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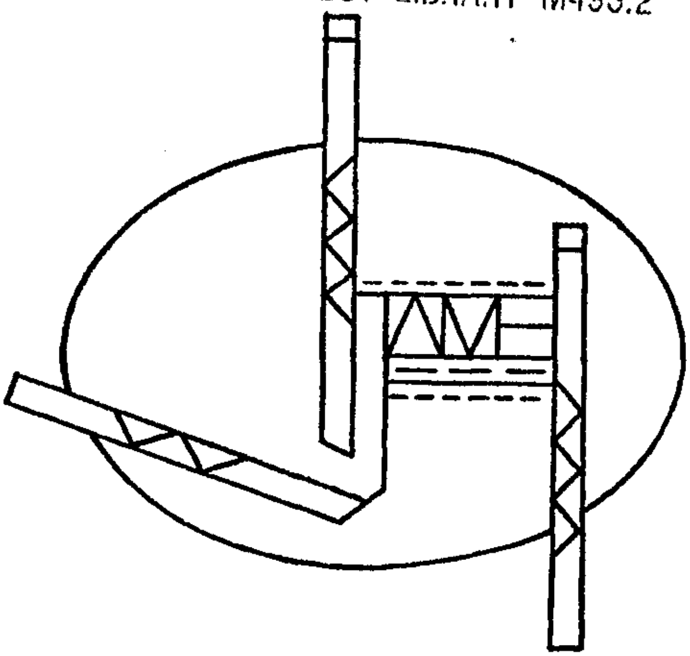
U.S. Department of Transportation
Federal Aviation Administration

Airport Design Standards-Transport Airports

REPRINT INCORPORATES CHANGE 1

AC: 150/5300-12
Date: 2/28/83

Advisory Circular



U.S. Department of Transportation
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Advisory Circular

Subject: AIRPORT DESIGN STANDARDS--TRANSPORT AIRPORTS
Date: 2/28/83
Initiated by: AAS-100
AC No: 150/5300-12
Change:

1. PURPOSE. This advisory circular presents the Federal Aviation Administration's (FAA) standards for the development of transport airports. A transport airport accommodates, or is expected to accommodate, airplanes in Aircraft Approach Categories C or D, i.e., airplanes with approach speeds of 121 knots or greater.

2. CANCELLATION. This advisory circular (AC) cancels the following publications:

a. AC 150/5300-6A, Airport Design Standards--General Aviation Airports--Basic and General Transport, dated February 24, 1981.

b. AC 150/5320-13, Locating Runway Approach Thresholds, dated March 1, 1978.

c. AC 150/5325-2C, Airport Design Standards--Airports Served by Air Carriers--Surface Gradient and Line-of-Sight, dated February 6, 1975.

d. AC 150/5325-6A, Airport Design Standards--Effects and Treatment of Jet Blast, dated July 13, 1972.

e. AC 150/5335-1A, Airport Design Standards--Airports Served by Air Carriers--Taxiways, dated May 15, 1970.

f. AC 150/5335-3, Airport Design Standards--Airports Served by Air Carriers--Bridges and Tunnels on Airports, dated April 19, 1971.

g. AC 150/5335-4, Airport Design Standards--Airports Served by Air Carriers--Runway Geometrics, dated July 21, 1975.

Leonard E. Mudd

LEONARD E. MUDD
Director, Office of Airport Standards

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CHAPTER 1. INTRODUCTION

1. GENERAL. Section 103 of the Federal Aviation Act of 1958 states in part, "In the exercise and performance of his power and duties under this Act the Secretary of Transportation shall consider the following, among other things, as being in the public interest: (a) The regulation of air commerce in such manner as to best promote its development and safety and fulfill the requirements of defense; (b) The promotion, encouragement, and development of civil aeronautics . . . ." This public charge to promote, encourage, and develop civil aeronautics carries with it the need to foster a national system of safe and efficient airports. The Federal Aviation Administration (FAA) presents the standards and recommendations in this publication to guide interested persons in the development of safe and efficient airports.

a. Companion Document. The standards, recommendations, and guidance material in Advisory Circular (AC) 150/5300-4, Utility Airports--Air Access to National Transportation, current edition, define an airport suitable for the less demanding Aircraft Approach Category A and B airplanes, i. e., airplanes with approach speeds of less than 121 knots. For convenience, appendix 11 of AC 150/5300-4 contains a list of current aircraft arranged by aircraft manufacturer, approach speed, and wingspan. The definitions, standards, recommendations, and guidance material contained in AC 150/5300-4 which are made part of this publication by reference include: Chapter 1, Introduction; Chapter 3, Wind Analysis and Runway Orientation; Chapter 5, Land Consideration, Obstruction Restriction, and Airport Hazard Removal; Chapter 6, Site Investigation; Chapter 10, Buildings and Hangars; Chapter 11, Marking, Lighting, and Visual Aids; Chapter 12, Airport Paving; Chapter 13, Operation, Maintenance, and Administration; Chapter 14, Airport Layout Plans; Chapter 15, Construction Plans; Appendix 2, Preliminary Engineering Checklist for Field Investigation; Appendix 3, Analyzing Wind Data; Appendix 4, Typical Set of Plans; Appendix 6, Runway Clear Zone Dimensions; Appendix 7, Airport Reference Point (ARP); Appendix 8, Compass Calibration Pad; Appendix 9, Locating Runway Approach Thresholds; Appendix 11, Current Aircraft Arranged by Aircraft Manufacturer, Approach Speed, and Wingspan; and, Appendix 12, Index.

b. Metric Units. Airport authorities may design their facilities either in the metric or in the U.S. customary system of units. In general, when additions or expansions are planned to an existing facility, such as a runway, taxiway, or apron, either system of units may be used. When a new facility is to be built, the use of metric units is encouraged. The policy for the use of and conversion to metric units is contained in chapter 14 of AC 150/5300-4.

c. Technical Assistance. Technical assistance in the planning, design, construction, maintenance, and modernization of airports may be obtained from state aviation officials, FAA airport engineers, and experienced engineering firms. The addresses for all FAA Regional Airport Divisions and Airports District/Field Offices are contained in AC 150/5000-3, Address List for Regional Airports Divisions and Airports District/Field Offices, current edition.

2. AIRPORT STANDARDS. The FAA uses the standards and recommendations in this publication to provide technical guidance for the design of safe and efficient airports; to evaluate the effect of the proposed construction, alteration, activation, and deactivation of airports on the national airport system; and, to evaluate the effect of the proposed construction and alteration of objects on air navigation. These standards and recommendations complement but are not intended to take precedence over aircraft operating rules and procedures.

3. NOTICE REQUIREMENTS. The requirements for providing notice to the FAA of construction activities on or near an airport are stated in Parts 77, Objects Affecting Navigable Airspace, and 157, Notice of Construction, Alteration, Activation, and Deactivation of Airports, of the Federal Aviation Regulations.

a. FAR Part 77. Section 307(a) of the Federal Aviation Act of 1958 states, in part, "The Secretary of Transportation is authorized and directed to develop plans for and formulate policy with respect to the use of the navigable airspace; and assign by rule, regulation, or order the use of the navigable airspace under such terms, conditions, and limitations as he may deem necessary in order to insure the safety of aircraft and the efficient utilization of such airspace. . . ." The FAA has published FAR Part 77 to carry out this responsibility. AC 70/7460-2, Proposed Construction or Alteration of Objects That May Affect the Navigable Airspace, current edition, advises persons proposing to erect or alter an on- or off-airport object which may affect the navigable airspace of the requirement to submit a notice to the FAA. That advisory circular also lists the addresses and geographic jurisdictions of the FAA offices concerned with FAR Part 77 actions.

b. FAR Part 157. Section 309 of the Federal Aviation Act of 1958 states, "In order to assure conformity to plans and policies for, and allocations of, airspace by the Secretary of Transportation under section 307 of this Act, no airport or landing area not involving expenditure of Federal funds shall be established, or constructed, or any runway layout substantially altered unless reasonable prior notice thereof is given the Secretary of Transportation, pursuant to regulations prescribed by him, so that he may advise as to the effects of such construction on the use of airspace by aircraft." The FAA has published FAR Part 157 to carry out this responsibility. AC 70-2, Airspace Utilization Considerations in the Proposed Construction, Alteration, Activation, and Deactivation of Airports, current edition, points out the importance of giving notice and describes some of the airspace utilization consideration factors. AC 70-2 also lists the addresses and geographic jurisdictions of the FAA offices concerned with FAR Part 157 actions.

4. AIRPORT ENCROACHMENT PROTECTION. Good planning prompts airport authorities to protect their airports against such off-airport construction and alteration which may have a substantial adverse effect on aeronautical operations. Detailed guidance on airport encroachment protection is contained in: AC 150/5050-6, Airport-Land Use Compatibility Planning; AC 150/5190-4, A Model Zoning Ordinance to Limit Height of Objects Around Airports; and, AC 150/5320-11, Runway Categorization--Aeronautical Studies--Airport Owners' Responsibilities, current editions.

5. AIRPLANE DESIGN GROUPS (PHYSICAL CHARACTERISTICS). In designing the airport elements to accommodate an airplane within an Aircraft Approach Category, consideration of the physical characteristics of the airplane is required. An airplane's wingspan is the principal physical characteristic affecting airport design. Since the magnitude of other airplane physical characteristics correlates with the wingspan, the FAA has developed an airplane design group concept which groups airplanes by wingspan and relates airport design standards to these airplane design groups.

a. To assist the airport designer in selecting the proper airplane design group, a list of current aircraft, arranged by aircraft manufacturer, approach speed, and wingspan is presented in AC 150/5300-4, appendix 11.

b. Appendix 1, herein, explains the relationship between airplane physical characteristics and the dimensions of airport elements. The rationale presented may be used, on a case-by-case basis, to adapt FAA airport design standards and recommendations, primarily at existing airports, to meet unusual local conditions or to accommodate a specific airplane within an airplane design group.

Table 1-1. Airplane design groups

AIRPLANE DESIGN GROUP	WINGSPAN
I	Up to but not including 49 feet (15 m)
II	49 feet (15 m) up to but not including 79 feet (24 m)
III	79 feet (24 m) up to but not including 118 feet (36 m)
IV	118 feet (36 m) up to but not including 171 feet (52 m)
V	171 feet (52 m) up to but not including 197 feet (60 m)
VI	197 feet (60 m) up to but not including 262 feet (80 m)

CHAPTER 2. AIRPORT GEOMETRY

6. INTRODUCTION. This chapter presents the airport geometric standards and recommendations to ensure the safety of aeronautical operations, as well as the economy, efficiency, and longevity of each airport.

7. PRINCIPLES OF APPLICATION.

a. Need to Plan. The significance of the interrelationship of the various airport features cannot be overemphasized. It is important that airport authorities look to both the present and potential functions of the airport.

b. Airport Function. The airport's immediate and long range functions are defined in coordination with the users of the airport to satisfy the needs of the community and traveling public. This involves determining the following:

(1) The types, sizes, and operating weights of the airplanes expected at the airport;

(2) The meterological conditions in which operations will be conducted;

(3) The volume and mix of operations to be accommodated;

(4) The possible constraints on navigable airspace; and,

(5) The environmental and compatible land-use considerations associated with topography, residential development, schools, churches, hospitals, sites of public assembly, and the like.

c. Airport Master Plan. Once the function of the airport is defined, the airport geometry can be determined by the use of the standards and recommendations in this publication and depicted on the airport master plan. Guidance on the preparation of individual airport master plans is found in AC 150/5070-6, Airport Master Plans, current edition, and AC 150/5300-4.

d. Airport Design. The airport needs to be designed to the standards associated with the most demanding airplane(s) to be accommodated. The most demanding airplane for runway length may not be the same airplane used for determining the appropriate airplane design group or for pavement strength. If the airport is to be comprised of two or more runways, it is highly desirable to design all airport elements to the standards associated with the most demanding airplane(s). However, it may be more practical for some of the airport elements, e.g., a secondary runway and its associated taxiway, to be designed to the standards associated with the less demanding airplanes which will use the airport. The design standards presented in AC 150/5300-4 may be used for airport elements specifically designed to accommodate airplanes in Aircraft Approach Categories A and B.

8. RUNWAY LOCATION AND ORIENTATION. Runway location and orientation are paramount to aviation safety, environmental impact, and airport efficiency and economics. The weight and degree of concern given to each of the following factors depend, in part, on: the airplanes expected to use each runway; the meteorological conditions to be accommodated; the surrounding environment; and, the volume of air traffic expected on each runway.

a. Wind. Appendix 3 of AC 150/5300-4 provides information on wind data analysis for airport planning and design. Such an analysis should consider the wind by time of day, velocity, and direction as related to the existing and forecasted operations. Also, it should be determined whether a runway with a high percentage of wind coverage is usable during instrument meteorological conditions. For further discussion, see paragraph 9.

b. Airspace Availability. Existing and planned instrument approach procedures, missed approach procedures, departure procedures, control zones, special use airspace, restricted airspace, and other traffic patterns, should be carefully analyzed in airport layouts and locations.

c. Environmental Factors. Environmental studies should be made to ensure that runway development will be as compatible as possible with the airport environs. These studies should include analyses of the impact upon air and water quality, wildlife, existing and proposed land use, and historical/archeological factors.

d. Obstructions to Air Navigation. An obstruction survey should be conducted to identify those objects which might affect airplane operations. Approaches free of obstructions are desirable and encouraged, but, as a minimum, runways require a location which will ensure that the approach areas associated with the ultimate development of the airport can be maintained clear of airport hazards. Refer to AC 150/5300-4 for discussion on airport hazards.

e. Land Consideration. The location and size of the site, with respect to the airport's geometry, should be such that all of the planned airport elements, including the runway clear zone, are located on airport property.

f. Topography. Topography affects the amount of grading and drainage work required to construct a runway. In determining runway orientation, the costs of both the initial work and ultimate airport development should be considered. For guidance, see chapter 5 and AC 150/5320-5, Airport Drainage, current edition.

g. Airport Facilities. The relative position of a runway to associated facilities such as other runways, the terminal, hangar areas, taxiways, aprons, fire stations, navigational aids (navaids), and the airport traffic control tower, will affect the safety and efficiency of operations at the airport. A general overview of the siting requirements for navaids located on or in close proximity to the airport, including references to other appropriate technical publications, is presented in AC 150/5300-2, Airport Design Standards--Site Requirements for Terminal Navigational Facilities, current edition.

h. Airport Traffic Control Tower Visibility. The runways and taxiways are located and oriented so that the existing (or future) air traffic control tower has a clear line-of-sight to: all traffic patterns; the final approaches to all runways; all runway structural pavement; and, the centerlines of taxiways. A clear line-of-sight to taxilanes' centerlines is also desirable. See AC 150/5300-2 for guidance on clear line-of-sight and air traffic control tower siting.

i. Bird Hazards. The relative locations of bird sanctuaries or other areas which might attract large numbers of birds or which might create bird hazards to aviation should be considered in orienting runways. Where bird hazards exist, the airport authority should develop and implement bird control procedures to minimize such hazards. For further guidance, consultation with the U.S. Fish and Wildlife Service on bird control measures is encouraged.

9. ADDITIONAL RUNWAYS. There are instances where an additional runway is necessary to minimize adverse wind conditions or environmental impact, or to accommodate excessive operational demand.

a. Wind Conditions. Where a single runway or set of parallel runways cannot be oriented to provide 95 percent wind coverage, an additional runway (or runways), oriented in a manner to raise coverage to at least that value, should be provided. For airplanes in Aircraft Approach Category C or D, the recommended limiting crosswind for airport design is 13 knots. For instructions on how to compute wind coverage, see appendix 3 of AC 150/5300-4.

b. Operational Demands. An additional runway or runways may be warranted when the traffic volume, measured in terms of the number of airplane operations in a limited period of time, exceeds the existing runway's capability, or, by a combination of traffic volume and aircraft noise problems. With rare exception, capacity-justified runways are oriented parallel to the primary runway.

10. PARALLEL RUNWAY SEPARATION--SIMULTANEOUS IFR OPERATIONS. The following paragraphs discuss the required centerline separations for parallel runways with operations involving instrument flight rules (IFR). To minimize taxi operations across active runways and to increase operational efficiency of the airport, the terminal area should be placed between the parallel runways. To accommodate these areas, greater separation than specified below may be required. When more than one of the following conditions apply to parallel runways, the larger resulting separation is required as the minimum. When centerline spacings under 2,500 feet (750 m) are involved, wake turbulence avoidance procedures must be observed.

a. Simultaneous Approaches. For operations under instrument meteorological conditions (IMC), specific electronic navigational aids and monitoring equipment, air traffic control, and approach procedures are required. With these, simultaneous precision instrument approaches may be authorized for parallel runways whose centerlines are separated by at least 4,300 feet (1 300 m).

b. Simultaneous Departures-or-Approach and Departure. Simultaneous departures may be authorized at locations where radar air traffic control is not used. Simultaneous approach and departure may be authorized where radar is used. In both cases, additional air traffic control procedural requirements must be met, and the following minimum separation distances between runway centerlines are required:

(1) Simultaneous Departures.

(i) Simultaneous, nonradar, departures may be conducted from parallel runways whose centerlines are separated by at least 3,500 feet (1 000 m).

(ii) Simultaneous, radar, departures may be conducted from parallel runways whose centerlines are separated by at least 2,500 feet (750 m).

(2) Simultaneous Approach and Departure. Simultaneous, radar controlled, approach and departure may be conducted on parallel runways whose centerlines are separated as follows:

(i) When the thresholds are not staggered, a separation distance between runway centerlines of 2,500 feet (750 m) is required.

(ii) When the thresholds are staggered and the approach is to the nearer threshold, the 2,500 feet (750 m) separation may be reduced by 100 feet (30 m) for each 500 feet (150 m) of threshold stagger to a minimum limiting separation of 1,000 feet (300 m). However, for Airplane Design Group V, a minimum centerline separation of 1,200 feet (360 m) is recommended.

(iii) When the thresholds are staggered and the approach is to the farther threshold, the 2,500 feet (750 m) separation must be increased by 100 feet (30 m) for every 500 feet (150 m) of threshold stagger.

11. PARALLEL RUNWAY SEPARATION--SIMULTANEOUS VFR OPERATIONS. For simultaneous landings and takeoffs using visual flight rules (VFR), the standard minimum separation between centerlines of parallel runways is 700 feet (210 m). The minimum runway centerline separation distance recommended with Airplane Design Group V is 1,200 feet (360 m). A greater separation distance may be required if aircraft are to be held between the runways for air traffic control purposes.

12. TAXIWAY SYSTEM. As the rate at which the runway accepts traffic increases, the capacity of the taxiway system may become the limiting operational factor. Taxiways link the independent airport elements and require careful planning for optimum airport utility. The taxiway system should be designed to provide freedom of movement to and from the runways. It is desirable to maintain a smooth, continuous flow with a minimum number of points requiring a change in the airplane's taxiing speed. Figure 2-1 shows taxiway systems for a fundamental and a complex airport.

a. System Composition. Through-taxiways and intersections comprise the taxiway system. It includes entrance and exit taxiways; bypass, crossover or transverse taxiways; apron taxiways and taxilanes; and, parallel and dual parallel taxiways. Each is discussed in chapter 4.

b. Design Principles:

(1) Provide each runway with a parallel taxiway;

(2) Build taxiways as direct as possible;

(3) Provide bypass capability or multiple access to runway ends;

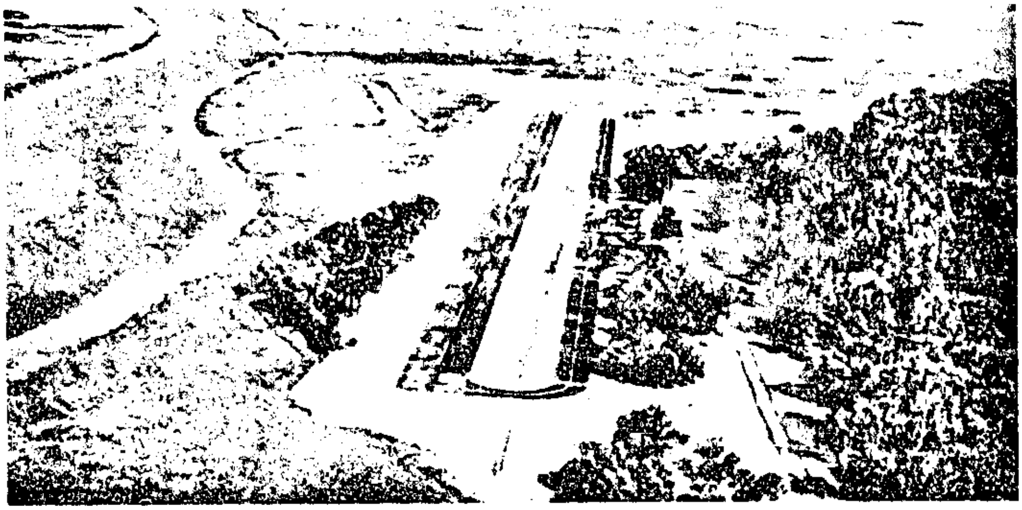
(4) Minimize crossing runways;

(5) Provide ample curve and fillet radii;

(6) Consider air traffic control tower visibility; and,

(7) Avoid traffic bottlenecks.

13. SEPARATION STANDARDS. Separation standards are presented in table 2-1 and depicted in figure 2-2. The potential growth of the airport may justify greater separations. Appendix 1 discusses the relationship between airplane physical characteristics and the design of airport elements. The rationale presented there may be used, on a case-by-case basis, to adapt the separation standards in table 2-1, primarily at existing airports, to meet unusual local conditions or to accommodate a specific airplane within an airplane design group.



