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Heliport VFR Airspace Design Based on Helicopter Performance

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16. Abstract

This document presents the results of the efforts to classify helicopters and heliports based on the performance capabilities of a given rotorcraft and the protected ground and airspace available at a given heliport. Current VFR heliport protected airspace requirements are not broad enough to cover the wide range of helicopter models and conditions in which they operate. Additionally, they do not always provide an adequate margin of safety from allowable obstructions near heliports with regard to the performance capabilities of the helicopters using those heliports.

A recommendation is made to replace the single heliport imaginary surface with a system of surfaces which allow use of the heliport based on helicopter performance and also provides a safety margin between obstructions and rotorcraft climb capability. Another recommendation encourages helicopter manufacturers to include necessary performance data in their helicopter flight manuals to inform pilots of their aircraft's capability for operations at a confined area heliport or landing site.

This is one of a series of five reports that addresses helicopter performance profiles and their relationship to the VFR protected imaginary surfaces of approach and departure airspace at heliports. The other four are:

1) Helicopter Physical and Performance Data, DOT/FAA/RD-90/3,
2) Operational Survey - VFR Heliport Approaches and Departures, DOT/FAA/RD-90/5,
3) Rotorcraft, Acceleration and Climb Performance Model, DOT/FAARD-90/6, and
4) Helicopter Rejected Takeoff Airspace Requirements, DOT/FAA/RD-90-7.

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1.0 INTRODUCTION

During the development of the current Federal Aviation Administration (FAA) Advisory Circular 150/5390-2, Heliport Design, numerous questions arose regarding the size of the minimum required approach and departure protected airspace for VFR heliport operations. The opinions of participants in the development process ranged from:

> The protected airspace and surface areas are too big; it needs to be reduced to benefit the heliport operators and to encourage the development of heliports in confined areas in downtown city centers;

to:

> The protected airspace and surface areas are too small for safe operations; these standards leave little room for error and helicopter pilots would not fly into a heliport with the minimum required protected airspace except in extraordinary circumstances.

In an effort to resolve this issue, the FAA initiated analysis and flight test activities for the purpose of developing a body of knowledge which would provide the data necessary to address these opposing positions. This document presents the results of one of these activities, specifically, a performance based heliport design system which allows safe and efficient operations at a variety of heliports by defining useable heliport airspace/groundspace and required helicopter performance.

This report is one of a series of five that addresses helicopter performance profiles and their relationships to VFR approach and departure protected surfaces around heliports. The others are:

Helicopter Physical and Performance Data, DOT/FAA/RD-90/3, August 1991:

> Contains physical and performance data for eight civil helicopters. The data were taken from a number of sources to include aircraft flight manuals, industry publications, and computer performance simulations.

Operational Survey - VFR Heliport Approaches and Departures, DOT/FAA/RD-90/5, August 1991:

> Presents the results of a field survey which collected pilots' opinions about their helicopter performance and operational considerations. Survey results are compared with the performance data contained in "Helicopter Physical and Performance Data."

Rotorcraft Acceleration and Climb Performance Model, DOT/FAA/RD-90/6, August 1991:

Presents the methodology and computer programs used to develop the helicopter departure profiles presented in "Helicopter Physical and Performance Data."

Helicopter Rejected Takeoff Airspace Requirements, DOT/FAA/RD-90/7, August 1991:

Contains performance data for helicopters that are certificated to have one engine inoperative (OEI) performance capability. This capability is known in the industry as Category A. The report relates rejected takeoff and OEI performance capabilities to airspace requirements for those heliports where Category A operations are of concern.

The report contained herein, "Heliport VFR Airspace Design Based on Helicopter Performance," applies data contained in "Helicopter Physical and Performance Data" and "Operational Survey - VFR Heliport Approaches and Departures" to the issue of minimum required VFR airspace around the heliport and develops a performance based system for both heliports and helicopters that allows operational credit for certificated performance capability.

NOTE: This report is an analysis of Part 77 VFR surface requirements only. A similar effort addressing IFR issues should be undertaken to evaluate Part 77 IFR surface requirements.

2.0 OBJECTIVES

With sufficient information available, urban heliports located in confined areas could be developed applying either of two concepts. In one, the critical (design) rotorcraft is identified and a site selected on the basis of that rotorcraft's performance characteristics. In the other concept, the site is the given starting point and to be utilized it is necessary to identify rotorcraft with sufficient performance. To pursue either case, the heliport designer must be able to determine the performance capabilities of the current civil rotorcraft fleet.

With the above heliport design considerations in mind, this investigation was undertaken to achieve the following specific objectives:

Develop a helicopter performance-based system that permits a designer to select potential heliport sites that have the necessary ground and airspace characteristics to support operation of a specific helicopter which has been selected as a design point.

Develop a heliport airspace system based on site specific heliport characteristics, that permits a designer to specify the minimum certified performance class of helicopters that can operate to and from that heliport.

This particular effort focuses on the performance of helicopters during departure and approach operations and the relationships between that performance and the associated heliport protected airspace.

In pursuing this investigation, a considerable amount of helicopter performance data were generated for the eight helicopters selected for detailed analysis. It is appropriate to note that it was not the intent of this study to perform a comparative analysis of the performance capabilities of these aircraft. The performance data presented in this report and its three companion reports were developed using assumptions and guidelines specifically aimed at investigating the design of heliports in confined areas. Therefore, these data do not necessarily reflect the performance capabilities of these helicopters in a broader operational or economic context.

3.0 STUDY METHODOLOGY

The study methodology used during the investigation of helicopter performance and the development of a performance based system is shown in figure 1.

3.1 REVIEW OF APPLICABLE DOCUMENTATION

The study was initiated with a review of the applicable FAA regulatory documents, primarily the Code of Federal Regulations (CFR) and FAA Advisory Circulars (AC). In particular, the following parts of the regulations were reviewed:

14 CFR Part 77, Objects Affecting Navigable Airspace; Subpart C, Obstruction Standards; Paragraph 77.29, Airport imaginary surfaces for heliports,

14 CFR Part 27, Airworthiness Standards: Normal Category Rotorcraft, Subpart B, Flight - Performance, and

14 CFR Part 29, Airworthiness Standards: Transport Category Rotorcraft, Subpart B, Flight - Performance.

In addition the companion Advisory Circulars relating to these regulations were reviewed. These ACs included:

AC 150/5390-2, "Heliport Design," January 4, 1988,

AC 27-1, "Certification of Normal Category Rotorcraft," August 2?, 1985, and

AC 29-2a, "Certification of Transport Category Rotorcraft," September 16, 1987.

Next, available sources of helicopter performance data were reviewed. These included a number of helicopter flight manuals and reports contained in open literature. Previous studies of a similar nature were also of interest, in particular, three reports by PACER Systems, Inc. entitled:

"Study of Helicopter Performance and Terminal Instrument Procedures," DOT/FAA/RD-80/58, June 1980;

"Study of Heliport Airspace and Real Estate Requirements," DOT/FAA/RD-80/107, August 1980; and

"Development of a Heliport Classification Method and an Analysis of Heliport Real Estate and Airspace Requirements," DOT/FAA/RD-81/35, June 1981.

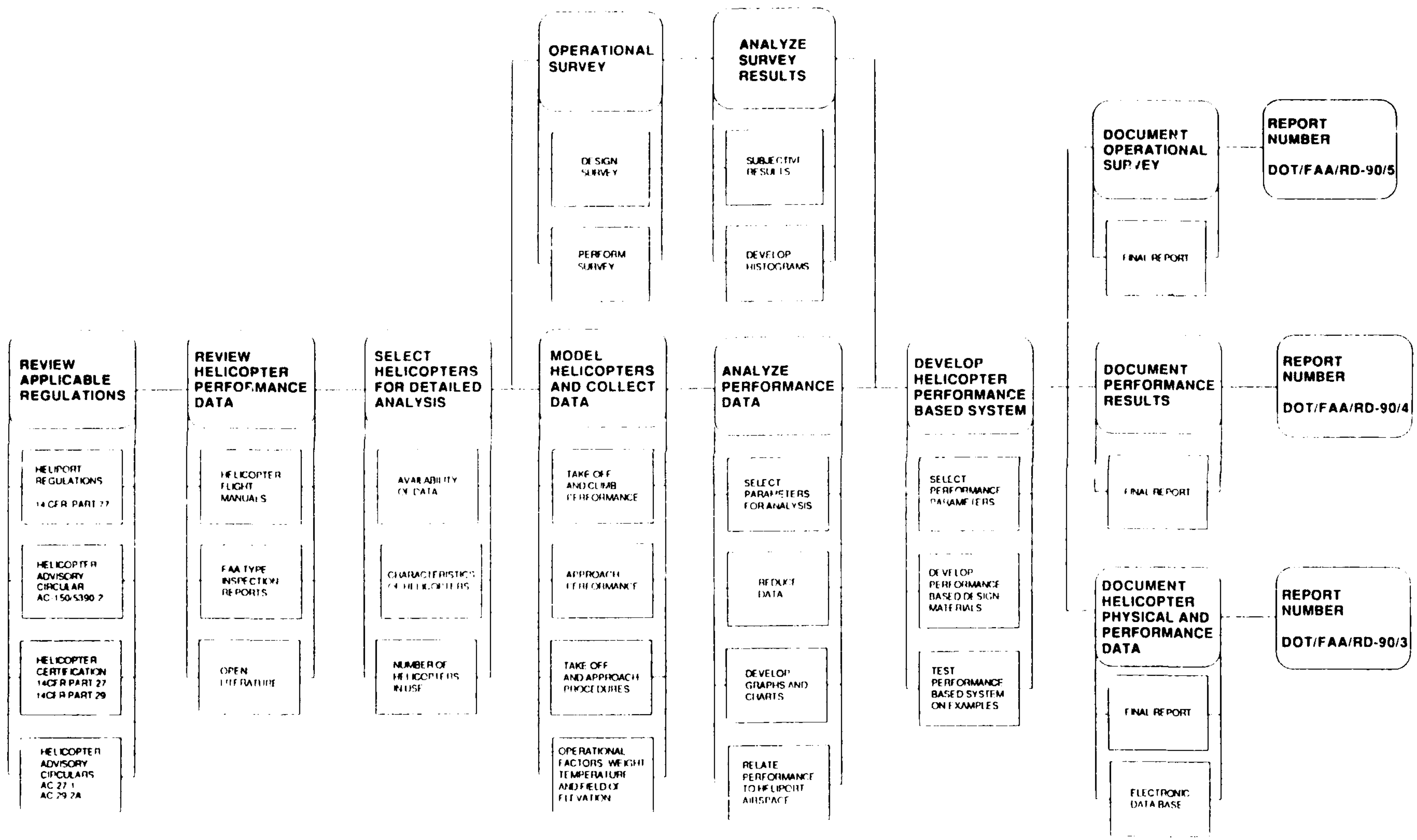


FIGURE 1 HELIPORT VFR AIRSPACE BASED ON HELICOPTER PERFORMANCE - STUDY METHODOLOGY

3.2 SELECTION OF REPRESENTATIVE HELICOPTERS

Following an initial evaluation of capabilities, a representative set of helicopters was selected for detailed performance assessments. Selected helicopters, along with basic capabilities data, are shown in table 1.

TABLE 1 HELICOPTERS SELECTED FOR DETAILED ANALYSIS

Helicopter	Max Gross Wt (lbs)	No. of Engines	Percent of Fleet	Certified IFR/VFR	Performance Category
Enstrom F28F	2,600	1	4	VFR	NCR
McDon'l/Douglas 500E	3,000	1	8	VFR	NCR
Bell 206B3	3,200	1	17	VFR	NCR
Aerospatiale 355F	5,071	2	2	VFR/IFR	NCR
MBB BO 105 CBS	5,291	2	2	VFR	NCR
Sikorsky S76A	10,500	2	2	VFR/IFR	TCR/A/B
Aerospatiale 332C	18,959	2	0.1	VFR/IFR	TCR/A/B
Boeing Vertol 234 LR	48,500	2	0.1	VFR/IFR	TCR/A

VFR - Certified for Visual Flight Rules Operations
IFR - Certified for Instrument Flight Rules Operations
NCR - Normal Category Rotorcraft
TCR/A/B - Transport Category Rotorcraft, Categories A and B
TCR/A - Transport Category Rotorcraft, Category A

3.3 PERFORMANCE MODELING

The aerodynamic and propulsion characteristics of these eight helicopters were modeled in some detail. The models were then used to determine the takeoff performance of each helicopter over a range of operational conditions. These conditions included:

a. aircraft weight - 70, 85 and 100 percent of maximum gross weight,
b. field elevation - sea level, 2000 and 4000 feet, and
c. temperatures - ISA and ISA + 20 degrees C.

ISA - temperature profile of the International Standard Atmosphere

In addition, profiles were calculated for applicable takeoff procedures, to include:

a. those recommended by the manufacturers,
b. Category A procedures where applicable,
c. Category B procedures, where applicable,
d. a departure procedure for confined heliport operations, referred to as the HV + 5 knot procedure (see description page 20), and
e. a departure procedure for confined heliport operations, referred to as the translational lift procedure.

Similarly, a data collection effort was accomplished for the approach phase of flight. Sufficient data were found in the open literature and in the aircraft flight manuals to allow approach profiles to be developed without extensive aircraft performance modeling.

3.4 AIRSPACE REQUIREMENTS COMPARISON

Following the data collection effort was a comparison of performance capability with the current heliport design standards. In several cases, helicopters operated in accordance with certificated performance data would not be assured obstacle clearance based on current heliport design standards.

The results of these comparisons were summarized in a set of findings concerning the current methods of describing airspace around heliports and the adequacy of information in the current helicopter flight manuals regarding confined heliport operations.

3.5 DEVELOPMENT OF THE HELIPORT AIRSPACE/HELICOPTER PERFORMANCE SYSTEM

Having identified areas of concern, a compatible heliport and helicopter performance-based system was developed. The basis of this system is the performance capabilities of the helicopters under varying operating conditions as identified in the data collection effort. The effort takes into consideration potential changes to both the heliport airspace standards and helicopter performance/procedures for confined heliport operations.

3.6 CONCLUSIONS AND RECOMMENDATIONS

The final activity in the investigation was identification of specific conclusions and recommendations based on the findings of the research effort.

The study efforts were then collected into this final report for the project.

4.0 ANALYSIS

This section of the report describes the analyses that led to the development of the heliport airspace/helicopter performance system.

4.1 DISCUSSION OF THE REGULATORY REQUIREMENTS

The regulatory requirements associated with operations and airspace at heliports can be divided into two general categories; those dealing with the heliport, and those related to the performance of the helicopter in departure and approach situations.

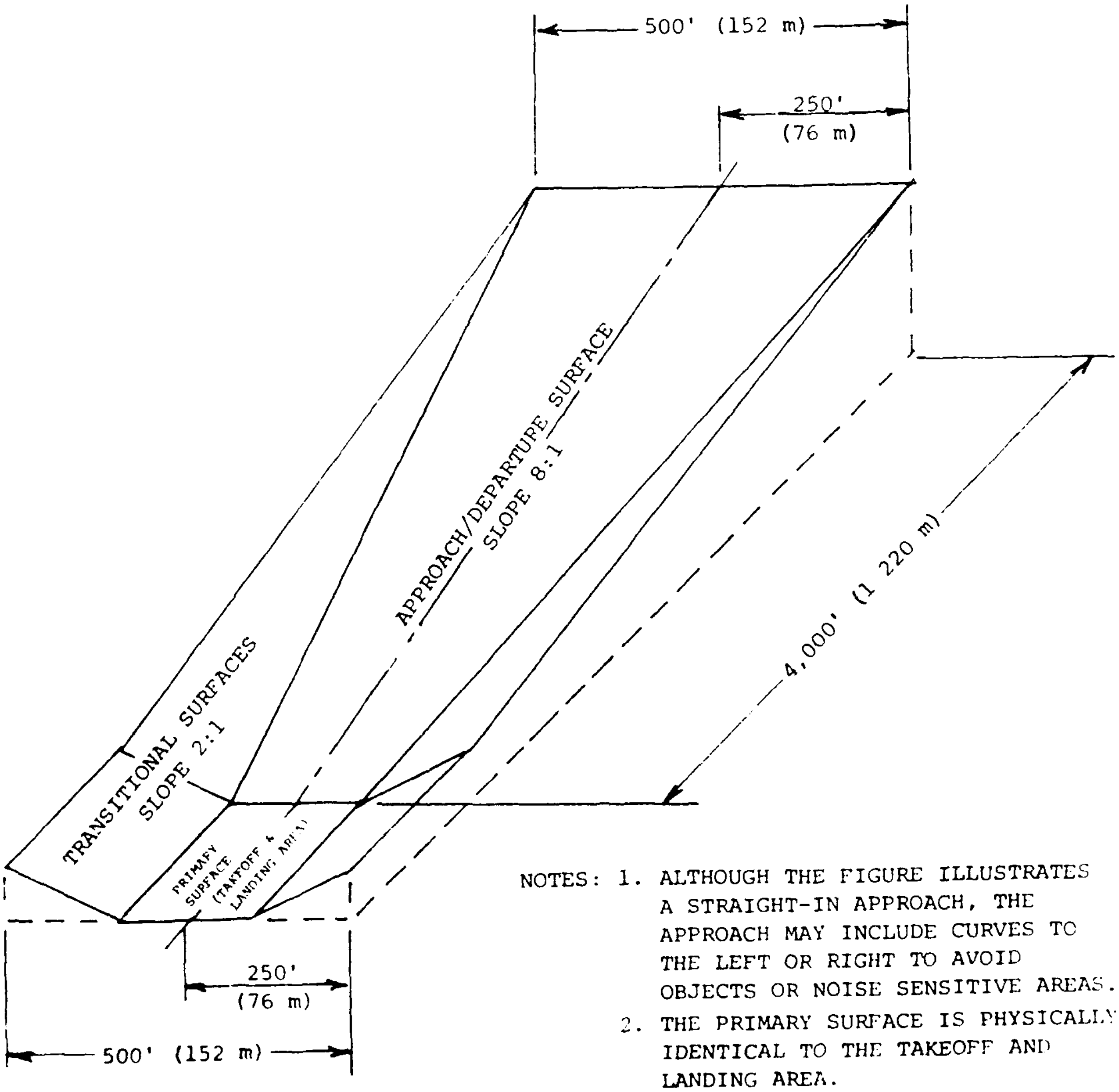
4.1.1 Heliport Airspace Regulations

The airspace around airports and heliports is monitored by the FAA through 14 CFR Part 77, Objects Affecting Navigable Airspace. Identification of obstacles resulting from new construction or alteration of existing structures which may be obstructions to air navigation is accomplished by defining a series of imaginary surfaces in the vicinity of airports and heliports. Objects that penetrate these surfaces must be evaluated to determine the impact on air navigation. Part 77 of 14 CFR defines the imaginary surfaces (figure 2) for heliports as follows:

> Paragraph 77.29 Airport imaginary surfaces for heliports.
>
> (a) *Heliport primary surface*. The area of the primary surface coincides in size and shape with the designated take-off and landing area of a heliport. This surface is a horizontal plane at the elevation of the established heliport elevation.
>
> (b) *Heliport approach surface*. The approach surface begins at each end of the heliport primary surface with the same width as the primary surface, and extends outward and upward for a horizontal distance of 4,000 feet where its width is 500 feet. The slope of the approach surface is 8 to 1 for civil heliports and 10 to 1 for military heliports.
>
> (c) *Heliport transitional surfaces*. These surfaces extend outward and upward from the lateral boundaries of the heliport primary surface and from the approach surfaces at a slope of 2 to 1 for a distance of 250 feet measured horizontally from the centerline of the primary and approach surfaces.

Of primary interest to this investigation is the slope of the heliport approach surface which is set at 8 to 1 for civil heliports. This slope corresponds to an angle of 7.125 degrees above the horizon. This slope begins at the approach edge of the takeoff and landing area.

Additional information on the airspace requirements for heliports can be found in the FAA Advisory Circular 150/5390-2, Heliport Design. In



NOTES: 1. ALTHOUGH THE FIGURE ILLUSTRATES A STRAIGHT-IN APPROACH, THE APPROACH MAY INCLUDE CURVES TO THE LEFT OR RIGHT TO AVOID OBJECTS OR NOISE SENSITIVE AREAS.

2. THE PRIMARY SURFACE IS PHYSICALLY IDENTICAL TO THE TAKEOFF AND LANDING AREA.

FIGURE 2 HELIPORT IMAGINARY SURFACES

addition to describing the heliport primary and approach surfaces, the AC defines a visual approach and departure protection area which coincides with the first 280 feet of the heliport approach surface nearest the heliport primary surface. The AC recommends that the heliport operator own or control the property underlying the protection area, that it be reasonably free of surface irregularities or objects, while permitting heliport related uses which do not create a hazardous condition.

Heliport design standards are advisory only, unless the heliport is a public use facility that is funded or administered by the federal government.

4.1.2 Helicopter Regulatory Requirements

Helicopters are certified by the FAA under 14 CFR, Parts 27 and 29. Part 27 applies to Normal Category Rotorcraft with a maximum weight of 6,000 pounds. Part 29, Transport Category Rotorcraft, applies to helicopters weighing over 6,000 pounds. Part 29 helicopters are further divided into Category A or Category B helicopters. The various certification conditions are shown in figure 3.

Part 29 helicopters weighing 20,000 pounds or less and having nine or less passenger seats may be certified as Category B.

Part 29 helicopters weighing 20,000 pounds or less and having 10 or more passenger seats may be certified as Category B providing the helicopter meets Category A requirements for; strength (Subpart C), design and construction (Subpart D), powerplant (Subpart E), and equipment (Subpart F), as well as the one engine inoperative (Para 29.67) and conditions to determine the height-velocity envelope required by Parts 29.79 and 29.1513.

Helicopters weighing more than 20,000 pounds and having nine or less passenger seats may be certified as Category B providing the helicopter meets Category A requirements in the areas of strength, design and construction, powerplant and equipment.

All helicopters with maximum weight greater than 20,000 pounds and having 10 or more passenger seats must meet Category A requirements.

4.1.2.1 Part 27 Performance Certification Requirements

The performance requirements from Part 27 which are of interest in this investigation are contained in paragraphs:

- 27.51 Takeoff;
- 27.65 Climb: all engines operating (AEO);
- 27.73 Performance at minimum operating speed;
- 27.75 Landing; and
- 27.79 Limiting height-speed envelope.

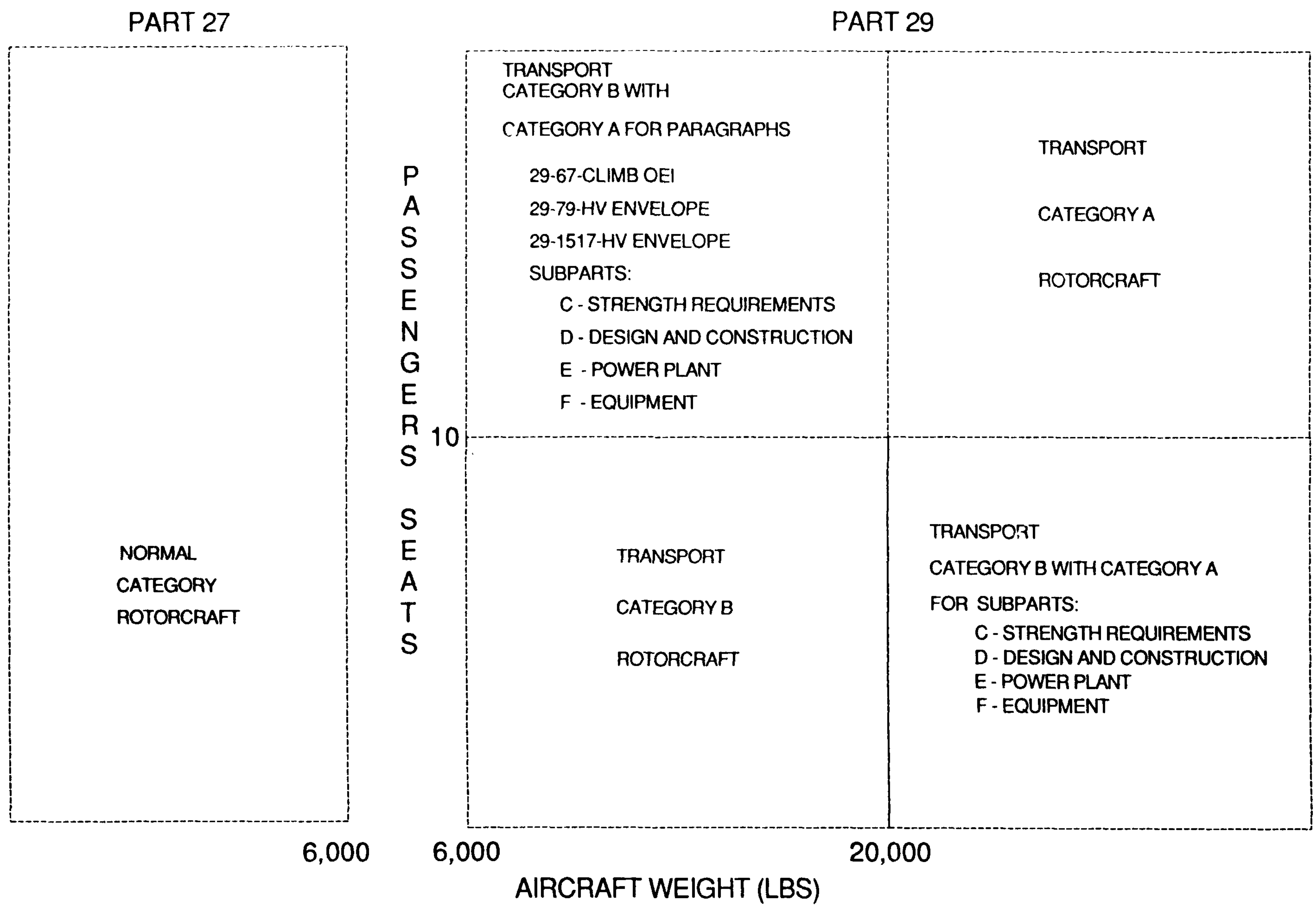


FIGURE 3 AIRCRAFT CERTIFICATION CATEGORIES

Appendix A contains applicable sections of the regulations for reference purposes. The following paragraphs summarize the main elements of these regulations as they apply to takeoff and landing operations for normal category rotorcraft.

General

Performance requirements must be met for still air and international standard atmospheric (ISA) conditions. They must also correspond to the engine power available under particular atmospheric conditions, and be based upon approved engine power less installation losses and losses associated with the operation of accessories.

Takeoff

The takeoff procedure must not require exceptional piloting skill or exceptionally favorable conditions.

Takeoffs must be made in such a manner that a landing can be made safely at any point along the flight path in the event of an engine failure.

Climb with All Engines Operating (AEO) - Helicopters

The best rate of climb speed, V_Y, must be determined for sea level conditions, at maximum gross weight, with maximum continuous power on each engine.

If, at any altitude for which the helicopter is certified, V_Y is greater than the never-exceed speed (V_{NE}), the rate of climb (ROC) must be determined for the altitudes indicated by the term "ROC Required" in figure 4.

Climb with One Engine Inoperative (OEI) - Helicopters

At V_Y, or at a speed for minimum rate of descent, the steady rate of climb (or descent) must be determined at maximum gross weight, with one engine inoperative, and maximum continuous power (except when 30-min power certification is requested).

Landing

The rotorcraft must be controllable and have good handling qualities at appropriate approach and landing speeds, and, whether single or multiengine, be capable of being landed safely following complete power failure.

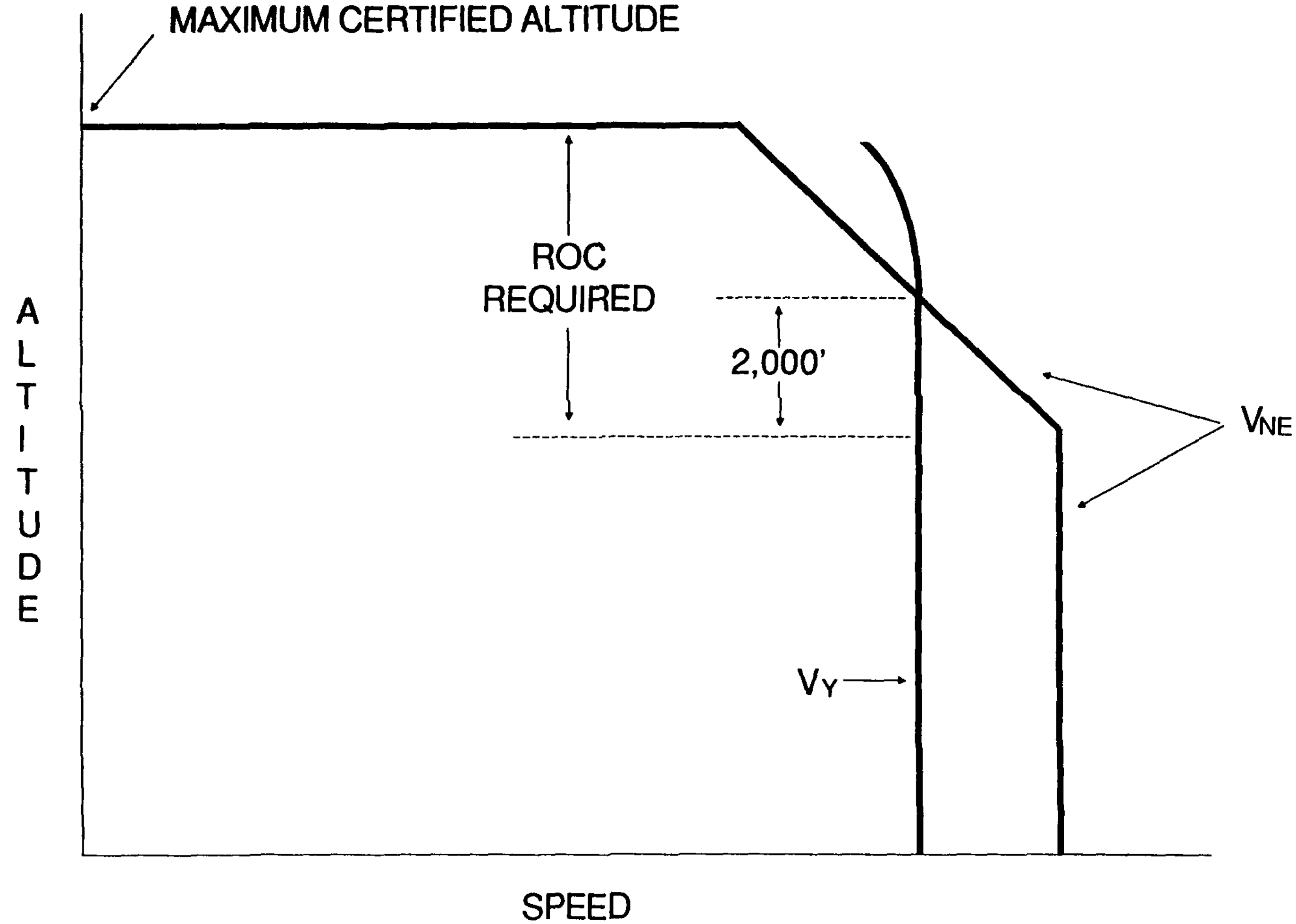


FIGURE 4 SPEED - ALTITUDE CONDITIONS REQUIRING RATE OF CLIMB DETERMINATION

Limiting Height-Velocity (HV) Envelope

Conditions of height and speed from which safe landings cannot be made in the event of a power failure must be identified. For a single engine aircraft and multiengine aircraft with non-approved engine isolation, this must be demonstrated from a full autorotation. For multiengine helicopters where engine isolation procedures ensure continued operation of the remaining engine(s), this can be demonstrated with one engine inoperative.

