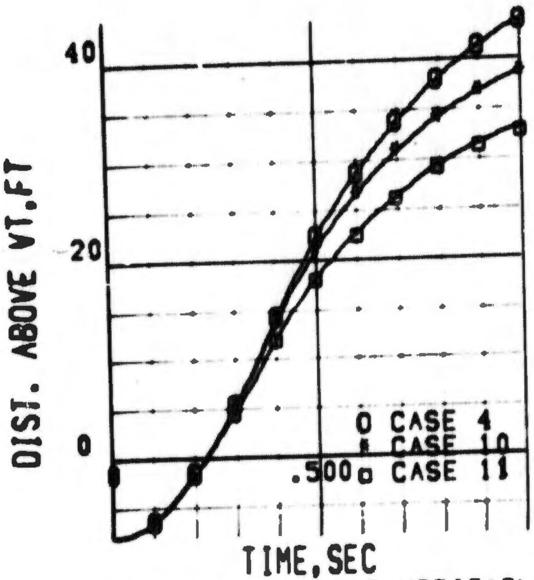


FIG 123 HEMISFLO CHUTE(TABLE1)
VERT. TAIL VERT. CLEARANCE

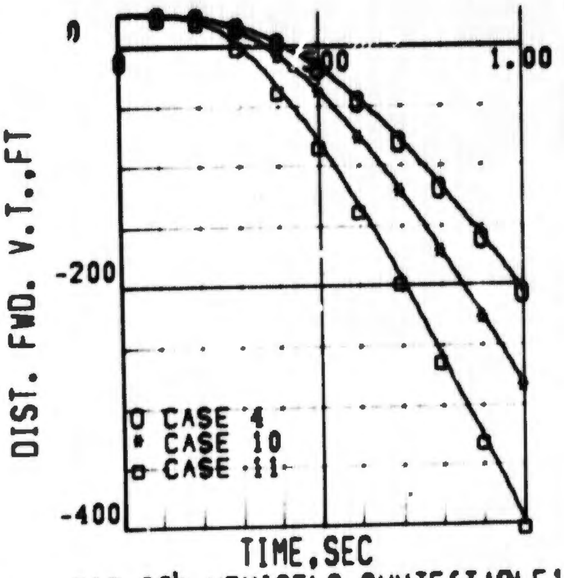


FIG 124 HEMISFLO CHUTE(TABLE1)
VERT. TAIL LONG. CLEARANCE

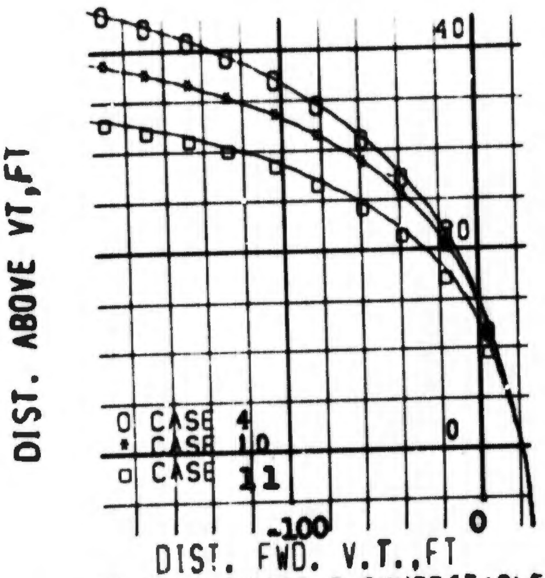


FIG 125 HEMISFLO CHUTE(TABLE1)
VERTICAL TAIL CLEARANCE

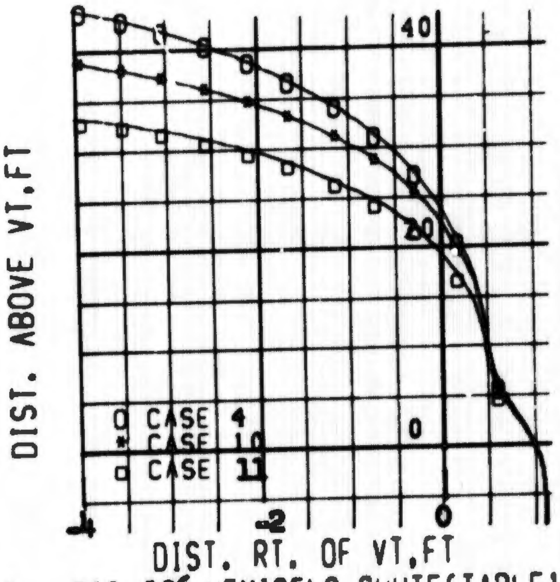


FIG 126 HEMISFLO CHUTE(TABLE1)
VERTICAL TAIL CLEARANCE

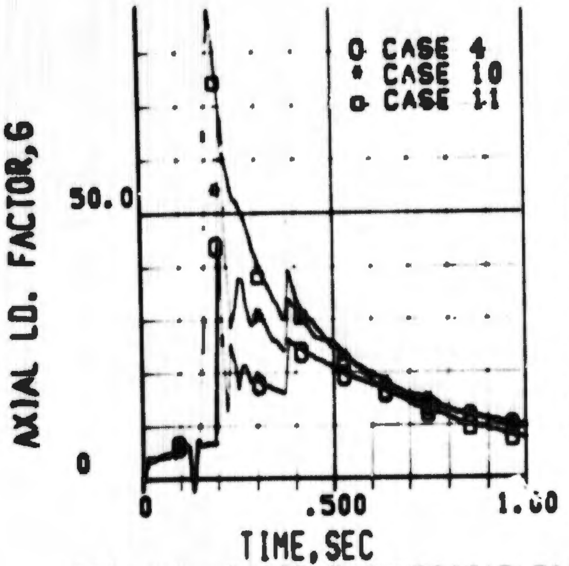


FIG 127 HEMISFLO CHUTE(TABLE1)
SEAT AXIAL LOAD FACTOR

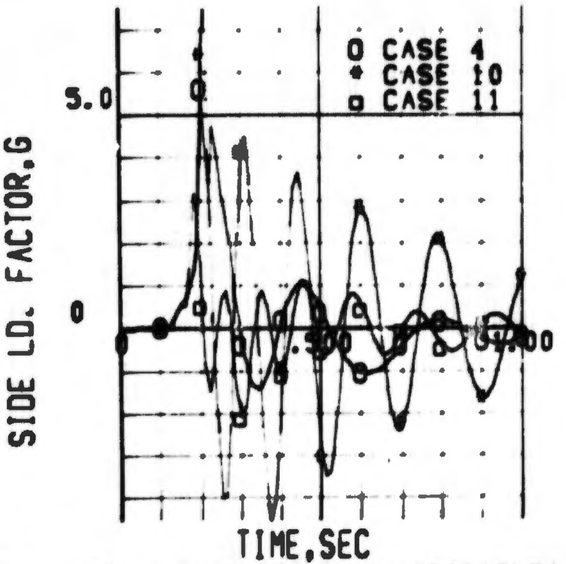


FIG 128 HEMISFLO CHUTE(TABLE1)
SEAT SIDE LOAD FACTOR

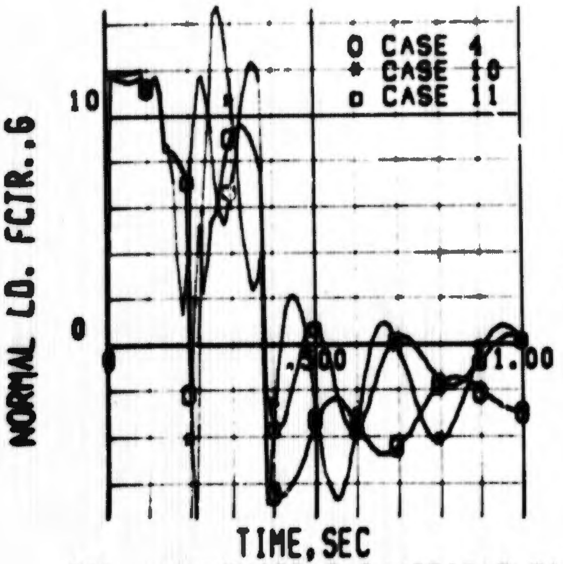


FIG 129 HEMISFLO CHUTE(TABLE1)
SEAT NORMAL LOAD FACTOR

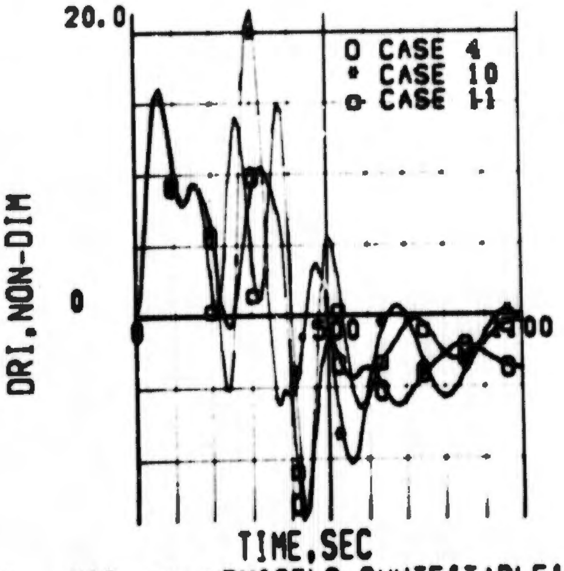


FIG 130 HEMISFLO CHUTE(TABLE1)
MAN DYNAMIC RESPONSE INDEX

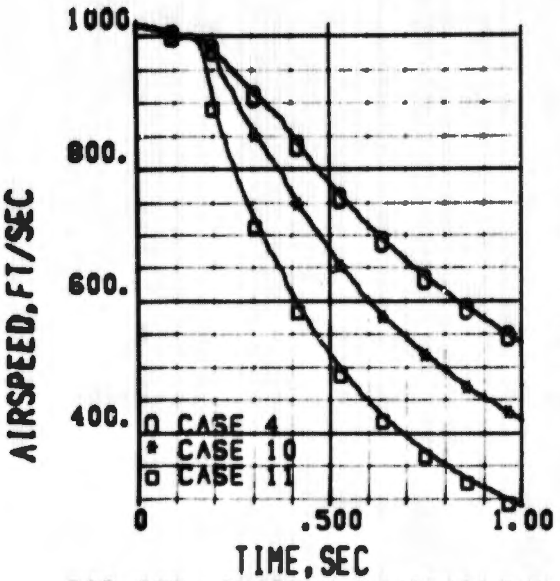


FIG 131 HEMISFLO CHUTE(TABLE1)
SEAT AIRSPEED

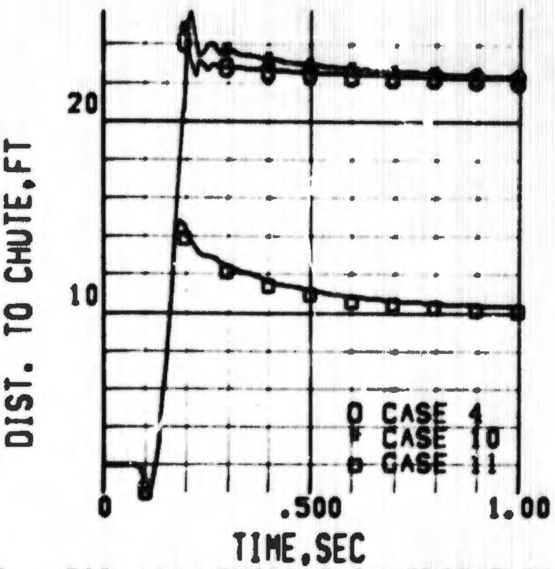


FIG 132 HEMISFLO CHUTE(TABLE1)
DIST. FROM BRIDLE TO CHUTE CG

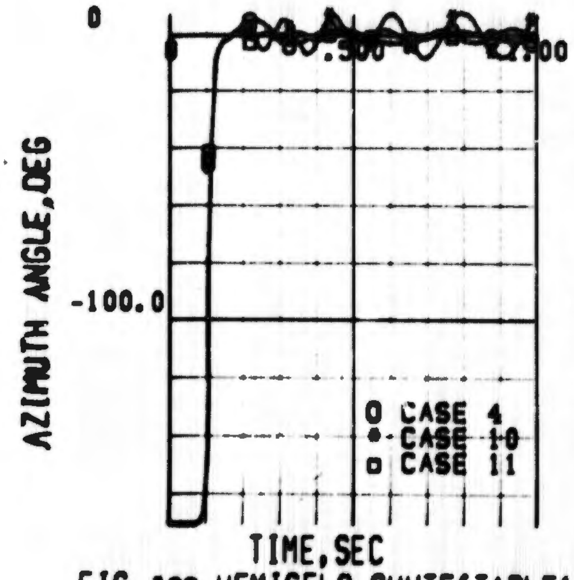


FIG 133 HEMISFLO CHUTE(TABLE1)
SEAT-PARACHUTE AZIMUTH ANGLE

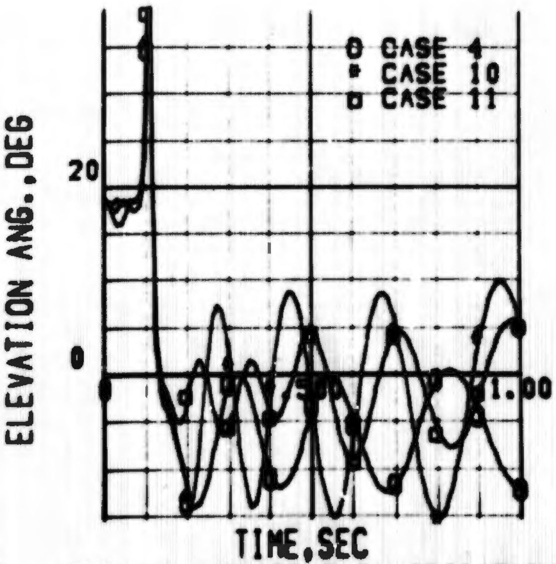


FIG 134 HEMISFLO CHUTE(TABLE1)
SEAT-PARACHUTE ELEVATION ANGLE

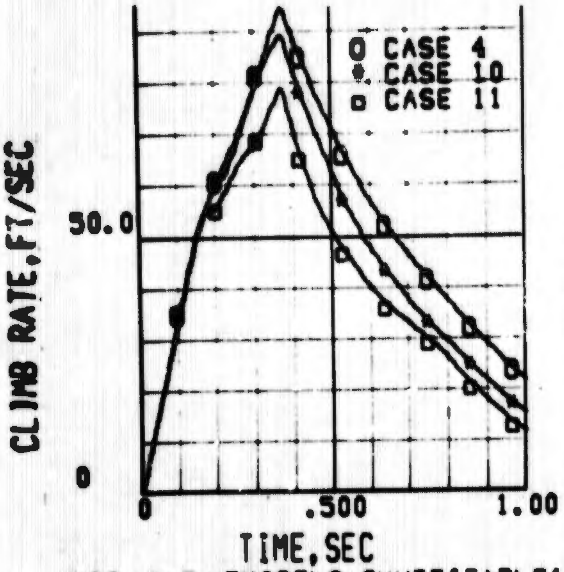


FIG 135 HEMISFLO CHUTE(TABLE1)
SEAT CLIMB RATE

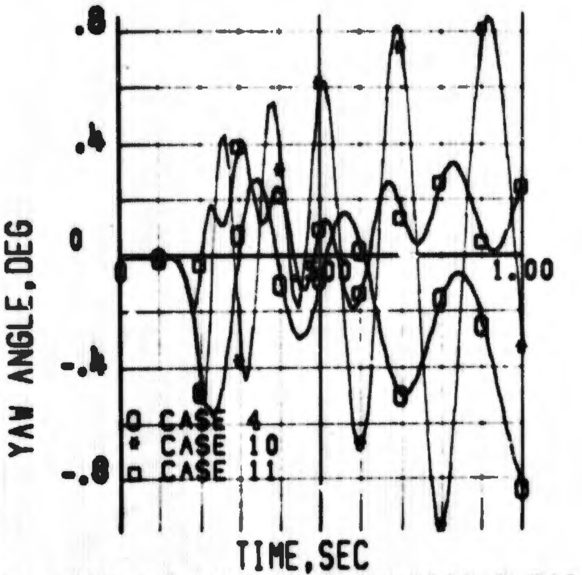


FIG 136 HEMISFLO CHUTE(TABLE1)
SEAT EARTH AXIS YAW ANGLE

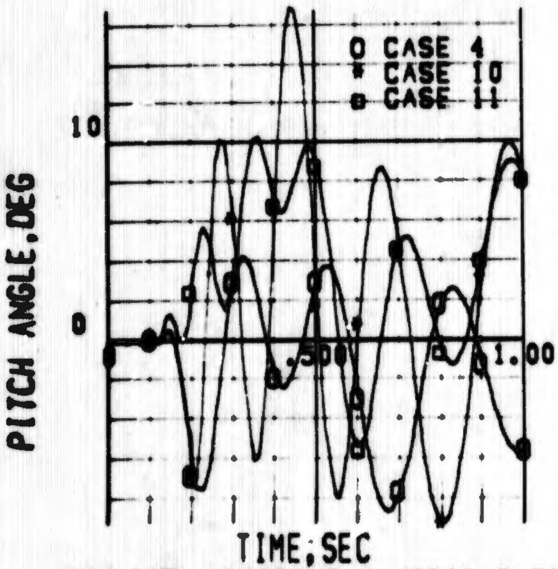


FIG 137 HEMISFLO CHUTE(TABLE1)
SEAT EARTH AXIS PITCH ANGLE

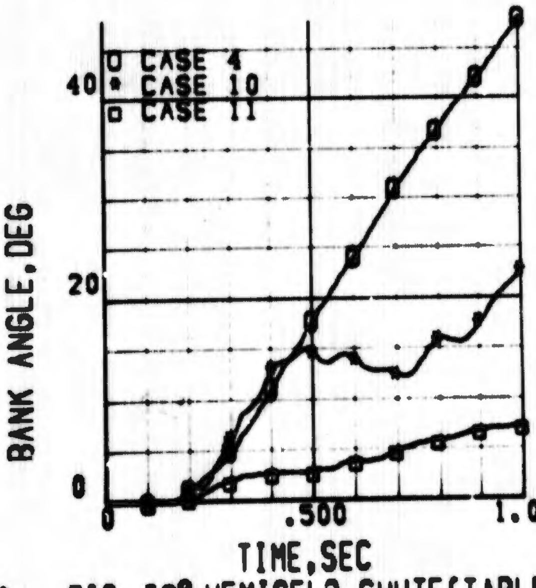


FIG 138 HEMISFLO CHUTE(TABLE1)
SEAT EARTH AXIS BANK ANGLE

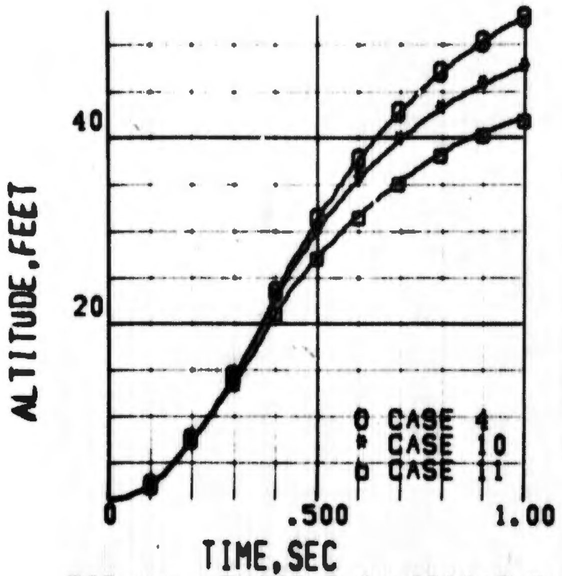


FIG 139 HEMISFLO CHUTE(TABLE1)
SEAT ALTITUDE

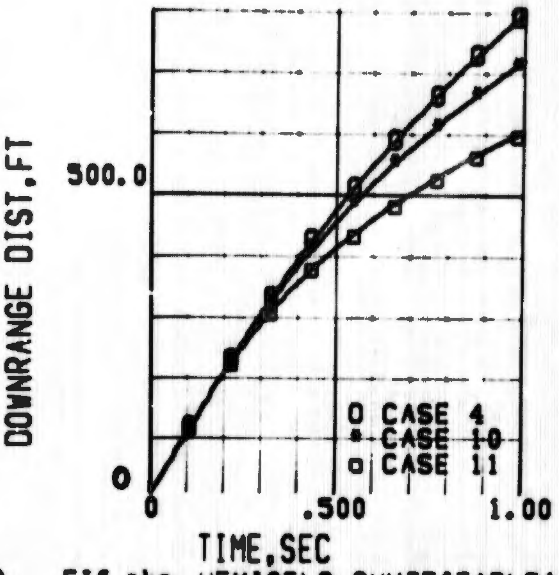


FIG 140 HEMISFLO CHUTE(TABLE1)
SEAT DOWNRANGE DISTANCE

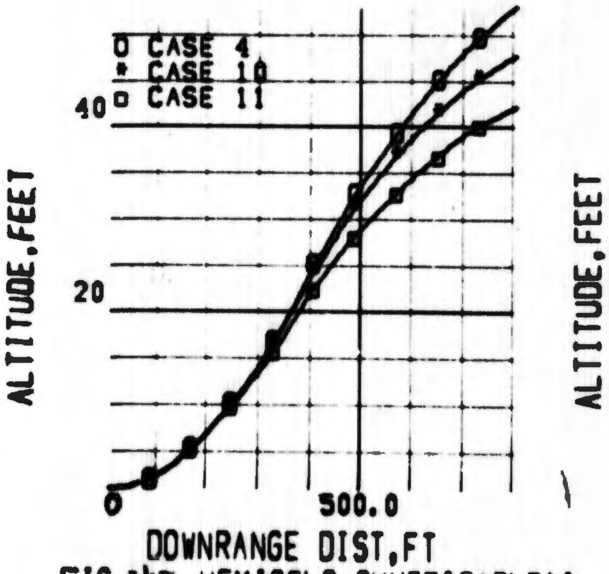


FIG 141 HEMISFLO CHUTE(TABLE1)
SEAT TRAJECTORY

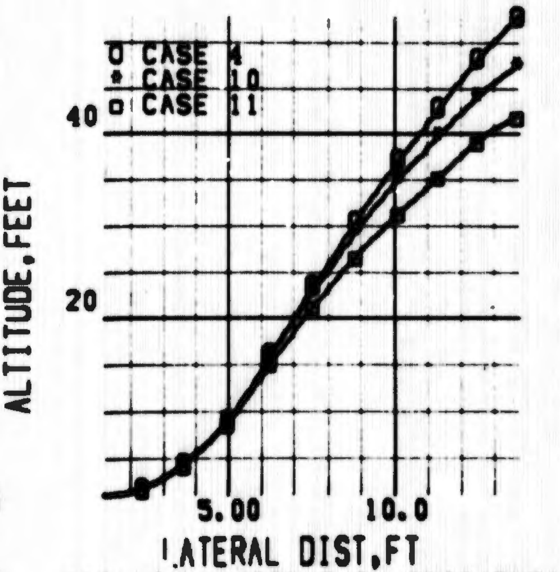


FIG 142 HEMISFLO CHUTE(TABLE1)
SEAT TRAJECTORY

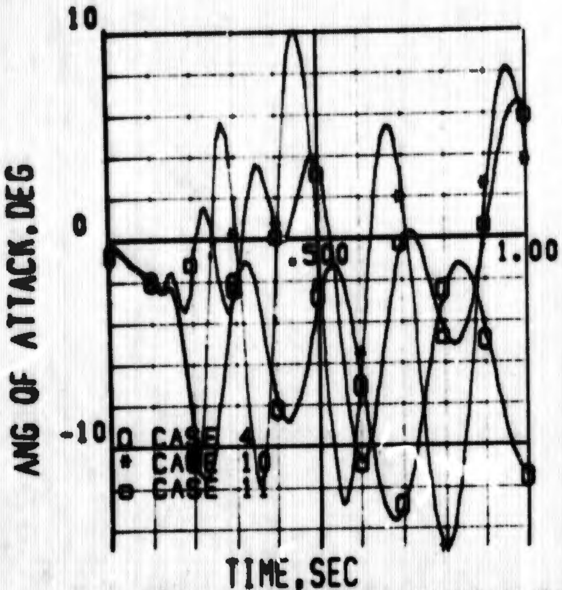


FIG 143 HEMISFLO CHUTE(TABLE1)
SEAT ANGLE OF ATTACK

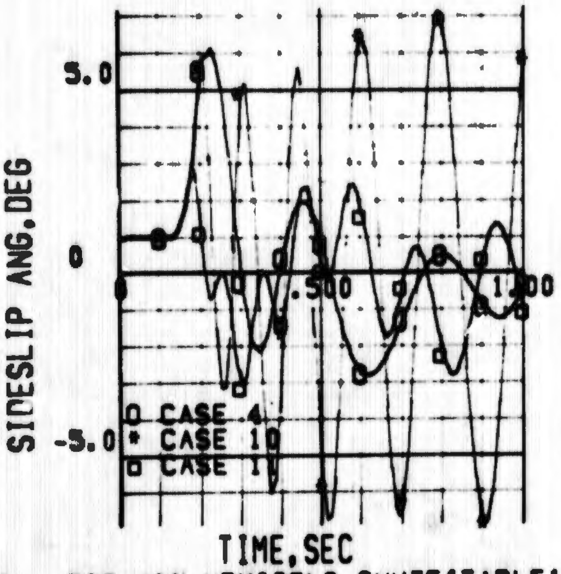


FIG 144 HEMISFLO CHUTE(TABLE1)
SEAT SIDESLIP ANGLE

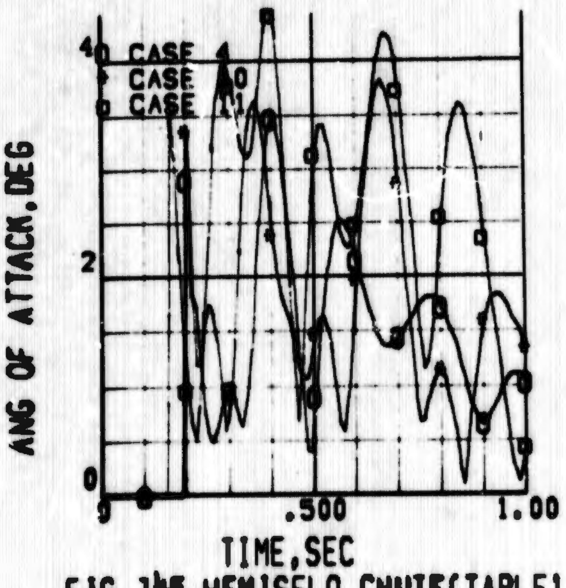


FIG 145 HEMISFLO CHUTE(TABLE1)
PARACHUTE ANGLE OF ATTACK

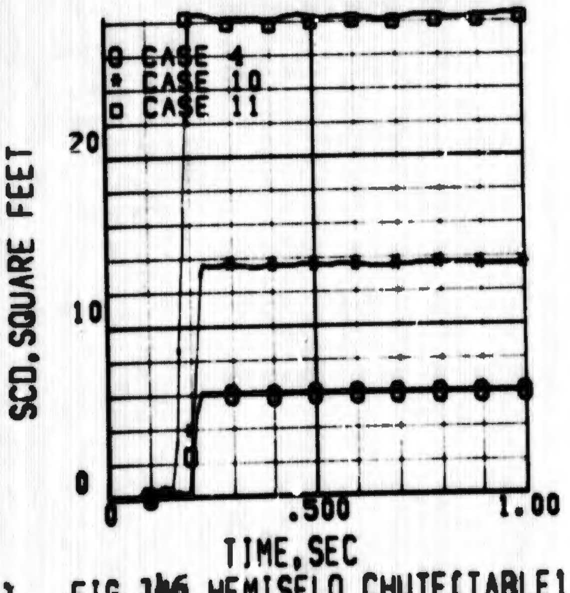


FIG 146 HEMISFLO CHUTE(TABLE1)
PARACHUTE AREA DRAG COEFF

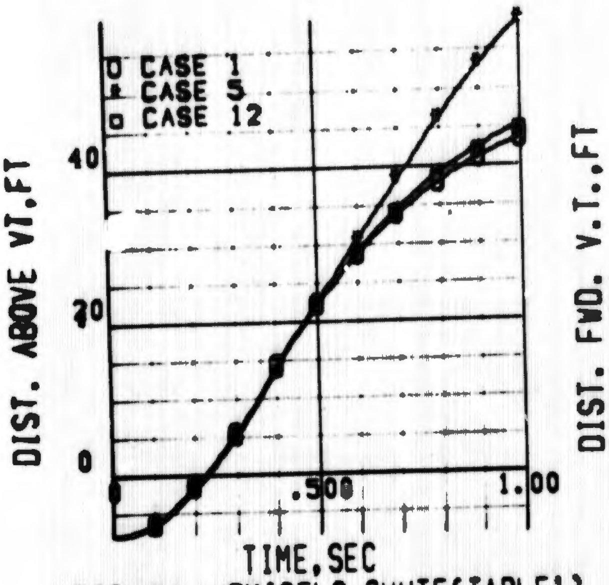


FIG 147 HEMISFLO CHUTE(TABLE1)
VERT. TAIL VERT. CLEARANCE

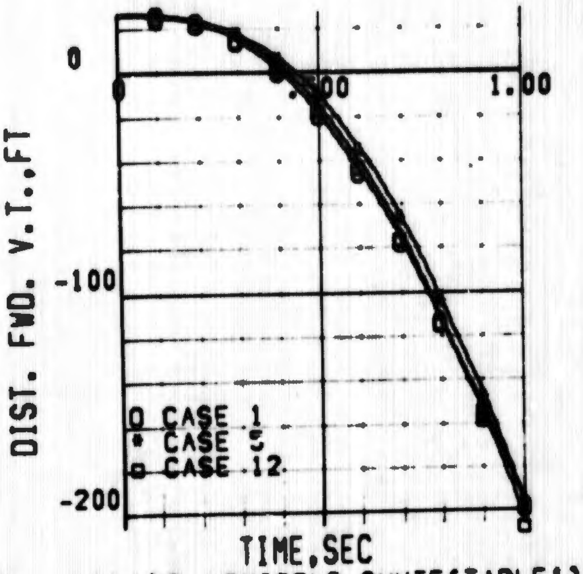


FIG 148 HEMISFLO CHUTE(TABLE1)
VERT. TAIL LONG. CLEARANCE

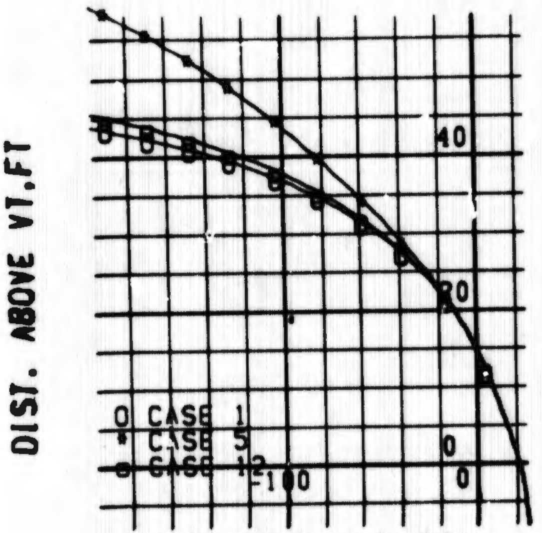


FIG 149 HEMISFLO CHUTE(TABLE1)
VERTICAL TAIL CLEARANCE

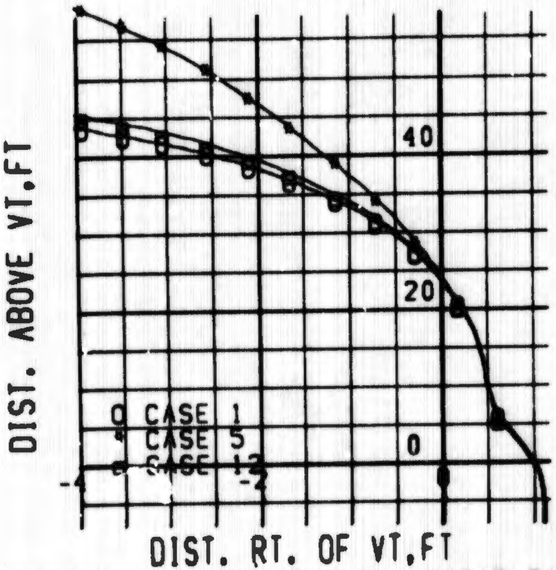


FIG 150 HEMISFLO CHUTE(TABLE1)
VERTICAL TAIL CLEARANCE

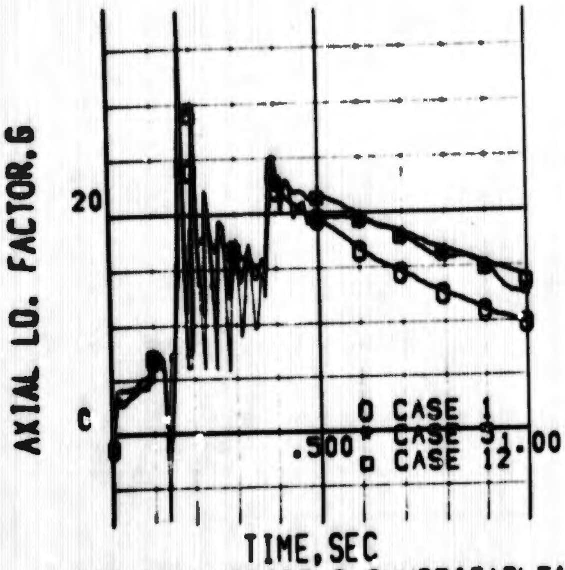


FIG 151 HEMISFLO CHUTE(TABLE1)
SEAT AXIAL LOAD FACTOR

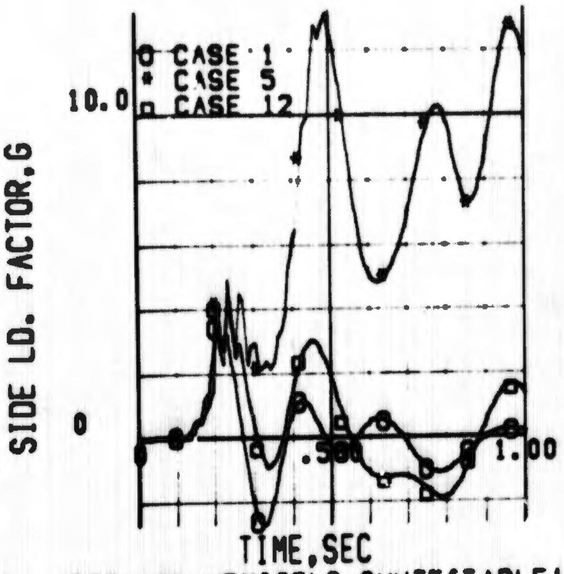


FIG 152 HEMISFLO CHUTF(TABLE1)
SEAT SIDE LOAD FACTOR

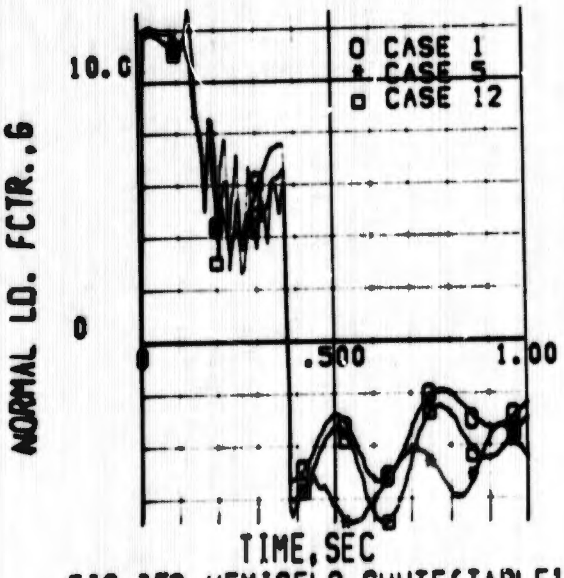


FIG 153 HEMISFLO CHUTE(TABLE1)
SEAT NORMAL LOAD FACTOR

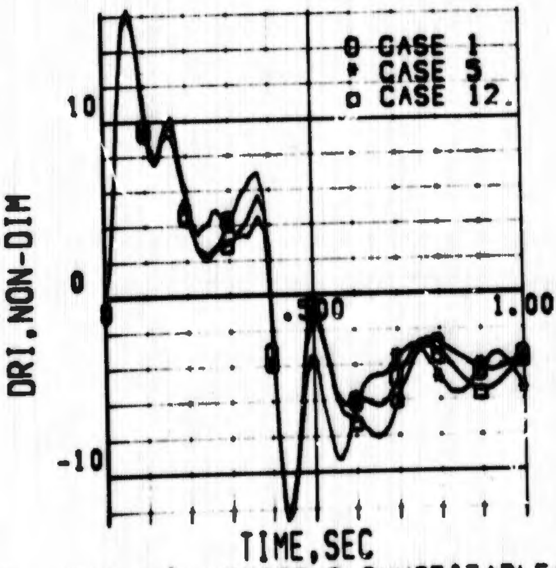


FIG 154 HEMISFLO CHUTE(TABLE1)
MAN DYNAMIC RESPONSE INDEX

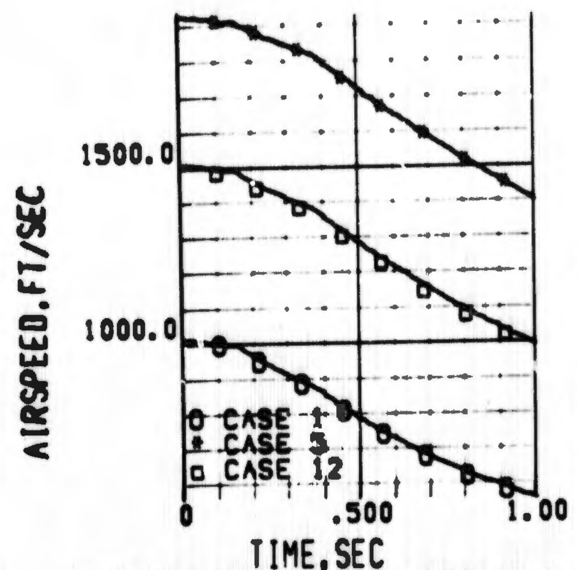


FIG 155 HEMISFLO CHUTE(TABLE1)
SEAT AIRSPEED

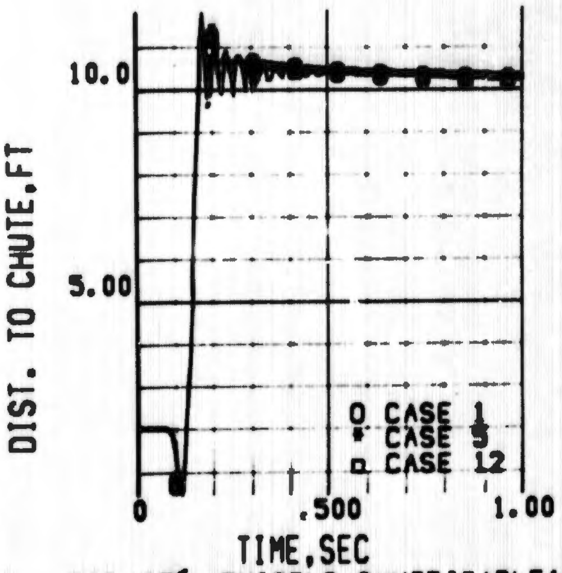


FIG 156 HEMISFLO CHUTE(TABLE1)
DIST. FROM BRIDLE TO CHUTE CG

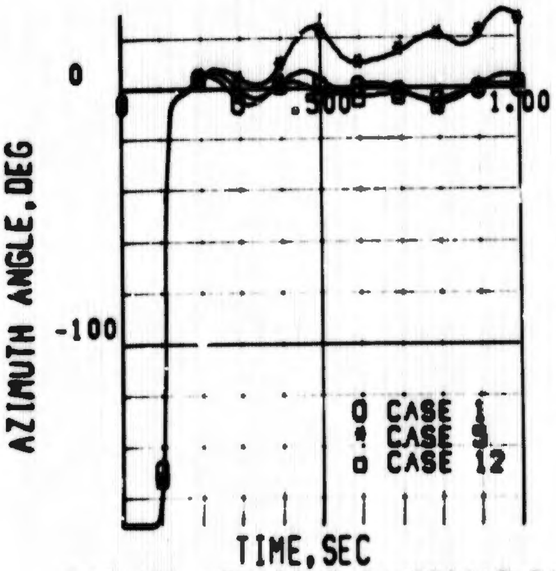


FIG 157 HEMISFLO CHUTE(TABLE1)
SEAT-PARACHUTE AZIMUTH ANGLE

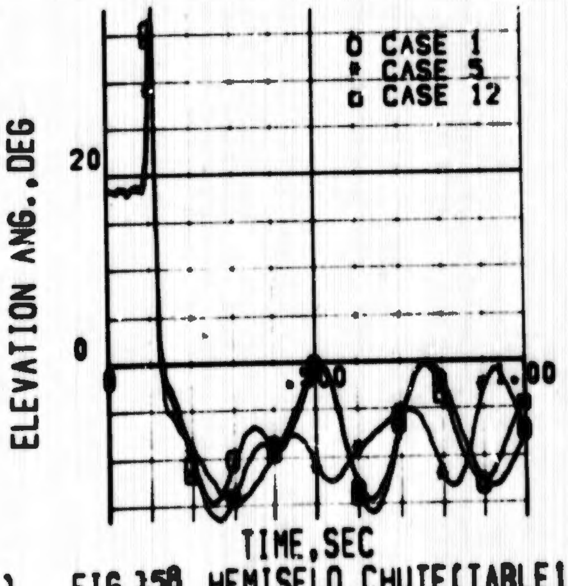


FIG 158 HEMISFLO CHUTE(TABLE1)
SEAT-PARACHUTE ELEVATION ANGLE

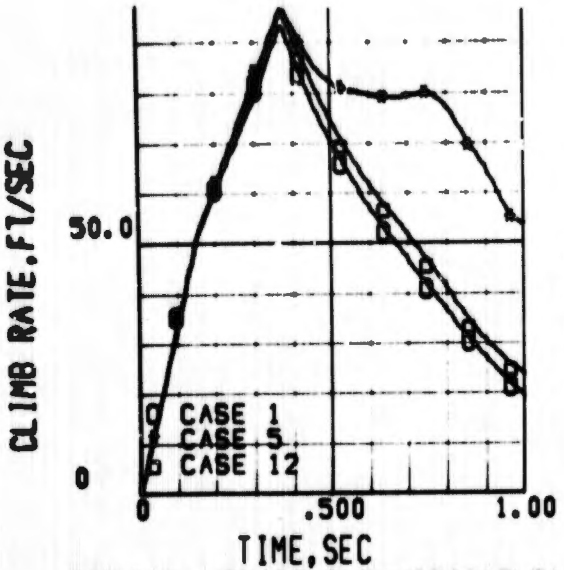


FIG 159 HEMISFLO CHUTE(TABLE1)
SEAT CLIMB RATE

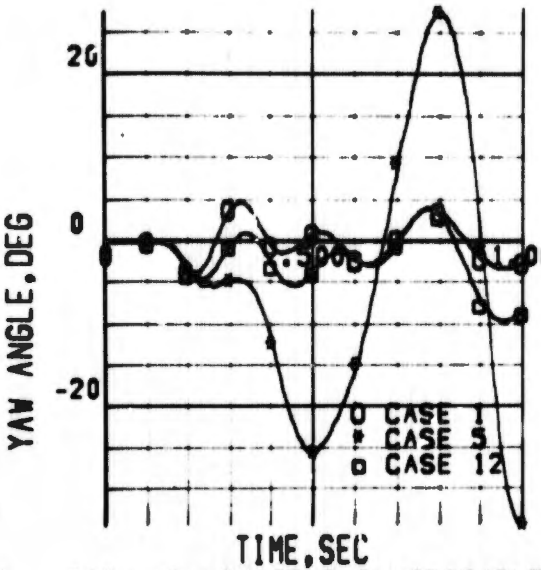


FIG 160 HEMISFLO CHUTE(TABLE1)
SEAT EARTH AXIS YAW ANGLE

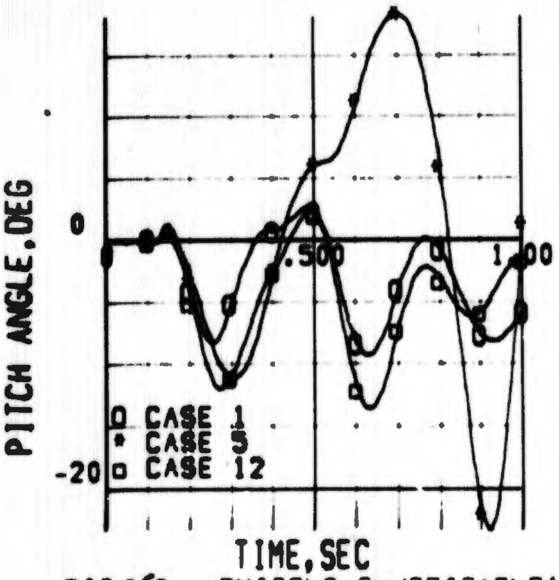


FIG 161 HEMISFLO CHUTE(TABLE1)
SEAT EARTH AXIS PITCH ANGLE

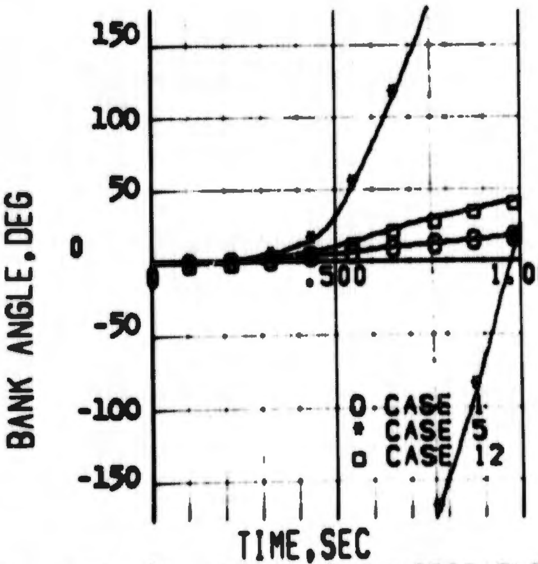


FIG 162 HEMISFLO CHUTE(TABLE1)
SEAT EARTH AXIS BANK ANGLE

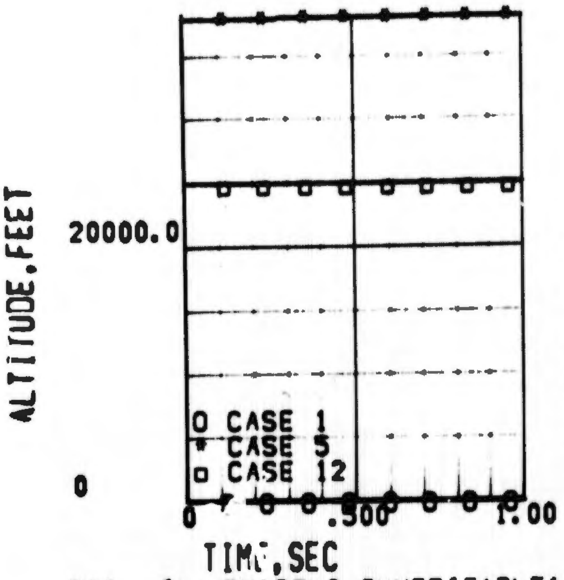


FIG 163 HEMISFLO CHUTE(TABLE1)
SEAT ALTITUDE

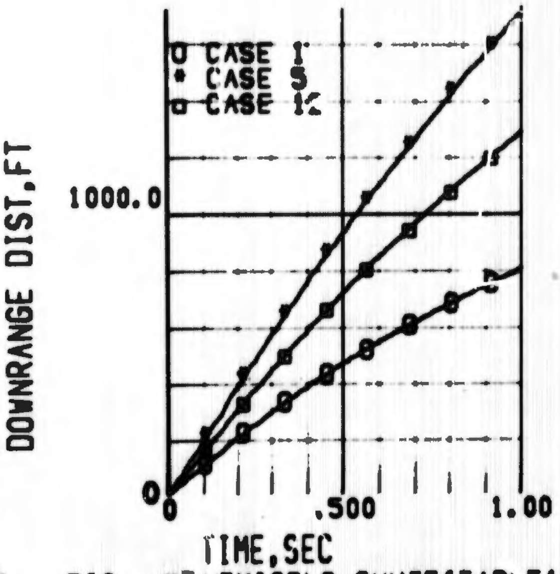


FIG 164 HEMISFLO CHUTE(TABLE1)
SEAT DOWNRANGE DISTANCE

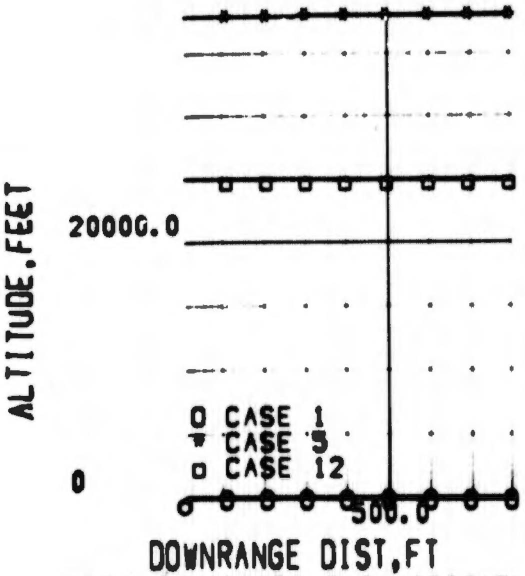


FIG 165 HEMISFLO CHUTE(TABLE1)
SEAT TRAJECTORY

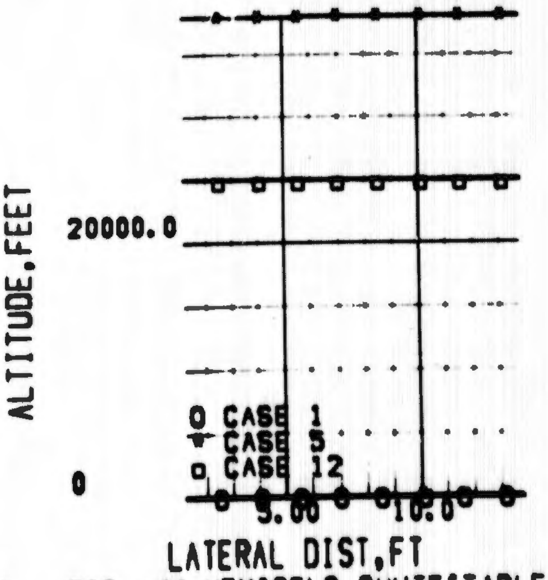


FIG 166 HEMISFLO CHUTE(TABLE1)
SEAT TRAJECTORY

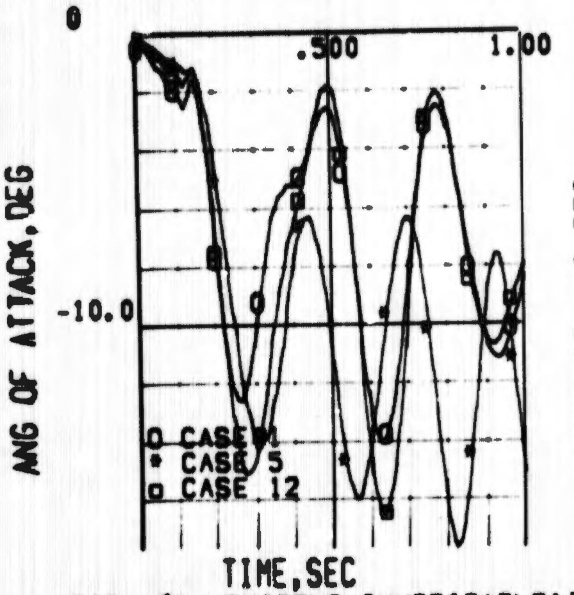


FIG 167 HEMISFLO CHUTE(TABLE1)
SEAT ANGLE OF ATTACK

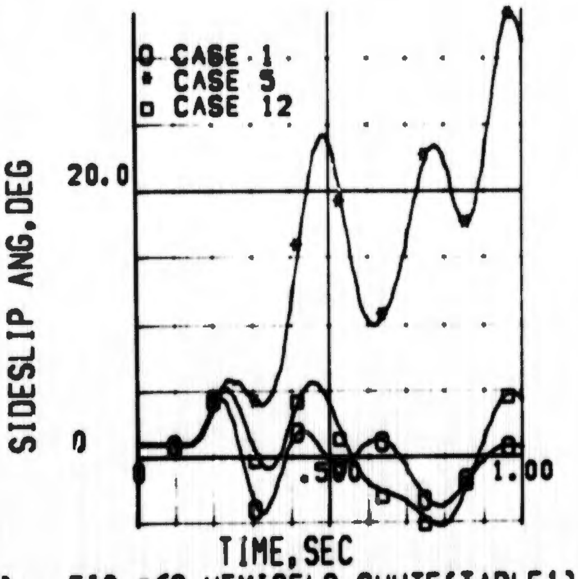


FIG 168 HEMISFLO CHUTE(TABLE1)
SEAT SIDESLIP ANGLE

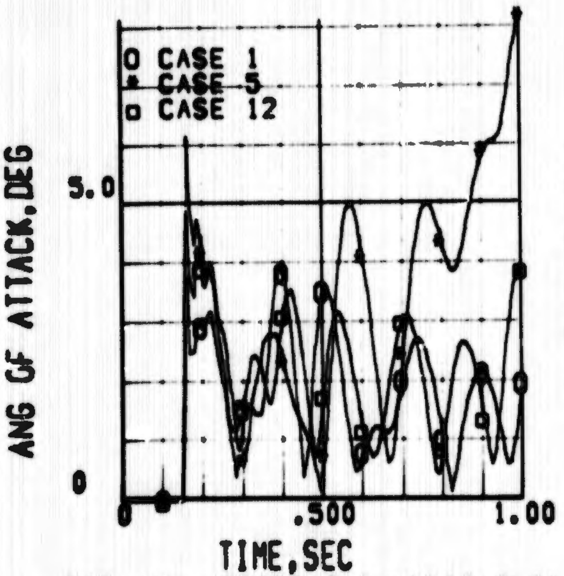


FIG 169 HEMISFLO CHUTE(TABLE1)
PARACHUTE ANGLE OF ATTACK

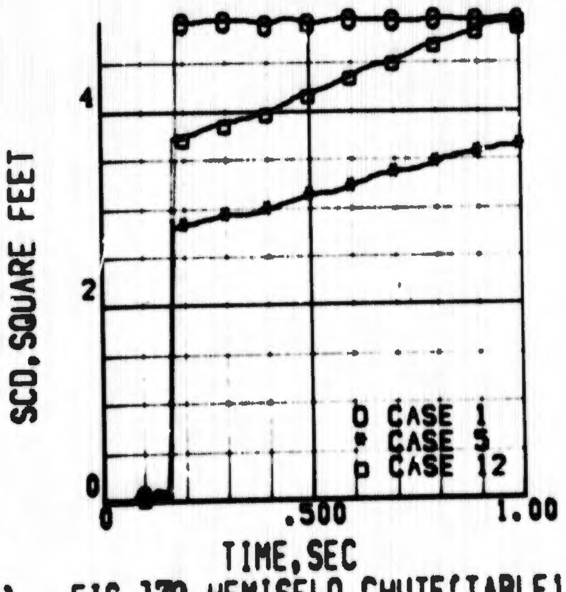


FIG 170 HEMISFLO CHUTE(TABLE1)
PARACHUTE AREA DRAG COEFF

APPENDIX I

VTOL FLIGHT FAILURE TIME HISTORIES

Figures 175 through 300 show the VTOL ejection system performance during the critical aircraft failures in the VTOL flight regime in the form of time history plots and cross plots of the seat-man, the recovery parachute, and the man alone spatial positions, velocities and accelerations. These plots begin at the instant of failure occurence and are continued for 5.0 seconds to assess the safe recovery potential. In addition, other time histories, extending only to the time of recovery parachute line stretch, are included to show in greater detail the seat-man earth referenced displacements and rates and body axis rates and accelerations during the powered trajectory period. These plots show the seat-man response to the primary propulsion and the pitch, roll and yaw vernier motors.

During VTOL flight the escape system is in the "automatic initiation" mode of operation. When the aircraft attitude and rate reach the "out-of-control" value as described in Section 4.0, ejection is initiated by the "Emergency Detection and Ejection Initiation System". From that time the sequence of events is automatic and in accordance with Table VI. Additional simulation data inputs are shown in Table VII.

A detailed explanation of the "lateral control failure" plots, Figures 175 through 216, follow and may be used as an example in interpreting the others. Throughout these time histories the left seat is occupied by a 95% tile crew and the right by a 5% tile. The rocket catapult thrust vector is located 1.0 inches above and 3.0 inches below the seat-man center of gravity for the left and right seats respectively. Ejected mass properties may be seen in Table VII.

Following the hardover lateral control failure the "Emergency Detection and Ejection Initiation System (EDEIS)" detects an out-of-control condition and after a sampling period of 100 milliseconds initiates escape as shown in Figure 172. Figures 171 and 173 present the same information for the other two failure modes. This event arms the "Post Ejection Event Programmer (PEEP) and fires the seat catapult, powered haul-back reel, canopy glass reverance system and triggers emergency IFF on both left and right seats; all with aircraft electrical power.

Figures 175, 176 and 177 show the seat-man and man alone spatial displacements, referenced to earth axis, versus time. The seat itself is ignored following seat-man separation.

Figures 178, 179 and 180 are cross plots defining the trajectories of each crewman. These six plots are useful in determining the separation distance between crewmen.

Figures 181 and 182 show the man total airspeed and rate of climb respectively. The time zero airspeed is the same as the aircraft airspeed of 46 knots.

Figures 183, 184, 185 and 186 show the total airspeed and displacement, referenced to earth axis, of the recovery parachute center of gravity.

Figure 185 shows a lateral separation of parachute canopies of 13 feet and 30 feet at line stretch and full canopy respectively. Figure 183 shows the inflated canopy has reached terminal velocity at about 1.6 seconds for both crew. At this time the left man is 52. ft. and the right 60 ft. above ejection altitude. In assessing safe recovery the parachute total airspeed is more reliable than man total airspeed or climb rate since the latter two curves are drastically affected by the oscillations of the unstable flat circular parachute canopy.

Figures 187, 188, 189 and 190 show the load factors and the DRI experienced by each ejectee. The load factors are referenced to body axes and the DRI values to the spinal column. Specification MIL-S-9479A defines the DRI in detail and the equations for this computation are given in Appendix I of Part I, Volume 2.

Time history plots of the seat-man dynamics covering the period from failure occurrence until recovery parachute line stretch are shown in Figures 191 through 216 for the lateral control failure. Figure 174, showing the orientation of the various thrust vectors, is included to assist in plot interpretation.

Figures 191, 192 and 193 show the seat orientation with the earth axis. Reference to Figure 193 reveals that the aircraft roll angle at seat tip-off is 43 degrees and that the seat mounted roll motors immediately begin reducing this angle.

Figures 194 and 195 show the seat-man downrange and lateral velocities. For the vertical velocities refer to the five second time histories.

Figures 196, 197 and 198 show the seat body axes rotational rates. The action resulting from the sustainer motor thrust offset can be seen in Figure 197. The right seat receives a positive pitch rate from the 3.0 inch low thrust and the left seat a negative rate from the 1.0 inch high thrust line. In both cases these rates are reduced by the seat pitch rate control system. For example, by extending the straight portion of the curve for the right seat the rate to be expected without the correcting pitch motor would be about three times the final rate shown.

The initial negative rate experienced by the right seat is a tip-off effect from the seat catapult force. This seat is occupied by the 5% tile crew and consequently starts from the full up adjustment position. A 1.0 inch unguided stroke results from this seat position. The pitch down rate from the catapult is quickly overcome by the positive pitching moment imparted by the 3.0 inch low thrust of the sustainer motor. The left seat occupied by the 95% tile crew has a fully guided catapult stroke and the tip-off perturbation is very small. Figure 196 shows the aircraft roll rate to be about 50 degrees per second at seat tip-off. That rate is quickly reversed by the action of the seat mounted roll vernier motors. Careful examination of the plot of seat yawing rate reveals that the roll motors impart a yaw as well as a roll rate to the seat. The yaw motor and the roll motor produce a right yawing moment to the right seat. The roll motor on the left seat produces a right yawing moment which overcomes, for a short time, the left moment from the yaw motor. After burnout of the first roll motor the yaw motor produces the expected left yawing rate. The net result is adequate lateral separation of the simultaneously ejected seats.

Figures 199, 200 and 201 show the load factors, referenced to the seat axes, at the center of gravity and Figures 202, 203 and 204 the load factors at the crewmans head. About 3.5 g side load is experienced from the seat roll motors.

Figure 205 shows the seat-man total airspeed.

The performance of the forcibly deployed recovery parachute may be seen in Figure 206. The right seat engages the rail trip switch which fires the tractor rocket at t = .92 seconds. The tractor rocket is catapulted to the end of a four foot tow line at which point the full 300 pound thrust is available. Full line stretch is reached in about 300 milliseconds. These plots are terminated slightly prior to actual line stretch (23.0 feet of shroud lines and bridle) so that the automatic plotter would provide curves of optimum ordinate scale values.

Vertical tail clearance of both seats is shown in Figures 207, 208, 209 and 210.

Figures 211, 212, 213, 214, 215 and 216 show the performance of the rocket catapult and each of the seat vernier motors. Figure 216 shows that both the pitch up and the pitch down motors of the seat pitch rate control system were triggered during this ejection. The explanation is found in the tip-off pitch rate shown in Figure 197. The pitch up motor is fired by the rate gyro in the PEEP when seat rate reaches -1.0 radians per second. This rate occurs only on the right seat because of the 1.0 inch unguided catapult stroke.

TABLE VI - LOW SPEED MODE

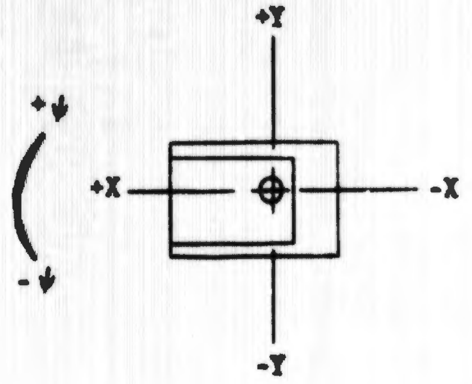
EVENT	AUTO. INIT. VERT. AUTH.	TIME (SEC.)	AUTO. INIT. ROLL AUTH.	TIME (SEC.)	AUTO. INIT. PITCH AUTH.	TIME (SEC.)
Canopy Shaped Charge	Yes	0	Yes	0	Yes	0
Canopy Jettison Act.	No	-	No	-	No	-
Inertia Reel	Yes	0	Yes	0	Yes	0
Seat Catapult	Yes	0	Yes	0	Yes	0
Seat Sustainer	Yes	Note 1	Yes	Note 1	Yes	Note 1
Yaw Motor	Yes	Note 1	Yes	Note 1	Yes	Note 1
Chute Extraction Rocket	Yes	Note 1	Yes	Note 1	Yes	Note 1
#1 Roll Vernier Motor	No	-	Yes*	Note 1	No	-
#2 Roll Vernier Motor	No	-	Yes*	Note 2	No	-
#1 Pitch Vernier Motor	Note 3	→				
#2 Pitch Vernier Motor	Note 3	→				
Canopy Spreading Gun	Note 4	→				
Seat/Man Sep.	Yes	Note 5	Yes	Note 5	Yes	Note 5

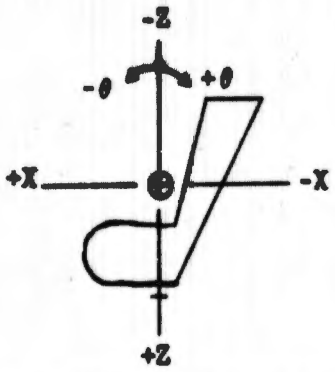
NOTES:

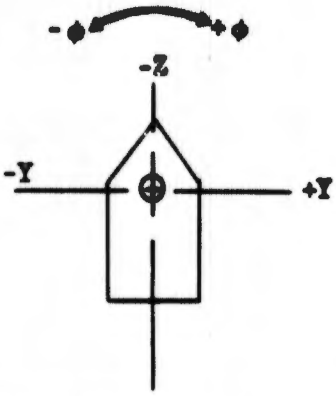
1. Fires at rail trip switch
2. Fires at rail trip switch plus 0.14 seconds
3. Fired by PEEP if seat pitch rate of 2.0 rad/sec or -1.0 rad/sec.
4. Fires at parachute line stretch. Spreads canopy in 0.8 sec.
5. Restraint released at rail trip switch plus 0.30 seconds

* Ref. Figure 57

TABLE VII SIMULATION INPUT DATA VTOL SEAT







	X	Y	Z	Angle	Thrust	Burn Time
Catapult	-1.04 ft.	0	-.75 ft.	+17°	6000.#	34" stroke
Rocket Sustainer	-.48[1](-.61)[2]	0	+1.11[1](+.71)[2]	-35°	5000.#	0.25 sec.
-θ Pitch Motor	-.42	-.50	+1.32	+47°	500.	0.18
-θ Pitch Motor	-.42	+.50	+1.32	+47°	500.	0.18
+θ Pitch Motor	-.06	0	+1.47	-90°	200.	0.18
-θ Roll Motor	-.74	+.73	-1.01	-90°	500.	0.18
+φ Roll Motor	-.74	-.73	-1.01	+90°	500.	0.18
Yaw Motor	-.77	+.38	+.56	-53.25	200	0.18
Pers. Chute Rocket	-1.27	-.01	-2.23	+90/+20°	300	0.30
Drogue Chute Rocket	-1.29	+.32	-1.98	+90°	200	0.20

Mass Properties	R.H. Seat 5% Tile Man	L.H. Seat 95% Tile Man
Body Axes I_x	11.99 ft# sec^2	13.11 ft# sec^2
I_y	10.62	12.25
I_z	22.62	25.36
I_{xz}	+3.02	+2.98
Ejected Wt.	354.43#	419.43#
Man Wt.	150.00#	215.00#

	5% Tile Man	95% Tile Man
Seat Travel to Rail Trip Switch	2.41	2.83
Seat Guided Stroke	2.75 ft.	3.17 ft.

1. Sustainer Thrust Vector 3.0 in. Below Ejected Mass C.G. (Right Seat)
2. Sustainer Thrust Vector 1.0 in. Above Ejected Mass C.G. (Left Seat)

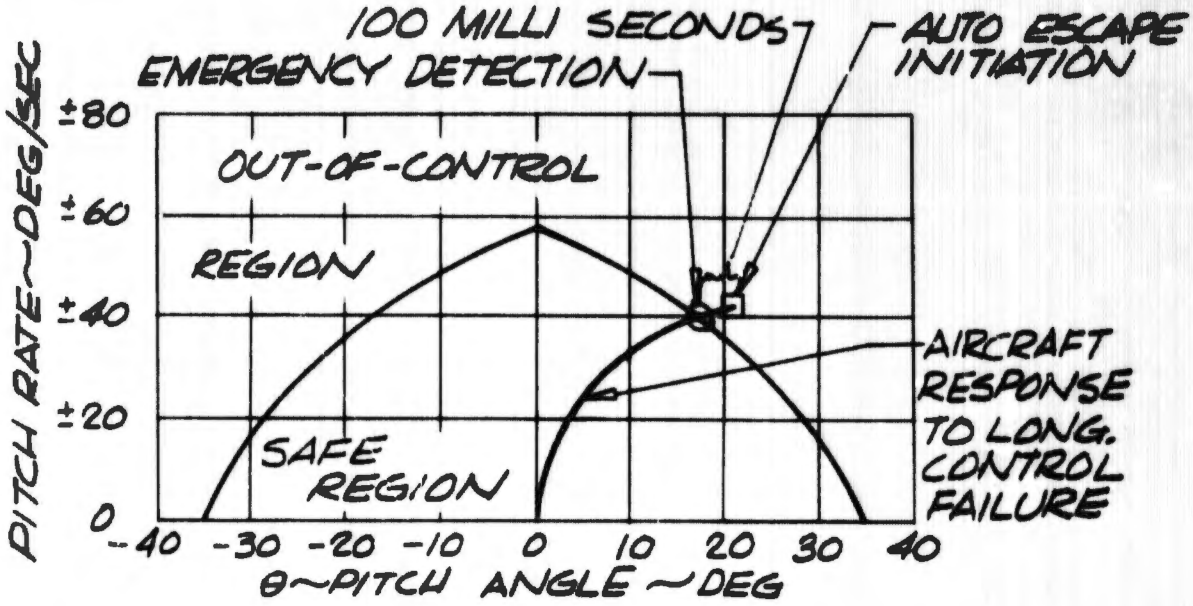


FIGURE 171
AUTOMATIC EJECTION - PITCH AUTHORITY

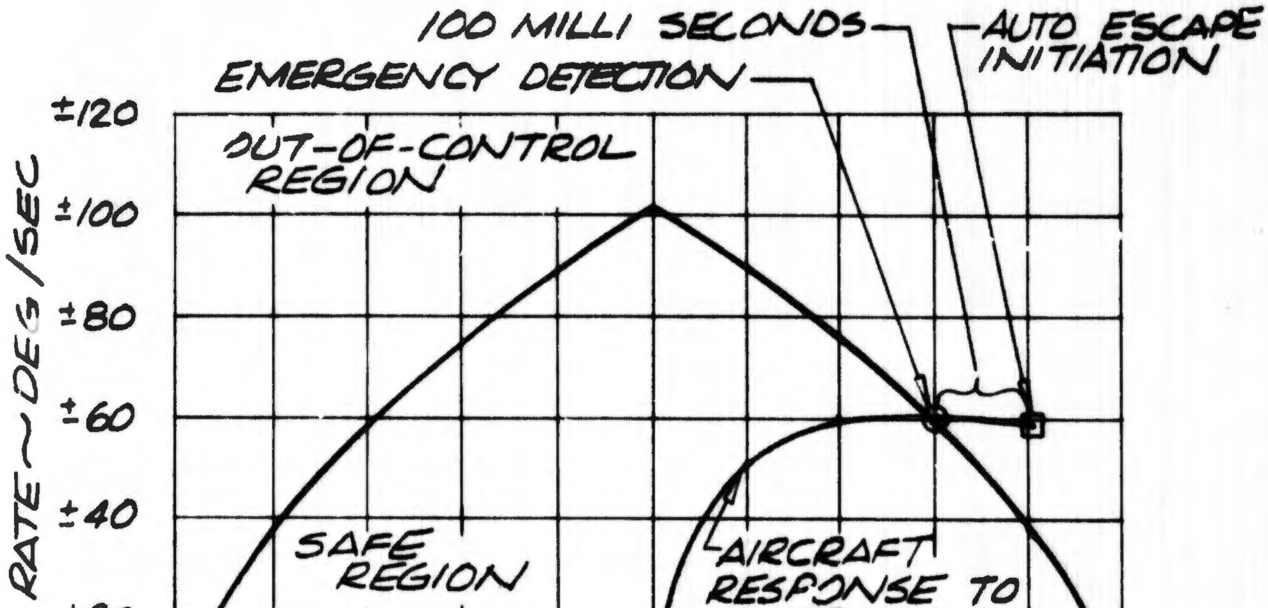


FIGURE 172
AUTOMATIC EJECTION - ROLL AUTHORITY

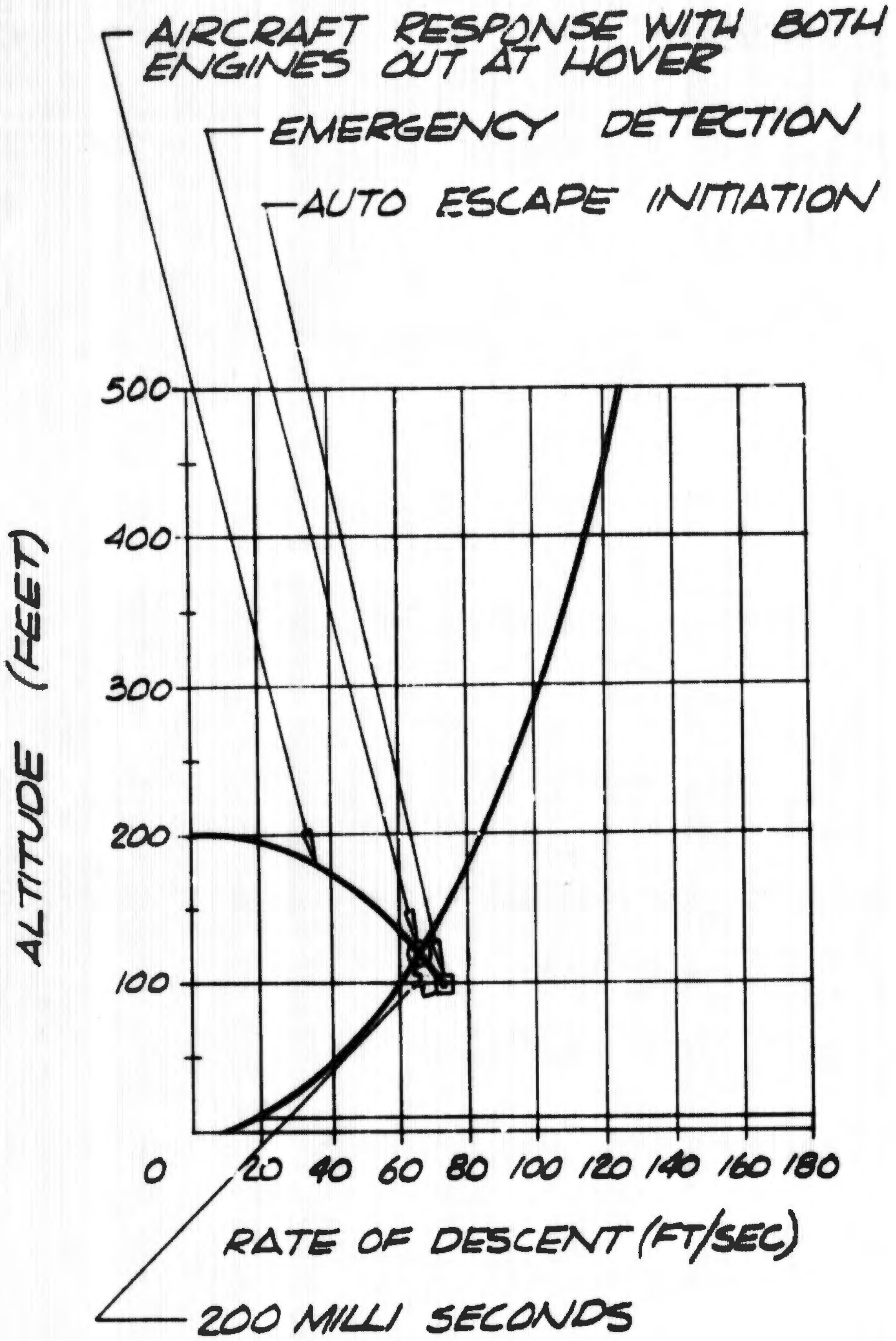


FIGURE 173
AUTOMATIC EJECTION-VERTICAL AUTHORITY

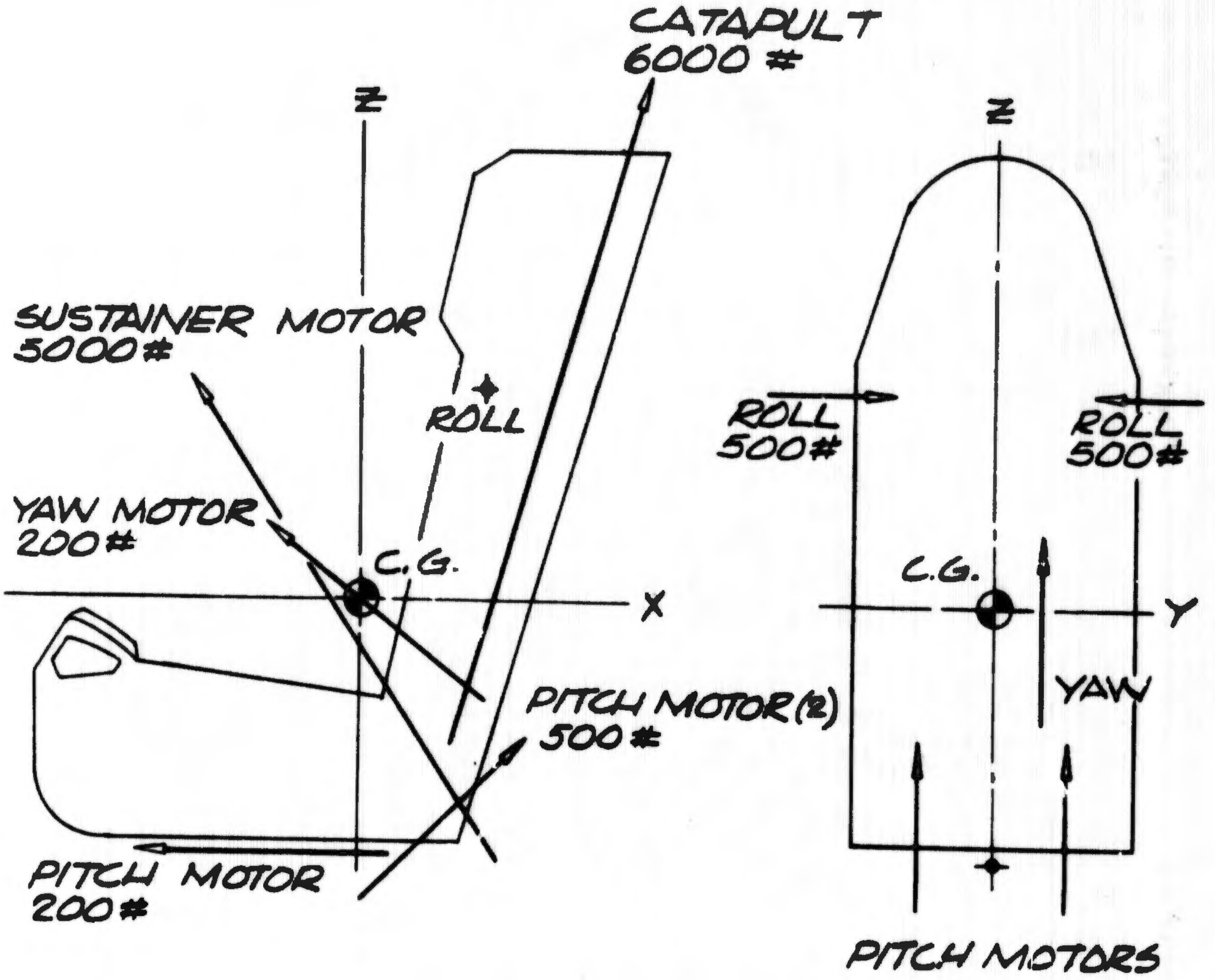


FIGURE 174
THRUST VECTORS ORIENTATION

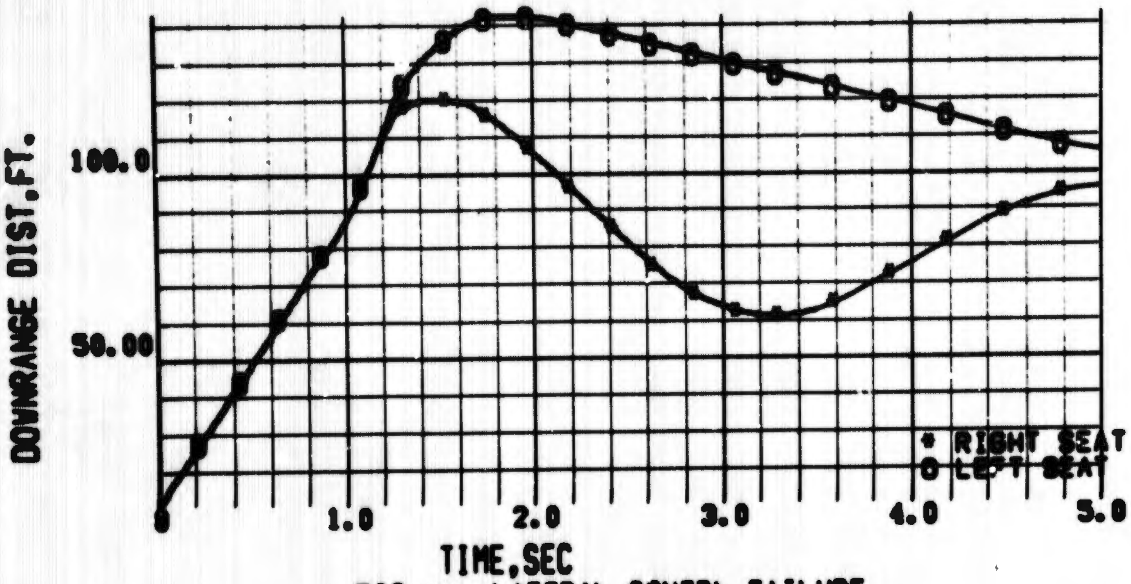


FIG 175 LATERAL CONTRL FAILURE
SEAT AND/OR MAN DOWNRANGE DIST

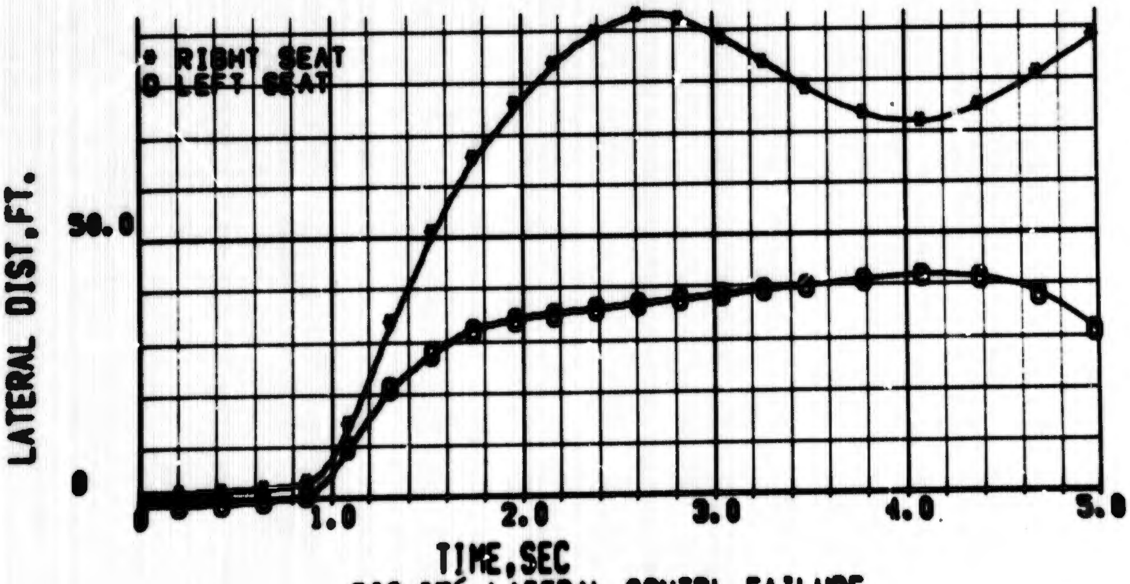


FIG 176 LATERAL CONTRL FAILURE
SEAT AND/OR MAN LATERAL DIST.