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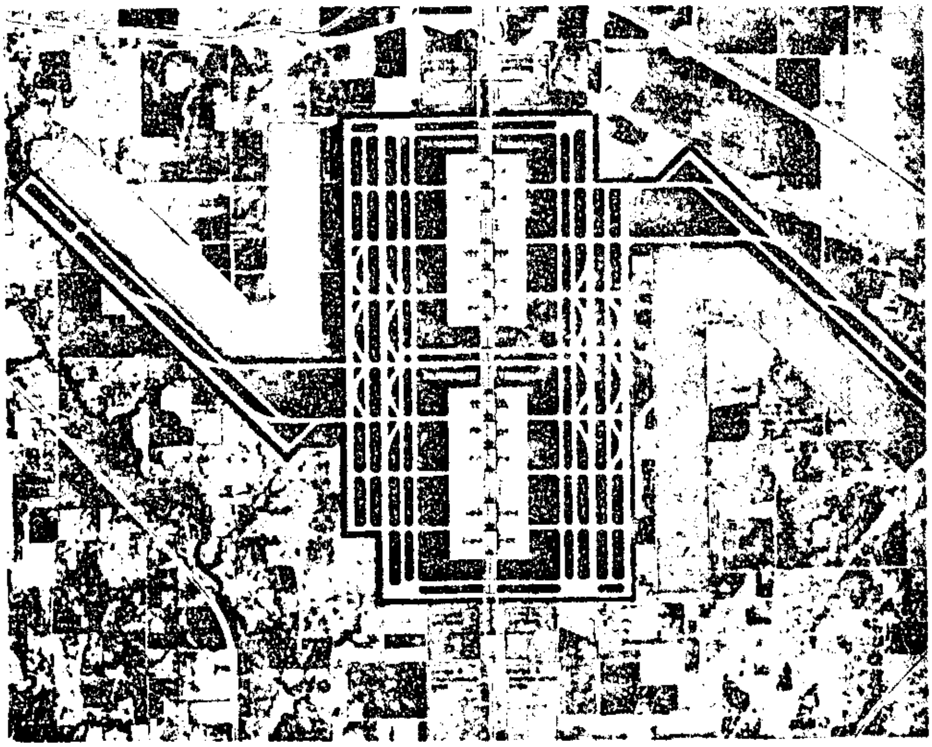

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Figure 2-1. Typical taxiway systems

Table 2-1. Separation standards

ITEM	DIM 2/	AIRPLANE DESIGN GROUP 1/					
		I	II	III	IV	V	VI
Runway Centerline to Taxiway Centerline 3/	D	400 ft 120 m	400 ft 120 m	400 ft 120 m	400 ft 120 m	4/ 4/	600 ft 180 m
Aircraft Parking Area 5/	G	500 ft 150 m	500 ft 150 m	500 ft 150 m	500 ft 150 m	500 ft 150 m	500 ft 150 m
Parallel Runway Centerline	H	- Refer to paragraphs 10 and 11 -					
Property/Building Restriction Line 6/	I	750 ft 230 m	750 ft 230 m	750 ft 230 m	750 ft 230 m	750 ft 230 m	750 ft 230 m
Helicopter Touchdown Pad		- Refer to Advisory Circular 150/5390-1 -					
Taxiway Centerline to Parallel Taxiway Centerline	J	69 ft 21 m	103 ft 31.5 m	153 ft 46.5 m	225 ft 68.5 m	251 ft 76.5 m	340 ft 102 m
Fixed or Movable Object and to Property Line	K	44 ft 13.5 m	64 ft 19.5 m	94 ft 28.5 m	139 ft 42.5 m	153 ft 46.5 m	205 ft 62 m
Taxilane Centerline to Fixed or Movable Object		39 ft 12 m	54 ft 16.5 m	80 ft 24.5 m	118 ft 36 m	131 ft 40 m	172 ft 52 m

1/ Airplane design groups are keyed to those of table 1-1.

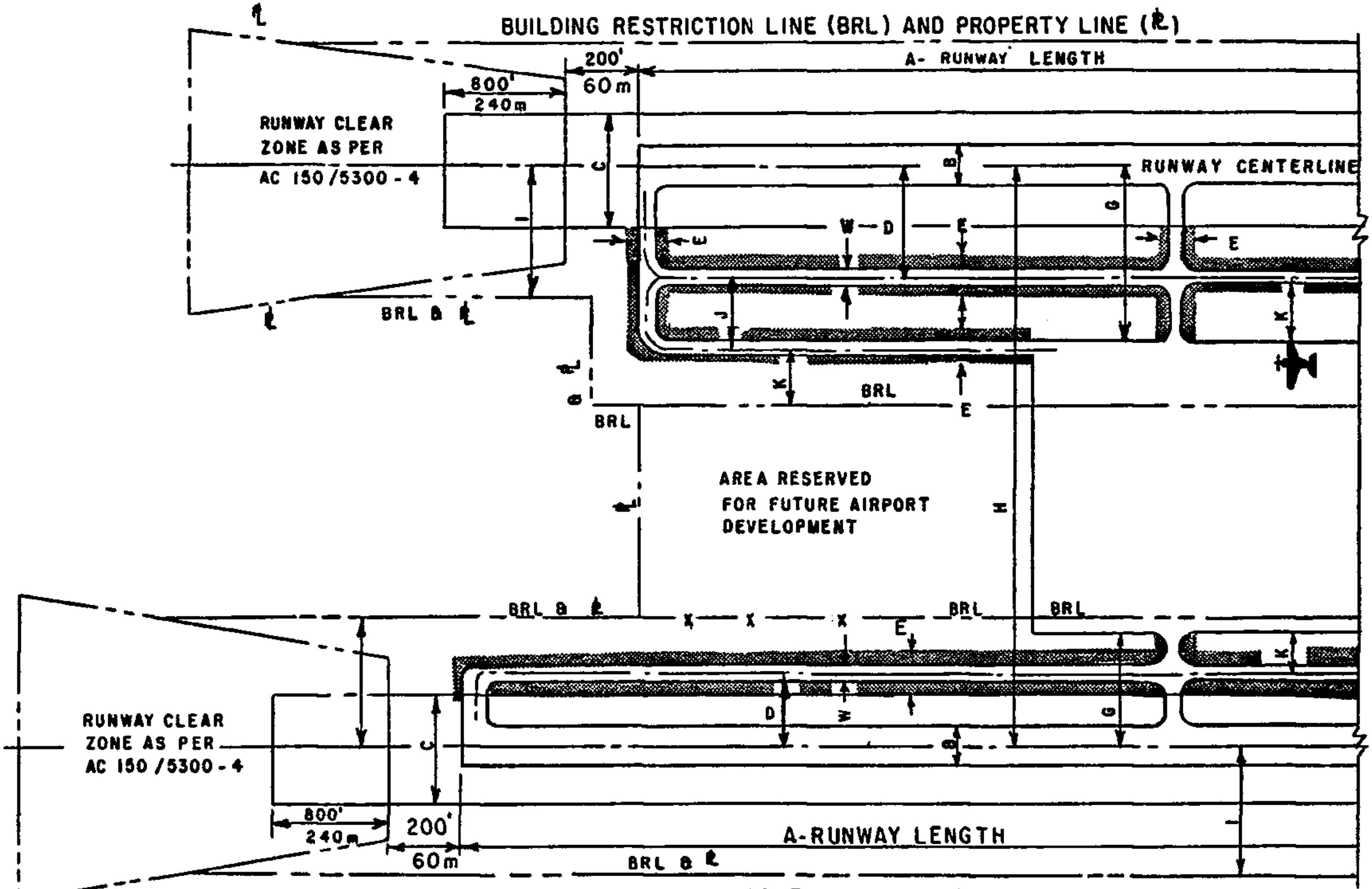
2/ Letters are keyed to those shown as dimensions on figure 2-2.

3/ The location of a parallel taxiway may be adjusted such that no part of an aircraft (tail tip, wing tip) on taxiway centerline is above the runway safety area or penetrates the obstacle free zone (OFZ). For a detailed discussion on the OFZ, see AC 150/5300-4. Figure 2-3, herein, illustrates a precision OFZ for Aircraft Approach Category C or D airplanes.

4/ For Airplane Design Group V, the standard minimum runway centerline to taxiway centerline separation distance is 400 feet (120 m) for airports at or below an elevation of 1,345 feet (410 m); 450 feet (135 m) for airports between elevations of 1,345 feet (410 m) and 6,560 feet (2 000 m); and 500 feet (150 m) for airports above an elevation of 6,560 feet (2 000 m).

5/ For Airplane Design Groups I and II, with no precision instrument operations, this separation may be reduced to 400 feet (120 m) when visibility minimums are 1 mile (1.6 km) or greater.

6/ For Airplane Design Groups I and II, with no precision instrument operations, this separation may be reduced to 500 feet (150 m) when visibility minimums are 1 mile (1.6 km) or greater. *



NOTES: 1. DIMENSION LETTERS ARE KEYED TO TABLES 2-1, 3-1, AND 4-1.

2. SHADED AREA SURROUNDING TAXIWAYS DELINEATES THE LIMITS OF THE TAXIWAY SAFETY AREA.

3. PREFERRED LOCATION FOR BUILDING AND AIRPLANE PARKING AREA IS MIDPOINT OF RUNWAY. THE SIZE AND SHAPE ARE VARIABLE AS REQUIRED.

Figure 2-2. Typical airport layout

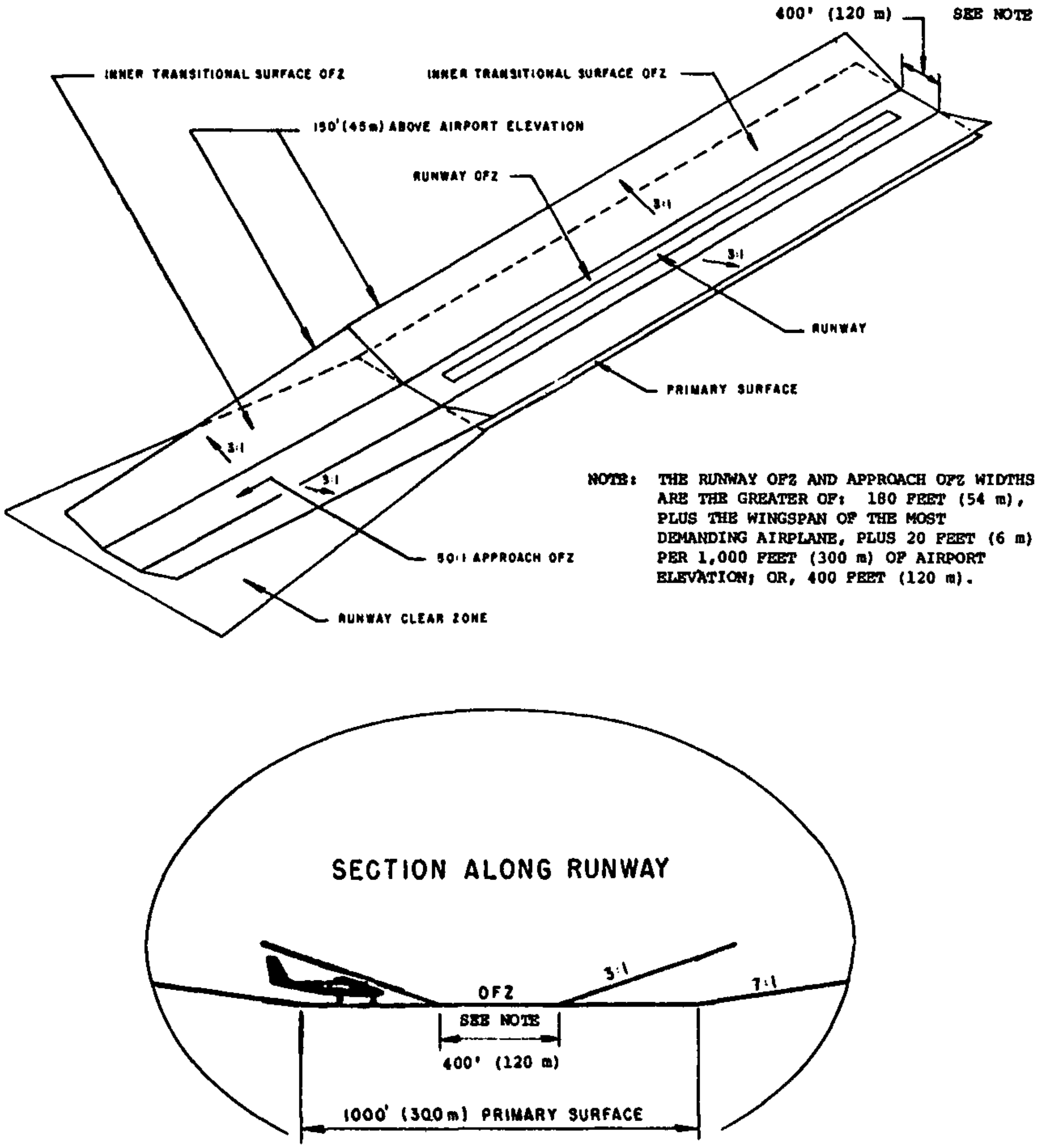


Figure 2-3. Obstacle free zone (OFZ) for precision instrument runway

CHAPTER 3. RUNWAY DESIGN

14. INTRODUCTION. This chapter provides the standards for such elements as runways, shoulders, the runway safety area, blast pads, clearways, and stopways. Also included are recommendations on firefighting and rescue access roads. Table 3-1 presents the minimum widths and lengths for runway elements.

Table 3-1. Runway design standards

ITEM	DIM 2/	AIRPLANE DESIGN GROUP 1/					
		I	II	III	IV	V	VI
Runway Length	A	- Refer to paragraph 15 -					
Runway Width	B	100 ft 30 m	100 ft 30 m	100 ft3/ 30 m3/	150 ft 45 m	150 ft 45 m	200 ft 60 m
Runway Shoulder Width		10 ft 3 m	10 ft 3 m	20 ft 6 m	25 ft 7.5 m	35 ft 10.5 m	40 ft 12 m
Runway Blast Pad Width		120 ft 36 m	120 ft 36 m	140 ft3/ 42 m3/	200 ft 60 m	220 ft 66 m	280 ft 84 m
Runway Blast Pad Length		100 ft 30 m	150 ft 45 m	200 ft 60 m	200 ft 60 m	400 ft 120 m	400 ft 120 m
Runway Safety Area Width 4/	C	500 ft 150 m	500 ft 150 m	500 ft 150 m	500 ft 150 m	500 ft 150 m	500 ft 150 m
Runway Safety Area Length 5/		1,000 feet (300 m) beyond each runway end					

1/ Airplane design groups are keyed to those of table 1-1.

2/ Letters are keyed to those shown as dimensions on figure 2-2.

3/ For airplanes in Design Group III with a maximum certificated takeoff weight greater than 150,000 pounds (68 000 kg), the standard runway width is 150 feet (45 m) and the runway blast pad width may be increased to 190 feet (57 m).

4/ For airplanes in Aircraft Approach Category C, the safety area width increases 20 feet (6 m) for each additional 1,000 feet (300 m) of airport elevation greater than 8,200 (2 500 m) above sea level. For airplanes in Aircraft Approach Category D, the safety area width increases 20 feet (6 m) for each 1,000 feet (300 m) of airport elevation above sea level.

5/ For a runway with a stopway over 1,000 feet (300 m) in length, the runway safety area extends to the end of the stopway.

15. RUNWAY LENGTH. AC 150/5325-4, Runway Length Requirements for Airport Design, current edition, airplane flight manuals (supplemented with user operating data), and the runway length curves in this chapter provide guidance on the runway lengths needed to accommodate the airplanes expected to use a transport airport. It should be noted that, at elevations above 5,000 feet (1 500 m) mean sea level (m.s.l.), the runway lengths for small propeller-driven airplanes contained in AC 150/5300-4 may be greater than those required for the smaller turbojet airplanes. The following paragraphs provide guidance on the runway lengths for turbojet-powered airplanes of 60,000 pounds (27 200 kg) or less maximum certificated takeoff weight.

a. The recommended runway lengths curves in figures 3-1 through 3-3 have been developed from FAA-approved airplane flight manuals in accordance with the provisions of FAR Part 25, Airworthiness Standards: Transport Category Airplanes, and FAR Part 91, General Operating and Flight Rules.

b. The curves in figures 3-1 and 3-2 are based on grouping the turbojet-powered airplanes of 60,000 pounds (27 200 kg) or less maximum certificated takeoff weight according to their performance capability. The FAA has derived these curves with data from airplane flight manuals and an assumed loading condition. The title of each curve set indicates the percentage of the fleet and the percentage of useful load accommodated by a runway length obtained from the curve set. For example, the "75% fleet at 60% useful load" curve set provides a runway length sufficient to satisfy the operational requirements of approximately 75 percent of the turbojet-powered airplanes of 60,000 pounds (27 200 kg) or less maximum certificated takeoff weight at 60 percent useful load.

c. The useful load of an airplane is considered to be the difference between the maximum certificated takeoff weight and the operating weight empty. A typical operating weight empty includes the airplane's empty weight, crew, crew's baggage and supplies, removable passenger service equipment, removable emergency equipment, engine oil, and unusable fuel. Passengers and baggage, cargo, and usable fuel comprise the useful load.

d. Curves have not been developed for turbojet-powered airplanes of 60,000 lb (27 200 kg) or less maximum certificated takeoff weight operating at 100 percent useful load. Operations above 90 percent useful load with these aircraft require a significant increase in runway length. Consequently, the length of runway resulting from the 90 percent load factor is considered to approximate the maximum cost effective length.

e. Those airplanes which comprise 75 percent of the turbojet-powered airplanes of 60,000 lb (27 200 kg) or less maximum certificated takeoff weight and can be accommodated by runway lengths specified in the curves of figure 3-1 are:

Manufacturer	Model
Gates Learjet Corporation	Learjet (20, 30, 50 series)
Rockwell International	Sabreliner (40, 60, 75, 80 series)
Cessna Aircraft	Citation (I, II, III)

Manufacturer	Model
Dassault - Breguet	Fan Jet Falcon (10, 20, 50 series)
British Aerospace Aircraft Group	HS-125 (400, 600, 700 series)
Israel Aircraft Industries	1124 Westwind

f. The curves in figures 3-1 and 3-2 were derived assuming conditions of no wind, zero gradient, a dry runway, and clear departures and approaches. The runway lengths obtained from figures 3-1 and 3-2 may need to be increased to account for the effect of obstacles in the departure or approach areas and either runway gradient (takeoff) or wet runway conditions (landing). Runway gradient and wet runway effects are not cumulative and, when both conditions apply, the larger of the increases is used to determine the recommended runway length.

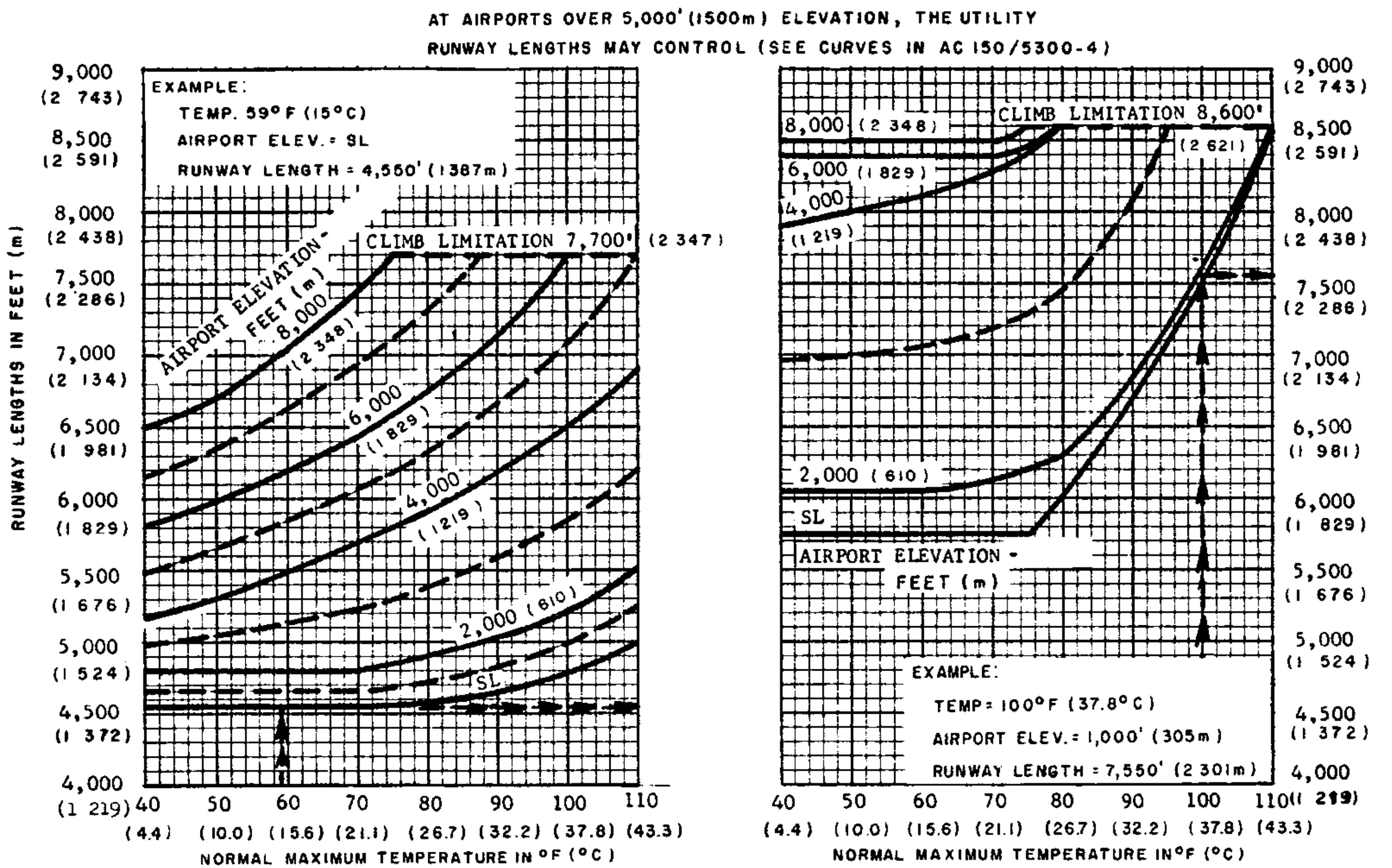
g. The runway lengths obtained from the curves in figures 3-1 and 3-2 need to be increased to account for an effective runway gradient other than zero. To determine the increase, enter figure 3-3 on the left with the runway length obtained from figures 3-1 or 3-2 and proceed horizontally to the right to the effective runway gradient of the runway being considered. The required runway length will be directly below this point on the bottom scale.

h. The runway length required for landing may be the controlling length at lower elevations and temperatures. An increase of up to 15 percent in runway length may be required for wet runway conditions. The following paragraphs provide guidance on the appropriate increase in runway length:

(1) 60 Percent Useful Load Curves. Landing operations govern when the runway length is less than 5,500 feet (1 680 m). In these cases, the runway lengths obtained from the 60 percent useful load curves need to be increased by 15 percent, or up to 5,500 feet (1 680 m), whichever is less.