4.1.2.2 Performance Data Contained in Part 27 Rotorcraft Flight Manuals

Table 2 presents a listing of the performance data for climb and approach phases of flight contained in the manuals of the five normal category helicopters investigated in this study. These data correspond very closely with the regulatory requirements for flight performance.

Note that the flight manuals contain very little, if any, performance data relating to confined heliport operations. Rate of climb data are either available for V_Y or are not available at all. Rate of descent data are not presented for any of the five helicopters. Only the BO 105CBS manual has data on takeoff distances, climb and descent rates.

TABLE 2 PERFORMANCE DATA FROM HELICOPTER FLIGHT MANUALS
NORMAL CATEGORY ROTORCRAFT

Data Item	F28F	MD500E	B206B3	AS355F	BO105CBS
V_{NE} Envelope	Yes	Yes	Yes	Yes	Yes
HV Diagram	Yes	Yes	Yes	Yes	Yes
Rates of Climb at V_Y					
With AEO	Yes	No	Yes	Yes	Yes
With OEI	N/A	N/A	N/A	Yes	Yes
Climb Profiles	No	No	No	No	Yes
Descent Profiles	No	No	No	No	Yes

4.1.2.3 Part 29, Category A Performance Certification Requirements

The performance requirements of interest in this investigation are contained in paragraphs:

29.51 Takeoff data: general;
29.53 Takeoff: Category A;
29.59 Takeoff path: Category A;
29.63 Takeoff: Category B;
29.65 Climb: all engines operating;
29.75 Landing; and
29.79 Limiting height-speed envelope.

Appendix A contains applicable sections of the regulations. The following paragraphs summarize the main elements of these regulations as they apply to takeoff and approach operations.

General

Performance requirements must be met for still air and ISA standard atmosphere conditions. They must also correspond to the engine power available under particular atmospheric conditions, and must be based upon approved engine power less installation losses and losses associated with the operation of accessories.

Takeoff: General

No takeoff applicable to demonstrating the performance of the aircraft for certification shall require exceptional piloting skill or exceptionally favorable conditions.

Takeoff: Category A

The takeoff performance must show that, if one engine fails at any time after the start of takeoff, the aircraft can either return to, and stop safely on the takeoff area, or continue the takeoff and climbout to attain at least:

Takeoff Safety Speed (V_{TOSS}) and an altitude of 35 feet and then climb to 100 ft above the takeoff surface. V_{TOSS} is defined as the minimum speed at which 100 fpm rate of climb can be achieved while avoiding the limiting HV envelope.

150 ft/min. rate of climb at a point 1,000 ft above the takeoff surface with maximum continuous power (30-min where certified), most favorable center of gravity (CG), and the landing gear up. The speed at 1,000 feet above the surface is either V_y OEI or as selected by the applicant.

A critical decision point (CDP) must be established which defines the combination of speed and height which determines whether, in the event of an engine failure, the takeoff could continue. The CDP must be obtained while avoiding the HV envelope.

Takeoff path: Category A

The rejected takeoff path must be established with not more than takeoff power on each engine from the start of takeoff to the CDP. At or prior to this point the critical engine is failed and the rotorcraft is brought to a safe stop to establish the rejected takeoff distance.

Similarly, in the flyaway case, the takeoff path must be established with the same conditions up to the CDP. At or after CDP, the critical engine is failed and the rotorcraft must be accelerated so as to achieve V_{TOSS} and a positive rate of climb at 35 feet or more above the ground. The helicopter must be capable of meeting the climb requirements for one engine inoperative. (See Climb: One Engine Inoperative - for Category A - page 15).

Takeoff: Category B

The horizontal distance required to takeoff and climb over a 50 feet obstacle must be determined.

If an engine fails at any point along the takeoff path, a safe landing must be achieved.

Climb: All Engines Operating

For Category B rotorcraft, the rate of climb must be determined at V_Y or, if V_{NE} is less than V_Y, at a speed not greater than V_{NE}.

For Category A helicopters, if V_{NE} is less than V_Y at any altitude, the rate of climb must be determined at a speed not greater than V_{NE} for the altitude range indicated in figure 4.

Climb: One Engine Inoperative (OEI)

For Category A aircraft, a steady rate of climb at V_{TOSS}, out of ground effect (OGE), of 100 ft/min must be achieved with approved power on the remaining engine, with most unfavorable CG, landing gear extended, increasing to 150 ft/min 1,000 ft above the takeoff area, at V_{YOEI} or as selected by the applicant, landing gear retracted.

For Category B aircraft that meet Category A engine isolation requirements, the steady rate of climb (or descent) must be determined using the best rate of climb speed with one engine inoperative and maximum approved power, (maximum continuous or 30 minute OEI) at all weights, altitudes, and temperatures where takeoffs and landings are approved.

Landing

The rotorcraft must be controllable and have good handling qualities at appropriate approach and landing speeds.

Category A Rotorcraft

The landing performance must be determined so that, if one engine fails at any point in the approach path, the rotorcraft can either land and stop safely or climb out and achieve a Category A takeoff path.

The speeds and altitudes along the approach and landing path must avoid the HV limitations.

It must be possible to make a safe landing after a complete power failure occurring during cruise.

The horizontal distance to land and come to a complete stop from a point on the approach path 50 feet above the landing surface must be determined.

Category B Rotorcraft

The horizontal distance to land and come to a complete stop from a point on the approach path 50 feet above the landing surface must be determined with the power off and the approach entered from a steady autorotation.

Exceptions are multiengine rotorcraft meeting Category A powerplant installation requirements. These aircraft are allowed to meet all the Category A requirements for landing excluding the requirement for achieving Category A performance in the event of an engine failure. In essence, this exception gives OEI performance credit to these aircraft.

Balked landing: Category A

Following engine failure from a selected point in the approach defined by altitude and speed, a smooth and safe transition to climbout can be performed achieving the rates of climb specified in the OEI climb requirement while descending no lower than 35 feet above the landing surface.

Limiting Height-Velocity (HV) Envelope

Conditions of height and speed from which a safe landing cannot be made in the event of a power failure must be identified. For Category B rotorcraft with single engines and multiengine rotorcraft without approved engine isolation, the safe operating envelope must be demonstrated with complete power failure. For Category A rotorcraft and Category B multiengine rotorcraft where engine isolation procedures ensure continued operation of the remaining engine(s), the safe operating envelope can be demonstrated with the critical engine inoperative.

4.1.2.4 Performance Data Contained in Part 29 Rotorcraft Flight Manuals

Table 3 presents a listing of the flight performance data contained in the flight manuals of the three transport category helicopters used in this investigation. These manuals provide information that closely match the requirements of 14 CFR Part 29. These data are more comprehensive than that found in the flight manuals of normal category rotorcraft.

TABLE 3 PERFORMANCE DATA FROM HELICOPTER FLIGHT MANUALS
TRANSPORT CATEGORY ROTORCRAFT

Sikorsky S76A performance data under various weights and temperature conditions:

Category A
- Rejected takeoff distance
- Distance to achieve V_{TOSS}
- OEI rate of climb at V_{TOSS}, 2.5 minute power, gear down
- OEI rate of climb at V_Y, 30 minute power, gear up
- OEI rate of climb at V_Y, maximum continuous power, gear up
- V_Y as a function of altitude
- OEI Landing distance from 100 ft height

Category B
- Takeoff distance to 50 ft height
- Landing distance from 50 ft height to a full stop

General
- AEO rate of climb at 52 knots, takeoff power, gear up
- AEO rate of climb at V_Y, maximum continuous power, gear up
- AEO rate of climb at V_Y, cruise power, gear up

Aerospatiale AS 332C performance data under various weights and temperature conditions:

Category A
- Accelerate-stop distance (accelerate to CDP, decelerate to a full stop)
- Distance to climb to 35 ft height
- Distance to climb from 35 ft height to 200 ft height
- Distance to accelerate from V_{TOSS} to V_Y
- Distance to climb from 200 ft to 1,000 ft

Category B
- Maximum takeoff and landing distance to clear a 50 ft obstacle
- AEO rate of climb at 45 knots, takeoff power, gear down
- AEO rate of climb at V_Y, maximum continuous power, gear up
- OEI rate of climb at 45 knots, 2.5 minute power, gear down
- OEI rate of climb at V_Y, 30 minute power, gear up

Boeing BV 234LR performance data under various weights and temperature conditions:

Category A
- Takeoff distance
- Long field takeoff distance
- OEI rate of climb at V_{TOSS}, 30 minute power
- OEI rate of climb at V_Y, 30 minute power
- V_{TOSS} as a function of altitude
- AEO rate of climb at V_Y, maximum continuous power
- OEI Landing distance from a 50 ft height

The information provided in these flight manuals for Category A performance are useful in evaluating the helicopter's performance for confined heliport operations. The departure information is complete up to the point where V_{TOSS} speed is reached. After that point in the departure, the manuals differ in the information provided. All manuals present data on the AEO and OEI climbouts at V_Y. The S76A and the BV 234LR manuals provide OEI data at V_{TOSS} while the AS 332C manual provides OEI data at 45 knots, a speed between V_{TOSS} and V_Y. The S76A and the AS 332C manual provide AEO rate of climb information at 52 and 45 knots respectively. The BV 234LR manual does not contain AEO rate of climb data for speeds less than V_Y.

Some approach information is likewise available in the Category A manuals. The S76A provides OEI landing distance from a 100 feet height and the BV 234LR from 50 feet. The AS 332C presents maximum values for landing distance from a 50 feet height for OEI and AEO conditions.

Because no Part 29 rotorcraft used in the study was certified as Category B only, comment on the adequacy of information provided in those manuals regarding confined heliport operations is not made. However, judging from the close correspondence of the information in the flight manuals with the requirements contained in Parts 27 and 29, it is likely the Category B manuals would contain more information than the normal category rotorcraft but less information than the Category A rotorcraft.

4.1.2.3 Adequacy of Flight Manuals for Confined Heliport Operations

The five normal category rotorcraft flight manuals reviewed in this study do not provide the pilot with sufficient performance data for confined heliport operations. The manuals are lacking in both distance and climb related data. Most manuals do not provide any acceleration distance information for takeoff nor do they provide angle of climb (or rate of climb) data for airspeeds less than V_Y. Similarly, the manuals do not provide landing profile information in terms of distance or angle of descent.

The three transport category rotorcraft manuals provide adequate information regarding Category A departure and approach performance of the aircraft in the near vicinity of the heliport, to a height of 35 feet for departures and from a height of 50 feet for arrivals. Some manuals provide more information than others in the areas beyond the vicinity of the heliport.

Failure to provide this information is not intended to be a criticism of the manufacturers. The manuals contain data supporting the requirements in 14 CFR Parts 27 and 29. Adding new requirements in the regulations can be equated to adding additional cost to the manufacturers to demonstrate these certification requirements, a cost ultimately passed to the customers in the price of the helicopter.

However, as a result of this and companion studies, additional flight manual information on takeoff performance may be recommended.

4.2 ANALYSIS OF THE OPERATIONAL PROCEDURES

The flight manuals describe departure and approach procedures that are recommended by the manufacturers. Procedure descriptions vary widely in the amount of detail that is provided. The following paragraphs present a summary of the procedures.

4.2.1 Departure Procedures

Three types of departure procedures were analyzed during the study. They are:

1) Manufacturer's recommended procedures. For normal category rotorcraft this was a single procedure as defined in the flight manual. For transport category rotorcraft, Category A and/or Category B departures were used as specified by the manufacturer. Both procedures were used for the S76 and AS332C. Only the Category A procedure was used for the BV234LR. A vertical departure was also specified for the AS332C under conditions where there are no areas to avoid in the HV diagram.

2) Short field departure for confined heliports designed to avoid operations in the "avoid" area of the aircraft's HV diagram. This is called the HV+5 knot departure procedure.

3) Short field departure for confined heliports based on the results of the survey reported in "Operational Survey - VFR Heliport Approaches and Departures," DOT/FAA/RD-90/5. This is called the translational lift departure procedure.

4.2.1.1 Manufacturer's Recommended Departure Procedure

Departure procedures presented in the flight manuals of the eight helicopters analyzed during this study are presented in table 4. HV diagrams referred to in the procedures are contained in appendix B.

The departure procedures recommended by the manufacturers varied widely in both operational application and the amount of detail provided. Two of the eight manuals provided specific short field or confined area procedures, while at the other extreme, one manual provided no specific information as to recommended speeds or altitudes to be used in the departure procedure.

The departure procedures shown in table 4 were used in a performance model described in "Helicopter Physical and Performance Data,"

TABLE 4 MANUFACTURER'S RECOMMENDED DEPARTURE PROCEDURES

Helicopter	Flight Manual Procedure

F 28F

Maximum performance takeoff in a confined area

Stabilize at hover of 2 ft aligned with desired takeoff course. Check hover power, smoothly apply forward cyclic to accelerate to effective translational lift. Apply aft cyclic to maintain best angle of climb speed (35 mi/hr) to clear barriers. If distance to barriers precludes level acceleration to translational lift, use a coordinated climb and acceleration.

MD 500E

Follow recommended takeoff profile shown on HV diagram. (Interpreted as: Level acceleration to 35 knots, climbing acceleration to 60 knots at a height of 70 ft, climb at 60 knots to desired altitude)

B 206B3

Establish hover, turn to desired heading, accelerate to obtain desired rate of climb and airspeed.

AS 355F

Establish hover in ground effect, synchronize engines, initiate forward flight in a slight climb to an indicated airspeed of 55 knots, V_Y.

MBB BO105CBS

Establish hover in ground effect at about 6 ft, level acceleration to 40 knots, accelerating climb to 45 knots at 30 ft, climbout at 45 knots, V_Y.

S 76A

Category A

Establish a hover in ground effect at about 5 ft, accelerate forward and maintain a 5 to 10 ft. wheel height, at 35 knots rotate nose up and maintain 35 knots, at CDP of 40 ft accelerate to V_Y.

Category B

Establish a hover in ground effect at 5 ft, accelerate forward and maintain a 5 to 10 ft. wheel height, at 45 to 50 knots raise nose to maintain 52 knots, climb until obstacles are cleared.

AS 332C

Category A short field procedure

Determine takeoff weight, CDP, V_{TOSS} and V_Y; establish hover in ground effect at 15 ft; increase pitch to achieve a climbing acceleration to V_{TOSS} at 35 ft; accelerating climb to V_Y at 200 ft, retract gear at V_Y.

Category B short takeoff procedure

Hover at 15 ft, accelerate at constant height until there is a positive airspeed indication, accelerating climb to 40 knots at 100 ft, climb to cruise altitude and cruise airspeed.

Category B vertical procedure (applicable only at conditions where there are no areas to avoid in the HV diagram)

Hover at 15 ft, increase collective pitch until desired altitude is reached, initiate forward flight in the same manner as with the short takeoff procedure.

BV 234LR

Category A

Hover at 15 ft, level acceleration to achieve 14° nosedown prior to 30 knots, climb at V_{CDP} to CDP height, accelerate to V_{TOSS}, accelerating climb to V_Y.

DOT/FAA/RD-90/3. The results of the modeling effort showed that, because they were not designed to be confined area procedures, most used a considerable amount of airspace.

4.2.1.2 HV+5 Knot Departure Procedure

In order to develop departure performance data that specifically addressed the confined heliport issues, a uniform short field departure was designed for each of the aircraft used in the study. This procedure took into account the "avoid" areas of the HV diagram while providing slow speed climbs to achieve steep angle departures. The description of the procedure follows:

HV + 5 knot procedure
Establish a hover in ground effect at the altitude recommended by the manufacturer, apply nose down cyclic and collective pitch to establish a level acceleration to effective translational lift, apply aft cyclic to achieve an accelerating climb to a speed 5 knots above the highest value shown in the avoid flight (upper portion) of the applicable HV diagram and an altitude that remains clear of the avoid area. Continue climb at that speed.

An example of the HV + 5 knot procedure profile determination is shown in figure 5 for the S 76A. The resultant performance from its application to the F 28F and AS 355F are shown in figures 6 and 7.

*NOTE: The HV + 5 knot procedure does not optimize all parameters under all circumstances, but does demonstrate, for purposes of this evaluation, that confined area airspace needs can be minimized over the manufacturers recommended procedure.

4.2.1.3 Translational Lift Departure Procedure

The results of the operational survey, reported in DOT/FAA/RD-90/5, indicated most helicopter pilots prefer to use the translational lift departure procedure at confined heliports. In this procedure the pilots perform a liftoff to a hover in ground effect. The pilot then accelerates the aircraft in a level acceleration to the speed of effective translational lift. For this analysis, the speed of effective translational lift was conservatively chosen to be 20 knots true airspeed. Upon reaching this speed, the pilot performs an accelerating climb at a rate of approximately 1 foot of altitude per 1 knot increase in speed. This rate is maintained until the obstacle is cleared or until a comfortable climbout speed is reached. A comfortable climb-out speed is one between the HV+5 knot speed and the best-rate-of-climb speed.

SIKORSKY 76®
FLIGHT MANUAL

LIMITING HEIGHTS AND CORRESPONDING SPEEDS FOR SAFE LANDING AFTER AN ENGINE SUDDENLY BECOMES INOPERATIVE

THESE CURVES ARE APPLICABLE TO ALL ALTITUDES AND TEMPERATURES AT THE CORRESPONDING MAXIMUM ALLOWABLE TAKE-OFF GROSS WEIGHT AS DETERMINED FROM FIGURES 1-1 AND 1-2. THE HIGH HOVER POINT IS BASED ON MAXIMUM OGE HOVER WEIGHT AND HAS BEEN DEMONSTRATED AT 10,300 POUNDS.

INFORMATION ON TEST CONDITIONS:
1. HARD SURFACE RUNWAY
2. WINDS 5 KN OR LESS
3. STRAIGHT TAKEOFF AND CLIMBOUT PATH
4. GEAR DOWN AT ENTRY
5. 34 KN. BRAKE APPLICATION LIMIT WAS OBSERVED
6. NO BLEED-AIR
7. ANTI-ICE OFF

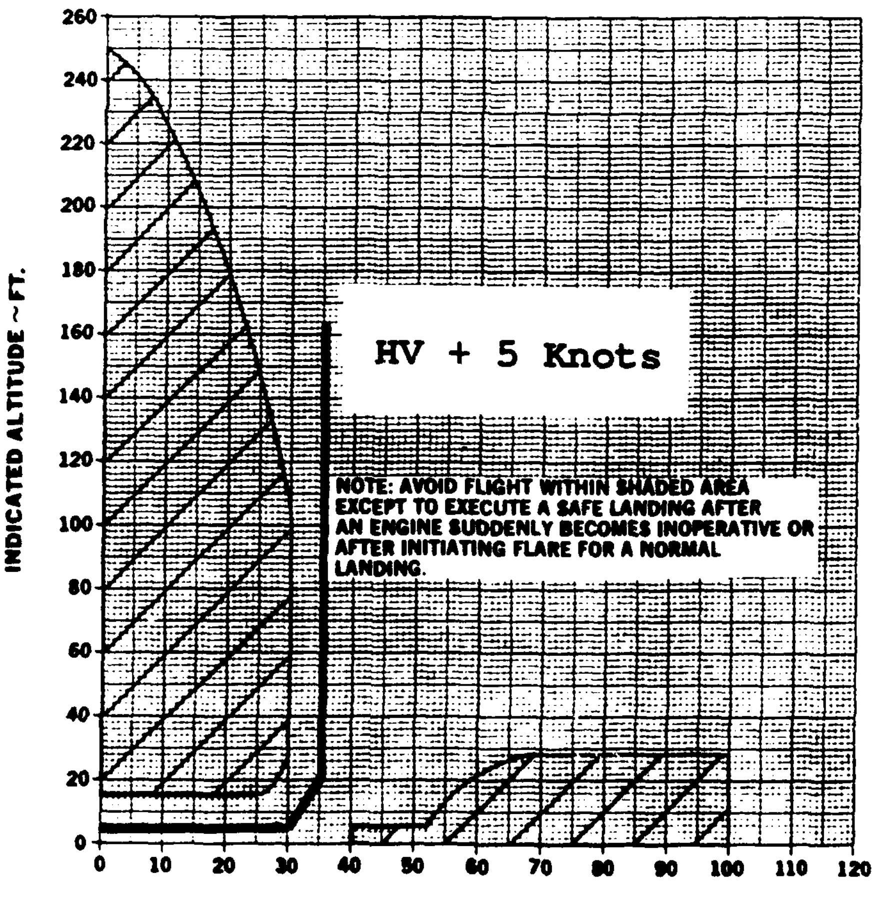


FIGURE 5 HV + 5 KNOTS DEPARTURE PROCEDURE

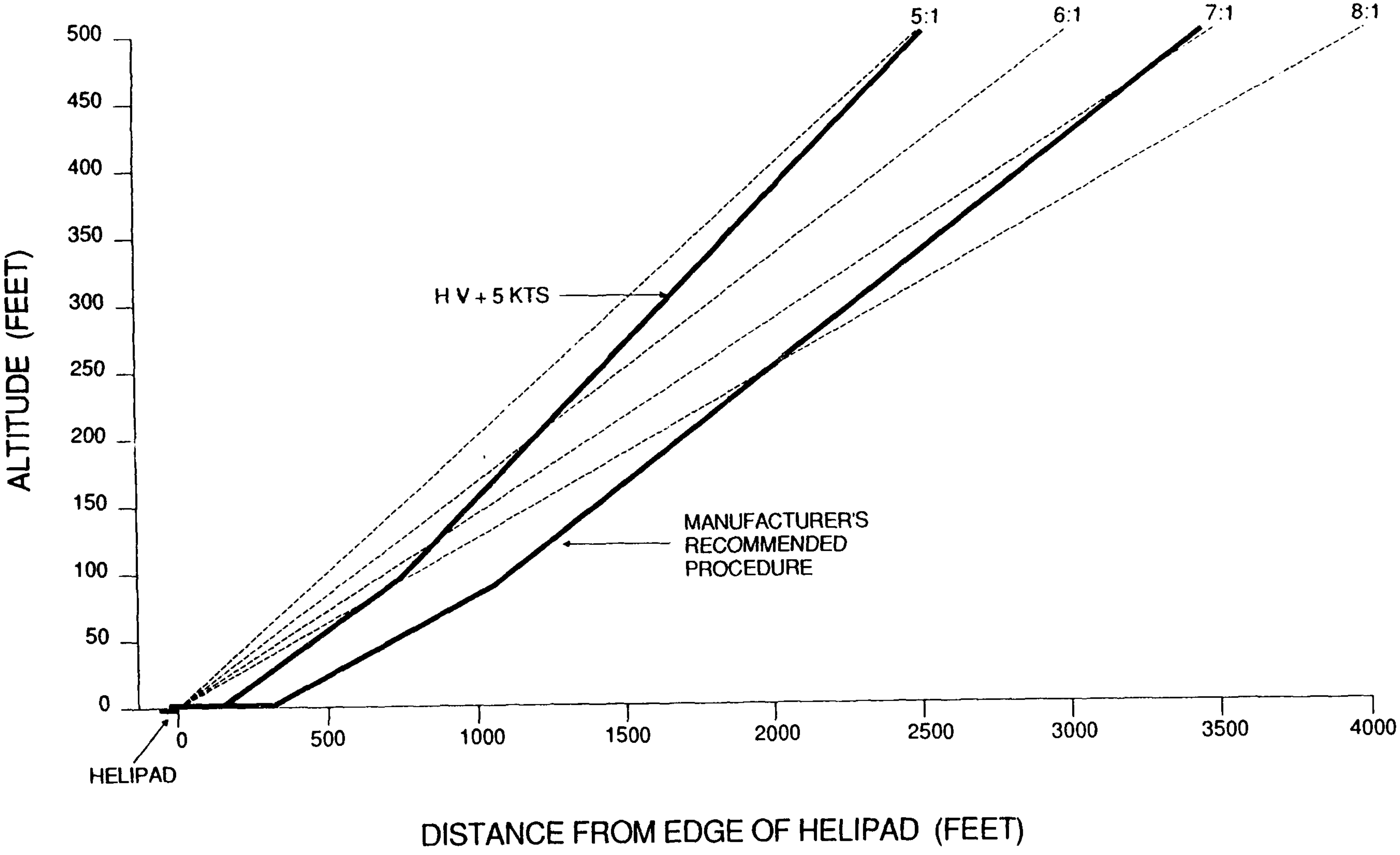


FIGURE 6 F 28F DEPARTURE PROFILES MAX. G.W., SEA LEVEL, STANDARD DAY

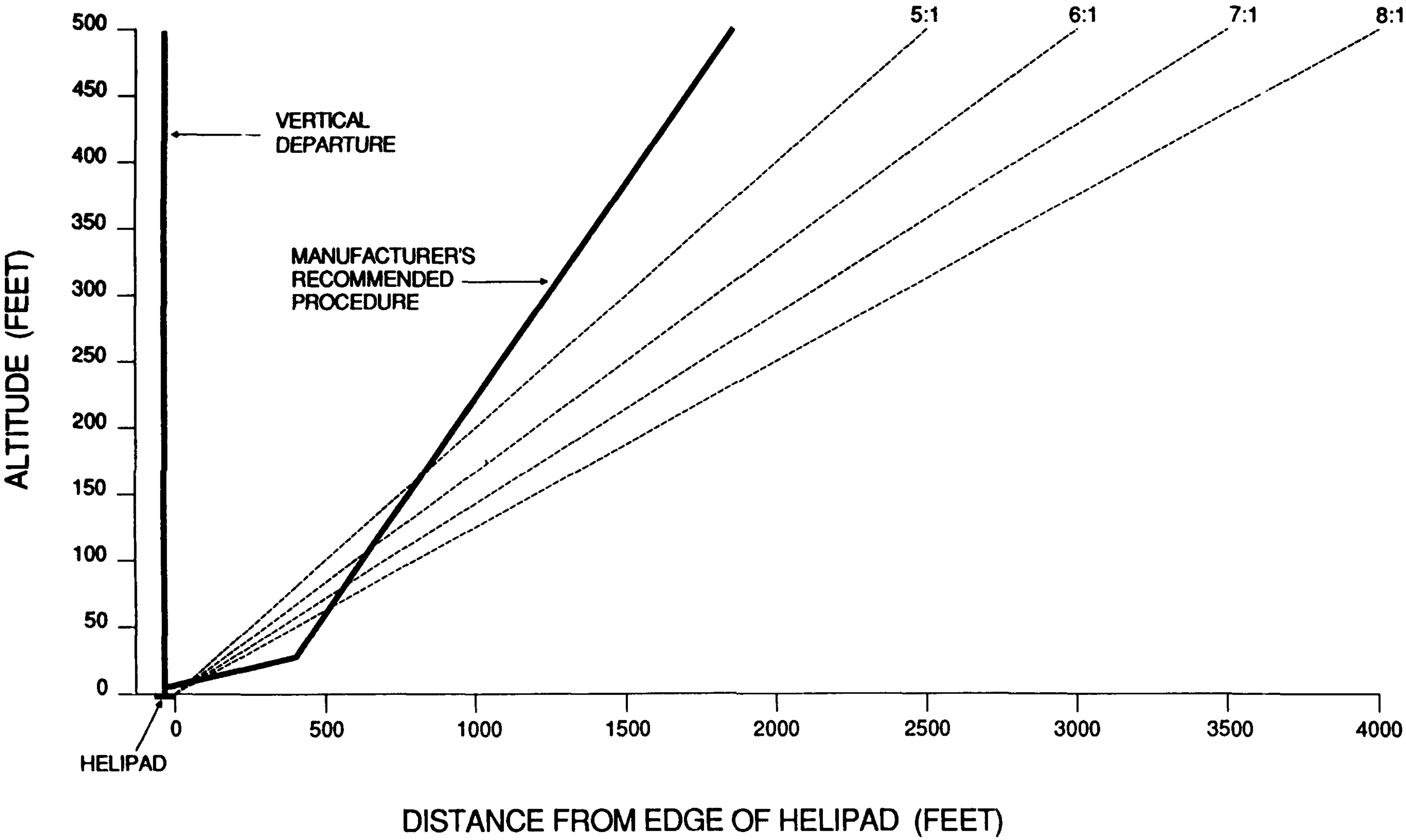


FIGURE 7 AS 355F DEPARTURE PROFILES MAX. G.W., SEA LEVEL, STANDARD DAY

4.2.2 Analysis of the HV Diagrams

The use of the HV diagram in defining procedures for the confined heliport pointed out several differences in the way manufacturers present the avoid areas in the flight manuals. In general, three types of HV diagrams were contained in the flight manuals of the eight helicopters used in the study. They were the maximum conditions diagram, the density altitude diagram, and the operational conditions diagram. The differences in these diagrams and their affect on the short field performance of the helicopter is described in the following paragraphs.

