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## Helicopter Physical and Performance Data

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Edwin D. McConkey  
Robert K. Anoll  
Margaret B. Renton  
James Young

Systems Control Technology, Inc.  
1611 N. Kent Street, Suite 910  
Arlington, VA 22209

August 1991

Final Report

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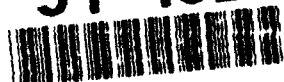
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| 16. Abstract<br><br>A determination of physical and performance data for eight civil helicopters was made. The helicopters used in the study were chosen to exhibit a wide range of characteristics representative of the current civil fleet. Flight manual data as well as certification, flight test, and computer generated performance data were used to complete the study. Approach and departure profiles were developed for several gross weights and ambient conditions and translated into graphs. A menu-driven database was designed to provide easy access to the data.<br><br>The airspace required for approaches is dependent upon pilot skill and desired approach slope. Pilots can fly approaches steeper than the current standard 8:1 surface if required though pilot workload tends to increase and comfort levels tend to decrease.<br><br>The airspace required for departures is a function of aircraft performance and ambient conditions. Three types of departure procedures were studied: "optimum" with respect to airspace, manufacturer's recommended, and Category A. Results show that minimum VFR heliport airspace requirements are dictated by departure profiles. Current flight manual departure procedures often break the 8:1 surface described in Heliport Design, Advisory Circular 150/5390-2. Implications are considered in detail in Heliport VFR Airspace Based on Helicopter Performance, DOT/FAA/RD-90/4.<br><br>This is one of a series of five reports that addresses helicopter performance profiles and their relationship to the VFR protected imaginary surfaces of approaches and departures at heliports. The other four are:<br><br>1) Heliport VFR Airspace Design Based on Helicopter Performance, DOT/FAA/RD-90/4.<br>2) Operational Survey - VFR Heliport Approaches and Departures, DOT/FAA/RD-90-5<br>3) Rotorcraft Acceleration and Climb Performance Model, DOT/FAA/RD-90-6, and<br>4) Helicopter Rejected Takeoff Airspace Requirements, DOT/FAA/RD-90/7. |  |                                                      |  |                                                                                                                                                             |  |
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# TABLE OF CONTENTS

|                                               | <u>Page</u> |
|-----------------------------------------------|-------------|
| Introduction.....                             | 1           |
| Methodology.....                              | 1           |
| Source Data.....                              | 4           |
| Data Traceability.....                        | 4           |
| Performance Data Generation.....              | 9           |
| Approach Profiles.....                        | 17          |
| Departure Profiles.....                       | 24          |
| Discussion.....                               | 24          |
| Conclusion.....                               | 33          |
| References.....                               | 35          |
| Acronyms.....                                 | 37          |
| Appendix A Subcontractor Summary Reports..... | A-1         |
| Appendix B Departure Profiles.....            | B-1         |

|                                      |                                           |
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| Availability Codes                   |                                           |
| Dist                                 | Avail and/or Special                      |
| A-1                                  |                                           |



## LIST OF FIGURES

|                                                        | <u>Page</u> |
|--------------------------------------------------------|-------------|
| Figure 1 Methodology Flow Diagram.....                 | 2           |
| Figure 2 NASA VFR Altitude Profiles.....               | 15          |
| Figure 3 NASA Characteristic Approach Profiles.....    | 16          |
| Figure 4 FAATC S 76 7.125 Degree Approach Profile..... | 18          |
| Figure 5 FAATC S 76 8.0 Degree Approach Profile.....   | 19          |
| Figure 6 FAATC S 76 10.0 Degree Approach Profile.....  | 20          |
| Figure 7 FAATC S 76 Composite Approach Profiles.....   | 21          |
| Figure 8 40 Knots Approach Profiles.....               | 25          |
| Figure 9 50 Knots Approach Profiles.....               | 26          |
| Figure 10 70 Knots Approach Profiles.....              | 27          |
| Figure 11 90 Knots Approach Profiles.....              | 28          |
| Figure 12 H-V+5 Knots Departure Procedure.....         | 31          |

## LIST OF TABLES

|                                                             | <u>Page</u> |
|-------------------------------------------------------------|-------------|
| Table 1 Physical Data Base File.....                        | 5           |
| Table 2 Performance Data Source Traceability Matrix.....    | 10          |
| Table 3 Physical Data Base Traceability Matrix.....         | 11          |
| Table 4 NASA Approach Test Helicopter Characteristics ..... | 14          |
| Table 5 Approach Rate of Descent Limits.....                | 22          |
| Table 6 Maximum Rates of Descent.....                       | 22          |
| Table 7 Achievable Approach Slopes.....                     | 23          |
| Table 8 Approach Procedures.....                            | 29          |
| Table 9 Departure Procedures.....                           | 30          |

## INTRODUCTION

Current FAA criteria for visual meteorological conditions (VMC) heliport takeoff/landing surfaces and approach/departure airspace is based on operational judgment. This report documents the methodology, assumptions, analyses, and discussion of a study conducted by Systems Control Technology, Inc. to determine approach and departure performance of eight civil helicopters. These eight helicopters were chosen as a representative sample of the current civil fleet. The conclusions drawn as a result of this study are discussed in "Heliport VFR Airspace Based on Helicopter Performance," DOT/FAA/RD-90/4. The entirety of these analyses will be considered to determine if current FAA VMC requirements for heliport airspace and real estate should be modified. Airspace requirements related to rejected takeoff and one engine inoperative (OEI) capability for heliports intended to support Category A operations are discussed in "Helicopter Rejected Takeoff Airspace Requirements," DOT/FAA/RD-90/7.

## METHODOLOGY

The objective of the study was to assemble and generate helicopter physical and performance data, traceable to flight manuals and manufacturer data, to be used to make recommendations regarding changes to heliport airspace and real estate requirements. The product of the study is a data base of physical and performance data stored on a floppy disk. The data was generated to support the computation of helicopter approach and departure profiles. The data base provides the FAA with the capability to test operational VMC takeoff and landing scenarios under a variety of helicopter loading and ambient conditions. This chapter explains the methodology used to create this product.

A flowchart of the methodology used to achieve the required product is shown in figure 1. After reviewing previous studies of heliport real estate and airspace requirements, a list of helicopters for the study was chosen. Source data for each helicopter was gathered and reviewed. From these source data a physical data base of the helicopters' characteristics was developed. Physical and performance data were provided to a subcontractor to generate more detailed departure performance data using a helicopter sizing and performance computer program. Departure procedures were applied to this computer-generated performance data to produce departure profiles. Approach profiles were derived from flight manual approach procedures and results of VMC approach testing performed by the FAA Technical Center and NASA. A menu driven program was written to provide the user easy access to the physical, approach and departure profiles data, and all were stored on a floppy disk. Graphs of the profiles were generated separately for this report.

SCT reviewed a previous study of heliport airspace and real estate requirements that was generated for the FAA in 1980 by PACER Systems, Inc. The study cited an earlier performance analysis of twelve helicopters and generalized the results to determine heliport airspace and real estate requirements. As a result of this generalization all traceability to individual helicopter flight manuals was erased. Two actions were recommended in the report with regard to VFR airspace and real estate requirements; that current VFR obstacle surfaces for ground

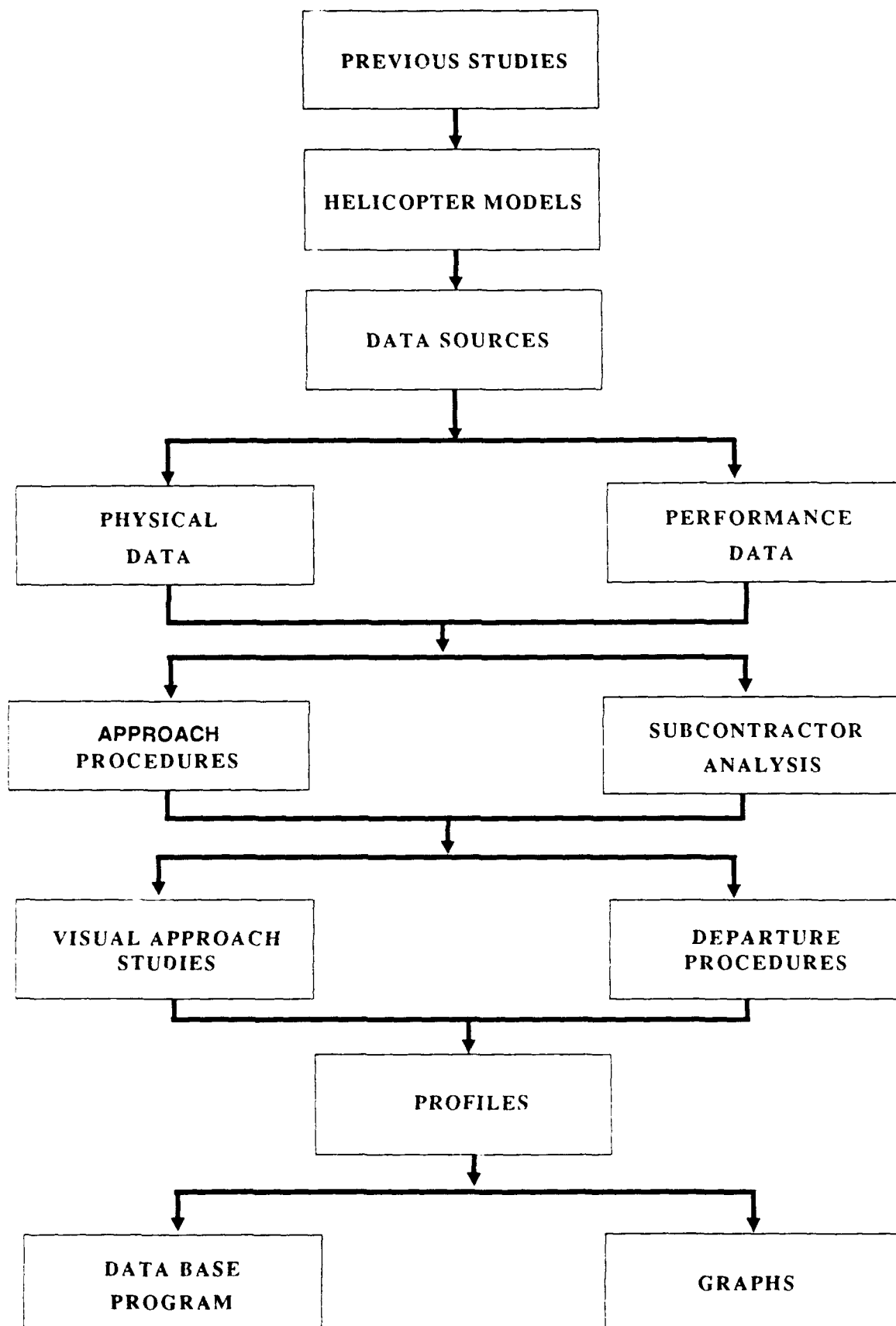


FIGURE 1. METHODOLOGY FLOW DIAGRAM

level heliports be applied to both fixed and mobile offshore helicopter landing facilities, and to amend rotorcraft flight manual standards to include performance charts to determine vertical climb capability, best angle of climb airspeed, hover performance and acceleration distance to reach selected airspeeds at various combinations of weight, altitude and temperature. As a consequence of choosing not to implement the recommended changes to the flight manual standards, the report suggested that the FAA require additional real estate and airspace to accommodate the execution of a level acceleration through effective translational lift prior to the beginning of a climb for all helicopters. These recommendations were not well-received by the rotorcraft industry for a variety of operational and economic reasons. Primary among these was that historically, safe operations had been conducted using the current real estate and airspace requirements so that the imposition of additional requirements was thought to not be warranted.

The intent of this study was to analyze the performance of eight helicopters and retain traceability to their respective flight manuals. Eight helicopters were chosen for the study on the basis that they represent a substantial portion of the current civil fleet and cover a wide range of gross weights, engine types and instrument equipage. The table that follows illustrates these qualifying characteristics of the eight helicopters chosen for the study. Percent fleet figures were determined by the number of aircraft titled in the U.S. as of October 1987 and were obtained from the 1988 Helicopter Annual published by Helicopter Association International. The specific variation of each helicopter used in the study is listed.

| <u>HELICOPTER</u> | <u>GROSS WEIGHT</u> | <u>ENGINE</u>    | <u>NO.</u> | <u>% FLEET</u> | <u>VFR/IFR</u> |
|-------------------|---------------------|------------------|------------|----------------|----------------|
| F 28F             | 2600                | LYC H10-360-F1AD | 1          | 4              | VFR            |
| MD 369/500        | 3000                | ALL 250-C20B     | 1          | 8              | VFR            |
| B 206 A/B         | 3200                | ALL 250-C20J     | 1          | 17             | VFR            |
| AS 355            | 5071                | ALL 250-C20F     | 2          | 2              | VFR/IFR        |
| MBB BO 105        | 5512                | ALL 250-C20B     | 2          | 2              | VFR            |
| S 76              | 10500               | ALL 250-C30S     | 2          | 2              | VFR/IFR        |
| AS 332            | 18959               | TMECA MAKILA IA  | 2          | .1             | VFR/IFR        |
| BV 234            | 48500               | LYC AL5512       | 2          | .1             | VFR/IFR        |

TOTAL % FLEET 35.2

| <u>HELICOPTER MODEL</u> | <u>VARIATION</u> | <u>NAME</u>                                 |
|-------------------------|------------------|---------------------------------------------|
| F 28F                   | F 28F            | Enstrom Falcon                              |
| MD 369/500              | MD 500E          | McDonnell Douglas 500E                      |
| B 206 A/B               | B 206B III       | Bell Jet Ranger III                         |
| AS 355                  | AS 355F          | Aerospatiale Twin Star                      |
| MBB BO 105              | MBB BO 105 CBS   | Messerschmitt-Bolkow-Blohm GmbH Twin Jet II |
| S 76                    | S 76A            | Sikorsky Spirit                             |
| AS 332                  | AS 332C          | Aerospatiale Super Puma                     |
| BV 234                  | BV 234 LR        | Boeing Vertol Passenger Chinook             |

## SOURCE DATA

Based on the completeness of military helicopter flight manuals reviewed by SCT for previous studies it was originally planned that all the information needed to conduct this study would be available in the civil helicopter flight manuals. A request was made to the FAA coordinator at each manufacturer's facility for a flight manual. Enstrom, Bell, and Aerospatiale each sent a master copy of their respective helicopter flight manual(s). Complete flight manuals were not received from all manufacturers, but all manufacturers were extremely helpful in providing sections of their flight manuals and relevant information. After intensive review of each flight manual and flight manual sections provided, it was apparent that additional performance and physical data were needed to perform this study. Most of the additional information was requested and obtained from the manufacturers but some were available from the FAA and existing documentation.

The Official Helicopter Blue Book published by Helicopter Financial Services Inc. contains a variety of information on rotorcraft. This guide was consulted when other sources failed to yield specific information.

## DATA TRACEABILITY

Physical data for the eight helicopters of this study are housed within the physical data base file stored on the floppy disk delivered as part of this task to the FAA. This data base file is presented as table 1. A description of each physical data category of the data base file in order of presentation follows. The corresponding category titles shown in table 1 are listed in parentheses. Not applicable is represented by N/A while a dash indicates the data was not available.

Name (NAME). The name of the aircraft is abbreviated. The eight aircraft are the Enstrom F 28F, McDonnell Douglas 500E, Bell 206B III, Aerospatiale 355F, MBB BO105 CBS, Sikorsky S 76A, Aerospatiale 332C and Boeing Vertol 234 LR.

Engine Manufacturer (ENG MANU). Each engine manufacturer is listed. Lycoming, Allison and Turbomeca are represented.

Engine Number (ENG NO). The number of engines per aircraft. Three single engine and five twin engine aircraft are used for this study.

Engine Model (ENG MODEL). The manufacturer's engine model number.

Takeoff Power Available (PR TO). The takeoff power available per engine for each aircraft in terms of horsepower.

Maximum Continuous Power Available (PR MAX). The power available for maximum continuous operation per engine in units of horsepower.

Single Engine 30 Minute Power Available (PR 130M). For twin engine aircraft, the 30 minute power available rating for a single engine after the power loss of the other engine occurs is shown in terms of horsepower.

TABLE 1. PHYSICAL DATA BASE FILE

| RECORD# | NAME       | ENG_MNU   | ENG_NO | ENG_MODEL    | PR_ID | PR_MAX | PR_LEN | RS_BLM | RS_RPT | RS_DIA | RS_CHRM | RS_CHRT | RS_DAREM | RS_DAREAT |         |         |
|---------|------------|-----------|--------|--------------|-------|--------|--------|--------|--------|--------|---------|---------|----------|-----------|---------|---------|
| 1       | F 28F      | LYCOMING  | 1      | H1D-360-F1AD | 225   | 225    | N/A    | 3      | 2      | 350    | 2504    | 32.00   | 4.78     | 0.37      | 804.25  | 17.95   |
| 2       | MD 500E    | ALLISON   | 1      | 250-C208     | 420   | 370    | N/A    | 5      | 4      | 487    | 2188    | 26.41   | 4.60     | 0.56      | 547.81  | 16.62   |
| 3       | B 2068 III | ALLISON   | 1      | 250-C20J     | 420   | 370    | N/A    | 2      | 2      | 394    | 2550    | 33.30   | 5.42     | 1.08      | 873.00  | 23.10   |
| 4       | AS 355F    | ALLISON   | 2      | 250-C20F     | 420   | 370    | -      | 3      | 2      | 394    | 2088    | 35.07   | 6.10     | 1.15      | 966.12  | 29.28   |
| 5       | 80 105 CBS | ALLISON   | 2      | 250-C20B     | 420   | 400    | -      | 4      | 2      | 424    | 2220    | 32.28   | 6.23     | 0.89      | 818.56  | 30.57   |
| 6       | S 76A      | ALLISON   | 2      | 250-C305     | 650   | 557    | 650    | 4      | 4      | 244    | 609     | 44.00   | 8.00     | 1.28      | 1520.53 | 50.27   |
| 7       | AS 332C    | TURBOMECA | 2      | MAKILA 1A    | 1662  | 1515   | 1662   | 4      | 5      | 265    | 1279    | 51.17   | 10.00    | 2.00      | 2057.27 | 78.70   |
| 8       | BV 234 LP  | LYCOMING  | 2      | AL5512       | 4075  | 2975   | 4355   | 3      | 3      | 225    | 225     | 60.00   | 60.00    | 2.67      | 5652.00 | 5652.00 |

| REPORT# | NAME       | RS_DISCD | RS_PNRD | EX_LFOUSE | EX_TTHRM | EX_BTURN | EX_WFEUSE | EX_WIPT | EX_BETP           | EX_WLGP | EX_BELB | EX_MURHT | EX_TARCHT | EX_BFEUSE | AC_SEAT | AC_DENS | MT_GROSS | MT_EMPTY | MT_FUEL |
|---------|------------|----------|---------|-----------|----------|----------|-----------|---------|-------------------|---------|---------|----------|-----------|-----------|---------|---------|----------|----------|---------|
| 1       | F 28F      | 3.23     | 11.56   | 25.73     | 28.08    | 30.30    | 5.25      | 7.33    | SK10              | 7.33    | 8.00    | 9.00     | 7.81      | 1.58      | 3       | 3       | 2600     | 1550     | 810     |
| 2       | MD 500E    | 5.46     | 7.14    | 23.20     | 28.50    | 30.80    | 4.60      | 6.50    | SK10              | 6.50    | 8.28    | 8.70     | 8.20      | 1.30      | 5       | 7       | 3000     | 1455     | 1116    |
| 3       | B 2068 III | 3.67     | 7.62    | 31.20     | 31.20    | 39.10    | 4.33      | 6.40    | SK10              | 6.40    | 8.02    | 9.50     | 7.56      | 1.00      | 5       | 5       | 3200     | 1635     | 955     |
| 4       | AS 355F    | 5.25     | 6.04    | 25.79     | 35.79    | 42.65    | 5.90      | 8.30    | SK10              | 6.89    | -       | 9.65     | 8.00      | 1.27      | 5       | 6       | 5071     | 2900     | 1119    |
| 5       | 80 105 CBS | 6.73     | 6.56    | 28.90     | 0.00     | 38.91    | 5.18      | 8.30    | SK10              | 8.30    | -       | 9.83     | 12.47     | 1.05      | 5       | 6       | 5291     | 2694     | 1793    |
| 6       | S 76A      | 6.77     | 7.92    | 43.37     | 45.20    | 57.50    | 7.00      | 10.00   | WHEEL/TRI-SF, SA  | 8.46    | 16.42   | 13.50    | 14.48     | 1.00      | 14      | 14      | 10500    | 5930     | 2687    |
| 7       | AS 332C    | 9.22     | 5.70    | 48.43     | 50.92    | 61.33    | 6.56      | 11.08   | WHEEL/TRI-DF, SA  | 9.83    | 14.67   | 15.08    | 16.14     | 1.42      | 19      | 22      | 18959    | 9259     | 6946    |
| 8       | BV 234 LP  | 4.29     | 7.18    | 52.08     | N/A      | 99.00    | 15.67     | 15.67   | WHEEL/QUAD-DF, SA | 11.71   | 25.83   | 18.65    | N/A       | -         | 46      | 46      | 48500    | 25900    | 8509    |

| REPORT# | NAME       | MT_LOAD | FUE_TANK | RAN_MAX | RAN_ENDER | PER_SC | PER_SCISTD | PER_SCINOT | PER_HIGE | PER_HIGENT | PER_HOGE | PER_HOSENT | PER_ROCOR | PER_ROCUE | PER_ROC1 | PER_VNE | CERT_VFR | CERT_IVR |
|---------|------------|---------|----------|---------|-----------|--------|------------|------------|----------|------------|----------|------------|-----------|-----------|----------|---------|----------|----------|
| 1       | F 28F      | 1000    | 40       | 228     | 3.5       | 9000   | N/A        | N/A        | 7700     | 2200       | 0        | 0          | 1450      | 0         | N/A      | 74      | 12/30/80 | N/A      |
| 2       | MD 500E    | 2000    | 64       | 261     | 2.8       | 15000  | N/A        | N/A        | 8400     | 5800       | 7200     | 4400       | 1716      | 910       | N/A      | 152     | 11/23/82 | N/A      |
| 3       | B 2068 III | 1500    | 91       | 369     | 3.2       | 13500  | N/A        | N/A        | 12800    | 10200      | 8800     | 3800       | 1280      | 304       | N/A      | 122     | 07/01/77 | N/A      |
| 4       | AS 355F    | 2304    | 193      | 391     | 4.7       | 13120  | 2790       | -          | 9400     | 6750       | 7800     | 5300       | 1600      | 848       | 420      | 150     | 11/20/81 | 08/06/82 |
| 5       | 80 105 CBS | 1984    | 157      | 310     | 3.5       | 17000  | 2700       | 0          | 7500     | 5400       | 5200     | 2800       | 1510      | 560       | 100      | 145     | 07/25/77 | N/A      |
| 6       | S 76A      | 3300    | 281      | 404     | 3.5       | 14167  | 4300       | 0          | 2400     | 0          | 1200     | 0          | 1600      | 0         | 240      | 155     | 11/21/78 | 11/21/78 |
| 7       | AS 332C    | 9921    | 411      | 343     | 3.3       | 15100  | 4500       | 1250       | 8300     | 5000       | 6000     | 2500       | 1600      | 218       | 550      | 150     | 10/14/81 | 10/14/81 |
| 8       | BV 234 LP  | 28000   | 2090     | 730     | 5.4       | 6467   | -          | -          | 7400     | 4400       | 2700     | 500        | 1180      | 257       | 295      | 149     | 06/19/81 | 06/19/81 |

Takeoff Transmission Power Available (TR TO). The takeoff power available limit of the main gearbox in units of horsepower.

Maximum Continuous Transmission Power Available (TR MAX). The main gearbox maximum continuous power available limit, in horsepower.

Single Engine Transmission Power Available (TR LENG). The main gearbox power available limit for a twin engine aircraft in the one engine inoperative condition, in horsepower.

Number of Main Rotor Blades (RS BLM). The number of blades in the main rotor.

Number of Tail Rotor Blades (RS BLT). The number of tail rotor blades.

Main Rotor Revolutions Per Minute (RS RPM). The number of revolutions per minute of the main rotor.

Tail Rotor Revolutions Per Minute (RS RPMT). The number of tail rotor revolutions per minute.

Main Rotor Diameter (RS DIAM). The diameter of the main rotor of the aircraft, in feet.

Tail Rotor Diameter (RS DIAT). The tail rotor diameter of the aircraft, in feet.

Main Rotor Chord (RS CHORM). The chord of the main rotor as measured in feet.

Tail Rotor Chord (RS CHORT). The tail rotor's chord, in feet.

Main Rotor Disc Area (RS DAREAM). The disc area of the main rotor in feet squared.

Tail Rotor Disc Area (RS DAREAT). The tail rotor disc area in terms of square feet.

Main Rotor Disc Loading (RS DISCLD). The disc loading in dimensions of pounds per square feet. Disc loading is calculated by dividing the helicopter's maximum gross weight by the main rotor disc area.

Main Rotor Power Loading (RS PWRLD). The power loading is determined by dividing the helicopter's maximum gross weight by the total takeoff power available and is measured in units of pounds per horsepower.

Fuselage Length (EX LFUSE). The length of the fuselage is measured in feet from nose to tail of the aircraft and may include portions of the vertical stabilizer.

Fuselage Length With Tail Rotor Turning (EX TTURN). The length of the fuselage is measured in feet and includes the extreme point described by the tail rotor arc.

Fuselage Length With Main and Tail Rotors Turning (EX BTURN). The length of the fuselage is measured in feet and includes the extreme points of the arcs described by both the main and tail rotors.

Fuselage Width (EX WFUSE). The maximum fuselage width of the aircraft measured in feet.

Widest Point Width (EX WIPT). The widest point of the aircraft in units of feet as determined by any fuselage structure which may include the horizontal stabilizer.

Landing Gear Type (EX GEPT). The type of landing gear (skid or wheel) and configuration if fitted with wheels (tri or quad with single (SF) or dual (DF) wheels in forward position and single wheels in aft position (SA)).

Landing Gear Width (EX WLGP). The width of the landing gear measured in feet.

Landing Gear Length (EX GELG). The length of the landing gear measured in feet.

Ground To Main Rotor Hub Height (EX HUBHT). The height measured in feet from the ground to the top of the main rotor hub of the aircraft.

Ground To Tail Rotor Arc Height (EX TARCHT). The height measured in feet from the ground to the top of the arc described by the tail rotor.

Ground Clearance (EX GFUSE). The height measured in feet from the ground to the lowest point on the aircraft.

Standard Seating (AC SEAT). The normal seating capacity of the aircraft in terms of number of persons.

High Density Seating (AC DENS). The absolute seating capacity of the aircraft in terms of the number of persons.

Maximum Gross Weight (WT GROSS). The maximum gross weight of the aircraft in pounds.

Empty Gross Weight (WT EMPTY). The empty gross weight of an aircraft in normal configuration with oil and undrainable fuel, in pounds.

Fuel Weight (WT FUEL). The weight of a standard tank of fuel, in pounds.

External Load Weight (WT LOAD). The maximum weight in pounds of any sling load or material that can be suspended from the helicopter's cargo hook.

Standard Fuel Tank Capacity (FUE TANK). The standard fuel capacity of the aircraft, in gallons.

Maximum Range (RAN MAX). The maximum distance in nautical miles that the aircraft can achieve at maximum gross weight with a full fuel load at sea level on a standard day.

Endurance (RAN ENDCR). The maximum time the helicopter can stay aloft at economy cruise speed in hours.

Service Ceiling (PER SC). The maximum operating altitude of the aircraft in feet at sea level and standard day temperature.

Single Engine Service Ceiling, Standard Day (PER SC1STD). The maximum operating altitude in feet of a twin engine aircraft with one engine inoperative at sea level on a standard day temperature.

Single Engine Service Ceiling, Hot Day (PER SC1HOT). The maximum operating altitude in feet of a twin engine aircraft with one engine inoperative at sea level and hot day temperature.

Hover Ceiling, In-Ground-Effect, Standard Day (PER HIGE). The maximum altitude in feet at which an aircraft can hover in-ground-effect on a standard day.

Hover Ceiling, In-Ground-Effect, Hot Day (PER HIGEHT). The maximum altitude in feet at which an aircraft can hover in-ground-effect on a hot day.

Hover Ceiling, Out-of-Ground-Effect, Standard Day (PER HOGE). The maximum altitude in feet at which an aircraft can hover out-of-ground effect on a standard day.

Hover Ceiling, Out-of-Ground-Effect, Hot Day (PER HOGEHT). The maximum altitude in feet at which an aircraft can hover out-of-ground effect on a hot day.

Oblique Rate of Climb (PER ROCOB). The maximum rate of climb in feet per minute of an aircraft with some forward airspeed.

Vertical Rate of Climb (PER ROCVE). The rate of climb in feet per minute of an aircraft with no forward airspeed.

Single Engine Rate of Climb (PER ROC1). The maximum rate of climb in feet per minute of a twin engine aircraft with one engine inoperative.

Never Exceed Speed (PER VNE). The maximum allowable speed of the aircraft measured in knots.

VFR Certification Date (CERT VFR). The date of FAA certification for visual flight.

IFR Certification Date (CERT IFR). The date of the FAA certification for instrument flight.

A number of data sources were used to generate the physical and performance data of this report. Helicopter flight manuals were obtained from helicopter manufacturers and in some cases, flight test results were consulted. The Helicopter Blue Book, published by Helicopter Financial Services Inc., was also referenced.

Helicopter flight manuals are the most reliable data source. Generally, a flight manual contains descriptions of the aircraft dimensions, physical characteristics, operating limitations, normal and

emergency procedures, performance data, weight and balance data, systems and servicing information, conversion charts and tables, optional equipment, and FAA approved supplements. However, not all flight manuals contain the same detail of description. Table 2 compares the information needed to generate the departure performance data contained in this report with its availability in each of the eight flight manuals and other data sources used for this study. An "F" marked in a column indicates that the data was available in the flight manual. Information needed that was not available in the flight manual was requested from the FAA coordinator at each manufacturer's facility. The information supplied by this resource is indicated by an "M". Subcontractor-generated data is represented by an "S". As a last resort, data was gathered from the Helicopter Blue Book and is indicated by a "B". The performance data obtained from the Blue Book was considered to be the least reliable in that the specific conditions stated at which the data were valid often were not in agreement with data contained in the flight manual for those same conditions.

Table 3 is a traceability matrix that directly relates the physical database file components to their source for each of the eight aircraft. The symbols used are the same as those in table 2 except for the addition of two new symbols; an "N" indicates the data type is not applicable to the specific aircraft, and a "-" shows that the data could not be obtained.

#### PERFORMANCE DATA GENERATION

This section elaborates on the intermediate steps taken to prepare for the generation of approach and departure profiles. After the data sources were collected, information to develop departure profiles for different combinations of gross weight, altitude and temperature were not readily available. To obtain this information SCT employed a sub-contractor which used the Helicopter Sizing and Performance Computer Program (HESCOMP) to generate rates of climb, accelerations, distances and times to accelerate and maximum climb angles as a function of forward airspeed for the desired combinations of gross weight, altitude and temperature for each aircraft. This computer model was originally developed by Boeing Vertol Company under contract to NASA and the U.S. Navy. HESCOMP is widely accepted by industry and used to define design requirements to meet specified mission requirements and to perform sensitivity studies involving both design and performance trade-offs.

The application of HESCOMP pertaining to this study was in the simulation of helicopter mission performance for which sizing details were known. HESCOMP was modified to include a more accurate representation of low speed power characteristics, more detailed weights algorithms, center of gravity locations, advanced rotor characteristics and maneuver analyses. When available, dimensional, propulsion, aerodynamics, weights, rotor limits, atmospheric, mission profile, rotor tip speed schedule and engine cycle information, and rotor and propulsion performance data were input into HESCOMP. A 10 percent data accuracy was achieved using the model. The aircraft data used in the HESCOMP calculations and the resultant performance data was then sent to aerodynamicists at each of the manufacturers. Upon review, three aircraft were cited as having flawed data; the S76A, the BV234 LR and the AS355F. The performances of these aircraft were then recomputed by a

**TABLE 2. PERFORMANCE DATA SOURCE TRACEABILITY MATRIX**

| HELICOPTER | GROSS WEIGHT | MAXIMUM POWER AVAILABLE | ENGINE TORQUE LIMIT | MINIMUM POWER REQUIRED | TRUE AIRSPEED AT MINIMUM POWER REQUIRED | POWER REQUIRED TO HOVER | FORWARD RATE OF CLIMB AT AN AIRSPEED | HORIZONTAL AIRSPEED CORRESPONDING TO FORWARD RATE OF CLIMB |
|------------|--------------|-------------------------|---------------------|------------------------|-----------------------------------------|-------------------------|--------------------------------------|------------------------------------------------------------|
| F 28F      | F            | F                       | F                   | M                      | M                                       | M                       | F                                    | F                                                          |
| MD 500E    | F            | F                       | F                   | M                      | M                                       | M                       | M                                    | M                                                          |
| B 206B III | F            | B                       | F                   | M                      | M                                       | M                       | F                                    | F                                                          |
| AS 355F    | F            | B                       | F                   | M                      | M                                       | M                       | F                                    | F                                                          |
| BO 105 CBS | F            | B                       | F                   | S                      | F                                       | S                       | F                                    | F                                                          |
| S 76A      | F            | F                       | F                   | M                      | M                                       | M                       | F                                    | F                                                          |
| AS 332C    | F            | F                       | F                   | M                      | M                                       | M                       | F                                    | F                                                          |
| BV 234 LR  | F            | M                       | F                   | M                      | M                                       | M                       | M                                    | M                                                          |

F - FLIGHT MANUAL      M - MANUFACTURER      B - BLUE BOOK      S - SUBCONTRACTOR DATA

TABLE 3. PHYSICAL DATA BASE TRACEABILITY MATRIX

| HELICOPTER | ENGINE MANUFACTURER | NO. OF ENGINES | ENGINE MODEL | TAKEOFF POWER | MAX. CONTINUOUS POWER | SINGLE ENGINE 30 MINUTE POWER | TAKEOFF TRANSMISSION POWER | MAXIMUM CONTINUOUS TRANSMISSION POWER | SINGLE ENGINE TRANSMISSION POWER | NO. OF MAIN ROTOR BLADES | NO. OF TAIL ROTOR BLADES | MAIN ROTOR RPM | TAIL ROTOR RPM | MAIN ROTOR DIAMETER | TAIL ROTOR DIAMETER | MAIN ROTOR CHORD | TAIL ROTOR CHORD | MAIN ROTOR DISC AREA | TAIL ROTOR DISC AREA | MAIN ROTOR DISC LOADING | MAIN ROTOR POWER LOADING | FUSELAGE LENGTH | FUSELAGE LENGTH WITH TAIL ROTOR TURNING | FUSELAGE LENGTH WITH BOTH ROTORS TURNING | FUSELAGE WIDTH | WIDEST POINT WIDTH | LANDING GEAR TYPE |
|------------|---------------------|----------------|--------------|---------------|-----------------------|-------------------------------|----------------------------|---------------------------------------|----------------------------------|--------------------------|--------------------------|----------------|----------------|---------------------|---------------------|------------------|------------------|----------------------|----------------------|-------------------------|--------------------------|-----------------|-----------------------------------------|------------------------------------------|----------------|--------------------|-------------------|
| F 28F      | F                   | F              | F            | F             | F                     | N                             | M                          | M                                     | N                                | F                        | F                        | F              | M              | F                   | F                   | F                | F                | F                    | F                    | B                       | B                        | B               | F                                       | B                                        | M              | F                  | F                 |
| MD 500E    | F                   | F              | F            | F             | M                     | N                             | M                          | M                                     | N                                | F                        | M                        | F              | M              | F                   | M                   | F                | F                | M                    | M                    | M                       | M                        | M               | M                                       | F                                        | F              | F                  | F                 |
| B 206B III | F                   | F              | F            | B             | B                     | N                             | B                          | B                                     | N                                | B                        | B                        | B              | B              | B                   | B                   | B                | B                | B                    | B                    | B                       | B                        | B               | B                                       | B                                        | B              | B                  | B                 |
| AS 355F    | F                   | F              | F            | B             | B                     | ..                            | B                          | ..                                    | ..                               | F                        | F                        | F              | B              | F                   | F                   | B                | B                | B                    | B                    | B                       | B                        | B               | F                                       | F                                        | F              | F                  | F                 |
| BO 105 CBS | F                   | F              | F            | B             | B                     | ..                            | B                          | B                                     | B                                | B                        | B                        | B              | B              | B                   | B                   | B                | B                | B                    | B                    | B                       | B                        | B               | B                                       | B                                        | B              | B                  | B                 |
| S 76A      | F                   | F              | F            | F             | M                     | M                             | B                          | B                                     | B                                | F                        | F                        | M              | M              | F                   | F                   | B                | B                | B                    | B                    | B                       | B                        | B               | F                                       | F                                        | F              | F                  | F                 |
| AS 332C    | F                   | F              | F            | F             | F                     | F                             | F                          | ..                                    | F                                | F                        | F                        | F              | F              | F                   | F                   | B                | B                | B                    | B                    | B                       | B                        | B               | F                                       | F                                        | F              | F                  | F                 |
| BV 234 LR  | F                   | F              | F            | B             | F                     | F                             | B                          | B                                     | B                                | F                        | F                        | M              | M              | M                   | M                   | M                | M                | M                    | M                    | M                       | M                        | M               | F                                       | F                                        | F              | F                  | F                 |

F = FLIGHT MANUAL      M = MANUFACTURER      B = BLUE BOOK      .. = NOT AVAILABLE      N = NOT APPLICABLE      S = SUBCONTRACTOR DATA

TABLE 3. PHYSICAL DATA BASE TRACEABILITY MATRIX (continued)

| HELICOPTER | LANDING GEAR WIDTH | LANDING GEAR LENGTH | GROUND TO MAIN ROTOR HUB HEIGHT | GROUND TO TAIL ROTOR ARC HEIGHT | GROUND CLEARANCE | STANDARD SEATING | HIGH DENSITY SEATING | MAXIMUM GROSS WEIGHT | EMPTY GROSS WEIGHT | FUEL WEIGHT | EXTERNAL LOAD WEIGHT | STANDARD FUEL TANK CAPACITY | MAXIMUM RANGE | ENDURANCE | SERVICE CEILING | SINGLE ENGINE SERVICE CEILING, STANDARD DAY | SINGLE ENGINE SERVICE CEILING, HOT DAY | HOVER CEILING, KGE, STANDARD DAY | HOVER CEILING, KGE, HOT DAY | HOVER CEILING, OGE, STANDARD DAY | HOVER CEILING, OGE, HOT DAY | OBLIQUE RATE OF CLIMB | VERTICAL RATE OF CLIMB | SINGLE ENGINE RATE OF CLIMB | NEVER EXCEED SPEED | VFR CERTIFICATION DATE | IFR CERTIFICATION DATE |
|------------|--------------------|---------------------|---------------------------------|---------------------------------|------------------|------------------|----------------------|----------------------|--------------------|-------------|----------------------|-----------------------------|---------------|-----------|-----------------|---------------------------------------------|----------------------------------------|----------------------------------|-----------------------------|----------------------------------|-----------------------------|-----------------------|------------------------|-----------------------------|--------------------|------------------------|------------------------|
| F 28F      | F                  | F                   | F                               | F                               | M                | B                | B                    | F                    | F                  | B           | B                    | F                           | B             | F         | F               | N                                           | N                                      | F                                | F                           | F                                | M                           | S                     | N                      | F                           | F                  | F                      | N                      |
| MD 500E    | F                  | M                   | F                               | M                               | F                | M                | M                    | F                    | M                  | M           | B                    | M                           | M             | M         | B               | N                                           | N                                      | F                                | F                           | F                                | F                           | M                     | N                      | F                           | F                  | F                      | N                      |
| B 206B III | B                  | M                   | B                               | M                               | B                | B                | B                    | F                    | B                  | B           | B                    | B                           | B             | B         | B               | N                                           | N                                      | F                                | F                           | F                                | F                           | M                     | N                      | F                           | F                  | F                      | N                      |
| AS 355F    | F                  | ..                  | F                               | B                               | F                | B                | B                    | F                    | B                  | B           | B                    | F                           | B             | B         | B               | B                                           | ..                                     | F                                | F                           | F                                | F                           | S                     | F                      | F                           | F                  | B                      | B                      |
| BO 105 CBS | B                  | ..                  | B                               | B                               | B                | B                | B                    | F                    | B                  | B           | B                    | B                           | F             | F         | B               | F                                           | F                                      | F                                | F                           | F                                | F                           | F                     | F                      | B                           | B                  | B                      | B                      |
| S 76A      | F                  | F                   | M                               | F                               | B                | M                | M                    | F                    | M                  | M           | B                    | M                           | M             | B         | M               | M                                           | M                                      | F                                | F                           | F                                | F                           | S                     | F                      | M                           | F                  | F                      | F                      |
| AS 332C    | F                  | F                   | F                               | F                               | B                | F                | B                    | F                    | B                  | B           | B                    | F                           | B             | F         | F               | F                                           | F                                      | F                                | F                           | F                                | S                           | S                     | F                      | F                           | F                  | F                      | F                      |
| BV 234 LR  | B                  | F                   | F                               | N                               | ..               | M                | M                    | F                    | B                  | B           | B                    | F                           | M             | M         | M               | F                                           | F                                      | F                                | F                           | F                                | M                           | M                     | F                      | F                           | F                  | F                      | F                      |

F = FLIGHT MANUAL      M = MANUFACTURER      B = BLUE BOOK      .. = NOT AVAILABLE      N = NOT APPLICABLE      S = SUBCONTRACTOR DATA

second subcontractor. Summary reports of the analysis completed by each of the subcontractors are contained in this report as appendix A. Assumptions, data traceability and a discussion of data accuracy are covered.

The preparations made for the generation of approach profiles included the analysis of previously published approach test data. A NASA study (NASA-TN-D-8275) presented the variation in approach profile shape as a function of approach speed determined from a total of 236 visual approaches flown by 4 helicopters (table 4). The results of the study showed approach profile shape to be independent of helicopter gross weight. Average altitude profiles from initial conditions of 500 feet at 50, 80 and 100 knots are shown in figure 2. The altitude standard deviations are not significantly affected by variations in initial airspeed.

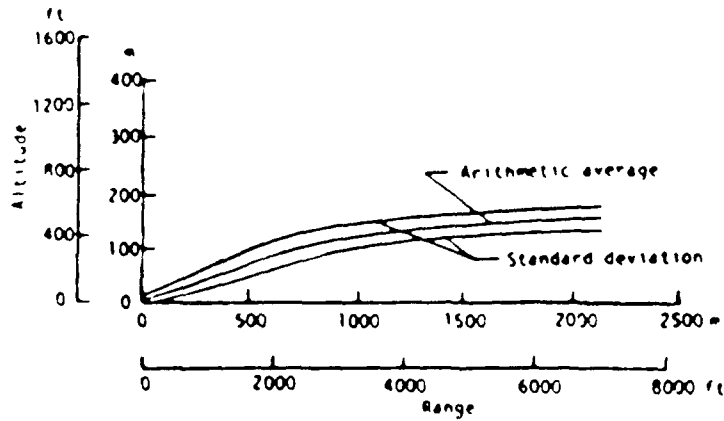
An example of the characteristic approach profile shape is shown in figure 3. This shape is representative of all data from the NASA study, but is graphed from specific data generated by one pilot performing two approaches at each airspeed. This characteristic shape results from pilots flying approaches they perceive as natural from a pilot's perspective and comfortable to commercial passengers. As the initial airspeed decreases the concave down portion of the approach is accentuated and the interception of the desired slope is delayed. Slope lines of 8:1, 7:1, 6:1 and 5:1 have been sketched into the figure and show that the characteristic approaches (except for a segment between 500 and 2500 feet from the helipad of the 100 knot approach) do not break the current 8:1 approach surface.

Test data from FAA Technical Center VMC approach testing were also analyzed. The tests were performed to validate current FAA heliport design approach surfaces criteria and to recommend modifications to the surfaces, if appropriate. Heliport visual approach test data are presented in DOT/FAA/CT-TN87/40. A total of 270 straight-in approaches were performed, 108 for which no specific approach angles were required to be flown by the pilot. The remaining 162 approaches were comprised of 54 approaches flown per required approach angle (7, 8 and 10 degrees). Ninety approaches were performed using a Sikorsky S-76, 130 using a Bell UH-1H and 50 using a Hughes OH-6. Initial approach conditions consisted of a 70 knot entrance into the approach from an altitude of 500 feet.

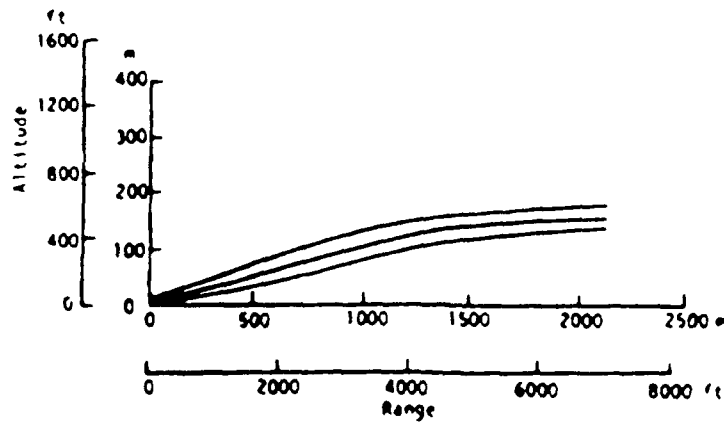
Initially the approach test data were assumed to be characterized by a Gaussian (Normal) distribution. Questions arose during the data analysis regarding the validity of this assumption. A follow-up project was established to study the characteristics of the underlying distributions of the approach test data. The results of this effort are reported in "Analysis of Distributions of Visual Meteorological Conditions (VMC) Heliport Data," DOT/FAA/CT-TN89/67. The report is written in two volumes. Volume 1 is a summary report and volume 2 contains 1,054 pages including graphs depicting the results of the graphical method used to determine the approach data distribution. The results of the effort showed that the assumption of a Normal distribution was not valid. The majority of the data seemed to exhibit characteristics of some form of the Beta distribution. Airspace

**TABLE 4. NASA APPROACH TEST HELICOPTER CHARACTERISTICS**

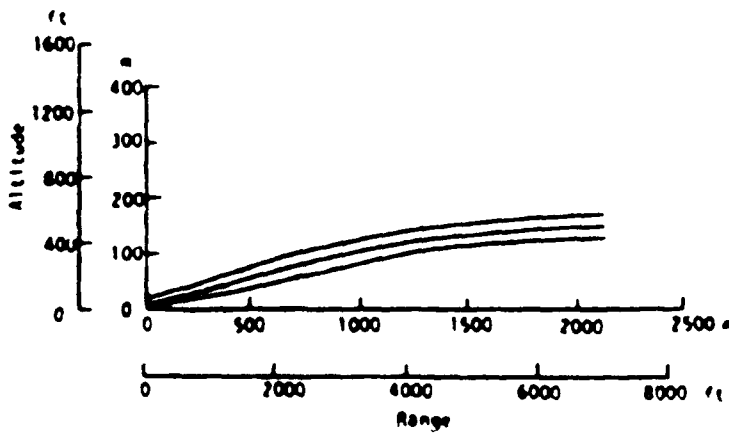
| Characteristic        | Helicopter 1                          | Helicopter 2                          | Helicopter 3                          | Helicopter 4                          |
|-----------------------|---------------------------------------|---------------------------------------|---------------------------------------|---------------------------------------|
| Type                  | Light observation                     | Light utility                         | Medium transport                      | Medium transport                      |
| Maximum gross weight  | 12 233 N<br>(2750 lb)                 | 37 810 N<br>(8500 lb)                 | 68 947 N<br>(15 500 lb)               | 84 961 N<br>(19 100 lb)               |
| Maximum airspeed      | 115 knots                             | 120 knots                             | 120 knots                             | 142 knots                             |
| Configuration         | Single rotor                          | Single rotor                          | Tandem rotor                          | Single rotor                          |
| Disk loading          | 148.4 Pa<br>(3.1 lb/ft <sup>2</sup> ) | 225.0 Pa<br>(4.7 lb/ft <sup>2</sup> ) | 201.1 Pa<br>(4.2 lb/ft <sup>2</sup> ) | 301.6 Pa<br>(6.3 lb/ft <sup>2</sup> ) |
| Power plant           | Single turbine                        | Single turbine                        | Twin turbine                          | Twin turbine                          |
| Total power           | 410 kW<br>(550 hp)                    | 820 kW<br>(1100 hp)                   | 1565 kW<br>(2100 hp)                  | 1565 kW<br>(2100 hp)                  |
| Control stabilization | None                                  | Augmented rate<br>(gyro bar)          | Rate                                  | Attitude                              |



50 knots, 150 m (500 ft).



80 knots, 150 m (500 ft).



100 knots, 150 m (500 ft).

FIGURE 2. NASA VFR ALTITUDE PROFILES

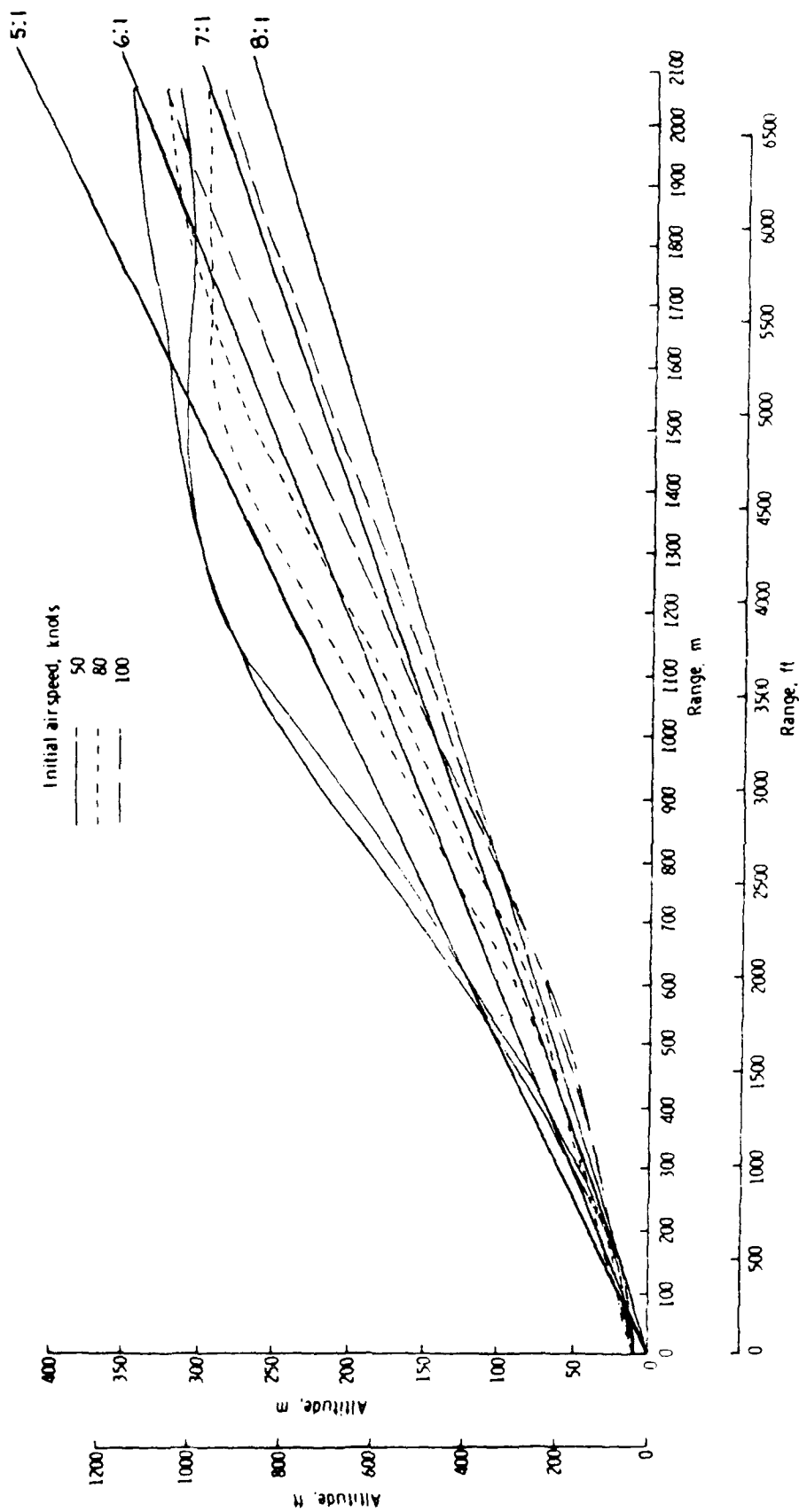


FIGURE 3. NASA CHARACTERISTIC APPROACH PROFILES

envelopes depicting  $10^{-7}$  target levels of safety (6 sigma) were computed for the Normal, Beta, and Gamma distributions and plotted on graphs along with the mean approach data.

Figures 4 through 6 are graphs depicting FAATC S-76 approach test data excerpted from volume 2 of "Analysis of Distributions of Visual Meteorological Conditions (VMC) Heliport Data." These figures show the mean approach profiles and the  $10^{-7}$  target level of safety envelopes for each of these approach angles flown (7, 8, and 10 degrees). It is apparent that the relative deviation increases as the approach angle increases. These figures also show that the  $10^{-7}$  envelope of the Beta distribution usually falls well inside the envelope of the Normal distribution. This shows the overly conservative nature of the Normal distribution when applied to the VFR approach data. At all three angles the mean profiles show the characteristic flight path to be on or above the required slope within 2000 feet of the helipad. A composite approach profile plot for the three angles flown is shown as figure 7. This figure was taken from volume 2 of "Heliport Visual Approach and Departure Airspace Tests." Test pilots rated all three angles as adequate with respect to safety, but considered both pilot visibility and passenger comfort as issues for the 10 degree approach.

Table 5 illustrates the approach rates of descent that must be maintained to descend along a specified slope at a constant airspeed. Minimum autorotation rates of descent for each helicopter in this study were determined for each combination of gross weight, altitude and temperature. The smallest of these values per helicopter was chosen to be the minimum autorotation rate of descent for all conditions. Four hundred feet per minute was subtracted from each value to yield a value for the maximum assumed approach rate of descent attainable without entering into autorotation. These are shown in table 6 and corresponds to minimum power required airspeeds. Four hundred feet per minute was used to provide an acceptable margin between the autorotation and approach rates of descent to provide a control margin which allows for 1) variations in specific helicopter performance, 2) light tailwind, and 3) airspeed variations.

A comparison of tables 5 and 6 determine the combinations of approach slopes and speeds each helicopter can safely achieve with respect to the assumptions previously made, without entering into autorotation. When the approach rate of descent is greater than the helicopter's maximum assumed rate of descent, the approach is undesirable. The achievable approach slopes resulting from these comparisons are shown in table 7. The shaded blocks of the table indicate the approach speeds at their corresponding slopes are undesirable. Based on the assumptions made, none of the aircraft listed can effect a 90 knot approach at the 5:1 slope, while half cannot effect the 70 knot approach at the same slope.

#### APPROACH PROFILES

Approach profiles were developed by considering the characteristic shape (figure 3) and its variations with initial approach speeds as determined by NASA (reference 16). FAATC test data from references 22 and 23 (figures 4 through 7) indicate that pilots can fly on or above slope approaches (7, 8, 10 degrees) though pilot workload tends to

VMC DISTRIBUTION ANALYSIS S76 DATA ONLY  
 7 DEGREE STRAIGHT IN APPROACHES  
 ALTITUDE (FT) VS. BIN RANGE (FT)  
 ○ INDICATES BETA DISTRIBUTION RANGE LIMIT  
 ... INDICATES NORMAL DISTRIBUTION ENVELOPE

DATA TRANSMITTED BY PAW TECHNICAL CENTER  
 ATLANTIC CITY AIRPORT, NJ 08403

\* INDICATES GAMMA DISTRIBUTION RANGE LIMIT  
 ALL ENVELOPES ARE FOR 99.99999 % PROBABILITY

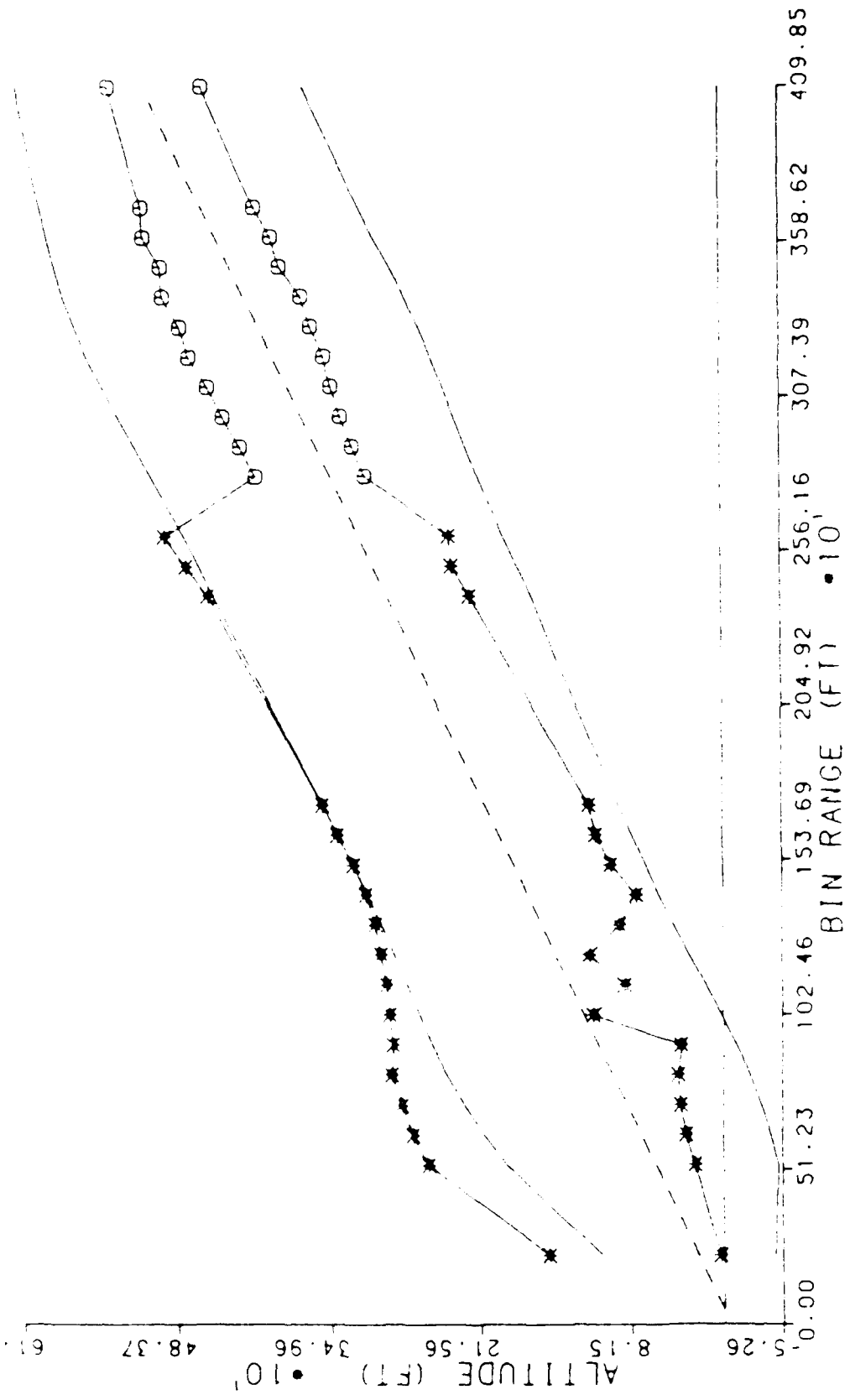


FIGURE 4. FAATCS 76 7.125 DEGREE APPROACH PROFILE

VMC DISTRIBUTION ANALYSIS-- S76 DATA ONLY

8 DEGREE STRAIGHT IN APPROACHES

ALTITUDE (FT) VS. BIN RANGE (FT)

○ INDICATES BETA DISTRIBUTION RANGE LIMIT

— INDICATES NORMAL DISTRIBUTION ENVELOPE

\* INDICATES GAMMA DISTRIBUTION RANGE LIMIT  
ALL ENVELOPES ARE FOR 99.99999 % PROBABILITY

DATA PROCESSED BY FAA TECHNICAL CENTER  
ATLANTIC CITY AIRPORT, NJ 08405

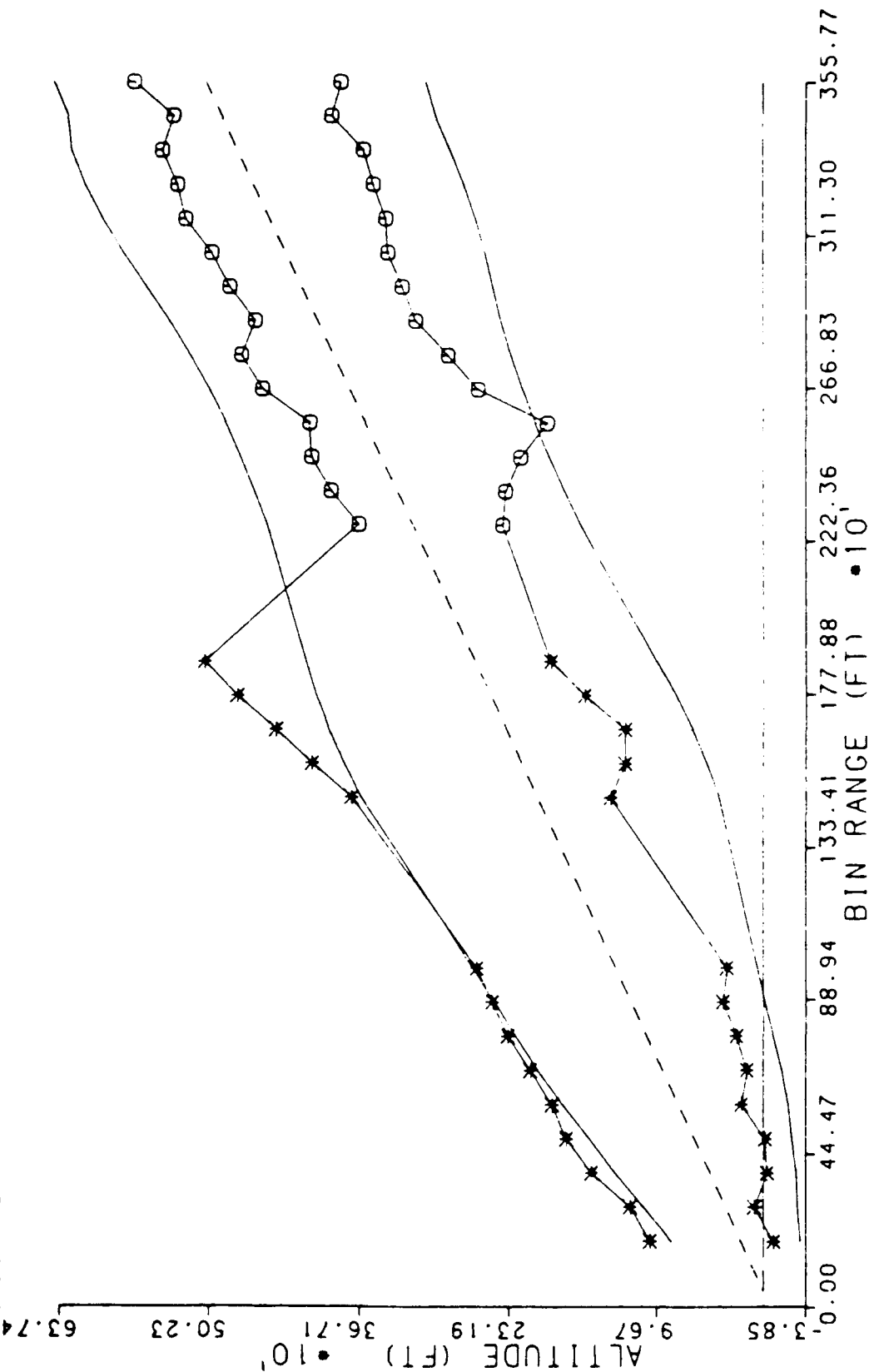


FIGURE 5. FAATCS 76 8.0 DEGREE APPROACH PROFILE

VMC DISTRIBUTION ANALYSIS-- S76 DATA ONLY  
 10 DEGREE STRAIGHT IN APPROACHES  
 ALTITUDE (FT) VS. BIN RANGE (FT)  
 O INDICATES BETA DISTRIBUTION RANGE LIMIT  
 --- INDICATES NORMAL DISTRIBUTION ENVELOPE

DATA PROCESSED BY FAA TECHNICAL CENTER  
 ATLANTIC CITY AIRPORT, NJ 08403

\* INDICATES GAMMA DISTRIBUTION RANGE LIMIT  
 ALL ENVELOPES ARE FOR 99.99999 % PROBABILITY

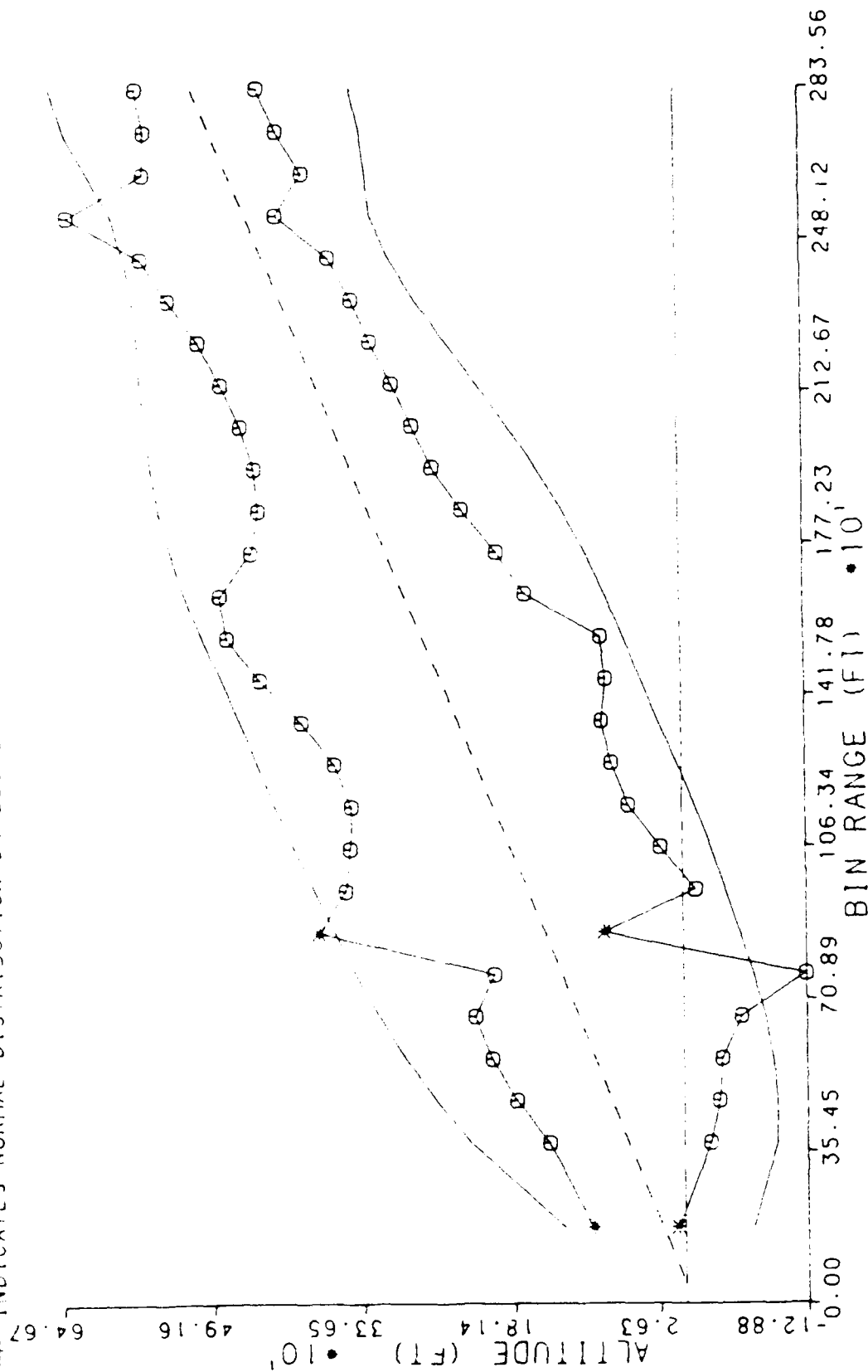


FIGURE 6. FAATCS 76 10.0 DEGREE APPROACH PROFILE

DATA PROCESSED BY  
F.A.A. TECHNICAL CENTER  
ATLANTIC CITY AIRPORT  
ATLANTIC CITY NJ. 08405

VISUAL METEOROLOGICAL CONDITIONS PROJECT USING THE S76  
COMPOSITE STATISTICS PLOTS -- MEAN ALTITUDE V. BIN RANGE  
ALL ANGLES STRAIGHT IN APPROACHES

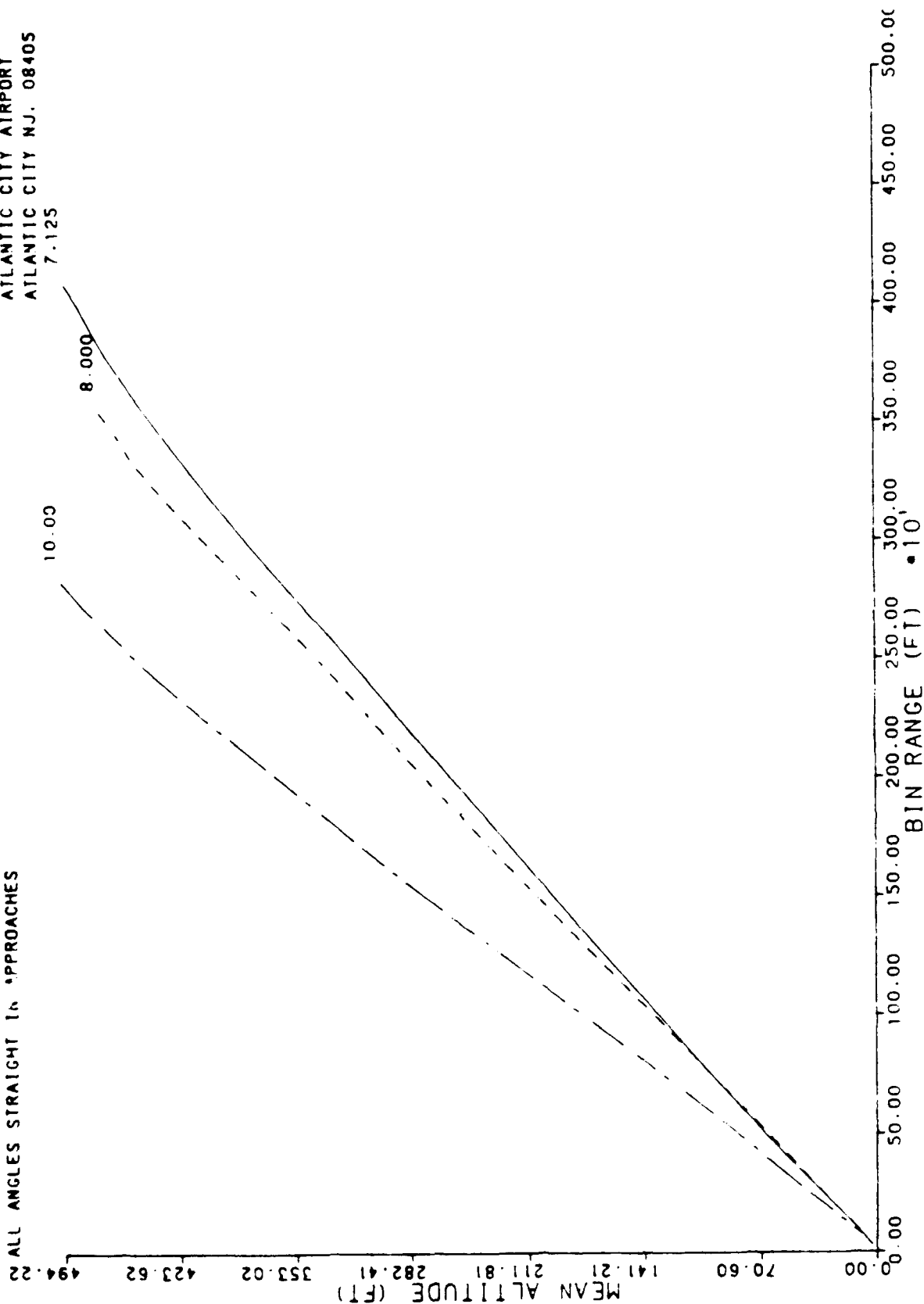


FIGURE 7. FAATC S 76 COMPOSITE APPROACH PROFILES

**TABLE 5. APPROACH RATE OF DESCENT LIMITS**

| APPROACH<br>SLOPE | APPROACH RATE OF DESCENT LIMITS (FT/MIN) |      |      |     |
|-------------------|------------------------------------------|------|------|-----|
|                   | APPROACH SPEED (KNOTS)                   |      |      |     |
|                   | 90                                       | 70   | 50   | 40  |
| 8 : 1             | 1131                                     | 879  | 628  | 502 |
| 7 : 1             | 1285                                     | 999  | 714  | 571 |
| 6 : 1             | 1504                                     | 1170 | 836  | 668 |
| 5 : 1             | 1823                                     | 1418 | 1013 | 810 |

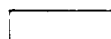
**TABLE 6. MAXIMUM RATES OF DESCENT**

| HELICOPTER<br>MODEL | MAXIMUM RATE OF DESCENT (FT/MIN) |
|---------------------|----------------------------------|
| F 28F               | 890                              |
| MD 500E             | 1400                             |
| B 206B III          | 1110                             |
| AS 355F             | 1540                             |
| BO 105 CBS          | 1510                             |
| S 76A               | 1250                             |
| AS 332C             | 1670                             |
| BV 234 LR           | 1540                             |

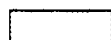
**TABLE 7. ACHIEVABLE APPROACH SLOPES**

| HELICOPTER<br>MODEL | ACHIEVABLE APPROACH SLOPES |    |       |    |       |    |       |    |
|---------------------|----------------------------|----|-------|----|-------|----|-------|----|
|                     | APPROACH SPEED (KNOTS)     |    |       |    |       |    |       |    |
|                     | 8 : 1                      |    | 7 : 1 |    | 6 : 1 |    | 5 : 1 |    |
| F 28F               | N/A                        | 70 | N/A   | 70 | N/A   | 70 | N/A   | 70 |
|                     | 50                         | 40 | 50    | 40 | 50    | 40 | 50    | 40 |
| MD 500E             | 90                         | 70 | 90    | 70 | 90    | 70 | 90    | 70 |
|                     | 50                         | 40 | 50    | 40 | 50    | 40 | 50    | 40 |
| B 206B III          | 90                         | 70 | 90    | 70 | 90    | 70 | 90    | 70 |
|                     | 50                         | 40 | 50    | 40 | 50    | 40 | 50    | 40 |
| AS 355F             | 90                         | 70 | 90    | 70 | 90    | 70 | 90    | 70 |
|                     | 50                         | 40 | 50    | 40 | 50    | 40 | 50    | 40 |
| BO 105 CBS          | 90                         | 70 | 90    | 70 | 90    | 70 | 90    | 70 |
|                     | 50                         | 40 | 50    | 40 | 50    | 40 | 50    | 40 |
| S 76A               | 90                         | 70 | 90    | 70 | 90    | 70 | 90    | 70 |
|                     | 50                         | 40 | 50    | 40 | 50    | 40 | 50    | 40 |
| AS 332C             | 90                         | 70 | 90    | 70 | 90    | 70 | 90    | 70 |
|                     | 50                         | 40 | 50    | 40 | 50    | 40 | 50    | 40 |
| BV 234 LR           | 90                         | 70 | 90    | 70 | 90    | 70 | 90    | 70 |
|                     | 50                         | 40 | 50    | 40 | 50    | 40 | 50    | 40 |

**LEGEND**



**Operationally Desirable Approach Speeds/Slopes**



**Operationally Undesirable Approach Speeds/Slopes**

**N/A**

**Not Applicable (90 kt Speed Exceeds Aircraft  $V_{ne}$ )**

increase and comfort levels tend to decrease. Figures 8 through 11 show characteristic approaches made at initial speeds of 40, 50, 70 and 90 knots for various slopes. As the initial speed increases, the slope is intercepted sooner. The approaches are flown to a 10 foot hover over a 100 foot diameter pad.

Manufacturers' recommended flight manual approach procedures for each helicopter used in this study are shown in table 8. Table 7 coupled with these procedures (when they provide adequate information) can be used to determine desirable approach profiles for each aircraft. For example, the F 28F flight manual approach procedure recommends an approach speed of 52 knots at 8 to 10 degrees. Table 7 indicates that the F 28F, based on the assumptions made, cannot fly 70 knot approaches at 8, 9.5 or 11.3 degrees and 50 knot approaches at 11.3 degrees. Additionally, 90 knot approaches for all slopes shown are unusable as the approach speed exceeds the designated  $V_{ne}$  for the aircraft at gross weights greater than 2,350 lbs. Therefore, the 70 knot 8:1 approach, the 50 knot 8:1, 7:1 and 6:1 approaches' and 90 knot approaches of figure 9 are desirable approaches for the F 28F. Coupled with the approach procedure in table 8, realistic approaches for the F 28F are the 50 knot 7:1 and 6:1 approaches.

#### DEPARTURE PROFILES

Departure profiles were generated by integrating the subcontractor-provided data with departure procedures listed in flight manuals. A computer model was developed for each helicopter takeoff procedure and tailored to the individual helicopter's characteristics. Gross weight limits, hover performance and temperature, height-velocity and altitude limitations were incorporated in the models. The takeoff procedures recommended in each flight manual are listed in table 9.

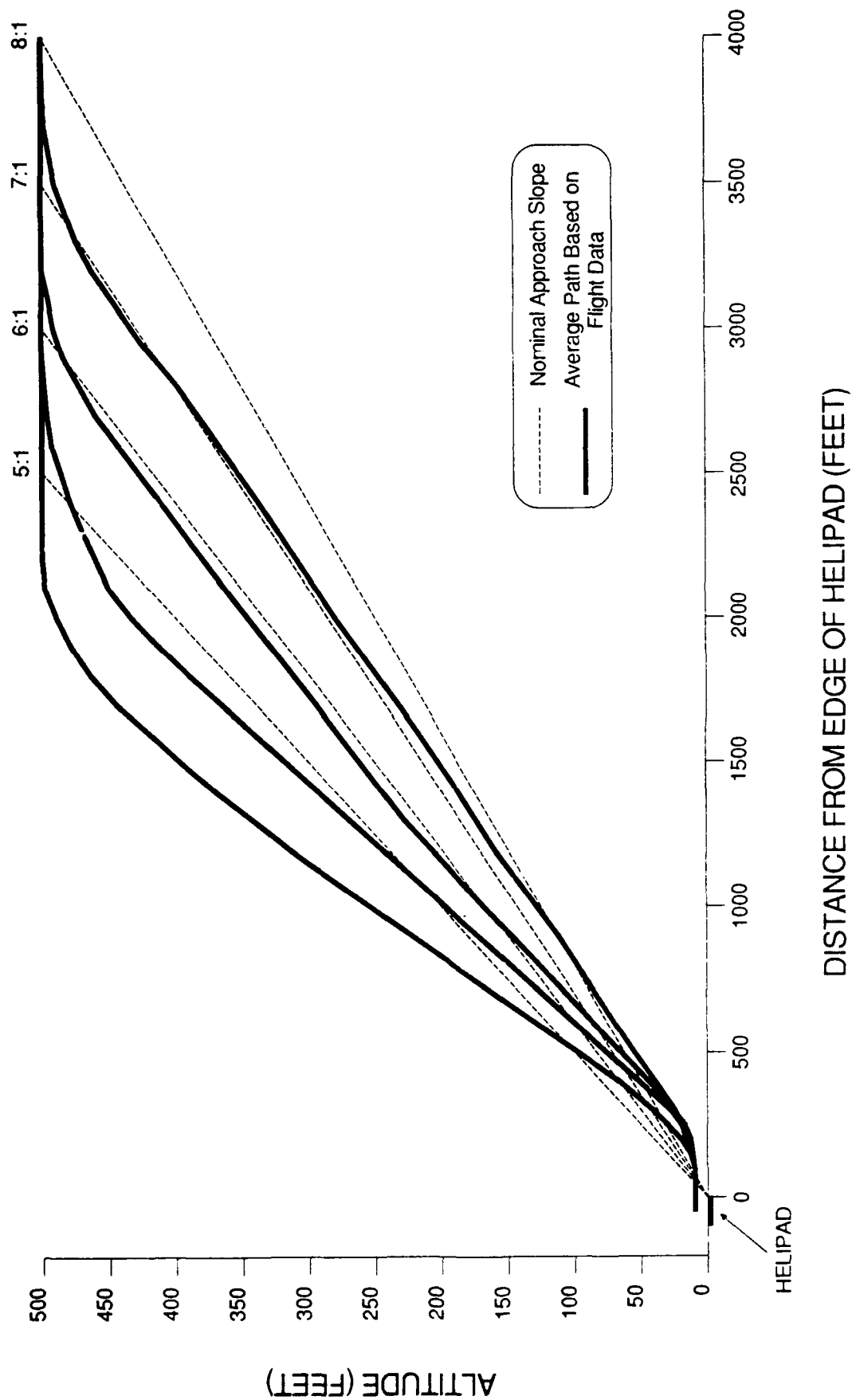
In developing each departure profile the horizontal distances required to intercept 8:1, 7:1, 6:1 and 5:1 slopes during departure were calculated. In addition to using the takeoff procedures stated in the flight manuals, "optimum" departure procedures were derived. These departure procedures were based on obeying the limits of the H-V diagram by flying a five knot parallel path to the diagram. An example of this is shown in figure 12 and is labeled "H-V+5 KTS". When the flight manual departure procedure was not defined well enough, one was developed to consist of a level acceleration, slight rotation and climb out at the best rate of climb speed.

Category A departures were provided for three aircraft. For the BV 234LR, only one departure procedure was recommended. This departure procedure was modified to create an additional procedure by climbing out at VToss instead of best rate of climb speed.