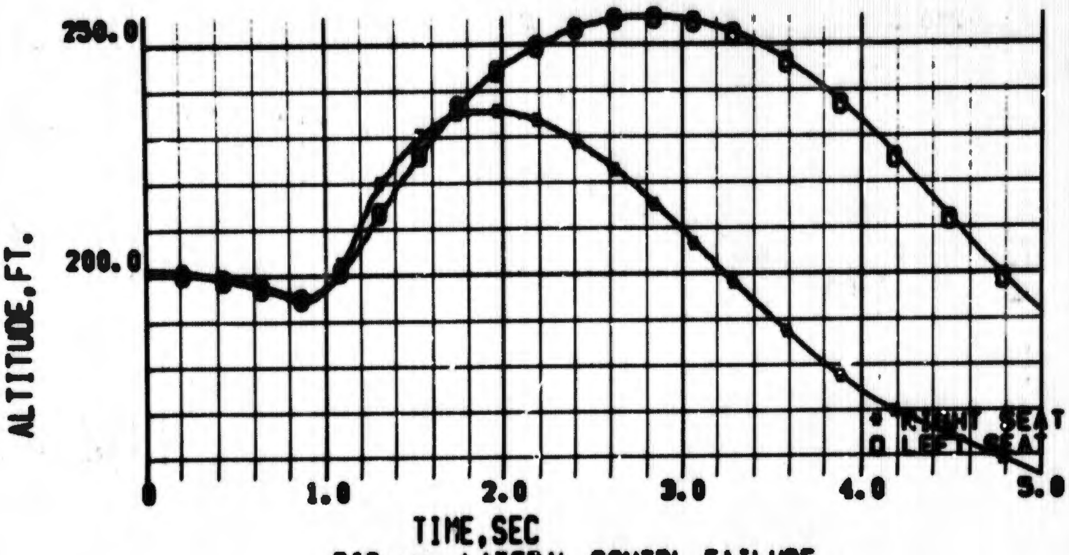


FIG 177 LATERAL CONTRL FAILURE
SEAT AND/OR MAN ALTITUDE

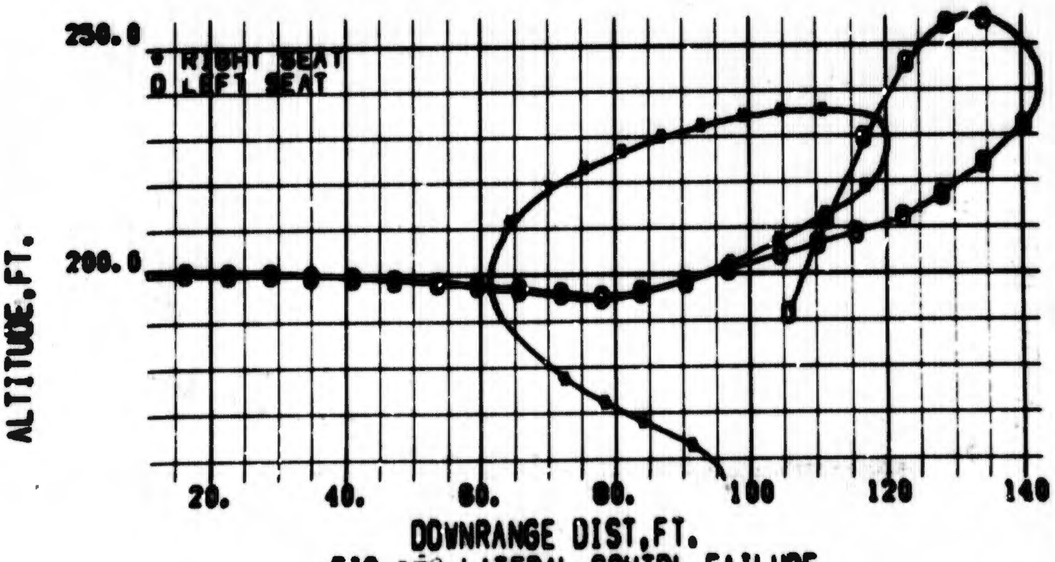


FIG 178 LATERAL CONTRL FAILURE
SEAT-MAN TRAJECTORY

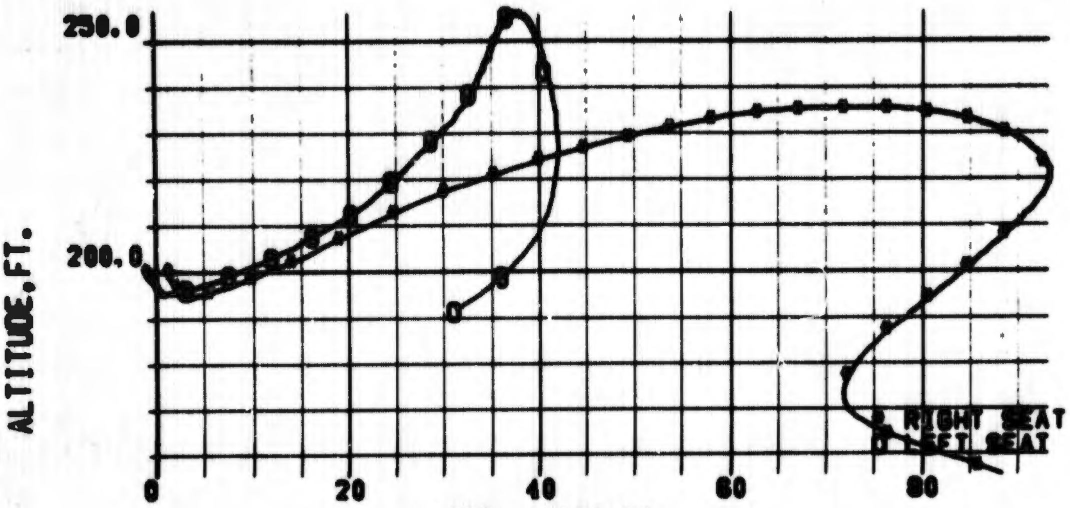


FIG 179 LATERAL CONTRL FAILURE
SEAT-MAN TRAJECTORY

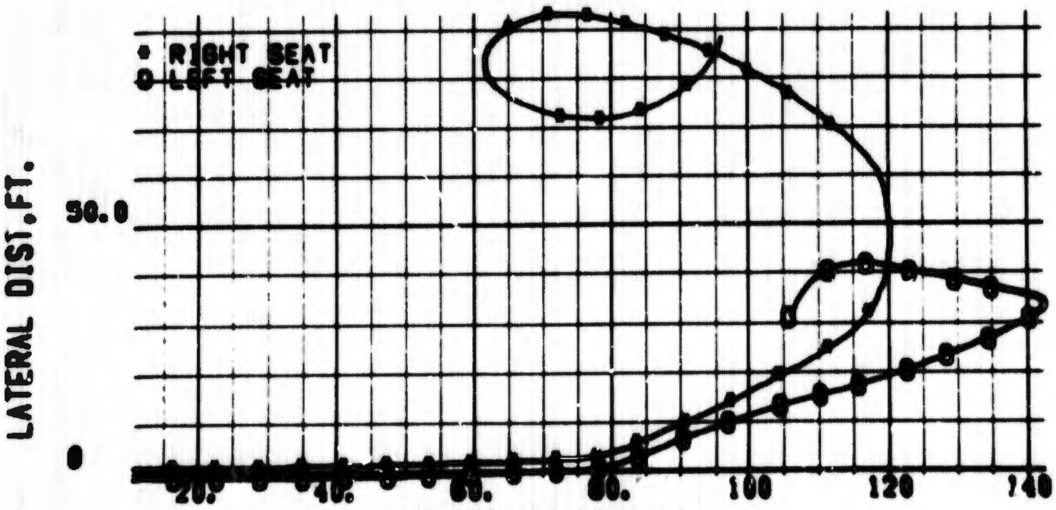


FIG 180 LATERAL CONTRL FAILURE
SEAT-MAN TRAJECTORY

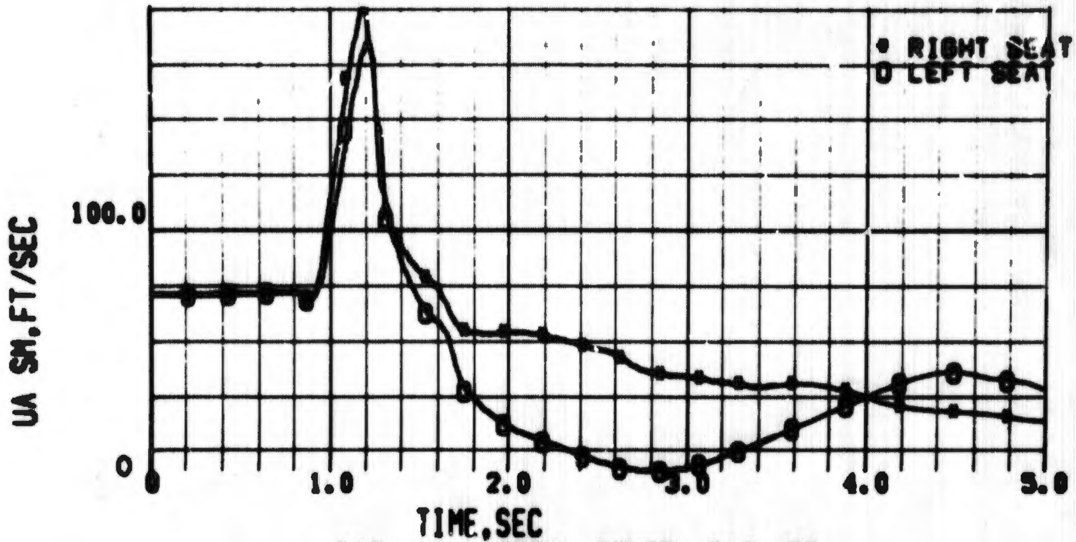


FIG 181 LATERAL CONTRL FAILURE
SEAT AND/OR MAN TOTAL AIRSPEED

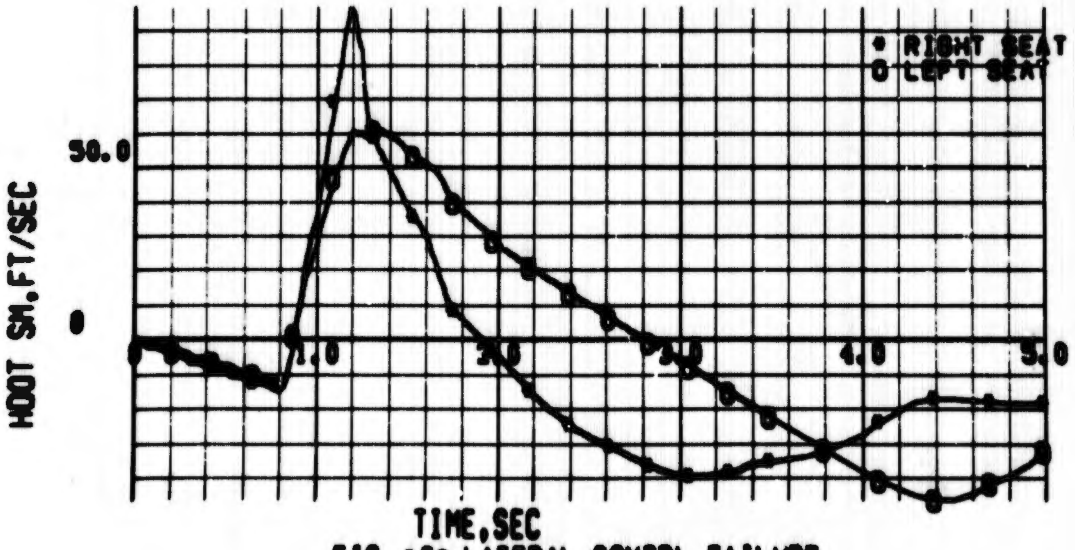


FIG 182 LATERAL CONTRL FAILURE
SEAT AND/OR MAN CLIMB RATE

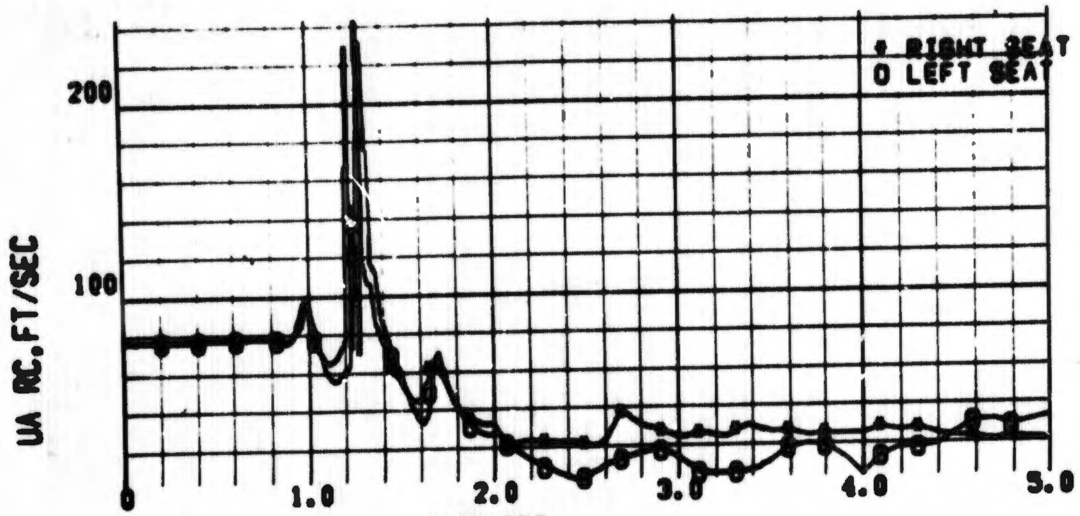


FIG 183 LATERAL CONTRL FAILURE
PARACHUTE TOTAL AIRSPEED

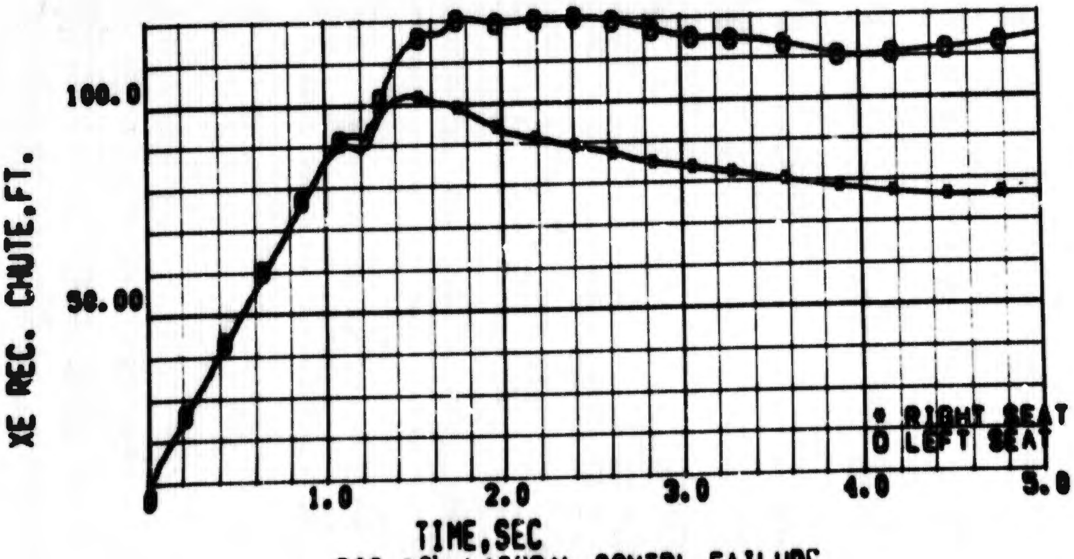


FIG 184 LATERAL CONTRL FAILURE
PARACHUTE DOWNRANGE DISTANCE

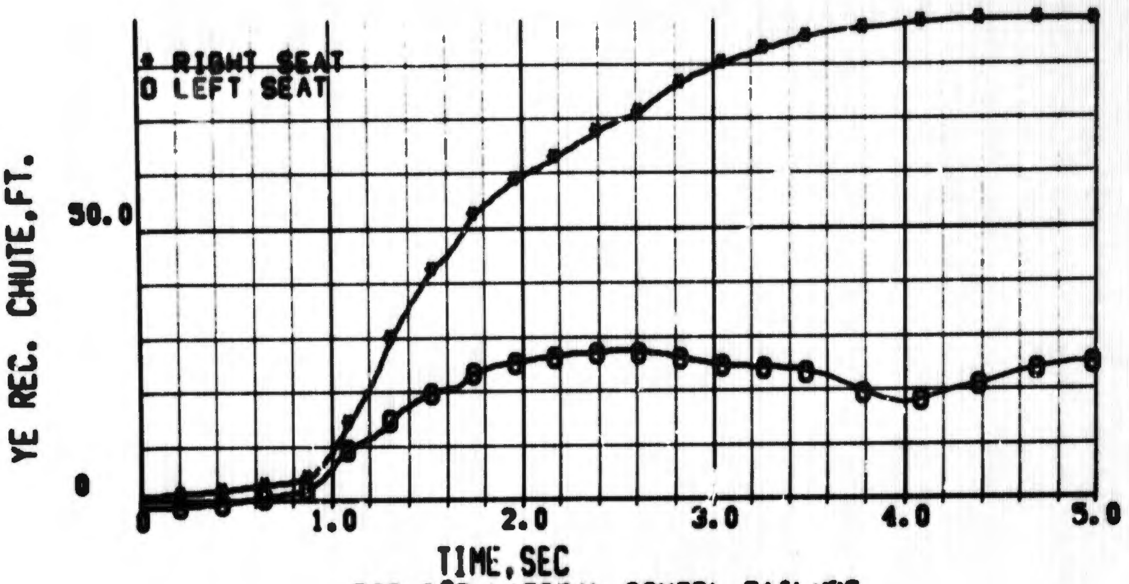


FIG 185 LATERAL CONTRL FAILURE
PARACHUTE LATERAL DISTANCE

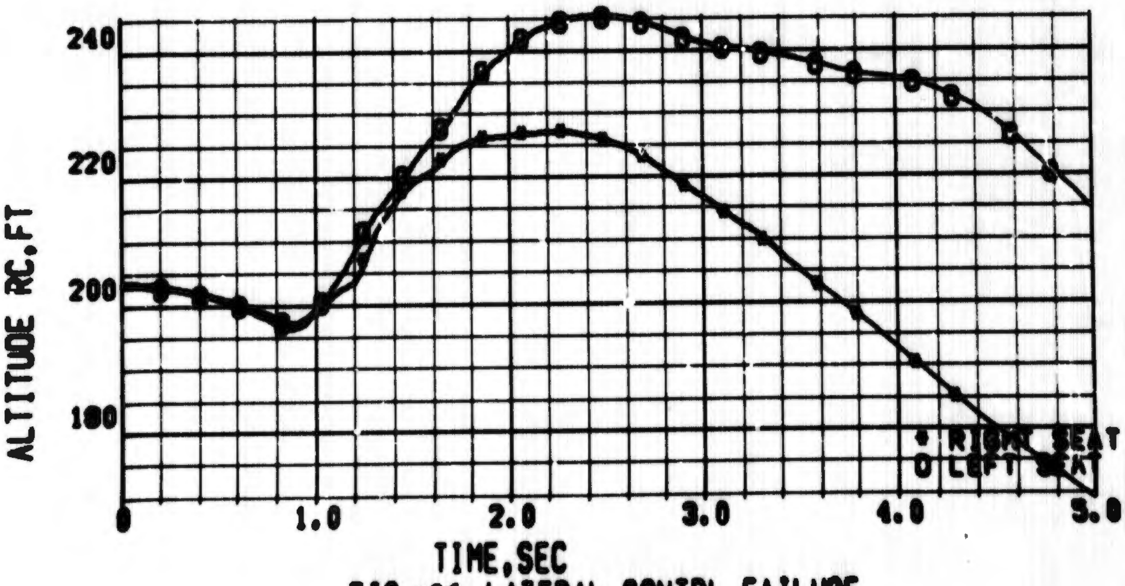
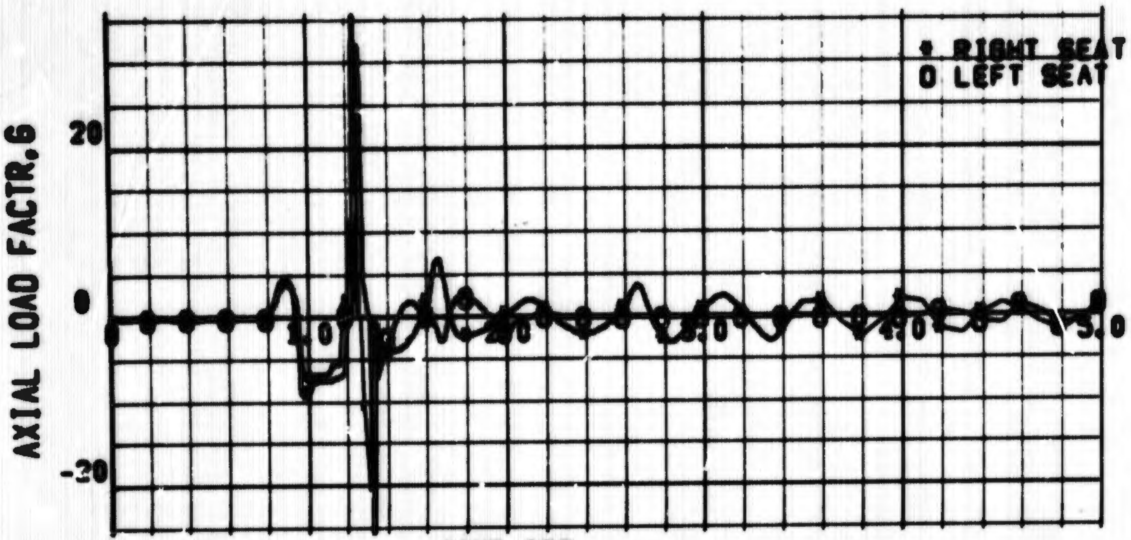
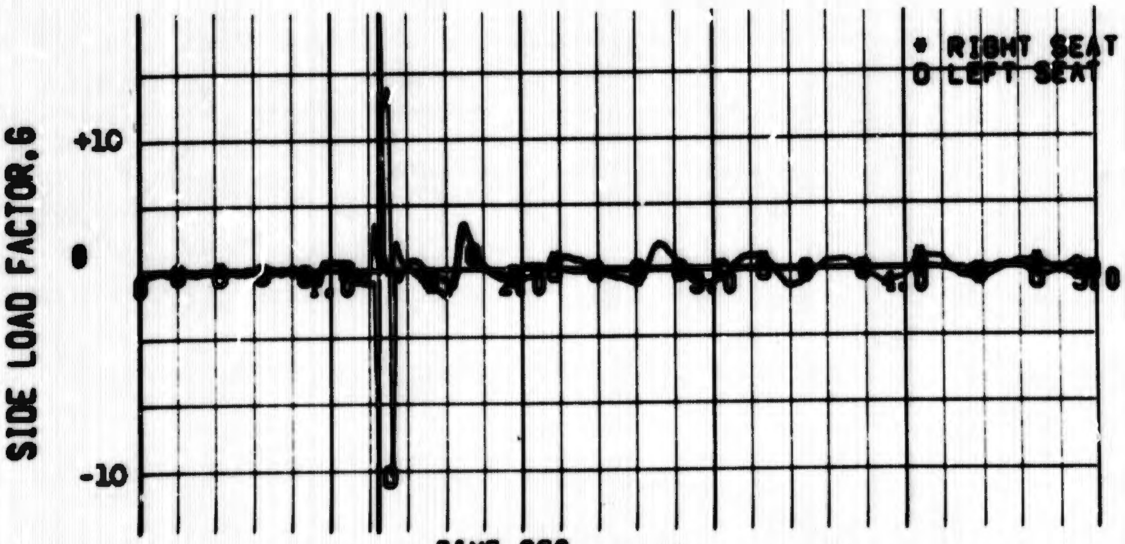


FIG 186 LATERAL CONTRL FAILURE
PARACHUTE ALTITUDE



TIME,SEC
FIG 187 LATERAL CONTRL FAILURE
SEAT-MAN AXIAL LOAD FACTOR,CG



TIME,SEC
FIG 188 LATERAL CONTRL FAILURE
SEAT-MAN SIDE LOAD FACTOR,CG

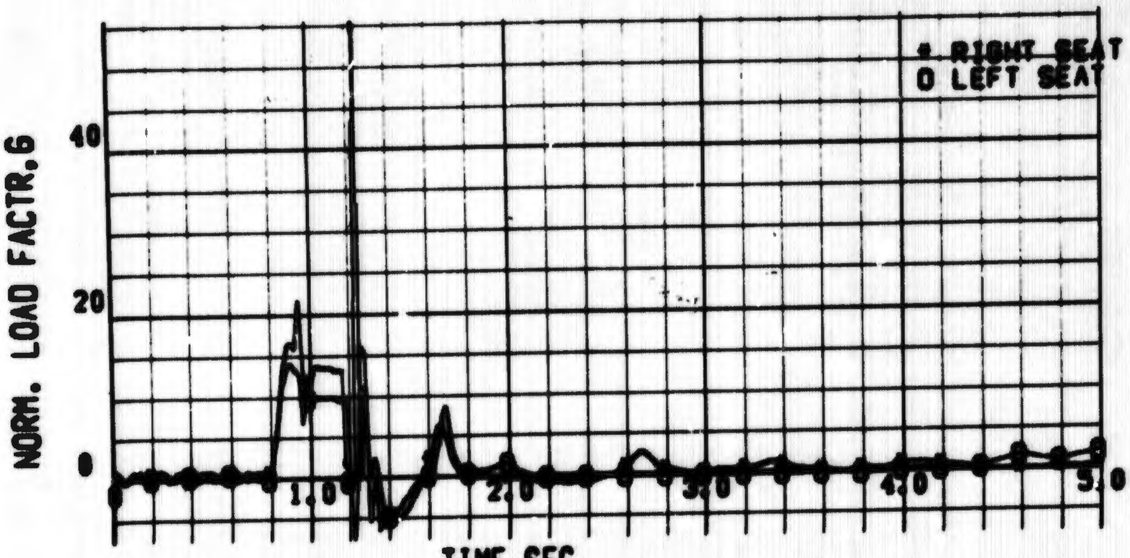


FIG 189 LATERAL CONTRL FAILURE
SEAT-MAN NORMAL LOAD FACTOR,CG

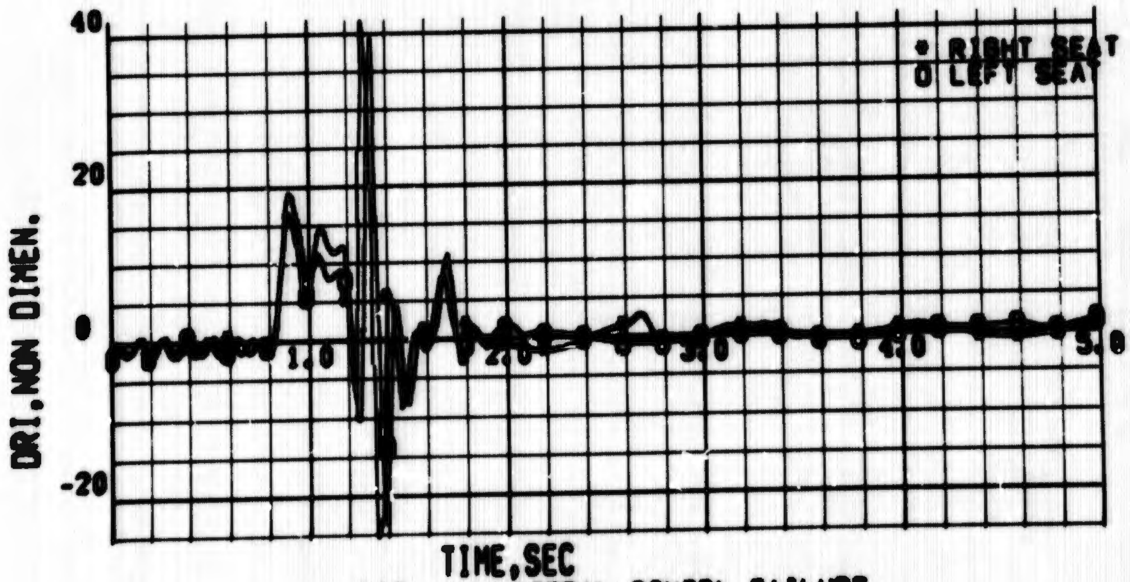


FIG 190 LATERAL CONTRL FAILURE
PILOT DYNAMIC RESPONSE INDEX

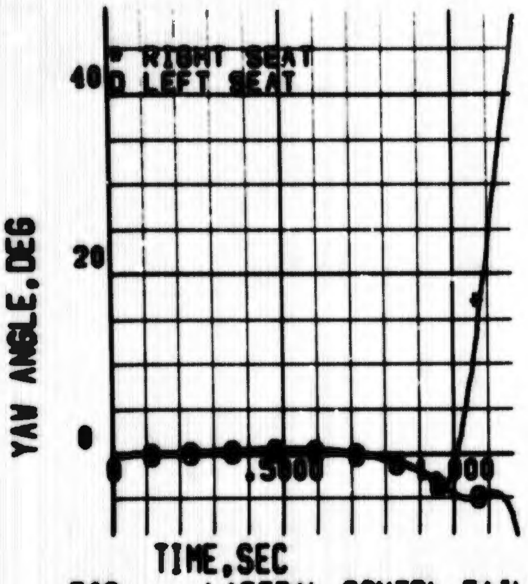


FIG 191 LATERAL CONTRL FAILURE
SEAT-MAN EARTH AXIS YAW ANGLE

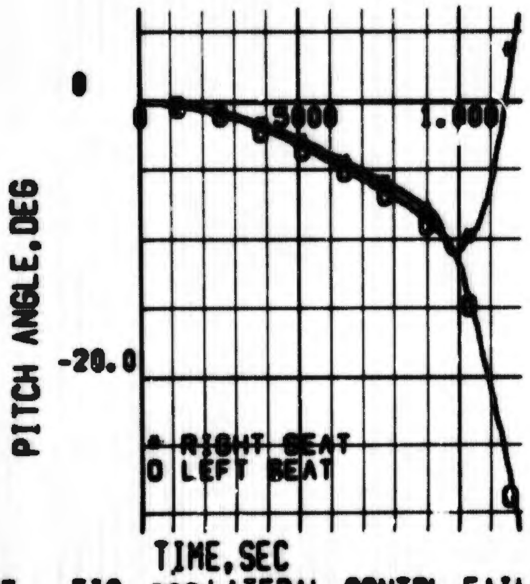


FIG 192 LATERAL CONTRL FAILURE
SEAT-MAN EARTH AXIS PITCH ANG.

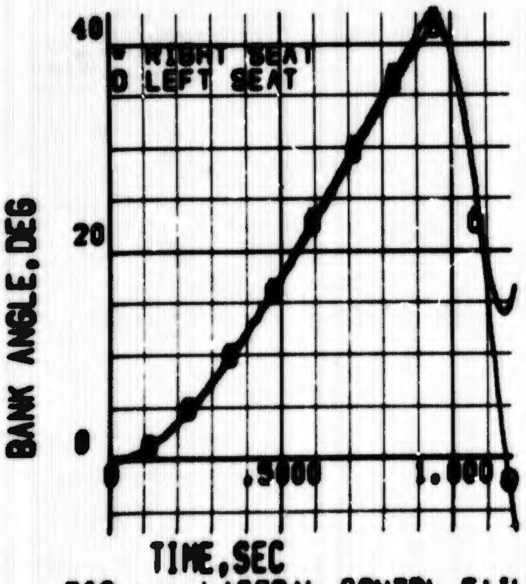


FIG 193 LATERAL CONTRL FAILURE
SEAT-MAN EARTH AXIS BANK ANGLE

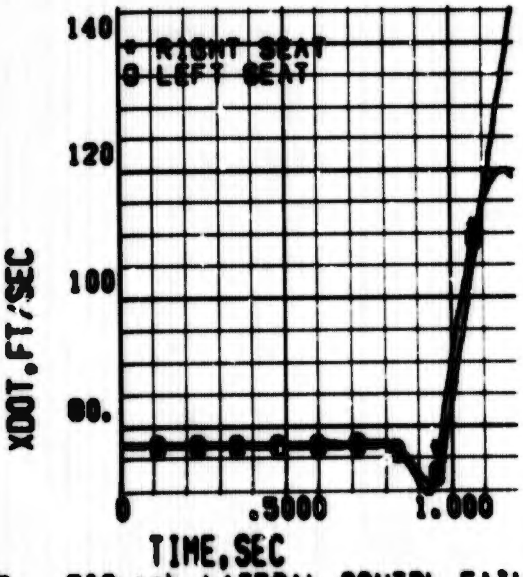


FIG 194 LATERAL CONTRL FAILURE
SEAT-MAN DOWNRANGE VELOCITY

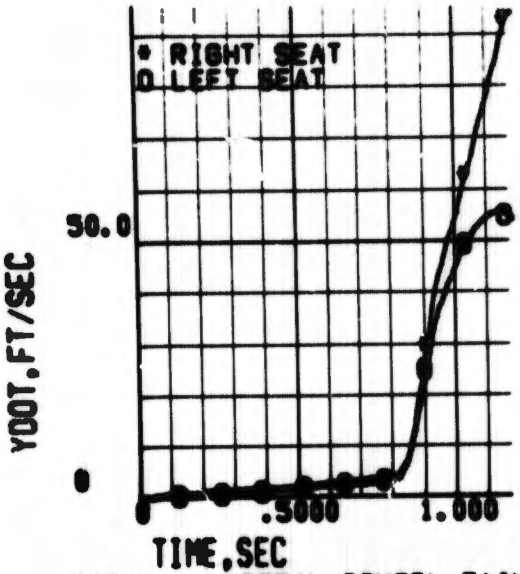


FIG 195 LATERAL CONTRL FAILURE
SEAT-MAN LATERAL VELOCITY

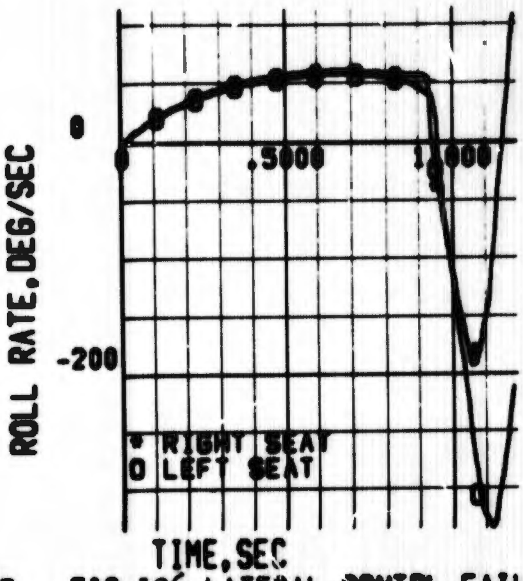


FIG 196 LATERAL CONTRL FAILURE
SEAT-MAN ROLL RATE

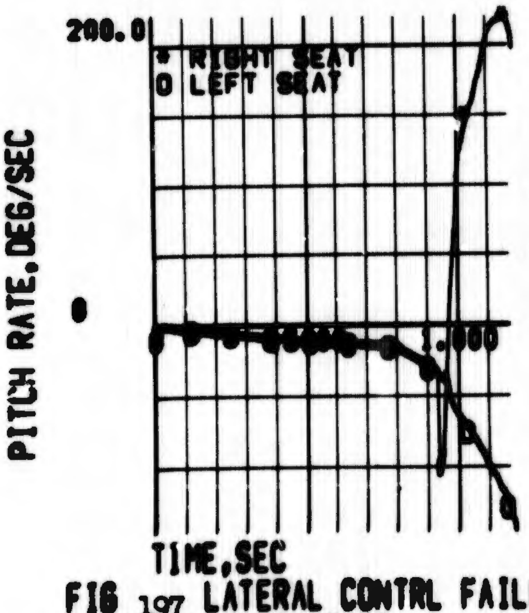


FIG 197 LATERAL CONTRL FAILURE
SEAT-MAN PITCH RATE

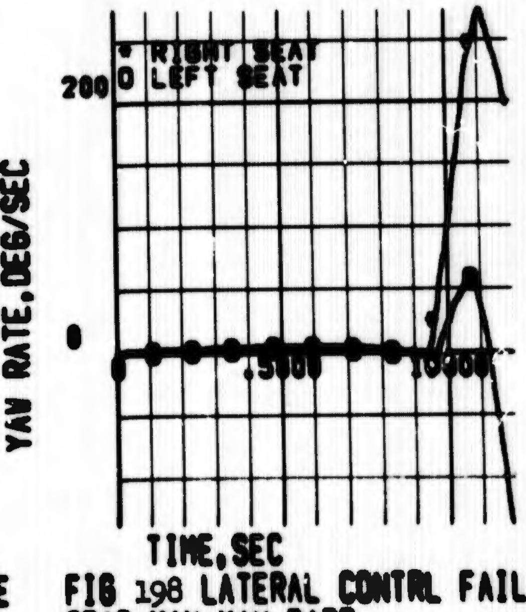


FIG 198 LATERAL CONTRL FAILURE
SEAT-MAN YAW RATE

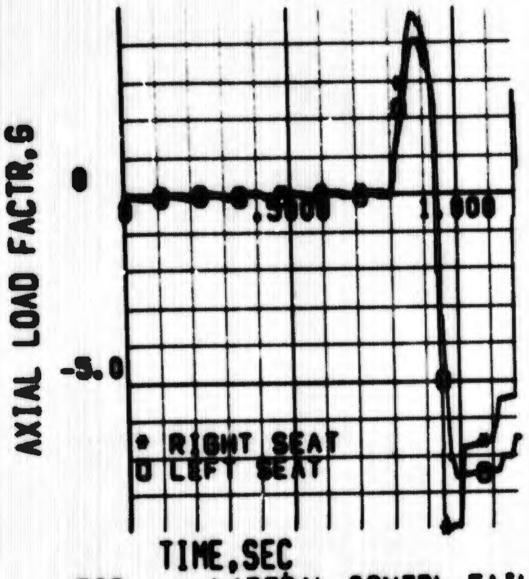


FIG 199 LATERAL CONTRL FAILURE
AXIAL LOAD FACTOR,SEAT-MAN CG

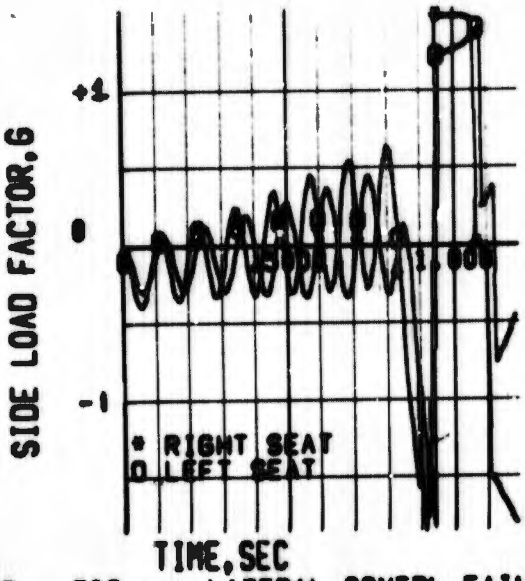


FIG 200 LATERAL CONTRL FAILURE
SIDE LOAD FACTOR,SEAT-MAN CG

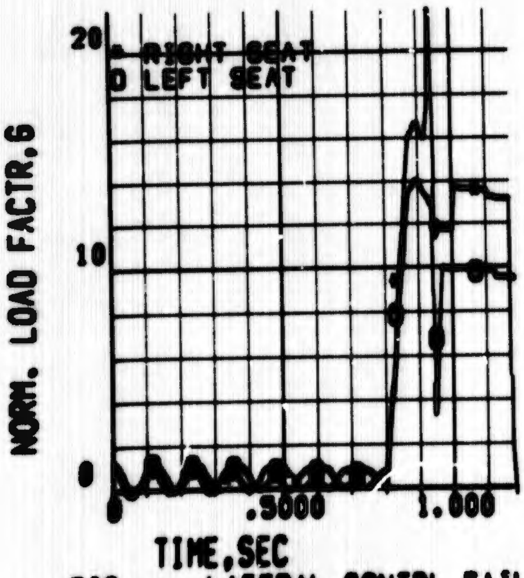


FIG 201 LATERAL CONTRL FAILURE
NORMAL LOAD FACTOR,SEAT-MAN CG

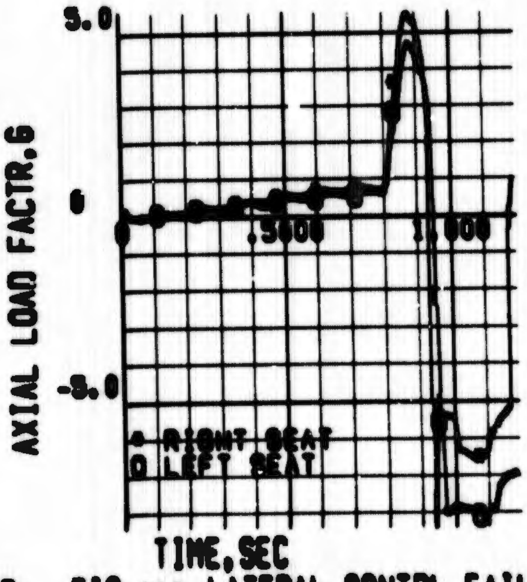


FIG 202 LATERAL CONTRL FAILURE
AXIAL LD. FACT. AT PILOTS HEAD

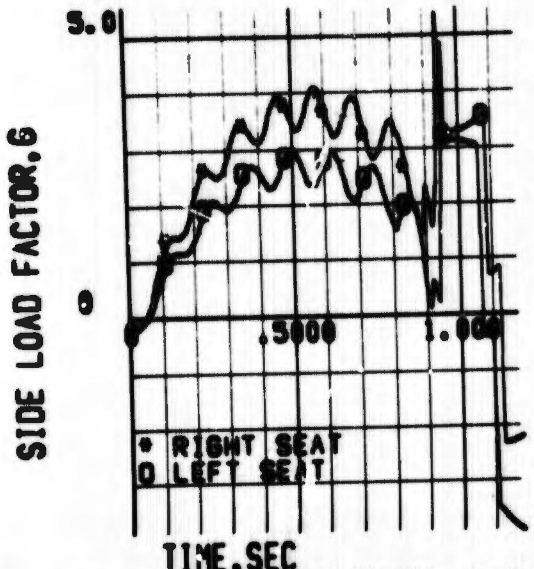


FIG 203 LATERAL CONTRL FAILURE
SIDE LOAD FACT. AT PILOTS HEAD

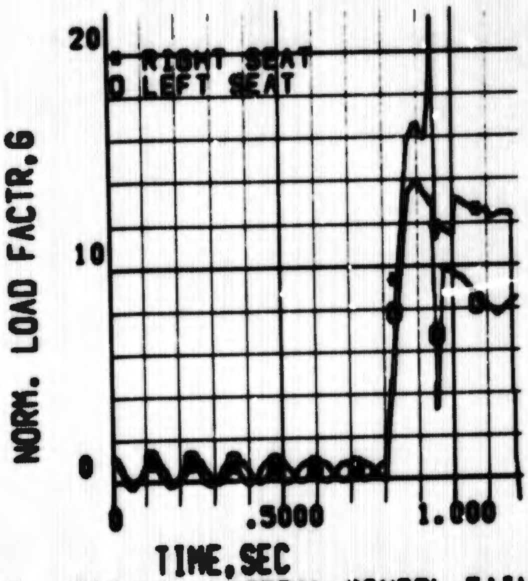


FIG 204 LATERAL CONTRL FAILURE
NORM. LD. FACT. AT PILOTS HEAD

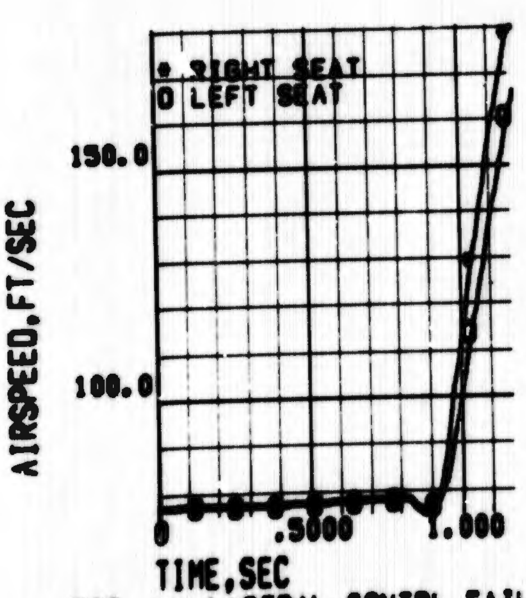


FIG 205 LATERAL CONTRL FAILURE
SEAT-MAN TOTAL AIRSPEED

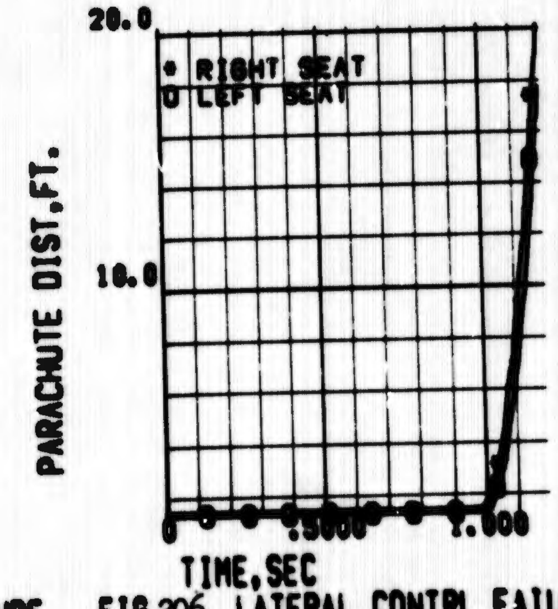


FIG 206 LATERAL CONTRL FAILURE
DIST. FROM BRIDLE TO CHUTE CG

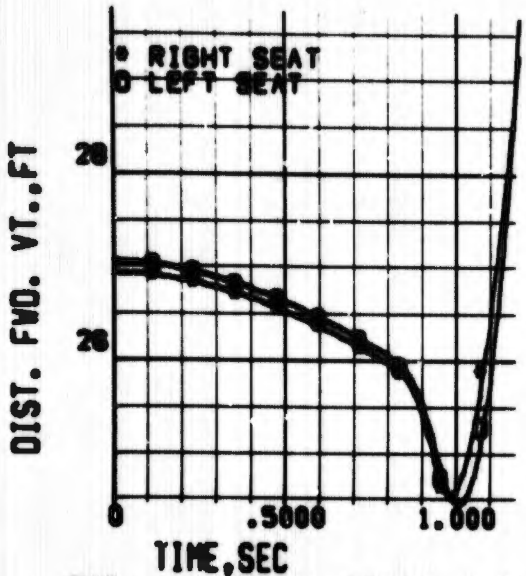


FIG 207 LATERAL CONTRL FAILURE
VERT. TAIL LONG. CLEARANCE

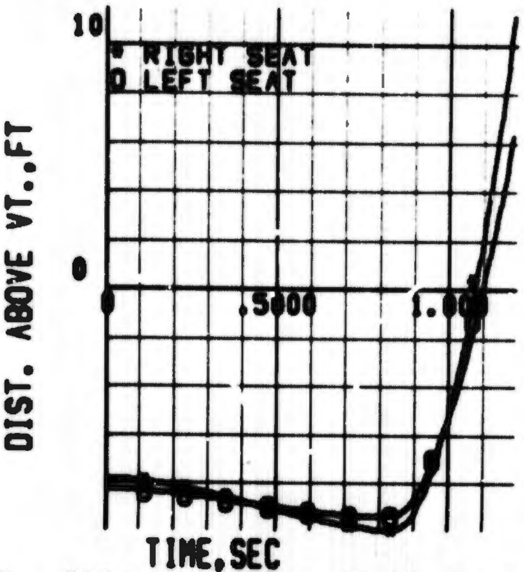


FIG 208 LATERAL CONTRL FAILURE
VERT. TAIL VERT. CLEARANCE

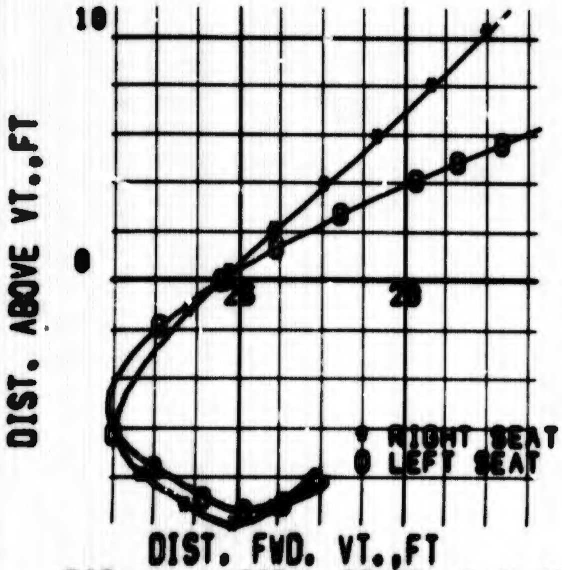


FIG 209 LATERAL CONTRL FAILURE
VERTICAL TAIL CLEARANCE

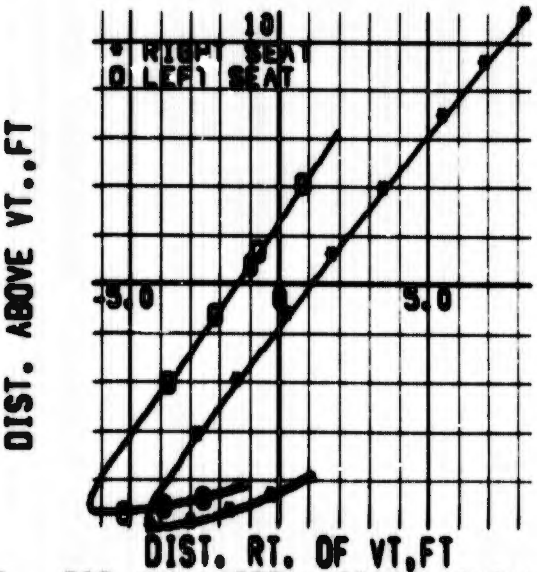


FIG 210 LATERAL CONTRL FAILURE
VERTICAL TAIL CLEARANCE

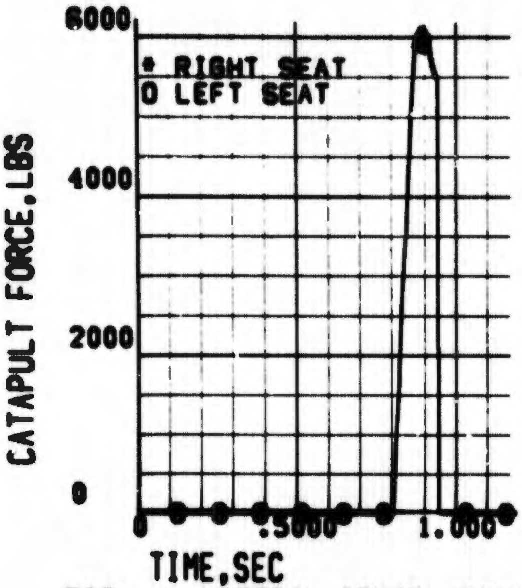


FIG 211 LATERAL CONTRL FAILURE
CATAPULT FORCE ON SEAT

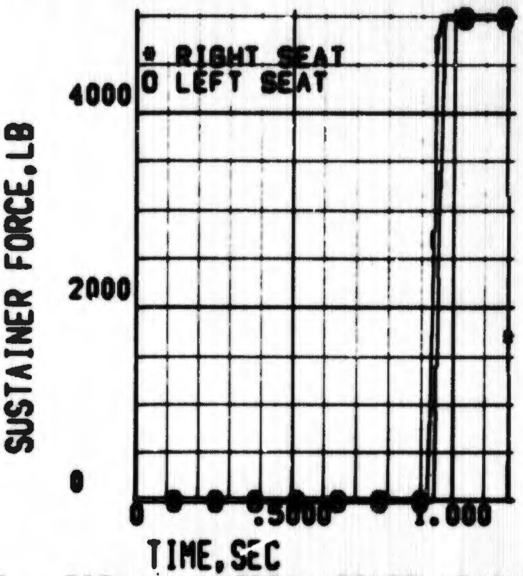


FIG 212 LATERAL CONTRL FAILURE
SUSTAINER ROCKET FORCE ON SEAT

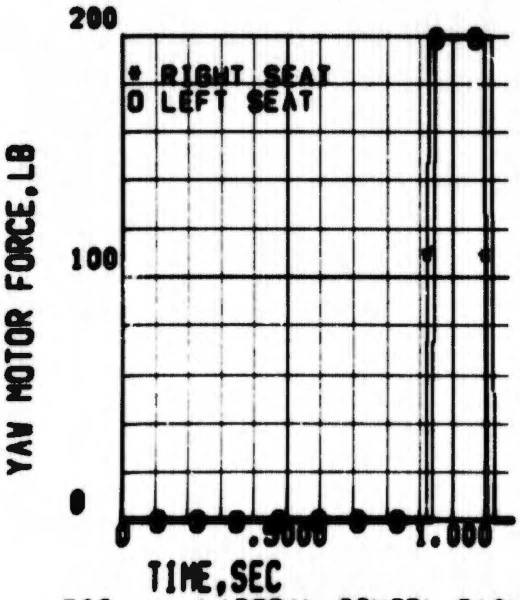


FIG 213 LATERAL CONTRL FAILURE
YAW MOTOR FORCE ON SEAT

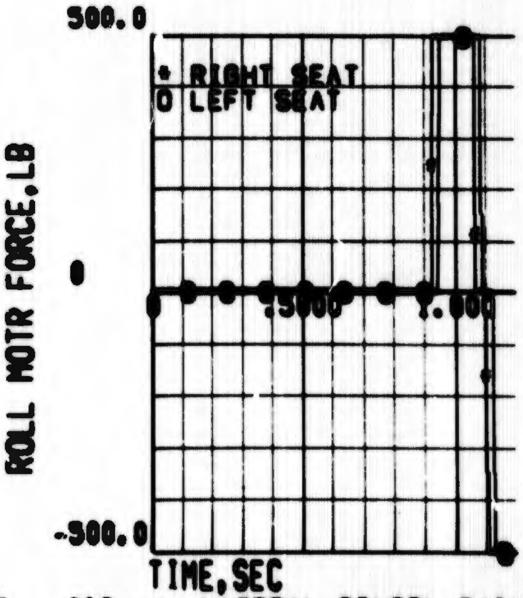


FIG 214 LATERAL CONTRL FAILURE
ROLL MOTOR FORCE ON SEAT

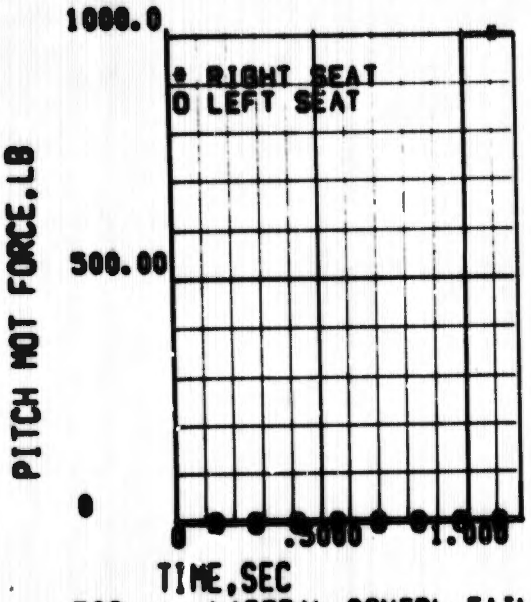


FIG 215 LATERAL CONTRL FAILURE
PITCH MOTOR FORCE ON SEAT

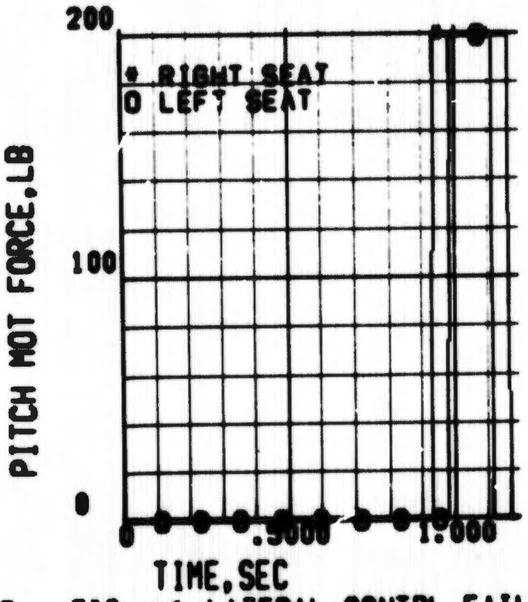


FIG 216 LATERAL CONTRL FAILURE
PITCH MOTOR FORCE ON SEAT

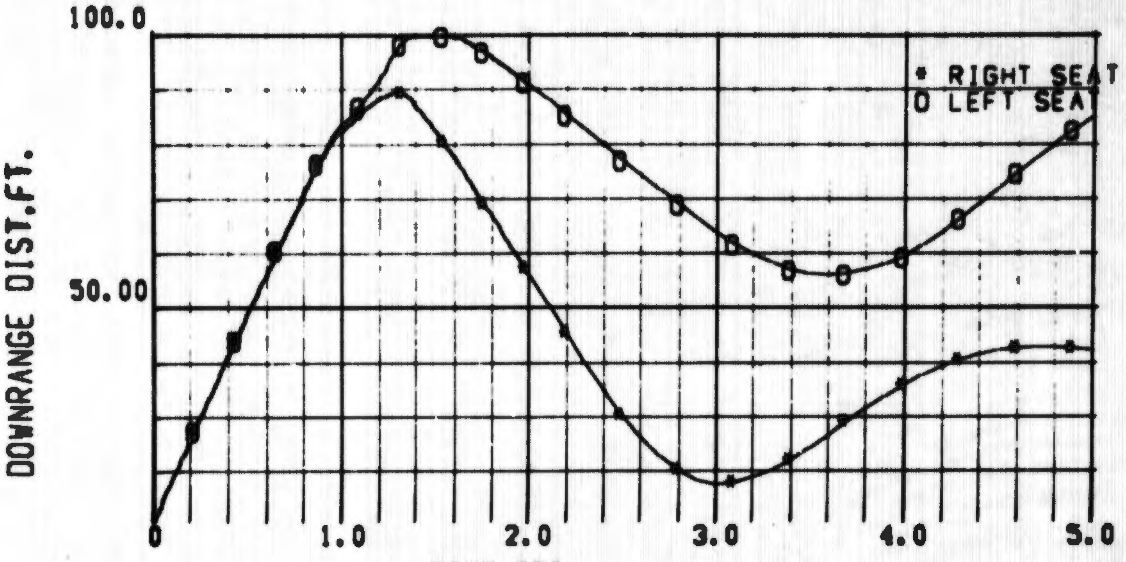


FIG 217 LONG. CONTROL FAILURE
SEAT AND/OR MAN DOWNRANGE DIST

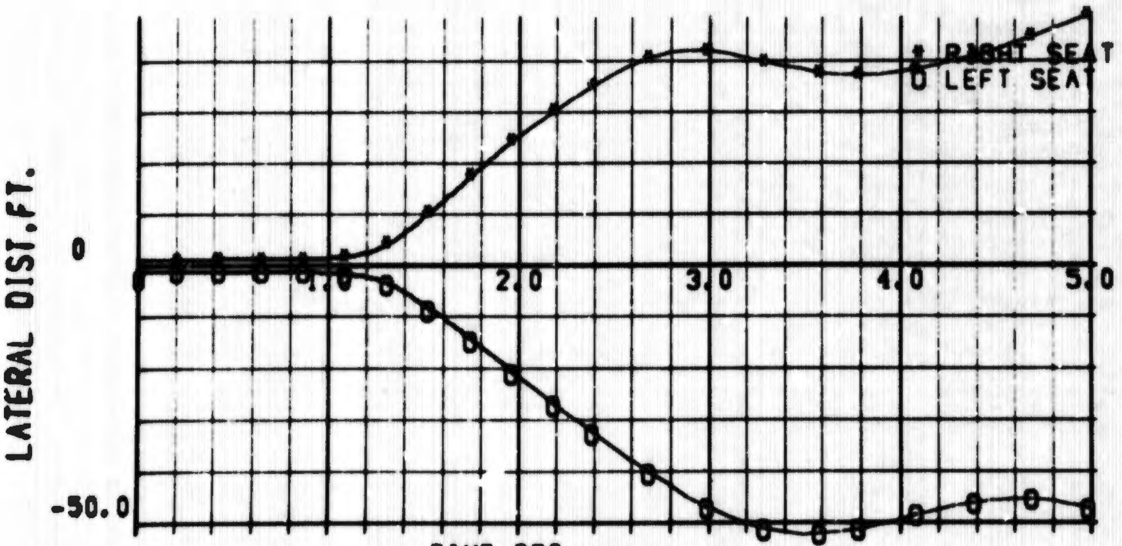


FIG 218 LONG. CONTROL FAILURE
SEAT AND/OR MAN LATERAL DIST.

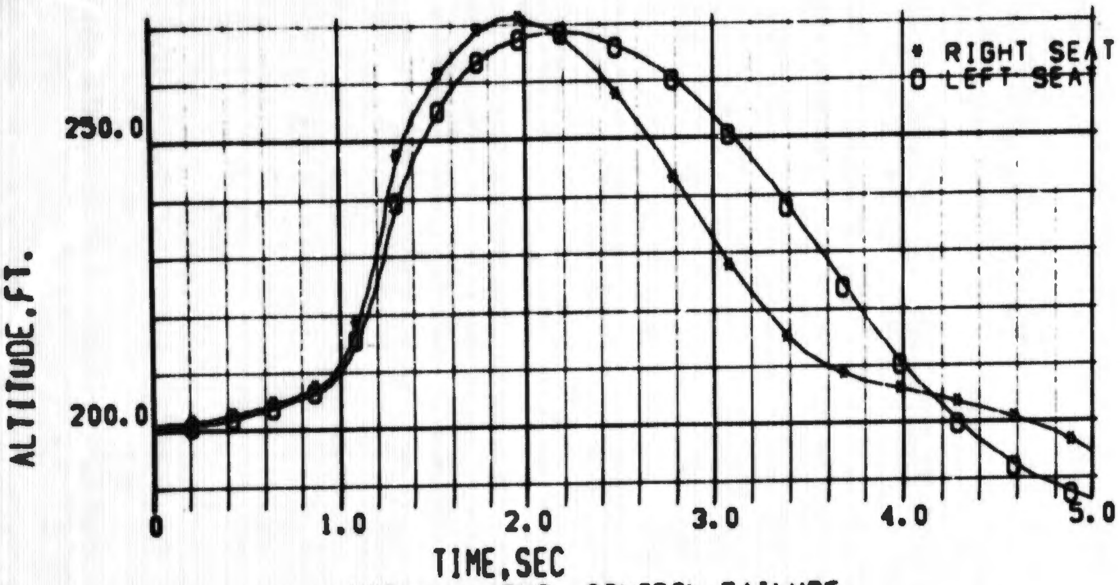


FIG 219 LONG. CONTROL FAILURE
SEAT AND/OR MAN ALTITUDE

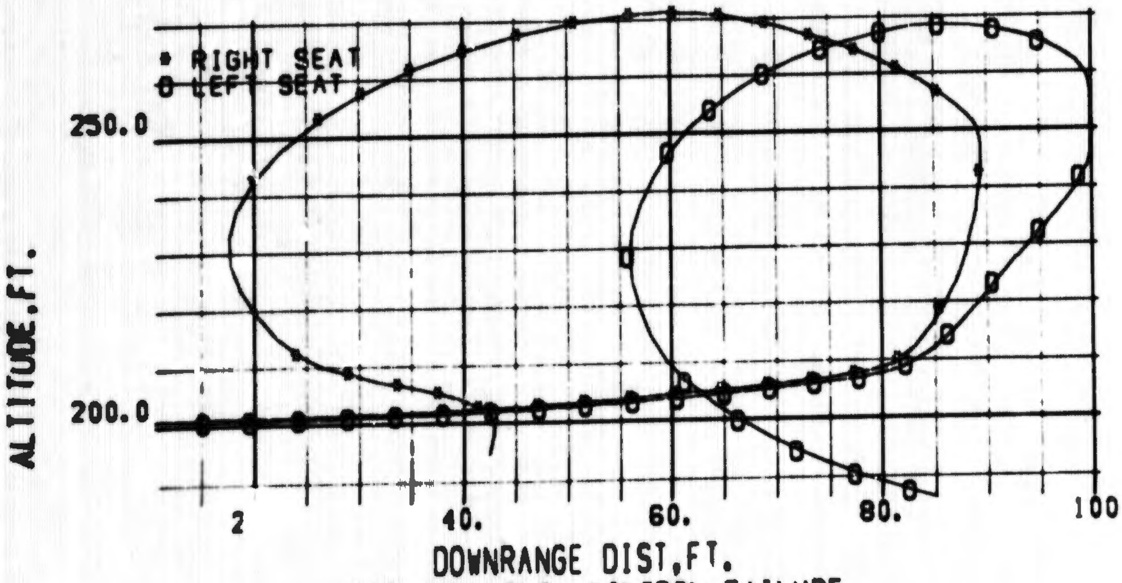


FIG 220 LONG. CONTROL FAILURE
SEAT-MAN TRAJECTORY

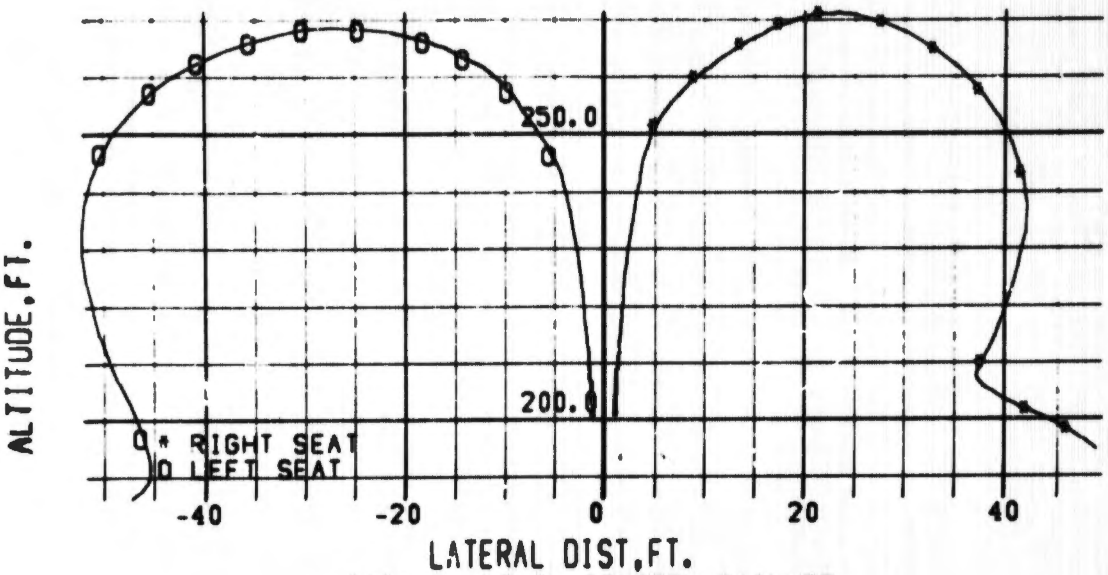


FIG 221 LONG. CONTROL FAILURE
SEAT-MAN TRAJECTORY

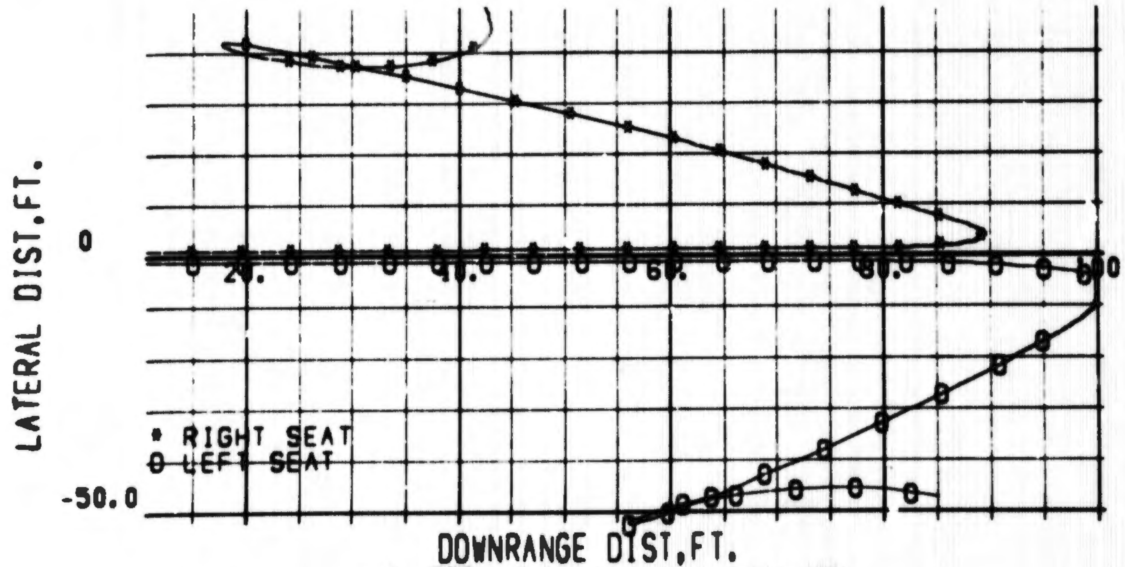


FIG 222 LONG. CONTROL FAILURE
SEAT-MAN TRAJECTORY

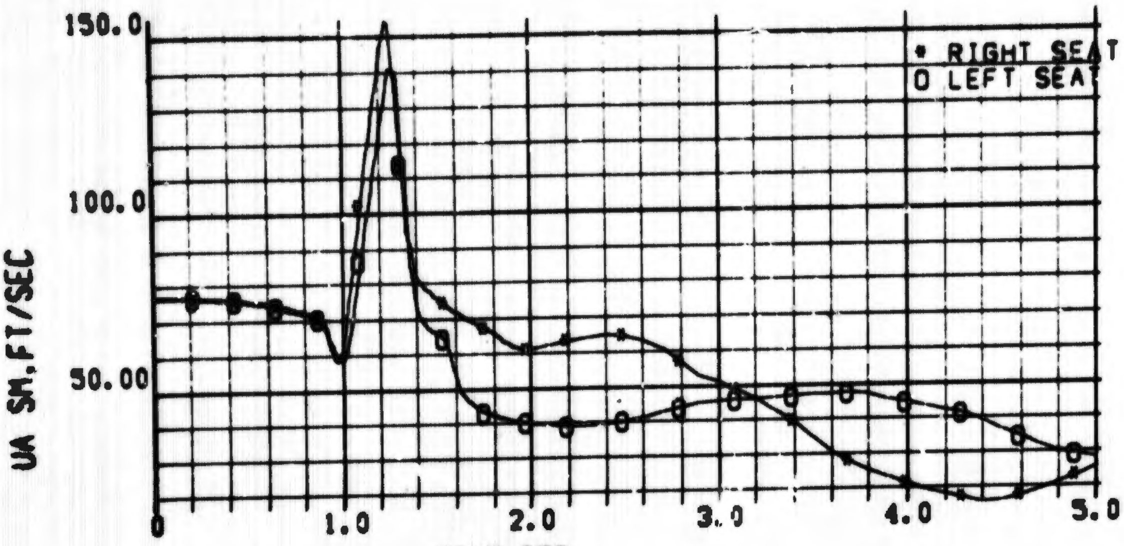


FIG 223 LONG. CONTROL FAILURE
SEAT AND/OR MAN TOTAL AIRSPEED

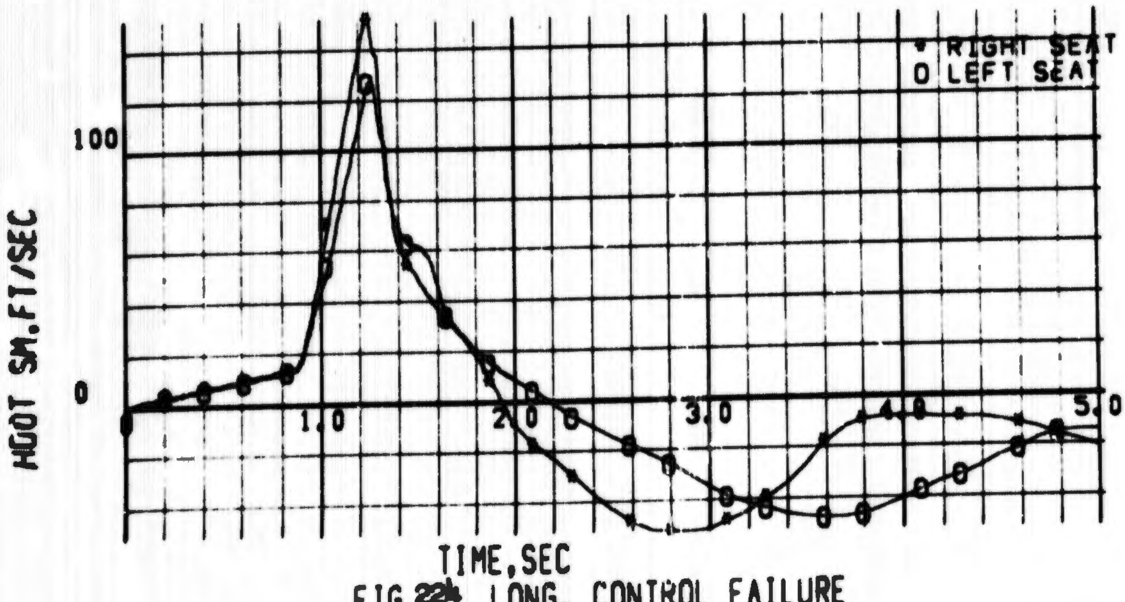


FIG 224 LONG. CONTROL FAILURE
SEAT AND/OR MAN CLIMB RATE

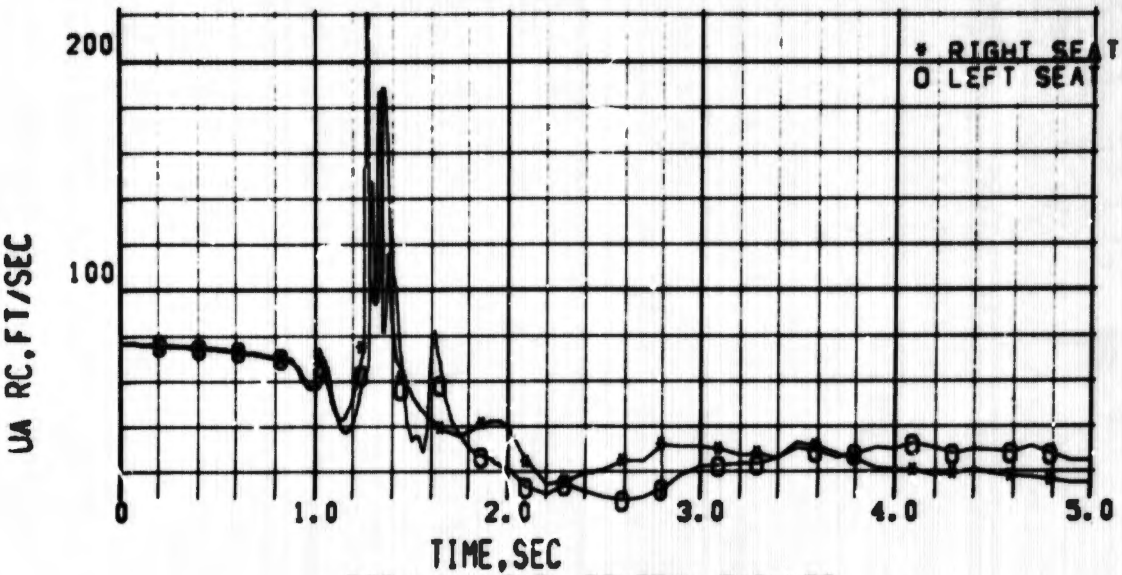


FIG 225 LONG. CONTROL FAILURE
PARACHUTE TOTAL AIRSPEED

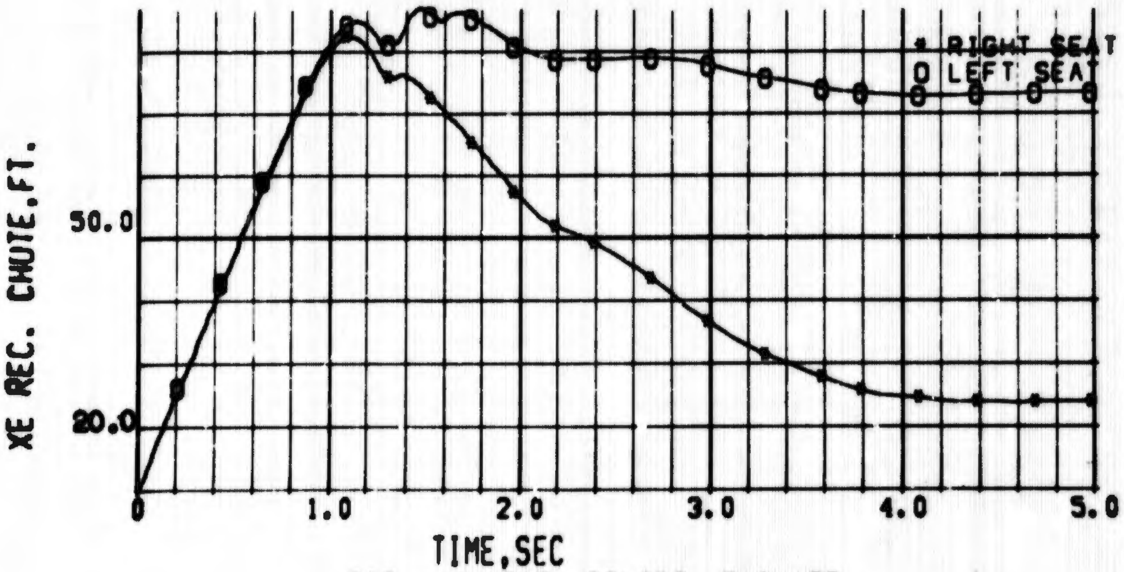


FIG 226 LONG. CONTROL FAILURE
PARACHUTE DOWNRANGE DISTANCE

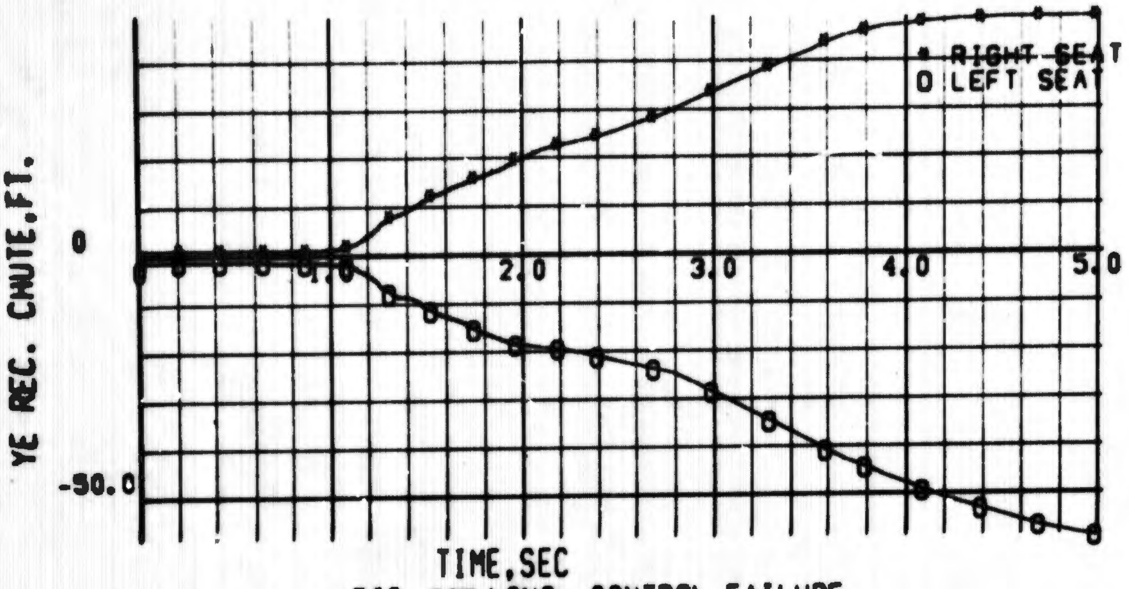


FIG 227 LONG. CONTROL FAILURE
PARACHUTE LATERAL DISTANCE

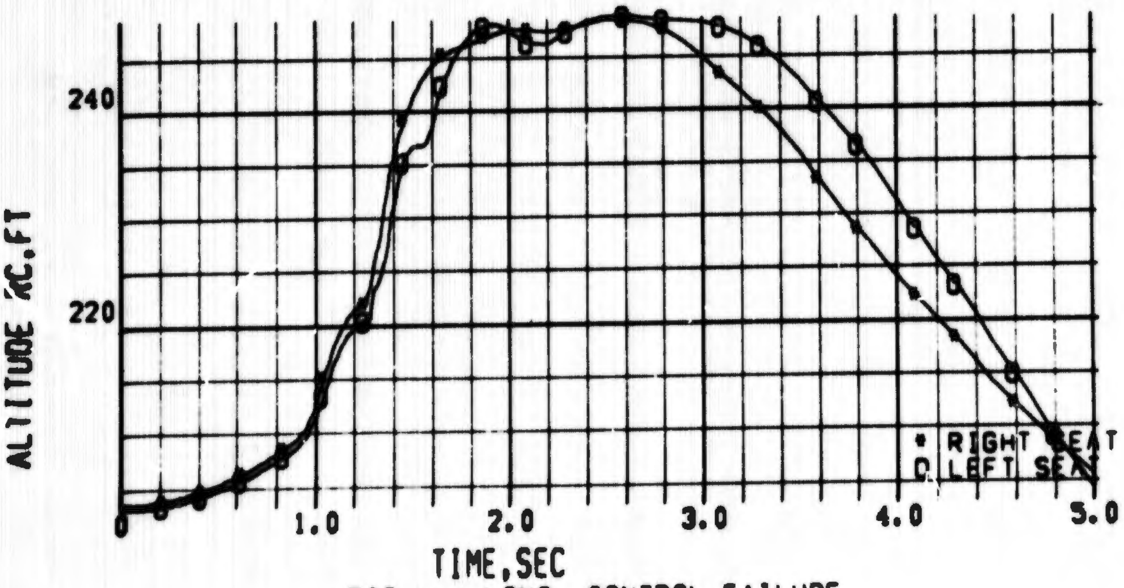


FIG 228 LONG. CONTROL FAILURE
PARACHUTE ALTITUDE

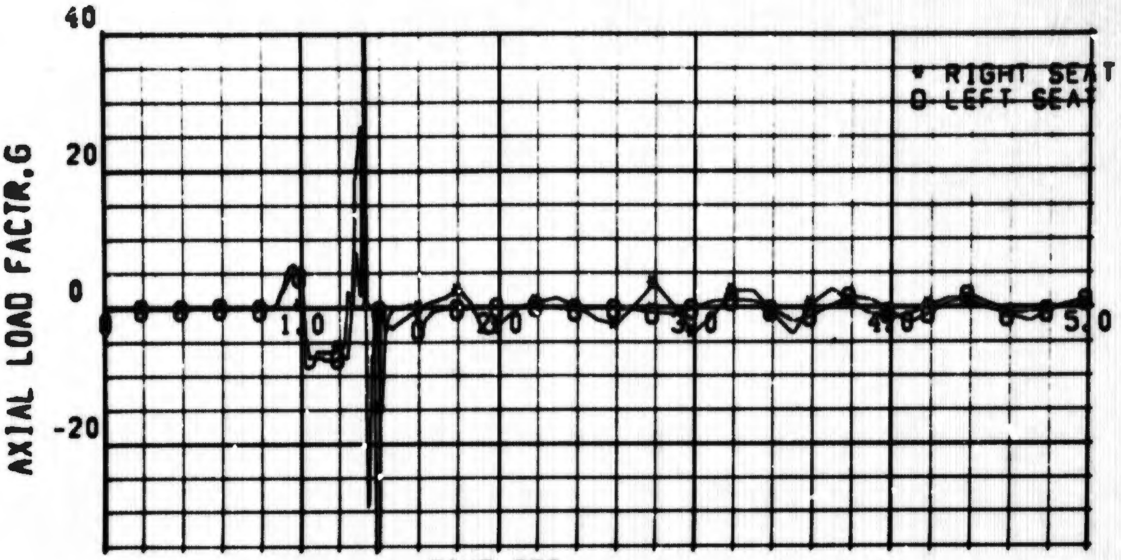


FIG 229 LONG. CONTROL FAILURE
SEAT-MAN AXIAL LOAD FACTOR, CG

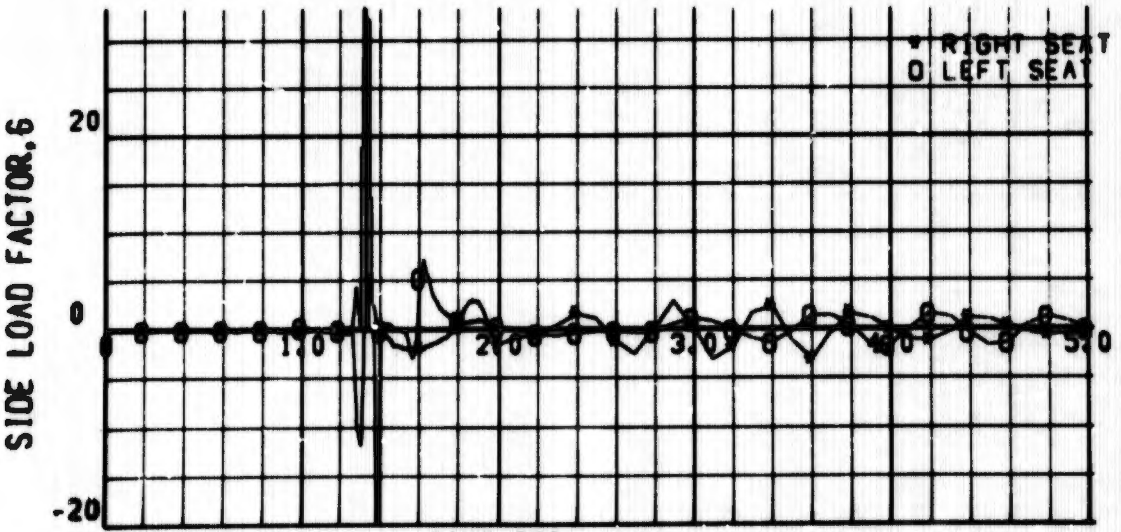


FIG 230 LONG. CONTROL FAILURE
SEAT-MAN SIDE LOAD FACTOR, CG

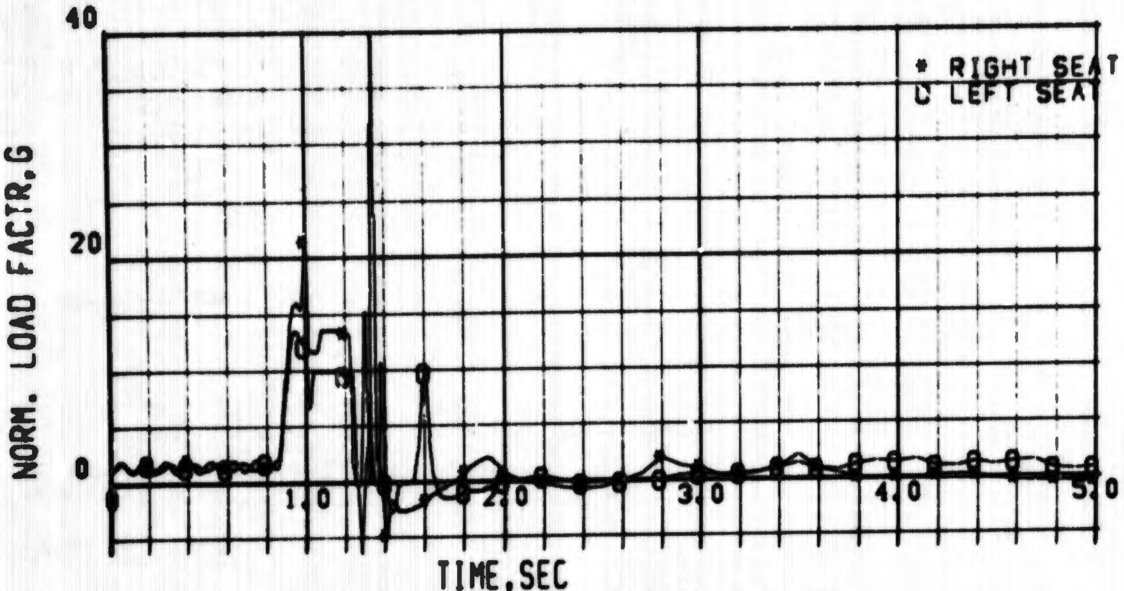


FIG 231 LONG. CONTROL FAILURE
SEAT-MAN NORMAL LOAD FACTOR,CG

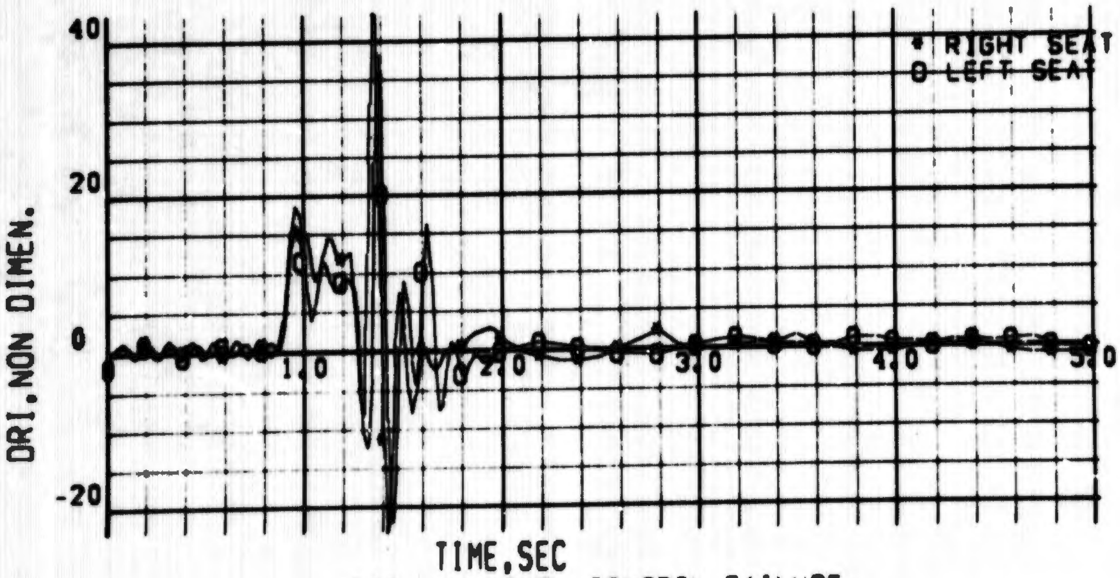


FIG 232 LONG. CONTROL FAILURE
PILOT DYNAMIC RESPONSE INDEX

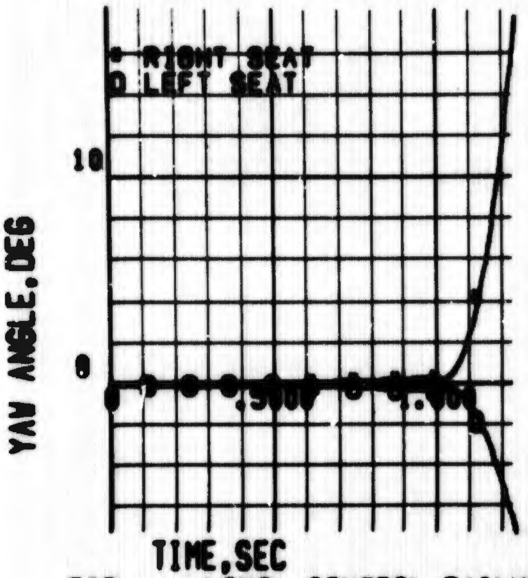


FIG 233 LONG. CONTROL FAILURE
SEAT-MAN EARTH AXIS YAW ANGLE

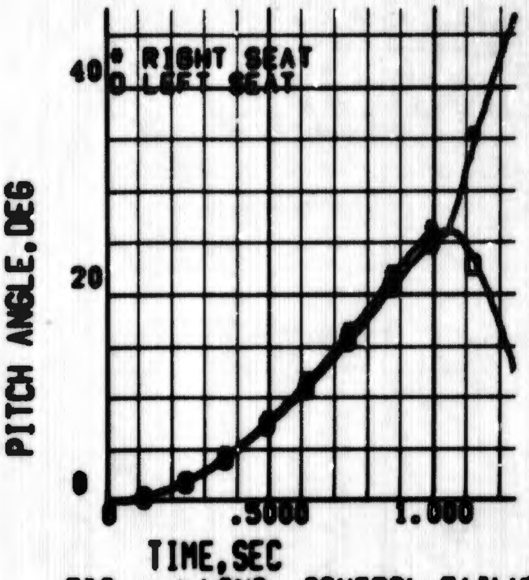


FIG 234 LONG. CONTROL FAILURE
SEAT-MAN EARTH AXIS PITCH ANG.