4.2.2.1 Maximum Conditions HV Diagram

The maximum conditions HV diagram consists of two charts, one an HV diagram representative of the avoid areas under conditions of maximum gross weight and sea level standard temperature conditions. A second chart establishes gross weight limits as the density altitude increases. An example of this type of diagram for the MD 500E is shown in appendix B, figures B-1 and B-2. Others making use of similar diagrams are the B 206B3, S 76A and the BV 234LR.

The characteristic of this diagram that affects short field procedures is that the size and shape of the avoid area remain constant under all operational conditions. This means that the speeds and altitudes used to define the procedure do not change under differing conditions of aircraft weight and density altitude.

4.2.2.2 Density Altitude HV Diagram

The density altitude HV diagram is a system of several charts, each representing a different gross weight condition. On each chart are a family of HV curves representing different density altitude conditions. In this type of presentation several charts are needed to show a range of operational conditions. This type of system was used in two of the flight manuals encountered in the study, the F 28F and the MBB BO105CBS. Representative examples of these diagrams are shown in appendix B, figures B-3 through B-5.

There is significant advantage to this type of presentation over the maximum conditions diagram. The size of the avoid area shrinks as gross weight is reduced and as density altitude is decreased. This provides more flexibility in establishing appropriate speeds and altitudes to achieve necessary profiles for confined heliport operations.

4.2.2.3 Operational Conditions HV Diagram

The operational conditions HV diagram is a system of several interrelated charts that permit the determination of the avoid areas for a broad range of weight and density altitude conditions. The procedure involves entering weight and altitude on one chart, transferring to a second chart to the outside air temperature and then transferring to yet a third chart to determine the HV limitation areas. The AS 355F and the AS 332C manuals use this technique. (See appendix B, figure B-6 [2 pages]).

This system has the advantage of being able to establish the avoid areas over a very broad range of weight and density altitude conditions without the added bulk of several additional charts. It is more complex from a presentation viewpoint and requires some familiarization with the procedure.

One important characteristic of the HV diagrams for the two Aerospatiale aircraft is that under some reduced weight and low density altitude conditions, the limiting area of the HV diagram disappears. That is, under some operational conditions there is no applicable HV diagram. This situation can occur in multiengine rotorcraft which meet Category A powerplant installation requirements and with the given conditions (gross weight, temperature, density altitude), have sufficient power with OEI to permit a safe takeoff or landing to be made from any associated operational altitudes and speed. When there are no HV limitations, the aircraft can theoretically make vertical departures and arrivals thereby minimizing the amount of airspace required.

4.2.3 Landing Procedures

Landing profiles are considerably less affected by conditions of weight and density altitude than are departure profiles. The primary variable in defining approach profiles is the approach airspeed. Table 5 contains the manufacturers recommended procedures as described in the various flight manuals. These procedures are appropriate for determining airspace required for operation to confined area heliports.

4.2.4 Summary

Two helicopters had takeoff procedures specifically developed for short field, confined heliport operations. The helicopters certified under Category A presented departure and approach procedures that are applicable to the confined heliport issue in the region from the heliport out to the CDP for the departure and from landing decision point (LDP) into the heliport for arrival. Beyond CDP the manuals presented data for climbout at V_Y which in many cases leads to a flight path angle that is too shallow to be effective at confined heliports.

The size and shape of the "avoid" area of the HV diagram has a significant effect on the takeoff profile for helicopters using procedures designed to avoid this area. The techniques used by the manufacturers in presenting these areas have an effect on their apparent size and shape. Operational benefits in terms of protected airspace reduction are possible if the HV diagrams take into account helicopter weight and density altitude factors.

TABLE 5 LANDING PROCEDURES

Helicopter	Procedure Description
F28F	Adjust the collective and altitude to establish 8° to 10° approach angle. Adjust airspeed to 60 mi/hr. As the landing area is approached, reduce airspeed and rate of descent until a zero ground speed hovering altitude of 2 to 5 feet is attained.
MD 500E	None.
B 206B3	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 105CBS	Start final descent as directed and maintain airspeed. Reduce airspeed and initiate a smooth flare.

S76A

Category A - Establish approach to arrive at landing decision point (100 ft above touchdown elevation at 50 knots and not more than 750 ft/min rate of descent). Continue descent to about 50 ft above touchdown, then reduce the rate of descent with a cyclic flare to about 20° nose up. Level the nose to 5° to 10° at about 30 ft above touchdown. Establish hover.

Category B - Establish approach to arrive at a point 100 ft above the touchdown elevation at 50 knots at a rate of descent no more than 500 ft/min. Decelerate to pass 50 ft and 40 knots and continue approach and deceleration to hover.

AS 332C

Category A - Proceed with final approach to reach landing decision point (100 ft at 40 knots with a rate of descent between 300 to 500 ft/min). At the critical decision point slowly decrease speed to 30 knots and continue descent to height of 15 ft.

Category B - Gradually reduce speed to descend to 80 ft over the landing area at 40 knots. Recommended rate of descent is 300 ft/min. From 15 ft gradually increase collective pitch to obtain final reduction in speed and to cancel rate of descent. Land.

BV 234LR

Category A - Stabilize descent at 400 ft/min at 60 knots through landing decision point at 150 ft. Rotate helicopter nose up as required to arrive at the desired touchdown point.

4.3 PERFORMANCE MODELING RESULTS

As a means of comparing helicopter profile data to heliport airspace, a helicopter modeling effort was performed. A discussion of the modeling techniques and the results in terms of 141 departure profiles and 4 approach profiles are contained in "Helicopter Physical and Performance Data," DOT/FAA/RD-90/3.

The performance modeling was performed in two parts. Initially, the manufacturer's recommended procedures and the HV+5 knots procedures were modeled. When the results of the operational survey became available, a second effort was performed modeling the translational lift departure procedure.

4.3.1 Departure Performance

Departure data were developed for 18 combinations of weight, temperature and heliport field elevation for each of the 8 helicopters in the study. One exception was the BV 234LR where only 15 combinations were studied. The combinations included:

Weight	Temperature	Field Elevation
100% max. gross wt	ISA	sea level
85% max. gross wt	ISA + 20° C.	2,000 ft
70% max. gross wt		4,000 ft

In cases where the density altitude limited the allowable weight, the weight for the 100 percent case was reduced to conform to the limitations shown in the flight manuals. For the BV 234LR the flight manual did not contain data for the ISA + 20 degrees C, 4,000 feet condition. Departure profiles were therefore omitted for these three cases.

A minimum of three and up to five takeoff procedures were used for each helicopter depending upon performance category. Manufacturers recommended procedures, Category A procedures, Category B procedures, and vertical departures were developed as appropriate. For minimum airspace considerations, the HV + 5 knot procedure, the vertical departure procedure, and the translational lift departure procedure were used.

It is noteworthy that although the HV + 5 knot procedure produces the minimum airspace profile while remaining outside of the HV envelope, this departure procedure may not be appropriate for operations involving flight over inhabited areas or for those flights with passengers. Category A procedures have been developed for these situations.

The 141 departure plots contained in "Helicopter Physical and Performance Data" have been compressed into 8 acceleration distance plots and 8 climb angle plots (figures 8-23). The acceleration distance plots include the distance to accelerate to the maximum speed shown on the upper part of the HV envelope plus 5 knots and climb to a height of 50 feet. The height of 50 feet was chosen for a number of reasons. It encompasses the 50 feet height requirement of the Category B takeoff and the 35 feet requirement of the Category A takeoff; and for all aircraft in the study, the 50 feet height permits the aircraft to perform a climbing acceleration while staying clear of the HV envelope. Distances are measured from the edge of the helipad assuming a minimum helipad measuring twice the rotor diameter of the helicopter under study.

The climb angle shown on the plots is the climb angle that can be achieved at the HV + 5 knot speed under the conditions shown at the right side of the curve. This climb angle can be maintained from the 50 feet height point to an altitude that is clear of barriers.

The current heliport slope requirements are also shown on each of the plots. On the acceleration distance plots this is shown as a horizontal line at the 400 feet distance level. This is determined by applying the 8:1 slope requirement of the heliport standard to the 50 feet height represented by the plots. On the climb angle plots, the 8:1 slope is shown as a horizontal line at 7.125 degrees, the angular equivalent of the slope value.

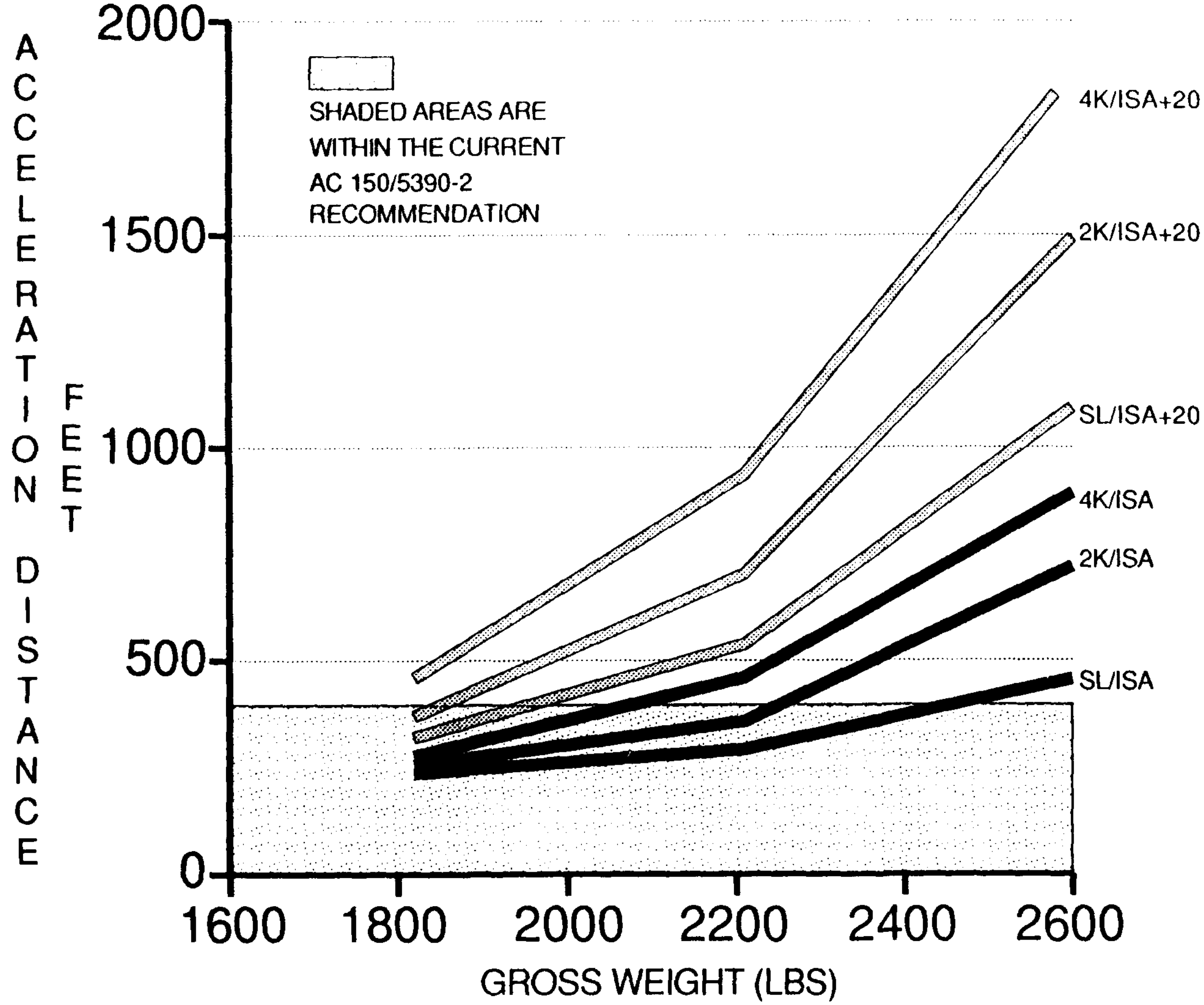
4.3.2 Departure Modeling Results for the HV+5 Knots Procedure and the Vertical Departure Procedure

In this section the individual helicopter performance capabilities are discussed with regard to the heliport departure and approach protected surfaces. The interpretation of the curves with respect to the current standard values is worthy of note. For the acceleration distance plots, good performance is noted by the curves being below the current standard line, meaning that the acceleration capability of the helicopter is greater than that required to meet the minimum distance/angle required by the standard. For the climb angle curves the opposite interpretation is valid. Good performance is depicted by the climb angle plots being above the current standard line, meaning that the climb capability is equal to or greater than that required to remain above the slope provided by the heliport design standard.

4.3.2.1 F28F

The acceleration distance and climb angle plots for the F28F helicopter are presented in figures 8 and 9. A considerable portion of the acceleration distance curves for the heavy weight, high temperature and high field elevation cases do not meet the requirements of the current standard. This means that the current standard heliport does not have sufficient protected airspace in the vicinity of the heliport (0 to 400 feet from the pad) to accommodate the F28F for many operational situations.

F 28F



SL - SEA LEVEL
2K - 2000 FT FIELD ELEVATION
4K - 4000 FT FIELD ELEVATION
ISA - TEMPERATURE PROFILE OF INT'L STANDARD ATMOSPHERE
ISA+20 - ISA TEMPERATURE PLUS 20° C

NOTES: H V+5 KNOT DEPARTURE PROCEDURE
WIND SPEED - 0 KNOTS
CURVES ARE BASED ON THREE DATA POINTS WITH LINEAR INTERPOLATION BETWEEN POINTS

FIGURE 8 DISTANCE TO CLEAR A 50 FT. OBSTACLE - F 28F

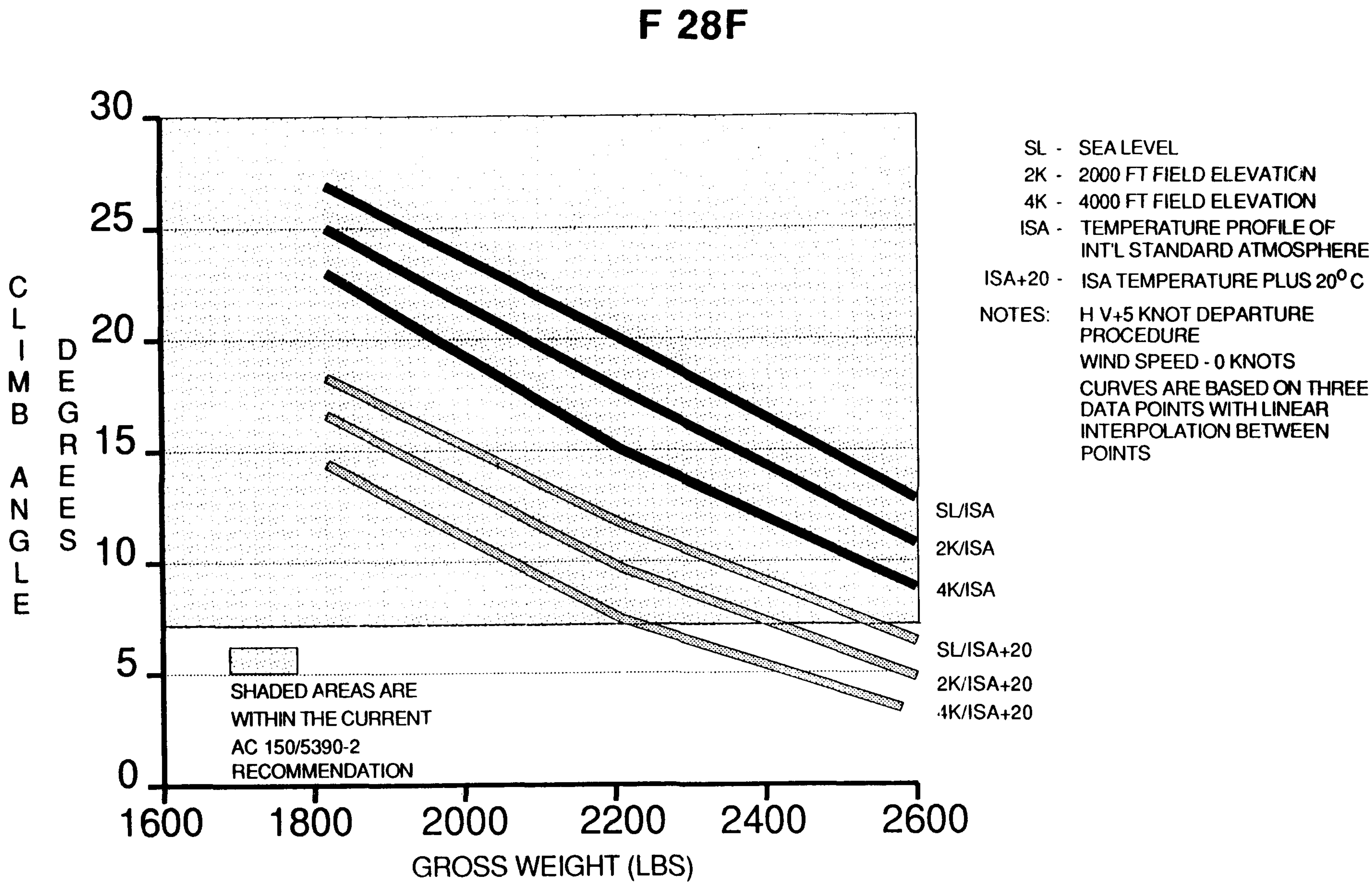


FIGURE 9 CLIMB OUT ANGLE - F 28F

The climb angle curves show a better performance over many of the operational situations than do the acceleration distance curves. However, at heavy weights and high field elevations, the F28F cannot achieve the standard 8:1 slope.

4.3.2.2 MD 500E

The acceleration distance curves for the MD 500E (figure 10) all exceed the current standard value of 400 feet. This is likely caused by the size of the HV envelope. The HV curve chosen by the manufacturer is the type that does not change with weight or density altitude. Therefore, in all cases the helicopter must accelerate to a speed of about 53 knots to achieve HV + 5 knots.

The climb angle curves (figure 11) show a much better picture than do the acceleration distance curves. All climb curves are well above the current standard 8:1 slope.

4.3.2.3 B 206B3

The acceleration distance curves for the B 206B3 (figure 12) show some of the same problems as the MD 500E, and for the same reason. The HV diagram of this aircraft does not change with density altitude or weight. Therefore, in all cases the helicopter must accelerate to a speed of 52 knots to attain the HV + 5 knot speed.

The climb angle curves for the B 206B3 (figure 13) are all above the current standard indicating that upon completion of the acceleration phase, the performance of the helicopter exceeds that required by the heliport design standard.

4.3.2.4 AS 355F

In figure 14 the AS 355F shows, in dramatic fashion, the benefits of using an HV diagram that accounts for variations in gross weight and density altitude. For the light and medium weight cases, there is no HV envelope for this aircraft. Therefore the helicopter is capable of safely making a vertical takeoff. Even in the hot day, maximum weight, high altitude case the performance of the AS 355F nearly meets the 400 feet standard.

Similar observations are apparent in the climb angle curves (figure 15) for the AS 355F. Since 16 of the 18 cases use the vertical takeoff, the climb angle is 90 degrees. The two remaining cases have slopes above the current 8:1 standard.

4.3.2.5 MBB BO105CBS

The acceleration distance for the MBB BO105CBS (figure 16) does not meet the 400 ft standard for any test case. This is caused in large part by the large HV envelope, extending beyond 60 knots, to nearly

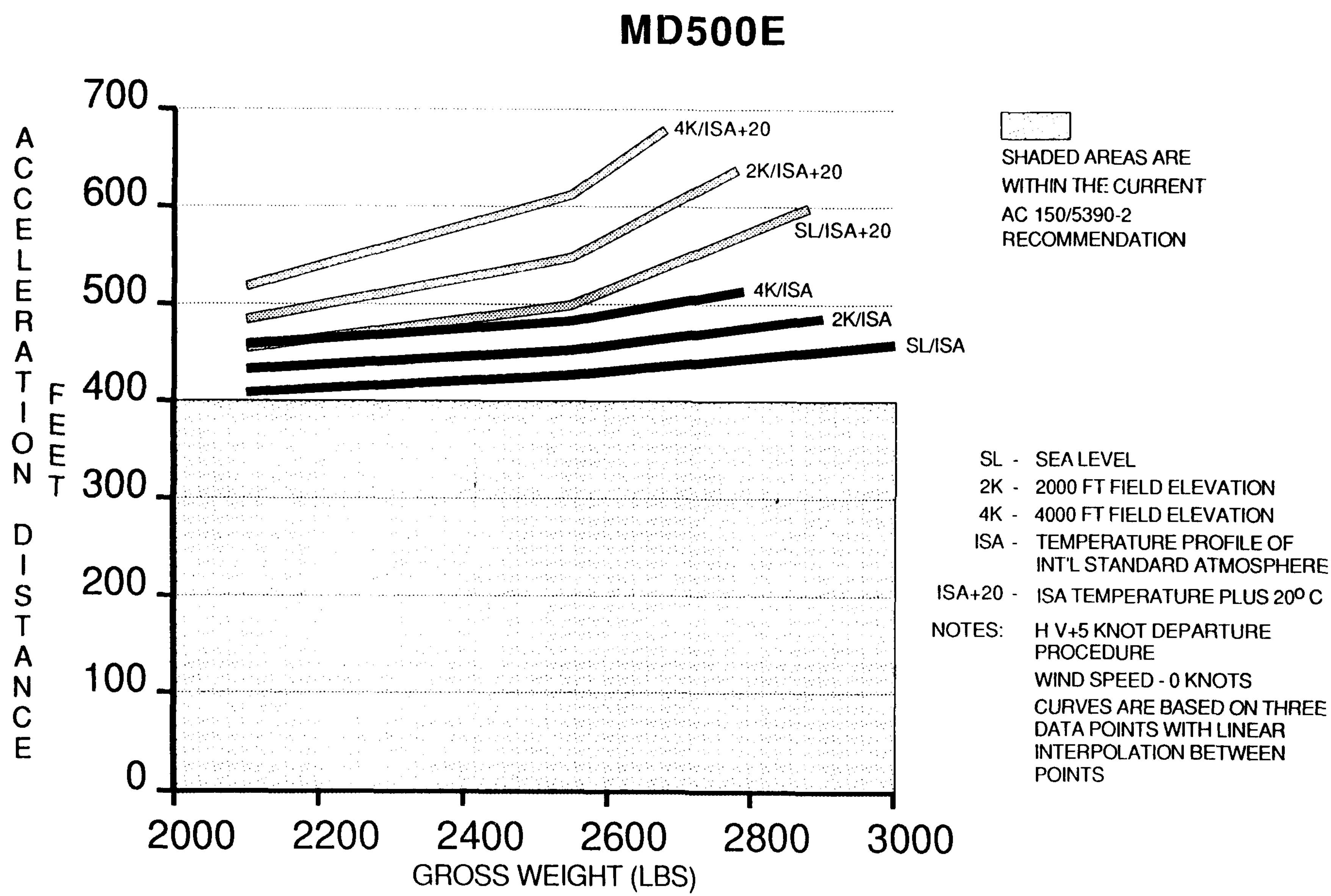
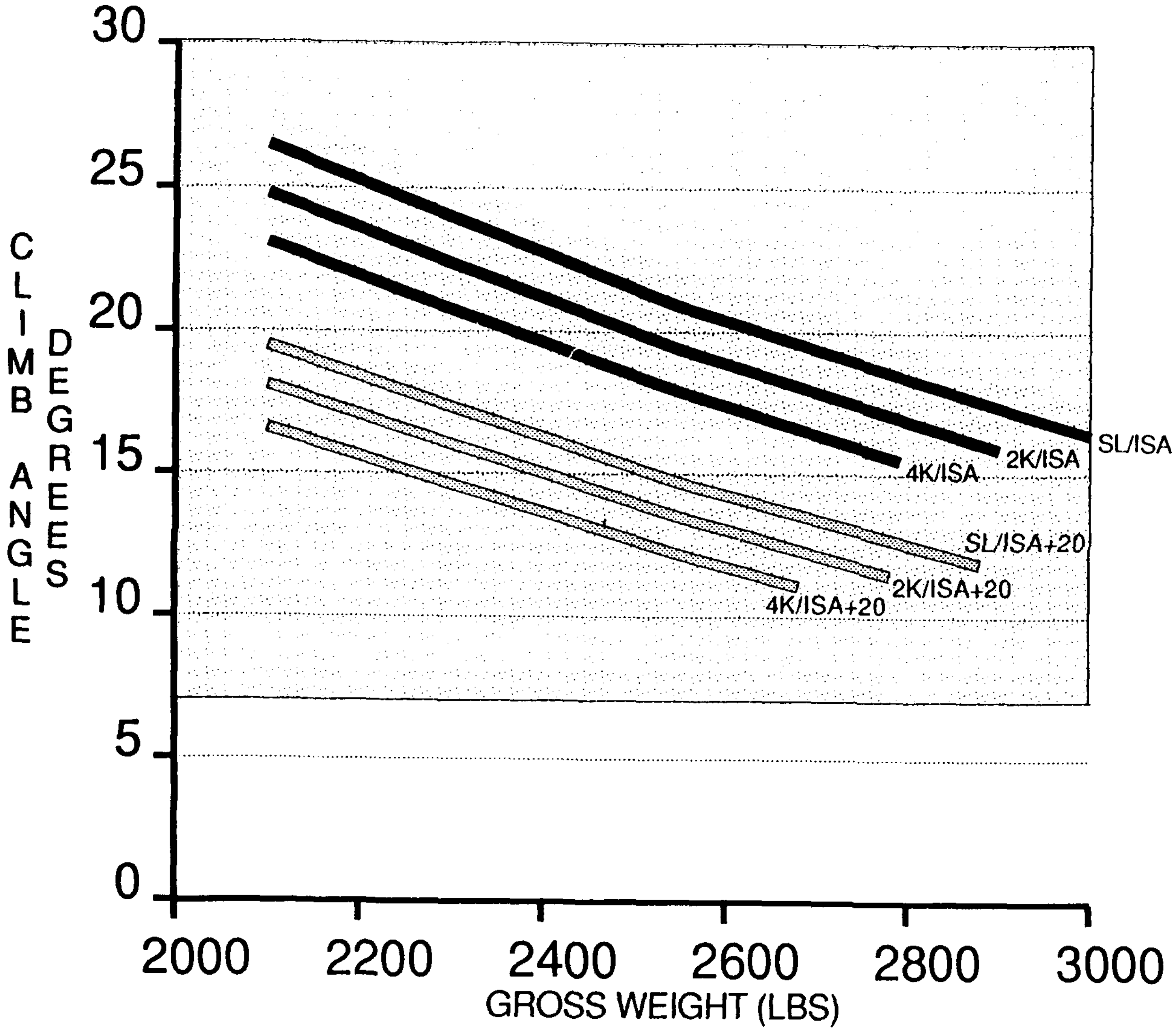


FIGURE 10 DISTANCE TO CLEAR A 50 FT. OBSTACLE - MD500E

MD500E



SL - SEA LEVEL
2K - 2000 FT FIELD ELEVATION
4K - 4000 FT FIELD ELEVATION
ISA - TEMPERATURE PROFILE OF INT'L STANDARD ATMOSPHERE
ISA+20 - ISA TEMPERATURE PLUS 20^{0} C

NOTES: H V+5 KNOT DEPARTURE PROCEDURE
WIND SPEED - 0 KNOTS
CURVES ARE BASED ON THREE DATA POINTS WITH LINEAR INTERPOLATION BETWEEN POINTS