(2) 90 Percent Useful Load Curves. Landing operations govern when the runway length is less than 7,000 feet (2 130 m). In these cases, the runway lengths obtained from the 90 percent useful load curves need to be increased by 15 percent, or up to 7,000 feet (2 130 m), whichever is less.

i. The runway lengths obtained from AC 150/5300-4, AC 150/5325-4, airplane flight manuals, and this chapter may also need to be increased because of a displaced threshold. Threshold displacement usually results from the presence of objects in the approach to the runway. In many cases, the object which caused the displaced threshold will also adversely affect departures in the opposite direction. In these circumstances, the recommended runway length should be increased by an amount equal to the threshold displacment.



75% FLEET @ 60% USEFUL LOAD

75% FLEET @ 90% USEFUL LOAD

Figure 3-1. Performance curves for 75% of fleet

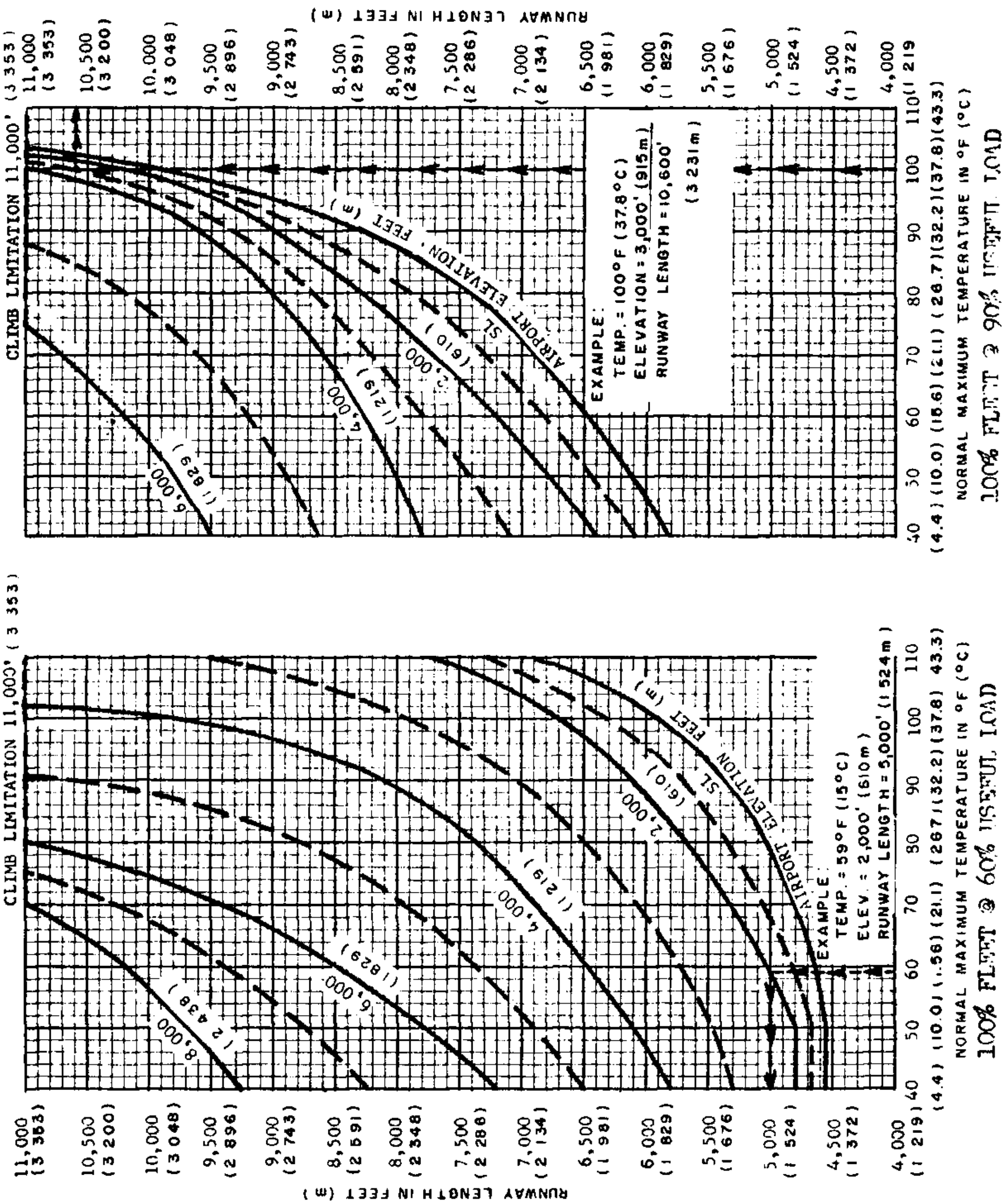


Figure 3-2. Performance curves for 100% of fleet

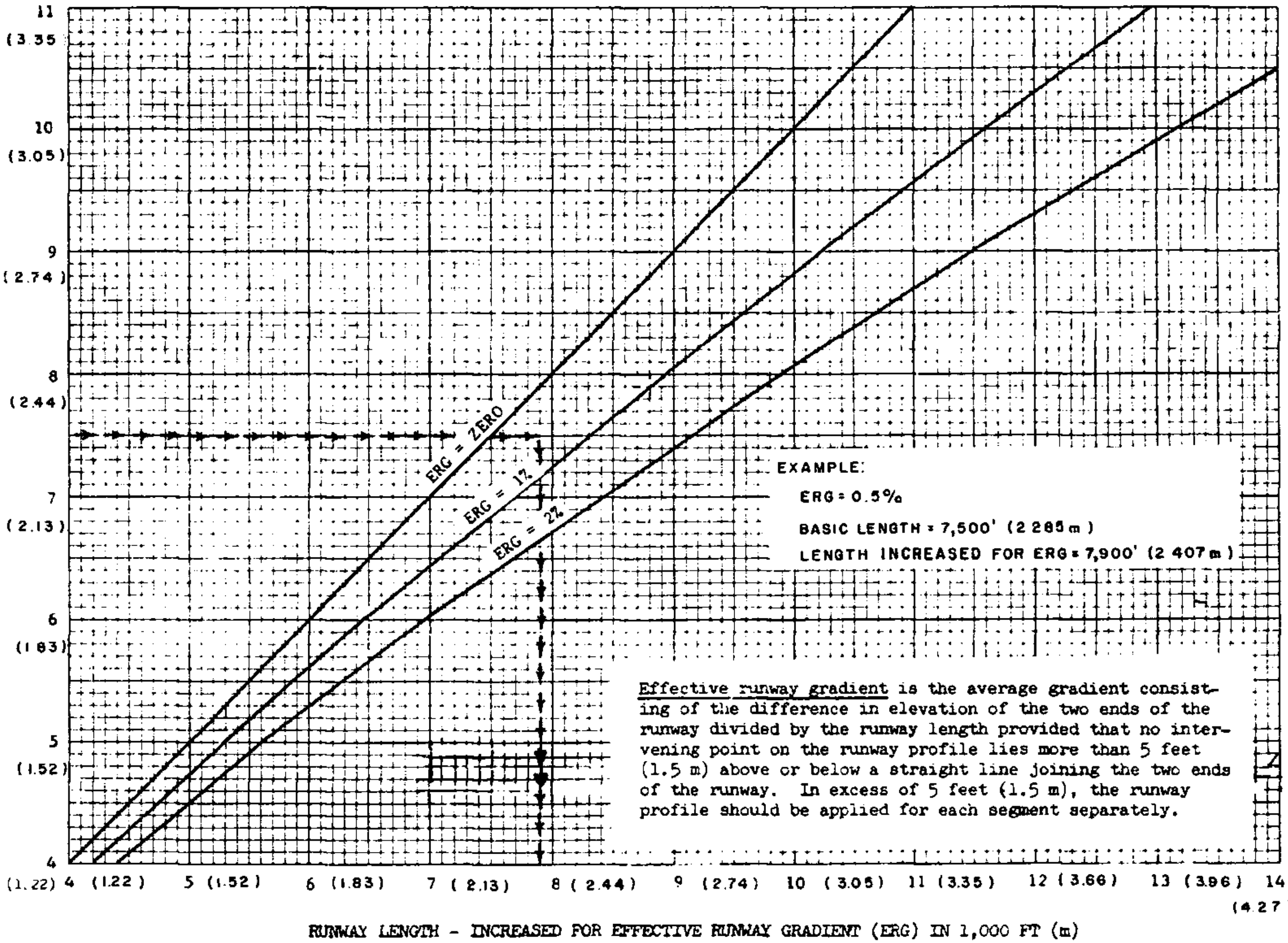


Figure 3-3. Runway increased for gradient

16. RUNWAY WIDTH. The runway width standards in table 3-1 are predicated on: operations being conducted during periods of reduced visibility; variables in the degree of control, maneuverability, and stability of airplanes during final approach and landing; and, certain airplane dimensions. As altitude and speed are reduced during approach, only minor directional changes can be made, particularly with modern, high performance airplanes. Hence, an adequate target in runway width is necessary.

17. RUNWAY SHOULDER. The runway shoulder is the area abutting the edge of the runway structural pavement. This area is prepared to resist jet blast erosion and to accommodate maintenance and emergency equipment as well as the occasional passage of the most demanding airplane for runway pavement design. Provision of the shoulders specified in table 3-1, along with a stabilized or paved surface, will reduce the possibility of soil erosion and engine ingestion. While a natural surface, e.g., turf, may suffice in certain cases, a low cost paved surface may be required in others. Paved shoulders require marking for differentiation from full strength pavement. Refer to chapter 6 for further discussion.

18. RUNWAY BLAST PAD. A runway blast pad serves the same function as the runway shoulder but is located beyond the end of the runway. Blast pads of the length and width given in table 3-1 need to be provided where blast erosion control from takeoff operations is required. Blast pads need to be marked as nontraffic areas. For additional information on this subject, see chapter 6.

19. RUNWAY SAFETY AREA. In the early years of aviation, all airplanes operated from relatively unimproved airfields. As aviation developed, the alignment of takeoff and landing paths centered on a well defined area known as a landing strip. Thereafter, the requirements of more advanced airplanes necessitated improving or paving the center portion of the landing strip. The term "landing strip" was retained to describe the graded area surrounding and upon which the runway or improved surface was constructed. The primary role of the landing strip changed to that of a safety area surrounding the runway. This area had to be capable, under normal (dry) conditions, of supporting airplanes without causing structural damage to the airplanes or injury to their occupants. Later, the designation of the area was changed to "runway safety area," to reflect its functional role. The runway safety area enhances the safety of airplanes which undershoot, overrun, or veer off the runway and it provides greater accessibility for firefighting and rescue equipment during such incidents. The runway safety area is depicted in figure 3-4 and its dimensions are given in table 3-1.

a. Clearing. The standard runway safety area is graded and free of structures, ditches, soft spots, and ponding areas. However, subsurface drainage, covered culverts, underground structures, gentle drainage swales, and frangibly mounted air navigational aids, which, because of their function, require location in the runway safety area, may be permitted. Security fencing, if required, must be located outside of the runway safety area. Traverse ways (roadways, railroads, and waterways), except those provided for firefighting and rescue equipment, should be excluded from the runway safety area. It is a standard that the entire runway safety area be within 330 feet (100 m) either of paved operational surfaces or roads suitable for firefighting and rescue operations. Figure 3-5 depicts a typical access road layout in the runway safety area. All objects, which, because of their function, must be maintained within the runway safety area, should be constructed with frangible supports and be of minimum practical height.

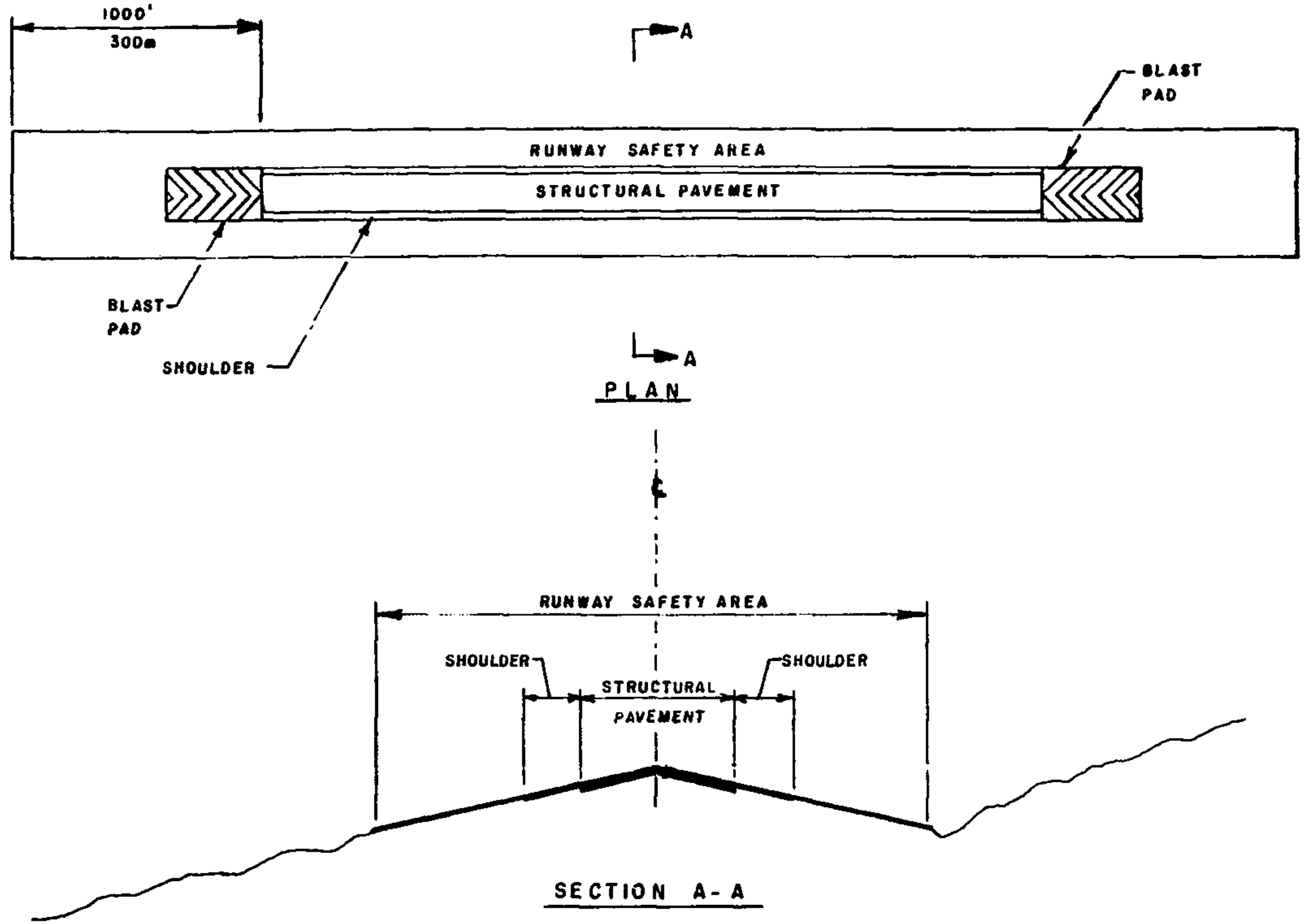


Figure 3-4. Runway safety area

b. Construction. The FAA recommends that runway safety areas be constructed to FAA specification P-152. See AC 150/5370-10, Standards for Specifying Construction of Airports, current edition, for details on Specification P-152.

c. Application. Runway safety area standards apply to all runways. However, for existing runways constructed prior to the adoption of this standard, or for new runways or runway extensions identified on an FAA approved airport layout plan prior to the adoption of this standard, the maximum feasible length of runway safety area should be provided without reducing the existing or planned length of the runway. Comparable conditions apply with respect to the width of the runway safety area. NOTE: To maintain the integrity of the runway safety area, an area beyond the runway safety area is needed to accommodate a localizer antenna and its associated equipment. Refer to AC 150/5300-2 for additional information on localizer siting requirements.

20. FIREFIGHTING AND RESCUE ACCESS ROADS. Firefighting and rescue access roads should be designed and constructed to provide unimpeded two-way access for firefighting and rescue equipment to reach a potential accident area. To facilitate firefighting and rescue operations, access roads must, to the extent practical, be connected to the operational surfaces and other roads. It is desirable that the entire runway clear zone be accessible to firefighting and rescue vehicles, i.e., that no portion of a runway clear zone be more than 330 feet (100 m) distant from an all-weather road. However, as a minimum, the entire runway safety area must be accessible as noted in paragraph 19.

a. All Weather Capability. Firefighting and rescue access roads are all weather roads designed to support firefighting and rescue equipment traveling at normal response speeds. The width of the access roads are designed on a case-by-case basis considering the type of firefighting and rescue equipment available at the airport. The first 300 feet (90 m) adjacent to a paved operational surface should be paved. At locations where an access road crosses a safety area, the safety area standards for smoothness, grade, etc., need to be maintained, i.e., no ditches or berms. For other design and construction features, local highway specifications may be used.

b. Multipurpose Roads. Firefighting and rescue access roads supplement any multipurpose road system. They do not duplicate or replace sections of the multipurpose road system. The use of a road, or section of road, that is an obstruction to air navigation, as defined in FAR 77.23, is presumed to be a hazard to air navigation unless an FAA aeronautical study determines otherwise. Firefighting and rescue access roads need to be restricted to the type of use that would not constitute a hazard to air navigation.

21. CLEARWAY AND STOPWAY.

a. Clearway. Federal Aviation Regulations permit the use of a clearway to provide part of the distance required for the takeoff of turbine powered airplanes certificated after September 30, 1958.

(1) The clearway concept is illustrated in figure 3-6 and is defined from FAR Part 1, Definitions and Abbreviations, as:

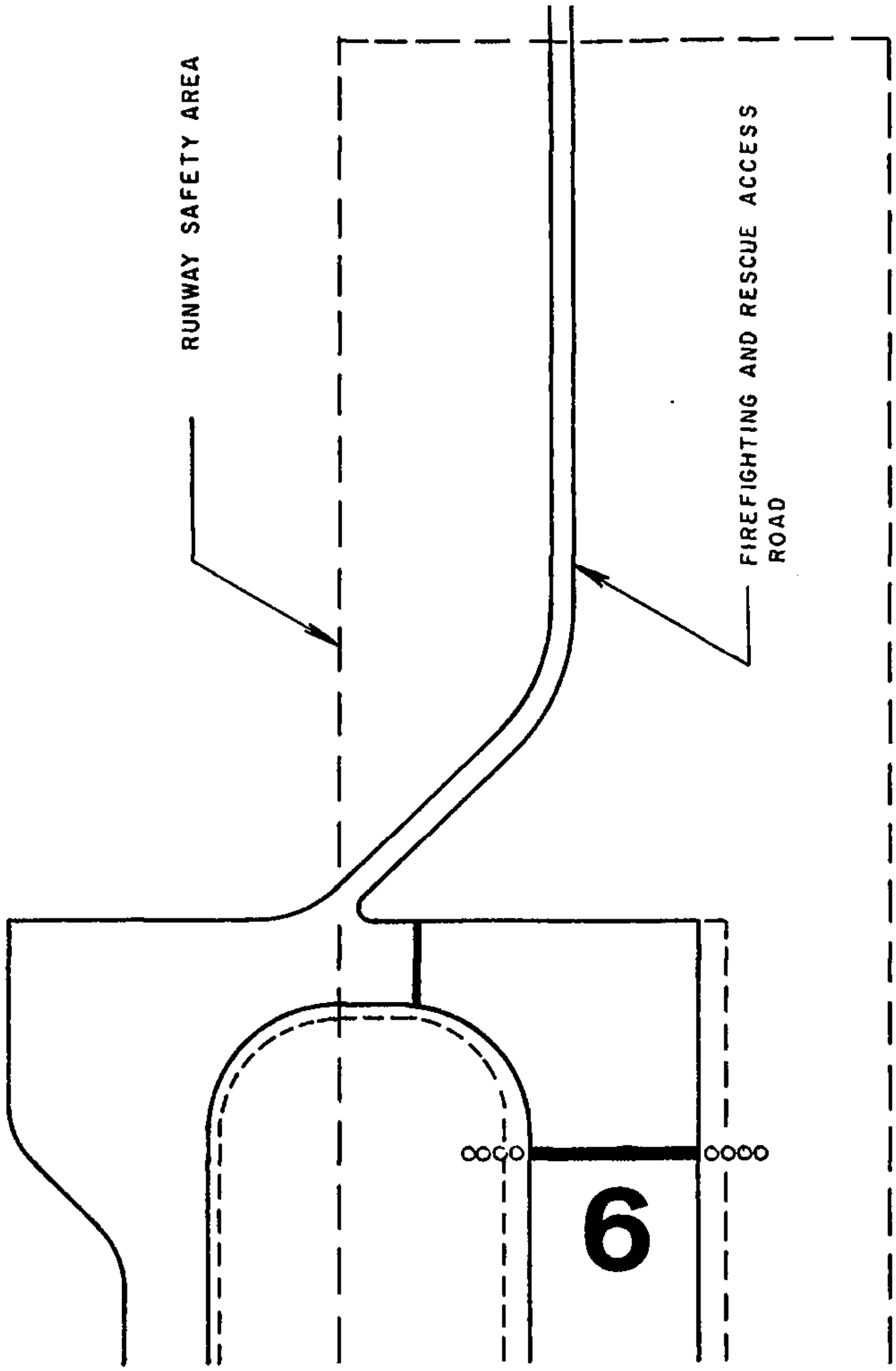


Figure 3-5. Typical access road layout in the runway safety area

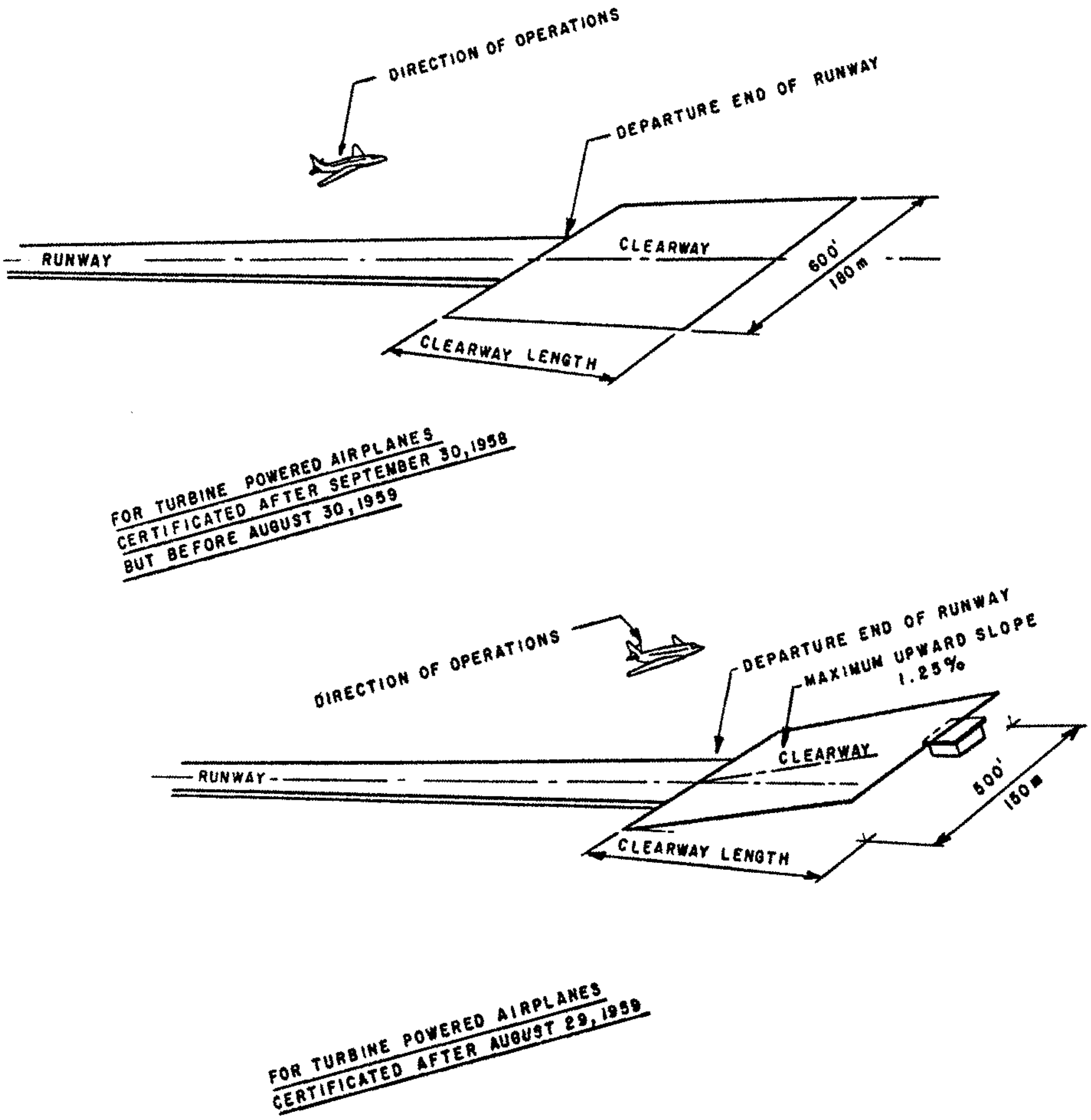


Figure 3-6. Clearway

(i) For turbine-powered airplanes certificated after September 30, 1958, but before August 30, 1959, an area beyond the takeoff runway extending no less than 300 feet (90 m) on either side of the extended centerline of the runway, at an elevation no higher than the elevation of the end of the runway, clear of all fixed obstacles, and under the control of the airport authority;

(ii) For turbine-powered airplanes certificated after August 29, 1959, an area beyond the runway, not less than 500 feet (150 m) wide, centrally located about the extended centerline of the runway, and under the control of the airport authorities. The clearway is expressed in terms of a clearway plane, extending from the end of the runway with an upward slope not exceeding 1.25 percent, above which no object nor terrain protrudes. However, threshold lights may protrude above the clearway plane if their height above the end of the runway is 26 inches (.66 m) or less and if they are located to each side of the runway.

(2) A clearway is a plane available for continuation of the takeoff operation which is above a clearly defined area connected to and extending beyond the runway end. The area over which the clearway lies need not be suitable for stopping aircraft in the event of an aborted takeoff. Although clearways are authorized for use with takeoff operations of turbine-powered airplanes certificated after September 30, 1958, it should be noted that the airplane manufacturers have not provided clearway takeoff performance data for airplanes certificated before August 30, 1959; nor are they expected to do so. Accordingly, the requirements for clearways relating to turbine-powered aircraft, certificated after August 29, 1959, should be used for airport design.

(3) A clearway may be used to increase allowable operating takeoff weights without increasing runway length. It has been determined that a clearway length of 1,000 feet (300 m) is the practical limit for takeoff operations.

(4) An airport owner interested in providing a clearway should be aware of the requirement that the clearway be under his control, although not necessarily by direct ownership. The purpose of such control is to insure that no takeoff operation intending to use a clearway is initiated unless it has been absolutely determined that no fixed or movable object, except threshold lights 26 inches (.66 m) or less in height and located to each side of the runway, will penetrate the clearway plane during that operation.

(5) Although the use of a clearway is a technique which permits higher allowable operating weights without an increase in runway length, the runway length recommended without use of a clearway (or stopway--see paragraph below) for the most demanding airplane should be provided. The clearway should only serve as a means of accommodating the takeoff distance requirements for that occasional operation requiring a greater takeoff distance than the most demanding airplane for which the runway length is designed. When the frequency of this occasional operation increases to the point where, in fact, a new "most demanding" airplane for runway length exists, the additional runway length should be provided.

b. Stopway.

(1) According to FAR Part 1, and as illustrated in figure 3-7, a stopway is an area beyond the takeoff runway which is designated by the airport authority for use in decelerating an airplane during an aborted takeoff. A stopway is at least as wide as the runway it serves. It is centered on the extended centerline of the runway and able to support an airplane during an aborted takeoff without causing structural damage to the airplane.

(2) Stopways are applicable for use only in takeoff operations of turbine-powered airplanes certificated after August 29, 1959. Due to the cost of providing stopways, which have a limited use, compared to a full strength runway usable in both directions, provision of the runway is recommended.

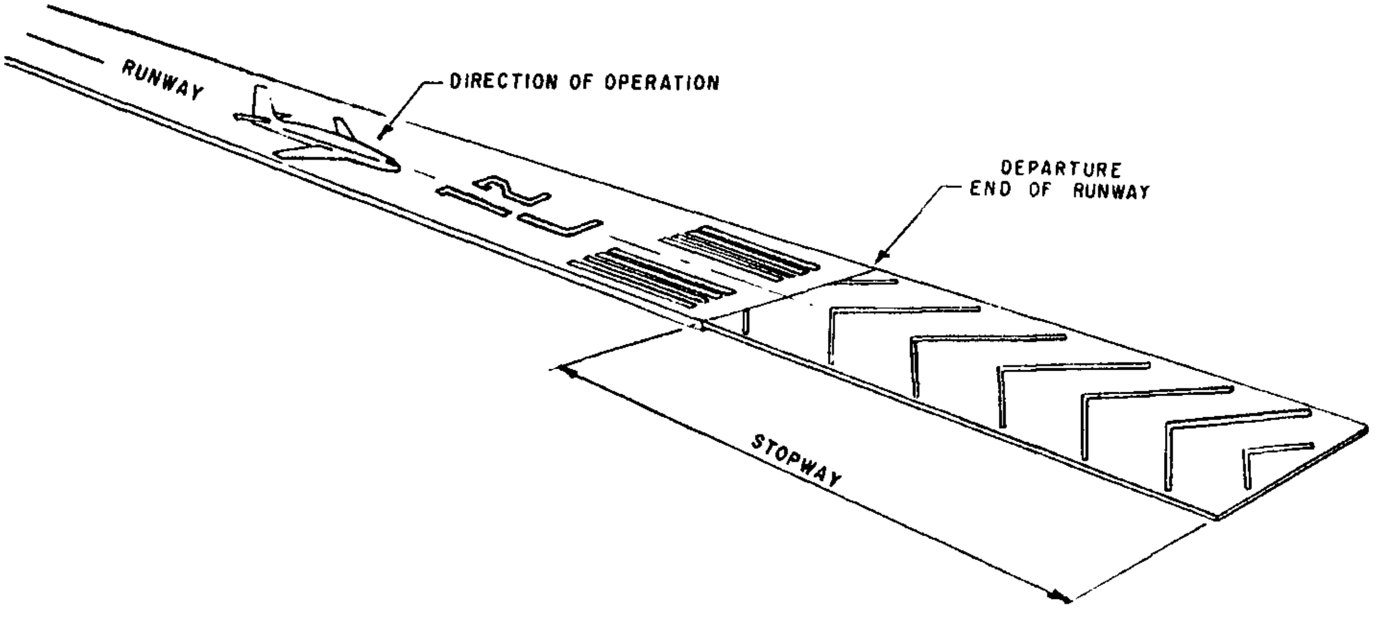


Figure 3-7. Stopway

CHAPTER 4. TAXIWAY DESIGN

22. INTRODUCTION. This chapter presents the standards for taxiway, shoulder, and safety area widths, and taxiway intersections, entrances, and exits.

23. DIMENSIONAL CRITERIA. The dimensional standards of table 4-1 are minimums and are to be used only when it is not practical to provide larger dimensions.

Table 4-1. Taxiway dimensional standards

ITEM	DIM 2/	AIRPLANE DESIGN GROUP 1/					
		I	II	III	IV	V	VI
Taxiway Width	W	25 ft 7.5 m	35 ft 10.5 m	50 ft3/ 15 m3/	75 ft 23 m	75 ft 23 m	100 ft 30 m
Taxiway Edge Safety Margin 4/	M	5 ft 1.5 m	7.5 ft 2.25 m	10 ft5/ 3 m5/	15 ft 4.5 m	15 ft 4.5 m	20 ft 5 m
Taxiway Pavement Fillet Configuration		- Refer to appendix 2 -					
Taxiway Shoulder Width		10 ft 3 m	10 ft 3 m	20 ft 6 m	25 ft 7.5 m	35 ft6/ 10.5 m6/	40 ft6/ 12 m6/
Taxiway Safety Area Width	E	49 ft 15 m	79 ft 24 m	118 ft 36 m	171 ft 52 m	197 ft 60 m	262 ft 80 m

1/ Airplane design groups are keyed to those of table 1-1.

2/ Letters are keyed to those shown as dimensions on figures 2-2 and A2-4.

3/ For Airplane Design Group III taxiways intended to be used by airplanes with a wheelbase equal to or greater than 60 feet (18 m), the standard taxiway width is 60 feet (18 m).

4/ The taxiway edge safety margin is the minimum acceptable distance between the outside of the airplane wheels and pavement edge.

5/ For airplanes in Design Group III with a wheelbase equal to or greater than 60 feet (18 m), the taxiway edge safety margin is 15 feet (4.5 m).

6/ For Airplane Design Groups V and VI, the taxiway shoulder surface should be stabilized or paved.

24. TAXIWAY SHOULDERS. Provision of stabilized or paved shoulders, to the dimensions specified in table 4-1, will reduce the possibility of blast erosion and engine ingestion associated jet engines which overhang the edge of the taxiway pavement. The type of surface provided will depend on the aircraft, local conditions, and the contemplated cost of maintenance. While a natural surface, e.g., turf, may suffice in some cases, a paved surface will be required in others. Chapter 6 contains additional information on this subject.

25. TAXIWAY SAFETY AREA. A taxiway safety area is provided to minimize the probability of serious damage to airplanes accidentally entering the area. A taxiway safety area requires the capability of supporting maintenance, firefighting, and rescue equipment, under normal (dry) conditions and needs to be graded to certain tolerances. Taxiway safety area widths are specified in table 4-1; gradient limitations are contained in chapter 5.

26. PARALLEL TAXIWAY. A basic airport consists of: a runway; an apron; a full length parallel taxiway, connected to each end of the runway; and, connecting transverse taxiways between the runway, parallel taxiway, and apron. Figure 2-1 illustrates taxiway systems at both fundamental and complex airports.

a. Separation Distance. The standard minimum separation distance of a parallel taxiway from the runway is specified in table 2-1.

b. Centerline Profile. The centerline profile of a parallel taxiway should be designed to prevent excessive longitudinal grades on crossover or transverse taxiways. The taxiway longitudinal grade standard is provided in chapter 5.

27. TAXIWAY INTERSECTIONS. An airplane pilot may negotiate a taxiway turn by judgemental oversteering or by maintaining the cockpit over the centerline. From a design standpoint, judgemental oversteering results in the least requirement for pavement widening at taxiway intersections. From an operational standpoint, maintaining the cockpit over the centerline reduces the possibility of excursions from the taxiway. Appendix 2 contains guidance on the selection and design of pavement fillets to provide the standard taxiway edge safety margin.

a. Design. The basic designs for the most common types of taxiway-taxiway intersections are shown in figure 4-1. Tables A2-1 (Appendix 2) and 4-1 present the dimensional standards. These intersection designs are also used for taxiway-apron intersections. Adjustment of these shapes to achieve more efficient construction procedures may be desirable and should be considered on the basis of cost. It may be cost effective to square the venturi areas or design the pavement fillets by using the methodology presented in paragraph 3 of appendix 2.

b. Limitations. The criteria depicted in figure 4-1 are applicable to taxiway-taxiway intersections and taxiway-apron intersections, but not to runway-taxiway intersections. Runway-taxiway intersections are discussed and detailed in subsequent text and accompanying figures.

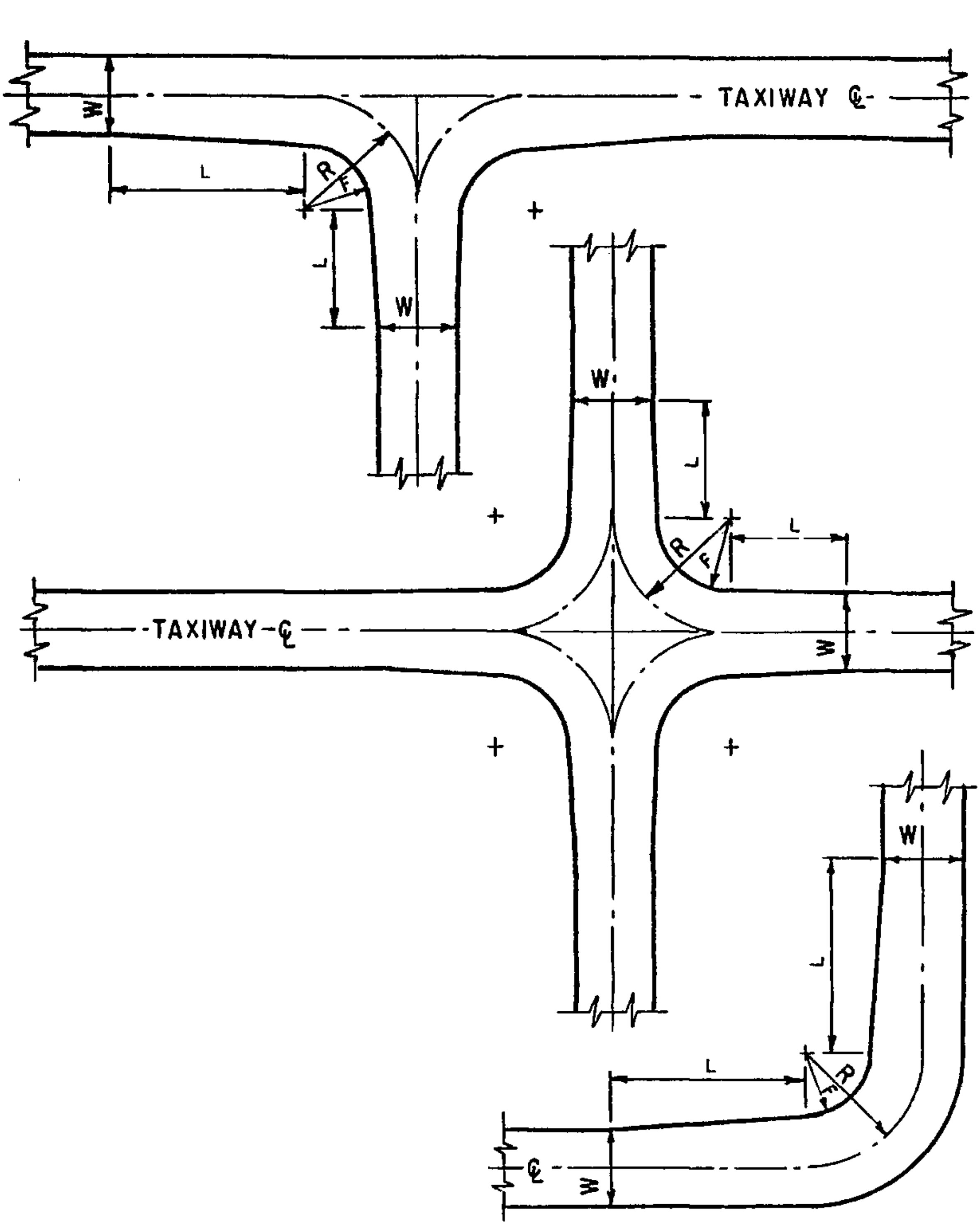


Figure 4-1. Taxiway intersection details

28. ENTRANCE TAXIWAYS. Various configurations of runway entrance taxiways have been proposed during recent years in an effort to increase the capacity of a runway. After consideration of the factors involved, the configuration shown in figure 4-2 has been found to be cost effective.

a. Dual Use. An entrance taxiway also serves as the last exit taxiway on a bi-directional runway. It is normally in the form of an "L" taxiway intersection with a right angle connection to the runway.

b. Radius. The centerline radius of curvature should be as large as possible to accommodate higher speeds. The largest radius which can be provided is usually-dependent on the separation distance between the runway and parallel taxiway.

c. Design. The entrance design shown in figure 4-2, with the minimum recommended fillet radii, will allow entrance speeds of 20 m.p.h. (30 km per hour), the minimum design speed for the taxiway system. Larger radii will allow higher entrance speeds. The width is designed to provide at least the standard taxiway edge safety margin.

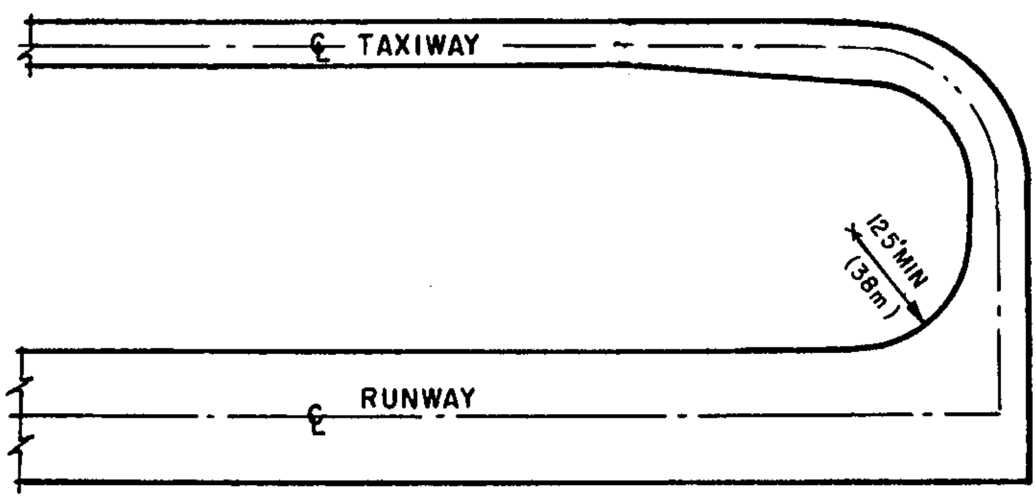


Figure 4-2. Entrance taxiway

29. BYPASS TAXIWAYS. On busy airports, airport traffic control tower personnel have encountered occasional bottlenecks in moving airplanes ready for departure to the desired takeoff runway when a preceding airplane not ready for takeoff blocks the access taxiway. Bypass taxiways provide flexibility in runway use by permitting ground maneuvering of departing airplanes. Analysis of existing and projected traffic should indicate whether a bypass taxiway would enhance traffic flow.

a. Location. Bypass taxiways are normally located at or near the runway entrance. They can be parallel to the main entrance taxiway serving the runway, as shown in figure 4-3, or used in combination with the dual parallel taxiways, as depicted in figure 4-4.

b. Design. The width of bypass taxiways is designed to provide at least the standard taxiway edge safety margin. Separation and clearance standards are the same as for parallel taxiways. Where bypass facilities are developed which reduce the usable runway length, the pilot must consider the runway length remaining from the bypass taxiway intersection as the available takeoff runway length.