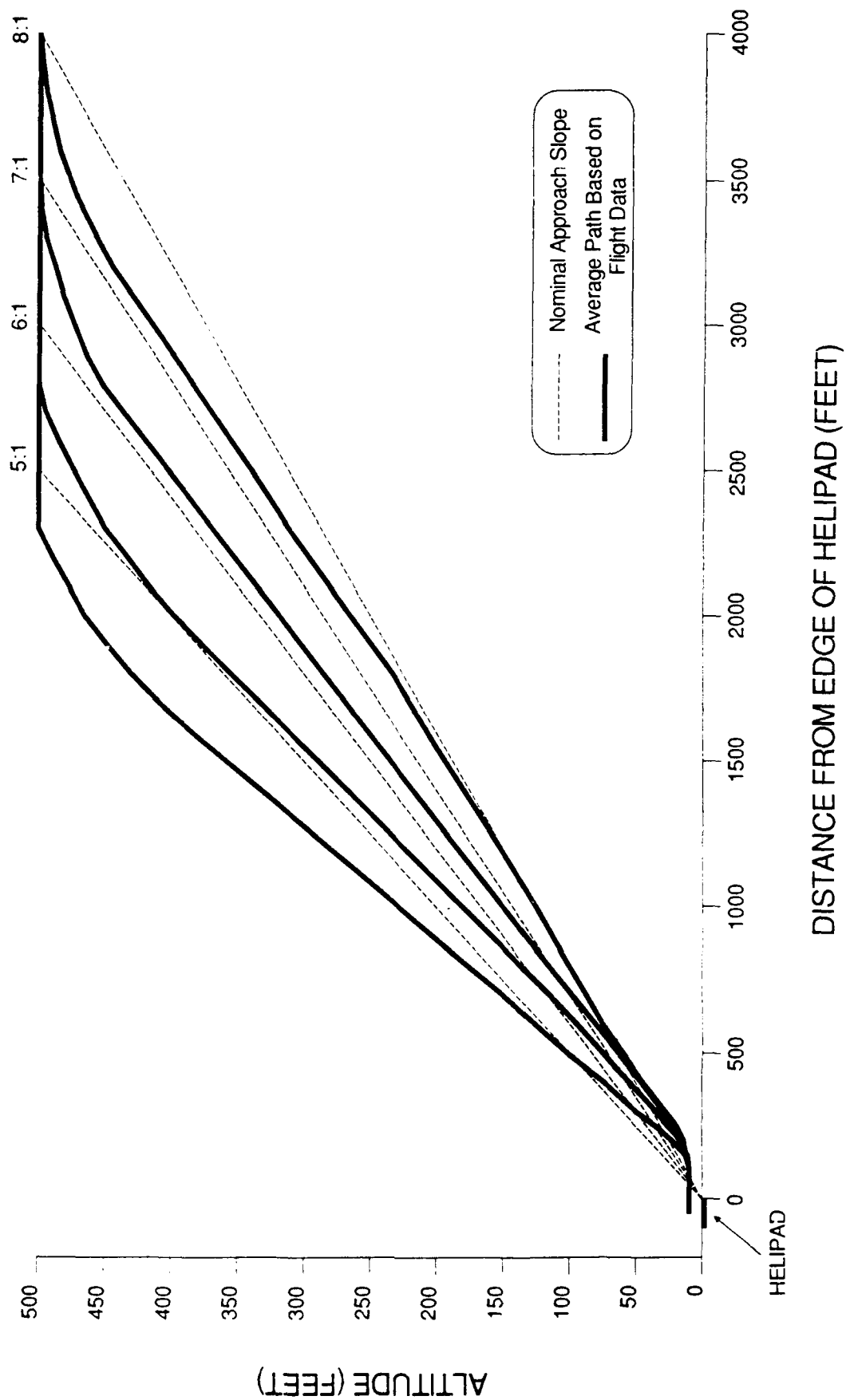
The departure profiles are contained in appendix B of this report.

#### DISCUSSION

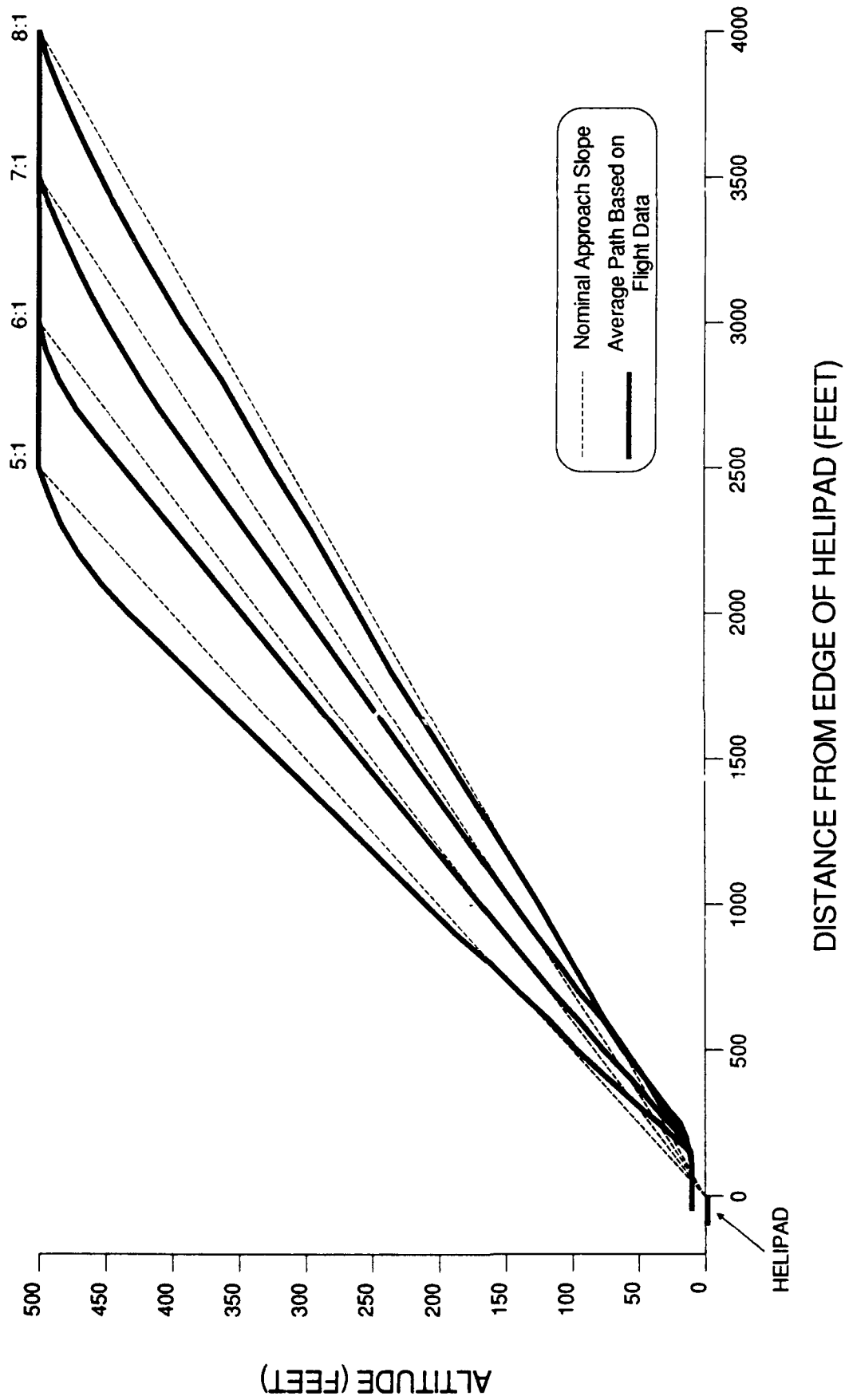
The FAATC test data has shown that the airspace required for approaches is more a function of approach slope and pilot skill than aircraft performance. As figures 8 through 11 indicate, a pilot can fly an approach above or on the desired slope, if required. At greater



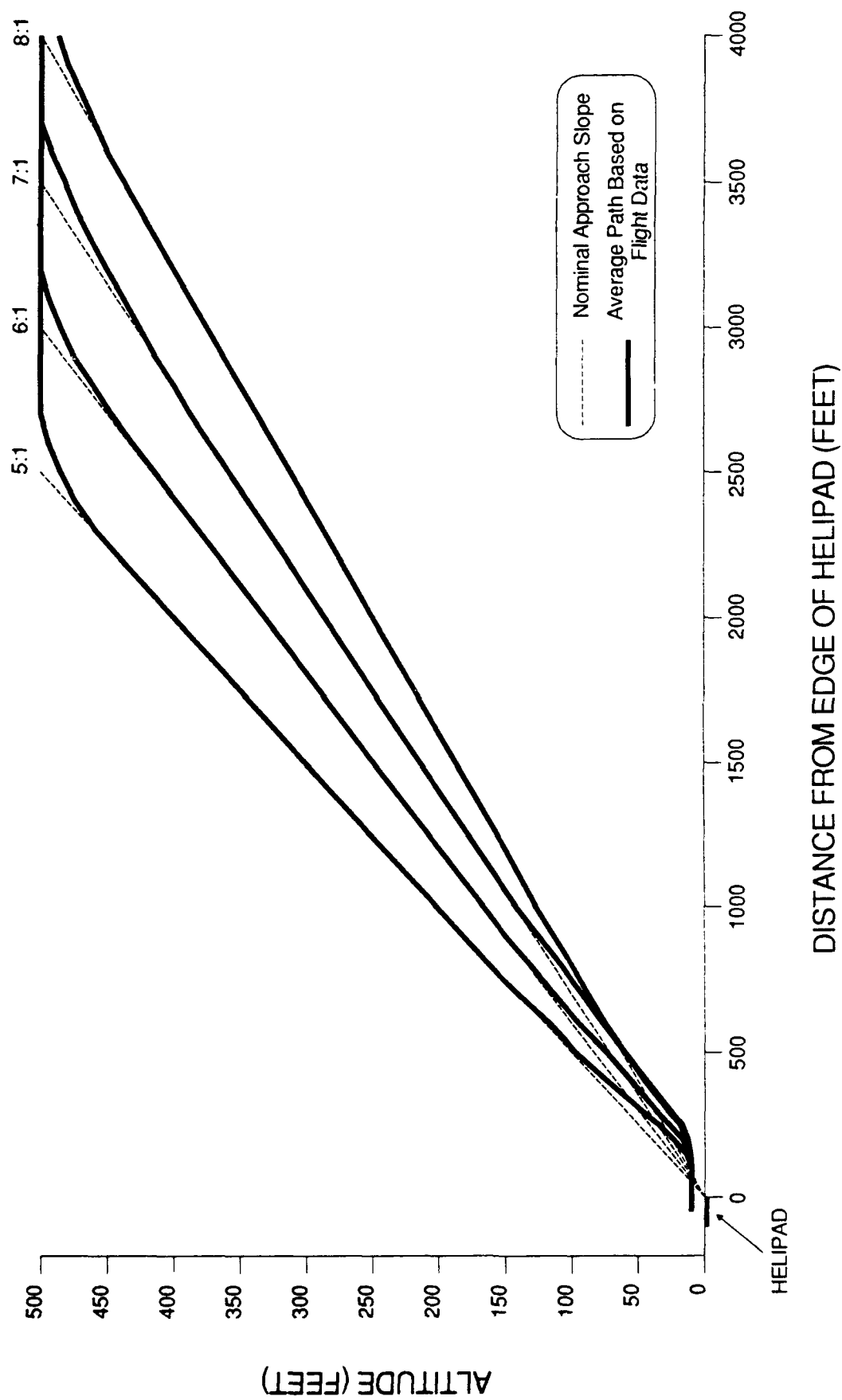
**FIGURE 8. 40 KNOTS APPROACH PROFILES**



**FIGURE 9. 50 KNOTS APPROACH PROFILES**



**FIGURE 10. 70 KNOTS APPROACH PROFILES**



**FIGURE 11. 90 KNOTS APPROACH PROFILES**

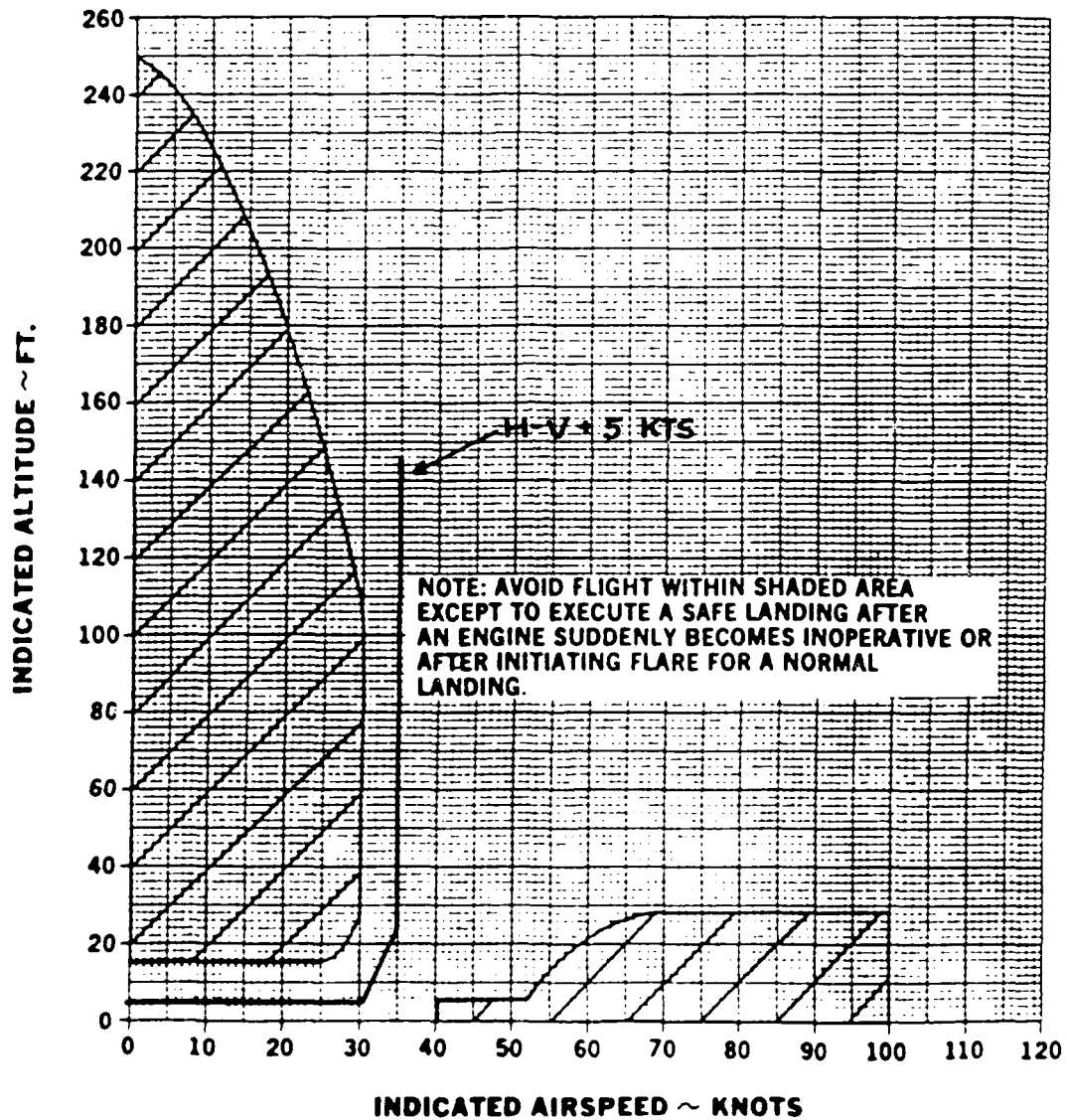
TABLE 8. APPROACH PROCEDURES

| HELICOPTER     | FLIGHT MANUAL PROCEDURE                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
|----------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| F 28F          | Establish 8-10 degree approach angle and adjust airspeed to 52 knots. As landing area is approached, reduce airspeed and rate of descent until a zero ground speed hovering altitude of 2-5 feet is attained.                                                                                                                                                                                                                                                                                                                                                                                                                      |
| MD 500E        | None.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| B 206B III     | Establish flight path as required for type of approach being made.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| AS 355F        | On final approach fly at about 45 knots. From hover, reduce pitch slowly and control landing until touchdown.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| MBB BO 105 CBS | After entering approach pattern, reduce airspeed to 100-110 knots. Start final descent as directed and maintain airspeed to visual contact at decision height. Reduce airspeed and initiate a smooth flare.                                                                                                                                                                                                                                                                                                                                                                                                                        |
| S 76A          | <p>Cat A: Establish approach to arrive at landing decision point (100 ft above touchdown elevation at 50 knots and not more than 750 fpm rate of descent). Continue descent to about 50 feet above touchdown, then reduce the rate of descent with a cyclic flare to about 20 degrees nose up. Level the nose to 5-10 degrees at about 30 feet above touchdown. Establish hover.</p> <p>Cat B: Establish approach to arrive at a point 100 ft above the touchdown elevation at 50 knots at a rate of descent of no more than 500 fpm. Decelerate to pass 50 feet and 40 knots and continue approach and deceleration to hover.</p> |
| AS 332C        | <p>Cat A: Proceed with final approach to reach landing decision point (100 ft at 40 knots with a rate of descent between 300-500 fpm). At the critical decision point slowly decrease speed to 30 knots and continue descent to height of 15 feet.</p> <p>Cat B: Gradually reduce speed to descend to 80 feet over the landing area at 40 knots. Recommended rate of descent is 300 fpm. From 15 ft gradually increase collective pitch to obtain final reduction in speed and to cancel rate of descent. Land.</p>                                                                                                                |
| BV 234 LR      | Cat A: Stabilized descent at 400 fpm at 60 knots through landing decision point at 150 ft. Rotate helicopter nose up as required to arrive at the desired touchdown point.                                                                                                                                                                                                                                                                                                                                                                                                                                                         |

TABLE 9. TAKEOFF PROCEDURES

| <u>HELICOPTER</u> | <u>FLIGHT MANUAL PROCEDURE</u>                                                                                                                                                                                                                                                                                                                                                     |
|-------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| F 28F             | Establish 2 ft HIGE, accelerate into effective translational lift, establish rate of climb and follow flight profile given in H-V diagram.                                                                                                                                                                                                                                         |
| MD 500E           | Follow recommended takeoff profile shown on H-V diagram.                                                                                                                                                                                                                                                                                                                           |
| B 206B III        | Establish HIGE, accelerate to obtain desired rate of climb and airspeed.                                                                                                                                                                                                                                                                                                           |
| AS 355F           | Establish HIGE, initiate forward flight in a slight climb to 55 kt (optimum climb speed).                                                                                                                                                                                                                                                                                          |
| MBB BO 105 CBS    | Establish 6 ft HIGE, level acceleration to 40 kt, climbing acceleration to CDP of 45 kt and 30 ft, climb out at best rate of climb.                                                                                                                                                                                                                                                |
| S 76A             | <p>Cat A: Establish 5 ft HIGE, accelerate forward and maintain a 5-10 ft wheel height, at 35 kt rotate nose up and maintain 35 kt, at CDP of 40 ft accelerate to best rate of climb speed.</p> <p>Cat B: Establish 5 ft HIGE, accelerate forward and maintain a 5-10 ft wheel height, achieve 45-50 kt and raise nose to maintain 52 kt, climb until obstructions are cleared.</p> |
| AS 332C           | <p>Cat A: Establish 15 ft HIGE, forward flight to best rate of climb speed, climb to constant best rate of climb speed.</p> <p>Takeoff-Transition to Forward Flight-Climb: Establish 15 ft HIGE, maintain acceleration path nearly parallel to the ground, at best rate of climb speed less 10 kt adjust to obtain and stabilize best rate of climb speed.</p>                     |
| BV 234 LR         | Cat A: Establish 15 ft HIGE, accelerate forward to 30 kt maintaining 10-20 ft height, rotate to VCDP, climb to HCDP at VCDP, gradually accelerate while climbing to best rate of climb speed.                                                                                                                                                                                      |

**SIKORSKY 16**  
FLIGHT MANUAL



**FIGURE 12. H - V + 5 KNOTS DEPARTURE PROCEDURE**

initial airspeeds, approaches are initiated and intercept the desired slope sooner. Approaches flown at slower airspeeds initially overshoot the slope, delaying its interception. The NASA test data (reference 16) support this variation in characteristic approach profile shape. The airspace required to perform these approaches is dependent upon the desired approach slope flown.

The airspace required for departures is dependent upon aircraft performance and ambient conditions. Appendix B contains departure profiles for 8 aircraft at 18 combinations of gross weight, altitude and temperature. Maximum allowable weight, 85% maximum gross weight and 70% maximum gross weight were matched with standard (ISA) and hot day (ISA +20 C) temperatures and altitudes of sea level, 2000 and 4000 feet. As the departure profiles indicate, aircraft performance decreases with increases in gross weight, altitude and temperature.

The performance data for the BV 234LR, the S76A and the AS 355F were calculated by a different subcontractor than were the other five helicopters. Two assumptions used in these calculations were also different:

- 1) takeoff power was used instead of maximum continuous power, and
- 2) a maximum tip path plane of 45 degrees was used instead of 25 degrees.

These assumptions yield data that produce very similar climbout angles for airspeeds in the 40 to 60 knot range and shorter level acceleration distances below 40 knots.

An explanation of anomalies in some departure profiles follows. For MD 500E departure profiles, two hover IGE heights are used. The flight manual procedure recommends HIGE at 7.5 feet while flight manual performance data indicate HIGE at 3.5 feet. The B 206B III flight manual did not recommend a specific departure procedure so one was developed that flies the H-V+5 knots departure until reaching best rate of climb speed where a climb out is effected. The BV 234LR's maximum allowable takeoff weight is below the 85% maximum gross weight at 4000 feet pressure altitude, hot day conditions. Therefore, the 100% maximum allowable and 85% maximum gross weight profiles were not presented for these conditions. Also, BV 234LR manufacturer's recommended procedure states that "at the CDP adjust the helicopter to accelerate while climbing to best climb speed." To represent this properly on the departure graph an intercept at  $V_y$  of 100 ft. above the CDP was used. This enables the aircraft to properly accelerate while maintaining a positive climb rate.

The height-velocity diagram defines an envelope of airspeed and height above the ground from which a safe power-off or one engine inoperative (OEI) landing cannot be made. The non-existence or disappearance of an H-V diagram indicates that at the stated conditions, the aircraft is able to continue the takeoff or land safely, regardless of the point during takeoff at which an engine failure occurs. For all but two of the AS 355F gross weight, temperature and altitude combinations, the H-V diagram does not exist. A vertical departure is

the "optimum" departure for those 16 cases without an H-V diagram. Half of the "optimum" departure profiles for the AS 332C are vertical departures due to the disappearance of the H-V diagram at those combinations of gross weight, altitude and temperature. Some departure profiles for the AS 332C and the MBB BO 105 CBS fall "inside" the H-V+5 knots departure profiles. This occurs because the angle of climbs are greater at airspeeds used in these procedures as compared to the H-V+5 knots procedure.

#### CONCLUSION

The airspace required to perform approaches is dependent upon approach slope and pilot skill more than aircraft performance. This analysis has shown not only 8:1 approach slopes to be achievable at the initial airspeeds studied, but also 7:1, 6:1 and 5:1 approach slopes. The constraints placed on aircraft in achieving approach slopes were flight manual procedures and autorotative rate of descent limits.

As evidenced by this study, minimum VMC airspace requirements are dictated by aircraft departure performance. Current flight manual departure procedures regularly violate the 8:1 FAA heliport design departure surface at the combinations of gross weight, altitude and temperature studied.

The results of this analysis are used to determine airspace requirements in "Heliport VFR Airspace Based on Helicopter Performance," DOT/FAA/RD-90/4. Rejected takeoff and one engine inoperative (OEI) capability are related to airspace requirements for heliports intended to support Category A operations in "Helicopter Rejected Takeoff Airspace Requirements," DOT/FAA/RD-90/7.

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## ACRONYMS

|         |                                                    |
|---------|----------------------------------------------------|
| AC      | Advisory Circular                                  |
| A/S     | Above Slope                                        |
| CAT     | Category                                           |
| CDP     | Critical Decision Point                            |
| DOT     | Department of Transportation                       |
| FAA     | Federal Aviation Administration                    |
| FAATC   | Federal Aviation Administration Technical Center   |
| H-V     | Height-Velocity                                    |
| HAI     | Helicopter Association International               |
| HCDP    | Height at Critical Decision Point                  |
| HESCOMP | Helicopter Sizing and Performance Computer Program |
| HIGE    | Hover-In-Ground-Effect                             |
| IFR     | Instrument Flight Rules                            |
| ISA     | International Standard Atmosphere                  |
| KT      | Knot                                               |
| N/A     | Not Applicable                                     |
| NASA    | National Aeronautics and Space Administration      |
| OEI     | One Engine Inoperative                             |
| S/U     | Slope Unachievable                                 |
| SCT     | Systems Control Technology, Inc.                   |
| VCDP    | Velocity at Critical Decision Point                |
| VFR     | Visual Flight Rules                                |
| VMC     | Visual Meteorological Conditions                   |
| VNE     | Never Exceed Speed                                 |

APPENDIX A  
SUBCONTRACTOR SUMMARY REPORTS

FIRST SUBCONTRACTOR'S SUMMARY REPORT  
(Praxis Technologies, Incorporated)

I. METHODOLOGY

This study was conducted using rotary-wing performance computer programs originally developed under contract to NASA and the U.S. Navy. Single and tandem rotor helicopter designs were analyzed using a Subcontractor modified version of HESCOMP, The Helicopter Sizing and Performance Computer Program. HESCOMP is a widely accepted sizing and performance computer program within the rotary-wing and V/STOL industry. HESCOMP has been modified to include a more accurate representation of the low-speed power characteristics, more detailed weights algorithms, center of gravity locations, advanced rotor characteristics, and maneuver analyses. Wherever possible, HESCOMP was correlated with actual flight test data from various civil and military helicopters. Because determination of the low speed powers required are critical to accurately assess takeoff and climb out capabilities, special consideration was given to the transition flight mode.

To simplify the approach to methodology assessment, the required engineering tasks were divided into seven areas: 1. geometric characteristics, 2. engine modeling, 3. airframe download, 4. drag prediction, 5. aerodynamics, 6. main and tail rotor performance, and 7. general performance. The prediction of air vehicle performance is based on an integration of these technology areas, which are separately addressed. Tasks 1-6 are external calculations which were then used as input to HESCOMP.

1. Geometric Characteristics

Accurate specification of air vehicle characteristics is essential to mathematical modeling programs, particularly to HESCOMP. The ability to provide three-dimensional helicopter data permits increased accuracy during performance analysis. The helicopters under study were physically "dissected" in order to be represented in the performance algorithms. In the case of the single rotor helicopter, the total fuselage length (in addition to the nose, tail, and constant sections) included the tail boom, the length of which, in turn, is established by the relationship between the main and tail rotors and separation distance. Additional concerns included main rotor and fuselage separation height, tail boom relative position on fuselage, center of gravity locations, lighting and gear configuration, horizontal and vertical tail relative positions, engine nacelle locations, and rotor pylon geometry. Fuselage fineness ratios, locations of maximum height and width, wetted areas, and overall length were also provided as input.

Additional considerations for the tandem rotor helicopter included rotor overlap, aft rotor pylon geometry and shaft inclination, and afterbody design.

The geometric characteristics for each helicopter under study were obtained from the appropriate corresponding flight manuals.

## 2. Engine Modeling

Basic turboshaft engine performance is determined through non-dimensionalized parameters as a function of Mach number versus turbine inlet temperature,  $T4.1$ . Referred engine parameters include horsepower, fuel flow, gas generator speed, and power turbine speed. Engine ratings from ground idle to maximum or contingency power setting are indicated. Non-dimensionalized engine shaft horsepower available and associated fuel flow are functions of the maximum static sea level installed power and ambient pressure and temperature ratios. Non-dimensionalized gas generator and power turbine speeds are functions of temperature ratio. Because of the normalized, referred format, all engine data are valid for any ambient condition, whether standard or nonstandard. With the exception of referred power, none of the engine parameters are dependent upon power turbine speed.

Manufacturer's data on some engines show significant variations in both referred power and lapse rate with respect to changes in altitude. These variations are due to Reynold's number effects. It has been found that these effects can be accounted for by means of a multiplicative factor on power available, which is a function of the Reynold's number based on compressor inlet conditions, compressor blade geometry, and tip speed.

It is imperative to have an accurate prediction of the engine power available when computing performance parameters. Engine certificated specifications were used for each configuration when available. Parameters that reduce engine power available to the rotor include appropriate engine inlet and exhaust losses and accessory horsepower extraction.

## 3. Airframe Download

Download is due to the presence of the airframe in the rotor downwash. Download affects the performance ability of the helicopter anytime the rotor downwash impinges on the airframe, such as in hover and very low-speed flight. As an example, in order to hover, the rotor must produce enough thrust to equal the weight of the vehicle plus the download. Typical values of the helicopter thrust-to-weight ratios are between 1.03 and 1.05. A semi-empirical method was used for estimating download yielded correlation within ten percent for most of the available data. Airframe shape, perimeter area, and vertical location under rotor were strip calculated as a function of fuselage station. Correspondingly, the rotor wake contraction and dynamic pressure were also strip calculated. The strip calculations were used to obtain the total airframe download.

## 4. Drag Prediction

The total minimum profile drag is estimated using a detailed skin friction and pressure drag calculation based on empirical trends. The skin friction drag was obtained by computing the skin friction drag of a flat plate as a function of Reynold's number, Mach number, and surface roughness, and then correcting the drag for three-dimensional effects. Pressure drag was computed using empirical equations defined as a function of fineness ratio and the chordwise location of the maximum thickness. Wherever possible, drag estimates were correlated with any published data from the airframe manufacturers. Detailed drag estimates

for each airframe component were calculated and then summed to provide total minimum drag.

## 5. Aerodynamics

Aerodynamics of the fuselage and horizontal and vertical tail surfaces were determined for trimmed flight conditions. Aerodynamic contribution of the vertical tail is important in determining the tail rotor thrust requirements for anti-torque. The horizontal tail, if present, provides fuselage pitch attitude in trim conditions. Both tail surface contributions are dependent upon lift and drag coefficients, pitch or yaw angle, surface area, and longitudinal and lateral locations in reference to fuselage.

## 6. Main and Tail Rotor Performance

The calculation of the total contributions of thrust and propulsive force from both the main and tail rotor systems are critical in predicting helicopter performance. Main rotor performance was calculated using a combination of momentum theory and empirical corrections. Main and tail rotor performance was correlated with manufacturer supplied data for the hover and minimum power required points. Total shaft horsepower required is dependent upon airfoil type, platform shape, blade number, twist, cutout, trim conditions, and gearbox efficiency. For single rotor helicopters, tail rotor parameters were also included. Typically, the four elements of main rotor power required are:

1. Induced Power - power required to generate lift.
2. Profile Power - power required to turn the rotor.
3. Parasite Power - power required to supply propulsive thrust in forward flight.
4. Nonuniform Downwash Power - power correction due to nonuniform inflow and downwash effects in forward flight.

Tail rotor power required was calculated as a function of the main rotor power required, the tail rotor arm length, vertical fin blockage and effectiveness, and tail rotor aerodynamics.

Rotor power prediction has traditionally been associated with hover and forward flight conditions. Transition powers from hover to minimum power speeds are difficult to analyze. Within published literature, helicopter performance data has been measured at hover and in forward flight at airspeeds from just below the airspeed for minimum power out to the maximum airspeed attainable. Climb performance is usually measured at the airspeed for best rate of climb (approximately the same airspeed as for minimum power required), and frequently, at the hover, or zero airspeed, condition. Generally, no data are taken for the transition airspeed range between hover and minimum power airspeed. For certain performance conditions, the low speed transition corridor is vital to helicopter operations. Most helicopters operate in the transition regime for a brief period of time, constituting takeoff to climb out, or coming in for a landing. When a helicopter had sufficient power to hover, it usually had enough power to pass safely through transition.

Methodology to accurately predict the transition regime is non-existent. Neither the simple momentum analysis used at hover, nor the fixed wing analogy commonly used for forward flight is valid. A simplification of the rotor induced power in forward flight results from assuming a zero rotor angle of attack. Assuming a rotor elliptical lift distribution in cruise flight implies a uniform induced rotor downwash over the rotor disk. This downwash is small compared to the forward flight airspeed. However, as the helicopter's airspeed is reduced from cruise into the transition regime, the rotor induced downwash becomes a significant portion of the flight airspeed, and increasingly non-uniform. This implies that the classical forward flight equation assumptions are not necessarily valid for predicting the transition powers required.

To obtain a reasonable estimation of power required at very low advance ratios where neither normal cruise nor hover rotor characteristics totally describe the operating environment of the rotor, HESCOMP uses an empirical fairing technique. This method is based on a contracted induced wake angle coupled with algorithms which insure a smooth transition between hover and cruise. For this study, a correlation of HESCOMP-type methodology with flight test data obtained from Edwards Air Force base for a variety of military helicopters was also used. This database provides a statistical method of correlating the prediction of transition power required based solely on inputs of hover and minimum powers required. The predictive methodology used was well within ten percent of the actual flight test data.

## 7. General Performance

Tasks 1 through 6 establish the mathematical algorithms necessary for input to HESCOMP. This task consisted of using HESCOMP as a general performance tool which provided powers available and required to perform a variety of mission requirements. Among the output from HESCOMP were flight path angles and airspeeds for climb performance, and engine and rotor performance for accelerations and takeoff distance calculations. Acceleration data were computed outside of HESCOMP. Time to program was considered and an estimated cost savings was achieved by not linking the acceleration algorithms inside the main HESCOMP program.

## II. ASSUMPTIONS

Several assumptions were required in the prediction of civil aviation helicopter performance. Eight helicopter configurations were examined of which five vehicles were multi-engine. The following assumptions apply:

1. Engine power available was assumed to collapse as the inverse function of both pressure ratio and square root of the temperature ratio.
2. Longitudinal acceleration data were generated at maximum power available or takeoff power.
3. Rate of climb data were generated at intermediate rated power or 30 minute power rating.
4. Gearbox torque limits were applied as indicated by the flight manuals.

5. Vertical rate of climb efficiencies were held constant for each configuration.
6. Transmission efficiencies were held constant at 97 percent.
7. Accessory horsepower extraction was estimated based on the installed avionics and held constant as a function of airspeed.
8. Rotor RPM was held constant at 100 percent.
9. One Engine Inoperative (OEI) powers required at hover and forward airspeeds were assumed to be the same as all engines operating.

### III. MANUFACTURER DATA USED

In order to accurately model the powers required and available throughout the low speed transitional flight regime, specific manufacturers' data were used. Powers available and required for hover and minimum power flight speed for steady state level flight was requested. Also, the vertical rate of climb at hover and the steady state rate of climb at a given airspeed was requested. However, not all data was supplied from the manufacturers, decreasing the accuracy of performance prediction. Otherwise, performance predictions are estimated to be within ten percent of the flight test data.

The following data were supplied by manufacturers and used accordingly:

NOTE: All rates of climb are in feet per minute.

|       |                                                                         |
|-------|-------------------------------------------------------------------------|
| GW    | = vehicle gross weight (lb) used for matching powers and climb rate     |
| HPavl | = maximum engine horsepower available                                   |
| Qlmt  | = engine torque limit as percentage of sea level engine power available |
| HPmin | = minimum horsepower required to maintain level flight                  |
| Vmin  | = true airspeed (knots) corresponding to HPmin                          |
| HPhov | = horsepower required for hover                                         |
| froc  | = forward rate of climb at Vcl                                          |
| Vcl   | = horizontal airspeed (knots) corresponding to froc                     |

#### 1. Enstrom F 28F

|       |                     |
|-------|---------------------|
| GW    | = 2,600             |
| HPavl | = 225               |
| Qlmt  | = N/A               |
| HPmin | = 126 at 2,350 lb   |
| Vmin  | = 50                |
| HPhov | = 245               |
| froc  | = 1,440 at 2,350 lb |
| Vcl   | = 50                |

#### 2. McDonnell Douglas 500E

|       |                   |
|-------|-------------------|
| GW    | = 3,000           |
| HPavl | = 420             |
| Qlmt  | = N/A             |
| HPmin | = 139 at 2,100 lb |
| Vmin  | = 50              |
| HPhov | = 332             |
| froc  | = 1,875 at 375 HP |
| Vcl   | = 50              |

## 3. Bell 206B III

GW = 3,200  
 HPavl = 420  
 Qlmt = N/A  
 HPmin = 158  
 Vmin = 50  
 HPhov = 300  
 froc = 1,186  
 Vcl = 50

## 4. Aerospatiale AS 355F

GW = 5,071  
 HPavl = 840  
 Qlmt = N/A  
 HPmin = 323  
 Vmin = 55  
 HPhov = 564  
 froc = 1,856  
 Vcl = 55

## 5. MBB BO 105 CBS

GW = 5,271  
 HPavl = 840  
 Qlmt = 86%  
 HPmin = 314  
 Vmin = 65  
 HPhov = 550  
 froc = 1,461  
 Vcl = 65

## 6. Sikorsky S 76A

GW = 10,500  
 HPavl = 1,300  
 Qlmt = N/A  
 HPmin = 564  
 Vmin = 75  
 HPhov = 1,242  
 froc = 1,491  
 Vcl = 75

## 7. Aerospatiale AS 332C

GW = 18,959  
 HPavl = 3,322  
 Qlmt = 90%  
 HPmin = 1,293  
 Vmin = 75  
 HPhov = 2,599  
 froc = 1,772  
 Vcl = 75

## 8. Boeing Vertol 234 LR

GW = 48,500  
 HPavl = 8,707  
 Qlmt = N/A  
 HPmin = 3,933  
 Vmin = 90  
 HPhov = 6,533  
 froc = 2,545  
 Vcl = 90

## IV. CONCLUSIONS

The development of the analytical models proved to be a greater effort than estimated due to the difficulty encountered in matching the computational data with the flight manual data. Matching manufacturer-supplied data (when provided) with computational data (horsepower required and corresponding rate of climb for a given true airspeed) was straight-forward. Manufacturer's estimates of horsepower extraction to drive accessories and transmission gearbox efficiency would have been helpful in developing the models.

Information available in each specific helicopter flight manual was used to collapse the data for different ambient conditions. Flight manual data were used to provide a first estimate while waiting for more specific data to be supplied from the manufacturers. Most flight manual data introduced ten percent error just in graph plot interpretation. This error is magnified when collapsing the data for density altitude. When manufacturers' data were supplied, results changed. The data received from most manufacturers usually included several different ambient conditions, enabling a much more accurate, and simplified, approach. The flight manual is required for helicopter definition and operating procedures but should not be used for performance matching with the analytical model, unless a lower accuracy than 10% is acceptable.

Vertical rate of climb was not supplied in most flight manuals nor by many of the manufacturers. This data would be very useful in estimating hover and very low speed rate of climb performance. Helicopters have different vertical drags which are difficult to accurately estimate. Vertical drag affects the vertical climb power required used to determine the vertical rate of climb. Without a good vertical drag estimate, an accurate vertical rate of climb is difficult to predict.

Realizing that data recorded during FAA flight qualification are limited, when used the data should be able to yield preliminary estimates of low speed performance. These additional data would enhance the accuracy of the low speed performance estimates. However, the effectiveness of increased accuracy above the level presented for this type of study is questionable.

SECOND SUBCONTRACTOR'S SUMMARY REPORT  
(University of Maryland, Aeronautical Engineering Department)

I. INTRODUCTION

This study was completed using HESCOMP (Helicopter Sizing and Performance Computer program) to determine the power required, rate of climb (ROC) and angle of climb (AOC) at the various weights, altitudes, and ambient conditions. The take-off and normal rated powers available for each of the aircraft were determined from the data supplied by SCT. The acceleration distance and time were calculated using an external proprietary program written in "C".

II. ACCELERATION DISTANCES AND TIMES

These data were determined by numerically integrating the acceleration capabilities of the aircraft. The acceleration capabilities are a function of the operating gross weight of the aircraft, the ambient conditions, power available, rotor system design, inertial loadings, and the operational procedures (control and attitude limitations, IGE, OGE, etc).

The response of the rotor system to the control changes associated with the transition from hover to forward acceleration is represented by an exponential function with an assumed time constant of one second. This time constant accounts for the delay associated with the thrust change required by the rotor system, thus disallowing instantaneous thrust changes within the rotor system.

The acceleration capabilities of each helicopter were estimated using semi-empirical methods previously developed from an extensive database. These data represent airborne acceleration capabilities and do not represent ground runs with the associated landing gear coefficients of friction. This limitation requires the aircraft to have the ability to hover (i.e., airborne or at minimum in-ground-effect) at the specific operating condition.

The airborne acceleration data are determined through scaling of semi-empirical data. The scaling requires knowledge of the maximum hover weight capability of the aircraft at the operating ambient condition, the operational weight of the aircraft, and the maximum speed of the aircraft at the operating ambient and weight.

Because of the limited scope of this study, it is imperative to understand the analytical procedure used to calculate the distance and time associated to accelerate to a given airspeed. In conversations with Praxis Technologies personnel regarding their original approach to this problem it was determined that they undertook a more rigorous analyses. In the Praxis Technologies approach they determined maximum overall acceleration accounting for ground run where more favorable. Also, in the original study the maximum thrust capability of the aircraft was used to determine the propulsive capability with tip-path plane tilt limited to 25 degrees. The ratio of the horizontal thrust less drag, to the weight of the helicopter was used to determine the acceleration. If the power available was insufficient for IGE hover at a given condition, they

calculated the acceleration of the aircraft in a ground run before achieving flight. It was found that it was sometimes beneficial to keep the aircraft on the ground regardless of the power required at certain conditions in order to gain enough speed to pull-up quickly once achieving high speed.

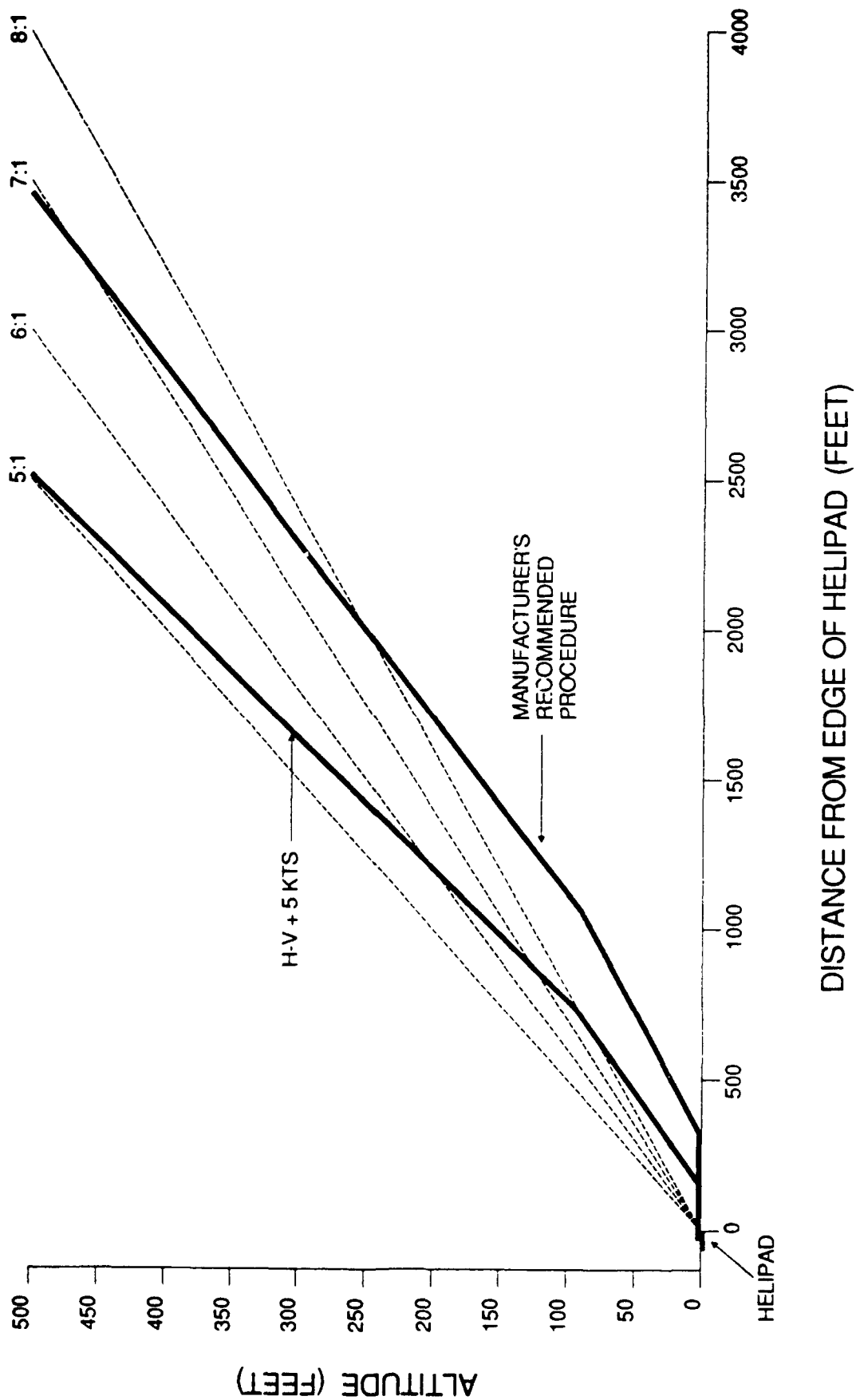
There are several variables that must be accounted for when determining take-off procedures. When ground runs are involved, the acceleration capabilities are different than with airborne conditions, and would provide an inconsistent comparison with data provided at weights where at minimum hover IGE is achievable. Therefore, a consistent takeoff procedure must be established to allow comparison of acceleration distances and times. The consistency within the data provided has been established by requiring airborne flight acceleration capability. No attempt was made to determine the trade-off between a ground run and airborne IGE flight due to the limited scope of this study.

In the case where the aircraft was not power limited and the Praxis Technologies study included a ground run, a difference in the acceleration distance and time would be expected. The data supplied by our approach would probably be somewhat more optimistic than the Praxis data up to maybe 40 or 50 knots and less optimistic at higher speeds depending on the take-off conditions. The reason for this is that during a ground run the aircraft has to overcome significant frictional forces at low speeds, but will accelerate very quickly once this is achieved. Output data from HESCOMP can be matched to the flight test data supplied for each aircraft by a variety of combinations of input. A match was made to the ROC data supplied in all cases. All other data, if supplied by SCT, was also matched.

APPENDIX B  
DEPARTURE PROFILES

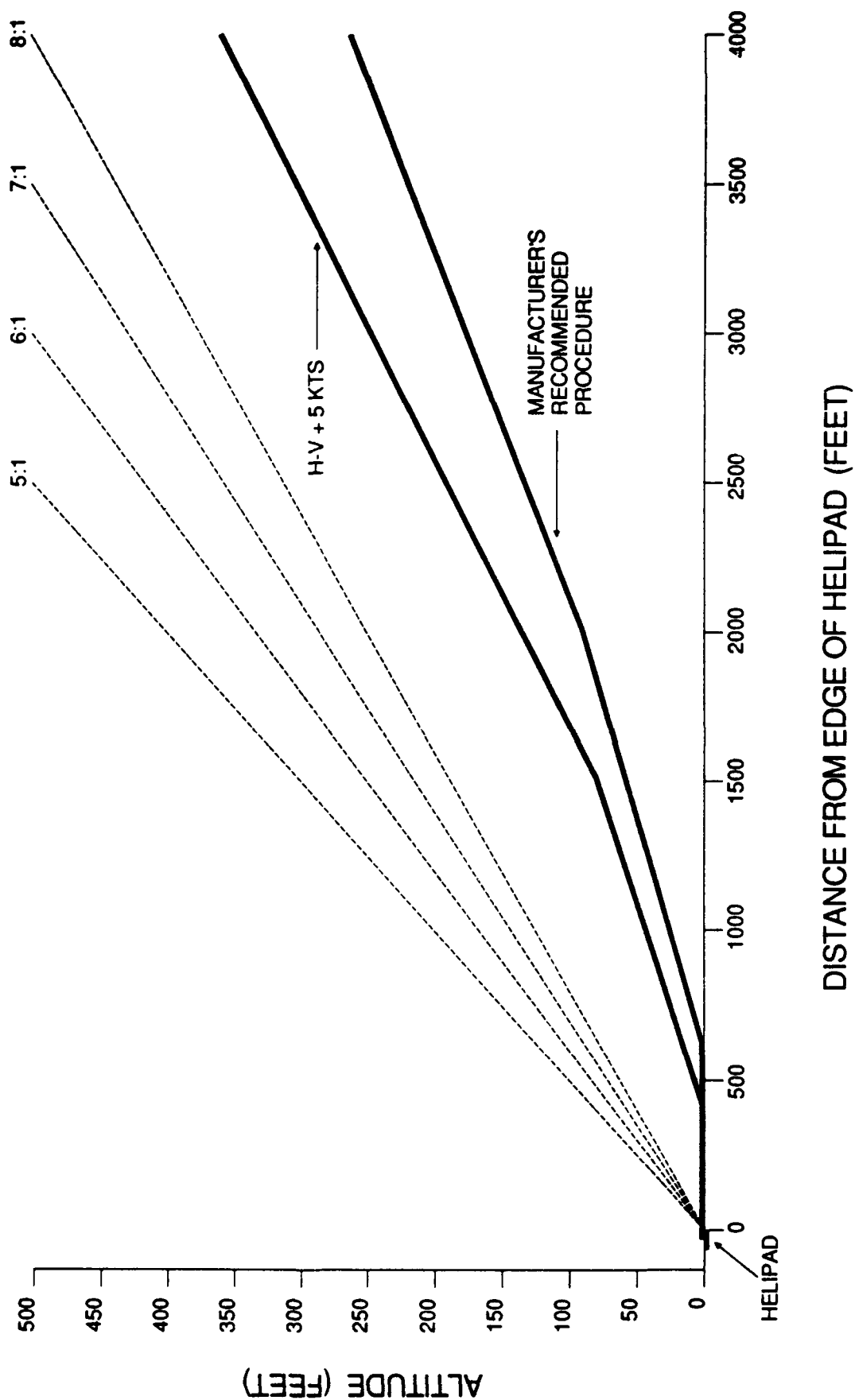
# F 28F DEPARTURE PROFILES

MAX. G.W., SEA LEVEL, STANDARD DAY



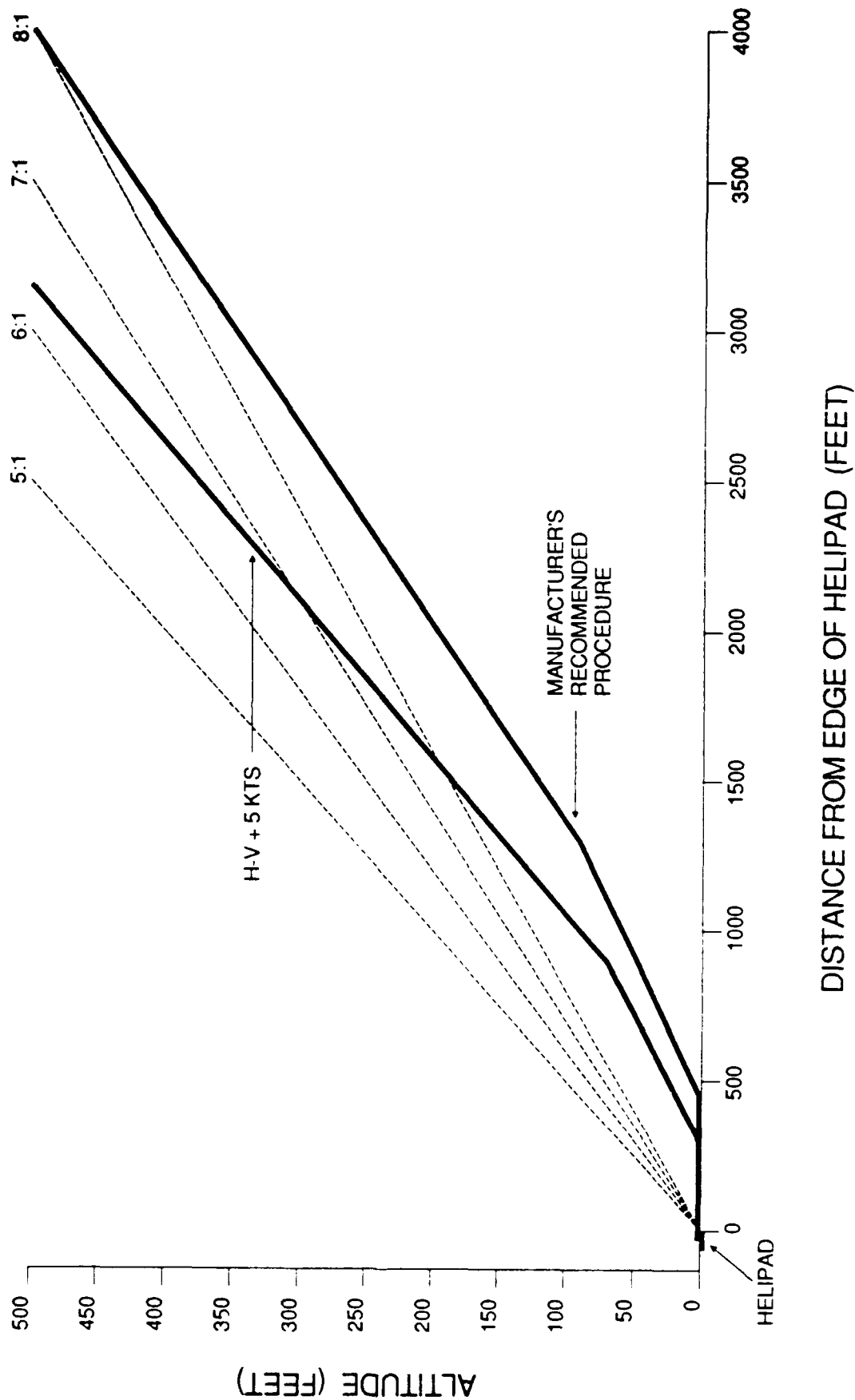
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MAX. G.W., SEA LEVEL, HOT DAY



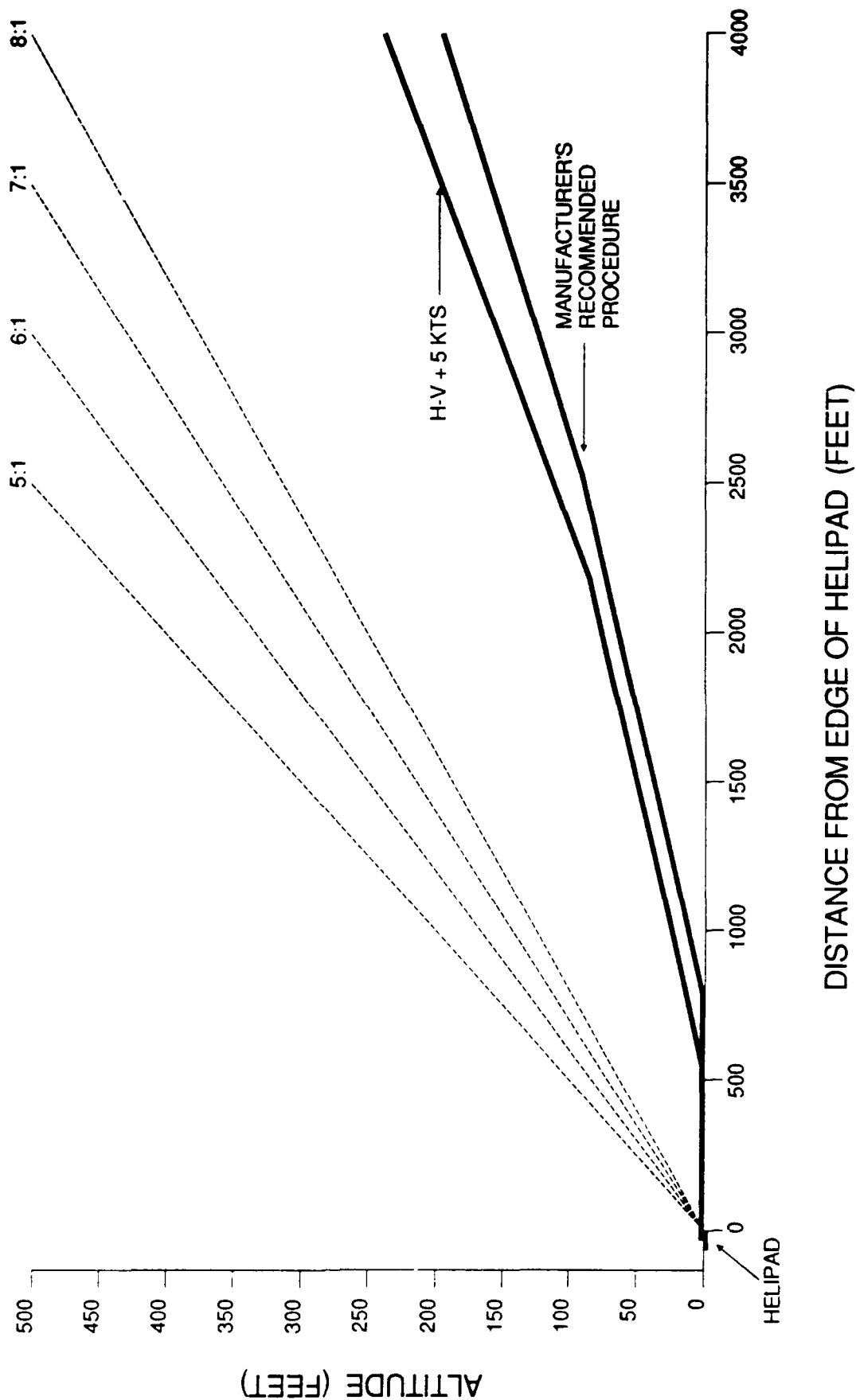
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MAX. G.W., 2000 FEET, STANDARD DAY



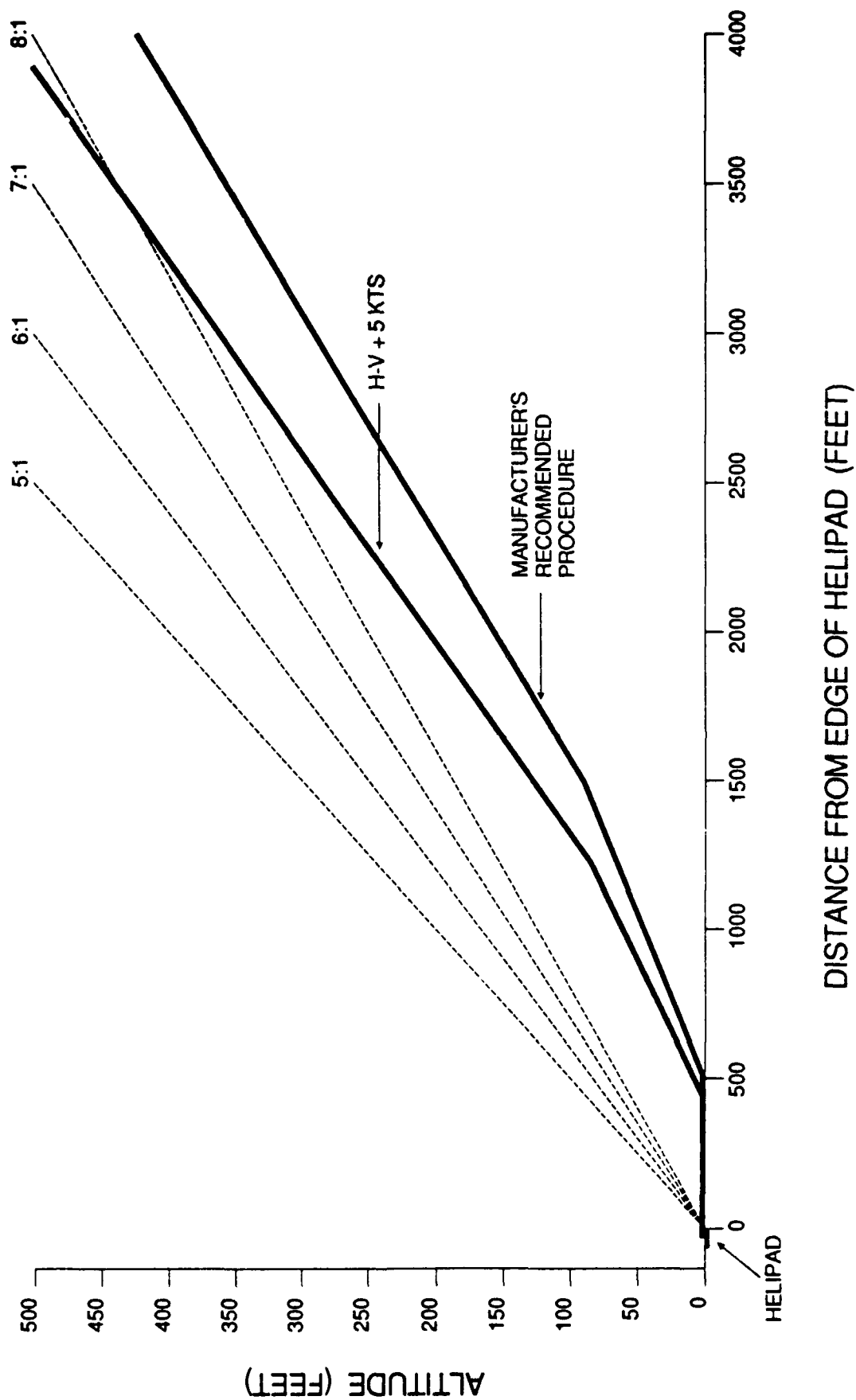
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MAX. G.W., 2000 FEET, HOT DAY



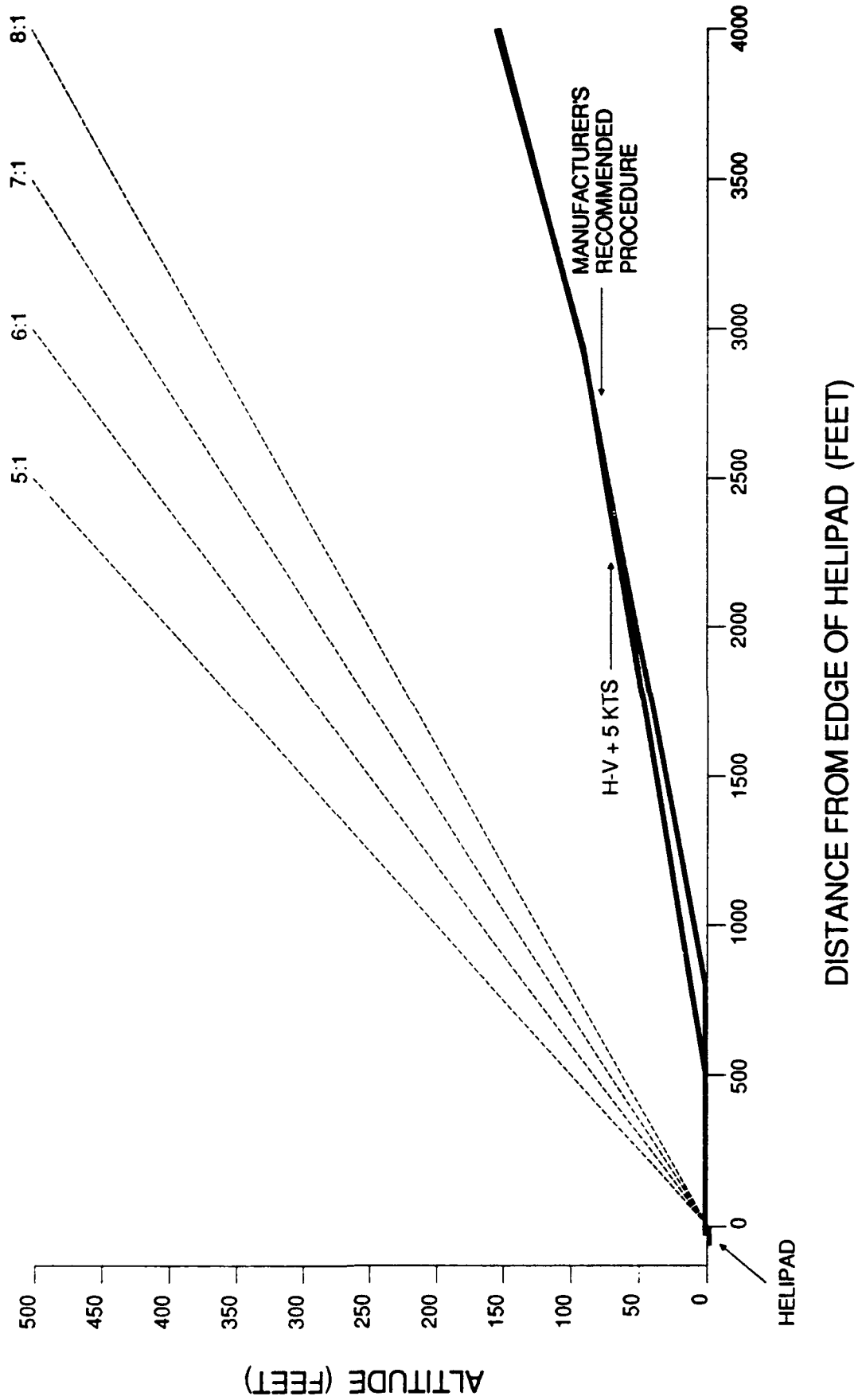
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MAX. G.W., 4000 FEET, STANDARD DAY



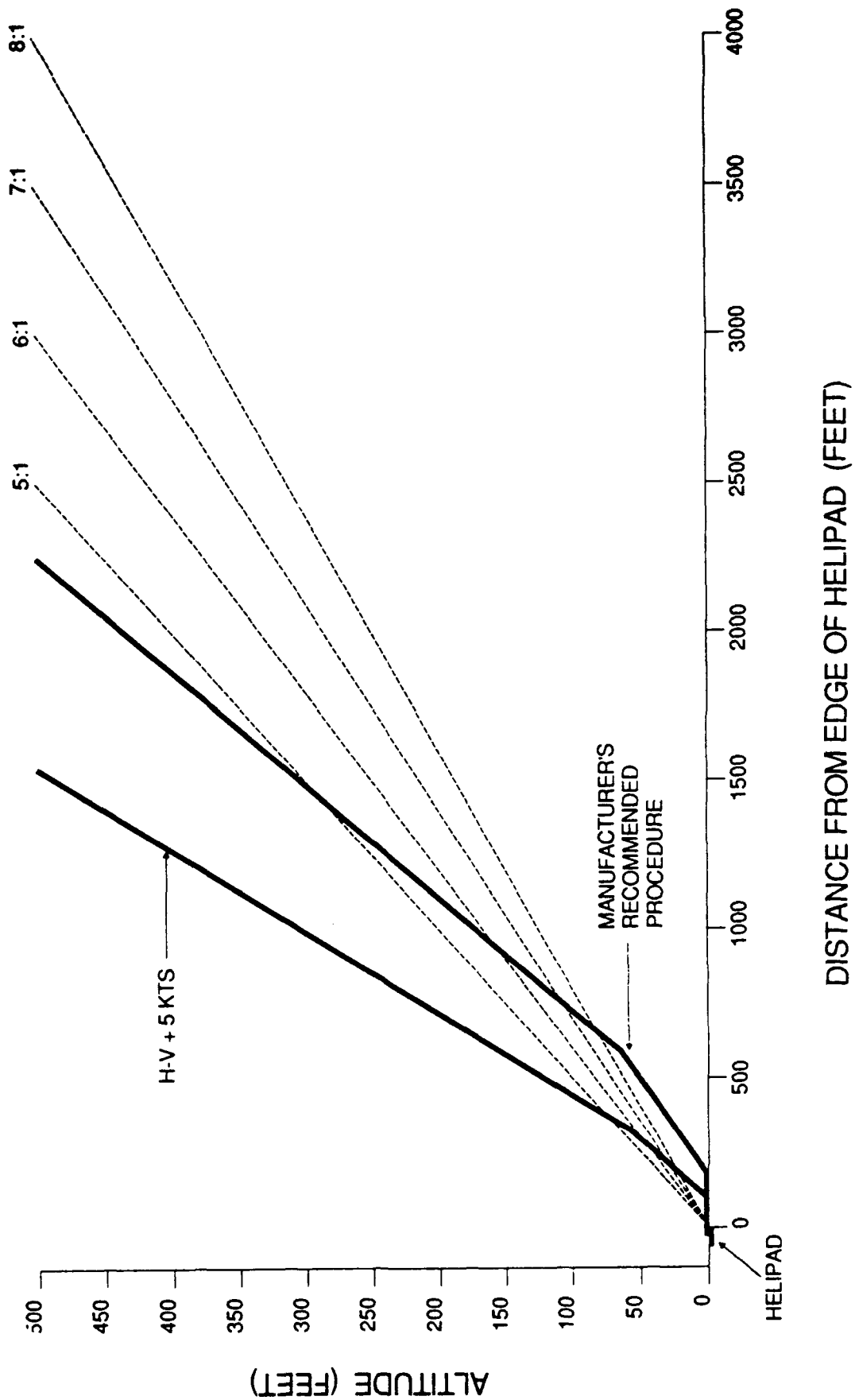
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MAX. G.W., 4000 FEET, HOT DAY



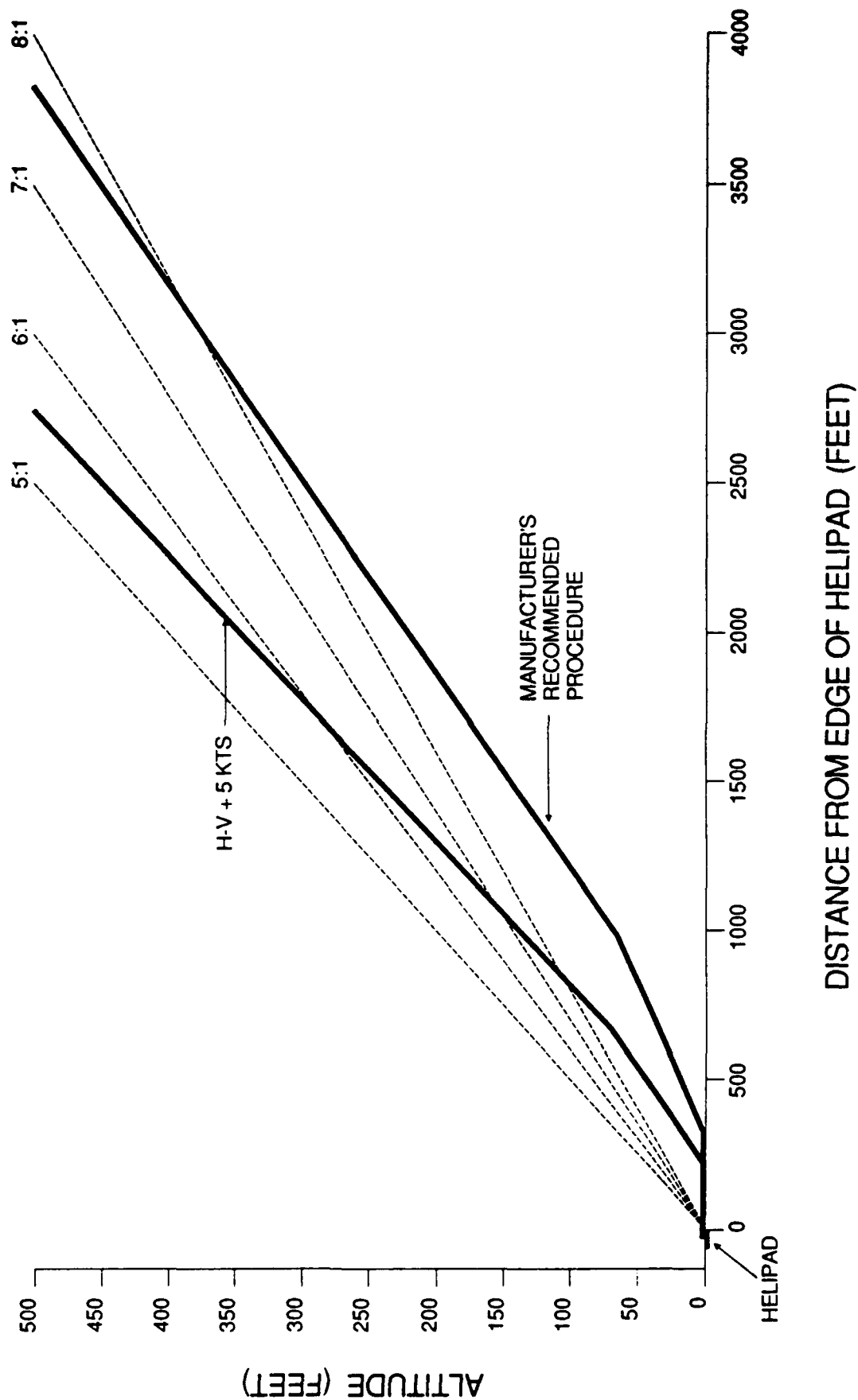
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85% MAX. G.W., SEA LEVEL, STANDARD DAY



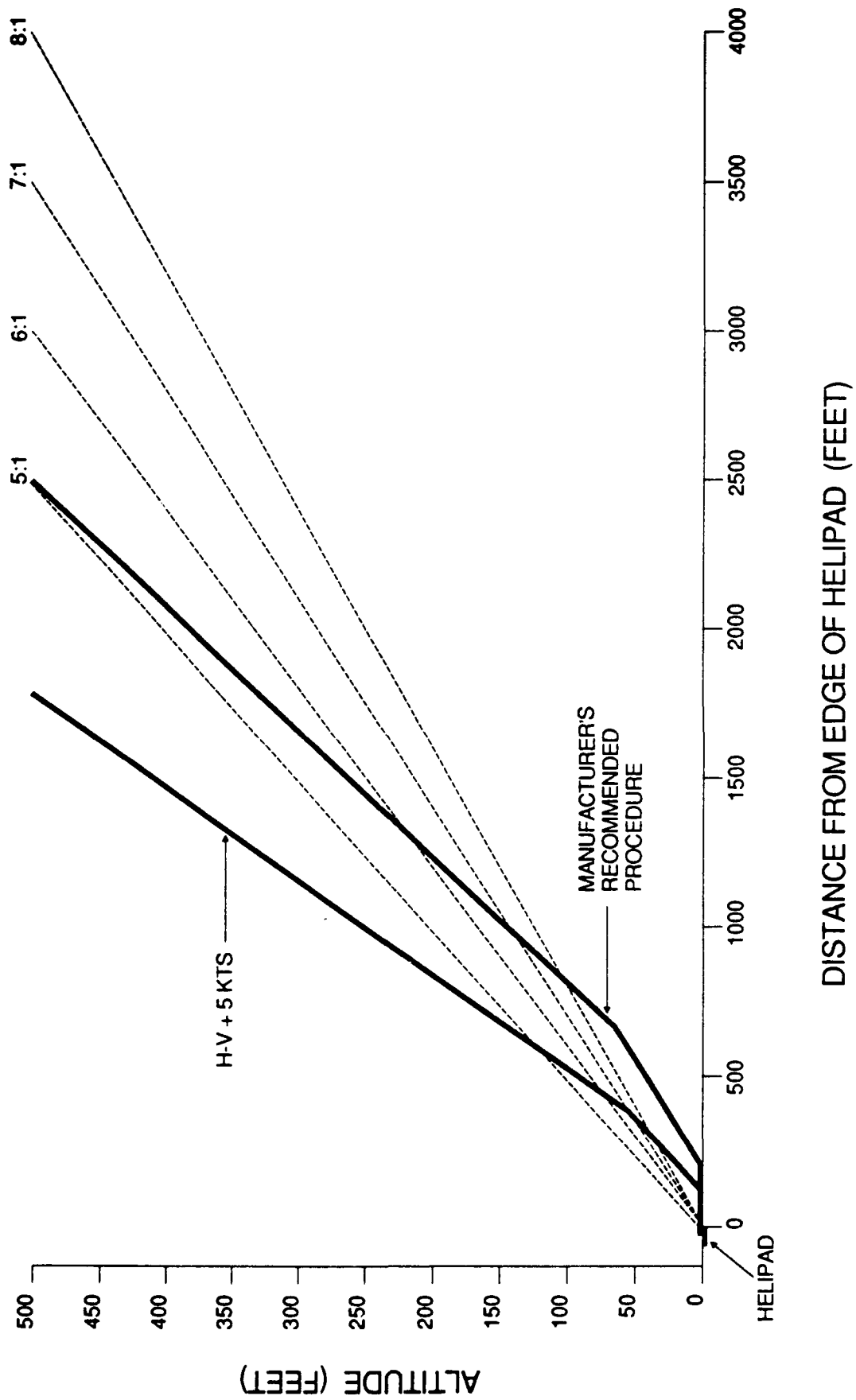
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85% MAX. G.W., SEA LEVEL, HOT DAY



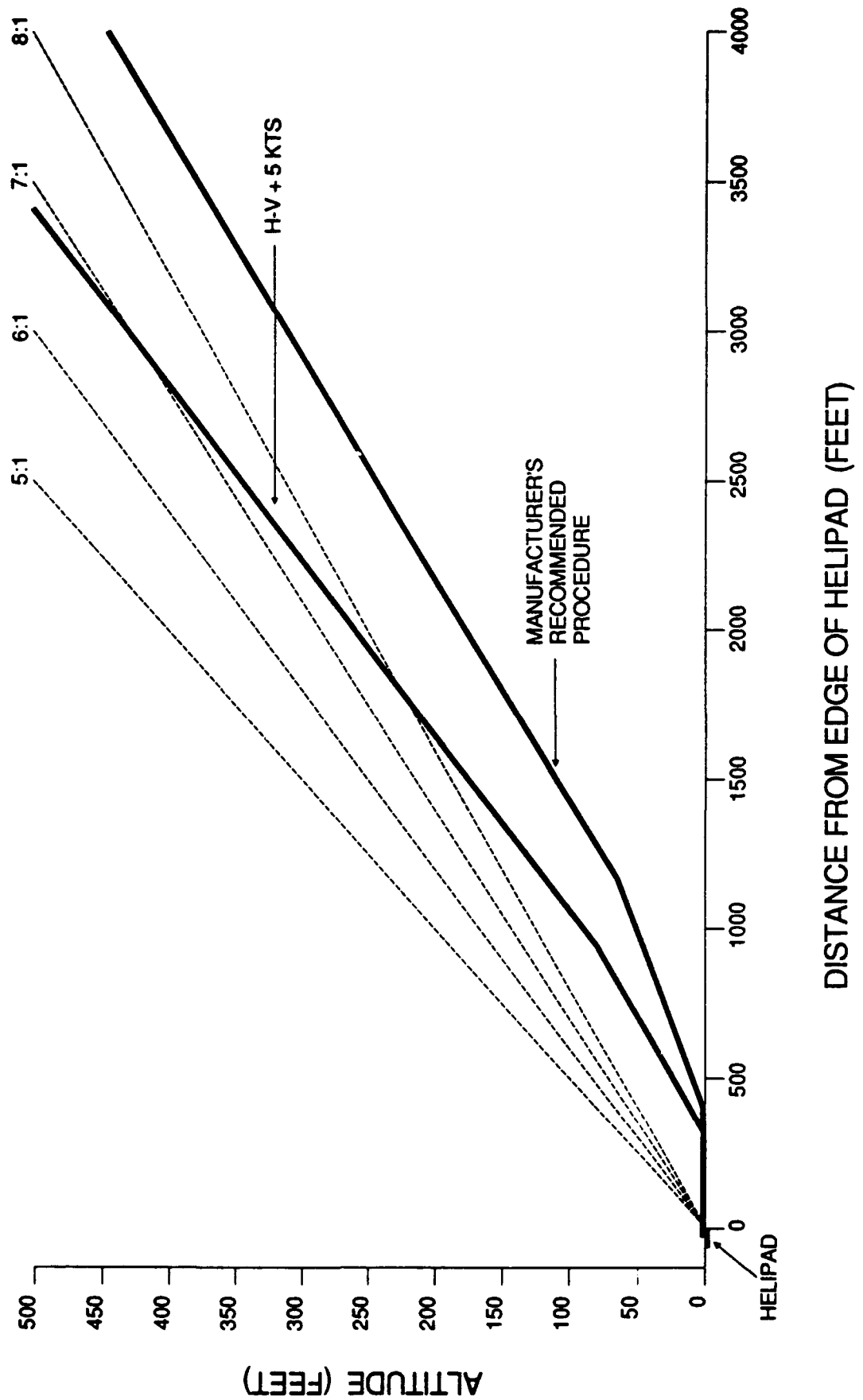
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85% MAX. G.W., 2000 FEET, STANDARD DAY



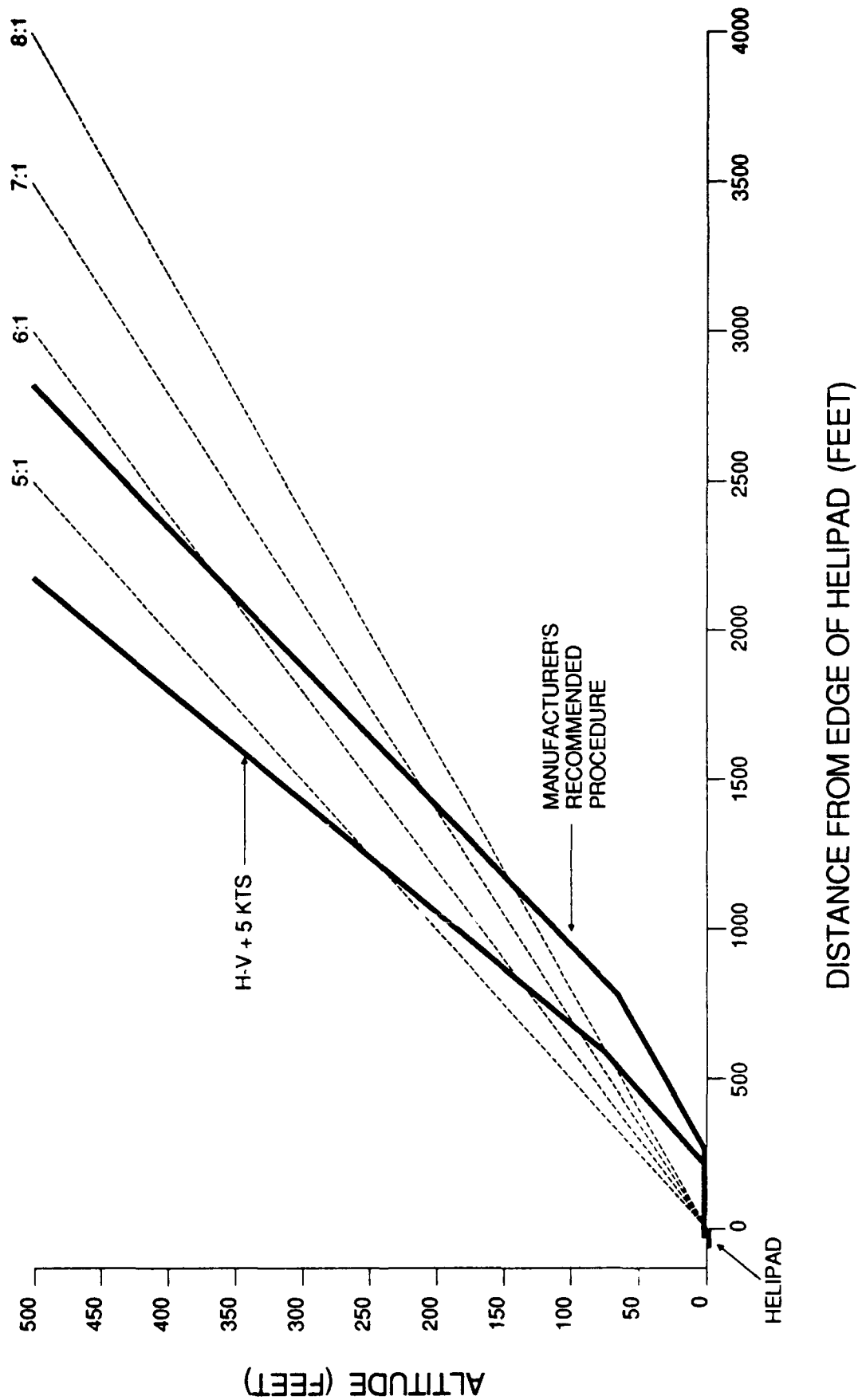
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85% MAX. G.W., 2000 FEET, HOT DAY