SHADED AREAS ARE WITHIN THE CURRENT AC 150/5390-2 RECOMMENDATION

FIGURE 11 CLIMB OUT ANGLE - MD500E

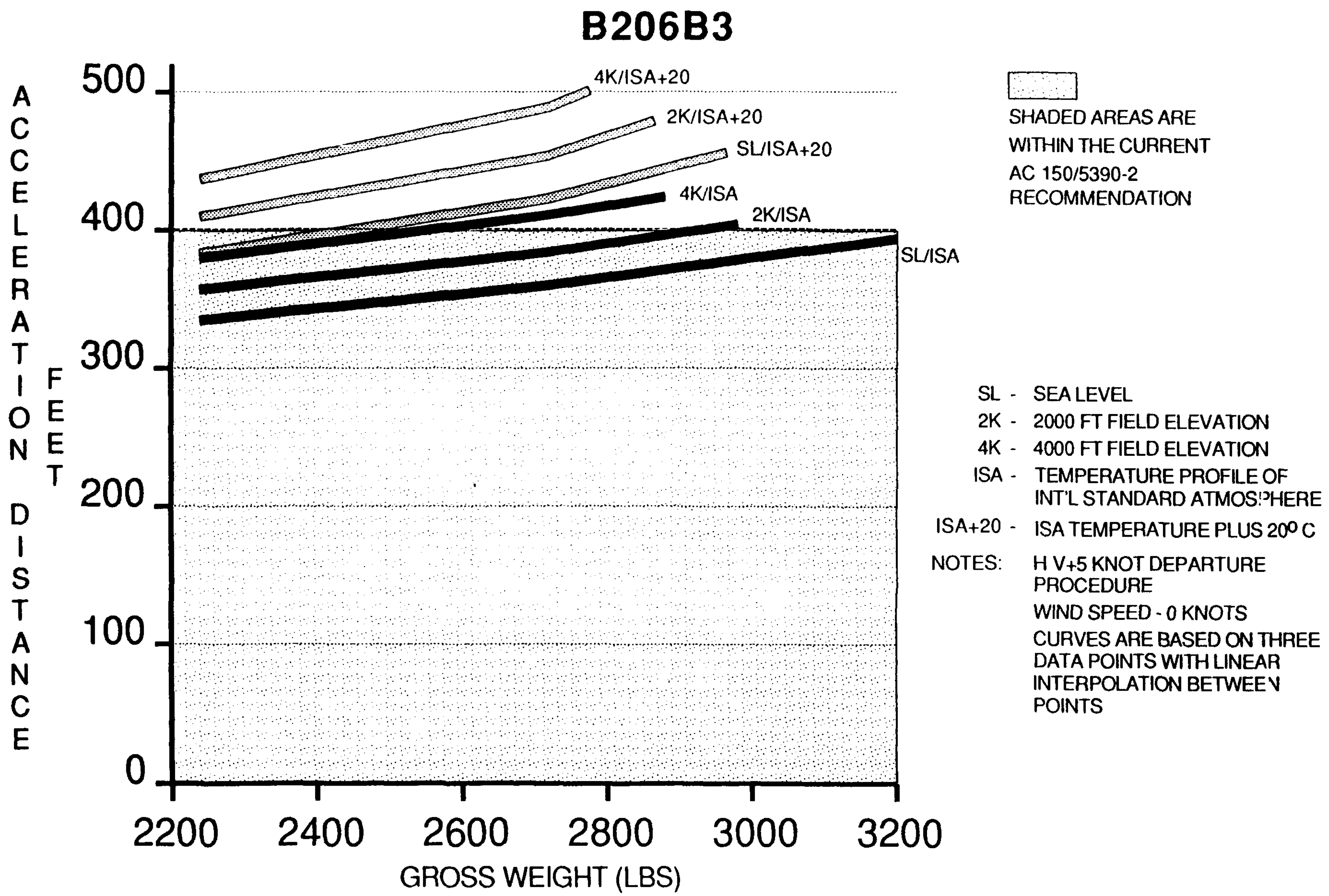


FIGURE 12 DISTANCE TO CLEAR A 50 FT. OBSTACLE - B206B3

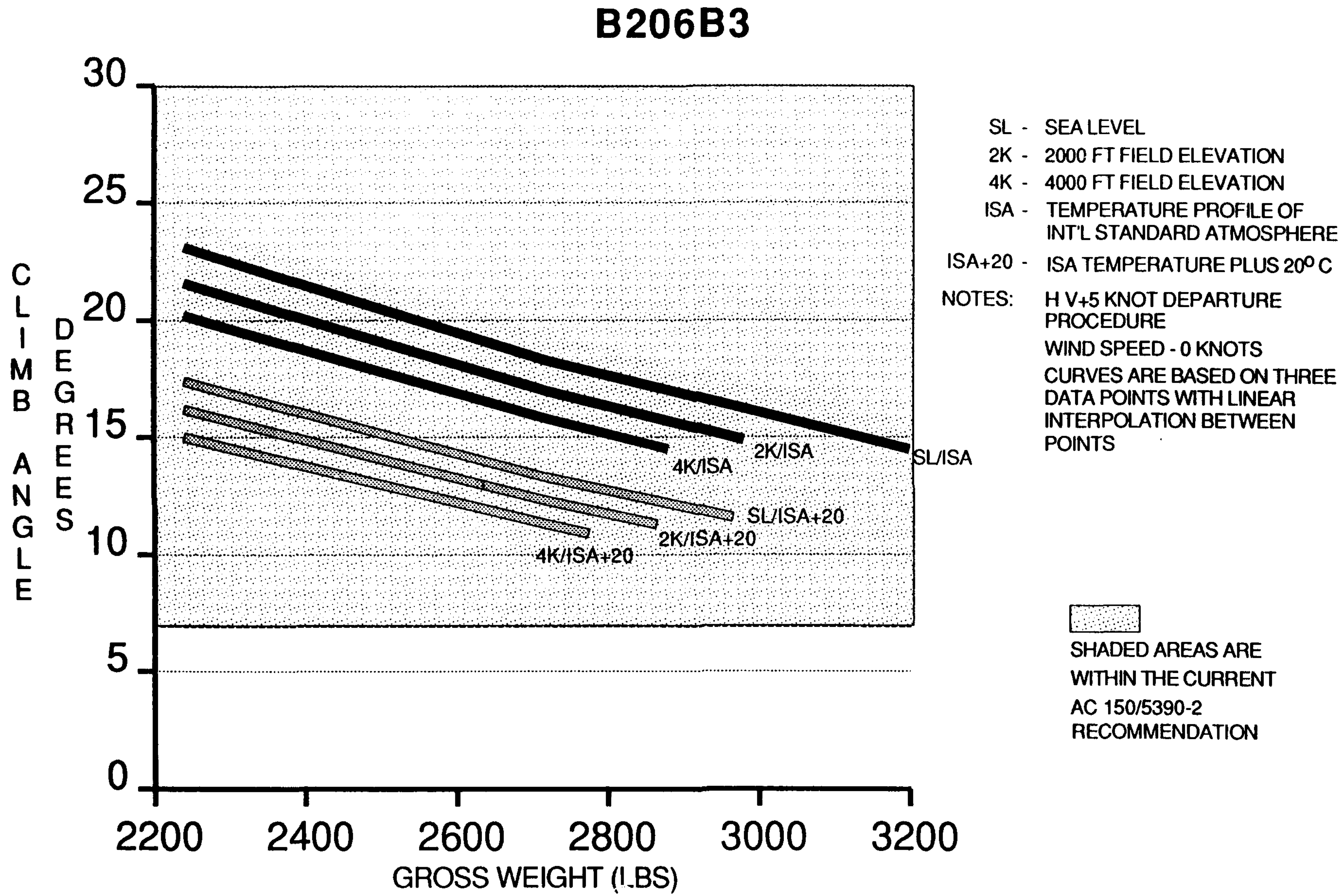


FIGURE 13 CLIMB OUT ANGLE - B206B3

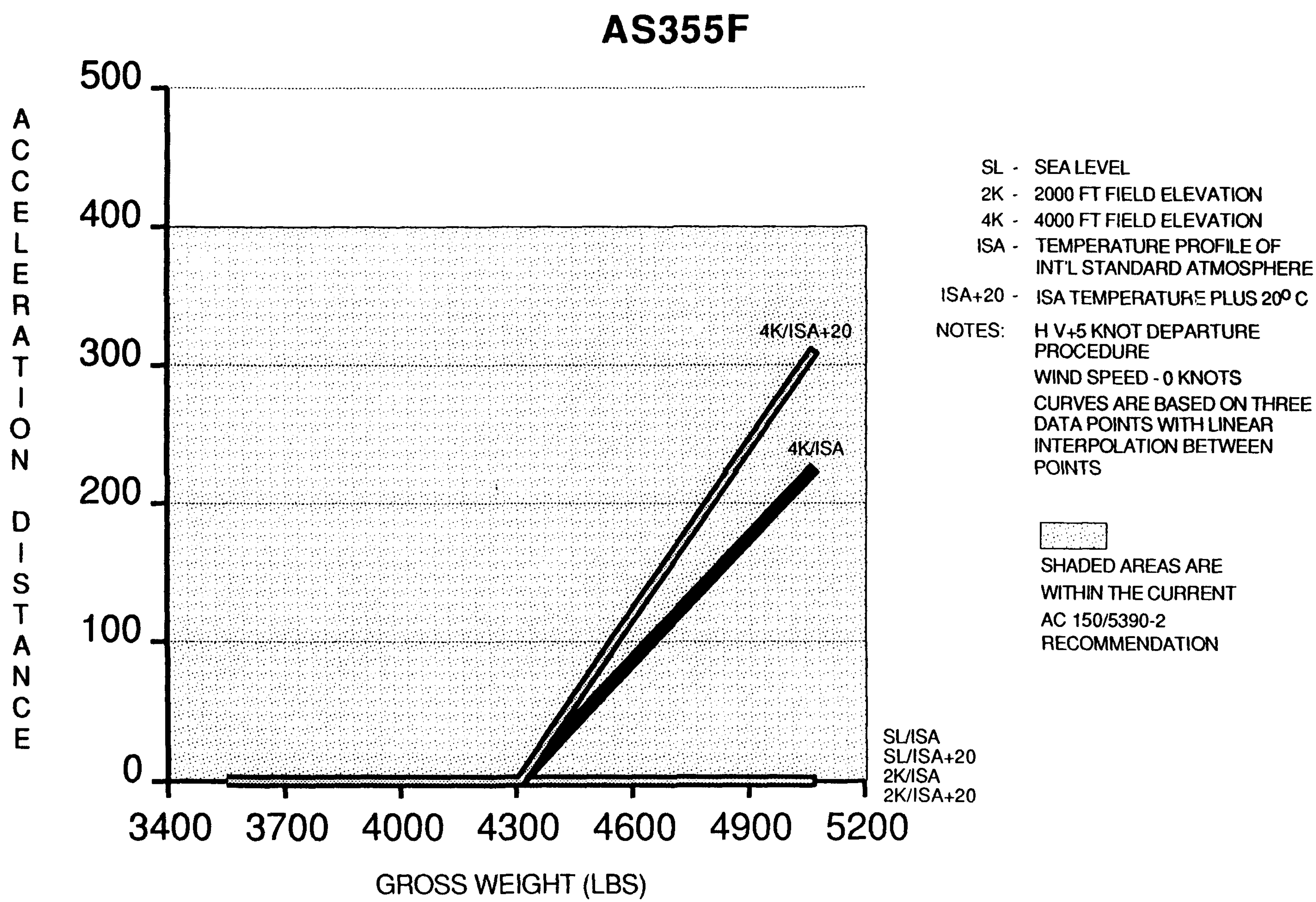


FIGURE 14 DISTANCE TO CLEAR A 50 FT. OBSTACLE - AS355F

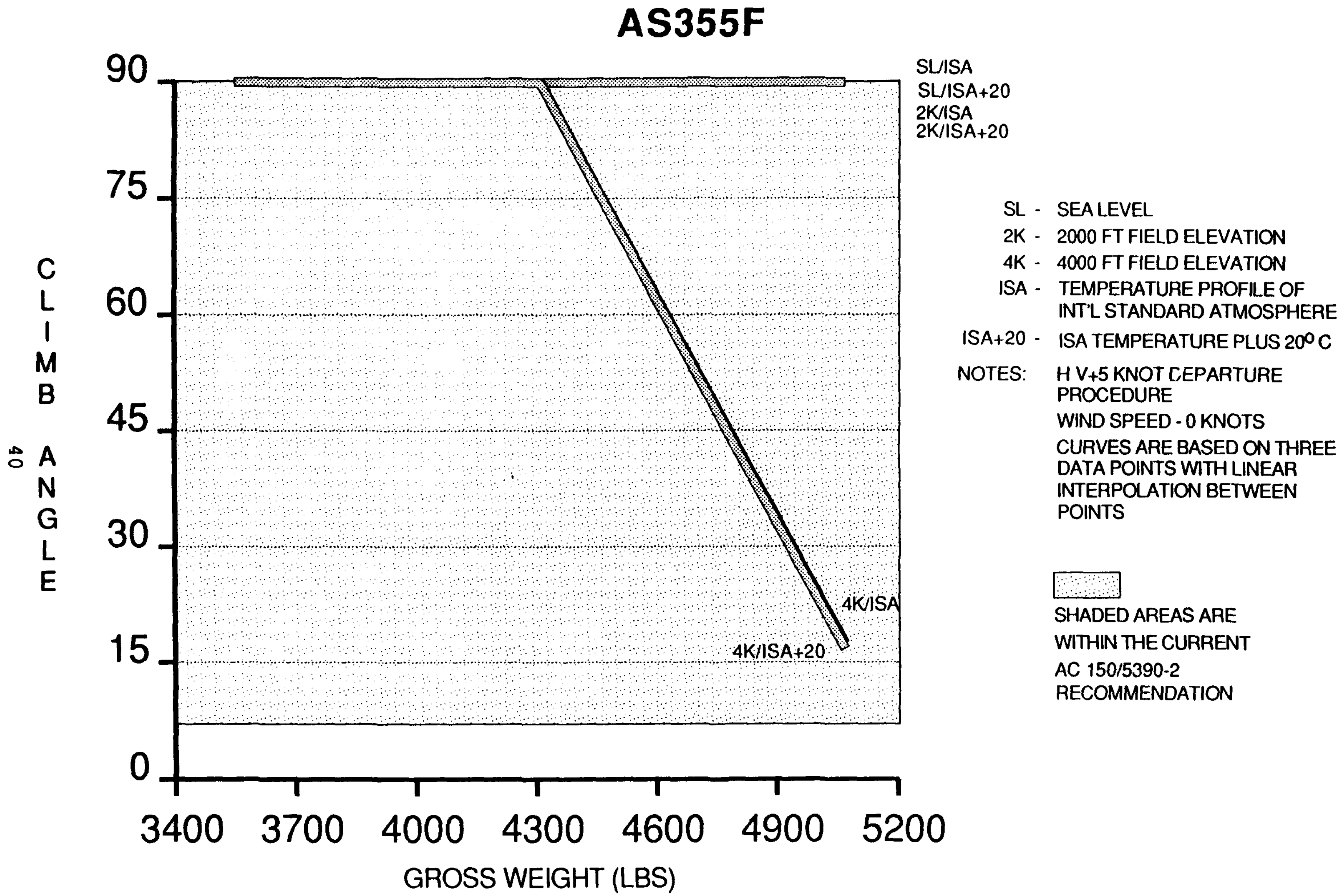


FIGURE 15 CLIMB OUT ANGLE - AS355F

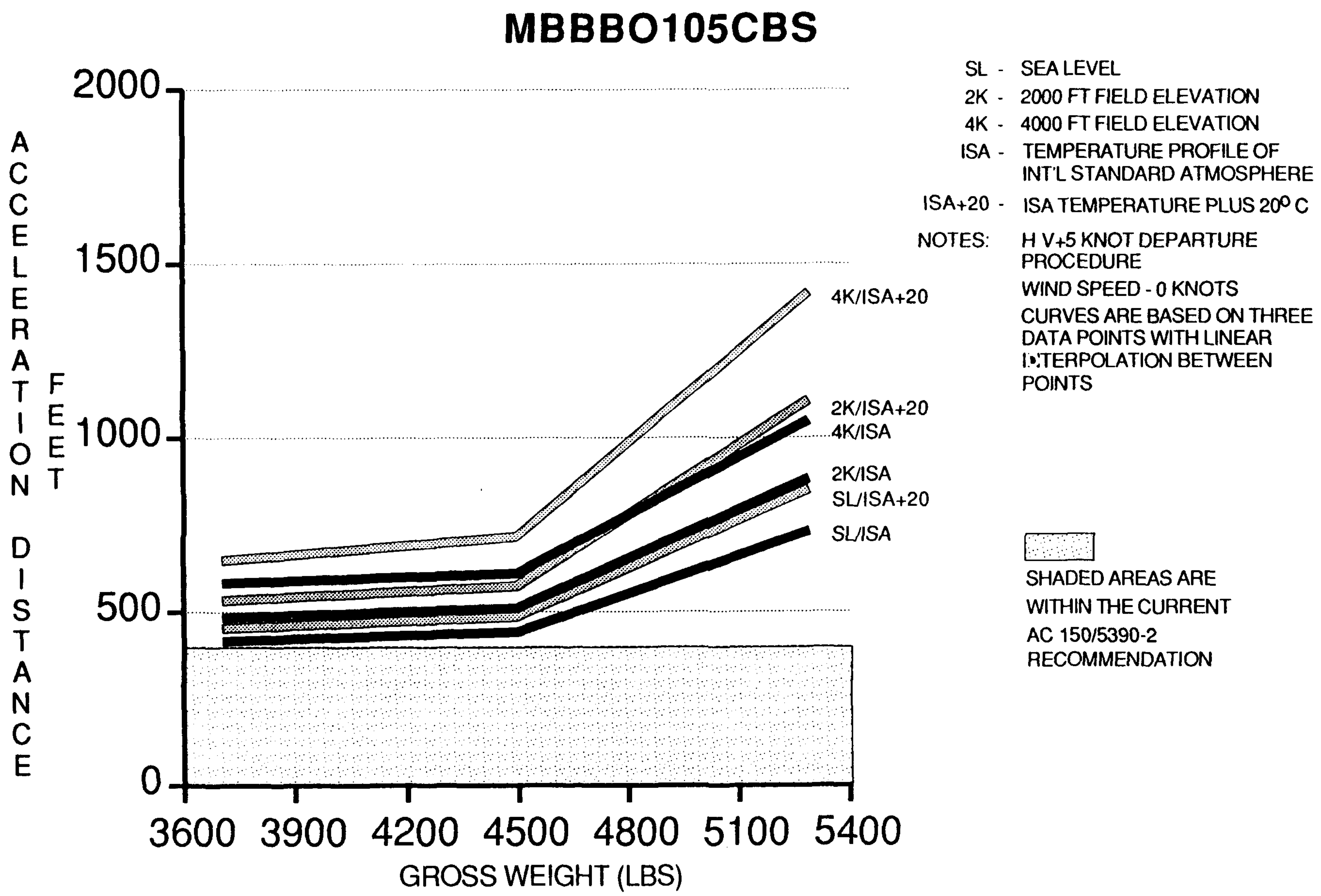


FIGURE 16 DISTANCE TO CLEAR A 50 FT. OBSTACLE - MBBBO105CBS

80 knots in some situations. This is likely due to the HV envelope being based on two engine inoperative conditions.

The climbout performance (figure 17) shows that in all cases, once achieving the 50 feet height, the aircraft can meet the standard 8:1 climb gradient.

4.3.2.6 S 76A

The S 76A (figure 18) shows a mixed relationship to the current 8:1 slope. At the light weights all cases are within the 400 feet that is derived from the standard slope. At the medium weights, the ISA temperature conditions remain within the 400 feet line, but the high temperature conditions are either at or above the standard line. At the higher weights, only the sea level, ISA condition remains within the 400 feet standard. The remaining cases exceed the protected airspace currently provided.

The climbout angles for the S76A (figure 19) are all above the 8:1 slope.

4.3.2.7 AS 322C

Most cases for the AS 322C (figure 20) remain within the 400 feet line that represents the current standard. Several light and medium weight cases can use the vertical takeoff as shown by the 0 value for acceleration distance and the 90 degrees value for climb angle. However, at high weights, high temperatures and high field elevations the acceleration distance exceeds the 400 feet line.

The climbout angles for the AS 332C (figure 21) remain above the 8:1 slope, with several (nine) occurring at 90 degrees.

4.3.2.8 BV 234LR

In all cases the acceleration distance for the BV 234LR (figure 22) remains below the 400 feet line representing the standard 8:1 slope.

Similarly, in all cases the climbout angle for the BV 234LR (figure 23) stays above the 8:1 standard slope represented by the 7.125 degrees line.

4.3.3 Departure Performance - Translational Lift Departure Procedure

The purpose of this analysis was to determine departure profiles when the translational lift departure procedure is used. This procedure consists of a liftoff from the heliport to a hover in ground effect. This is followed by an acceleration to the speed of effective translational lift; 20 knots is used as a conservative speed for all 8 helicopters in the analysis. The acceleration segment is followed by a climb segment at the speed of effective translational lift.