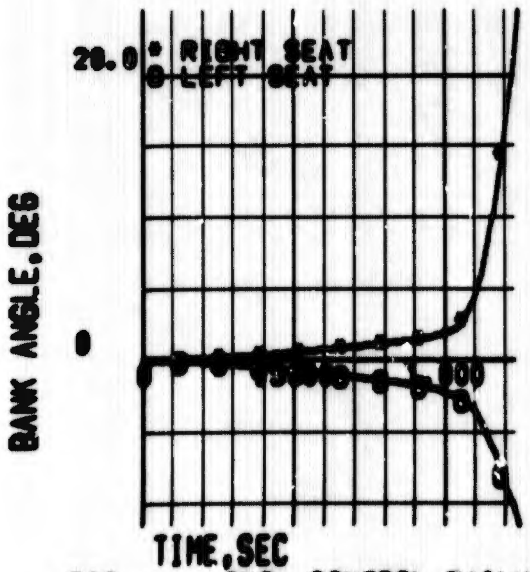


FIG 235 LONG. CONTROL FAILURE
SEAT-MAN EARTH AXIS BANK ANGLE

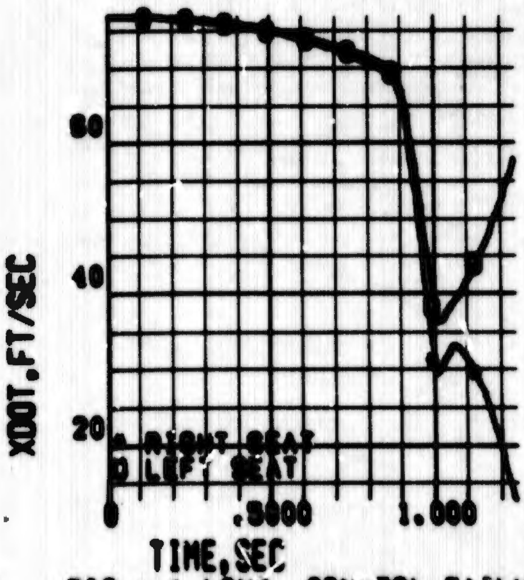


FIG 236 LONG. CONTROL FAILURE
SEAT-MAN DOWNRANGE VELOCITY

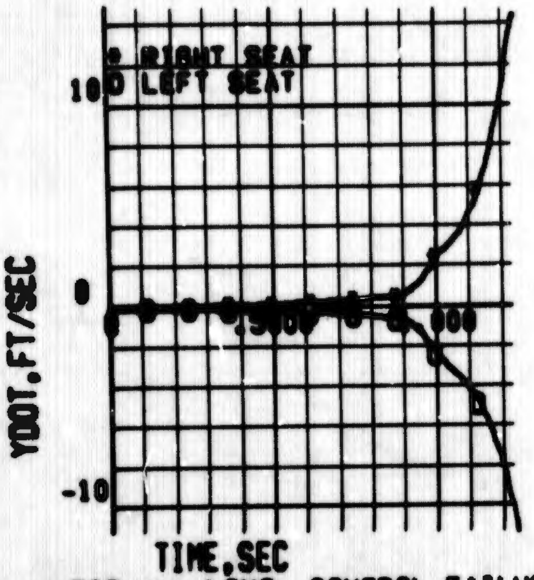


FIG 237 LONG. CONTROL FAILURE
SEAT-MAN LATERAL VELOCITY

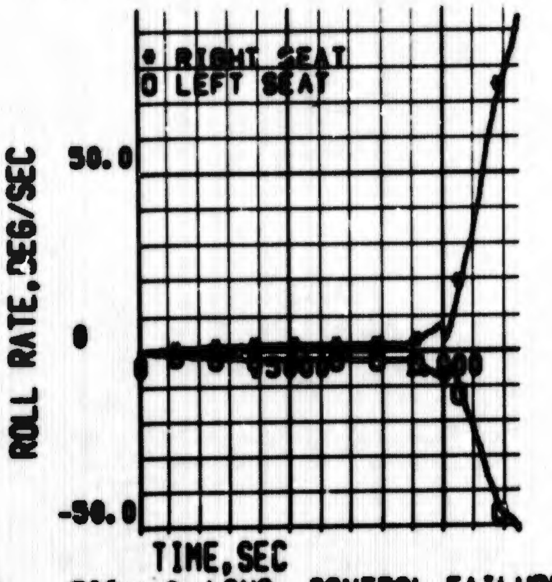


FIG 238 LONG. CONTROL FAILURE
SEAT-MAN ROLL RATE

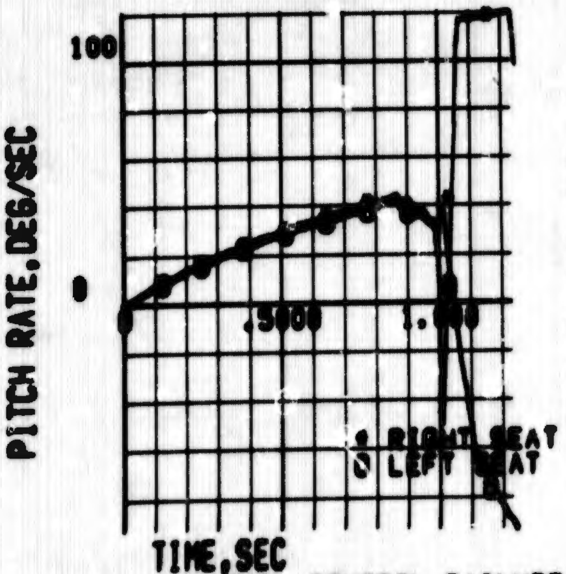


FIG 239 LONG. CONTROL FAILURE
SEAT-MAN PITCH RATE

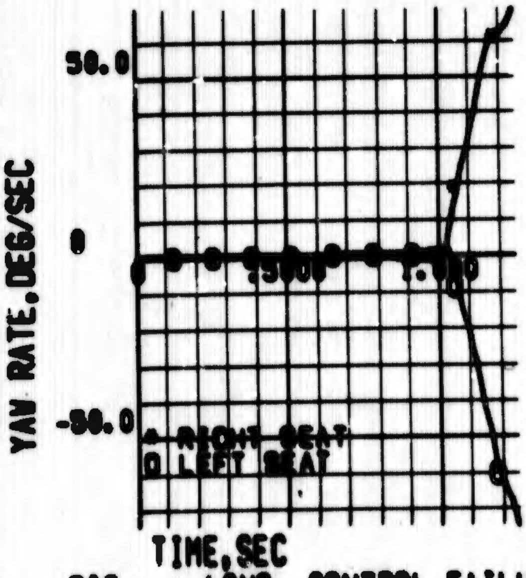


FIG 240 LONG. CONTROL FAILURE
SEAT-MAN YAW RATE

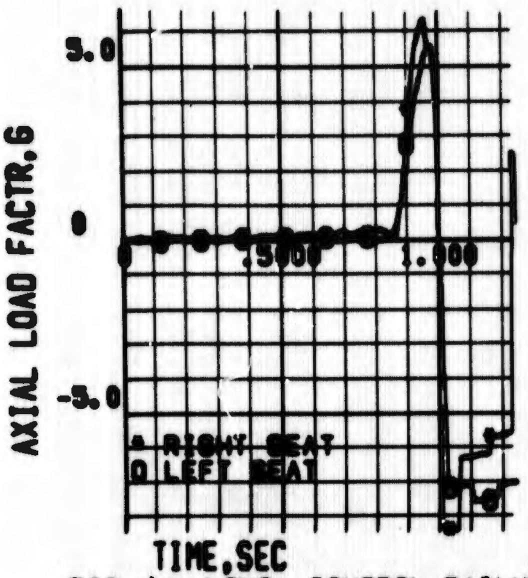


FIG 241 LONG. CONTROL FAILURE
AXIAL LOAD FACTOR,SEAT-MAN CG

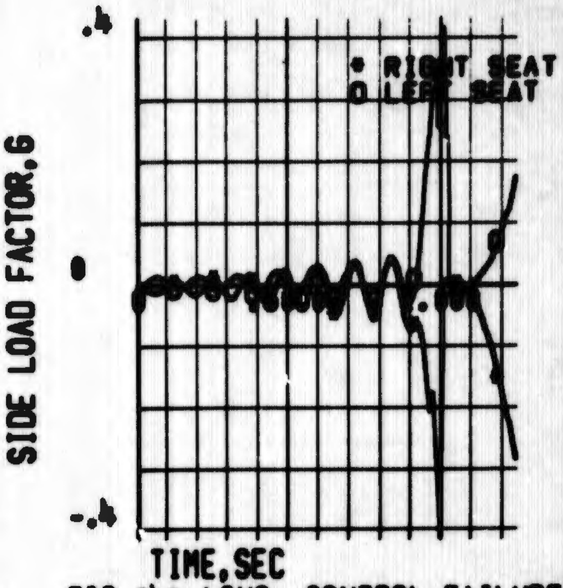


FIG 242 LONG. CONTROL FAILURE
SIDE LOAD FACTOR,SEAT-MAN CG

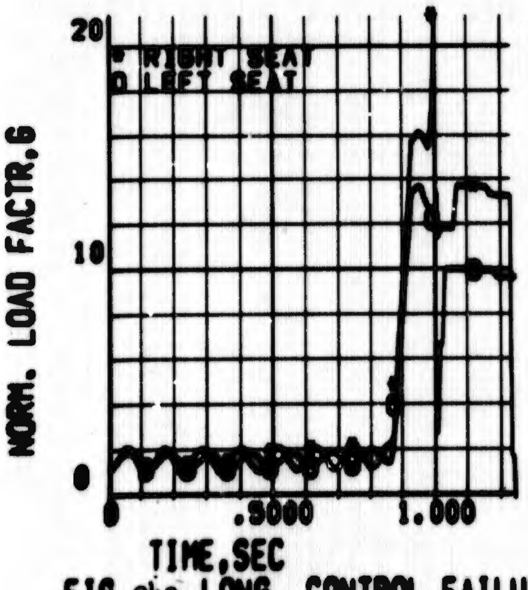


FIG 243 LONG. CONTROL FAILURE
NORMAL LOAD FACTOR,SEAT-MAN CG

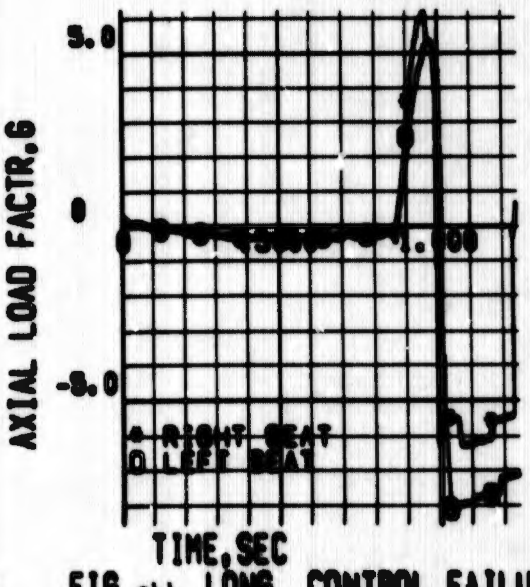


FIG 244 LONG. CONTROL FAILURE
AXIAL LD. FACT. AT PILOTS HEAD

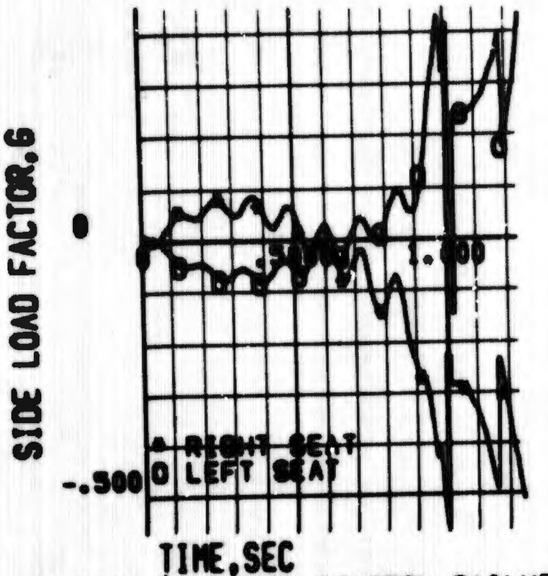


FIG 245 LONG. CONTROL FAILURE
SIDE LOAD FACT. AT PILOTS HEAD

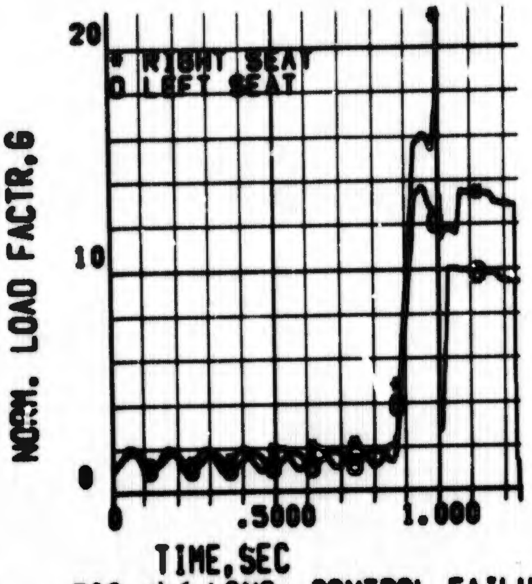


FIG 246 LONG. CONTROL FAILURE
NORM. LD. FACT. AT PILOTS HEAD

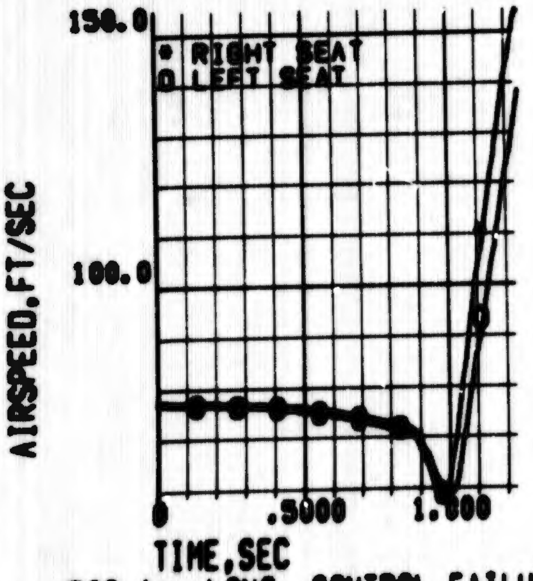


FIG 247 LONG. CONTROL FAILURE
SEAT-MAN TOTAL AIRSPEED

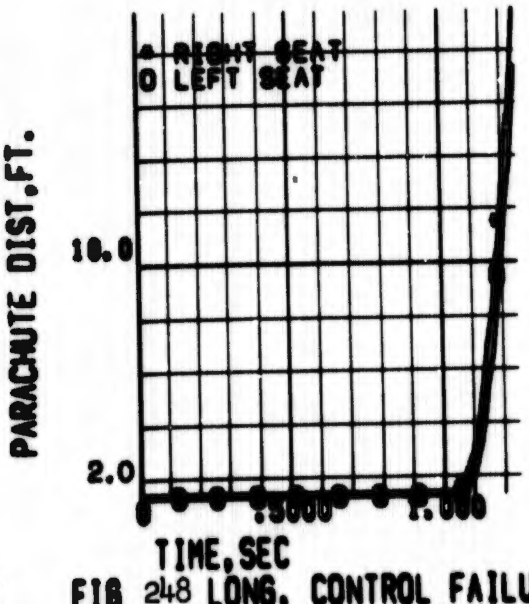


FIG 248 LONG. CONTROL FAILURE
DIST. FROM BRIDLE TO CHUTE CG

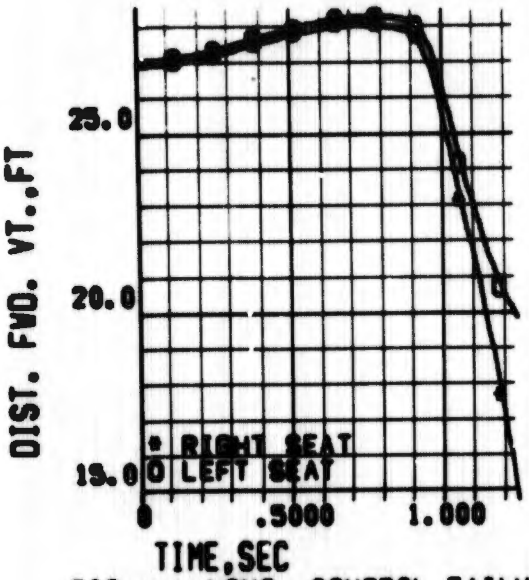


FIG 249 LONG. CONTROL FAILURE
VERT. TAIL LONG. CLEARANCE

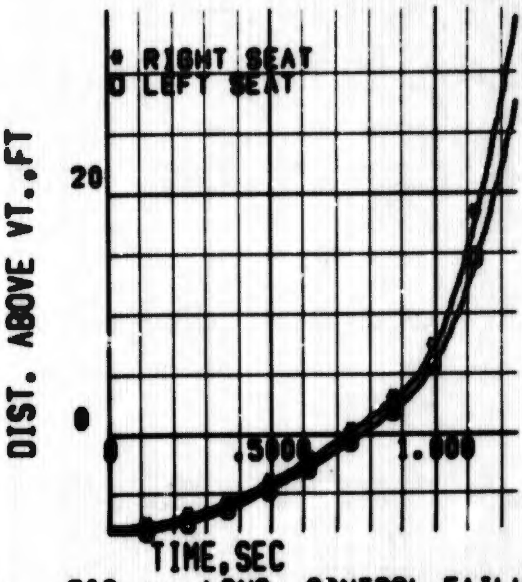


FIG 250 LONG. CONTROL FAILURE
VERT. TAIL VERT. CLEARANCE

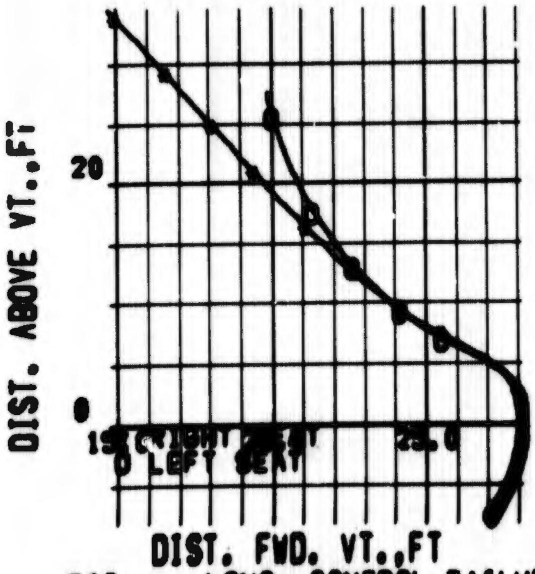


FIG 251 LONG. CONTROL FAILURE
VERTICAL TAIL CLEARANCE

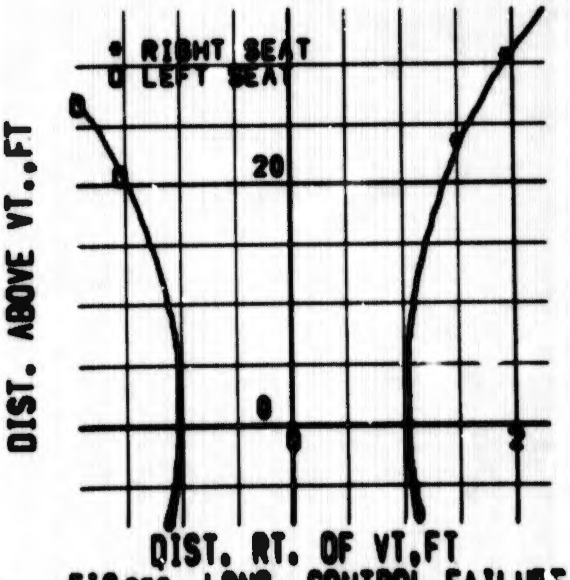


FIG 252 LONG. CONTROL FAILURE
VERTICAL TAIL CLEARANCE

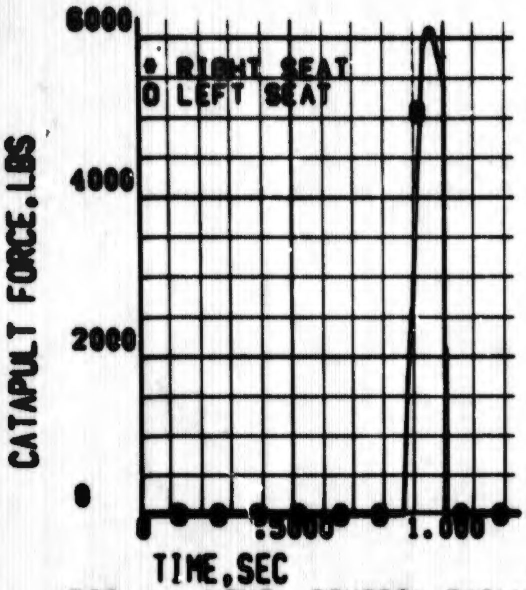


FIG 253 LONG. CONTROL FAILURE
CATAPULT FORCE ON SEAT

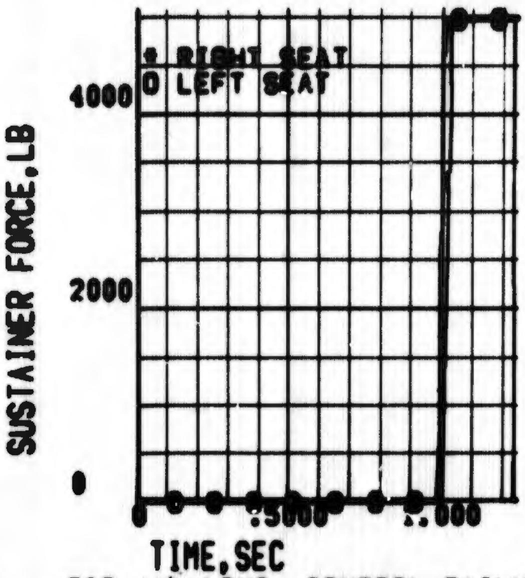


FIG 254 LONG. CONTROL FAILURE
SUSTAINER ROCKET FORCE ON SEAT

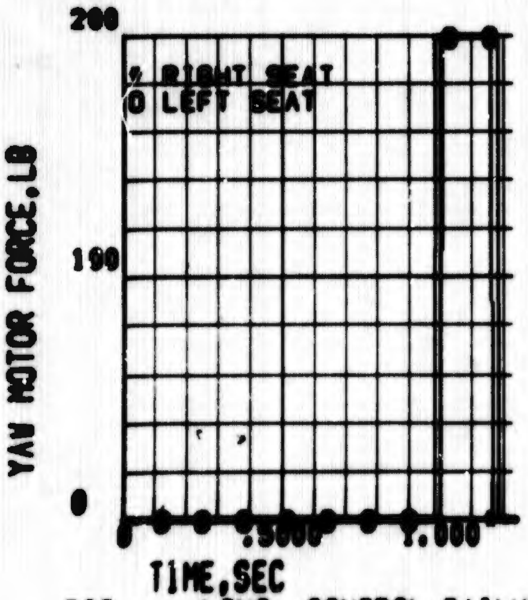


FIG 255. LONG. CONTROL FAILURE
YAW MOTOR FORCE ON SEAT

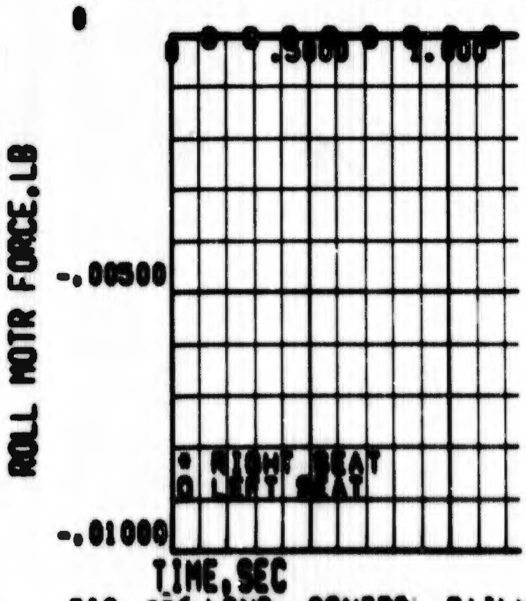


FIG 256 LONG. CONTROL FAILURE
ROLL MOTOR FORCE ON SEAT

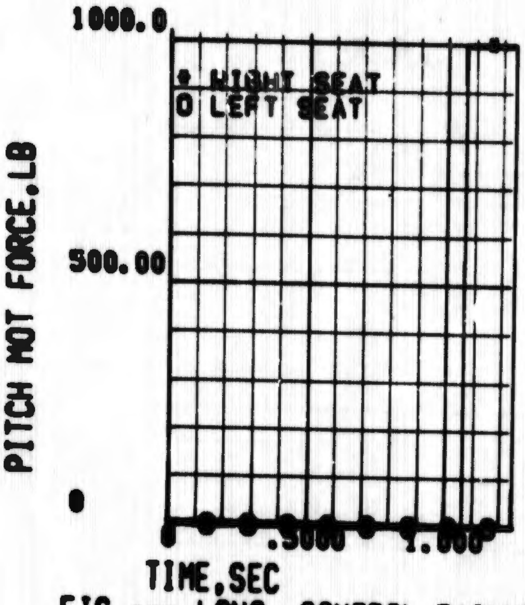


FIG 257 LONG. CONTROL FAILURE
PITCH MOTOR FORCE ON SEAT

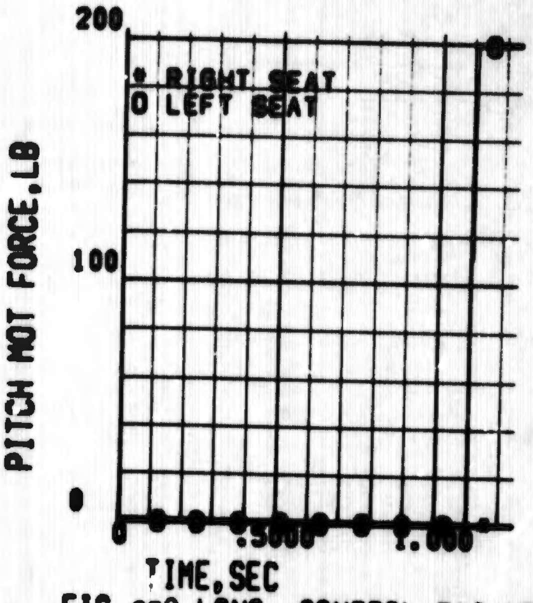


FIG 258 LONG. CONTROL FAILURE
PITCH MOTOR FORLE ON SEAT

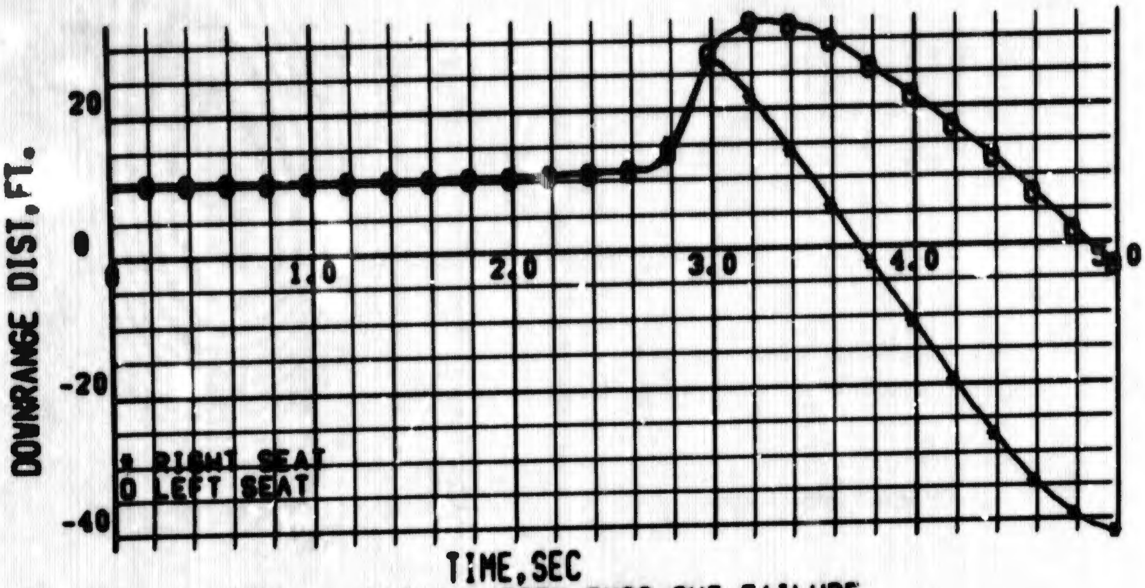


FIG 259 BOTH ENGS OUT FAILURE
SEAT AND/OR MAN DOWNRANGE DIST

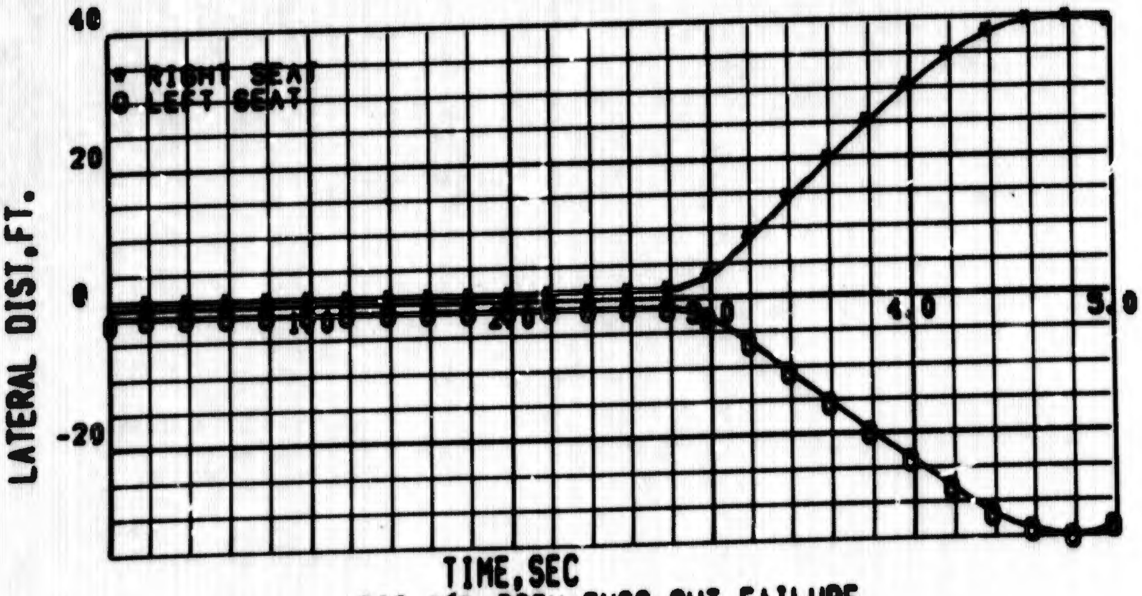


FIG 260 BOTH ENGS OUT FAILURE
SEAT AND/OR MAN LATERAL DIST.

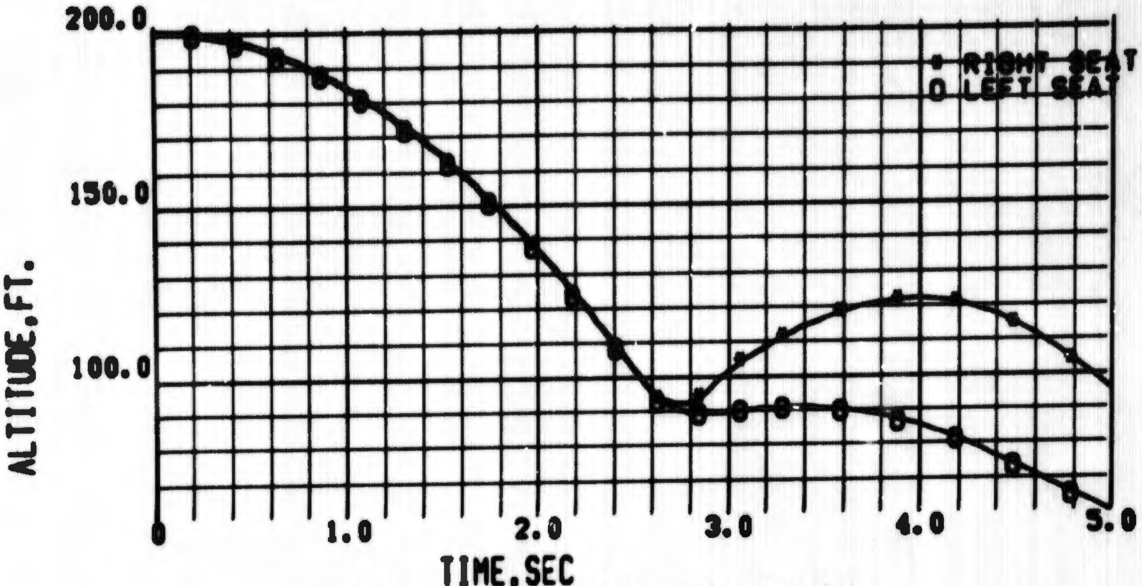


FIG 261 BOTH ENGS OUT FAILURE
SEAT AND/OR MAN ALTITUDE

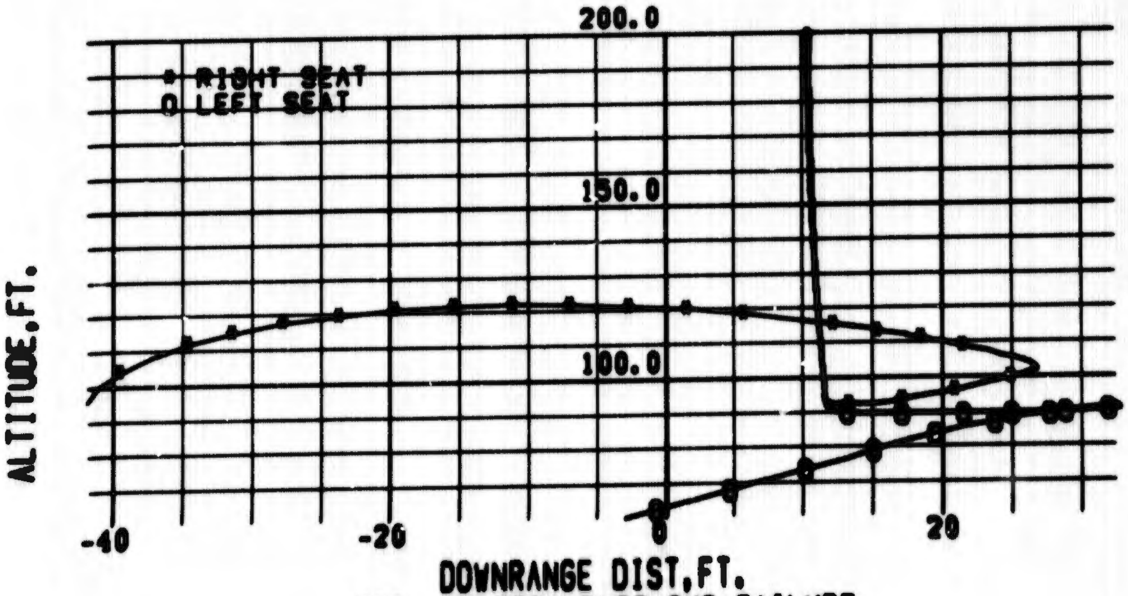


FIG 262 BOTH ENGS OUT FAILURE
SEAT-MAN TRAJECTORY

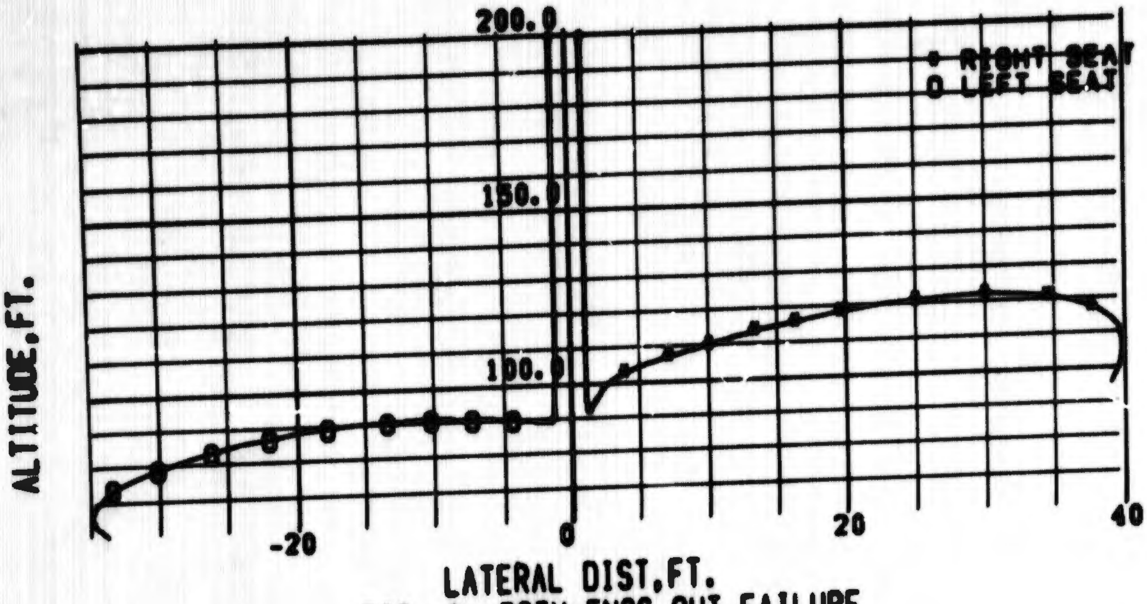


FIG 263 BOTH ENGS OUT FAILURE
SEAT-MAN TRAJECTORY

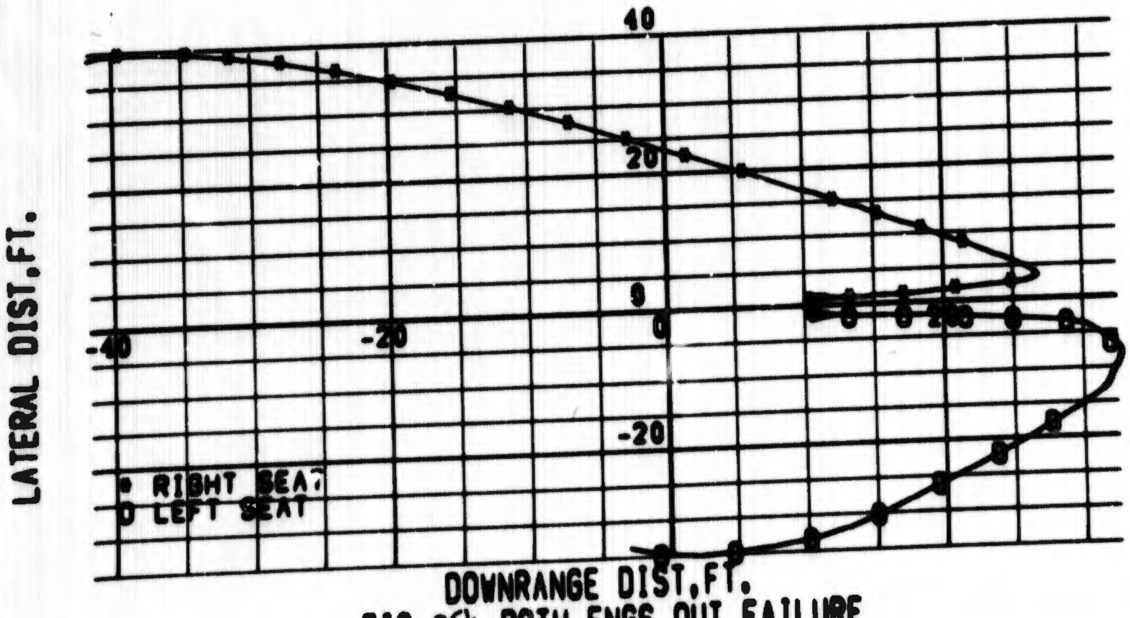


FIG 264 BOTH ENGS OUT FAILURE
SEAT-MAN TRAJECTORY

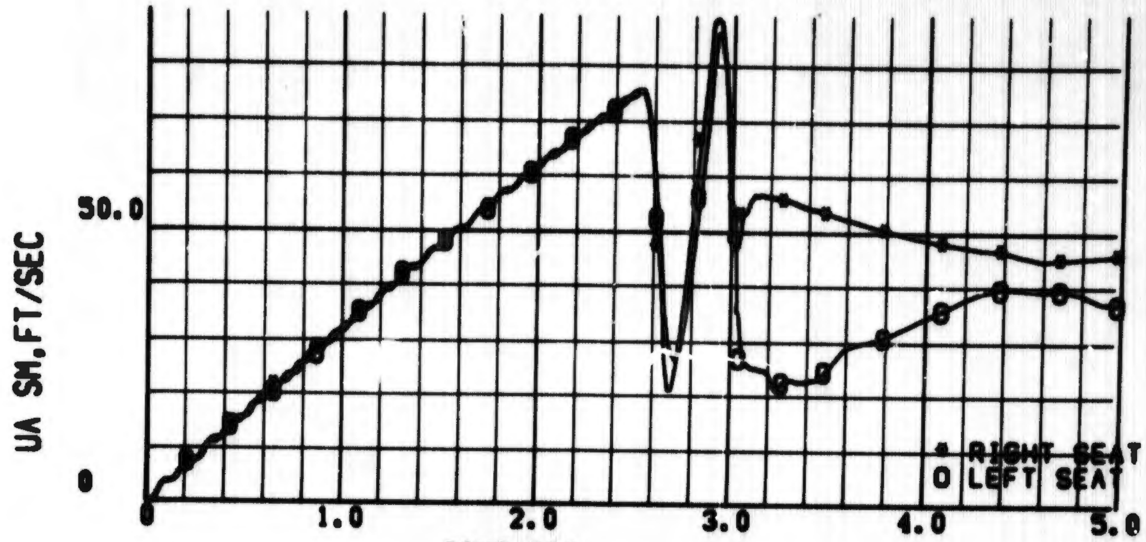


FIG 265 BOTH ENGS OUT FAILURE
SEAT AND/OR MAN TOTAL AIRSPEED

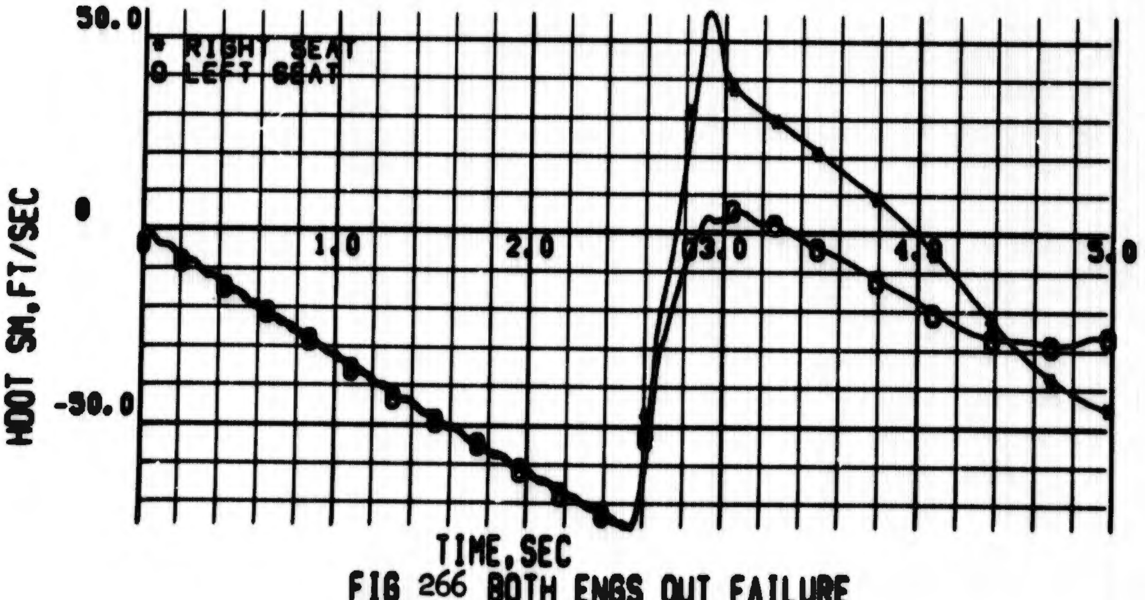


FIG 266 BOTH ENGS OUT FAILURE
SEAT AND/OR MAN CLIMB RATE

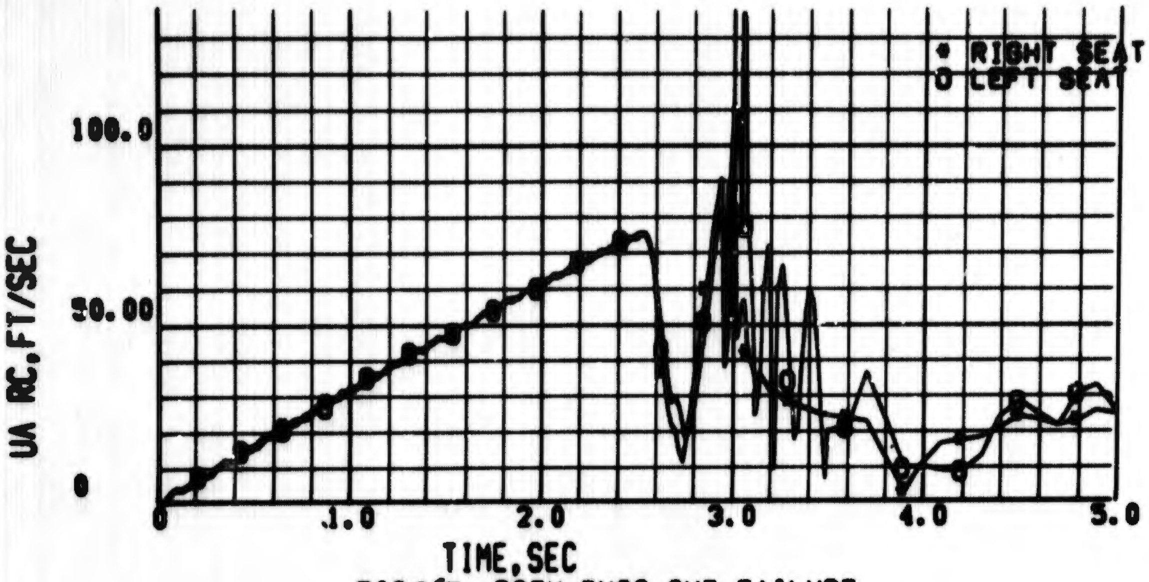


FIG 267 BOTH ENGS OUT FAILURE
PARACHUTE TOTAL AIRSPEED

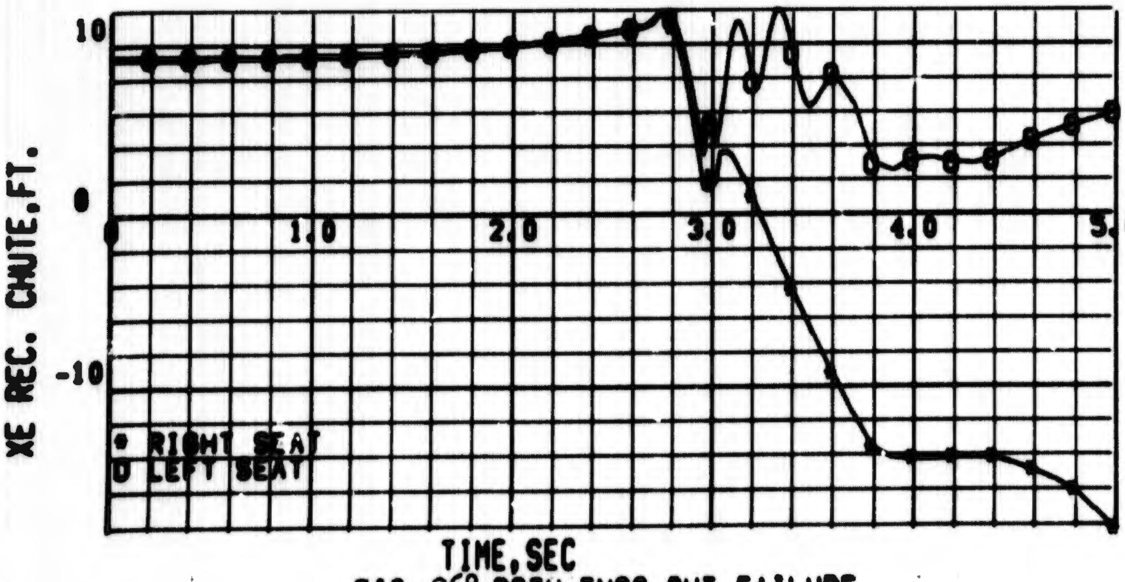


FIG 268 BOTH ENGS OUT FAILURE
PARACHUTE DOWNRANGE DISTANCE

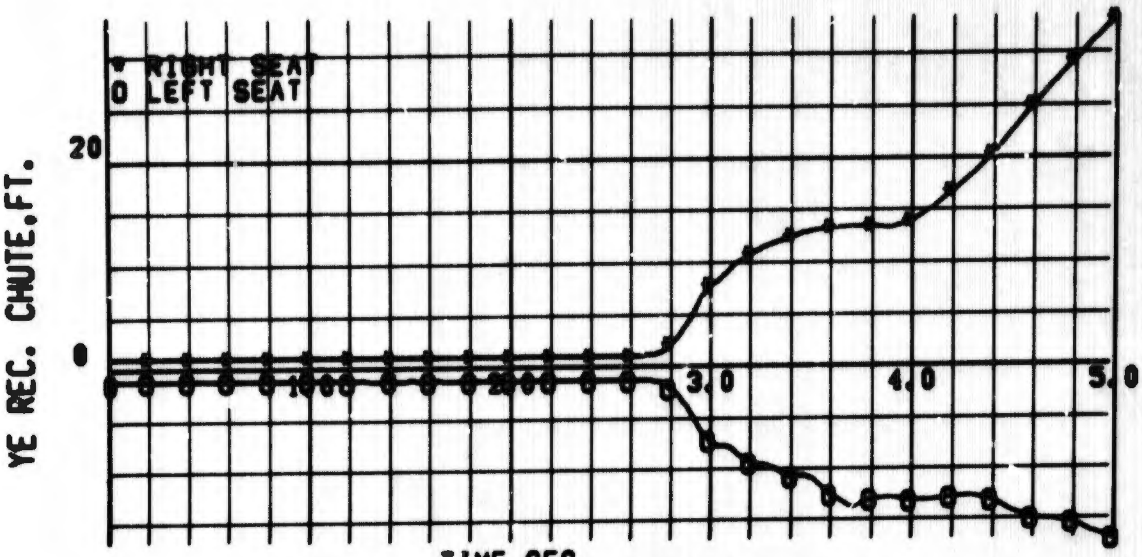


FIG 269 BOTH ENGS OUT FAILURE
PARACHUTE LATERAL DISTANCE

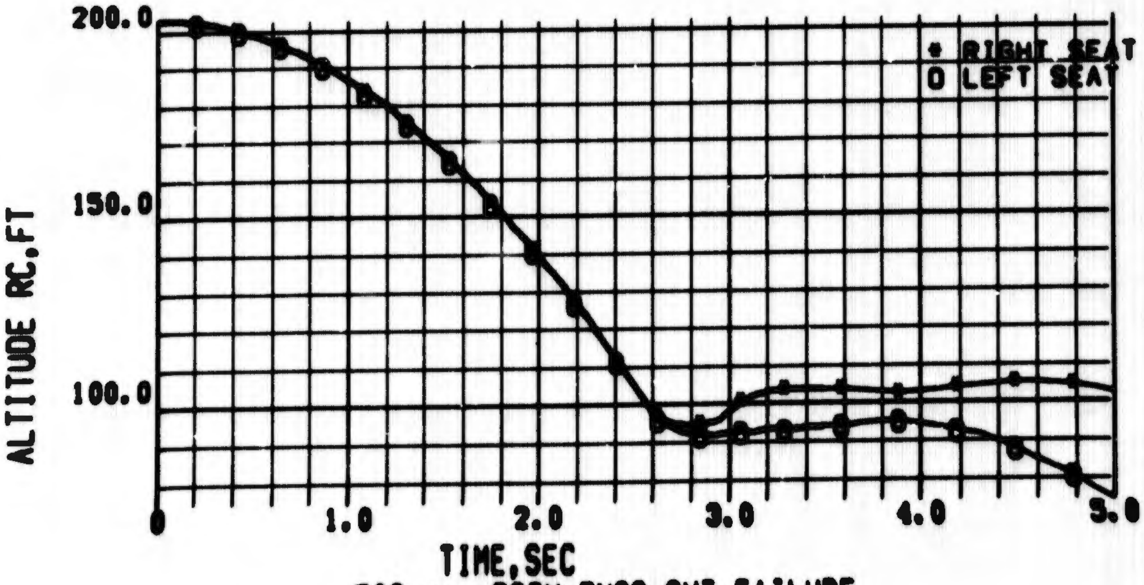


FIG 270 BOTH ENGS OUT FAILURE
PARACHUTE ALTITUDE

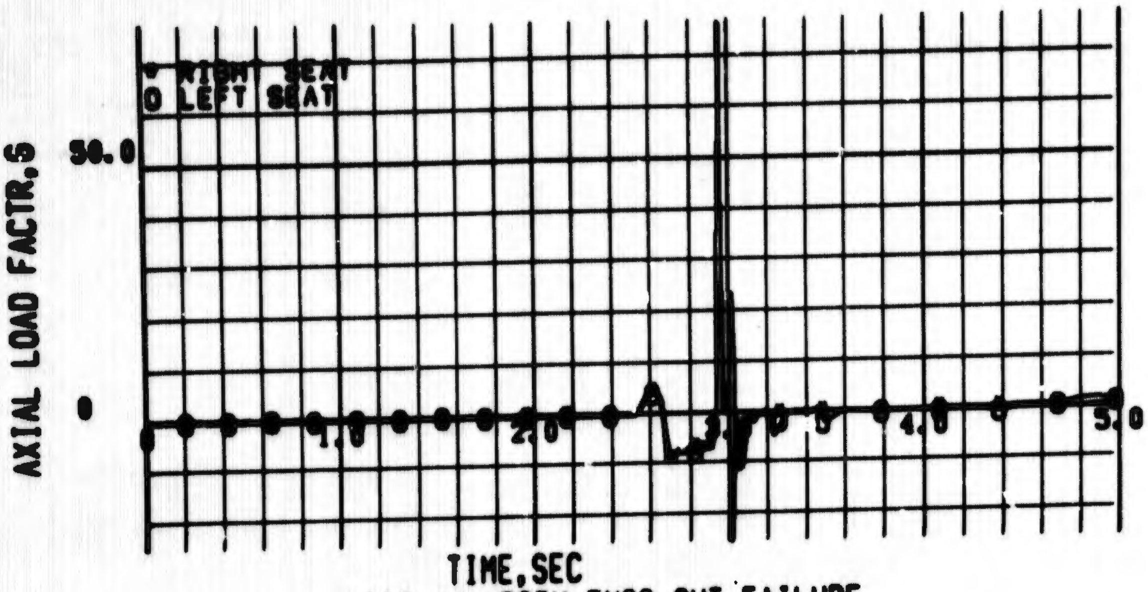


FIG 271 BOTH ENGS OUT FAILURE
SEAT-MAN AXIAL LOAD FACTOR,CG

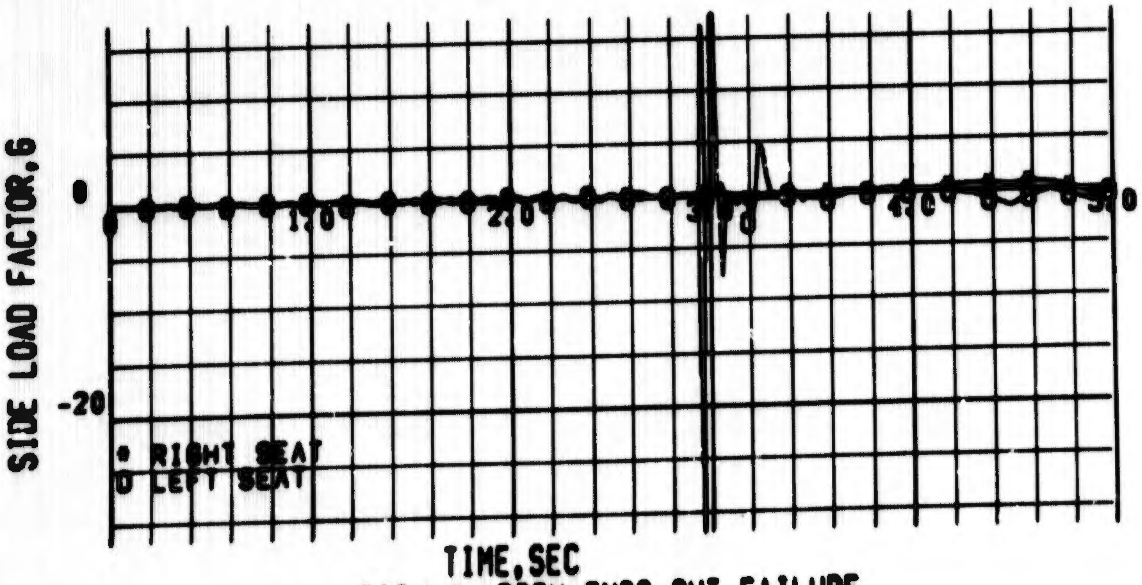


FIG 272 BOTH ENGS OUT FAILURE
SEAT-MAN SIDE LOAD FACTOR,CG

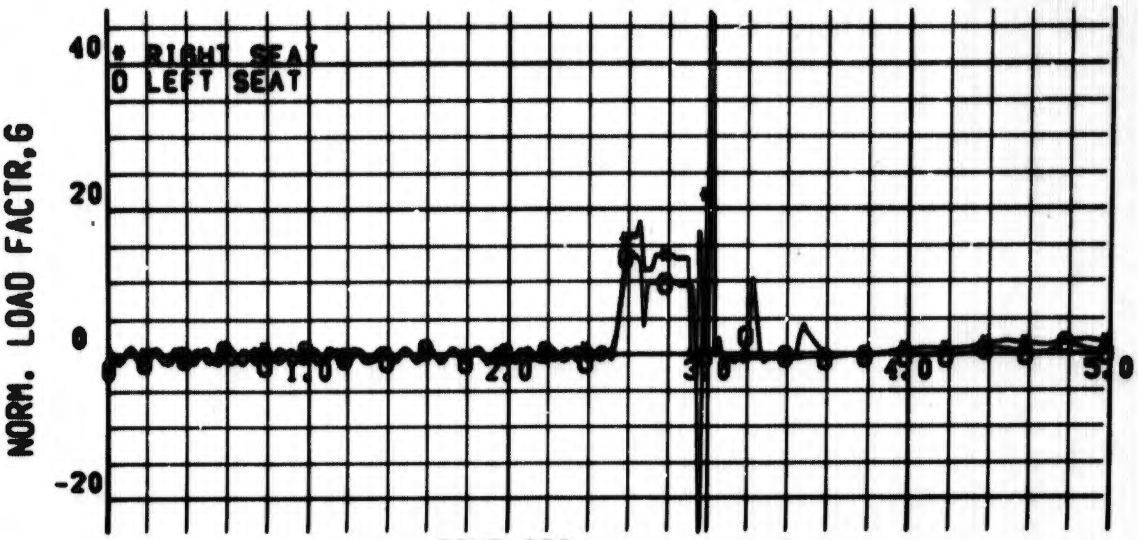


FIG 273 BOTH ENGS OUT FAILURE
SEAT-MAN NORMAL LOAD FACTOR, CG

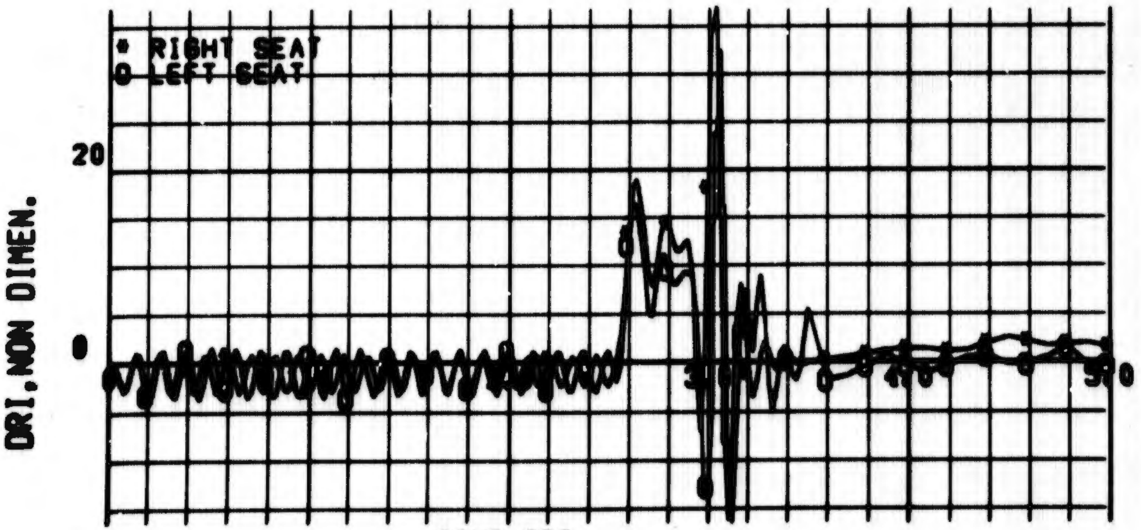


FIG 274 BOTH ENGS OUT FAILURE
PILOT DYNAMIC RESPONSE INDEX

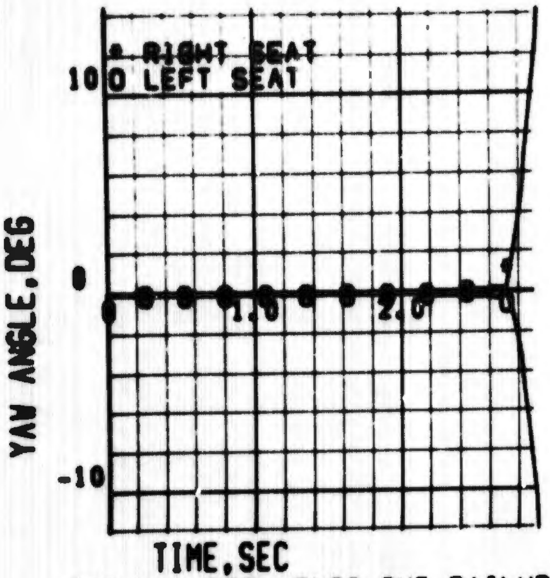


FIG 275 BOTH ENGS OUT FAILURE
SEAT-MAN EARTH AXIS YAW ANGLE

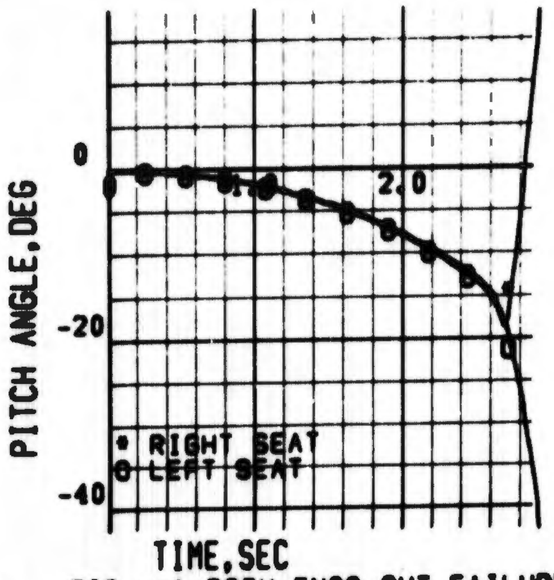


FIG. 276 BOTH ENGS OUT FAILURE
SEAT-MAN EARTH AXIS PITCH ANG.