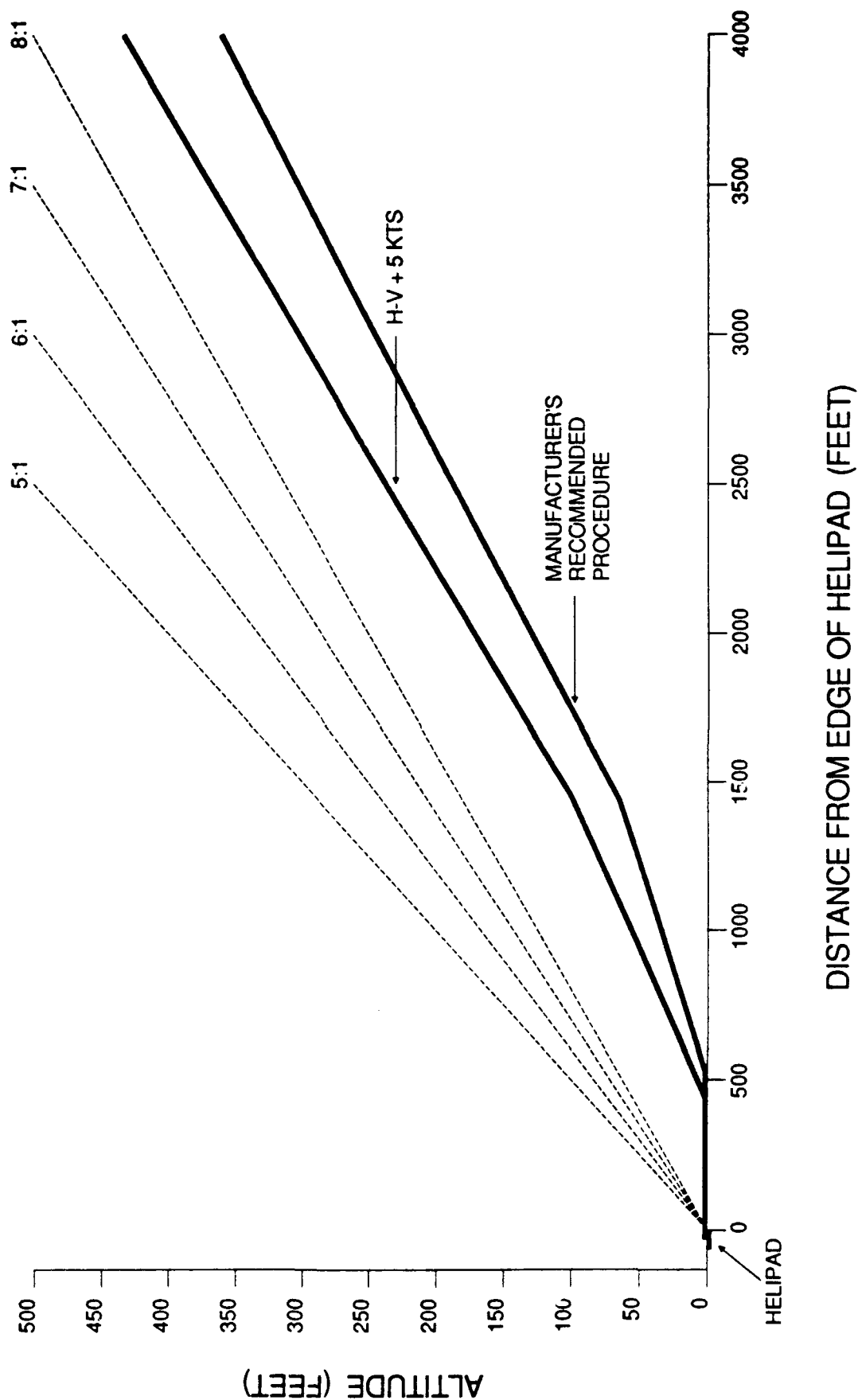
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85% MAX. G.W., 4000 FEET, STANDARD DAY



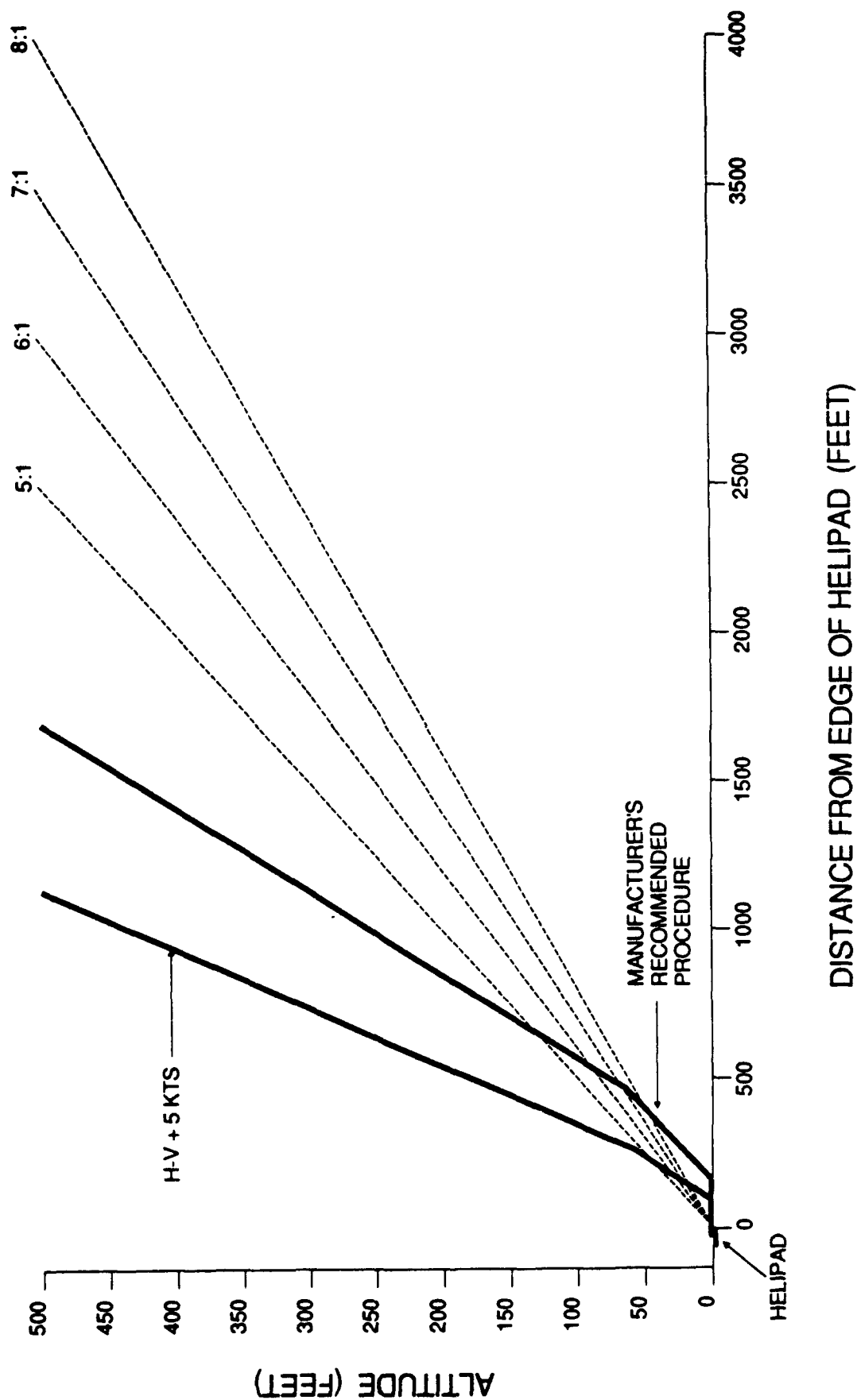
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85% MAX. G.W., 4000 FEET, HOT DAY



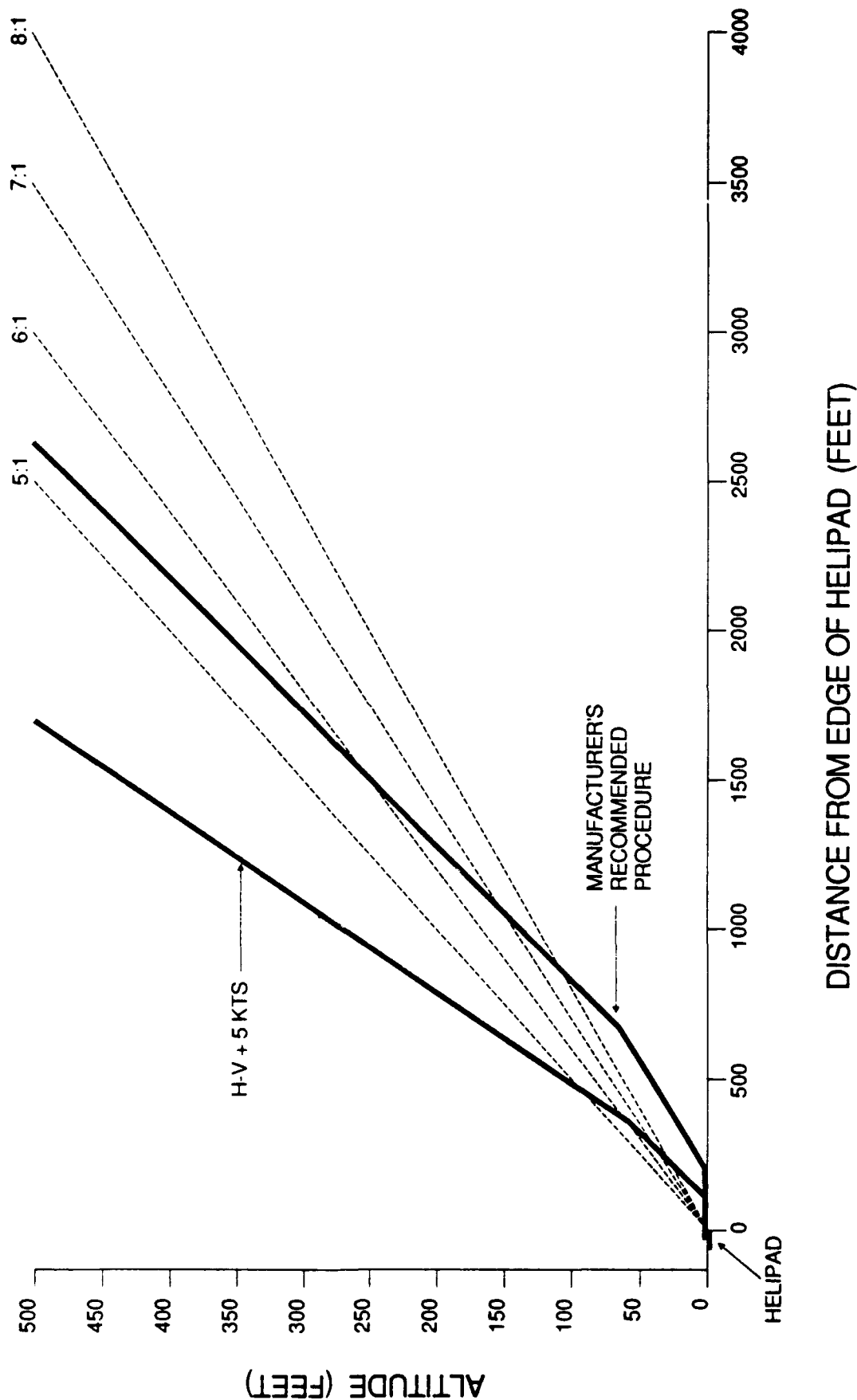
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70% MAX. G.W., SEA LEVEL, STANDARD DAY



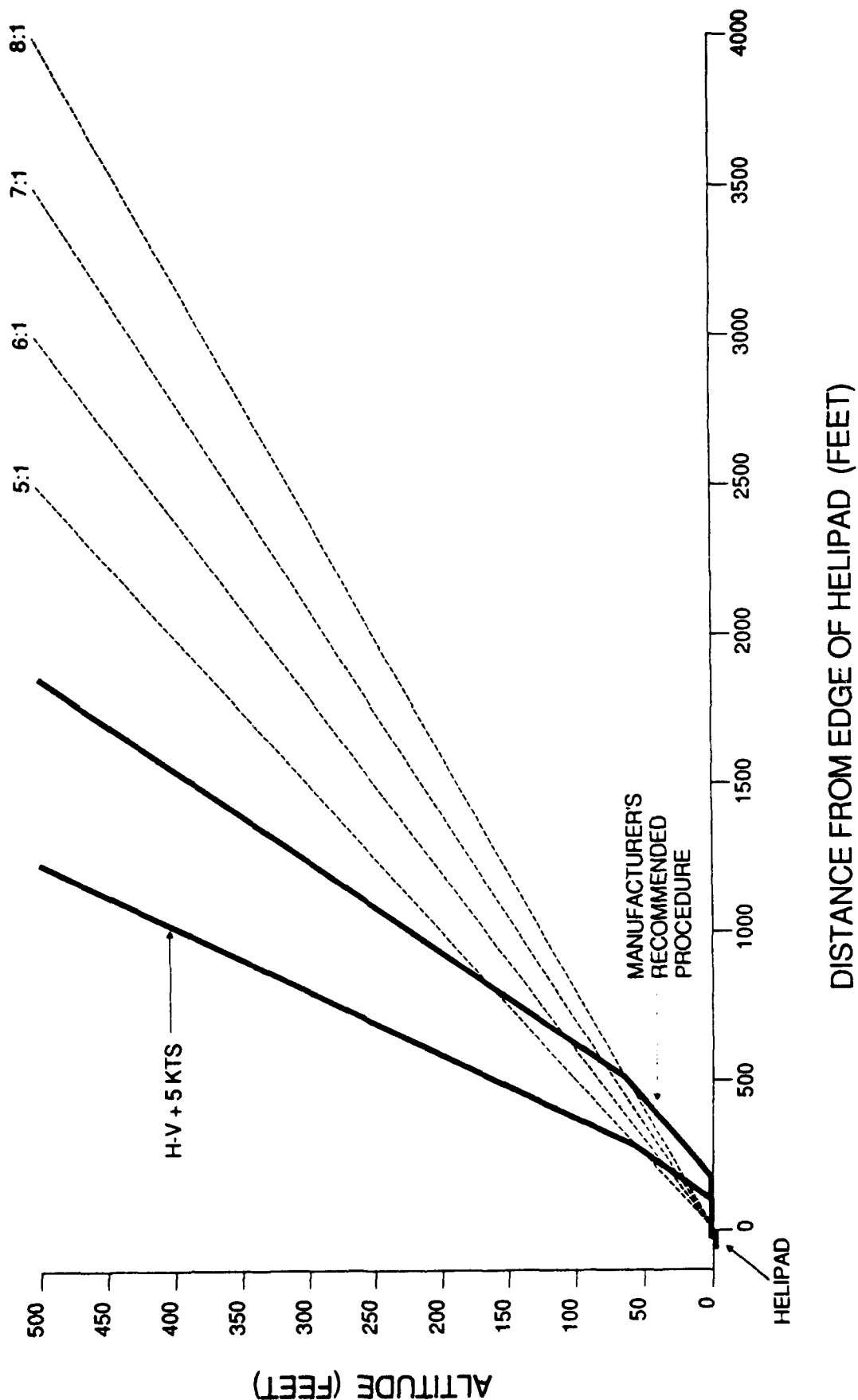
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70% MAX. G.W., SEA LEVEL, HOT DAY



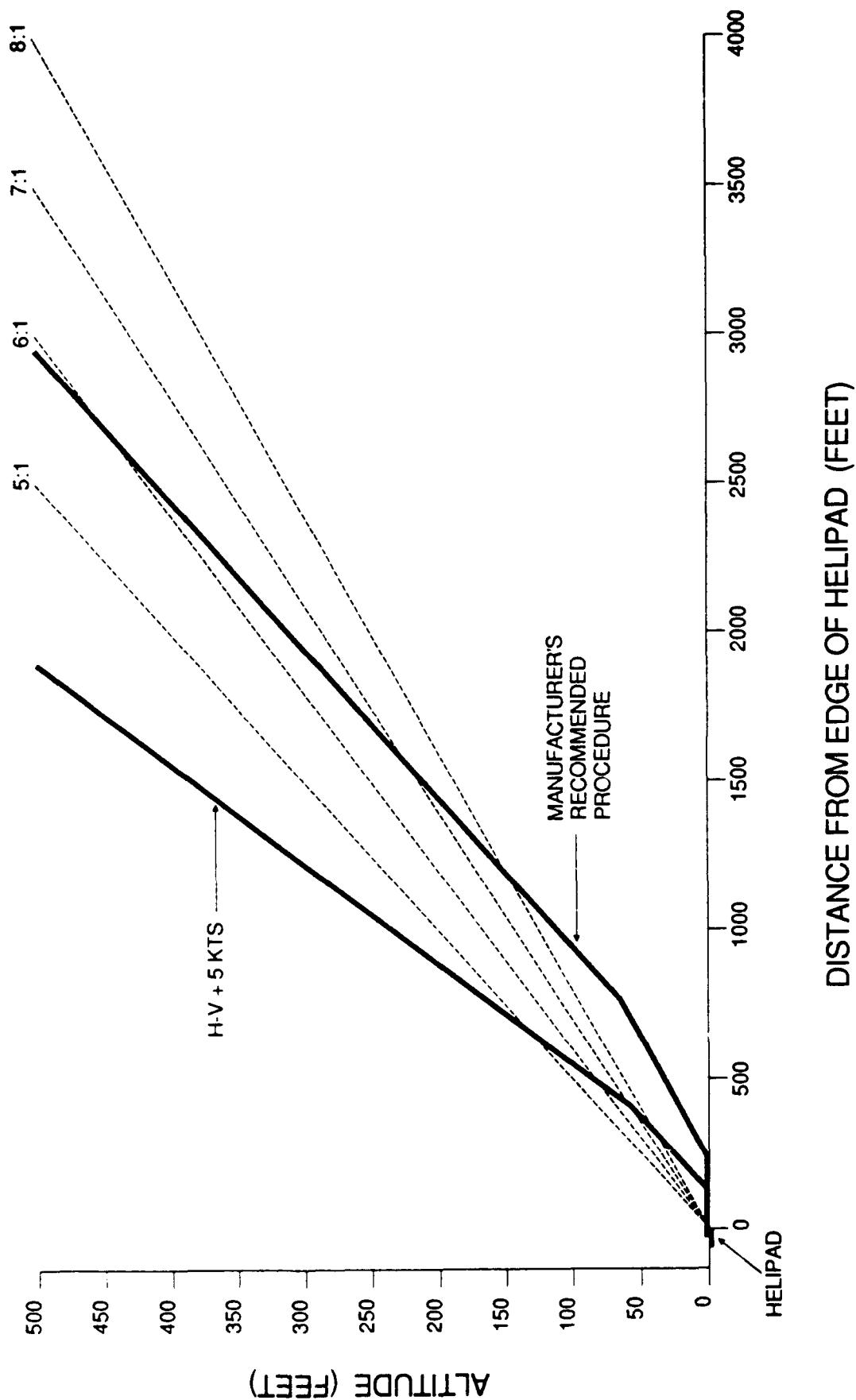
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70% MAX. G.W., 2000 FEET, STANDARD DAY



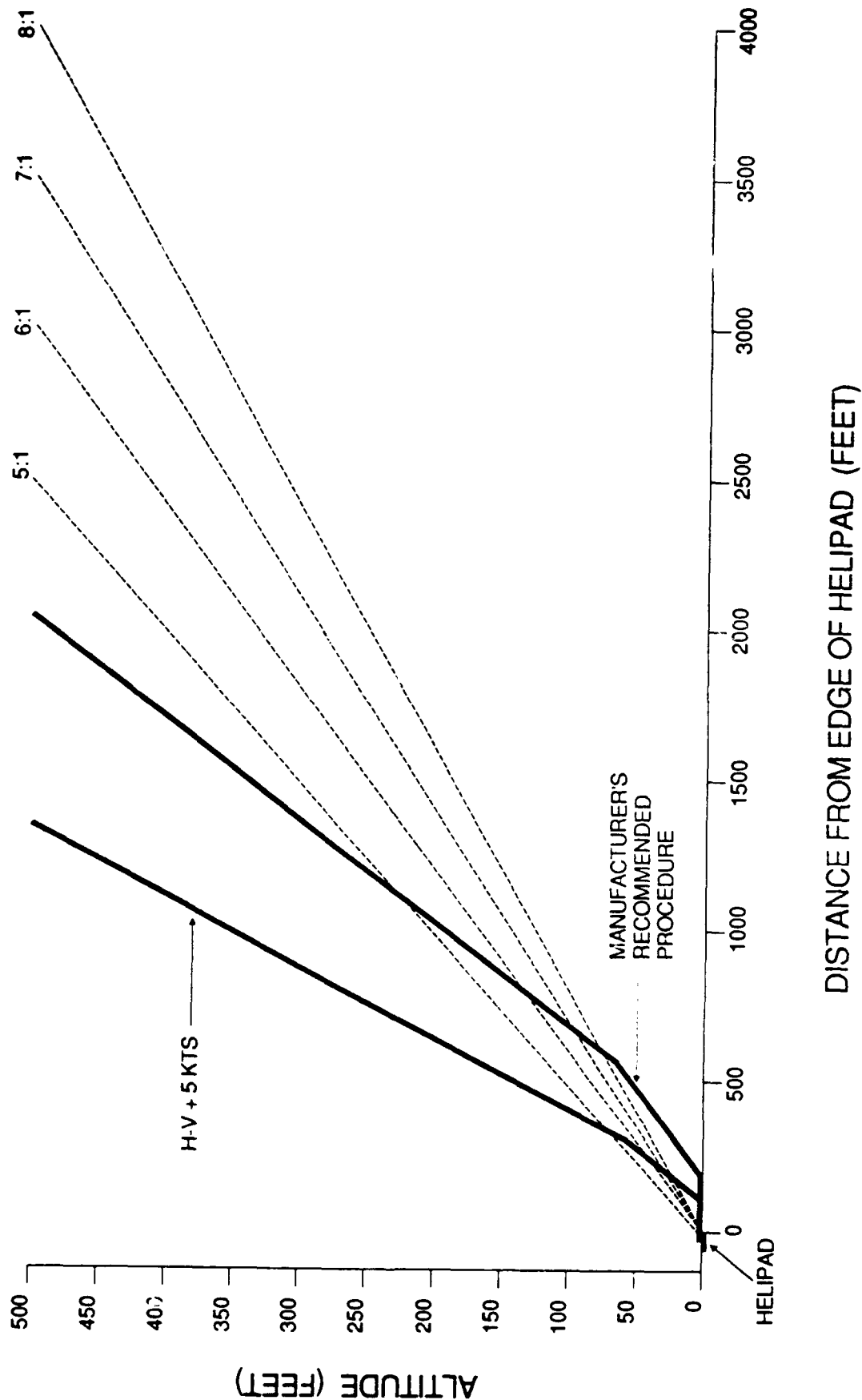
# F 28F DEPARTURE PROFILES

70% MAX. G.W., 2000 FEET, HOT DAY



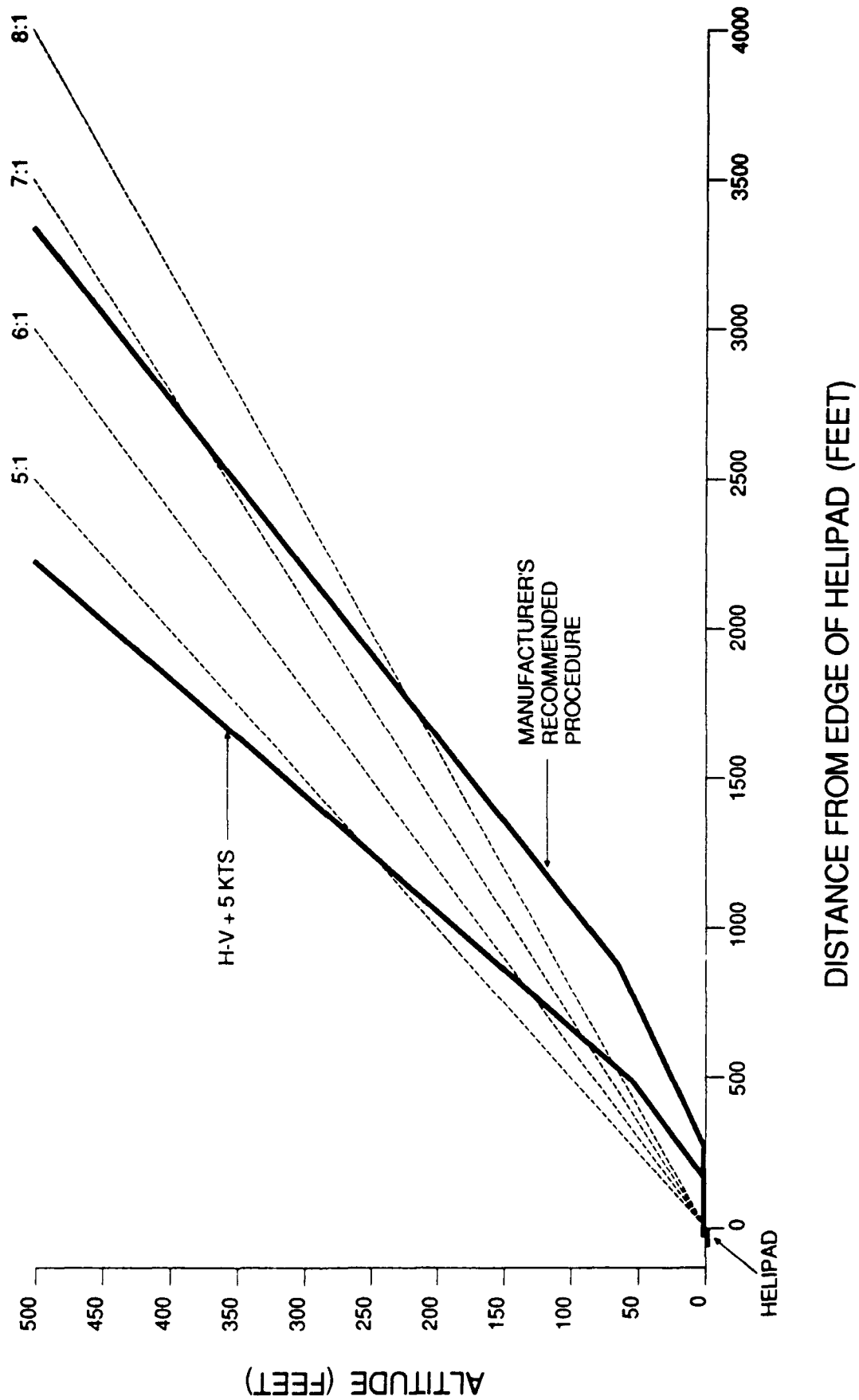
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70% MAX. G.W., 4000 FEET, STANDARD DAY



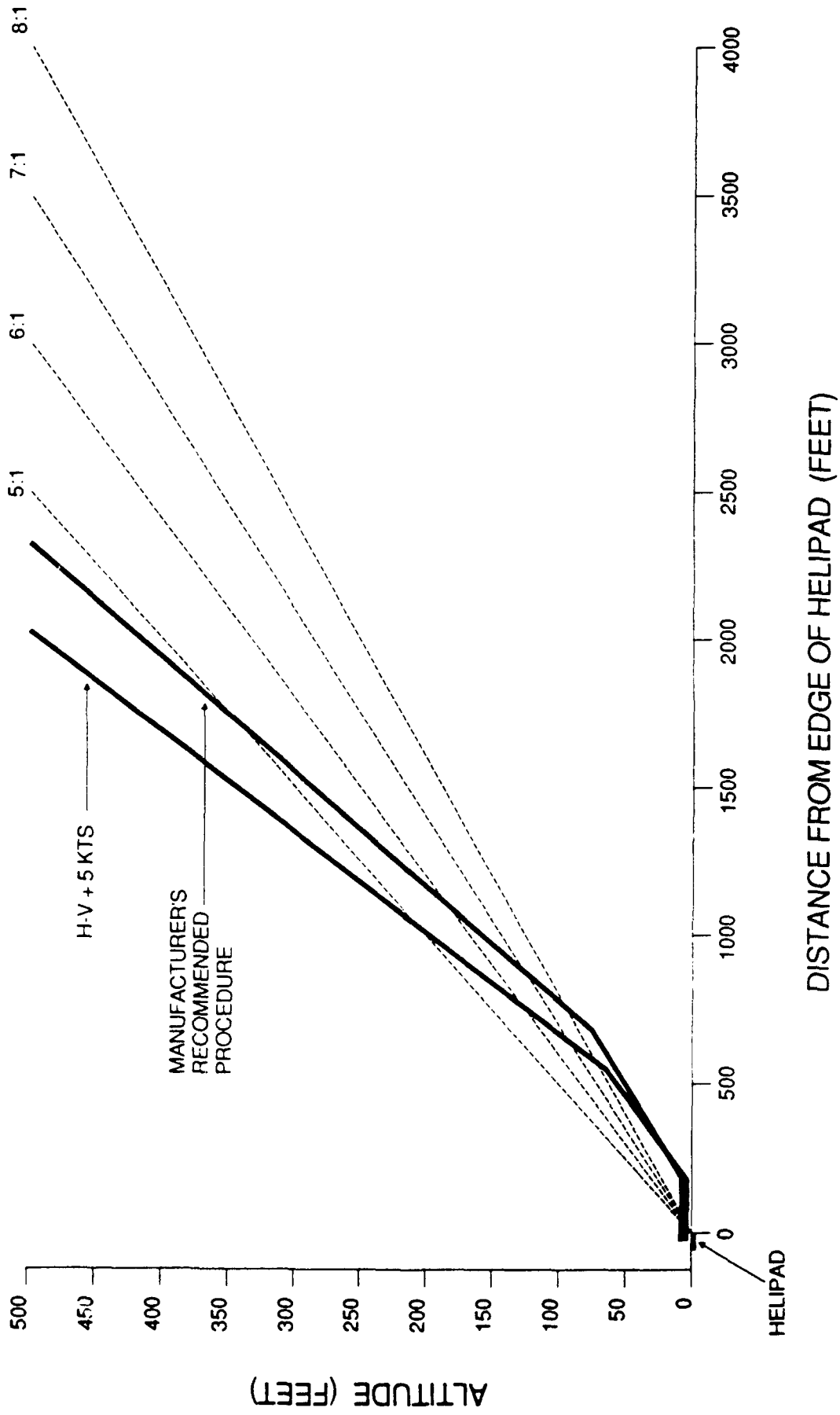
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70% MAX. G.W., 4000 FEET, HOT DAY



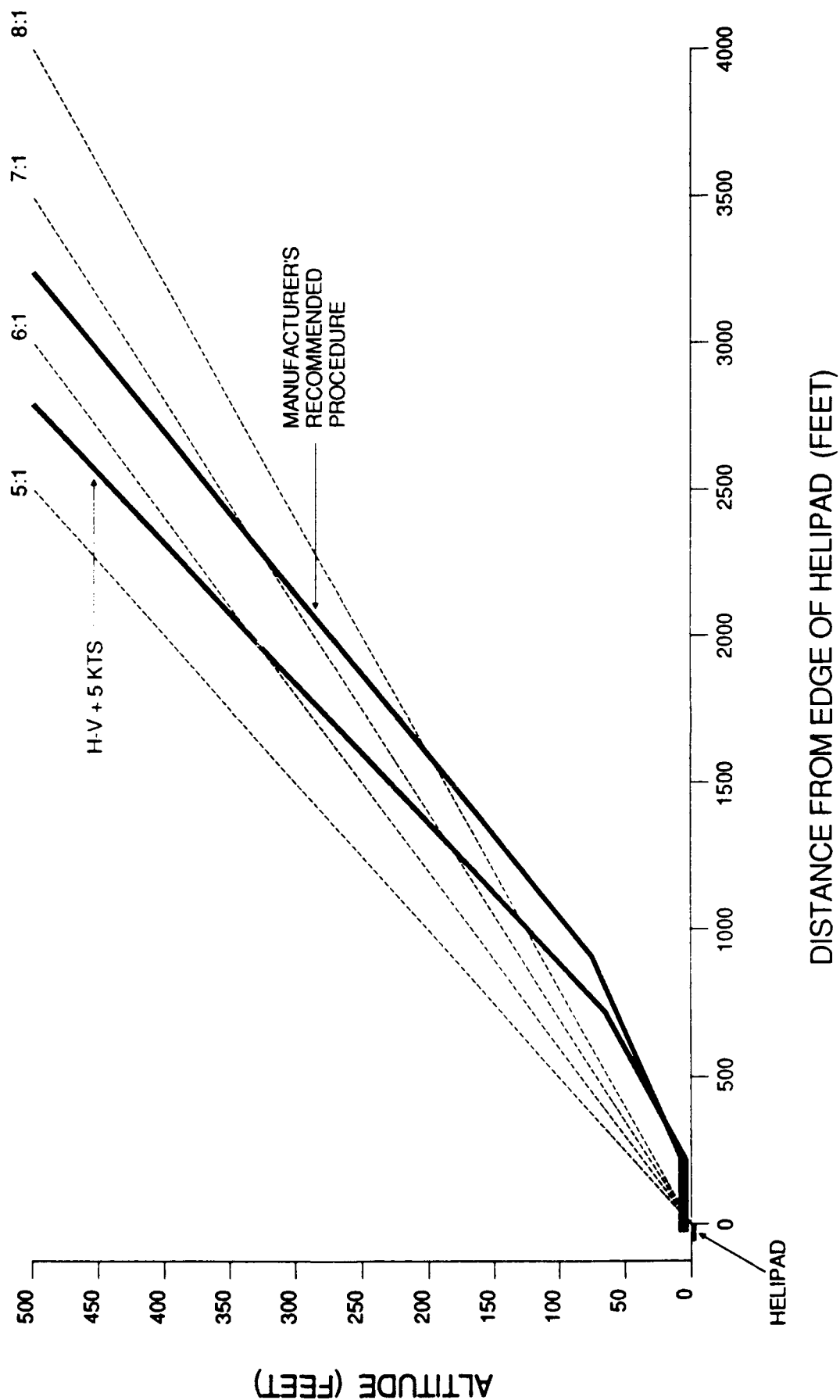
# MD 500E DEPARTURE PROFILES

MAX G.W., SEA LEVEL, STANDARD DAY



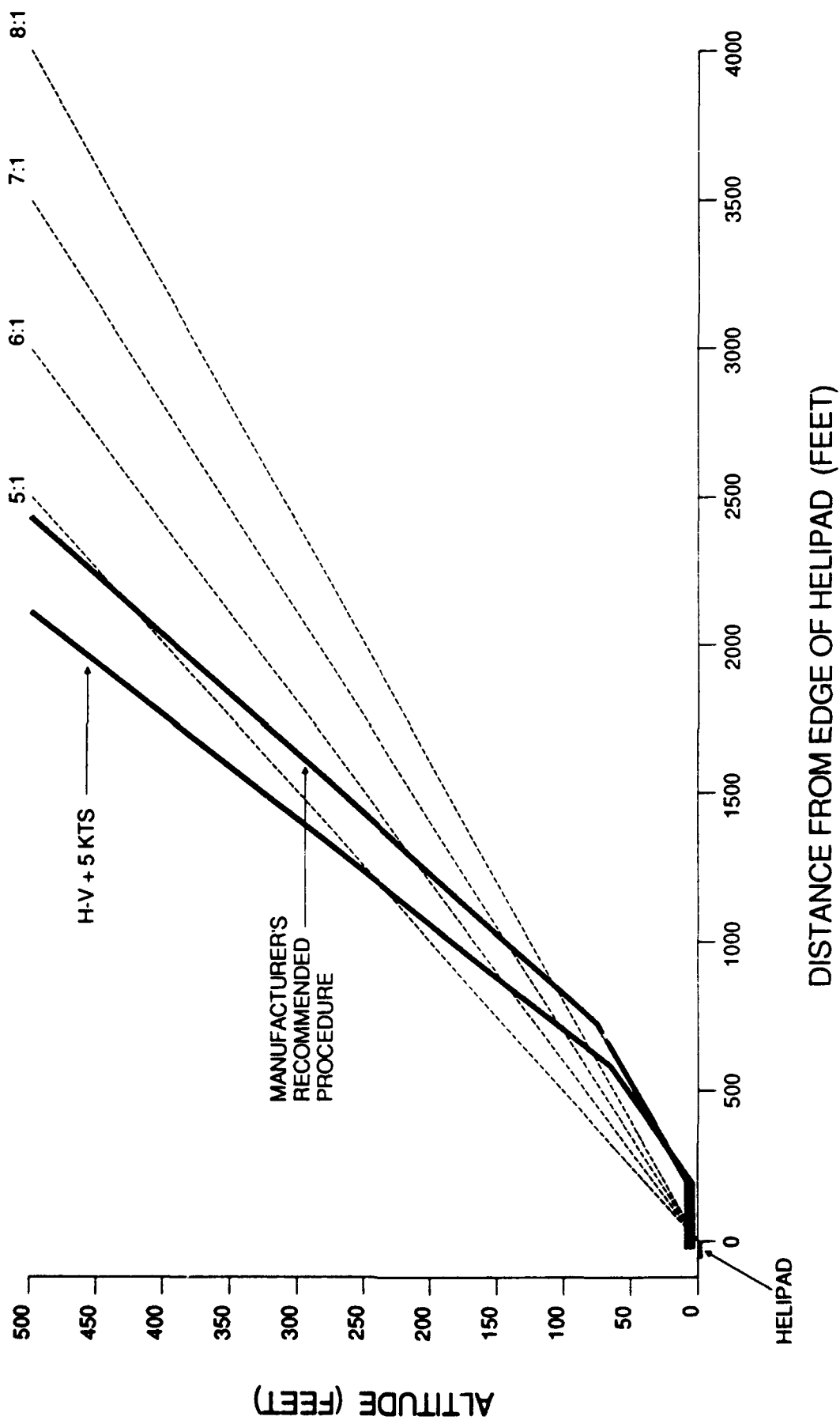
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MAX. G.W., SEA LEVEL, HOT DAY



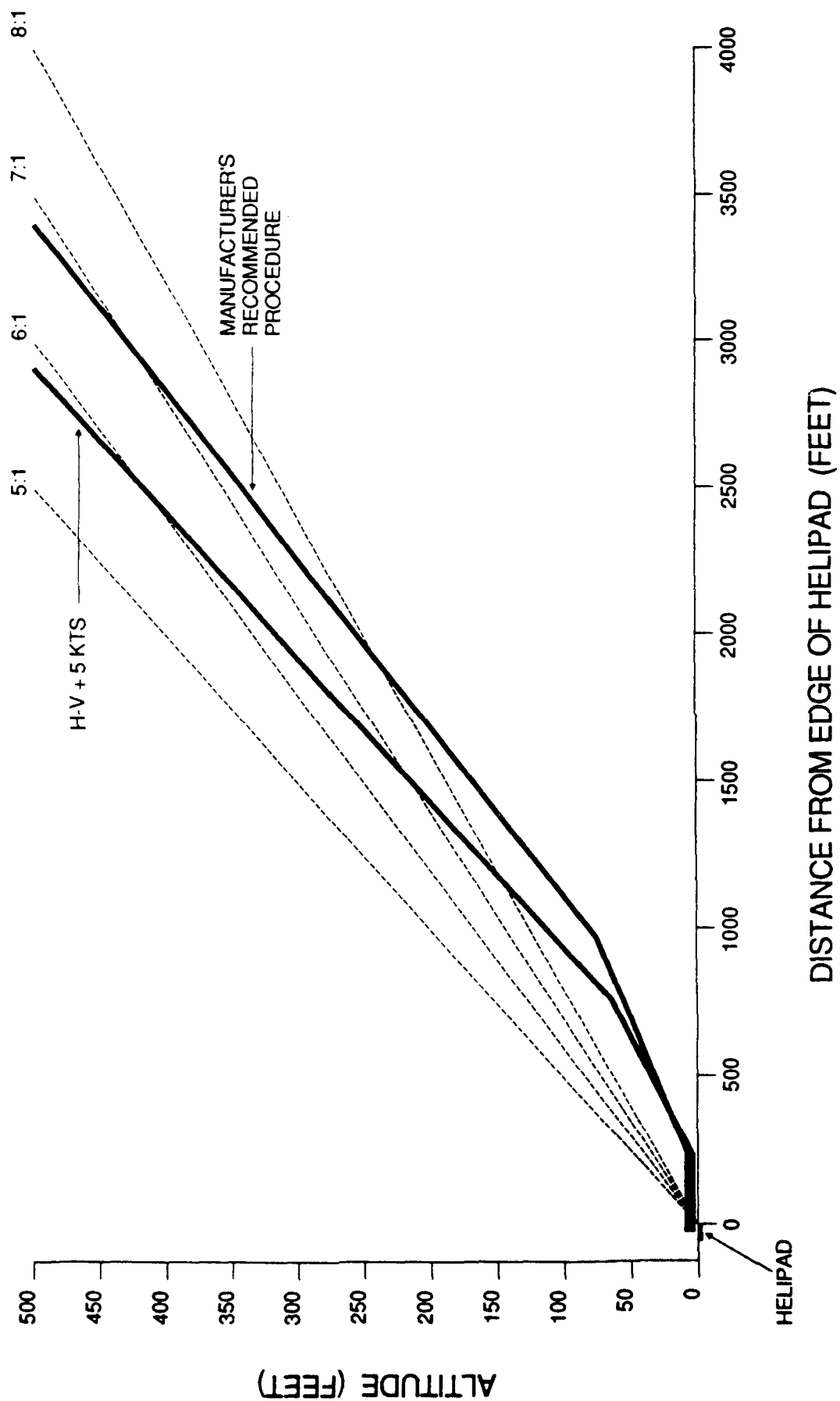
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MAX. G.W., 2000 FEET, STANDARD DAY



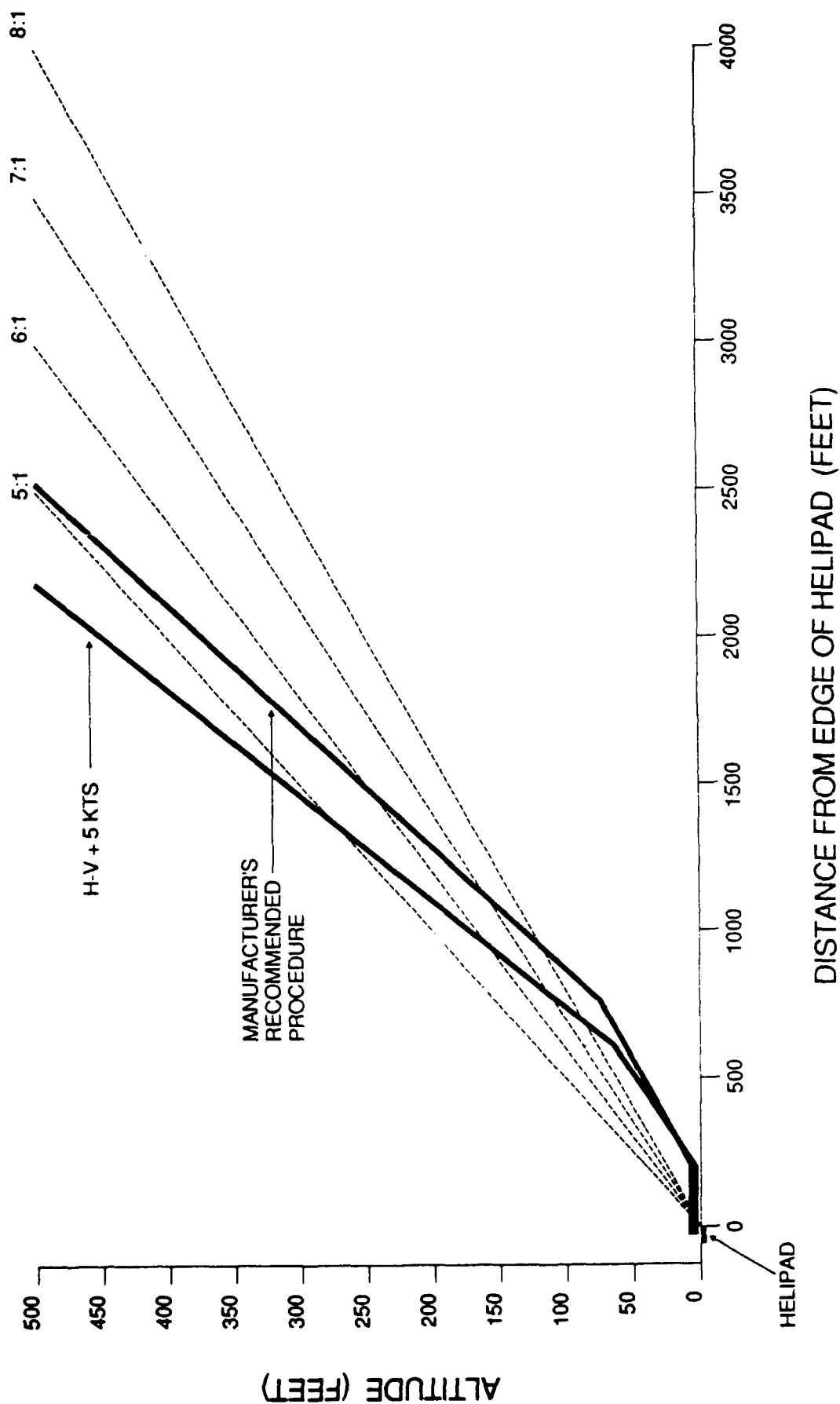
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MAX. G.W., 2000 FEET, HOT DAY



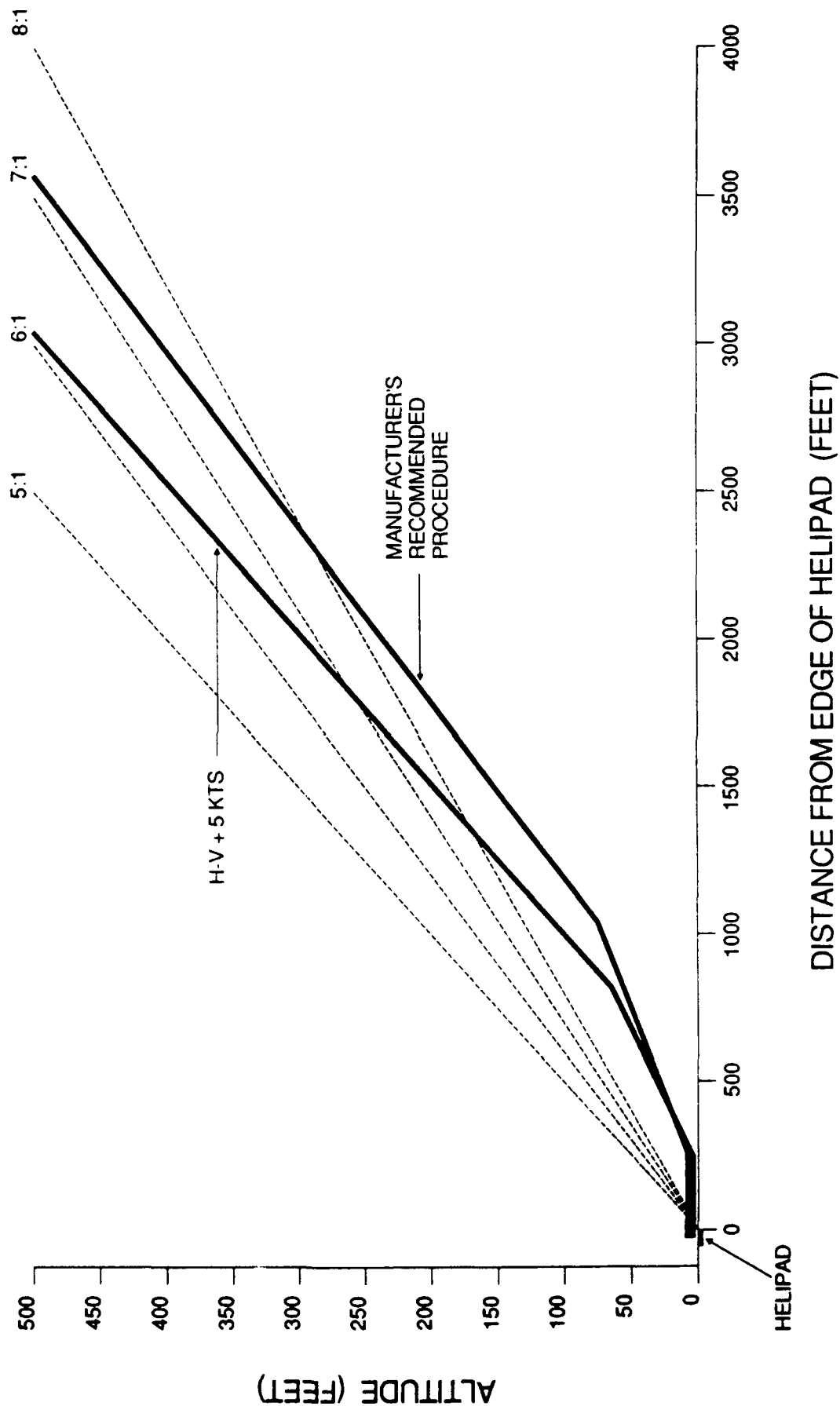
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MAX. G.W., 4000 FEET, STANDARD DAY



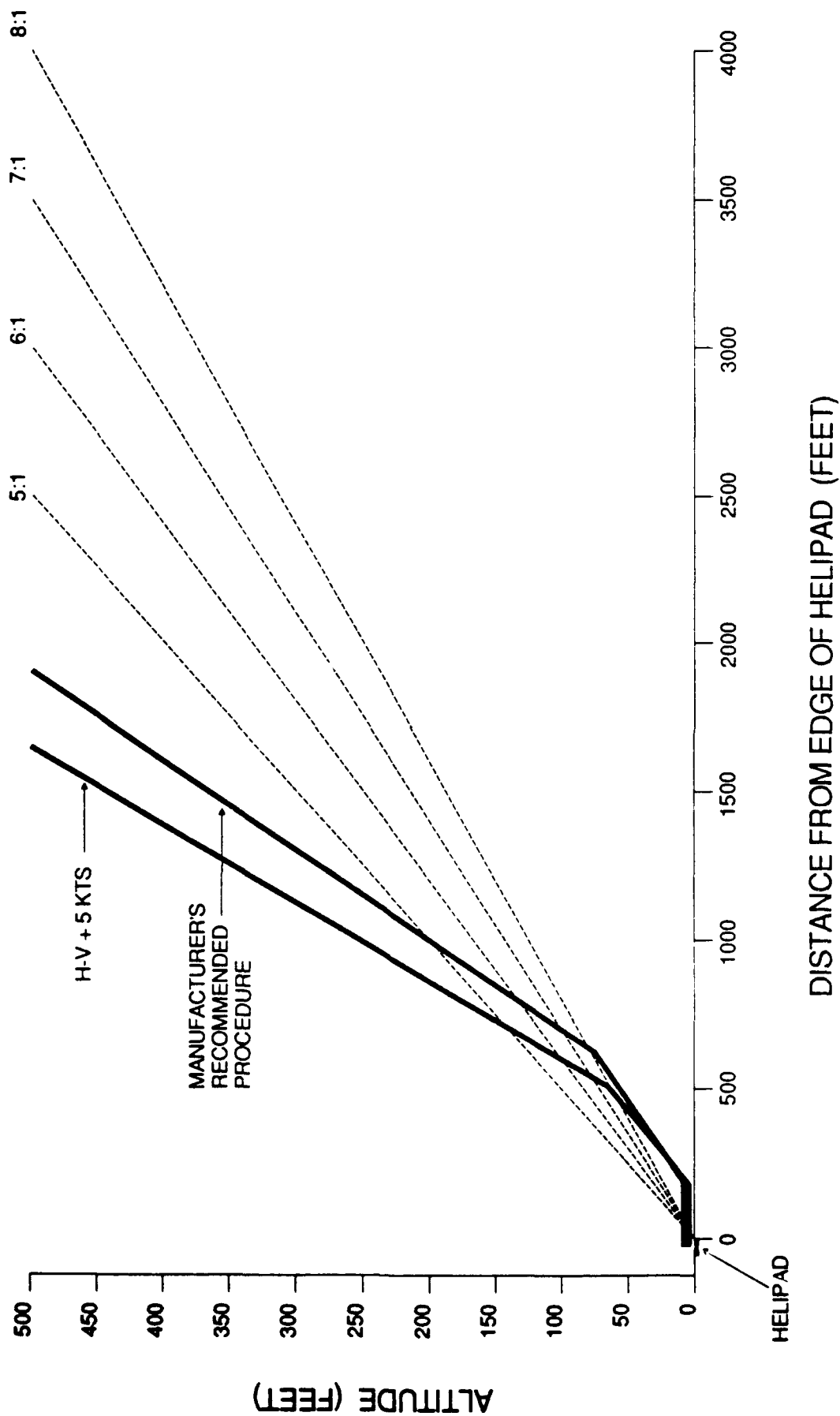
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MAX. G.W., 4000 FEET, HOT DAY



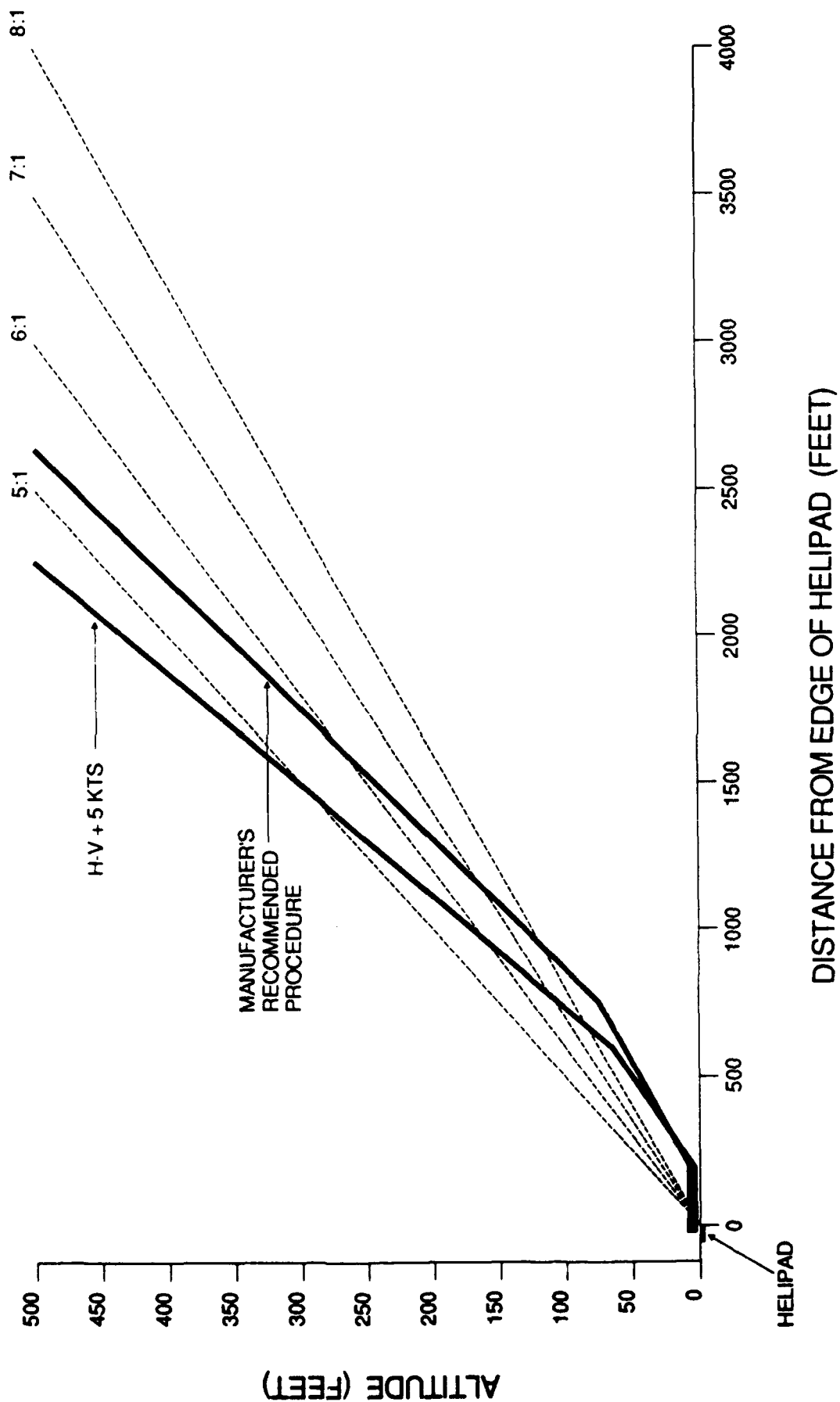
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85% MAX. G.W., SEA LEVEL, STANDARD DAY



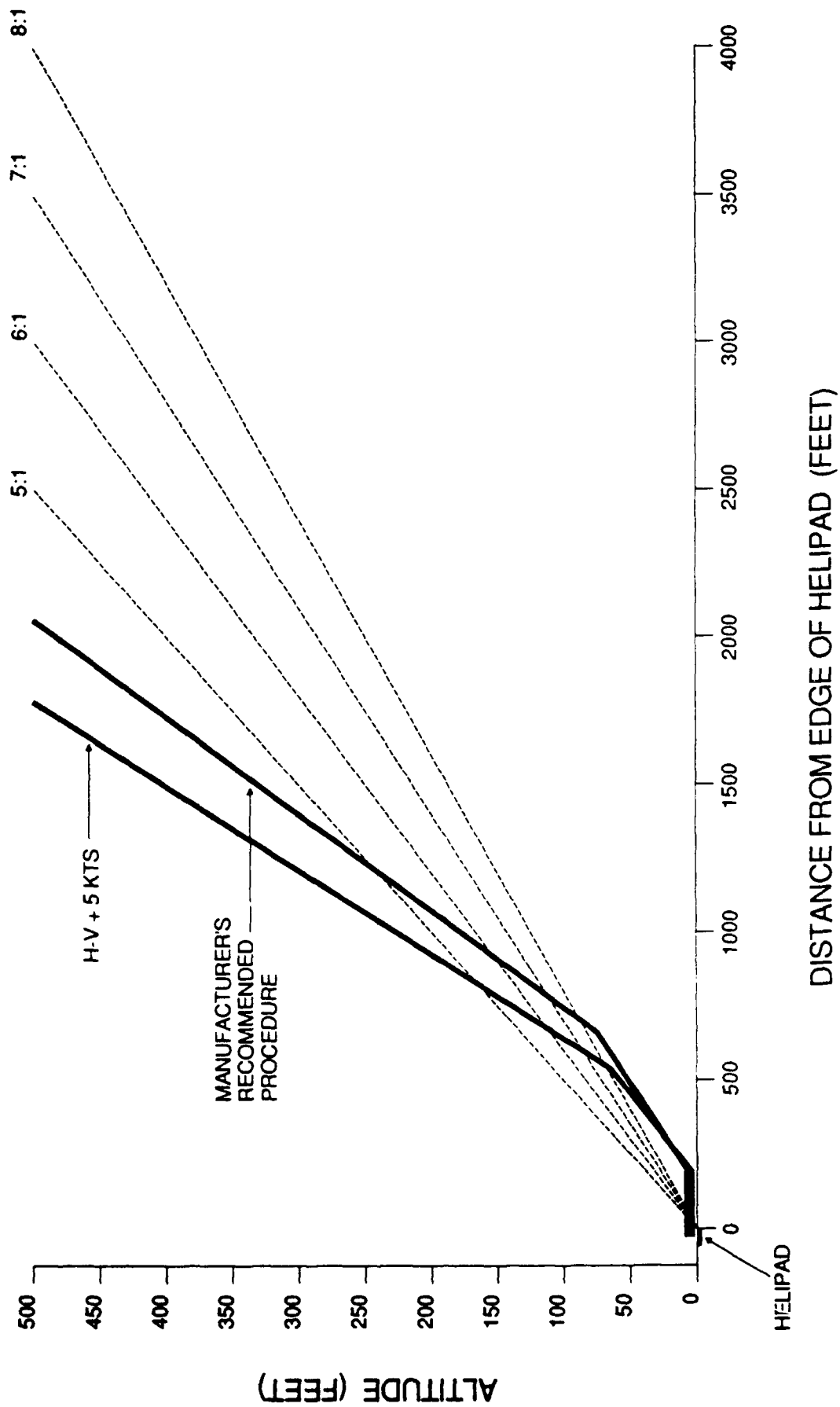
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85% MAX. G.W., SEA LEVEL, HOT DAY



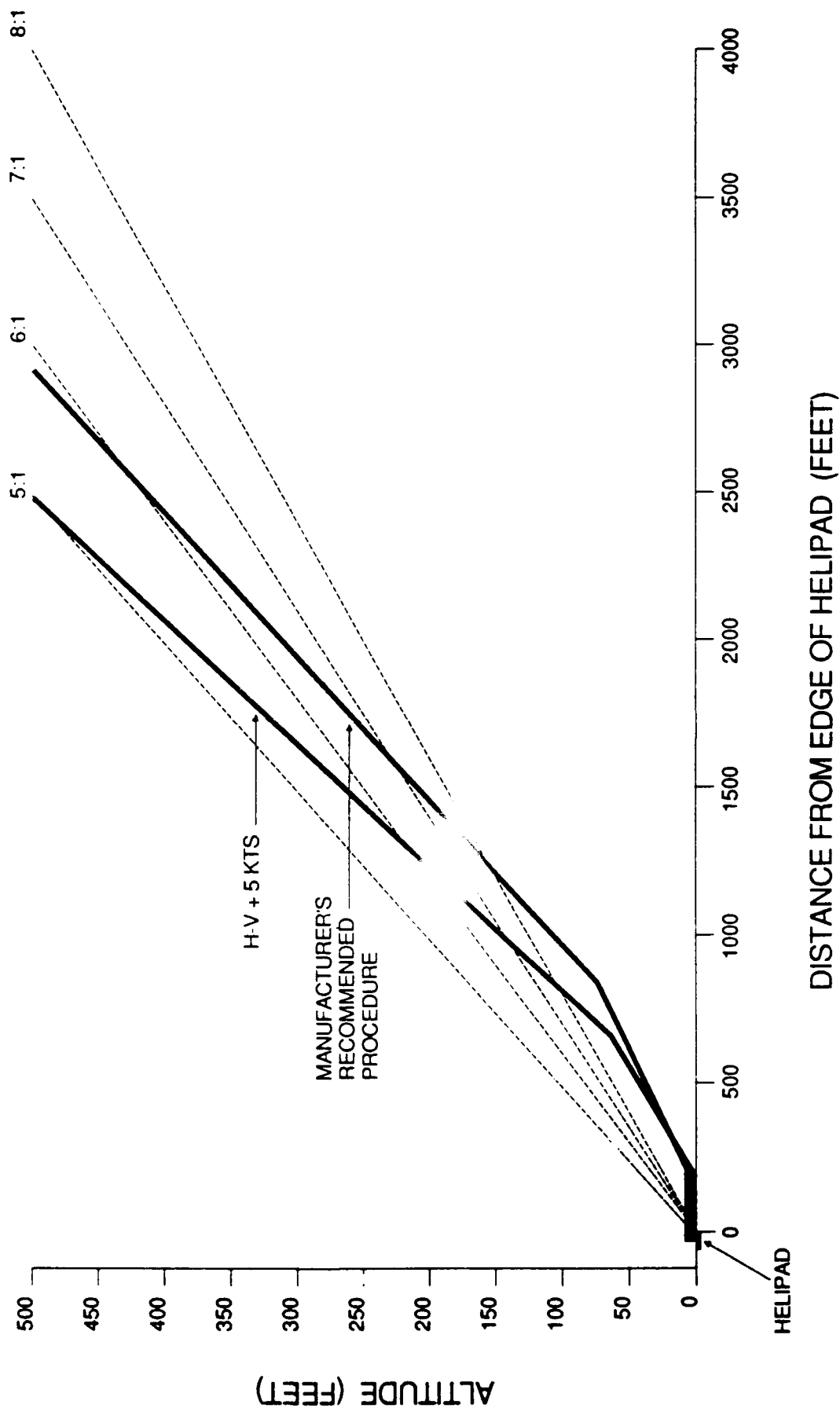
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85% MAX. G.W., 2000 FEET, STANDARD DAY



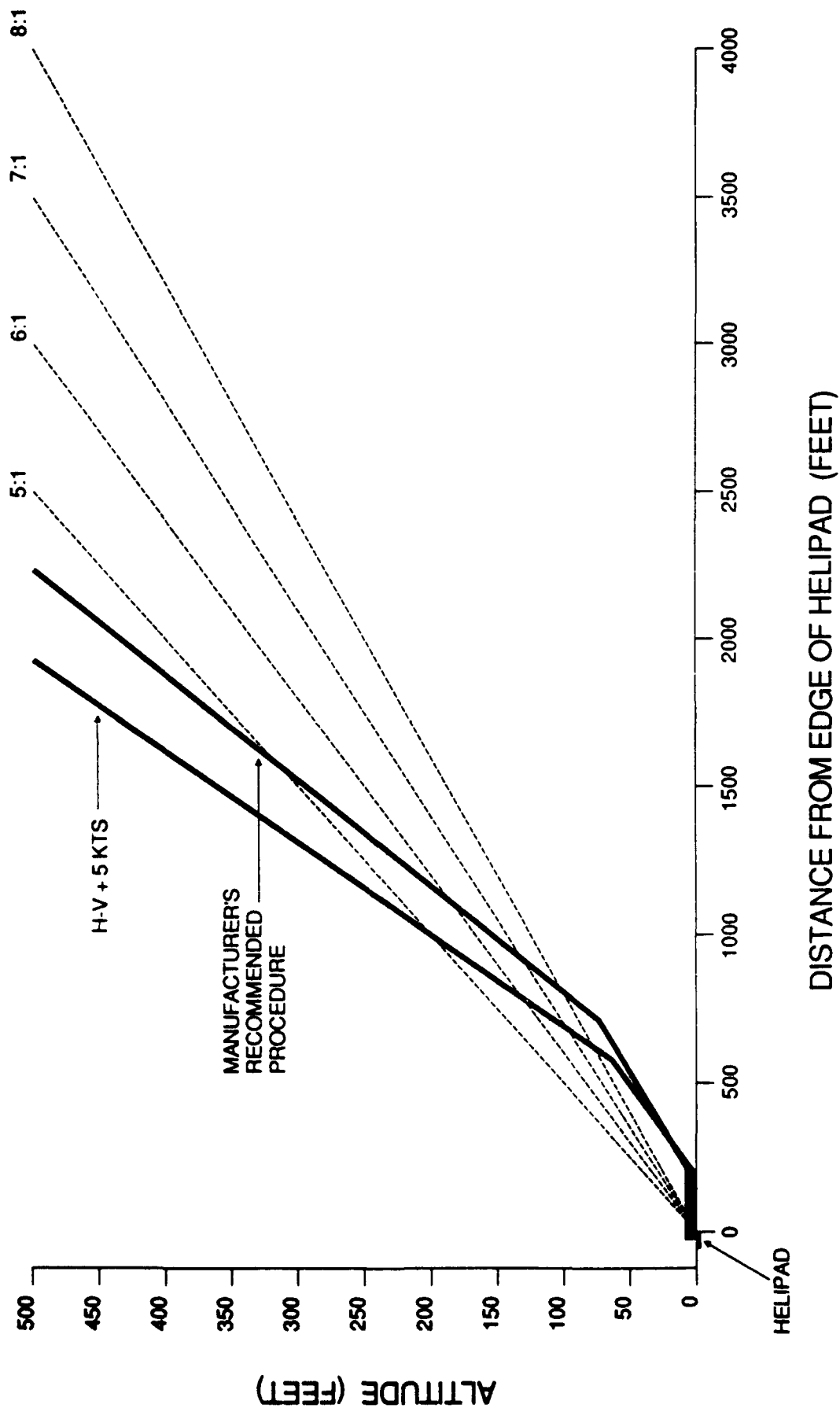
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85% MAX. G.W., 2000 FEET, HOT DAY



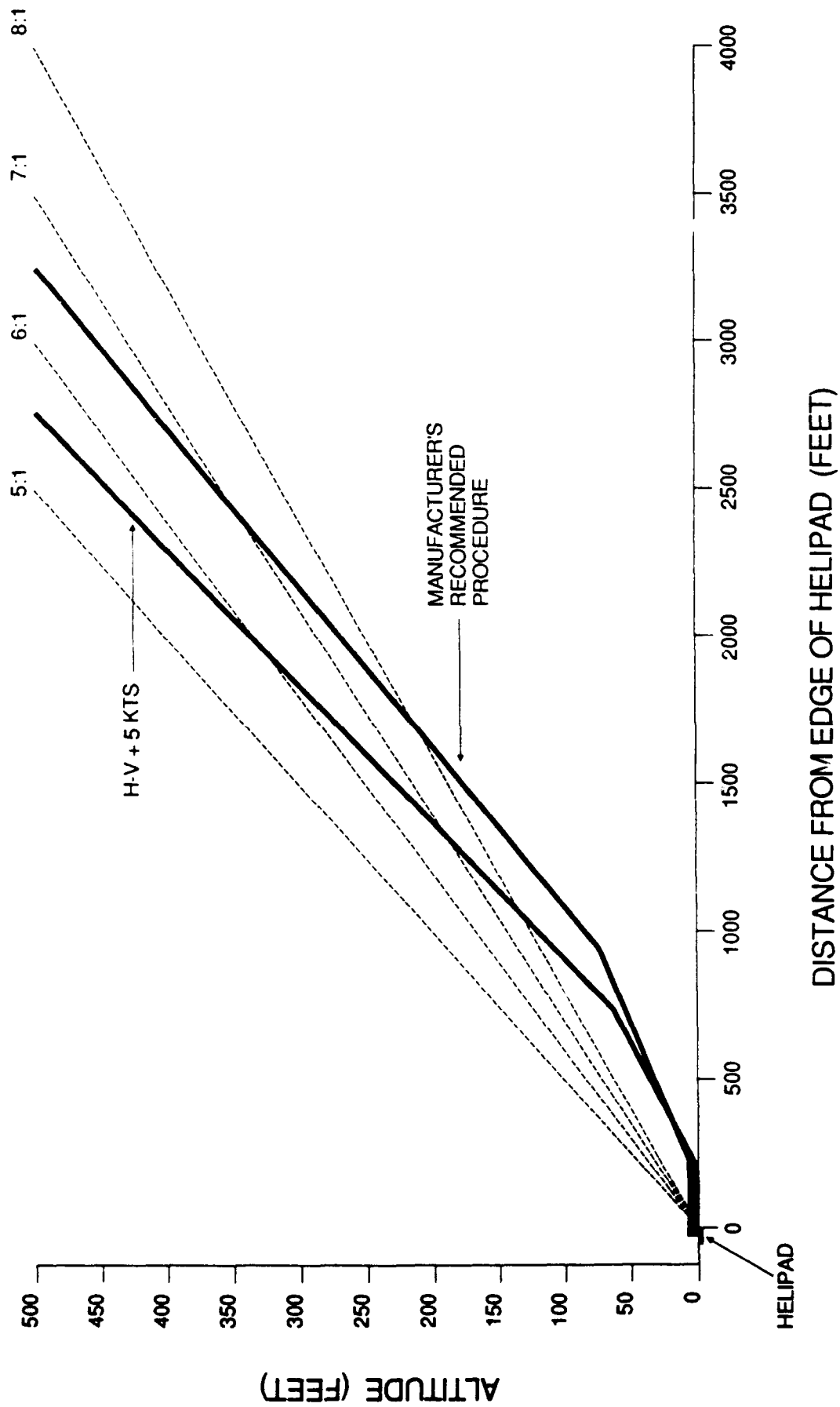
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85% MAX. G.W., 4000 FEET, STANDARD DAY



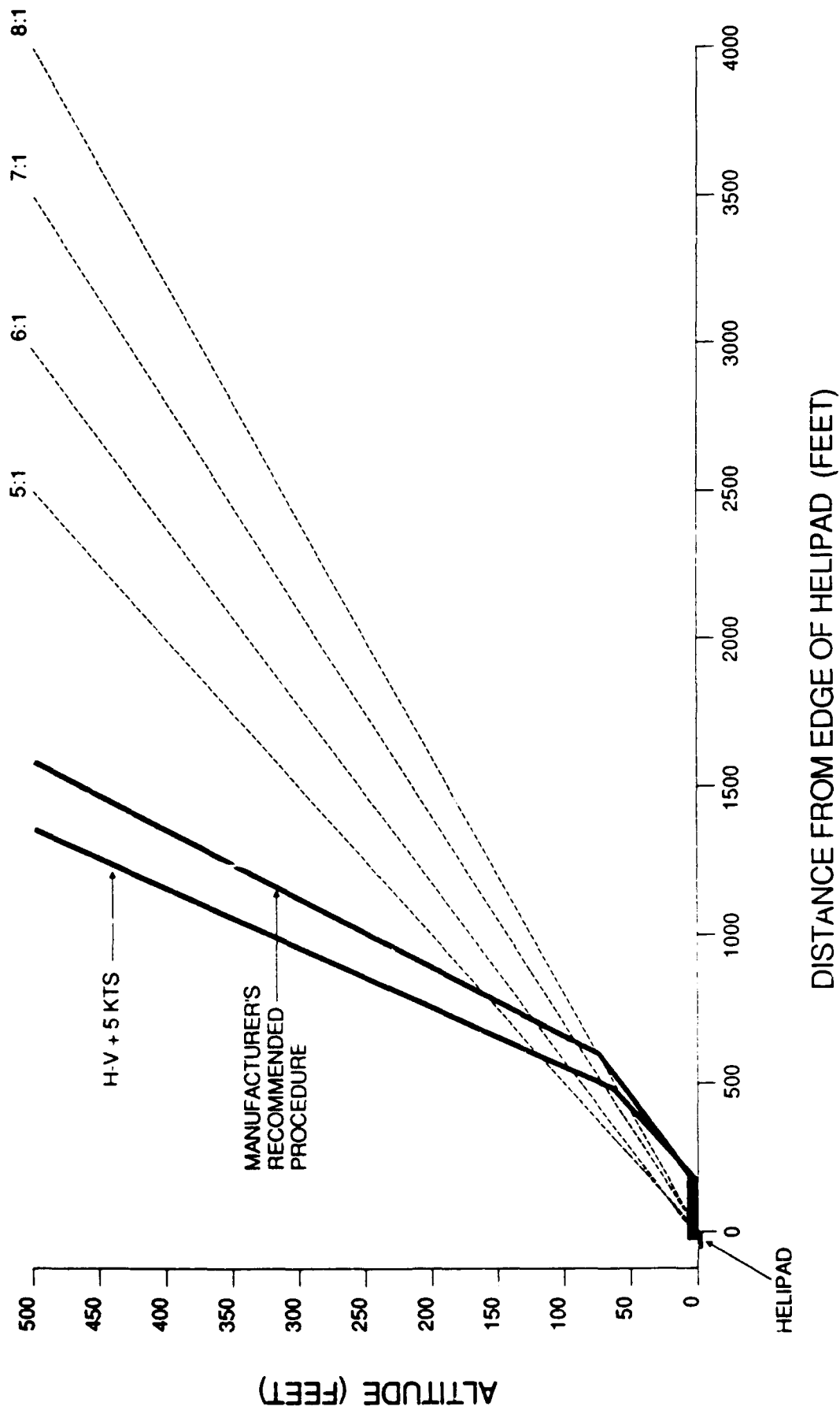
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85% MAX. G.W., 4000 FEET, HOT DAY



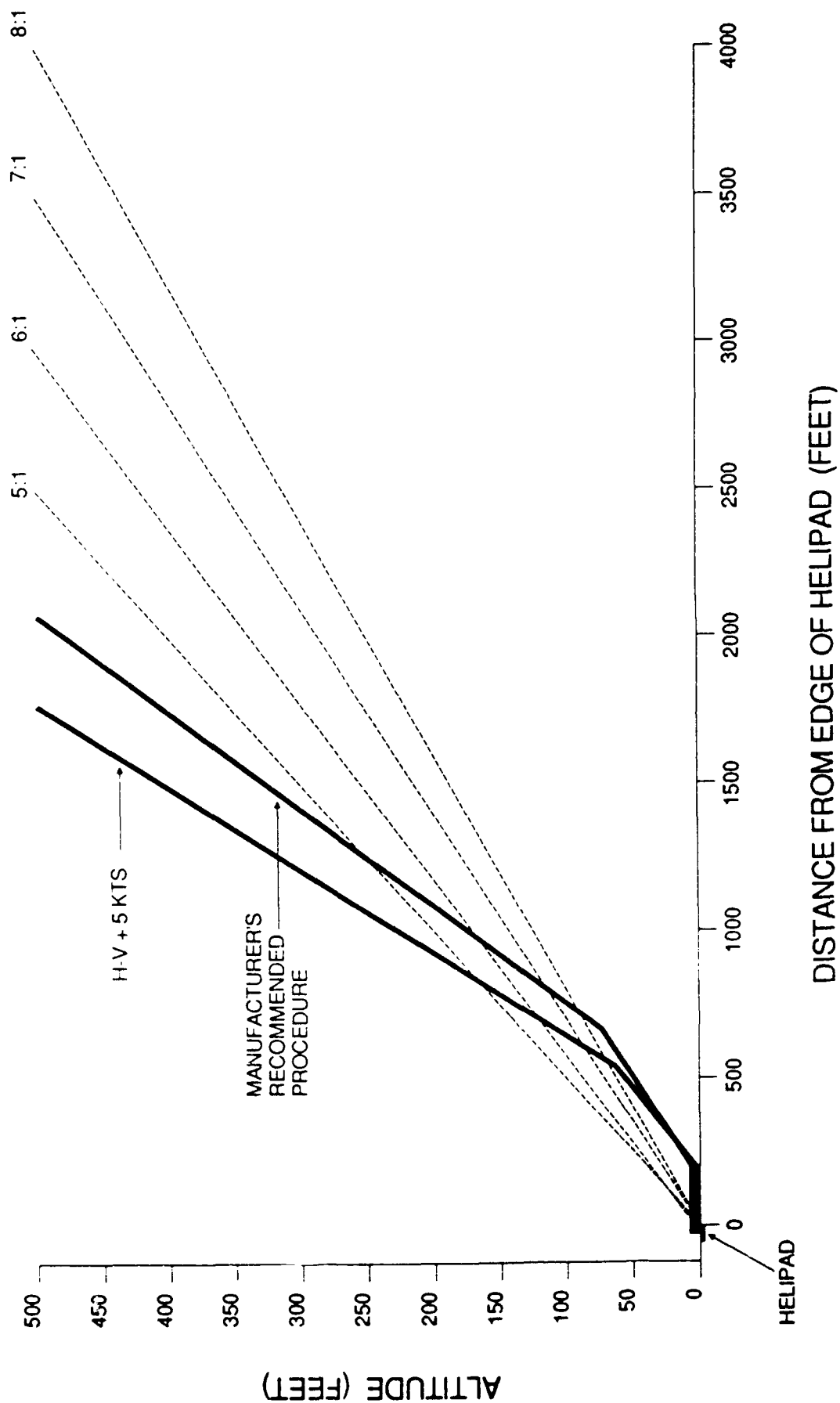
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70% MAX. G.W., SEA LEVEL, STANDARD DAY



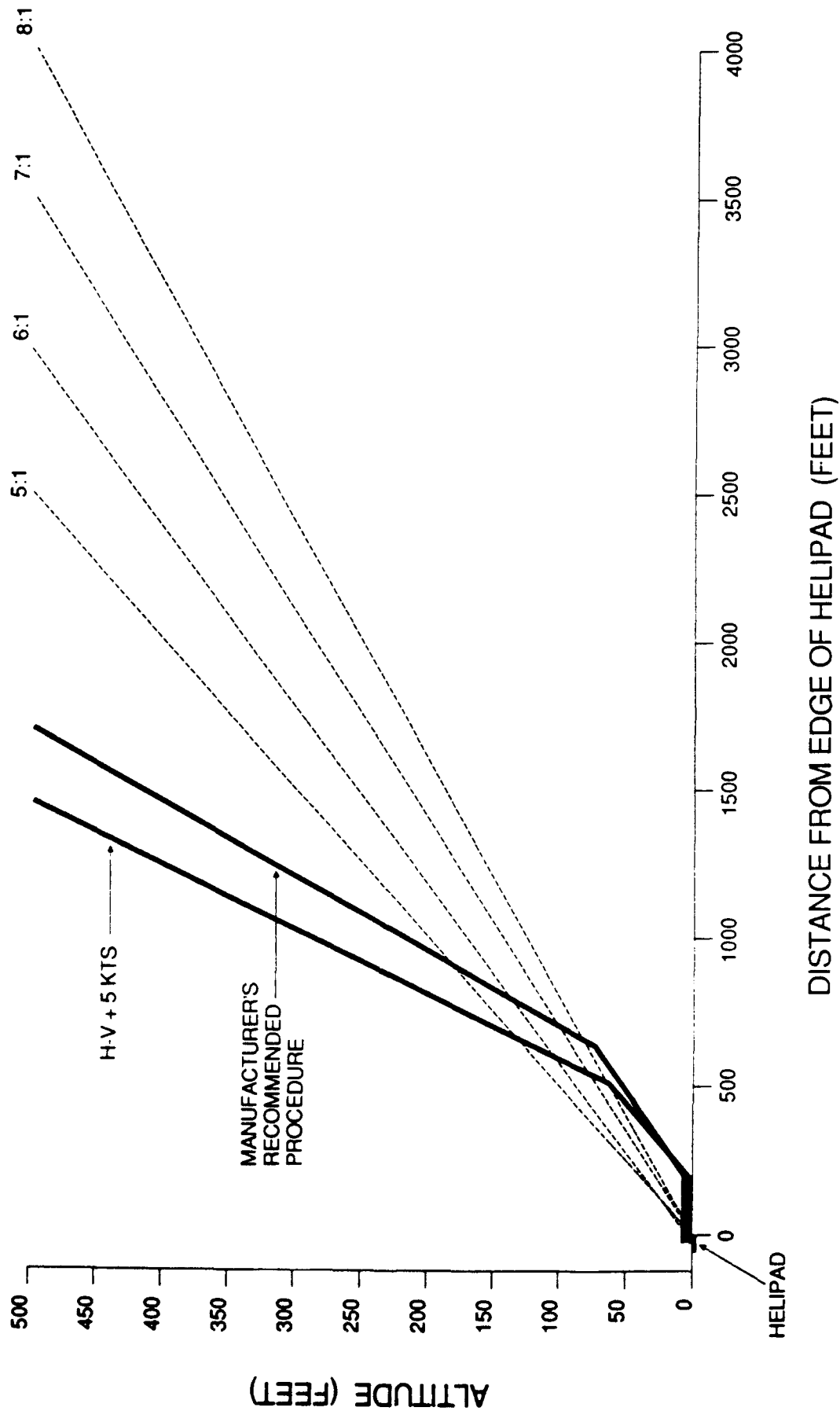
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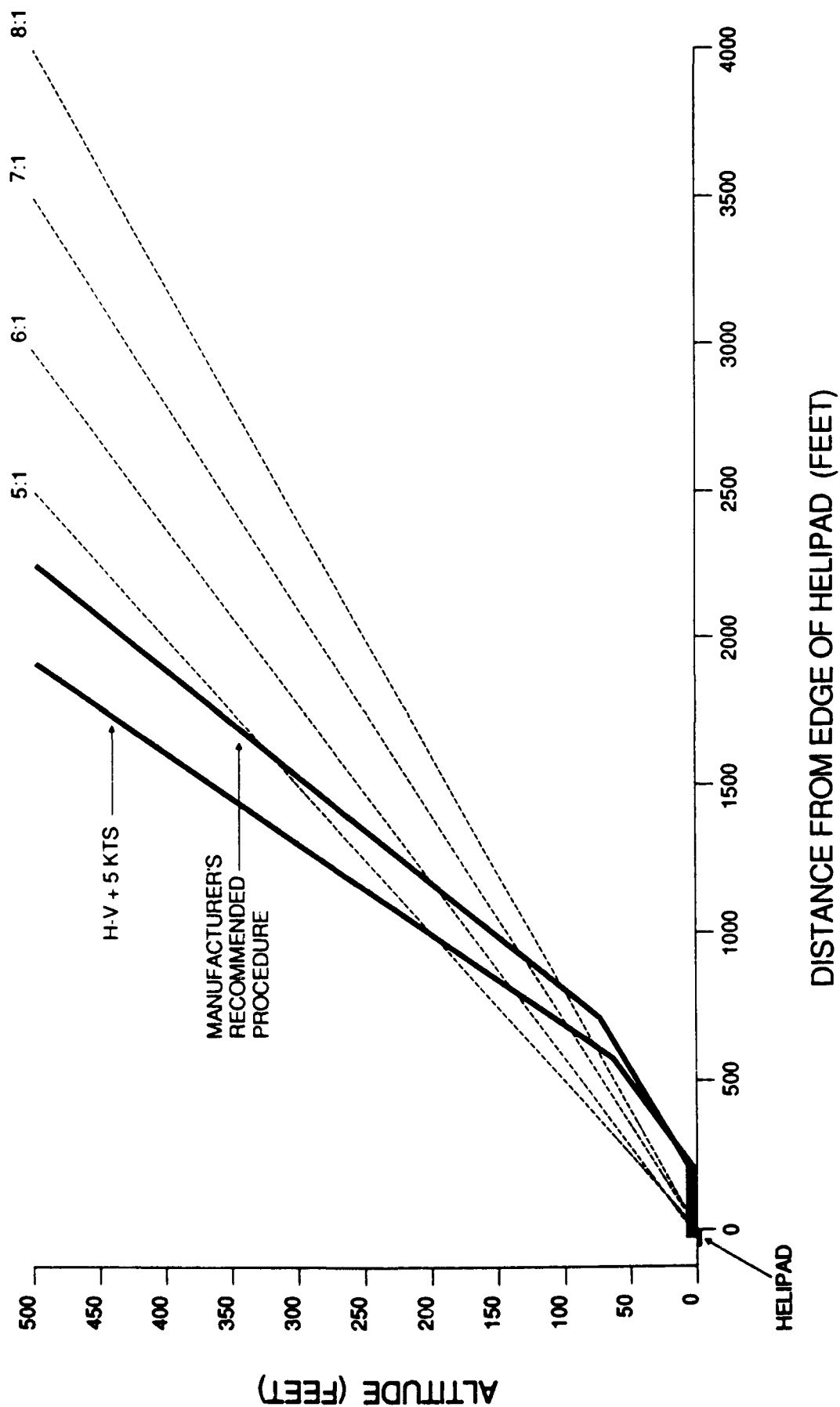
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70% MAX. G.W., 2000 FEET, STANDARD DAY