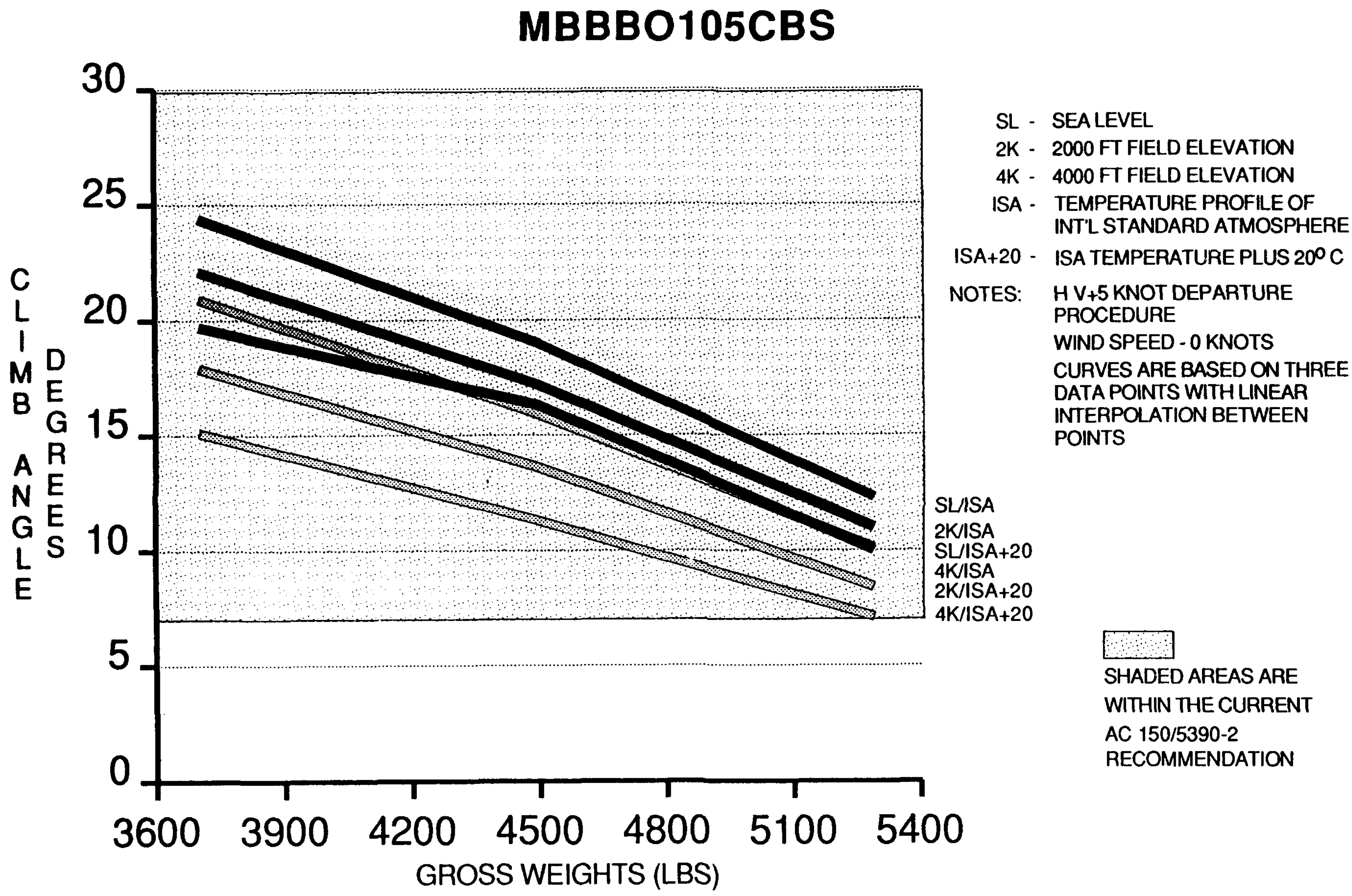


FIGURE 17 CLIMB OUT ANGLE - MBBBO105CBS

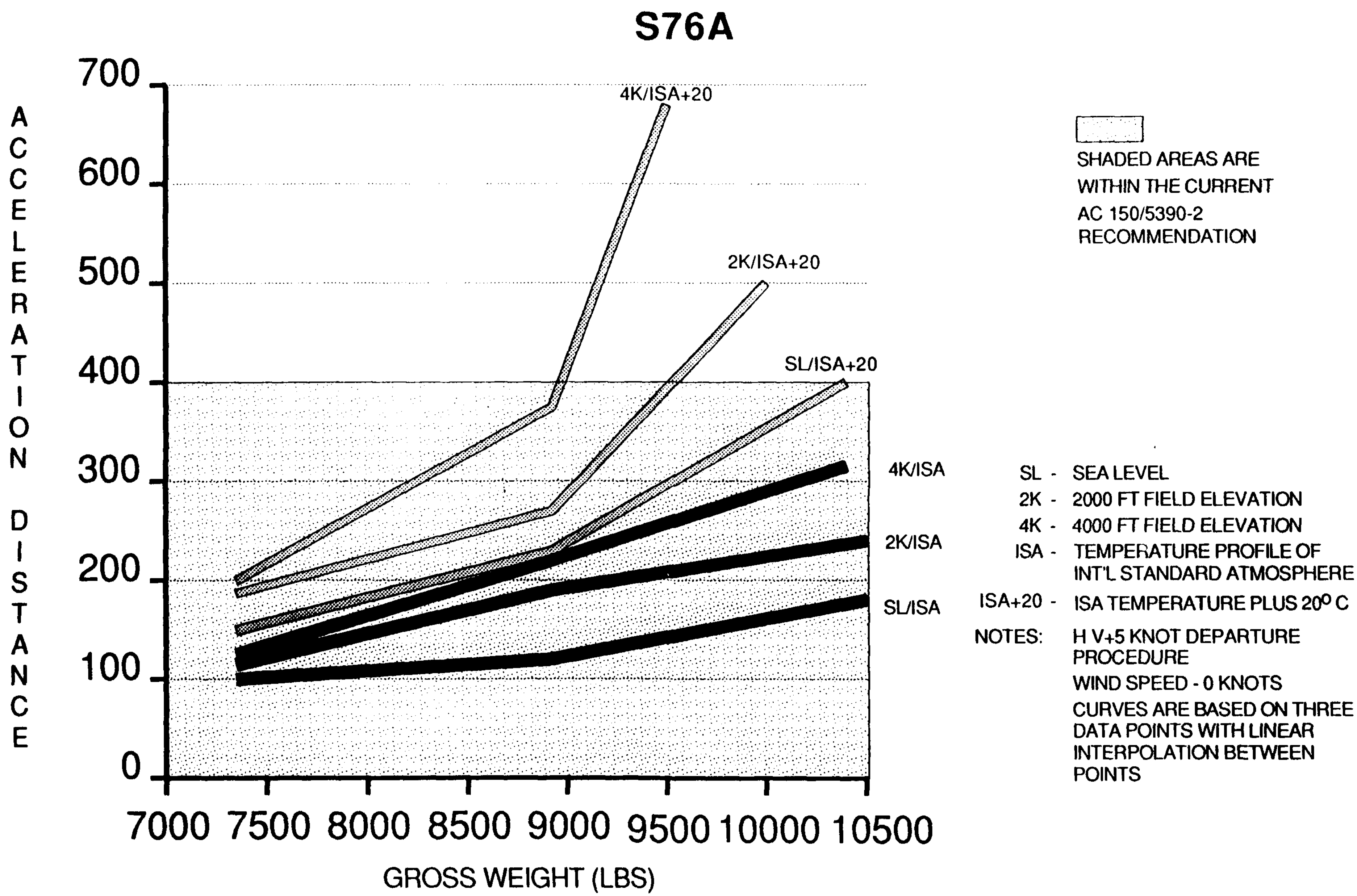


FIGURE 18 DISTANCE TO CLEAR A 50 FT. OBSTACLE - S76A

S76A

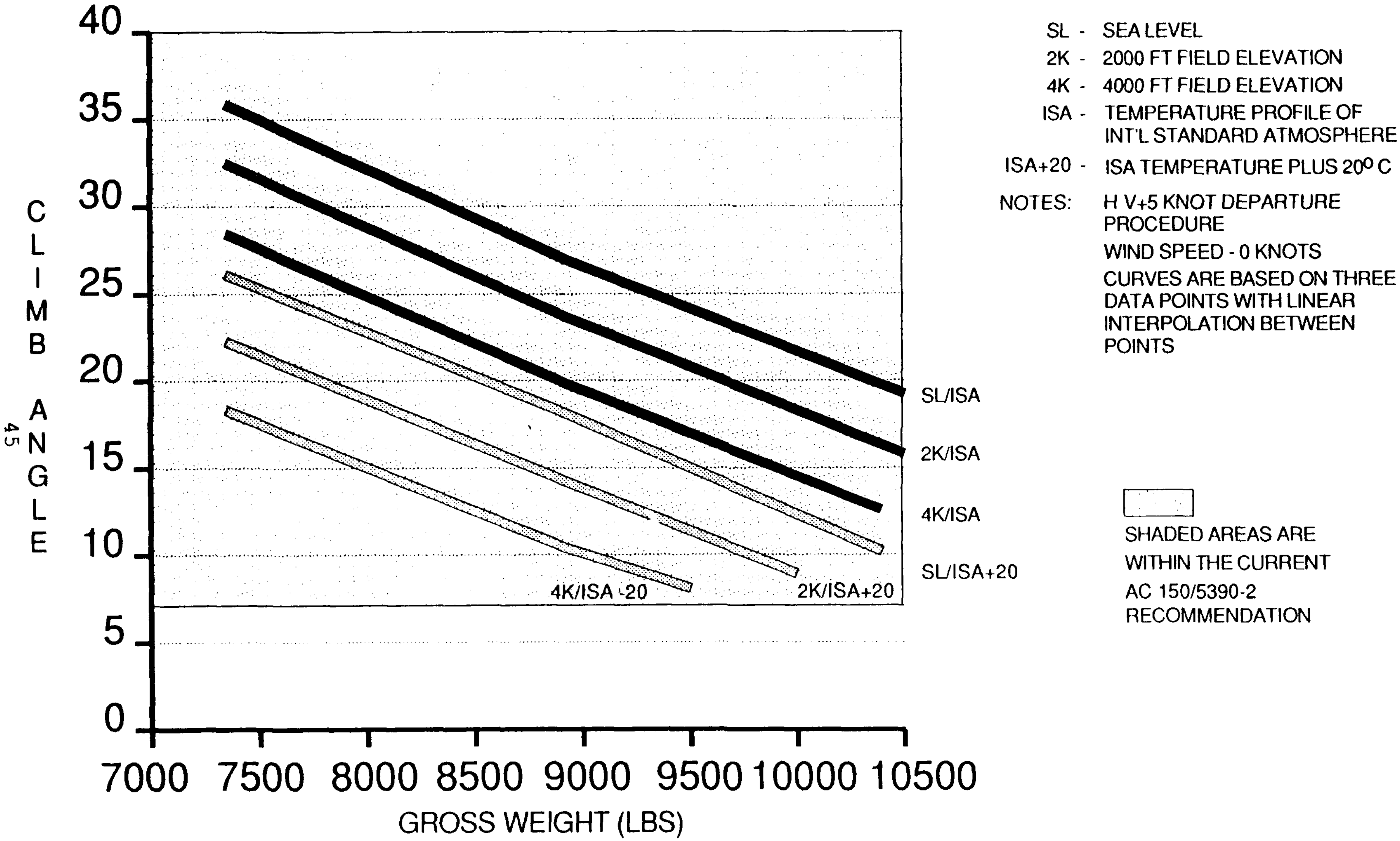


FIGURE 19 CLIMB OUT ANGLE - S76A

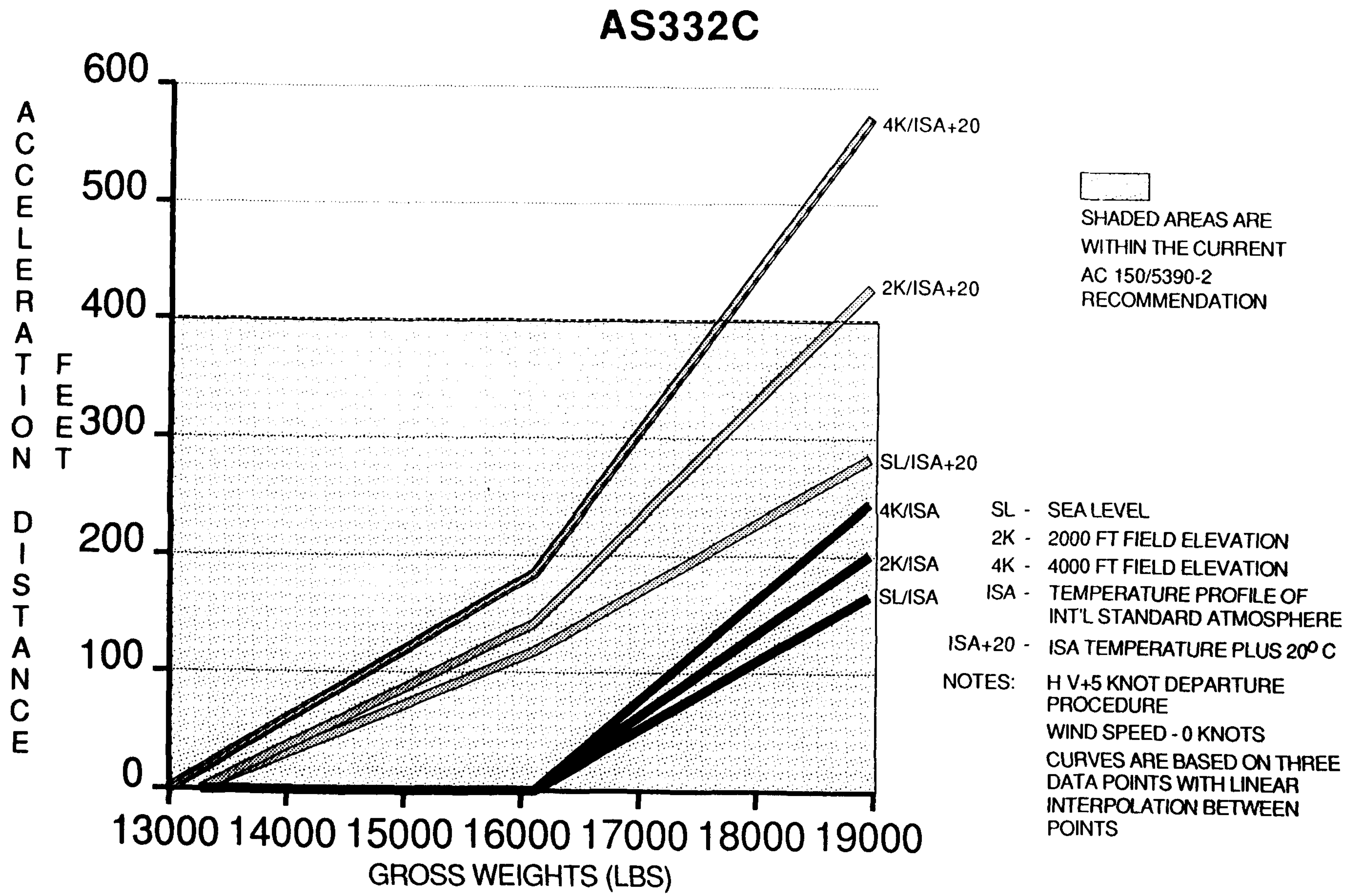


FIGURE 20 DISTANCE TO CLEAR A 50 FT. OBSTACLE - AS332C

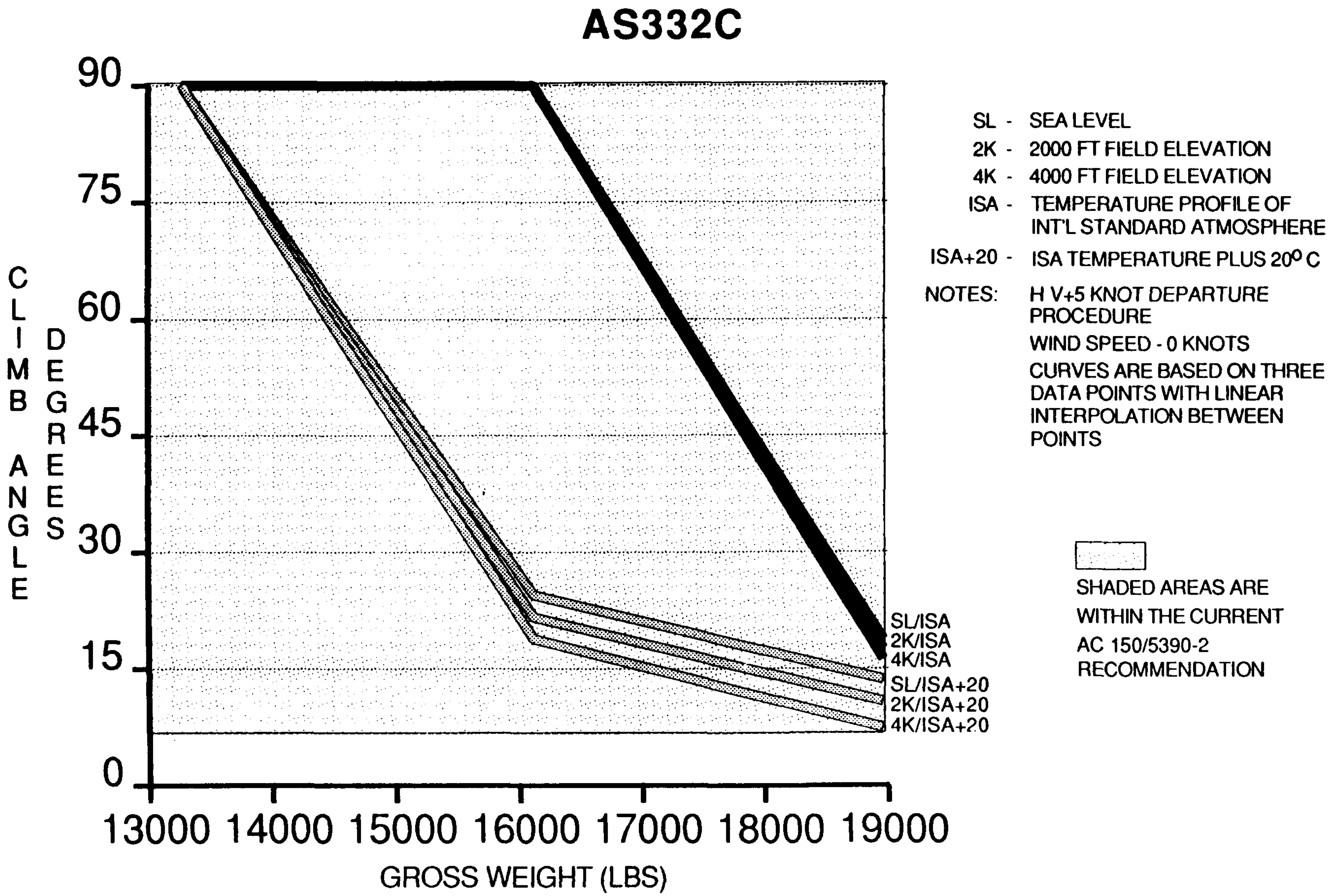


FIGURE 21 CLIMB OUT ANGLE - AS332C

BV234

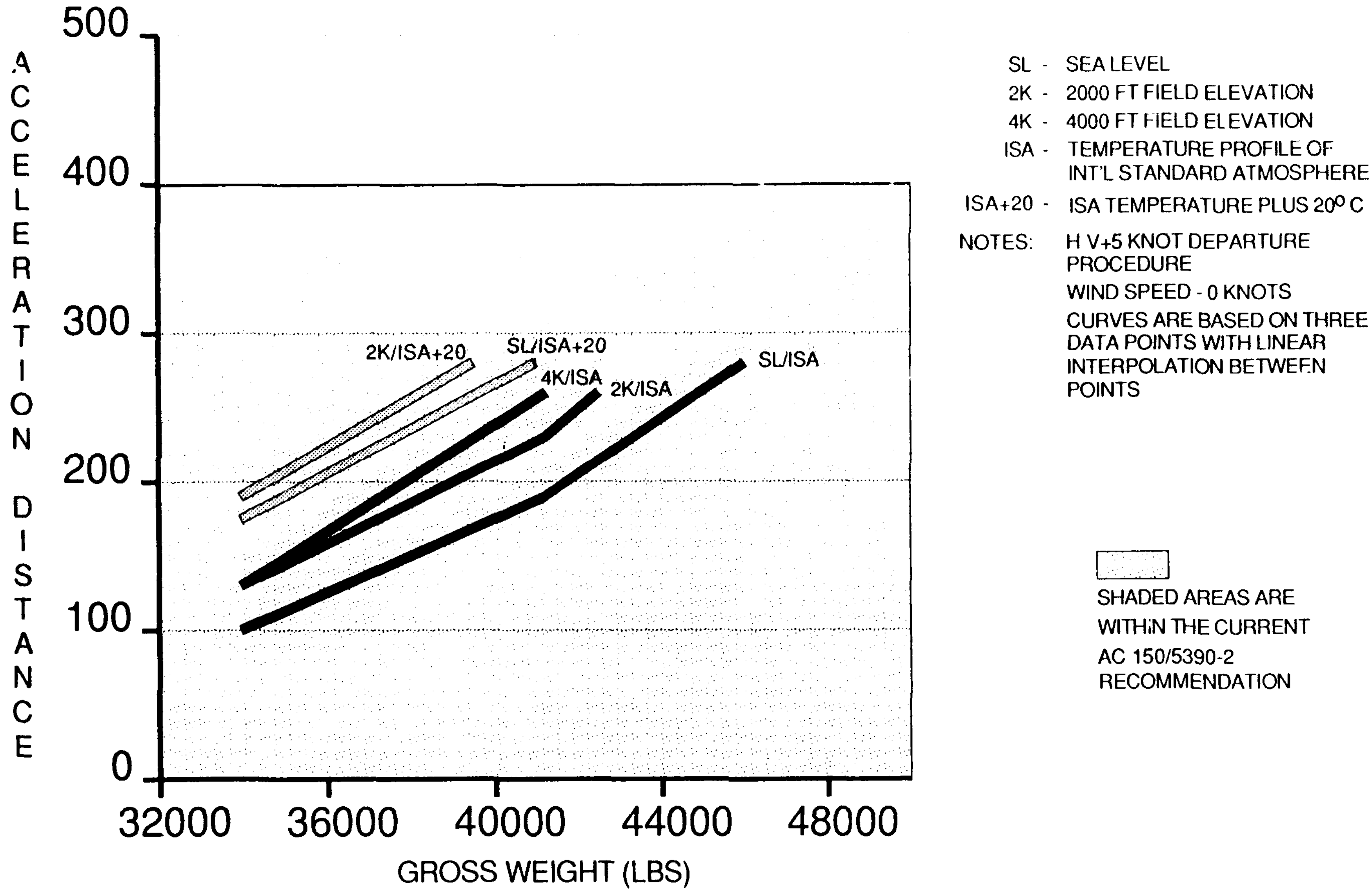


FIGURE 22 DISTANCE TO CLEAR A 50 FT. OBSTACLE - BV234LR

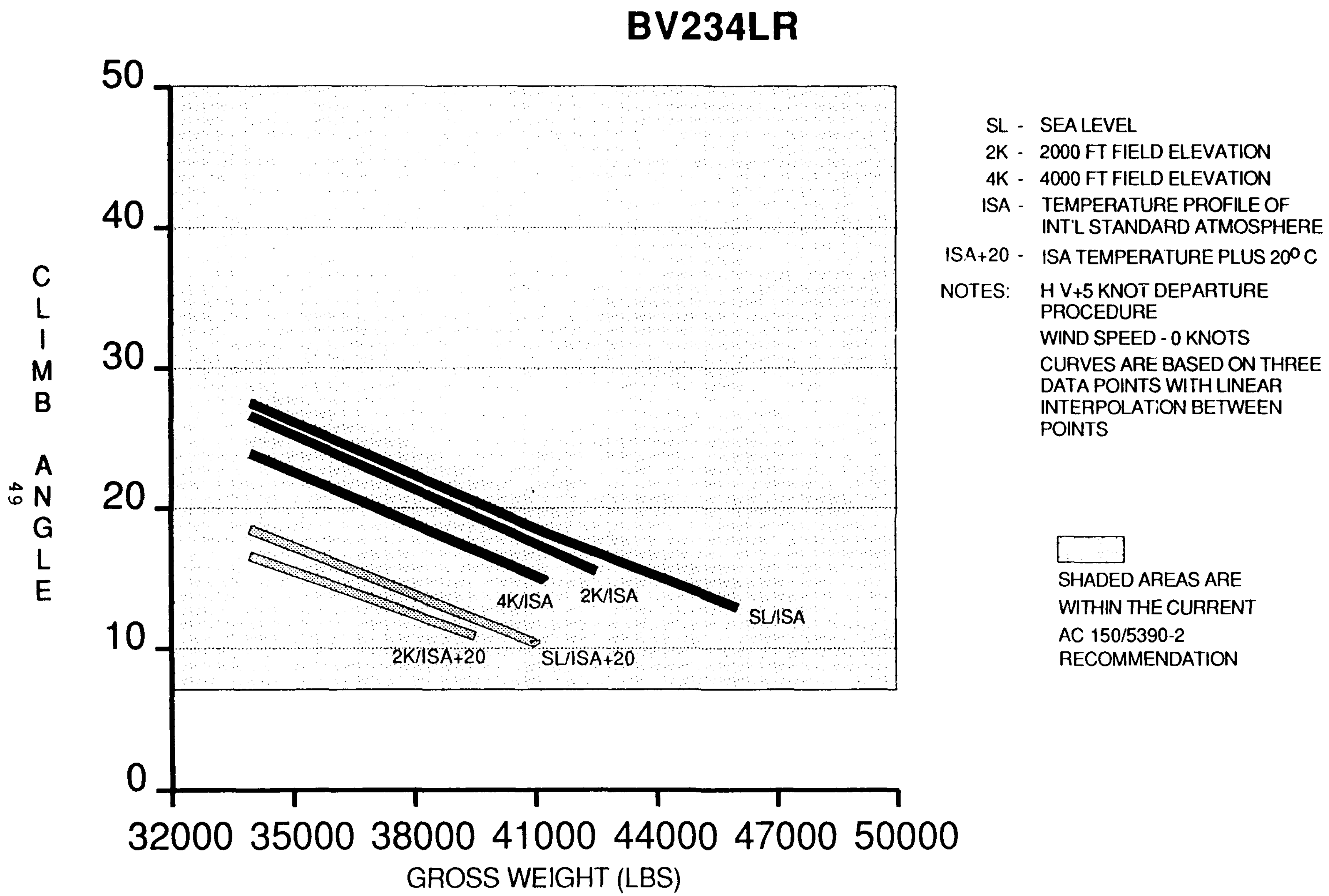


FIGURE 23 CLIMB OUT ANGLE - BV234LR

Two measurements were used to evaluate the departure performance of each helicopter. These are acceleration distance to achieve the speed of effective translational lift and the climb angle achievable at this speed. In a few cases some of the helicopters could not achieve climb under heavy weight and high temperature conditions. In these cases, data were taken at the best-angle-of-climb speed.

The analysis considered 18 conditions of weight, temperature, and field elevation. Three weight conditions (maximum allowable weight, 85 percent of maximum gross weight, and 70 percent of maximum gross weight); three field elevations (sea level, 2,000 feet, and 4,000 feet); and two temperatures (standard day - ISA and hot day - ISA + 20 degrees Celsius) were evaluated. For the BV234LR only 15 conditions were evaluated. The flight manual does not contain performance data for the hot day - 4,000 feet field elevation cases.

The results of the analysis of the translational lift departure procedure are presented in figures 24 and 25. These figures present cumulative percentages of helicopters achieving a specific acceleration distance or climb angle. Data are presented for the three field elevation conditions. It should be noted that a number of acceleration distance cases are grouped around the 68 and 69 feet value. This occurs because of operational constraints on the rotor-tip-path plane that limited acceleration to approximately 0.26 g's.

As a means of interpreting these results for heliport design criteria, the 90th percentile values of acceleration distance and climb angle were selected as being significant for design criteria. One can argue that other percentile values represent equally valid design points. However, based on the sample size and the range of helicopter performance, it is the opinion of the analysts that the 90th percentile represents an appropriate value for consideration as design criteria.

4.3.3.1 Acceleration Distance

The results of the performance modeling of acceleration distance are as follows:

Field Evaluation	Acceleration Distance Achieved (90th Percentile)
Sea Level	81 Feet
2,000 Feet	156 Feet
4,000 Feet	262 Feet

The distance is measured from the point on the heliport where the acceleration begins. Interpreting these results in terms of the recommendations in the Heliport Design Advisory Circular requires some further discussion. The advisory circular fixes the sloping approach/departure surface to the primary surface that overlies the

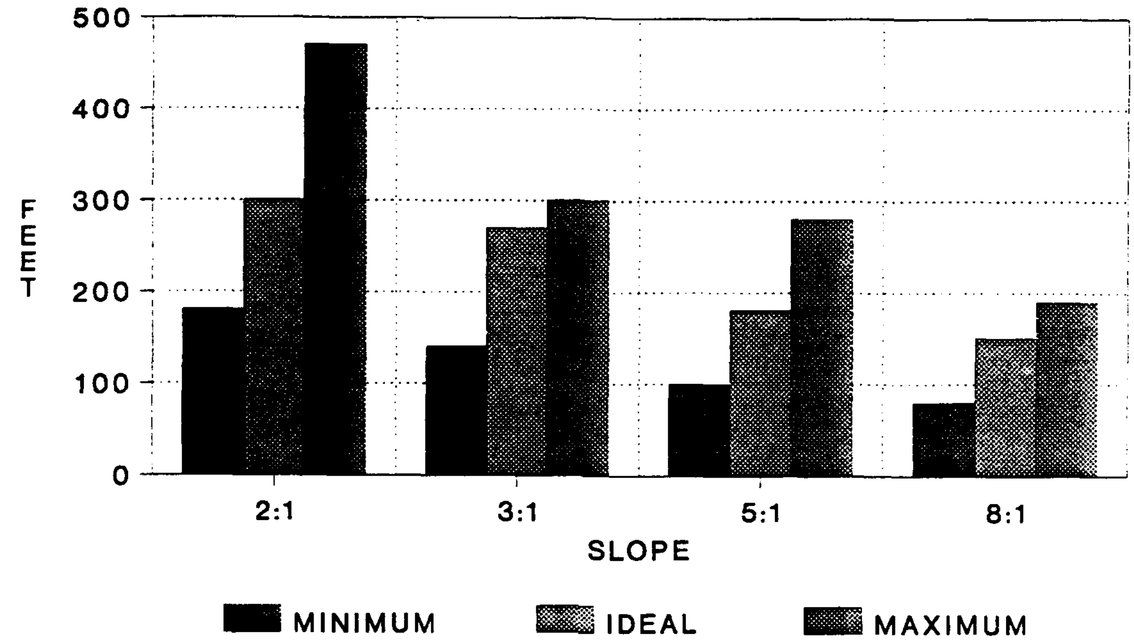


FIGURE 24 PILOTS' ACCELERATION DISTANCE REQUIREMENTS - 90 PERCENT RESPONSES

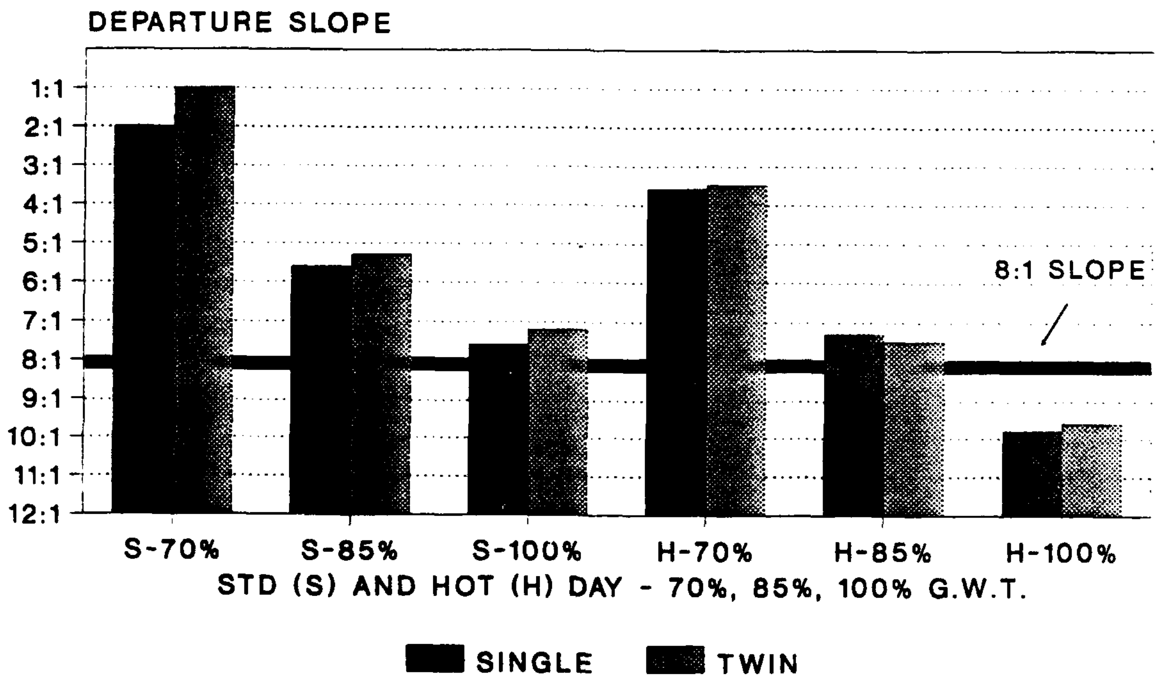


FIGURE 25 PILOTS' DESIRED DEPARTURE SLOPE - 90 PERCENT RESPONSES

final approach and takeoff area (FATO). This in effect attaches the sloping approach/departure surface to the edge of the FATO. To determine the amount of acceleration distance available, one must consider the size of the FATO and the point on the FATO where acceleration begins. Therefore, the results of the performance modeling are not directly comparable to the requirements stated in the advisory circular. Figure 26 depicts the difference between the performance modeling results and the advisory circular criteria.

The Heliport Design Advisory Circular recommends that the minimum FATO size be two rotor diameters of the largest helicopter expected to use the facility. Assuming the helicopter departs from the center of the FATO, this leaves one-half rotor diameter for the acceleration distance available at a minimum facility (see figure 27). This distance is shown in table 6 for the helicopters in the study.

TABLE 6 MINIMUM ACCELERATION DISTANCE AVAILABLE

DESIGN HELICOPTER	ACCELERATION DISTANCE AVAILABLE (1/2 ROTOR DIAMETER)
Enstrom F28F	16.0 feet
McDonnell Douglas 500E	13.2 feet
Bell 206B III	16.7 feet
Aerospatiale AS355F	17.6 feet
MBB BO105 CBS	16.2 feet
Sikorsky S76A	22.0 feet
Aerospatiale AS332C	25.6 feet
Boeing 234LR	30.0 feet

It is apparent that the acceleration distance required, determined from the departure performance analysis, exceeds the acceleration distance available at minimum heliports. Additional analysis of the modeling and its meaning for heliport design criteria are found in section 5.0.

4.3.3.2 Climb Angle

The results of the performance modeling of climb angles are as follows:

Field Elevation	Achieved Climb Angle (90th percentile)	Equivalent Slope (90th percentile)
Sea Level	11.4 degrees	5.0:1
2,000 Feet	9.6 degrees	6.0:1
4,000 Feet	7.6 degrees	7.5:1

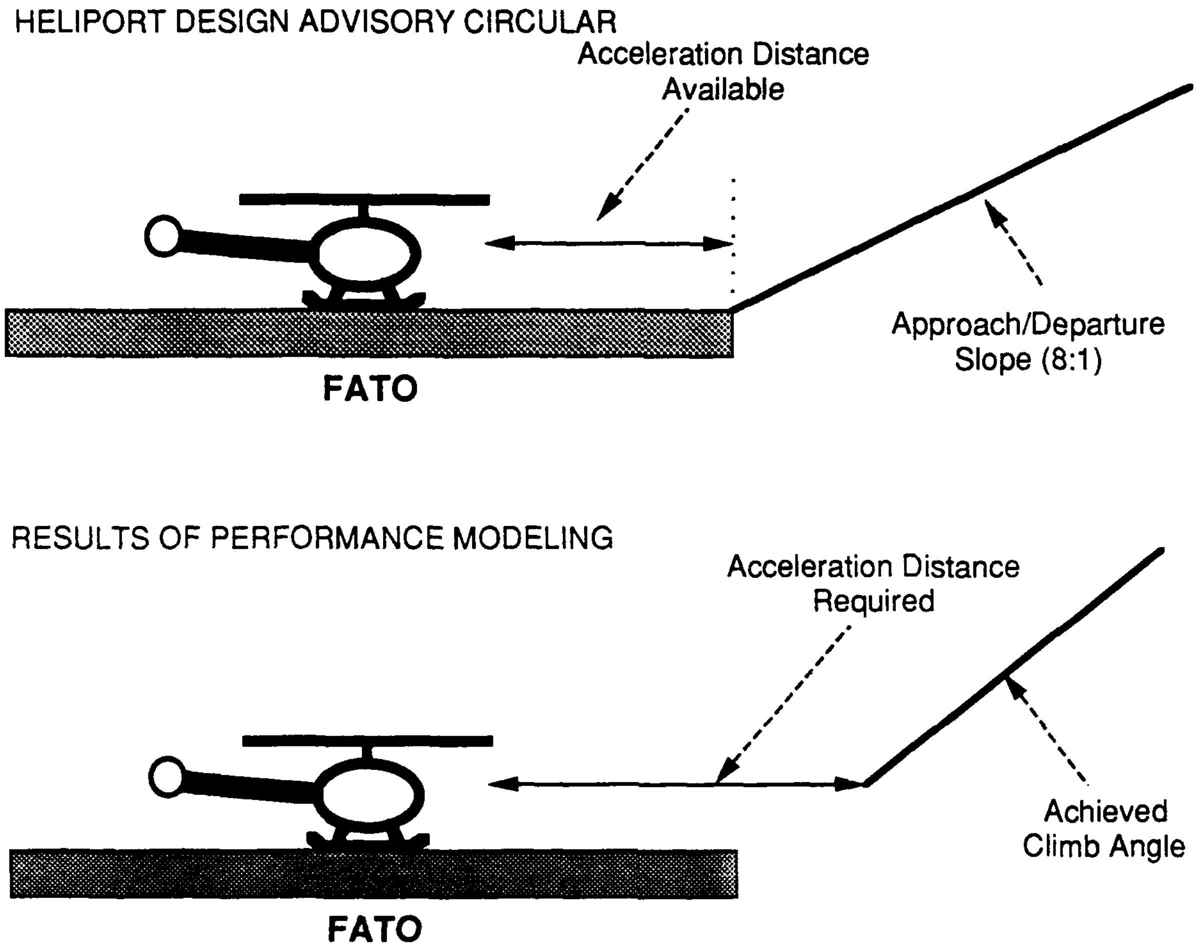


FIGURE 26 COMPARISON OF CURRENT ADVISORY CIRCULAR RECOMMENDATIONS AND PERFORMANCE MODELING

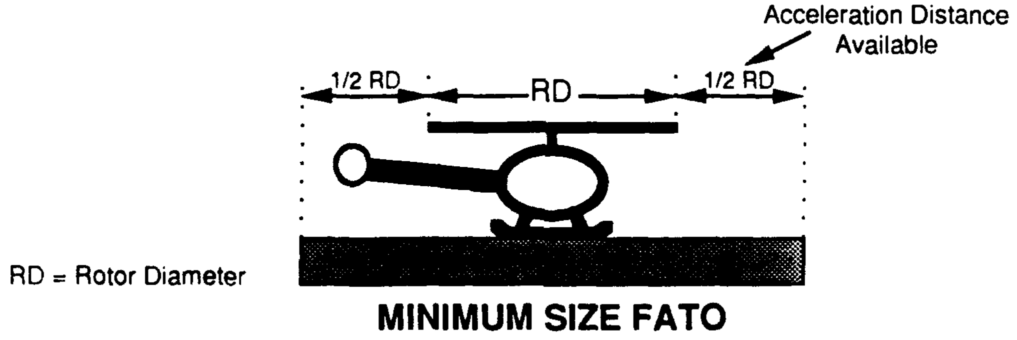


FIGURE 27 ACCELERATION DISTANCE AVAILABLE AT A MINIMUM HELIPORT

The performance modeling shows that the helicopters achieve a steeper climb slope than the 8:1 surface provided in the advisory circular. However, as the field elevation increases, the margin between the achieved climb angle and the airspace surface narrows considerable. Additional analysis of this margin and its meaning for heliport airspace criteria are contained in section 5.0.

4.3.4 Approach Modeling Results

Approach modeling is considerably simpler than departure modeling, primarily because the approach profiles are dependent on different variables; approach speed and desired approach slope. The details of the approach modeling are contained in "Helicopter Physical and Performance Data." The results of that effort will be presented here to evaluate the viability of the current heliport approach surfaces.

Figure 28 presents the results of the approach modeling for 50 knot approaches for a variety of approach slopes ranging from 8:1 to 5:1. A table converting these slopes to angular values is shown below.

Slope	Angular Value
8:1	7.125°
7:1	8.130°
6:1	9.462°
5:1	11.310°

These dark lines are representative of the average of the approaches for all helicopter weights, temperatures, and heliport elevations.

An analysis of these profiles with respect to the current heliport airspace recommendation contained in AC 150/5390 indicates that the 8:1 profile closely matches the 8:1 slope of the heliport design advisory circular. The average helicopter approach slope tends to be slightly above the 8:1 slope during the upper part of the approach, and slightly below the 8:1 slope as the helicopter nears the surface. The steeper approaches tend to remain above the 8:1 slope throughout a greater part of the approach.

4.3.5 Observation

It is of concern at this point that the heliport approach/departure surface, as currently defined, does not contain any margin of safety between performance required and the height up to which obstacles are allowed to grow. Obstacles are permitted right up to the 8:1 surface, while at the same time both departing and arriving aircraft often fly at or below that same 8:1 slope. This is unusual in protected airspace design and should be taken into account when developing heliport departure and approach surface requirements. A formula for such application is introduced in section 5.0.