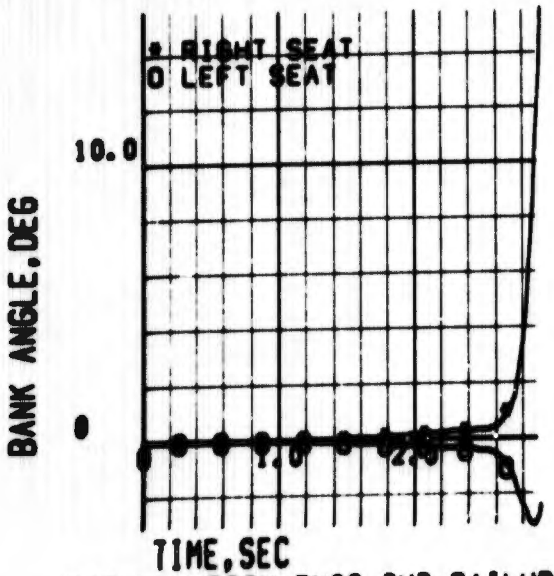


FIG 277 BOTH ENGS OUT FAILURE
SEAT-MAN EARTH AXIS BANK ANGLE

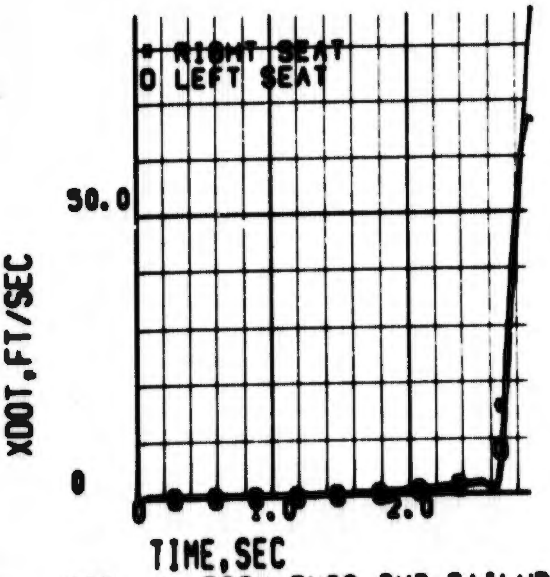


FIG 278 BOTH ENGS OUT FAILURE
SEAT-MAN DOWNRANGE VELOCITY

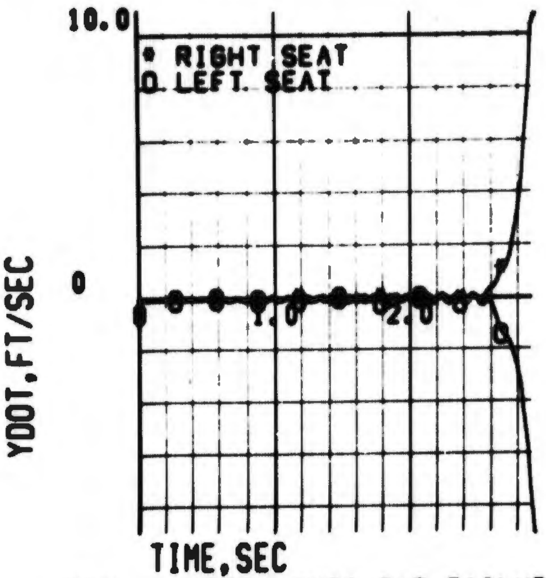


FIG 279 BOTH ENGS OUT FAILURE
SEAT-MAN LATERAL VELOCITY

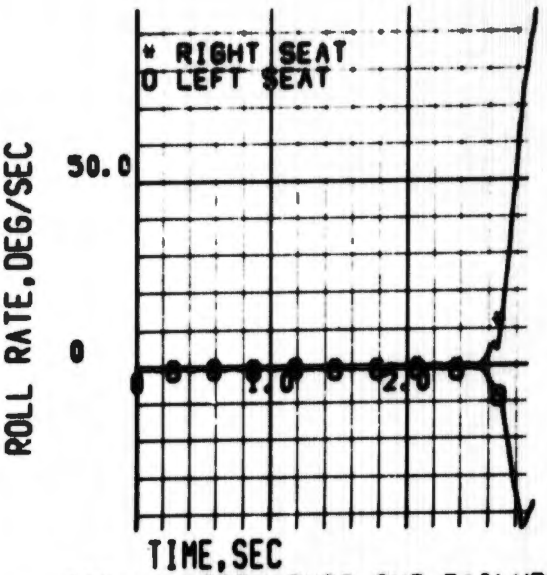


FIG 280 BOTH ENGS OUT FAILURE
SEAT-MAN ROLL RATE

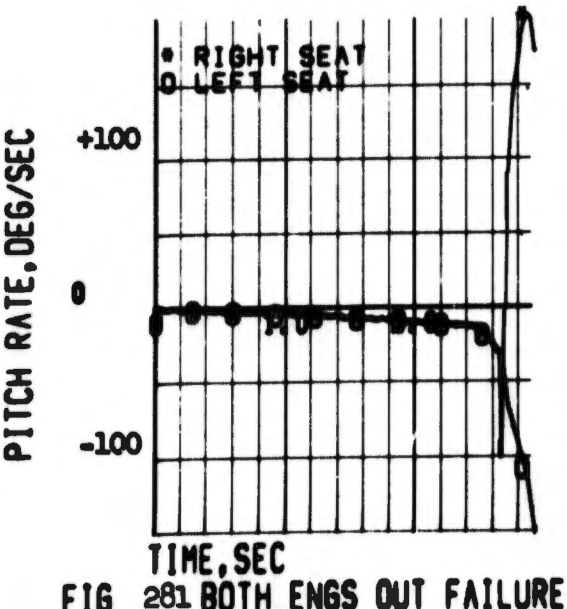


FIG 281 BOTH ENGS OUT FAILURE
SEAT-MAN PITCH RATE

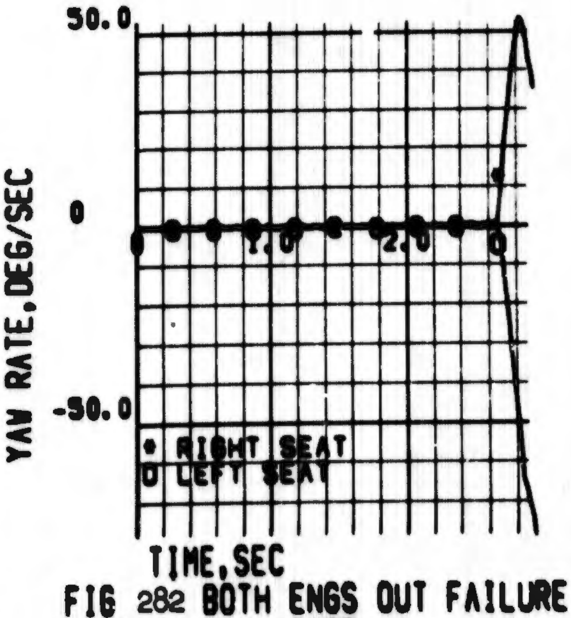


FIG 282 BOTH ENGS OUT FAILURE
SEAT-MAN YAW RATE

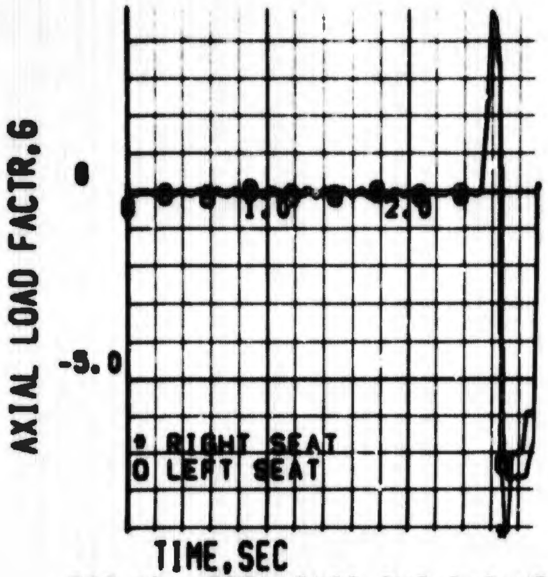


FIG 283 BOTH ENGS OUT FAILURE
AXIAL LOAD FACTOR,SEAT-MAN CG

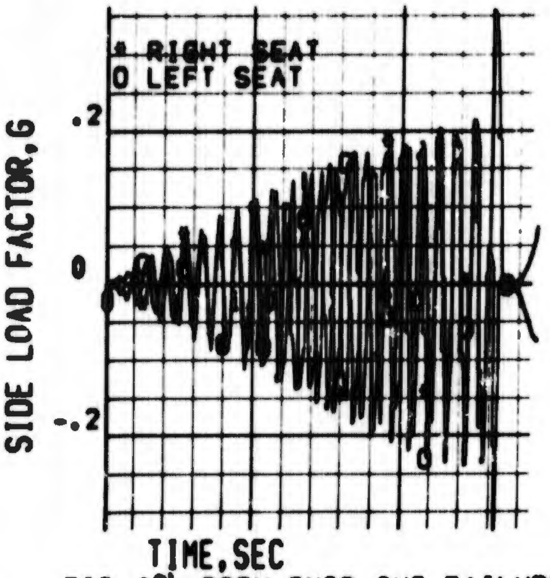


FIG 284 BOTH ENGS OUT FAILURE
SIDE LOAD FACTOR,SEAT-MAN CG

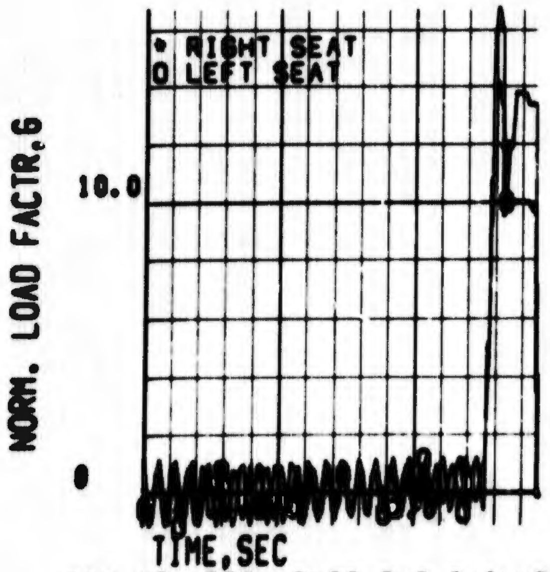


FIG 285 BOTH ENGS OUT FAILURE
NORMAL LOAD FACTOR,SEAT-MAN CG

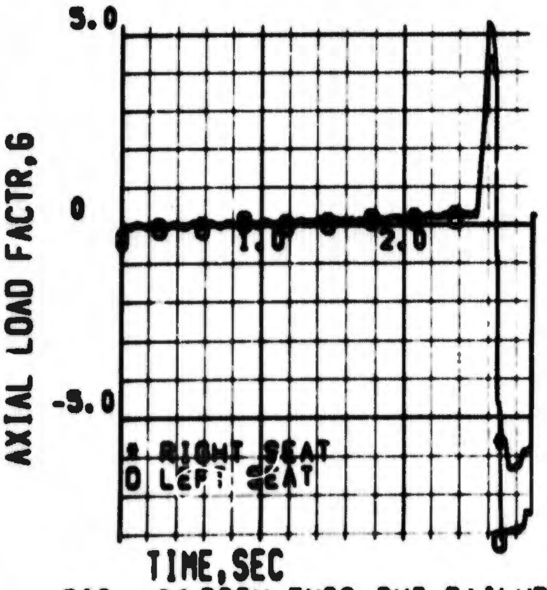


FIG 286 BOTH ENGS OUT FAILURE
AXIAL LD. FACT. AT PILOTS HEAD

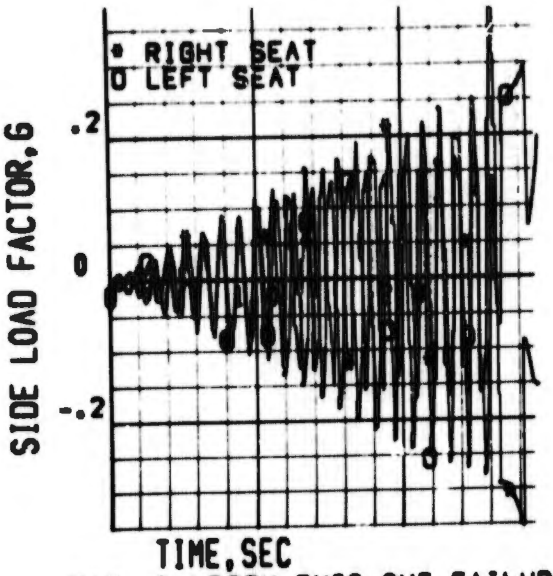


FIG 287 BOTH ENGS OUT FAILURE
SIDE LOAD FACT. AT PILOTS HEAD

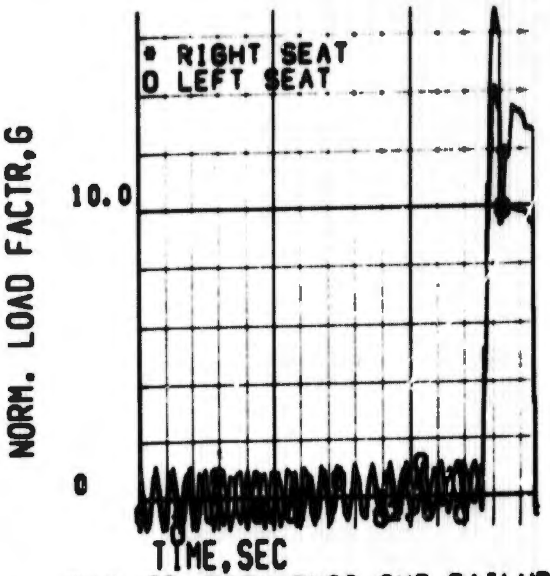


FIG 288 BOTH ENGS OUT FAILURE
NORM. LD. FACT. AT PILOTS HEAD

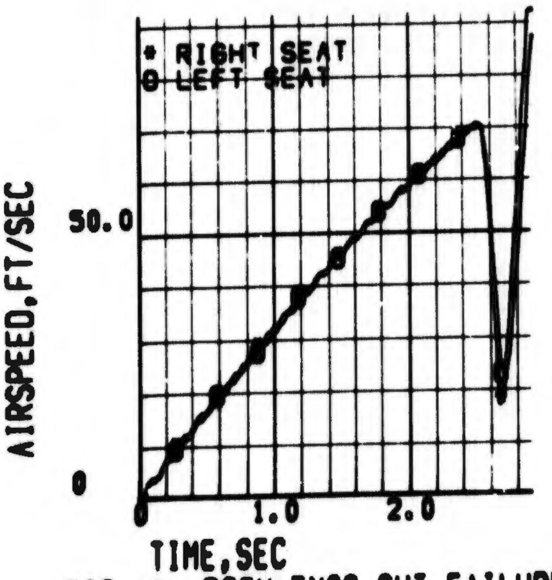


FIG 289 BOTH ENGS OUT FAILURE
SEAT-MAN TOTAL AIRSPEED

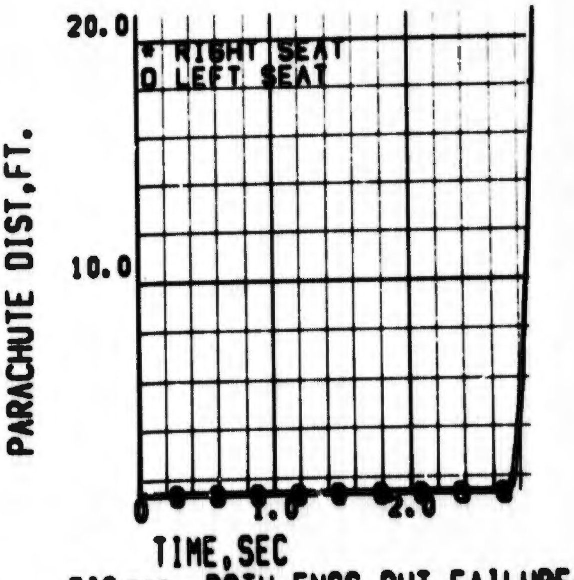


FIG 290 BOTH ENGS OUT FAILURE
DIST. FROM BRIDLE TO CHUTE CG

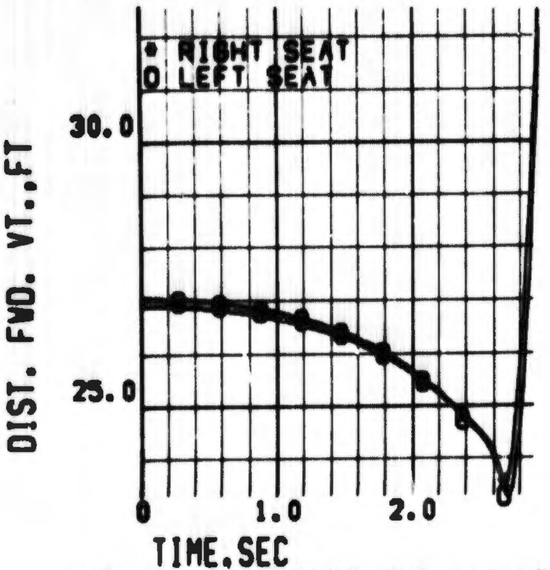


FIG 291 BOTH ENGS OUT FAILURE
VERT. TAIL LONG. CLEARANCE

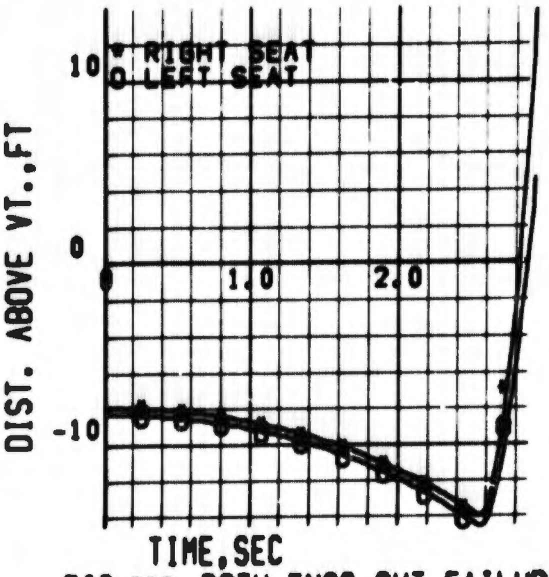


FIG 292 BOTH ENGS OUT FAILURE
VERT. TAIL VERT. CLEARANCE

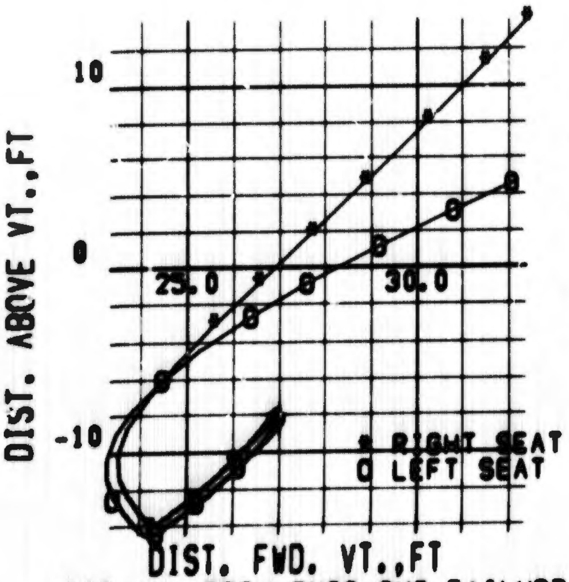


FIG 293 BOTH ENGS OUT FAILURE
VERTICAL TAIL CLEARANCE

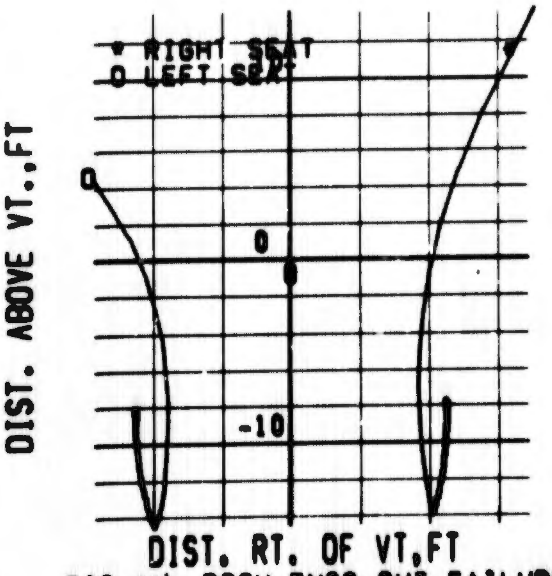


FIG 294 BOTH ENGS OUT FAILURE
VERTICAL TAIL CLEARANCE

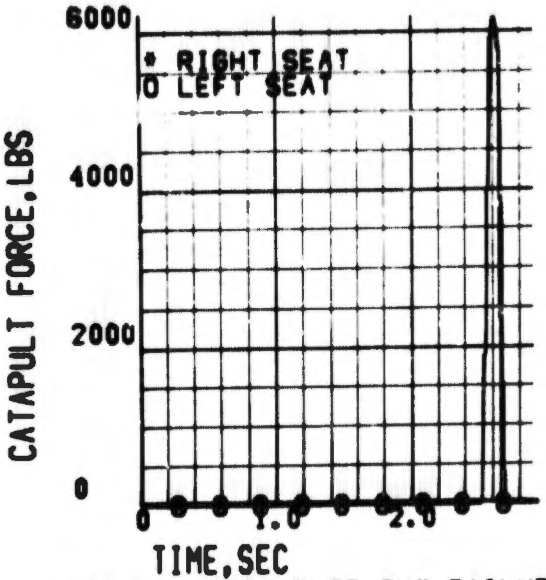


FIG 295 BOTH ENGS OUT FAILURE
CATAPULT FORCE ON SEAT

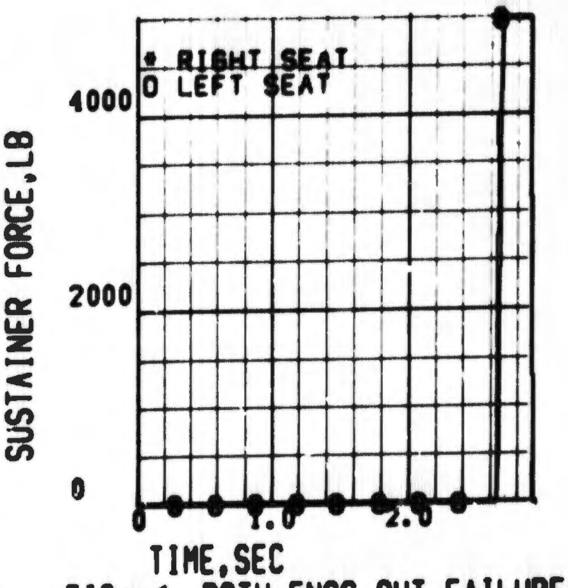


FIG 296 BOTH ENGS OUT FAILURE
SUSTAINER ROCKET FORCE ON SEAT

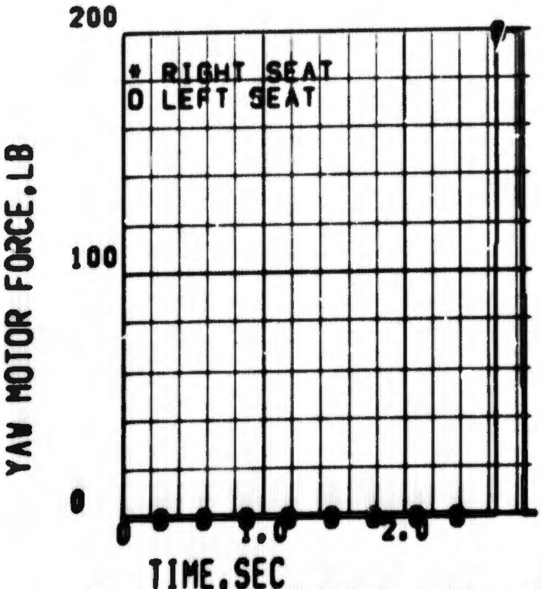


FIG 297 BOTH ENGS OUT FAILURE
YAW MOTOR FORCE ON SEAT

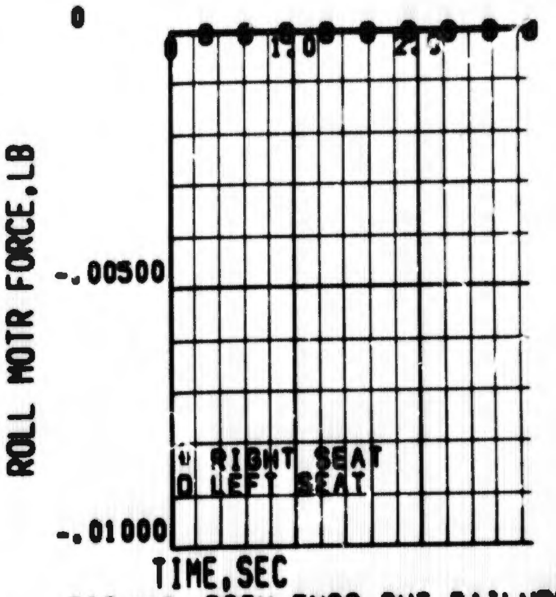


FIG 298 BOTH ENGS OUT FAILURE
ROLL MOTOR FORCE ON SEAT

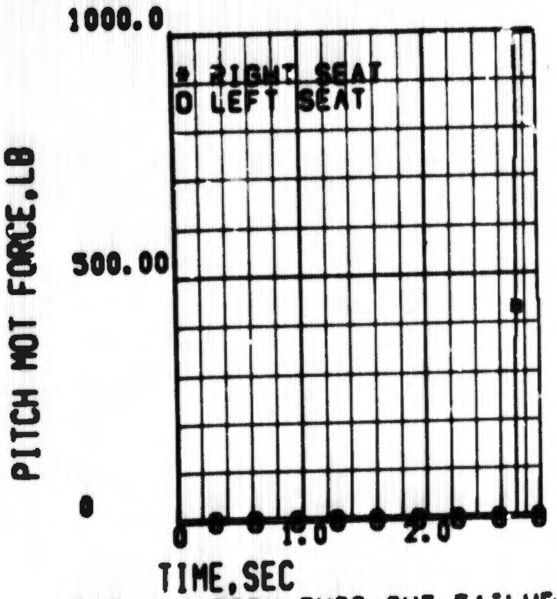


FIG 299 BOTH ENGS OUT FAILURE
PITCH MOTOR FORCE ON SEAT

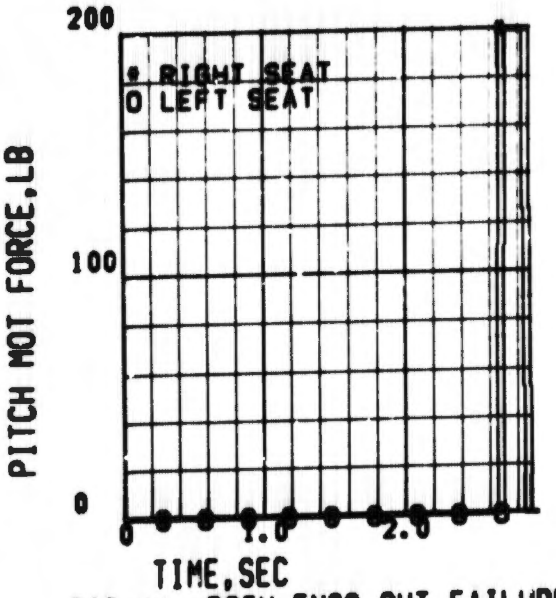


FIG 300 BOTH ENGS OUT FAILURE
PITCH MOTOR FORCE ON SEAT

APPENDIX II

CONVENTIONAL FLIGHT FAILURES

MIL-S-9479A INITIAL CONDITIONS TIME HISTORIES

Figures 301 through 484 show the performance of the VTOL escape system for the initial conditions specified in Spec. MIL-S-9479A "Seat System, Upward Ejection, Aircraft, General Specification for" in the form of time histories The initial conditions are tabulated in Table VIII. The time histories are plotted to show the seat-man, recovery parachute and the man alone spatial positions and velocities along with the accelerations imparted by catapult, rockets, parachutes, rail forces, and aerodynamic forces and moments.

Each time history is begun at the point of manual initiation of sequenced escape. Thereafter all events occur automatically and in accordance with Table VIII. It will be noted that 100 milliseconds is allowed for thermal battery rise time. This time plus the 275 millisecond delay incorporated in the PEEP for canopy clearance provides 375 milliseconds from ejection initiation to seat motion. The second seat, left hand, is sequenced 200 milliseconds later which, with the left seat thermal battery rise time of 100 milliseconds, yields a 300 millisecond separation in time. Table VII Appendix I gives detailed simulation input data.

Each time history is terminated at 5.0 seconds, a sufficient time to assess the recovery potential except Case 3 where ejection occurs at 38000 feet and the recovery parachute is deployed at 15000 feet mean sea level.

An explanation of the variables displayed in the time histories will be made by selecting Case 8, shown in Figures 421 through 436, as an example. In this case the aircraft is in a 60° dive at 200 KEAS with a 60° bank angle. The resulting sink rate is 17,500 feet per minute.

Figures 421 through 426 are plots and trajectory cross-plots of the earth axis relative positions of the seat-man center of gravity of the left and right seats.

Figures 430, 431 and 432 are plots of the earth axis relative positions of the parachute canopy centers of gravity of the left and right seats. These data allow an evaluation of the collision potential between seats and parachutes.

Velocity plots are shown in Figures 427 , 428, and 429. From these a determination of the position of safe recovery may be made. Since the dynamic behavior of the man suspended on the inflated parachute canopy cannot be controlled, it is concluded that the point of safe recovery is best defined as that point where the total velocity of the inflated parachute canopy is equal to the man-parachute terminal velocity.

Figure 429, the parachute total airspeed plot shows this velocity at 1.5 seconds and at 1.8 seconds for the right and left seats respectively. Reference to Figure 423, the seat and man altitude plot shows the center of gravity of the 5 percentile man at an altitude of 280' and the 95 percentile at 185 feet. Stated in terms of altitude loss, the first man ejected, right seat, required 270 feet and the second man, left seat, required 365 feet. This may be compared with the 550 feet allowable in MIL-S-9479. Figures 433 through 436 are plots of the load factors experienced by each man and the dynamic response index as defined by Reference 5 of Part I, Volume 2. It is important to remember that the acceleration plots show seat-man body axis values, not earth axis accelerations.

TABLE VIII - EVENT TIMING

CASE	AIRCRAFT INITIAL CONDITIONS					EVENT TIMES (NOTE 1) L.H. SEAT Ejected Weight = 419. #								R.H. SEAT Ejected Weight = 354. #	
	PITCH	ROLL	SINK RATE	VEL.	ALT.	CATAPULT	SUSTAINER	YAW MOTOR	CHUTE ROCKET	ROLL MOTOR	ROLL MOTOR	DROGUE CHUTE	SEAT/MAN SEP.	CATAPULT	
1	0	0	0	0	0	.675 sec. Note 7	Yes	2	2	No	No	No	6	.375 sec. Note 7	
2	0	0	0	600.K	200.'		Yes	2	3	No	No	2	4		Other data same as L.H. seat
3	0	0	0	MN = 2	38000.'		Yes	2	2	No	No	2			
4	0	60°	0	120.K	0		Yes	2	2	2	5	No			
5	0	180°	0	150.K	200.'		No	No	2	No	No	No			
6	0	0	-10000. FPM	150.K	300.'		Yes	2	2	No	No	No			
7	-60°	0	-17500. FPM	200.K	500.'		No	No	2	No	No	No			
8	-60°	60°	-17500. FPM	200.K	550.'		No	No	2	No	No	No			
9	-45°	180°	-18000. FPM	250.K	600.'		No	No	2	No	No	No			
10	0	180°	0	600.K	200.'		No	No	3	No	No	2	6		
11	0	90°	0	600.K	200.'	.675 sec.	No	No	3	No	No	2		.375 sec. Note 7	

L.H. SEAT THRUST LINE 1.00" ABOVE C.G.

R.H. SEAT THRUST LINE 3.00 " BELOW C.G.

NOTES:

1. Ejection initiation is t = 0.
2. Rail trip switch
3. Rail trip switch + 1.00 sec.
4. When altitude of seat/man = 15000. ft.
5. Rail trip switch + .14 sec.
6. Chute rocket + .30 sec.
7. Includes 100 M.S. thermal battery rise time

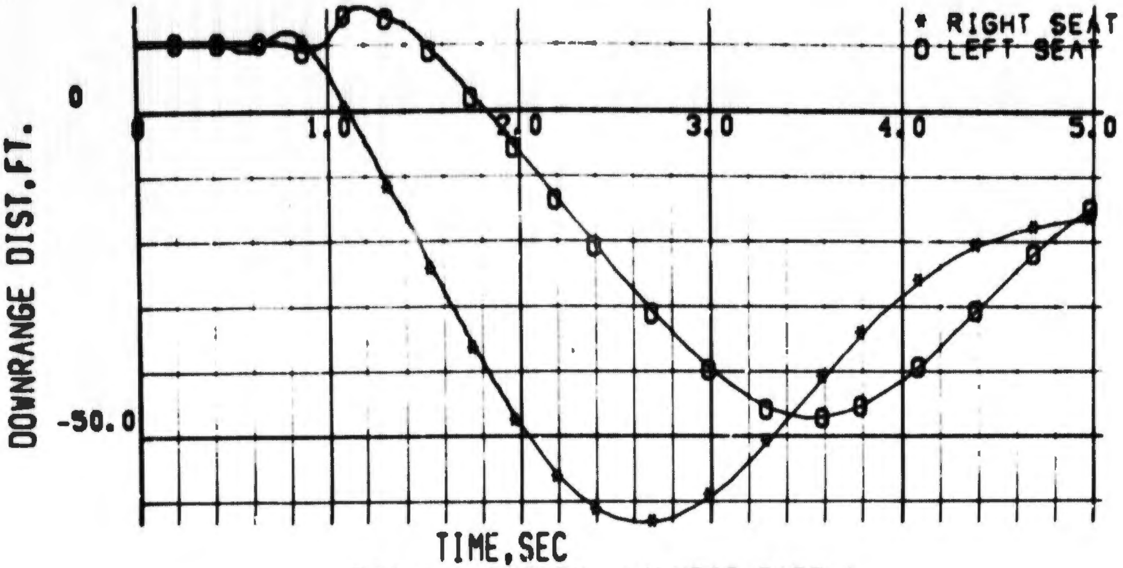


FIG 301 SYSTEM ANALYSIS,CASE-1
SEAT AND/OR MAN DOWNRANGE DIST

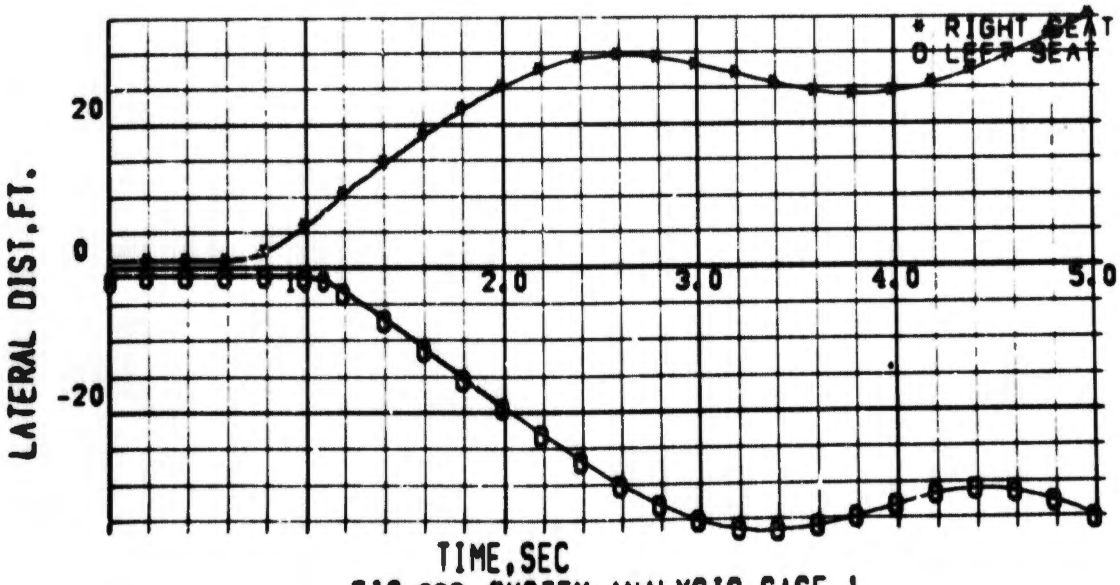


FIG 302 SYSTEM ANALYSIS,CASE-1
SEAT AND/OR MAN LATERAL DIST.

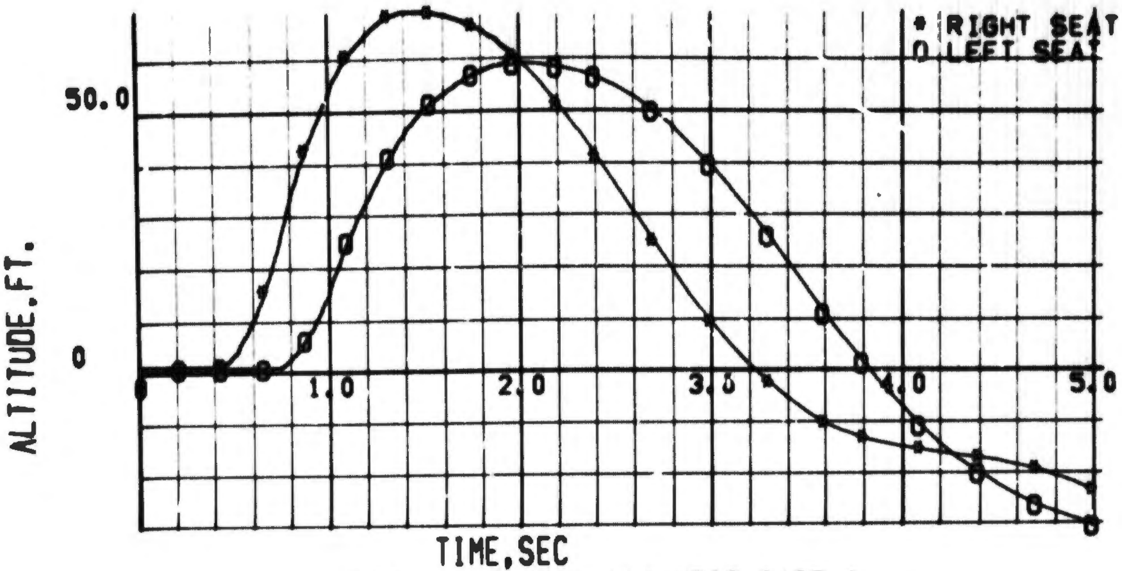


FIG 303 SYSTEM ANALYSIS, CASE-1
SEAT AND/OR MAN ALTITUDE

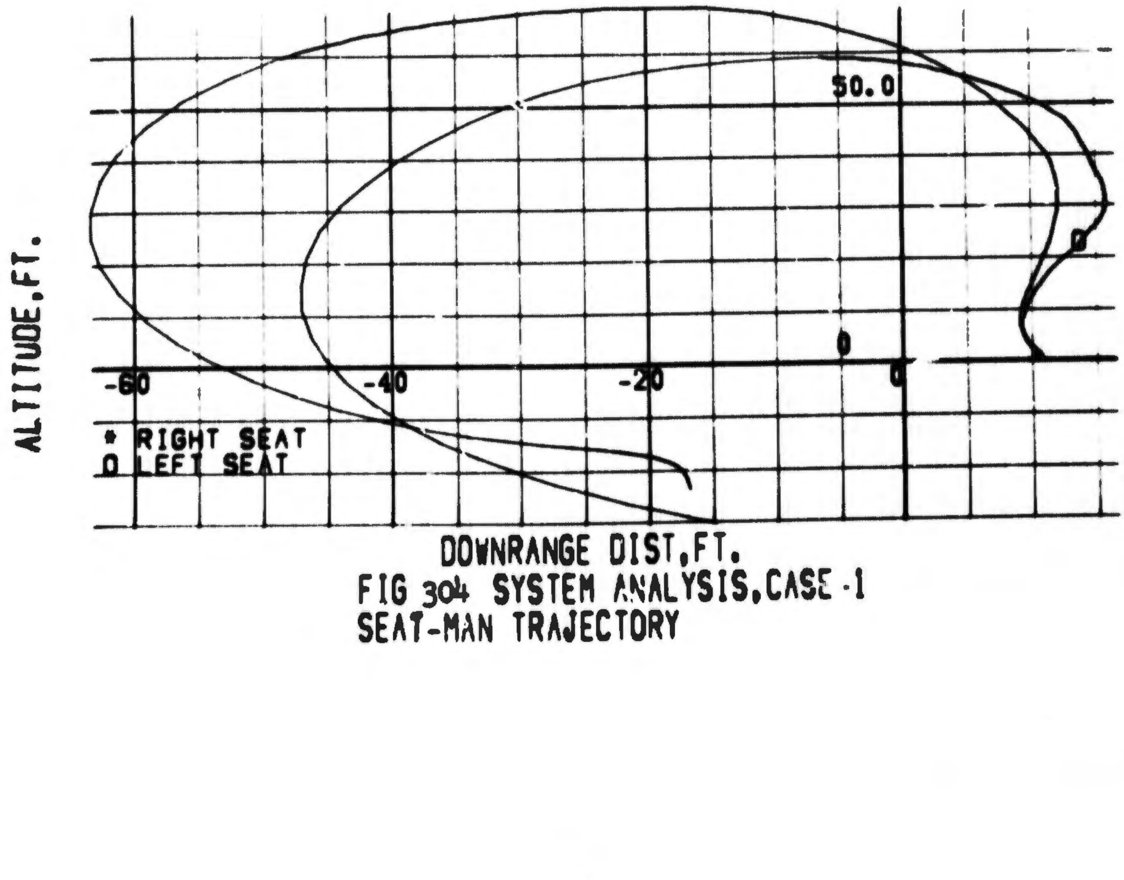


FIG 304 SYSTEM ANALYSIS, CASE-1
SEAT-MAN TRAJECTORY

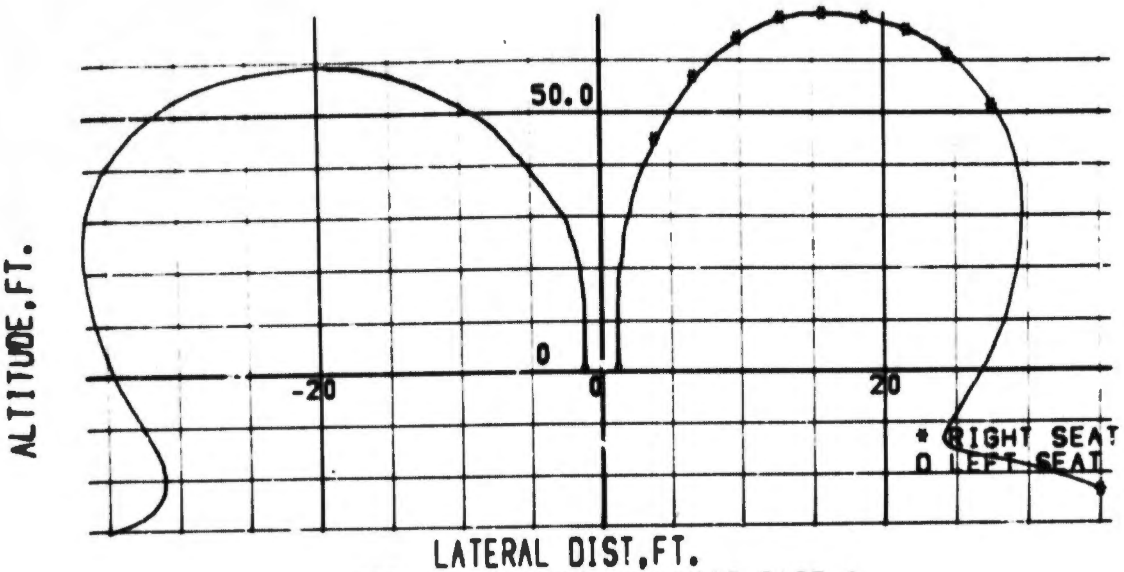


FIG 305 SYSTEM ANALYSIS, CASE-1
SEAT-MAN TRAJECTORY

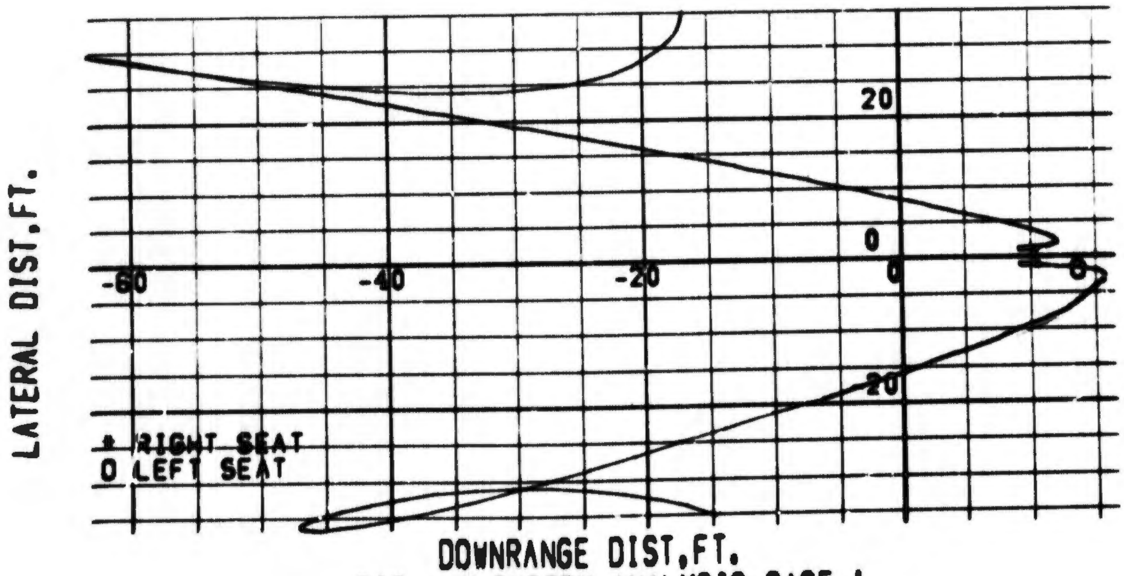


FIG 306 SYSTEM ANALYSIS, CASE-1
SEAT-MAN TRAJECTORY

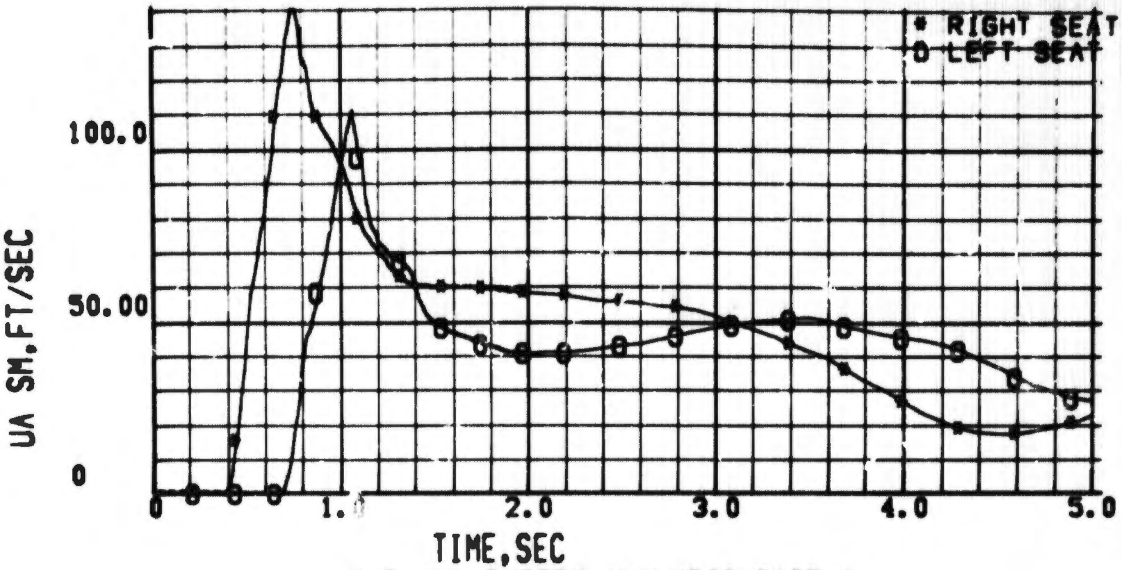


FIG 307 SYSTEM ANALYSIS,CASE-1
SEAT AND/OR MAN TOTAL AIRSPEED

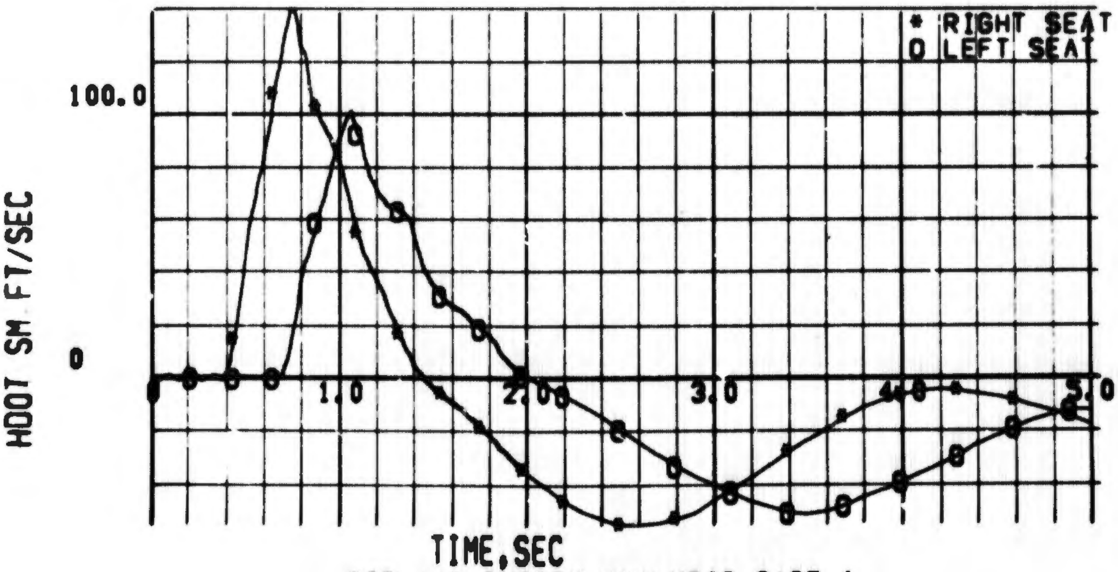


FIG 308 SYSTEM ANALYSIS,CASE-1
SEAT AND/OR MAN CLIMB RATE

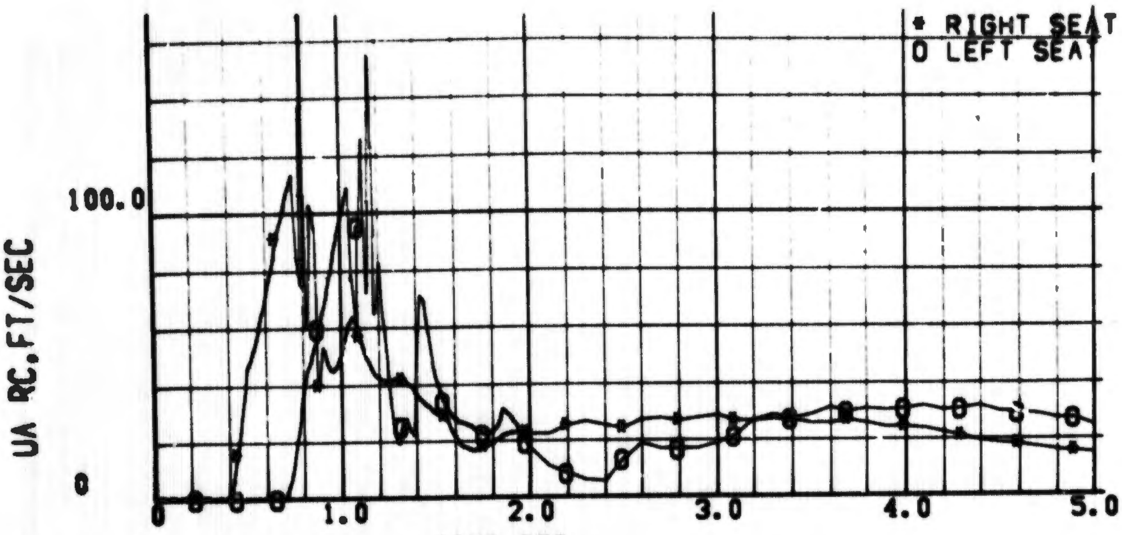


FIG 309 SYSTEM ANALYSIS,CASE-1
PARACHUTE TOTAL AIRSPEED

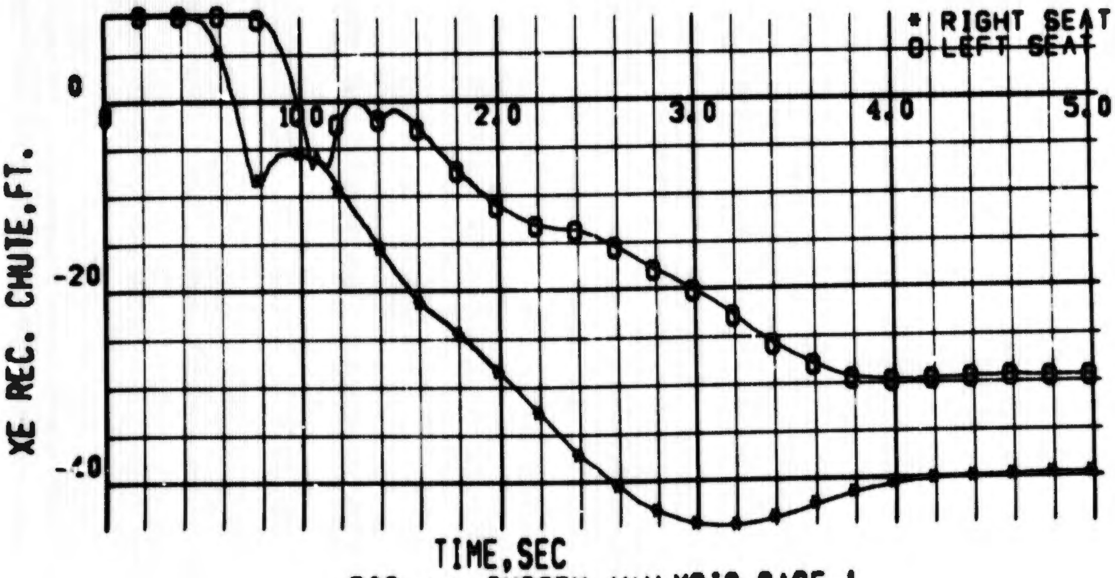


FIG 310 SYSTEM ANALYSIS,CASE-1
PARACHUTE DOWNRANGE DISTANCE

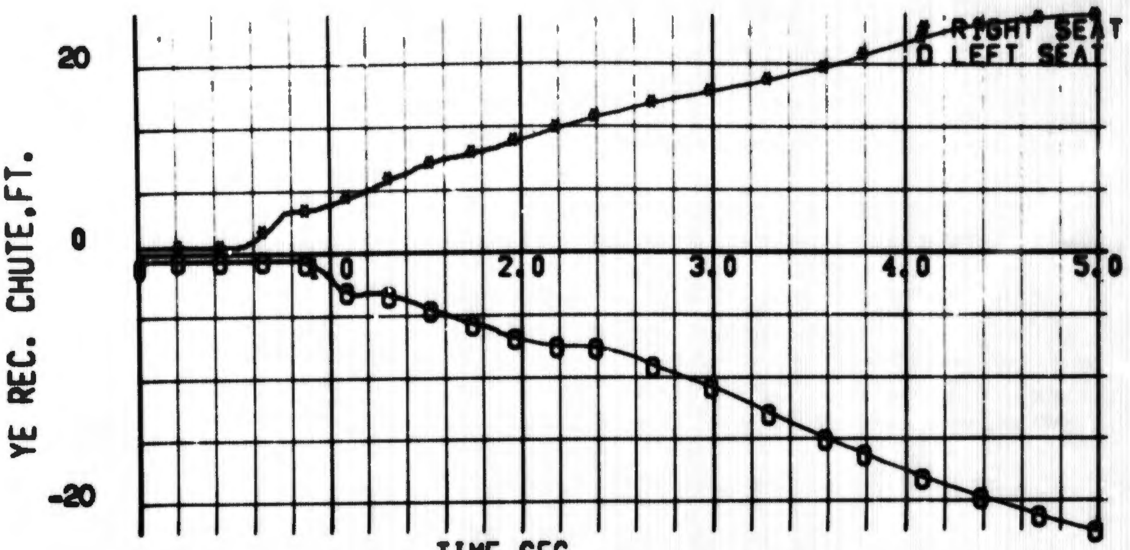


FIG 311 SYSTEM ANALYSIS,CASE-1
PARACHUTE LATERAL DISTANCE

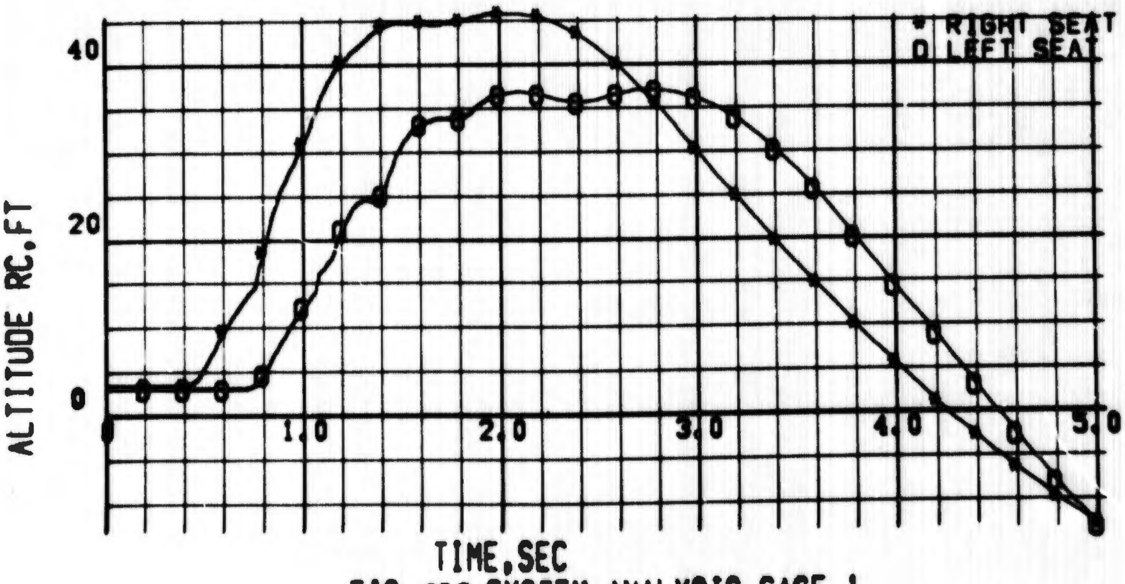


FIG 312 SYSTEM ANALYSIS,CASE-1
PARACHUTE ALTITUDE

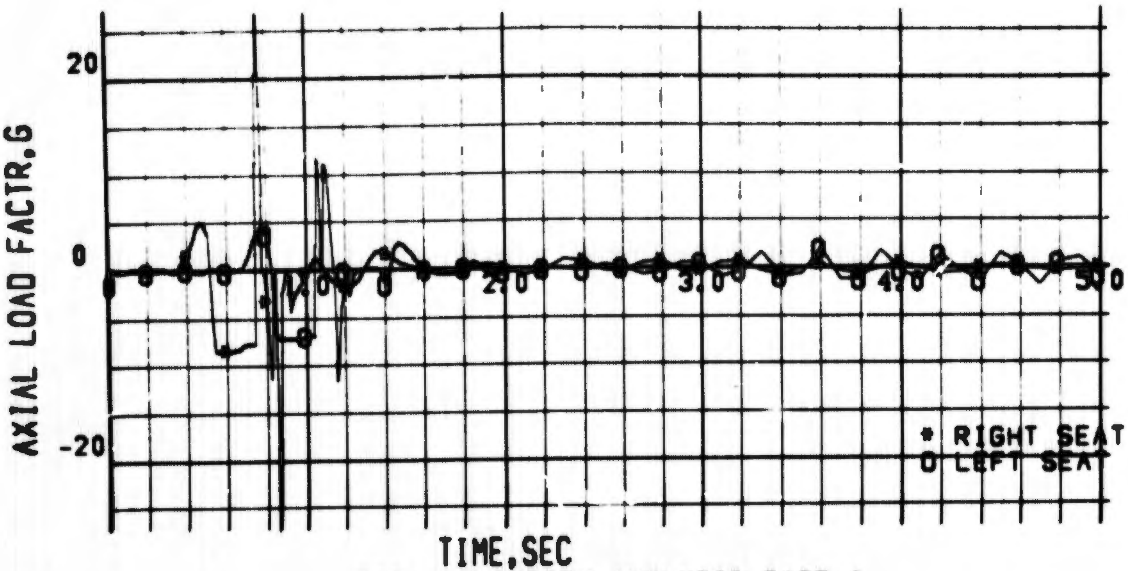


FIG 313 SYSTEM ANALYSIS,CASE-1
SEAT-MAN AXIAL LOAD FACTOR,CG

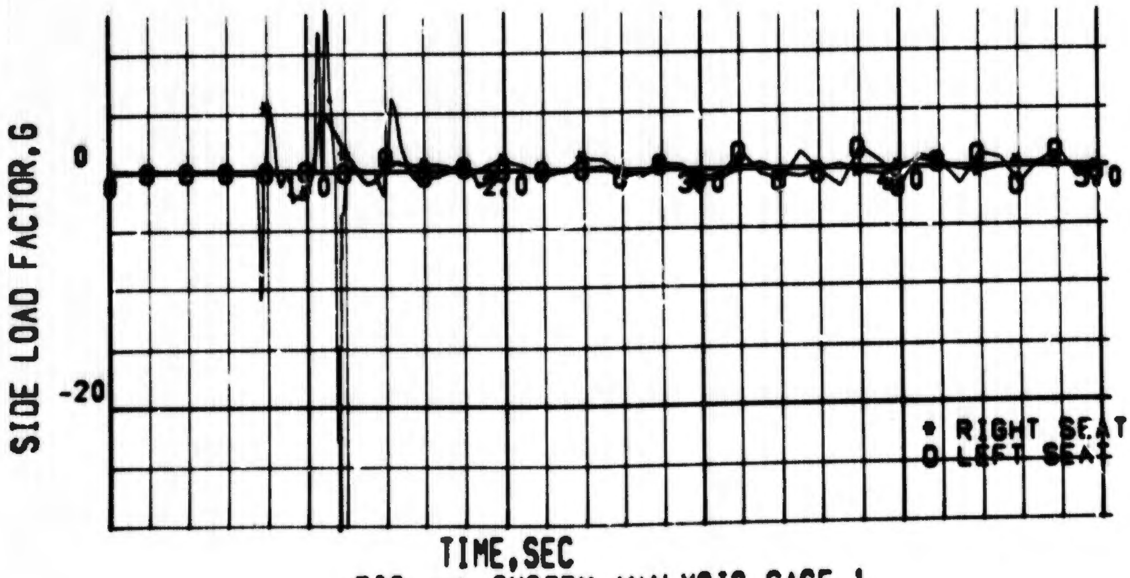


FIG 314 SYSTEM ANALYSIS,CASE-1
SEAT-MAN SIDE LOAD FACTOR,CG

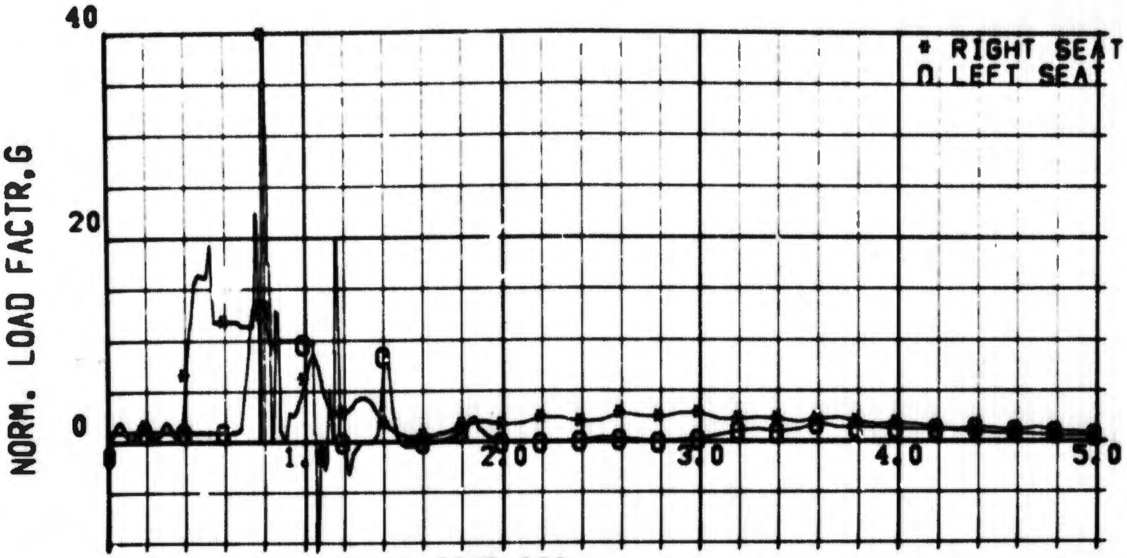


FIG 315 SYSTEM ANALYSIS,CASE-1
SEAT-MAN NORMAL LOAD FACTOR,CG

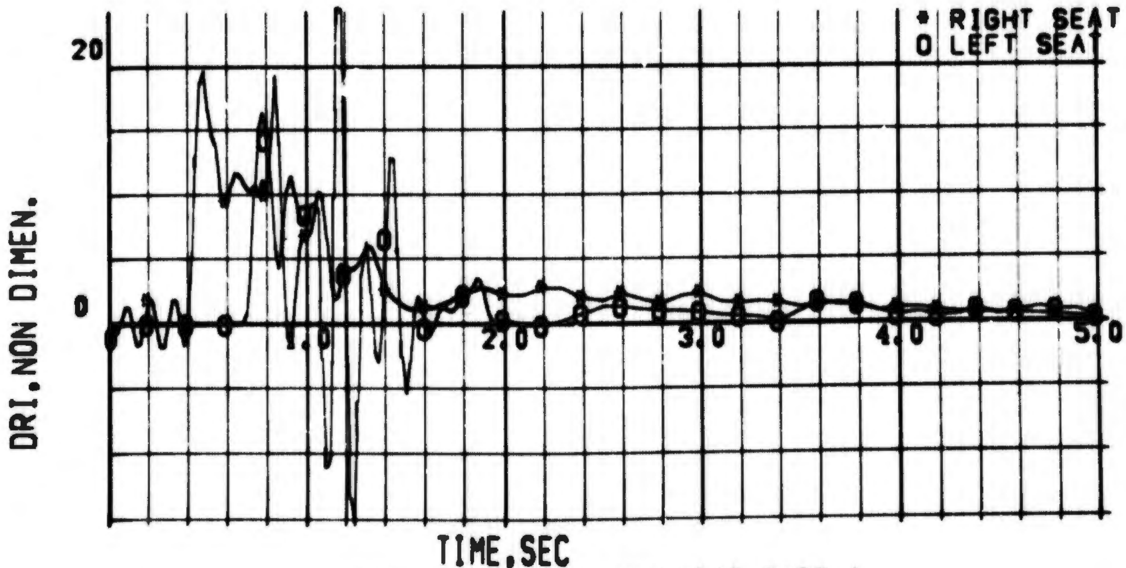


FIG 316 SYSTEM ANALYSIS,CASE-1
PILOT DYNAMIC RESPONSE INDEX

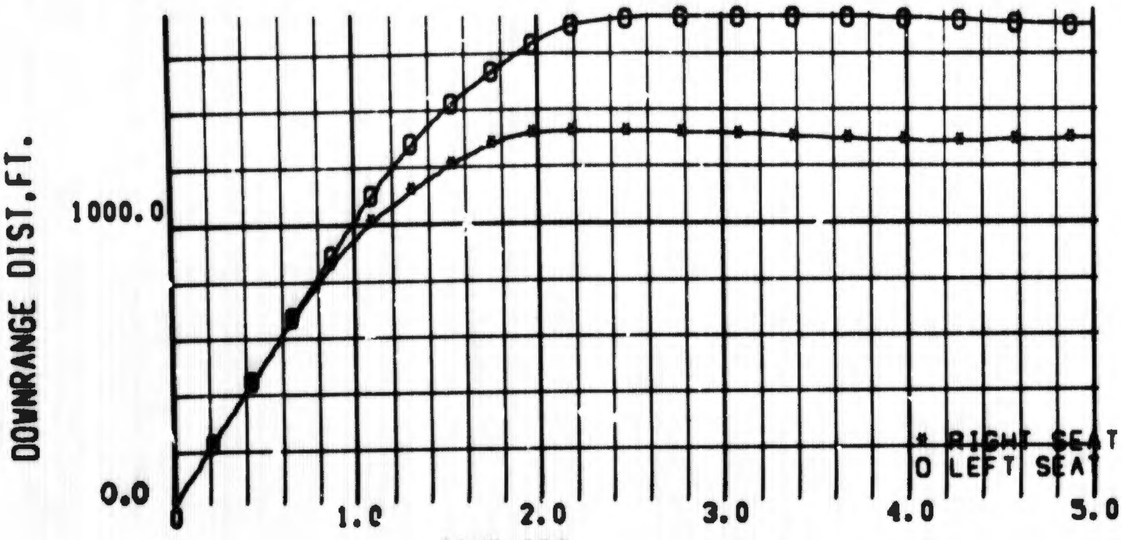


FIG 317 SYSTEM ANALYSIS,CASE-2
SEAT AND/OR MAN DOWNRANGE DIST

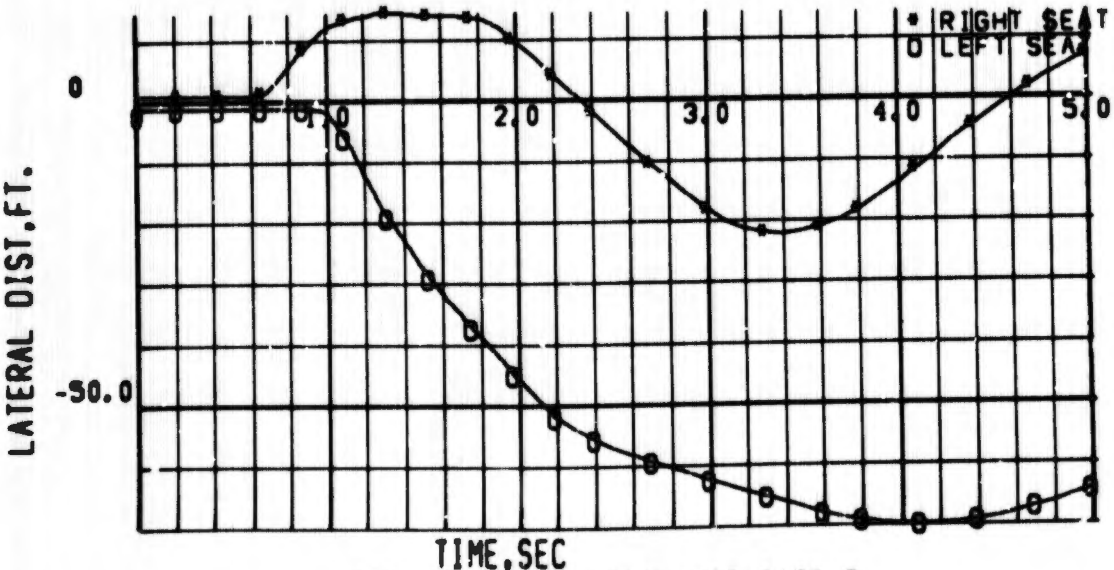


FIG 318 SYSTEM ANALYSIS,CASE-2
SEAT AND/OR MAN LATERAL DIST.

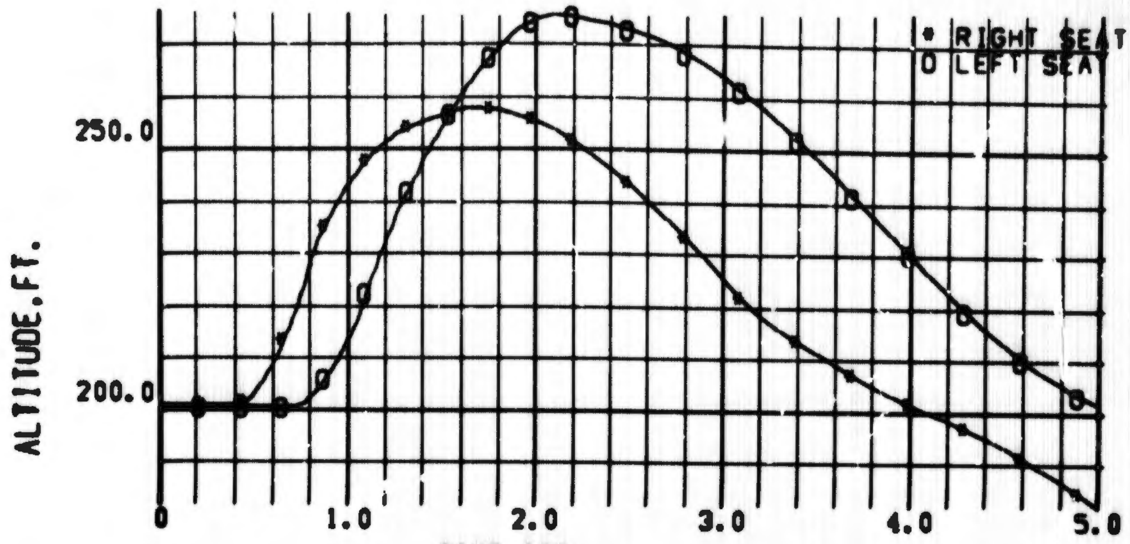


FIG 319 SYSTEM ANALYSIS,CASE-2
SEAT AND/OR MAN ALTITUDE

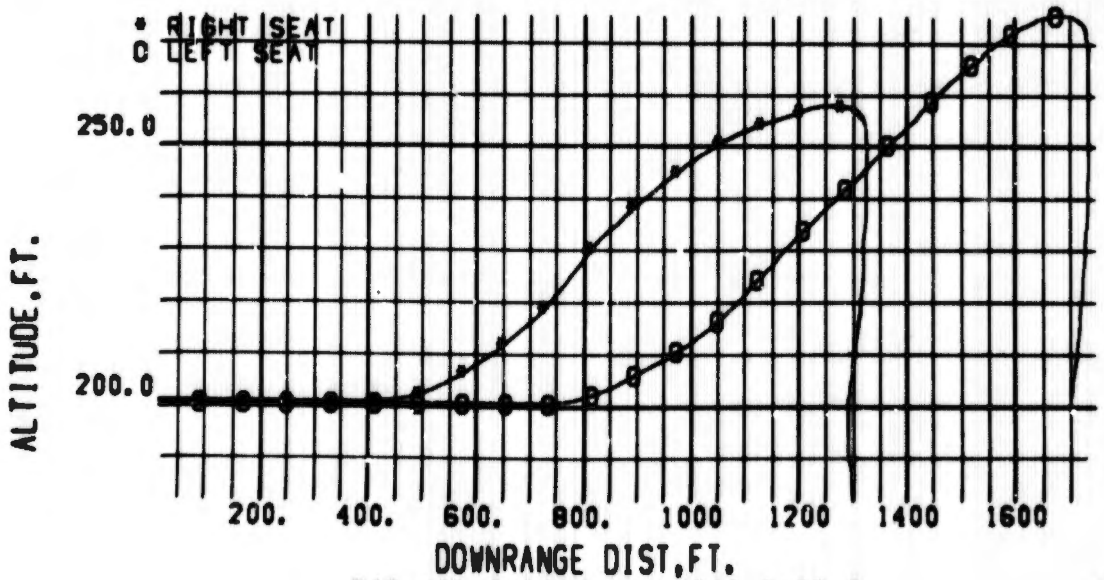


FIG 320 SYSTEM ANALYSIS,CASE-2
SEAT-MAN TRAJECTORY

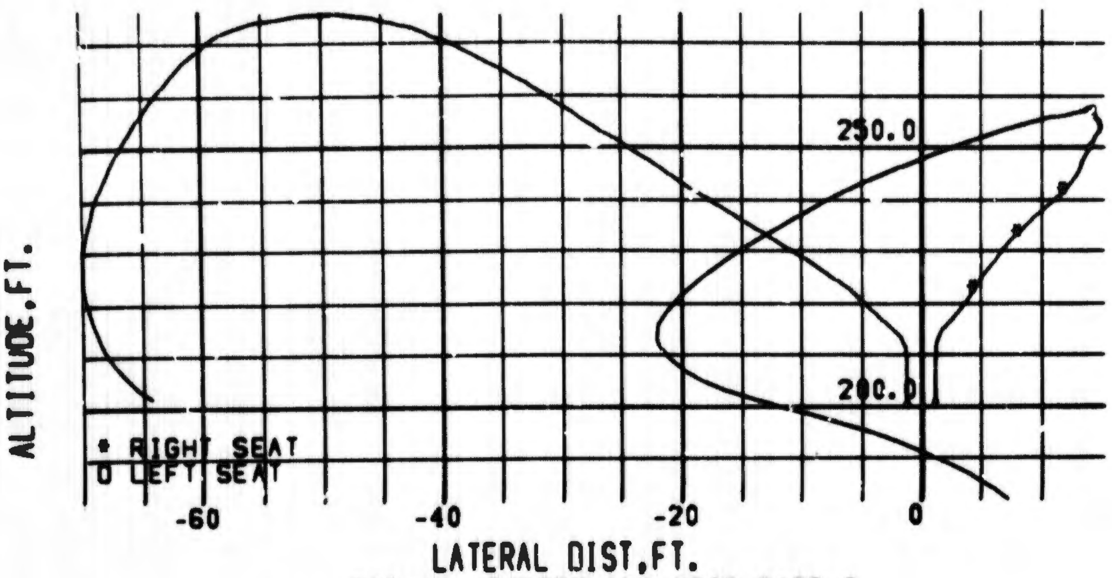


FIG 321 SYSTEM ANALYSIS,CASE-2
SEAT-MAN TRAJECTORY

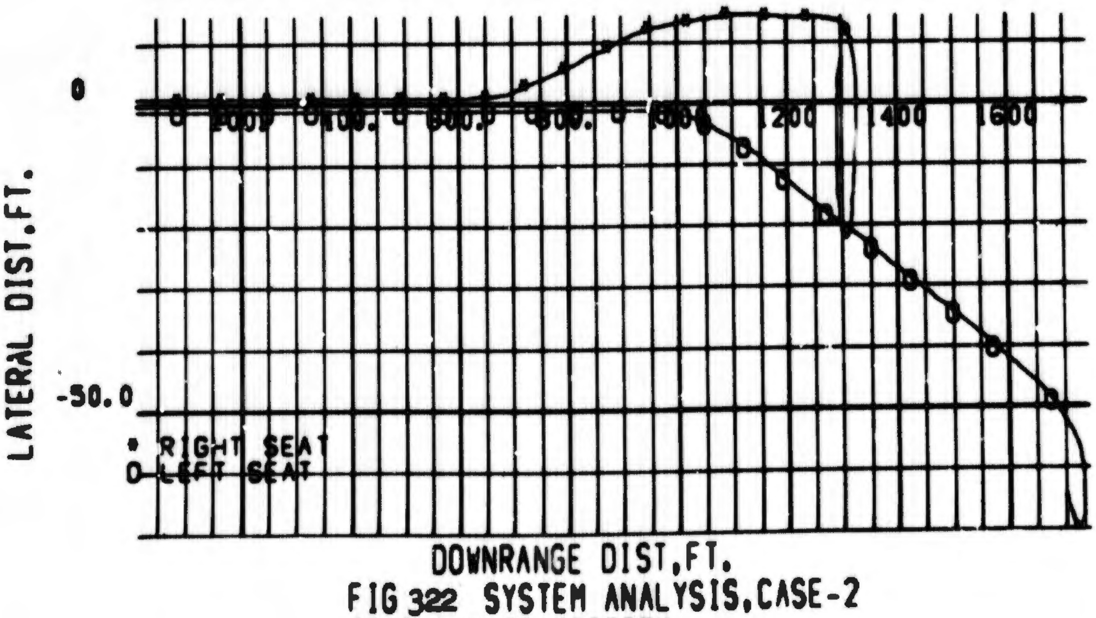


FIG 322 SYSTEM ANALYSIS,CASE-2
SEAT-MAN TRAJECTORY

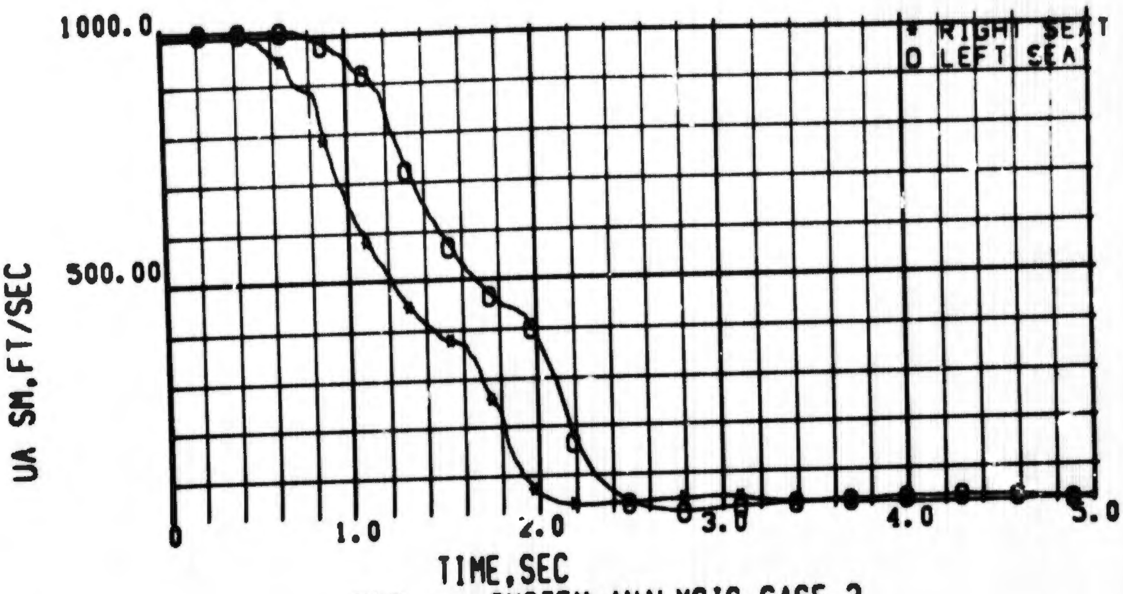


FIG 323 SYSTEM ANALYSIS,CASE-2
SEAT AND/OR MAN TOTAL AIRSPEED

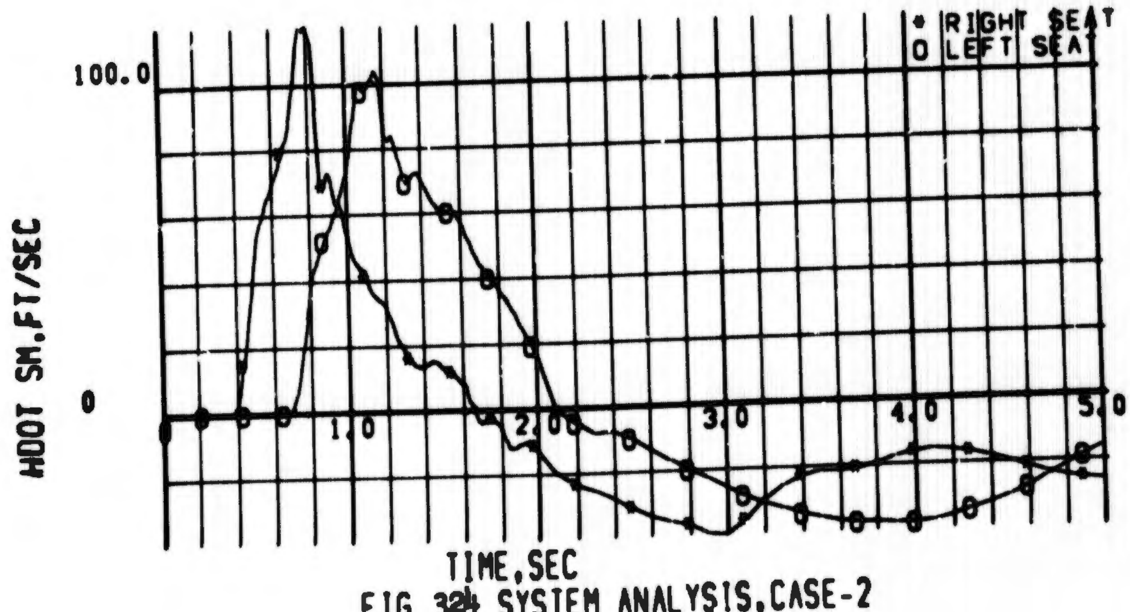


FIG 324 SYSTEM ANALYSIS,CASE-2
SEAT AND/OR MAN CLIMB RATE

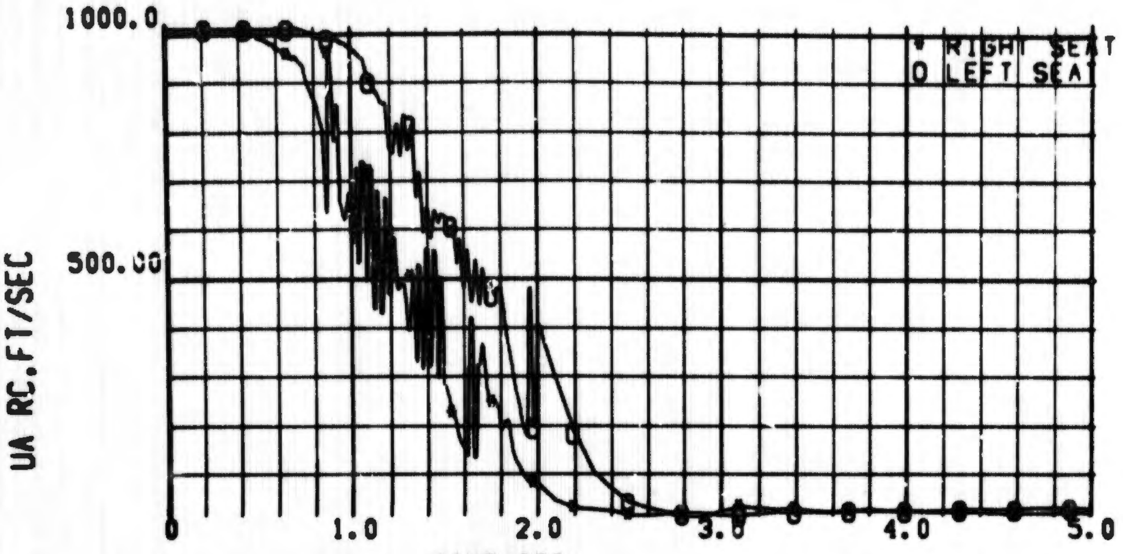


FIG 325 SYSTEM ANALYSIS,CASE-2
PARACHUTE TOTAL AIRSPEED

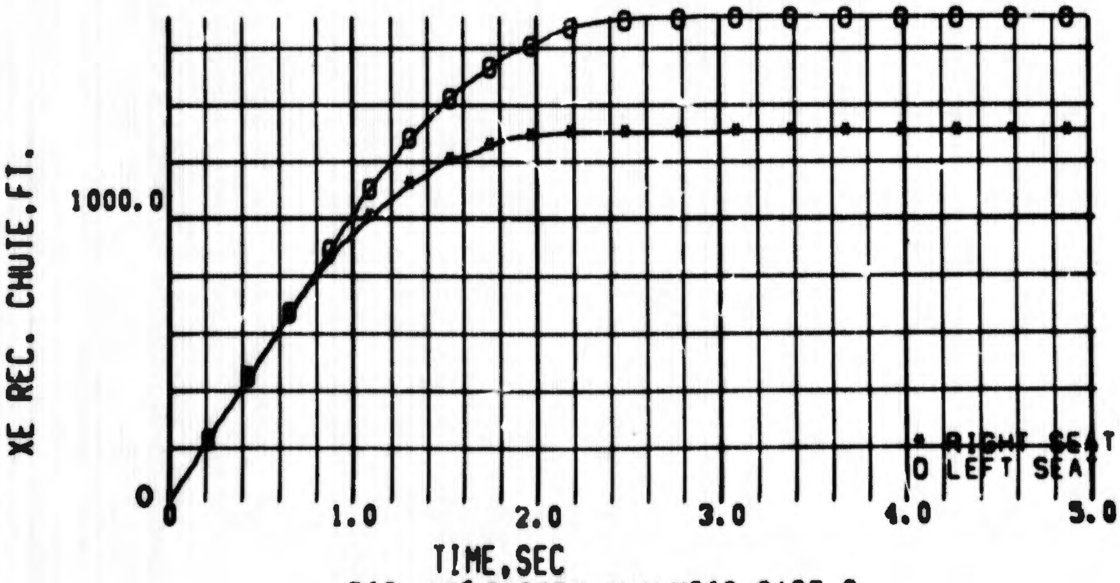


FIG 326 SYSTEM ANALYSIS,CASE-2
PARACHUTE DOWNRANGE DISTANCE

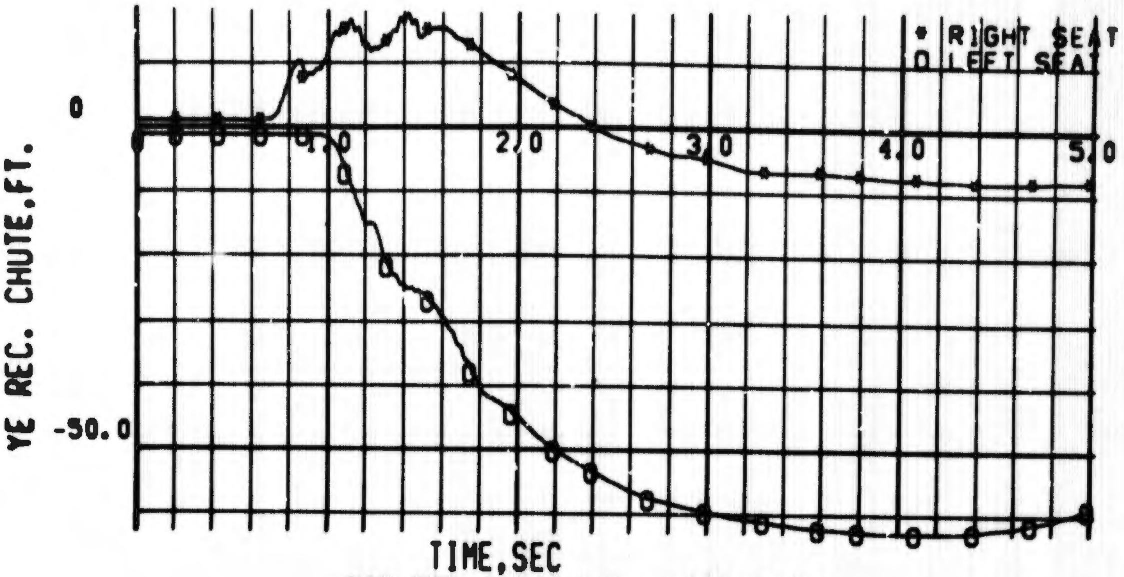


FIG 327 SYSTEM ANALYSIS,CASE-2
PARACHUTE LATERAL DISTANCE

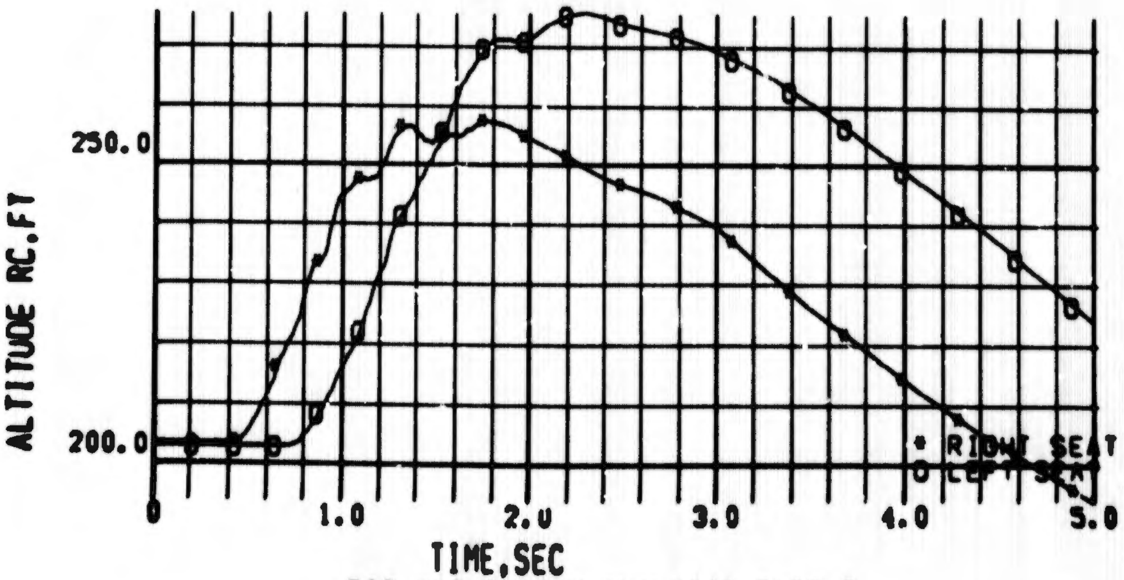


FIG 328 SYSTEM ANALYSIS,CASE-2
PARACHUTE ALTITUDE

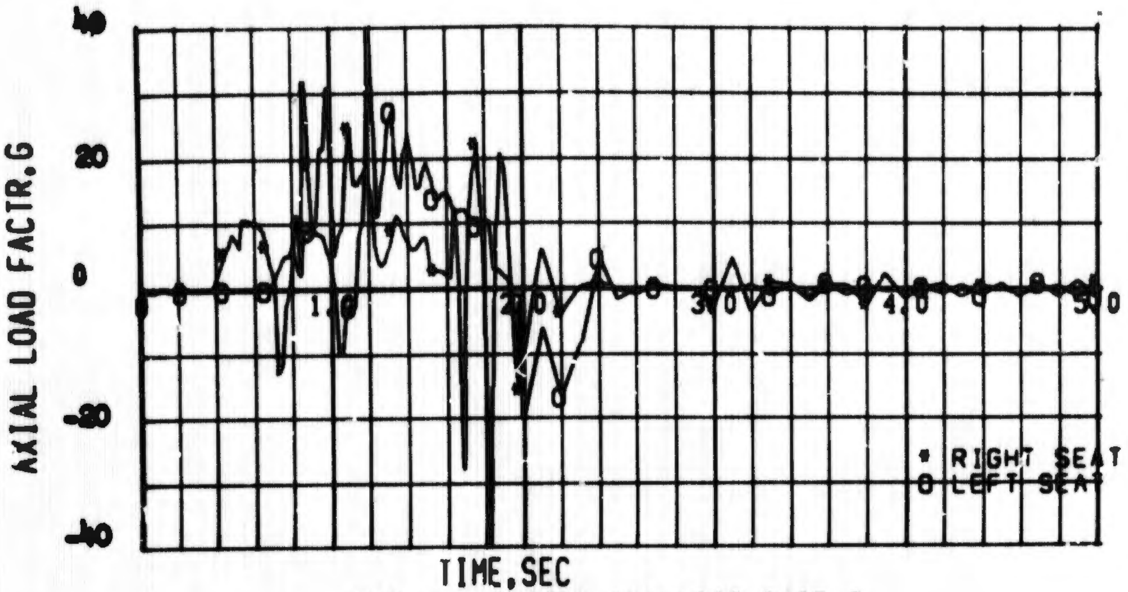


FIG 329 SYSTEM ANALYSIS,CASE-2
SEAT-MAN AXIAL LOAD FACTOR,CG

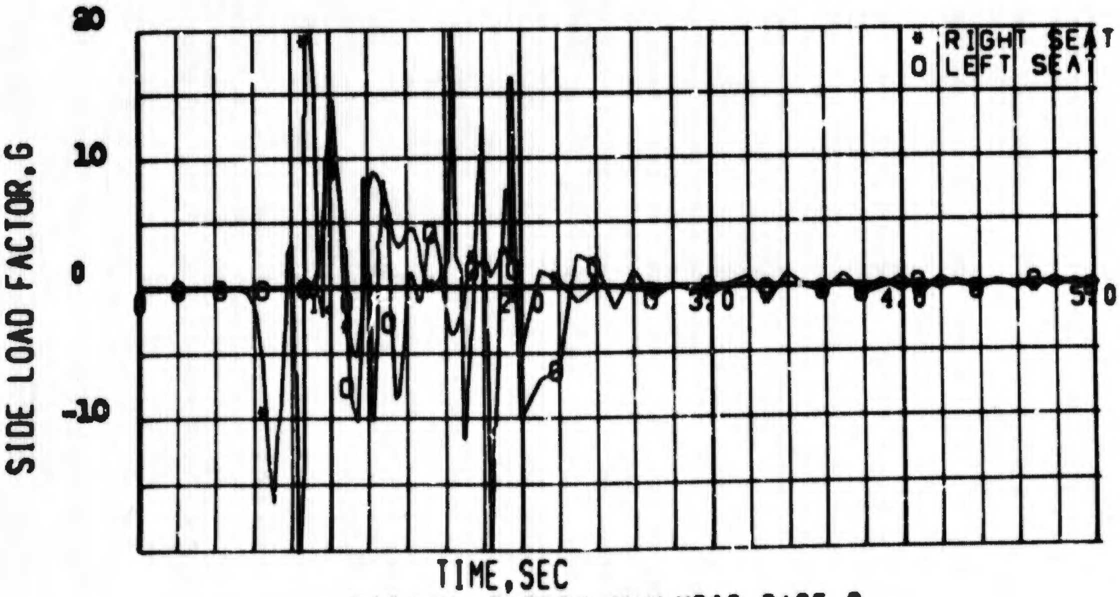


FIG 330 SYSTEM ANALYSIS,CASE-2
SEAT-MAN SIDE LOAD FACTOR,CG

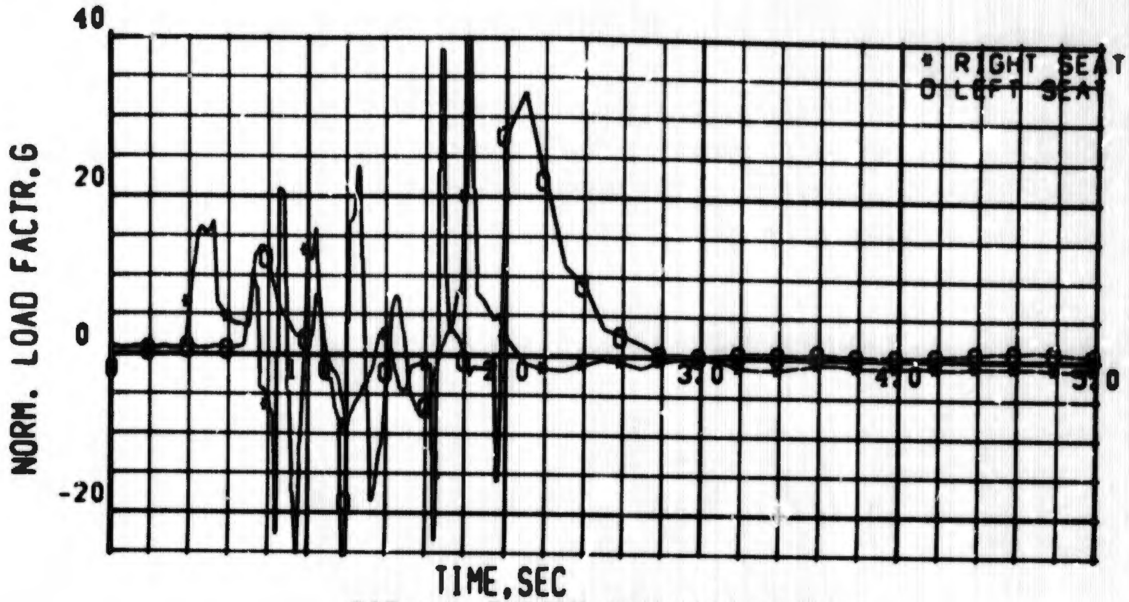


FIG 331 SYSTEM ANALYSIS, CASE-2
SEAT-MAN NORMAL LOAD FACTOR, CG

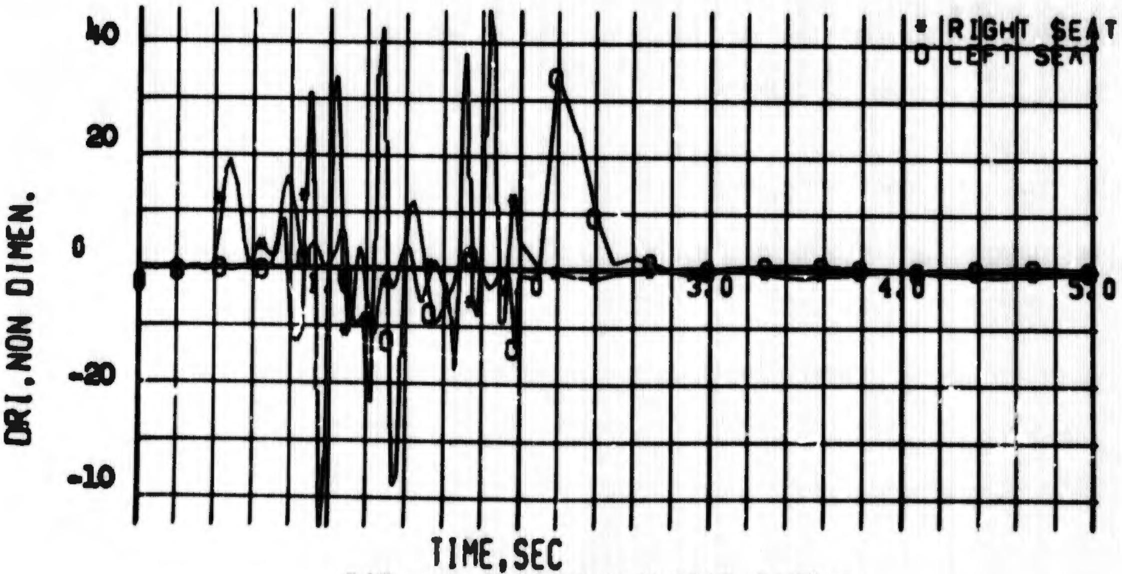


FIG 332 SYSTEM ANALYSIS, CASE-2
PILOT DYNAMIC RESPONSE INDEX

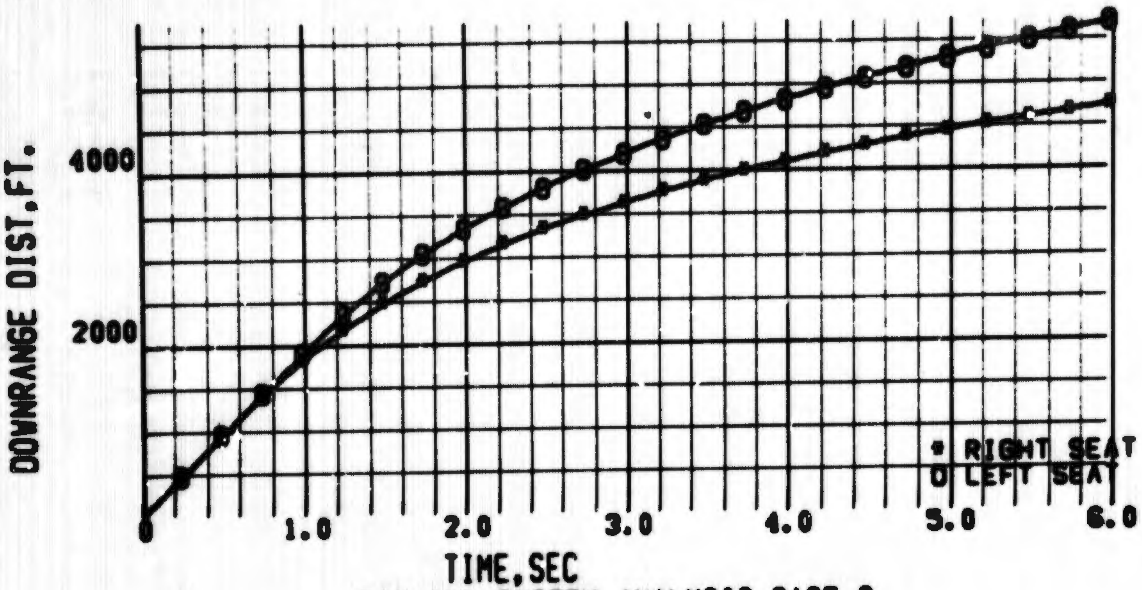


FIG 333 SYSTEM ANALYSIS,CASE-3
SEAT AND/OR MAN DOWNRANGE DIST

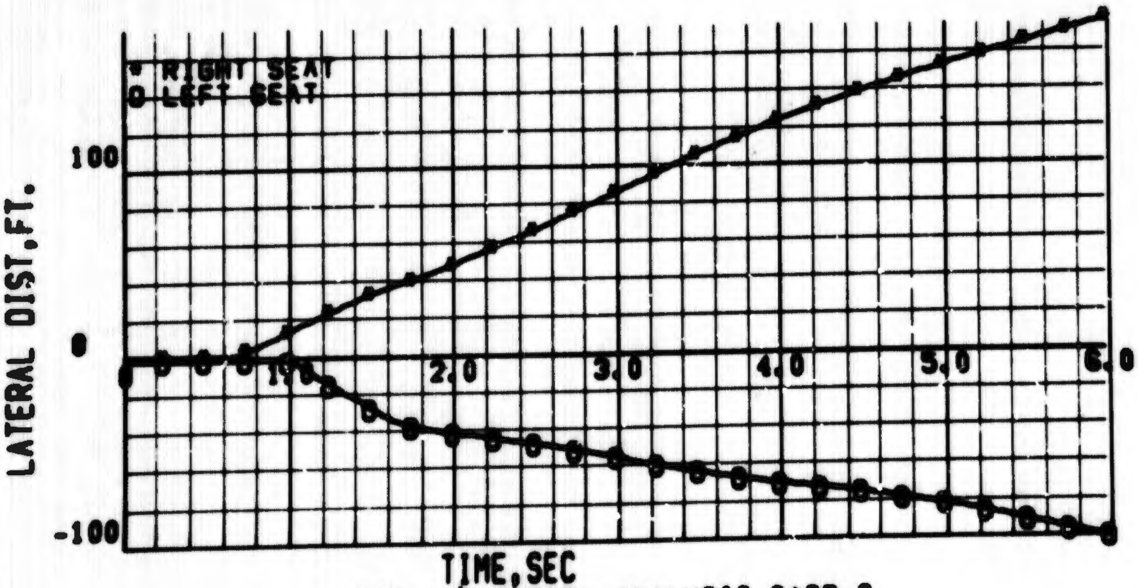


FIG 334 SYSTEM ANALYSIS,CASE-3
SEAT AND/OR MAN LATERAL DIST.