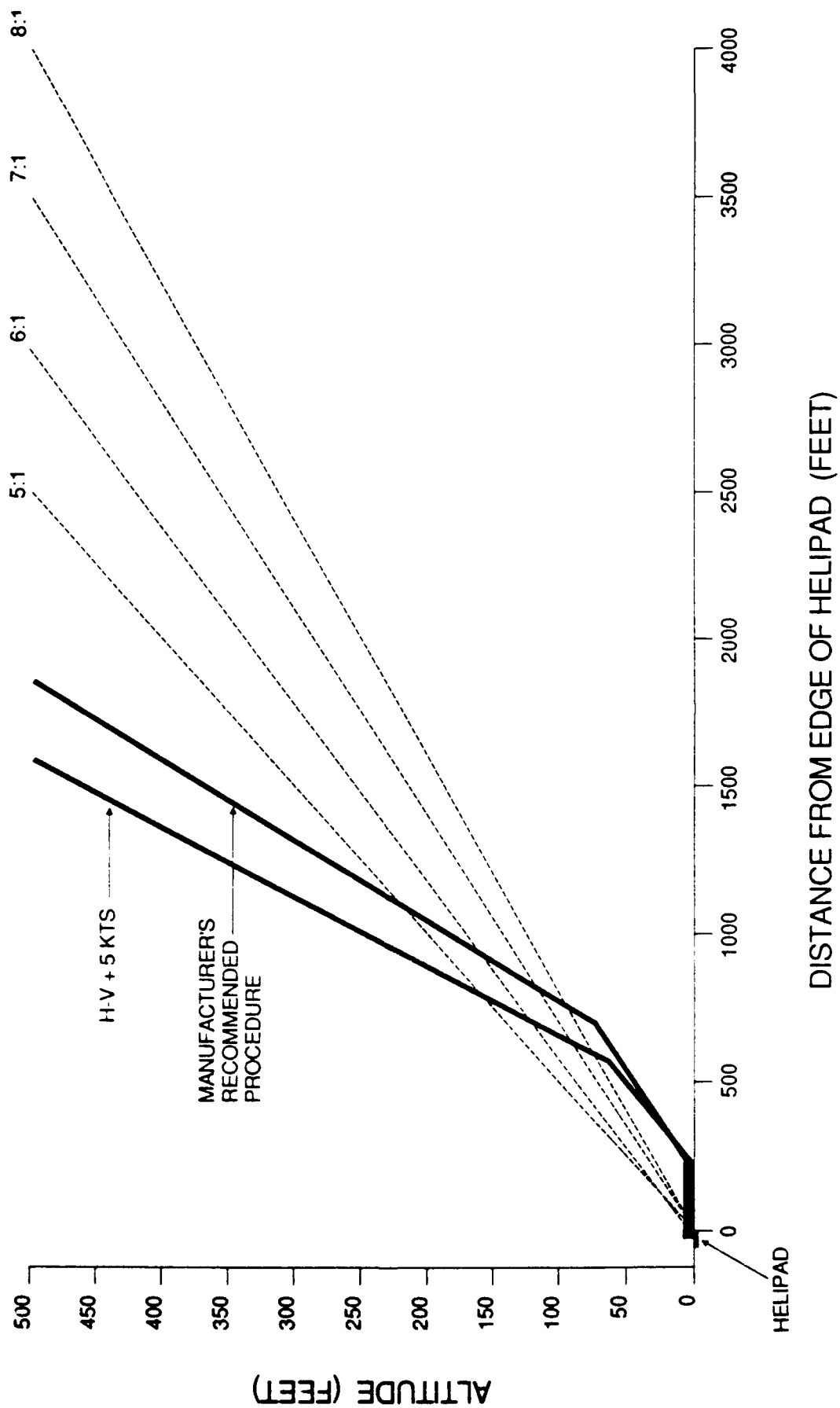
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70% MAX. G.W., 2000 FEET, HOT DAY



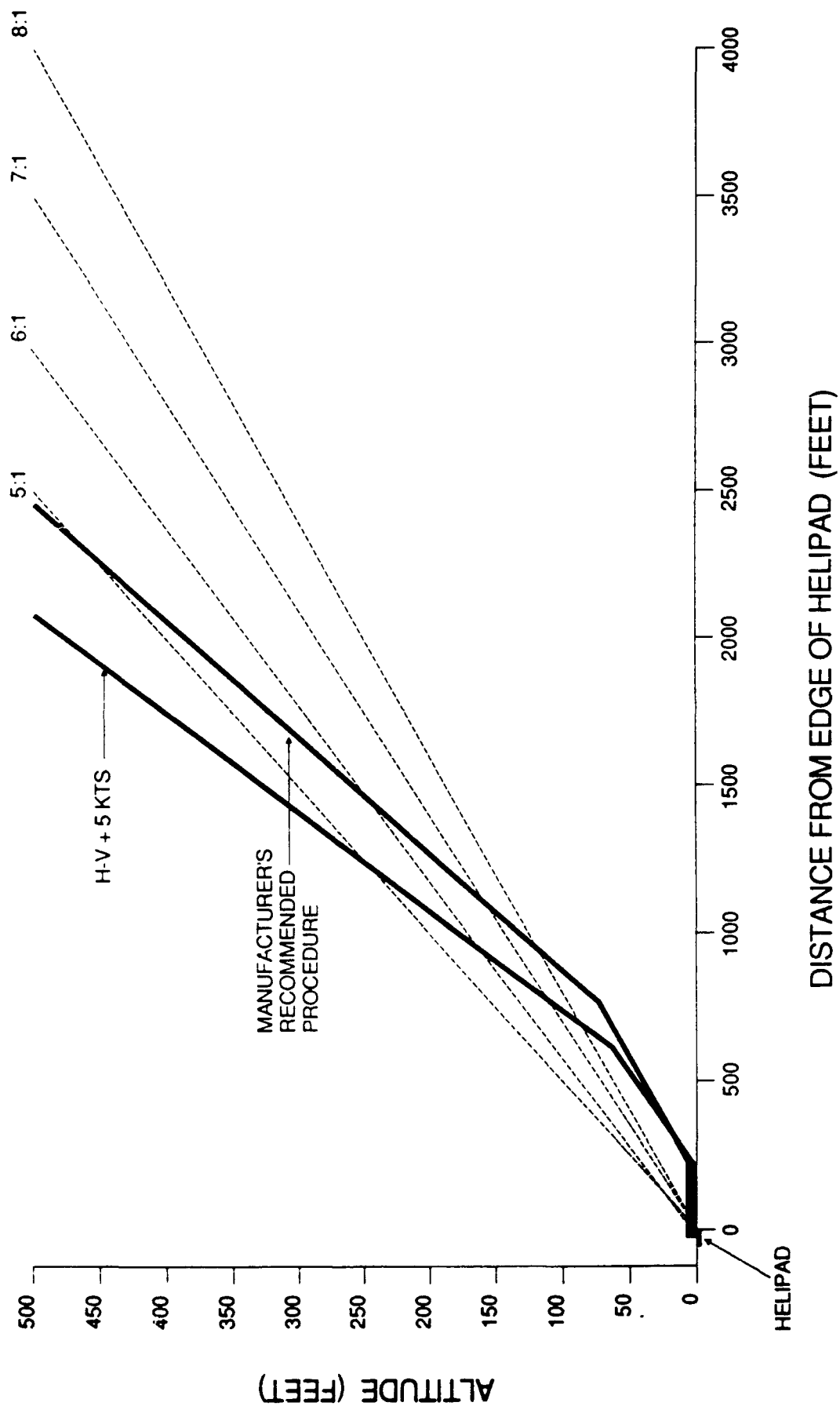
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70% MAX. G.W., 4000 FEET, STANDARD DAY



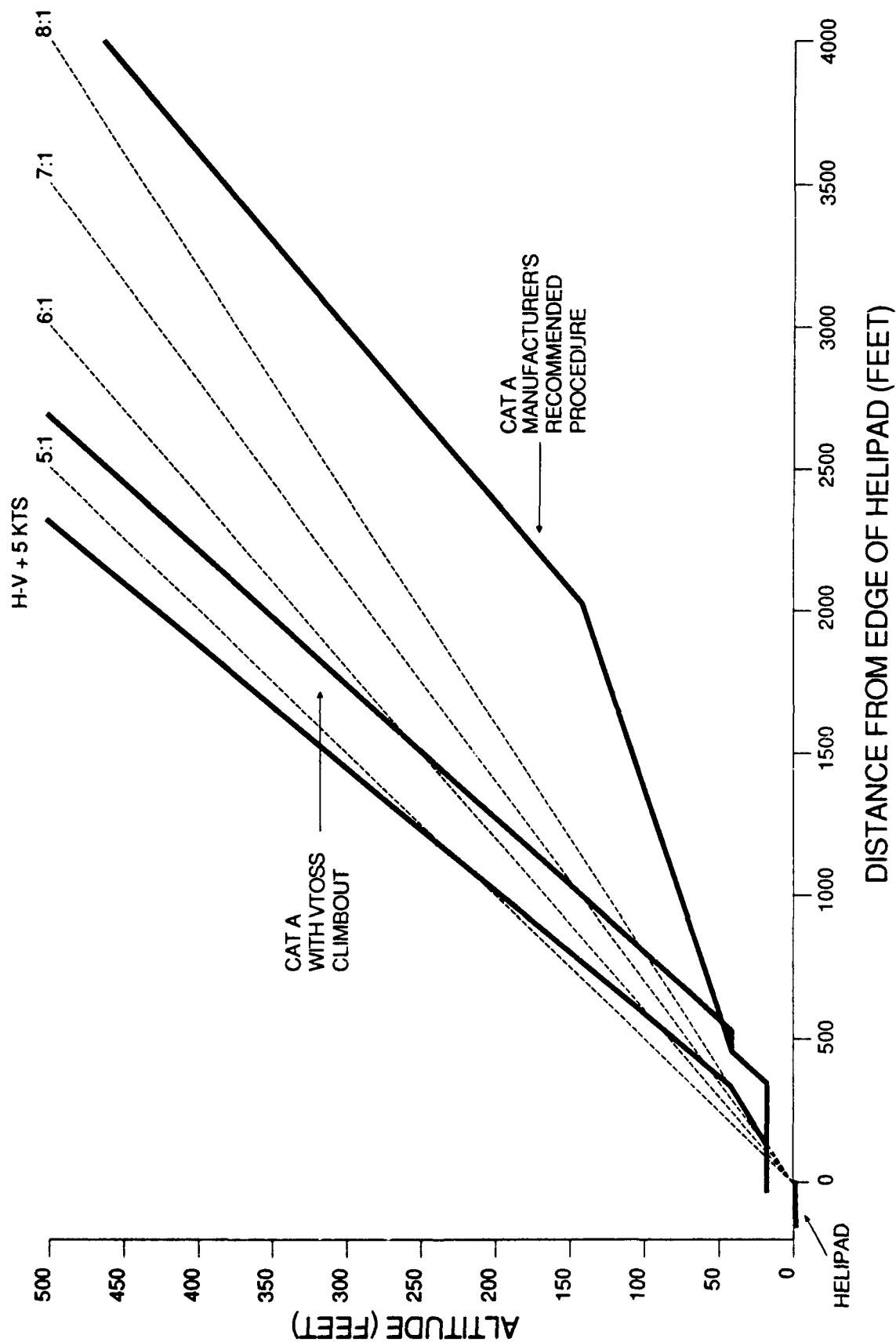
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70% MAX. G.W., 4000 FEET, HOT DAY



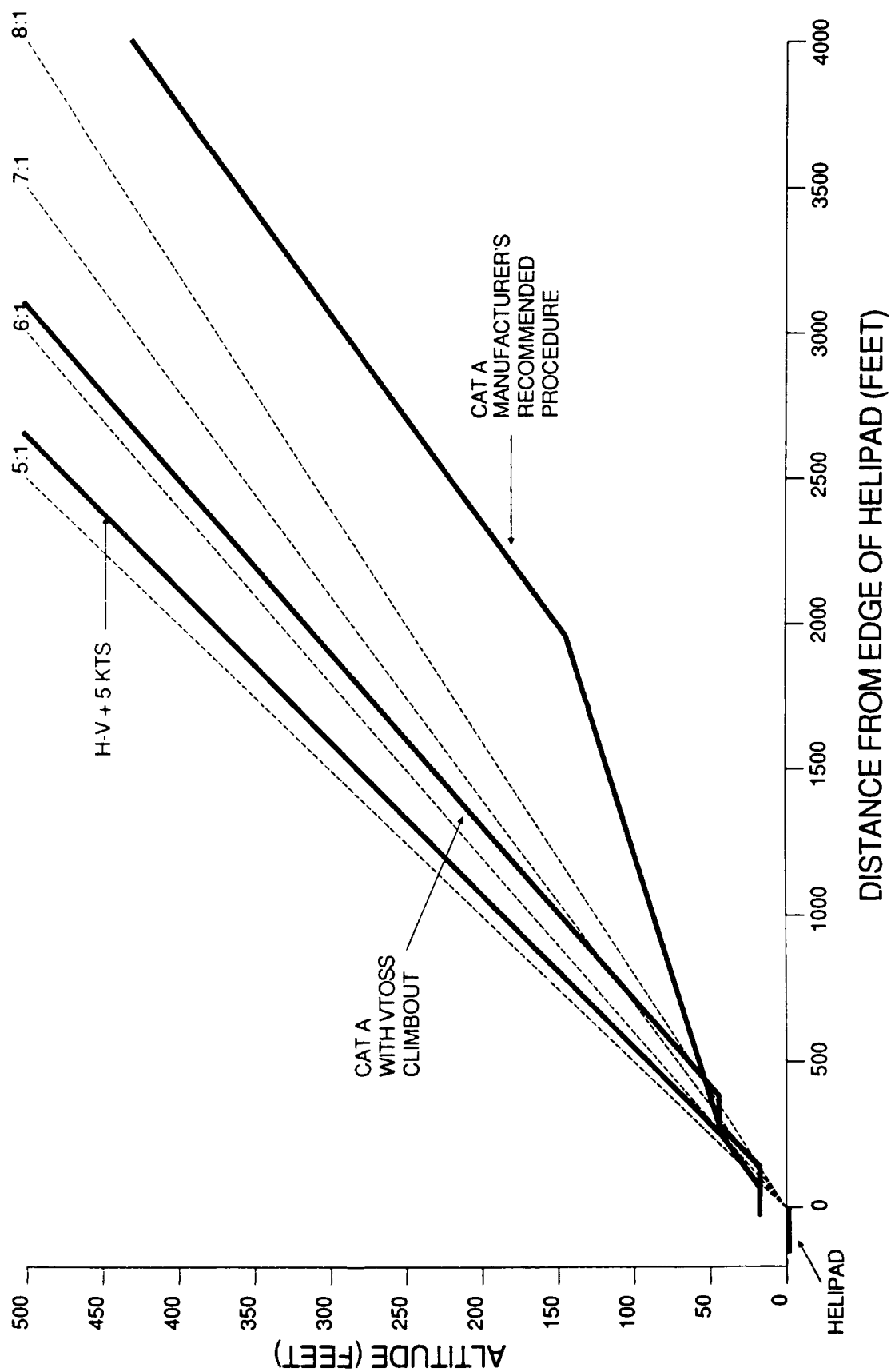
# BV 234 LR DEPARTURE PROFILES

MAX. G.W., SEA LEVEL, STANDARD DAY



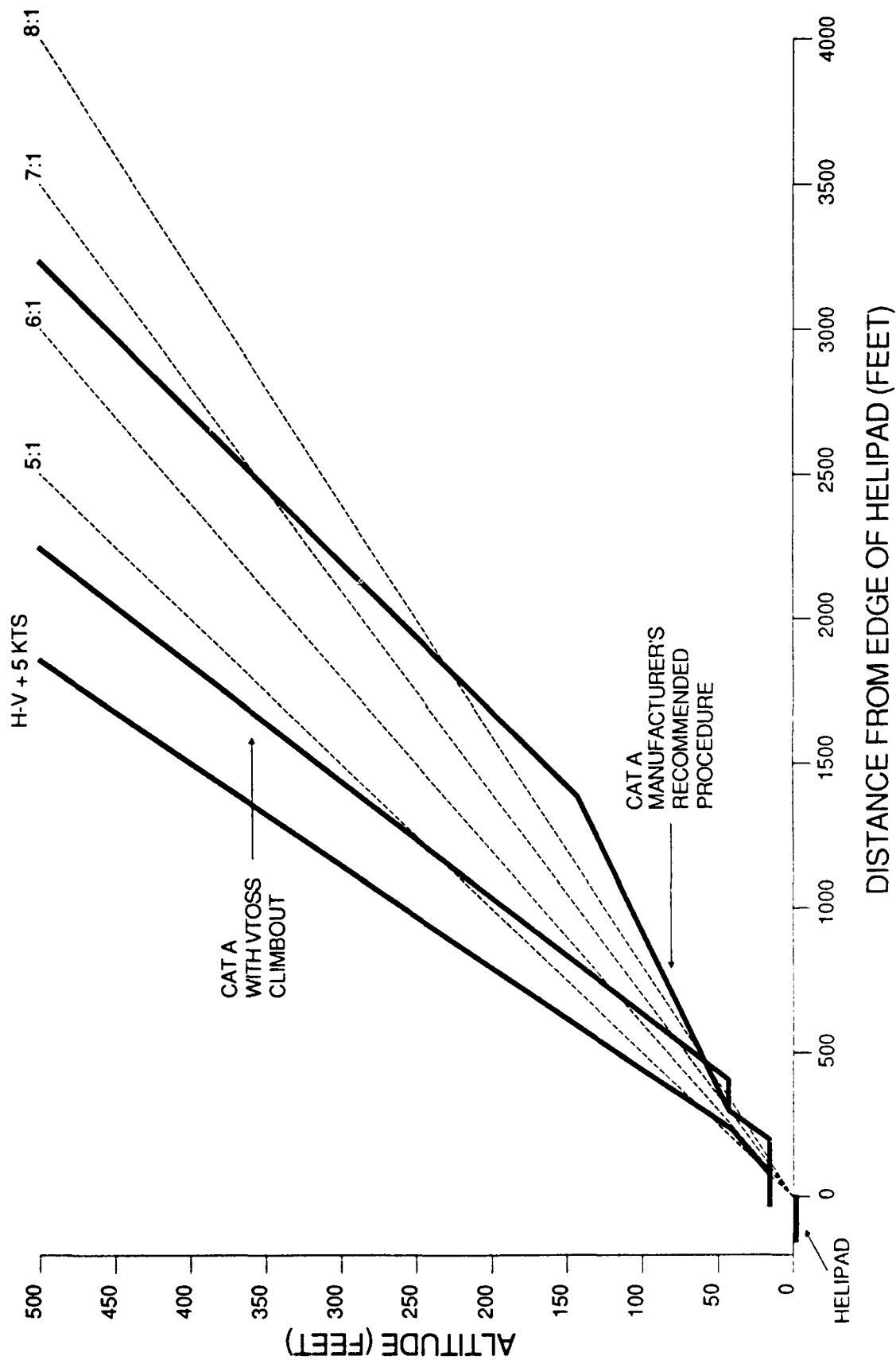
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MAX. G.W., SEA LEVEL, HOT DAY



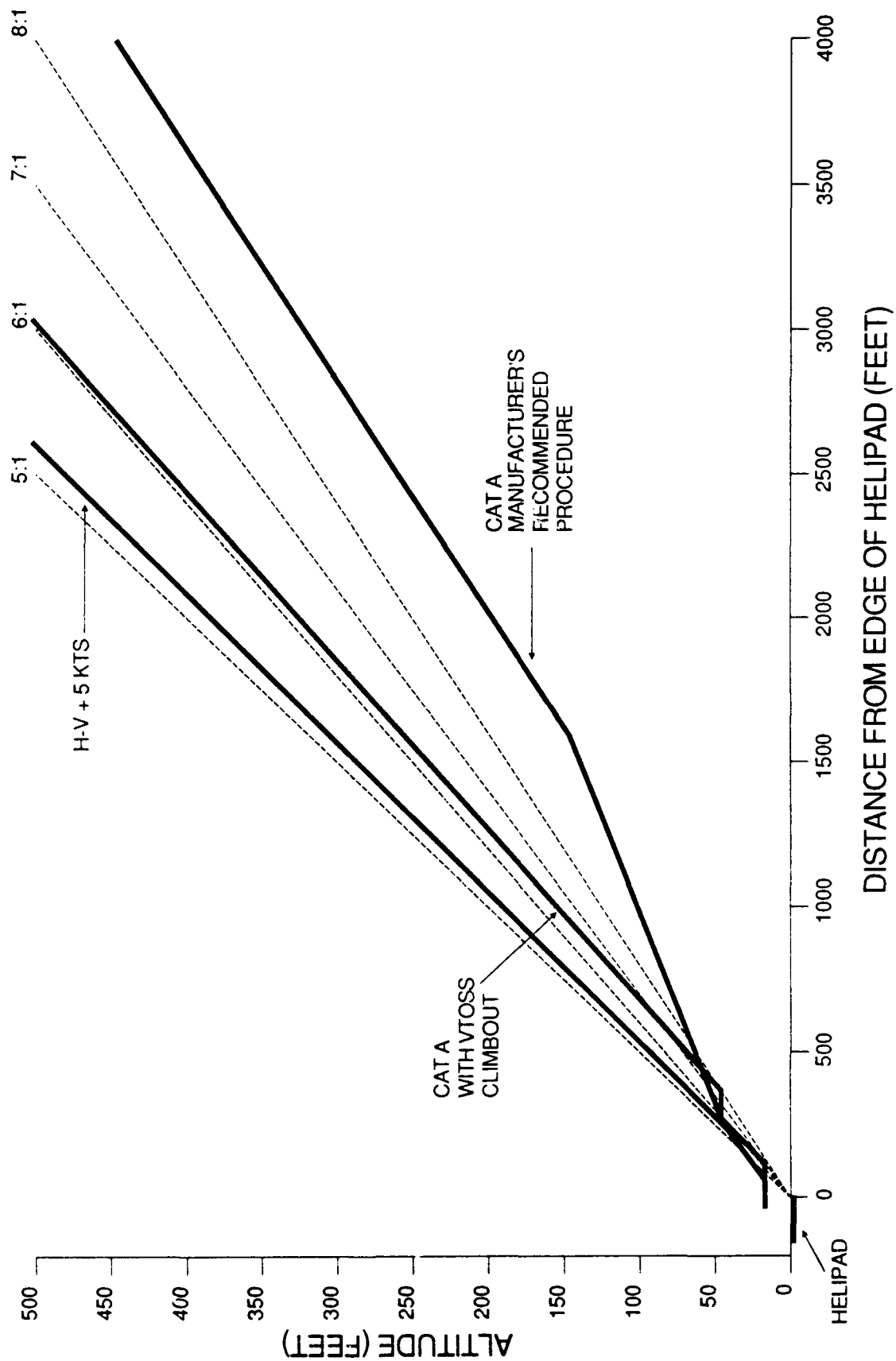
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MAX. G.W., 2000 FEET, STANDARD DAY



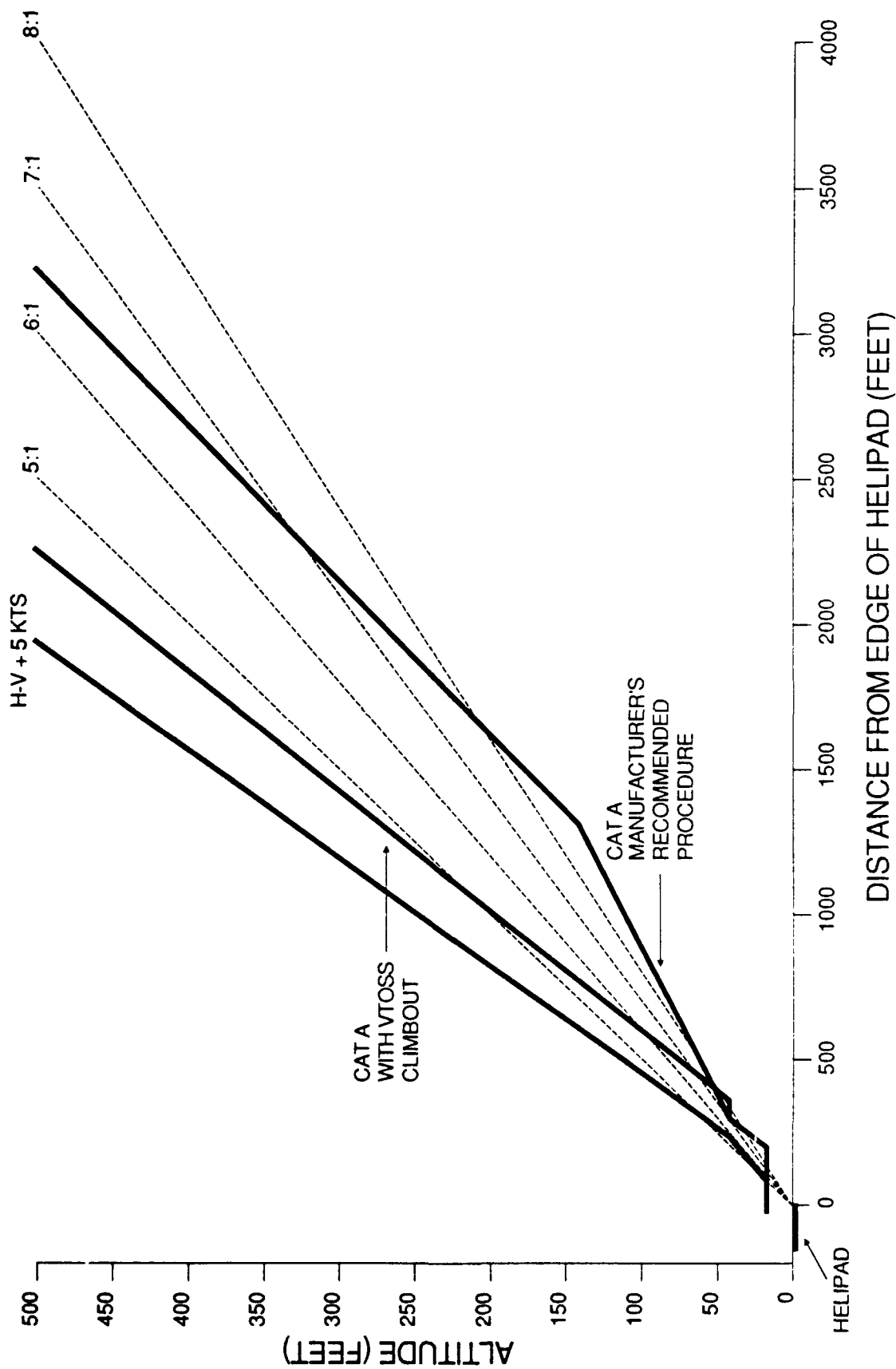
# BV 234 LR DEPARTURE PROFILES

MAX. G.W., 2000 FEET, HOT DAY



# BV 234 LR DEPARTURE PROFILES

MAX. G.W., 4000 FEET, STANDARD DAY

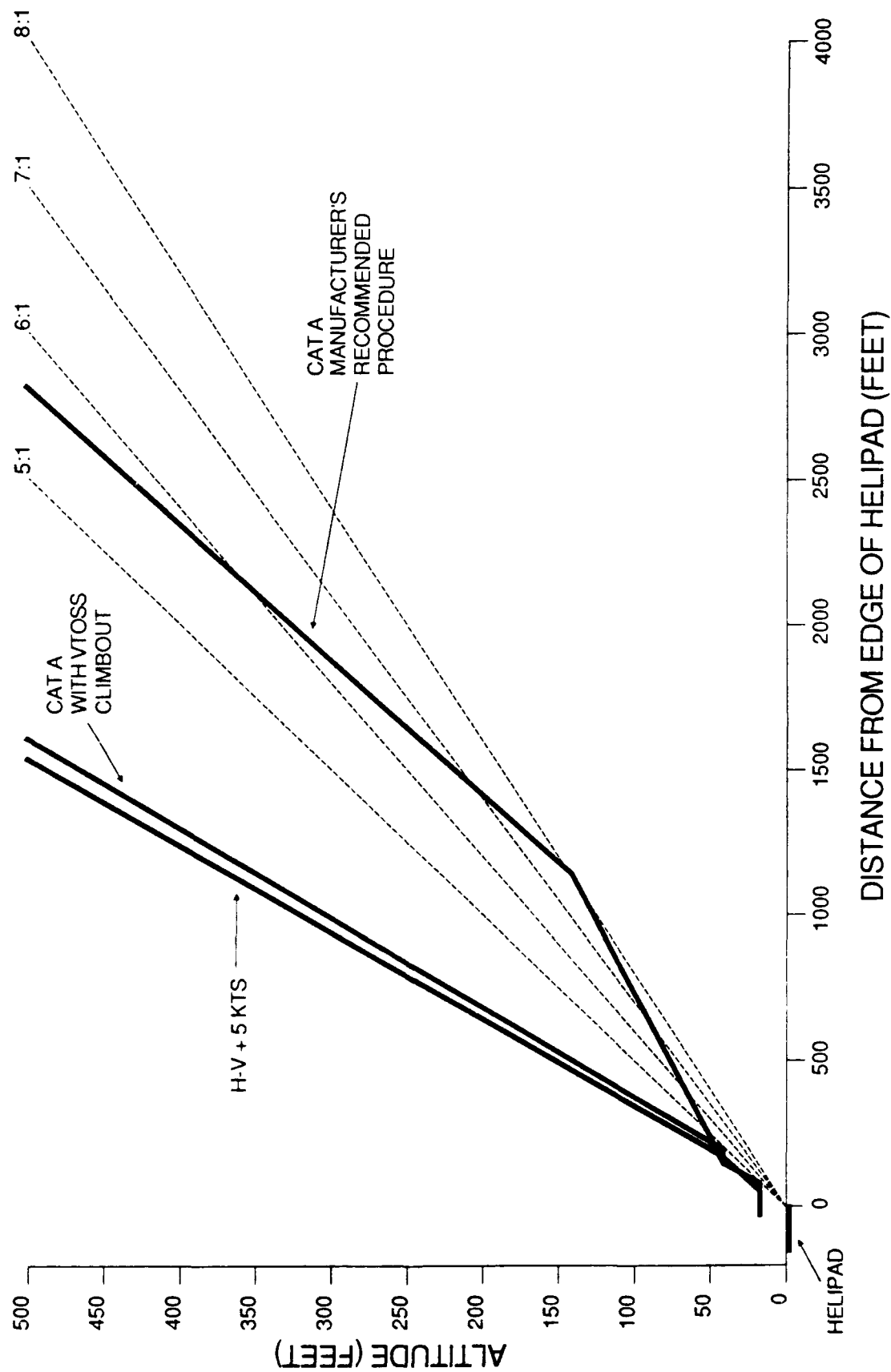


**MAXIMUM G.W., 4000 FEET, HOT DAY**

The maximum allowable takeoff weight is below the 85% max gross weight limit and therefore a profile was not created at this weight.

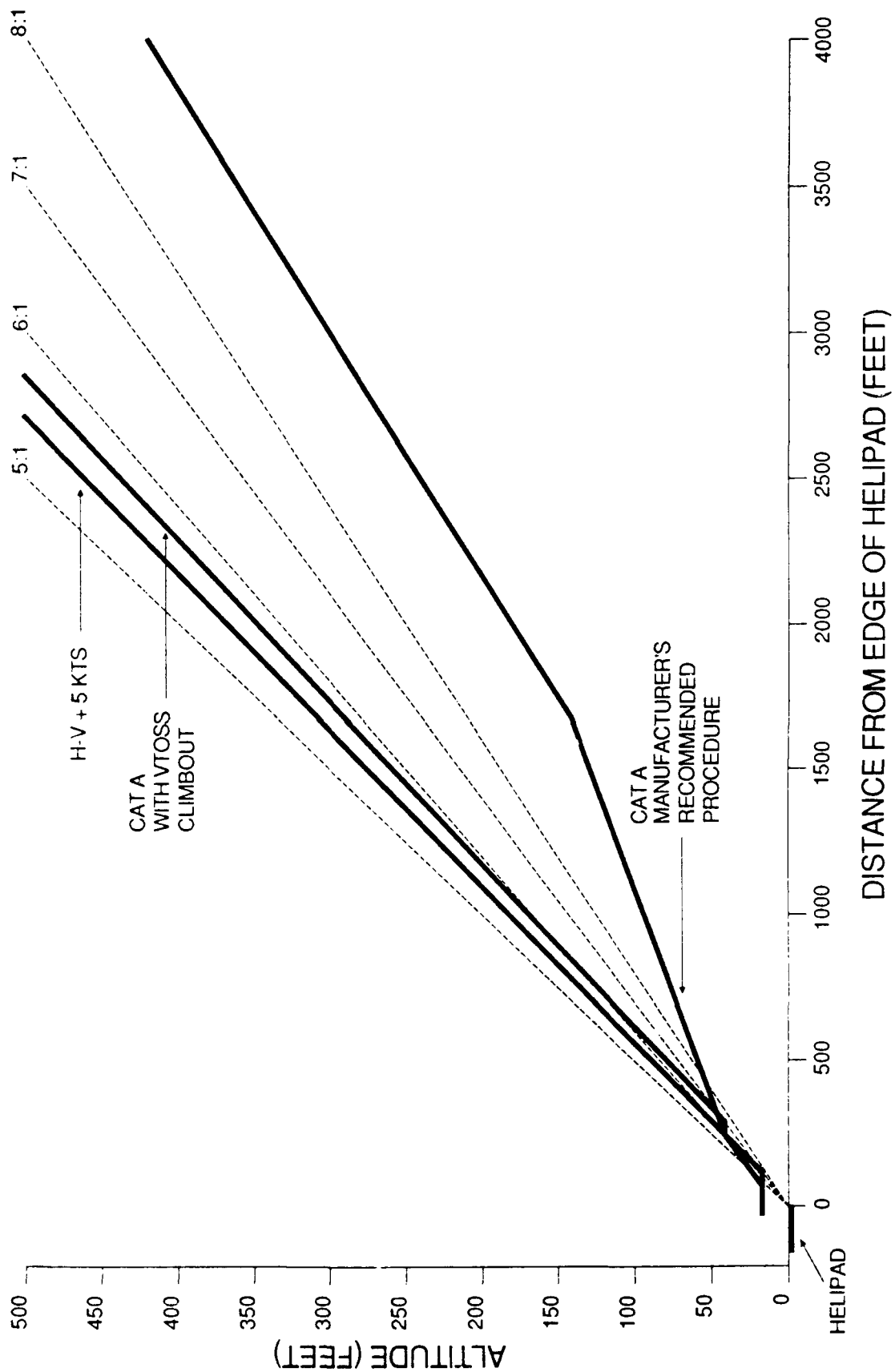
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85% MAX G.W., SEA LEVEL, STANDARD DAY



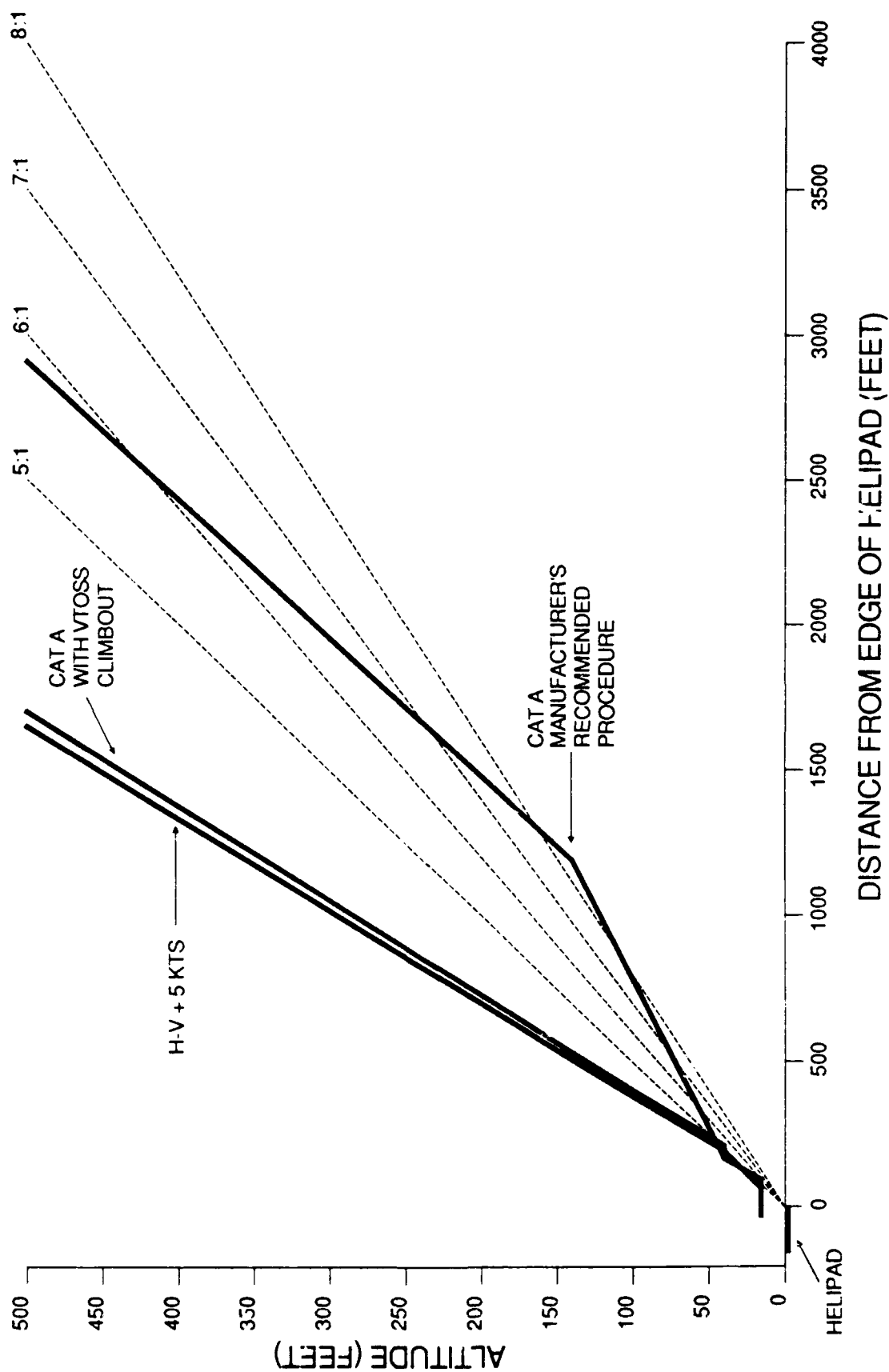
# BV 234 LR DEPARTURE PROFILES

85% MAX. G.W., SEA LEVEL, HOT DAY



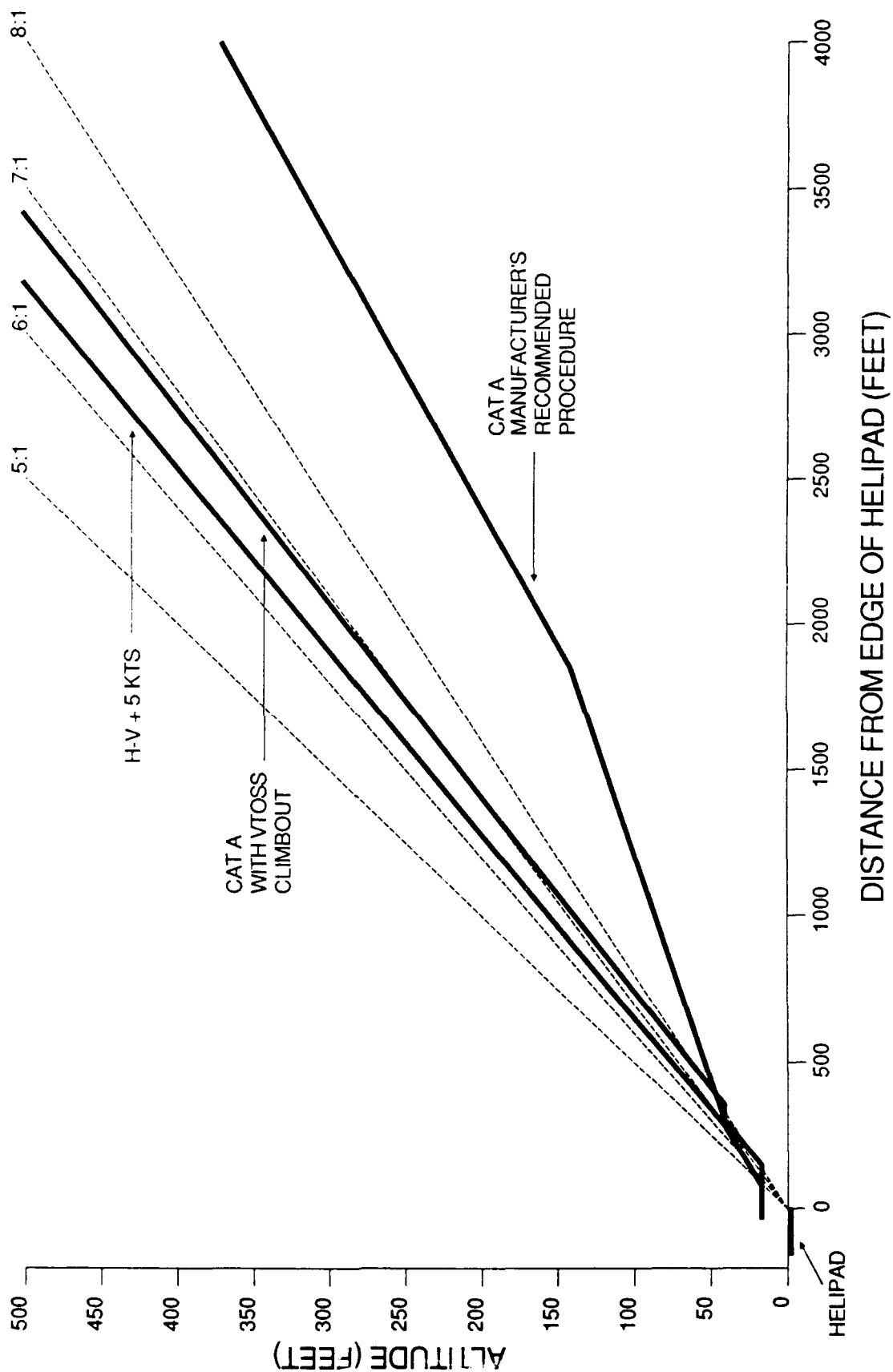
# BV 234 LR DEPARTURE PROFILES

85% MAX G.W., 2000 FEET, STANDARD DAY



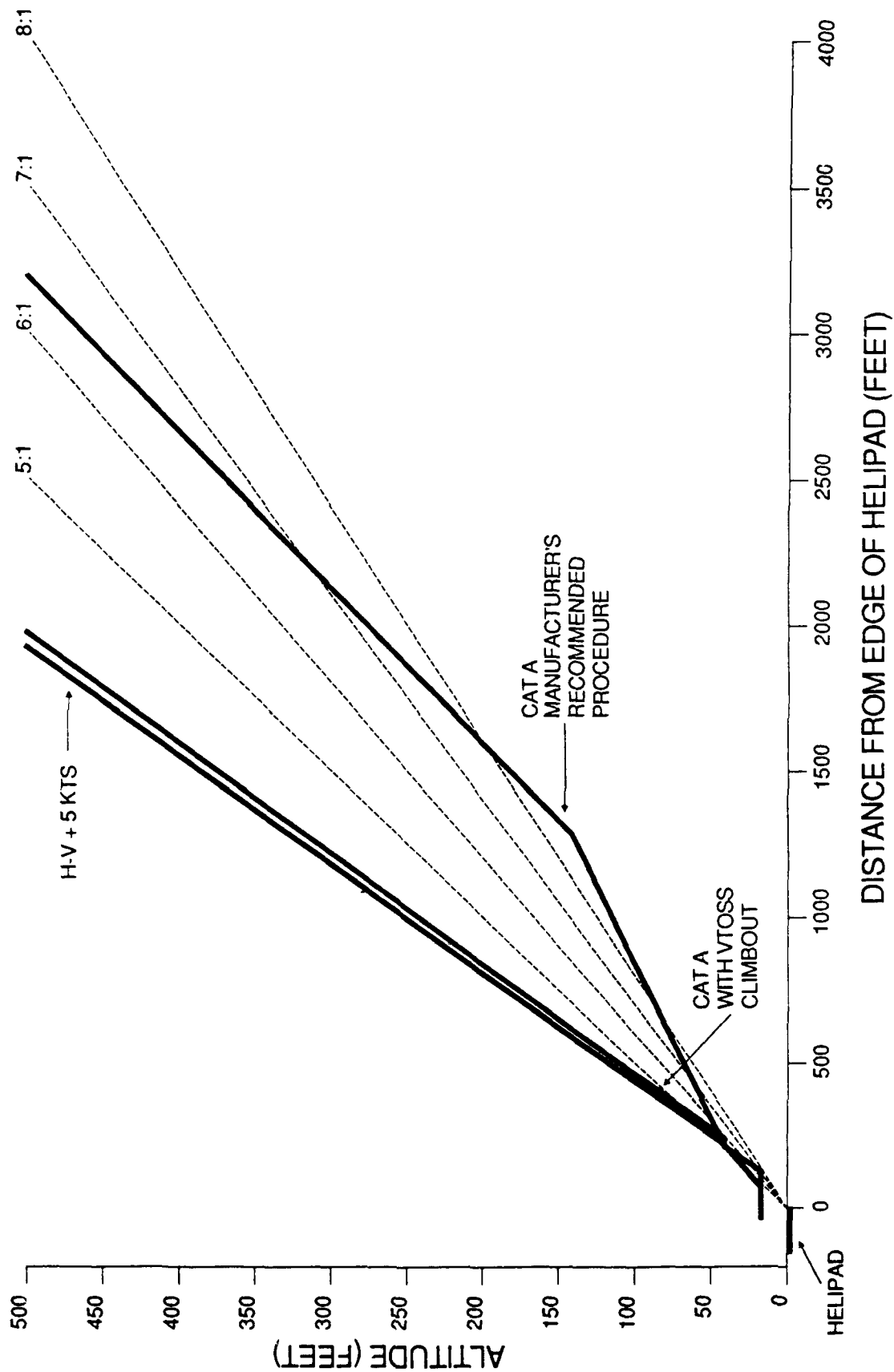
# BV 234 LR DEPARTURE PROFILES

85% MAX G.W., 2000 FEET, HOT DAY



# BV 234 LR DEPARTURE PROFILES

85% MAX G.W., 4000 FEET, STANDARD DAY

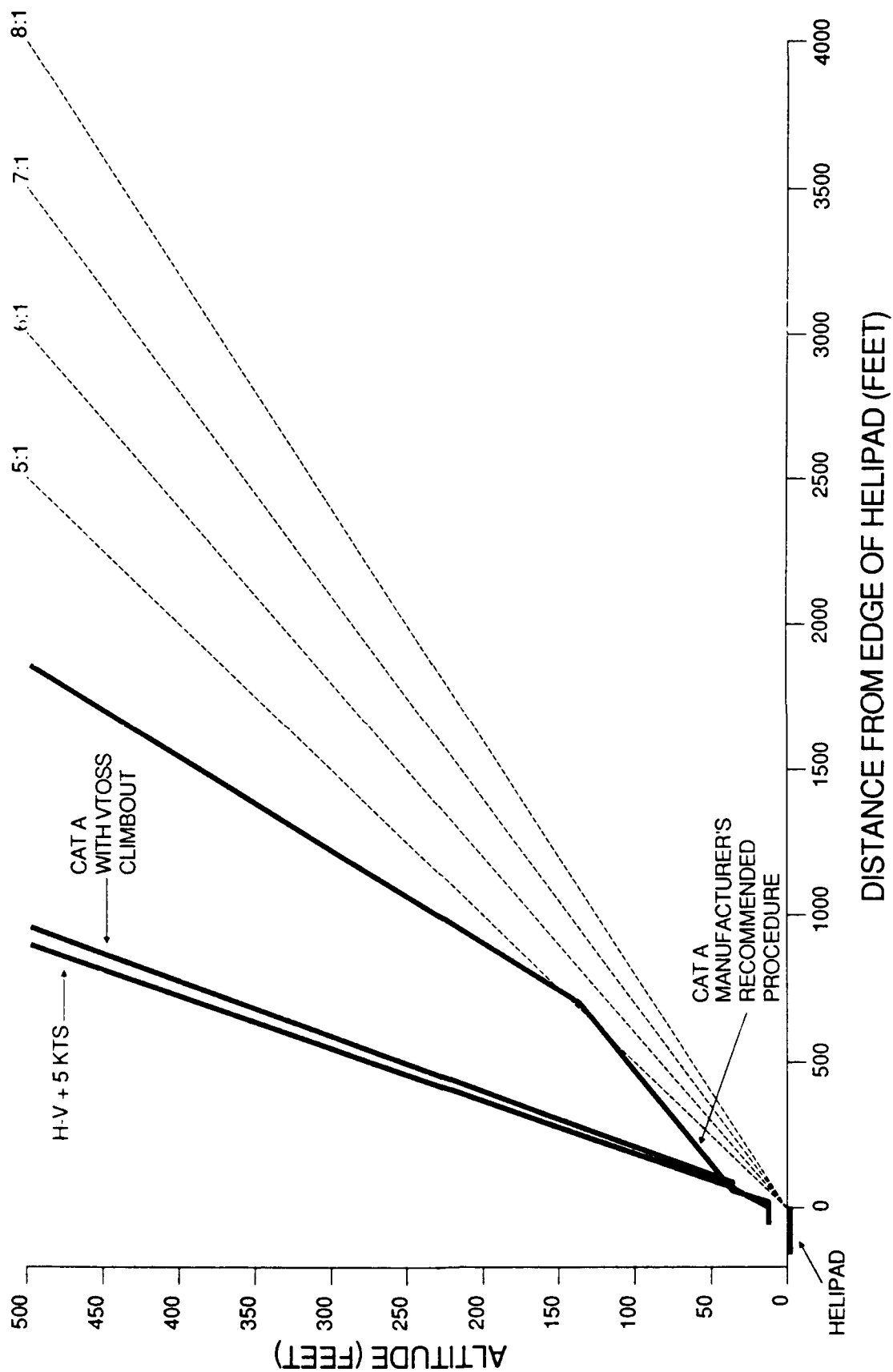


85% MAX G.W., 4000 FEET, HOT DAY

This weight exceeds the maximum allowable takeoff weight for the BV 234 LR. A departure profile was therefore excluded at this weight.