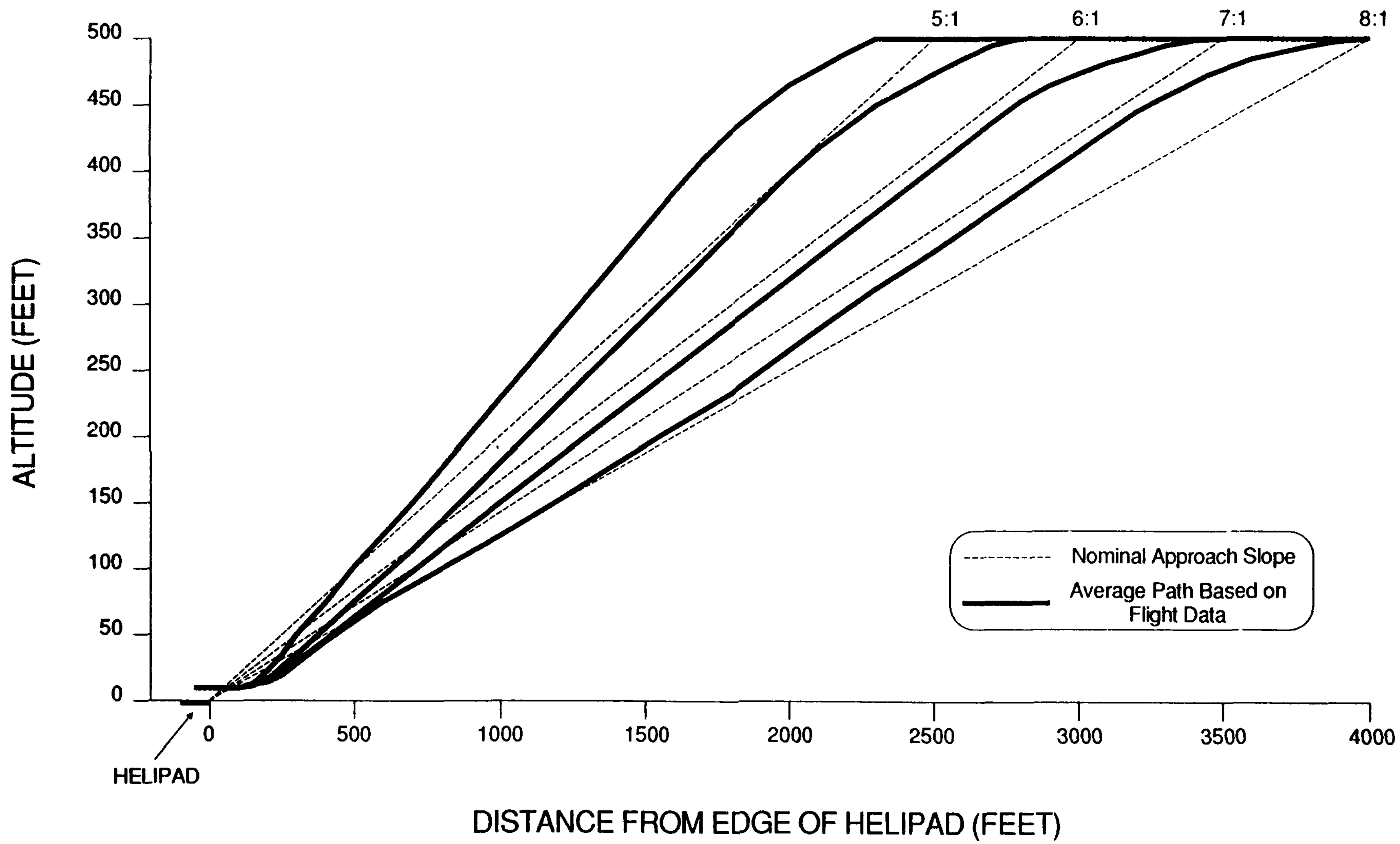


FIGURE 28 50 KNOTS APPROACH PROFILES

4.4 OPERATIONAL DATA RESULTS

An operational survey of pilots was conducted to better understand actual VFR helicopter operations at confined heliports. The results of this survey are presented in "Operational Survey - VFR Heliport Approaches and Departures" DOT/FAA/RD-90/5.

Interviews were conducted with 77 helicopter operators, 9 helicopter manufacturers' instructor pilots, and 2 FAA technical center pilots. The interviewees were based at locations across the continental United States and attention was given to ensure that a broad range of climatic and operational conditions were represented along with a variety of missions.

Pilots expressed their opinion on a number of performance subjects including normal and confined area procedures, height-velocity diagrams, level acceleration departures, acceleration distances required, and actual departure slopes. Their opinions were then compared with the computed departure profiles presented in "Helicopter Physical and Performance Data," DOT/FAA/RD-90/3.

4.4.1 Survey Results

Procedures - Takeoff and landing procedures were based primarily on whether pilots were operating single-engine or twin-engine helicopters.

Single-engine helicopter pilots were mostly interested in maintaining a safe autorotative capability. Many felt that a safe takeoff procedure which ensures this capability is one that climbs 1 foot for every 1 knot (or MPH) of airspeed. Similarly, with landing, maintaining a safe autorotative airspeed and altitude were important and flying an approach path of 8 to 10 degrees was the most common technique to ensure a safe flight envelope. Confined area takeoffs required that pilots modify this technique using a constant angle of climb sufficient to clear the controlling obstacle. Most pilots prefer flying the shallowest departure angle which allows them to clear the obstacle. Once clear, pilots then accelerate to attain a normal departure airspeed. Approaches likewise, require pilots to fly level until intercepting an approach angle to the helipad that will clear all obstructions and then descend into the confined area helipad at a constant angle.

Twin engine helicopter pilots were most interested in safely accelerating to takeoff safety speed (V_{Toss}) on departure and maintaining V_{Toss} for as long as practical on approach. This results in normal takeoffs being shallower than single engine helicopter takeoffs. Approaches, however are flown steeper than single engine helicopter approaches, usually 12 to 14 degrees, as pilots desire to maintain V_{Toss} until landing at the helipad is assured. For confined area approaches and departures, the preferred procedure was flying a constant angle as close to the normal procedure as possible while safely clearing the obstacles.

Height-Velocity Constraints - Actual confined area approaches and departures sometimes necessitate that pilots operate in the avoid area of the height-velocity diagram. Pilots were willing to fly through the avoid area if necessary based upon mission requirements and felt that operating for a few seconds in the avoid area did not appreciably increase their risk. Pilots also noted that in many cases, the height-velocity curves represented a worst case scenario in which they rarely operate. It was also apparent from the survey process that pilots had limited knowledge about their aircraft's height-velocity curves and needed to reference their flight manuals for specific information.

Acceleration Distances - Pilots were also questioned as to their need for an acceleration distance prior to climbing to clear obstacles. This acceleration in ground effect enables aircraft to achieve translational lift and gain an increase in performance.

The survey question read "If the availability of 'acceleration distance' prior to having to climb out over obstacle(s) assists your performance, please indicate on the drawing what you feel is the minimum, ideal, and practical maximum of acceleration distance you would like to have at a heliport." The interviewer presented the situation where "the aircraft could carry a particular load out of a location and in addition, a mission requirement to add approximately 10 percent of the maximum gross weight of the aircraft became necessary."

The results of the survey question regarding acceleration distance are summarized in figure 24. This set of bar charts shows the 90th percentile pilot responses for four obstacle slopes with three operational conditions each. The operational conditions are described as follows:

- minimum distance, below which pilots would not takeoff;
- an ideal distance, described as a distance at which pilots would feel comfortable operating on a regular basis; and
- a maximum distance, above which the space would be wasted or the space would be better utilized for other purposes (e.g., parking cars, storage, etc.).

The survey results of greatest interest relative to the FAA's Heliport Design Advisory Circular are those of the 8:1 departure slope. These results relate directly to the approach/departure surface requirements found in the advisory circular. The 90th percentile survey results for the 8:1 departure slope are as follows:

Pilots' Distance Requirements	Additional Distance Desired to Takeoff with a 10 Percent Greater Load*
Minimum required to operate	80 feet
Ideal for most operations	150 feet
Maximum needed without wasting airspace	190 feet

* 8:1 Initial Slope Conditions

Considering the 8:1 slope case, the range of values for acceleration distance from the operational survey is 80 to 190 feet depending on the pilot's preferences for minimum, ideal, and maximum distances. The range of values for acceleration distance from the performance analysis is 81 to 262 feet. These results are based on the translational lift departure procedure and the range considers the field elevation of the heliport. Even though the approach to developing these results was quite different, there appears to be a convergence on the values in the range of 80 to 260 feet. This is thought to be significant in establishing heliport airspace requirements for acceleration distance.

Departure Slopes - The 90th percentile responses for the pilots' desired departure slope of both single- and twin-engine helicopters were summarized in figure 25 in bar chart format.

The results showed very consistent, similar, and predictable responses for the single- and twin-engine helicopter pilots. Generally, as the weight of the helicopter increases, the pilots want a shallower slope for the approach/departure surface. Similarly, as the temperature increases from standard day to hot day, so does the pilots' desire for a shallower slope for the obstacle clearance plane.

In five of the six conditions, the pilots' desired obstacle clearance plane slope is steeper than the 8:1 surface described in FAR Part 77 and the Heliport Design Advisory Circular. Only in the hot-day/100-percent-maximum-weight case does the pilots' desired approach/departure slope fall below the nominal 8:1 surface.

The results of the performance modeling and the operational survey indicate the 8:1 slope is satisfactory if properly offset to account for acceleration distance. Both analyses indicate that most operations can achieve this departure slope. Steeper slopes would limit some operations with heavily loaded aircraft and/or at high density altitude conditions. Shallower slopes are not seen to provide operational benefits nor are they required for safe departure operations.

4.4.2 Observation

The large variation in performance estimates by some of the pilots demonstrates the difficulty in subjectively determining helicopter climb performance. Contributing to the difficulty are the absence of adequate performance data in the flight manuals, the lack of standardized confined area procedures, differences in pilots' safety margins and training, company operating policies, and varying pilot abilities.

NOTE: Upon review of the survey data, considerable disagreement occurred concerning pilots' perceptions of climb angles at the more demanding weight, altitude, and temperature combinations. It was frequently noted that these perceived climb angles exceed helicopter capabilities; the most likely explanation being that actual departure angles and pilot perceptions of these angles are known to differ.

5.0 HELIPORT AIRSPACE/HELICOPTER PERFORMANCE SYSTEM

Results from the operational survey and the computer generated departure profiles show that in many instances today's rotorcraft can not remain above the current 8:1 slope of the heliport approach and departure surface. These results also show that there can be a large variation in the airspace required based on aircraft weight, field elevation at the facility, and the normal range of temperatures encountered during the year.

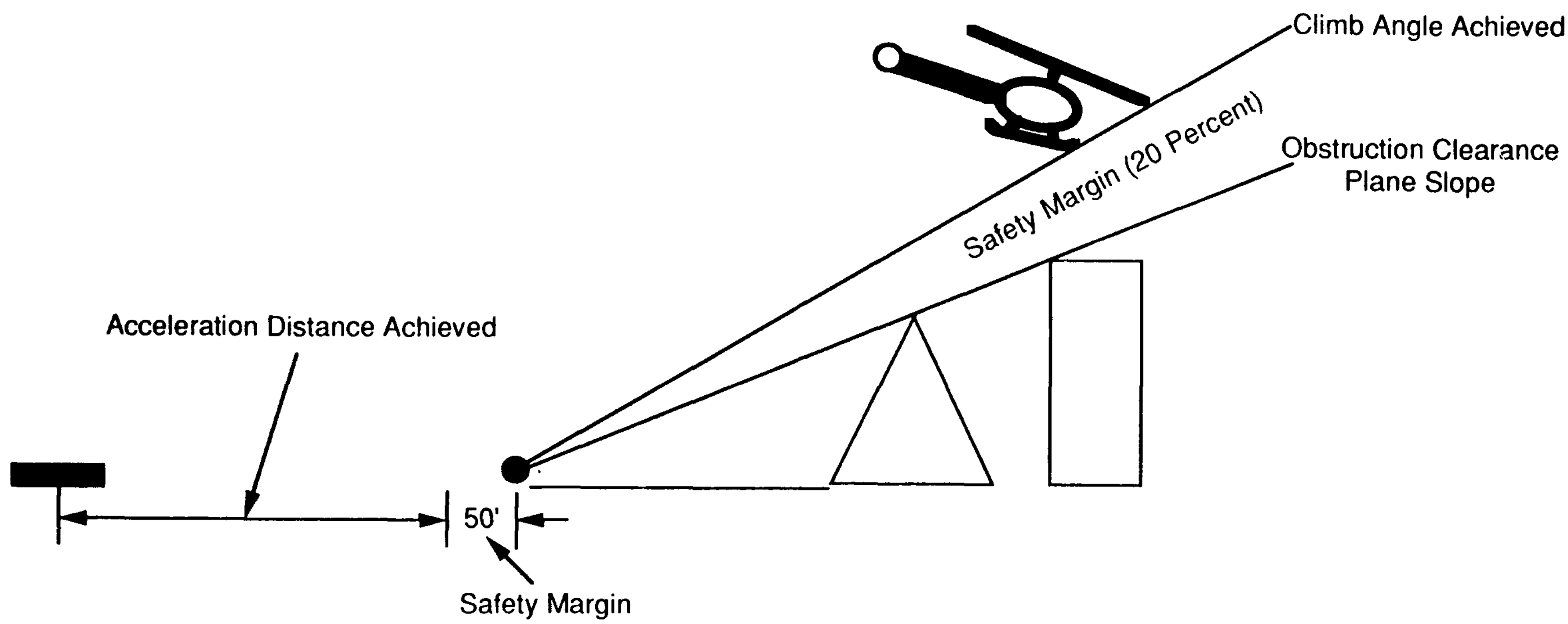
The operational survey indicates that pilots want increased takeoff distance for acceleration when operating a heavily loaded helicopter. For the 8:1 slope case, the 90th percentile responses range from 80 to 190 feet of additional acceleration distance with 150 feet considered as ideal.

Similarly, the performance analysis, based on the translational lift departure procedures, indicates that additional acceleration distance is necessary. The 90th percentile results show that 81 feet of acceleration distance is needed at sea level, 156 feet is needed at 2,000 feet, and 262 feet is needed for a heliport at 4,000 feet altitude. Even greater acceleration distance is needed for the HV+5 knots procedure and for the manufacturer's recommended procedures in the flight manuals.

In considering the availability of acceleration distance, this same variability also occurs at heliports. Some heliports are located in relatively rural or remote areas where airspace is not a problem and little operational constraint occurs. Other heliports are located in suburban or low density urban areas where airspace is not a problem at the present time but future development could threaten heliport airspace. Defensible standards are needed to protect this airspace. Finally, the demand for heliports is often in confined urban areas and in areas already laden with man-made or natural obstacles nearby. Some existing heliports do not meet the current 8:1 slope requirements in these confined areas. This need not however preclude the development of confined area heliports, but rather should indicate to operators and heliport developers that helicopters with extra margins of performance will be required to operate at these locations.

5.1 SAFETY MARGIN

As observed in paragraph 4.4, there is no safety margin provided in the definition of heliport protected airspace. Helicopter performance calculations are based upon meeting an 8:1 climb gradient. Man-made or natural obstacles are allowed to grow up to that same 8:1 slope. This hardly affords protection as the term protected airspace would imply. A proposal to address this issue could be established as shown in figure 29. This proposal calls for a 50 foot safety margin to be applied to the achieved acceleration distance of the helicopter to establish the point where the obstruction clearance plane slope begins. Further, the proposal provides a 20 percent safety margin



HELIPORT AIRSPACE REQUIREMENTS

Acceleration Distance Required = Acceleration Distance Achieved + 50 Feet

Obstruction Clearance Plane Slope = Climb Angle Achieved /1.2

FIGURE 29 SAFETY MARGIN ILLUSTRATION

between the obstruction clearance plane slope and the achieved climb angle of the helicopter.

5.1.1 Heliport Acceleration Distance Requirements

By applying the safety margins to the results of the performance modeling, it is possible to determine the heliport airspace requirements. The acceleration results were analyzed in section 4.3.3.1. The heliport acceleration distance requirements are calculated as follows:

Field Elevation	Acceleration Distance Achieved (90th Percentile)	Heliport Acceleration Distance Requirement*
Sea Level	81 feet	140 feet
2,000 feet	156 feet	210 feet
4,000 feet	262 feet	320 feet

* Calculated by adding 50 feet to the acceleration distance achieved and rounding up to the nearest 10 feet.

An equation was developed to permit calculation of values for acceleration distance at field elevations between sea level and 4,000 feet. This equation is:

$$HADR = 140 + 25\,(FE/1,000) + 5(FE/1000)^2$$

Where
HADR = Heliport acceleration distance required in feet
FE = Field elevation in feet

Note that the heliport acceleration distance requirement should be applied from the center of the FATO.

5.1.2 Heliport Obstruction Clearance Plane Requirements

By applying the 20 percent safety margin to the achieved climb angles presented in section 4.3.3.2, the recommended obstruction clearance plane slope can be determined. The results are:

Field Elevation	Achieved Climb Angle (90th Percentile)	Calculated Obstruction Clearance Plane Slope	Recommended Obstruction Clearance Plane Slope
Sea Level	11.4 degrees	6.0:1	8:1
2,000 feet	9.6 degrees	7.1:1	8:1
4,000 feet	7.6 degrees	9.0:1	9:1

The results show that slopes steeper than the current 8:1 requirement in the Heliport Design Advisory Circular can be supported at the field elevations below 2,000 feet. However, it is recommended that the slope requirement remain at 8:1 as a minimum standard. Above approximately 3,000 feet, consideration should be given to reducing the slope to accommodate the reduced climb performance of the helicopter at higher density altitudes.

5.2 PERFORMANCE BASED HELIPORT AIRSPACE SYSTEM

The airspace recommendations provided in section 5.1 are suitable at heliports where there is sufficient acceleration distance and obstruction clearance airspace. What happens at confined heliports where the required airspace is not available? To answer this need, a system of cataloging heliports and determining helicopter performance under various operational conditions is required.

5.2.1 Acceleration Distance and Climb Angle Determination

The vertical elements of the heliport protected airspace surfaces can be described using two parameters, acceleration distance and climbout angle. An illustration of how application of this system would work is shown in figure 30. The slope part is similar to the slope parameter set at 8:1 in the current standard. However, the acceleration distance (distance to accelerate to a given airspeed to achieve a particular climb angle) parameter is offset a distance from the edge of the helipad and becomes the point where the slope measurement begins. Changes in the acceleration distance may result in changes in the climbout angle required and obstruction clearance plane required due to the location of specific obstacles.

Implementation of such a system would require measurement of the available acceleration distance and climbout angle required at each heliport within the lateral airspace dimensions as defined in 14 CFR Part 77. These two values would be published in the facility directory along with other pertinent heliport information for use by pilots in planning and operating their helicopters into and out of that heliport.

5.2.2 Operational Application

In order to make a performance-based system described above effective from an operational standpoint, the performance capability of the helicopter must be available to pilots in the form of acceleration distance required and climbout angle charts.

A variety of systems could be employed. The following is an example of how one such system could be implemented from an operational viewpoint. In this example, the heliport has been measured to have an acceleration distance available of 420 feet and a climbout angle required of 8 degrees. A pilot intends to fly SAMPLE HELICOPTER into the heliport. It is mid-summer and the outside air temperature is 95 degrees F (35 degrees C). The heliport is located at sea level. The pilot wishes to determine if he can takeoff with a full load of

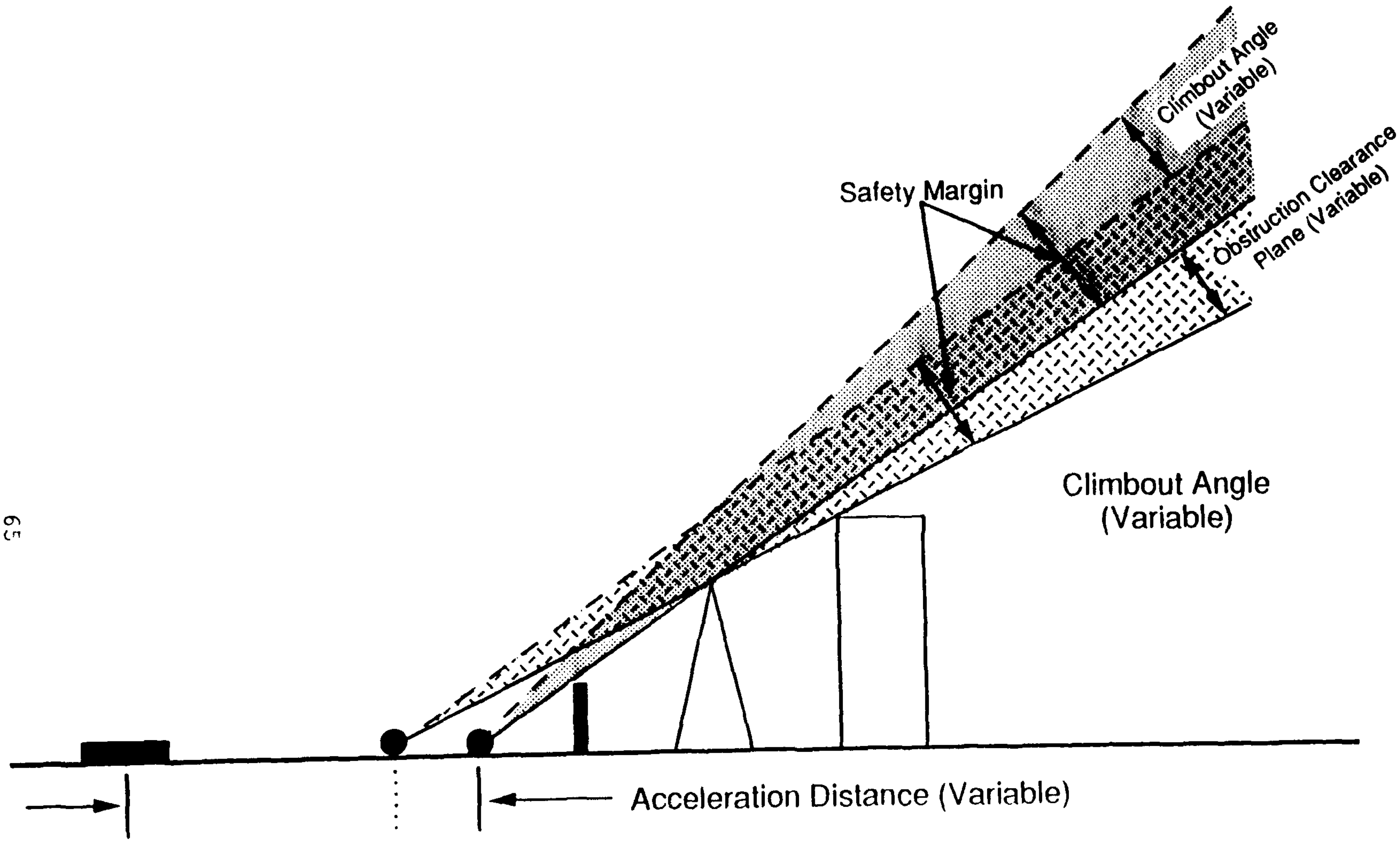


FIGURE 30 ACCELERATION DISTANCE/CLIMB ANGLE DETERMINATION

passengers and fuel (max gross wt). If not, then what is the maximum aircraft weight that he can operate from this heliport?

The answer requires the selection of two SAMPLE HELICOPTER charts. A full set would nominally include ten charts based on a requirement for the calculation of acceleration distance required and climb angle capability at sea level, 2,000, 4,000, 6,000 and 8,000 feet. It may be possible to condense this information into two multi-curve charts, one representing acceleration distance and the other presenting climb angle. The pilot would first select the sea level acceleration distance required chart (figure 31), entering at the acceleration distance available - 420 feet (from the facility directory), move across the chart to the temperature (35 degrees C), and read down to obtain maximum gross weight for takeoff - approximately 9,050 pounds.

Next the pilot selects the sea level climb angle chart (figure 32) entering at 8 degrees (from the facility directory) climb angle. Moving across the chart to the 35 degrees C temperature (interpolate), and then down gives the maximum gross weight based upon climb angle based upon the aircraft's airspeed when over the 50 foot obstacle. In this case the 35 degrees C temperature is not encountered prior to reaching maximum gross weight which means that SAMPLE HELICOPTER could climb in excess of 8 degrees at maximum gross weight.

The lesser of the two weights, in this case 9,050 pounds, is the maximum operating weight for takeoff given the conditions for that day. (Bear in mind that this example has not yet addressed the issue of safety margins discussed in section 5.1.)

5.2.3 Heliport Site Selection Based Upon A Design Helicopter

A second example illustrates how this same method can be used to select a heliport site based upon the use of a "design helicopter." In this case, an operator is in search of a suitable location from which to operate SAMPLE HELICOPTER in city XXX. The city elevation is for the most part at or near sea level. The operator would like to operate year round, which means encountering summer temperatures as high as 90 degrees F (32 degrees C). Economics dictate that operations be conducted at maximum payload (maximum gross weight).

In this case the operator selects the sea level acceleration distance required chart (figure 33), entering at maximum gross weight (10,500 pounds), and moves upward to 32 degrees C. Reading across to the left indicates an acceleration distance of 625 feet required.

The operator next selects the climb angle chart (figure 34), entering at maximum gross weight, moves up until reaching 32 degrees C, and reads across to the left to get a climb angle capability of 10.5 degrees.

This means that in order to ensure continued operational capability year round with SAMPLE HELICOPTER, the operator must find a site that