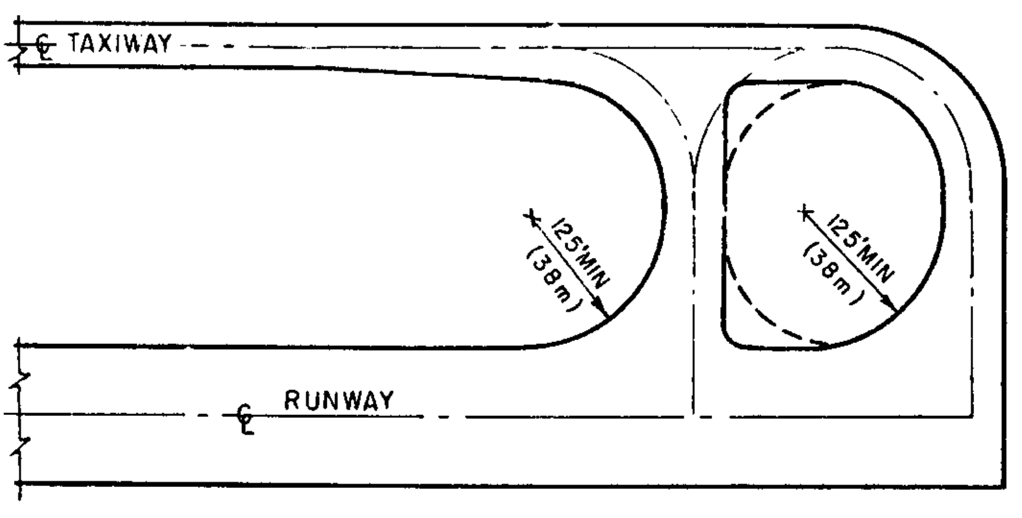


Figure 4-3. Bypass taxiway

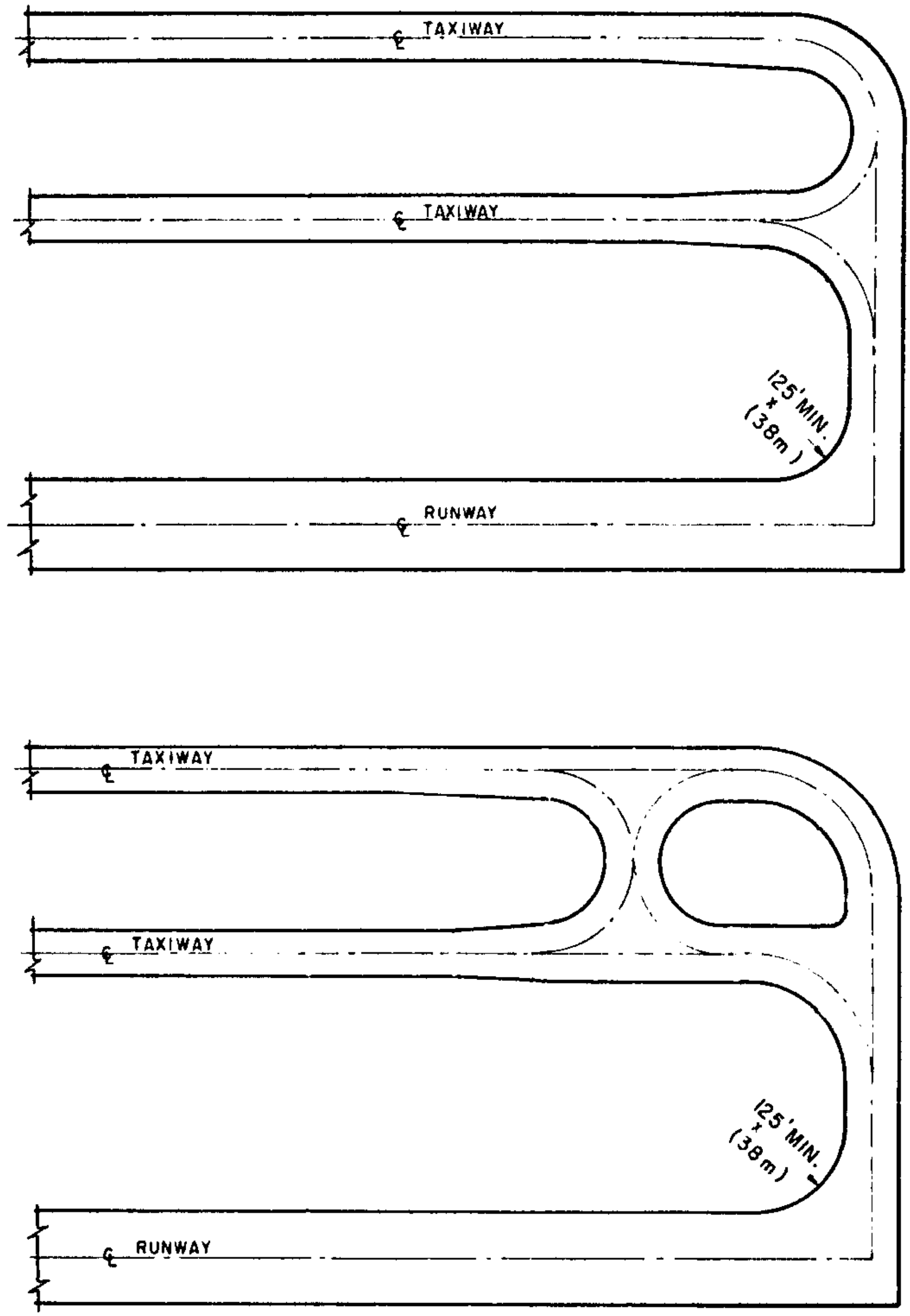


Figure 4-4. Dual parallel taxiway entrance

30. HOLDING BAYS. Holding bays may be used in lieu of bypass taxiways. Their major use is to provide a holding or parking space for airplanes awaiting final air traffic control (ATC) clearance and to permit those airplanes which have clearance to move to the runway takeoff position. Holding bays, by virtue of their spaciousness, enhance maneuverability for holding airplanes while also permitting bypass operations. Figure 4-5 shows some typical holding bay configurations.

a. Location. Although the most advantageous position for a holding bay is adjacent to the taxiway serving the runway end, it may be satisfactory in other locations. The location of holding bays is predicated on keeping airplanes out of the OFZ and the runway safety area, as well as avoiding interference with instrument landing system (ILS) localizer and glide slope operations.

b. Alternative. An alternate to providing a holding bay is to pave the area between dual parallel taxiways serving a runway end. However, bypass taxiways enable easier ATC direction and control. The choice between providing a holding bay or multiple access or bypass taxiways normally depends on local site conditions.

c. Size. The diameter of the space required to maneuver and hold an airplane may be approximated by applying the following ranges of factors to airplane wingspans:

(1) For dual-wheel gear - 1.35 to 1.50;

(2) For dual-tandem gear - 1.60 to 1.75; and,

(3) For single-wheel gear - 1.50 to 1.65.

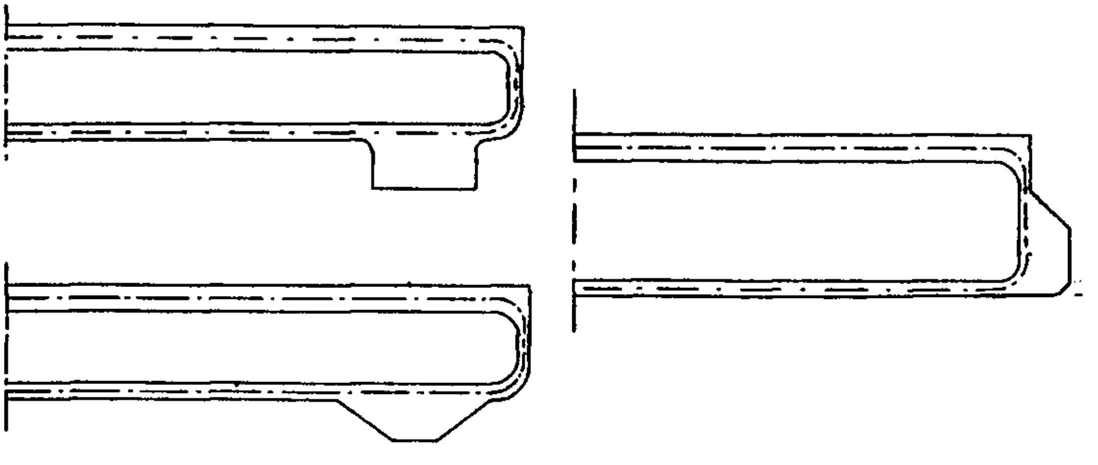


Figure 4-5. Typical holding bay configurations

31. TURNAROUNDS. When it is not economically feasible to provide a parallel taxiway, it is recommended that a turnaround be constructed to serve as a combination holding bay and bypass taxiway. Figure 4-6 shows a taxiway turnaround.

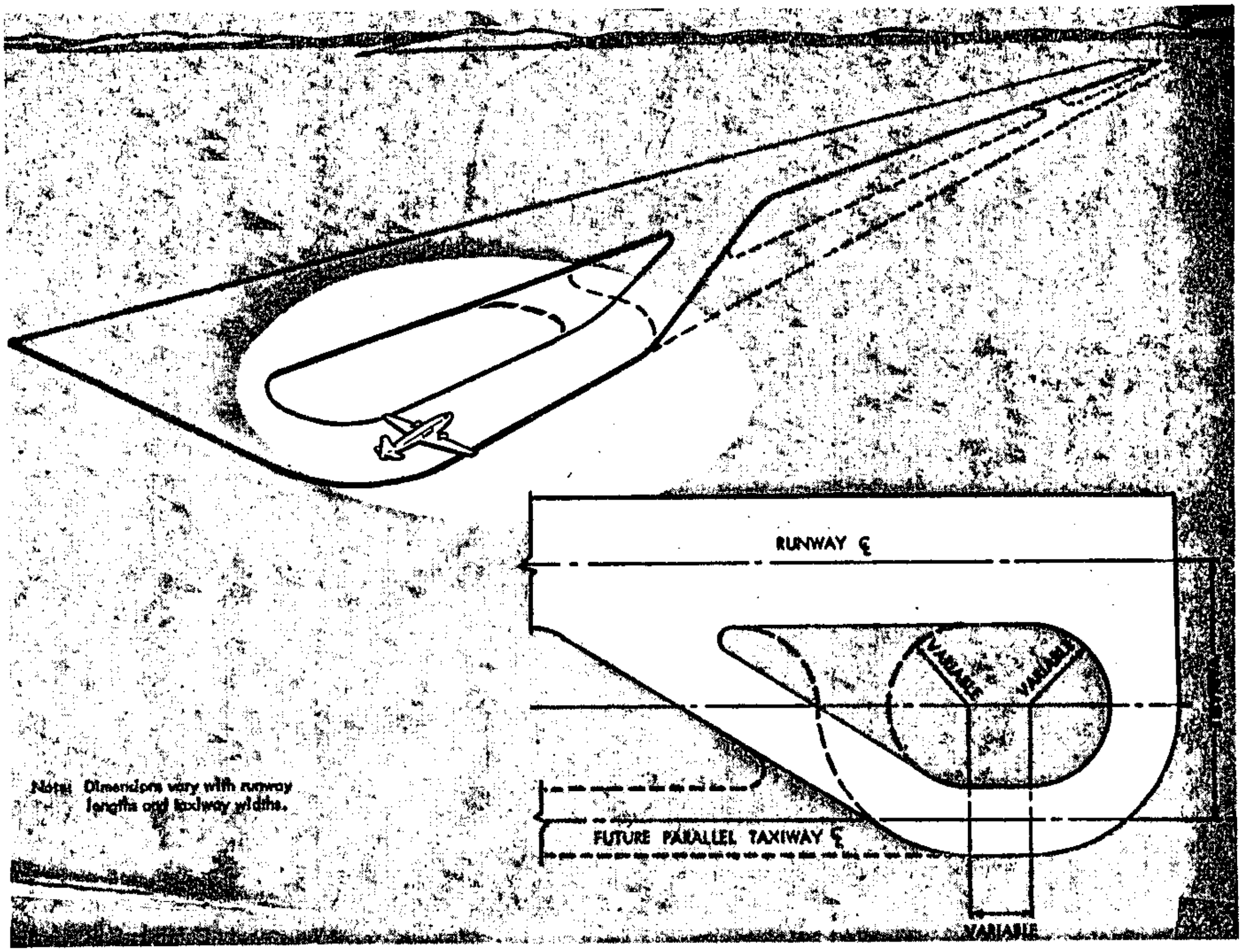


Figure 4-6. Taxiway turnaround

32. DUAL PARALLEL TAXIWAYS. Airport planning to accommodate high density traffic should consider multiple access to runways. For example, to facilitate ATC release using selected directional flow, i.e., south departure, west departure, etc., at some busy airports, airplanes are selectively queued on dual (or even triple) parallel taxiways. These parallel sections may not be required for the full length of the runway. Where dual parallel taxiways are used, crossover taxiways should be provided to increase flexibility, as shown in figure 4-7. When a central taxiway is located between two parallel runways to expedite traffic flow, its centerline separation from each runway at least equals the standard separation distance specified in table 2-1.

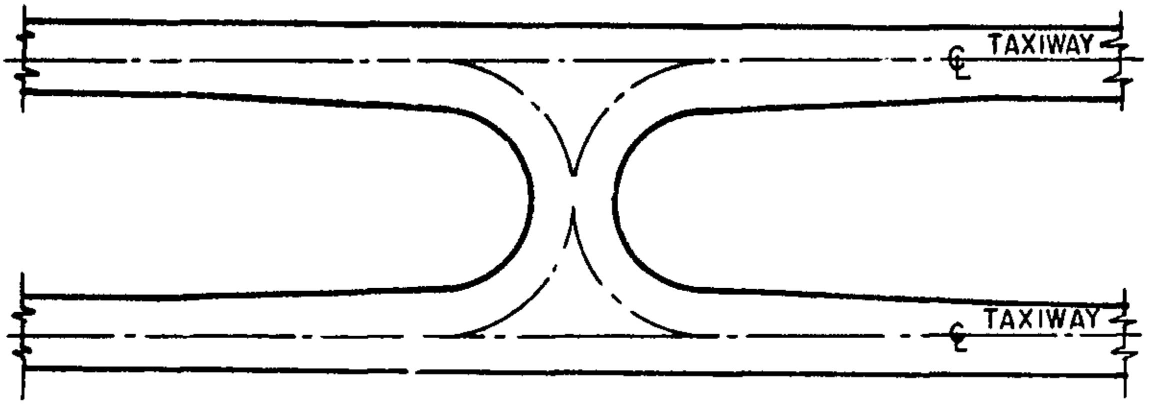


Figure 4-7. Crossover taxiway

33. EXIT TAXIWAYS. Exit taxiways are designed and located to meet the operational requirements of the airport.

a. Efficiency. Exit taxiways should be located at those intervals along the runway which correspond to the average turnoff points of the groups of airplanes using the runway. These taxiways should permit free flow to the parallel taxiway or at least to a point where the airplane is considered, for air traffic control purposes, clear of the runway.

b. Type. A decision to provide a right-angled exit taxiway or an acute-angled exit taxiway is based upon an analysis of the existing and contemplated traffic. The main purpose of the acute-angled exit taxiway, commonly referred to as the "high speed exit," is to enhance the capacity of the airport. However, when the design peak hour traffic is less than 30 operations (landings and takeoffs), the right-angled exit taxiway can be constructed at less cost and, when properly located along the runway, achieve an efficient flow of traffic.

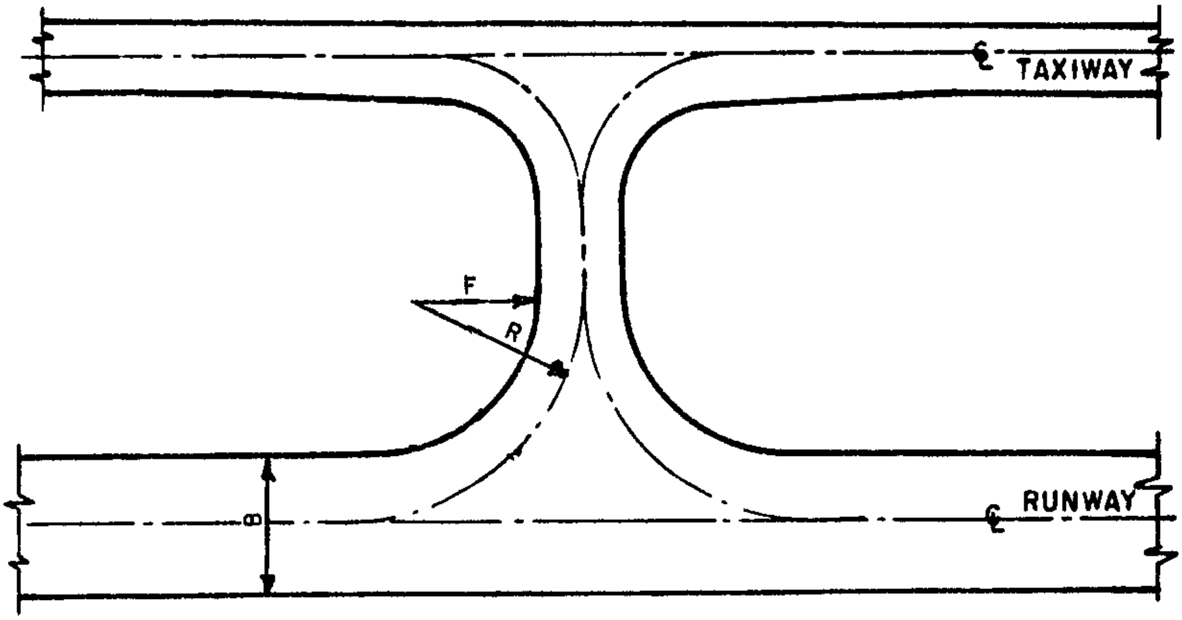


Figure 4-8. Right-angled exit taxiway

c. Separation. The type of exit taxiway selected will influence the separation between the runway and taxiway. The standard 400 foot (120 m) runway-taxiway separation is satisfactory with right-angled exit taxiway operations. To allow efficient use of an acute-angled exit taxiway, including a reverse curve for "double-back" operations, a separation distance of 600 feet (180 m) is recommended. A 400 foot (120 m) separation may be adequate, though, where the traffic flow is in one direction and control over runway-taxiway operations is available.

d. Configuration. Figure 4-8 presents the configuration for a right-angled exit taxiway. A 30 degree entrance spiral of at least a 300 foot (90 m) length should be provided. Figure 4-9 illustrates an acute-angled exit taxiway with a 30 degree angle of intersection. To achieve the higher speeds associated with this type of exit, an entrance spiral length of at least 1,400 feet (420 m) is required.

e. Location. The locations of exit taxiways depend upon the performance capabilities of the airplanes, the type of exit, and the length of the runway. To accommodate the average mix of airplanes on runways up to 7,000 feet (2 000 m) in length, the point of intersection (P.I) of the taxiway exits should be considered at approximately 3,000 feet (900 m) from the threshold and at approximately 2,000 feet (600 m) from the stop end of the runway. To accommodate the average mix of airplanes on runways longer than 7,000 feet (2 000 m), intermediate exits should be located at intervals of approximately 1,500 feet (450 m), depending upon local conditions and airport needs.

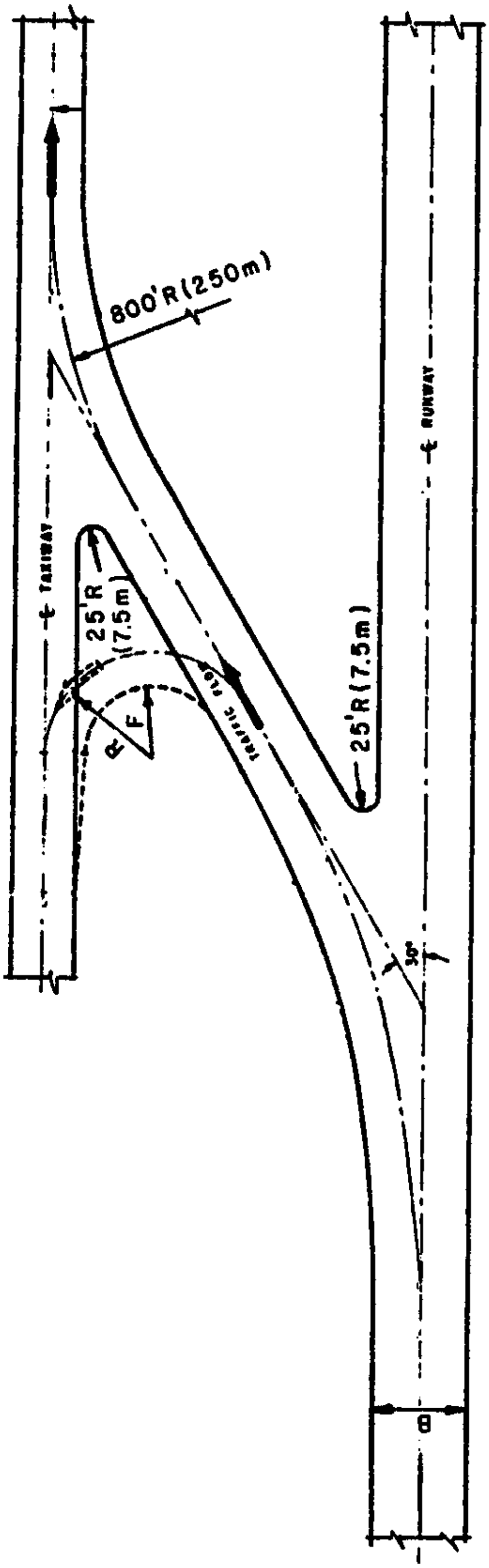


Figure 4-9. Acute-angled exit taxiway

34. EXITS FOR AIRCRAFT APPROACH CATEGORY A AND B AIRPLANES. On runways also used frequently by Aircraft Approach Category A and B airplanes, an exit located between 1,500 to 2,000 feet (450 to 600 m) from the threshold is recommended. This exit should have the capability of accepting a turnoff speed of up to 40 m.p.h. (60 km per hour), and requires a minimum curve radius of 800 feet (245 m). The recommended intersection angle of 45 degrees is depicted in the typical layout shown in figure 4-10.