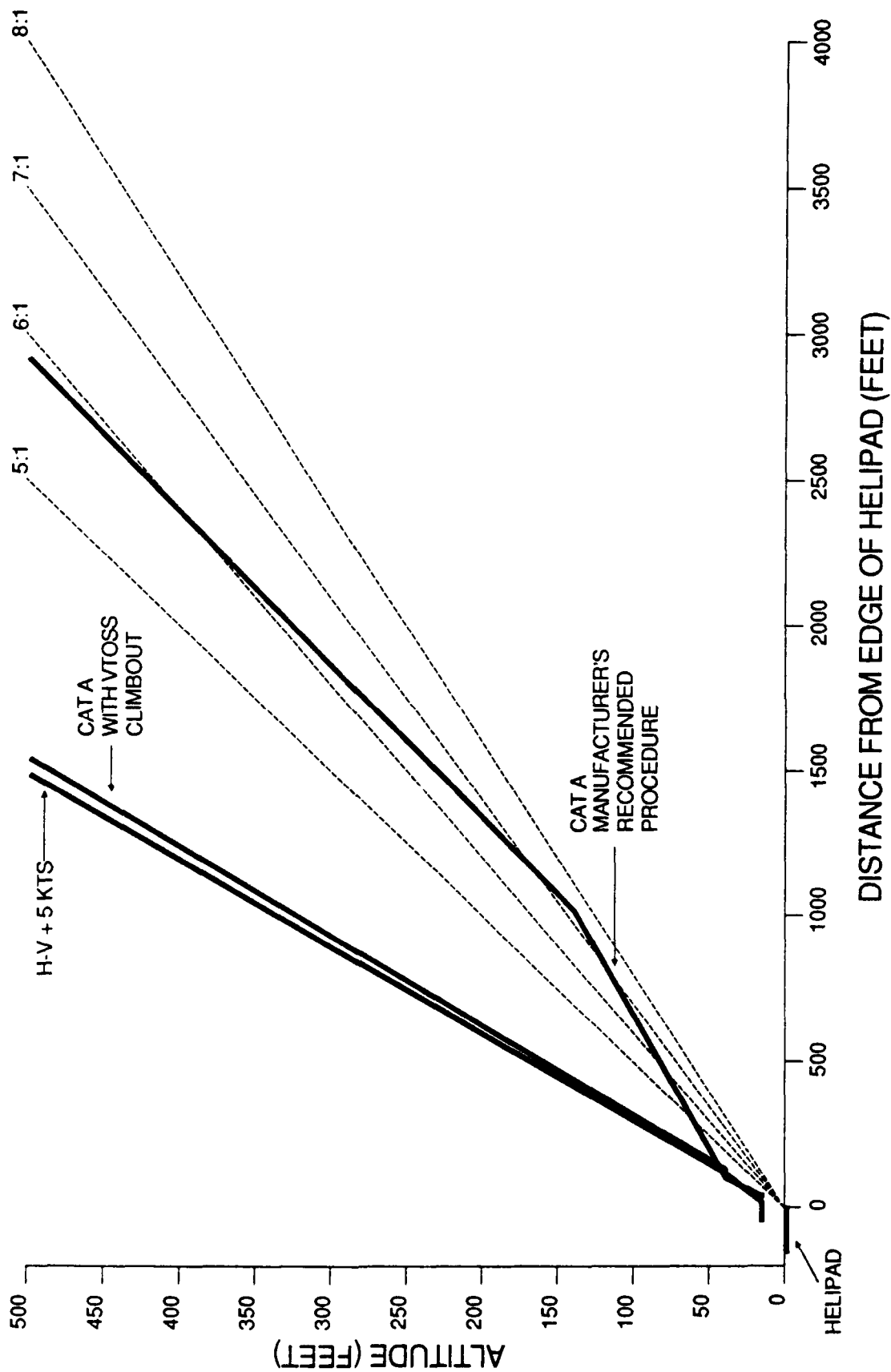
# BV 234 LR DEPARTURE PROFILES

70% MAX. G.W., SEA LEVEL, STANDARD DAY



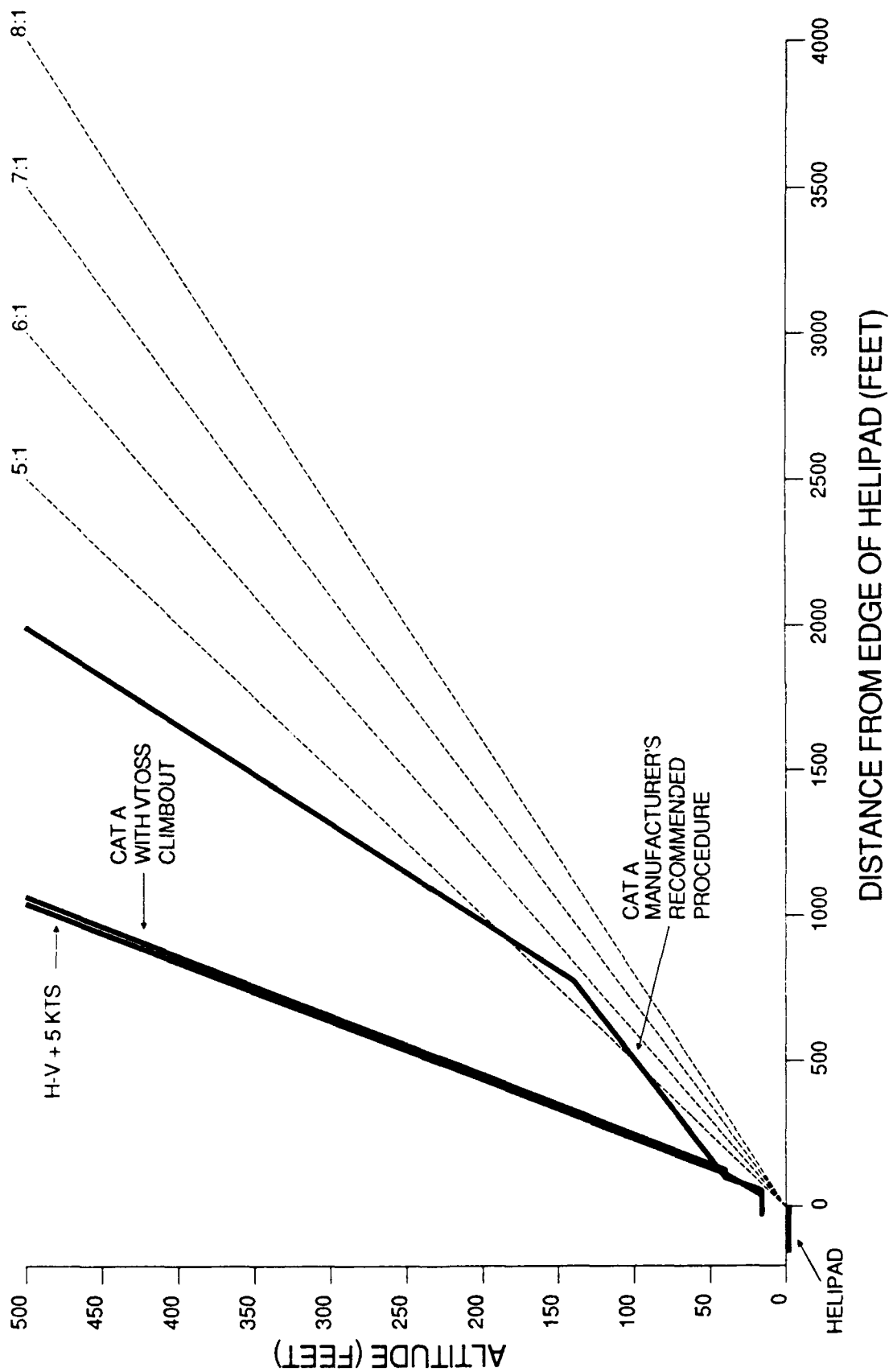
# BV 234 LR DEPARTURE PROFILES

70% MAX. G.W., SEA LEVEL, HOT DAY



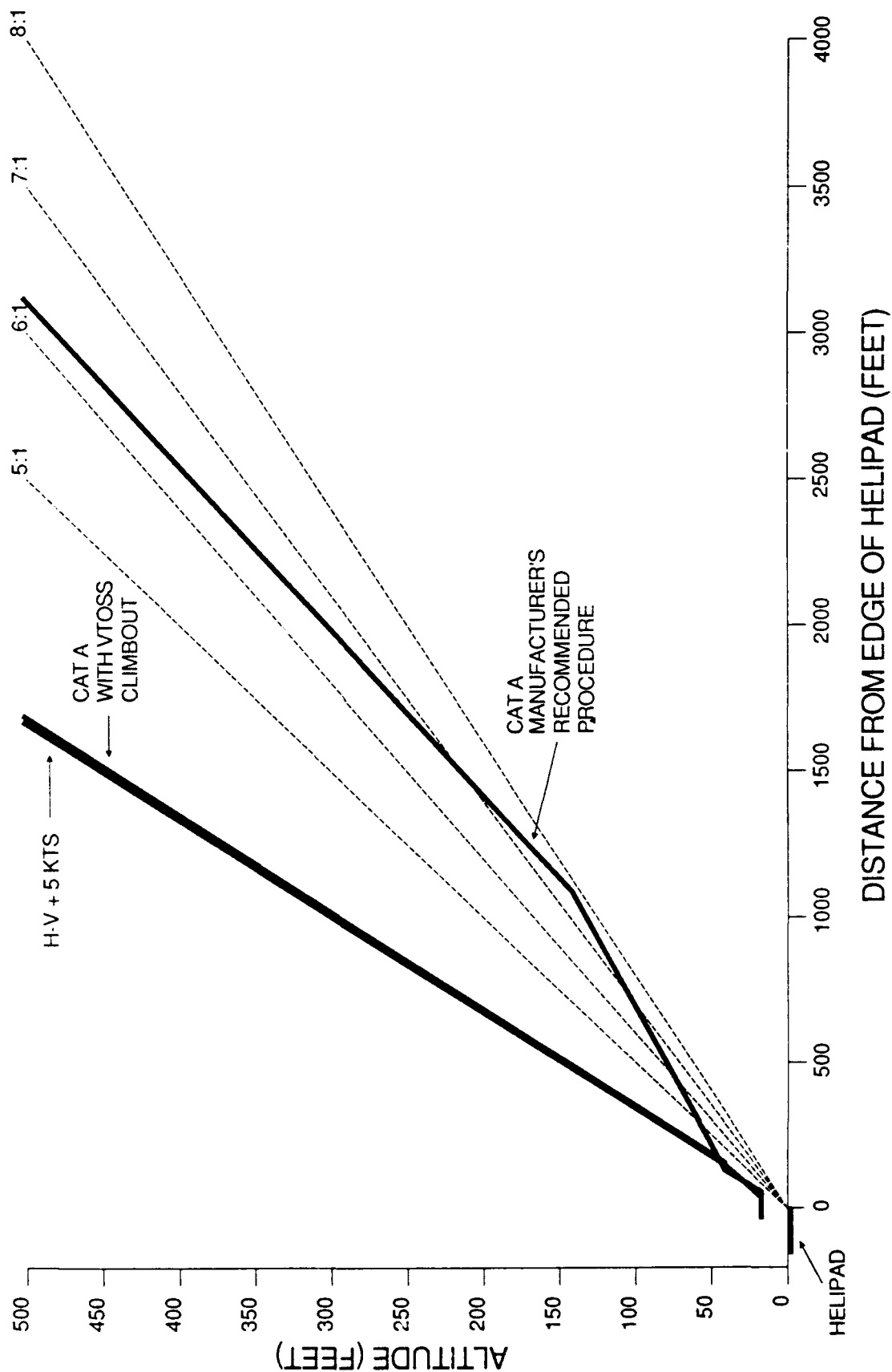
# BV 234 LR DEPARTURE PROFILES

70% MAX. G.W., 2000 FEET, STANDARD DAY



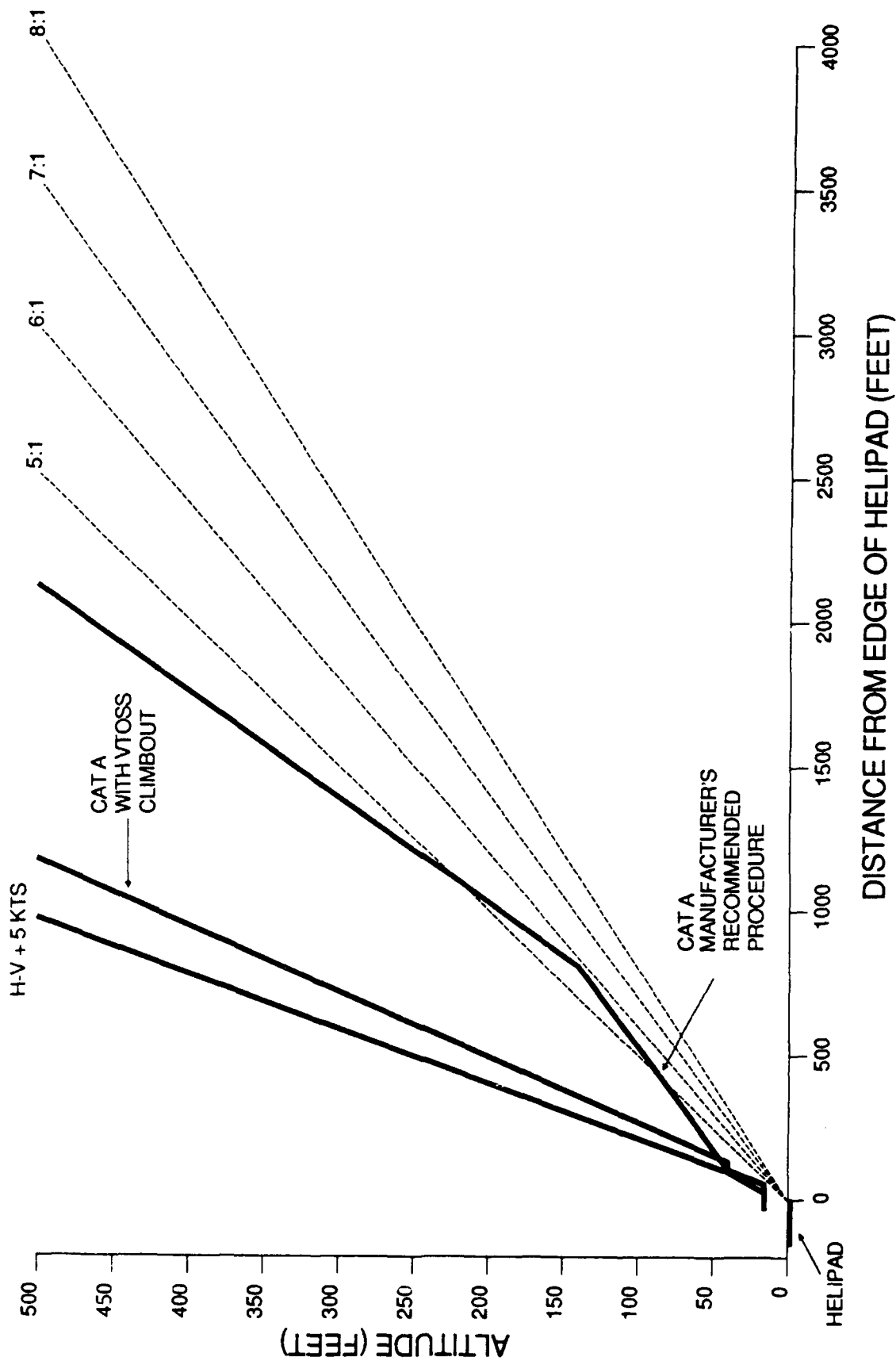
# BV 234 LR DEPARTURE PROFILES

70% MAX G.W., 2000 FEET, HOT DAY



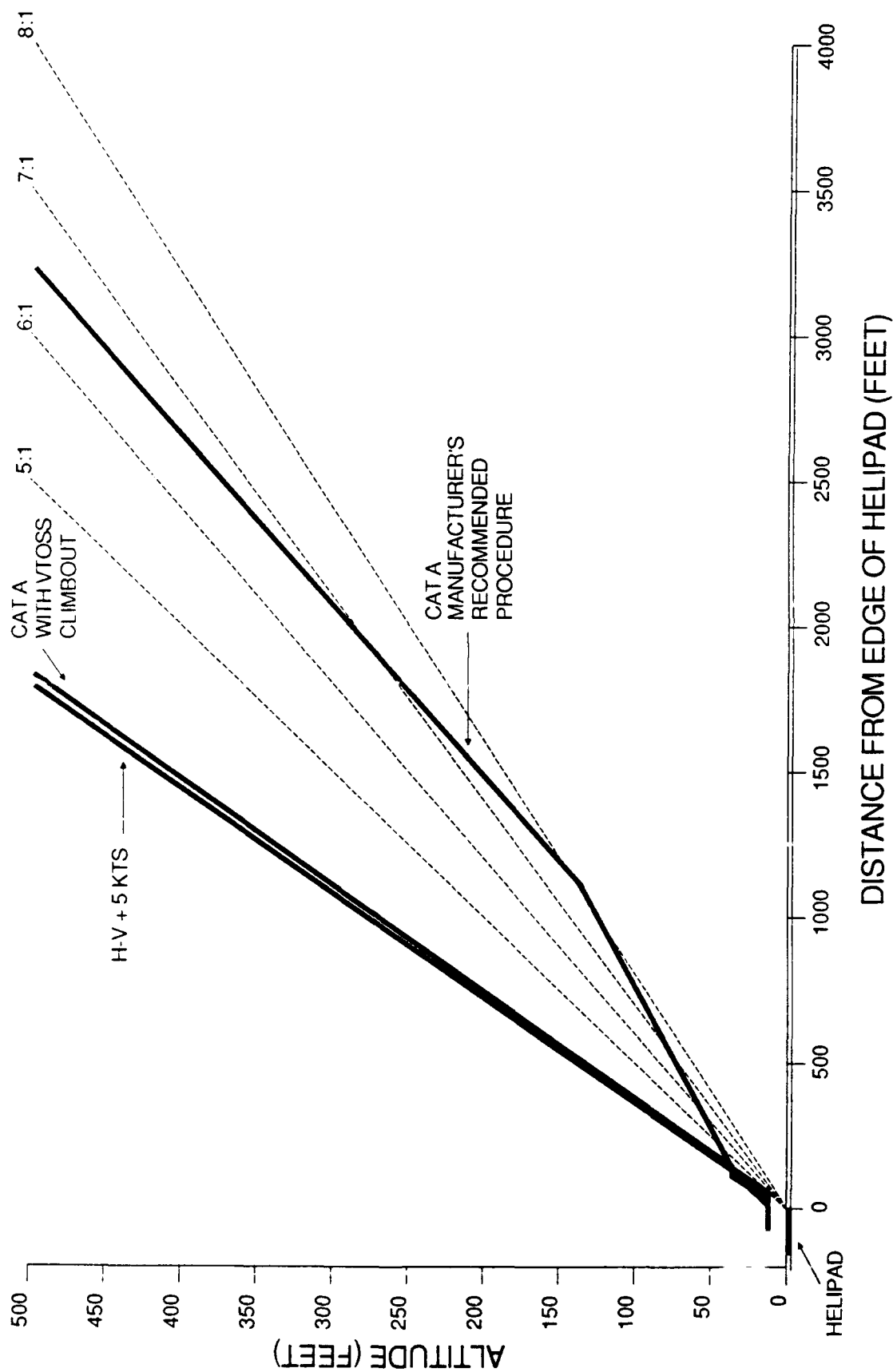
# BV 234 LR DEPARTURE PROFILES

70% MAX. G.W., 4000 FEET, STANDARD DAY



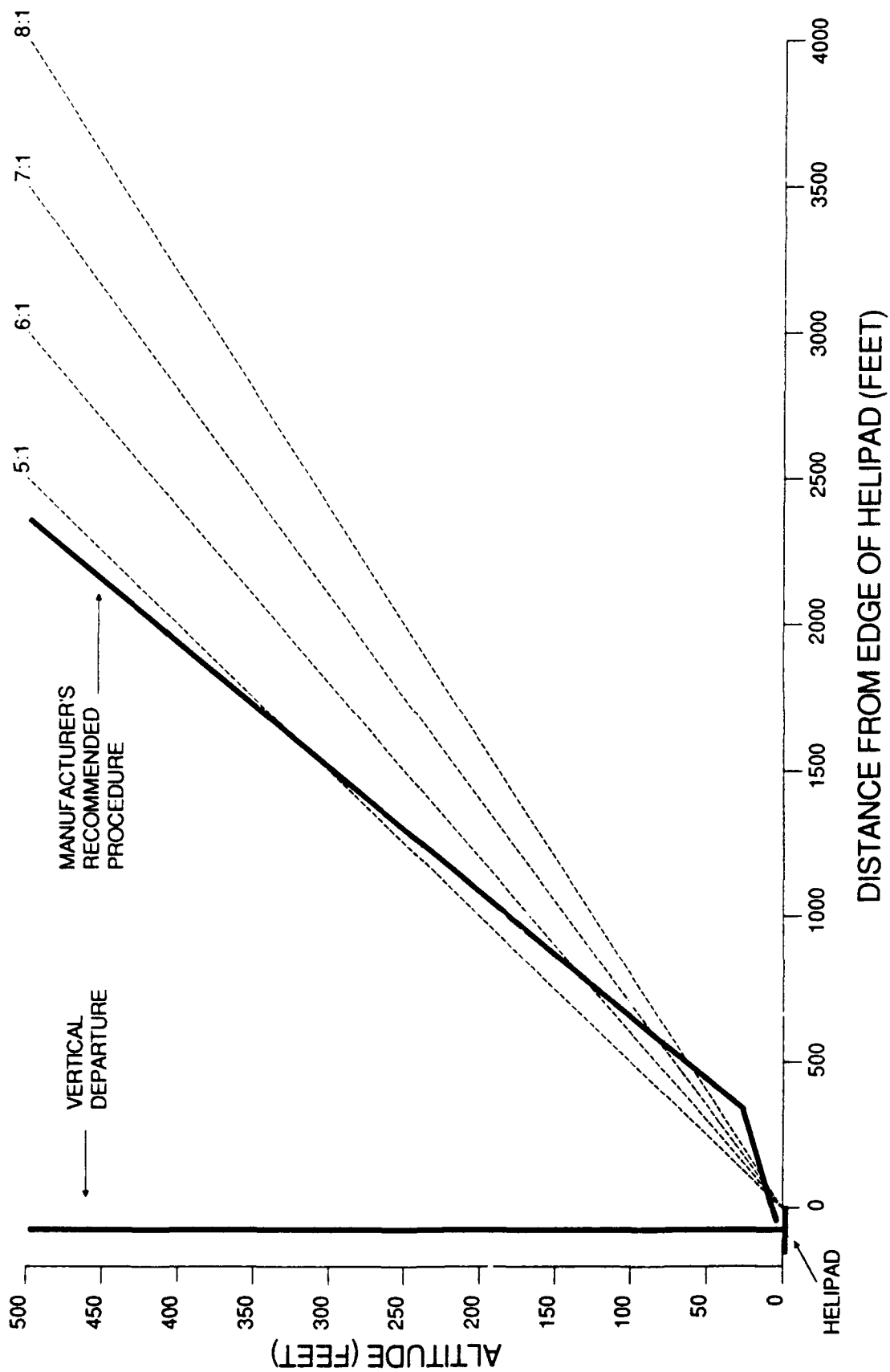
# BV 234 LR DEPARTURE PROFILES

70% MAX. G.W., 4000 FEET, HOT DAY



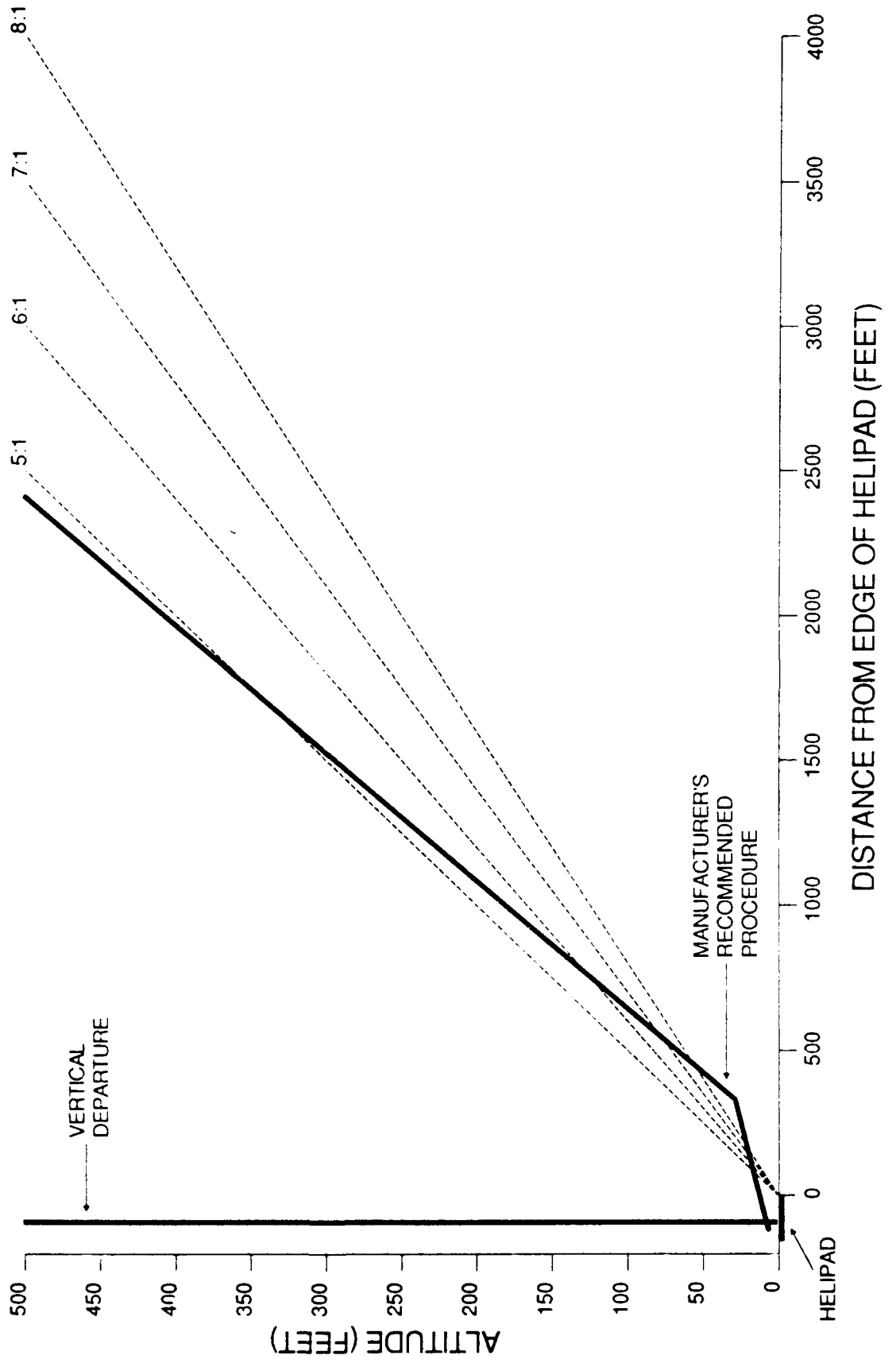
# AS 355F DEPARTURE PROFILES

MAX. G.W., SEA LEVEL, STANDARD DAY



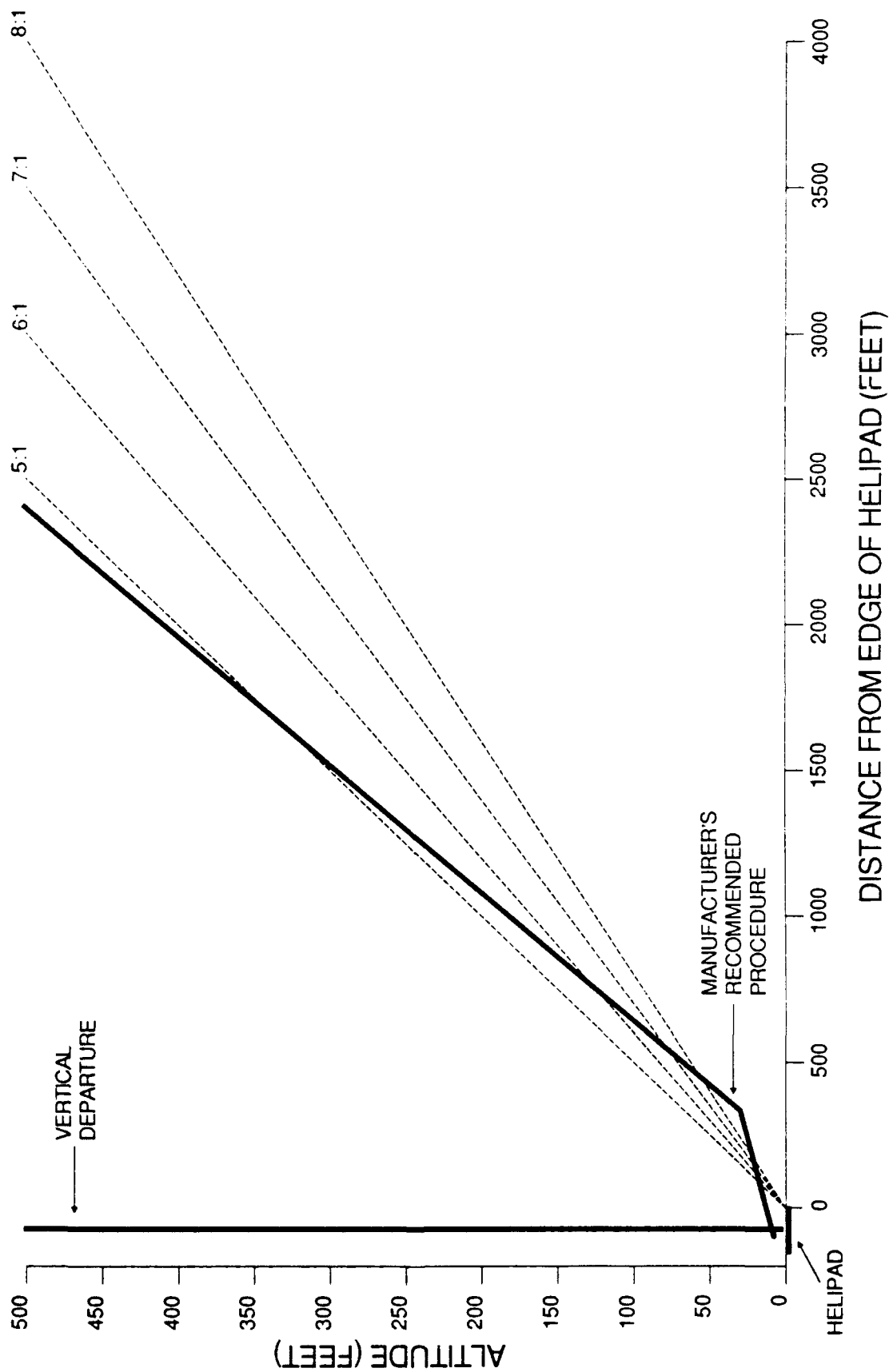
# AS 355F DEPARTURE PROFILES

MAX. G.W., SEA LEVEL, HOT DAY



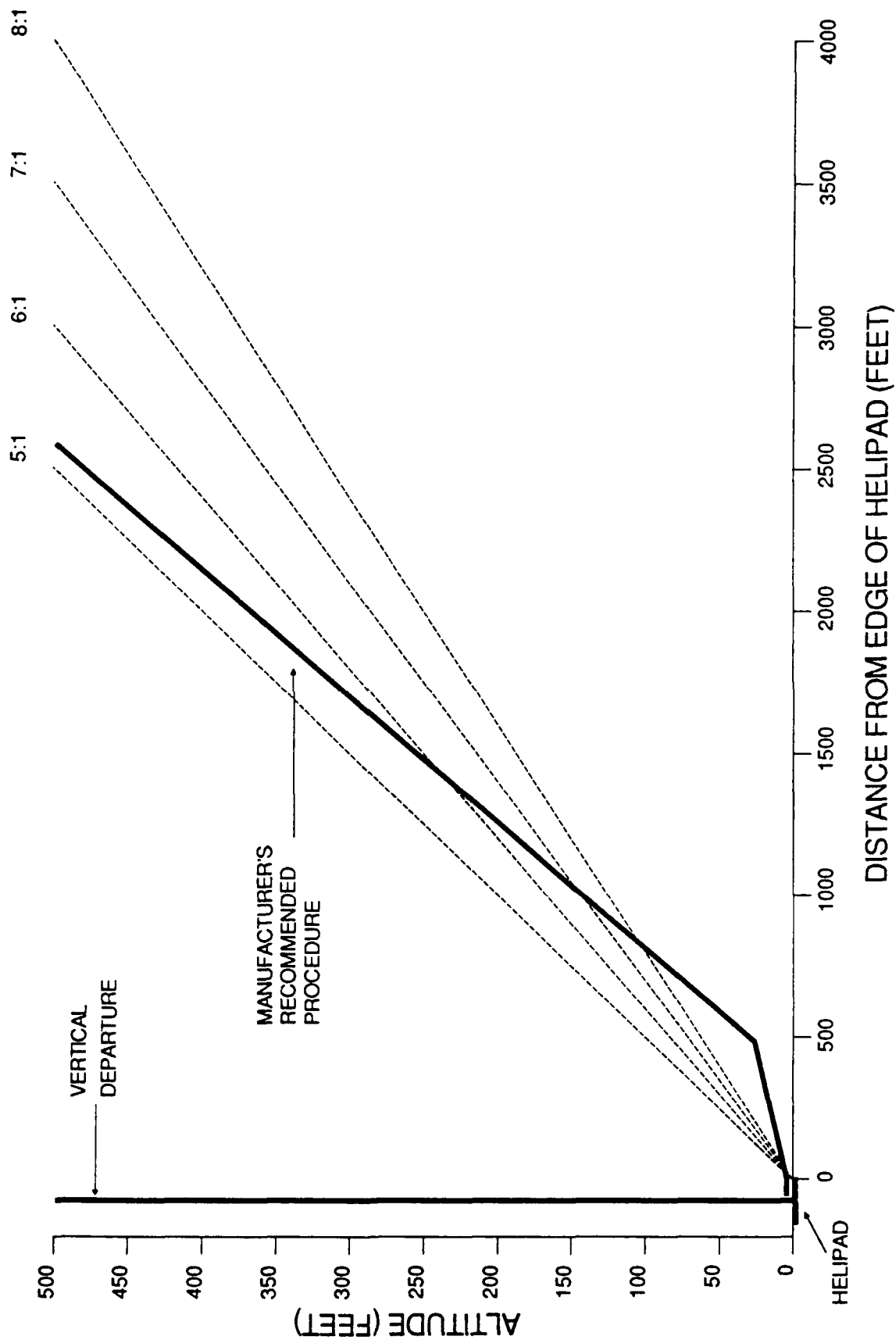
# AS 355F DEPARTURE PROFILES

MAX. G.W., 2000 FEET, STANDARD DAY



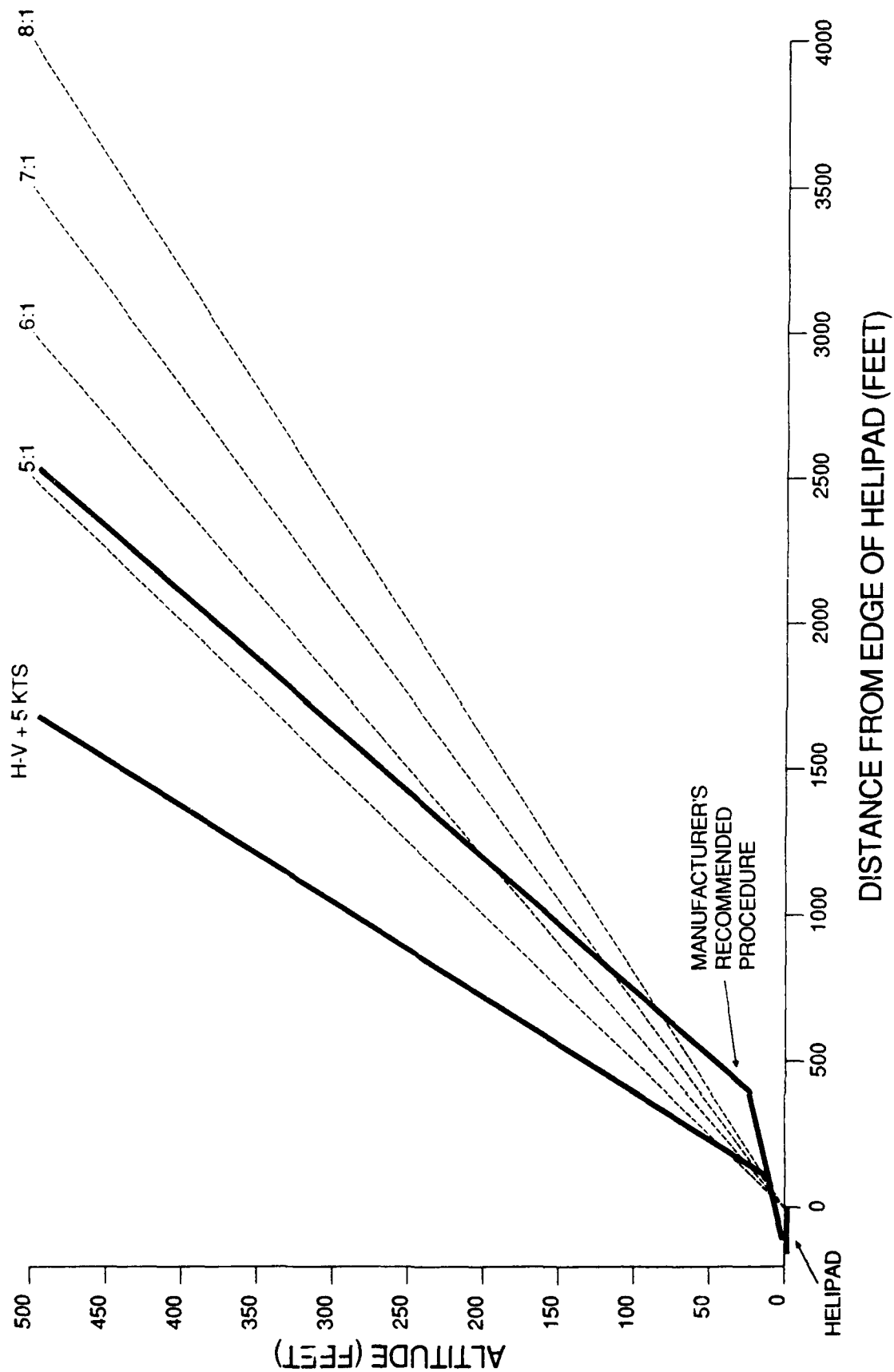
# AS 355F DEPARTURE PROFILES

MAX. G.W., 2000 FEET, HOT DAY



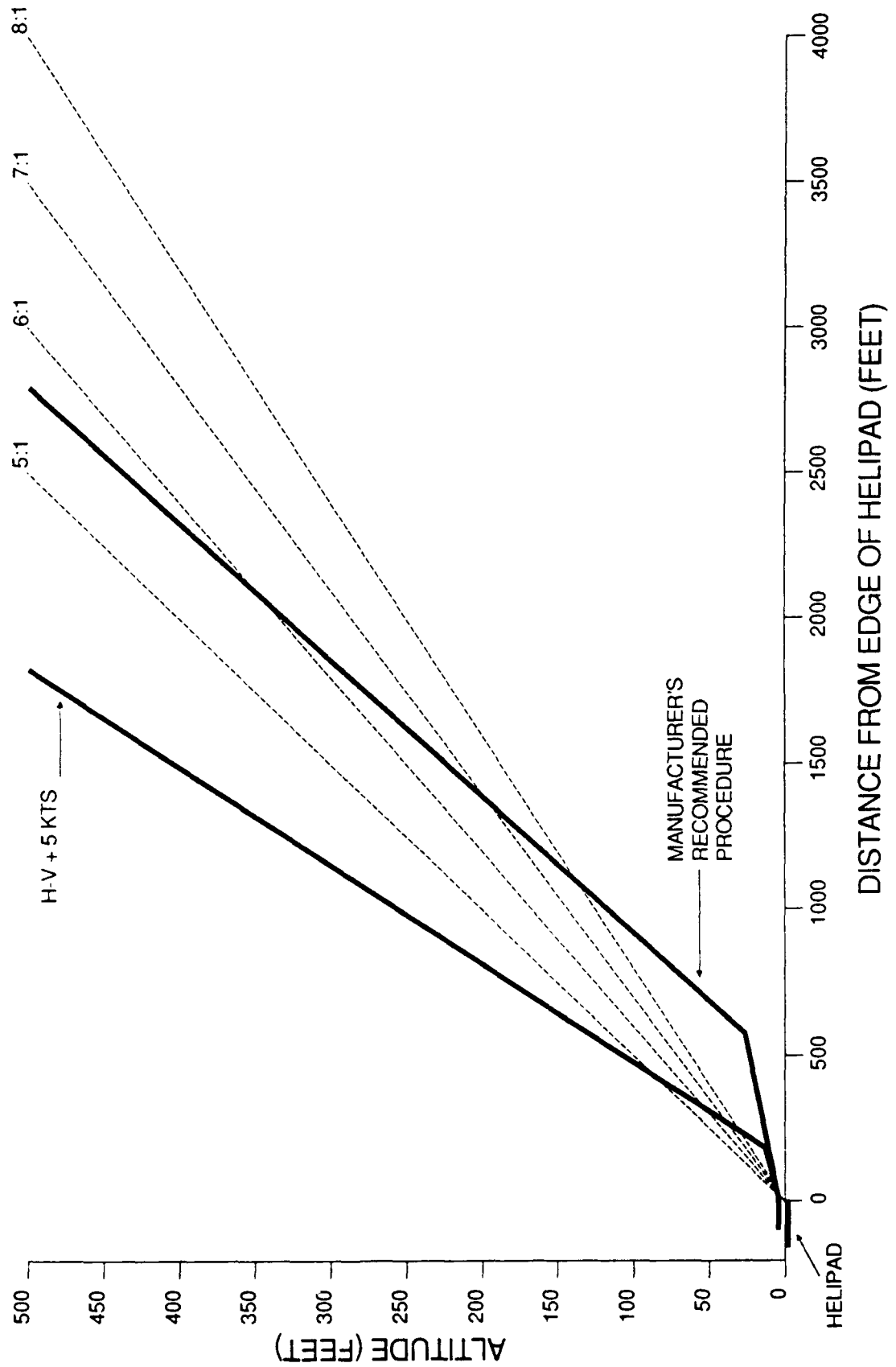
# AS 355F DEPARTURE PROFILES

MAX. G.W., 4000 FEET, STANDARD DAY



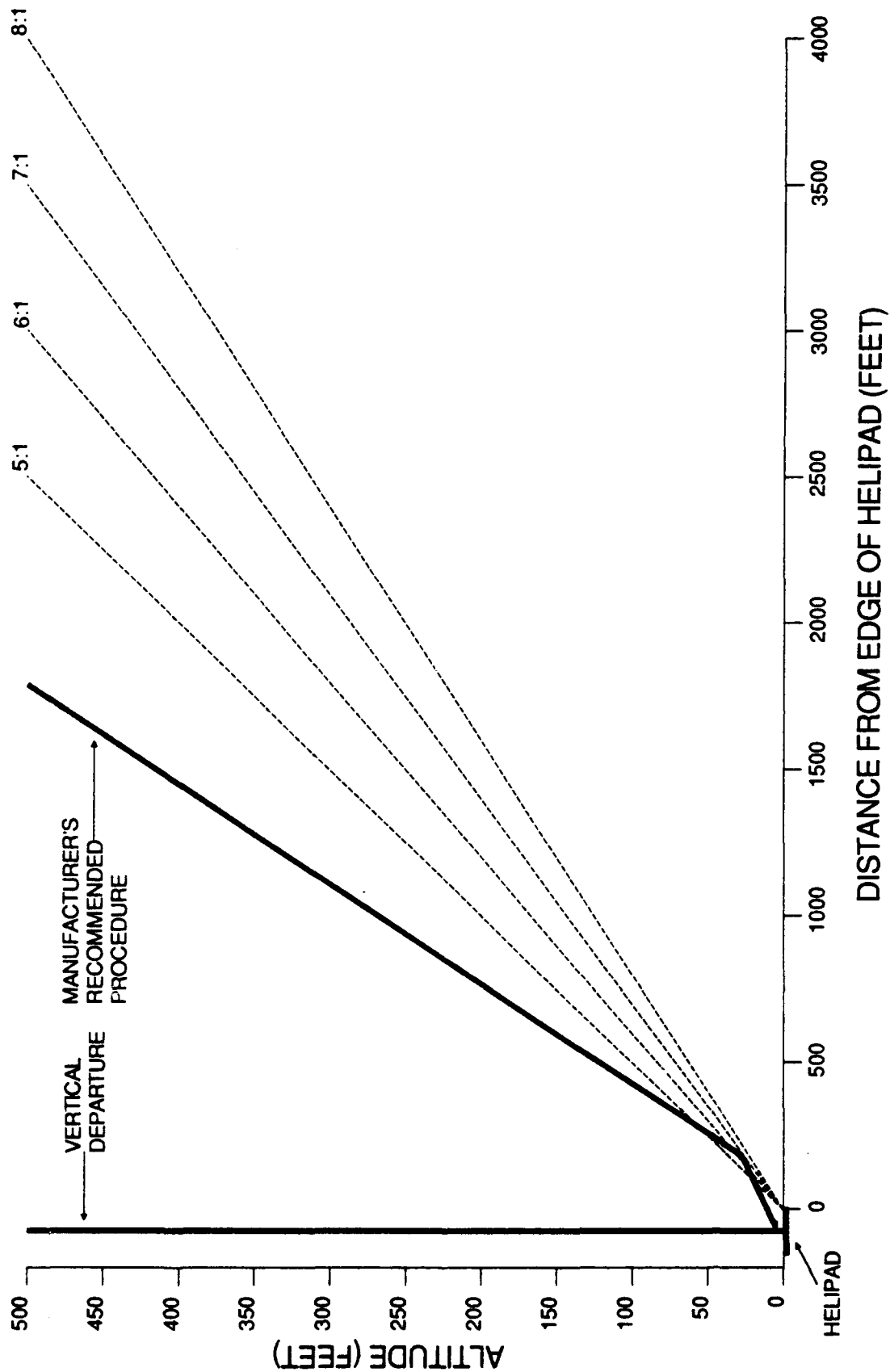
# AS 355F DEPARTURE PROFILES

MAX. G.W., 4000 FEET, HOT DAY



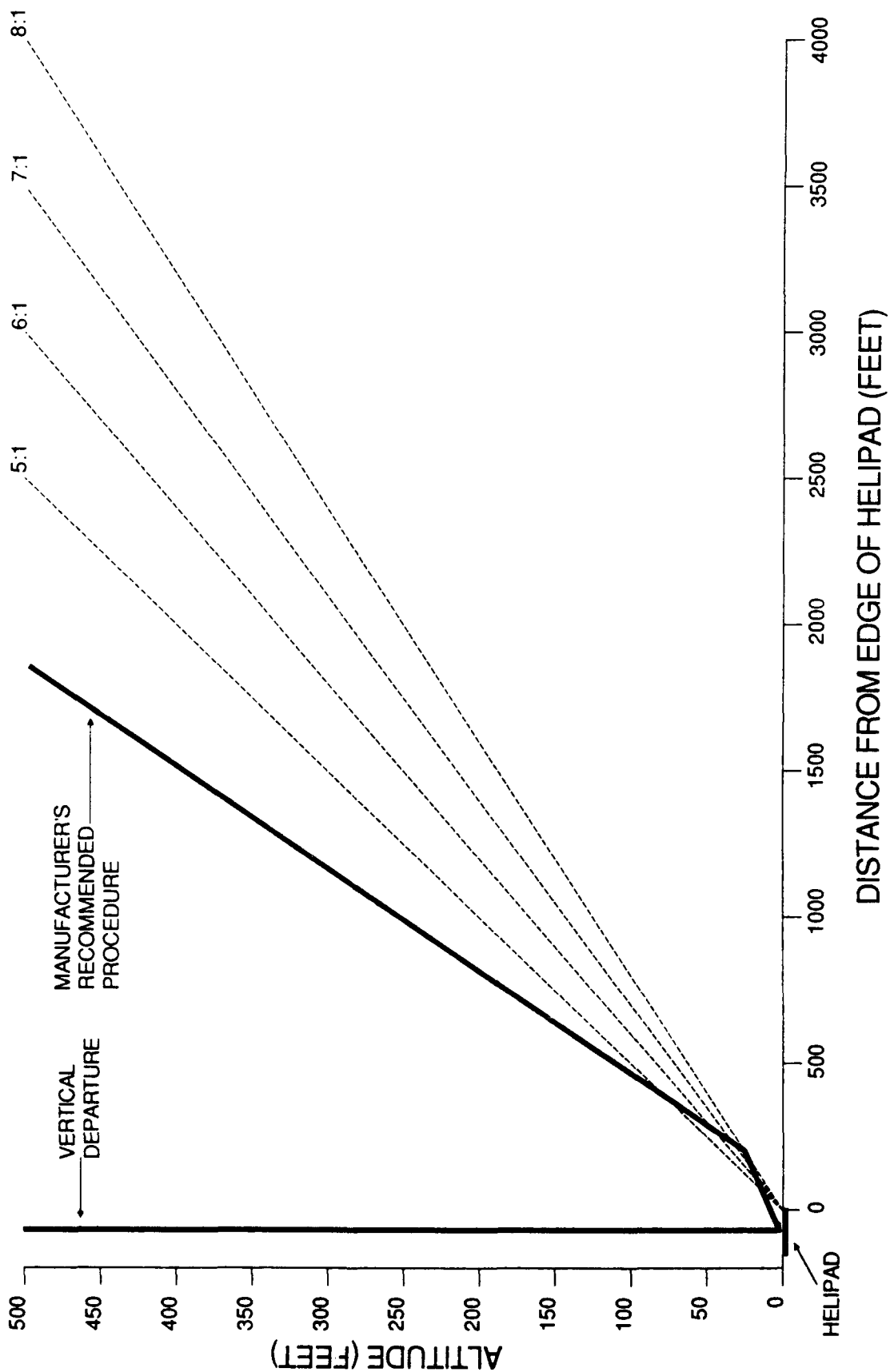
# AS 355F DEPARTURE PROFILES

85% MAX. G.W., SEA LEVEL, STANDARD DAY



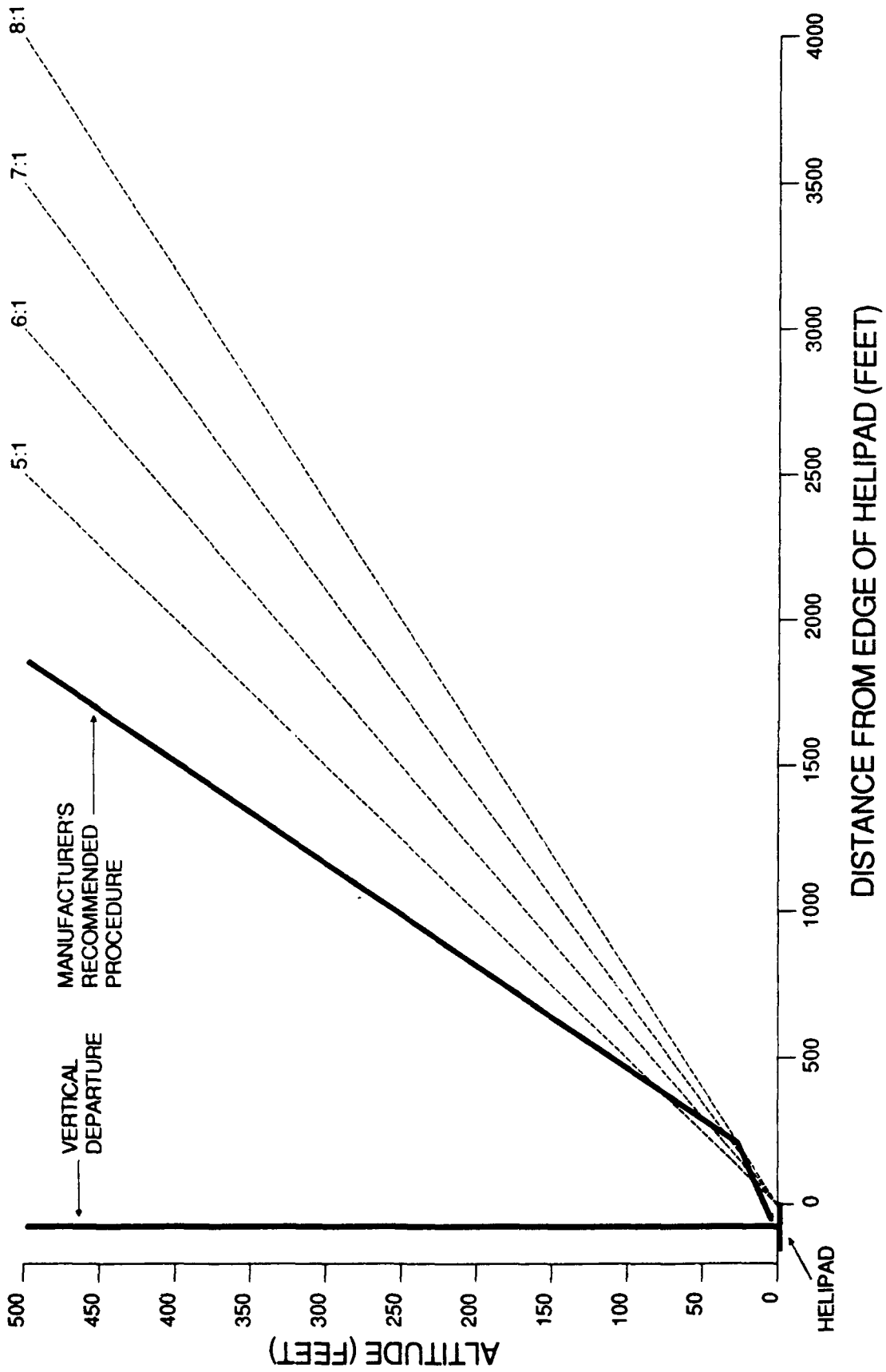
# AS 355F DEPARTURE PROFILES

85% MAX. G.W., SEA LEVEL HOT DAY



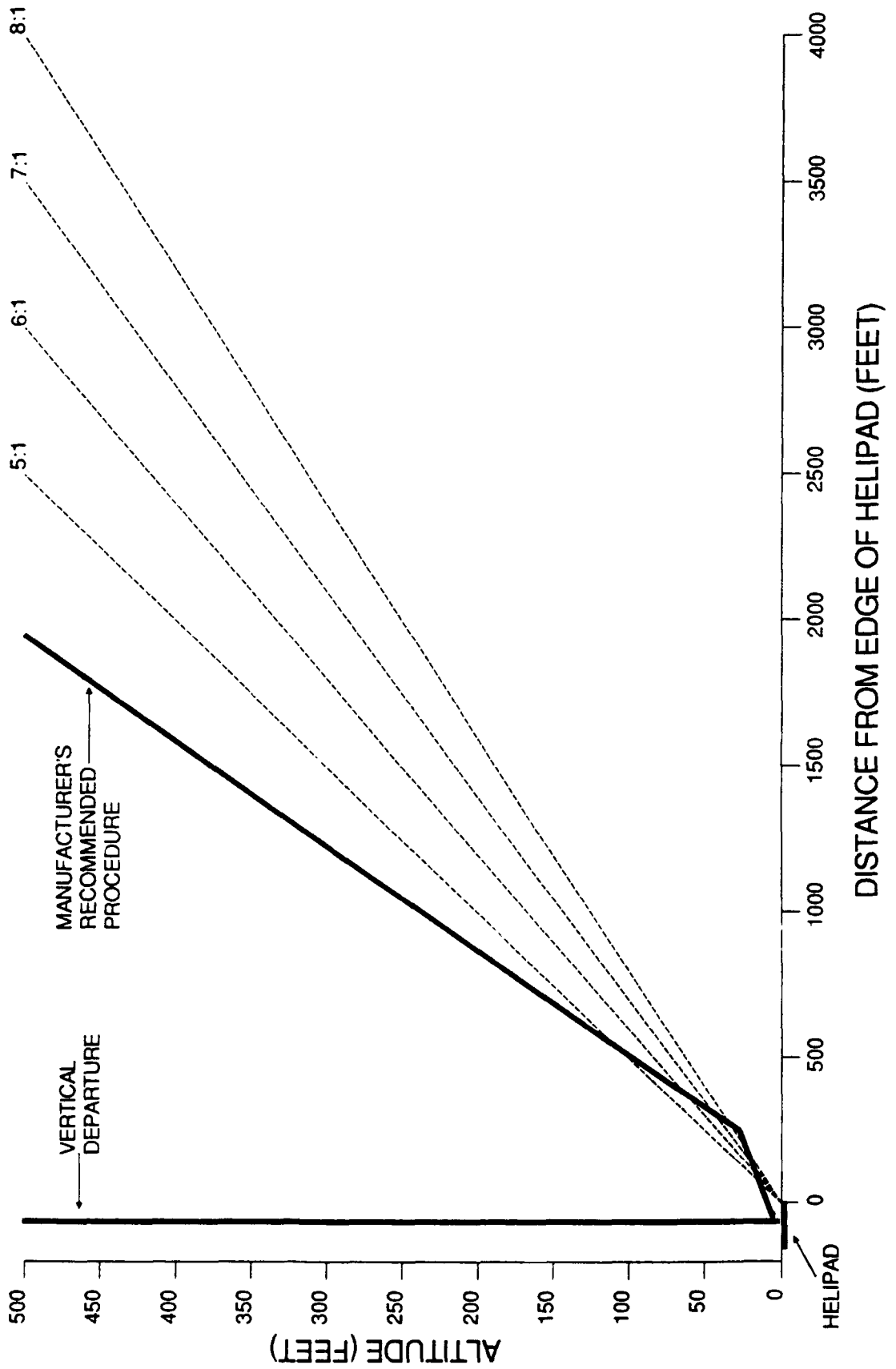
# AS 355F DEPARTURE PROFILES

85% MAX. G.W., 2000 FEET, STANDARD DAY



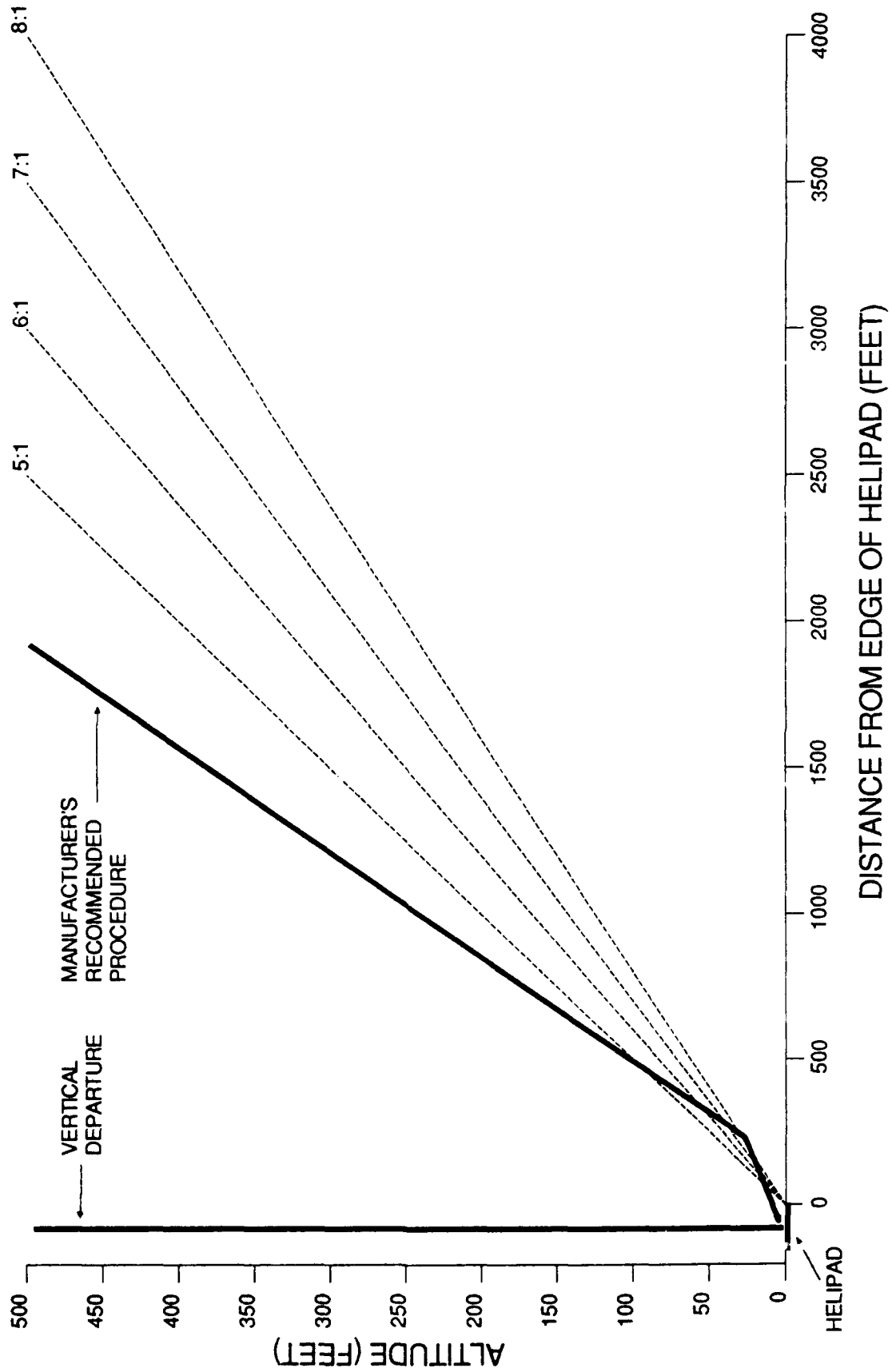
# AS 355F DEPARTURE PROFILES

85% MAX. G.W., 2000 FEET, HOT DAY



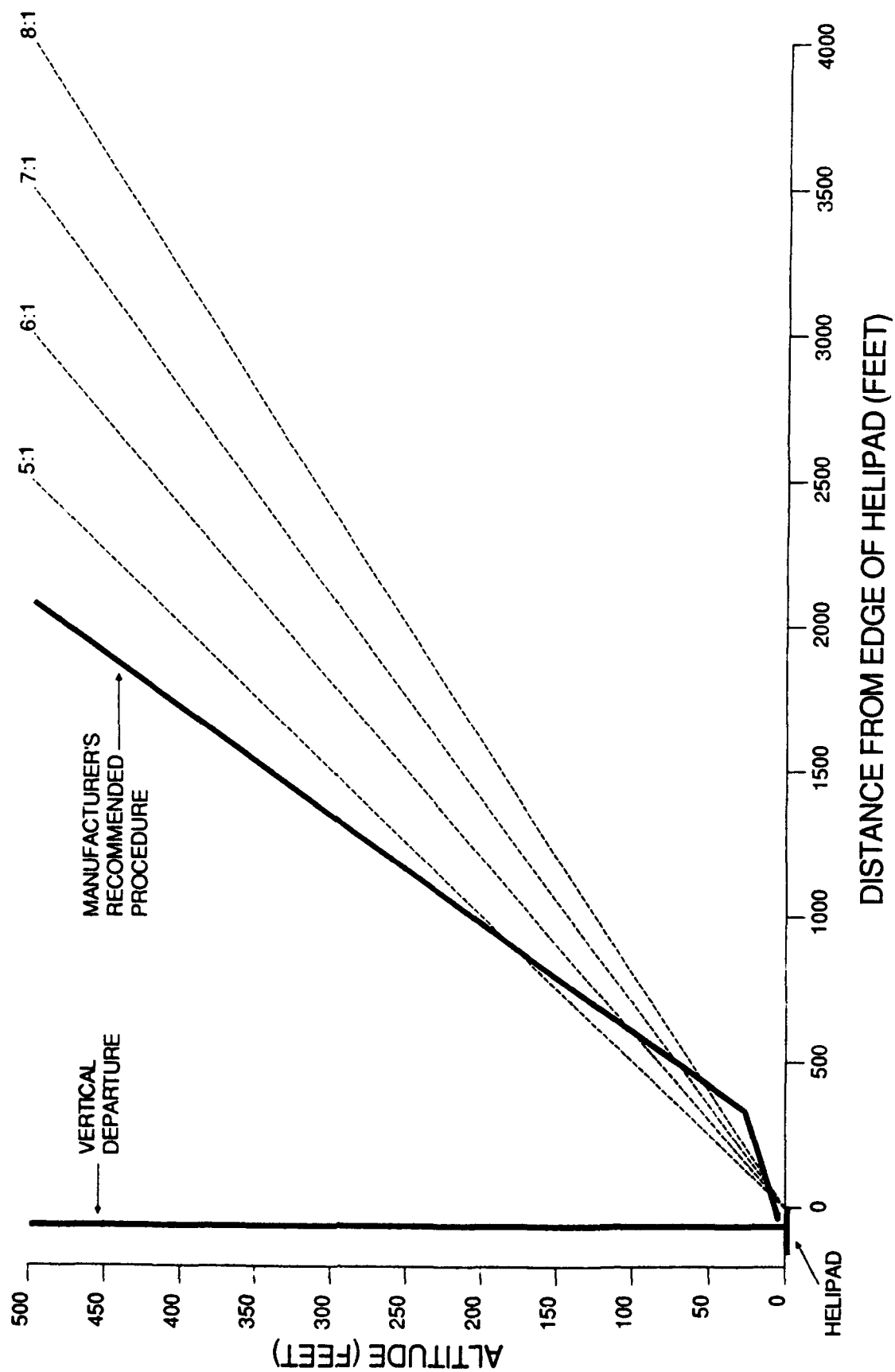
# AS 355F DEPARTURE PROFILES

85% MAX. G.W., 4000 FEET, STANDARD DAY



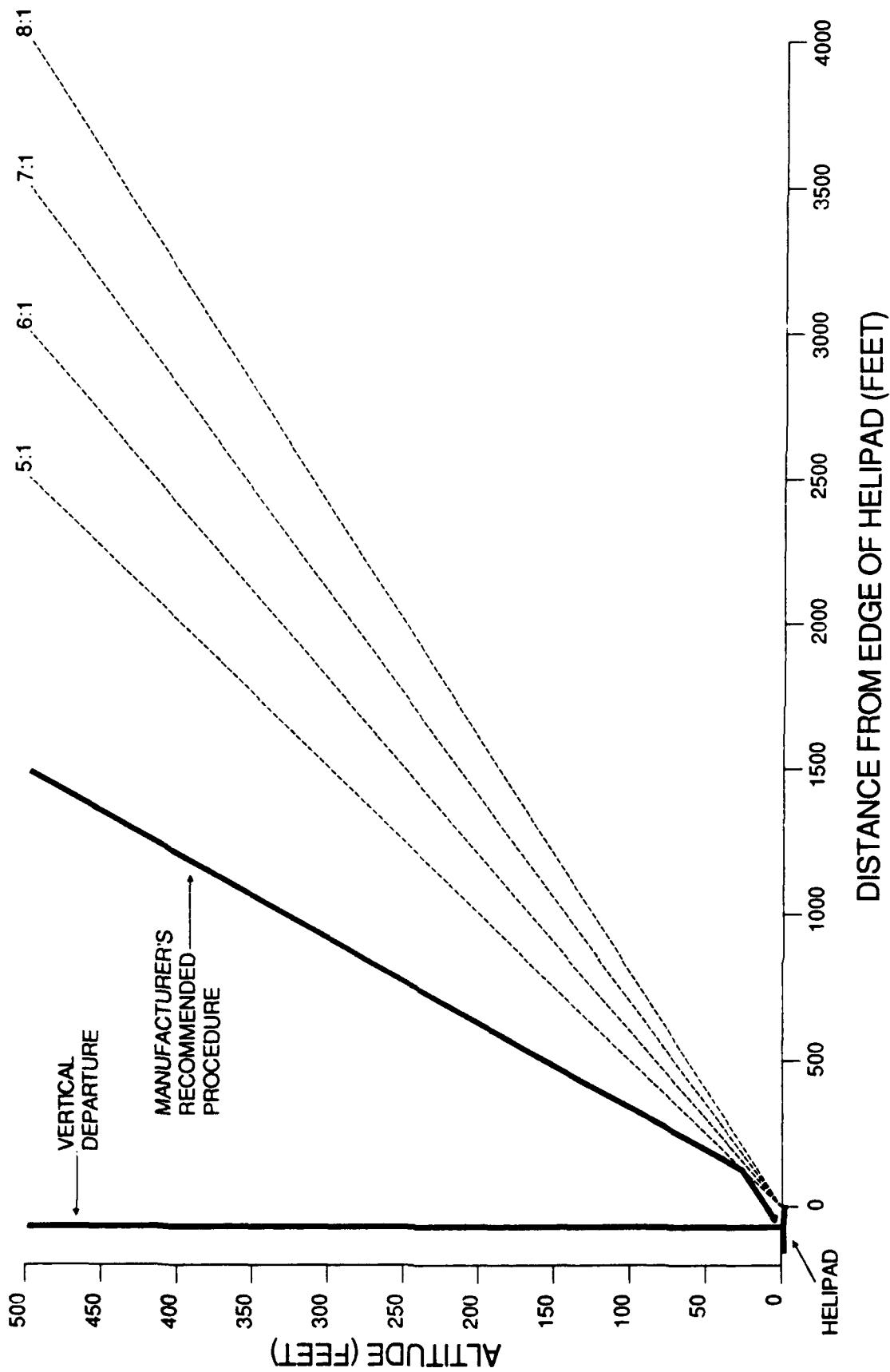
# AS 355F DEPARTURE PROFILES

85% MAX. G.W., 4000 FEET, HOT DAY



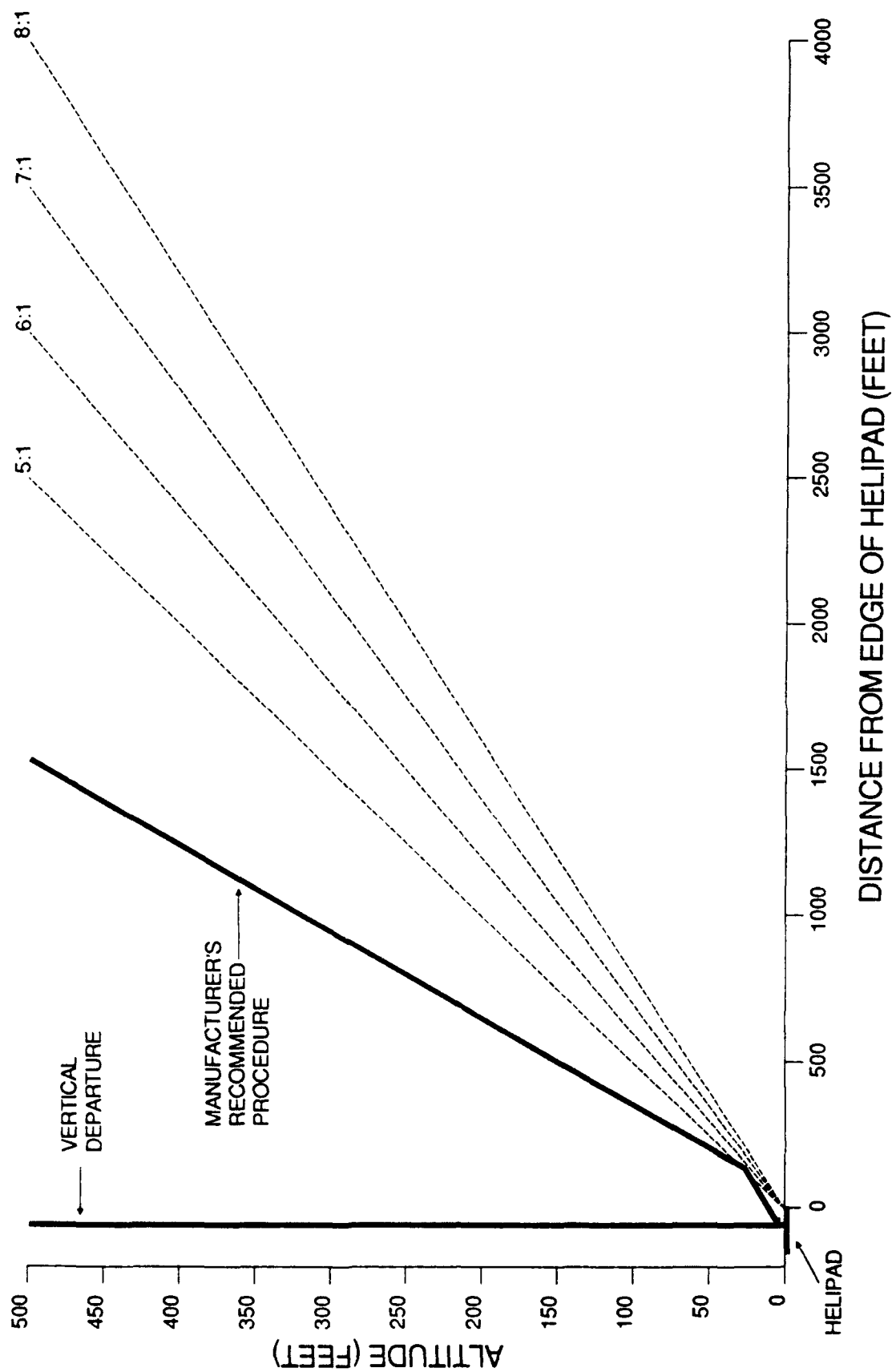
# AS 355F DEPARTURE PROFILES

70% MAX. G.W., SEA LEVEL, STANDARD DAY



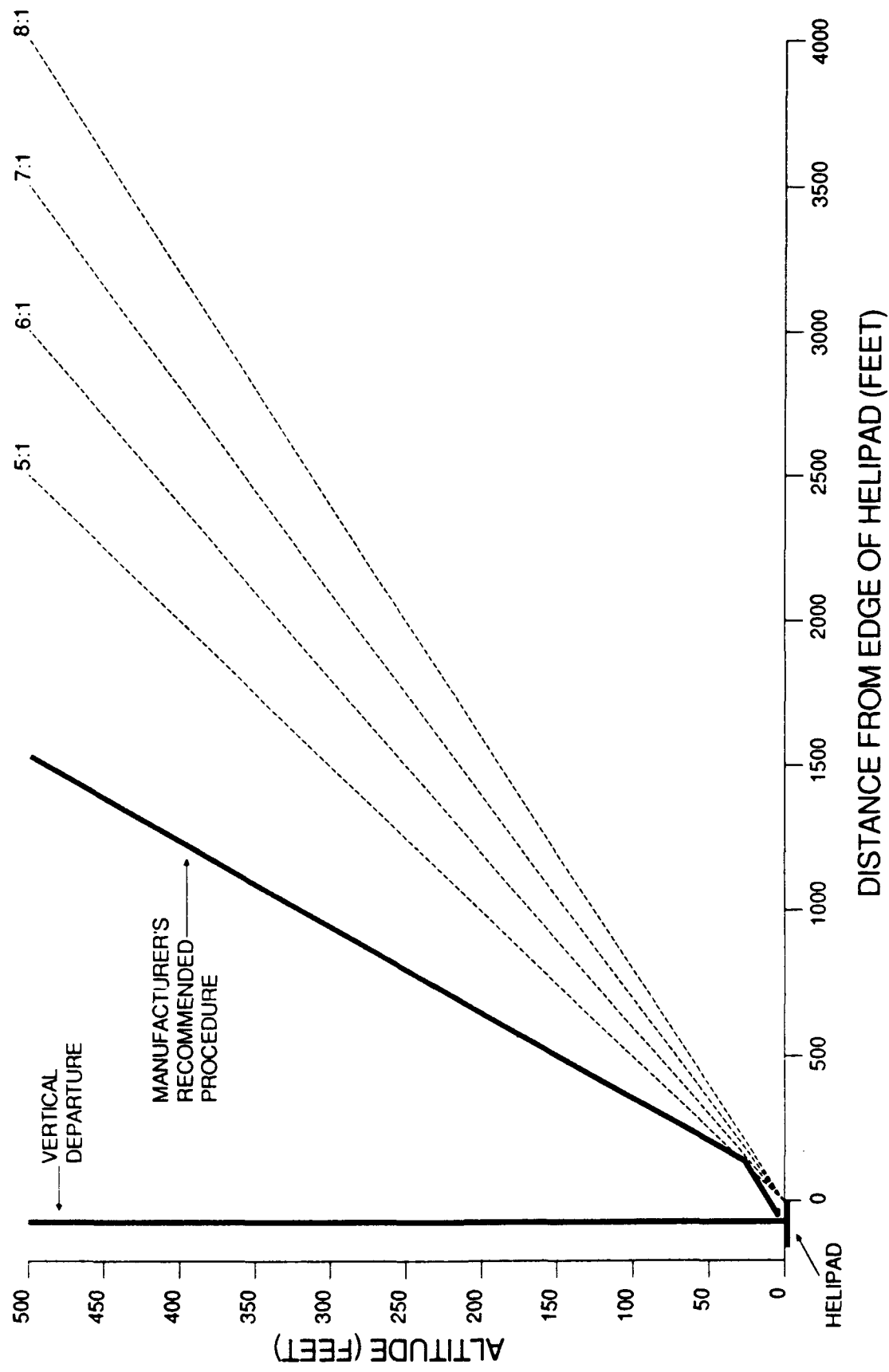
# AS 355F DEPARTURE PROFILES

70% MAX. G.W., SEA LEVEL, HOT DAY



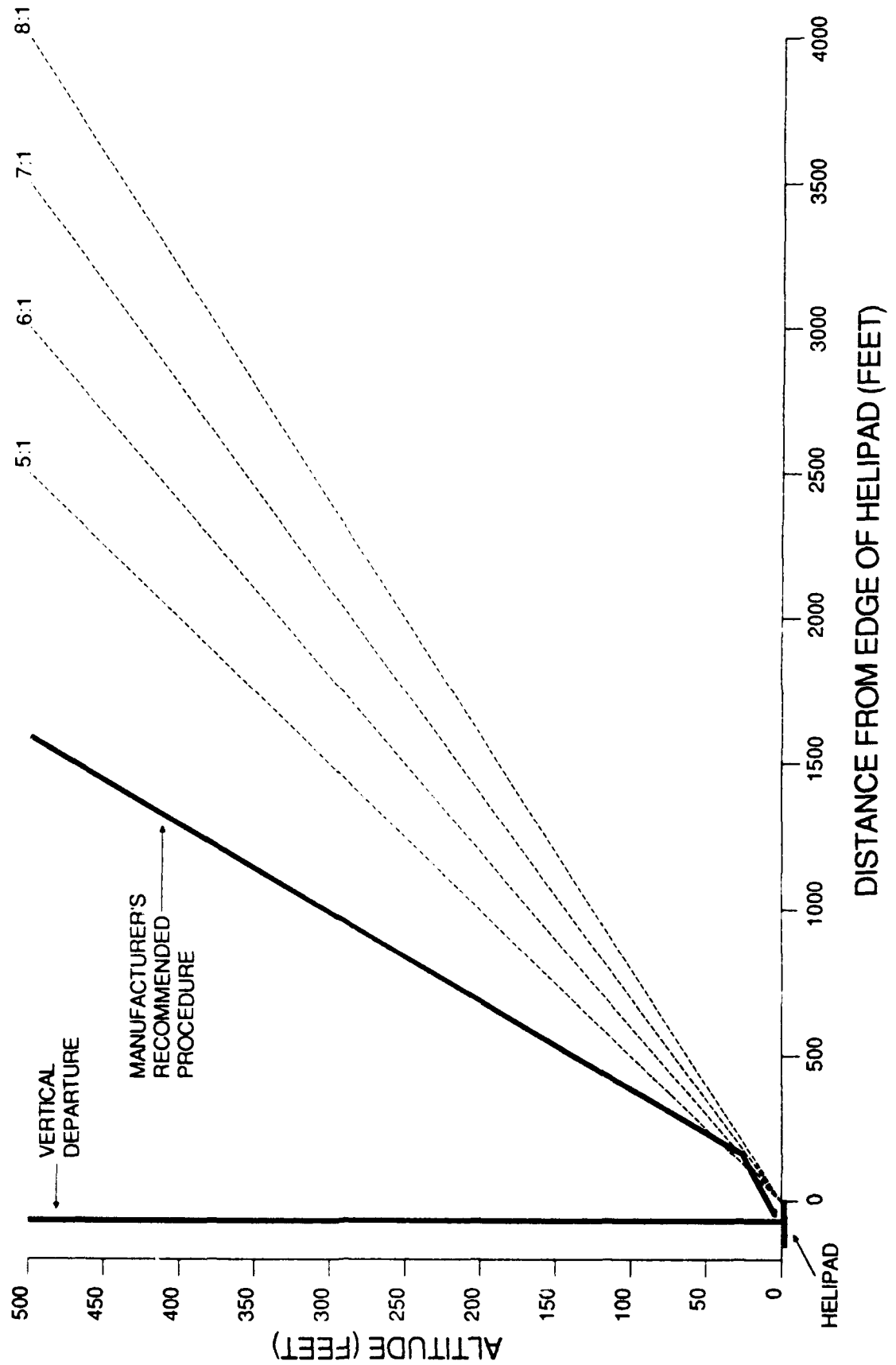
# AS 355F DEPARTURE PROFILES

70% MAX G.W., 2000 FEET, STANDARD DAY



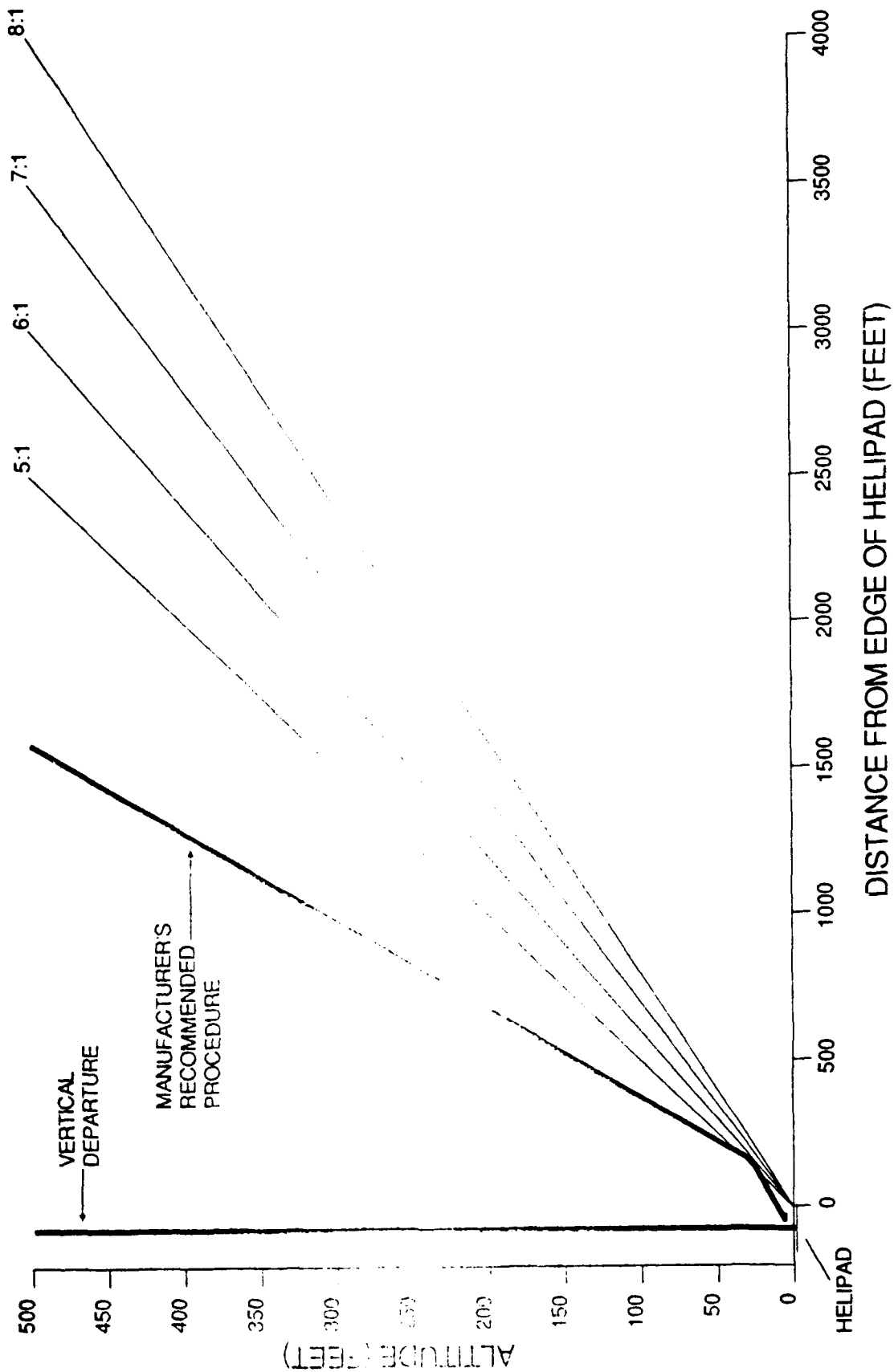
# AS 355F DEPARTURE PROFILES

70% MAX. G.W., 2000 FEET, HOT DAY



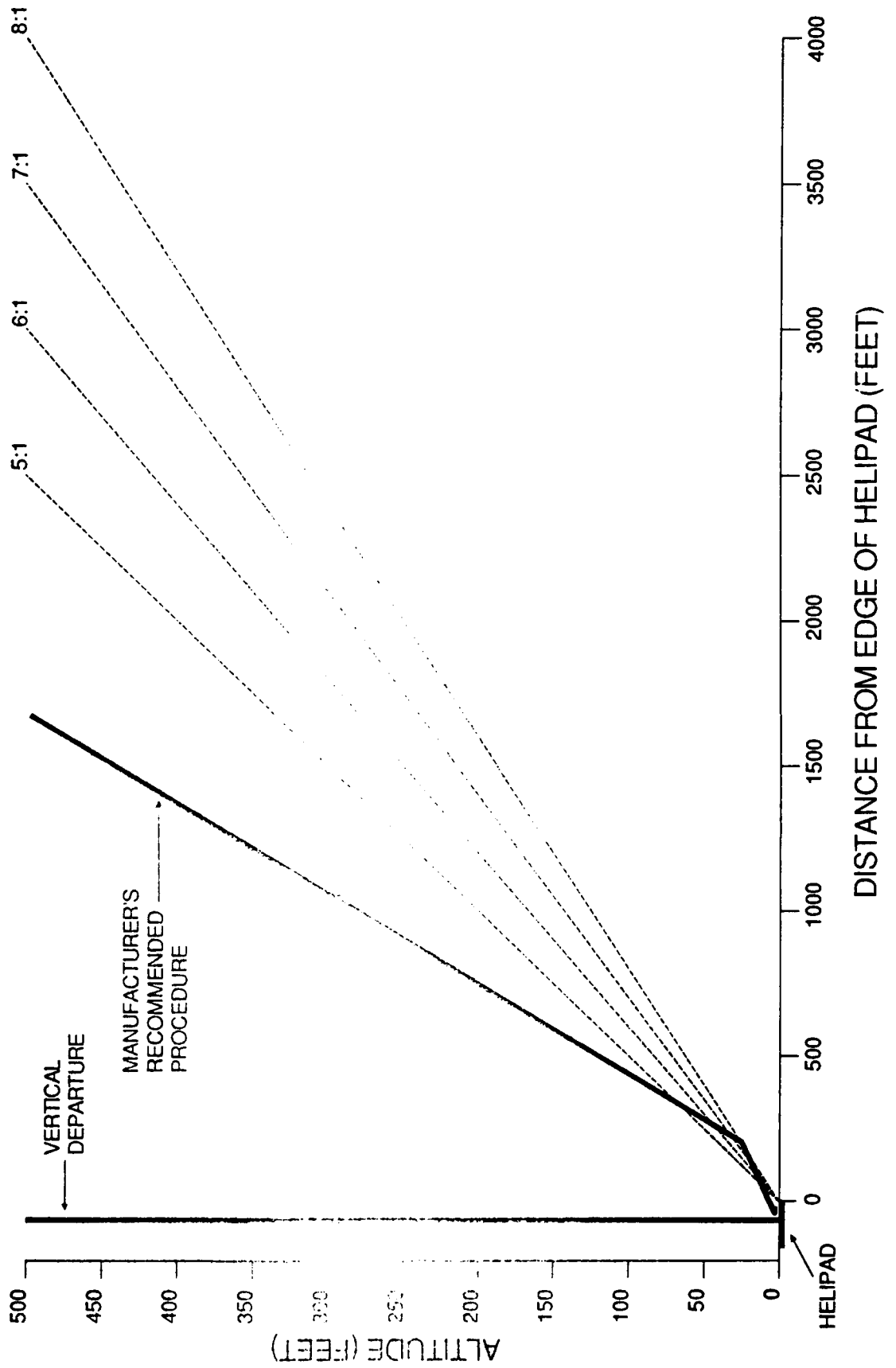
# AS 355F DEPARTURE PROFILES

70% MAX. G.W., 4000 FEET, STANDARD DAY



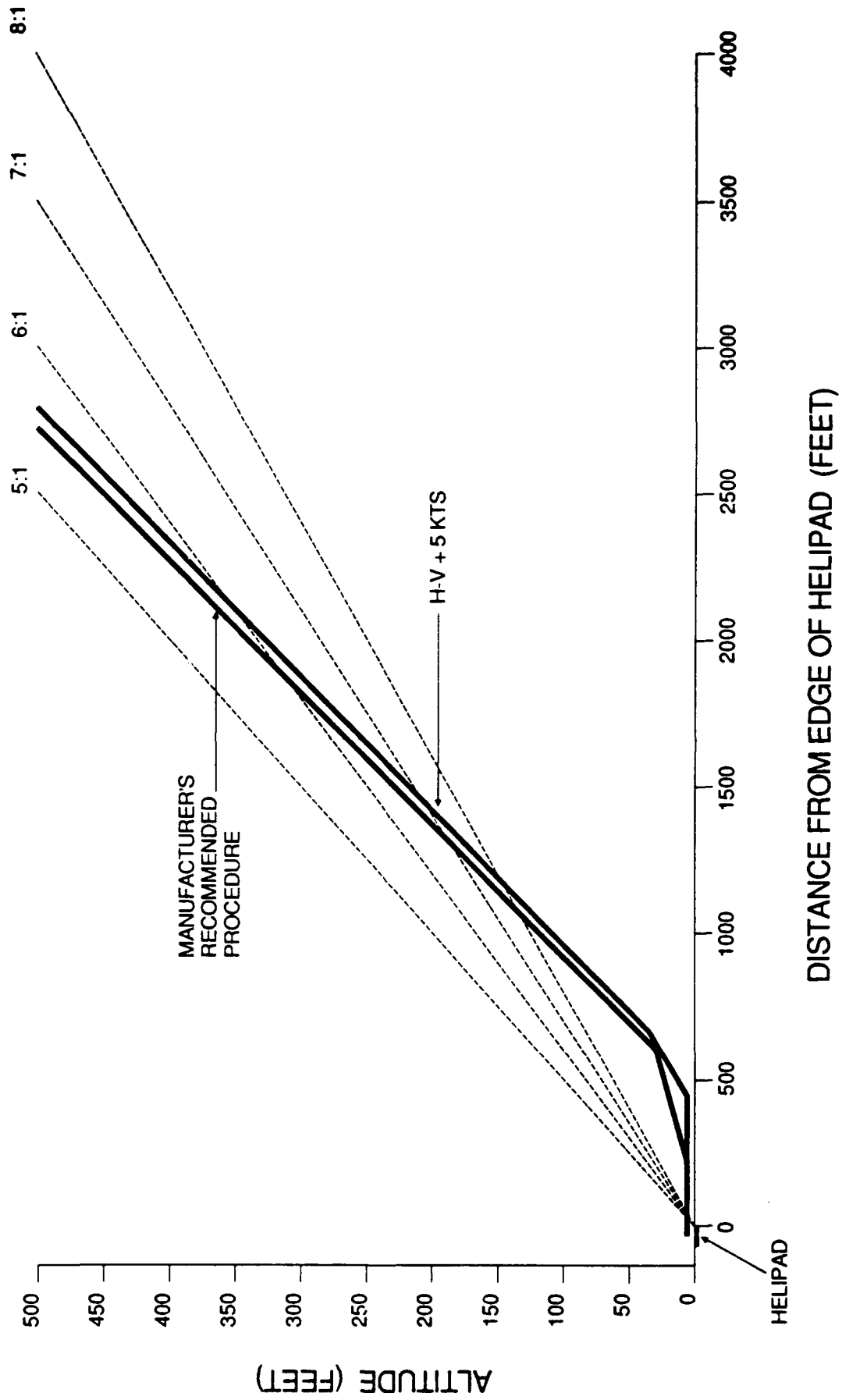
# AS 355F DEPARTURE PROFILES

70% MAX. G.W., 4000 FEET, HOT DAY



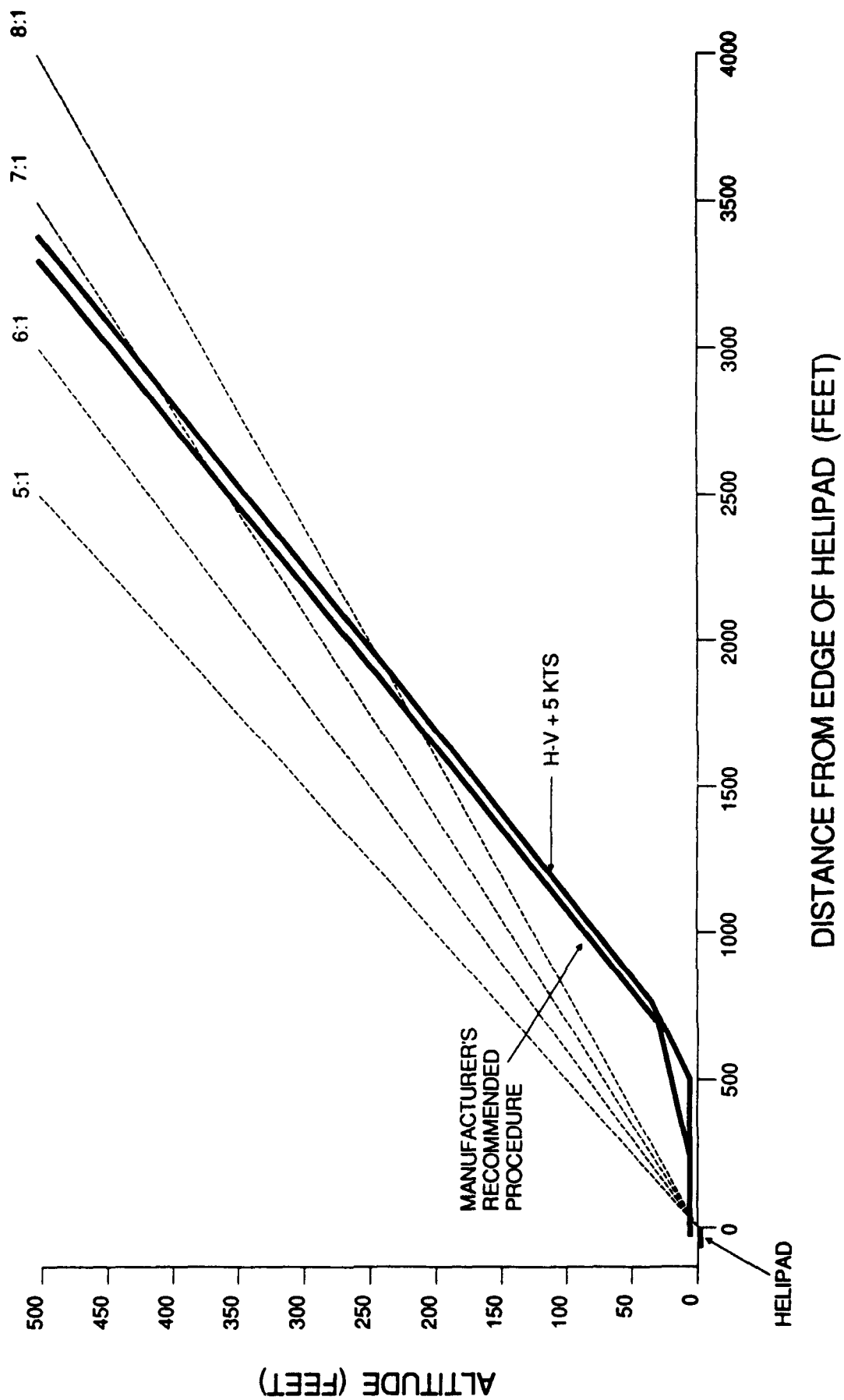