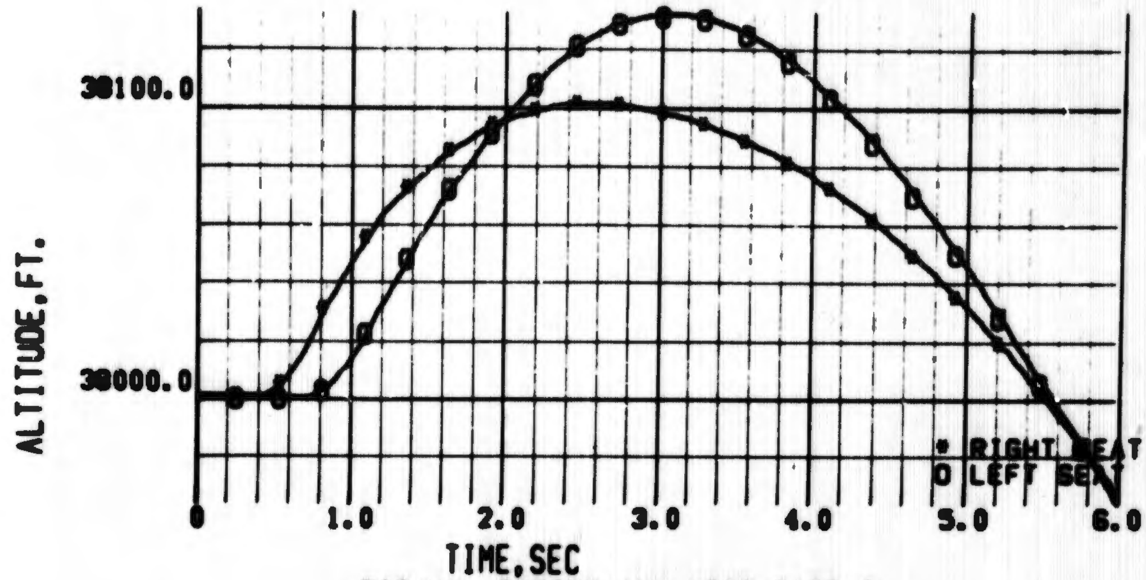


FIG 335 SYSTEM ANALYSIS,CASE-3
SEAT AND/OR MAN ALTITUDE

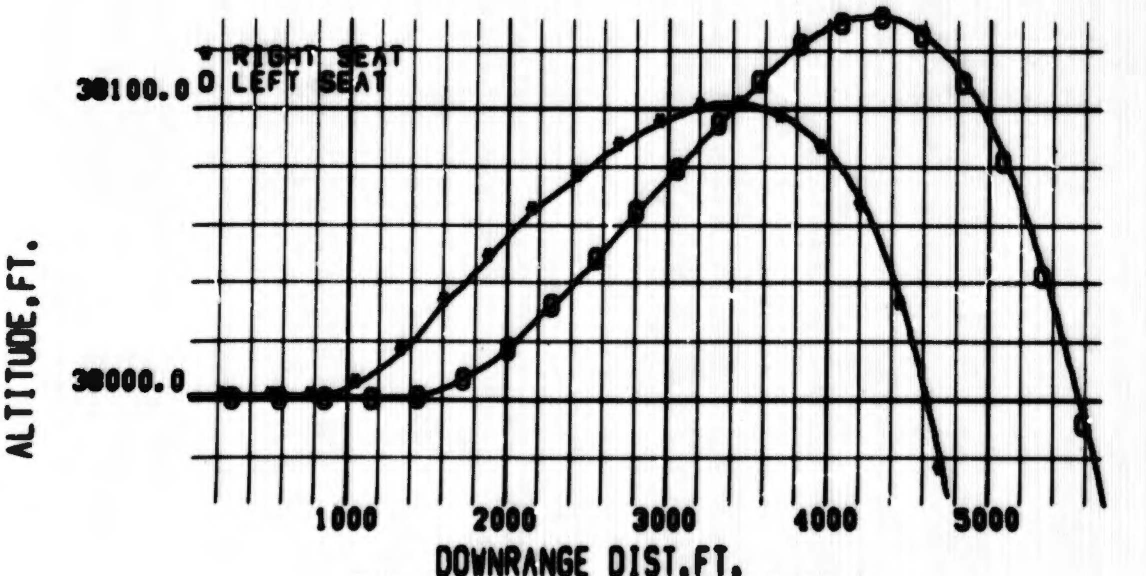


FIG 336 SYSTEM ANALYSIS,CASE-3
SEAT-MAN TRAJECTORY

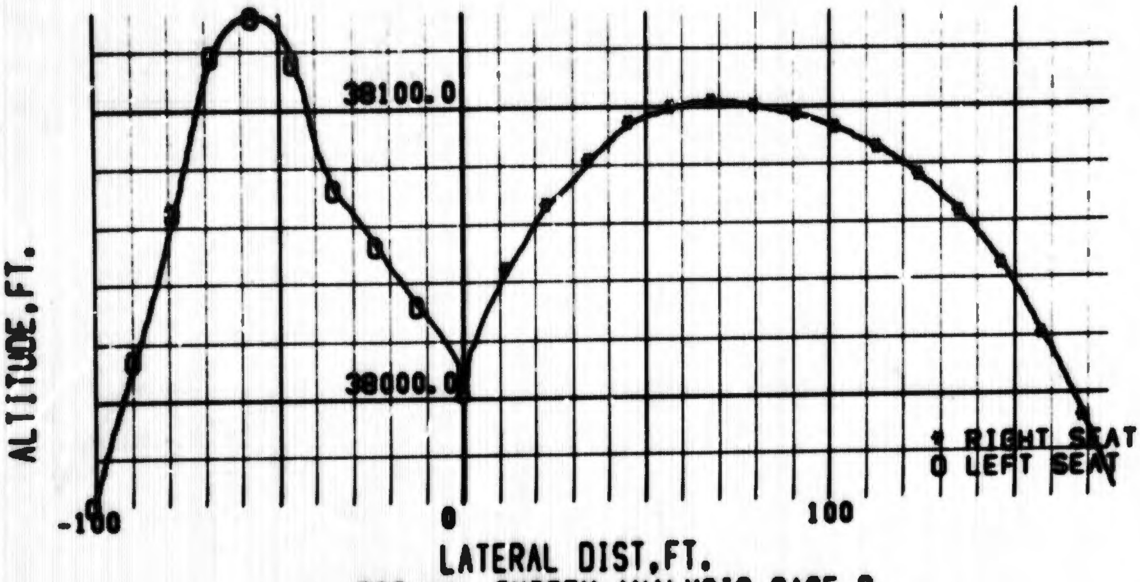


FIG 337 SYSTEM ANALYSIS,CASE-3
SEAT-MAN TRAJECTORY

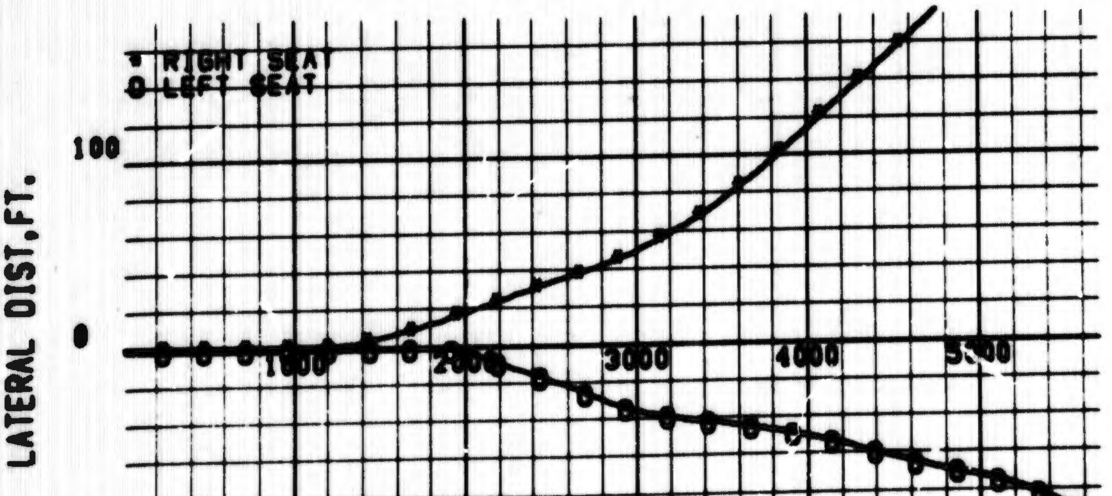


FIG 338 SYSTEM ANALYSIS,CASE-3
SEAT-MAN TRAJECTORY

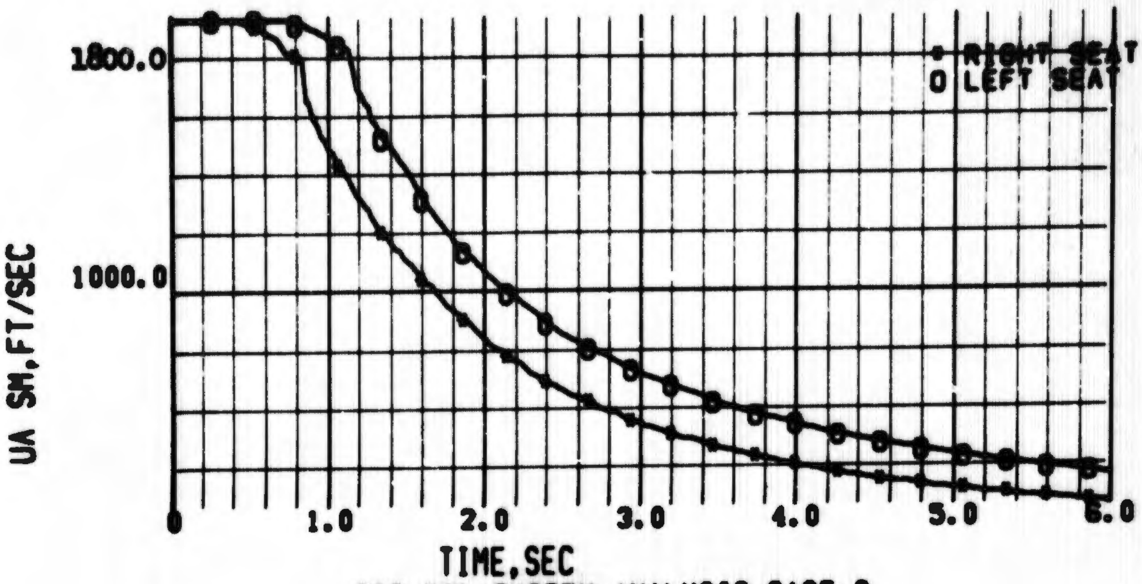


FIG 339 SYSTEM ANALYSIS,CASE-3
SEAT AND/OR MAN TOTAL AIRSPEED

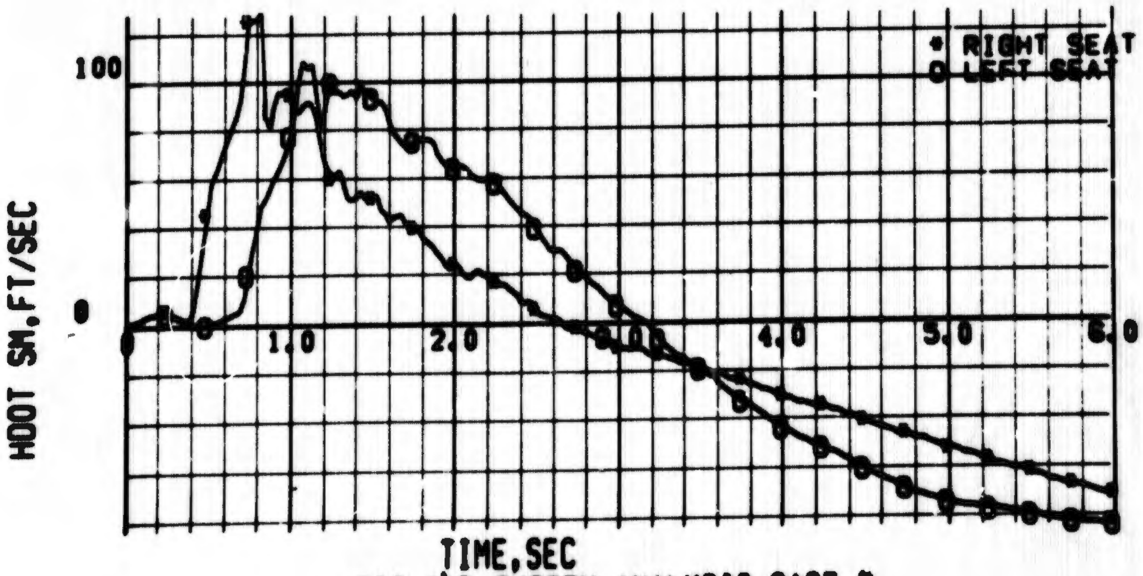


FIG 340 SYSTEM ANALYSIS,CASE-3
SEAT AND/OR MAN CLIMB RATE

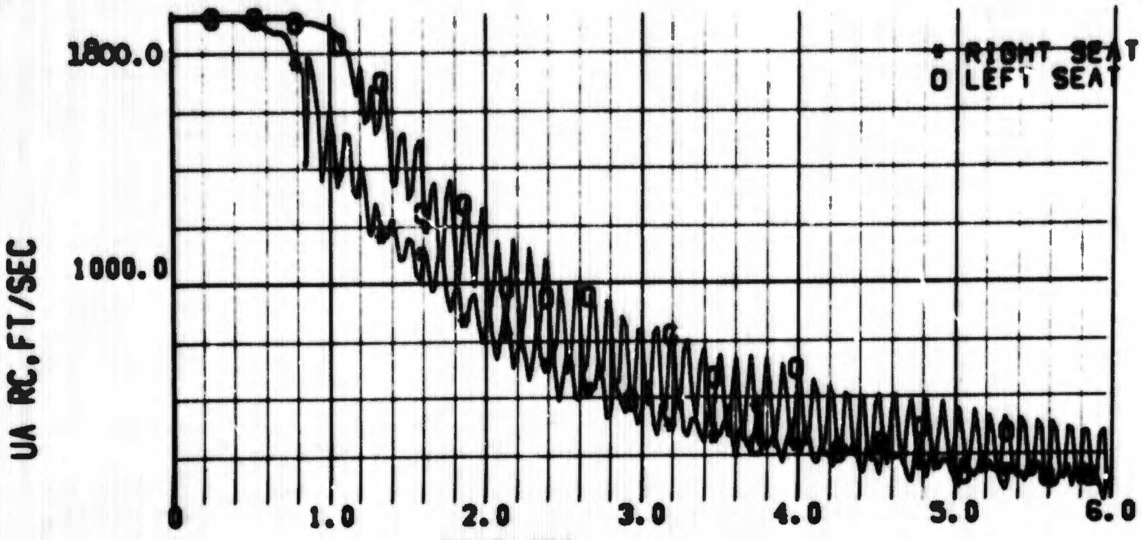


FIG 341 SYSTEM ANALYSIS,CASE-3
PARACHUTE TOTAL AIRSPEED

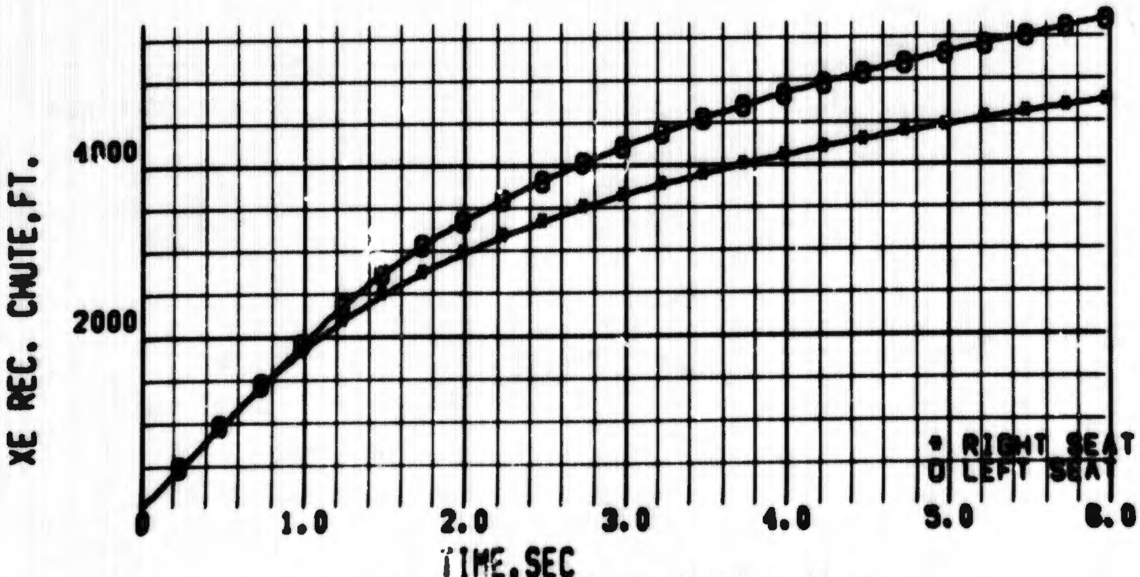


FIG 342 SYSTEM ANALYSIS,CASE-3
PARACHUTE DOWNRANGE DISTANCE

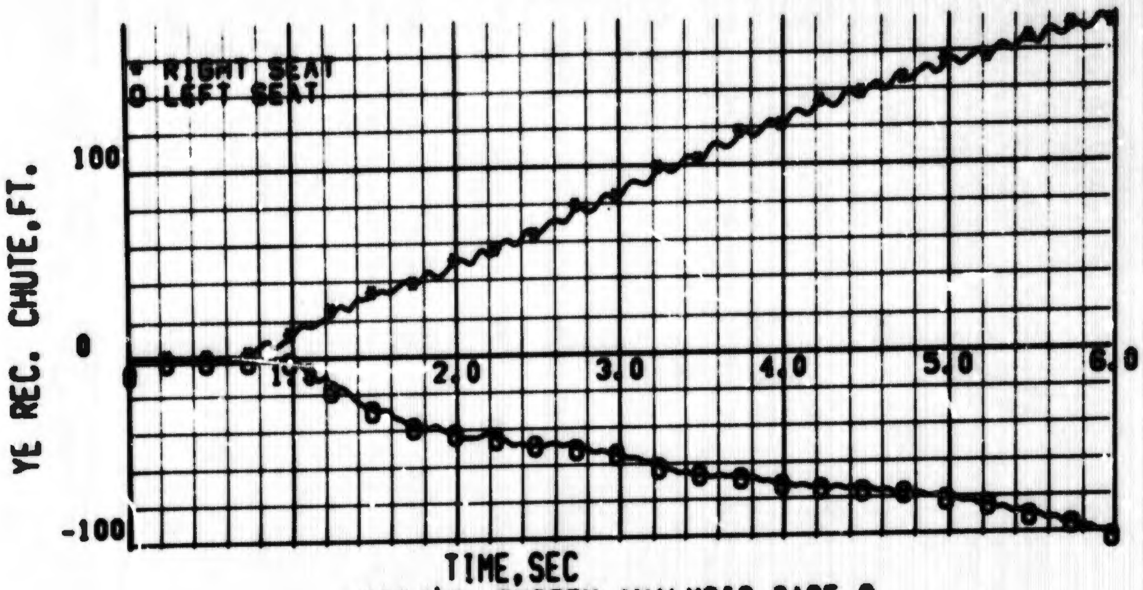


FIG 343 SYSTEM ANALYSIS,CASE-3
PARACHUTE LATERAL DISTANCE

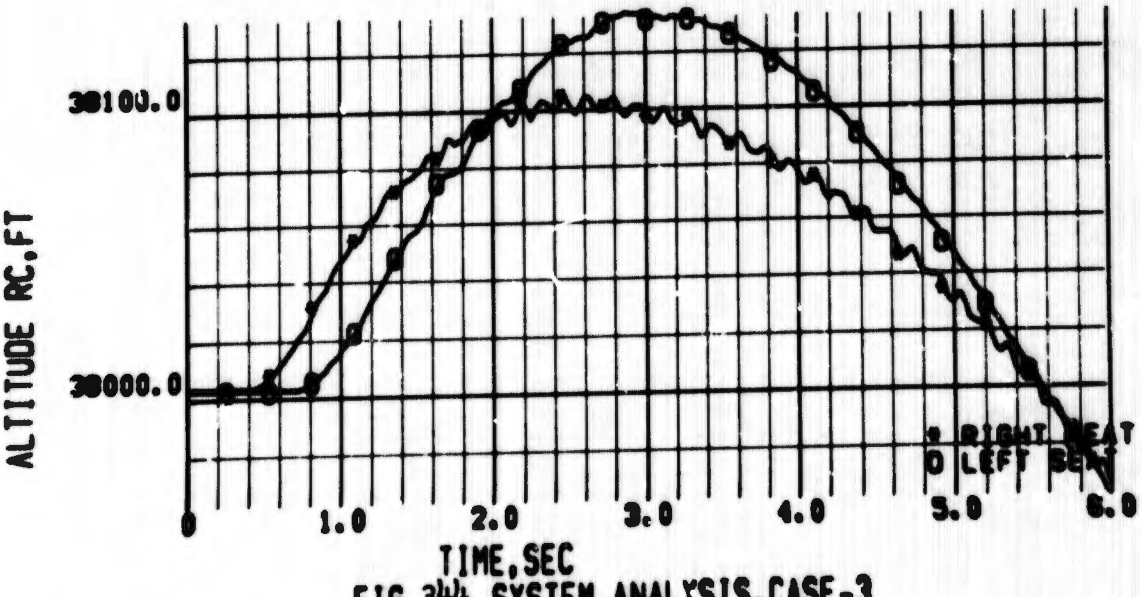


FIG 344 SYSTEM ANALYSIS,CASE-3
PARACHUTE ALTITUDE

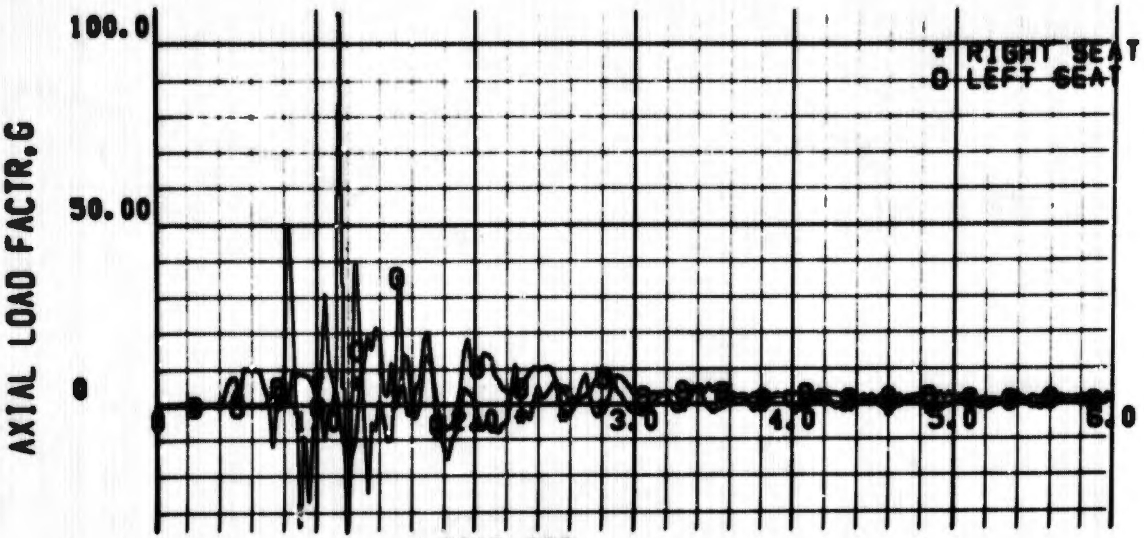


FIG345 SYSTEM ANALYSIS,CASE-3
SEAT-MAN AXIAL LOAD FACTOR,CG

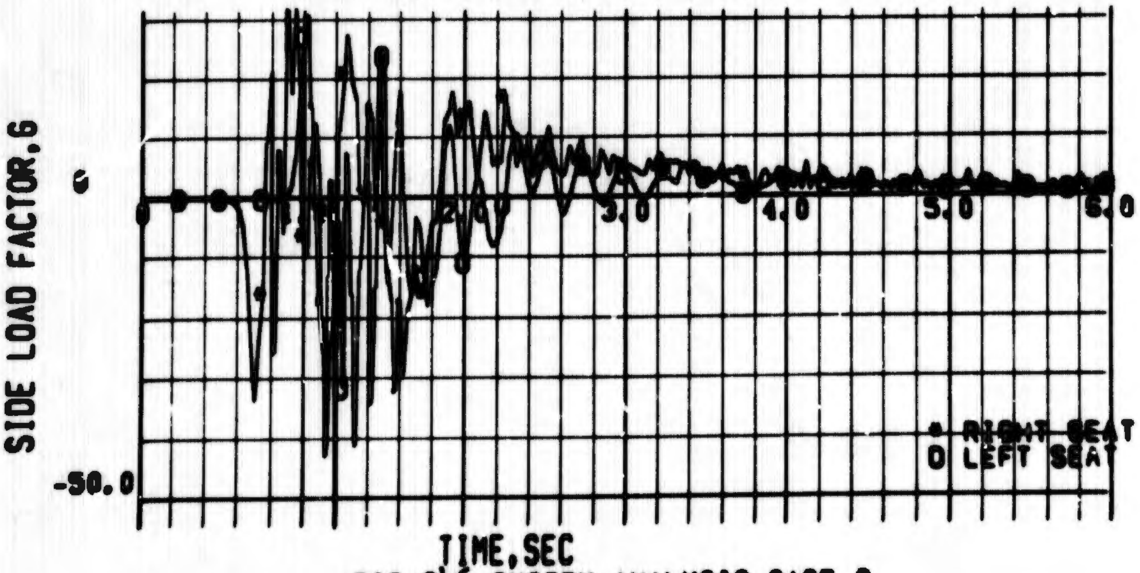


FIG 346 SYSTEM ANALYSIS,CASE-3
SEAT-MAN SIDE LOAD FACTOR,CG

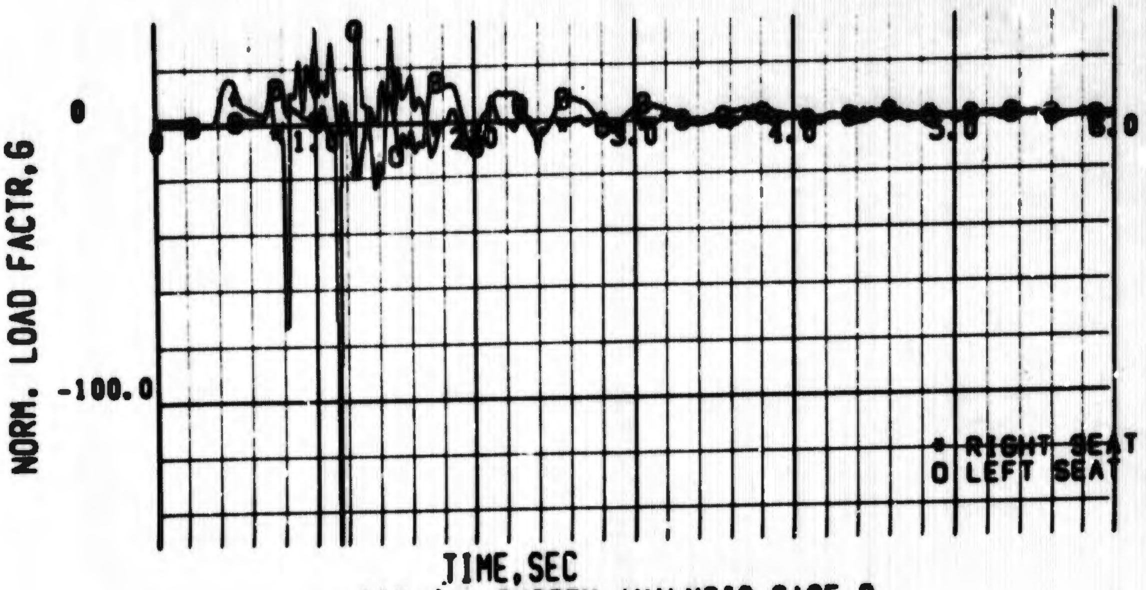


FIG 347 SYSTEM ANALYSIS,CASE-3
SEAT-MAN NORMAL LOAD FACTOR,CG

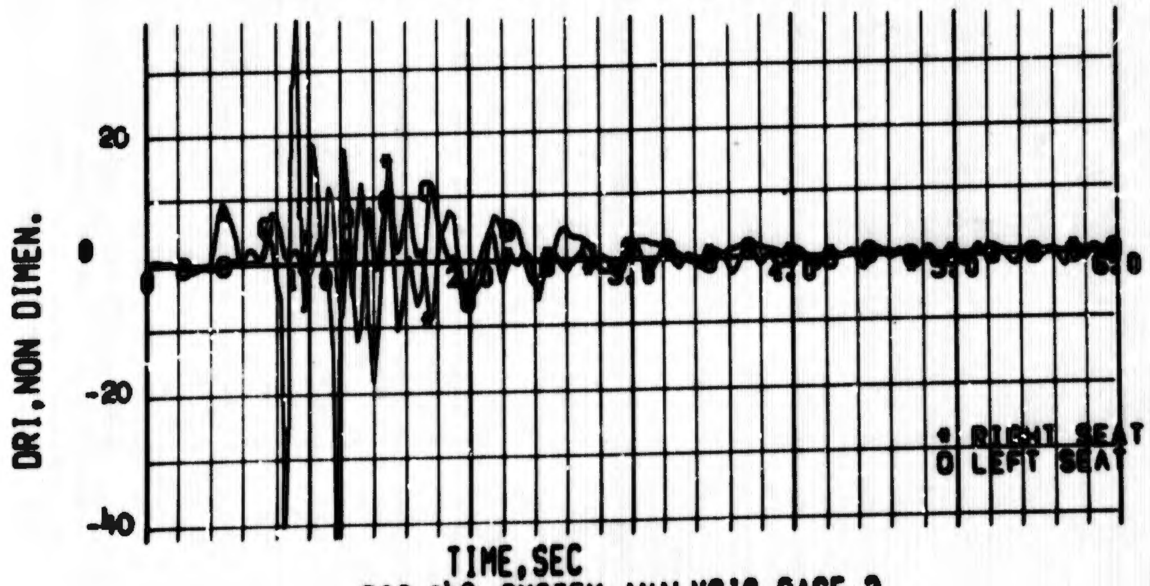


FIG 348 SYSTEM ANALYSIS,CASE-3
PILOT DYNAMIC RESPONSE INDEX

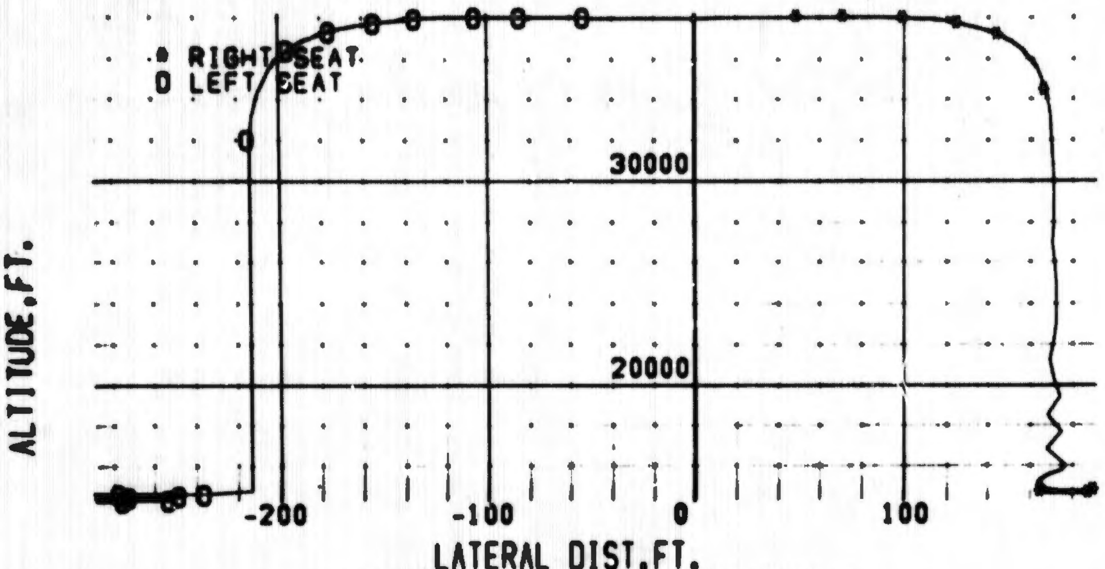


FIG349 SYSTEM ANALYSIS,CASE-3
SEAT-MAN TRAJECTORY

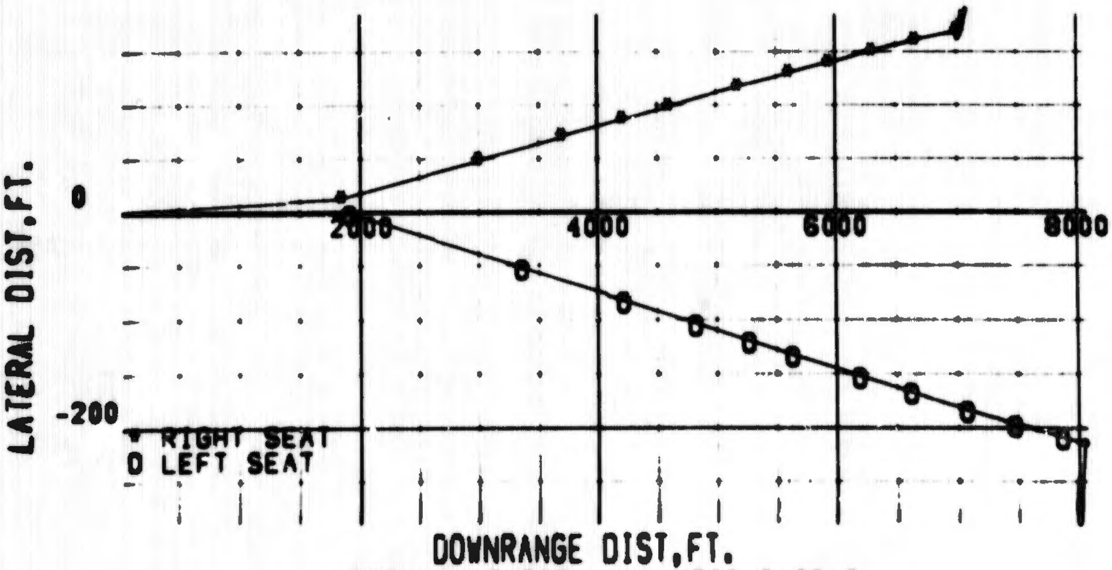


FIG 350 SYSTEM ANALYSIS,CASE-3
SEAT-MAN TRAJECTORY

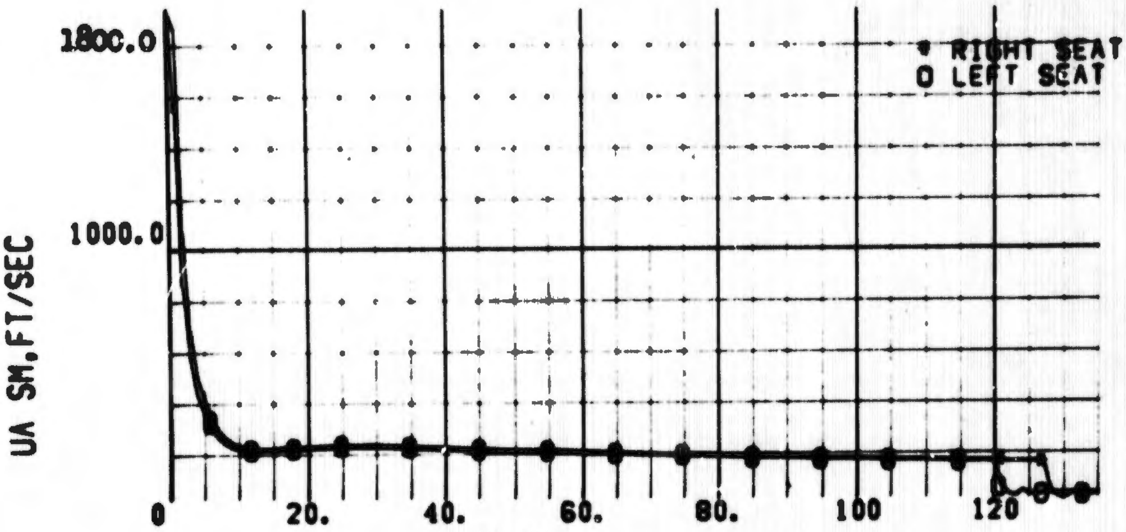


FIG351 SYSTEM ANALYSIS,CASE-3
SEAT AND/OR MAN TOTAL AIRSPEED

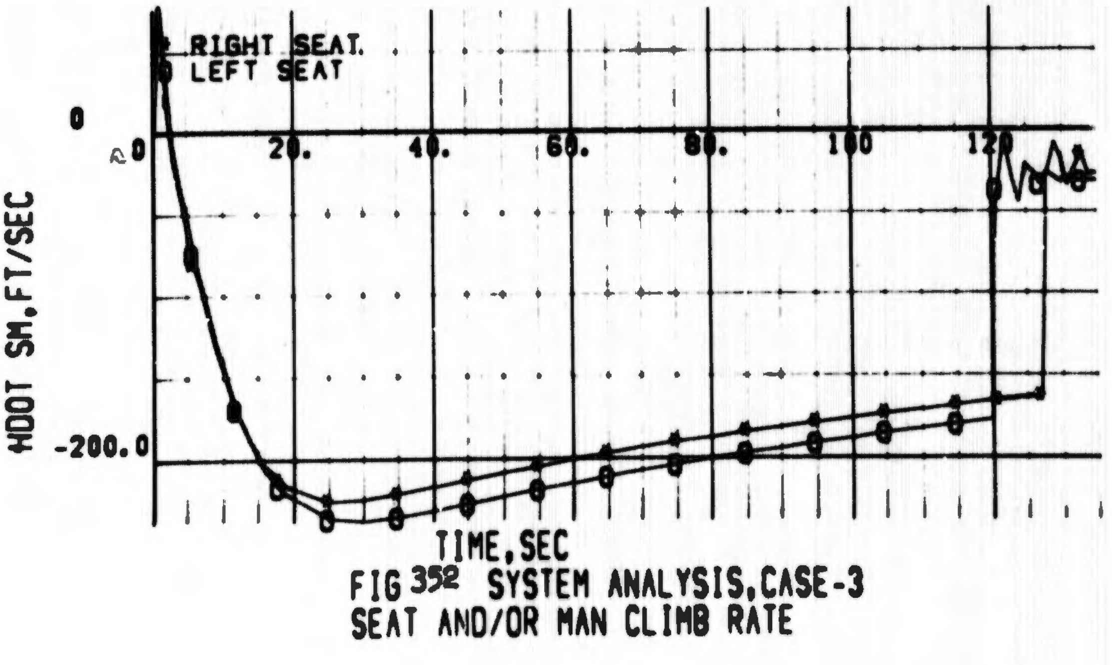


FIG 352 SYSTEM ANALYSIS,CASE-3
SEAT AND/OR MAN CLIMB RATE

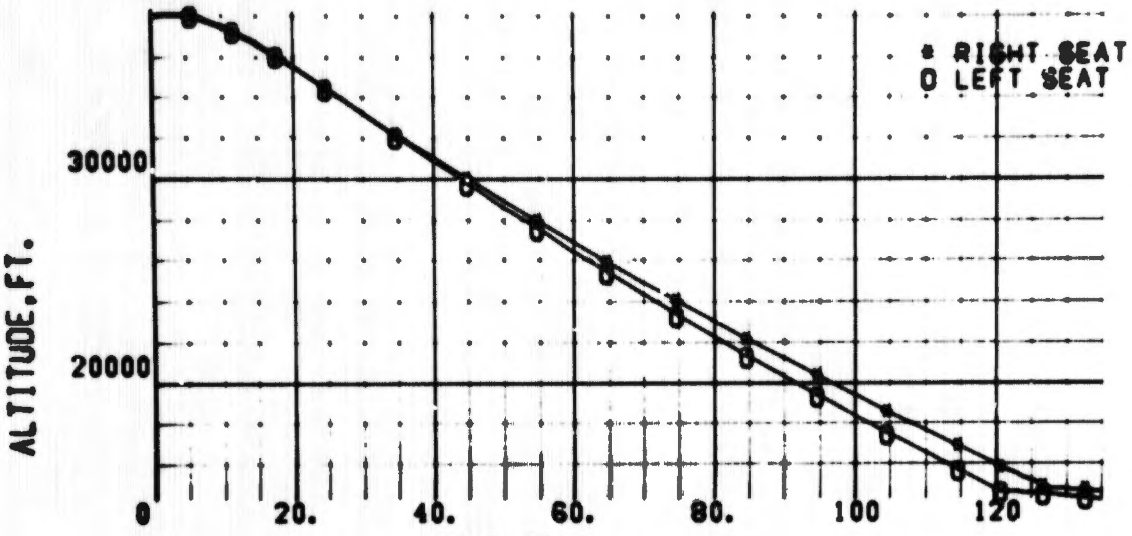


FIG 353 SYSTEM ANALYSIS,CASE-3
SEAT AND/OR MAN ALTITUDE

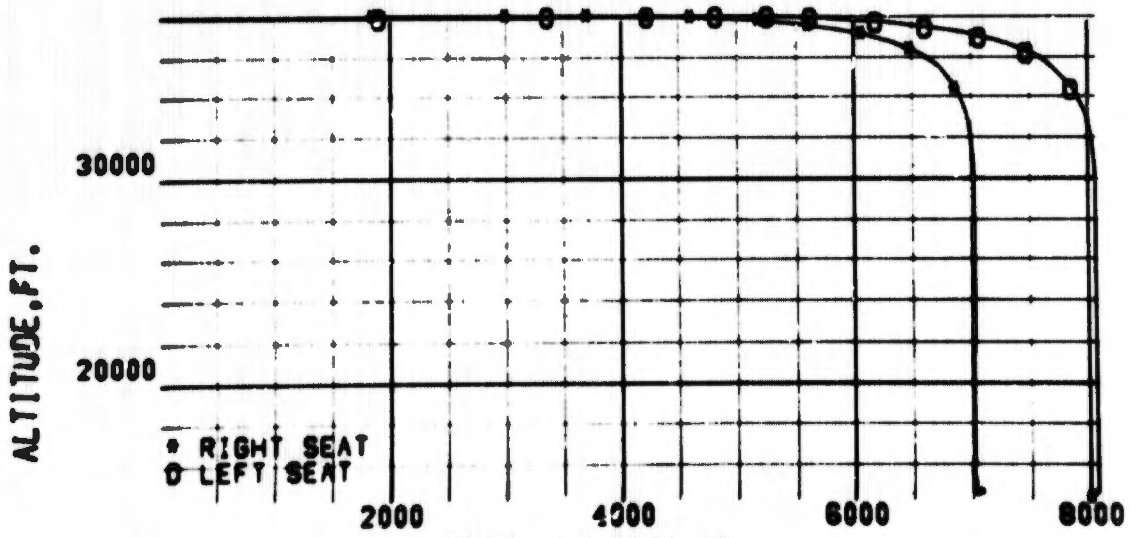


FIG 354 SYSTEM ANALYSIS,CASE-3
SEAT-MAN TRAJECTORY

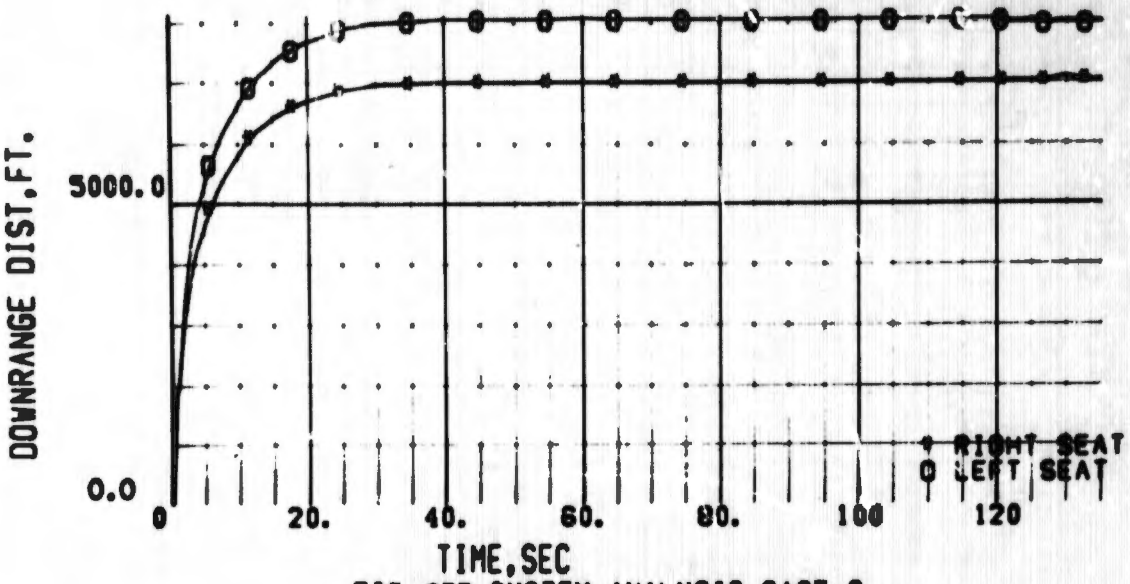


FIG 355 SYSTEM ANALYSIS,CASE-3
SEAT AND/OR MAN DOWNRANGE DIST

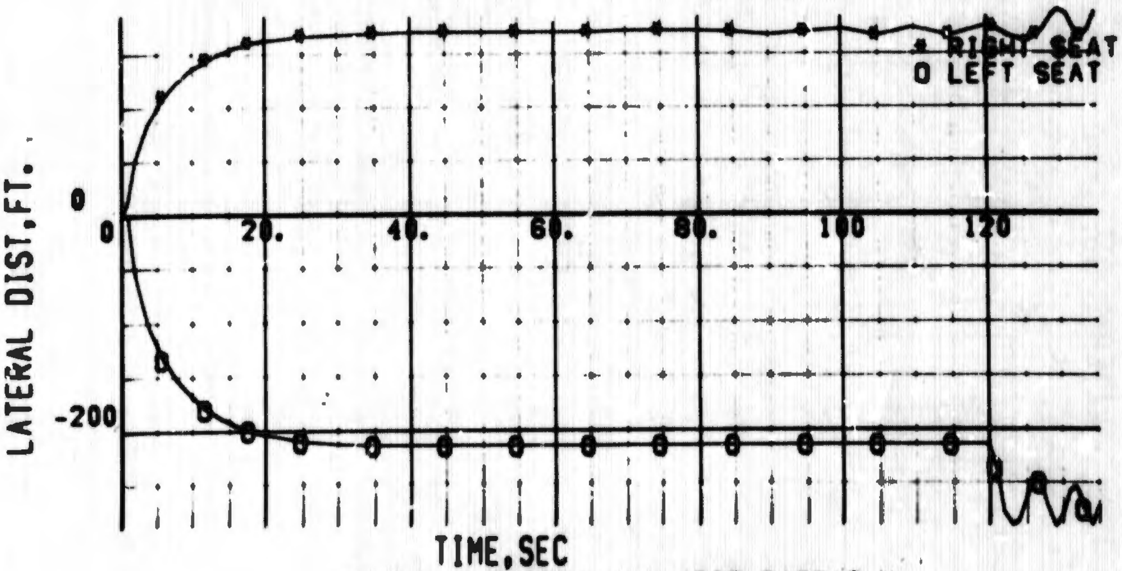


FIG 356 SYSTEM ANALYSIS,CASE-3
SEAT AND/OR MAN LATERAL DIST.

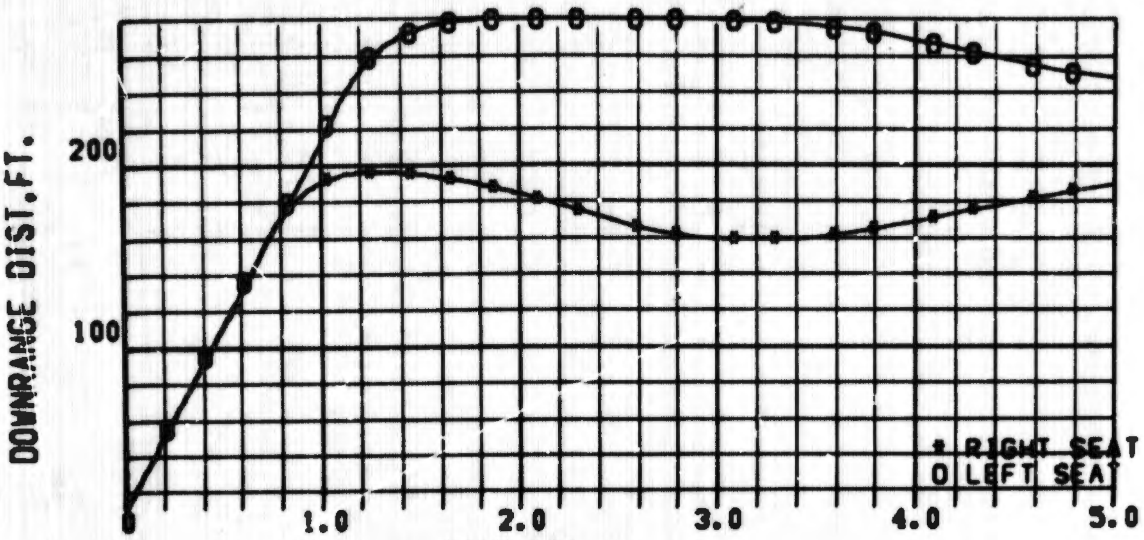


FIG 357 SYSTEM ANALYSIS,CASE-4
SEAT AND/OR MAN DOWNRANGE DIST

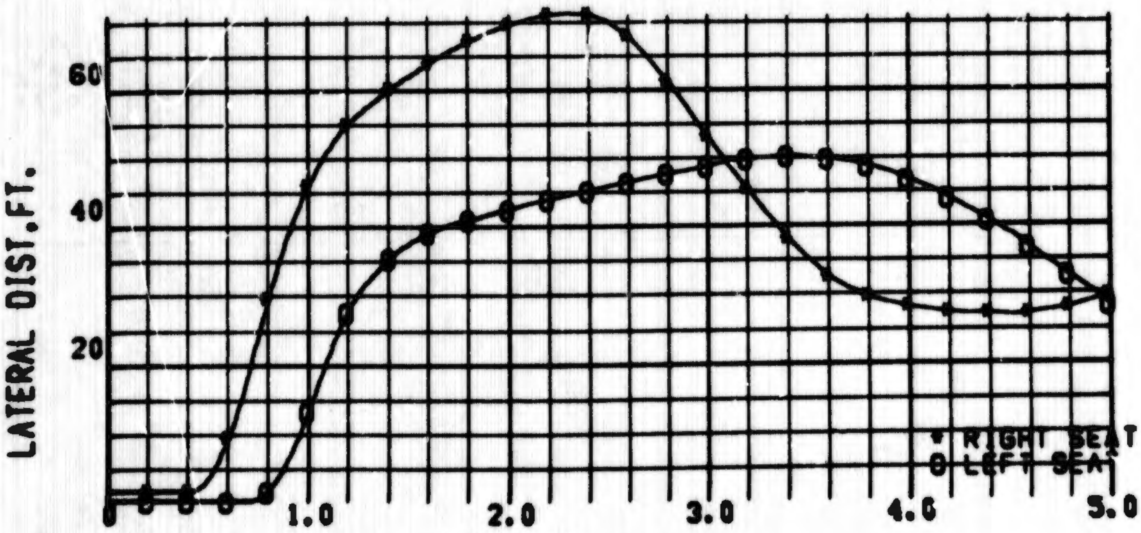


FIG 358 SYSTEM ANALYSIS,CASE-4
SEAT AND/OR MAN LATERAL DIST.

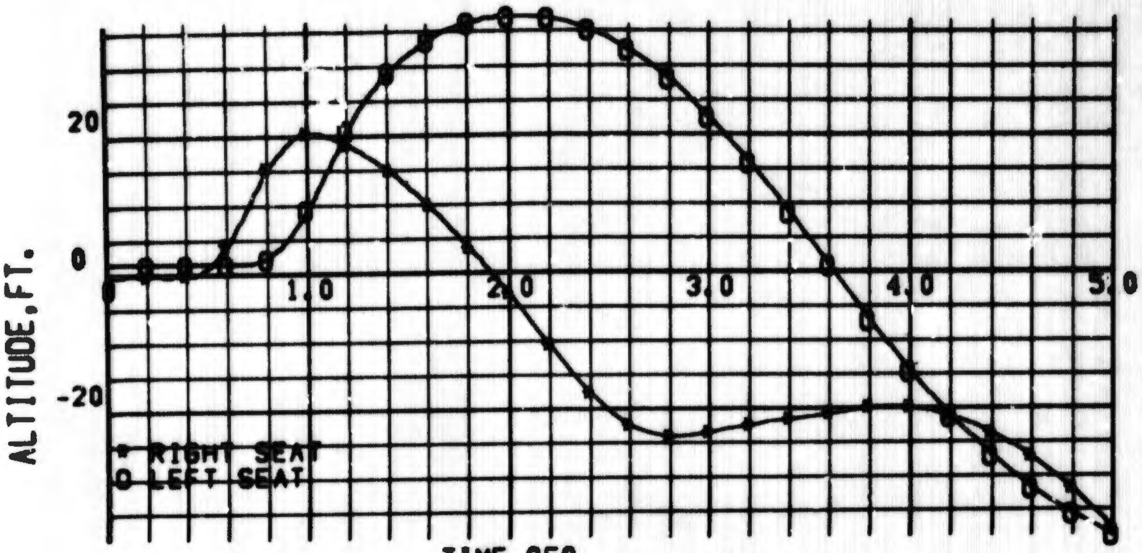


FIG 359 SYSTEM ANALYSIS,CASE-4
SEAT AND/OR MAN ALTITUDE

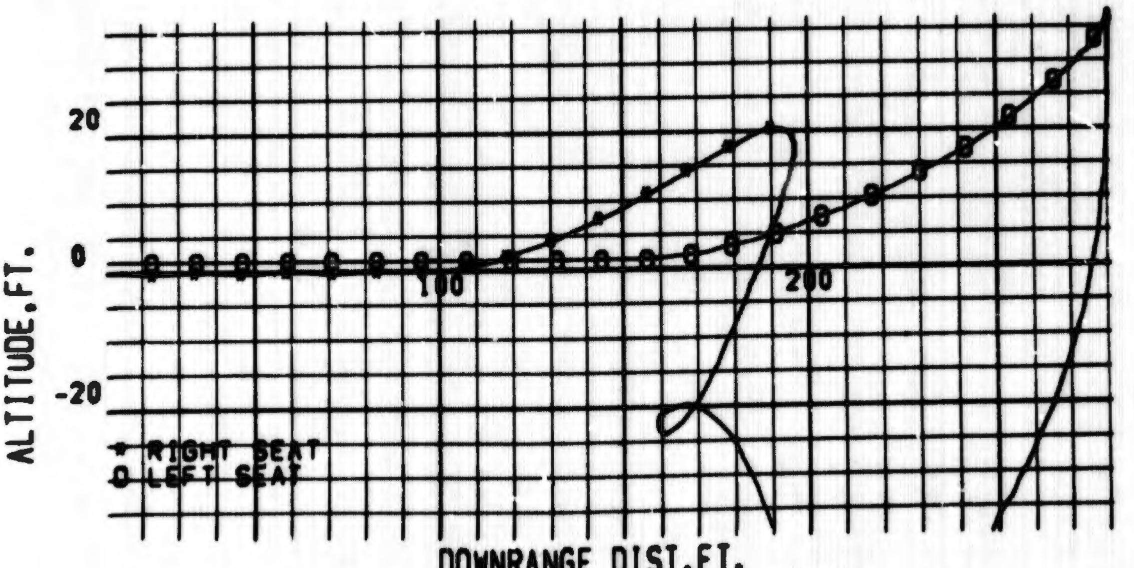


FIG 360 SYSTEM ANALYSIS,CASE-4
SEAT-MAN TRAJECTORY

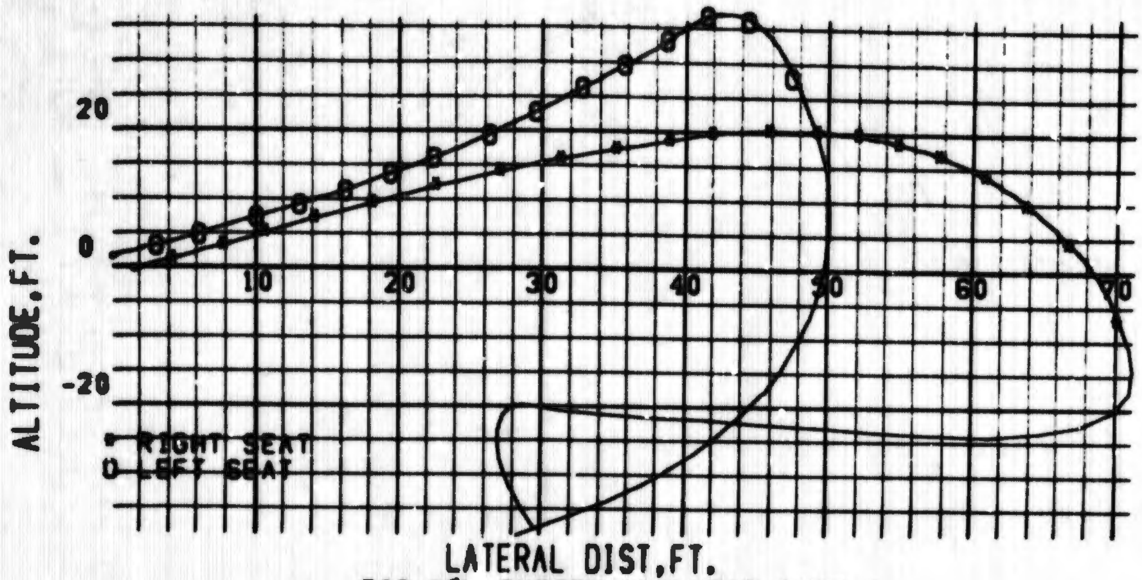


FIG 361 SYSTEM ANALYSIS,CASE-4
SEAT-MAN TRAJECTORY

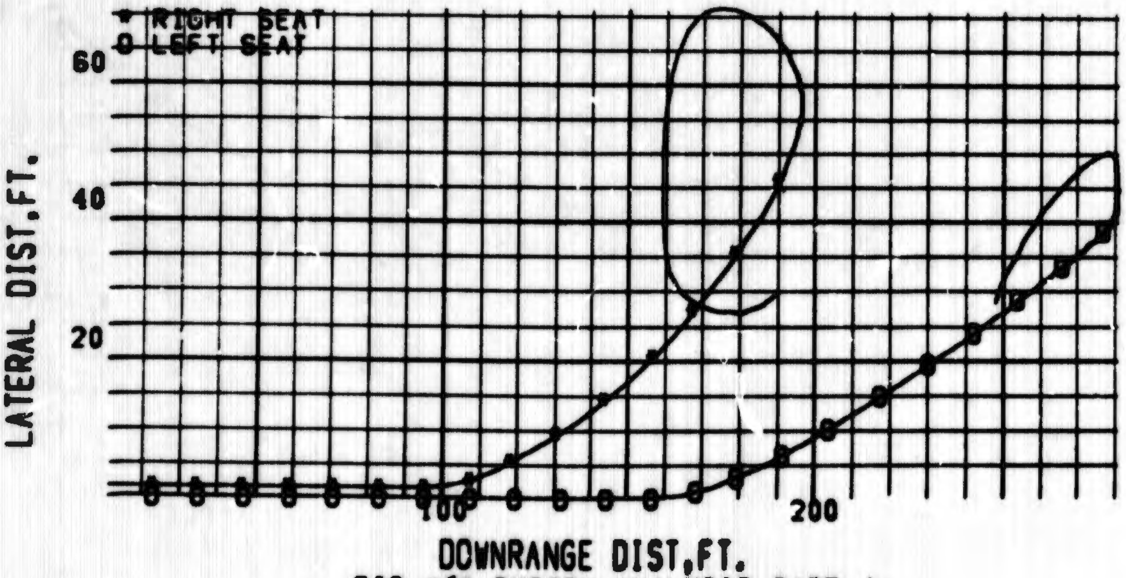


FIG 362 SYSTEM ANALYSIS,CASE-4
SEAT-MAN TRAJECTORY

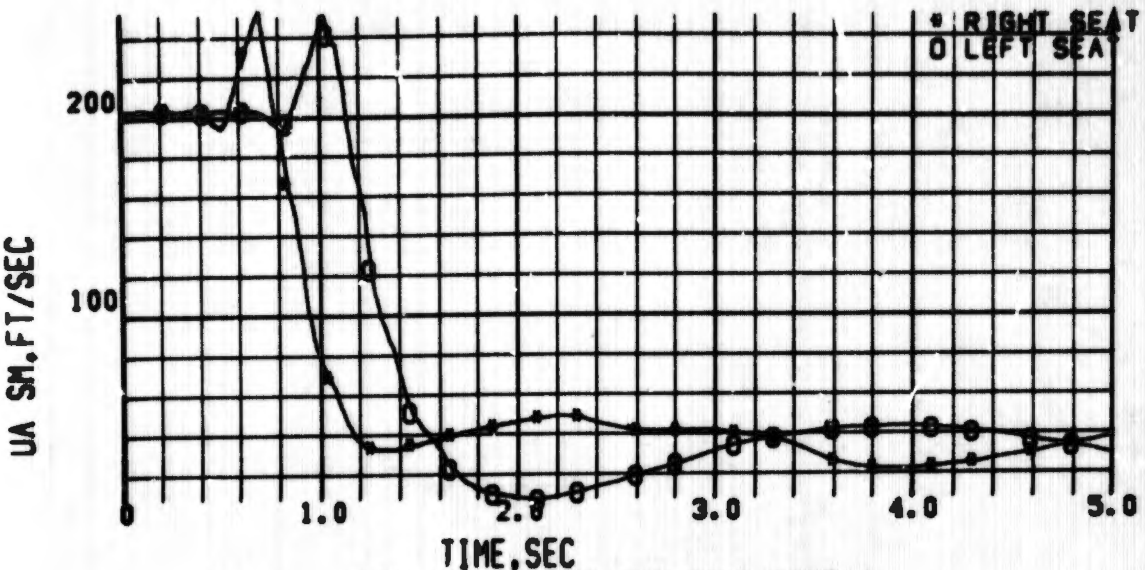


FIG 363 SYSTEM ANALYSIS,CASE-4
SEAT AND/OR MAN TOTAL AIRSPEED

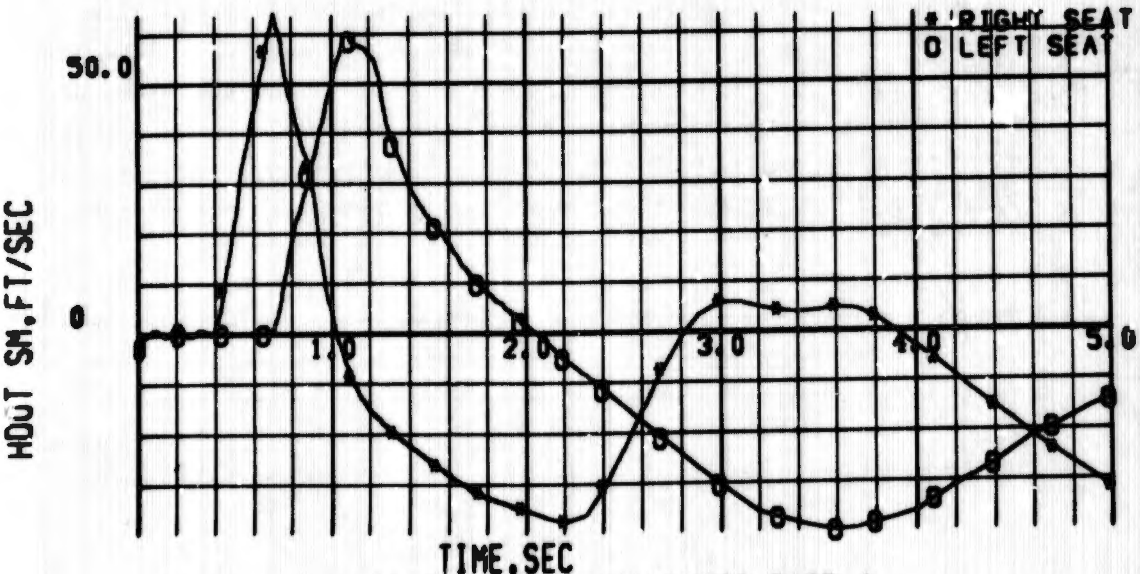


FIG 364 SYSTEM ANALYSIS,CASE-4
SEAT AND/OR MAN CLIMB RATE

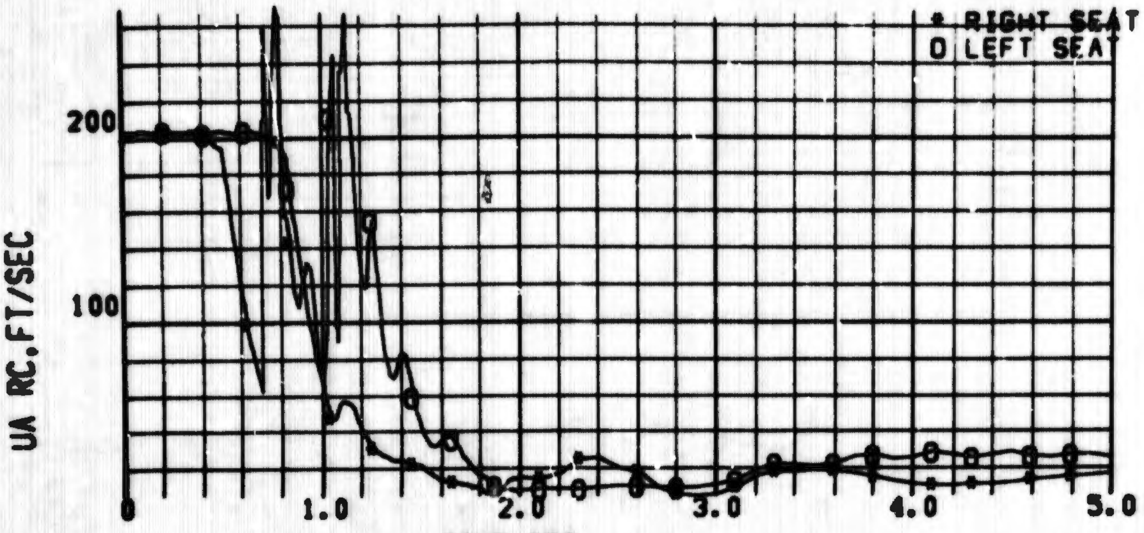
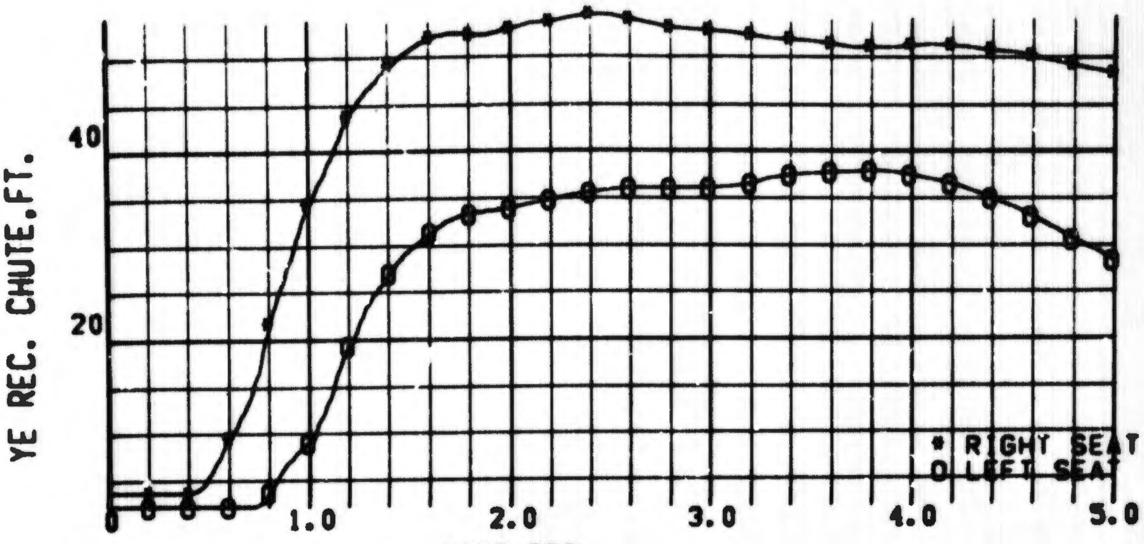
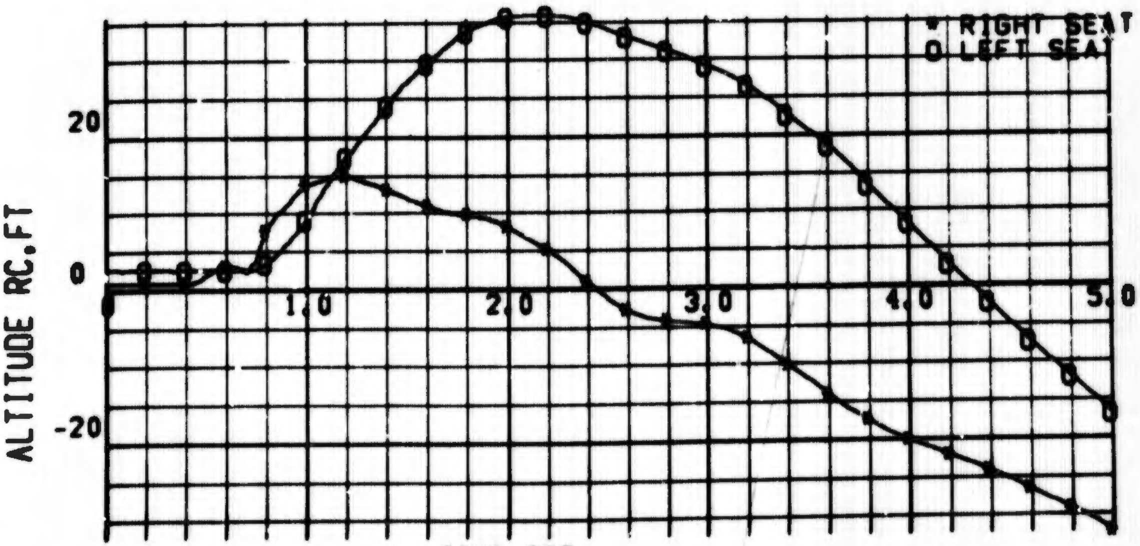


FIG 365 SYSTEM ANALYSIS,CASE-4
PARACHUTE TOTAL AIRSPEED

FIG 366 SYSTEM ANALYSIS,CASE-4
PARACHUTE DOWNRANGE DISTANCE



TIME,SEC
FIG 367 SYSTEM ANALYSIS,CASE-4
PARACHUTE LATERAL DISTANCE



TIME,SEC
FIG 368 SYSTEM ANALYSIS,CASE-4
PARACHUTE ALTITUDE

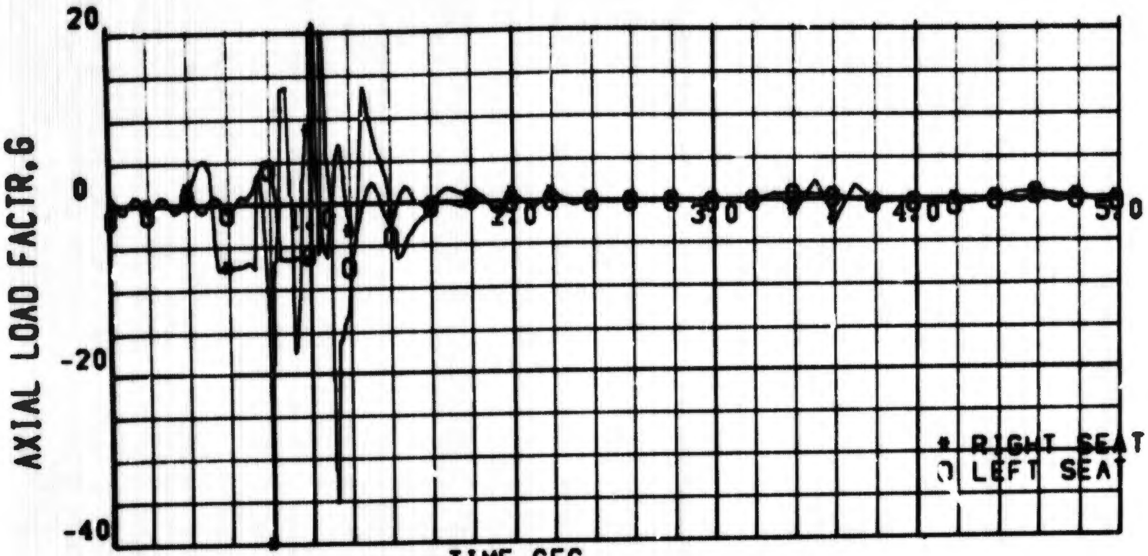


FIG 369 SYSTEM ANALYSIS,CASE-4
SEAT-MAN AXIAL LOAD FACTOR,CG

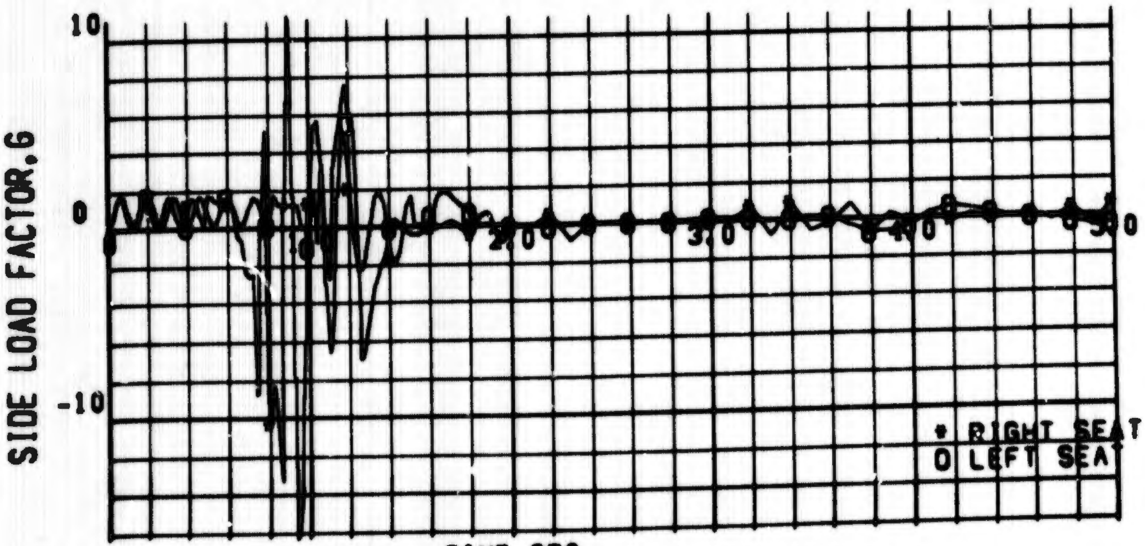


FIG 370 SYSTEM ANALYSIS,CASE-4
SEAT-MAN SIDE LOAD FACTOR,CG

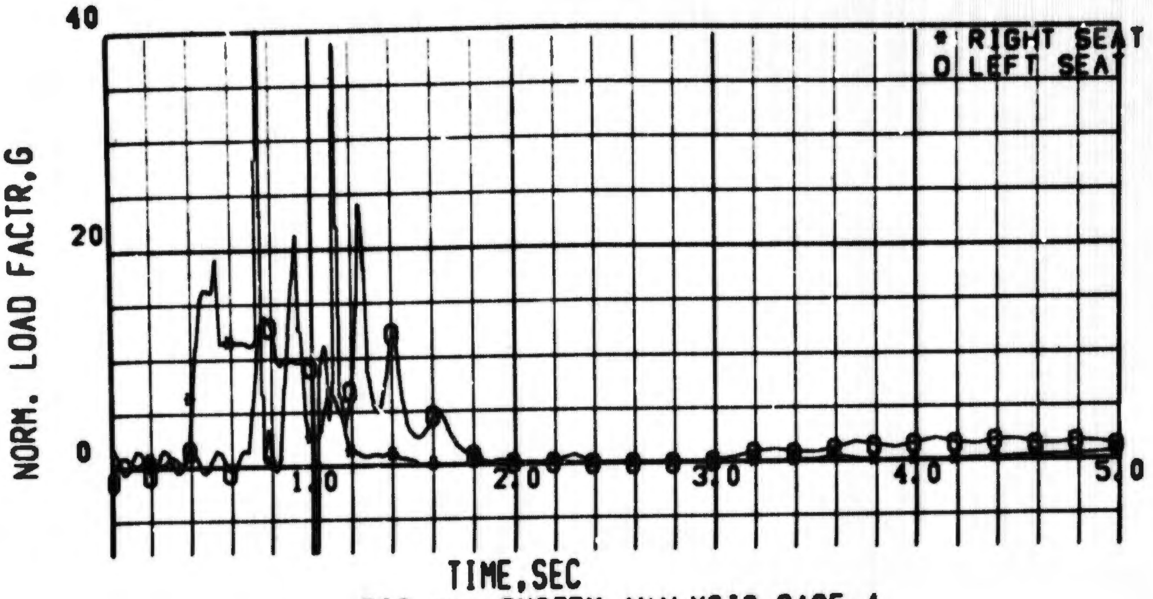


FIG 371 SYSTEM ANALYSIS,CASE-4
SEAT-MAN NORMAL LOAD FACTOR,CG

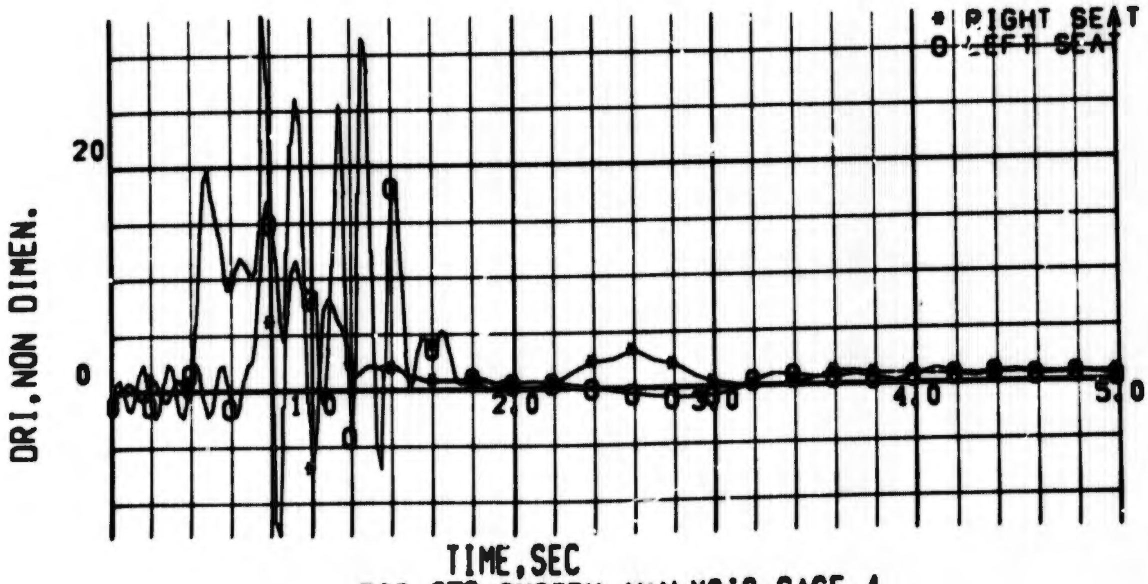


FIG 372 SYSTEM ANALYSIS,CASE-4
PILOT DYNAMIC RESPONSE INDEX

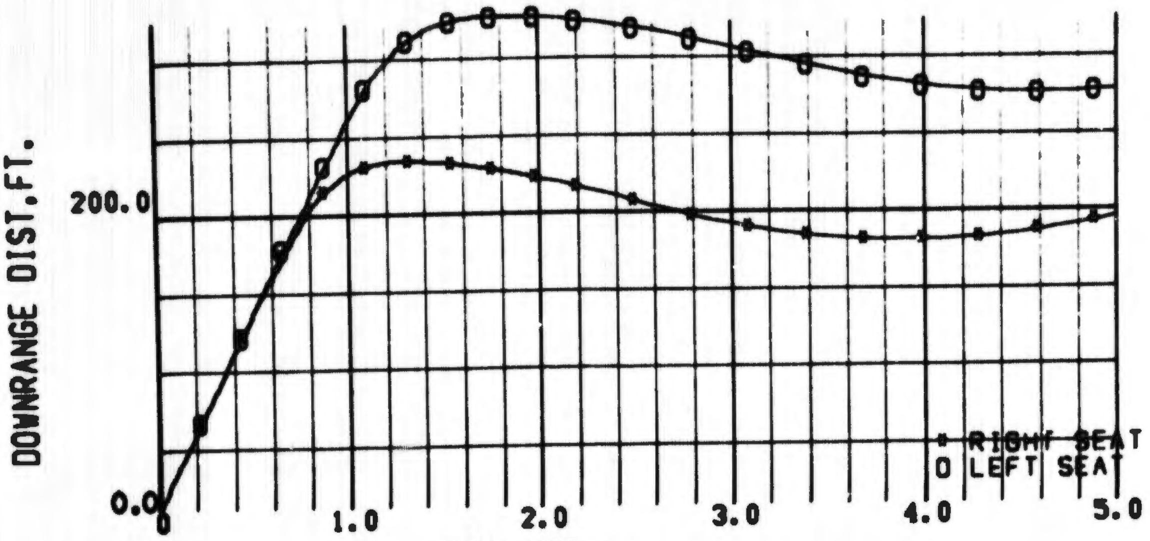


FIG373 SYSTEM ANALYSIS,CASE-5
SEAT AND/OR MAN DOWNRANGE DIST

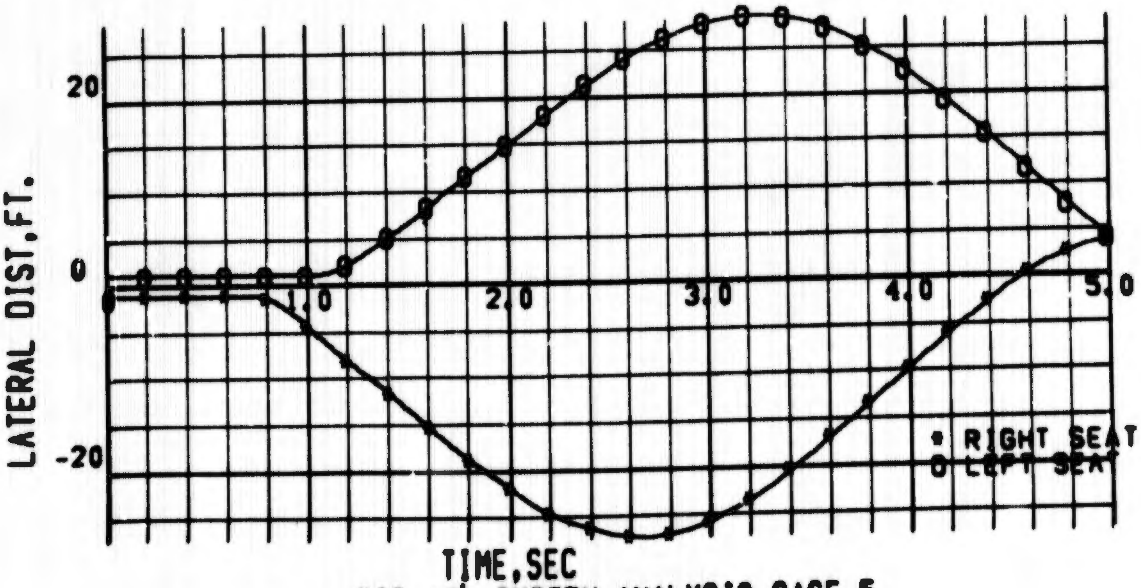


FIG 374 SYSTEM ANALYSIS,CASE-5
SEAT AND/OR MAN LATERAL DIST.