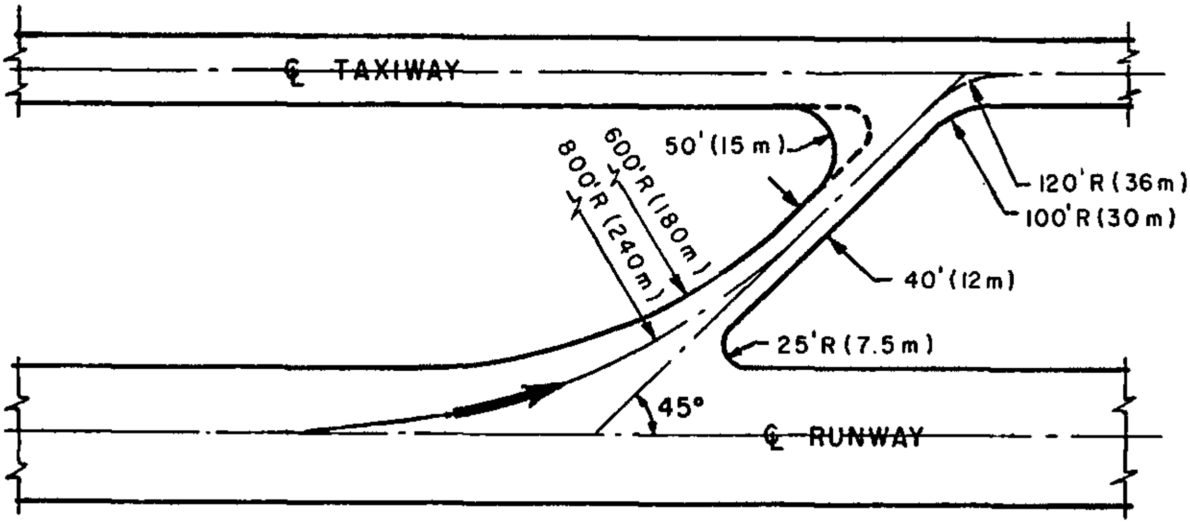


Figure 4-10. Acute-angled exit taxiway for Aircraft Approach Category A and B airplanes

35. APRON TAXIWAYS AND TAXILANES. Requirements often exist to provide through-taxi routes across an apron and to provide secondary access to gate positions or other terminal areas.

a. Separation. Apron taxiways require the same separations as normal taxiways. When the apron taxiway is located on the edge of the apron, its centerline is located inward from the edge at a distance equal to one-half of the recommended width of the taxiway structural pavement. A shoulder is required for the outer edge. The taxiway safety area and the lateral separation specified in table 2-1 are required.

b. Taxilanes. Taxilanes provide access from taxiways to airplane parking positions and other terminal areas. Their only design requirement is to provide the lateral separation specified in table 2-1.

c. Visibility. The airport traffic control tower should have a clear line-of-sight to the centerline of all apron taxiways. The same clear line-of-sight is also desirable for taxilanes (where the air traffic control tower is not responsible for controlling traffic).

CHAPTER 5. SURFACE GRADIENT AND LINE-OF-SIGHT

36. INTRODUCTION. This chapter contains gradient and line-of-sight standards. The standards are used to design the gradients of airport surfaces required for the landing, takeoff, and ground movement of airplanes.

37. BACKGROUND. Surface gradients must allow for design flexibility without adversely affecting operational safety. Line-of-sight standards impose additional restraints on surface gradients. This is due to the fact that runways are designed for bi-directional operations and may be intersected by other runways or taxiways. Therefore, it is important that a pilot be able to see anything on the runway or intersecting runway or taxiway which could endanger the operation. Airports with air traffic control towers exercise positive control of aircraft or surface vehicles on the airport runways and taxiways during hours of operation. Because of this, the standards for an unobstructed line-of-sight along individual runways or between intersecting runways, or between intersecting runways and taxiways, need not be as restrictive as they would be for an airport which is uncontrolled on a full or part-time basis.

38. SURFACE GRADIENT.

a. Runways and Stopways. The gradient standards for runways and stopways are as follows and are illustrated in figures 5-1 and 5-2.

(1) The maximum longitudinal grade is 1.5 percent; however, the longitudinal grade may not exceed 0.8 percent in the first and last quarter of the runway. *
It is desirable to keep longitudinal grades to a minimum.

(2) Whenever possible, longitudinal grade changes are to be avoided. The maximum allowable grade change is 1.5 percent and is only used when absolutely necessary.

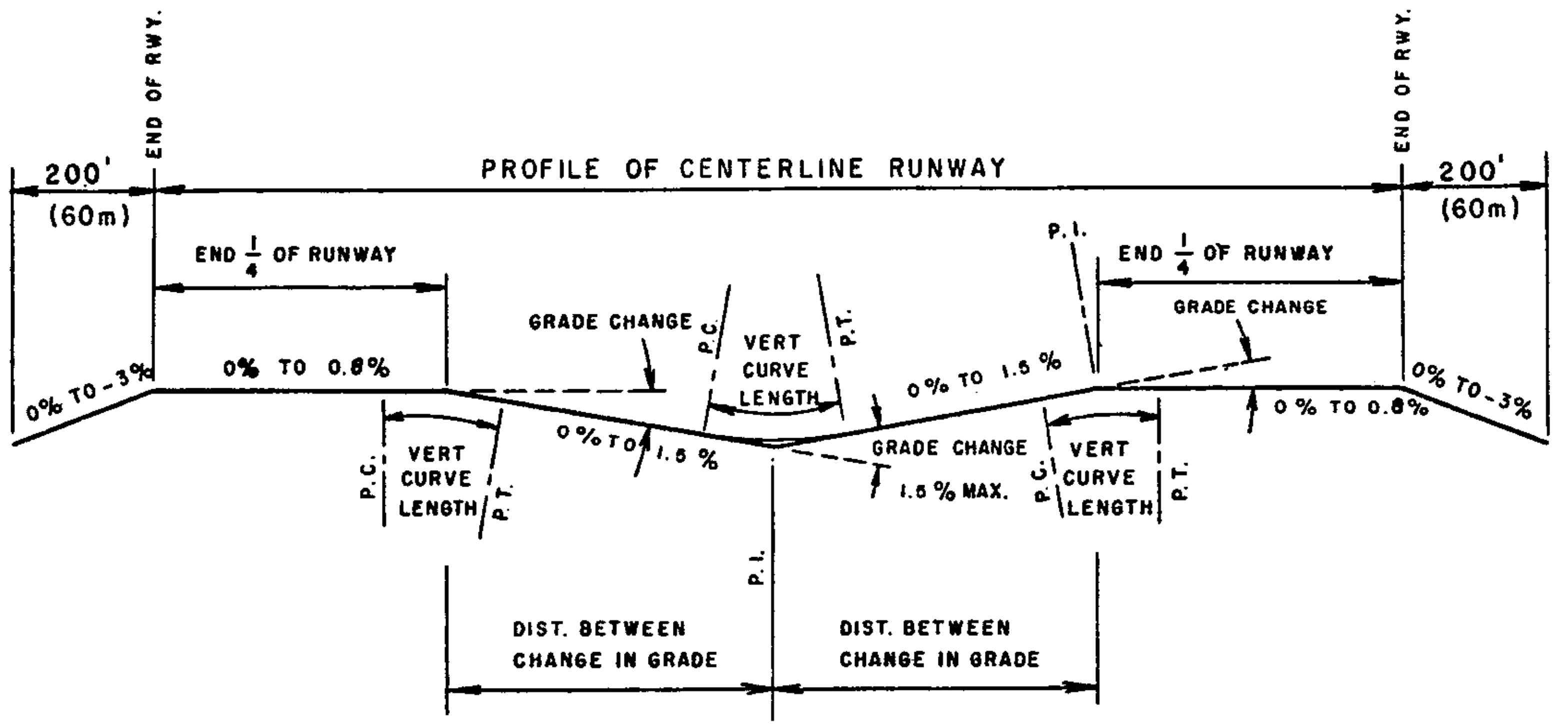
(3) When longitudinal grade changes are necessary, parabolic vertical curves are to be used. The length of the vertical curve is a minimum of 1,000 feet (300 m) for each 1 percent of change.

(4) The distance between the points of intersection of vertical curves is a minimum of 1,000 feet (300 m) multiplied by the sum of the grade changes (in percent) associated with the two vertical curves.

(5) The maximum allowable difference in runway centerline elevation is 1 percent of the runway length. For stopways, there is no maximum difference. If a clearway is to be provided, the stopway cannot penetrate the clearway plane. *

(6) For runways and stopways, the maximum transverse grade is 1.5 percent. However, the acceptable transverse grade range is from 1 to 1.5 percent.

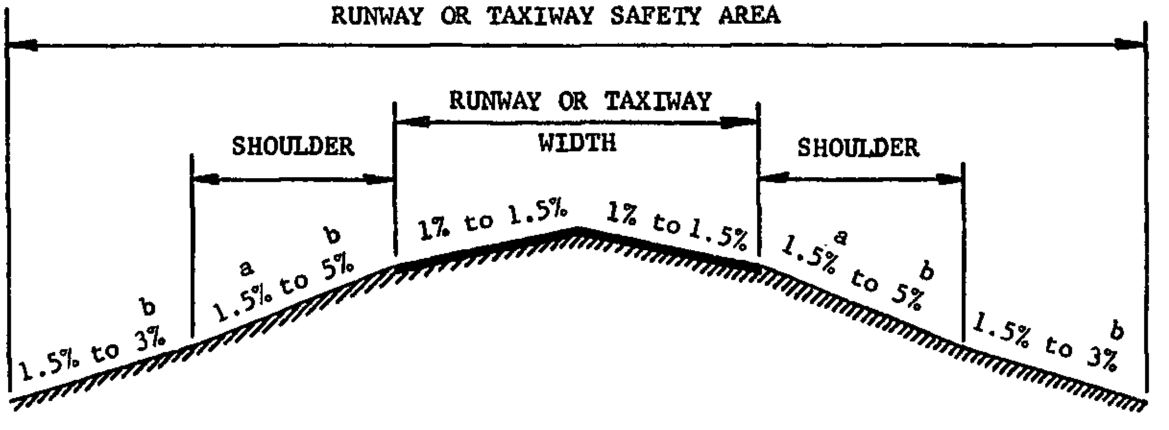
(7) Intersections on runways are designed to provide a smooth transition between the intersecting pavement surfaces as well as an adequate drainage of the intersection. The grades for the dominant (e.g., higher speed, higher traffic volume, etc.) runway in a runway-runway situation and for the runway in a runway-taxiway situation have precedence.



MINIMUM DISTANCE BETWEEN CHANGE IN GRADE = 1000' (300m) x SUM OF GRADE CHANGES (IN PERCENT).

MINIMUM LENGTH OF VERTICAL CURVES = 1000' (300m) x GRADE CHANGE (IN PERCENT).

Figure 5-1. Longitudinal grade limitations



a. 3% MINIMUM REQUIRED FOR TURF

b. A slope of 5% is recommended for a 10-foot (3 m) width adjacent to the pavement edges to promote drainage.

GENERAL NOTES:

1. A 1.5-inch (3.8 cm) drop from paved to unpaved surfaces is recommended.

2. Drainage ditches and swales may not be located within the safety area.

Figure 5-2. Transverse grade limitations

b. Runway Safety Area. Gradient standards for runway safety areas are stated in the following paragraphs and illustrated in figures 5-1, 5-2, and 5-3.

(1) Longitudinal grades, longitudinal grade changes, vertical curves, and distance between changes in grade standards for that part of the runway safety area between the runway ends are the same as the comparable standards for the runway and stopway, except where deviations are required by the presence of taxiways or other runways within the area. In such cases, the longitudinal grades of the runway safety area are modified by the use of smooth curves. For the first 200 feet (60 m) of the runway safety area beyond the runway ends (figure 5-1), the longitudinal grade is between 0 and 3 percent, with any slope being downward from the ends. For the remainder of the safety area (figure 5-3), the maximum longitudinal grade is such that no part of the runway safety area penetrates the approach surface or clearway plane. The maximum allowable negative grade is 5 percent. Longitudinal grade changes are limited to plus or minus 2 percent per 100 feet (30 m). Parabolic vertical curves should be used where practical.

(2) Maximum and minimum transverse grades for paved shoulders and for the the runway safety area along the runway and to 200 feet (60 m) beyond the runway end are shown in Figure 5-2. In all cases, the transverse grades are kept to a minimum, consistent with local drainage requirements. The criteria for the transverse grade beginning 200 feet (60 m) beyond the runway end are presented in figure 5-3.

(3) Grading requirements for navaids located in the runway safety area are, in most cases, more stringent than stated above and are found in AC 150/5300-2.

c. Runway Blast Pad. The longitudinal and transverse grades of the blast pad are the same as the respective grades of the safety area in which the blast pad is located.

d. Taxiways and Taxiway Safety Areas. Gradient standards for taxiways and taxiway safety areas are as follows:

(1) The maximum longitudinal grade is 1.5 percent. It is desirable to keep longitudinal grades to a minimum.

(2) Changes in longitudinal grade should be avoided. The maximum longitudinal grade change is 3 percent and should only be used when no other reasonable alternative is available.

(3) When longitudinal grade changes are necessary, parabolic vertical curves should be used. The minimum length of the vertical curve is 100 feet (30 m) for each 1 percent of change.

(4) The minimum distance between points of intersection of vertical curves is 100 feet (30 m) multiplied by the sum of the grade changes (in percent) associated with the two vertical curves.

(5) At any point on a taxiway centerline, the allowable difference in elevation between the taxiway and the corresponding point on the associated parallel runway, taxiway, or apron edge is 1.5 percent of the shortest distance between the points. For the purposes of this item, a parallel taxiway is any taxiway functioning as a parallel taxiway whether it is exactly parallel or not.

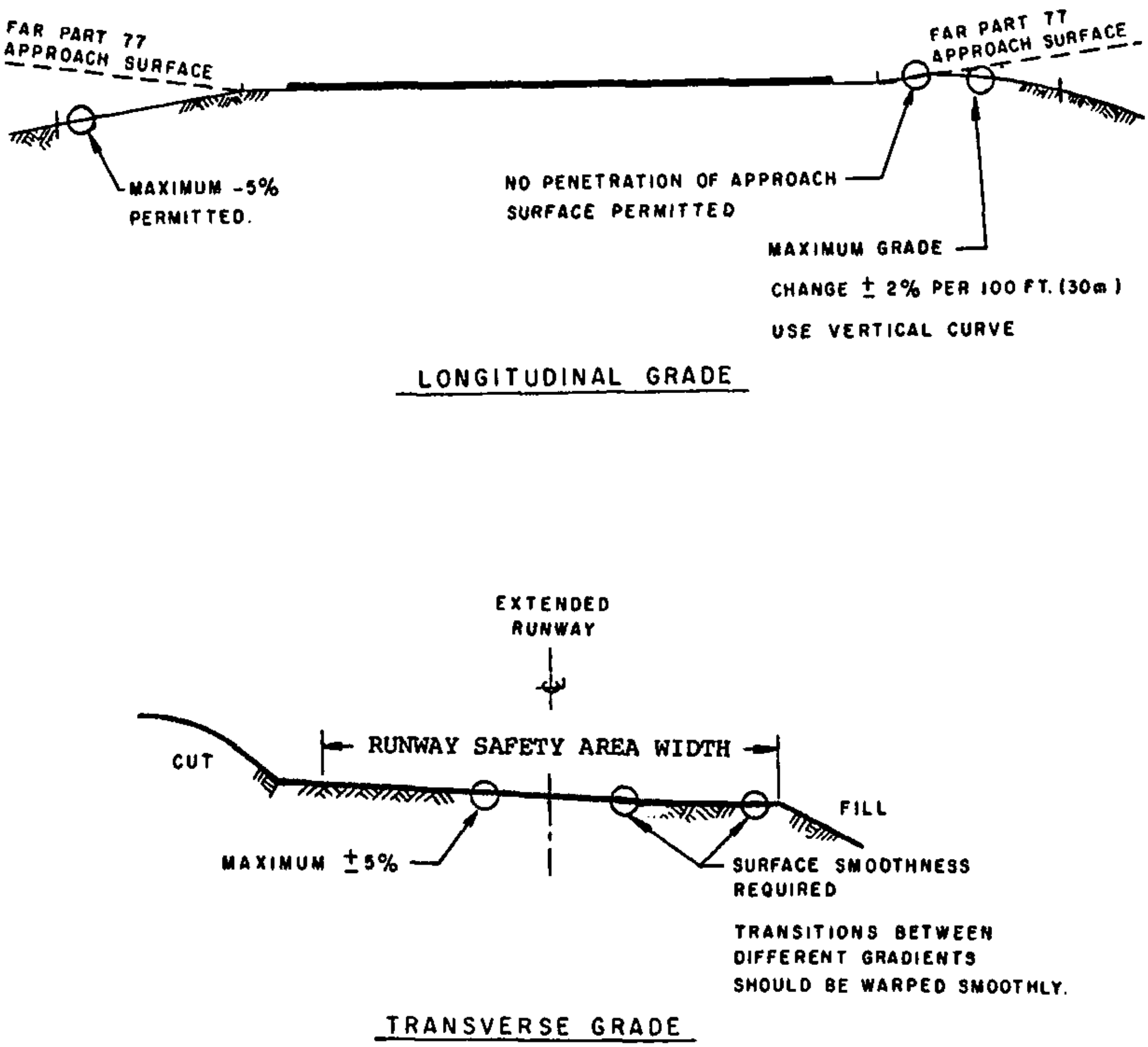


Figure 5-3. Runway safety area grade limitations - beyond 200 feet (60 m) from the runway end

This will allow the subsequent placement of a stub taxiway at any point to satisfy capacity requirements. Although desirable, it is not necessary to maintain the aforementioned elevation differential for the entire length of the taxiway when the locations of all future stub taxiways are known.

(6) Maximum and minimum transverse grades for taxiways and taxiway safety areas are shown in figure 5-2. In all cases, the transverse grades should be kept to a minimum, consistent with local drainage requirements.

e. Aprons. To ease aircraft towing and taxiing, apron grades (and drop inlets) should be kept to a minimum, consistent with local drainage requirements. The maximum allowable grade in any direction is 1 percent. Where possible, apron grades should be established to direct drainage away from the building areas. This is particularly important in fueling areas.

39. LINE-OF-SIGHT. The following paragraphs provide the minimum line-of-sight standards to be met:

a. Along Individual Runways.

(1) Airports Not Having a 24-hour Control Tower. Runway grade changes are limited so that any two points 5 feet (1.5 m) above the runway centerline will be mutually visible for the entire runway length. However, if the runway has a parallel taxiway for its full length, the runway grade changes may be such that an unobstructed line-of-sight will exist from any point 5 feet (1.5 m) above the runway centerline to all other points 5 feet (1.5 m) above the runway centerline within a distance of half the length of the runway.

(2) Airports Having a 24-hour Control Tower. Although it is desirable to provide an unobstructed line-of-sight for the entire runway length, adherence to longitudinal gradient standards will provide an adequate line-of-sight at these airports. However, before applying these criteria, a careful analysis should be made of the forecast airport activity to ascertain, within reason, that the tower will remain in 24-hour operation. Visibility requirements from the airport traffic control tower to the airport surface areas used for aircraft ground movement may not be violated. See paragraph 8h.

b. Between Intersecting Runways.

(1) Airports Not Having a 24-hour Control Tower. Runway grades, terrain, structures, and permanent objects must be such that there will be an unobstructed line-of-sight from any point 5 feet (1.5 m) above one runway centerline to any point 5 feet (1.5 m) above an intersecting centerline, both points being within the runway visibility zone. The runway visibility zone is an area formed by imaginary lines connecting the two runways' visibility points, as shown in figure 5-4. The locations of each runway's visibility points are determined in the following manner:

(i) When the distance from the intersection of two runway centerlines to a runway end is 750 feet (250 m) or less, the visibility point is located on the centerline at the runway end.

(ii) When the distance from the intersection of two runway centerlines to a runway end is greater than 750 feet (250 m) but less than 1,500 feet (500 m), the visibility point is located on the centerline, 750 feet (250 m) from the intersection of the runway centerlines.

(iii) When the distance from the intersection of two runway centerlines to a runway end is equal to or greater than 1,500 feet (500 m), the visi-bility point is located on the centerline equidistantly from the runway end and the intersection of the centerlines.

(2) Airports Having a 24-hour Control Tower. Although it is desirable to provide an unobstructed line-of-sight along the entire length of an intersecting runway, there are no mandatory line-of-sight requirements between intersecting runways at these airports. However, analysis should be made of the forecast airport activity to ascertain, within reason, that the tower will remain in 24-hour operation.

c. Taxiways. There are no specific line-of-sight requirements for taxiways. However, the sight distance along a runway from an intersecting taxiway must be sufficient to allow a taxiing aircraft to safely enter or cross the runway.