# MBB BO 105 CBS DEPARTURE PROFILES

MAX. G.W., SEA LEVEL, STANDARD DAY



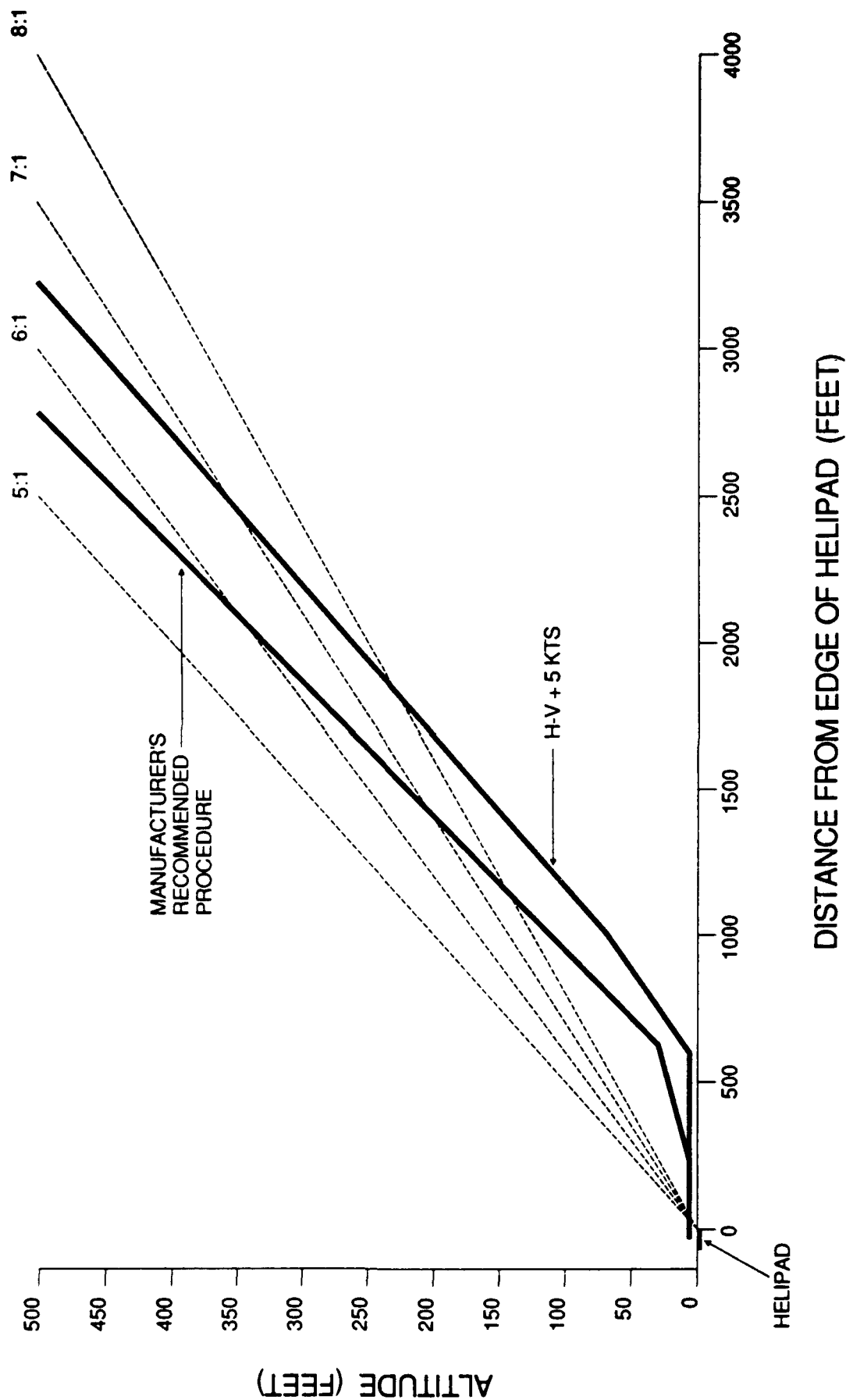
**MBB BO 105 CBS DEPARTURE PROFILES**

**MAX. G.W., SEA LEVEL, HOT DAY**



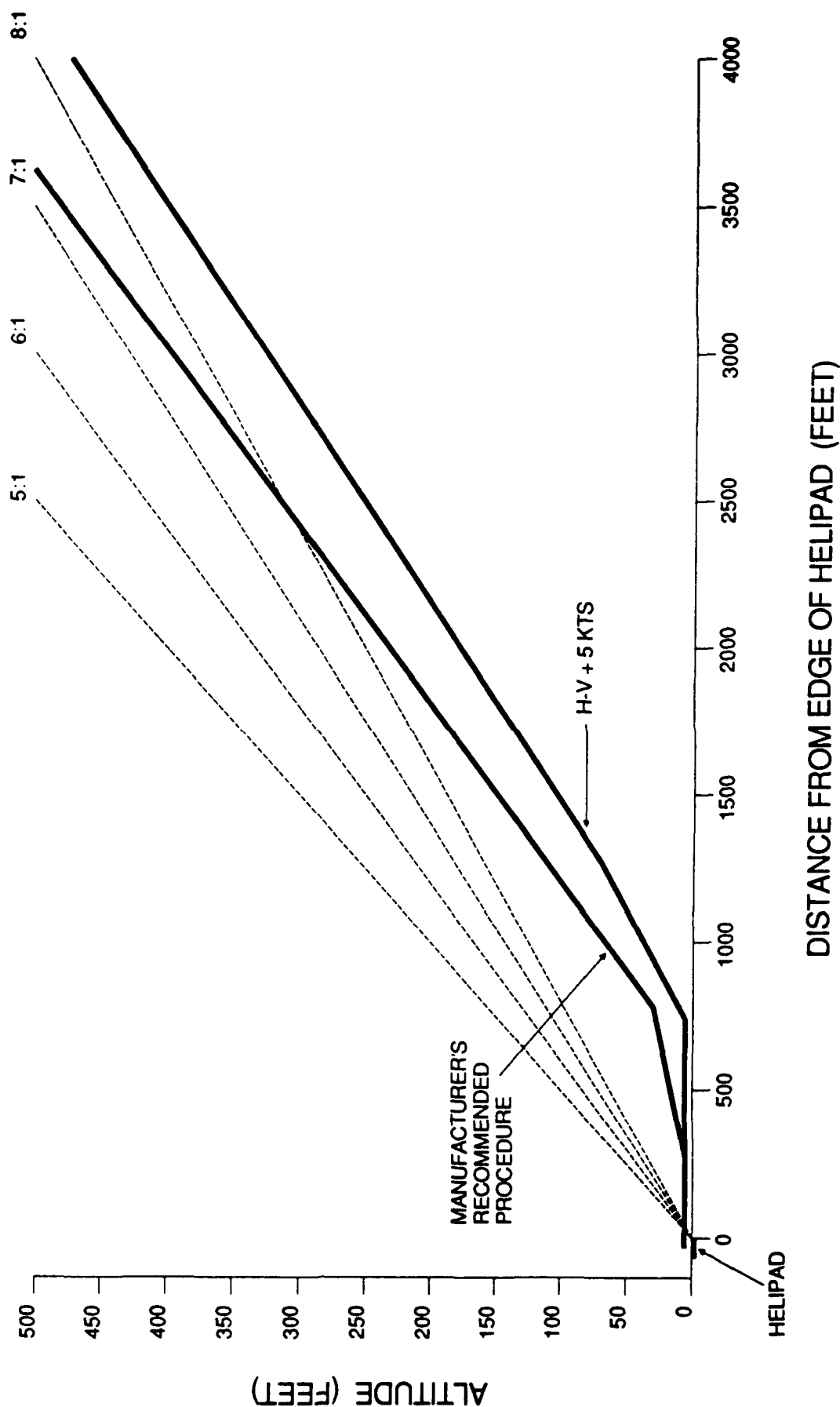
# MBB BO 105 CBS DEPARTURE PROFILES

MAX. G.W., 2000 FEET, STANDARD DAY



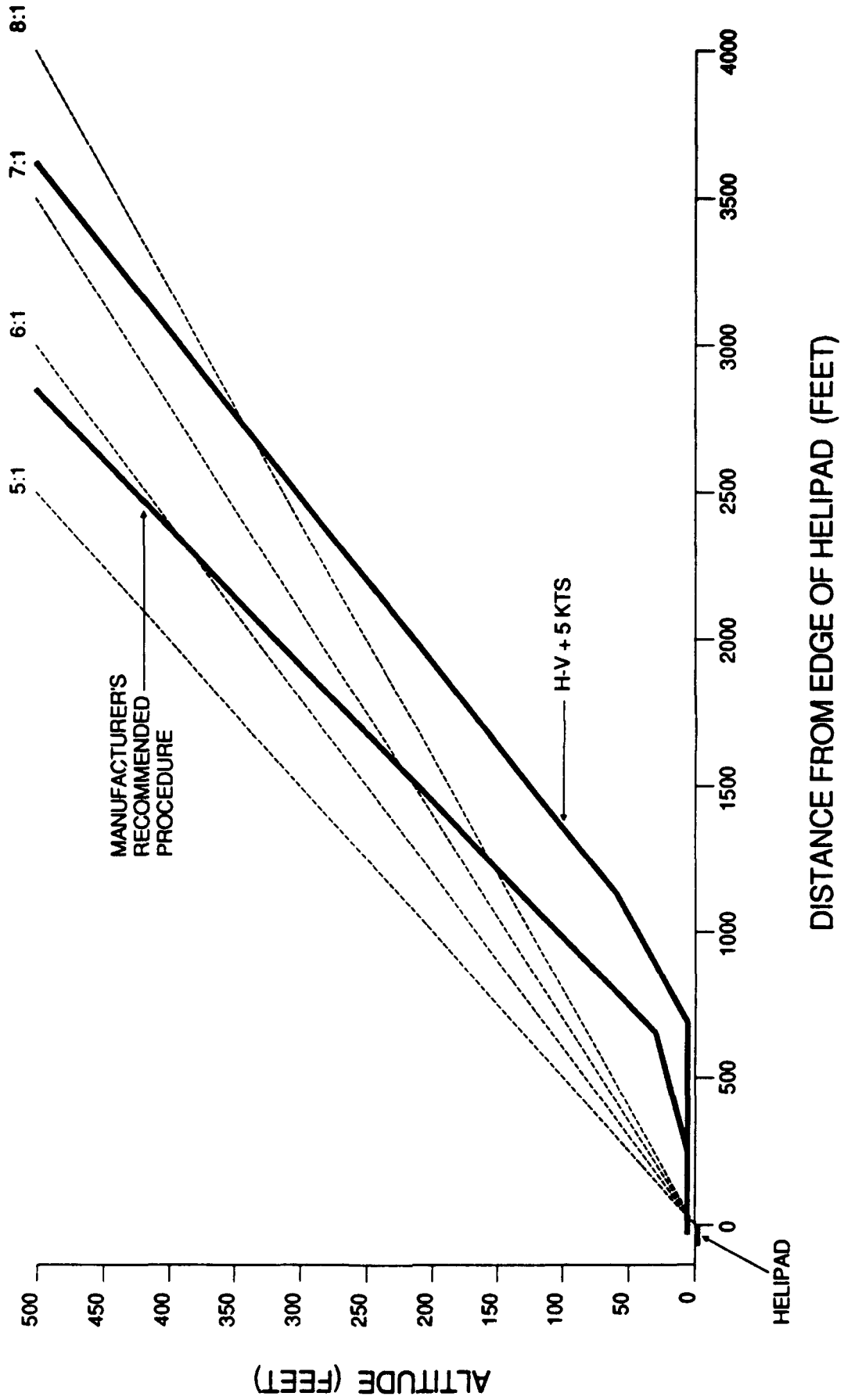
# MBB BO 105 CBS DEPARTURE PROFILES

MAX. G.W., 2000 FEET, HOT DAY



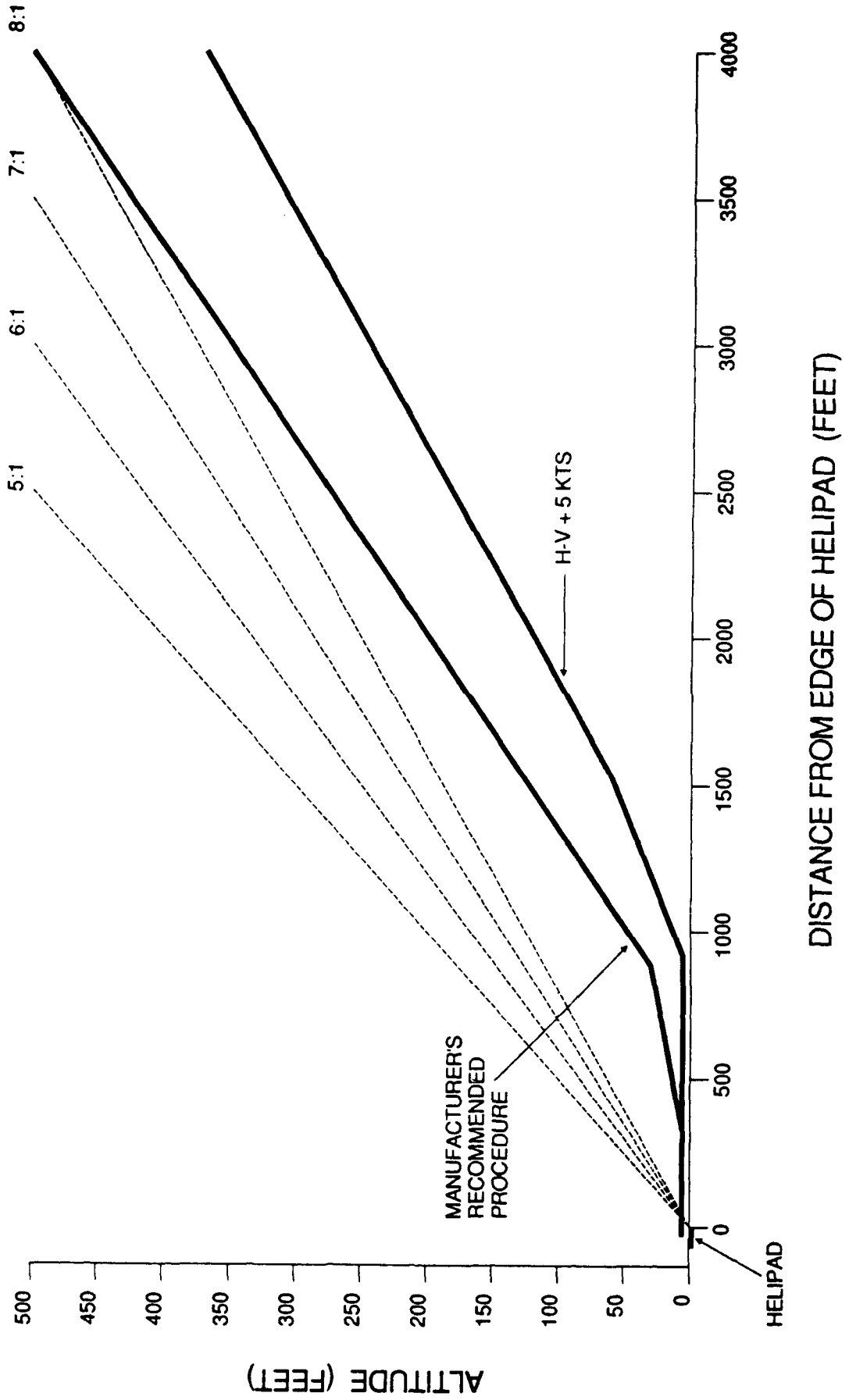
# MBB BO 105 CBS DEPARTURE PROFILES

MAX. G.W., 4000 FEET, STANDARD DAY



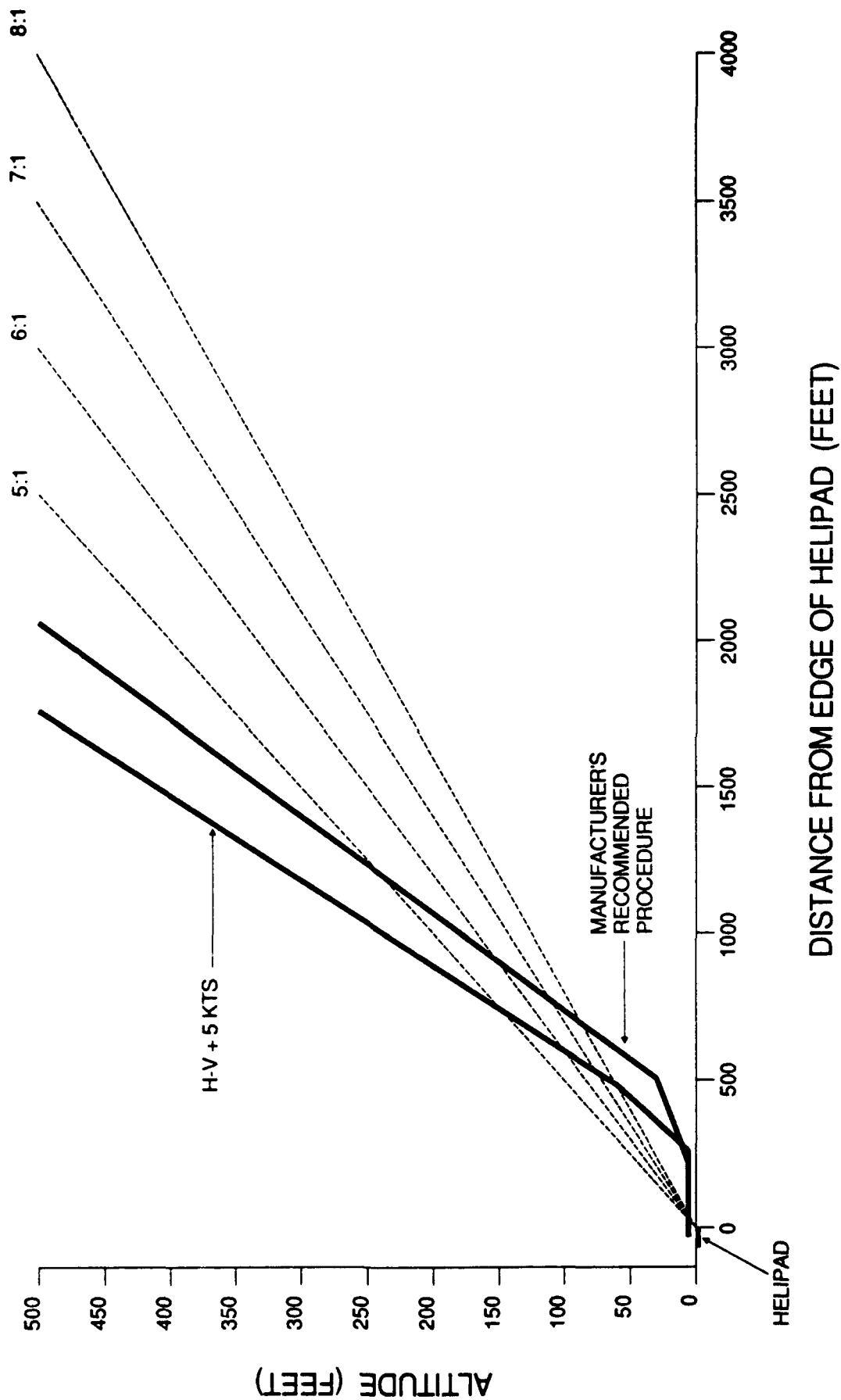
# MBB BO 105 CBS DEPARTURE PROFILES

MAX. G.W., 4000 FEET, HOT DAY



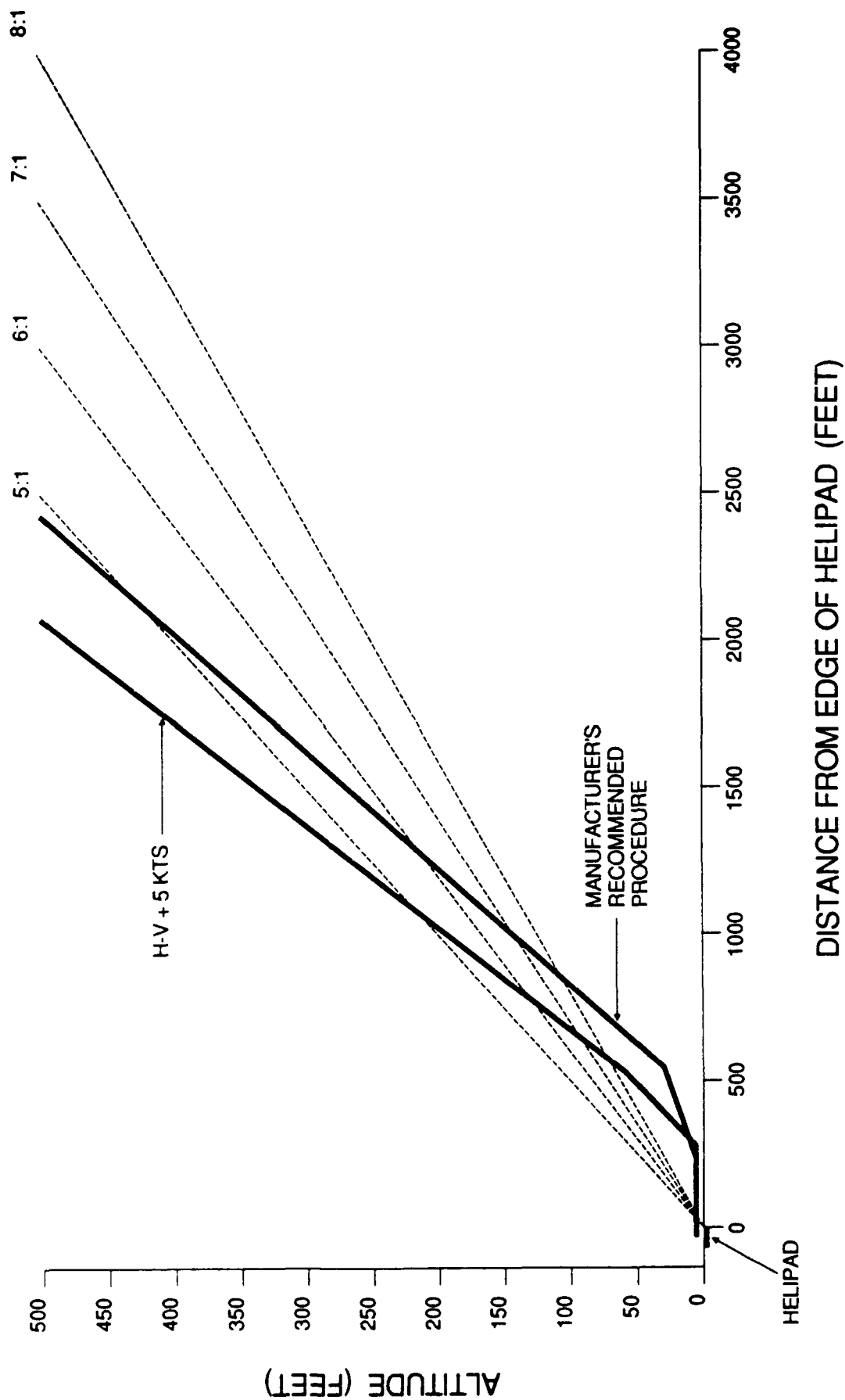
# MBB BO 105 CBS DEPARTURE PROFILES

85% MAX. G.W., SEA LEVEL, STANDARD DAY



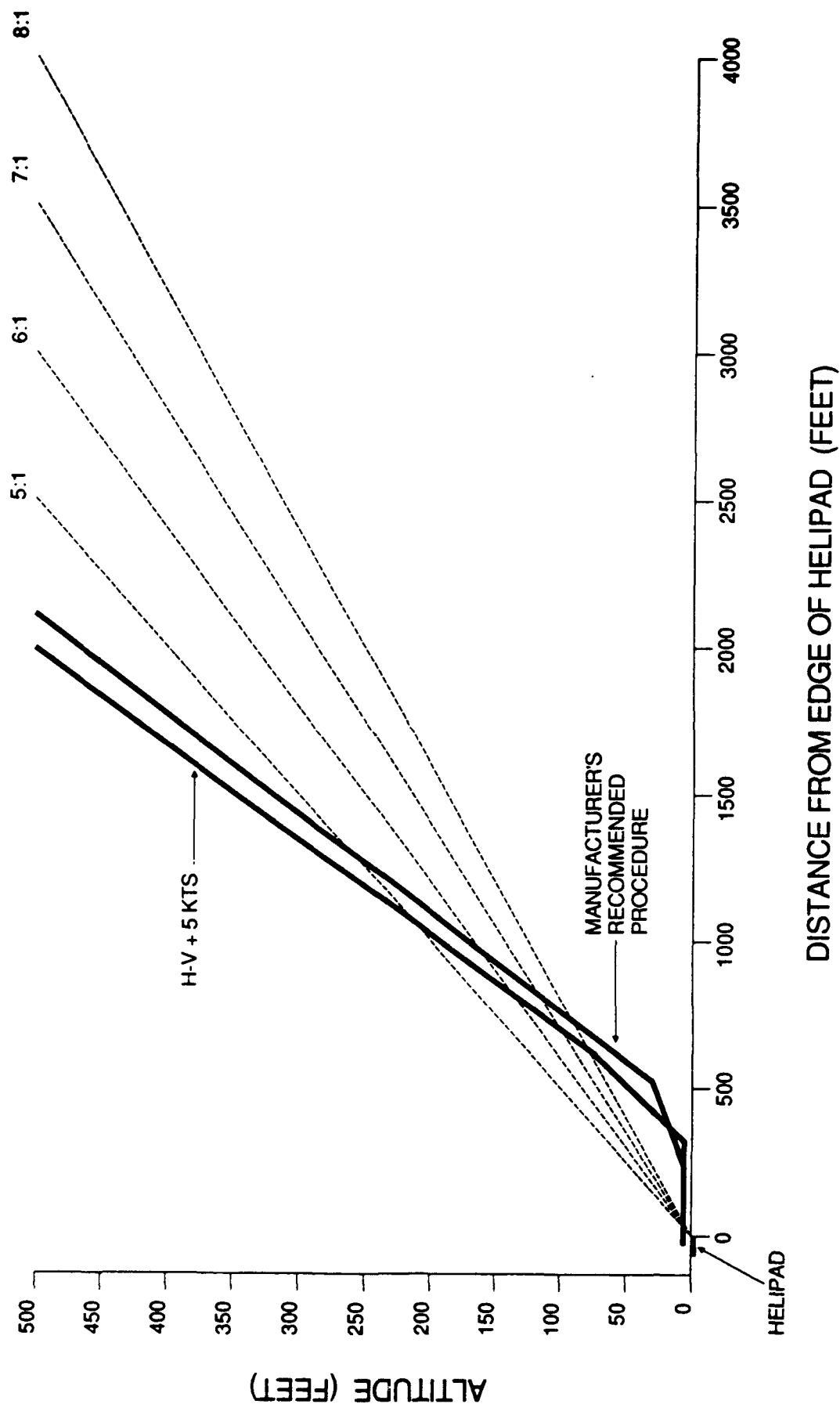
# MBB BO 105 CBS DEPARTURE PROFILES

85% MAX. G.W., SEA LEVEL, HOT DAY



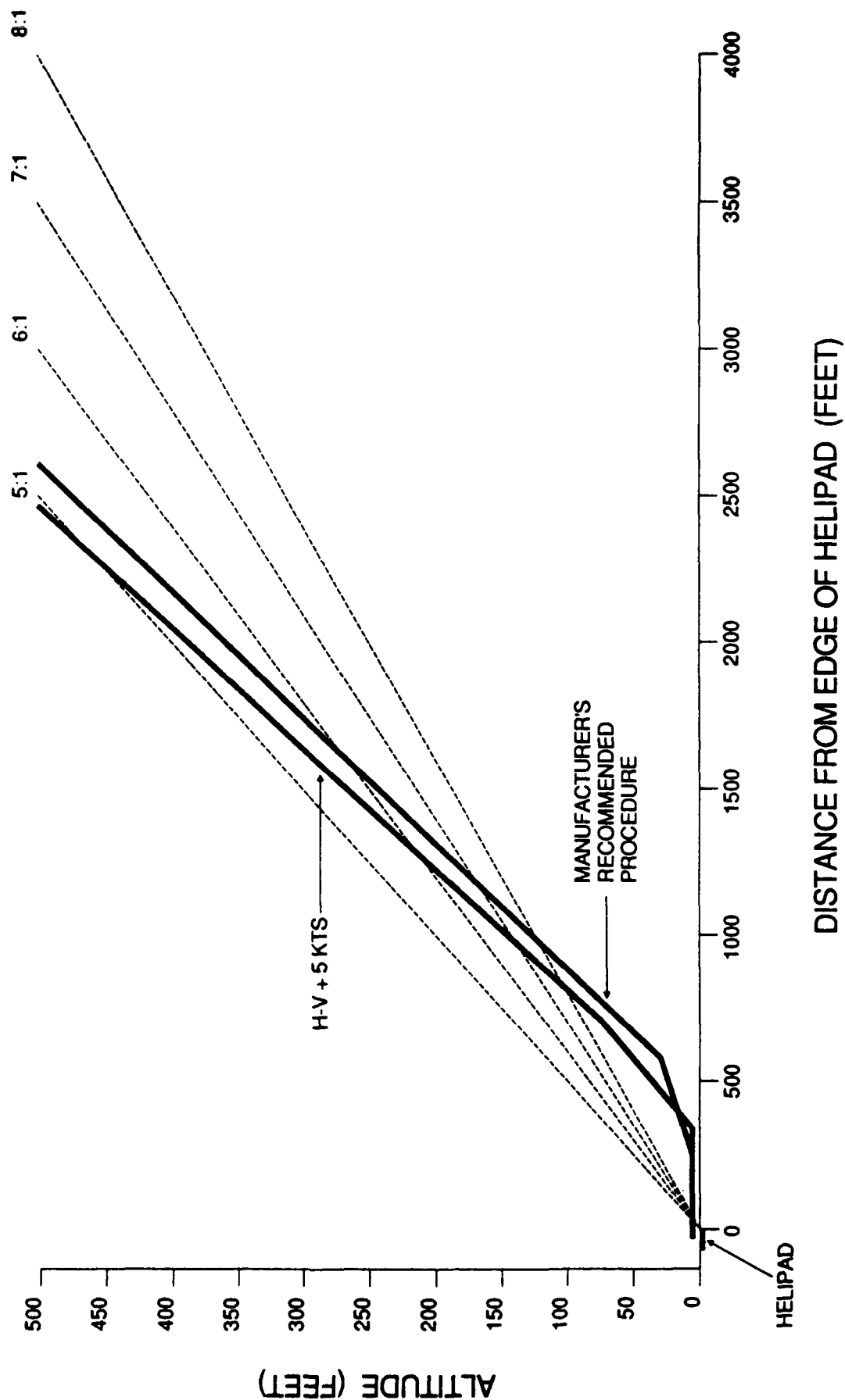
# MBB BO 105 CBS DEPARTURE PROFILES

85% MAX. G.W., 2000 FEET, STANDARD DAY



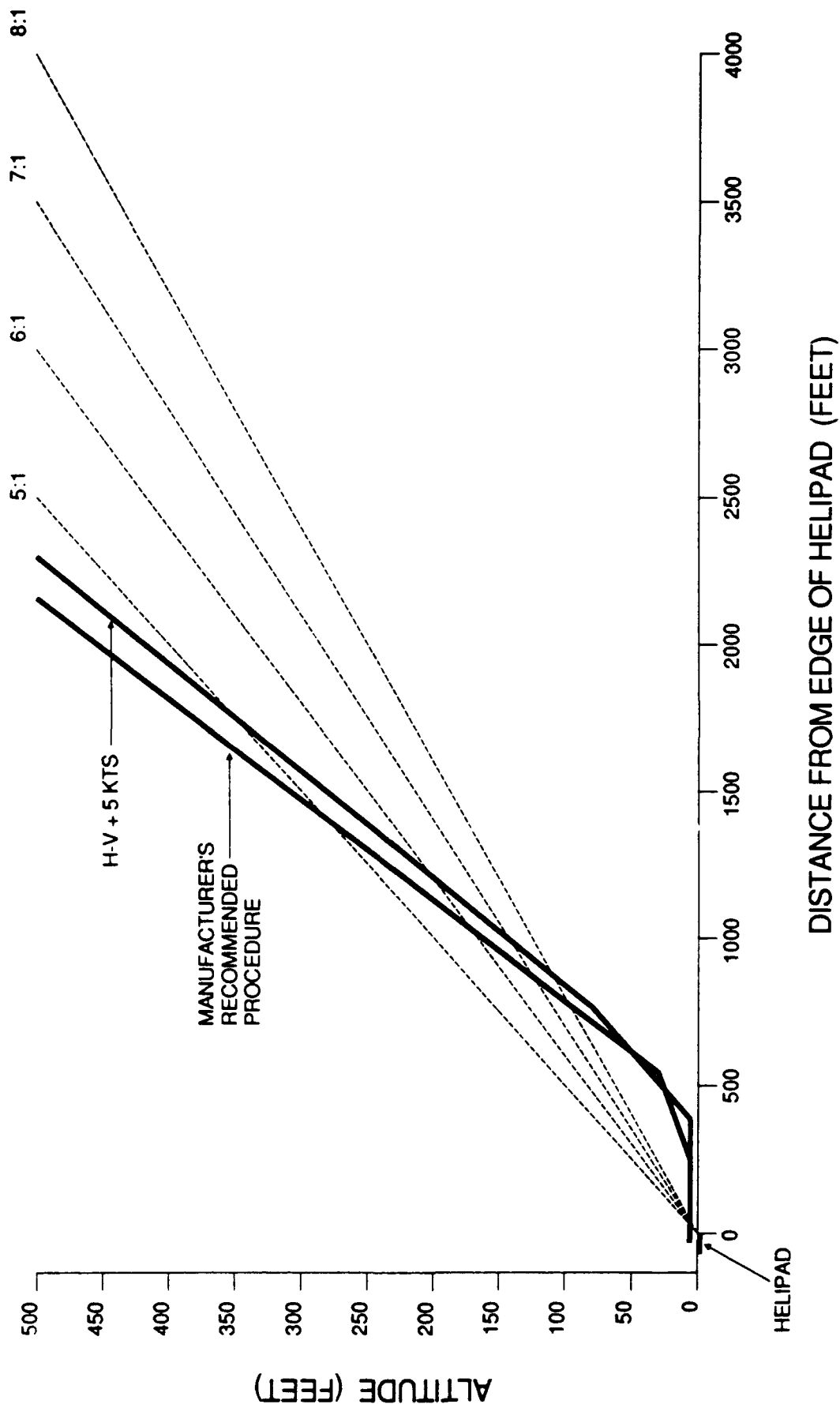
# MBB BO 105 CBS DEPARTURE PROFILES

85% MAX. G.W., 2000 FEET, HOT DAY



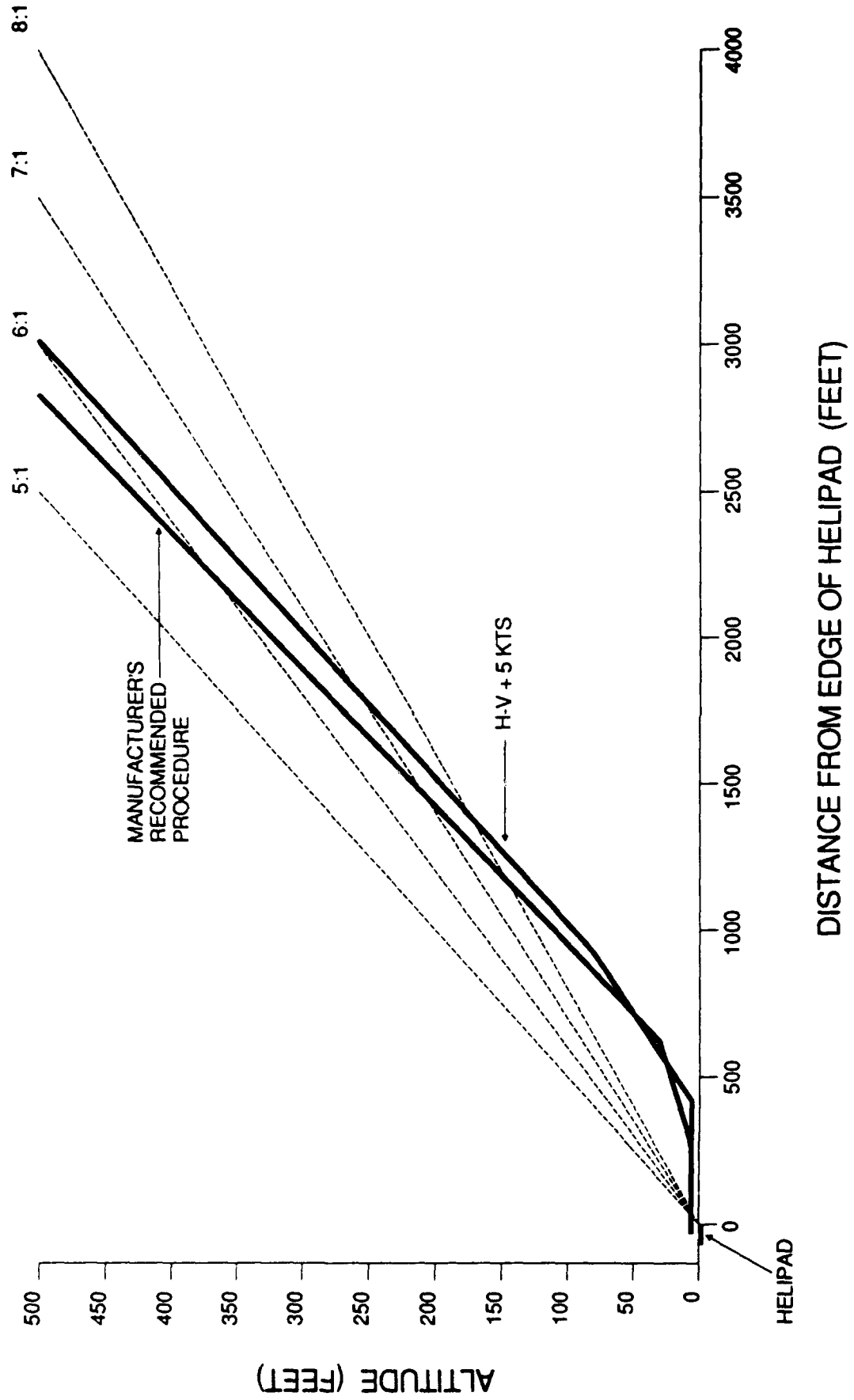
# MBB BO 105 CBS DEPARTURE PROFILES

85% MAX. G.W., 4000 FEET, STANDARD DAY



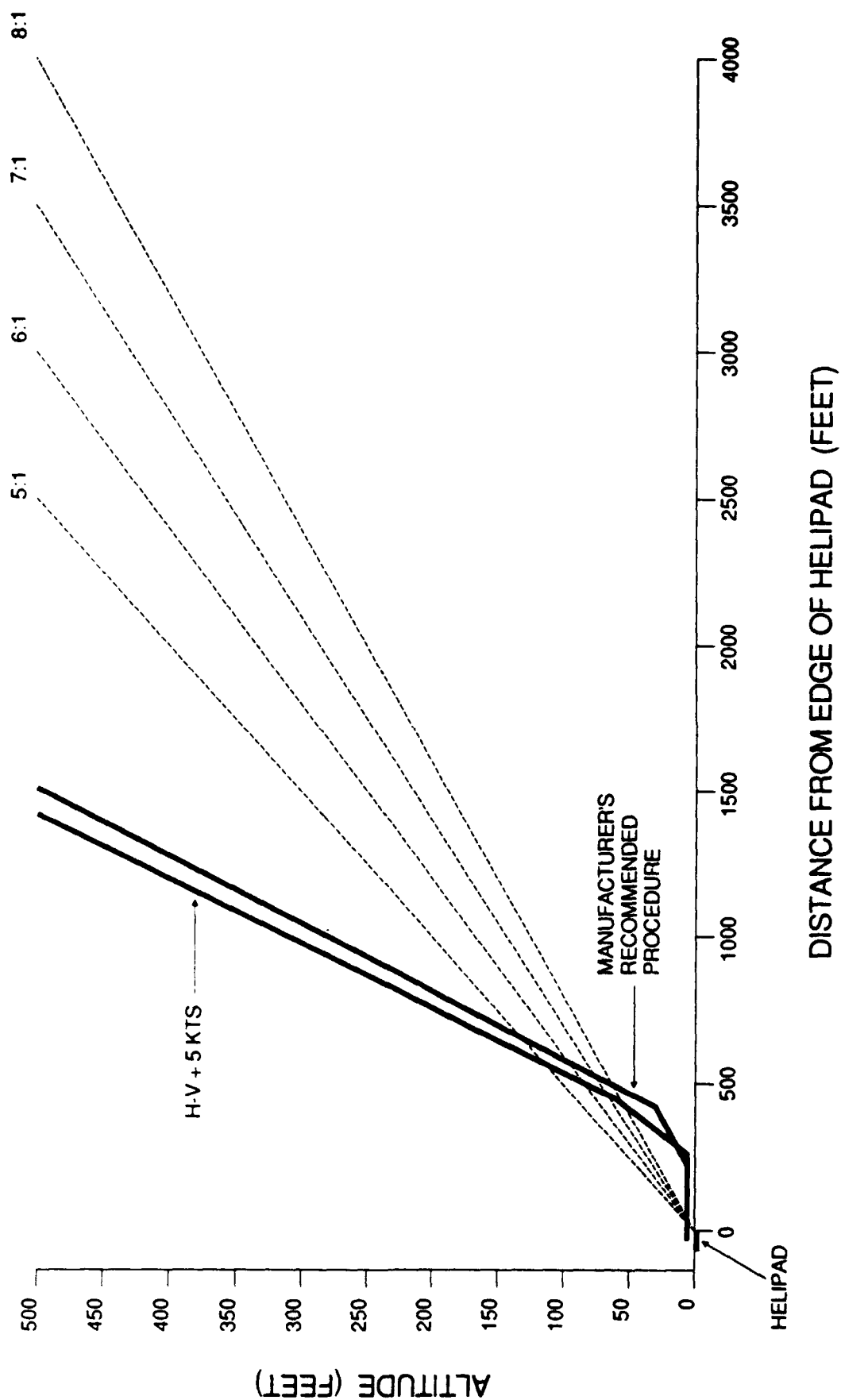
# MBB BO 105 CBS DEPARTURE PROFILES

85% MAX. G.W., 4000 FEET, HOT DAY



# MBB BO 105 CBS DEPARTURE PROFILES

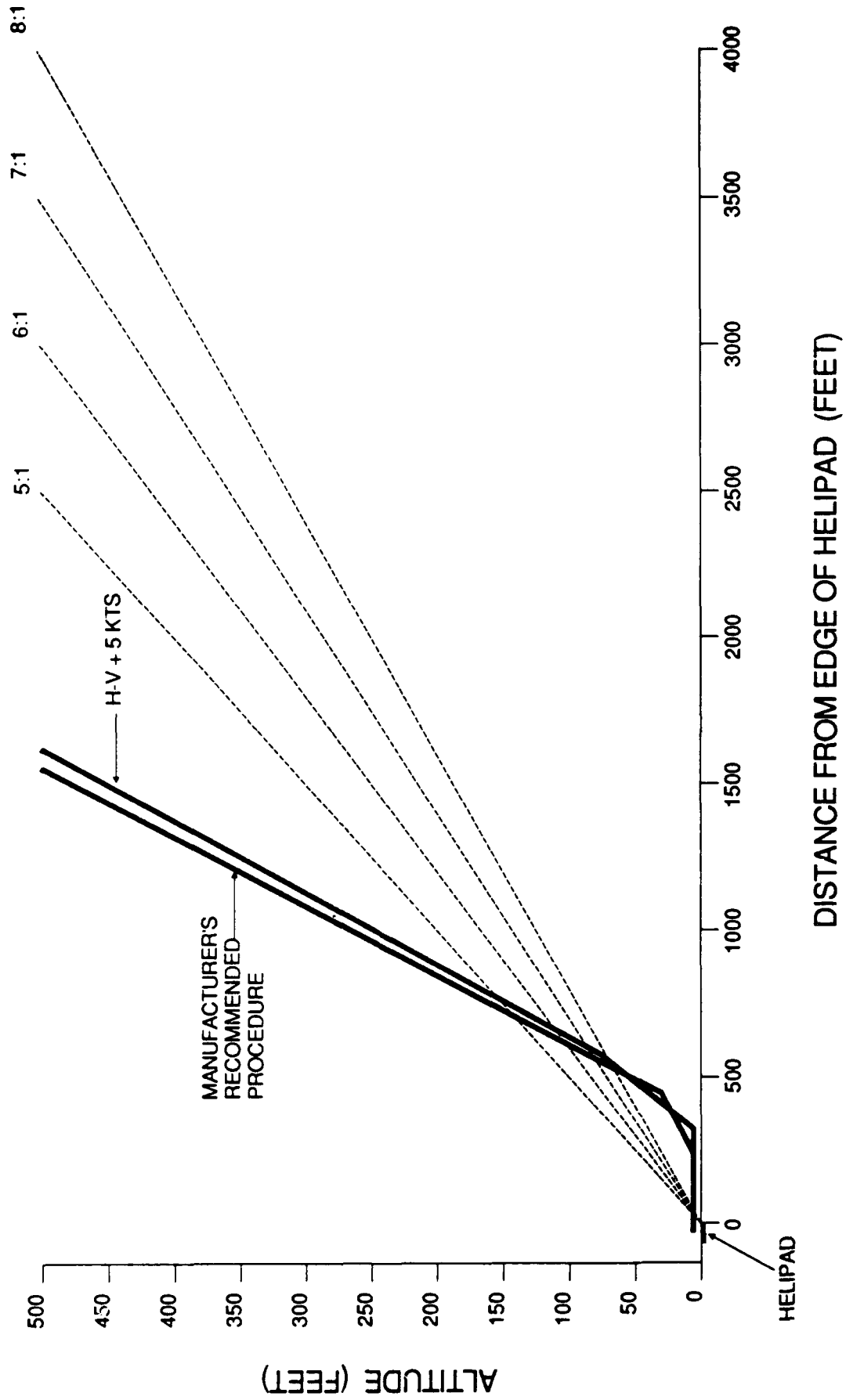
70% MAX. G.W., SEA LEVEL, STANDARD DAY





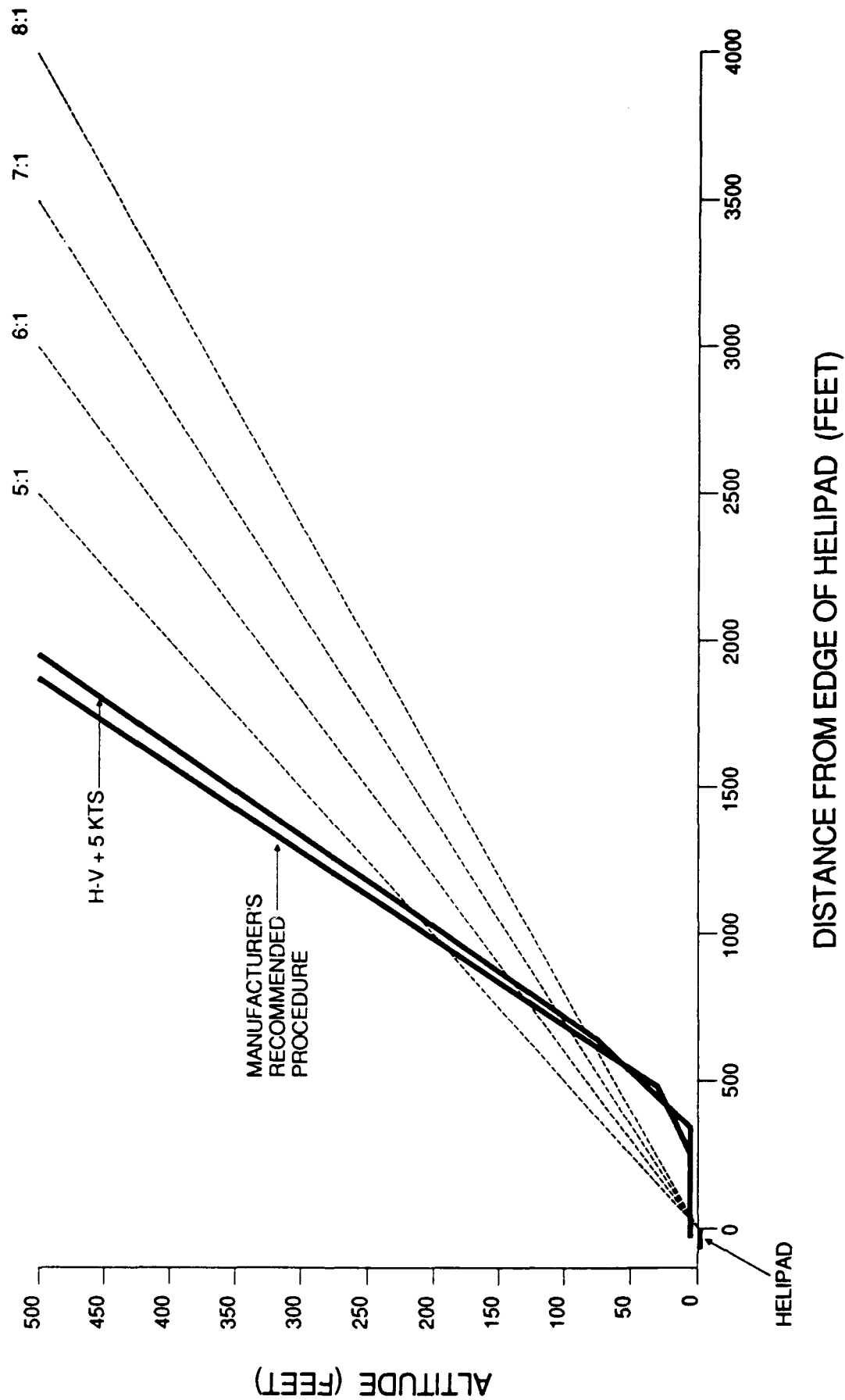
# MBB BO 105 CBS DEPARTURE PROFILES

70% MAX. G.W., 2000 FEET, STANDARD DAY



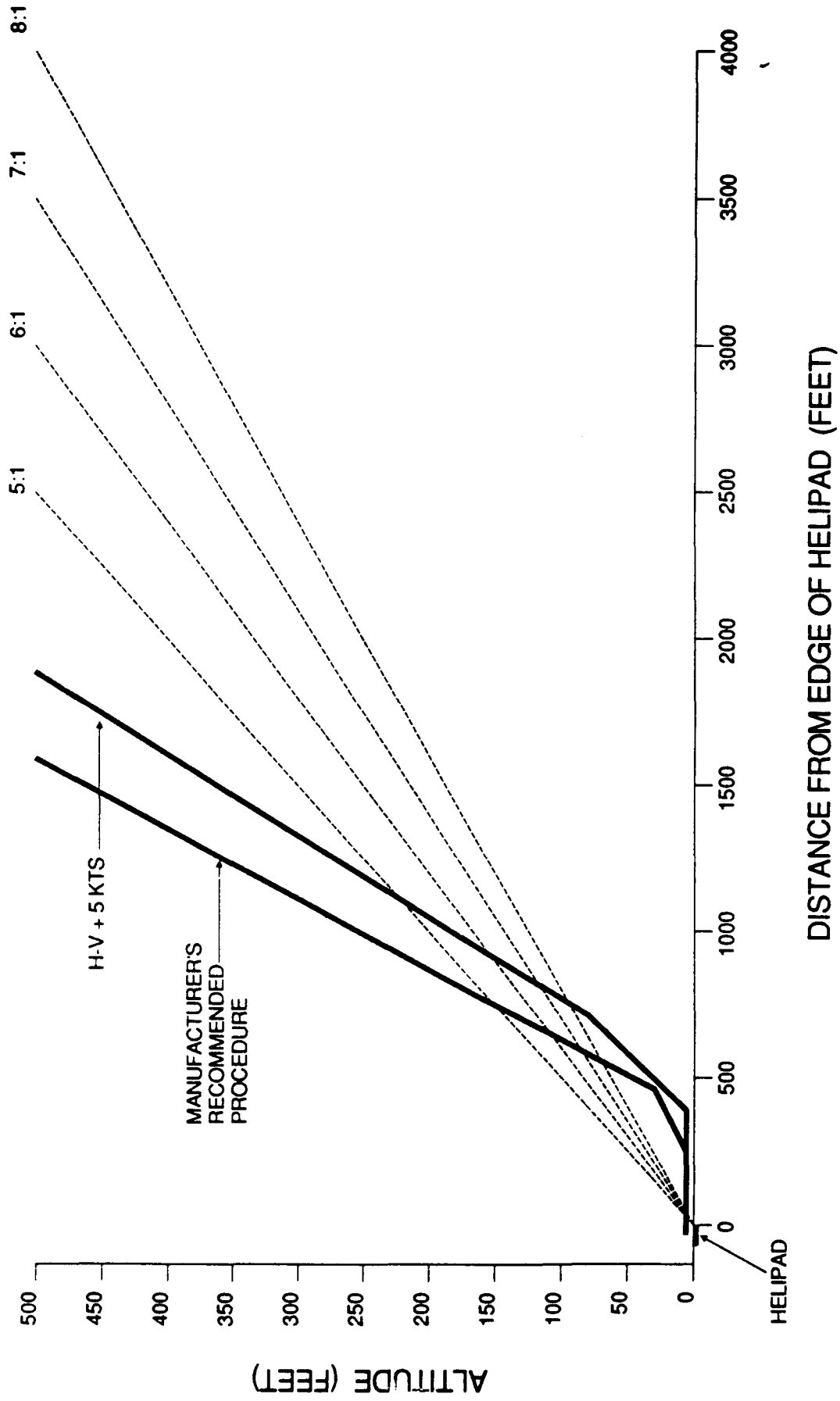
# MBB BO 105 CBS DEPARTURE PROFILES

70% MAX. G.W., 2000 FEET, HOT DAY



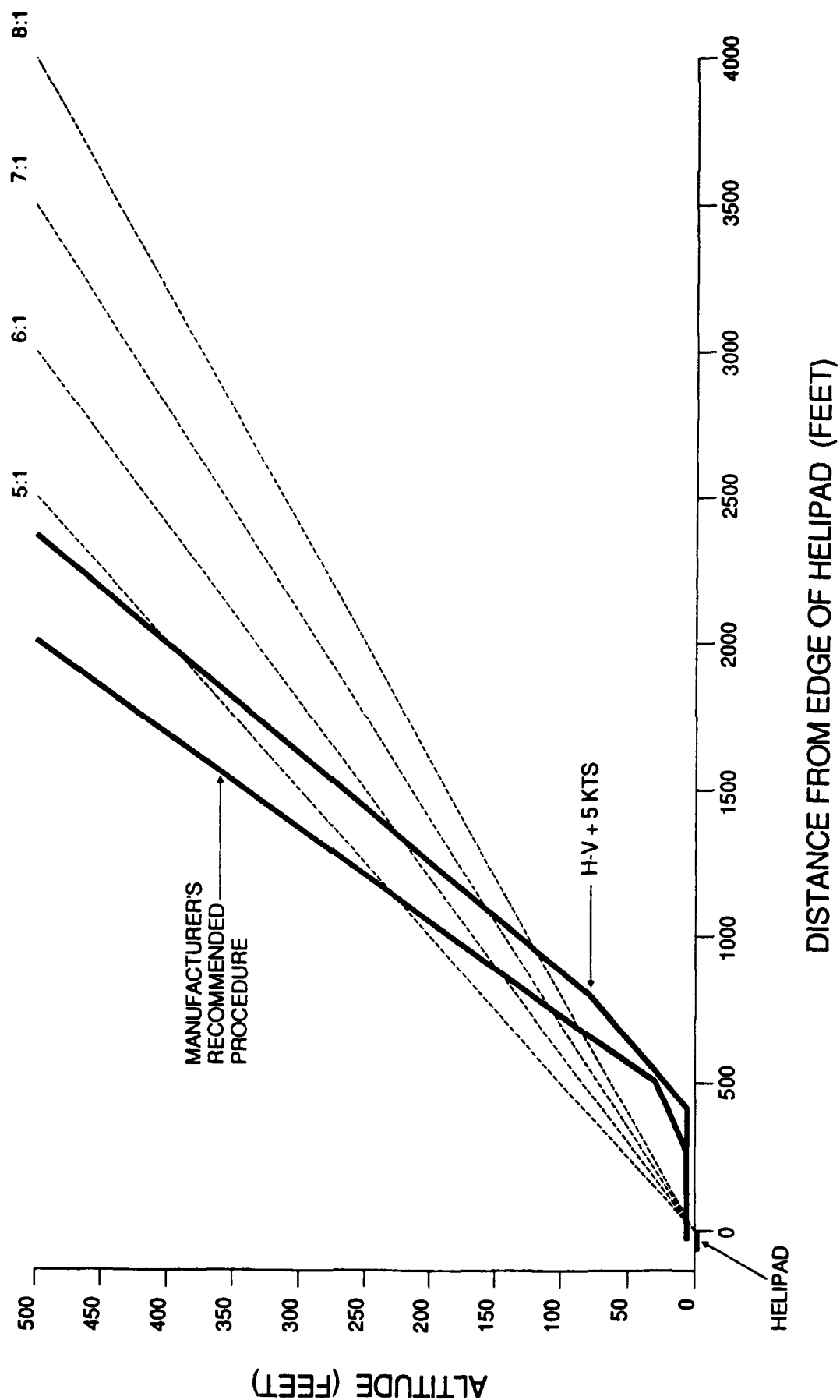
# MBB BO 105 CBS DEPARTURE PROFILES

70% MAX. G.W., 4000 FEET, STANDARD DAY



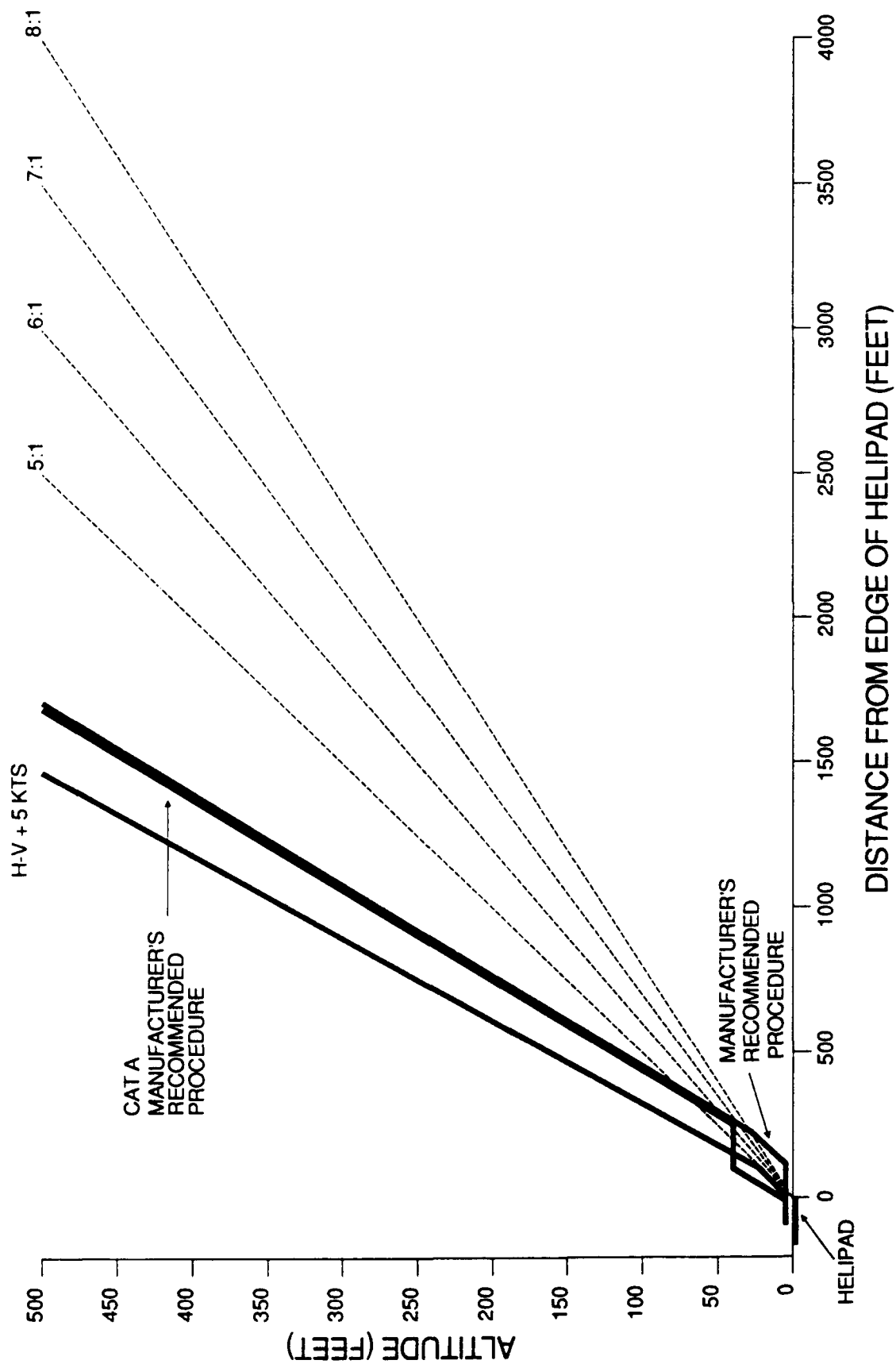
# MBB BO 105 CBS DEPARTURE PROFILES

70% MAX. G.W., 4000 FEET, HOT DAY



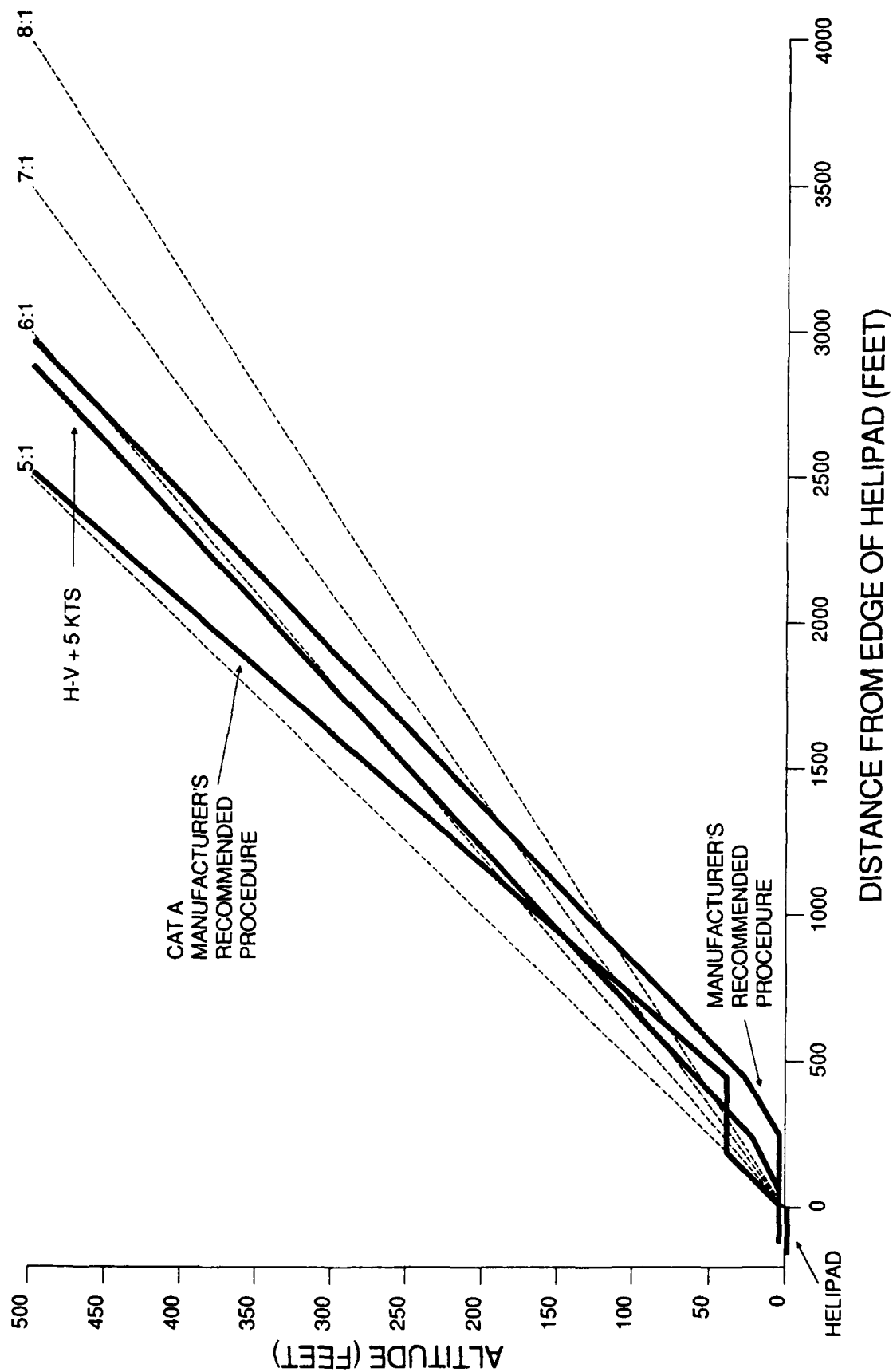
# S 76A DEPARTURE PROFILES

MAX. G.W., SEA LEVEL, STANDARD DAY



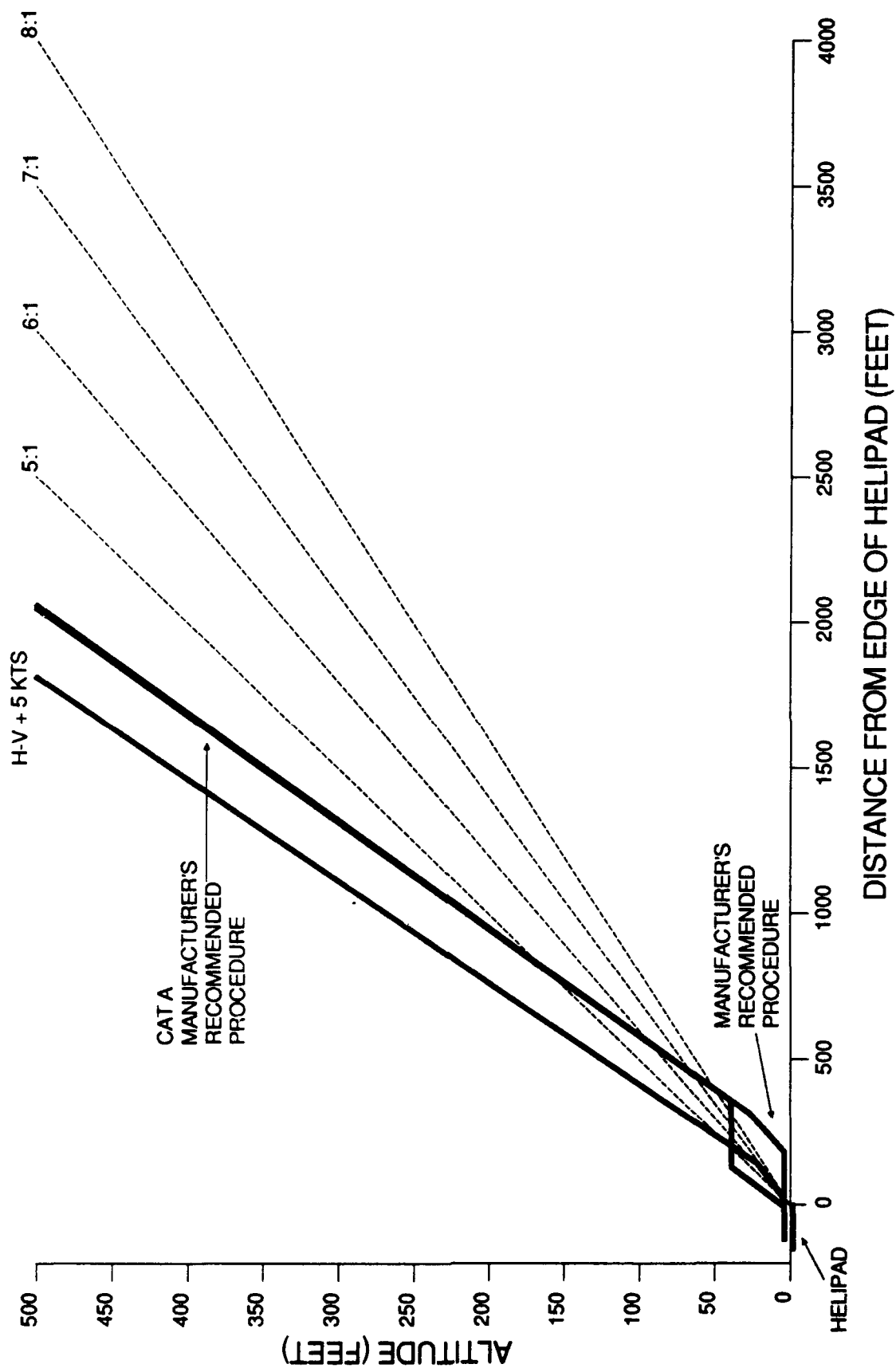
# S 76A DEPARTURE PROFILES

MAX. G.W., SEA LEVEL, HOT DAY



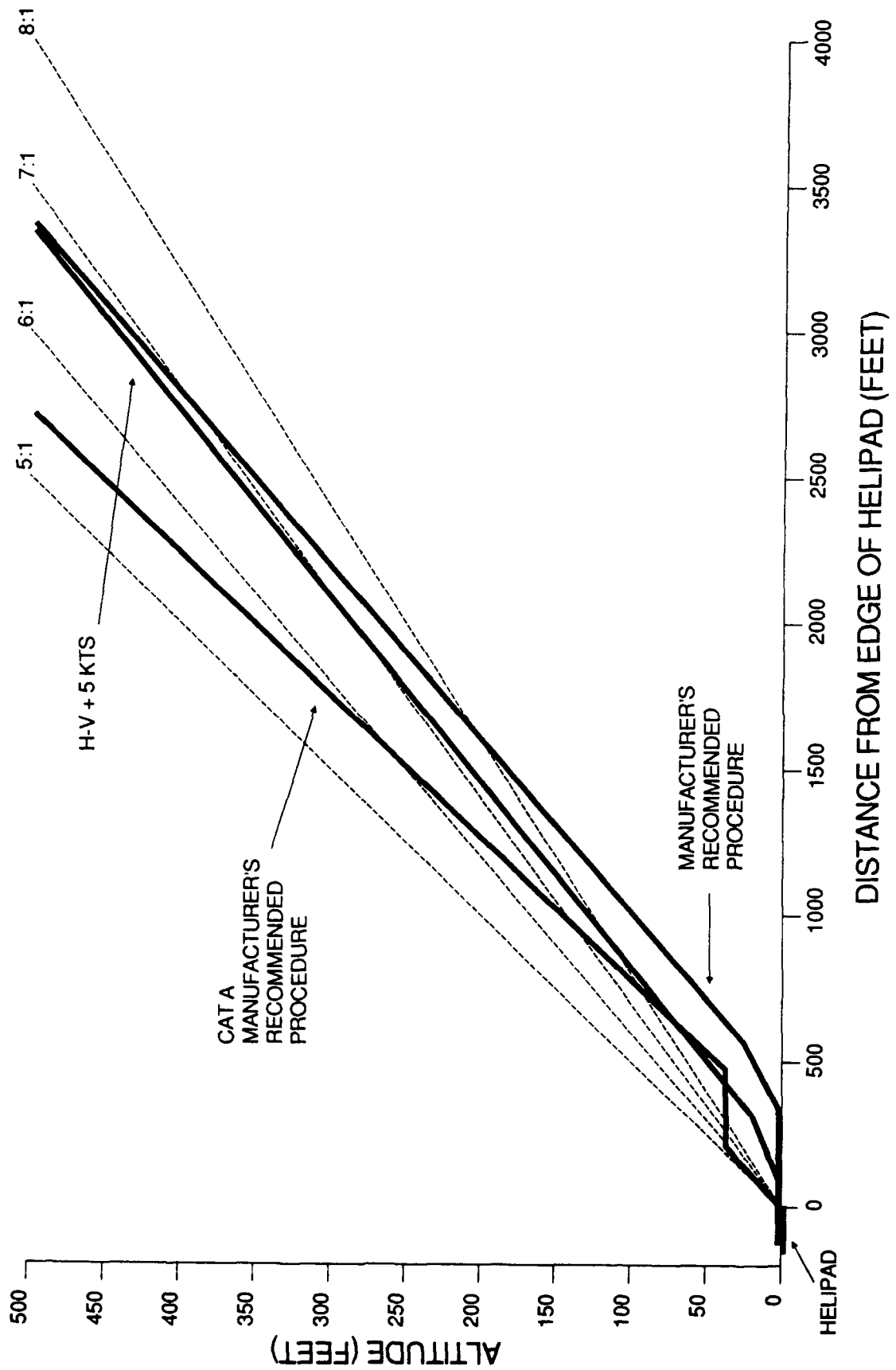
# S 76A DEPARTURE PROFILES

MAX. G.W., 2000 FEET, STANDARD DAY



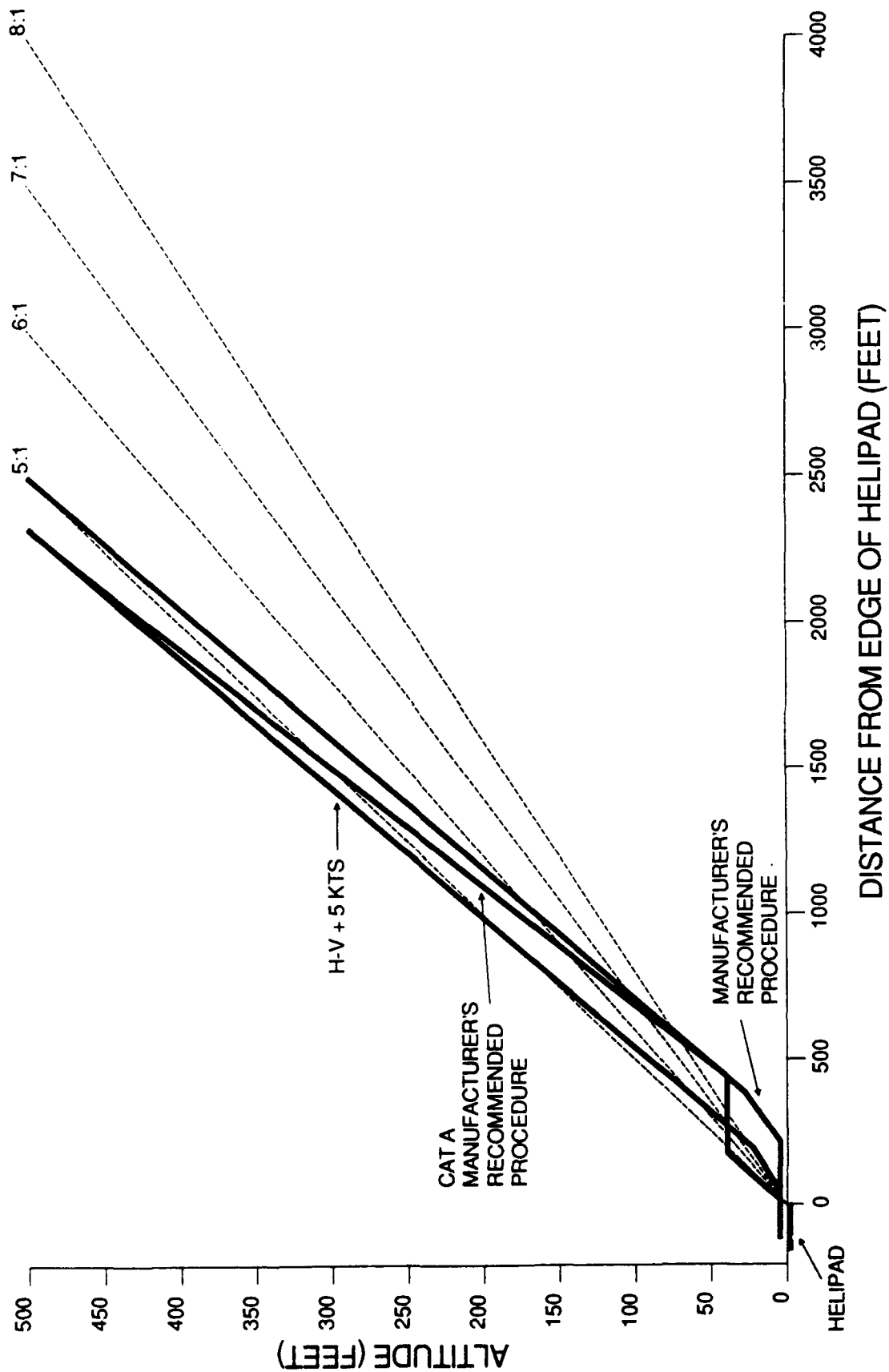
# S 76A DEPARTURE PROFILES

MAX. G.W., 2000 FEET, HOT DAY



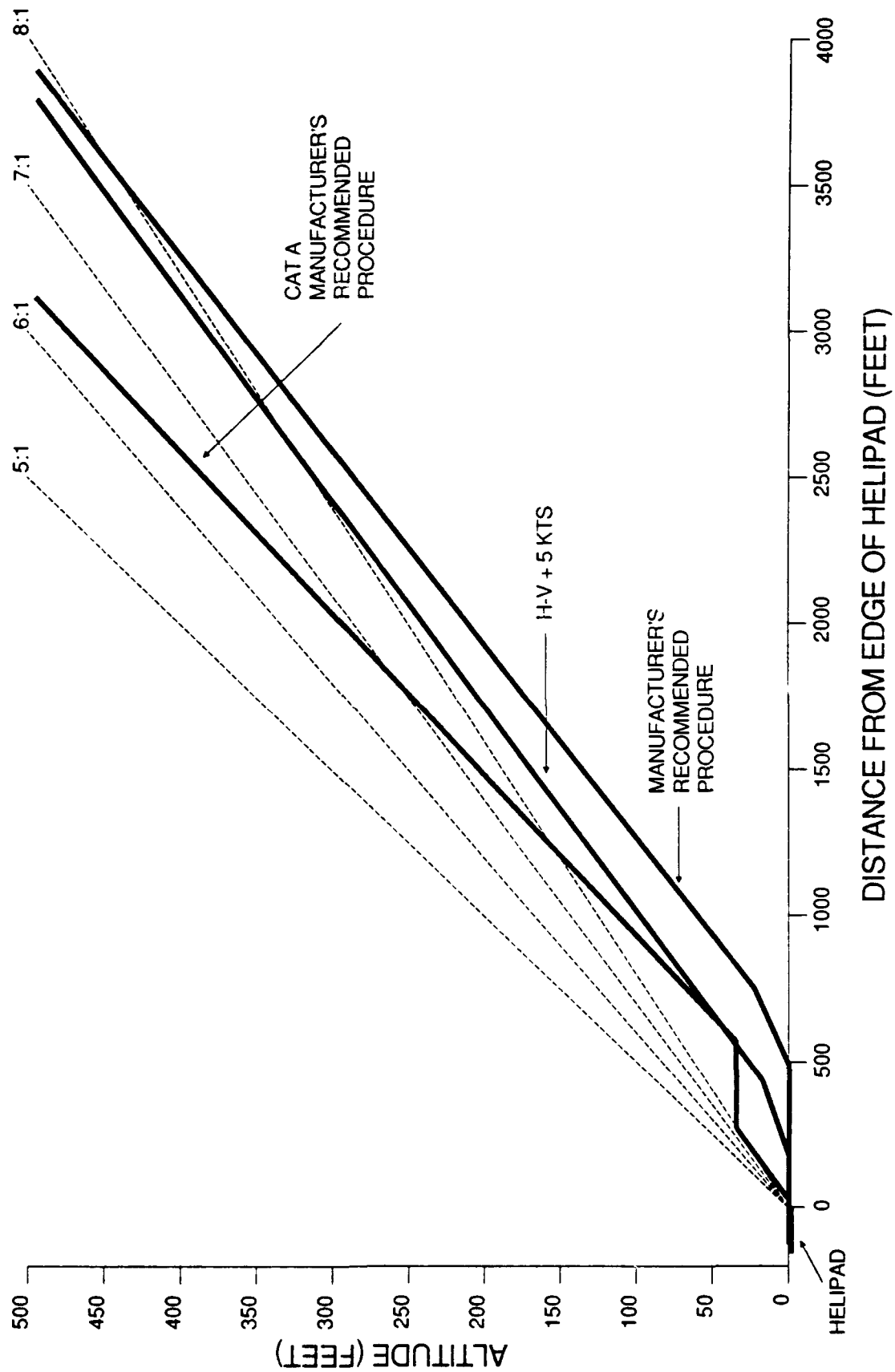
# S 76A DEPARTURE PROFILES

MAX. G.W., 4000 FEET, STANDARD DAY



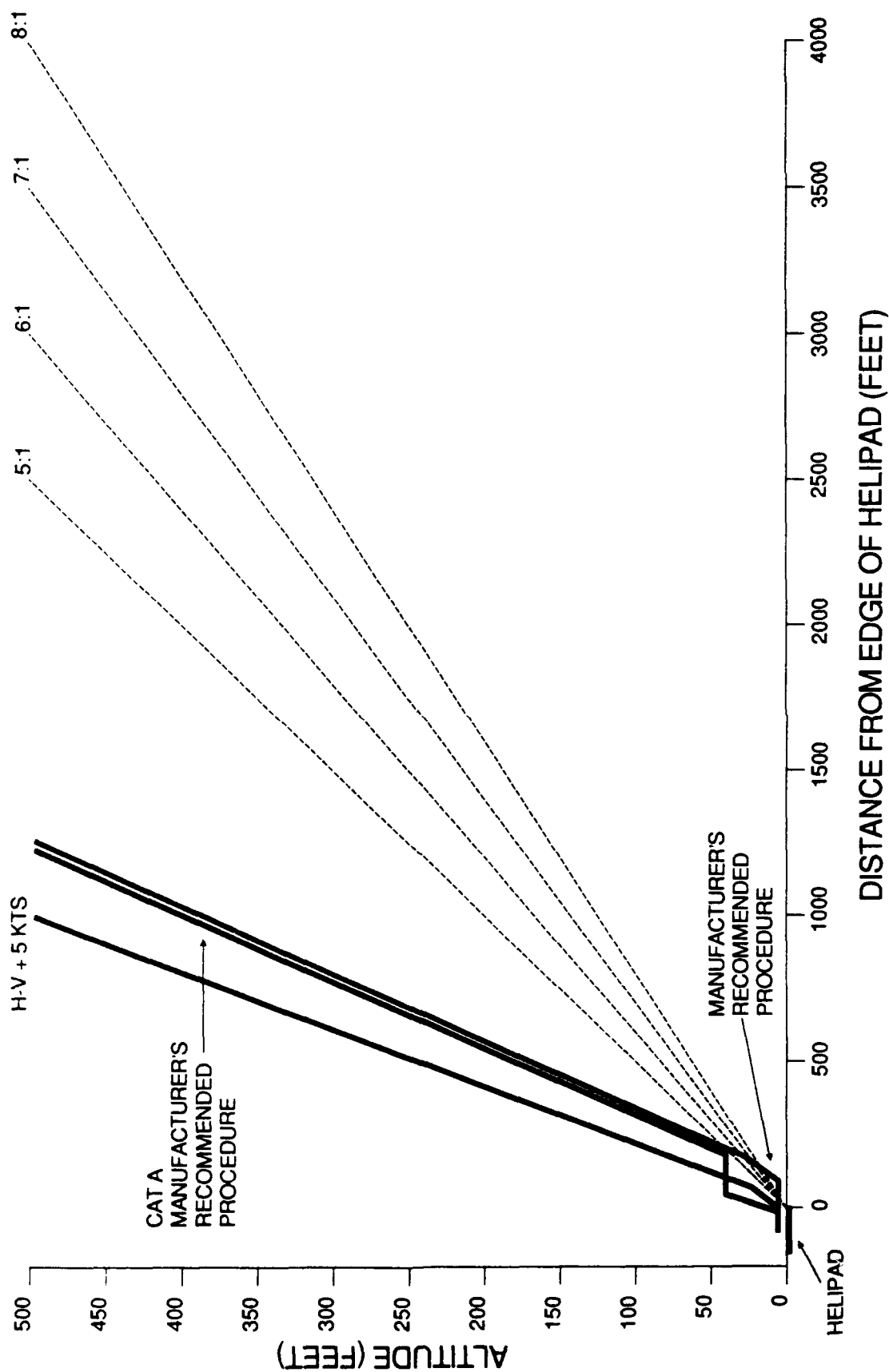
# S 76A DEPARTURE PROFILES

MAX. G.W., 4000 FEET, HOT DAY



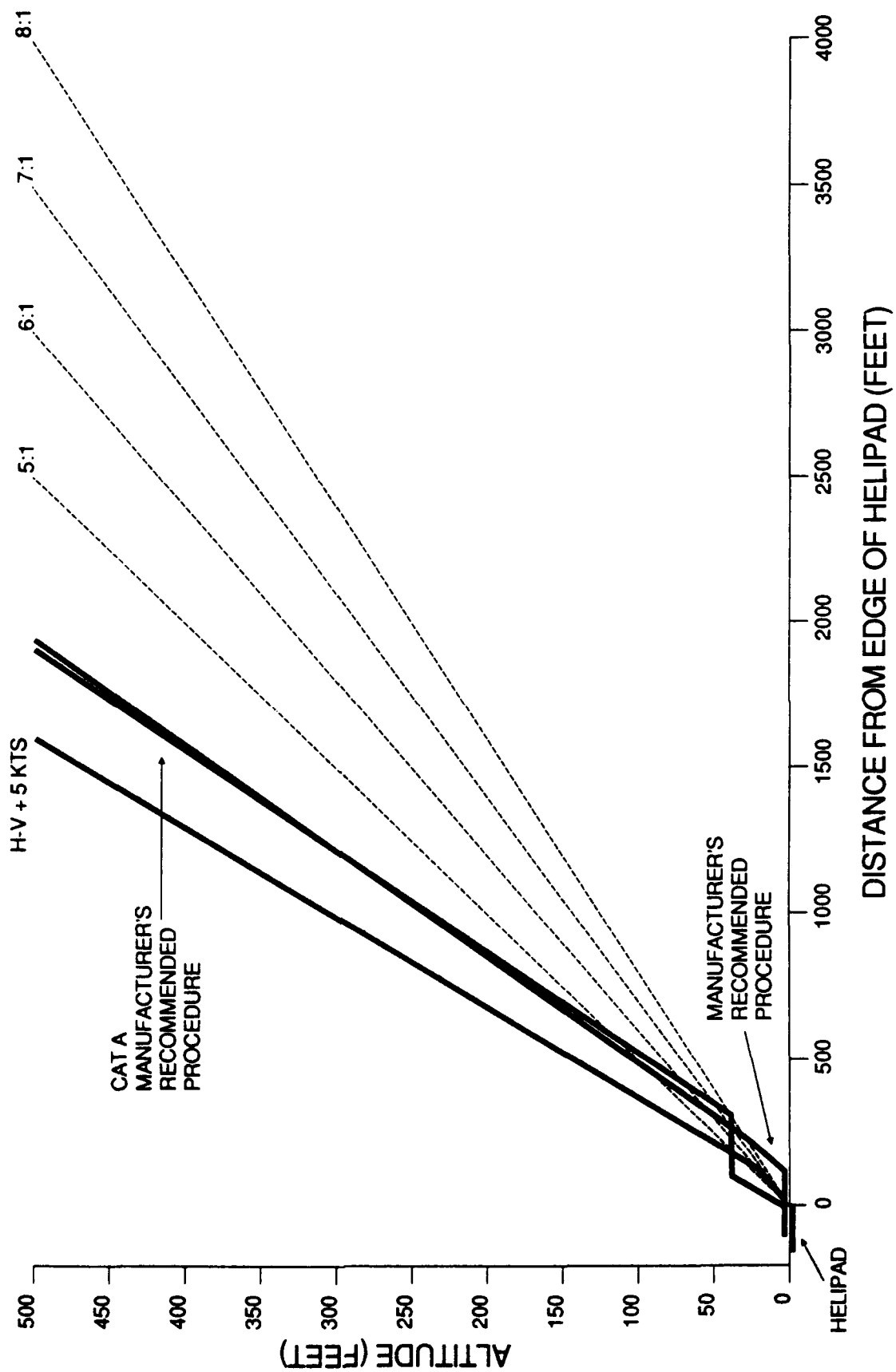
# S 76A DEPARTURE PROFILES

85% MAX. G.W., SEA LEVEL, STANDARD DAY