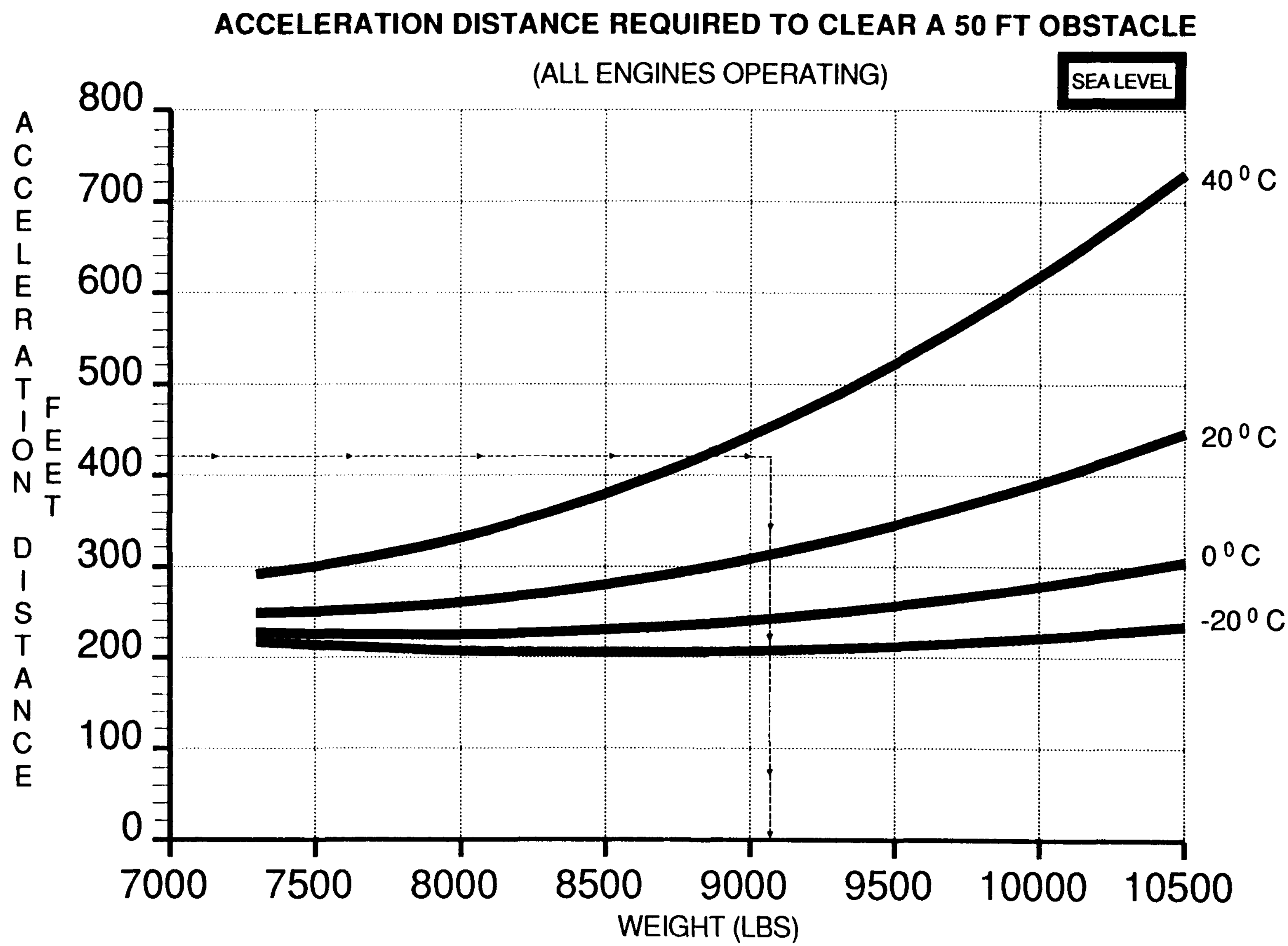


FIGURE 31 SAMPLE HELICOPTER OPERATING WEIGHT BASED ON ACCELERATION DISTANCE

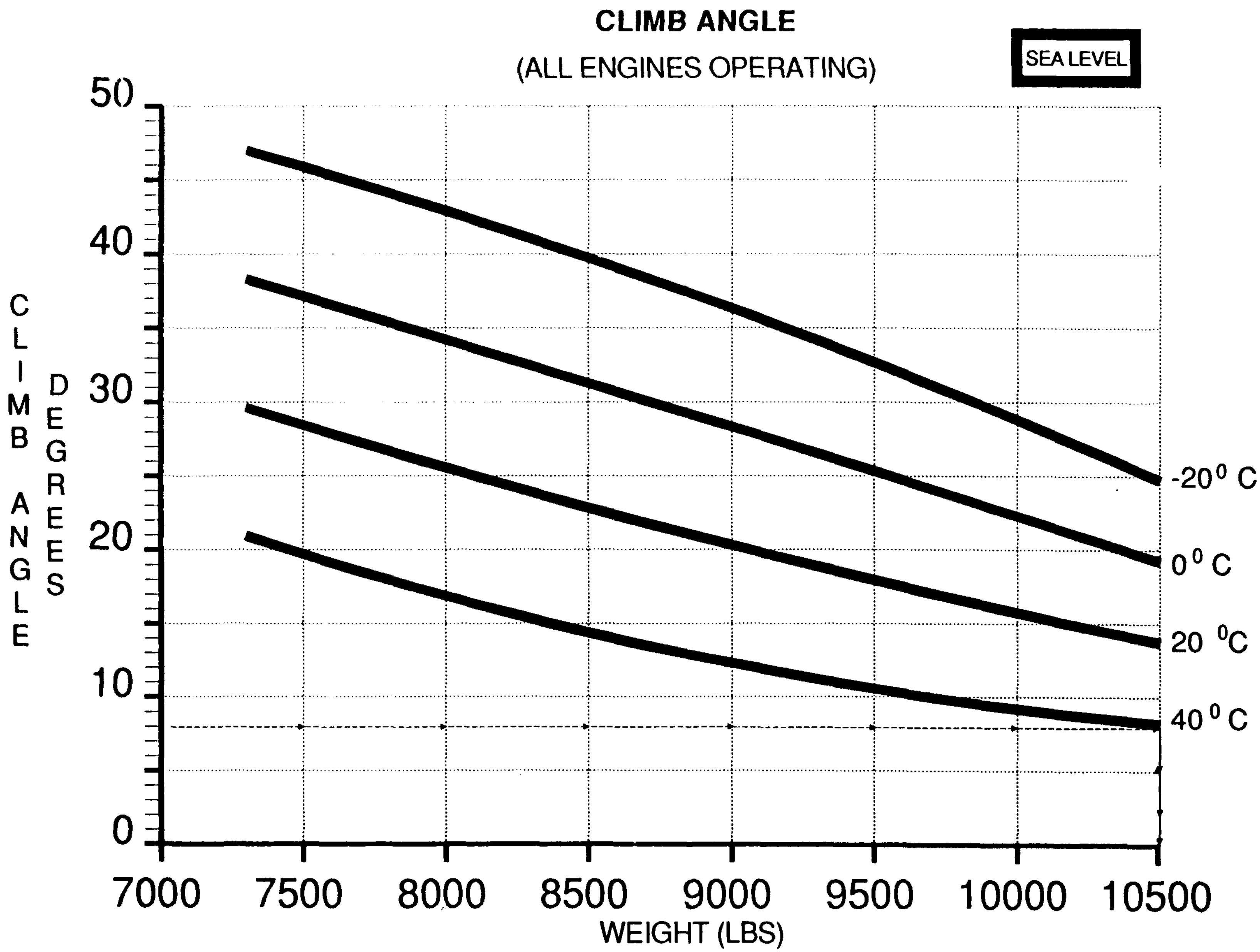


FIGURE 32 SAMPLE HELICOPTER OPERATING WEIGHT BASED ON CLIMB ANGLE

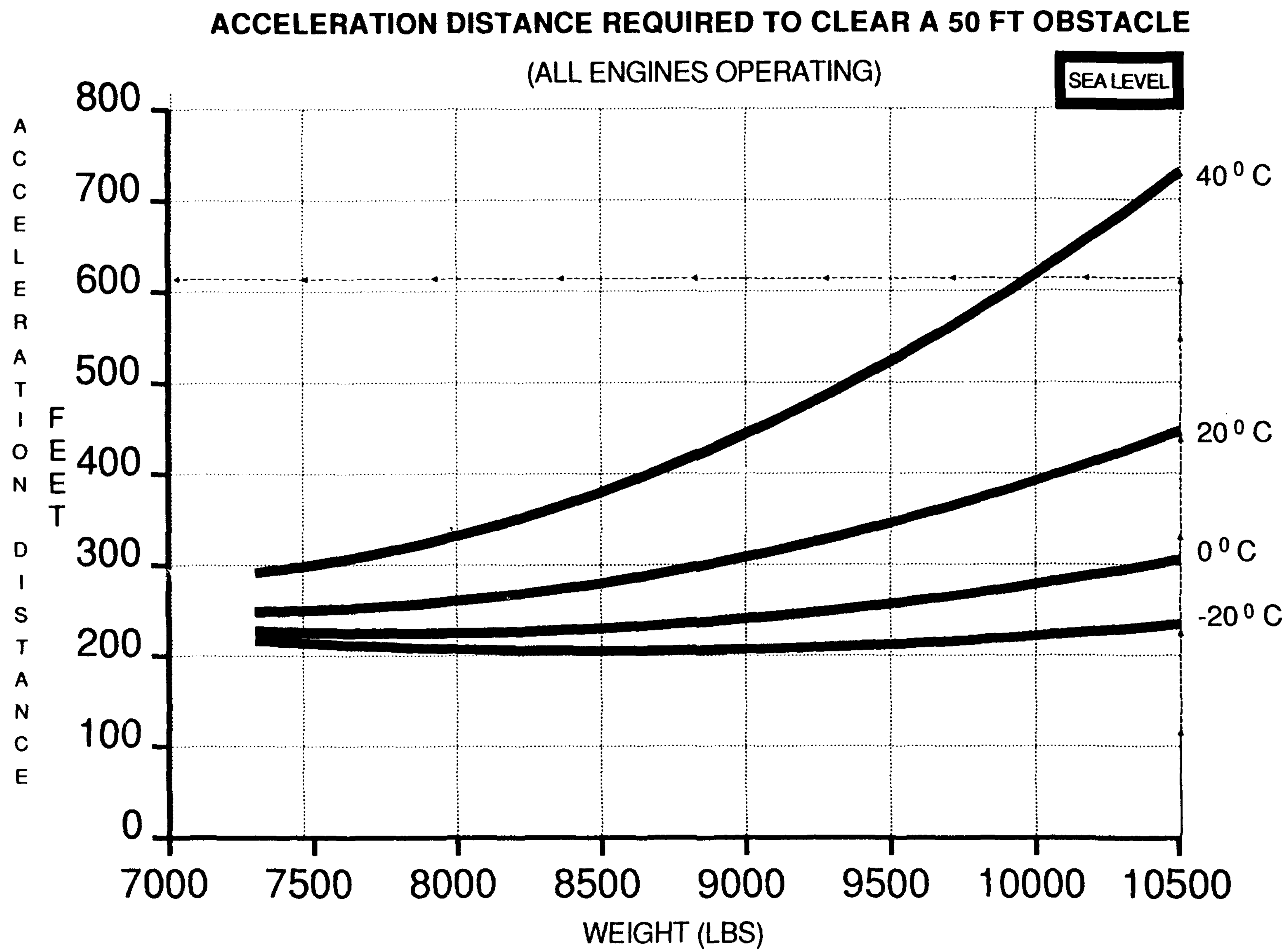


FIGURE 33 HELIPORT SITE SELECTION BASED ON ACCELERATION DISTANCE OF SAMPLE HELICOPTER

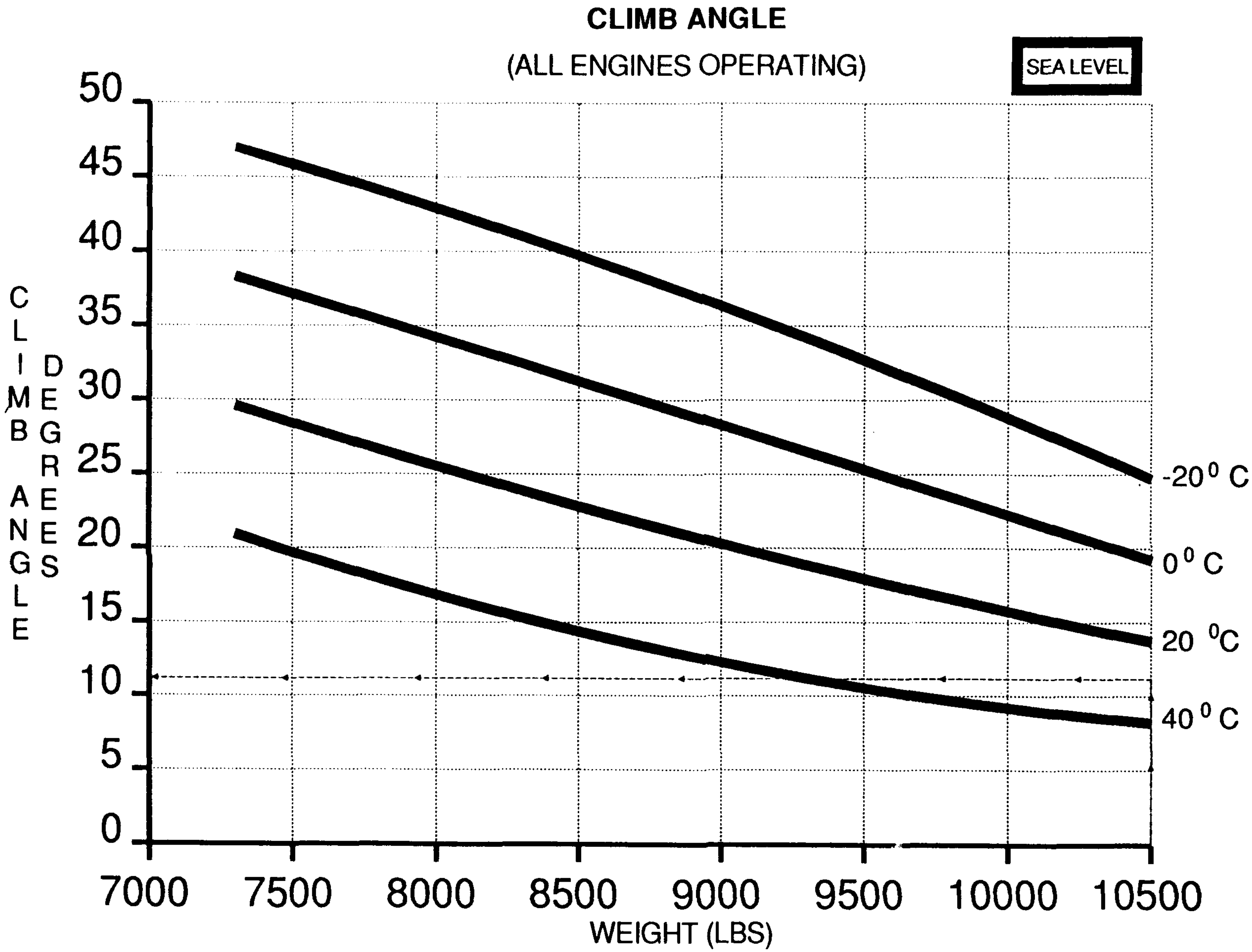


FIGURE 34 HELIPORT SITE SELECTION BASED ON CLIMB ANGLE OF SAMPLE HELICOPTER

will provide a 625 feet acceleration area and a minimum of 10.5 degrees protected airspace slope. (Bear in mind that this example has not addressed the issue of safety margins.)

5.2.4 Safety Margins Applied to the Performance-Based System

Safety margins, described in section 5.1, can be used with the performance-based heliport airspace system. The following procedures can be applied:

determine climb performance required per the methods described in section 5.2.3,

divide the performance requirement (e.g., 10.5°) by a factor of 1.2. (Safety Margin) which yields 8.7° (rounded down), and

height of obstacles would be limited by the lower figure, 8.7°, which would represent the Part 77 protected airspace surface, and performance dictated by the higher, 10.5 degrees.

When dealing with a given space and surfaces, the process is reversed.

EXAMPLE - Obstacles exist which allow a 550 feet acceleration distance followed by a climb angle of 7.125 degrees to clear existing obstacles. Multiplying 7.125 degrees times 1.2 (safety margin), yields 8.55 degrees rounded up to 8.6 degrees.

The facility directory would show a 500 feet (50 feet safety margin) acceleration area and a requirement for an 8.6 degrees climb. The Part 77 surface would be at 7.125 degrees. This would provide a margin of safety between allowable obstructions and aircraft performance capability. Either application correctly applies a slightly increased margin as the angle of climb required increases.

In cases where no acceleration distance is provided, the rising surface should begin one helicopter length from the edge of the helipad to account for the deceleration flare of arriving helicopters.

5.3 IMPLEMENTATION CONSIDERATIONS

Two methods of specifying heliport airspace requirements have been developed. A generally fixed system of requirements was presented in section 5.1. These airspace requirements change only with field elevation and are otherwise fixed. The performance-based airspace system, presented in section 5.2, is quite flexible and the airspace requirements are affected by aircraft weight, aircraft performance, and density altitude conditions prevailing at the time.

Both of the airspace systems have advantages over the current system of airspace requirements contained in the Heliport Design Advisory Circular. The proposed fixed system of requirements provides additional acceleration distance which is lacking in the current requirement. The performance-based system is very flexible and provides operational benefits for increased performance capability. Of the two proposed systems, the fixed airspace requirements is considerably easier to implement. This can be accomplished by changing the Heliport Design Advisory Circular. These changes can be accomplished in the near term time period.

The implementation of a performance-based heliport airspace system is considerably more complex and would likely take much longer to implement than would the fixed airspace system. The elements of complexity include the following:

- modifications to the helicopter flight manuals to provide performance data relating to confined heliport operations,

- modifications to some helicopter flight manuals to provide information on the changes to the HV diagrams to account for aircraft weight and density altitude,

- modifications to some flight manuals to include confined heliport departure and approach procedures, and

- development of a heliport information system that includes the measurement of, and maintenance of acceleration distance and obstruction clearance slopes available at heliports where the performance-based system is used.

Due to the complexity of the performance-based airspace system, it is considered a long term solution to the heliport airspace issue. The decision to implement such a system rests largely with industry.

6.0 HELIPORT AIRSPACE DESIGN ISSUES

The implementation of a performance-based heliport airspace system, as described in section 5.0, brings forth a number of issues for both helicopter operators and airspace regulators. The purpose of this section is to discuss these design issues and interpret the results of this study in an appropriate operational and regulatory context. These issues are considered in the development of the conclusions and recommendations of the study presented in section 7.0. The design issues are divided into economic and operational issues, safety and regulatory issues, and a discussion of these issues.

6.1 ECONOMIC AND OPERATIONAL ISSUES

There is a potential economic impact of a heliport airspace/helicopter performance system in a number of areas. These areas include:

a. Additional public-use heliports at locations with confined airspace. A number of potential heliport locations, particularly in city center areas, do not meet the current airspace requirements of the heliport design advisory circular. Because these locations do not meet FAA airspace requirements, these sites are not likely to be approved by local officials. In addition, they are not eligible for Federal funds for heliport development. If a performance-based airspace system were adopted, heliports could be built at a number of sites where this is currently difficult or impossible. In addition, these heliports could become eligible for Federal funding. Under the performance-based system, operations at these confined heliports would be available to helicopters meeting the required performance capability.

b. Operational limitations at heliports. A performance-based system could potentially limit operations at existing heliports that do not meet new heliport airspace criteria. Such limitations could conceivably occur for operators with low performance helicopters, during hot weather periods, and at heliports at high elevations.

c. Operation of more expensive helicopters. In order to circumvent the problems identified in paragraph b, operators might need to acquire helicopters with increased performance capability that would likely be more expensive.

d. Number of heliports affected. The acceleration distance and climb angles at current public use and private heliports are generally unavailable. Therefore the number of heliports that would be affected by a heliport airspace/helicopter performance system, based on these two parameters, is unknown at this time.

e. <u>Additional helicopter certification costs</u>. A requirement to document helicopter performance in the flight manual would lead to additional certification requirements which in turn would create additional costs. These costs would be borne by the helicopter operator and ultimately would be passed on to the user.

f. <u>Potentially higher liability costs</u>. A possible liability cost to both manufacturers and operators may arise if helicopter performance information is required in the flight manual. Manufacturers might be held accountable for the accuracy of the performance data, while operators might be held accountable for the proper use of the data in their operations.

6.1.1 Operator Opinions - Helicopter Performance-Based System

In addition to the economic concerns, the operators expressed opinions regarding the need for a helicopter performance-based system and confined area departure procedures. These opinions are related to:

1. <u>Training and experience</u>. The training and experience level of the pilots flying today are sufficient to ensure safe departure and approach procedures are carried out in confined areas.

2. <u>Transitory operations in the HV avoid area</u>. The technique of flying through some portion of the HV avoid area for a few seconds during confined areas takeoffs represents an acceptable level of risk to some helicopter operators. In addition some operators recognize that in some flight manuals the HV avoid area is based on maximum gross weight conditions, and, realistically for their operations, the actual size of the HV avoid area is smaller than shown in the flight manual.

6.1.2 Operator Opinions - Heliport Information System

Of the helicopter operators surveyed, many believed that a heliport information system describing heliport size, obstacles, and approach/departure paths would be of value. Specifically, the heliport data items mentioned were:

a. size, shape, and geographical representation of landing and takeoff areas;

b. acceleration distance available;

c. approach/departure paths including straight and/or curved paths with heading information for the straight segments;

d. prominent obstructions with slope gradients referenced to the helipad;

e. parking area size and location;

f. description of services; and

g. pertinent operating policies, ground information, frequencies, etc.

6.2 SAFETY AND REGULATORY ISSUES

In regard to safety, the following items are pertinent to a heliport airspace/helicopter performance system:

a. Heliport VFR protected airspace is inadequate. In particular the protected airspace in the near vicinity of the heliport is of primary concern. Currently the 8:1 slope begins at the edge of the heliport. The performance data showed a high percentage of cases where the flight profile penetrated the 8:1 slope near the helipad. From an operational viewpoint, locating the 8:1 slope at the edge of the helipad does not allow the helicopter to accelerate through the region of effective translational lift (approximately 15 to 20 knots airspeed) without penetrating the 8:1 slope surface.

b. Operations in the HV avoid area. Operations at heliports that are designed to exactly meet the current 8:1 slope requirements would require most single-engine helicopters and many twin-engine helicopters to fly through the avoid area of the HV diagram so as not to penetrate the 8:1 surface. This issue is closely related to the first issue because the current slope standard does not give the helicopter sufficient space to accelerate during a takeoff.

c. Civilian helicopter flight manuals do not contain adequate confined area procedures and performance data. In many flight manuals the takeoff procedures do not include a confined area takeoff procedure. In addition, most flight manuals only provide rate-of-climb information for V_y, the best rate-of-climb speed. Usually the only chart that gives the pilot some indication of slow speed performance is hover-out-of-ground-effect.

d. Need for a safety margin for the approach and departure slope. Helicopter performance calculations are based on meeting a 8:1 climb gradient. Man-made or natural obstacles are allowed to touch that same 8:1 slope. This hardly affords protection as the name "protected airspace" implies. There is the need for the development of a means to provide a safety margin between the protected airspace and the helicopter climb gradient.

There is a regulatory issue related to government funding of public use heliports. Applicants for Airport Improvement Program (AIP) funding must show that their planned heliport site meets the airspace requirements of FAA Advisory Circular 150-5390-2, "Heliport Design." Currently this means that sites, such as downtown locations, not meeting the 8:1 slope criteria can not be considered for Federal aid funding.

One of the objectives of this effort was to develop ways, based on site specific heliport airspace characteristics, that permit heliport designers/regulators to specify the minimum certified performance of helicopters that can operate to and from that heliport. The heliport airspace/helicopter performance system could serve as a basis to allow AIP funding for heliports that do not meet the current "Heliport Design" airspace criteria.

6.3 DISCUSSION OF ISSUES

Most of the concerns of the operators and the regulators fall along classical economics versus safety lines.

Economic Issues. The effort described herein did not address economic issues. Consequently, that phase of the heliport airspace work must be considered incomplete at this time.

Safety Issues. In conjunction with another study project on heliport safety, a brief review of National Transportation Safety Board (NTSB) helicopter accident databases for the years 1983 through 1987 was performed to get some idea of the magnitude of the safety issue. During this 5 year period, 20 accidents were found that had high density altitude during takeoff or hover reported as a contributing factor. Of these 20 accidents, 9 appeared to be directly related to helicopter performance issues, 7 did not contain enough information in the accident brief to determine if performance was an issue, and 4 were definitely unrelated to performance. In addition, the study found that 24 percent of the mishaps occurring near helicopter takeoff and landing areas (within 1 mile of the heliport, airport, or unimproved sites) involve low altitude obstacle strikes (21 percent) or insufficient climb angles (3 percent).

Based on this very brief review, helicopter performance is a significant but not major factor in the overall number of helicopter accidents. Additional information on heliport safety issues can be found in "Analysis of Helicopter Mishaps at Heliports, Airports, and Unimproved Sites," DOT/FAA/RD-90/8 (reference 20) and "Analysis of Helicopter Accident Risk Exposure at Heliports, Airports, and Unimproved Sites," DOT/FAA/RD-90/9 (reference 21).

Training and Experience. The training and experience issue was brought out in the operational survey. Over the past 20 years, the civil helicopter community has been able to take advantage of the availability of a large number of highly trained ex-military pilots. This supply of trained pilots is expected to decrease over the next several years due to reductions in military forces around the world. As with economics, training was not a subject of this effort. However, the ready supply of military trained and experienced pilots may not be available in the future.

HV Avoid Area. Operations in the avoid area of the HV diagram are treated differently in the normal category and transport category rotorcraft flight manuals. In the normal category manual, the HV diagrams are in the performance section, while the transport category manual has the HV diagrams in the performance limitations section. Clearly the intent of the regulators is to discourage operations in the HV avoid area particularly for the larger rotorcraft. Following this policy, it is therefore consistent to say that heliport airspace standards should not be constructed so as to require helicopters to fly through the HV avoid area in order to conduct operations.

7.0 CONCLUSIONS AND RECOMMENDATIONS

This section presents the conclusions and recommendations of this study and survey effort regarding a heliport airspace/helicopter performance system. These conclusions and recommendations are based on data contained in "Helicopter Physical and Performance Data," DOT/FAA/RD-90/3, "Operational Survey - VFR Heliport Approaches and Departures," DOT/FAA/RD-90/5, and the analysis contained in sections 4.0, 5.0, and 6.0 of this report. The two aforementioned reports are primarily data reports presenting, in one case, the results of a performance modeling effort based on certification data and, in the other case, a subjective survey of helicopter operators. The analysis contained in sections 4.0, 5.0, and 6.0 of this report are based on data contained in these two reports.

7.1 CONCLUSIONS

a. Helicopter Performance Classification - Helicopter performance varies with a number of operational and environmental factors including aircraft gross weight, takeoff procedures, air temperatures, and field elevation. Because performance depends on several variables, the development of a general classification system for helicopter performance is NOT feasible.

b. Heliport Classification - Heliport airspace, as it relates to helicopter performance, can be characterized by two parameters: 1) acceleration distance, and 2) climb gradient required to safely clear obstacles. These two parameters are interrelated as slope can be sacrificed to achieve a shorter acceleration distance and conversely.

c. VFR Heliport Airspace - Based on the helicopter performance profiles, the current VFR heliport protected airspace requirements are inadequate to cover the range of helicopters and operational conditions that are routinely encountered. The primary problems are the lack of an acceleration area adjacent to the helipad and the lack of a margin of safety between allowable obstructions and required helicopter performance.

d. Flight Manual Performance Data - Current civilian helicopter flight manuals do not contain sufficient performance data to adequately inform the pilot of aircraft confined area performance capability.

e. Flight Manual HV Diagrams - For four of the eight helicopters studied in "Helicopter Physical and Performance Data," the height-velocity curves (HV diagrams) did not show operational advantages for reduced aircraft weight or low density altitude conditions. These maximum condition HV diagrams unnecessarily constrain pilots from achieving better helicopter performance in confined area operations.

7.2 RECOMMENDATIONS

The study recommendations are divided into three groups: near-term heliport design recommendations, long-term heliport design recommendations, and non-design related recommendations.

7.2.1 Near-Term Heliport Design Recommendations

a. Heliport Acceleration Distance - Modify the Heliport Design Advisory Circular to provide airspace to allow departing helicopters to accelerate to the speed of effective translational lift. This should be accomplished by moving the approach/departure surface to a point that meets or exceeds the following acceleration distance formula:

$$HADR = 140+25(FE/1,000)+5(FE/1,000)^2$$

where
HADR = Heliport Acceleration Distance Required in Feet
FE = Heliport Field Elevation in Feet

HADR is measured from the center of the FATO to the approach/departure surface slope.

b. Heliport Approach/Departure Surface Slope - For heliports with field elevations of 3,000 feet or less, retain the current 8:1 slope. For heliports with field elevations exceeding 3,000 feet decrease the approach/departure surface slope to 9:1.

7.2.2 Long-Term Heliport Design Recommendations

The following five recommendations (c through g) are considered a long-term solution to the VFR heliport airspace requirement. Any or all of recommendations c through f could be implemented independently. However, recommendation g can NOT be implemented unless all of recommendations c through f are implemented. Incomplete implementation of these recommendations will not achieve the overall objective of having an airspace system that provides operational benefits for increased helicopter performance capability. The decision on whether to implement recommendations c through g largely rests with industry. This decision should be made on the basis of costs, benefits, and safety. In the absence of an industry decision on theses recommendations, the status quo should continue as modified by the near-term heliport design recommendations in section 7.2.1.

c. Flight Manual - Performance Data - Require helicopter manufacturers to include necessary performance data in the helicopter flight manuals to inform the pilot of the aircraft's capabilities for operations at confined area heliports.

d. Flight Manual - HV Diagrams - Require helicopter manufacturers to provide information in the helicopter flight manual regarding the height-velocity curve that informs the pilot of the changing nature of this information as aircraft weight and density altitude change.

e. Flight Manual - Confined Area Takeoff Procedures - Require helicopter manufacturers to include takeoff and landing procedures in the helicopter flight manuals for confined area heliport operations.

f. Provide and Publish Heliport Airspace Data - Develop procedures for measuring acceleration distance and climbout angles at heliports. Perform these measurements at public use facilities and publish the results in the airport facility directories containing this information. Encourage industry to provide similar information for private heliports. Include other useful operational data in the facility directory including heliport size, principal obstacles (azimuth, distance, and height above helipad), approach/departure paths, parking areas, services available, and operating policies.

g. Heliport VFR Imaginary Surface - Replace the single heliport imaginary surface with a surface or surfaces that give operational credit for helicopter performance. Require that the surface or surfaces provide adequate space for aircraft acceleration and provide a safety margin factor of 1.2 between allowable obstructions and aircraft climb capability. (Reference: Example presented in section 5). Revise Advisory Circular 150/5390-2 (Heliport Design) to incorporate design changes based on helicopter performance.

7.2.3 Other Recommendations

As a result of the study, the following non-design related recommendations are offered:

h. IFR Airspace/Performance Evaluation - Conduct a similar evaluative effort to assess Part 77 surfaces as they apply to IFR operations.

i. Height-Velocity Constraints - The FAA should look carefully at any heliport where the departure slope requires helicopters to fly through the avoid portion of the HV diagram. This is a particular concern if the heliport is a public facility. The FAA should consider this issue in any decision involving AIP funding of such a facility. If the FAA chooses to fund such facilities, the agency should develop a funding policy addressing this issue specifically. As a minimum, such an FAA policy should favor the funding of facilities that would require the smallest percentage of the user population to fly through the avoid portion of the HV diagram.

REFERENCES

1. Code of Federal Regulations (CFR), 14 CFR Part 77, Objects Affecting Navigable Airspace; Subpart C, Obstruction Standards; Paragraph 77.29, Airport Imaginary Surfaces for Heliports.

2. Code of Federal Regulations (CFR), 14 CFR Part 27, Airworthiness Standards: Normal Category Rotorcraft, Subpart B, Flight-Performance.

3. Code of Federal Regulations (CFR), 14 CFR Part 29, Airworthiness Standards: Transport Category Rotorcraft, Subpart B, Flight-Performance.

4. FAA AC 150/5390-2, "Heliport Design," January 4, 1988.

5. FAA AC 27-1, "Certification of Normal Category Rotorcraft," August 29, 1985.

6. FAA AC 29-2A, "Certification of Transport Category Rotorcraft," September 16, 1987.

7. DOT/FAA/RD-80/58, "Study of Helicopter Performance and Terminal Instrument Procedures," PACER Systems, Inc., June 1980.

8. DOT/FAA/RD-80/107, "Study of Heliport Airspace and Real Estate Requirements," PACER Systems, Inc., August 1980.

9. DOT/FAA/RD-81/35, "Development of a Heliport Classification Method and an Analysis of Heliport Real Estate and Airspace Requirements," PACER Systems, Inc., June 1981.

10 "Boeing Vertol 234 Flight Manual," Boeing Helicopter Company, Philadelphia, PA.

11. DOT/FAA/CT-TN/87-40, "Helicopter Visual Approach and Departure Airspace Tests," Federal Aviation Administration, August 1988.

12. DOT/FAA/DS-88/12, "Minimum Required Airspace Under Visual Flight Rules," Federal Aviation Administration, October 1988.

13. "AS 332 C Flight Manual", Aerospatiale Helicopter Corporation, Marignane, Cedex (France), October 14, 1981.

14. "Bell Model 206B Jet Ranger - III Flight Manual," Bell Helicopter Textron, Fort Worth, TX, Revision 15, November 11, 1986.

15. "MBB BO 105 Flight Manual," MBB Helicopter Corporation, West Chester, PA, Revised April 22, 1983.

16. "AS 355F Flight Manual," Aerospatiale Helicopter Corporation, Marignane, Cedex (France), November 20, 1981.

17. "Sikorsky S-76A Flight Manual," Sikorsky Aircraft, Stratford, Connecticut, November 21, 1978.

18. "Enstrom F28F Operator's Manual and FAA Approved Rotorcraft Flight Manual," The Enstrom Helicopter Corporation, Menominee, Michigan, Revised January 8, 1986.

19. "Hughes 500E, Model 369E Flight Manual," Hughes Helicopters, Inc., Culver City, California, November 23, 1982.

20. DOT/FAA/RD-90/8, "Analysis of Helicopter Mishaps at Heliports, Airports, and Unimproved Sites," Federal Aviation Administration, December 1990.

21. DOT/FAA/RD-90/9, "Analysis of Rotorcraft Accident Risk Exposure at Heliports, Airports, and Unimproved Sites," (draft technical report), Federal Aviation Administration, August 1991.