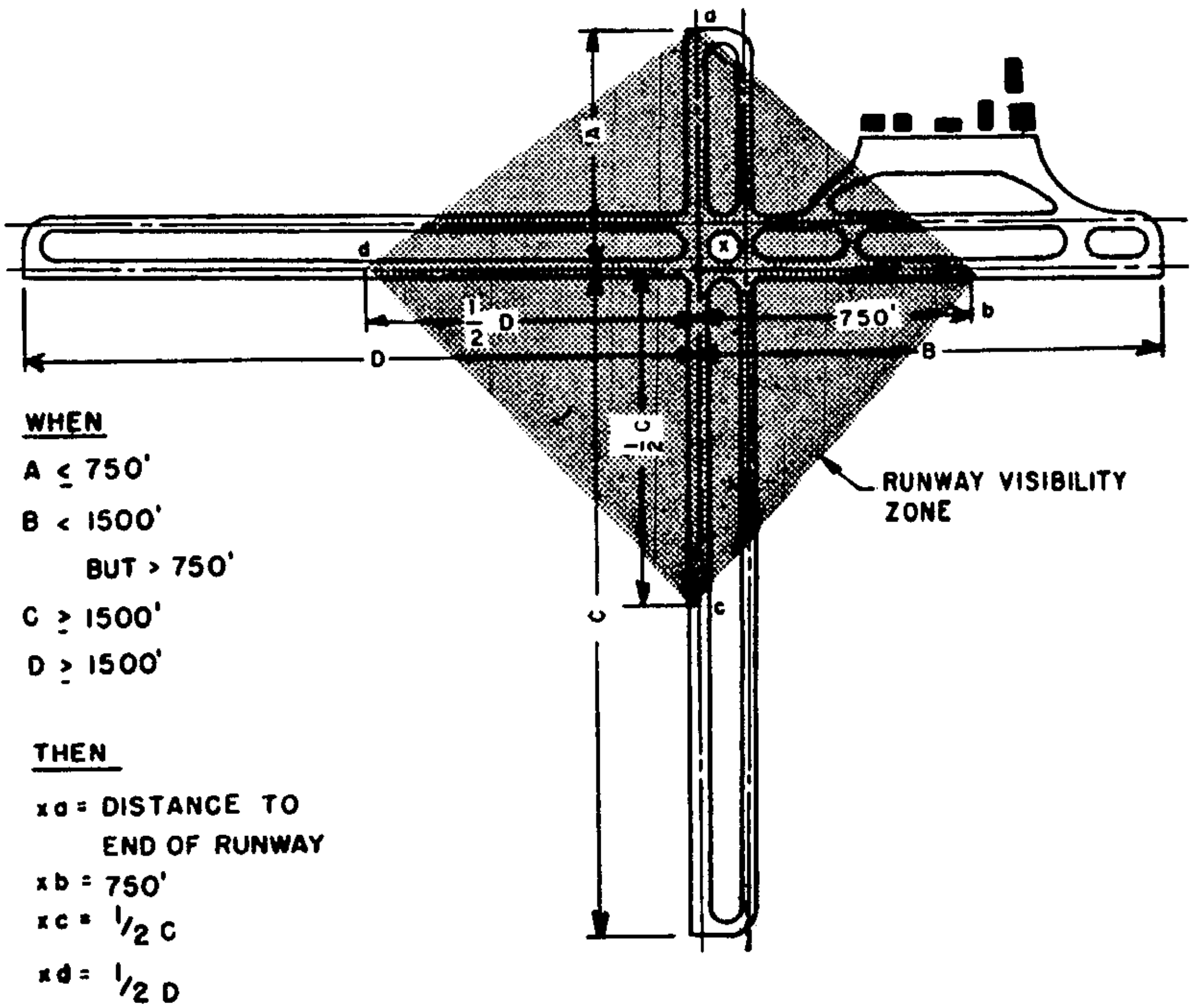


Figure 5-4. Runway visibility zone

CHAPTER 6. THE EFFECTS AND TREATMENT OF JET BLAST

40. INTRODUCTION. The forces of jet exhaust (jet blast) far exceed the forces of propwash from the most powerful propeller airplane. The high jet blast veloci-ties are capable of causing bodily injury to personnel and damage to airport equipment or facilities. This chapter suggests means to minimize the effects of jet blast.

41. JET BLAST EFFECTS. Jet blast affects all operational areas of the airport. In terminal, maintenance, and cargo areas, personnel safety is the overriding consideration. Blast velocities greater than 30 m.p.h. (48 km/hr) can cause loose objects on the pavement to become missiles capable of causing injury to personnel who may be at a considerable distance behind the airplane. In other operational areas, sudden gusts averaging more than 20 m.p.h. (31 km/hr) are considered hazardous, and, when striking moving vehicles or airplanes, are more dangerous than continuous velocities of the same magnitude. Velocities of this magnitude can occur over 2,000 feet (600 m) to the rear of certain airplanes when their engines are operating at takeoff thrust.

a. Jet Blast Pressures. Jet exhaust velocities are irregular and turbulent. The vibrations they induce over small areas should be considered in designing a building or structure subjected to jet blast. Over areas of 10 to 15 square feet (3 to 5 m^2), the velocities may be assumed to be periodic with peaks occuring 2 to 6 times per second. These peaks are not continuous laterally or vertically. The pressure they produce on a surface which is perpendicular to the exhaust stream may be computed using the equation:

$P = 0.00256\ V^2$, where:
P = pressure in pounds per square foot; and,
V = velocity in miles per hour.

$P = 0.04733\ V^2$, where:
P = pressure in pascals; and,
V = velocity in kilometers per hour.

b. Blast Velocity Distances. The drag and uplift forces produced by jet engines are capable of moving large boulders. A jet engine operating at maximum thrust is capable of lifting a 2-foot (0.6 m) boulder 35 feet (10 m) behind the airplane completely off the ground. Fortunately, these forces which cause severe erosion decrease rapidly with distance so that beyond 1,200 feet (365 m) behind a jet airplane only sand and cohesionless soils are affected. Figures 6-1 through 6-5 illustrate the velocity versus distance plots for representative airplanes. The distances shown are measured from the rear of the airplane and the velocities are for takeoff, breakaway, and idle thrust power settings. Similar data for other airplanes, including lateral and vertical velocity contours, may be obtained from the manufacturers.

c. Heat Effects. High temperatures are also associated with jet exhaust; but, the affected area is smaller than the area subject to hazardous jet blast velocities. Contours showing the level of heat at varying distances from jet engines are obtainable from airplane manufacturers.

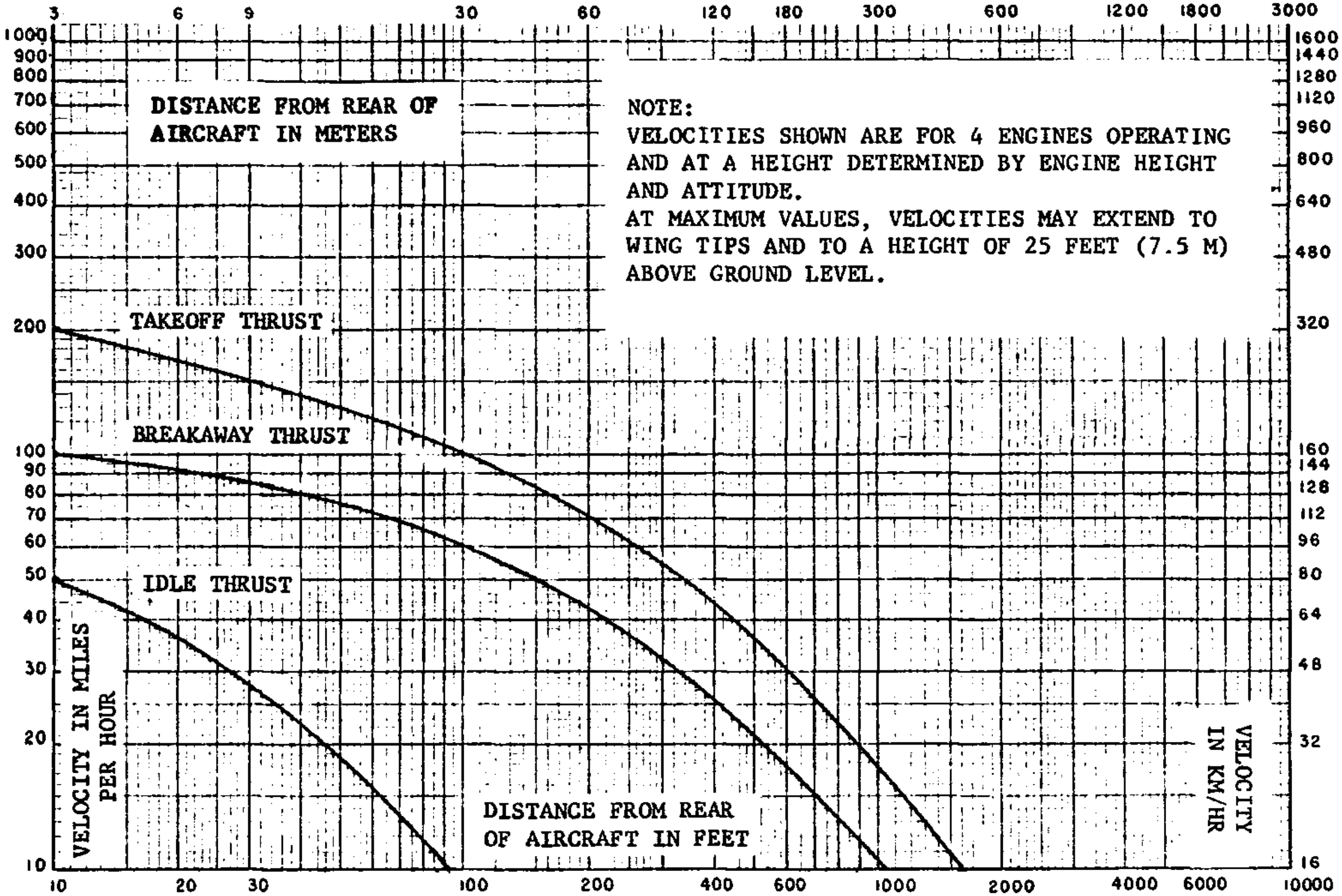


Figure 6-1. Velocity distance curves, DC-8

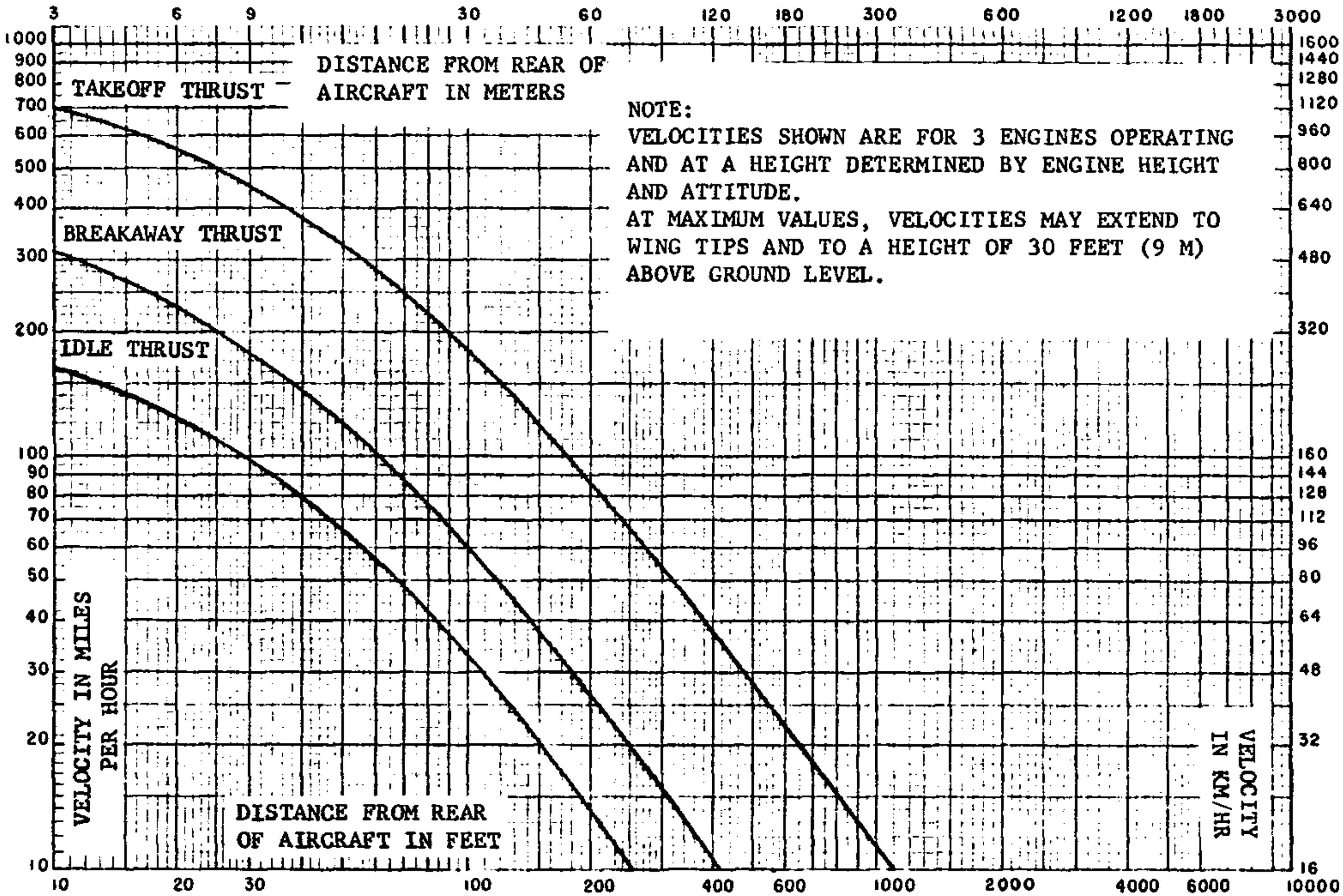


Figure 6-2. Velocity distance curves, B-727

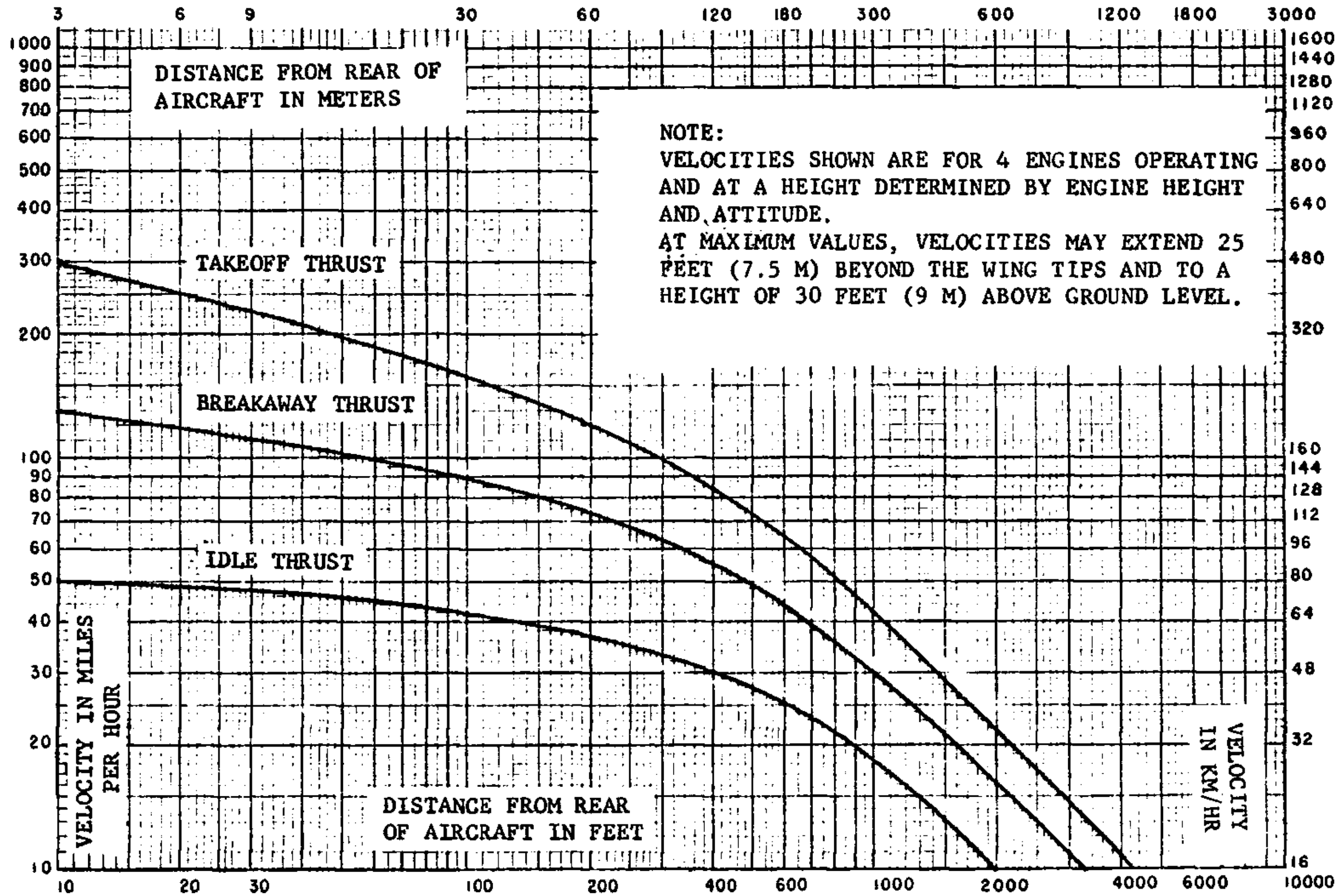


Figure 6-3. Velocity distance curves, B-747

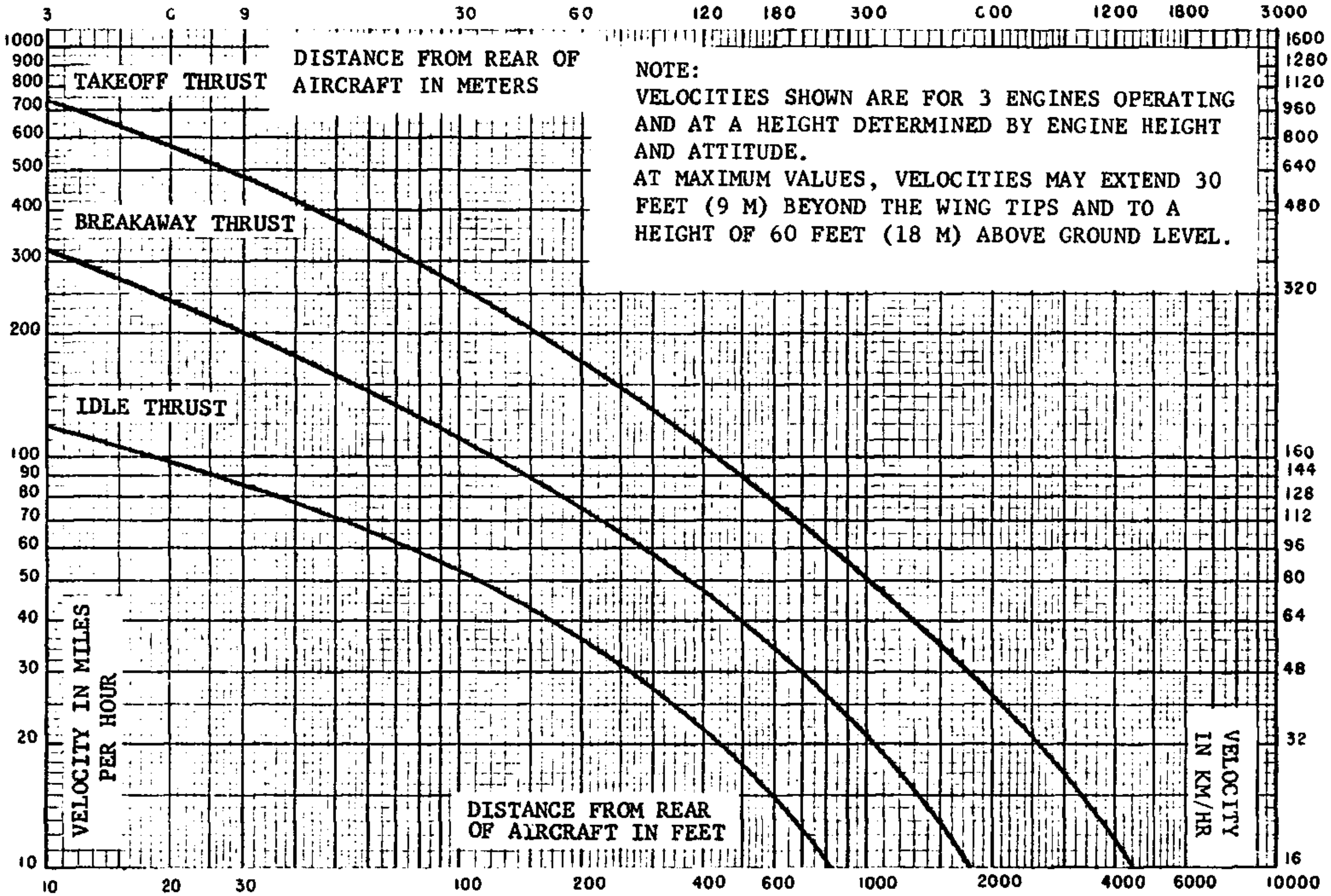


Figure 6-4. Velocity distance curves, DC-10

VELOCITY IN MILES/HOUR (KILOMETERS/HOUR)

Aircraft \ Distance Behind Engine	20'(6 m)	40'(12 m)	60'(18 m)	80'(24 m)	100'(30 m)
Fan Jet Falcon					
Idle	82(132)	36(58)	25(40)	22(35)	18(29)
Breakaway 1/	150(241)	68(109)	46(74)	33(53)	27(43)
Takeoff	341(549)	155(249)	106(171)	75(121)	62(100)
Jet Commander, Lear Jet, & Hansa					
Idle	54(87)	24(39)	15(24)	11(18)	9(14)
Breakaway	114(183)	50(80)	31(50)	22(35)	18(29)
Takeoff	259(417)	114(183)	68(109)	52(84)	42(68)
Jet Star & Sabreliner					
Idle	92(148)	41(66)	25(40)	18(29)	15(24)
Breakaway	195(314)	85(137)	52(84)	39(63)	31(50)
Takeoff	443(713)	194(312)	119(192)	89(143)	72(116)
Gulfstream II					
Idle	153(246)	75(121)	48(77)	41(66)	34(55)
Breakaway	330(531)	150(241)	102(164)	72(116)	60(97)
Takeoff	750(1207)	341(549)	232(373)	164(264)	136(219)

1/ "Breakaway" is that percentage of power required to start airplanes moving and usually is approximately 55 percent of maximum continuous thrust.

Figure 6-5. Blast velocities of business jet airplanes

42. BLAST FENCES. Properly designed blast fences can substantially reduce or eliminate the damaging effects of jet blast, as well as the related fumes and noise which accompany jet engine operation. Fences can be used near apron areas to protect personnel, equipment, or facilities from the jet blast of airplanes moving into or out of parking positions. In addition, blast fences may be needed near runway ends, run-up pads, etc., to shield off-airport, as well as, airport pedestrian or vehicular traffic.

a. Location. The location of the blast fence has an important bearing on its effectiveness. Generally, the closer the fence is to the source of blast, the better it performs, provided that the centerline of the exhaust stream falls below the top of the fence. Blast fences near runway ends are located in a manner which is not hazardous to aeronautical operations.

b. Design. Figures 6-6 and 6-7 illustrate several types of blast fence design which are readily available from various manufacturers.

c. Other Types of Blast Protection. Although blast fences are the most effective means of blast protection, other methods may achieve adequate results. Any surface, whether natural or manmade, located between the jet engine and the area to be protected will afford some measure of blast protection.