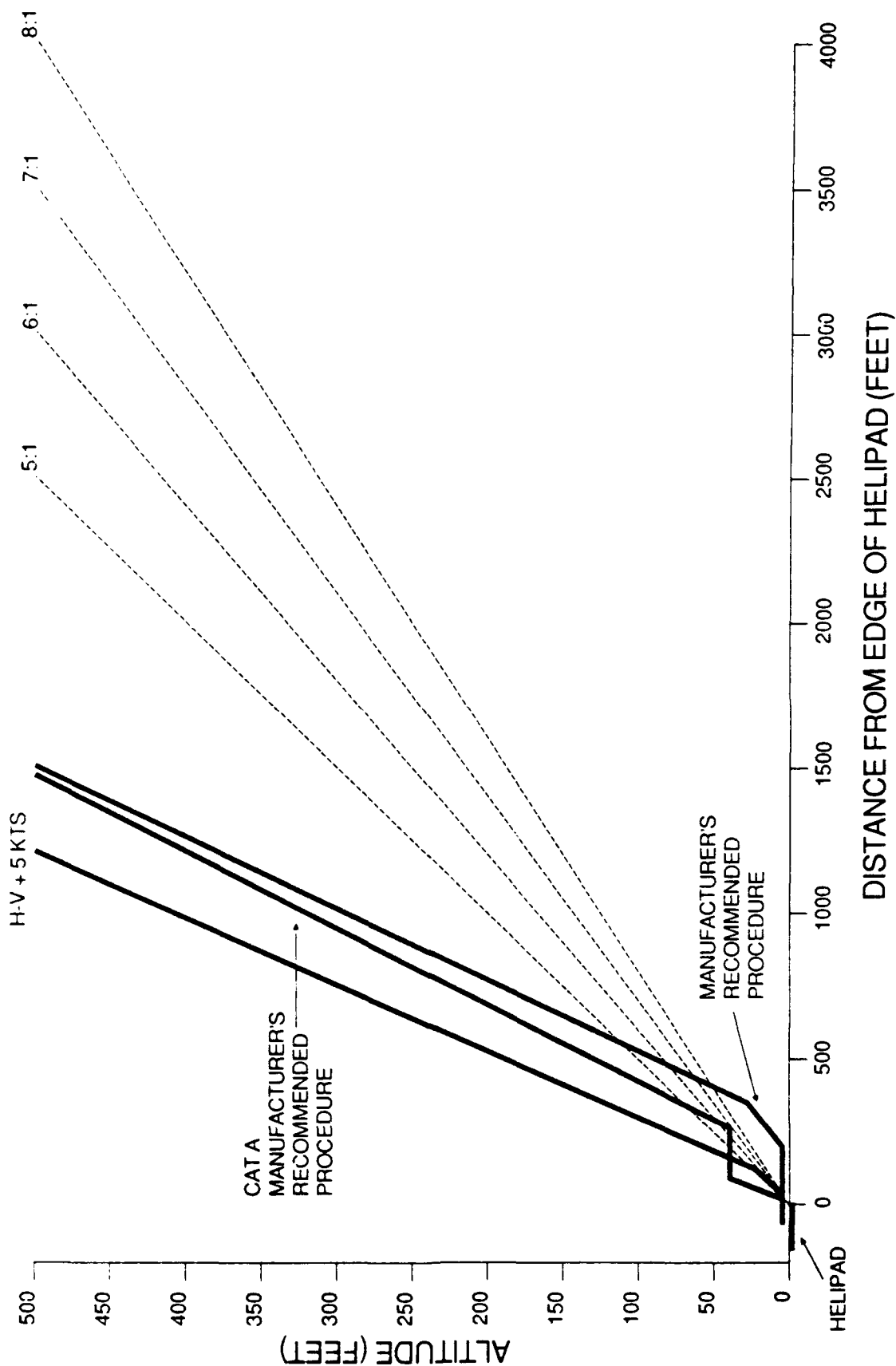
# S 76A DEPARTURE PROFILES

85% MAX. G.W., SEA LEVEL, HOT DAY



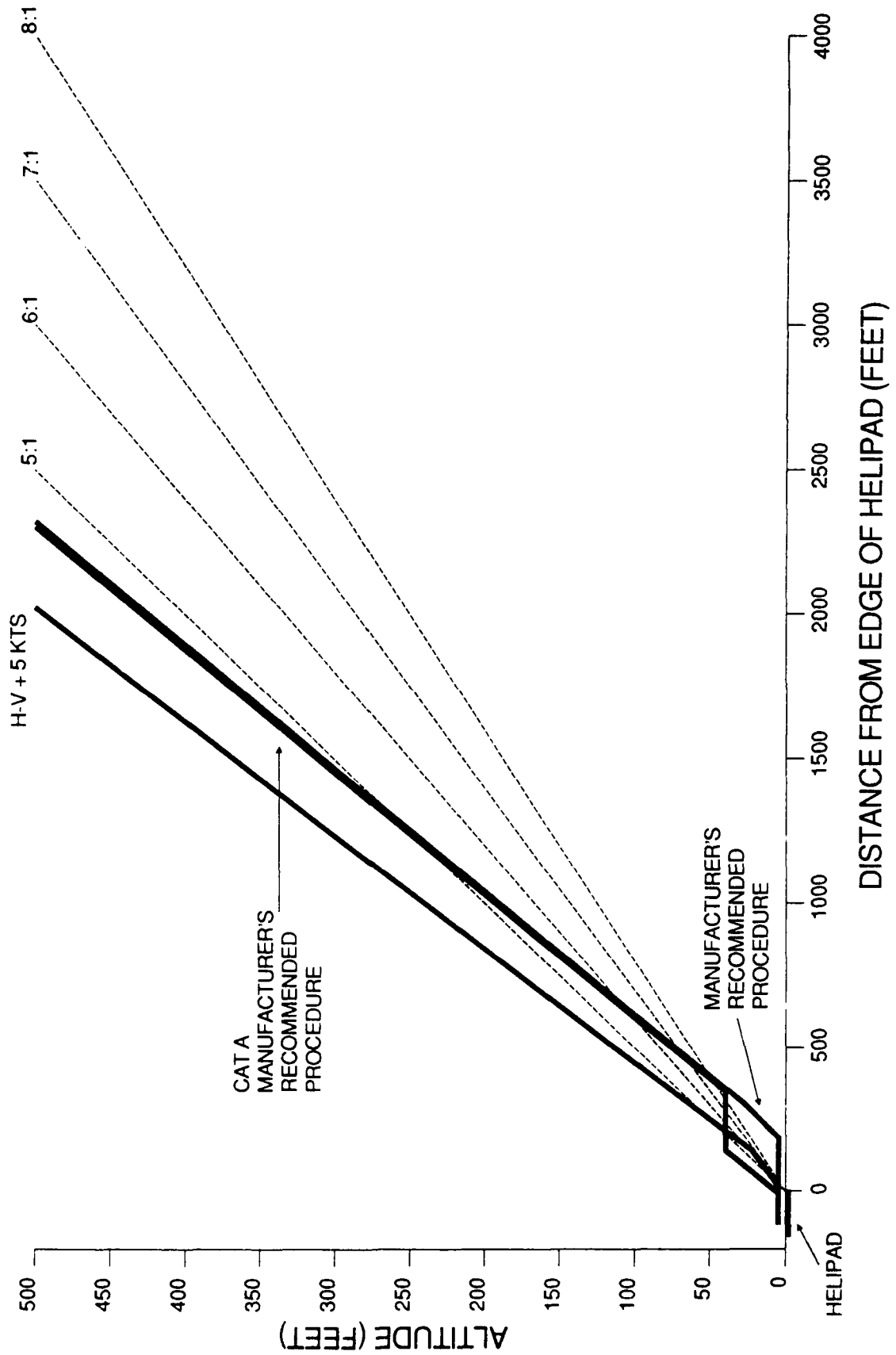
# S 76A DEPARTURE PROFILES

85% MAX. G.W., 2000 FEET, STANDARD DAY



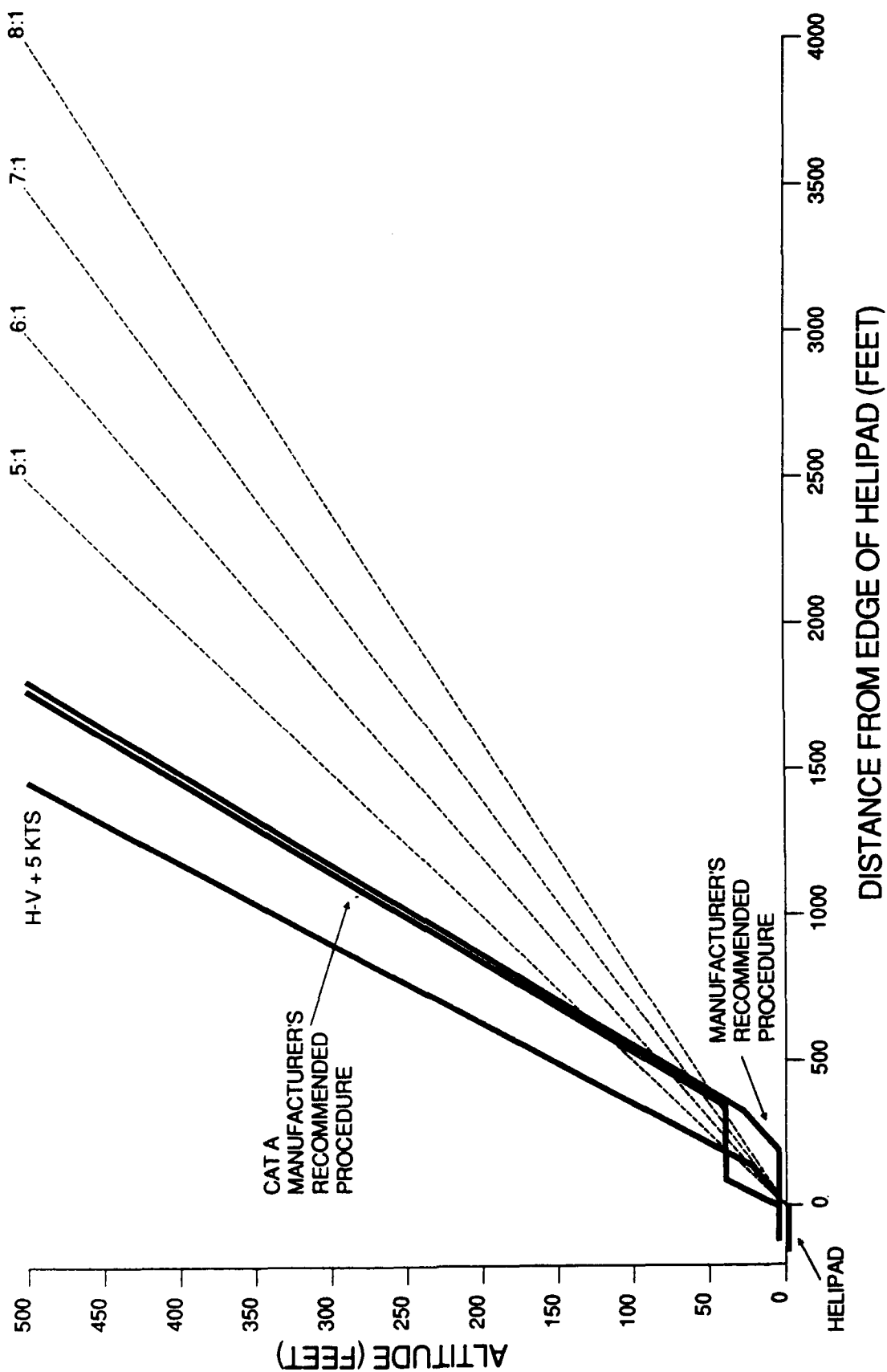
# S 76A DEPARTURE PROFILES

85% MAX G.W., 2000 FEET, HOT DAY



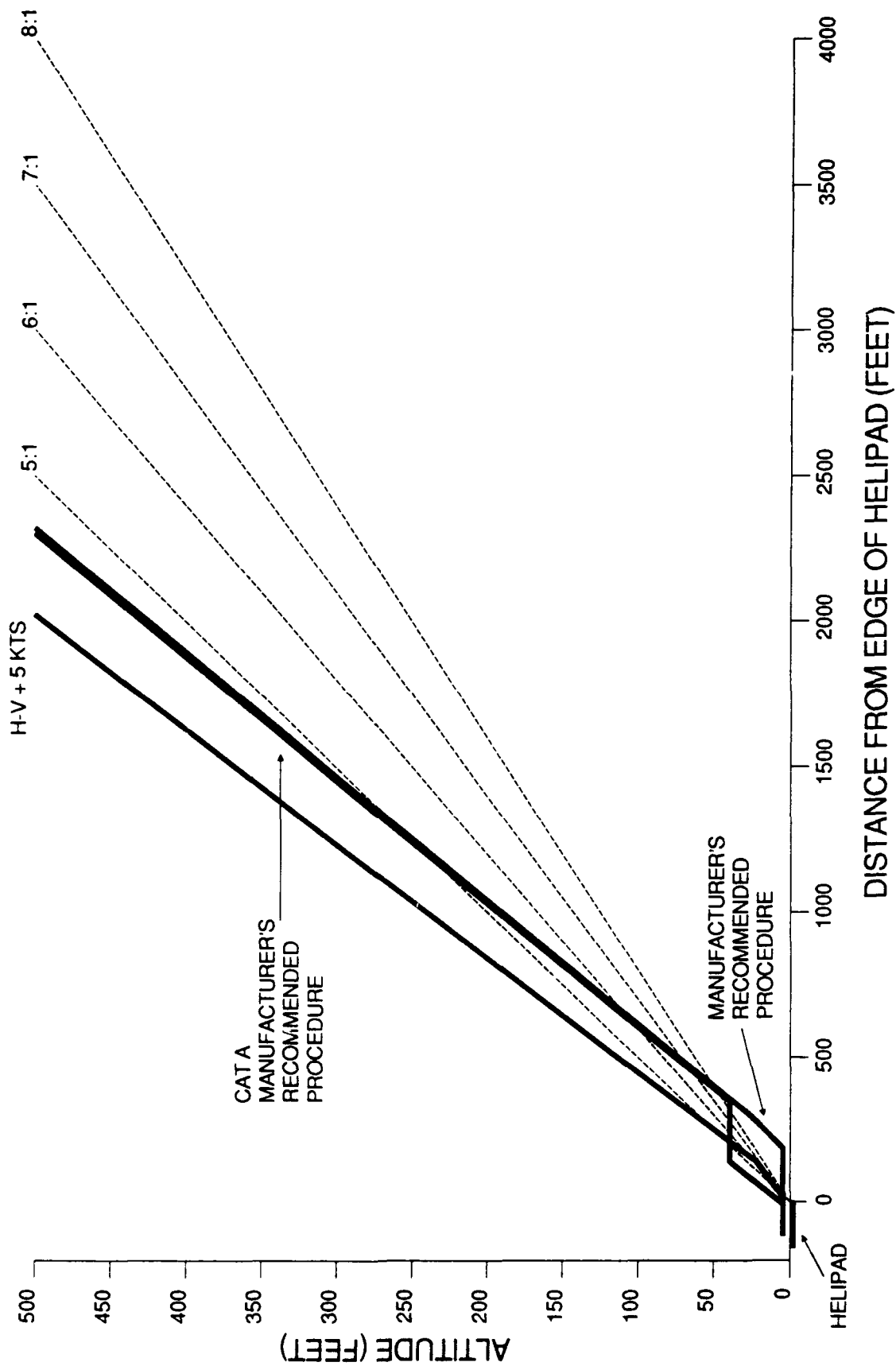
# S 76A DEPARTURE PROFILES

85% MAX G.W., 4000 FEET, STANDARD DAY



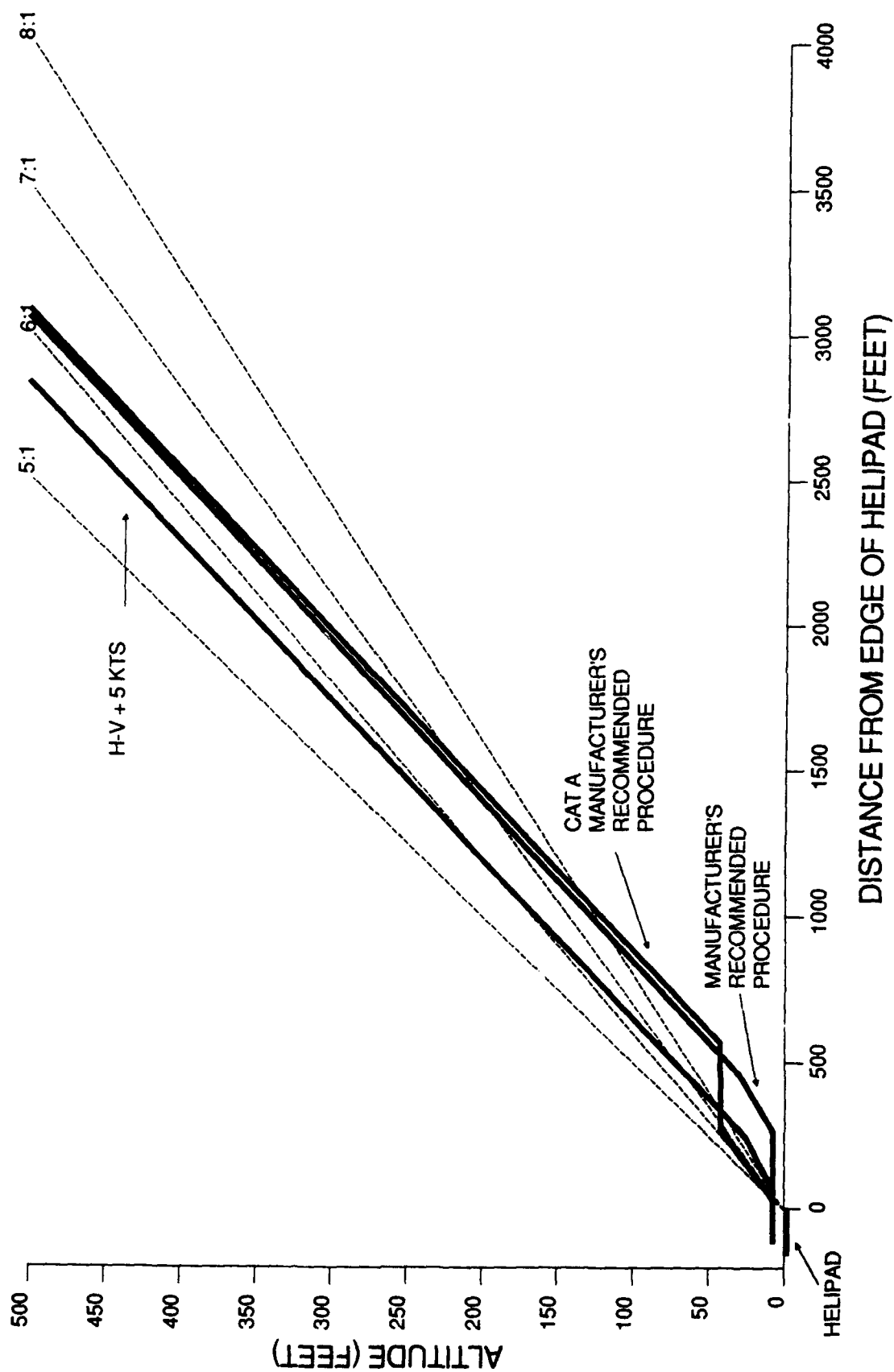
# S 76A DEPARTURE PROFILES

85% MAX G.W., 2000 FEET, HOT DAY



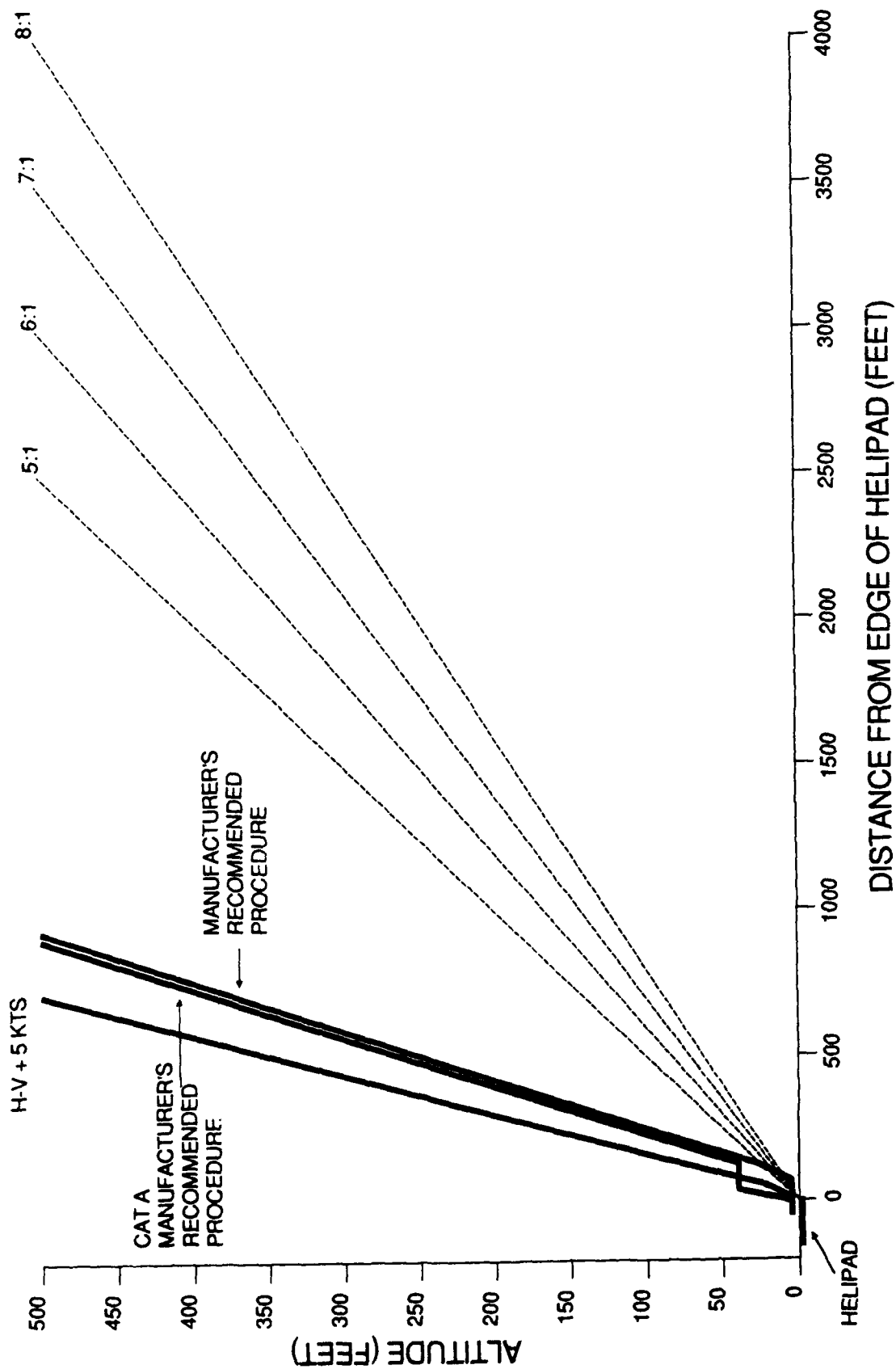
# S 76A DEPARTURE PROFILES

85% MAX. G.W., 4000 FEET, HOT DAY



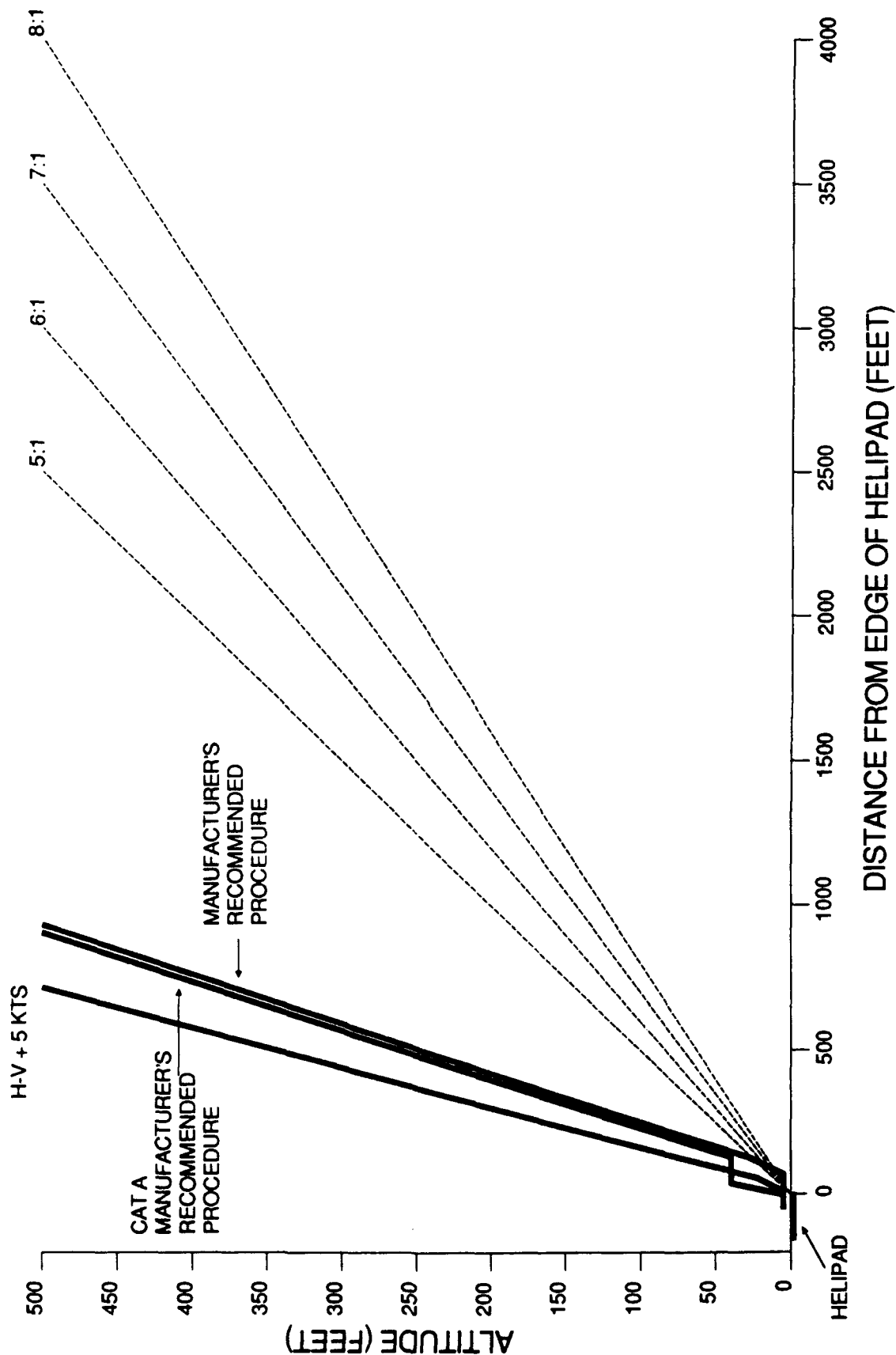
# S 76A DEPARTURE PROFILES

70% MAX. G.W., SEA LEVEL, STANDARD DAY



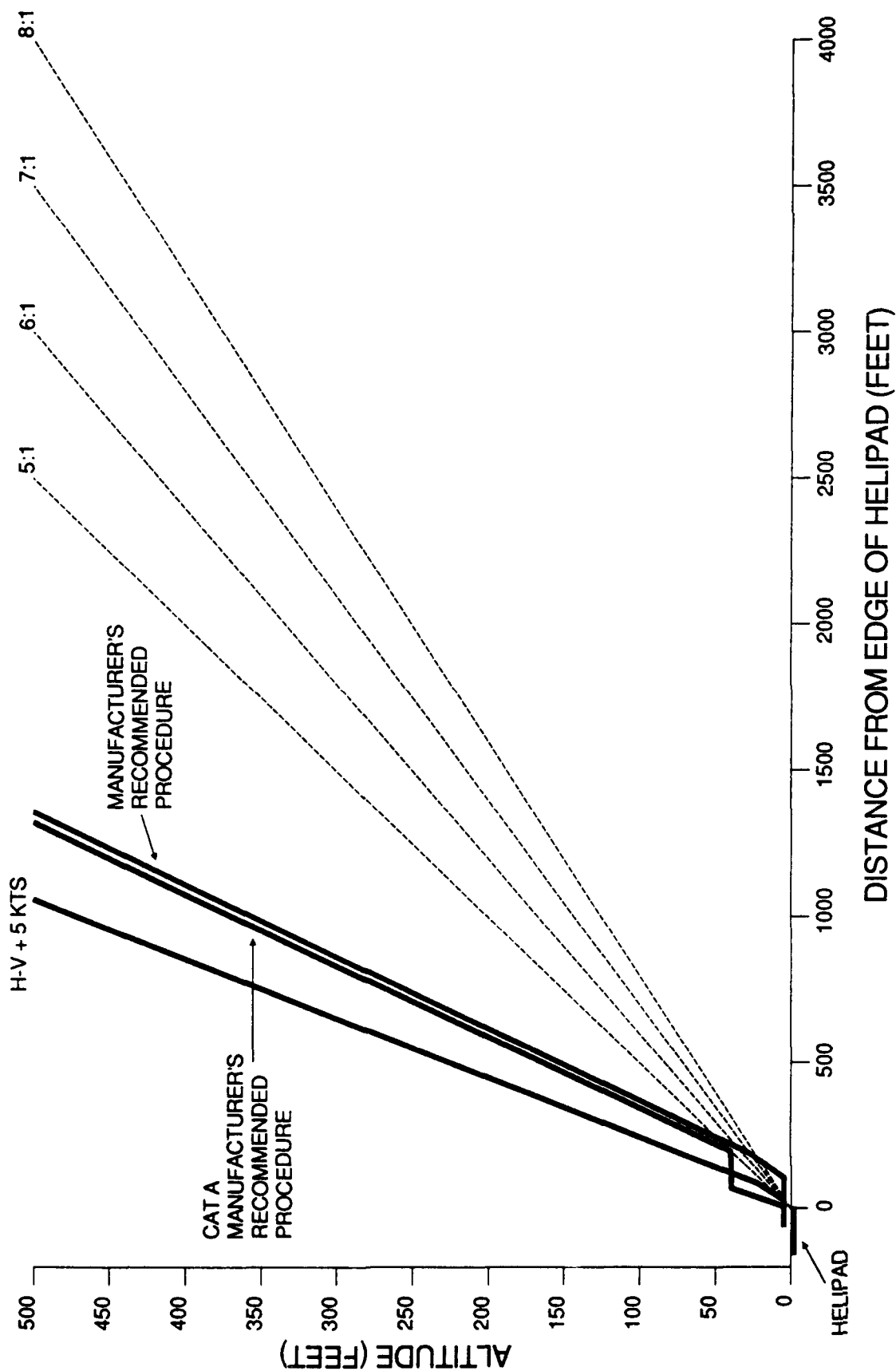
# S 76A DEPARTURE PROFILES

70% MAX. G.W., SEA LEVEL, STANDARD DAY



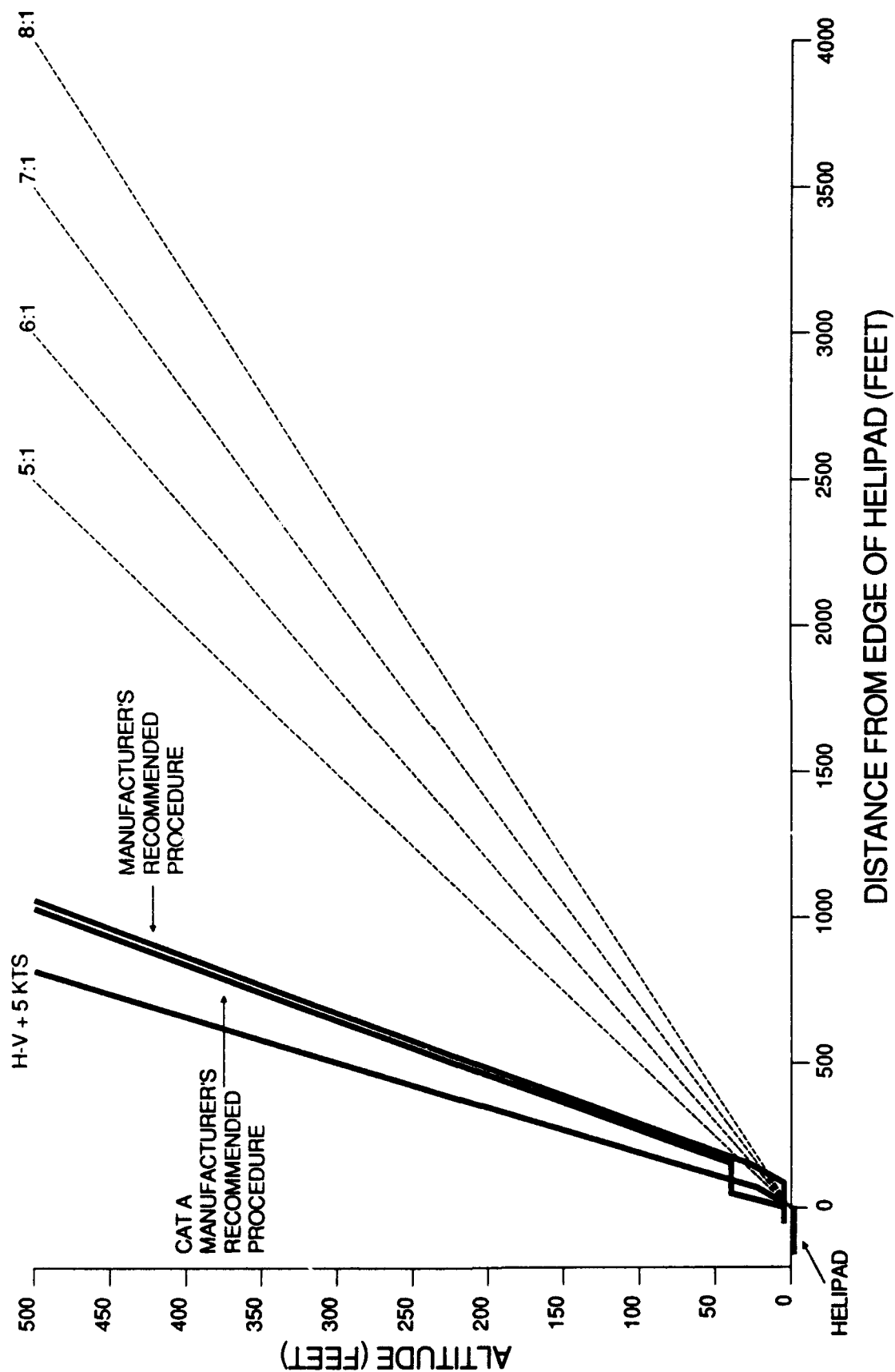
# S 76A DEPARTURE PROFILES

70% MAX. G.W., SEA LEVEL, HOT DAY



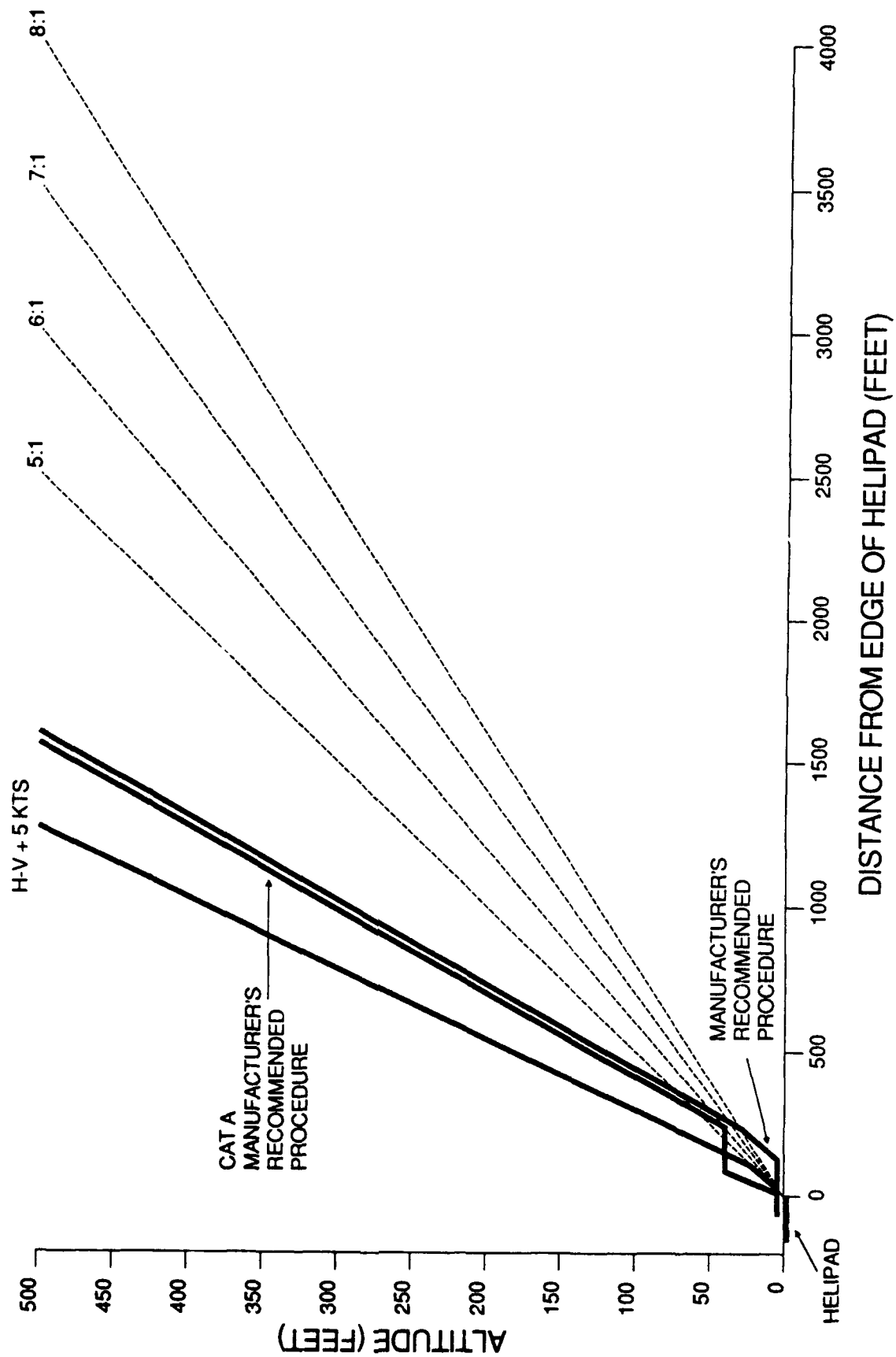
# S 76A DEPARTURE PROFILES

70% MAX. G.W., 2000 FEET, STANDARD DAY



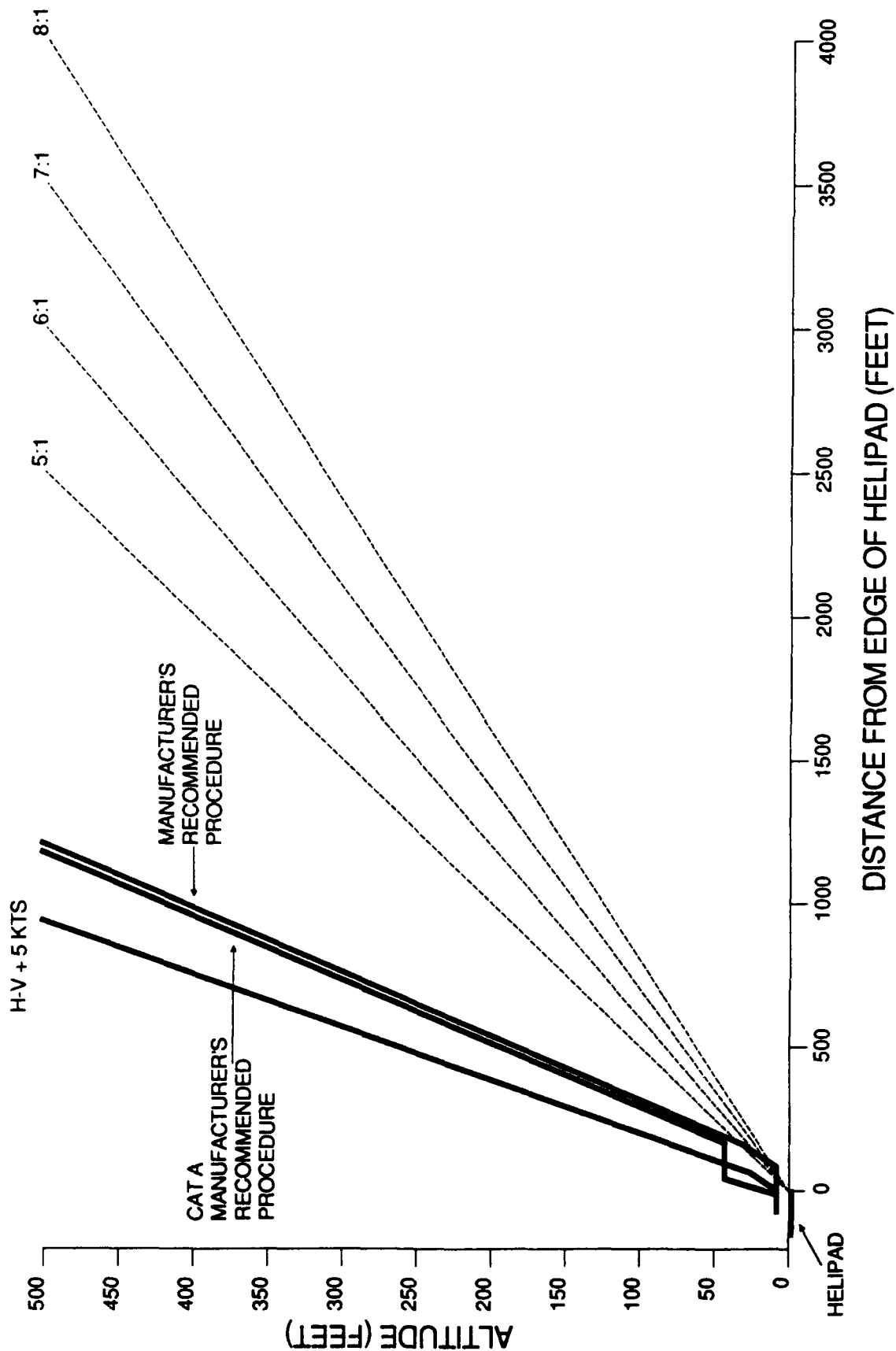
# S 76A DEPARTURE PROFILES

70% MAX. G.W., 2000 FEET, HOT DAY



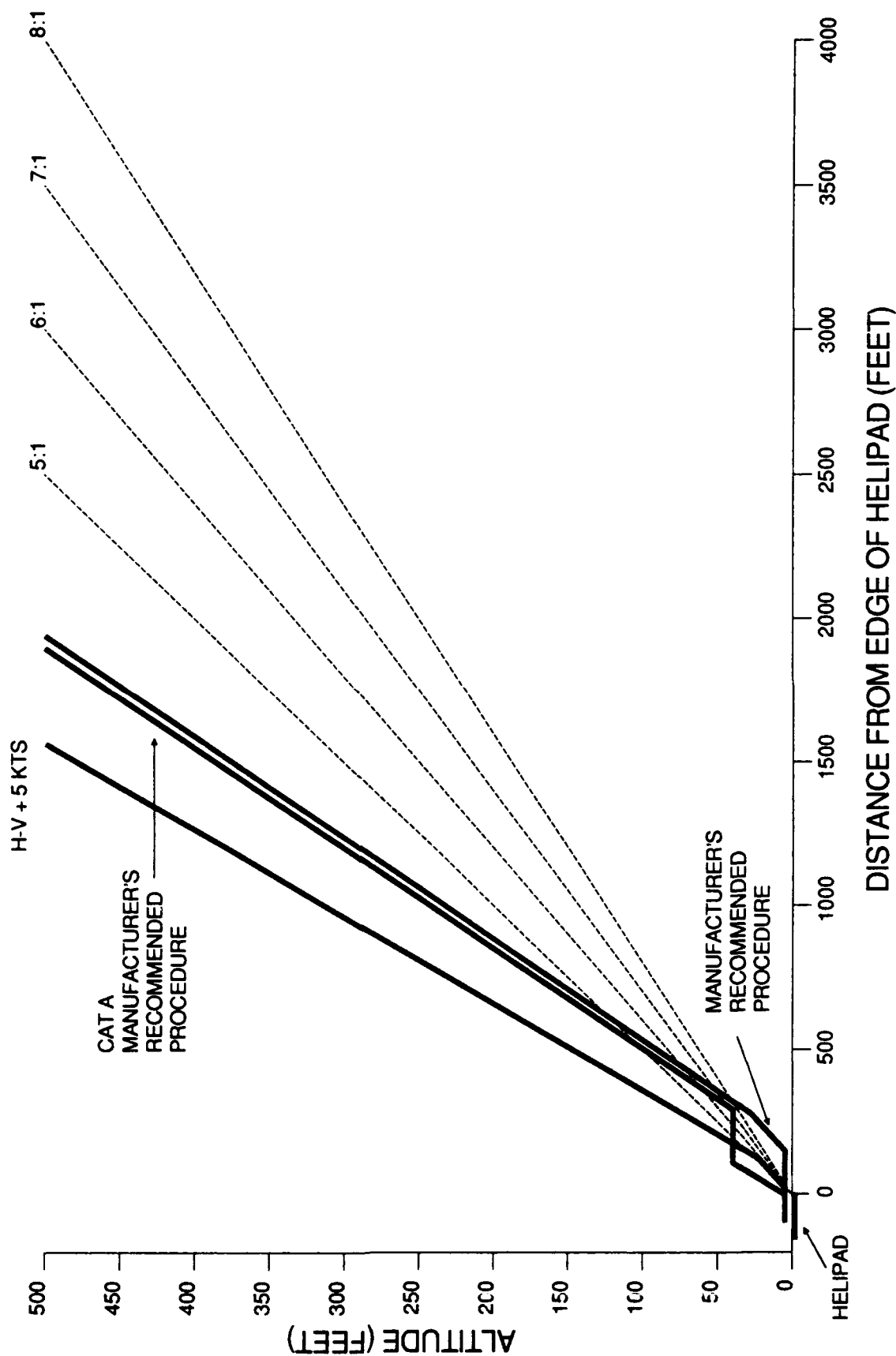
# S 76A DEPARTURE PROFILES

70% MAX. G.W., 4000 FEET, STANDARD DAY



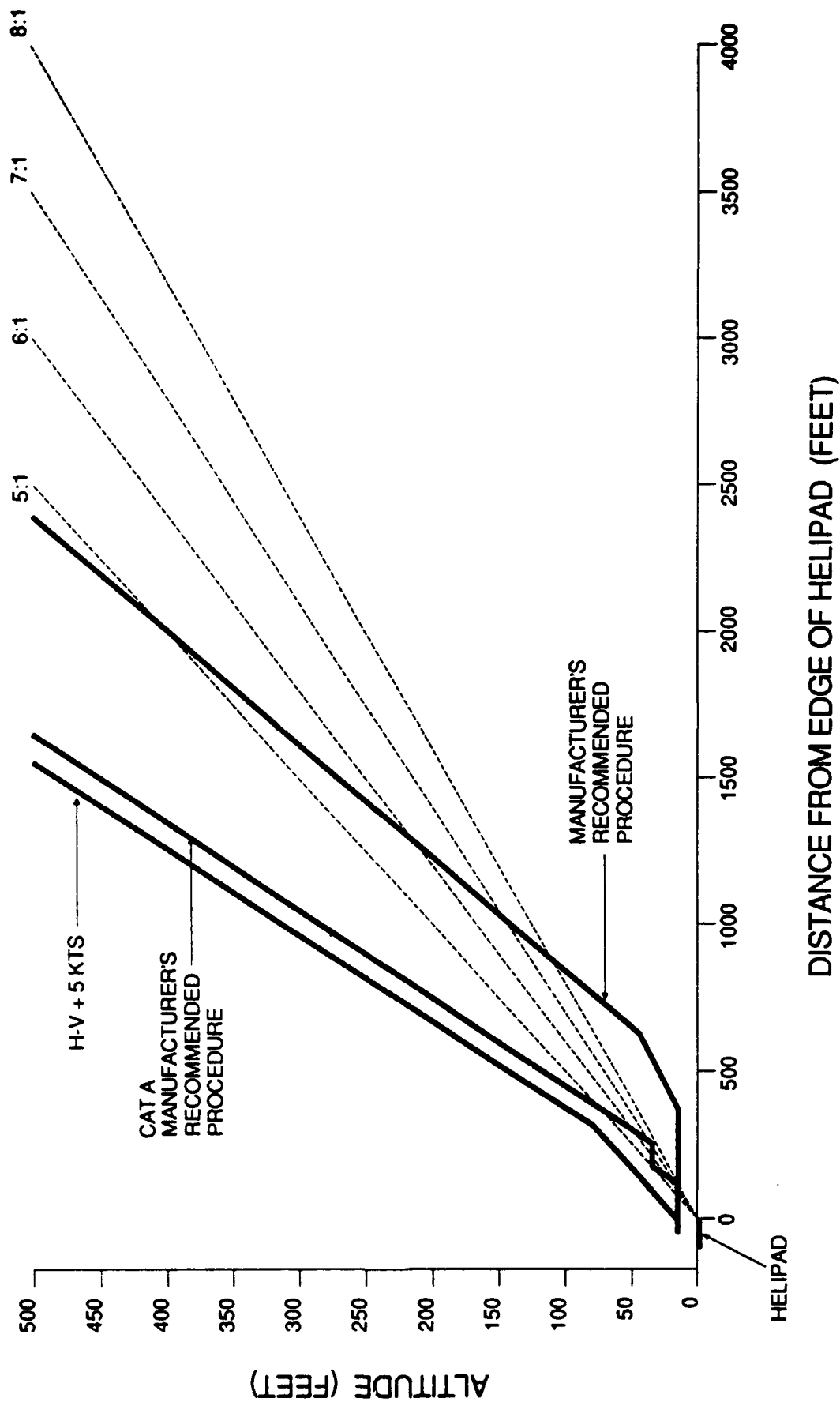
# S 76A DEPARTURE PROFILES

70% MAX. G.W., 4000 FEET, HOT DAY



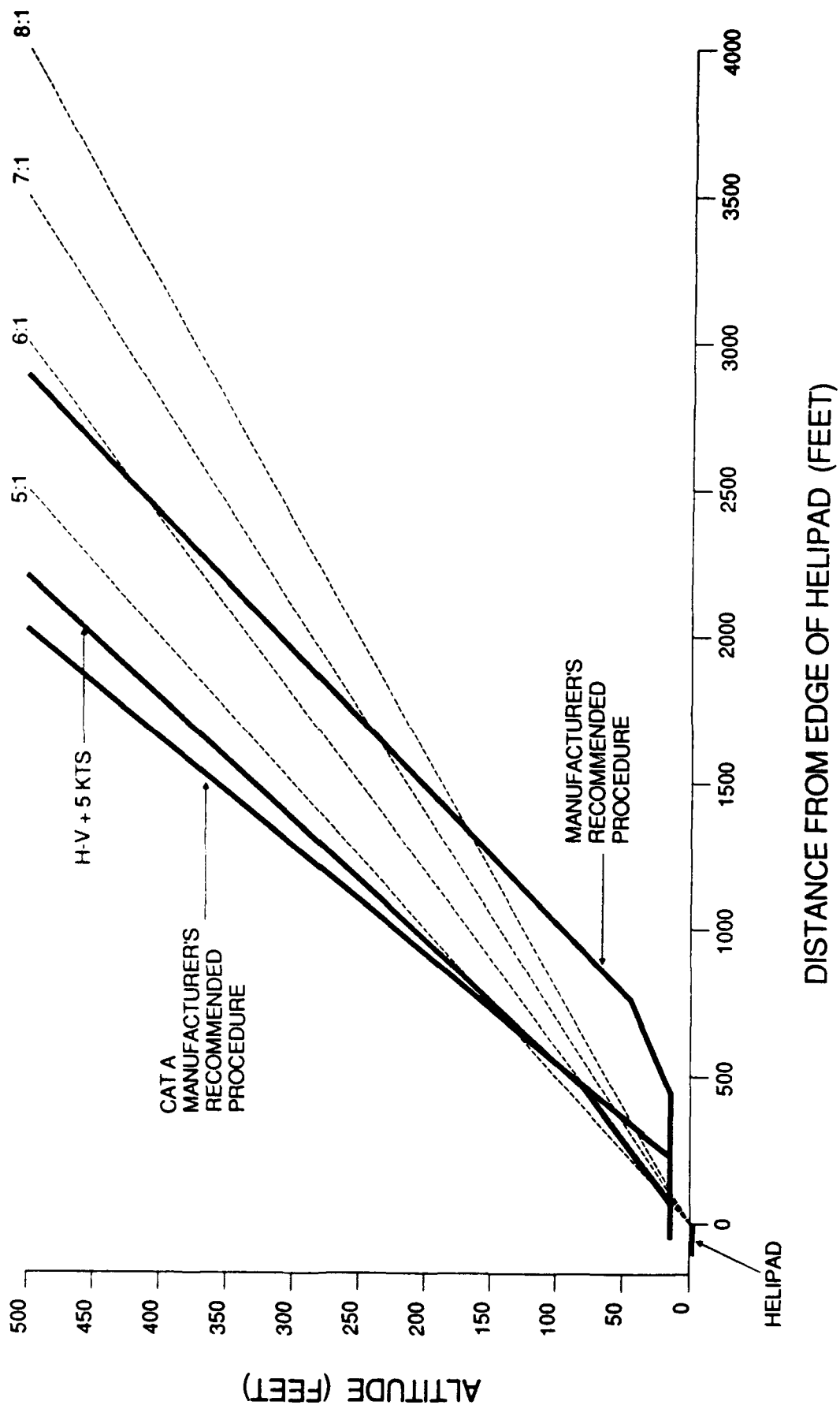
# AS 332C DEPARTURE PROFILES

MAX. G.W., SEA LEVEL, STANDARD DAY



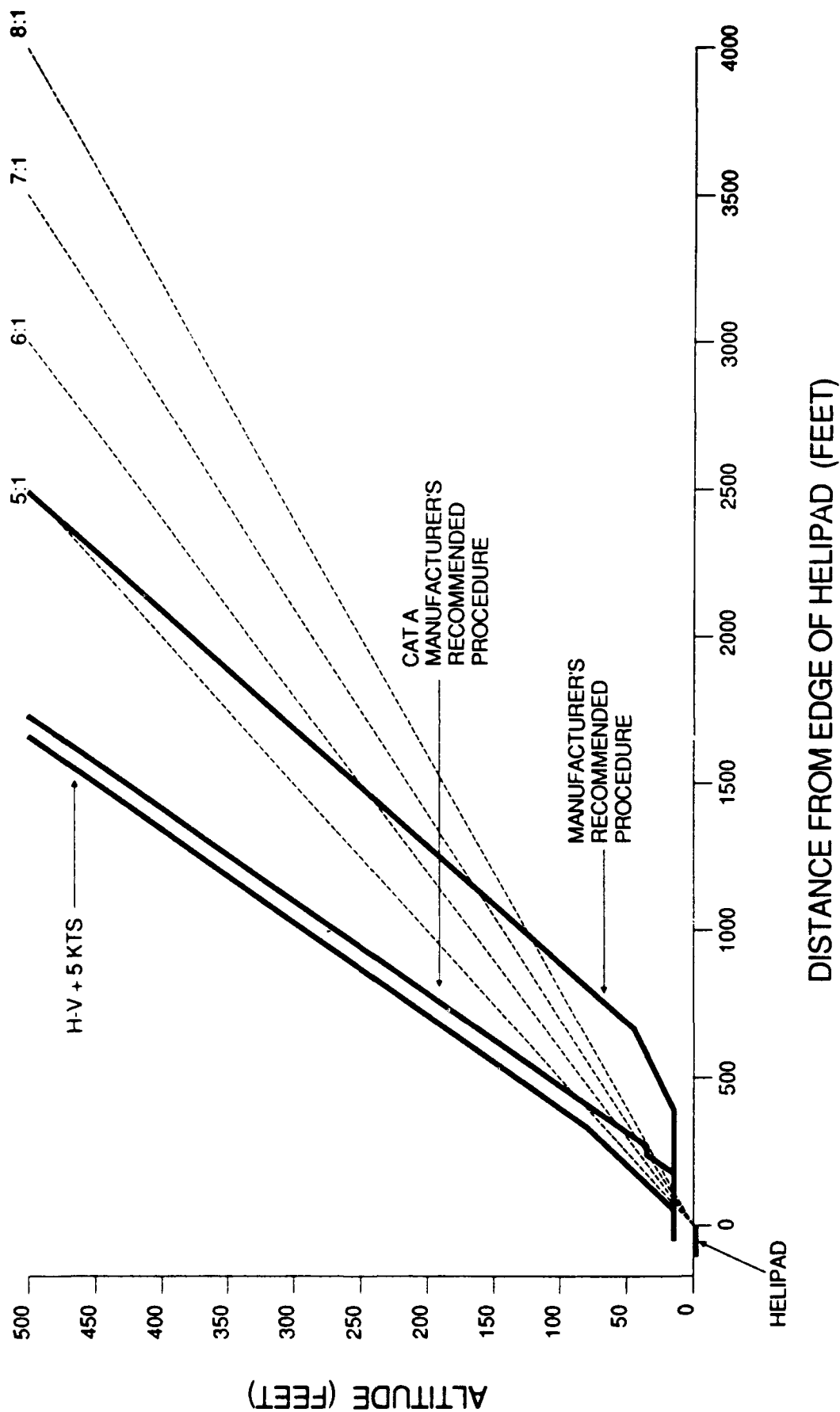
# AS 332C DEPARTURE PROFILES

MAX. G.W., SEA LEVEL, HOT DAY



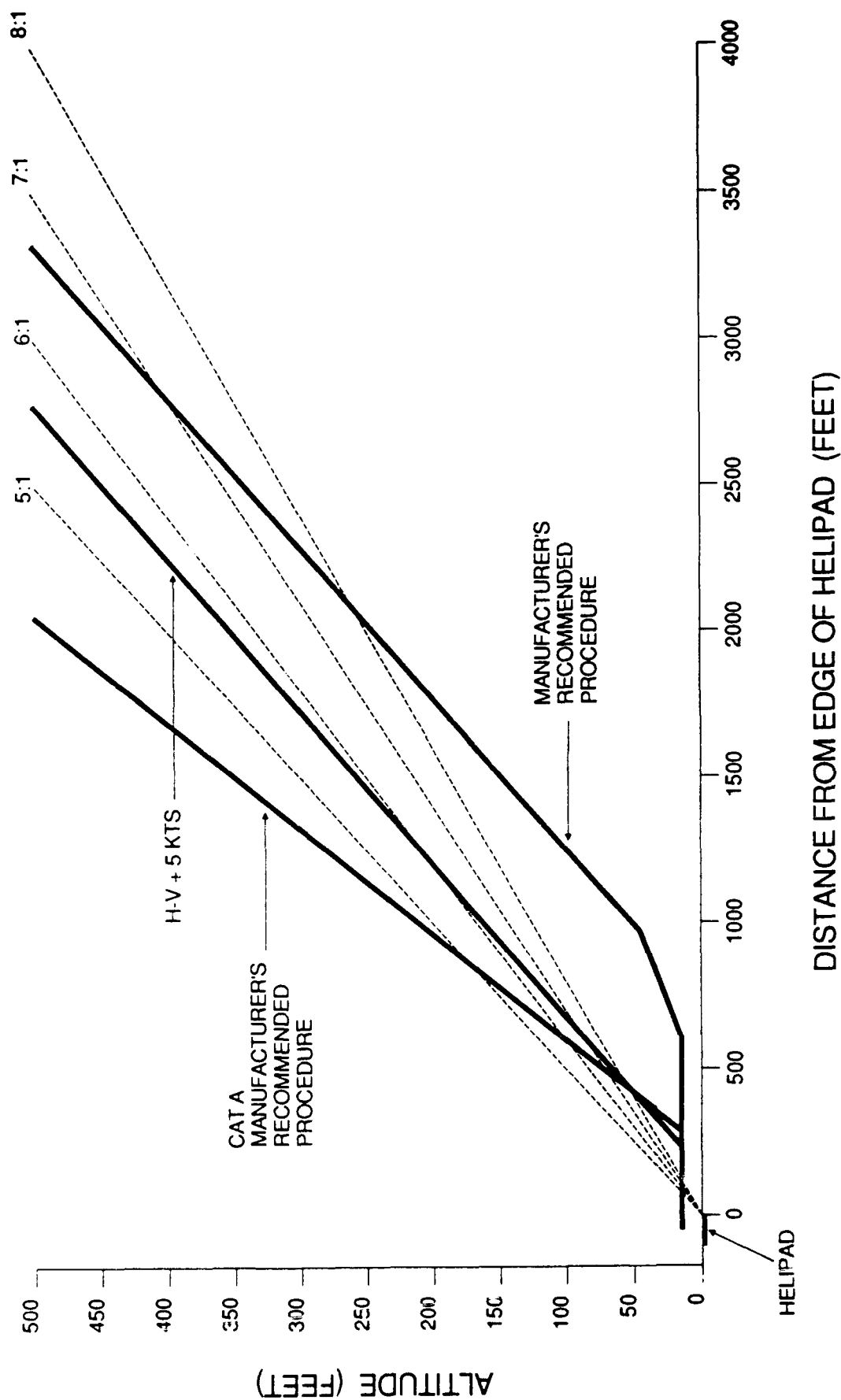
# AS 332C DEPARTURE PROFILES

MAX. G.W., 2000 FEET, STANDARD DAY



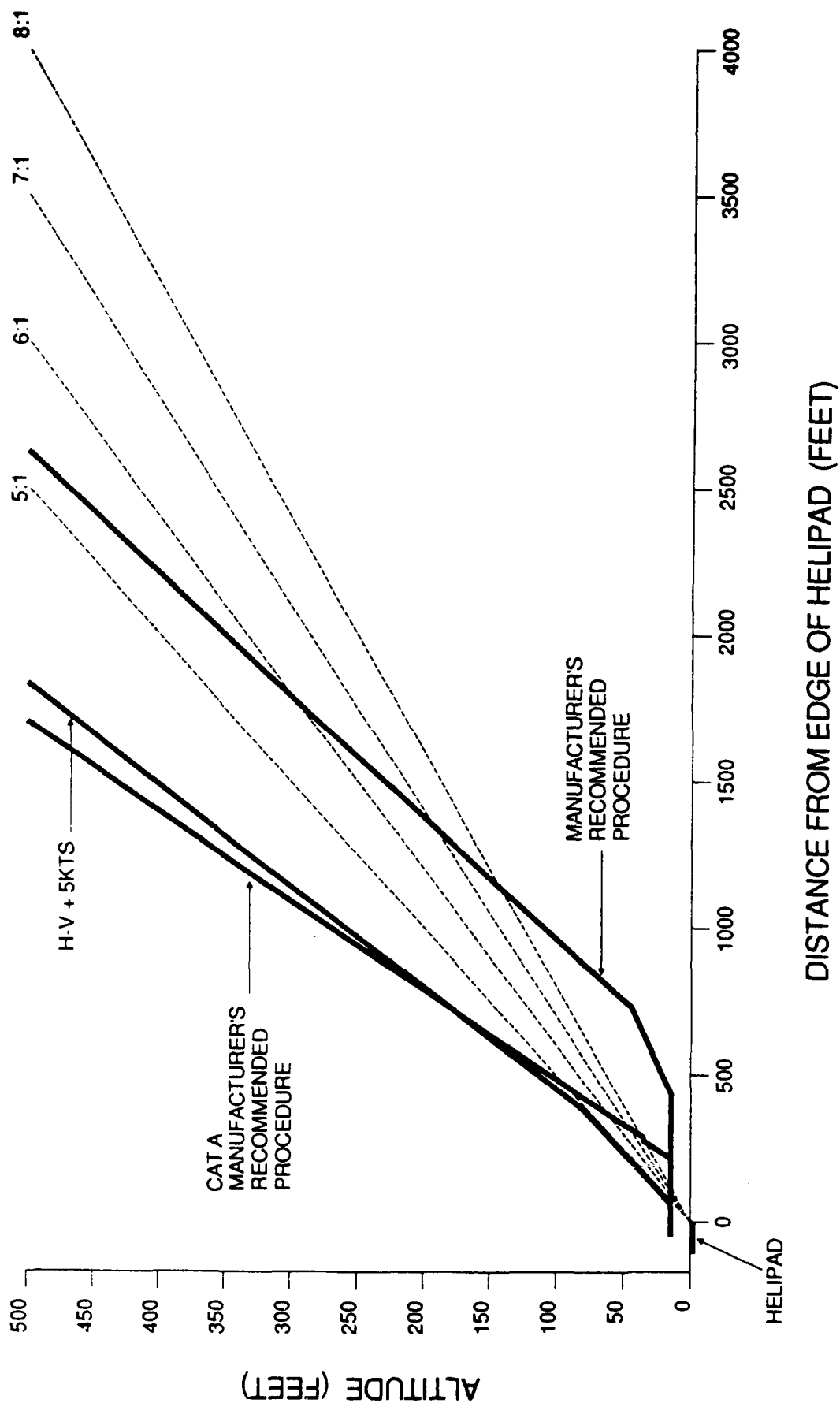
# AS 332C DEPARTURE PROFILES

MAX. G.W., 2000 FEET, HOT DAY



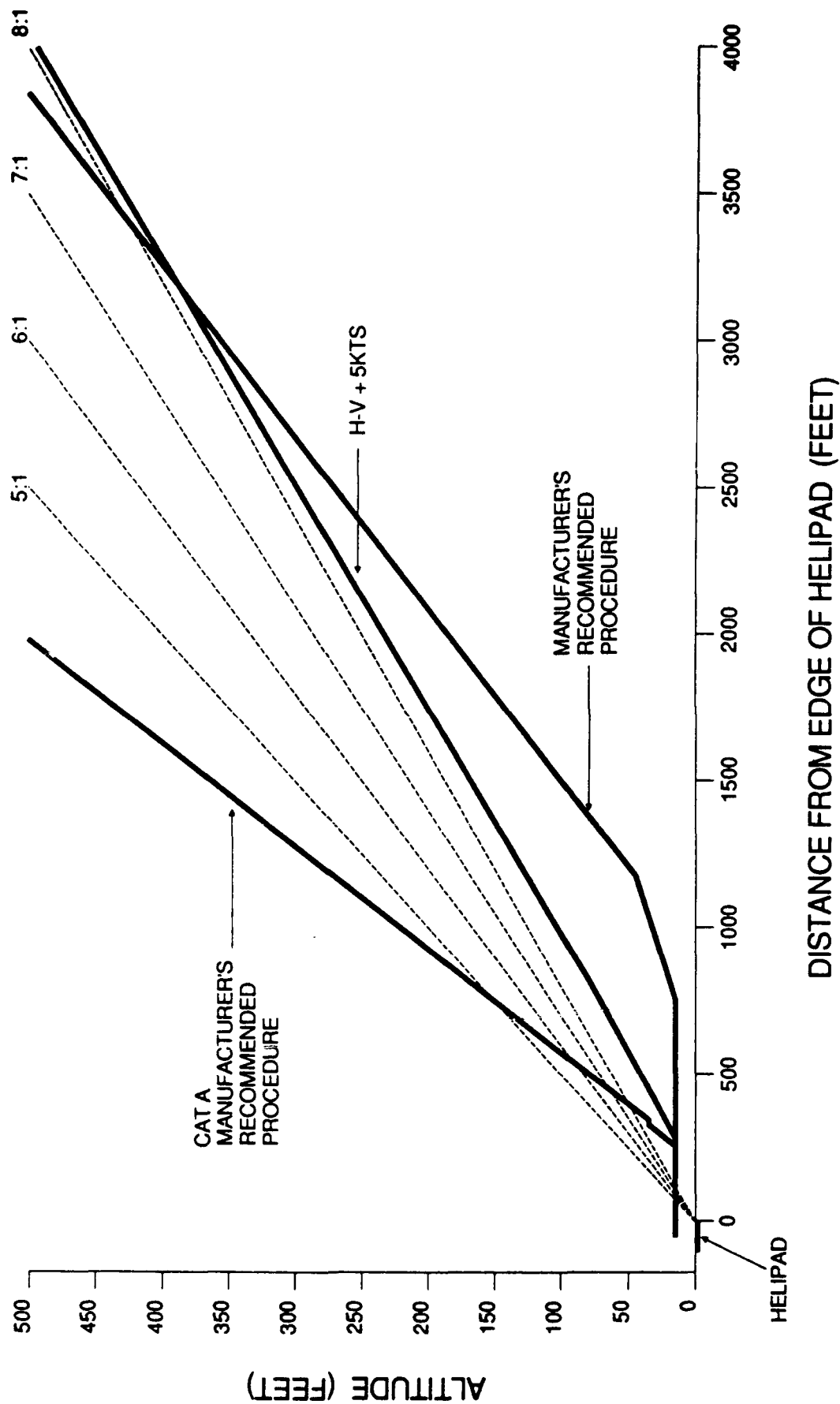
# AS 332C DEPARTURE PROFILES

MAX. G.W., 4000 FEET, STANDARD DAY



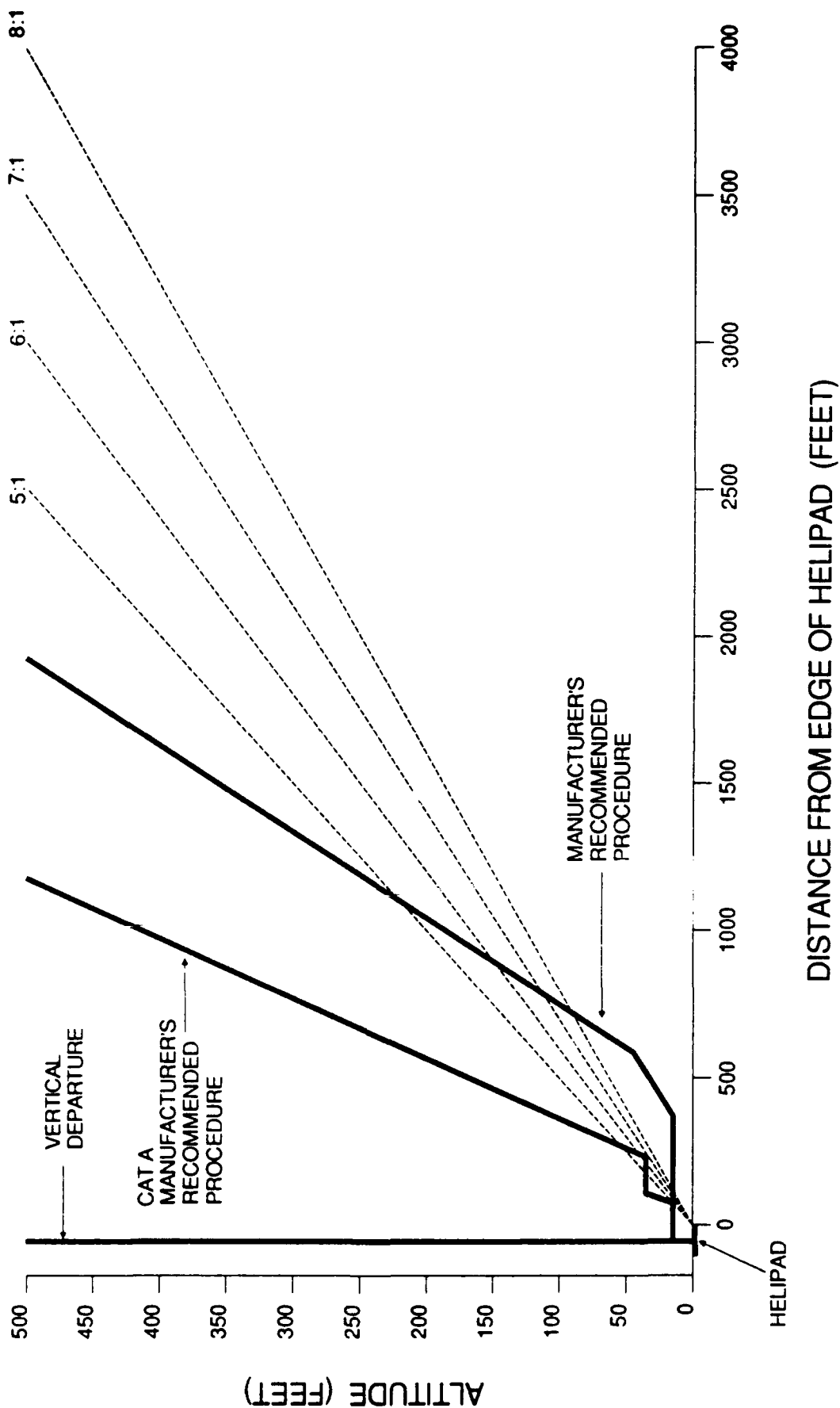
# AS 332C DEPARTURE PROFILES

MAX. G.W., 4000 FEET, HOT DAY



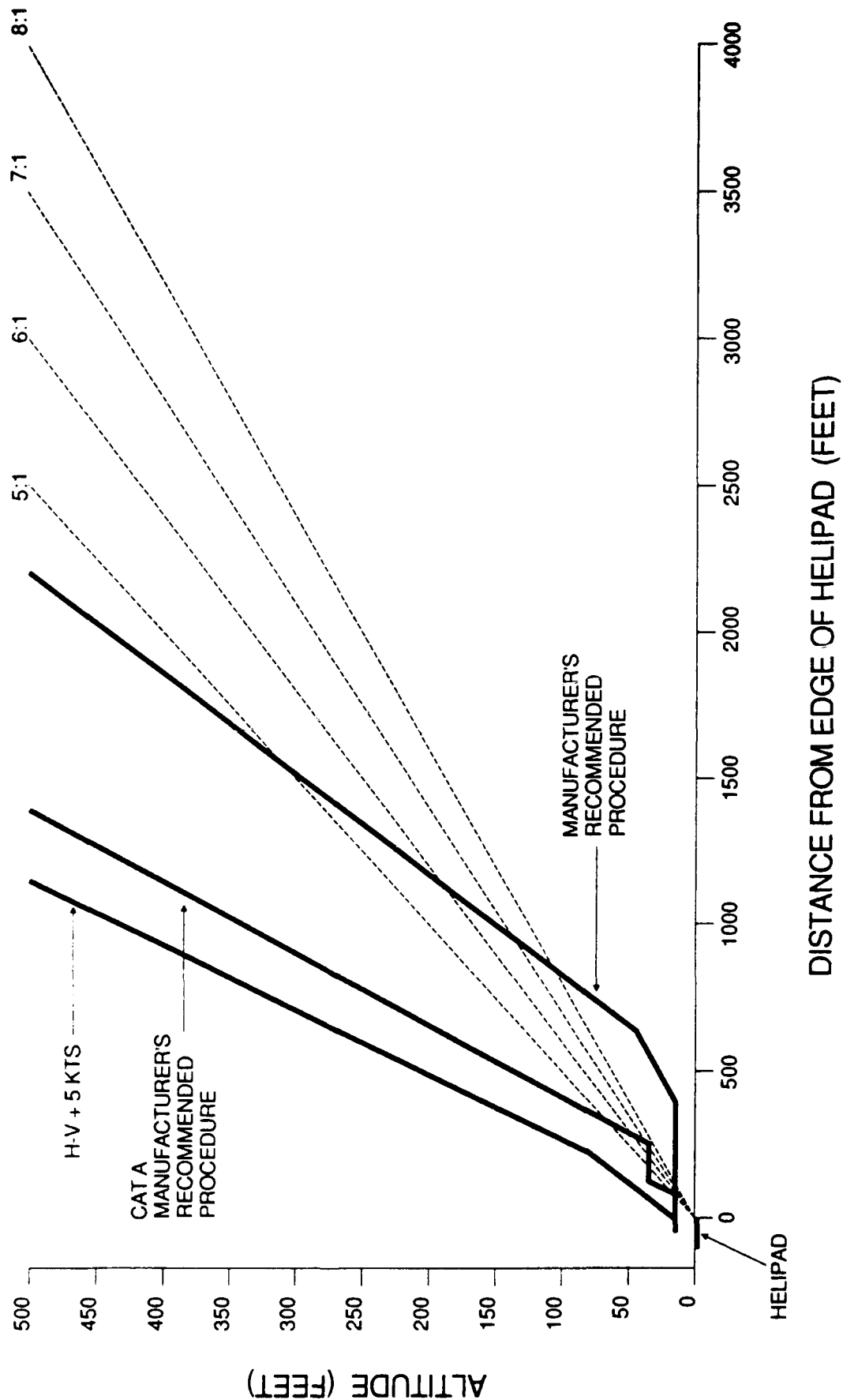
# AS 332C DEPARTURE PROFILES

85% MAX. G.W., SEA LEVEL, STANDARD DAY



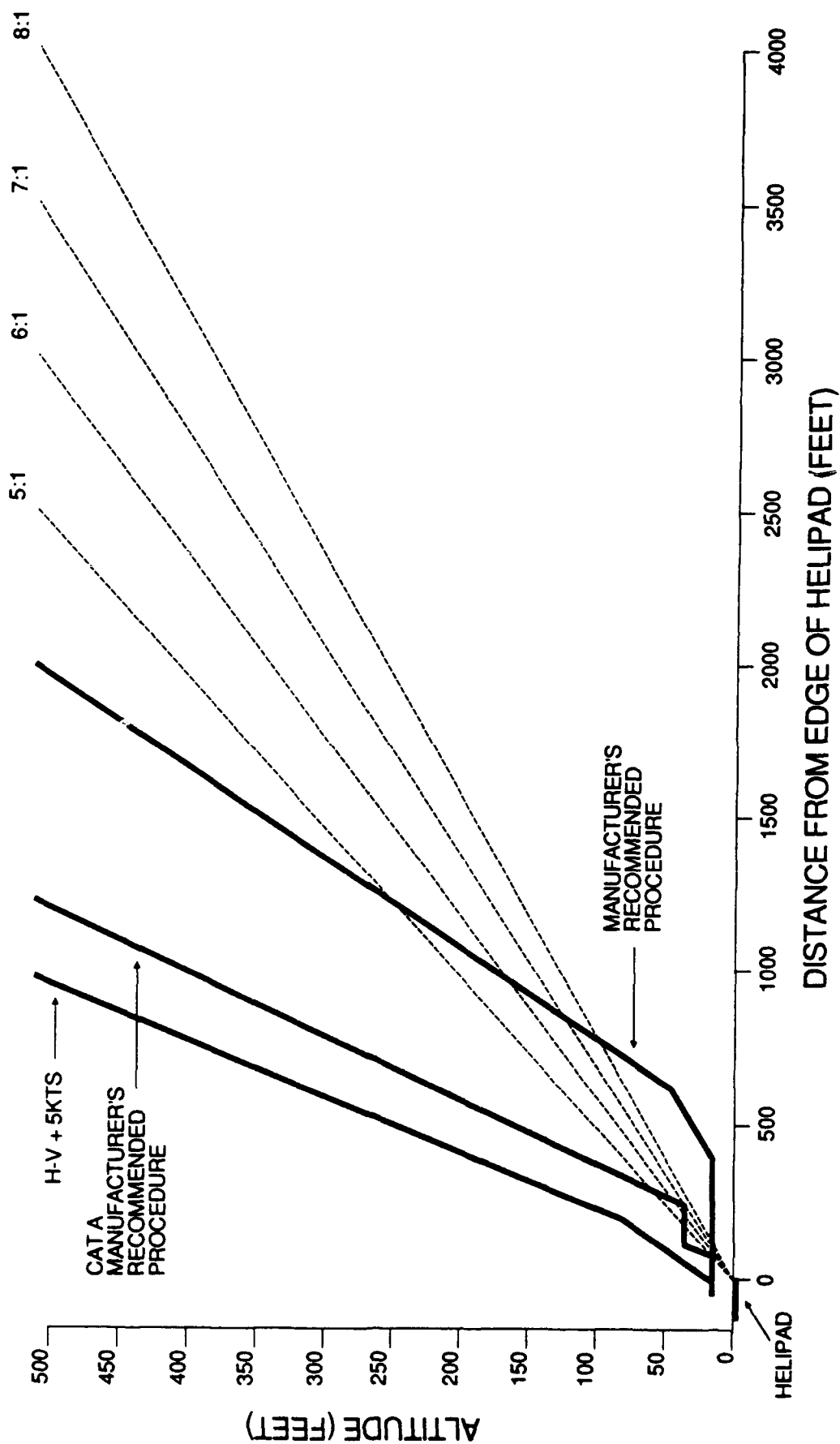
# AS 332C DEPARTURE PROFILES

85% MAX. G.W., SEA LEVEL, HOT DAY



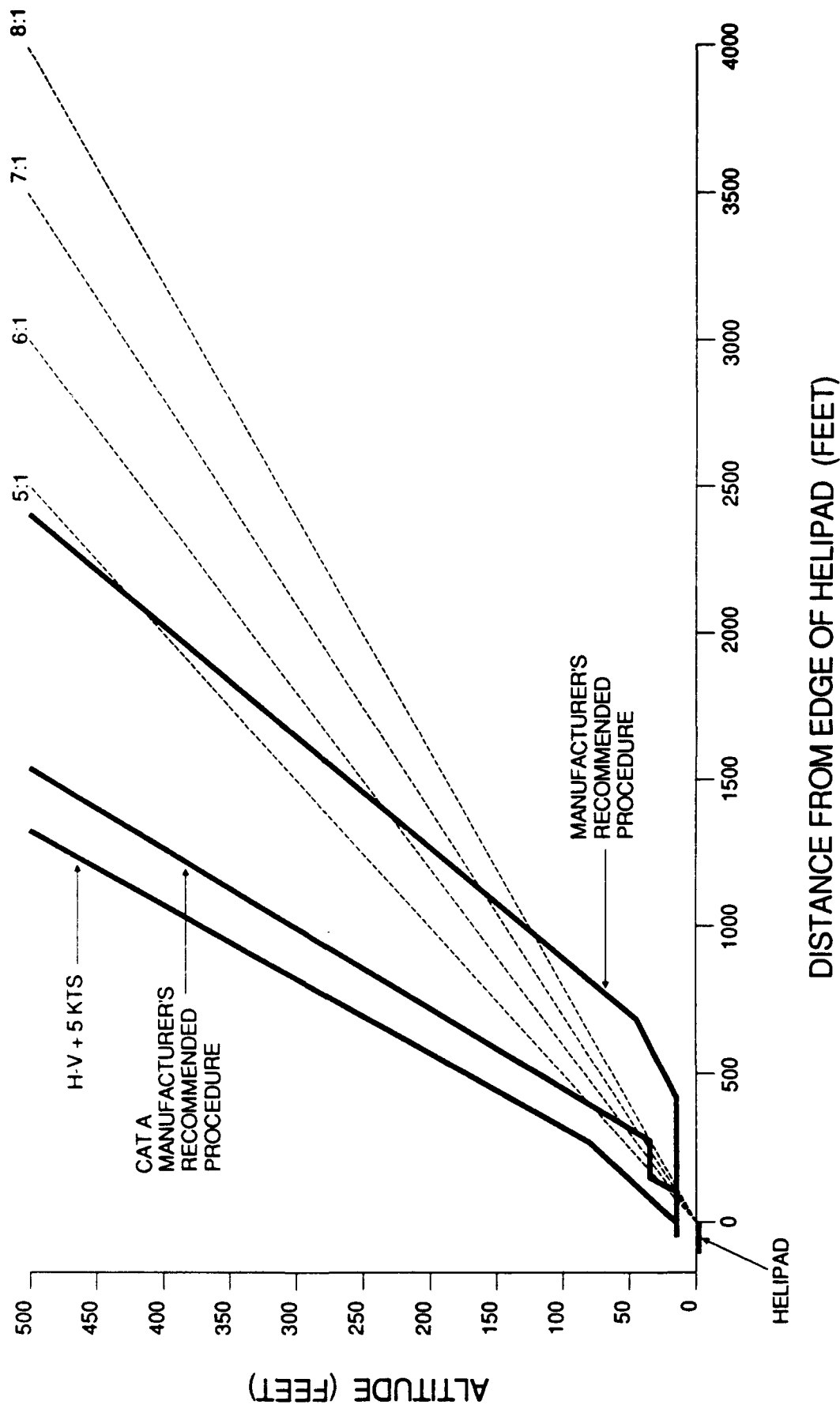
# AS 332C DEPARTURE PROFILES

85% MAX. G.W., 2000 FEET, STANDARD DAY



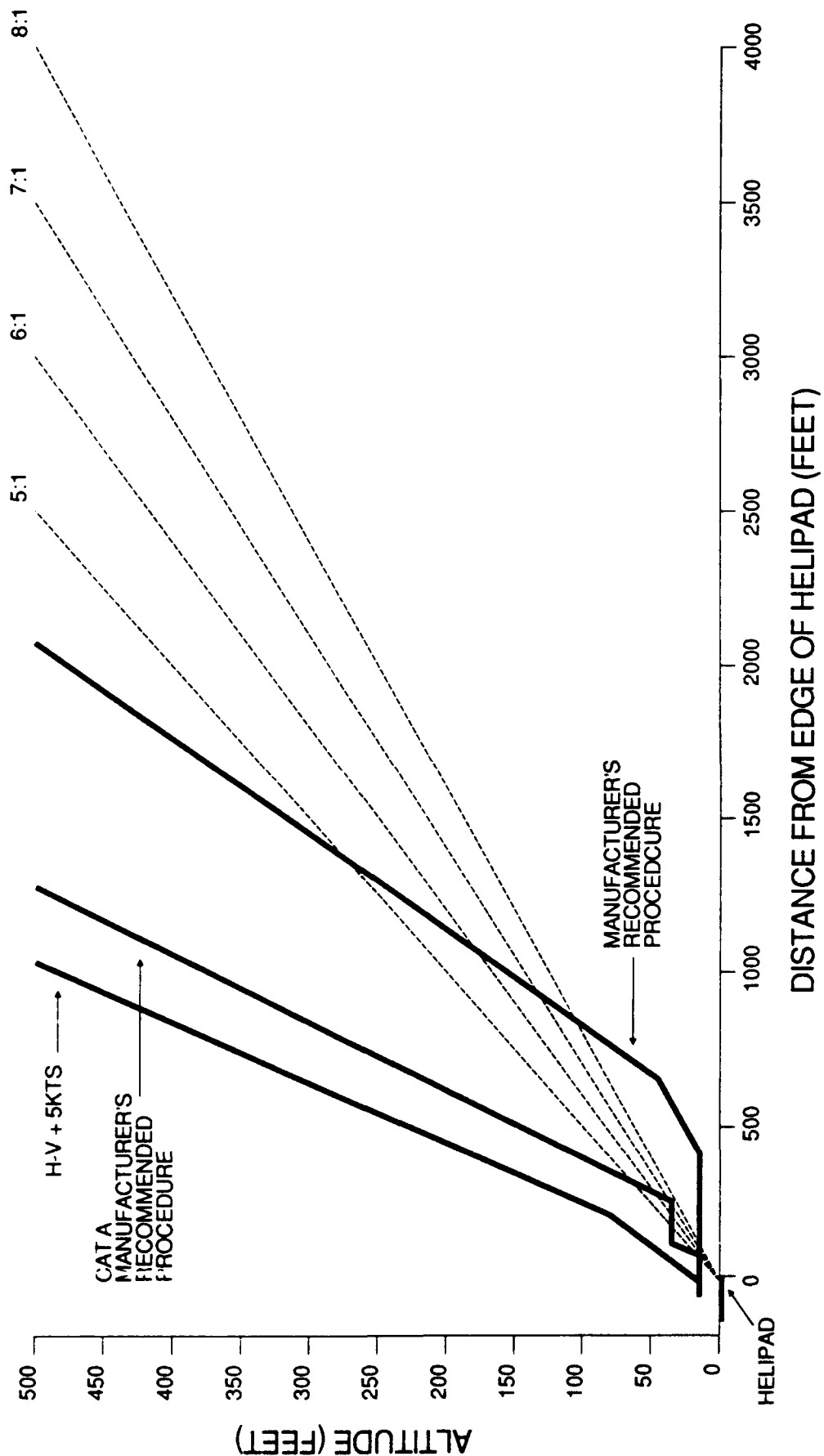
# AS 332C DEPARTURE PROFILES

85% MAX. G.W., 2000 FEET, HOT DAY



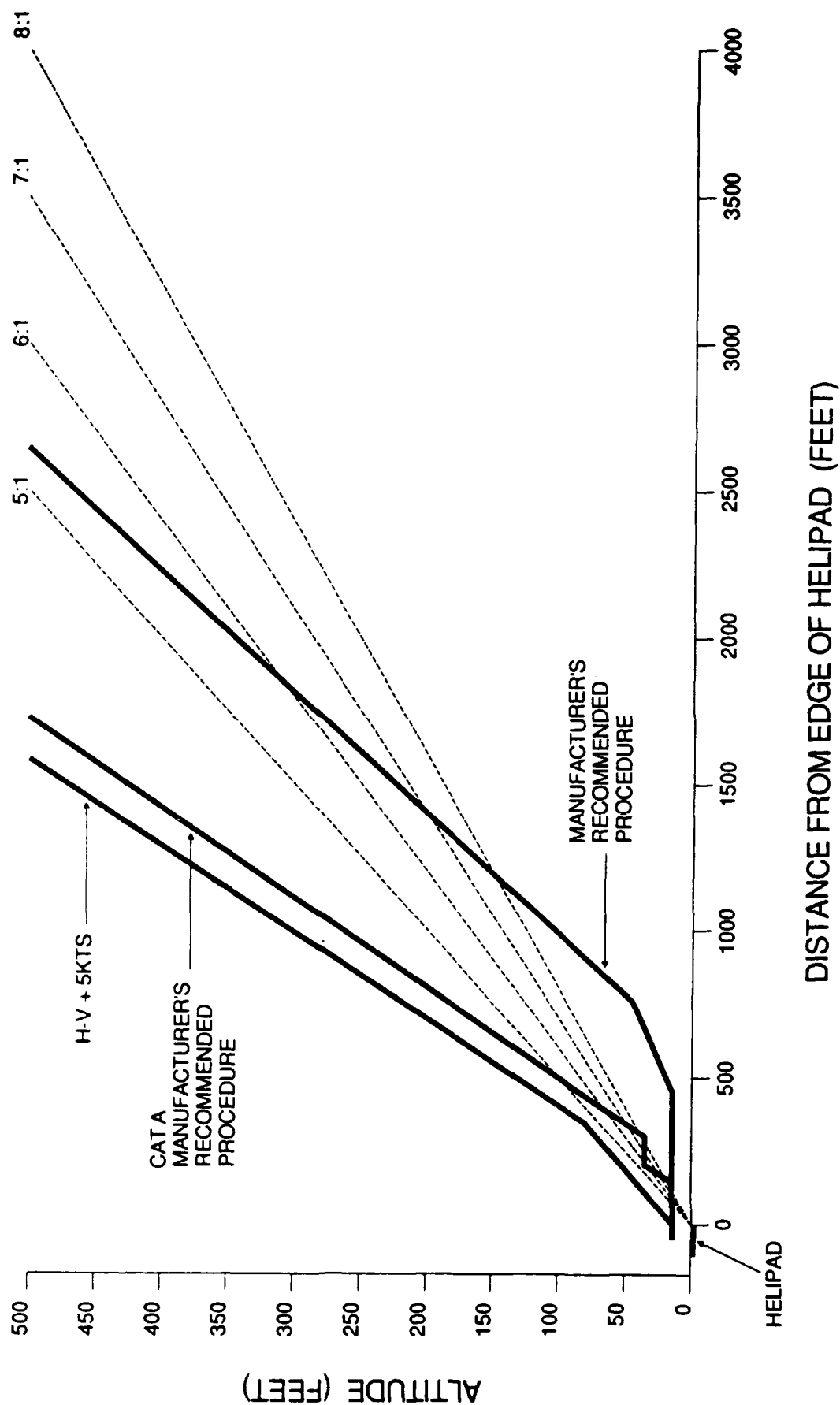
# AS 322C DEPARTURE PROFILES

85% MAX. G.W., 4000 FEET, STANDARD DAY



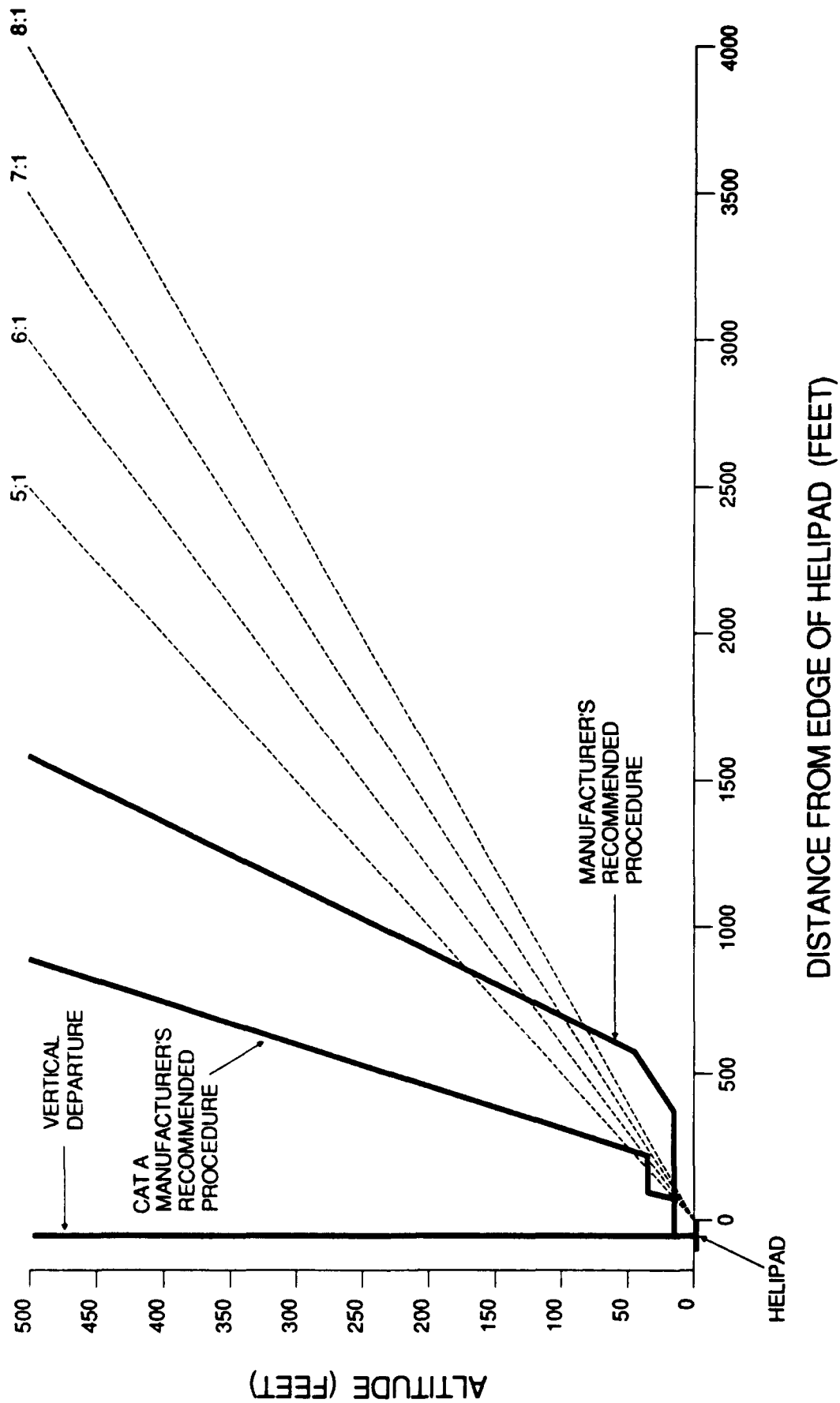