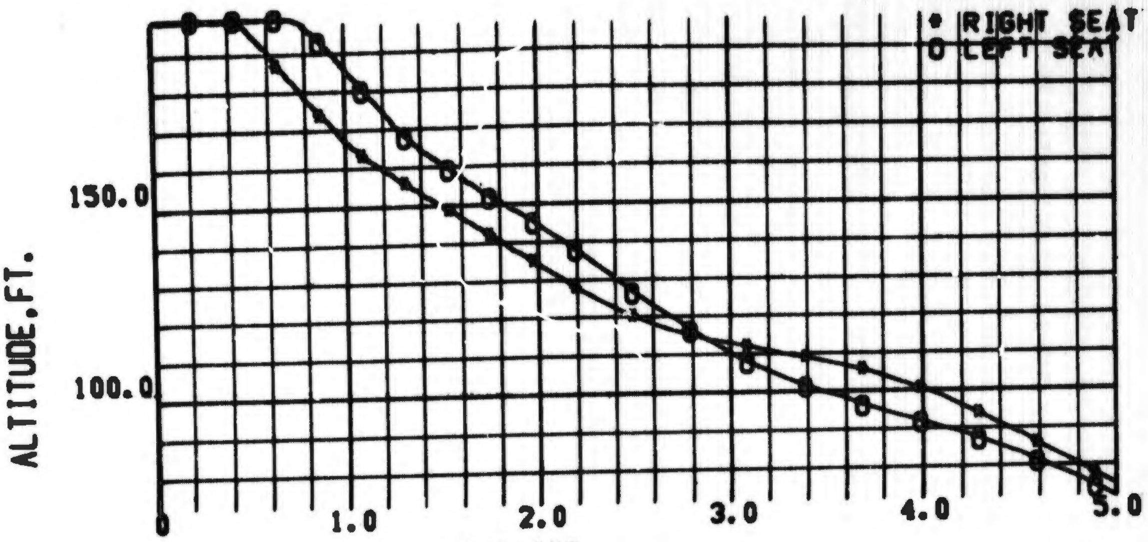


FIG 375 SYSTEM ANALYSIS, CASE-5
SEAT AND/OR MAN ALTITUDE

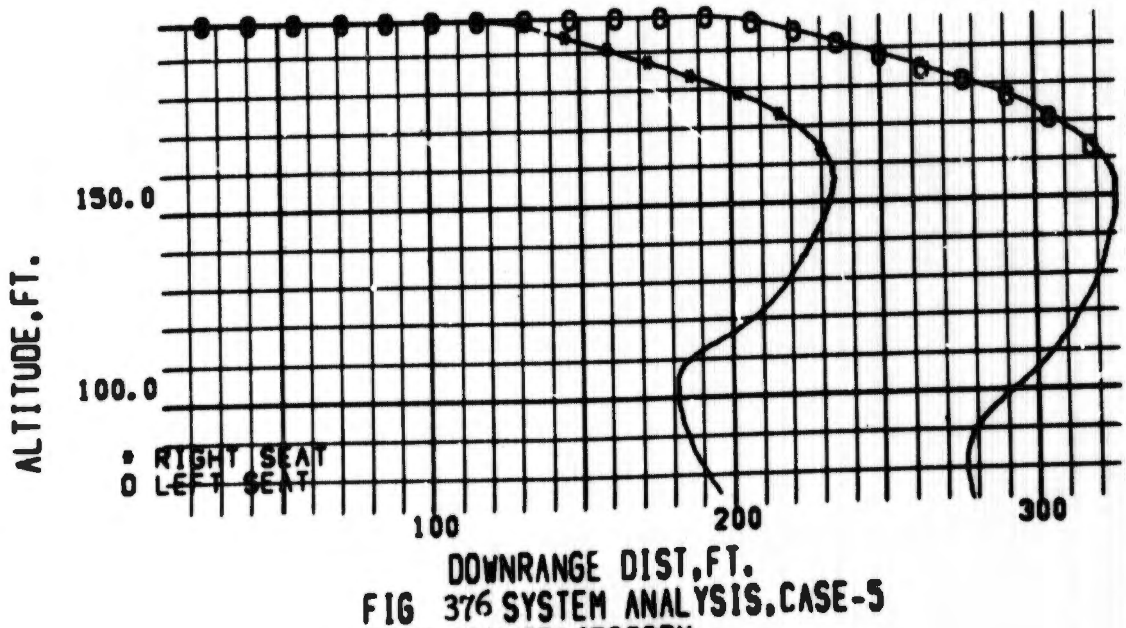


FIG 376 SYSTEM ANALYSIS, CASE-5
SEAT-MAN TRAJECTORY

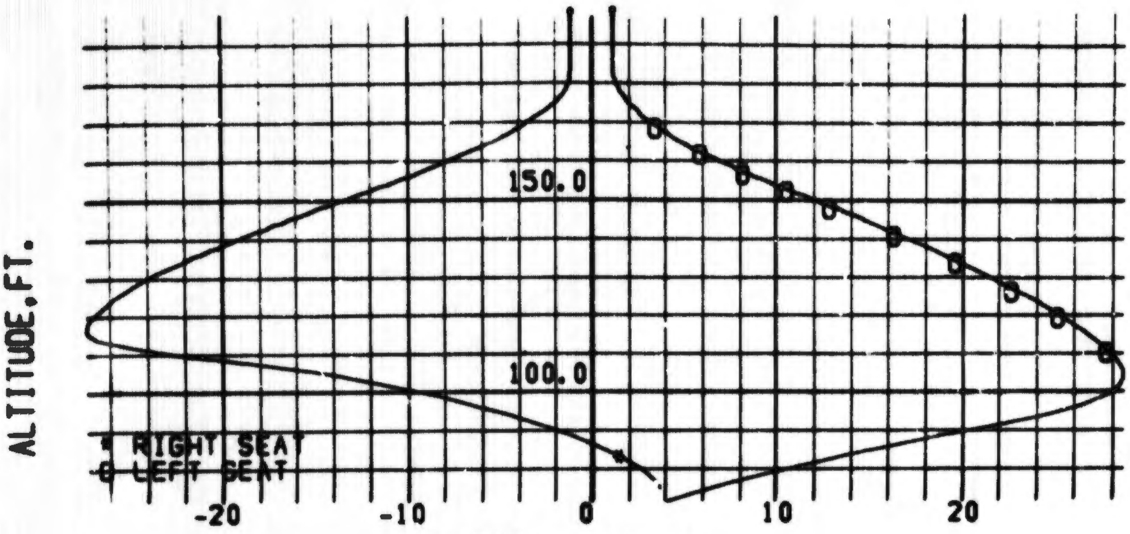


FIG 377 SYSTEM ANALYSIS,CASE-5
SEAT-MAN TRAJECTORY

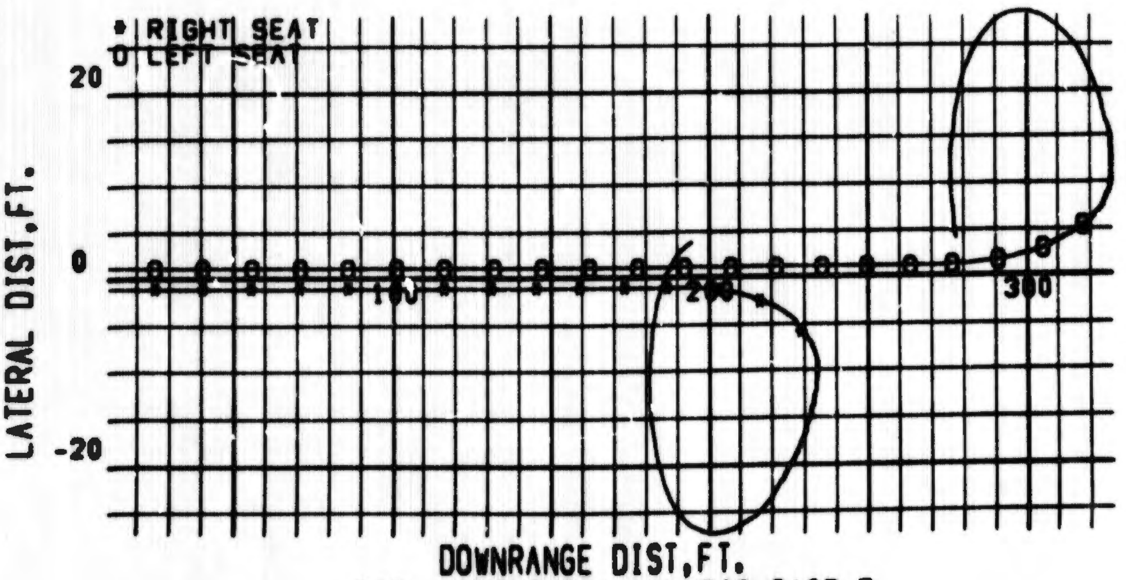


FIG 378 SYSTEM ANALYSIS,CASE-5
SEAT-MAN TRAJECTORY

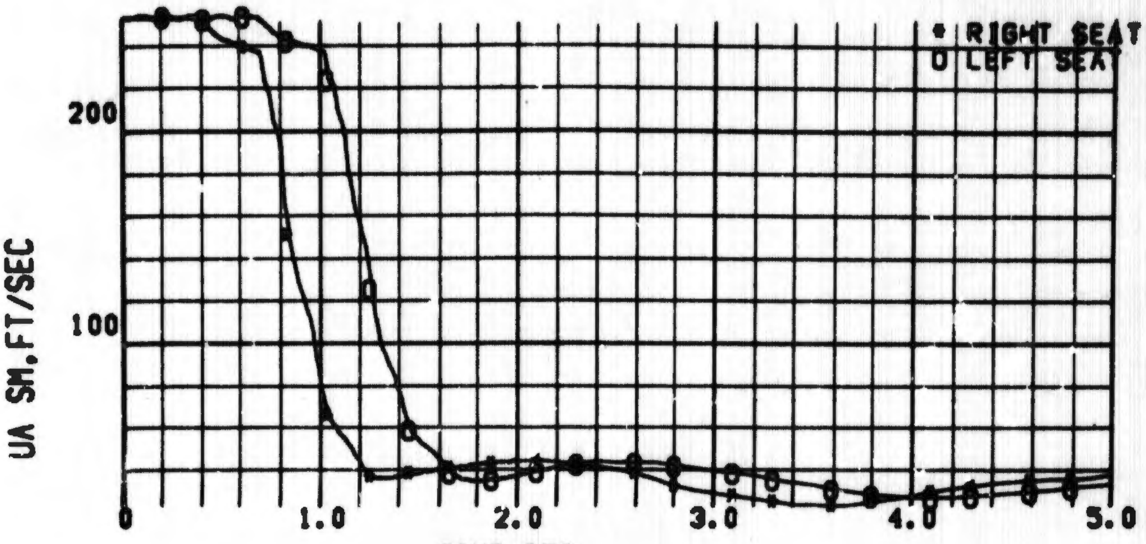


FIG 379 SYSTEM ANALYSIS,CASE-5
SEAT AND/OR MAN TOTAL AIRSPEED

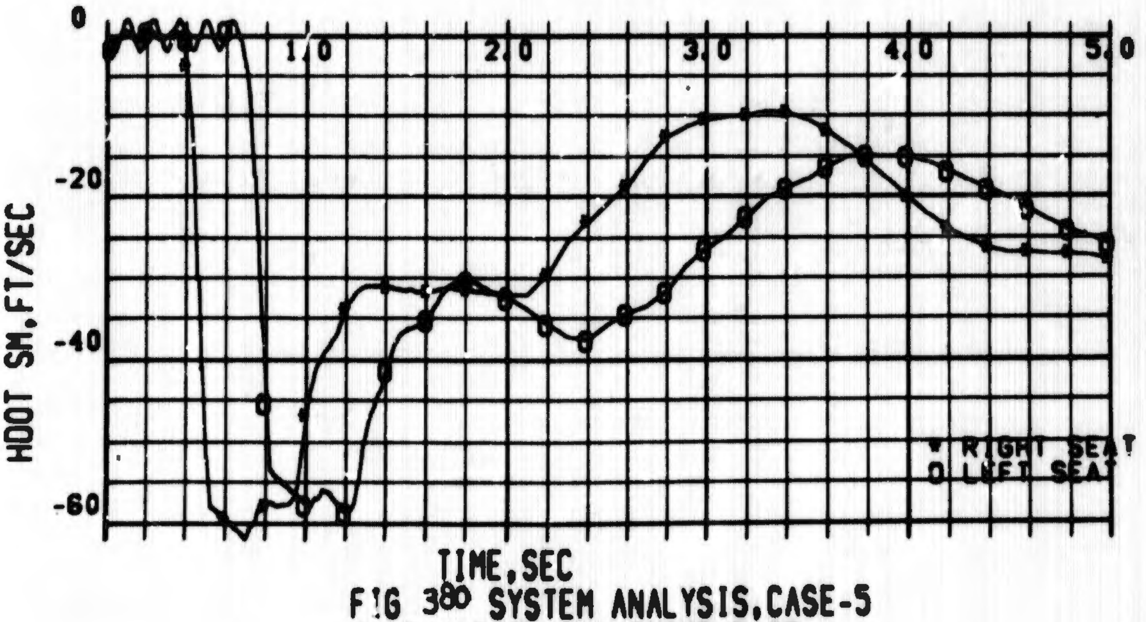


FIG 380 SYSTEM ANALYSIS,CASE-5
SEAT AND/OR MAN CLIMB RATE

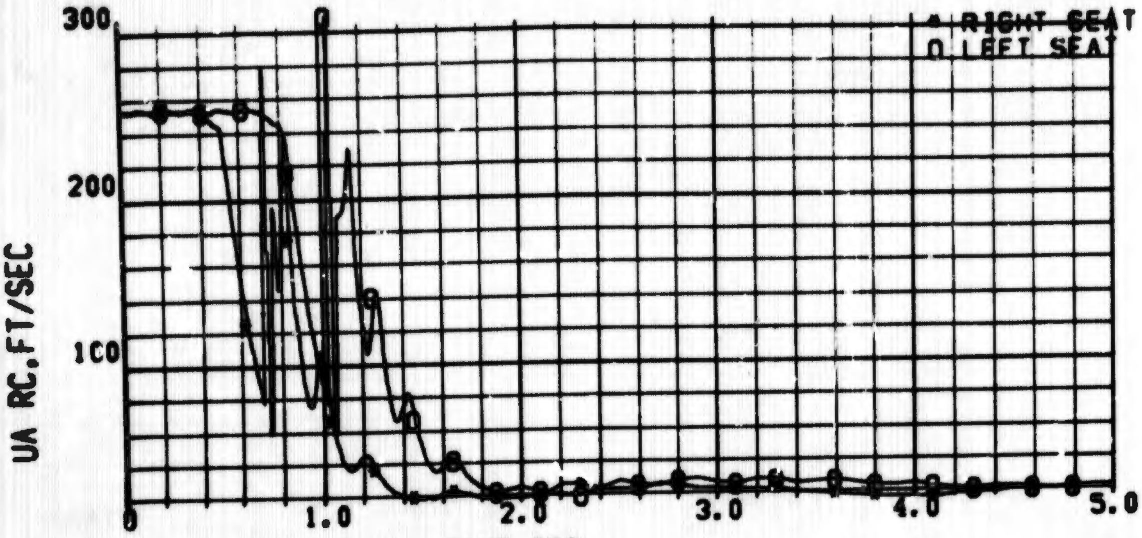


FIG 381 SYSTEM ANALYSIS,CASE-5
PARACHUTE TOTAL AIRSPEED

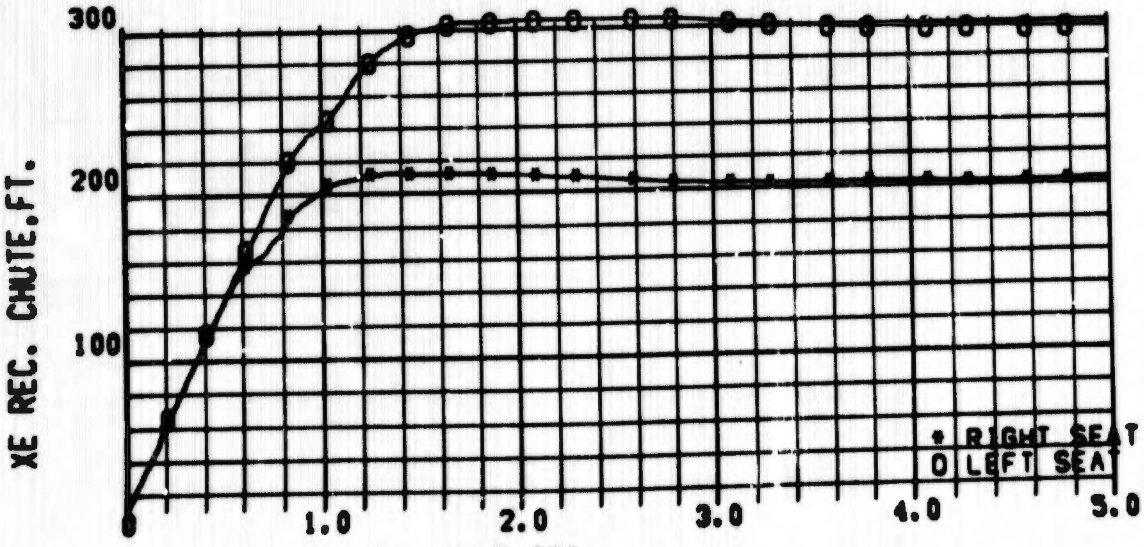


FIG 382 SYSTEM ANALYSIS,CASE-5
PARACHUTE DOWNRANGE DISTANCE

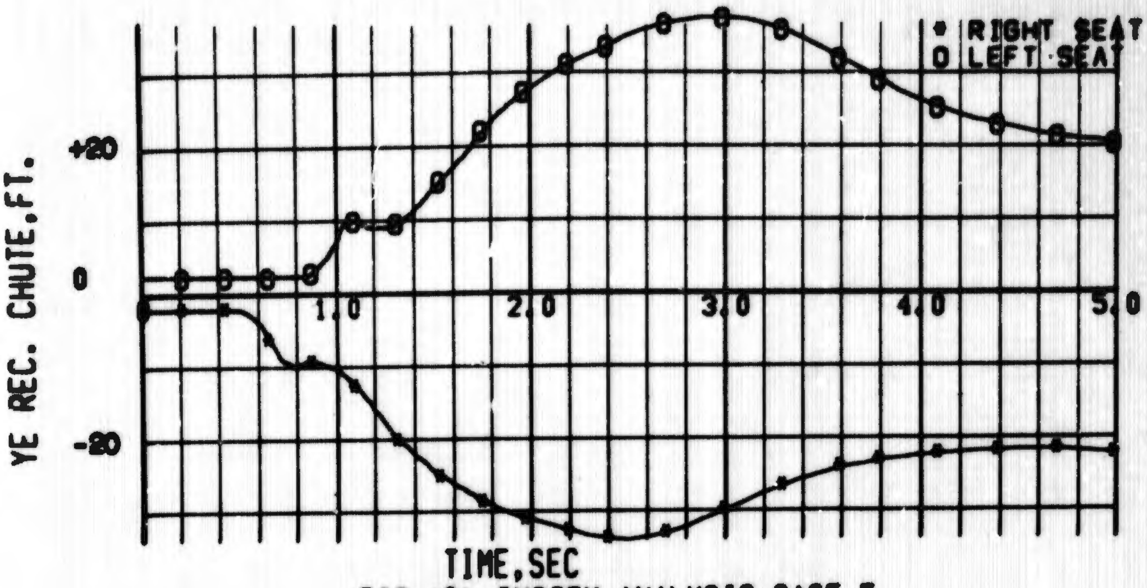


FIG 383 SYSTEM ANALYSIS,CASE-5
PARACHUTE LATERAL DISTANCE

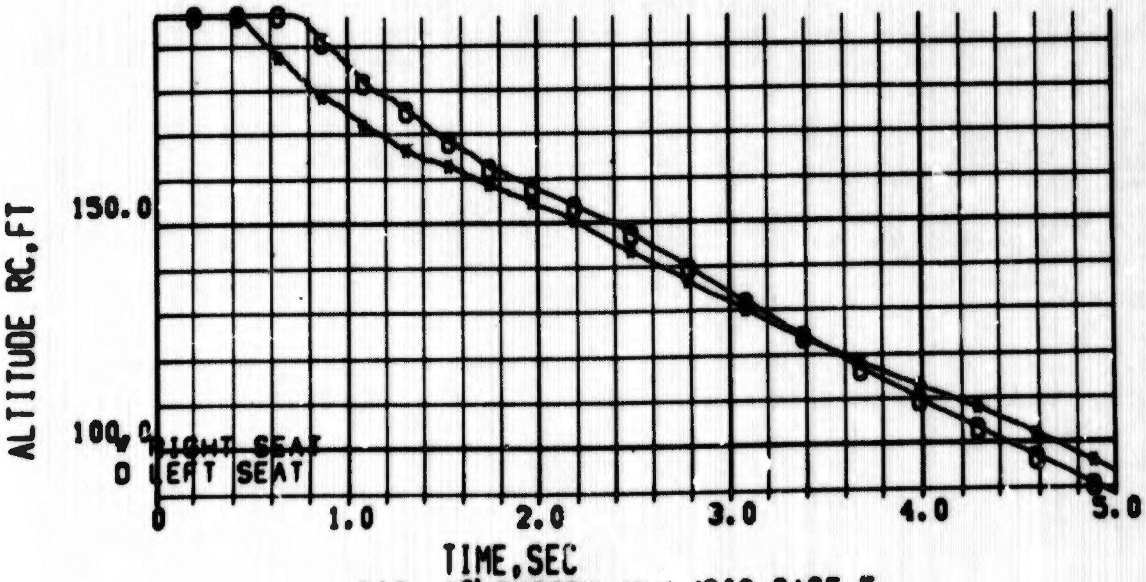


FIG 384 SYSTEM ANALYSIS,CASE-5
PARACHUTE ALTITUDE

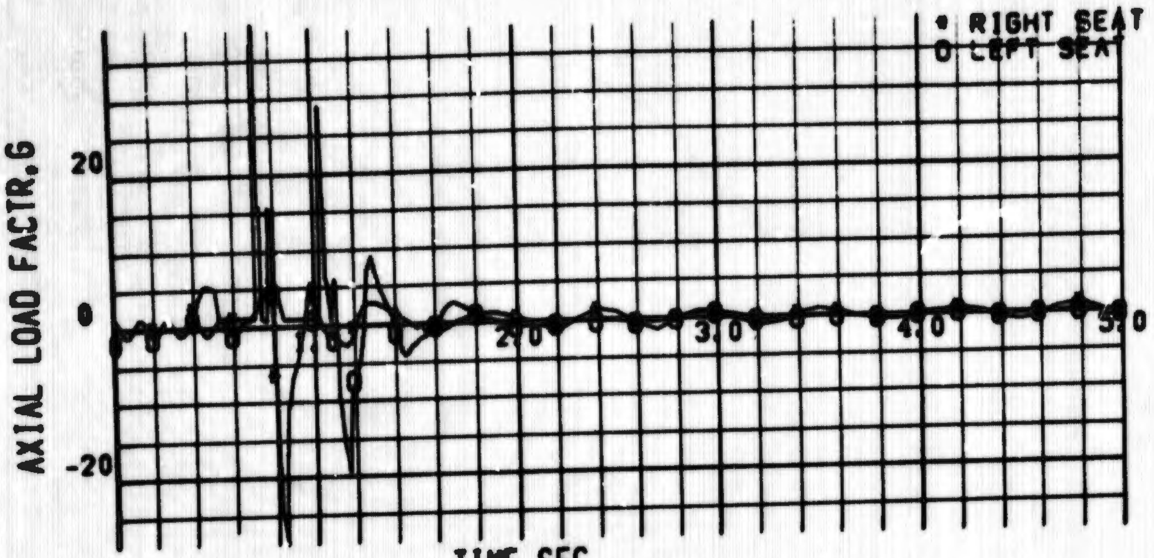


FIG 385 SYSTEM ANALYSIS,CASE-5
SEAT-MAN AXIAL LOAD FACTOR,CG

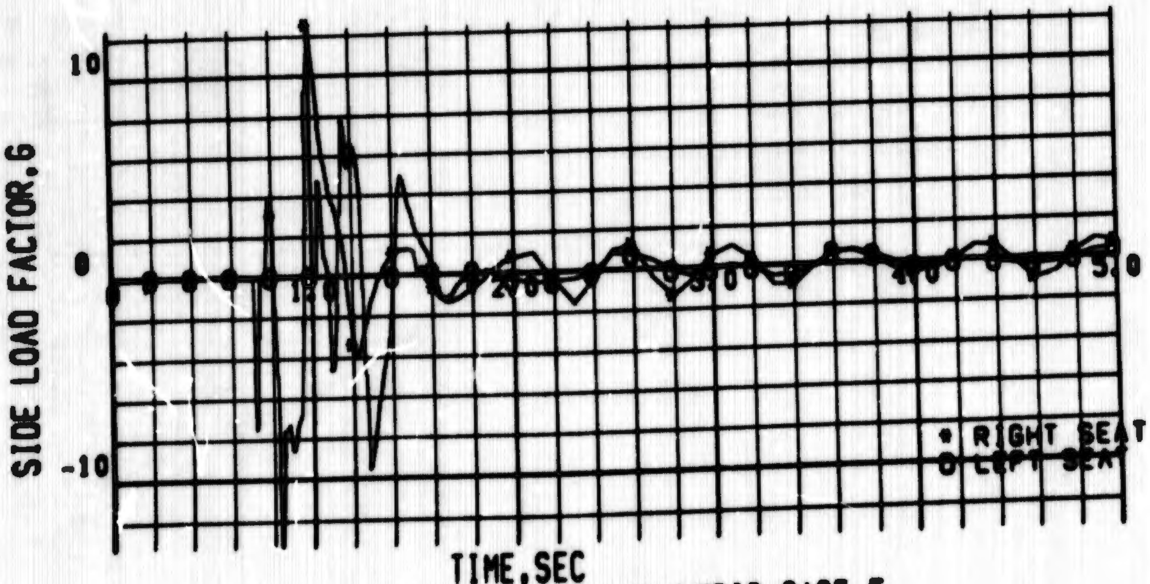


FIG 386 SYSTEM ANALYSIS,CASE-5
SEAT-MAN SIDE LOAD FACTOR,CG

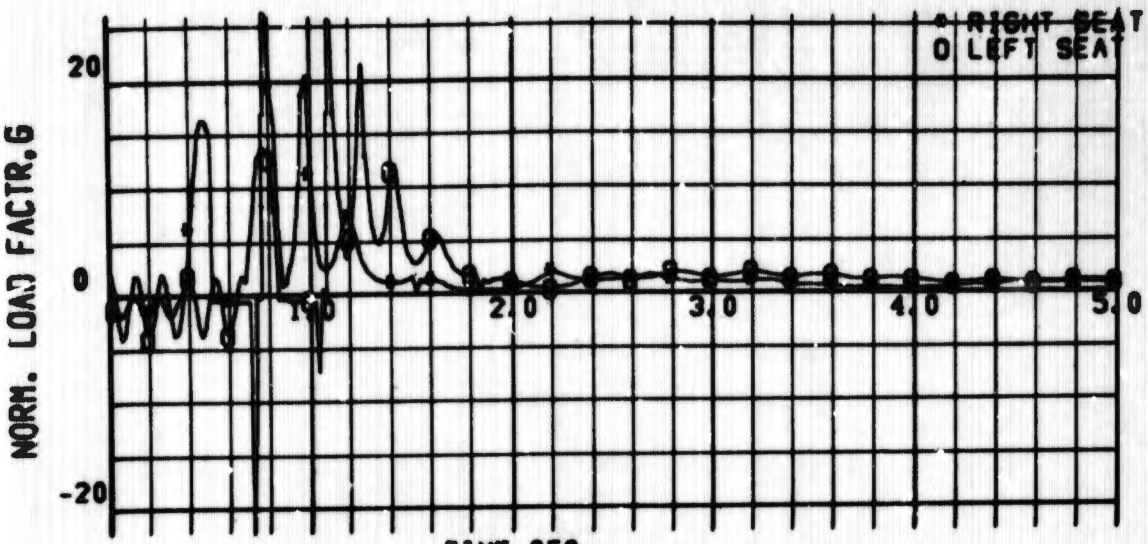


FIG 387 SYSTEM ANALYSIS,CASE-5
SEAT-MAN NORMAL LOAD FACTOR,CG

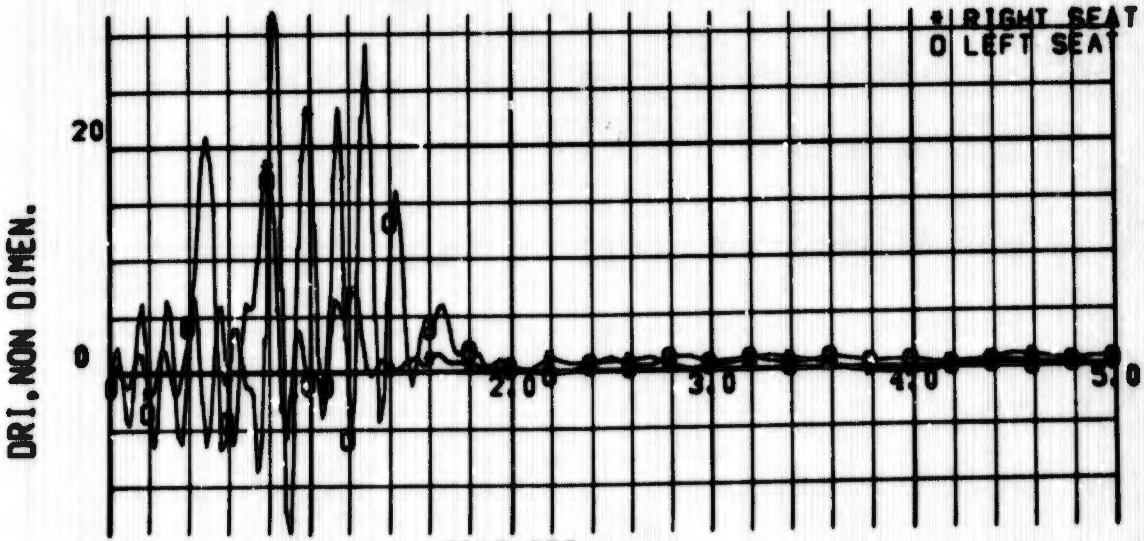


FIG 388 SYSTEM ANALYSIS,CASE-5
PILOT DYNAMIC RESPONSE INDEX

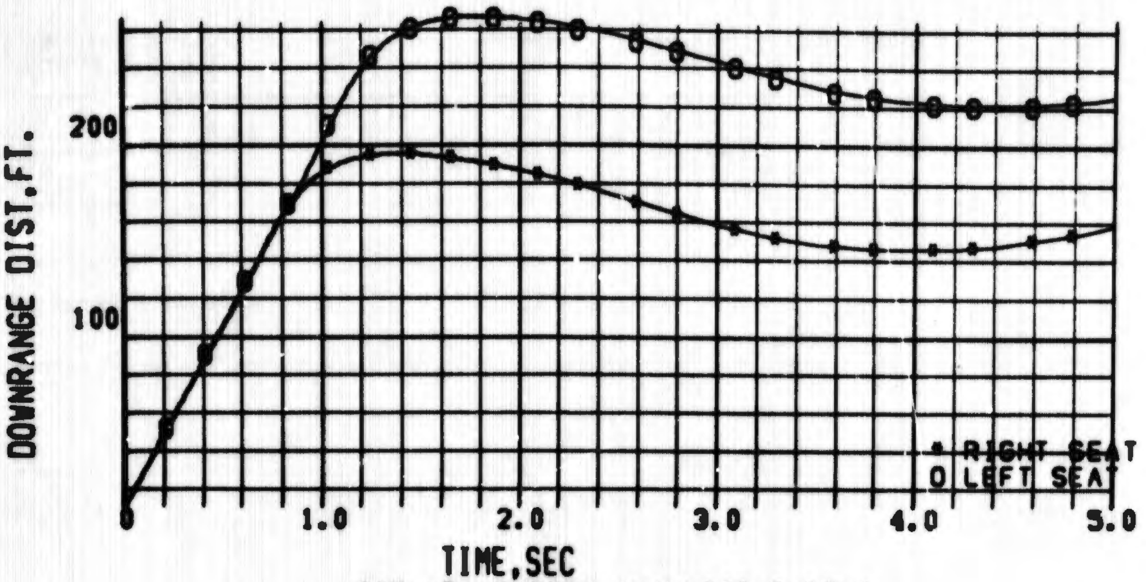


FIG 389 SYSTEM ANALYSIS,CASE-6
SEAT AND/OR MAN DOWNRANGE DIST

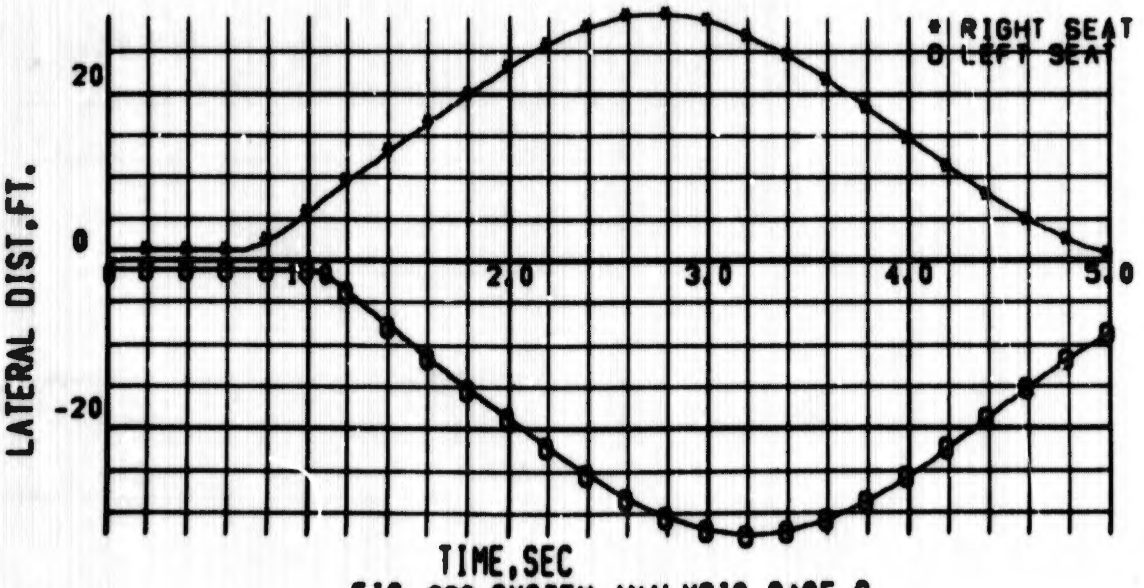


FIG 390 SYSTEM ANALYSIS,CASE-6
SEAT AND/OR MAN LATERAL DIST.

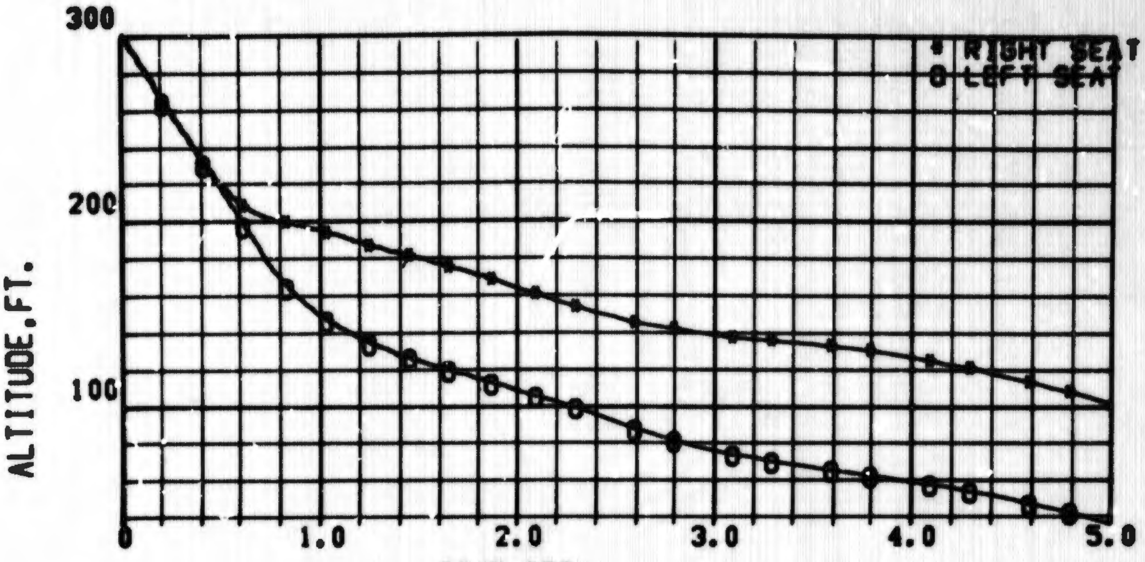


FIG 391 SYSTEM ANALYSIS,CASE-6
SEAT AND/OR MAN ALTITUDE

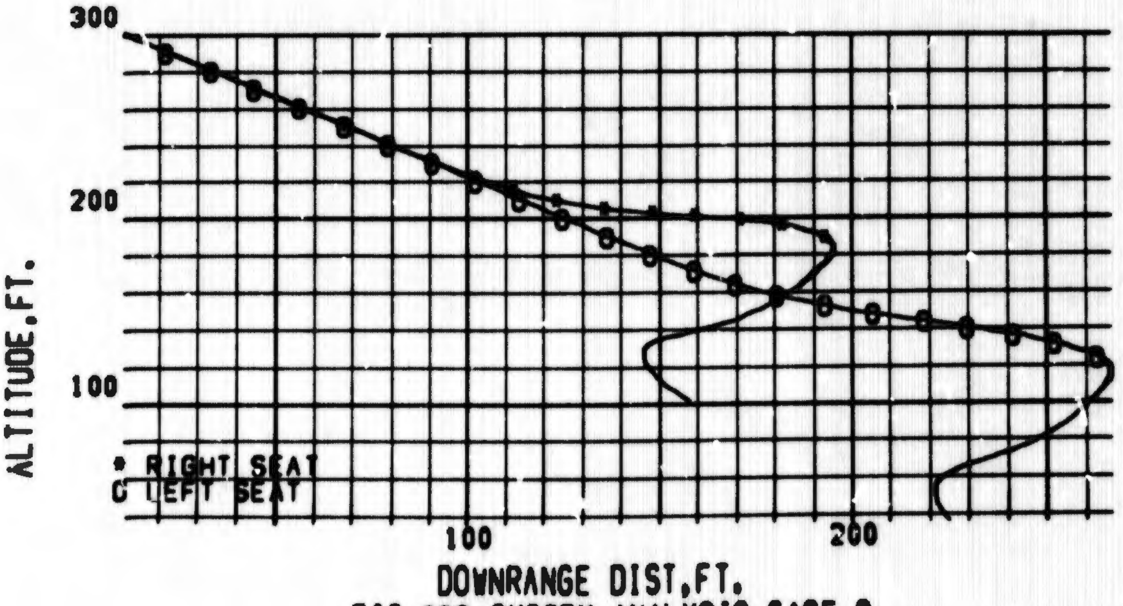


FIG 392 SYSTEM ANALYSIS,CASF-6
SEAT-MAN TRAJECTORY

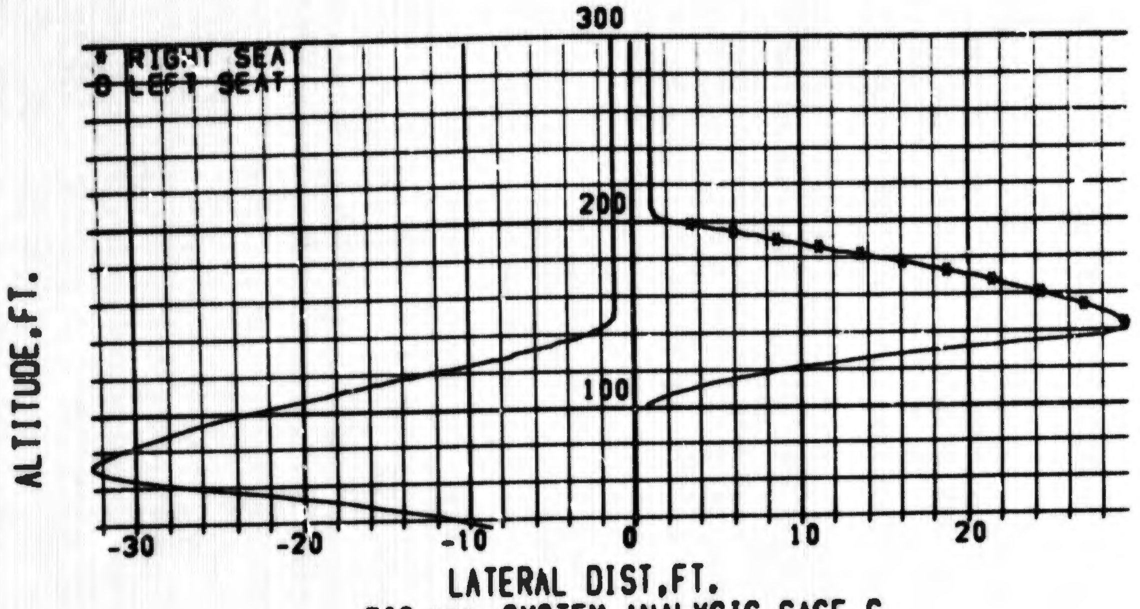


FIG 393 SYSTEM ANALYSIS,CASE-6
SEAT-MAN TRAJECTORY

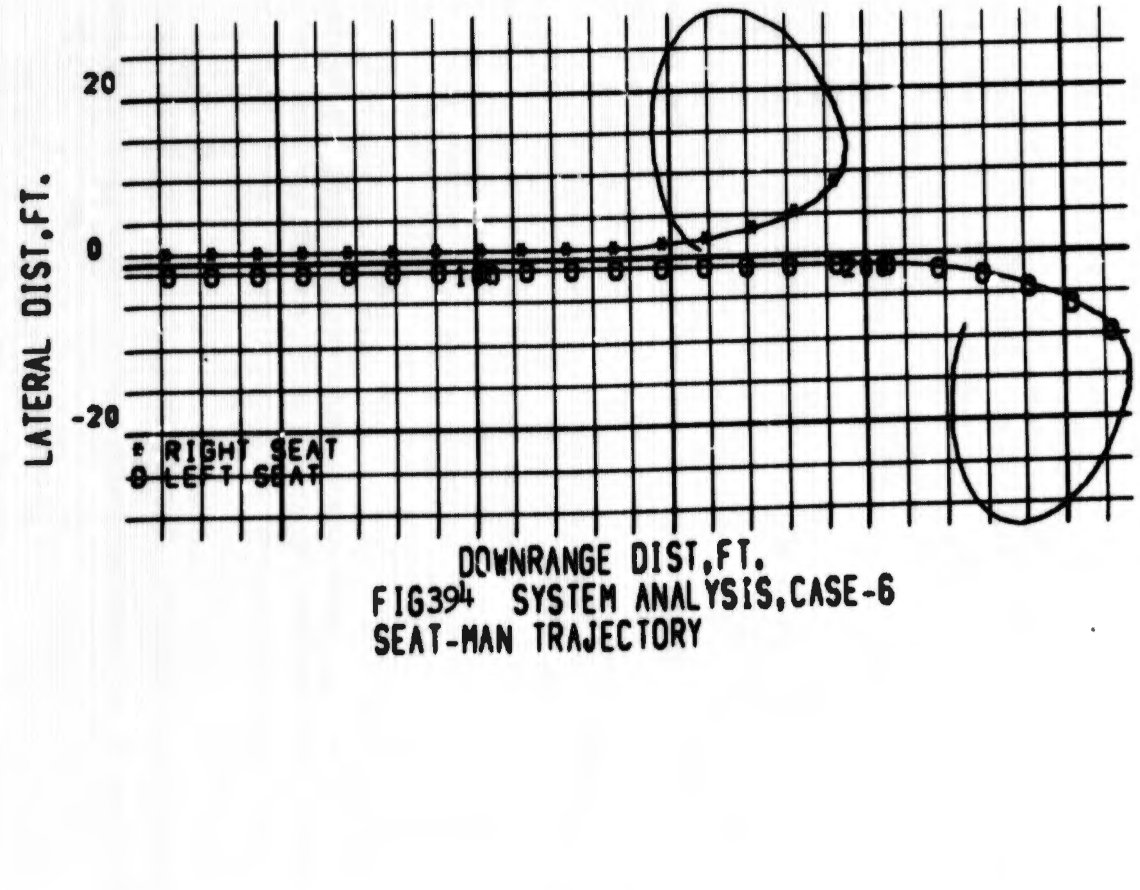


FIG394 SYSTEM ANALYSIS,CASE-6
SEAT-MAN TRAJECTORY

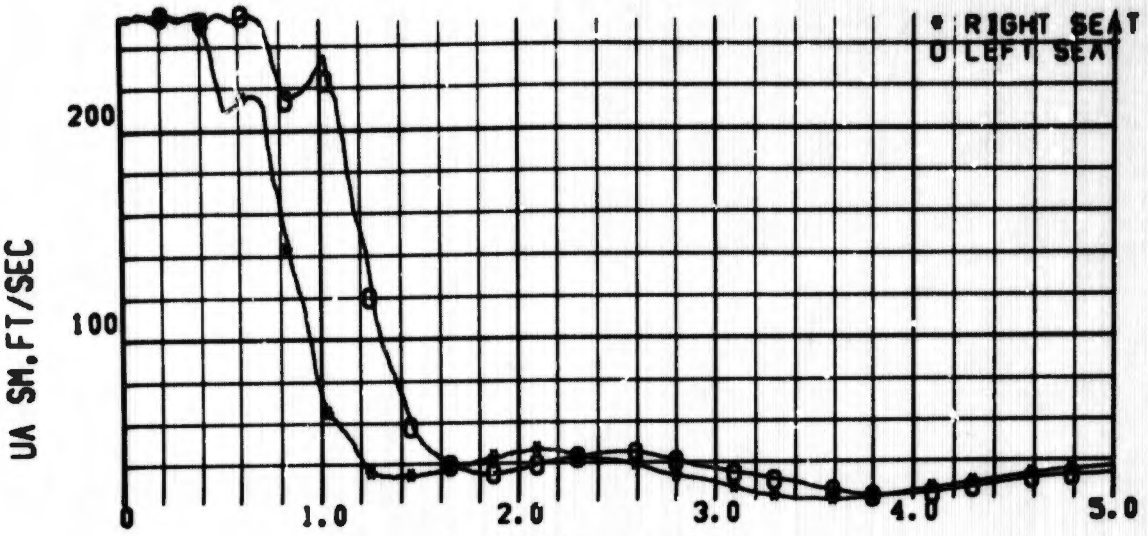


FIG 395 SYSTEM ANALYSIS,CASE-6
SEAT AND/OR MAN TOTAL AIRSPEED

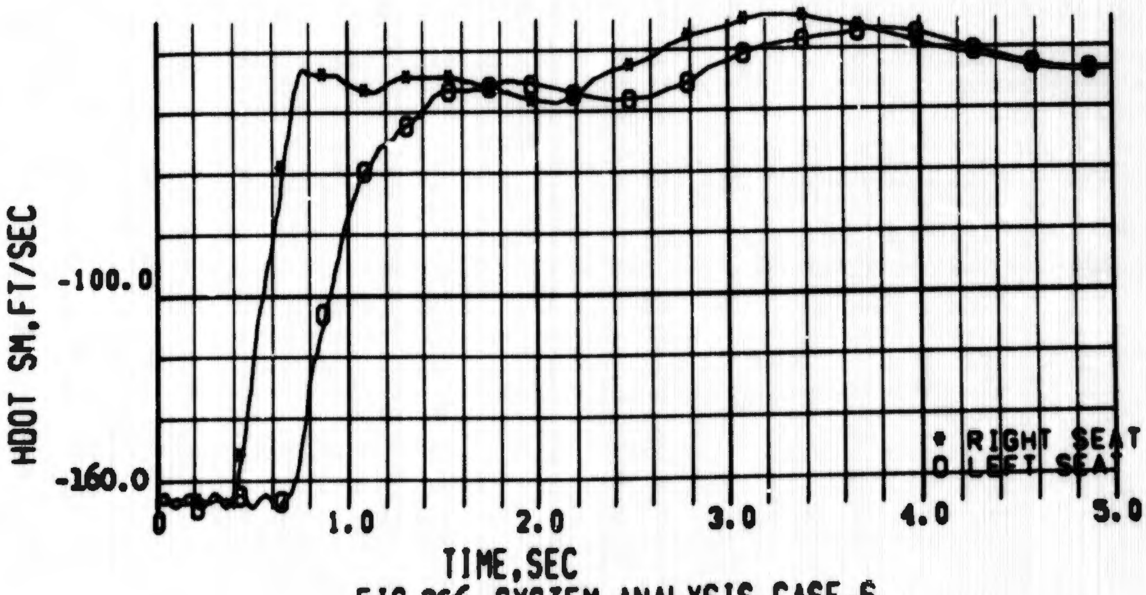


FIG 396 SYSTEM ANALYSIS,CASE-6
SEAT AND/OR MAN CLIMB RATE

FIG 397 SYSTEM ANALYSIS,CASE-6
PARACHUTE TOTAL AIRSPEED

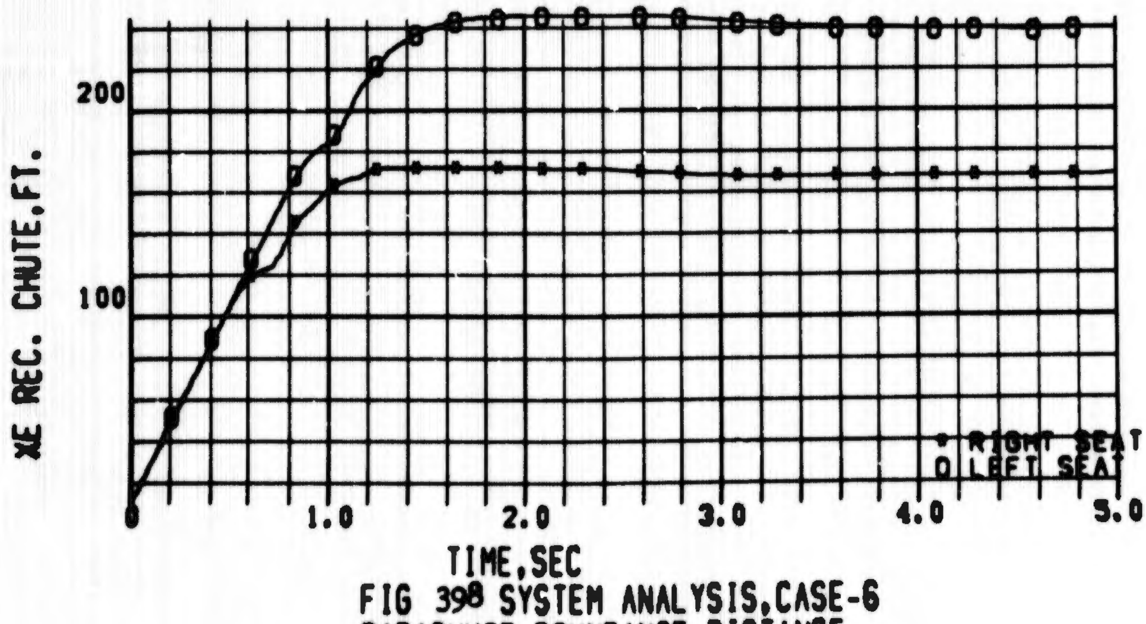


FIG 398 SYSTEM ANALYSIS,CASE-6
PARACHUTE DOWNRANGE DISTANCE

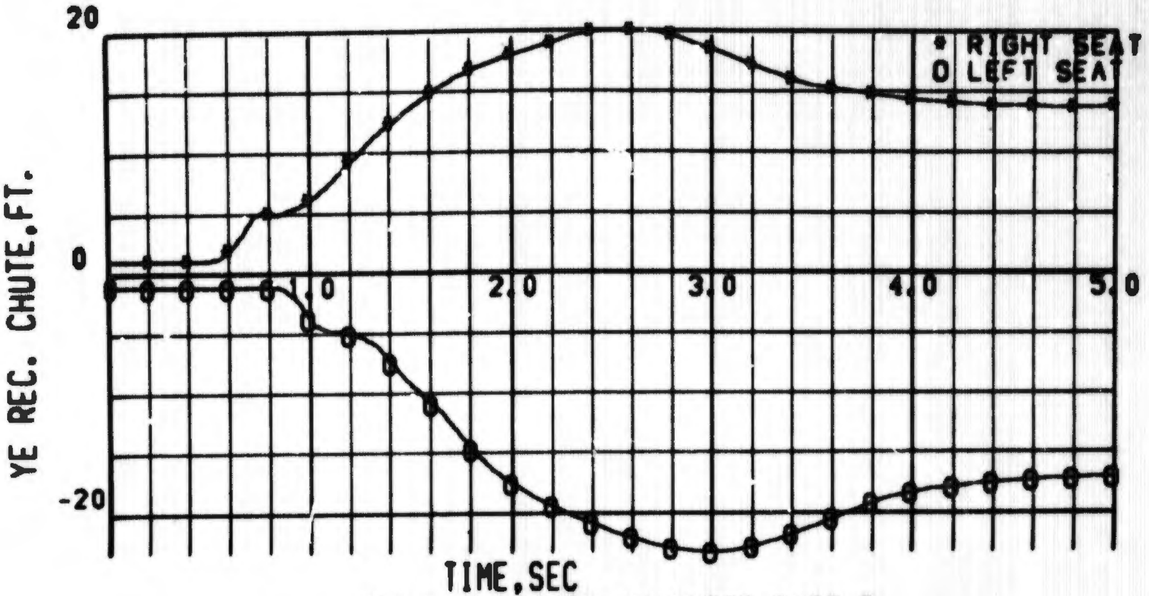


FIG 399 SYSTEM ANALYSIS, CASE-6
PARACHUTE LATERAL DISTANCE

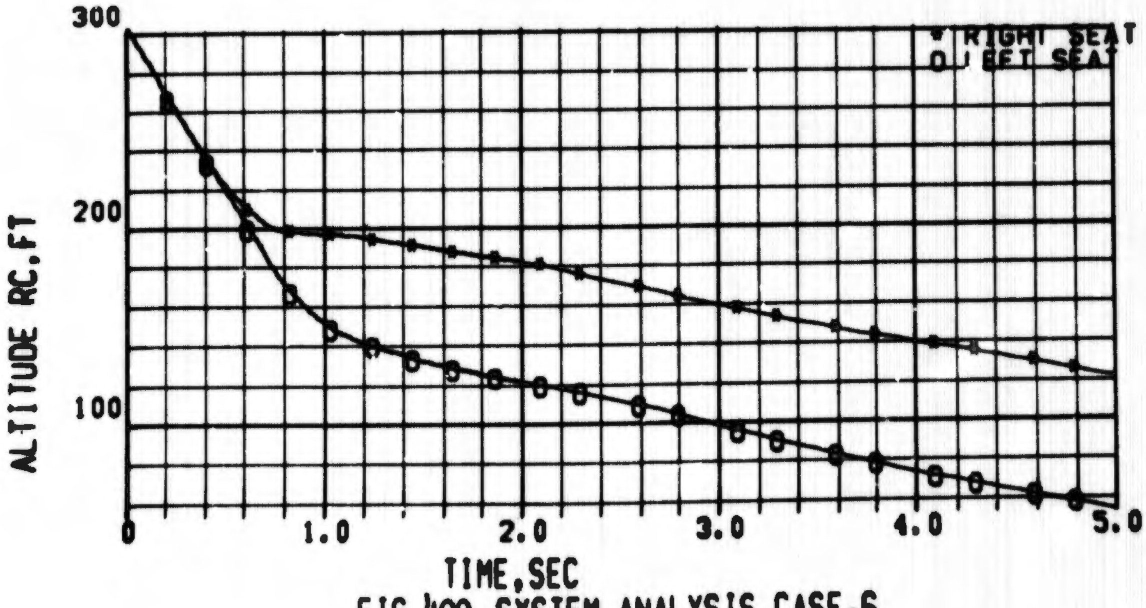


FIG 400 SYSTEM ANALYSIS, CASE-6
PARACHUTE ALTITUDE

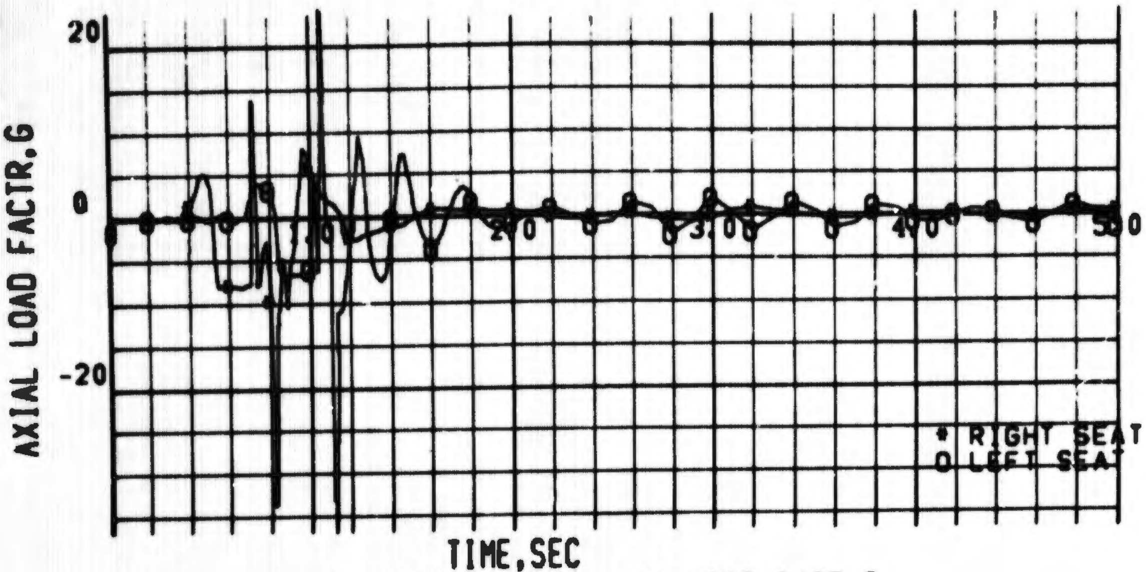


FIG 401 SYSTEM ANALYSIS,CASE-6
SEAT-MAN AXIAL LOAD FACTOR,CG

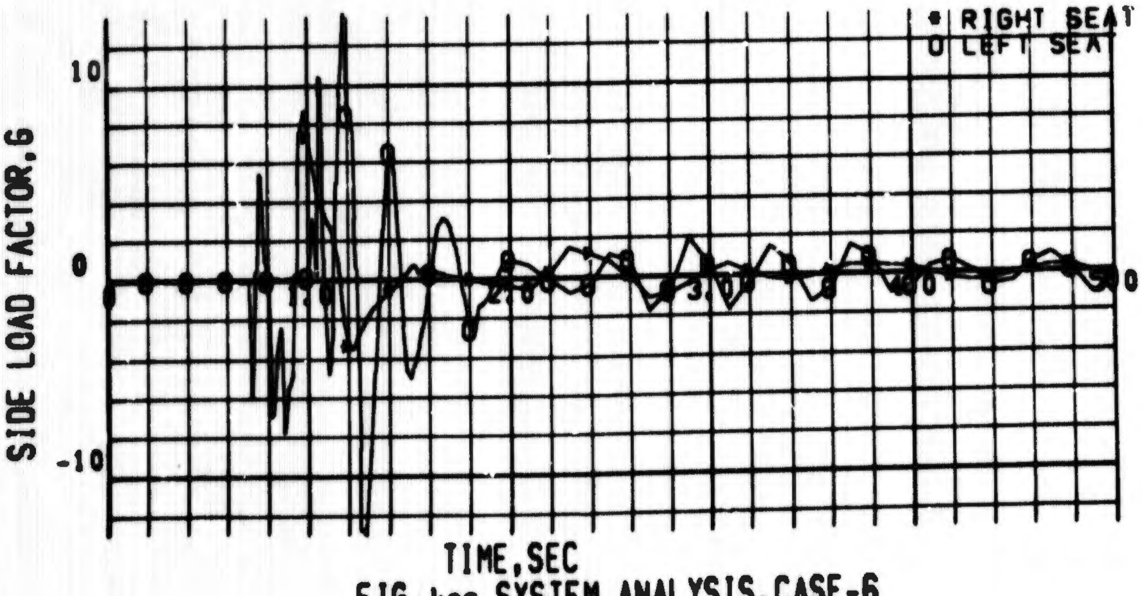


FIG 402 SYSTEM ANALYSIS,CASE-6
SEAT-MAN SIDE LOAD FACTOR,CG

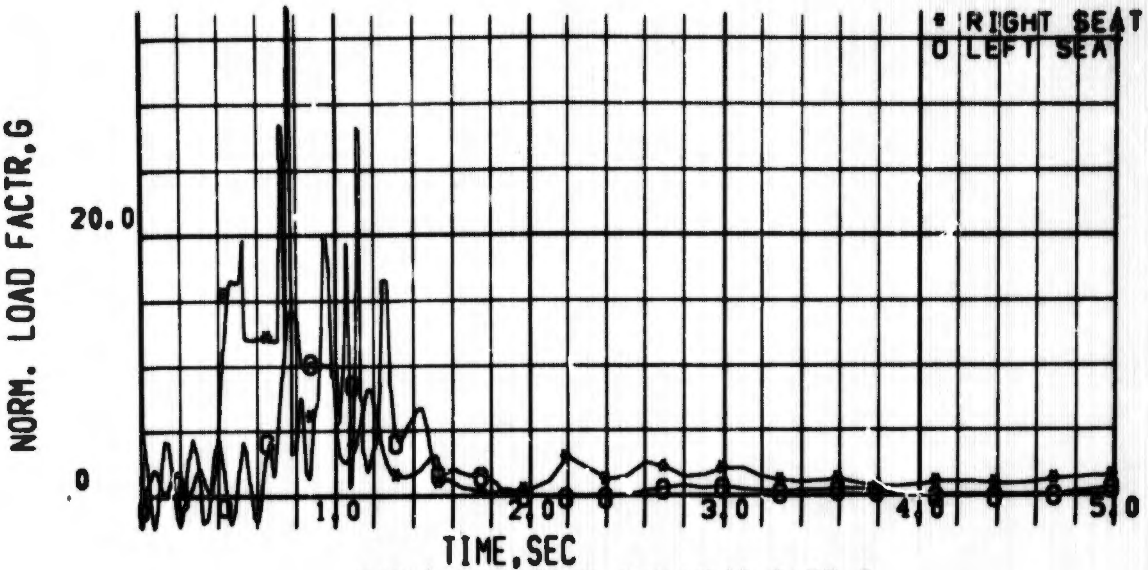


FIG 403 SYSTEM ANALYSIS,CASE-6
SEAT-MAN NORMAL LOAD FACTOR,CG

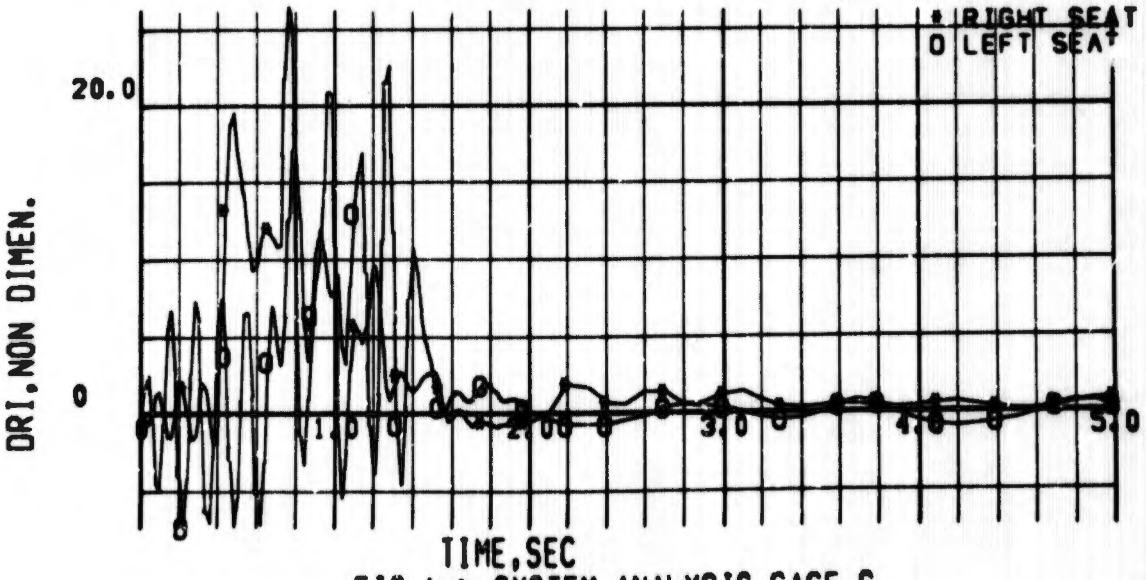


FIG 404 SYSTEM ANALYSIS,CASE-6
PILOT DYNAMIC RESPONSE INDEX

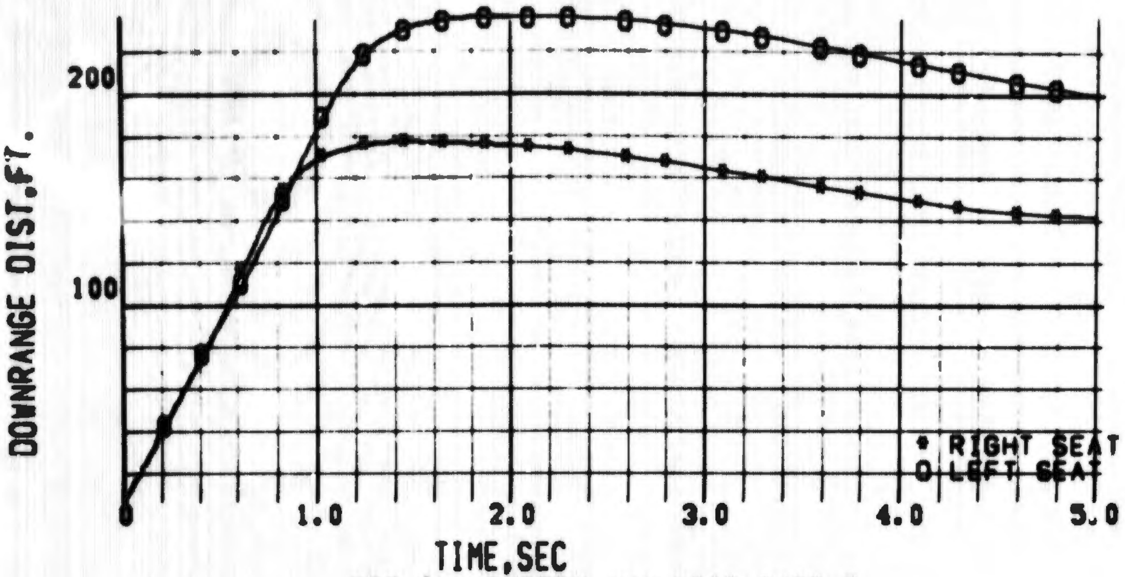


FIG 405 SYSTEM ANALYSIS,CASE-7
SEAT AND/OR MAN DOWNRANGE DIST

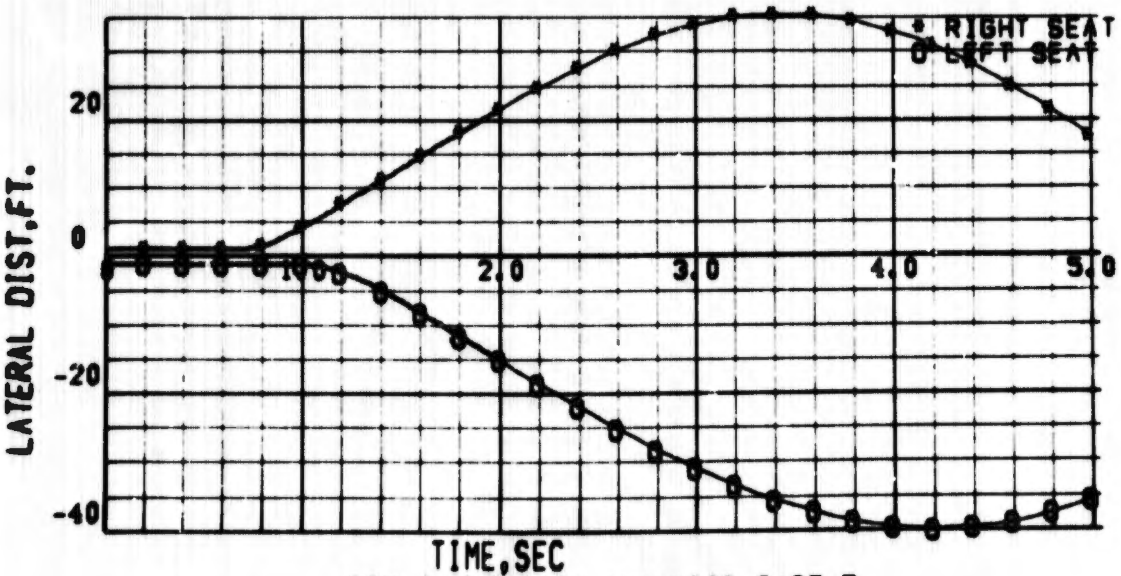


FIG 406 SYSTEM ANALYSIS,CASE-7
SEAT AND/OR MAN LATERAL DIST.