APPENDIX A
EXCERPTS FROM THE FAA HELICOPTER CERTIFICATION REGULATIONS

SELECTED PARAGRAPHS FROM:
14 CFR PART 27
14 CFR PART 29

Part 27 - Normal Category Rotorcraft

Subpart A - General

27.1 Applicability.

(a) This part prescribes airworthiness standards for the issue of type certificates, and changes to those certificates, for normal category rotorcraft with maximum weights of 6,000 pounds or less.
(b) Each person who applies under Part 21 for such a certificate or change must shown compliance with the applicable requirements of this part.

Subpart B - Flight

Performance

27.45 General.

(a) Unless otherwise prescribed, the performance requirements of this subpart must be met for still air and a standard atmosphere.
(b) The performance must correspond to the engine power available under the particular ambient atmospheric conditions, the particular flight condition, and the relative humidity specified in paragraphs (d) and (e) of this section, as appropriate.
(c) The available power must correspond to engine power, not exceeding the approved power, less -
(1) Installation losses; and
(2) The power absorbed by the accessories and services appropriate to the particular ambient atmospheric conditions and the particular flight condition.
(d) For reciprocating engine-powered rotorcraft, the performance, as affected by engine power, must be based on a relative humidity of 80 percent in a standard atmosphere.
(e) For turbine engine-powered rotorcraft, the performance, as affected by engine power, must be based on a relative humidity of -
(1) 80 percent, at and below standard temperature; and
(2) 34 percent, at an above standard temperature plus 50 degrees F. Between these two temperatures, the relative humidity must vary linearly.
(f) For turbine-engine-powered rotorcraft, a means must be provided to permit the pilot to determine prior to takeoff that each engine is capable of developing the power necessary to achieve the applicable rotorcraft performance prescribed in this subpart.

27.51 Takeoff.

(a) The takeoff, with takeoff power and r.p.m., and with the extreme forward center of gravity -

(1) May not require exceptional piloting skill or exceptionally favorable conditions; and

(2) Must be made in such a manner that a landing can be made safely at any point along the flight path if an engine fails.

(b) Paragraph (a) of this section must be met throughout the ranges of -

(1) Altitude, from standard sea level conditions to the maximum altitude capability of the rotorcraft, or 7,000 feet, whichever is less; and

(2) Weight, from the maximum weight (at sea level) to each lesser weight selected by the applicant for each altitude covered by paragraph (b)(1) of this section.

27.67 Climb: one engine inoperative.

For multiengine helicopters, the steady rate of climb (or descent), at Vy (or at the speed for minimum rate of descent), must be determined with -

(a) Maximum weight;

(b) One engine inoperative; and

(c) Maximum continuous power on the other engines and (for helicopters for with certification for the use of 30-minute power is requested) at 30-minute power.

27.71 Glide performance.

For single-engine helicopters and multi-engine helicopters that do not meet the Category A engine isolation requirements of Part 29 of this chapter, the minimum rate of descent airspeed and the best angle-of-glide airspeed must be determined in autorotation at -

(a) Maximum weight; and

(b) Rotor speed(s) selected by the applicant.

Part 29 - Transport Category Rotorcraft

Subpart A - General

29.1 Applicability.

(a) This part prescribes airworthiness standards for the issue of type certificates, and changes to those certificates, for transport category rotorcraft.

(b) Transport category rotorcraft must be certificated in accordance with either the Category A or Category B requirements of this part. A multiengine rotorcraft may be type certificated as both Category A and Category B with appropriate and different operating limitations for each category.

(c) Rotorcraft with a maximum weight greater than 20,000 pounds and 10 or more passenger seats must be type certificated as Category A rotorcraft.

(d) Rotorcraft with a maximum weight greater than 20,000 pounds and nine or less passenger seats may be type certificated as Category B rotorcraft provided the Category A reauirements of Subparts C, D, E, and F of this part are met.

(e) Rotorcraft with a maximum weight of 20,000 pounds or less but with 10 or more passenger seats may be type certificated as Category B rotorcraft provided the Category A requirements of 29.67(a)(2), 29.79, 29.1517, and of Subparts C, D, E, and F of this part are met.

(f) Rotorcraft with a maximum weight of 20,000 pounds r less and nine or less passenger seats may be type certificated as Category B rotorcraft.

(g) Each person who applies under Part 21 for a certificate or change described in paragraphs (a) through (f) of this section must show compliance with the applicable requirements of this part.

Subpart B - Flight

Performance

29.45 General.

(a) The performance prescribed in this subpart must be determined -

(1) With normal piloting skill and;

(2) Without exceptionally favorable conditions.

(b) Compliance with the performance requirements of this subpart must be shown -

(1) For still air at sea level with a standard atmosphere and;

(2) For the approved range of atmospheric variables.

(c) The available power must correspond to engine power, not exceeding the approved power, less -

(1) Installation losses; and

(2) The power absorbed by the accessories and services at the values for which certification is requested and approved.

(d) For reciprocating engine-powered rotorcraft, the performance, as affected by engine power, must be based on a relative humidity of 80 percent in a standard atmosphere.

(e) For turbine engine-powered rotorcraft, the performance, as affected by engine power, must be based on a relative humidity of -

(1) 80 percent, at and below standard temperature; and

(2) 34 percent, at and above standard temperature plus 50 degrees F.

Between these two temperatures, the relative humidity must vary linearly.

(f) For turbine-engine-power rotorcraft, a means must be provided to permit the pilot to determine prior to takeoff that each engine is capable of developing the power necessary to achieve the applicable rotorcraft performance prescribed in this subpart.

29.51 Takeoff data: general.

(a) The takeoff data required by 29.53(b), 29.59, 29.63, and 29.67(a)(1) and (2) must be determined-

(1) At each weight, altitude, and temperature selected by the applicant; and

(2) With the operating engines within approved operating limitations.

(b) Takeoff data must-

(1) Be determined on a smooth, dry, hard surface; and,

(2) Be corrected to assume a level takeoff surface.

(c) No takeoff made to determine the data required by this section may require exceptional piloting skill or alertness, or exceptionally favorable conditions.

29.53 Takeoff: Category A.

(a) General. The takeoff performance must be determined and scheduled so that, if one engine fails at any time after the start of takeoff, the rotorcraft can-

(1) Return to, and stop safely on, the takeoff area; or

(2) Continue the takeoff and climbout, and attain a configuration and airspeed allowing compliance with 29.67(a)(2).

(b) Critical decision point. The critical decision point must be a combination of height and speed selected by the applicant in establishing the flight paths under 29.59. The critical decision point must be obtained so as to avoid the critical areas of the limiting height-speed envelope established under 29.79.

29.59 Takeoff path: Category A.

(a) The takeoff climb-out path, and the rejected takeoff path must be established so that the takeoff, climb-out and rejected takeoff are accomplished with a safe, smooth transition between each stage of the maneuver. The takeoff may be begun in any manner if-

(1) The takeoff surface is defined; and

(2) Adequate safeguards are maintained to ensure proper center of gravity and control positions.

(b) The rejected takeoff path must be established with not more than takeoff power on each engine from the start of takeoff to the critical decision point, at which point it is assumed that the critical engine becomes inoperative and that the rotorcraft is brought to a safe stop.

(c) The takeoff climbout path must be established with not more than takeoff power on each engine from the start of takeoff to the critical decision point, at which point it is assumed that the critical engine becomes inoperative and remains inoperative for the rest of the takeoff. The rotorcraft must be accelerated to achieve the takeoff safety speed and a height of 35 feet above the ground or greater and the climbout must be made -

(1) At not less than the takeoff safety speed used in meeting the rate of climb requirements of 29.67(a)(1); and

(2) So that the airspeed and configuration used in meeting the climb requirement of 29.67(a)(2) are attained.

29.67 Climb: one engine inoperative.

(a) For Category A rotorcraft, the following apply:

(1) The steady rate of climb without ground effect must be at least 100 feet per minute for each weight, altitude, and temperature for which takeoff and landing data are to be scheduled with -

(i) The critical engine inoperative and the remaining engines within approved operating limitations;

(ii) The most unfavorable center of gravity;

(iii) The landing gear extended;

(iv) The takeoff safety speed selected by the applicant; and

(v) Cowl flaps or other means of controlling the engine-cooling air supply in the position that provides adequate cooling at the temperatures and altitudes for which certification is requested.

(2) The steady rate of climb without ground effect must be at least 150 feet per minute 1,000 feet above the takeoff and landing surfaces for each weight, altitude, and temperature for which takeoff and landing data are to be scheduled, with -

(i) The critical engine inoperative and the remaining engines at maximum continuous power, or (for helicopters for which certification for the use of 30-minute power, is requested), at 30-minute power;

(ii) The most unfavorable center of gravity;

(iii) The landing gear retracted;

(iv) A speed selected by the applicant; and

(v) Cowl flaps, or other means of controlling the engine-cooling air supply in the position that provides adequate cooling at the temperatures and altitudes for which certification is requested.

(3) The steady rate of climb, in feet per minute, at any altitude at which the rotorcraft is expected to operate, and at any weight within the range of weights for which certification is requested, must be determined with -

(i) The critical engine inoperative, and the remaining engines at maximum continuous power and (for helicopters for which certification for the use of 30-minute power is requested), at 30-minute power;

(ii) The must unfavorable center of gravity;

(iii) The landing gear retracted;

(iv) The speed selected by the applicant; and

(v) Cowl flaps, or other means of controlling the engine-cooling air supply in the position that provides adequate cooling at the temperatures and altitudes for which certification is requested.

(b) For multiengine category B helicopters meeting the requirements for category A in 29.79, the steady rate of climb (or descent) must be determined at the speed for the best rate of climb (or minimum rate of descent) with one engine inoperative and the remaining engines at maximum continuous power and (for helicopters for which certification for the use of 30-minute power is requested), at 30-minute power.

APPENDIX B
HEIGHT VELOCITY DIAGRAMS

Hughes Helicopters, Inc.
Hughes 500E Helicopter (Model 369E)

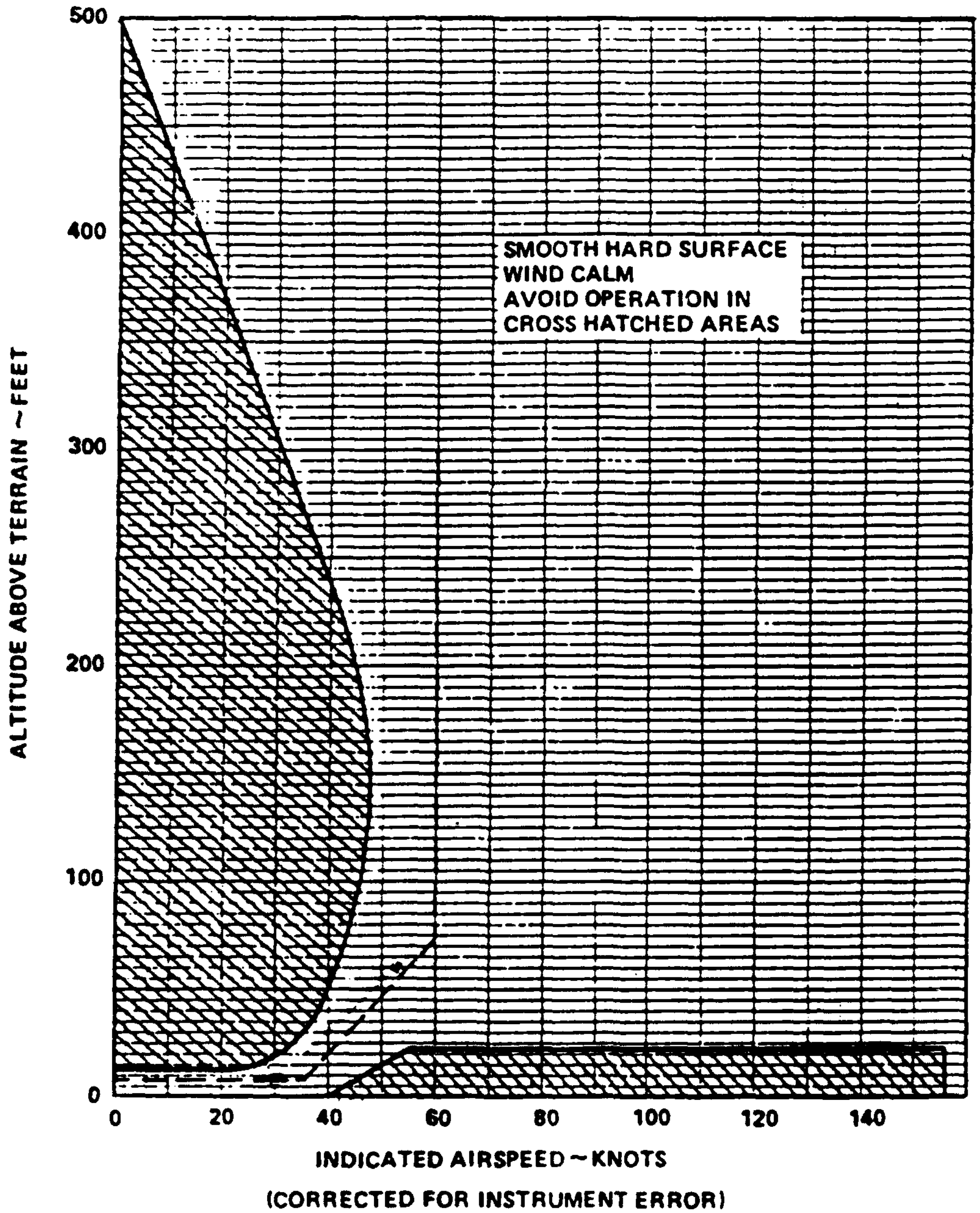


FIGURE B-1 HEIGHT VELOCITY DIAGRAM - HUGHES 500E

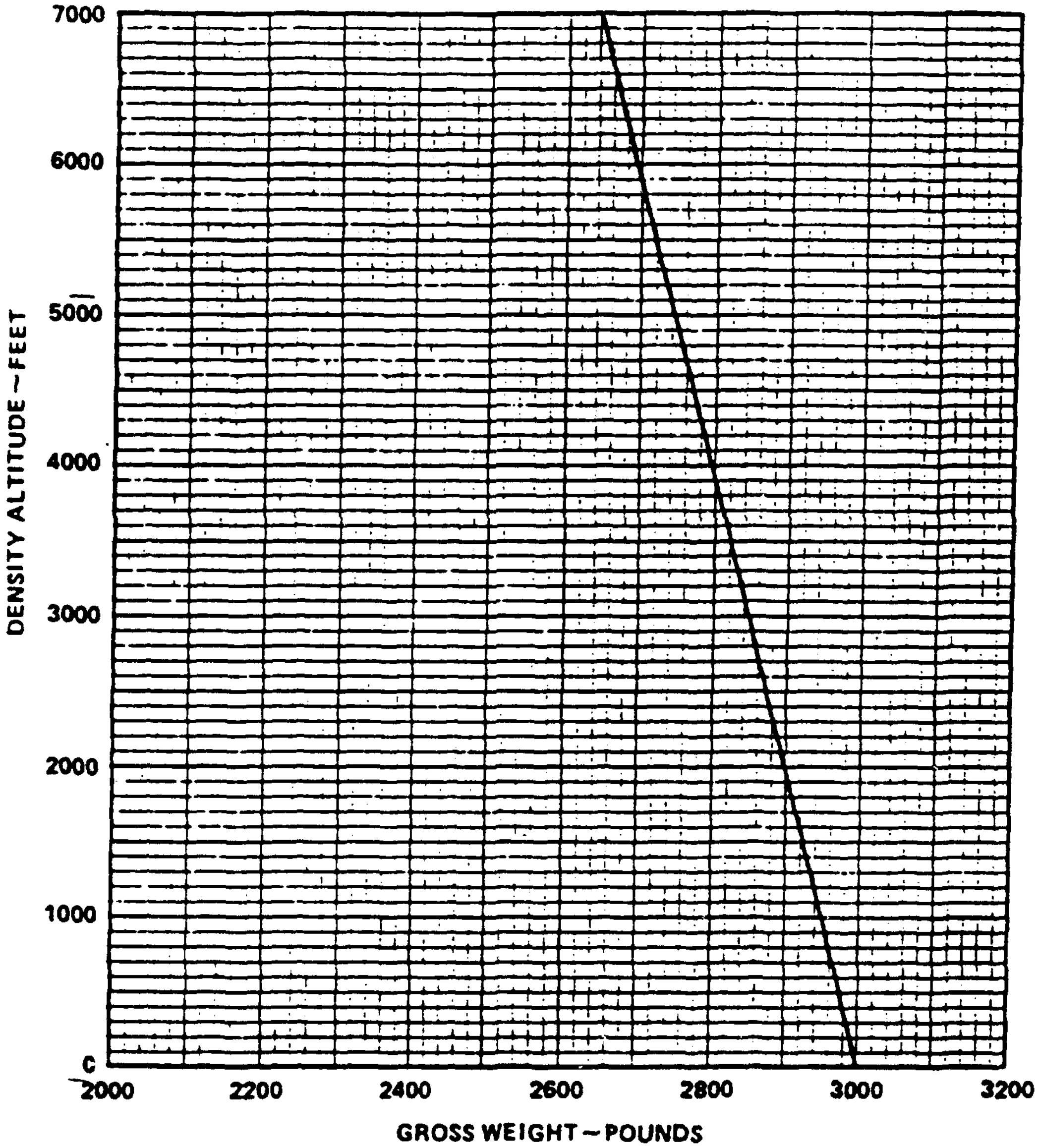


FIGURE B-2 GROSS WEIGHT LIMITS FOR HEIGHT VELOCITY DIAGRAM - HUGHES 500E

HEIGHT VELOCITY DIAGRAM

2350 LBS GROSS WEIGHT

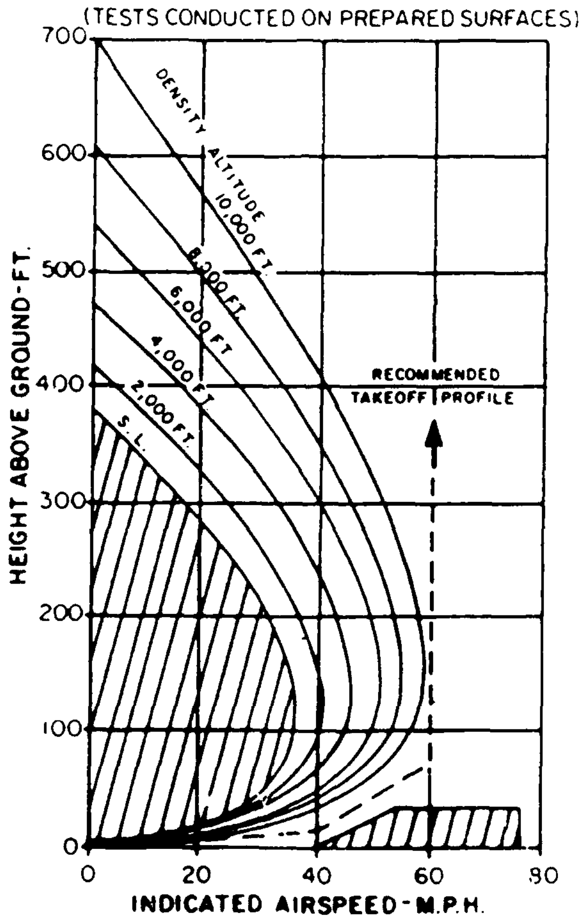


FIGURE B-3 HEIGHT VELOCITY DIAGRAM - ENSTROM F28F

EFFECT OF LOADING ON
CHOICE OF H-V ENVELOPE

The H-V curves presented in Figure 5.5 are valid for operations at 2350 lb gross weight for the specific density altitude conditions presented. For operation at other than 2350 lb gross weight, determine the proper H-V curve to be used for the intended gross weight and density altitude for the flight from the curves presented in Figure 5.6 below. For operations above 2500 lb gross weight, use the H-V curves presented in Figure 5.7 in place of Figures 5.6 and 5.5.

Example: (1) A gross weight of 2000 lbs and 3900 ft H_d would allow the use of the sea level envelope.

(2) A gross weight of 2200 lbs and 4500 ft H_d would require a 2800 ft curve. to be conservative, use the next higher curve, 4000 ft.

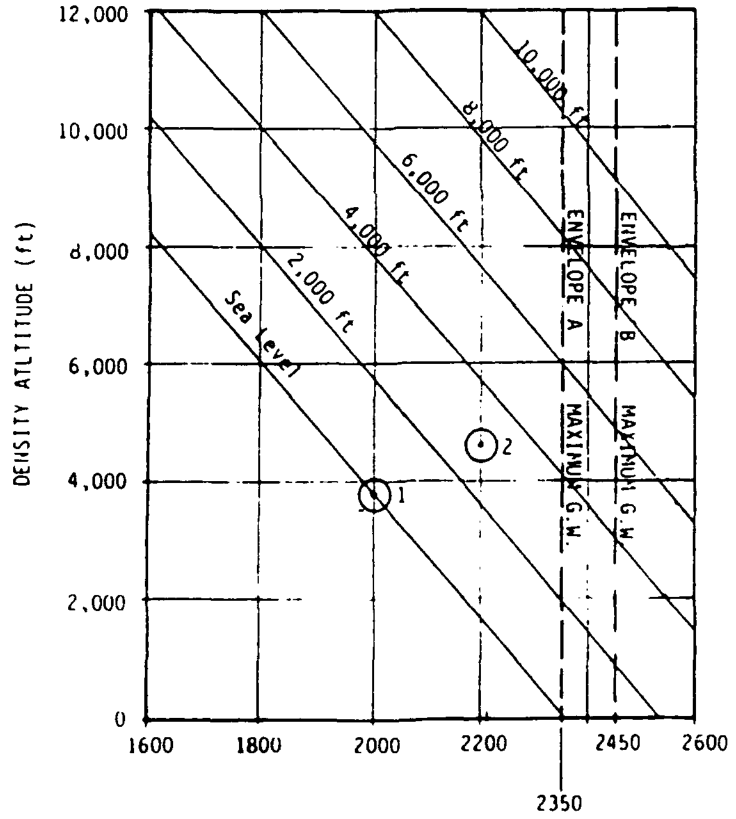


FIGURE B-4 EFFECT OF LOADING ON CHOICE OF H-V ENVELOPE - F28F

HEIGHT VELOCITY DIAGRAM

2600 LBS GROSS WEIGHT

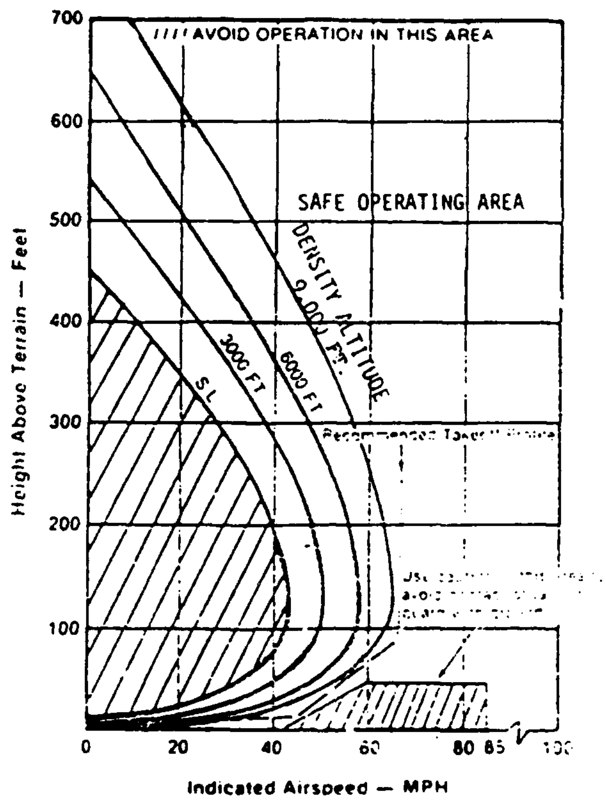


FIGURE B-5 HEIGHT VELOCITY DIAGRAM - F28F

HOW TO USE THE FIGURE RELATED TO HEIGHT - VELOCITY

For an all-up weight above 2150 kg (4720 lb), the aera to be avoided is defined by the three points A, B and C.

Determining point B

Point B is fixed and located at a 50 ft (15 m) height for a 30 kt (56 km/h - 35 MPH) velocity.

Determining points C and A

Points C and A are determined at a zero velocity and depend upon the actual weight and pressure - altitude.

- From the pressure - altitude (1), read across to the actual weight (2)
- Read vertically down to curves (3) and (4)
- From (3) and (4) read across to the height of points C and A

NOTE : When points C and A coincide, there is no unsafe area any longer
Example : 2000 ft and 2300 kg

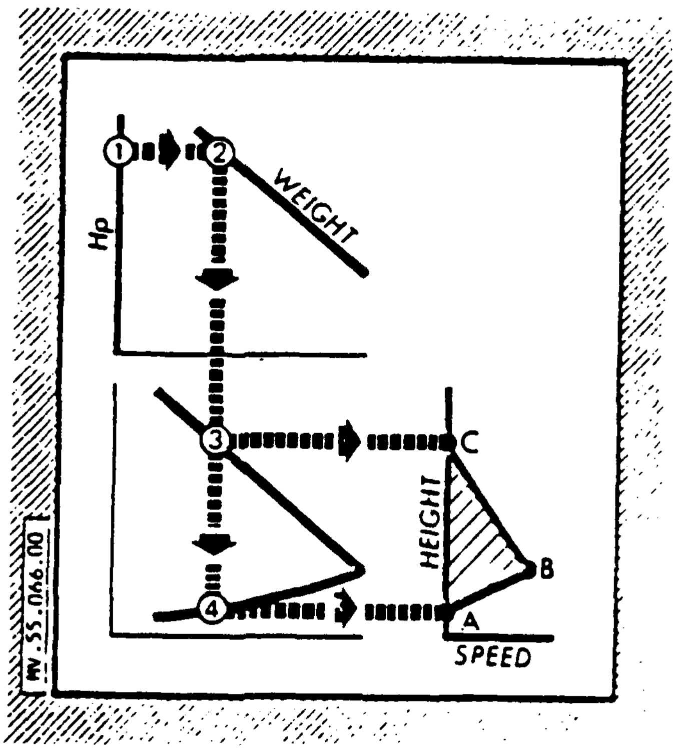


FIGURE B-6 DETERMINING THE HEIGHT VELOCITY - AS 355F

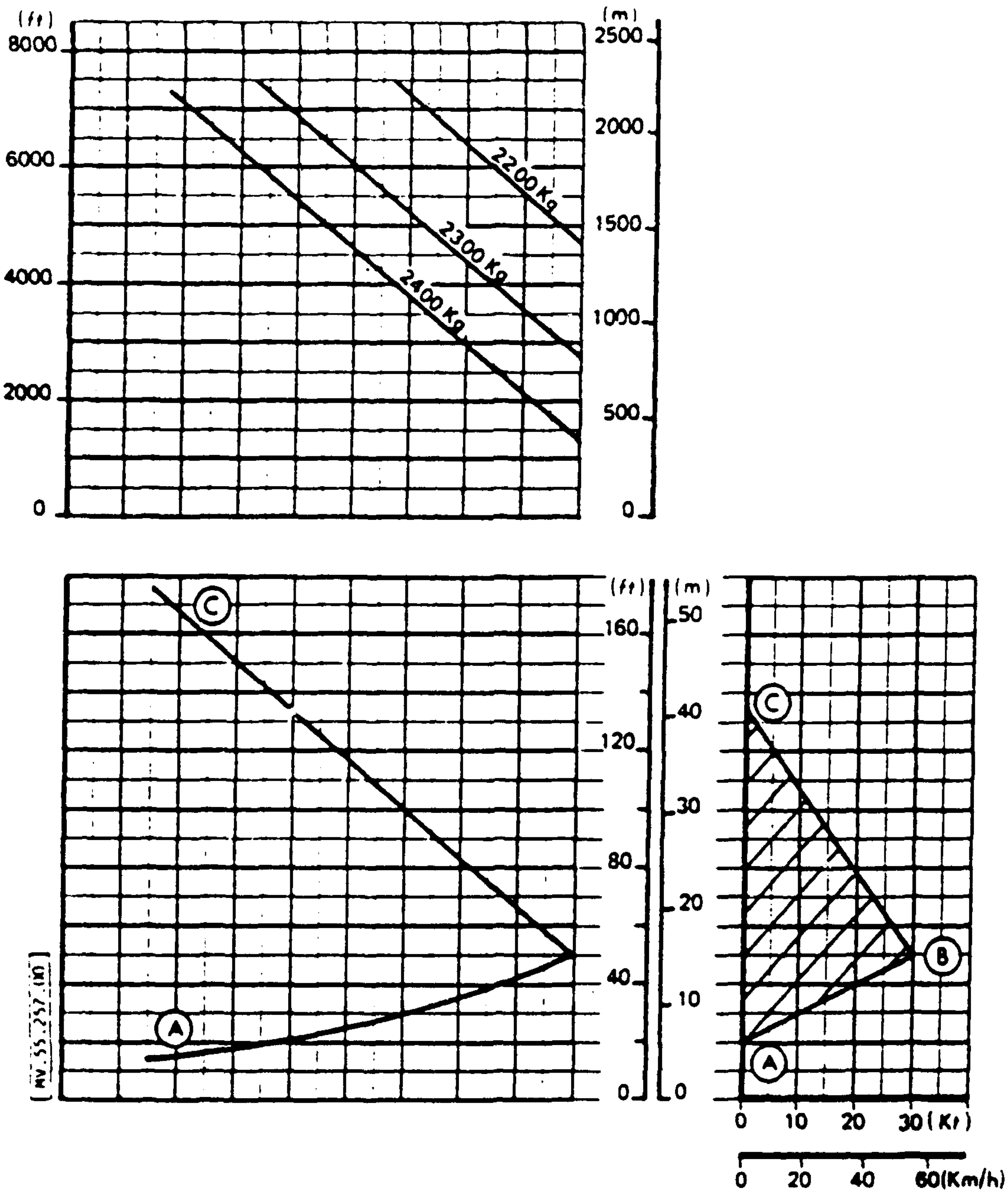


FIGURE B-6 DETERMINING THE HEIGHT VELOCITY DIAGRAM - AS 355F (Continued)

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