# AS 332C DEPARTURE PROFILES

85% MAX. G.W., 4000 FEET, HOT DAY



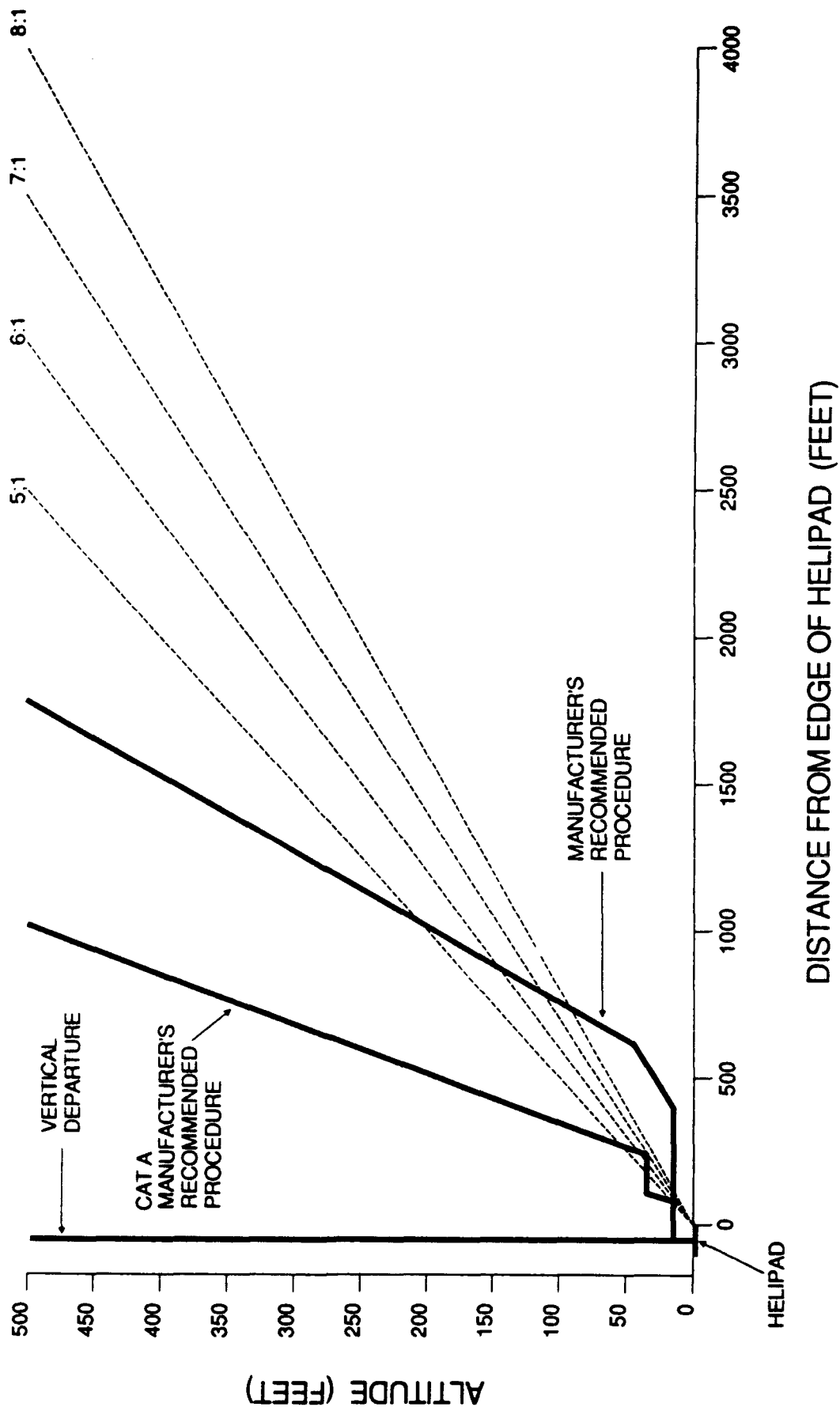
# AS 332C DEPARTURE PROFILES

70% MAX. G.W., SEA LEVEL, STANDARD DAY



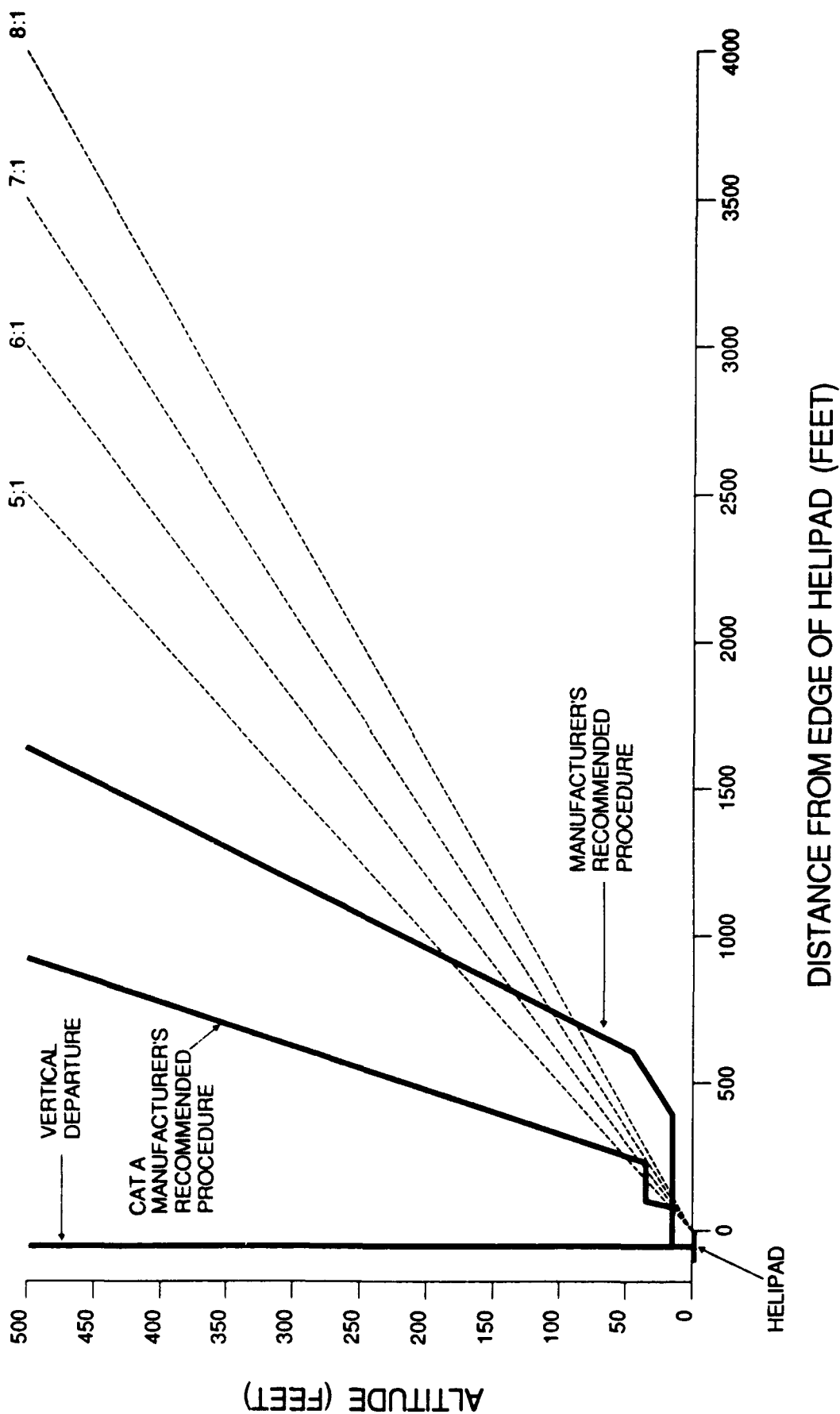
# AS 332C DEPARTURE PROFILES

70% MAX. G.W., SEA LEVEL, HOT DAY



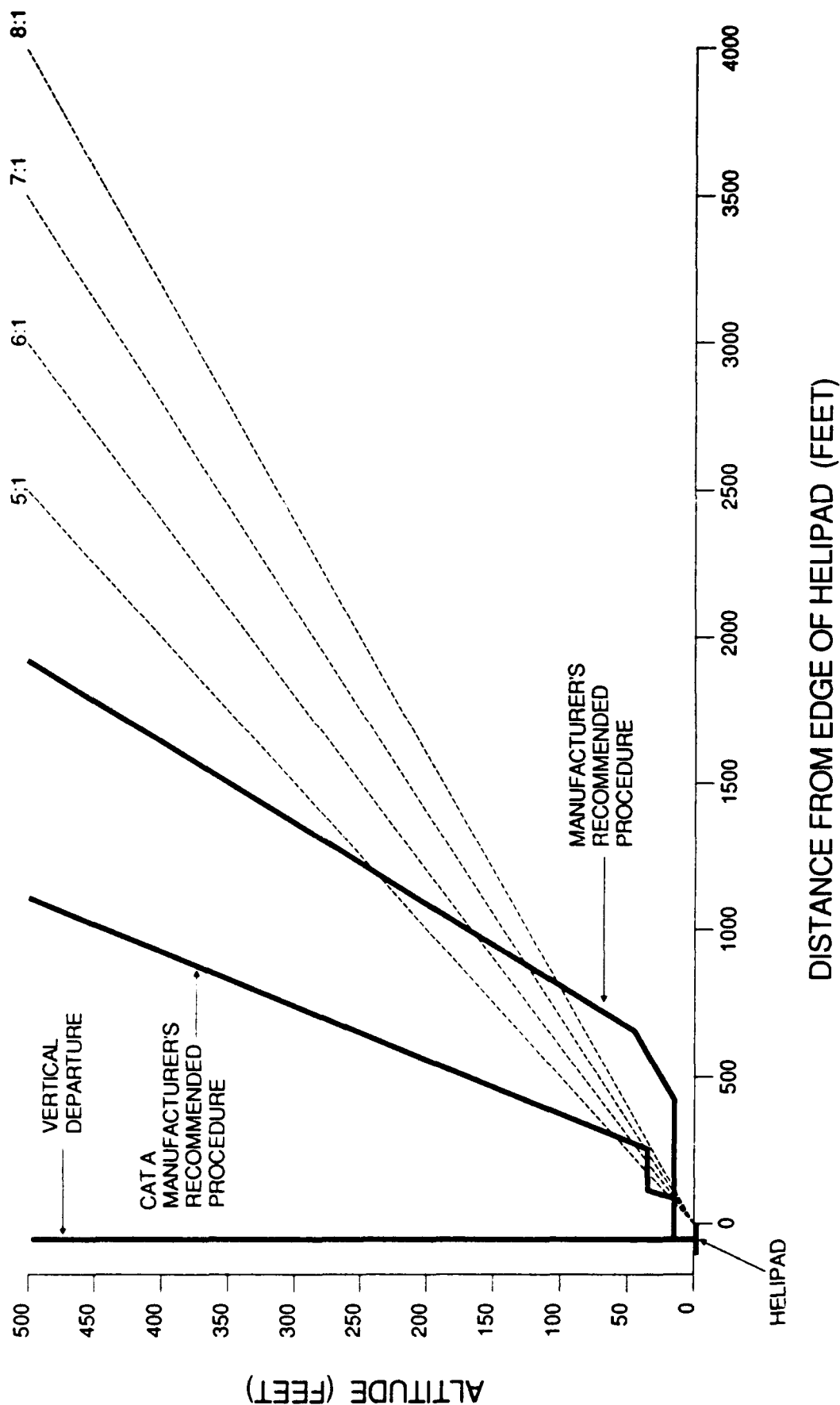
# AS 332C DEPARTURE PROFILES

70% MAX. G.W., 2000 FEET, STANDARD DAY



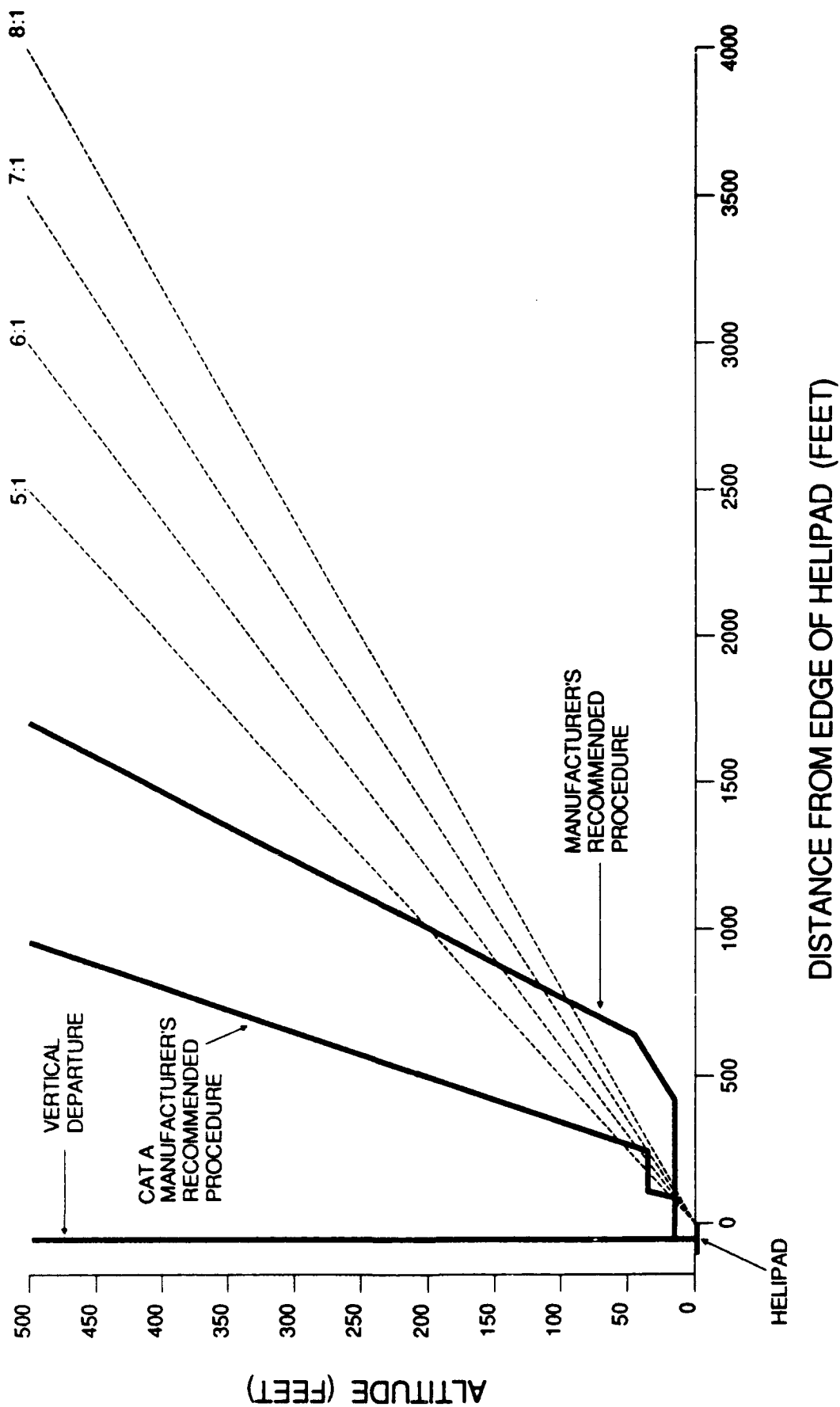
# AS 332C DEPARTURE PROFILES

70% MAX. G.W., 2000 FEET, HOT DAY



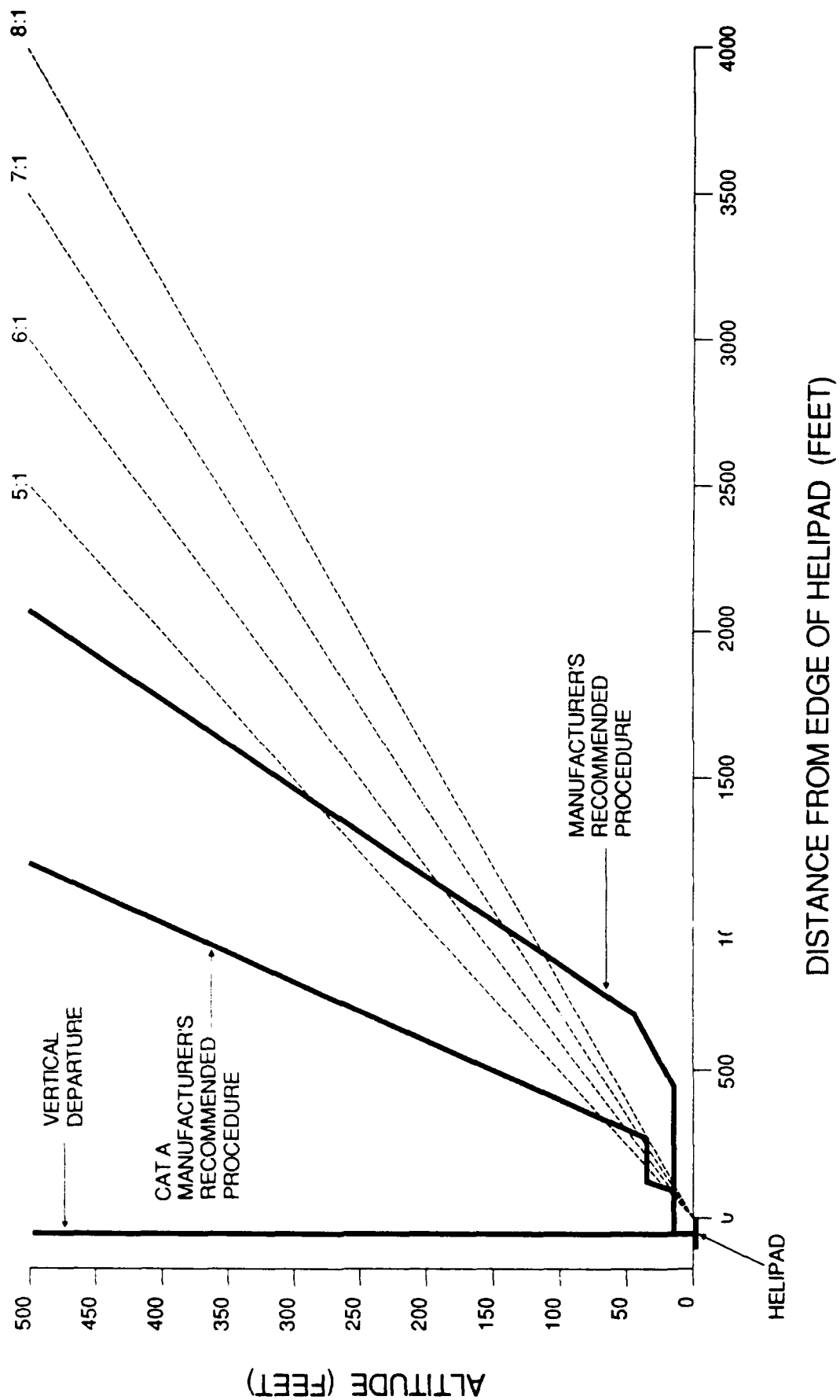
# AS 332C DEPARTURE PROFILES

70% MAX. G.W., 4000 FEET, STANDARD DAY



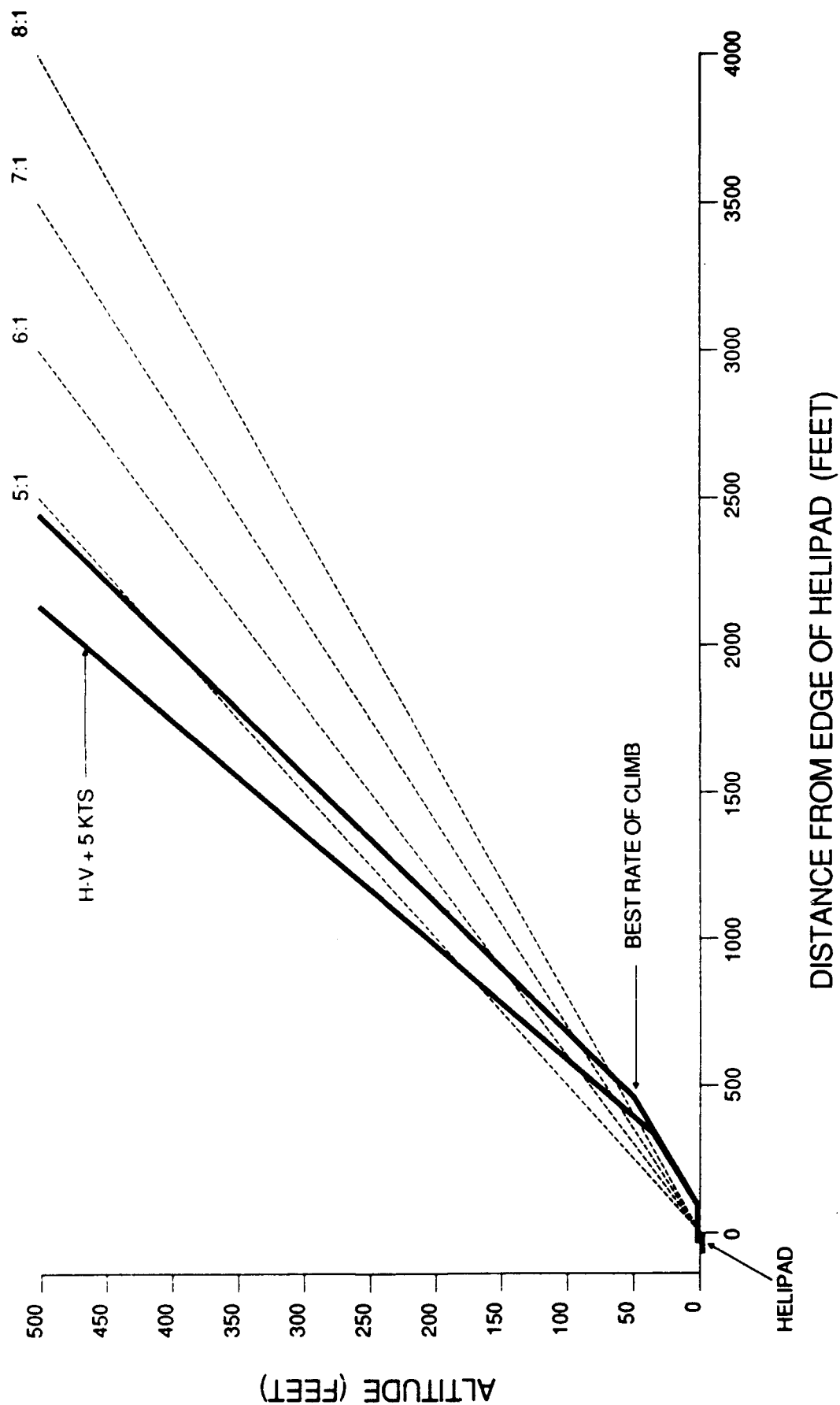
# AS 332C DEPARTURE PROFILES

70% MAX. G.W., 4000 FEET, HOT DAY



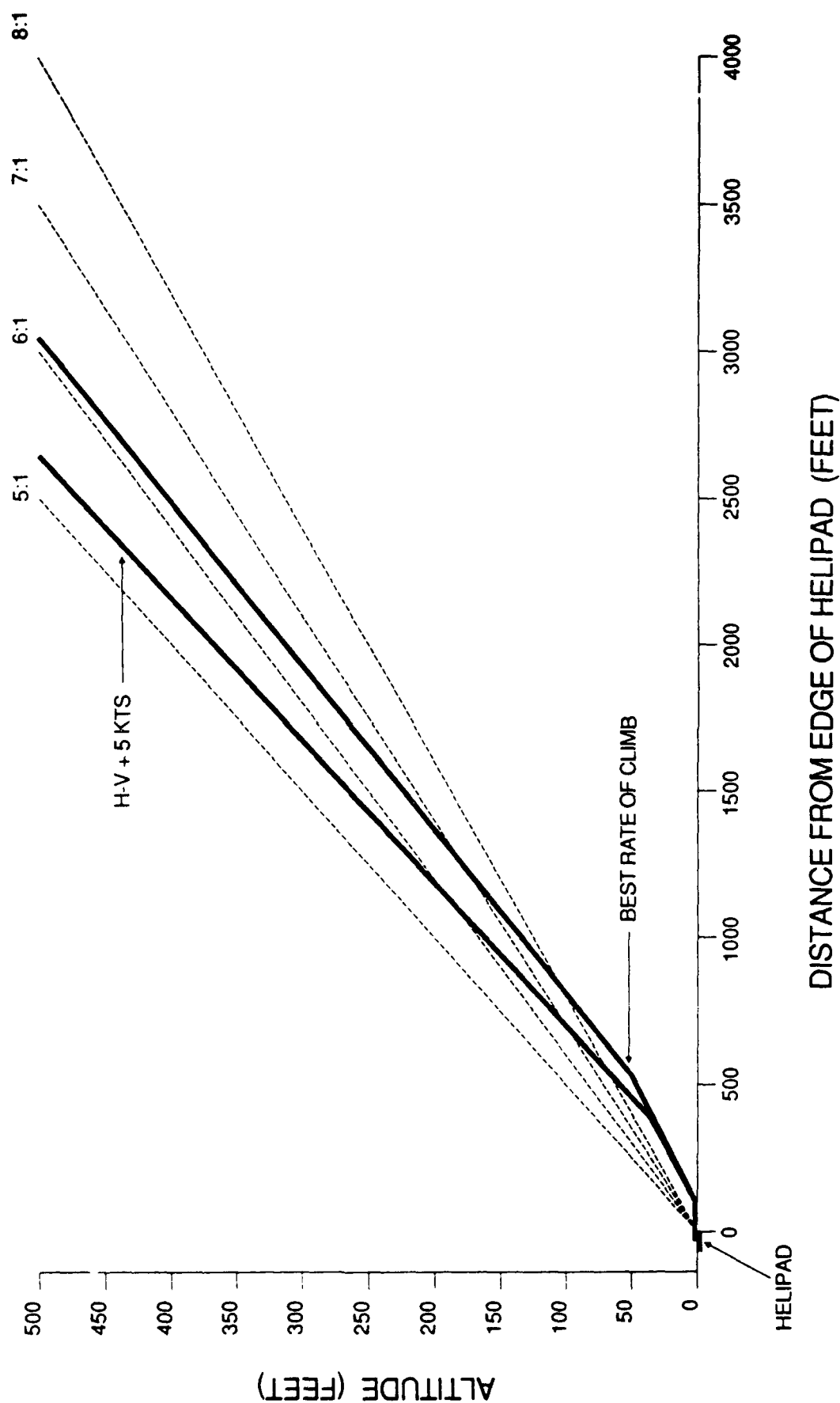
# B 206B III DEPARTURE PROFILES

MAX. G.W., SEA LEVEL, STANDARD DAY



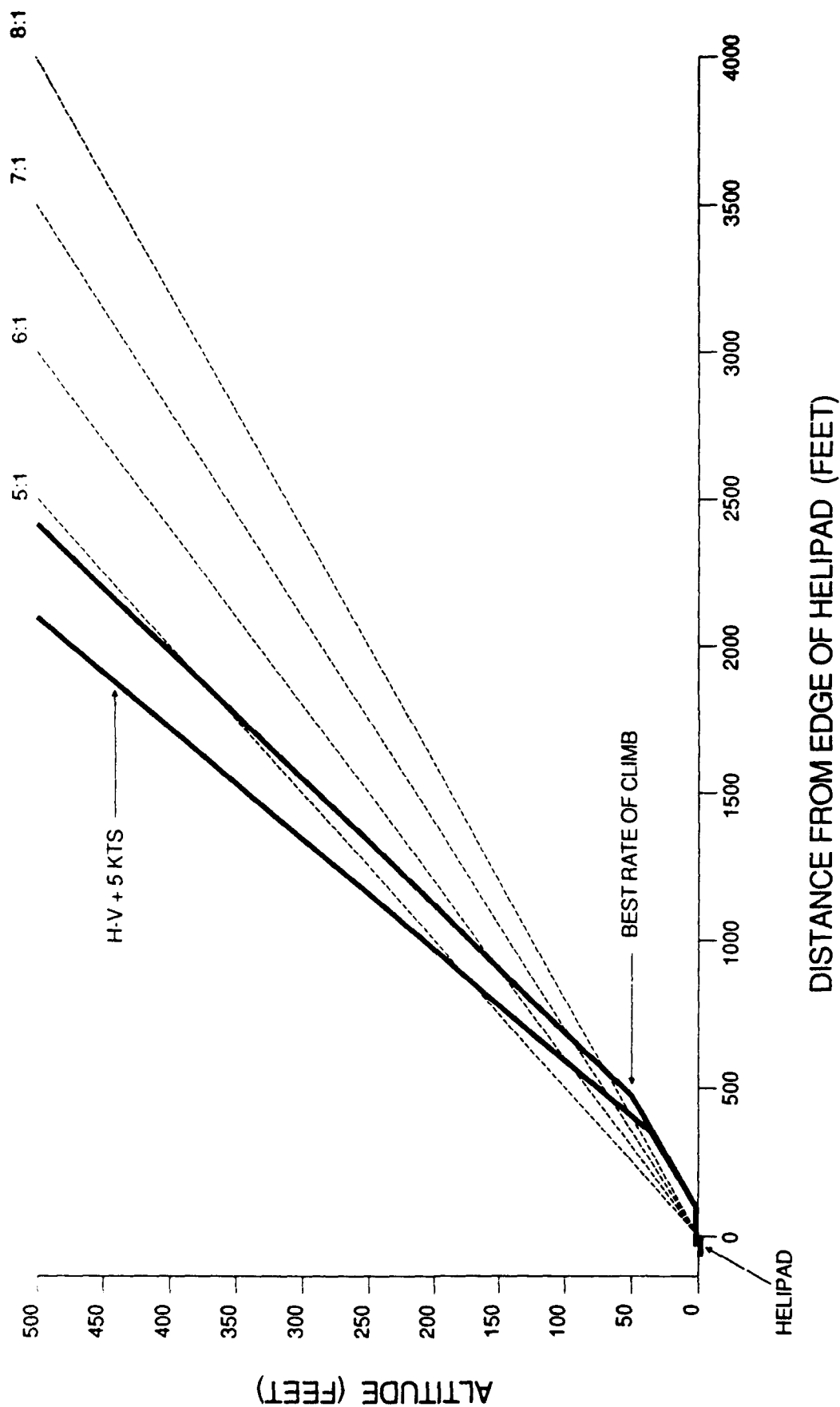
# B 206B III DEPARTURE PROFILES

MAX. G.W., SEALEVEL, HOT DAY



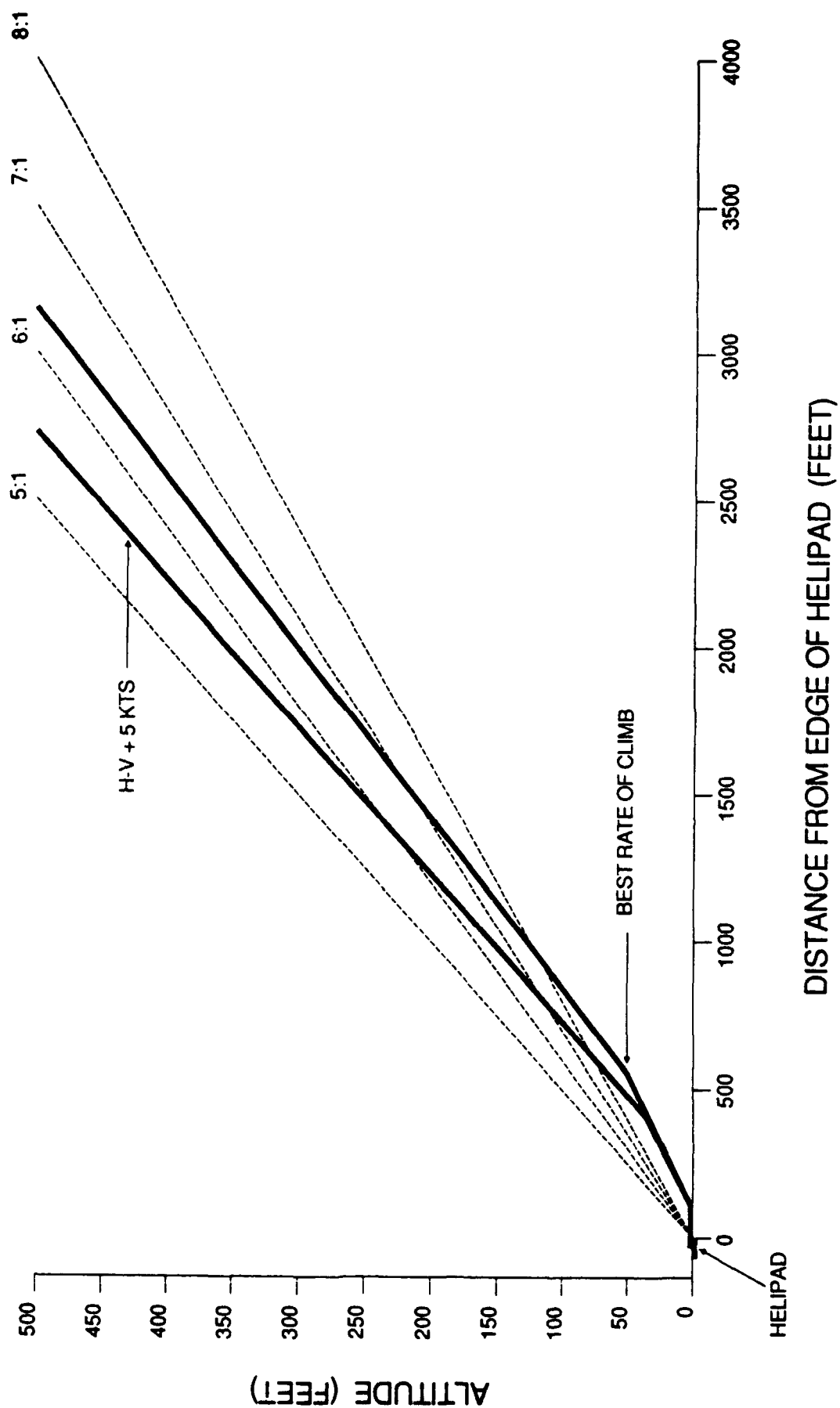
# B 206B III DEPARTURE PROFILES

MAX. G.W., 2000 FEET, STANDARD DAY



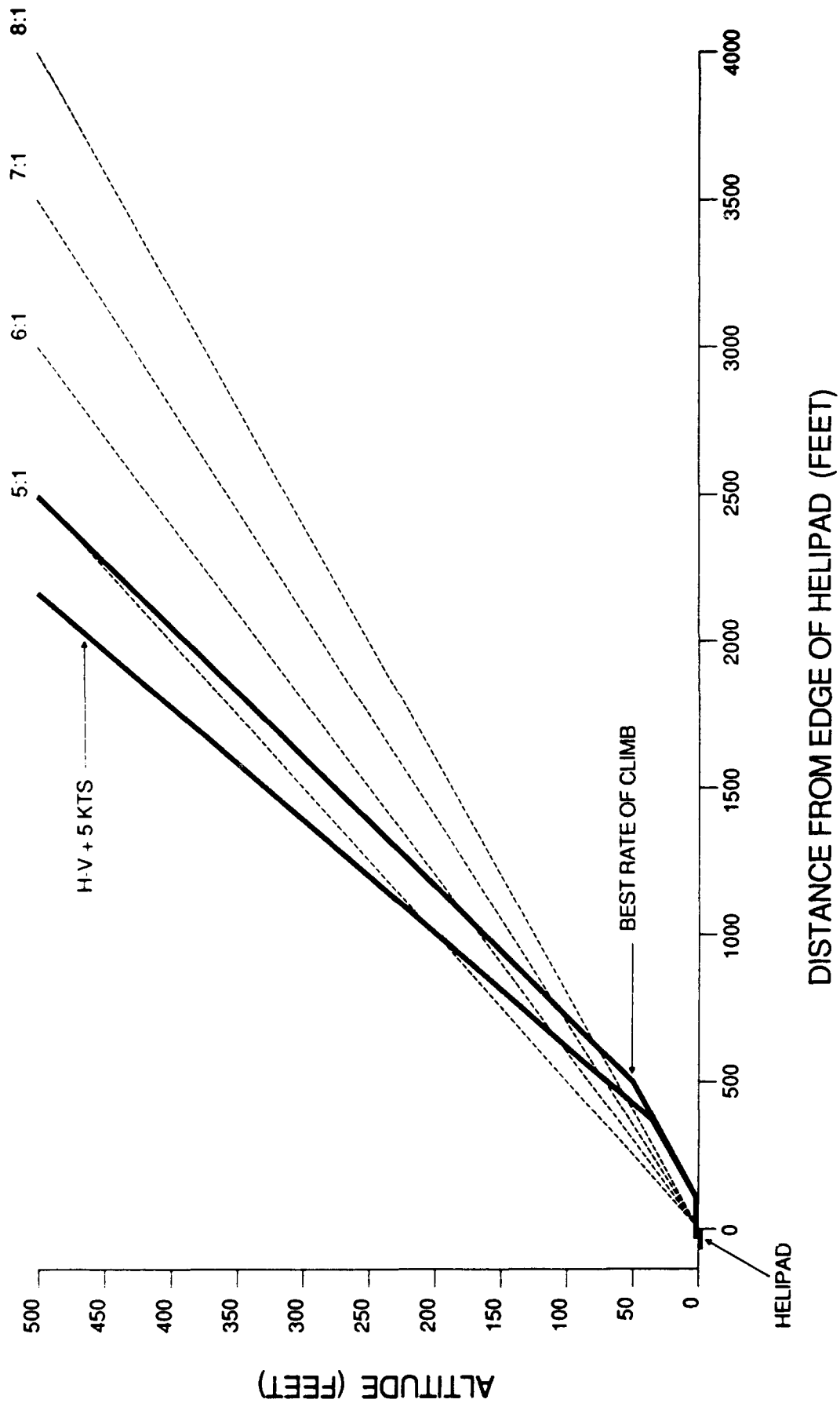
# B 206B III DEPARTURE PROFILES

MAX. G.W., 2000 FEET, HOT DAY



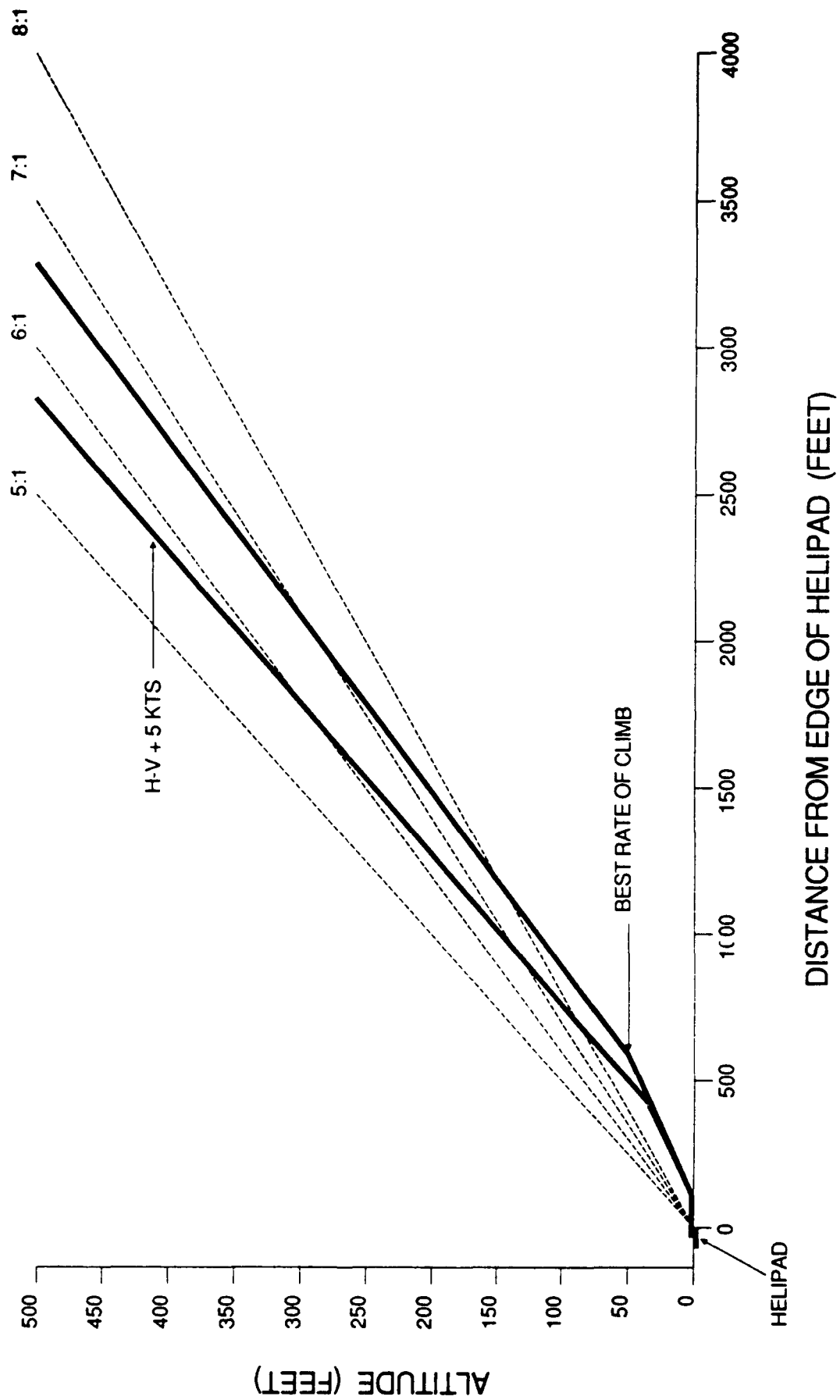
# B 206B III DEPARTURE PROFILES

MAX G.W., 4000 FEET, STANDARD DAY



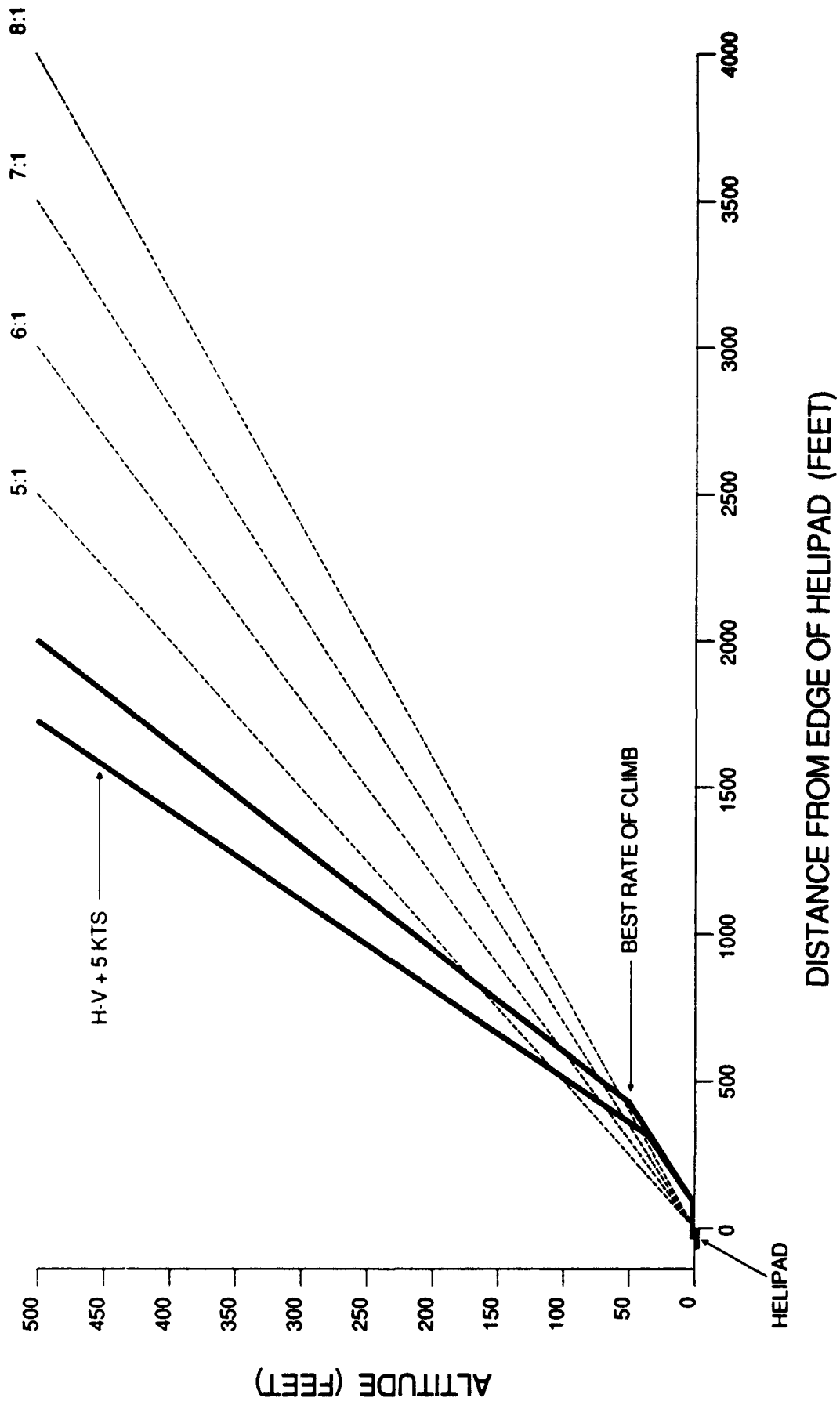
# B 206B III DEPARTURE PROFILES

MAX. G.W., 4000 FEET, HOT DAY



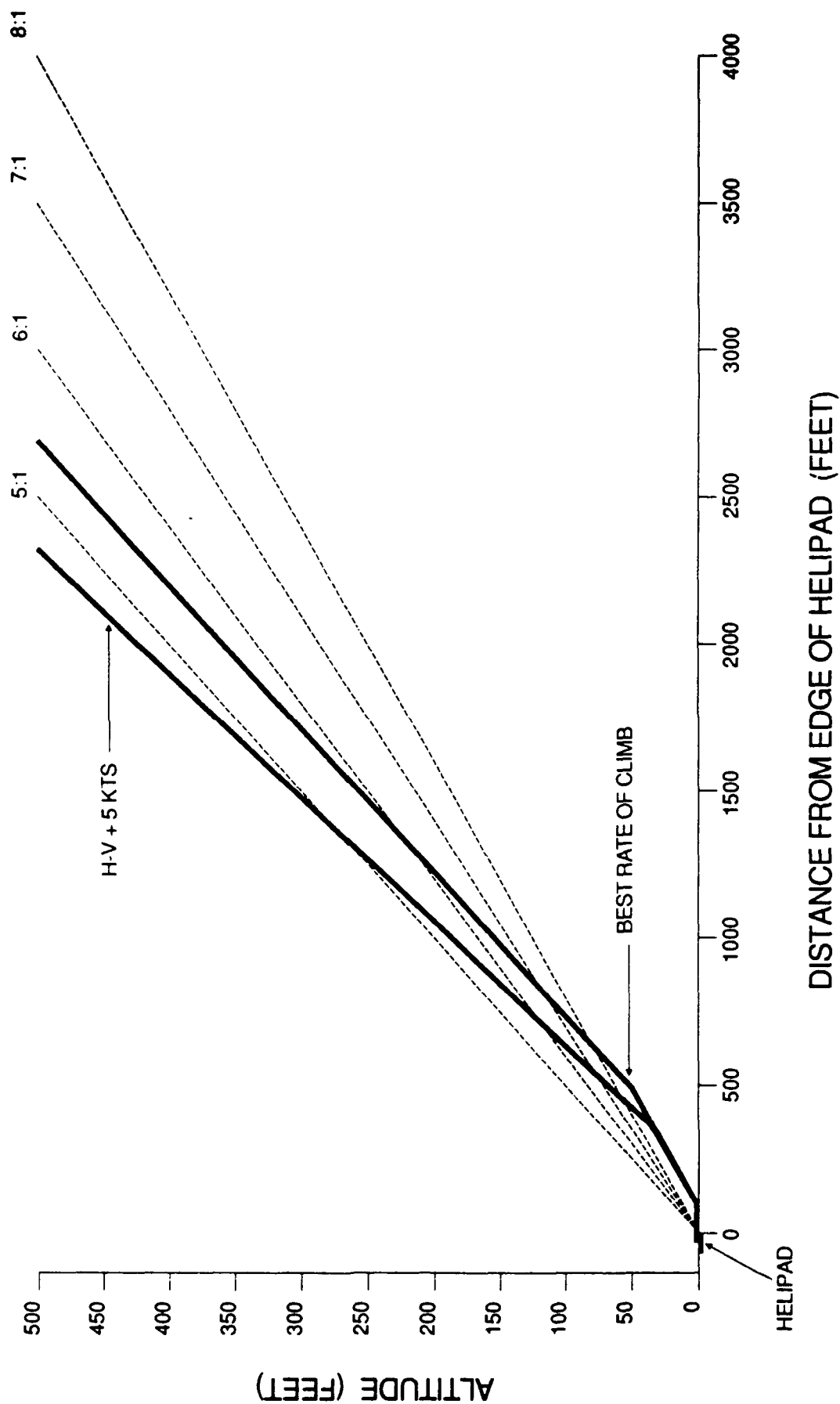
# B 206B III DEPARTURE PROFILES

85% MAX. G.W., SEA LEVEL, STANDARD DAY



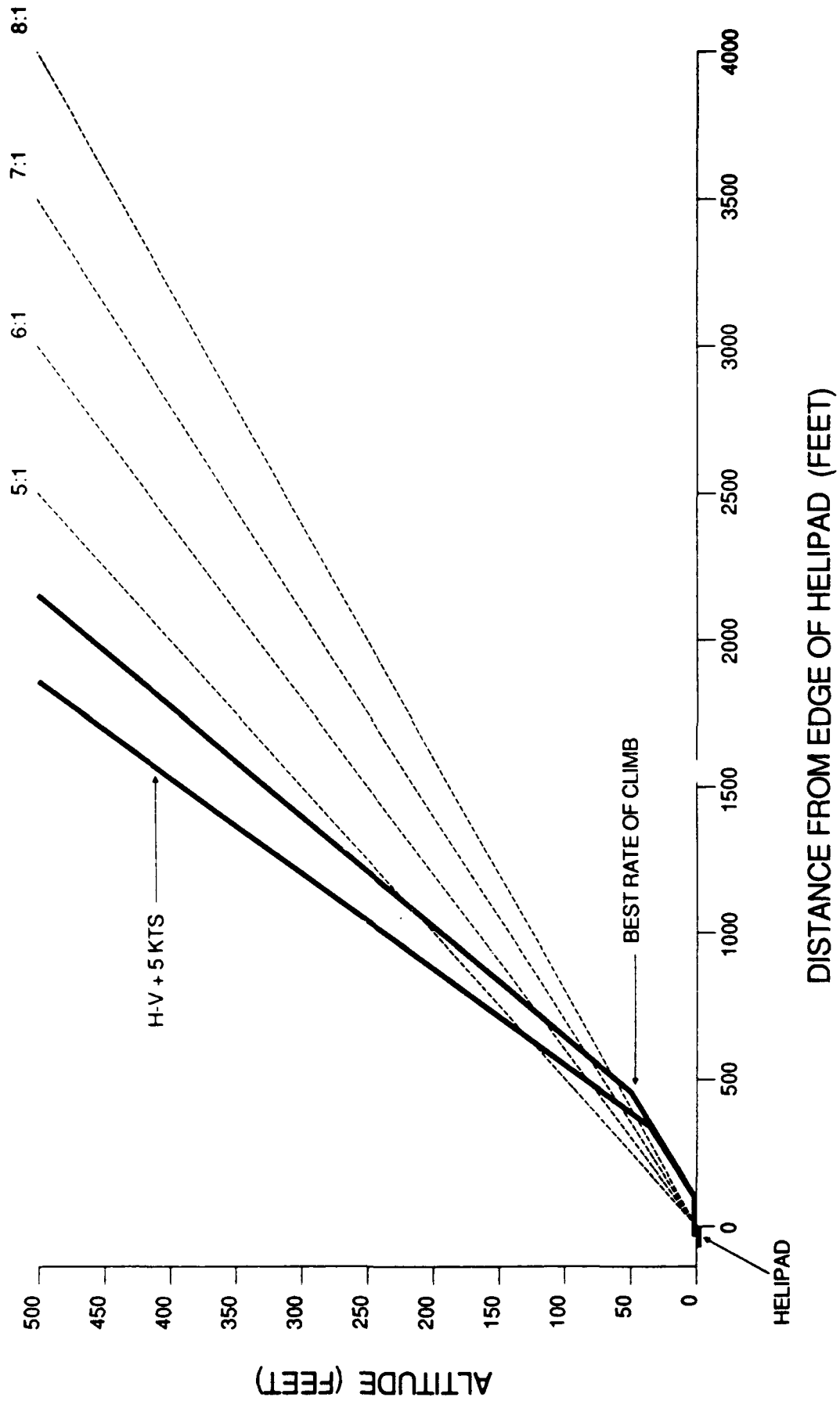
# B 206B III DEPARTURE PROFILES

85% MAX. G.W., SEA LEVEL, HOT DAY



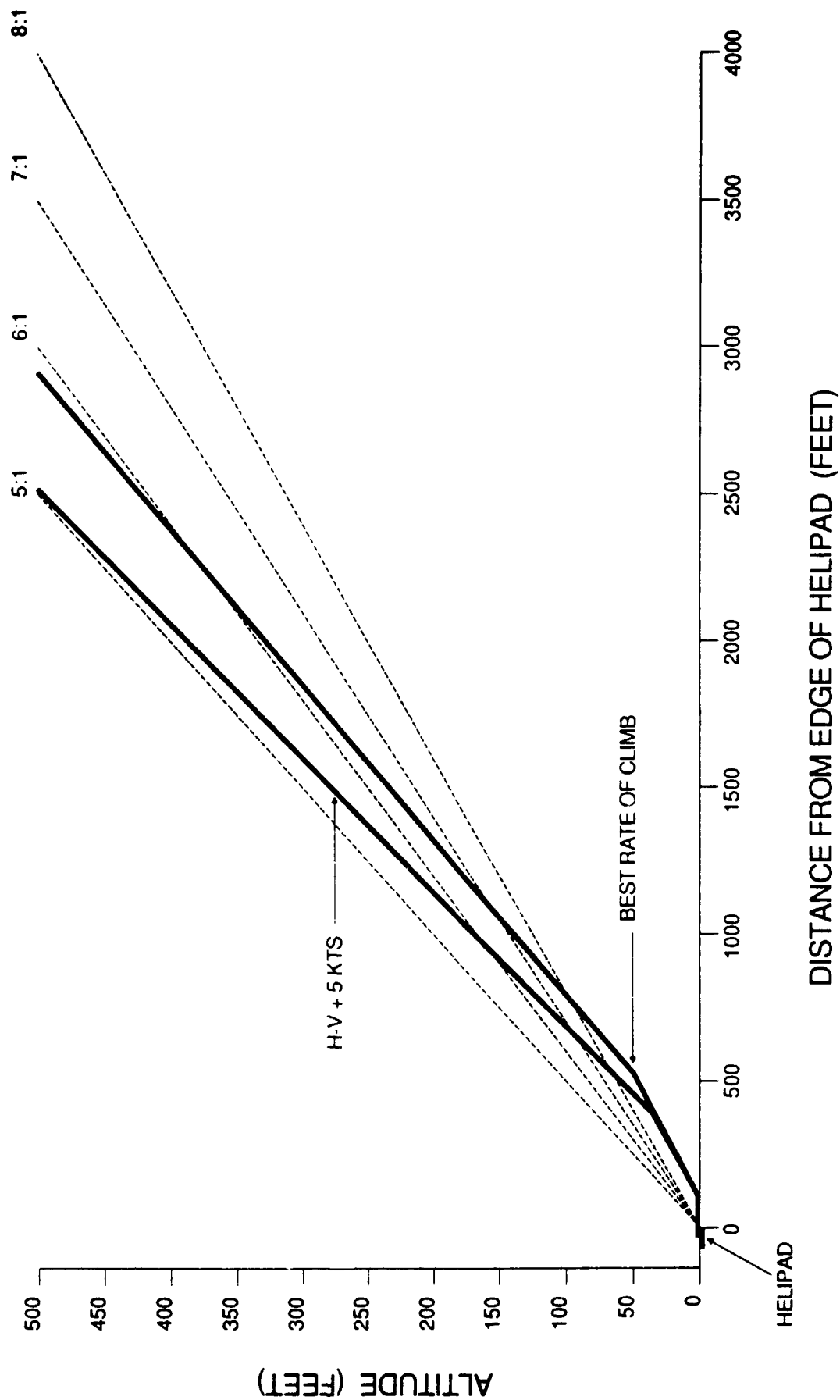
# B 206B III DEPARTURE PROFILES

85% MAX. G.W., 2000 FEET, STANDARD DAY



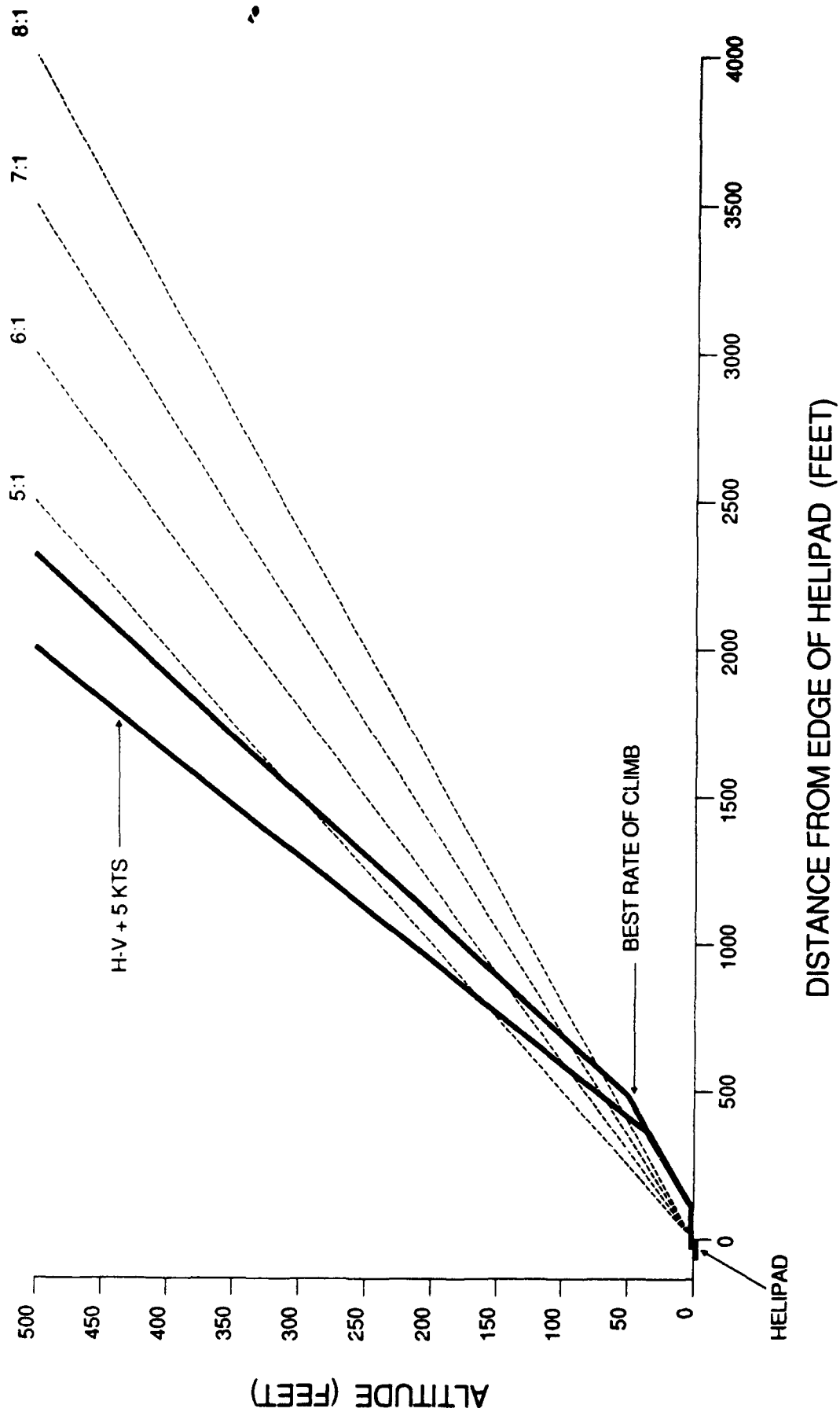
# B 206B III DEPARTURE PROFILES

85% MAX. G.W., 2000 FEET, HOT DAY



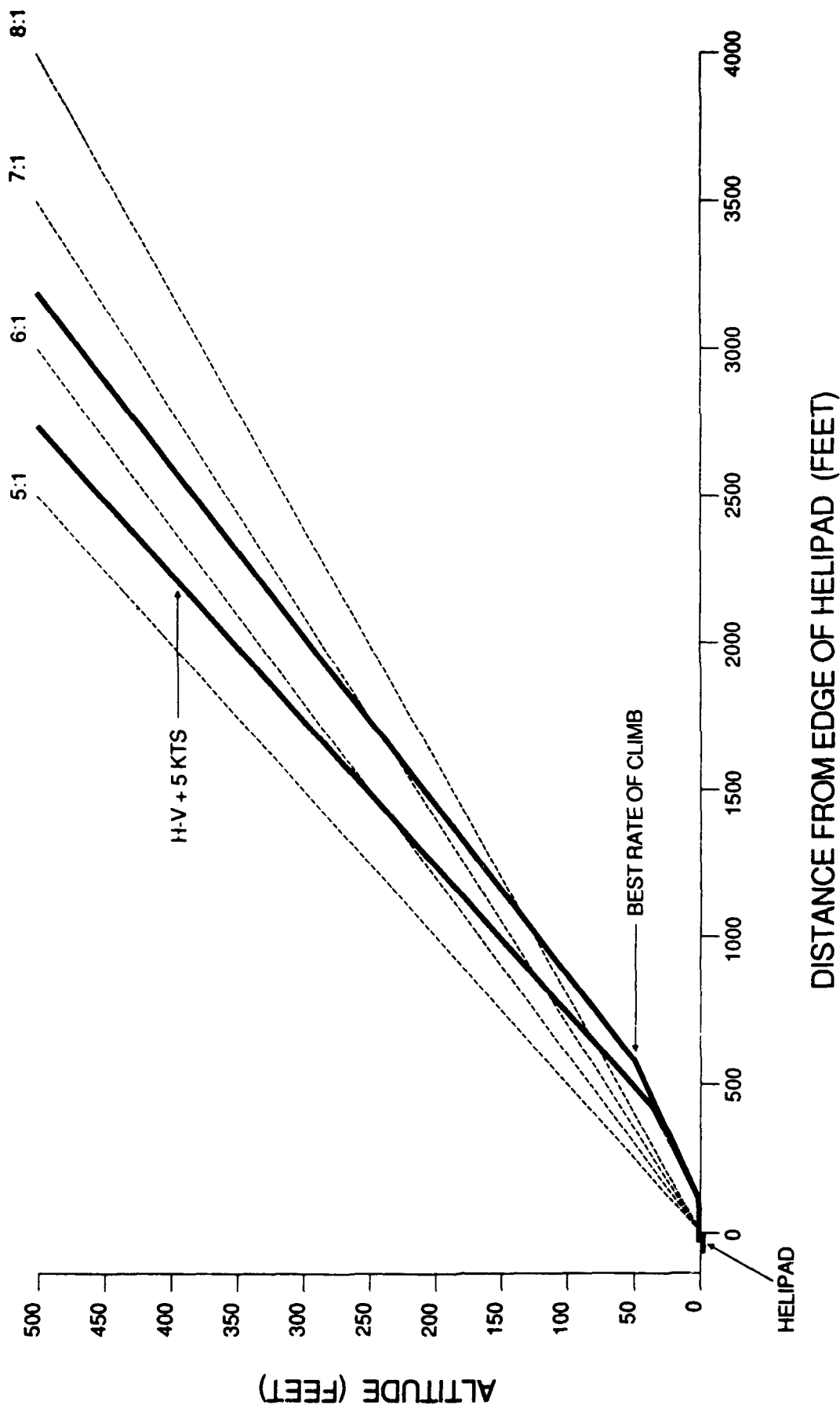
# B 206B III DEPARTURE PROFILES

85% MAX. G.W., 4000 FEET, STANDARD DAY



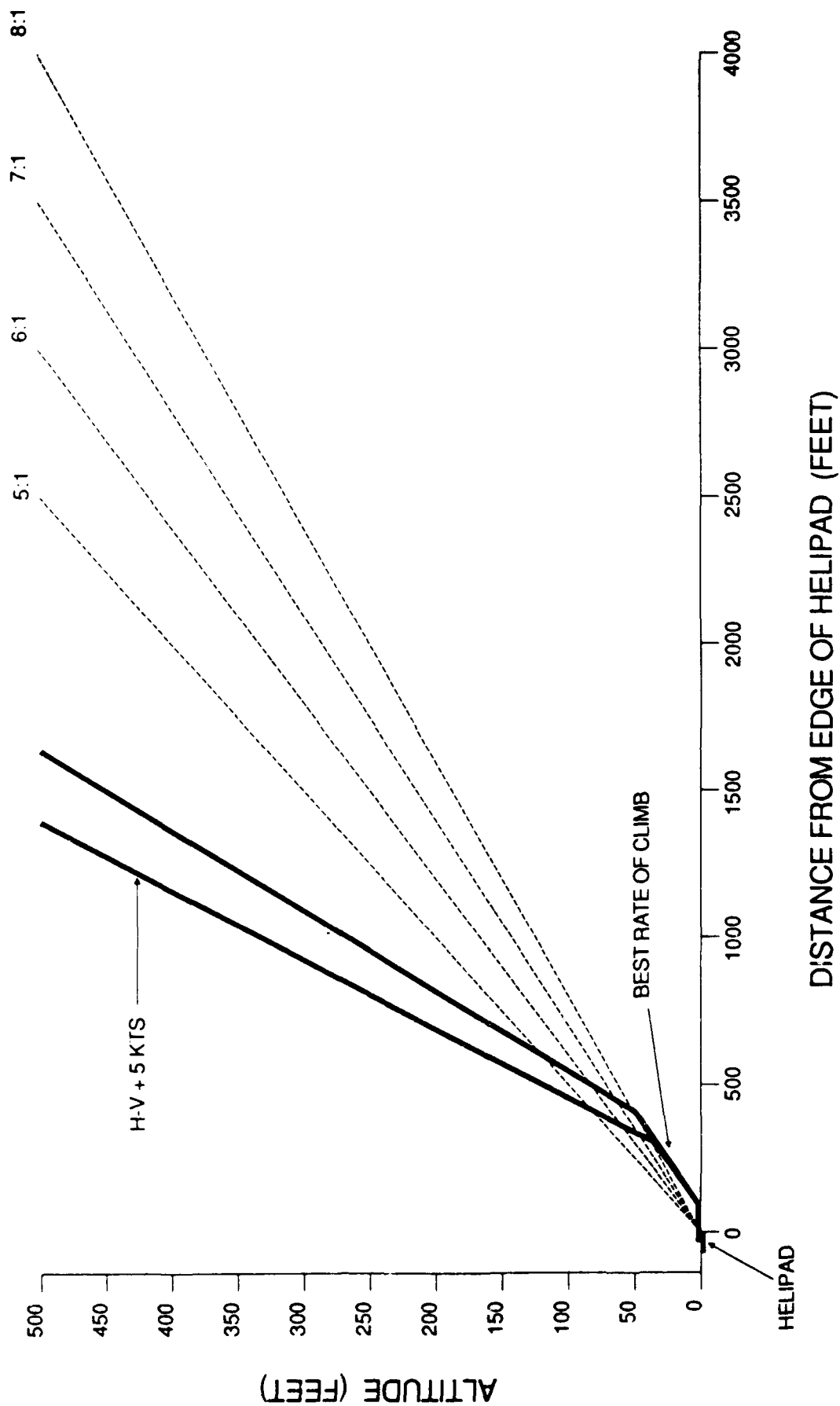
# B 206B III DEPARTURE PROFILES

85% MAX. G.W., 4000 FEET, HOT DAY



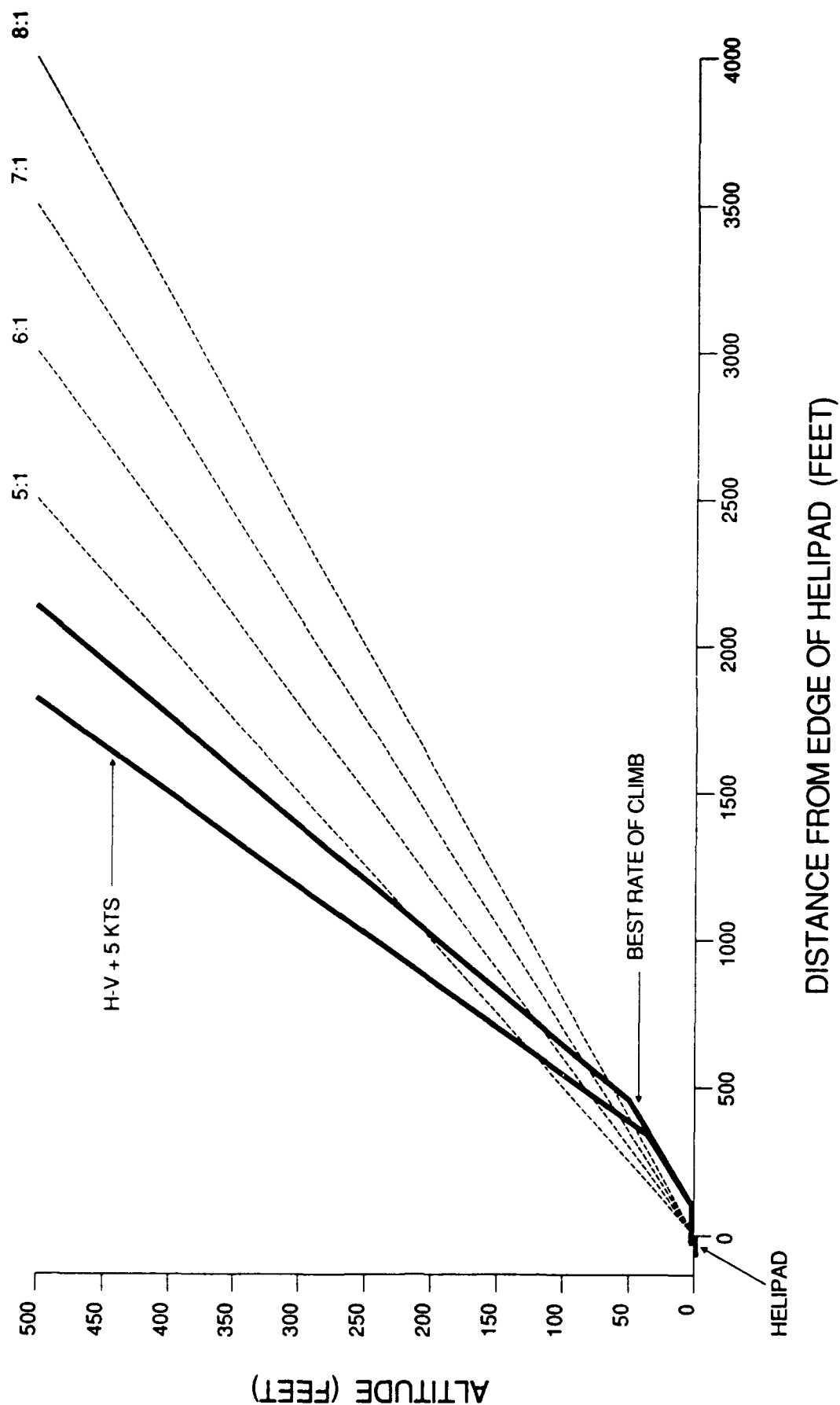
# B 206B III DEPARTURE PROFILES

70% MAX. G.W., SEA LEVEL, STANDARD DAY



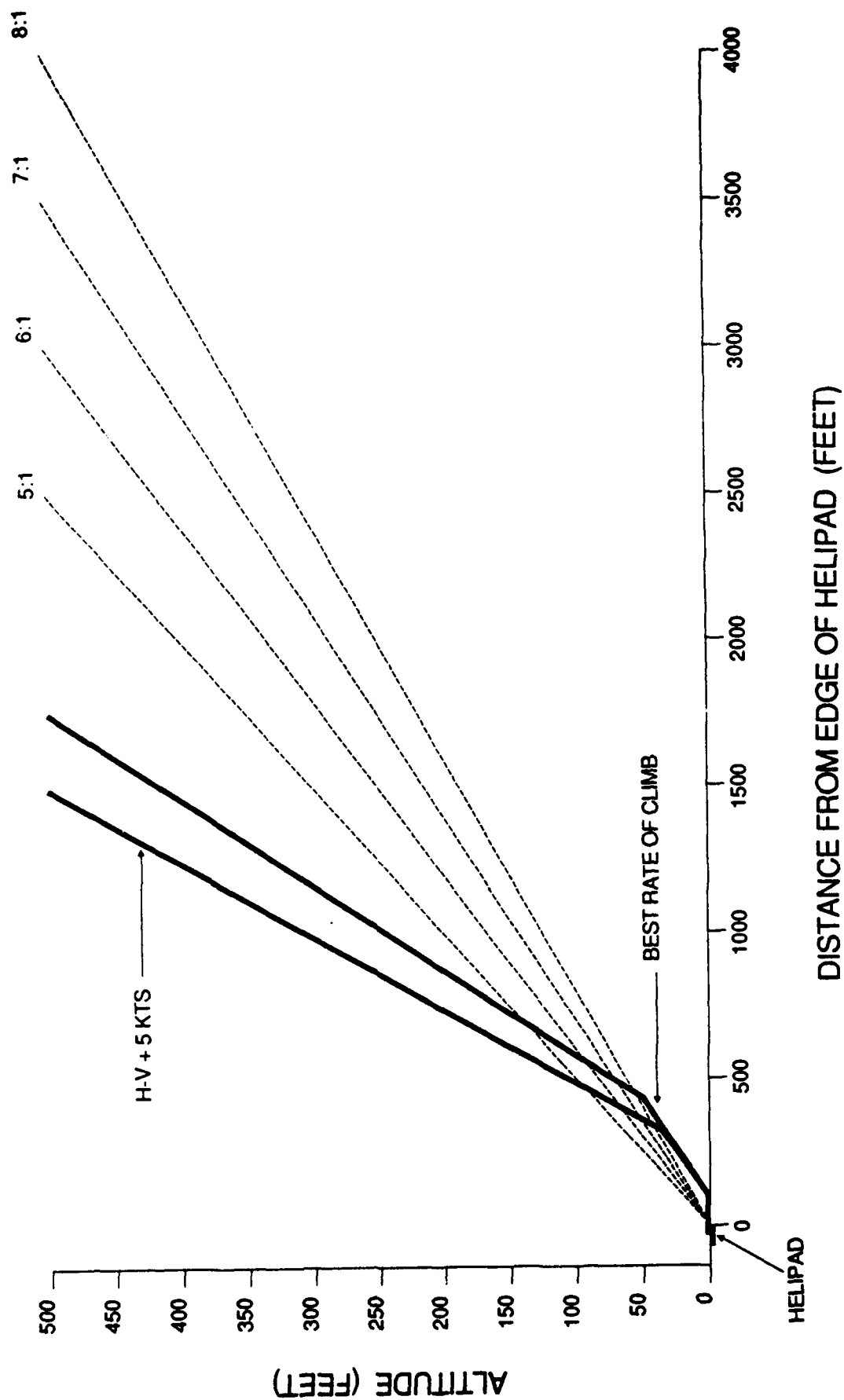
# B 206B III DEPARTURE PROFILES

70% MAX. G.W., SEA LEVEL, HOT DAY



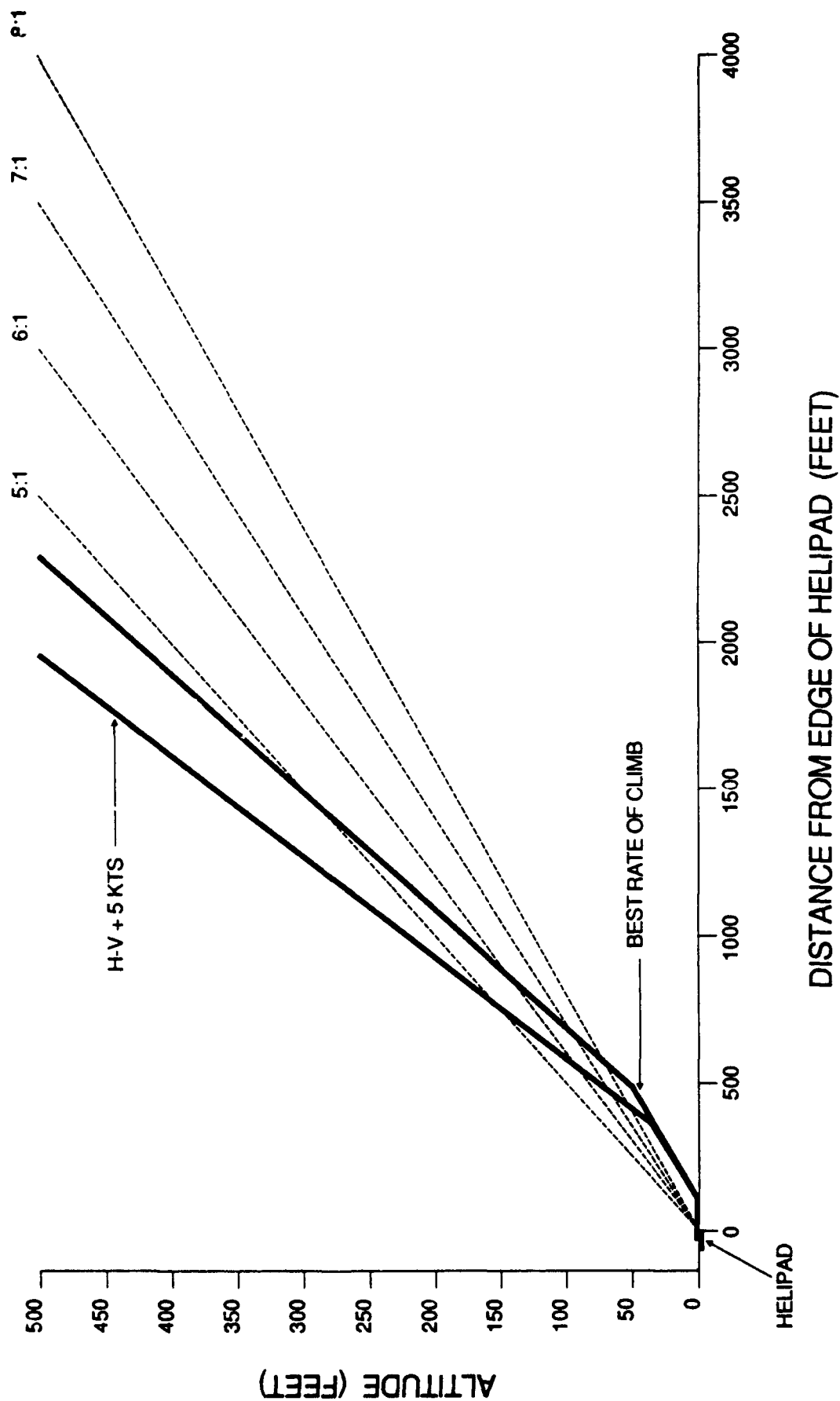
# B 206B III DEPARTURE PROFILES

70% MAX. G.W., 2000 FEET, STANDARD DAY



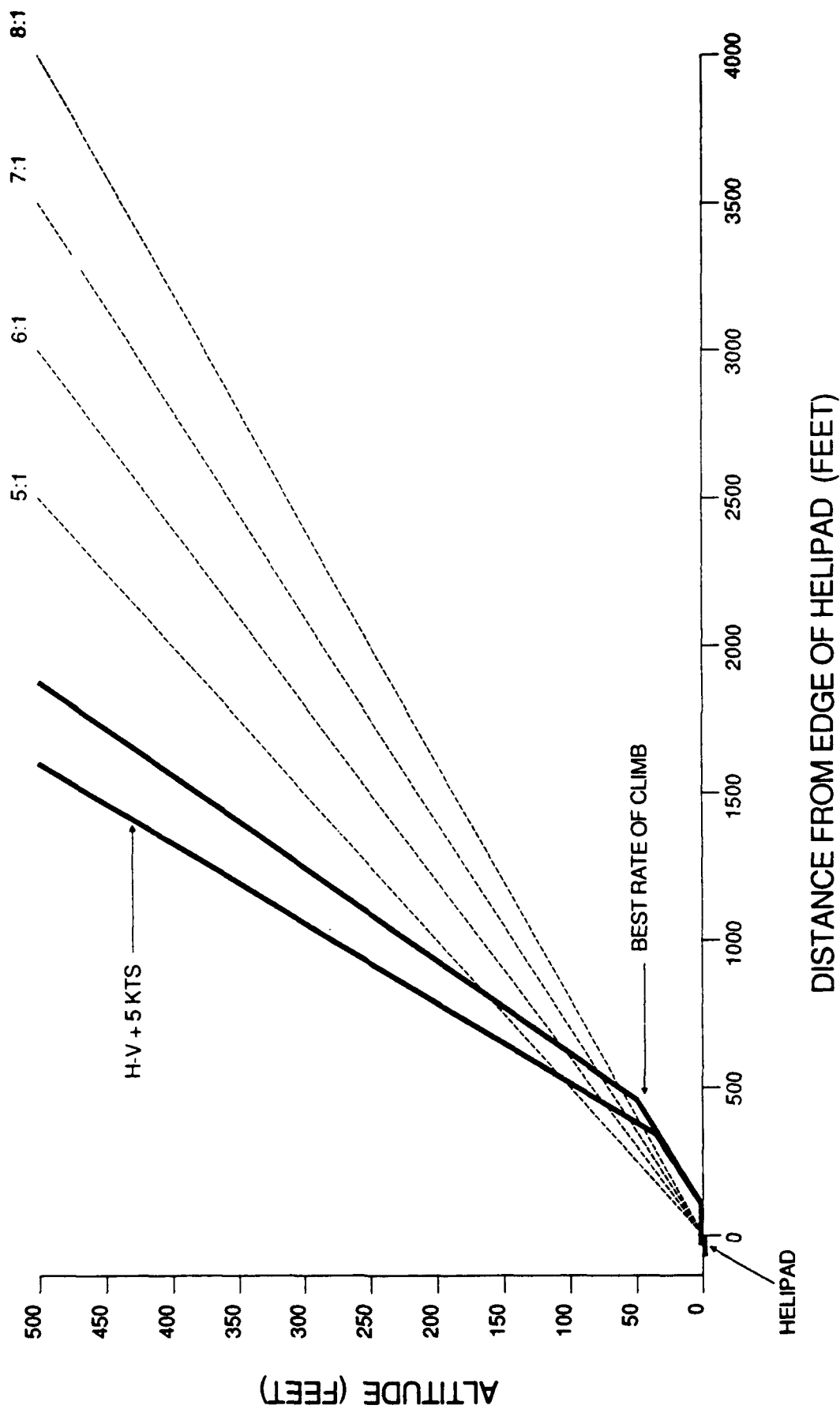
# B 206B III DEPARTURE PROFILES

70% MAX. G.W., 2000 FEET, HOT DAY



# B 206B III DEPARTURE PROFILES

70% MAX. G.W., 4000 FEET, STANDARD DAY



# B 206B III DEPARTURE PROFILES

70% MAX. G.W., 4000 FEET, HOT DAY