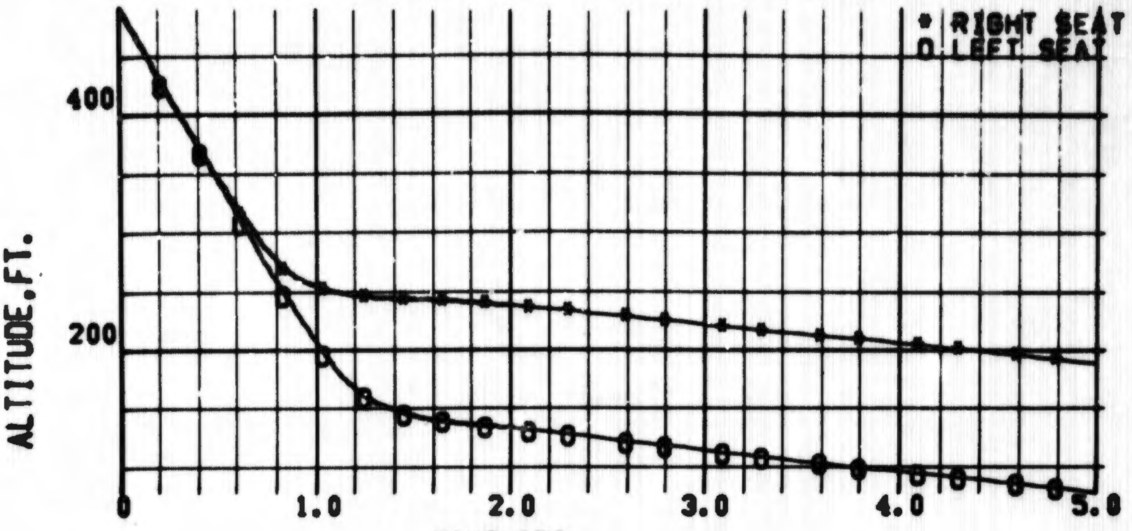


FIG 407 SYSTEM ANALYSIS,CASE-7
SEAT AND/OR MAN ALTITUDE

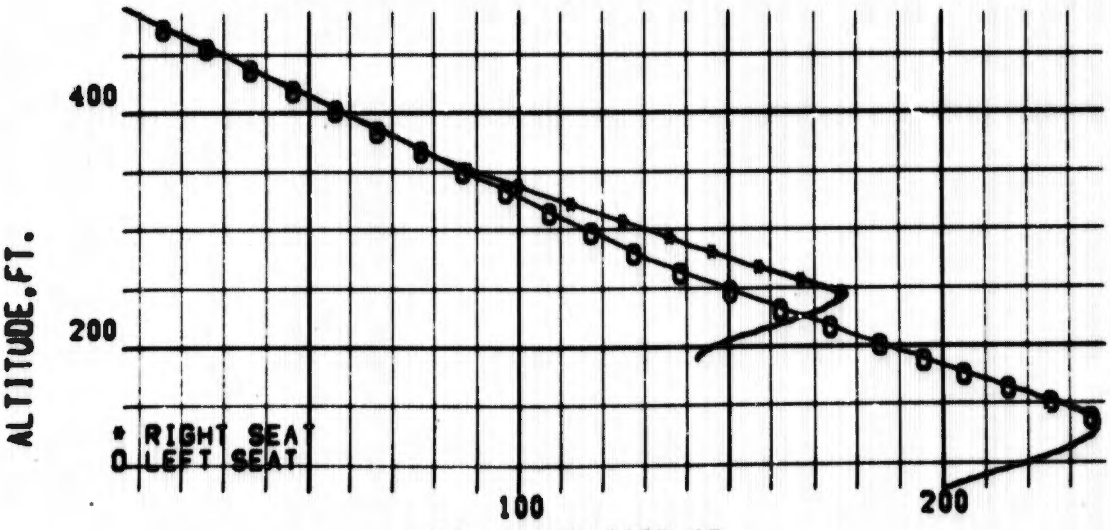


FIG 408 SYSTEM ANALYSIS,CASE-7
SEAT-MAN TRAJECTORY

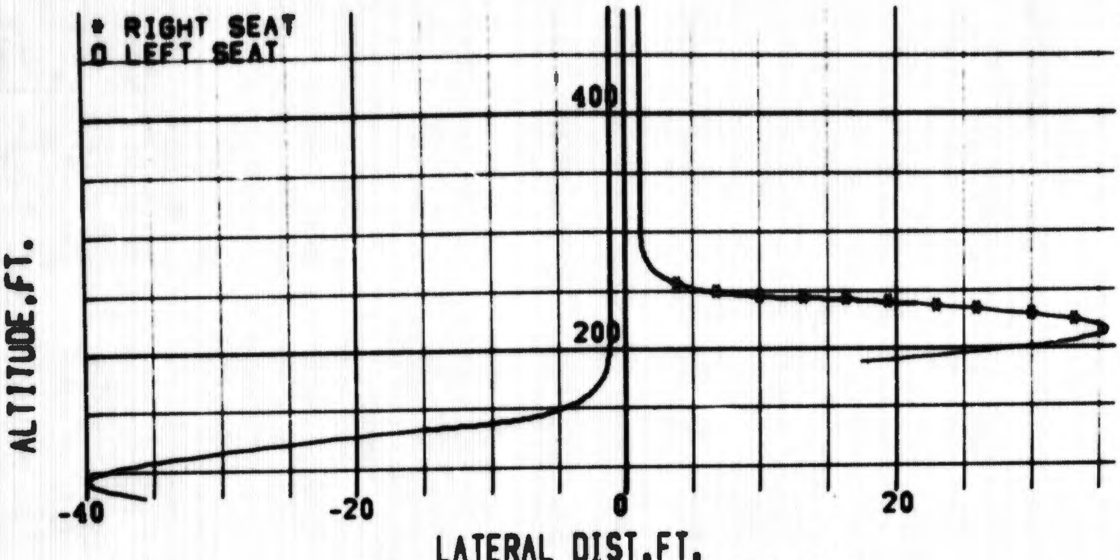


FIG 409 SYSTEM ANALYSIS,CASE-7
SEAT-MAN TRAJECTORY

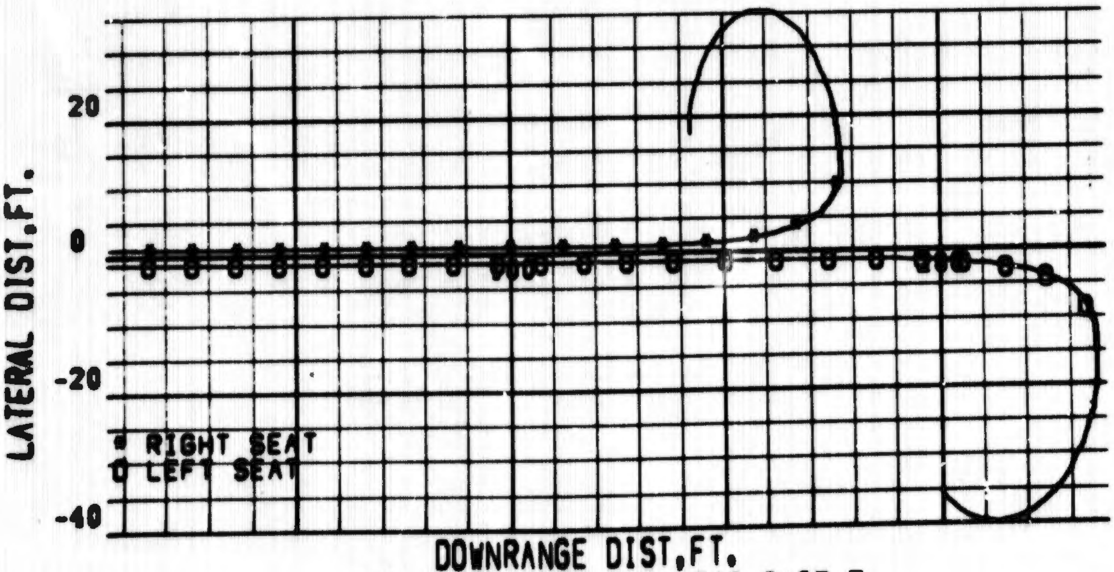


FIG 410 SYSTEM ANALYSIS,CASE-7
SEAT-MAN TRAJECTORY

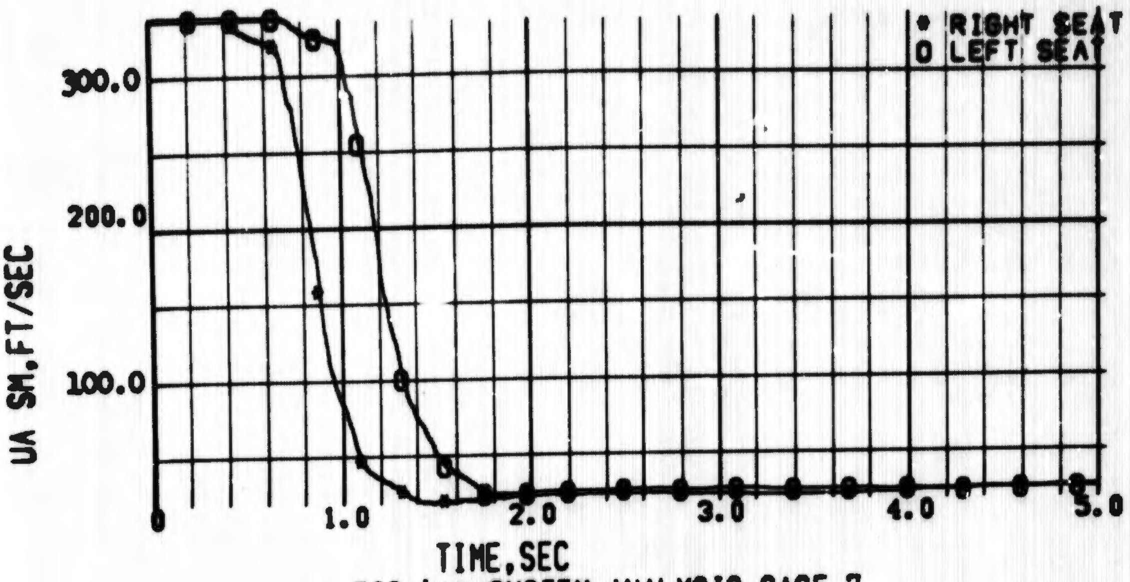


FIG 411 SYSTEM ANALYSIS,CASE-7
SEAT AND/OR MAN TOTAL AIRSPEED

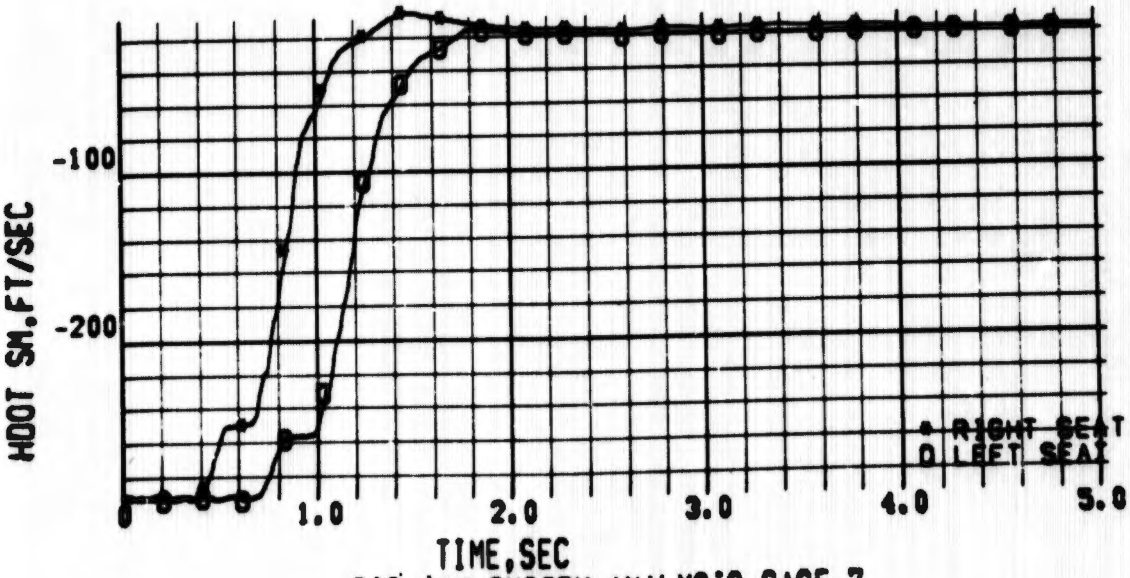


FIG 412 SYSTEM ANALYSIS,CASE-7
SEAT AND/OR MAN CLIMB RATE

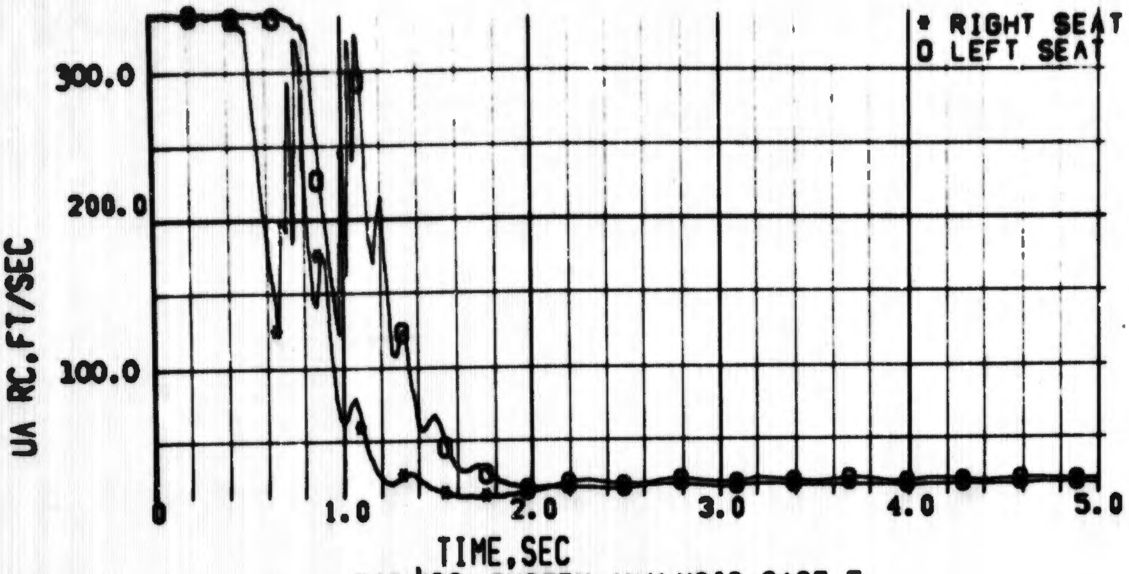


FIG 413 SYSTEM ANALYSIS,CASE-7
PARACHUTE TOTAL AIRSPEED

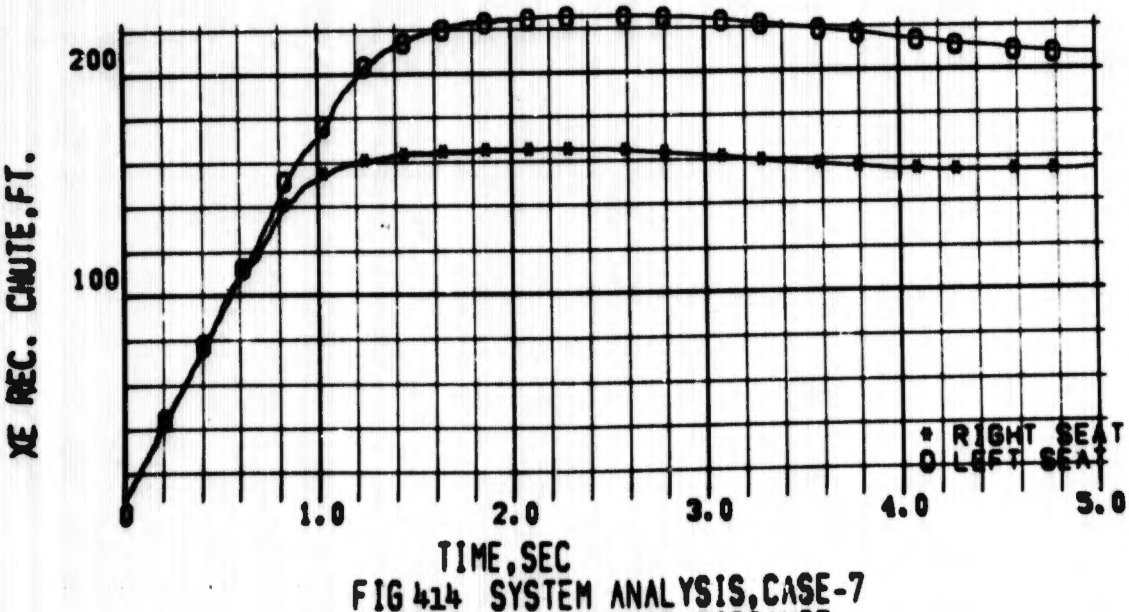


FIG 414 SYSTEM ANALYSIS,CASE-7
PARACHUTE DOWNRANGE DISTANCE

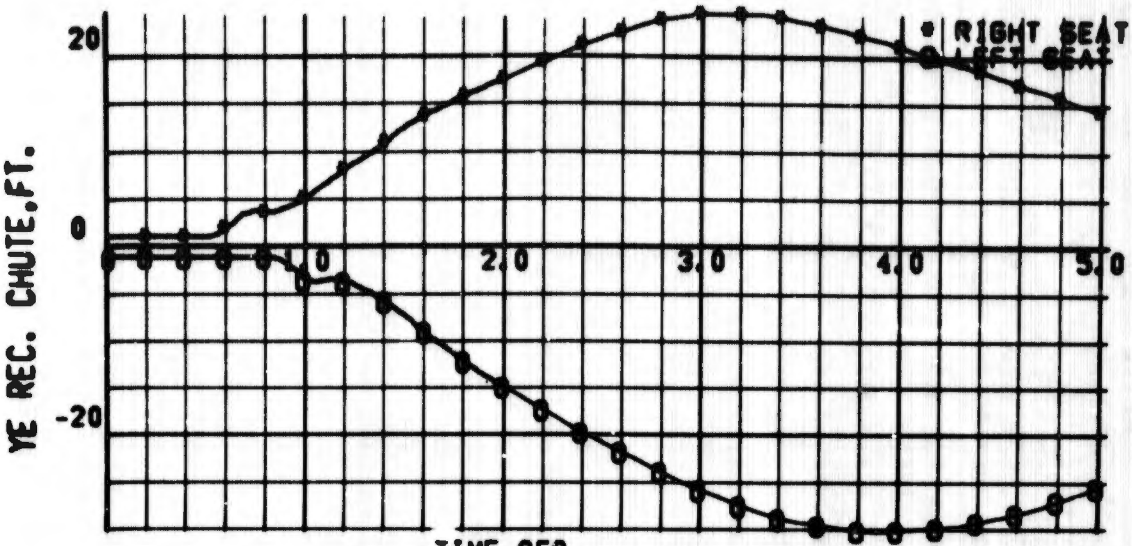


FIG 415 SYSTEM ANALYSIS,CASE-7
PARACHUTE LATERAL DISTANCE

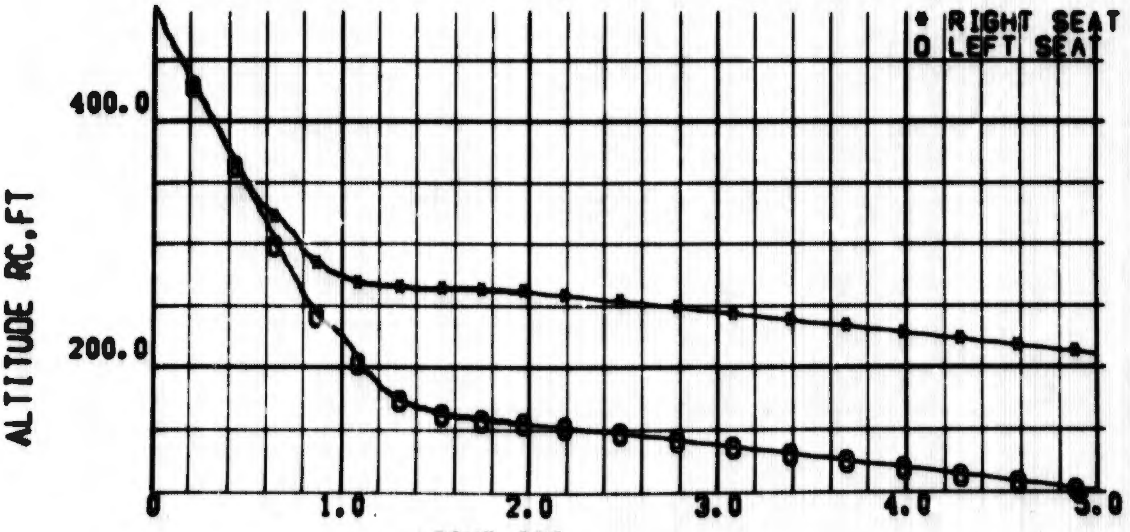


FIG 416 SYSTEM ANALYSIS,CASE-7
PARACHUTE ALTITUDE

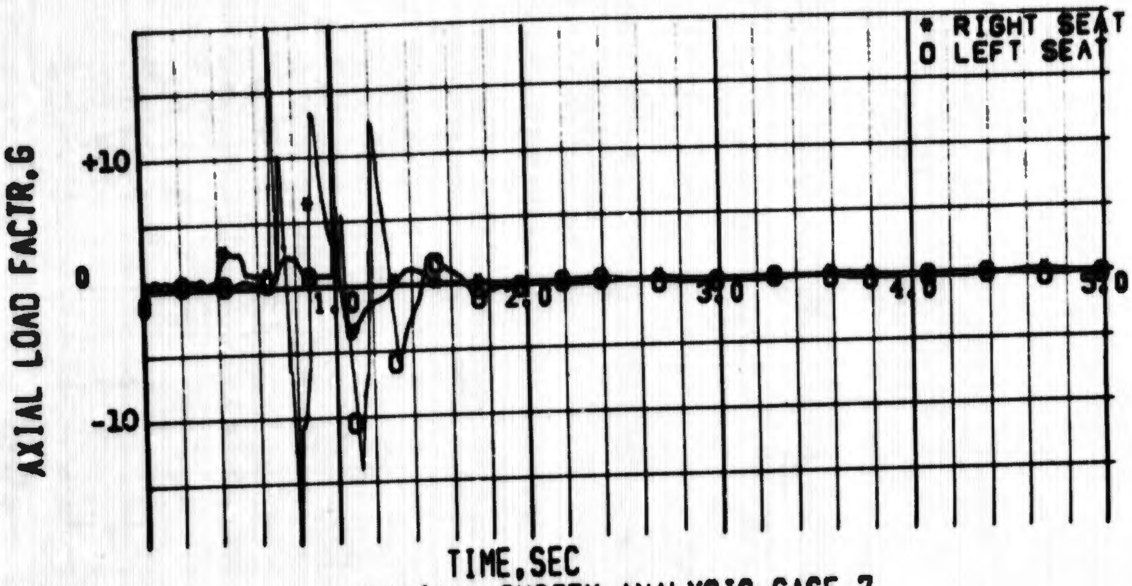


FIG 417 SYSTEM ANALYSIS,CASE-7
SEAT-MAN AXIAL LOAD FACTOR,CG

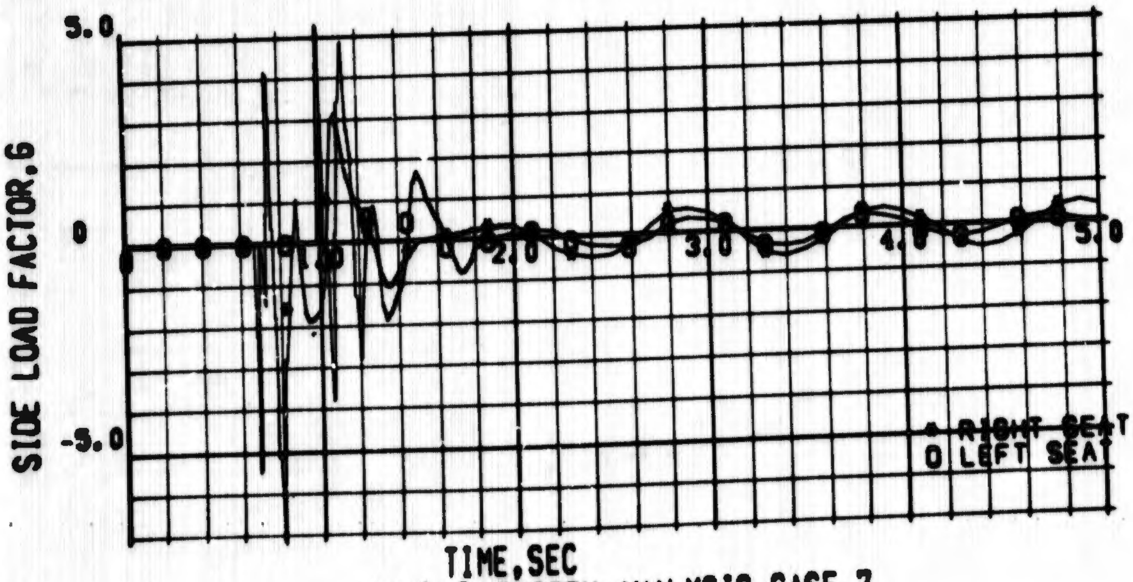


FIG 418 SYSTEM ANALYSIS,CASE-7
SEAT-MAN SIDE LOAD FACTOR,CG

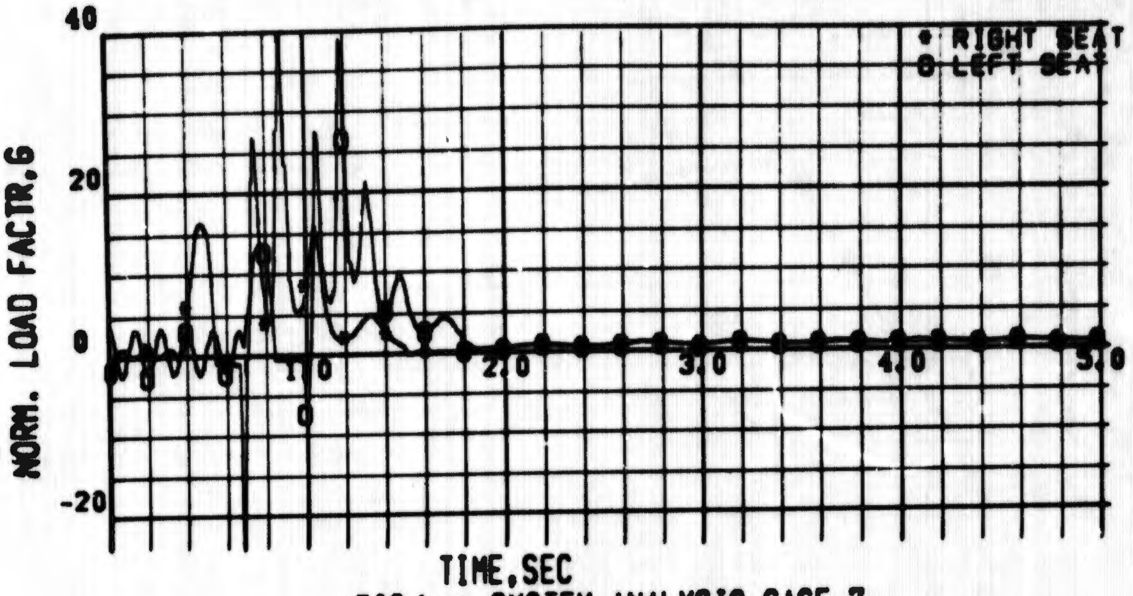


FIG 419 SYSTEM ANALYSIS,CASE-7
SEAT-MAN NORMAL LOAD FACTOR,CG

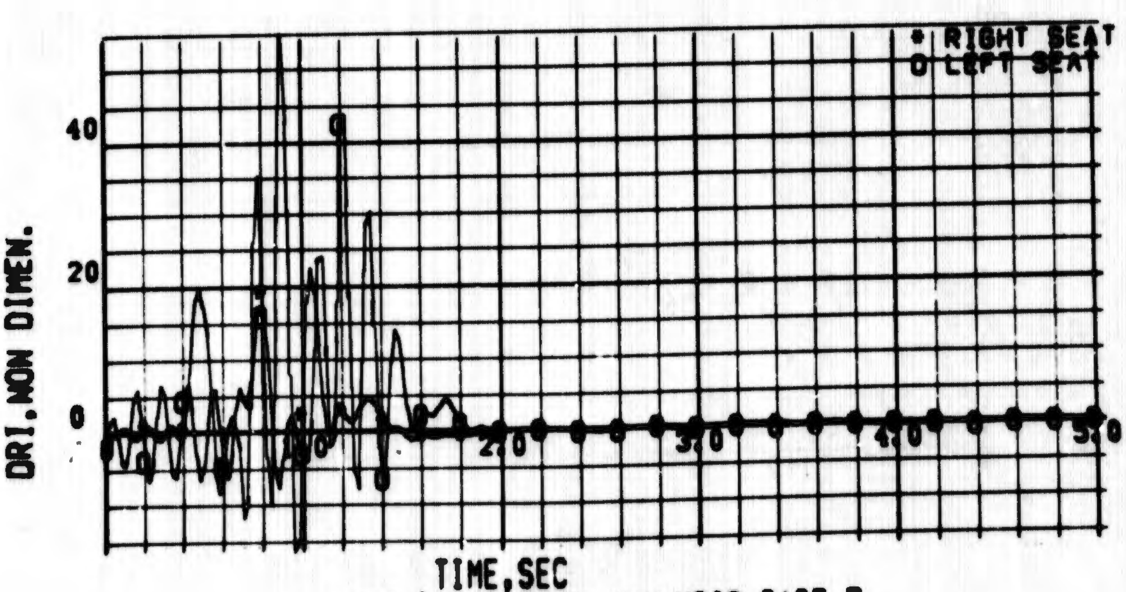
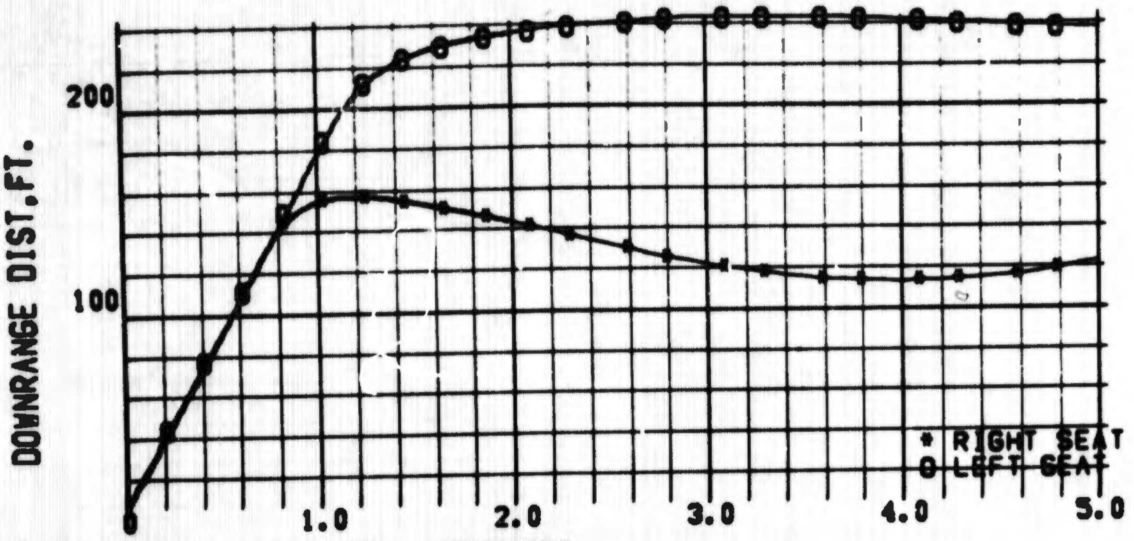
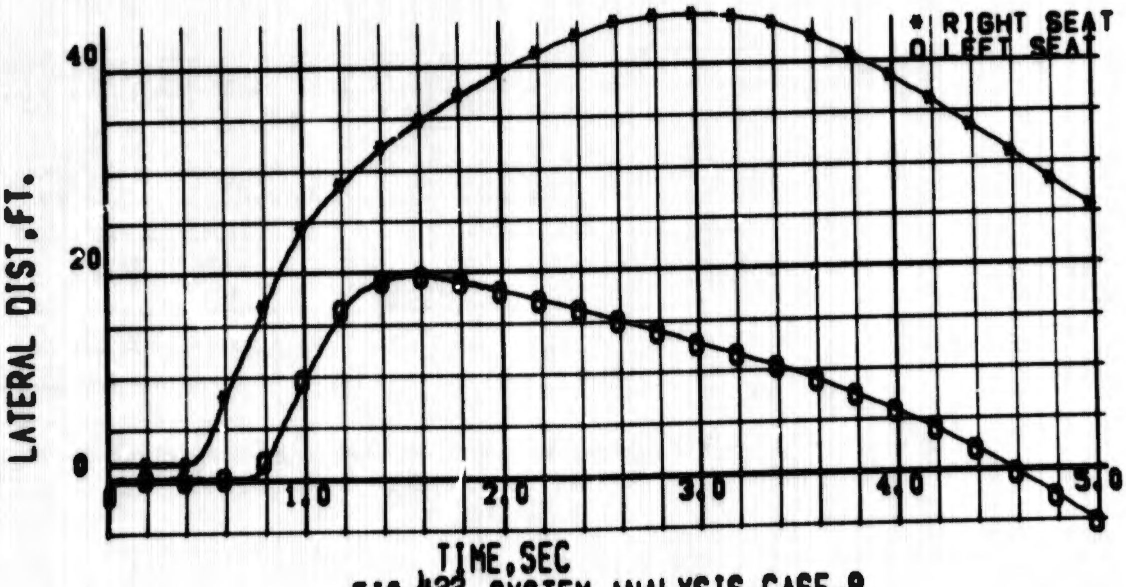


FIG 420 SYSTEM ANALYSIS,CASE-7
PILOT DYNAMIC RESPONSE INDEX



TIME,SEC
FIG 421 SYSTEM ANALYSIS,CASE-8
SEAT AND/OR MAN DOWNRANGE DIST



TIME,SEC
FIG 422 SYSTEM ANALYSIS,CASE-8
SEAT AND/OR MAN LATERAL DIST.

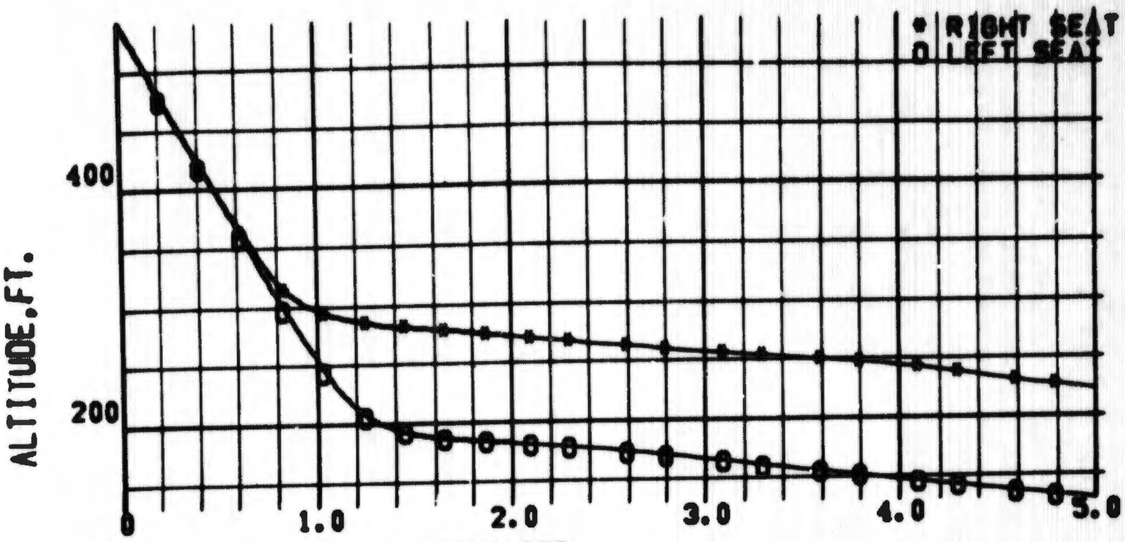


FIG 423 SYSTEM ANALYSIS,CASE-8
SEAT AND/OR MAN ALTITUDE

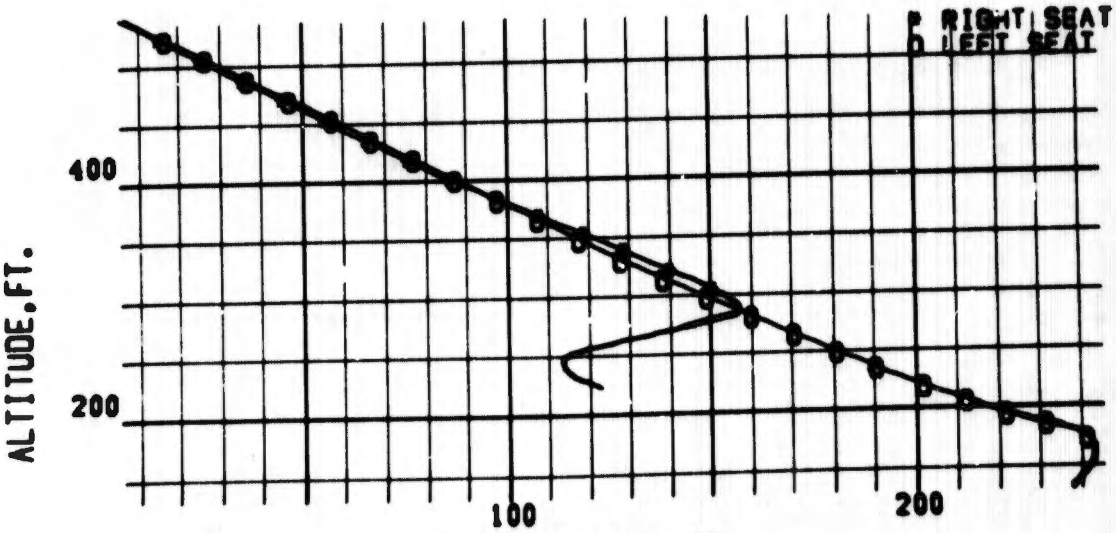


FIG 424 SYSTEM ANALYSIS,CASE-8
SEAT-MAN TRAJECTORY

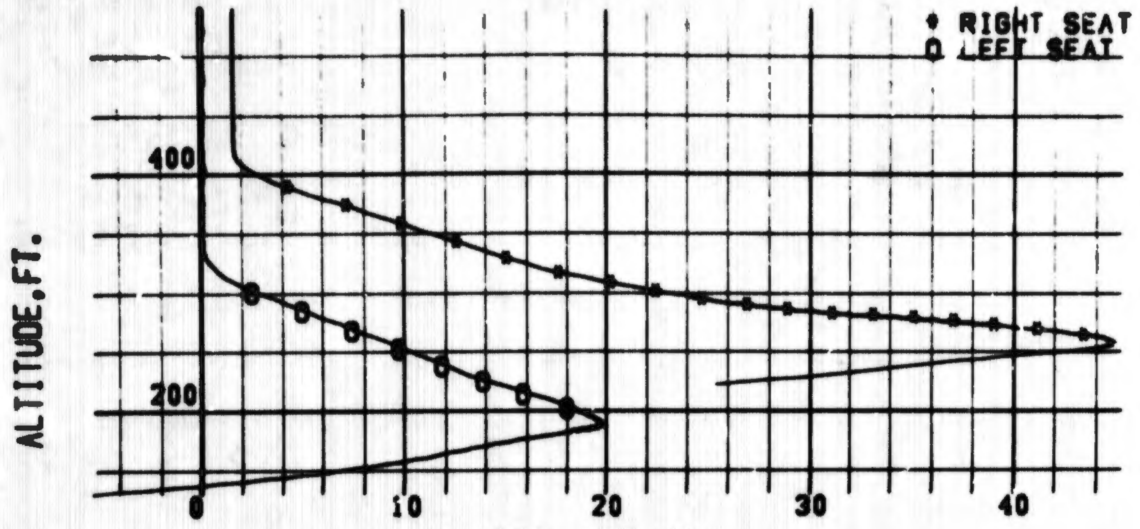


FIG 425 SYSTEM ANALYSIS,CASE-8
SEAT-MAN TRAJECTORY

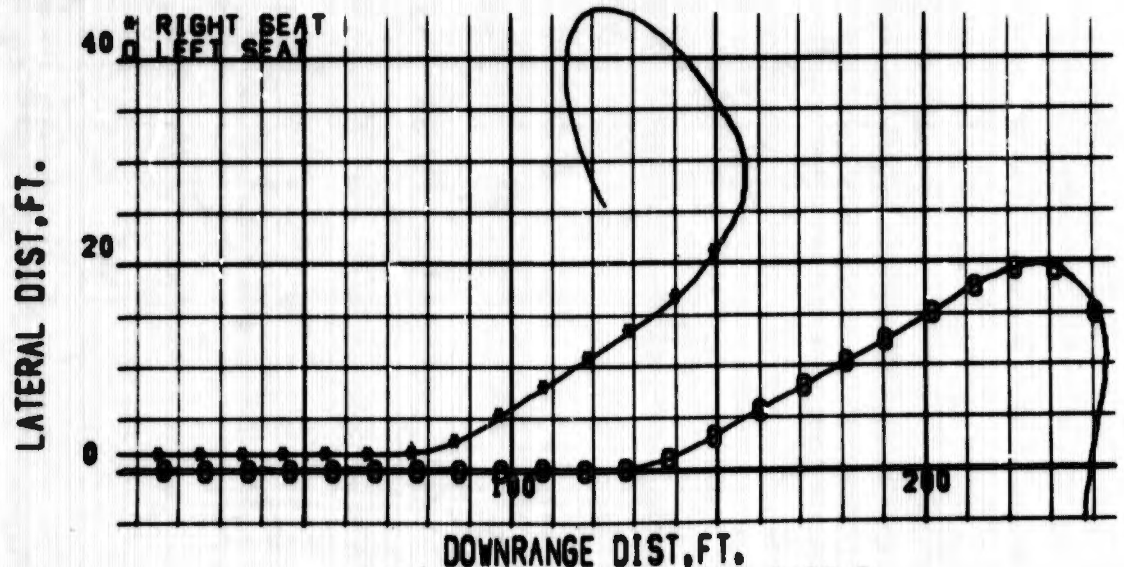


FIG 426 SYSTEM ANALYSIS,CASE-8
SEAT-MAN TRAJECTORY

FIG 427 SYSTEM ANALYSIS,CASE-8
SEAT AND/OR MAN TOTAL AIRSPEED

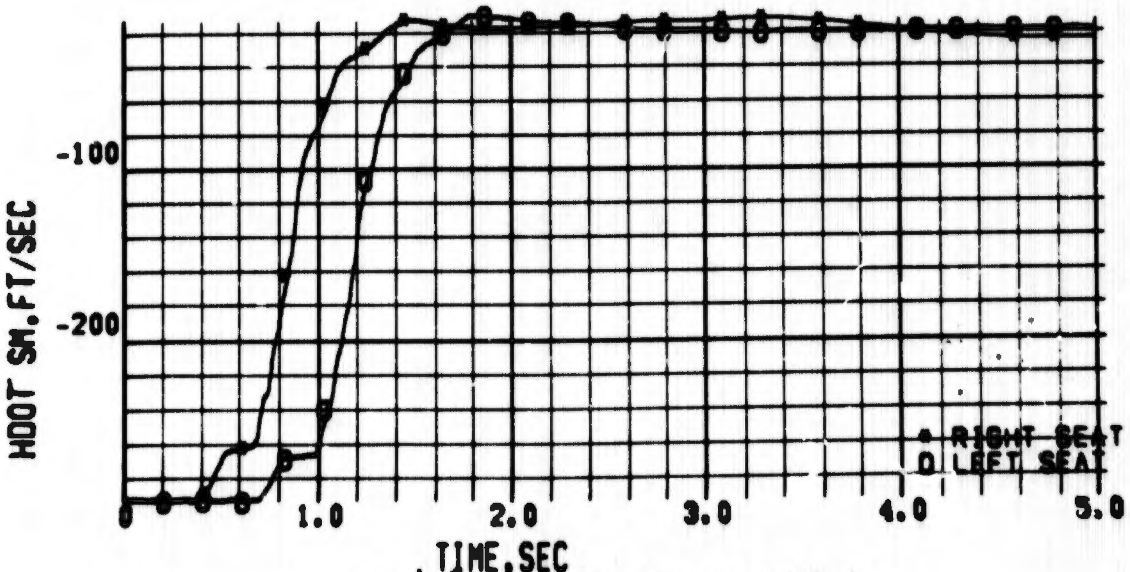


FIG 428 SYSTEM ANALYSIS,CASE-8
SEAT AND/OR MAN CLIMB RATE

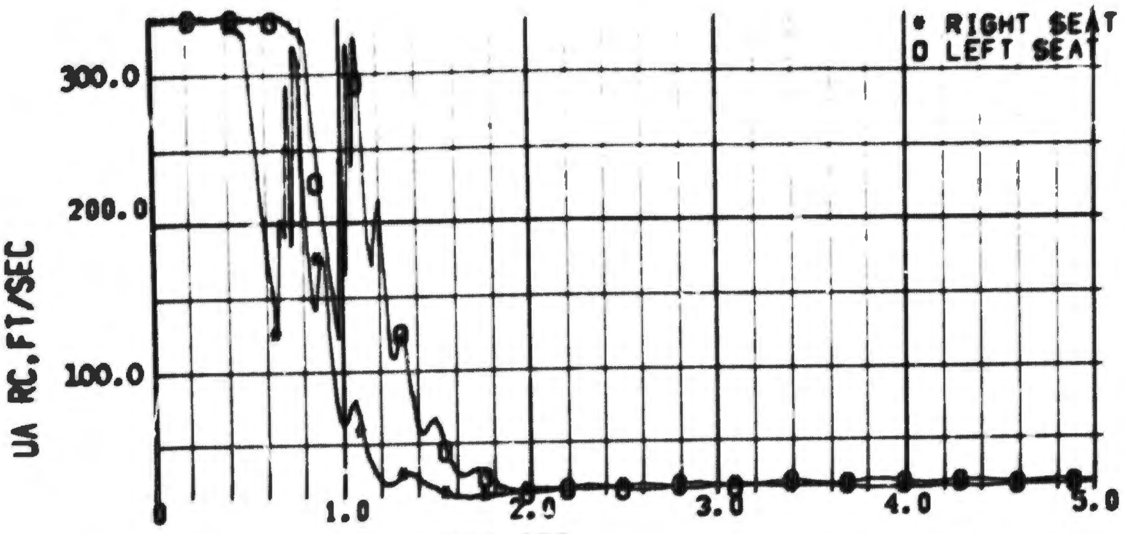


FIG 429 SYSTEM ANALYSIS,CASE-8
PARACHUTE TOTAL AIRSPEED

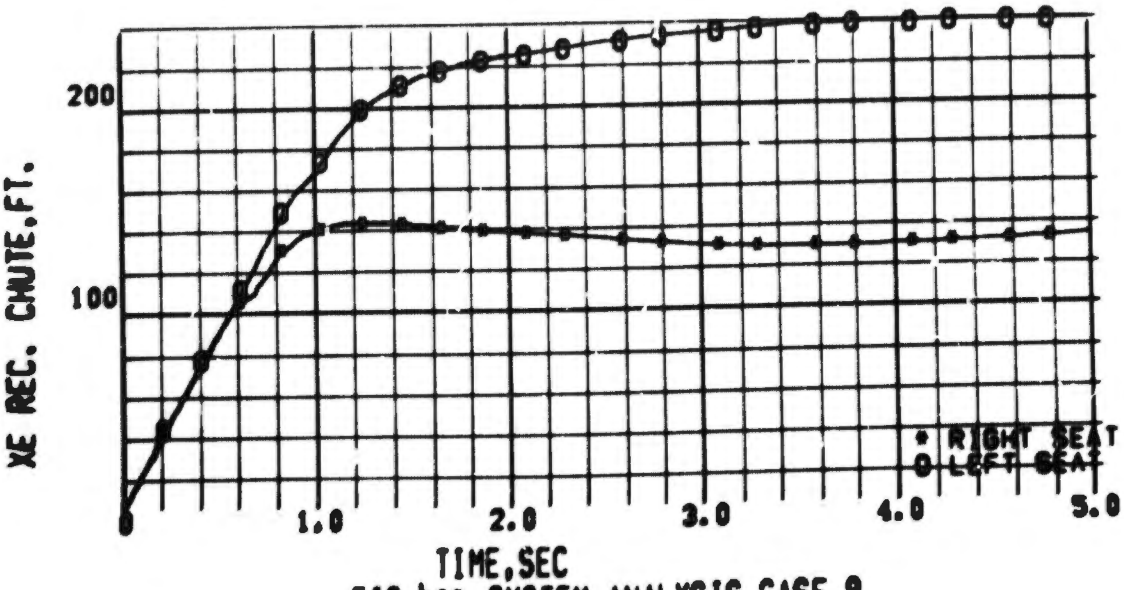
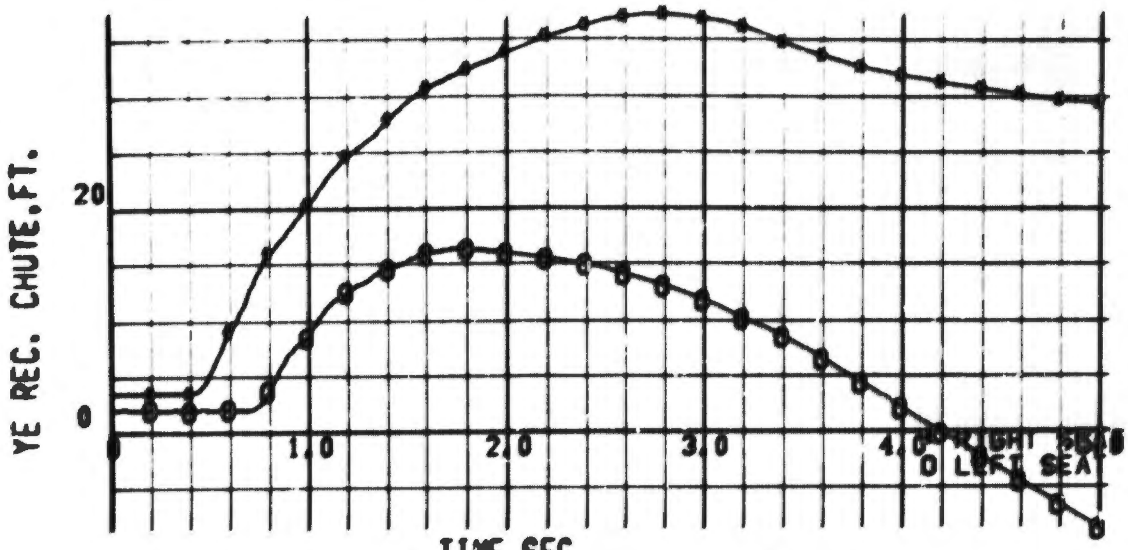
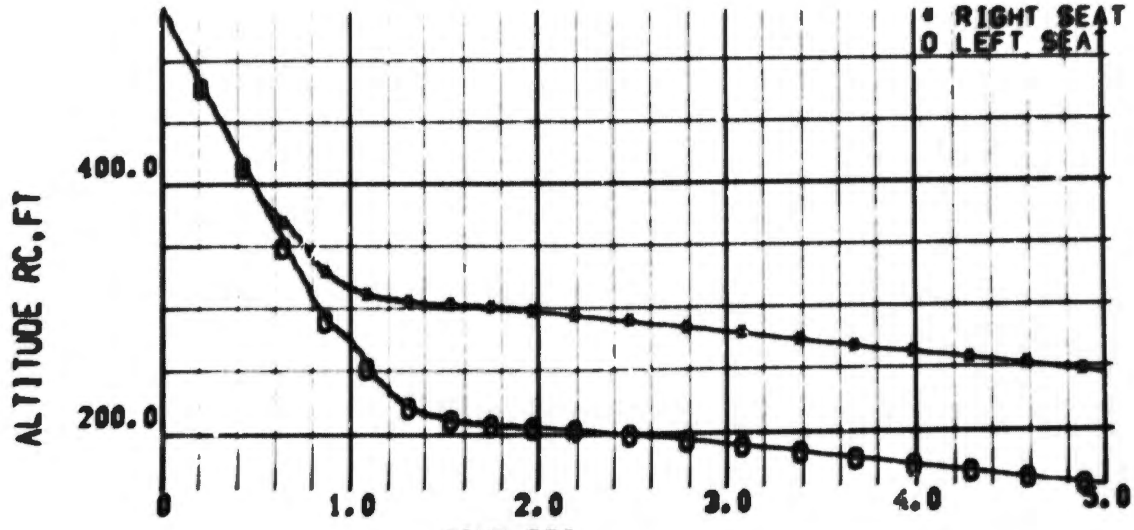


FIG 430 SYSTEM ANALYSIS,CASE-8
PARACHUTE DOWNRANGE DISTANCE



TIME,SEC
FIG 431 SYSTEM ANALYSIS,CASE-8
PARACHUTE LATERAL DISTANCE



TIME,SEC
FIG 432 SYSTEM ANALYSIS,CASE-8
PARACHUTE ALTITUDE

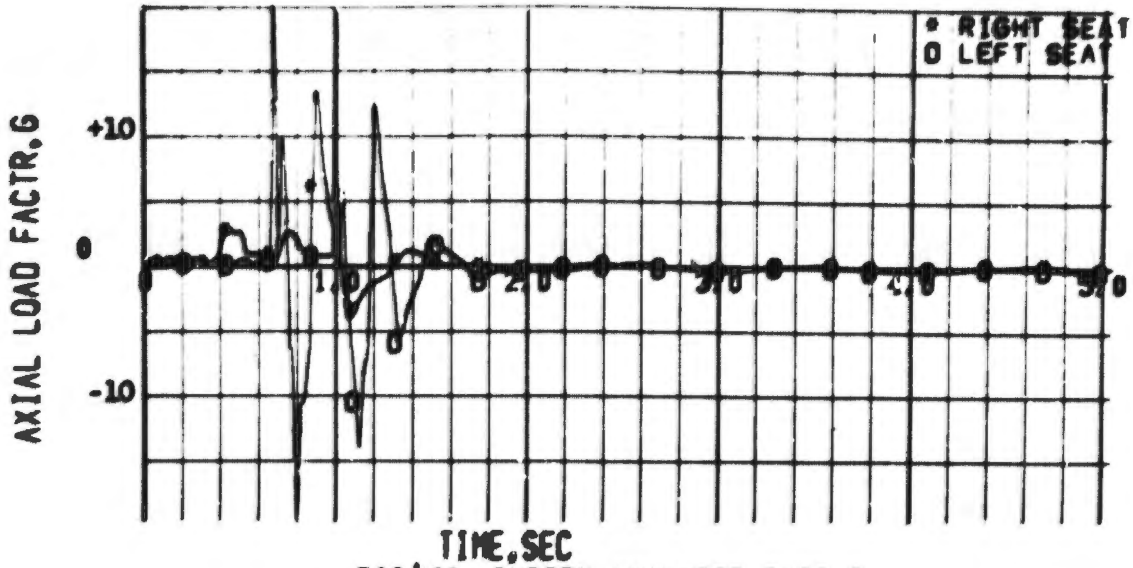


FIG 433 SYSTEM ANALYSIS,CASE-8
SEAT-MAN AXIAL LOAD FACTOR,CG

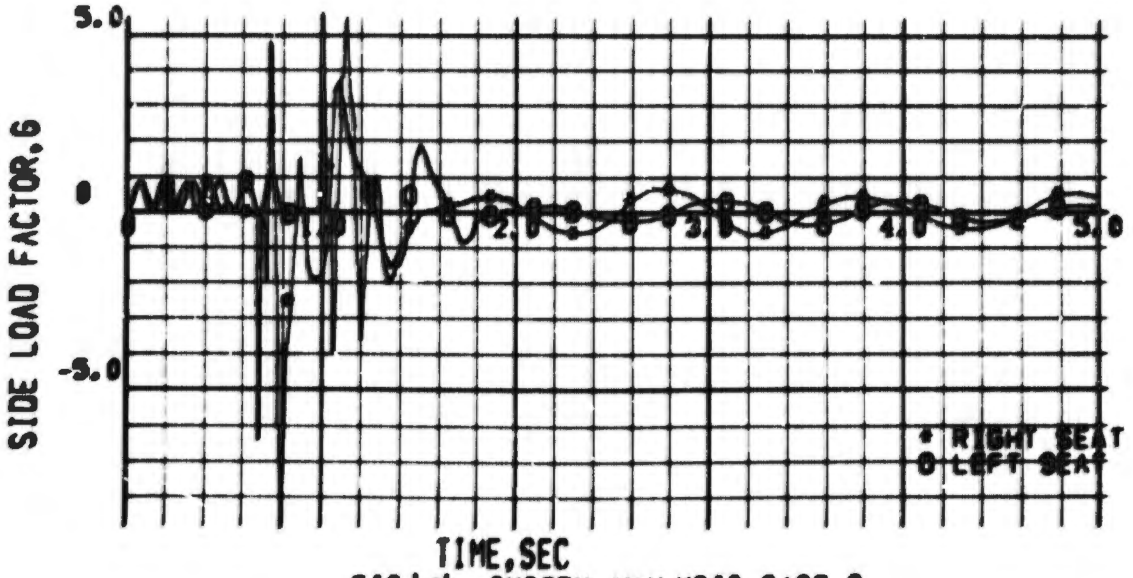


FIG 434 SYSTEM ANALYSIS,CASE-8
SEAT-MAN SIDE LOAD FACTOR,CG

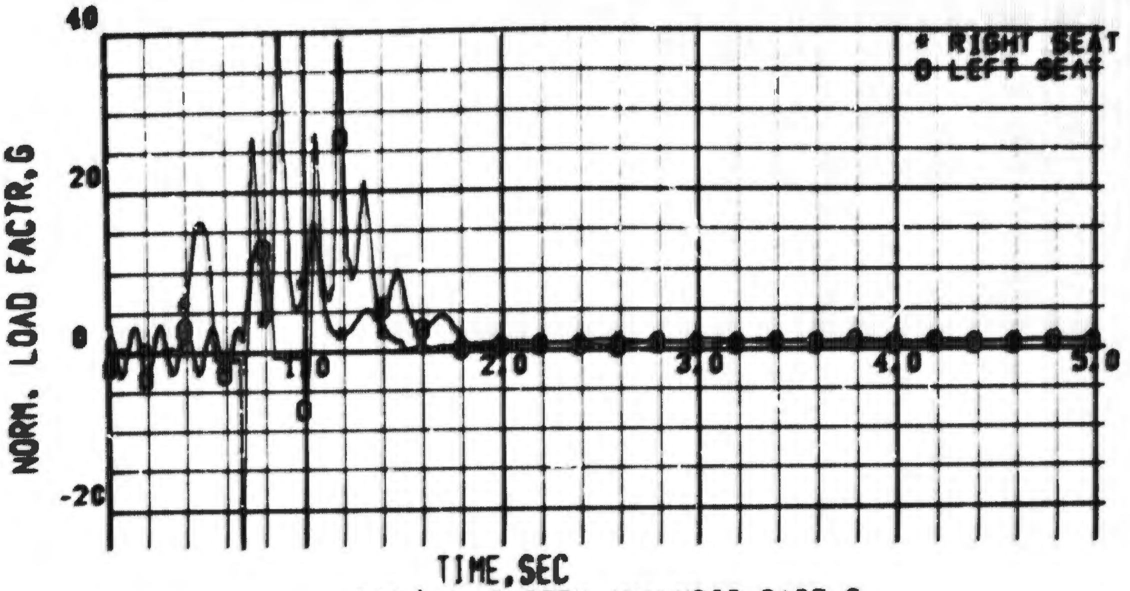


FIG 435 SYSTEM ANALYSIS,CASE-8
SEAT-MAN NORMAL LOAD FACTOR,CG

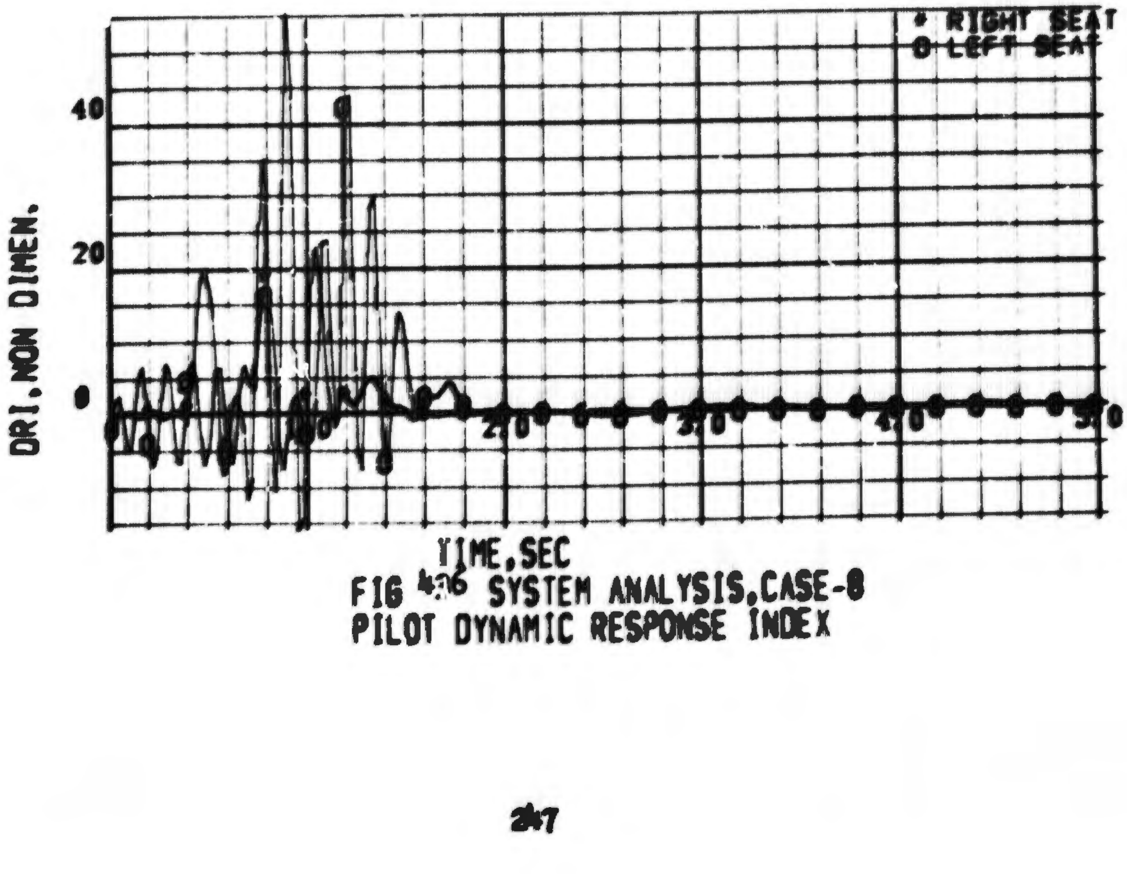


FIG 436 SYSTEM ANALYSIS,CASE-8
PILOT DYNAMIC RESPONSE INDEX

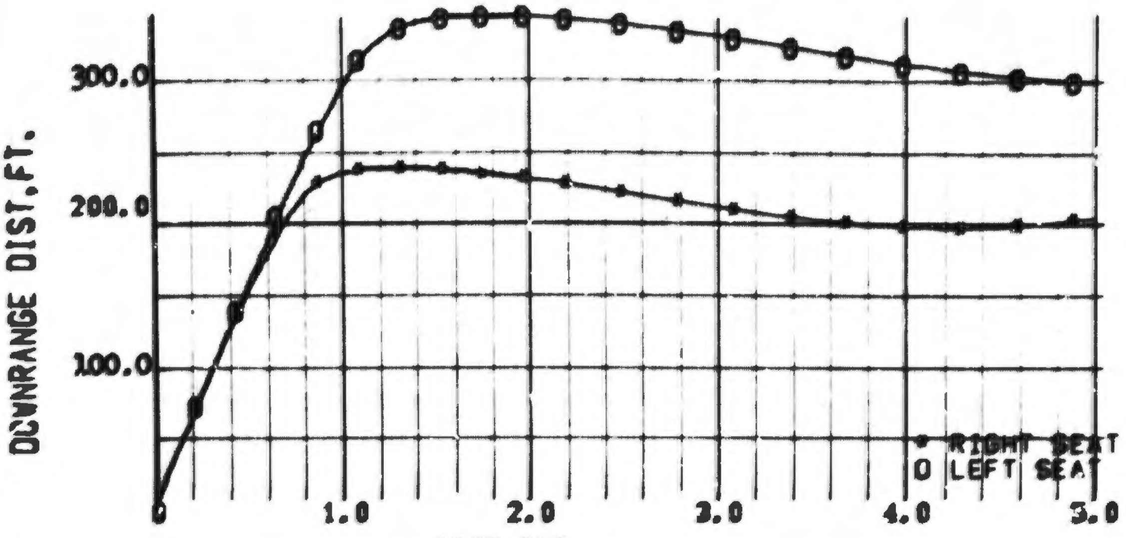


FIG 437 SYSTEM ANALYSIS,CASE-9
SEAT AND/OR MAN DOWNRANGE DIST

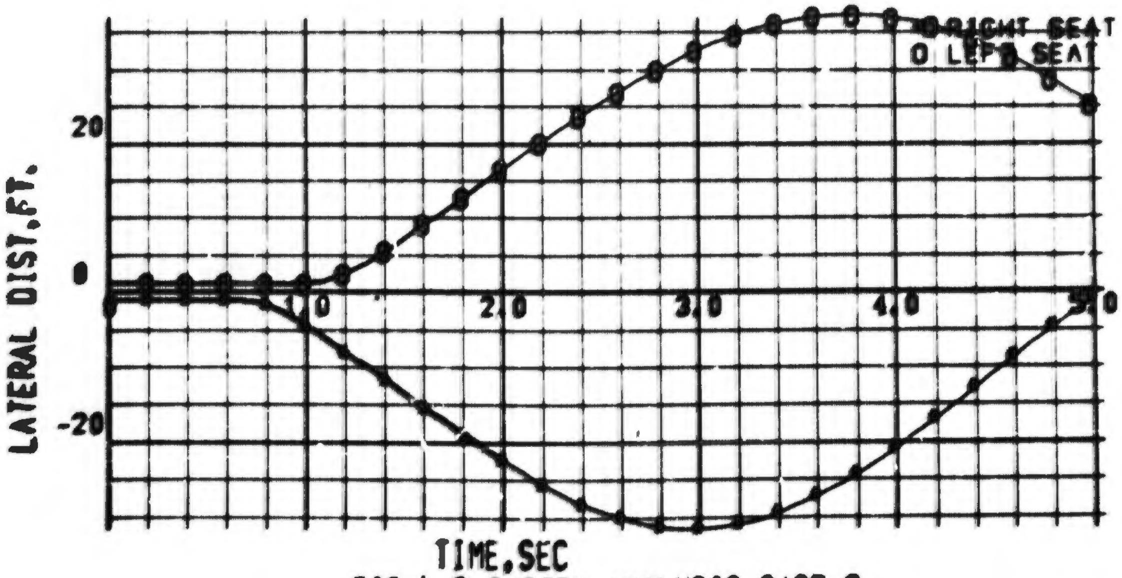


FIG 438 SYSTEM ANALYSIS,CASE-9
SEAT AND/OR MAN LATERAL DIST.

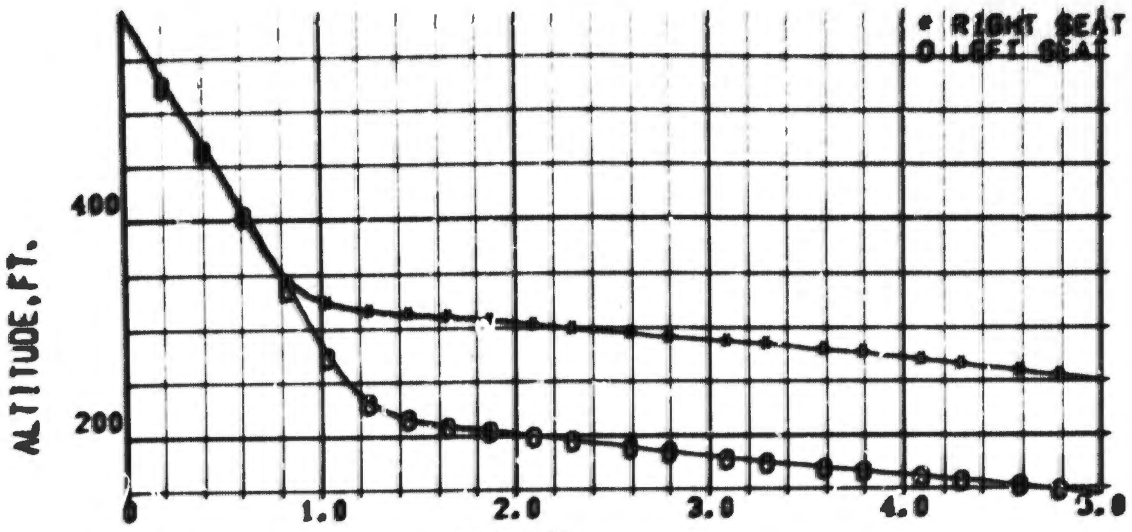


FIG 439 SYSTEM ANALYSIS, CASE-9
SEAT AND/OR MAN ALTITUDE

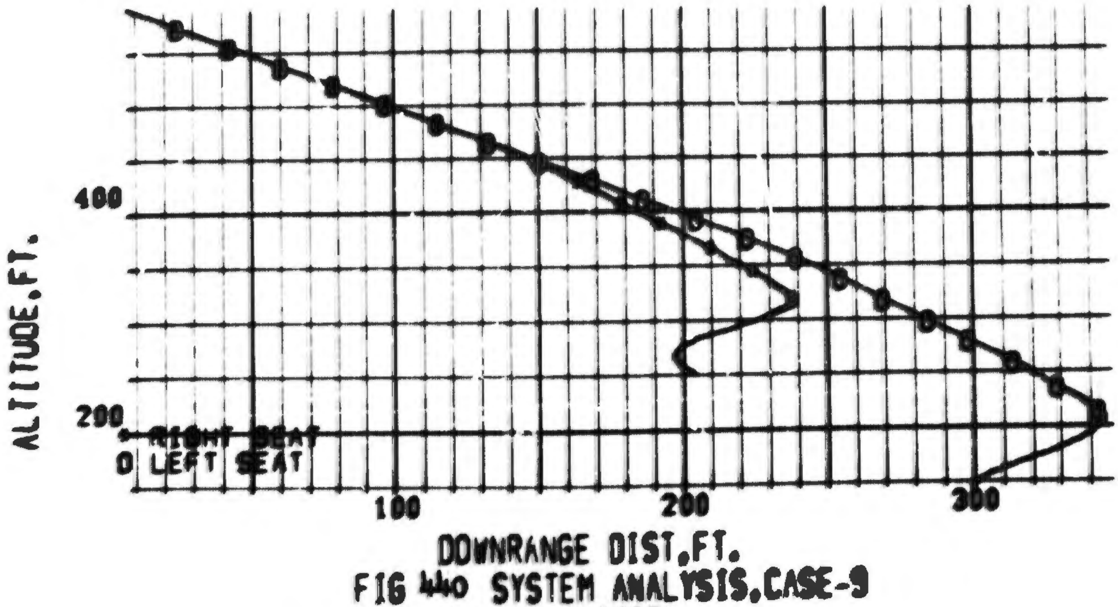


FIG 440 SYSTEM ANALYSIS, CASE-9
SEAT-MAN TRAJECTORY

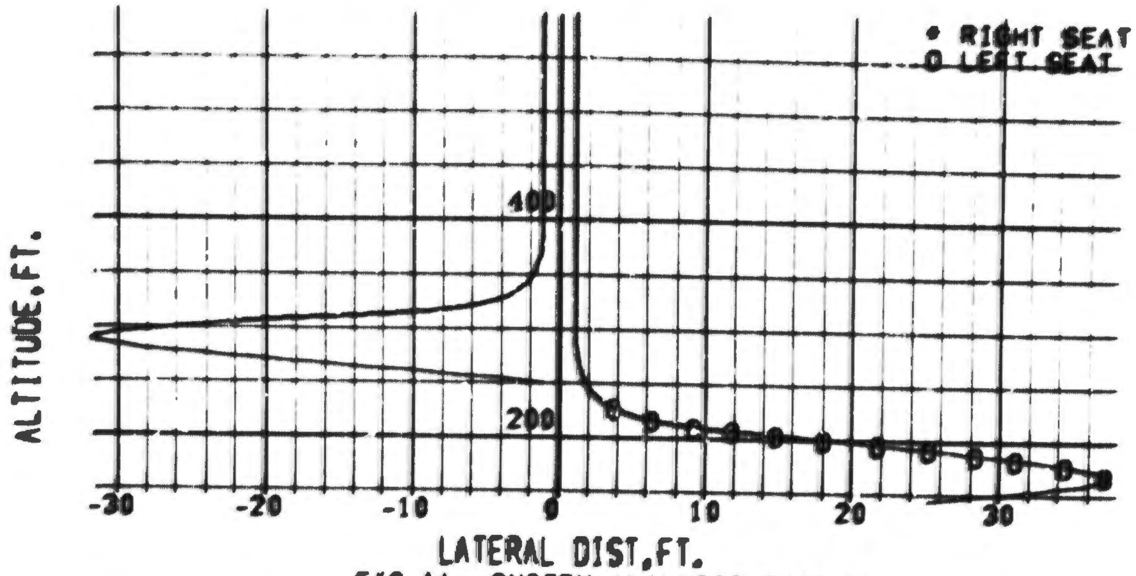


FIG 441 SYSTEM ANALYSIS, CASE-9
SEAT-MAN TRAJECTORY

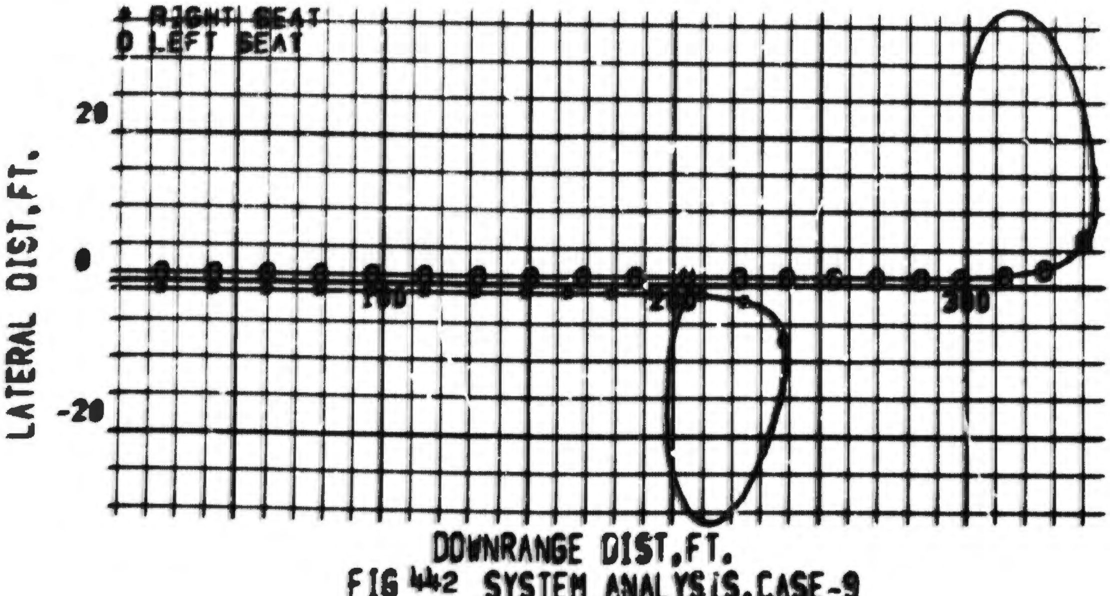


FIG 442 SYSTEM ANALYSIS, CASE-9
SEAT-MAN TRAJECTORY

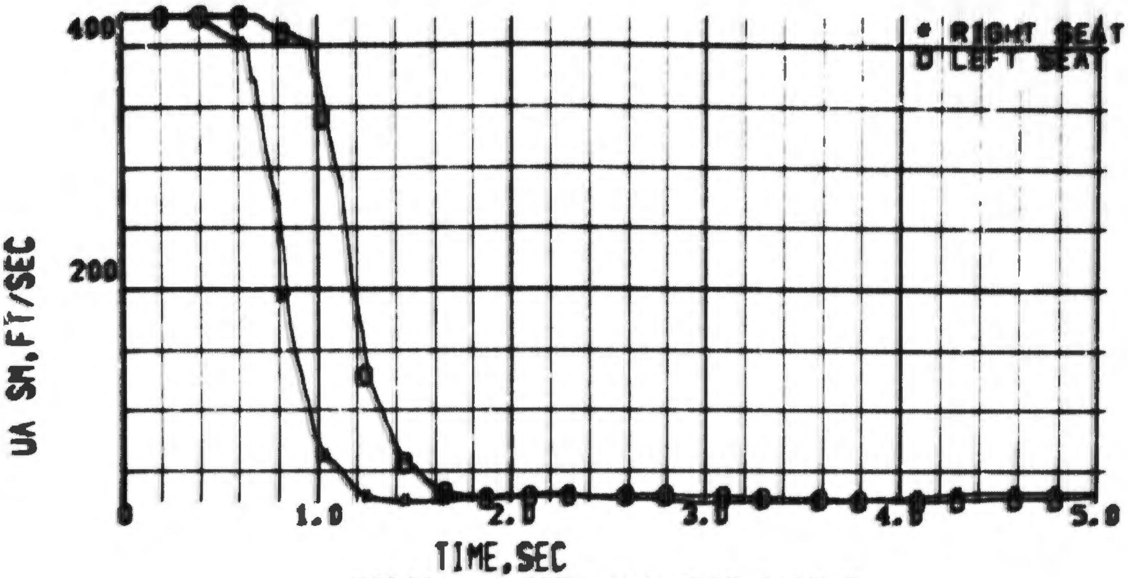


FIG 443 SYSTEM ANALYSIS,CASE-9
SEAT AND/OR MAN TOTAL AIRSPEED

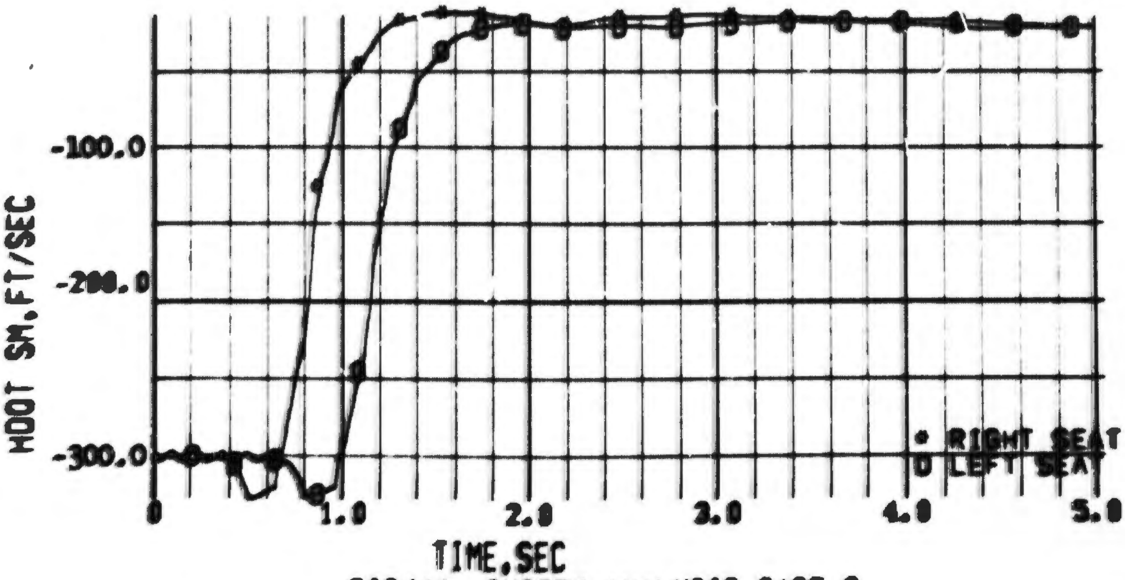


FIG 444 SYSTEM ANALYSIS,CASE-9
SEAT AND/OR MAN CLIMB RATE

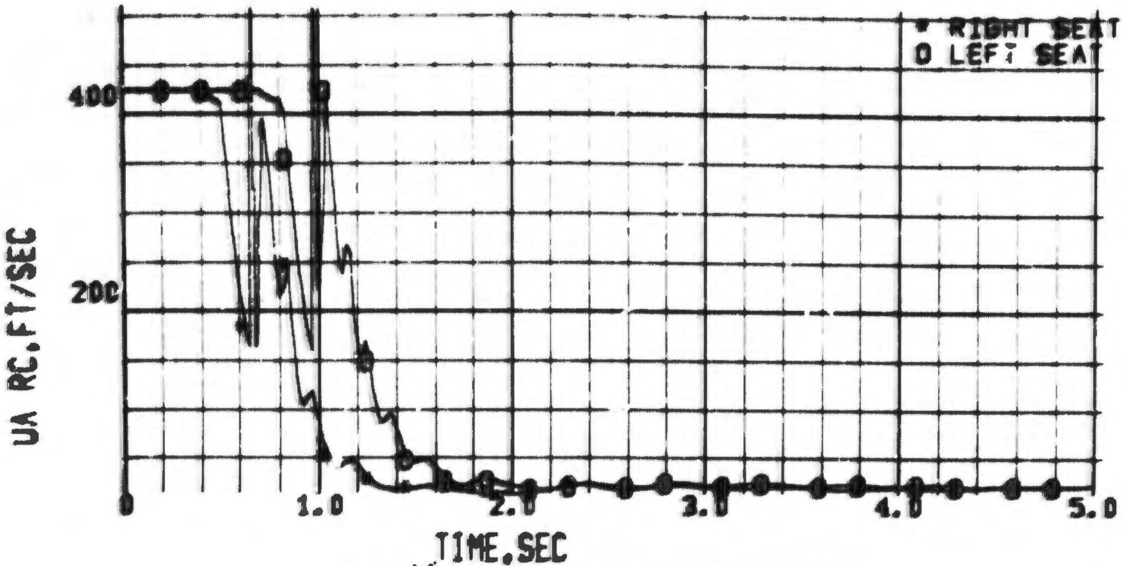


FIG 445 SYSTEM ANALYSIS,CASE-9
PARACHUTE TOTAL AIRSPEED

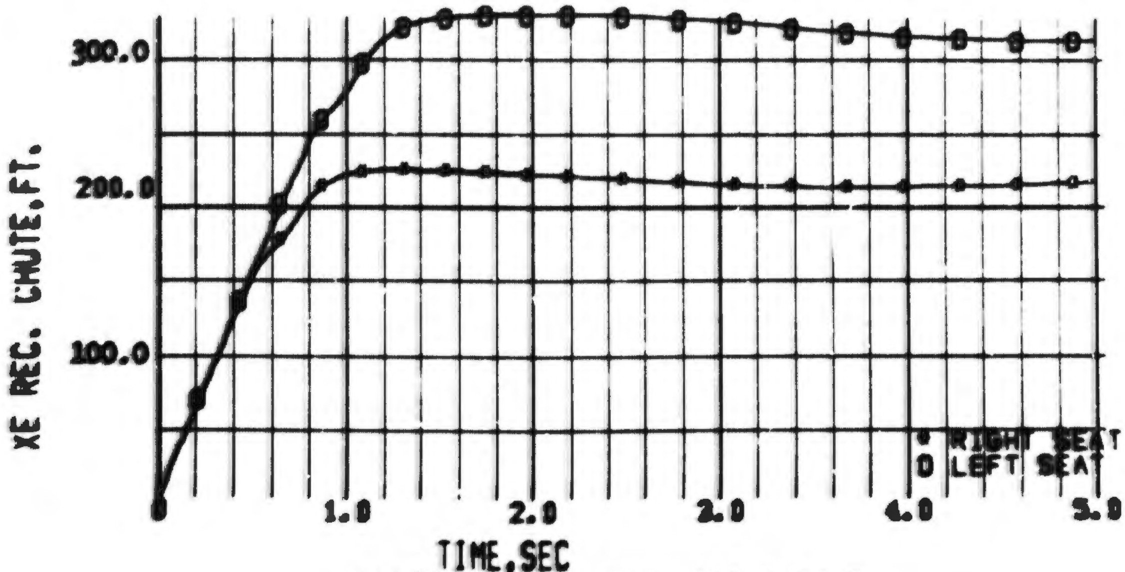


FIG 446 SYSTEM ANALYSIS,CASE-9
PARACHUTE DOWNRANGE DISTANCE

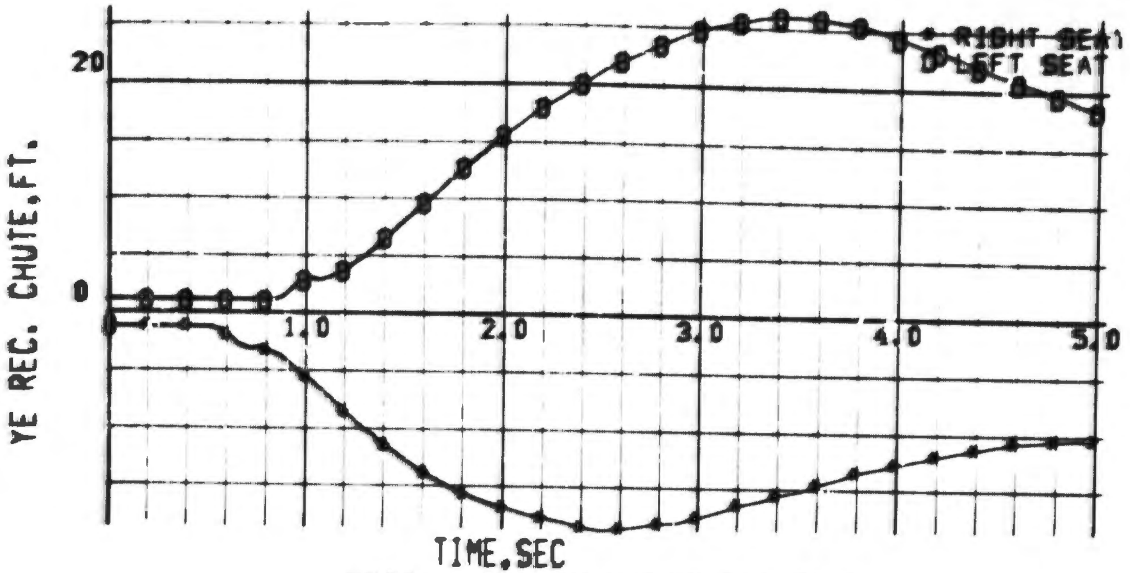


FIG 447 SYSTEM ANALYSIS, CASE-9
PARACHUTE LATERAL DISTANCE

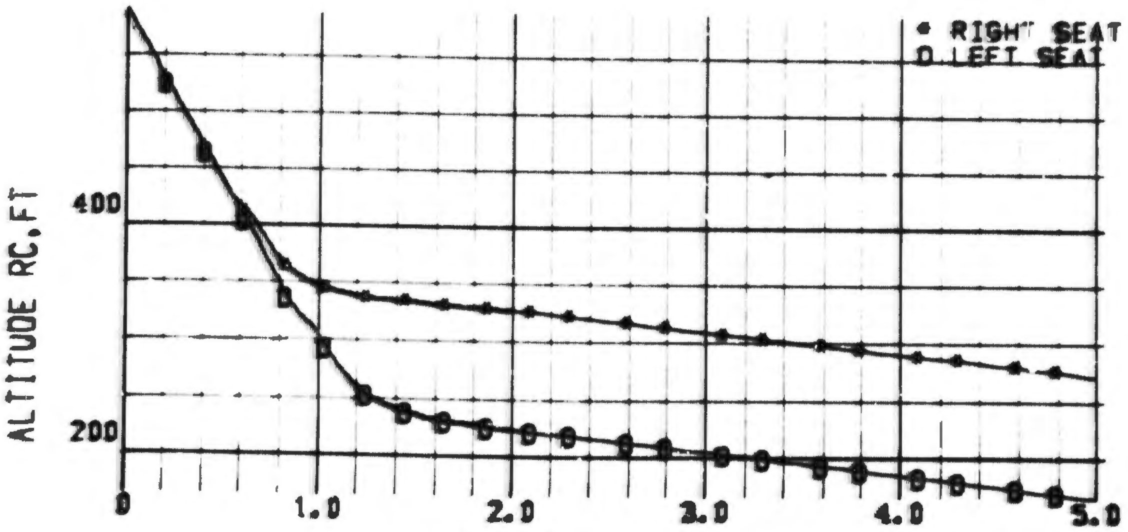


FIG 448 SYSTEM ANALYSIS, CASE-9
PARACHUTE ALTITUDE

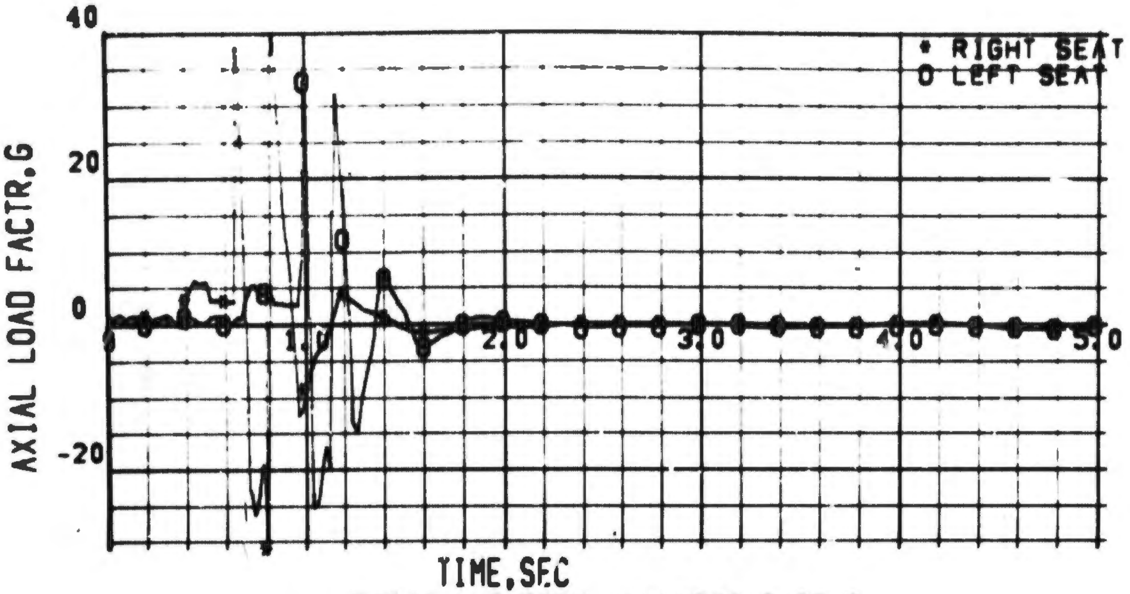


FIG 449 SYSTEM ANALYSIS,CASE-9
SEAT-MAN AXIAL LOAD FACTOR,CG

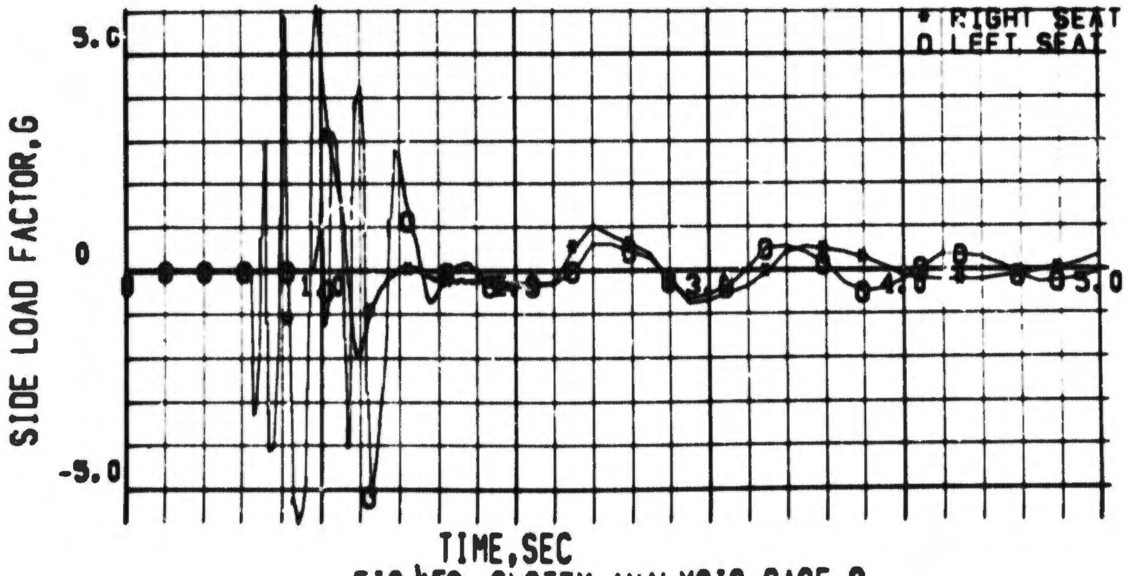


FIG 450 SYSTEM ANALYSIS,CASE-9
SEAT-MAN SIDE LOAD FACTOR,CG

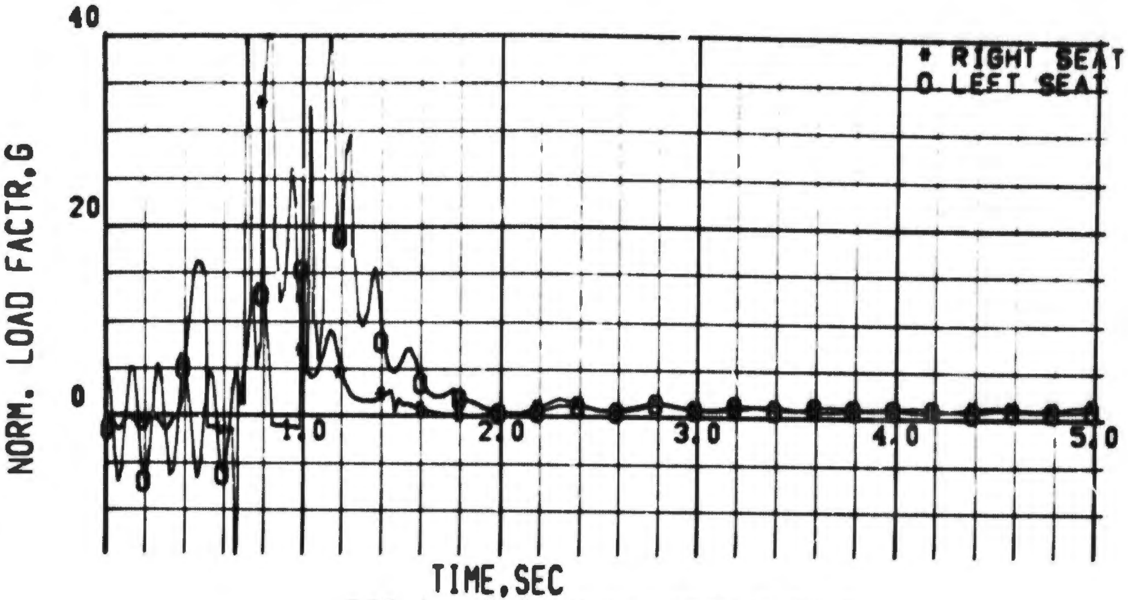


FIG 451 SYSTEM ANALYSIS,CASE-9
SEAT-MAN NORMAL LOAD FACTOR,CG

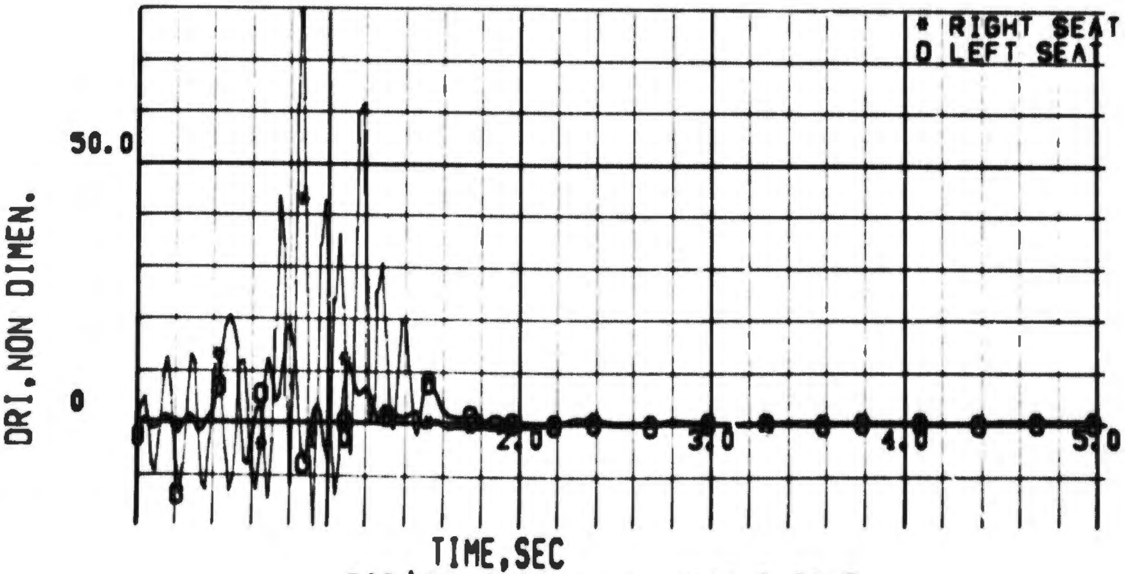


FIG 452 SYSTEM ANALYSIS,CASE-9
PILOT DYNAMIC RESPONSE INDEX

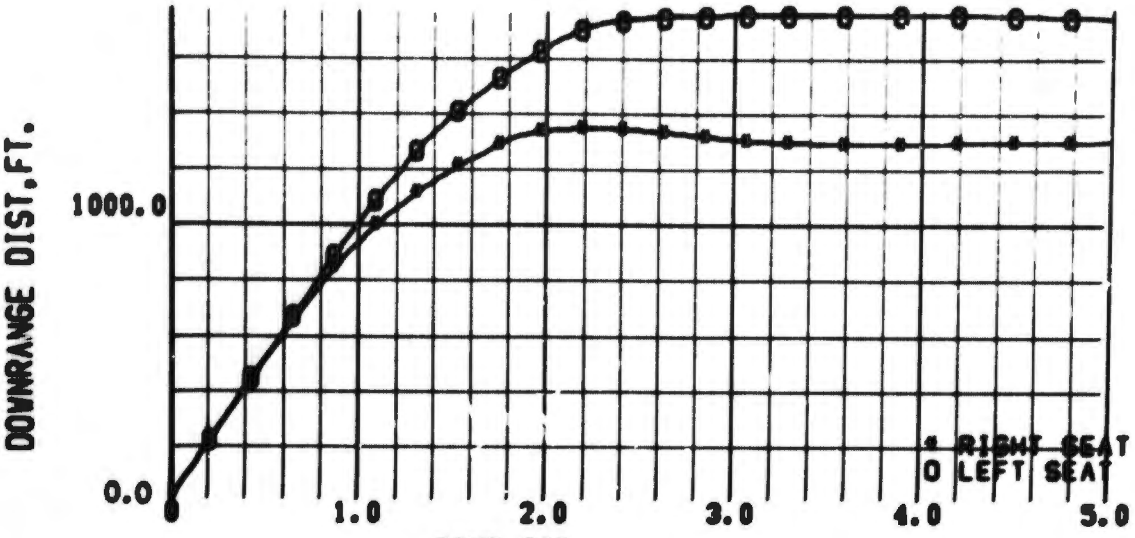


FIG 453 SYSTEM ANALYSIS,CASE10
SEAT AND/OR MAN DOWNRANGE DIST

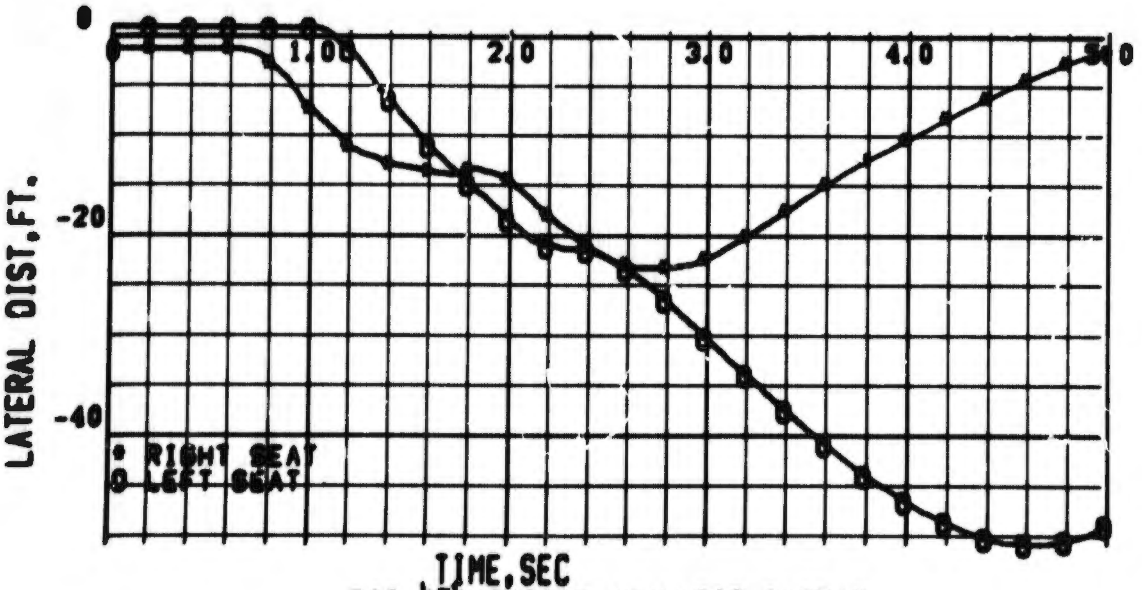


FIG 454 SYSTEM ANALYSIS,CASE10
SEAT AND/OR MAN LATERAL DIST.

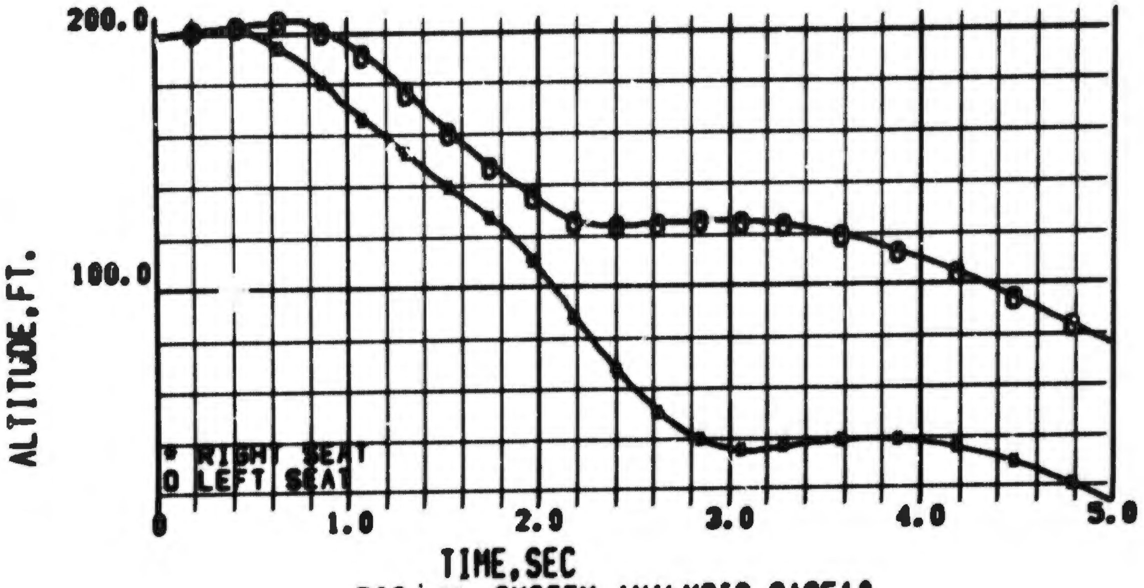


FIG 455 SYSTEM ANALYSIS,CASE10
SEAT AND/OR MAN ALTITUDE

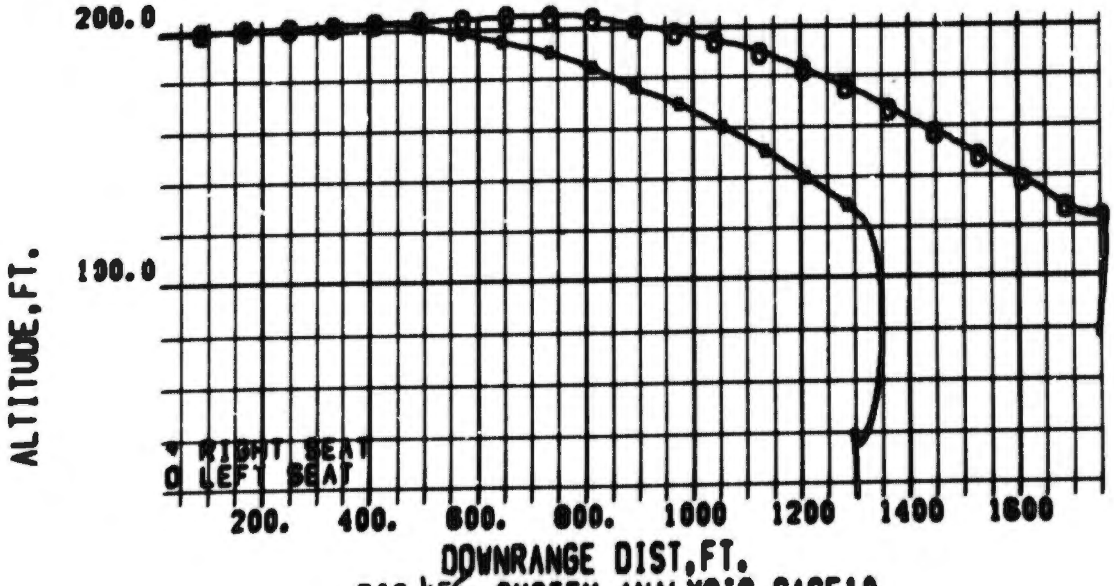


FIG 456 SYSTEM ANALYSIS,CASE10
SEAT-MAN TRAJECTORY

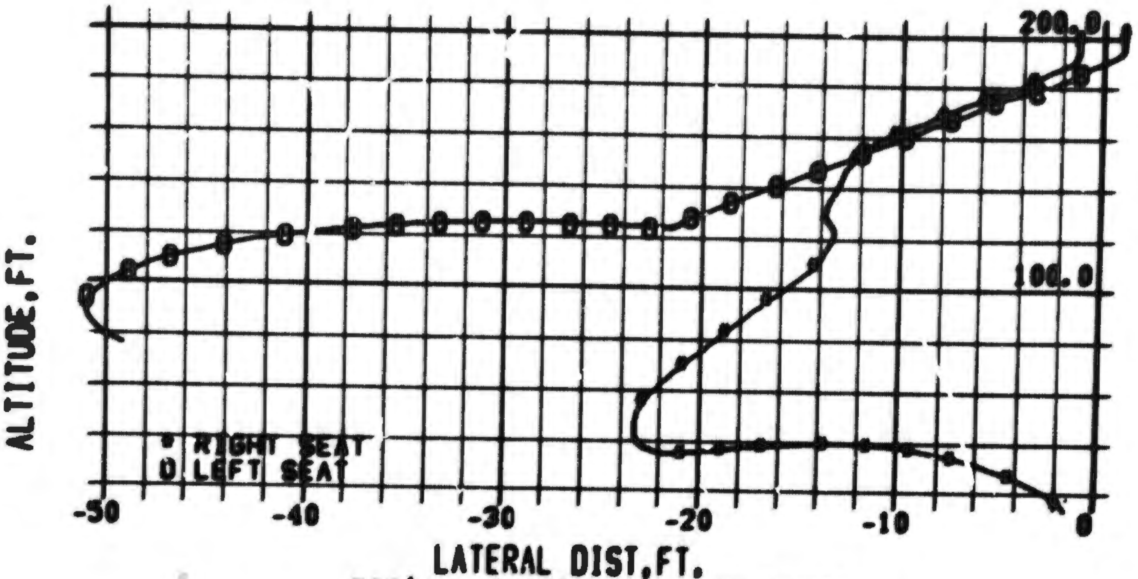


FIG 457 SYSTEM ANALYSIS, CASE10
SEAT-MAN TRAJECTORY

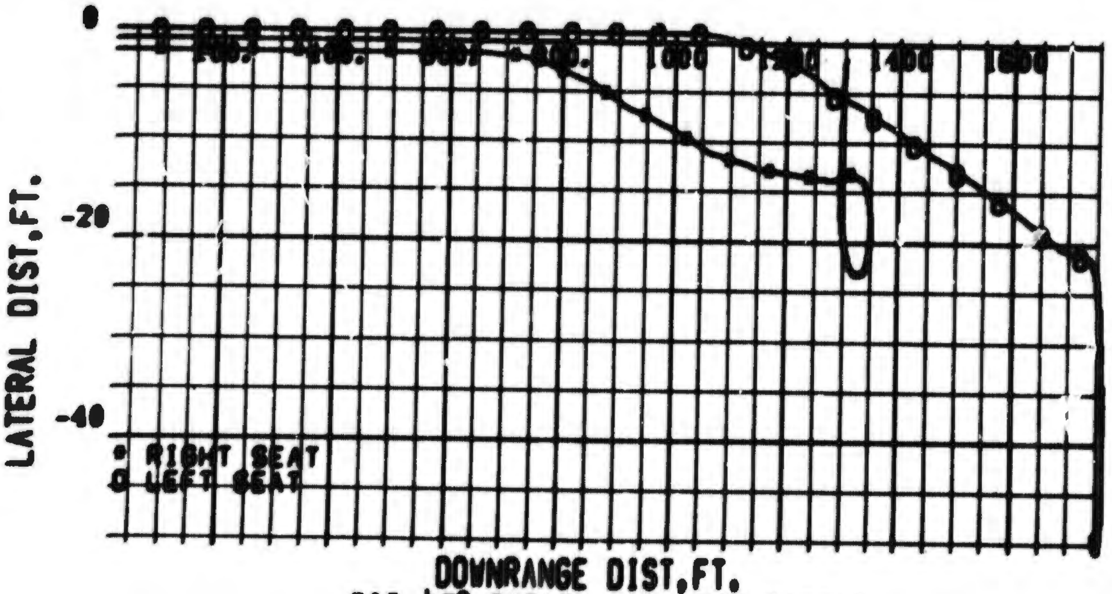


FIG 458 SYSTEM ANALYSIS, CASE10
SEAT-MAN TRAJECTORY

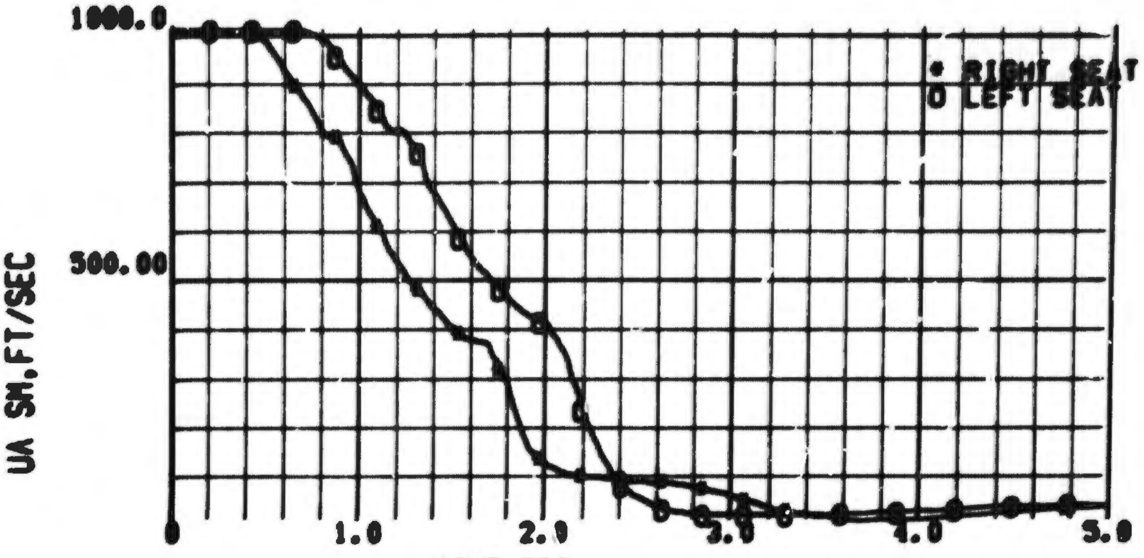


FIG 459 SYSTEM ANALYSIS,CASE10
SEAT AND/OR MAN TOTAL AIRSPEED

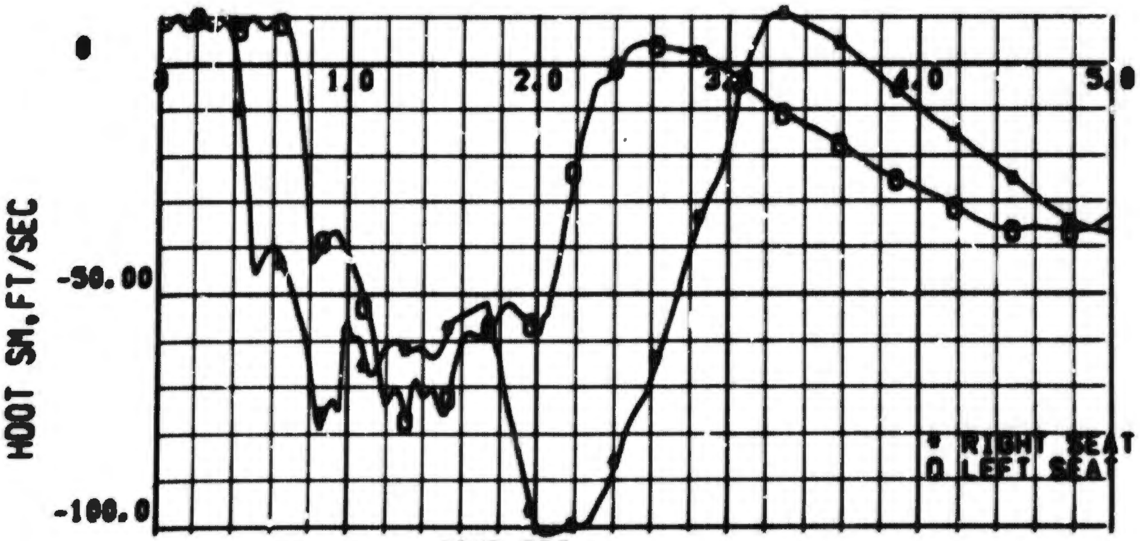
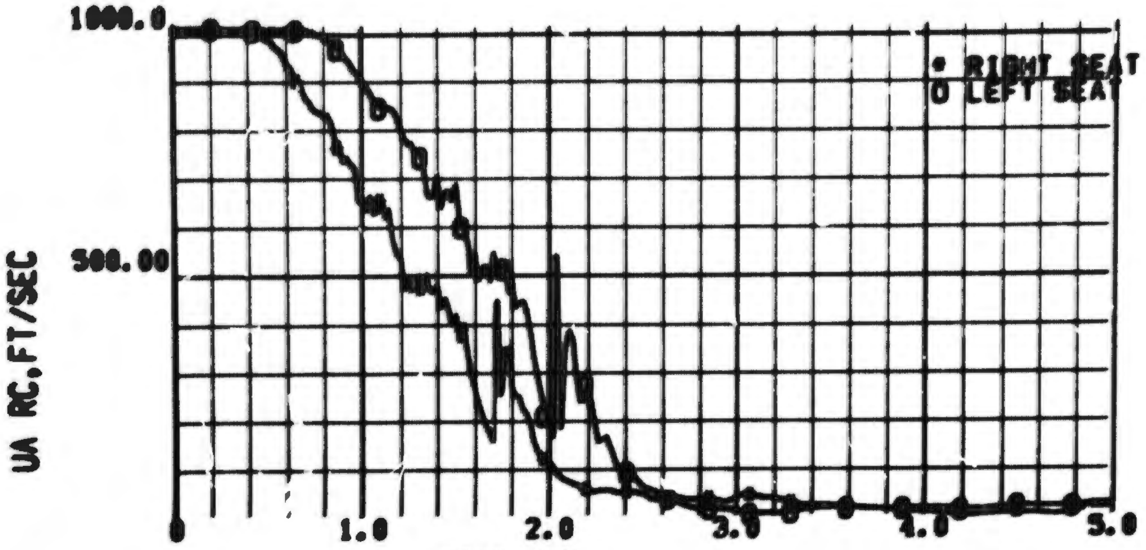
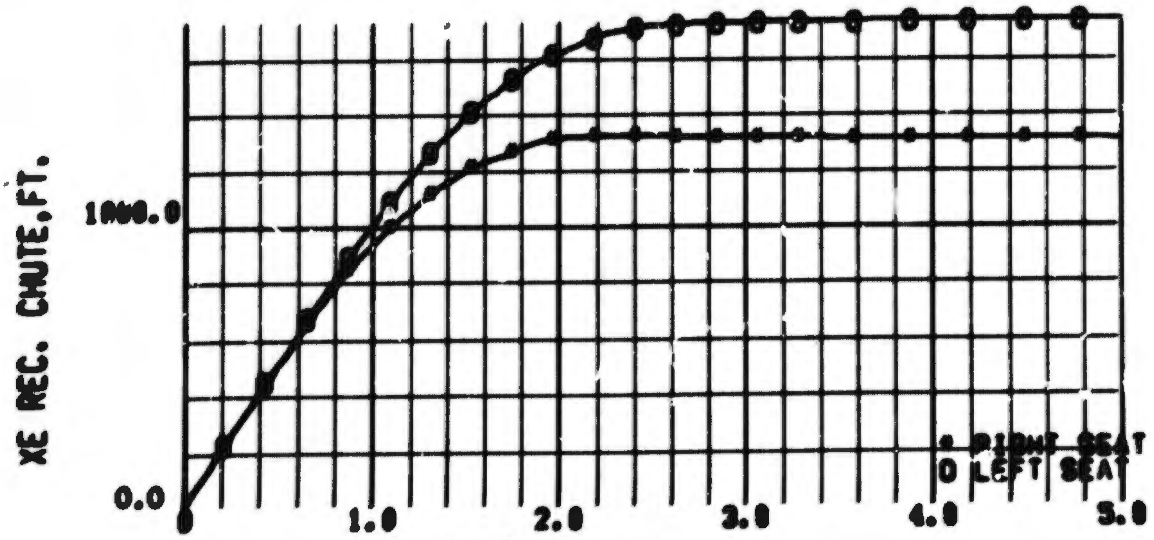


FIG 460 SYSTEM ANALYSIS,CASE10
SEAT AND/OR MAN CLIMB RATE



TIME,SEC
FIG 461 SYSTEM ANALYSIS,CASE10
PARACHUTE TOTAL AIRSPEED



TIME,SEC
FIG 462 SYSTEM ANALYSIS,CASE10
PARACHUTE DOWNRANGE DISTANCE

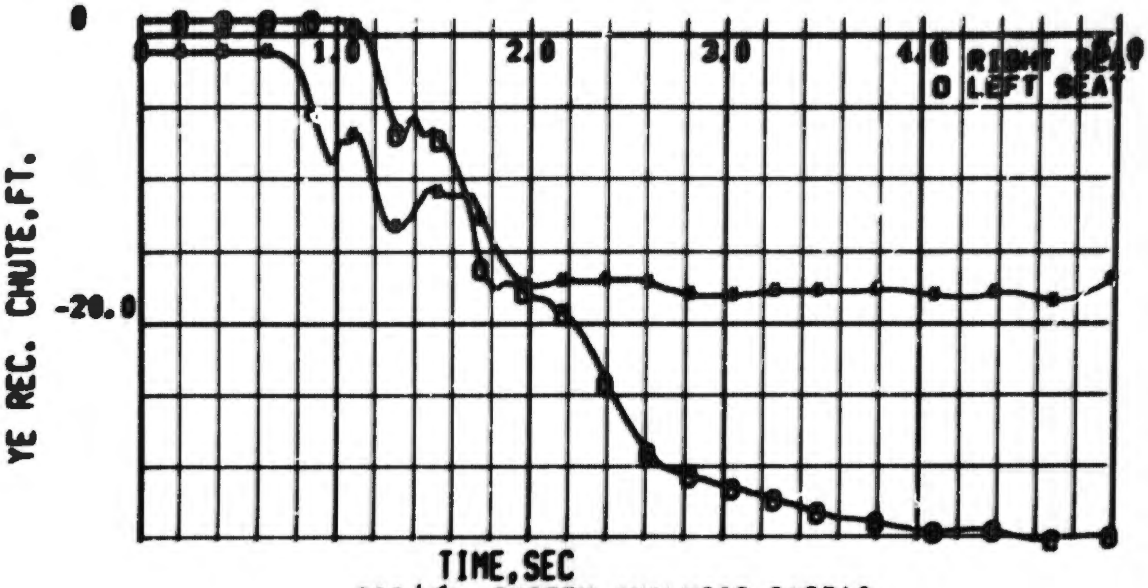


FIG 463 SYSTEM ANALYSIS,CASE10
PARACHUTE LATERAL DISTANCE

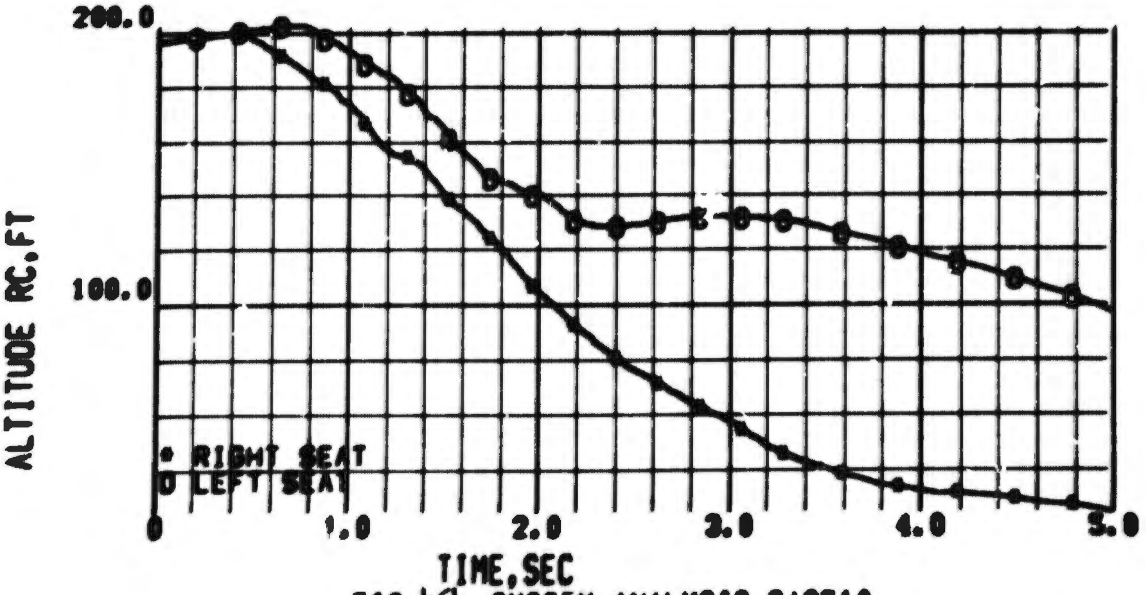


FIG 464 SYSTEM ANALYSIS,CASE10
PARACHUTE ALTITUDE

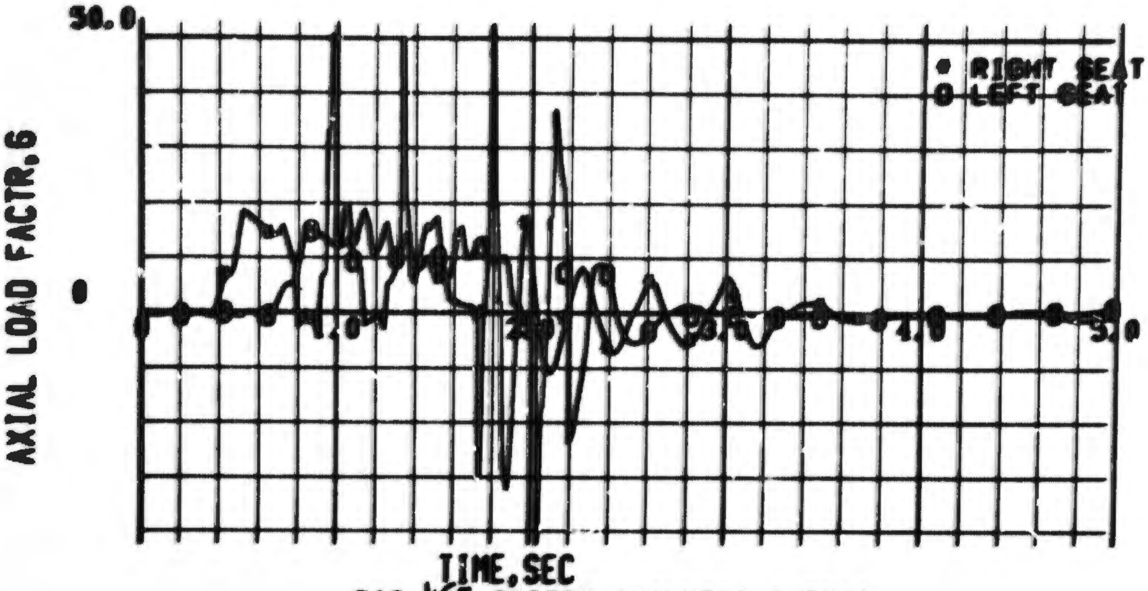


FIG 465 SYSTEM ANALYSIS,CASE10
SEAT-MAN AXIAL LOAD FACTOR,CG

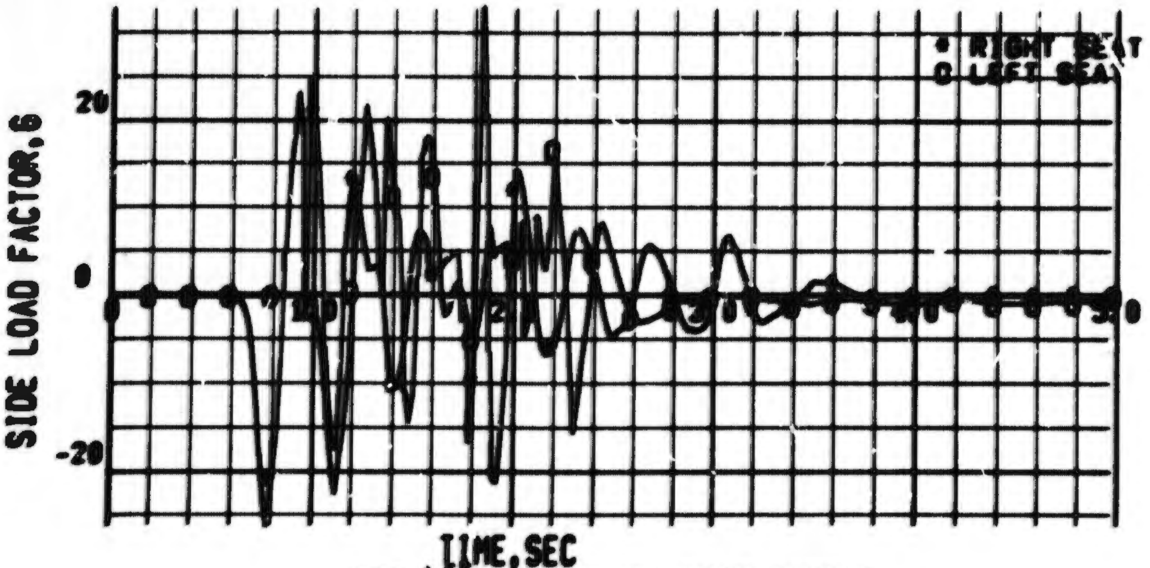


FIG 466 SYSTEM ANALYSIS,CASE10
SEAT-MAN SIDE LOAD FACTOR,CG

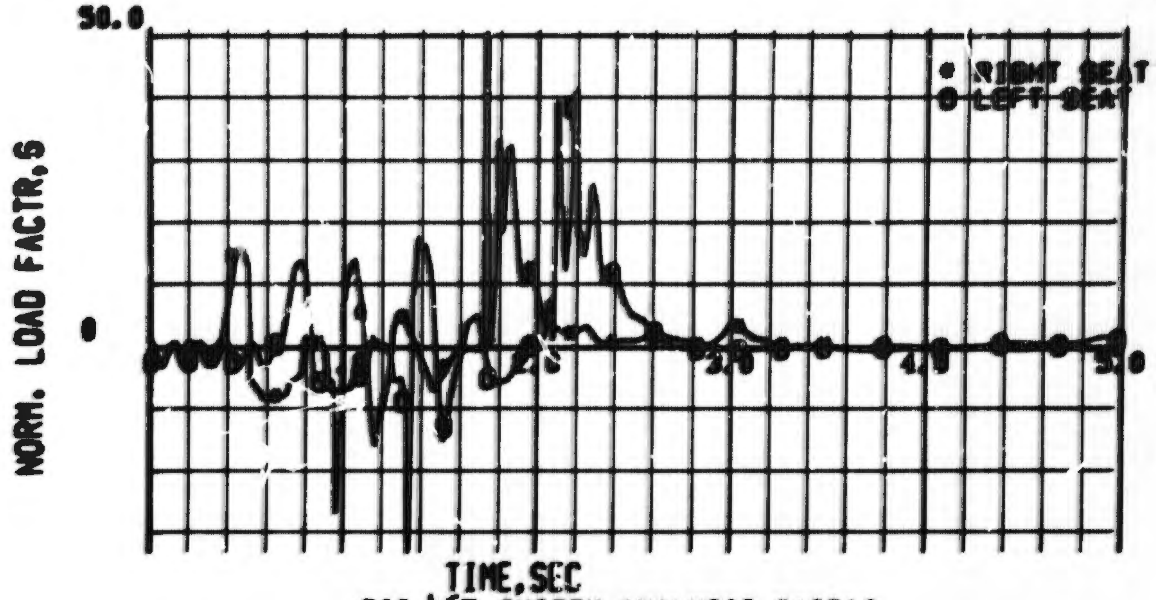


FIG 467 SYSTEM ANALYSIS,CASE10
SEAT-MAN NORMAL LOAD FACTOR,CG

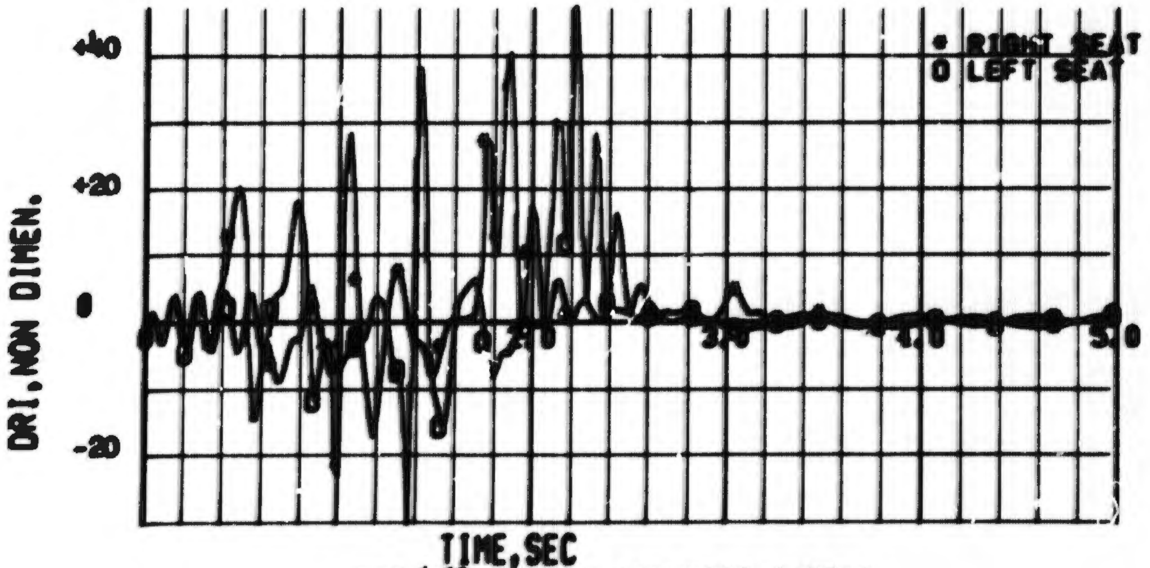


FIG 468 SYSTEM ANALYSIS,CASE10
PILOT DYNAMIC RESPONSE INDEX

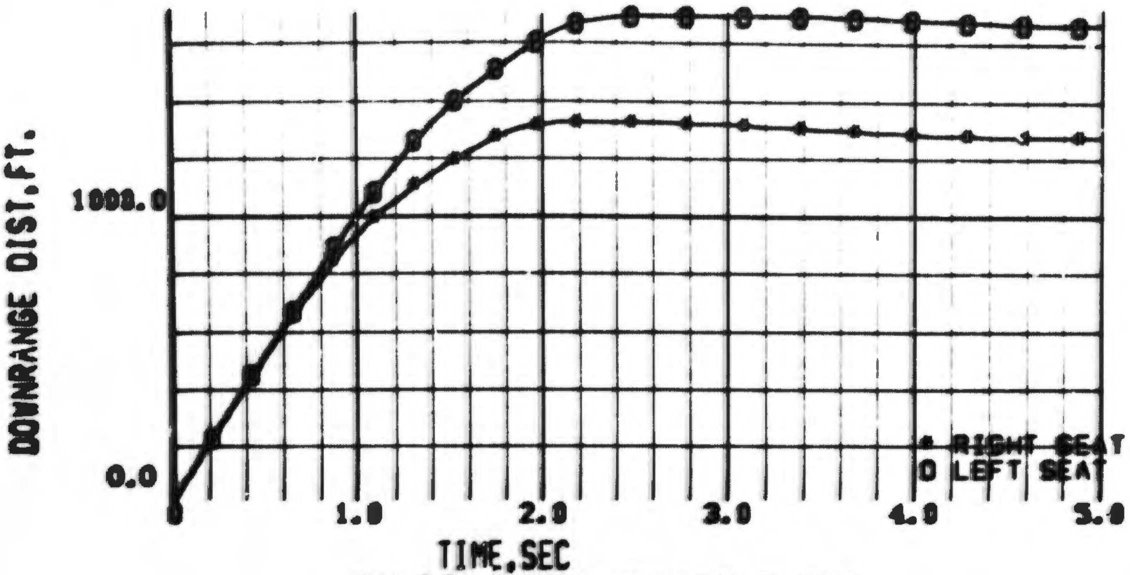


FIG 469 SYSTEM ANALYSIS,CASE11
SEAT AND/OR MAN DOWNRANGE DIST

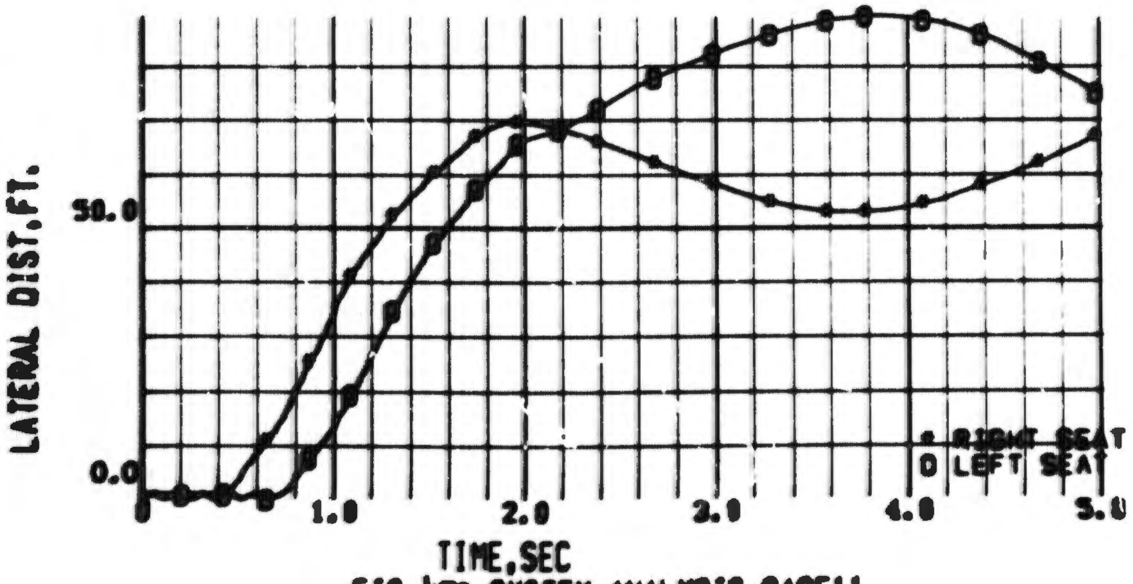


FIG 470 SYSTEM ANALYSIS,CASE11
SEAT AND/OR MAN LATERAL DIST.

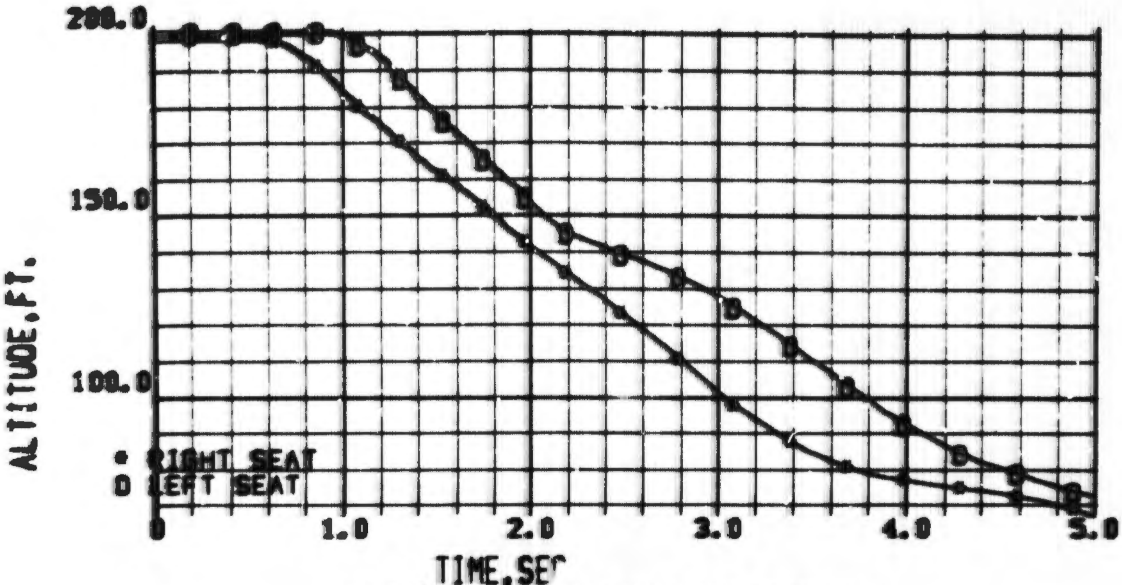


FIG 471 SYSTEM ANALYSIS,CASE11
SEAT AND/OR MAN ALTITUDE

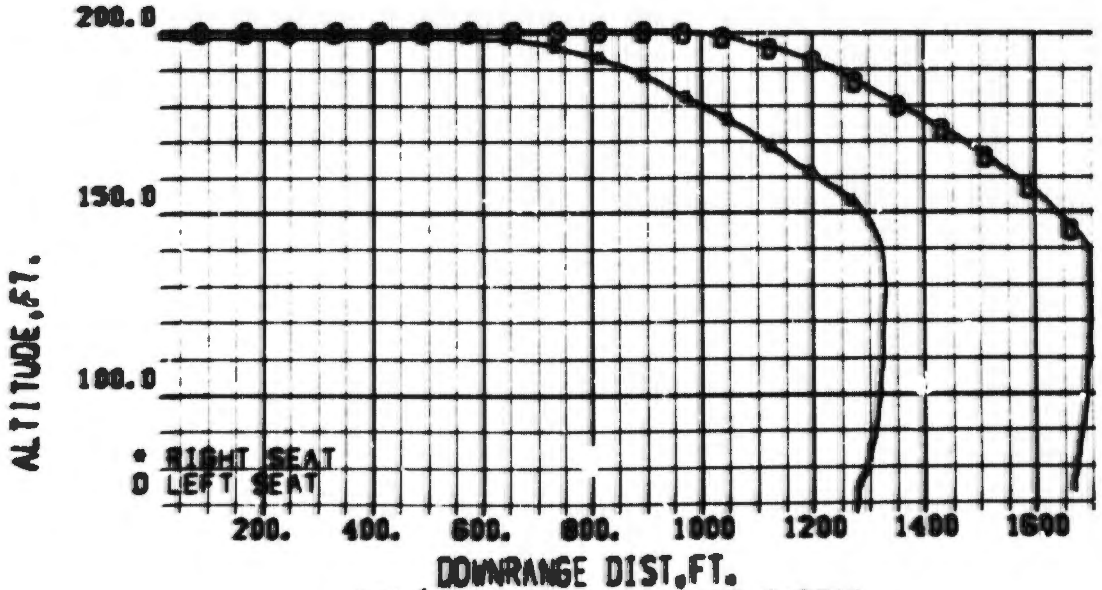


FIG 472 SYSTEM ANALYSIS,CASE11
SEAT-MAN TRAJECTORY

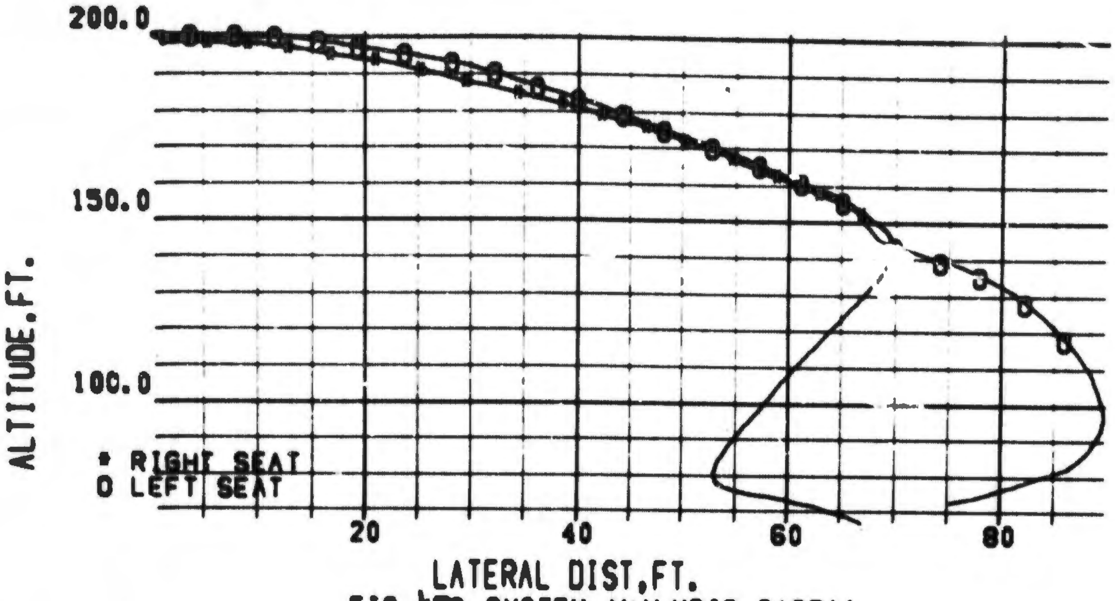


FIG 473 SYSTEM ANALYSIS,CASE11
SEAT-MAN TRAJECTORY

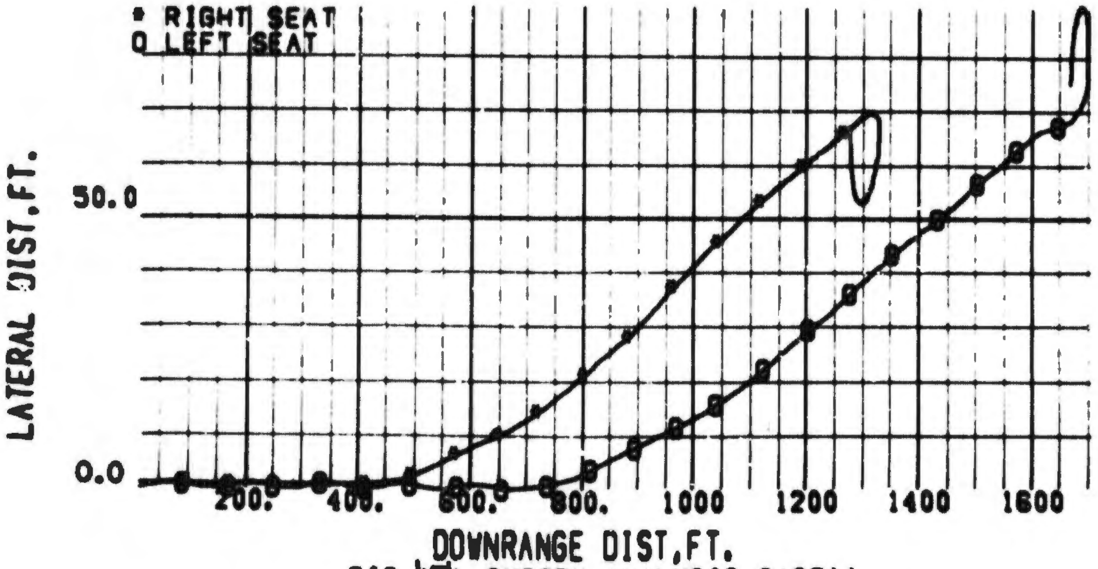


FIG 474 SYSTEM ANALYSIS,CASE11
SEAT-MAN TRAJECTORY

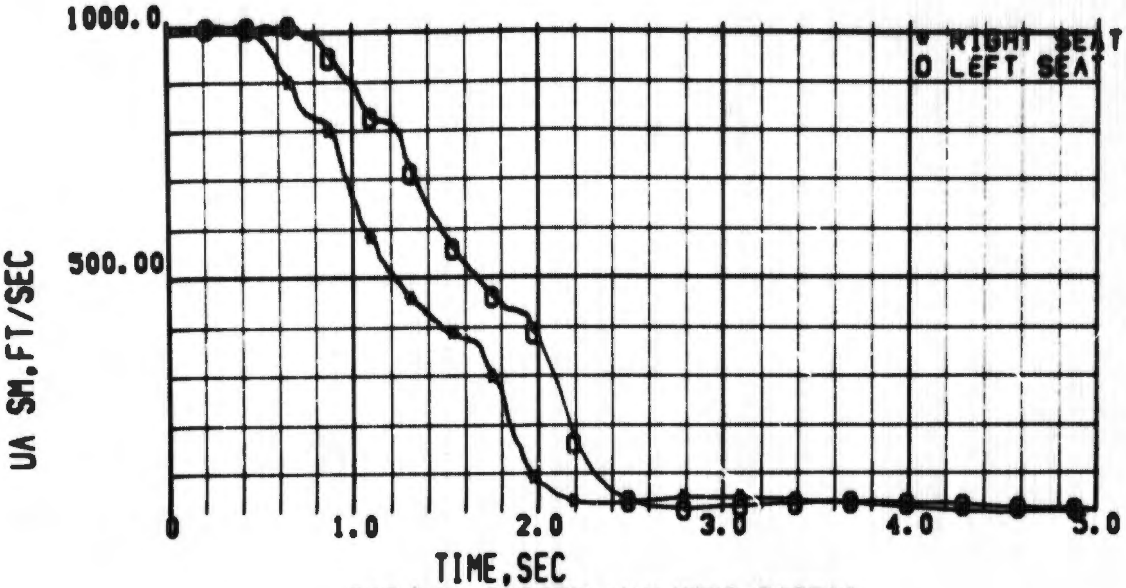


FIG 475 SYSTEM ANALYSIS,CASE11
SEAT AND/OR MAN TOTAL AIRSPEED

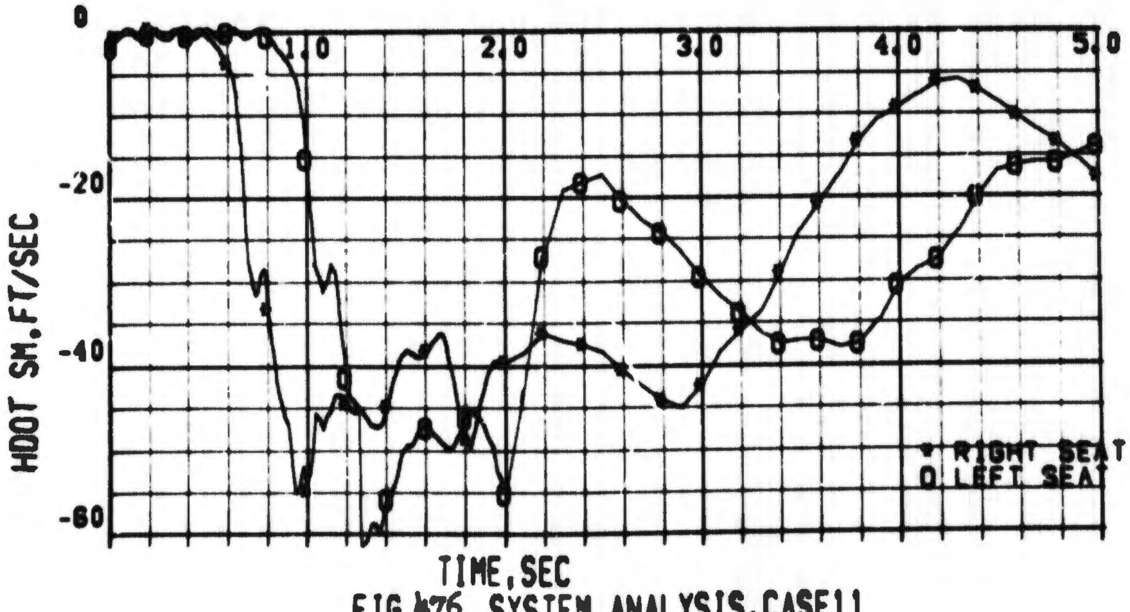
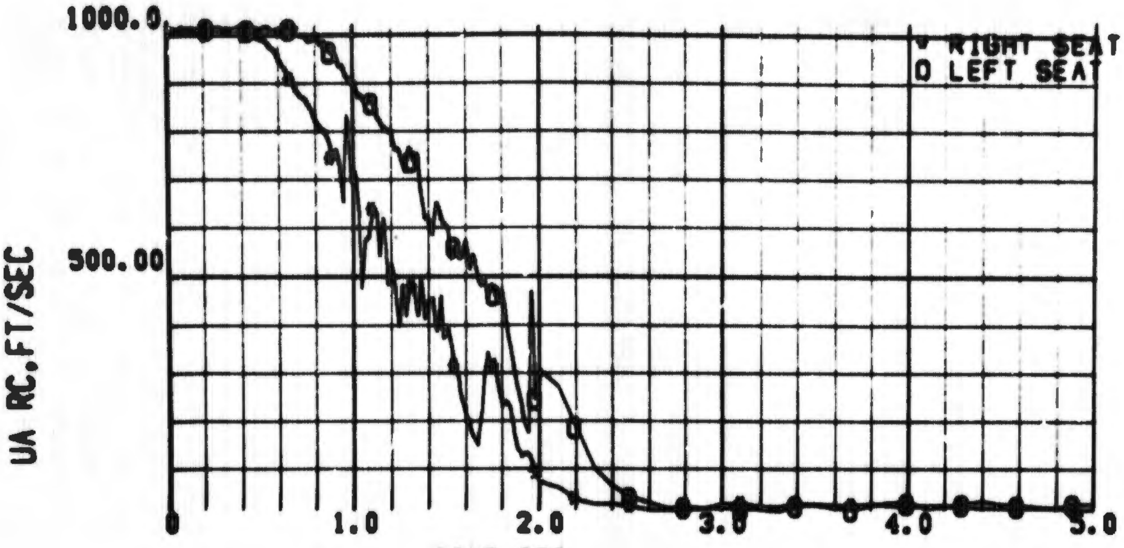
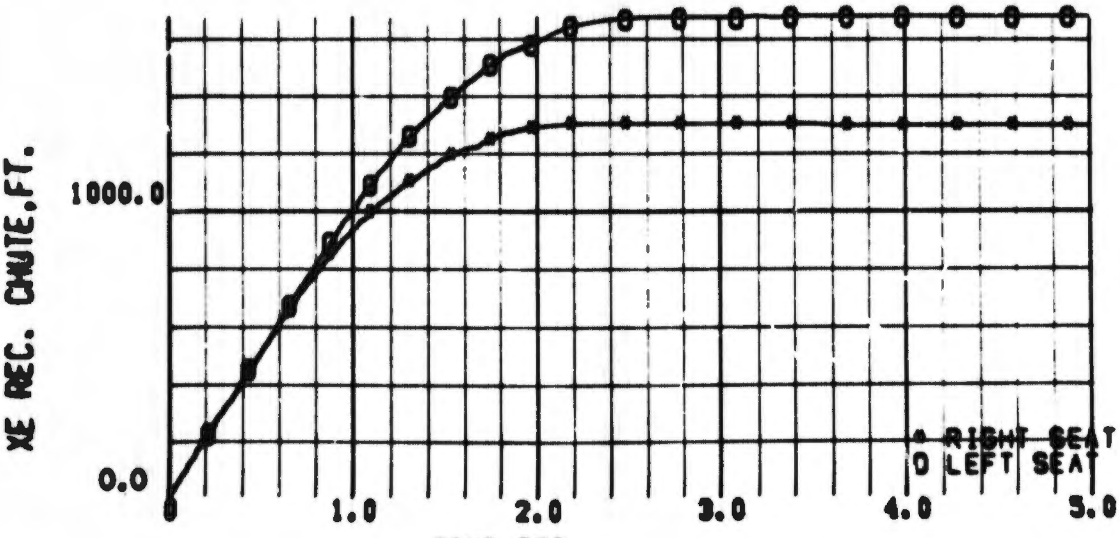


FIG 476 SYSTEM ANALYSIS,CASE11
SEAT AND/OR MAN CLIMB RATE



TIME,SEC
FIG 477 SYSTEM ANALYSIS,CASE11
PARACHUTE TOTAL AIRSPEED



TIME,SEC
FIG 478 SYSTEM ANALYSIS,CASE11
PARACHUTE DOWNRANGE DISTANCE

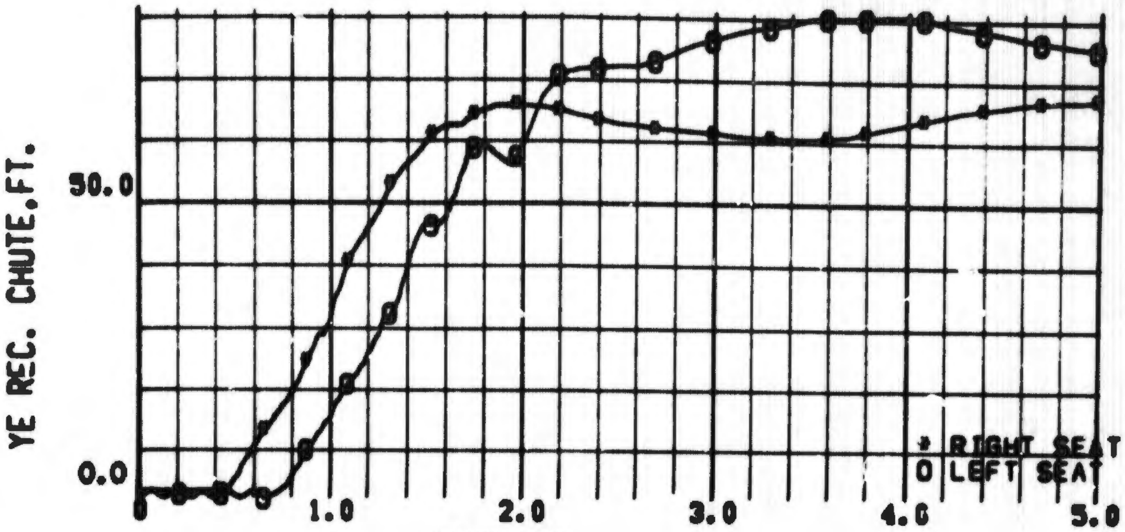


FIG 479 SYSTEM ANALYSIS,CASE11
PARACHUTE LATERAL DISTANCE

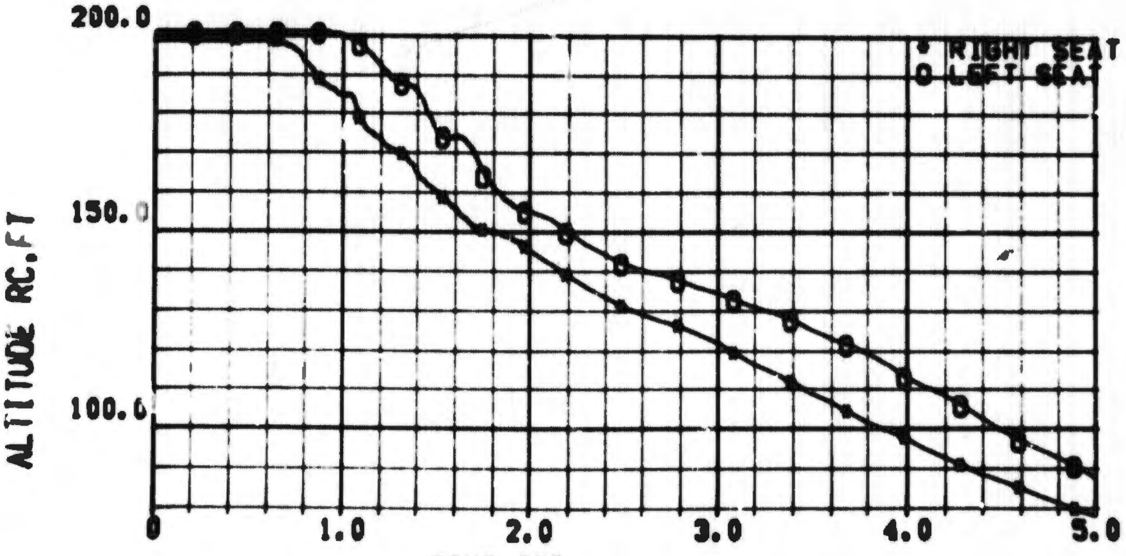


FIG 480 SYSTEM ANALYSIS,CASE11
PARACHUTE ALTITUDE

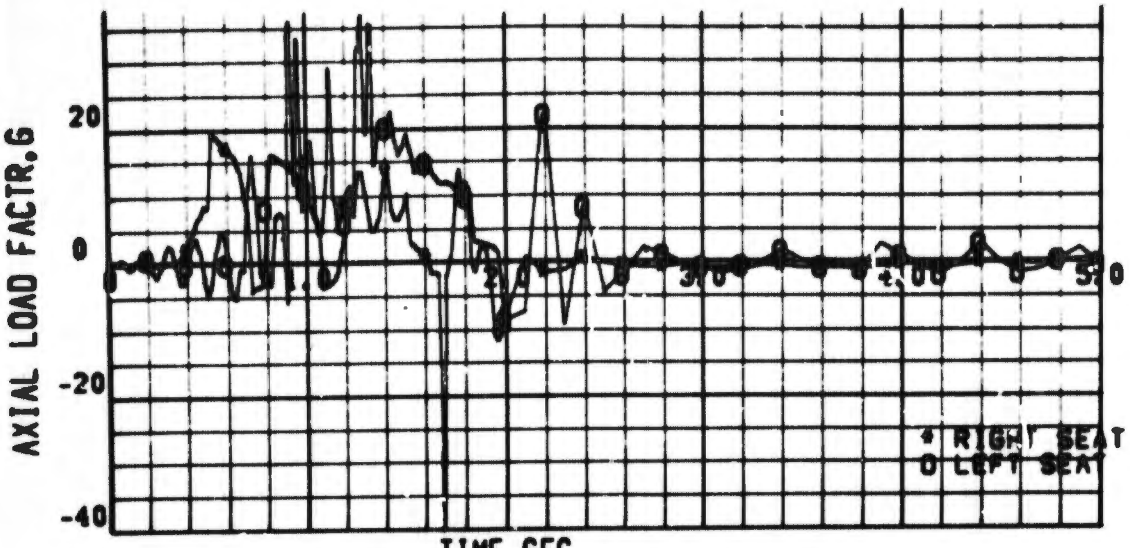


FIG 481 SYSTEM ANALYSIS,CASE11
SEAT-MAN AXIAL LOAD FACTOR,CG

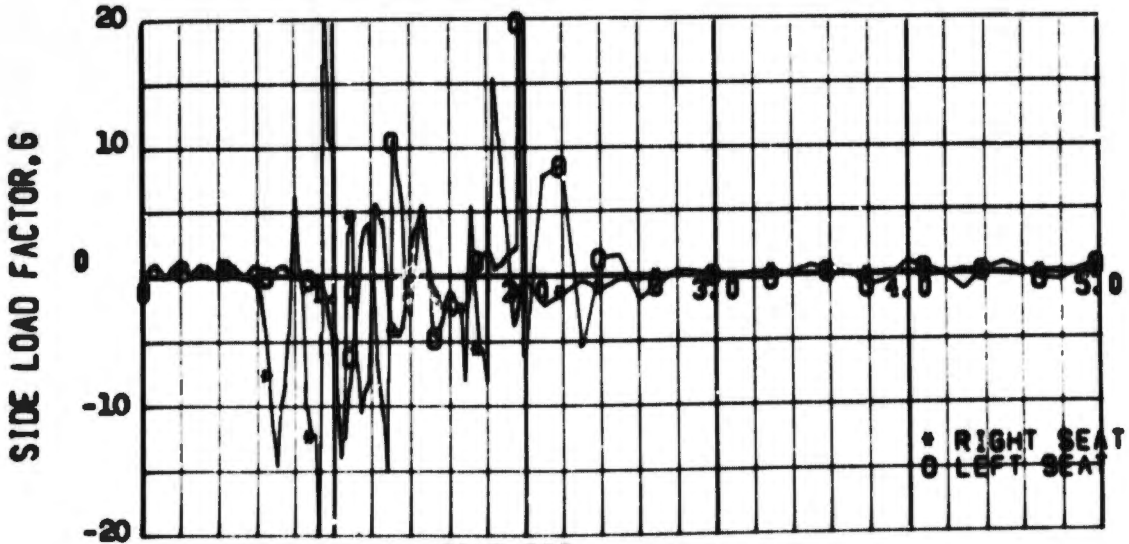
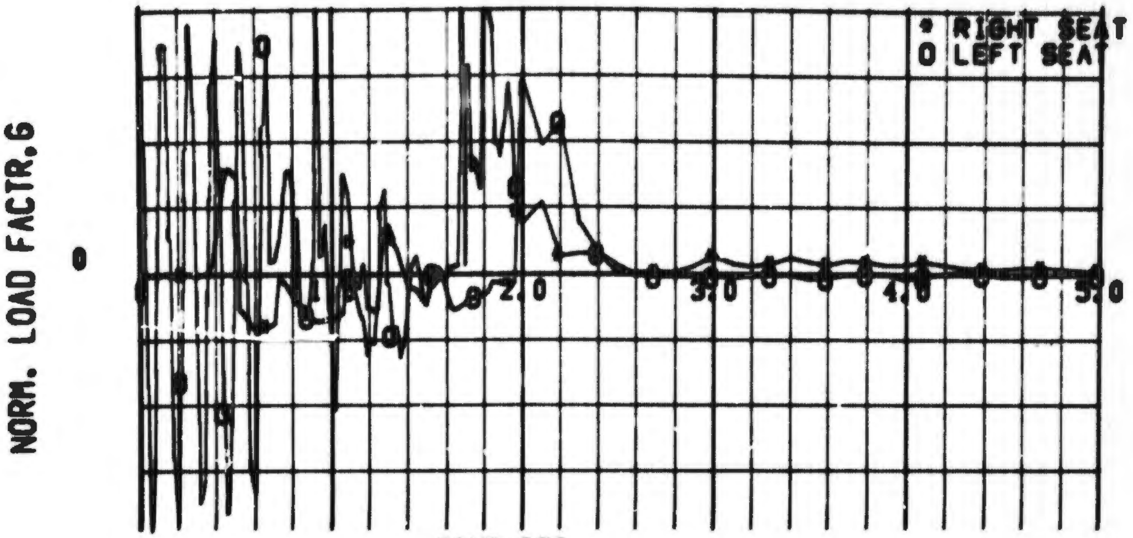
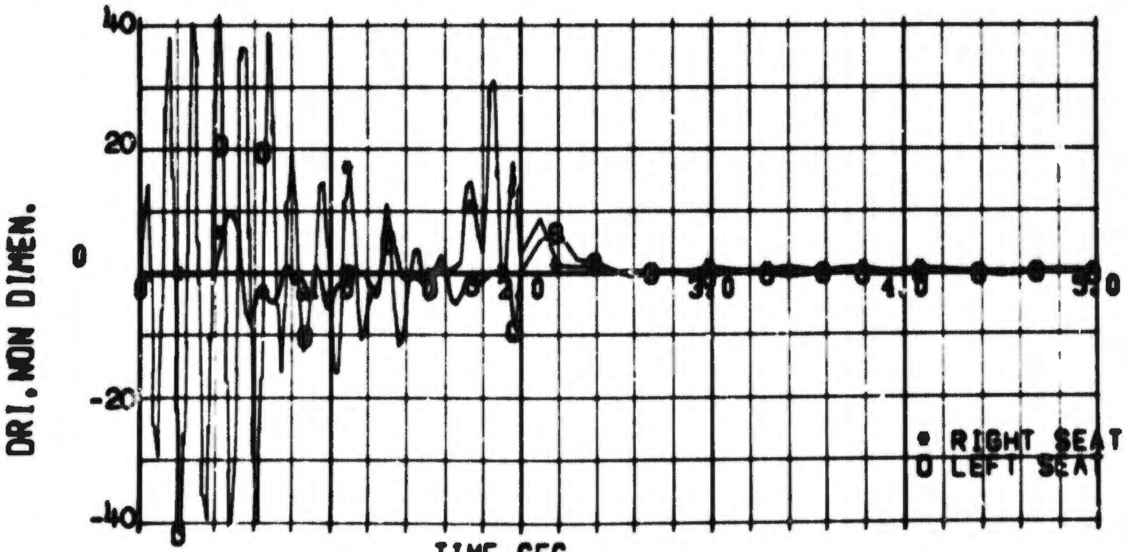


FIG 482 SYSTEM ANALYSIS,CASE11
SEAT-MAN SIDE LOAD FACTOR,CG



TIME,SEC
FIG 483 SYSTEM ANALYSIS,CASE11
SEAT-MAN NORMAL LOAD FACTOR,CG



TIME,SEC
FIG 484 SYSTEM ANALYSIS,CASE11
PILOT DYNAMIC RESPONSE INDEX

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APPENDIX III

VTOL ESCAPE SYSTEM MOCK-UP

FIGURE 485 VTOL ESCAPE SYSTEM MOCK-UP LEFT SIDE

FIGURE 486 VTOL ESCAPE SYSTEM MOCK-UP RIGHT SIDE

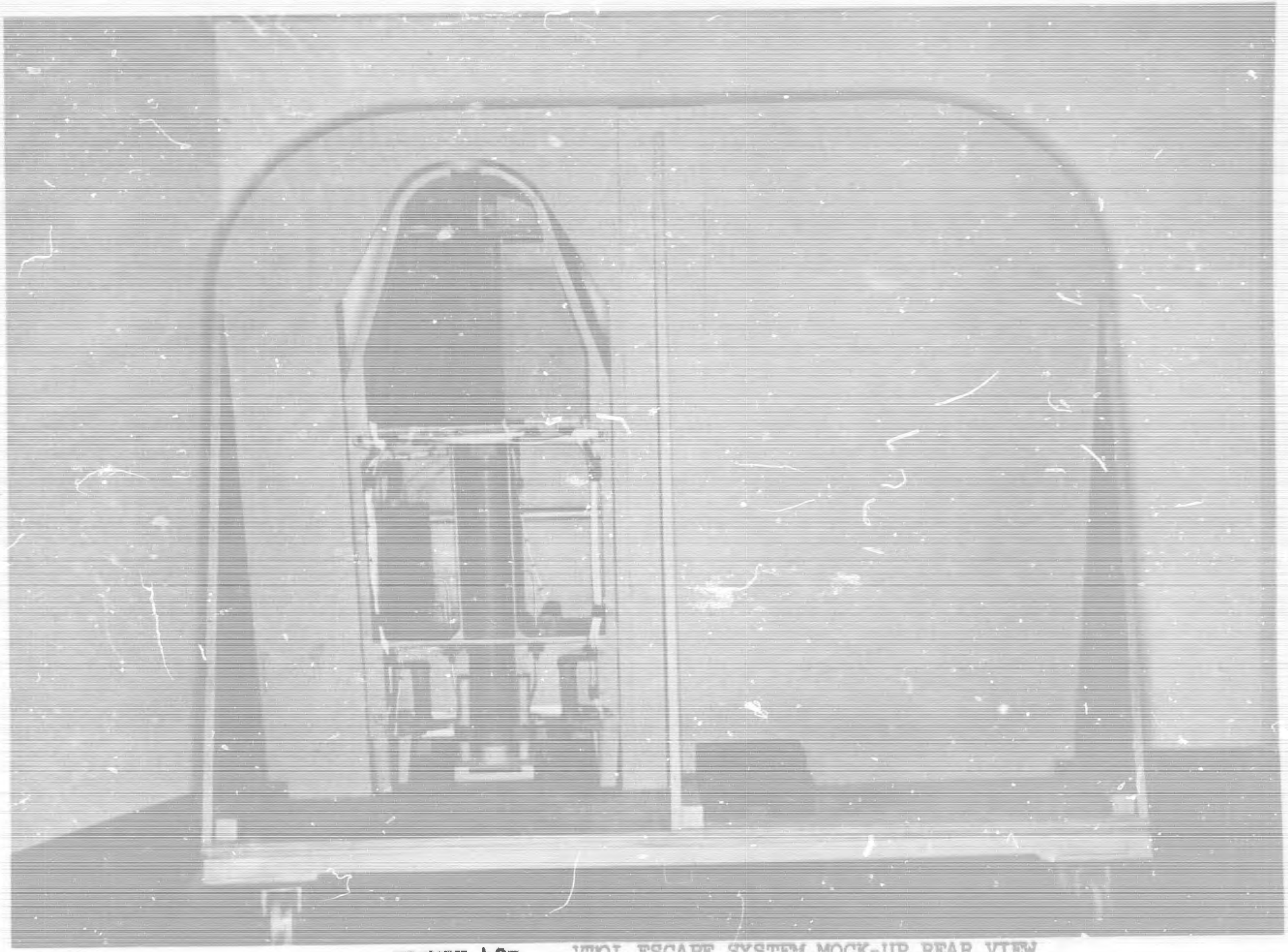

FIGURE 487 VTOL ESCAPE SYSTEM MOCK-UP REAR VIEW

FIGURE 488 VTOL ESCAPE SYSTEM MOCK-UP WARNING INDICATOR DETAIL

FIGURE 489 VTOL ESCAPE SYSTEM MOCK-UP RESTRAINT HARNESS DETAIL

FIGURE 490 VTOL ESCAPE SYSTEM MOCK-UP SEAT ASSEMBLY INSTALLED AFT VIEW

FIGURE 491 VTOL ESCAPE SYSTEM MOCK-UP SEAT ASSEMBLY BOTTOM VIEW

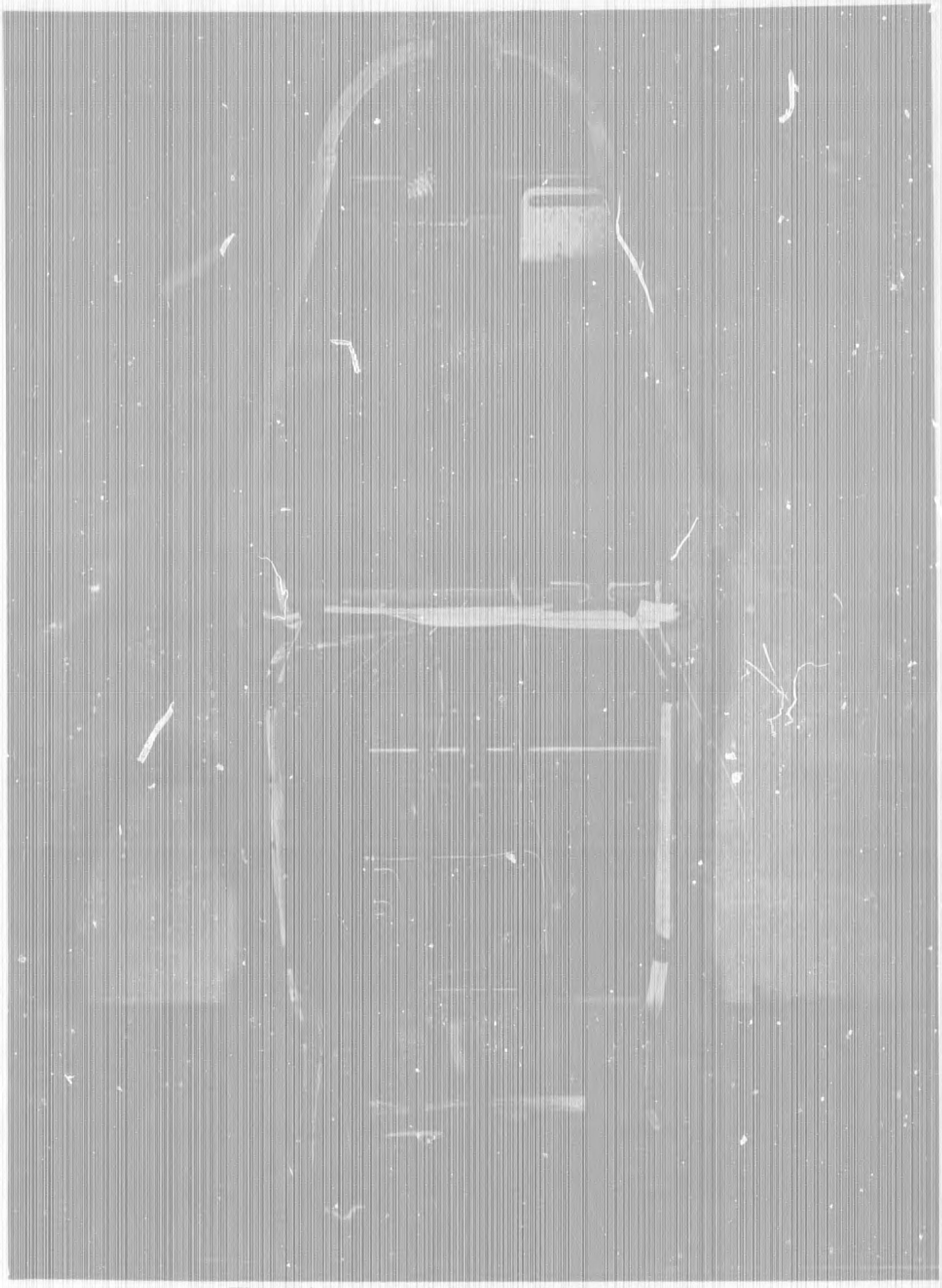

FIGURE 492 VTOL ESCAPE SYSTEM MOCK-UP
SEAT ASSEMBLY WITH CATAPULT-ROCKET REMOVED

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11\. SUPPLEMENTARY NOTES

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Air Force Flight Dynamics Laboratory
Air Force Systems Command
Wright-Patterson Air Force Base, Ohio 45433

13\. ABSTRACT

An ejection seat escape system is described for a hypothetical two-place fighter-attach VTOL aircraft. The system includes an emergency detection and escape initiation subsystem which functions independently of the crew. The performance required of the system is developed by an analysis of the parent aircraft modes of failure. The trajectory behavior of each of the seats in VTOL and conventional flight failures is presented in the form of time history plots generated by a six degree-of-freedom digital computer simulation.

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14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Emergency Detection and Ejection Initiation						
Automatic Escape						
Post Ejection						
Manual Ejection						
Ejection Propulsion Unit						
Vernier Rocket Installation						
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Canopy Severance						
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