43. SHOULDERS AND BLAST PADS. Unprotected soils in the areas adjacent to runways and taxiways are susceptible to erosion. A dense, well-rooted turf cover may prevent erosion when there are limited jet operations. However, with frequent jet operations or a lack of suitable turf cover, some type of paved protection will probably be required.

a. Shoulder and Blast Pad Dimensions. When paved shoulders are required, they should run the full length of the runway(s) and taxiway(s). When blast pads are required at runway ends, the pads should extend across the full width of the runway plus the shoulders. Standard blast pad dimensions and runway shoulder widths are specified in table 3-1. Standard taxiway shoulder widths are specified in table 4-1. These standard dimensions may be increased for unusual local conditions.

b. Pavement Strength. Shoulder and blast pad pavements are designed to accommodate an occasional passage of the most demanding airplane and vehicle. Either airplane gear configuration and gross weight or axle load of emergency or maintenance equipment may dictate the pavement design.

(1) The design thickness required for shoulders and blast pads is one-half of the total pavement design thickness determined from the design procedures in AC 150/5320-6, Airport Pavement Design and Evaluation, current edition. The design thickness required to accomodate the most demanding axle load of emergency or maintenance equipment is the full thickness determined for that axle load as applied on a single wheel. The greater of these two thicknesses is provided.

(2) For Airplane Design Groups III and IV, the minimum bituminous concrete surface thickness, constructed on an aggregate base, is 2 inches (5 cm) for shoulders and 3 inches (7.5 cm) for blast pads. These dimensions are increased by 1 inch (2.5 cm) for Airplane Design Groups V and VI.

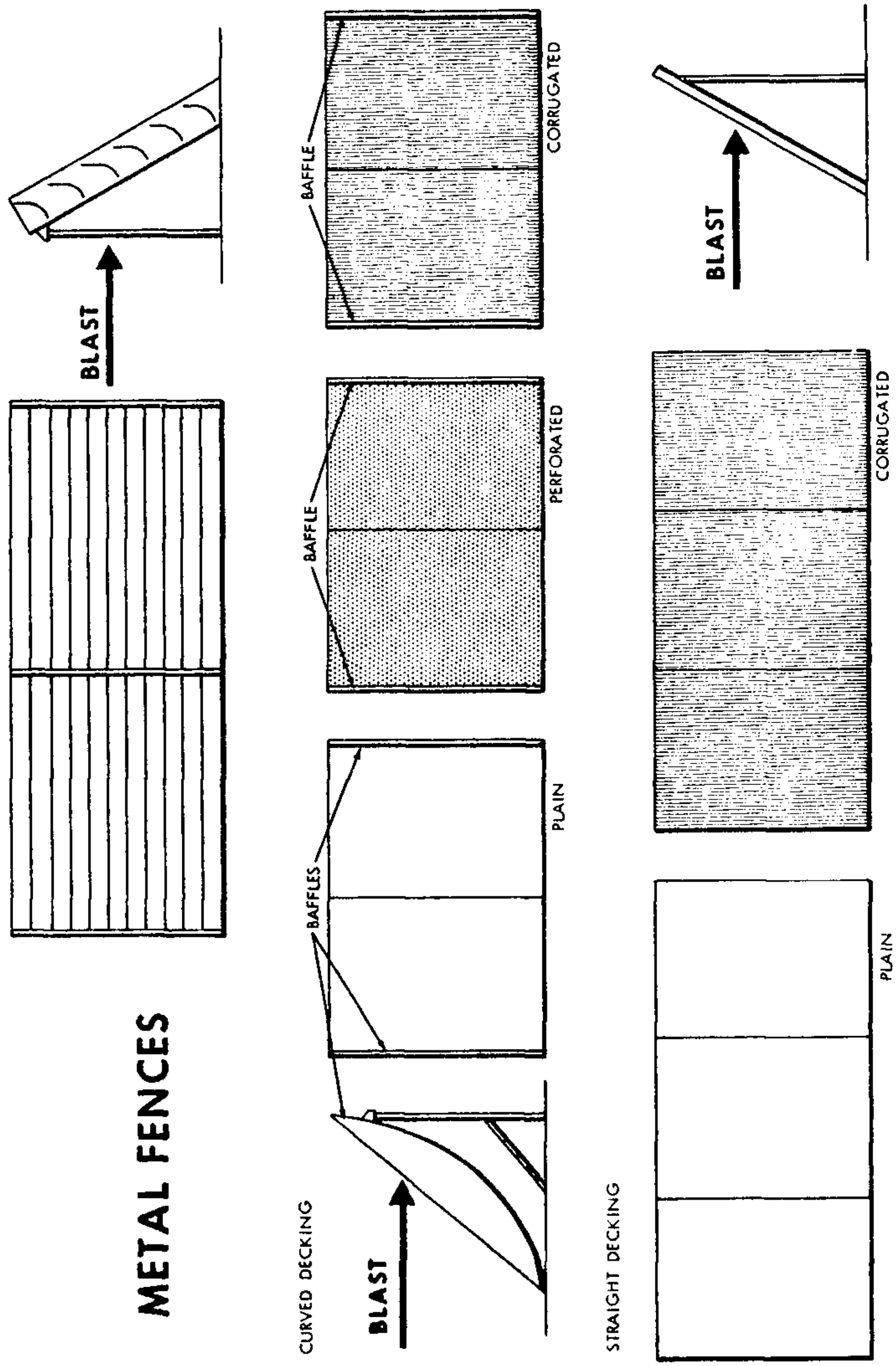
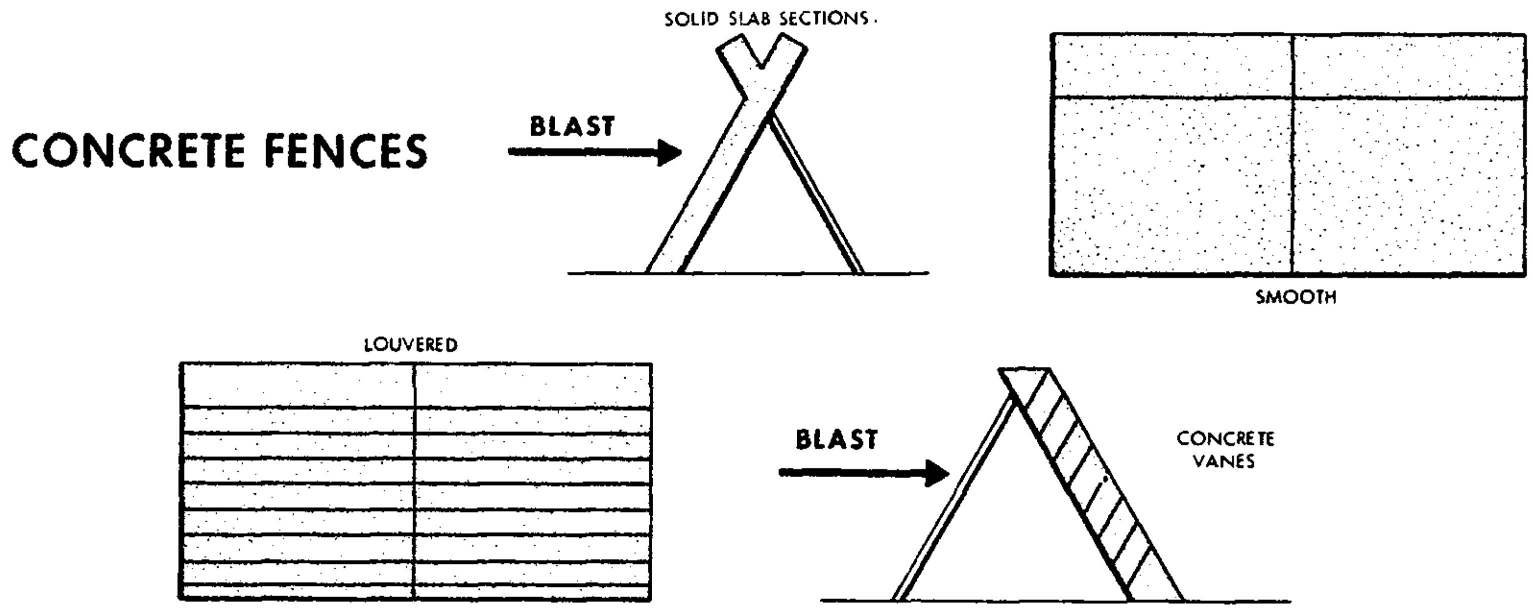


Figure 6-6. Typical blast deflector fences, metal


CONCRETE FENCES
SOLID SLAB SECTIONS
BLAST
SMOOTH
LOUVERED
BLAST
CONCRETE
VANES

(3) The use of a stabilized base in shoulder and blast areas is recommended. The design may use the 1.5 to 1 equivalency provisions of AC 150/5320-6; but, the standard bituminous concrete surface course thickness is not reduced.

(4) If it is advantageous to use portland cement concrete over a granular subbase, the minimum thickness of the concrete pavement is the 5 inches (13 cm) recommended in AC 150/5320-6.

(5) The compaction and construction criteria for subgrade and pavement courses in the shoulder and blast pad areas are identical to those for full strength pavement except the design may be based on 50-blow laboratory samples. A Marshall stability of 500 minimum and a flow of 20 maximum should be adequate.

(6) A 1.5 inch (3.8 cm) drop-off is the standard at the edge of paved shoulders and blast pads to enhance drainage and to prevent fine graded debris from accumulating on the pavement.

c. Drainage. Surface drainage should be maintained or improved in the shoulder and blast pad areas. Where a paved shoulder or blast pad abuts the runway, the joint should be flush, however, the 5 percent transverse slope may be retained in the shoulder. It is recommended that courses of sufficient depth to maintain the drainage properties of granular base or subbase courses under the runway, taxiway, or apron pavement be provided. An alternative is to provide a subdrain system with sufficient manholes to permit observation and flushing of the system.

d. Marking and Lighting. AC 150/5340-1 provides guidance for marking shoulders and blast pads. New construction should provide for edge lights to be base mounted and for any cable under the shoulder or blast pad pavement to be installed in conduit. When shoulders or blast pads are added to existing runways or taxiways, runway or taxiway edge lighting circuitry should be studied and required updating or modification carried out prior to shoulder or blast pad paving.

CHAPTER 7. RUNWAY AND TAXIWAY BRIDGES

44. INTRODUCTION. Efforts to extend a runway are in many cases complicated by an existing or proposed street, highway, or railroad which is important to the economy of the community. When closing or rerouting of the existing surface transportation mode is not practical, consideration should be given to bridging the runway over the impediment. This chapter presents guidance for that consideration.

45. SITING PRECEPTS. The extent of the structure(s) required may be minimized as follows:

a. Route. The surface modes should be routed or rerouted so that the least number of runway or taxiway bridges will be required.

b. Alignment. The surface modes, including utlities, should be routed or aligned so that all can be bridged with a single structure.

c. Locations. Bridges should be located on straight portions of taxiways and away from taxiway intersections or angled taxiway exits. Such airport features as the drainage system, utility service lines, runway and taxiway lighting circuits, ILS, and approach lighting system (ALS), may also affect bridge location and design.

46. DIMENSIONS. The design of runway and taxiway bridges is a complex engineering task. Dimensional considerations are discussed in this paragraph, while load considerations are contained in paragraph 47.

a. Length. Bridge length is measured parallel to the runway or taxiway centerline. Although minimum length structures are achieved when runways and taxiways cross surface modes at right angles, longer structures are needed when the surface mode to be crossed has a skewed or curved alignment.

b. Width. Bridge width is measured perpendicularly to the runway or taxiway centerline. The recommended bridge width is the width of the runway or taxiway safety areas. It is considered good practice to design a bridge for a runway and parallel taxiway as a continuous full-width, full-strength structure. Figures 7-1 and 7-2 illustrate full width structures. In unusual situations, site conditions may limit taxiway bridges to a width of the taxiway plus shoulders. A minimum width taxiway bridge requires: positive edge protection; adequate blast protection for vehicles or personnel on the mode being crossed; and, provision for the crossing and maneuvering of firefighting and rescue equipment. Figure 7-3 illustrates a minimum width taxiway bridge.

c. Height. Bridge height, essentially, is the vertical clearance provided over the surface mode being crossed. The required vertical clearances may be obtained from the office having jurisdiction over the surface mode in question. Except for positive edge restraints on minimum width taxiway bridges, no structural members should project above the runway or taxiway surface.

47. LOAD CONSIDERATIONS. Runway and taxiway bridges need to be designed to support the static and dynamic loads imposed by the heaviest airplane expected to use the structures. Airplanes weighing 836,000 pounds (370 100 kg) are in use today. Airplanes weighing 1,000,000 pounds (453 600 kg), or more, may exist by the turn of the century. Airport authorities should evaluate their community's potential need to accommodate these heavier airplanes and construct any runway or taxiway bridge accordingly. Over-design is preferable to the cost and operational penalties of replacing or strengthening an underdesigned structure at a later date.

48. LONGITUDINAL GRADES. Runway and taxiway grades are fixed at the time of airport design and, in most instances, dictate the grades when it becomes necessary to bridge a surface mode. To ensure adequate vertical clearances, it may be necessary to depress the grade of the surface mode. An alternative to avoid the excessive depression of the surface mode's grade is to make the bridge's structural deck coincident with the runway or taxiway surface. Whenever possible, however, it is recommended that the bridge be designed to incorporate a layer of select earth between the deck surface and the bottom of the runway or taxiway pavement. The earth acts as an insulator to minimize the possibility of bridge icing before adjacent pavement and maintains the continuity of appearance of the runway and taxiway safety areas.

49. MARKING AND LIGHTING. FAA standards for airport marking and lighting, found in the advisory circulars of the 150/5340 series, are augmented for runway and taxiway bridges.

a. Runways and Taxiways. When chevron marking is used, the standard spacing on a bridge is 25 feet (7.5 m).

b. Taxiways. The following elements are required on a taxiway bridge:

(1) Centerline lights or centerline reflectors;

(2) Edge lights or edge reflectors;

(3) Centerline and edge markings; and,

(4) Three equally-spaced L-810 obstruction lights on each bridge edge.

50. OTHER CONSIDERATIONS. The preceding paragraphs have covered design requirements applicable to all runway and taxiway bridges. The following identify additional design features which may be required as part of a specific runway or taxiway bridge project.

a. Guard Rails. Guard rails or safety curbs should be provided for minimum width taxiway bridges. Figure 7-3 shows a double-curb installation. Figures 7-6 and 7-7, respectively, illustrate vertical and horizontal guard rail installations.

b. Security Fences. Security fences are recommended at bridge-tunnel abutments to prevent inadvertent entry of persons, vehicles, or animals into operational areas. Figure 7-6 shows a security fence installation. AC 107-1, Aviation Security - Airports, current edition, furnishes additional guidance on the subject.

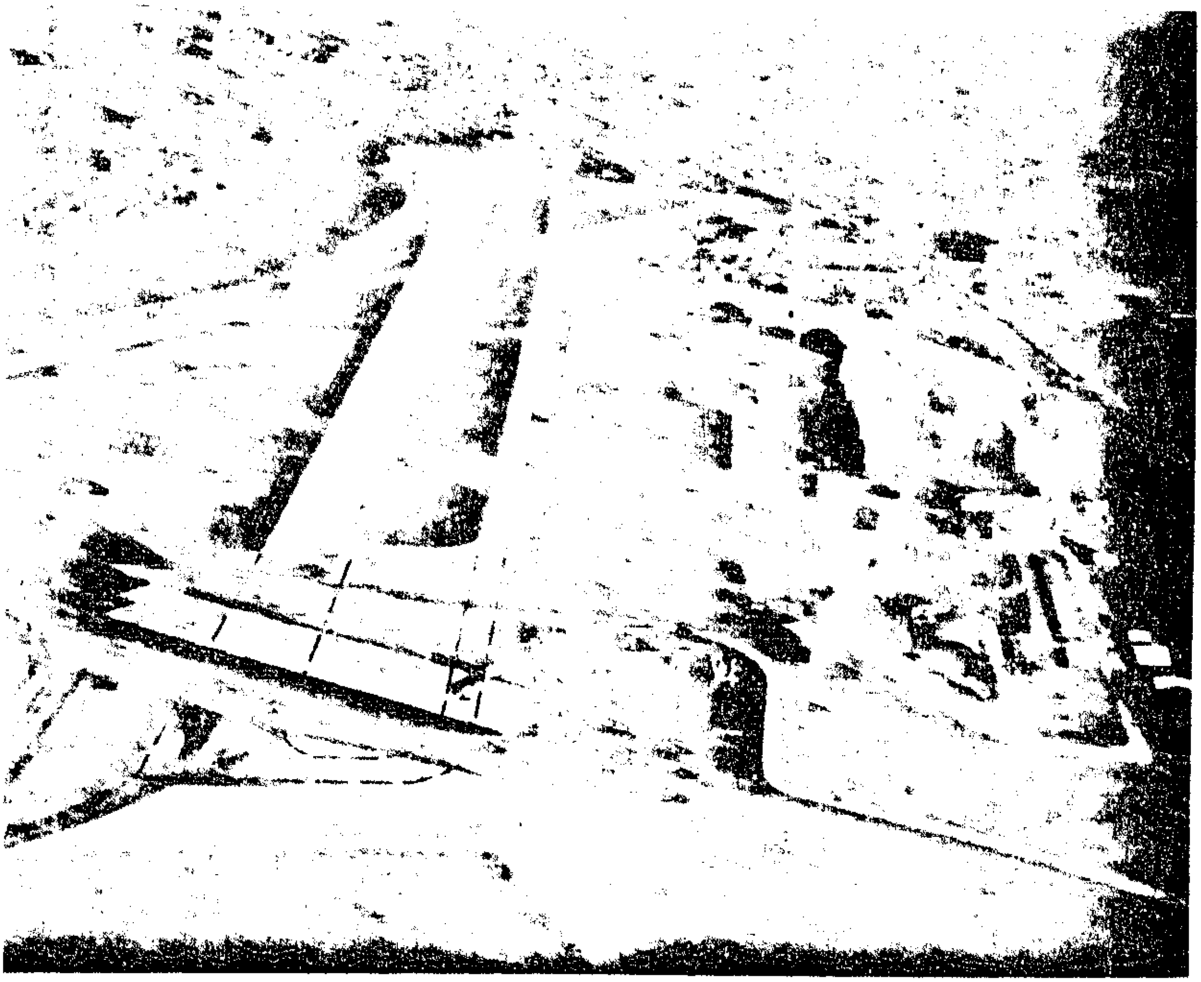
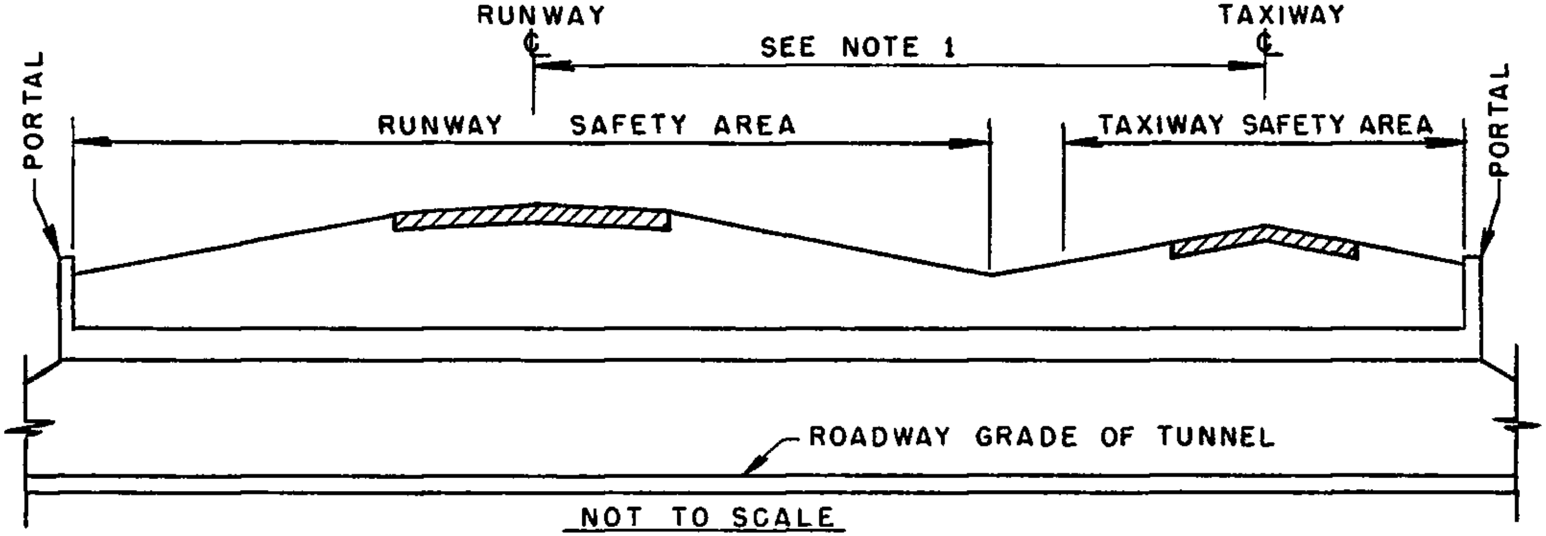


Figure 7-1. Full width runway-taxiway bridge under construction, Allegheny Co. Airport, Pittsburgh, PA



NOTES:

1. WIDTH OF TAXIWAY SAFETY AREA AND RUNWAY / TAXIWAY SEPARATION DISTANCE VARY DEPENDING ON AIRPLANE / TAXIWAY DESIGN GROUP.

2. ROADWAY TUNNEL NORMALLY HAS SLIGHT LONGITUDINAL GRADIENT AND SOME TYPE OF RETAINING WALL AT PORTALS

3. UNIFORM TUNNEL CROSS SECTION IS NORMALLY USED; AND A CONTINUOUS STRUCTURE WITHOUT OPEN SECTION IN INFIELD AREA IS PREFERRED AND RECOMMENDED WHEREVER FEASIBLE

Figure 7-2. Cross-section full width runway-taxiway bridge

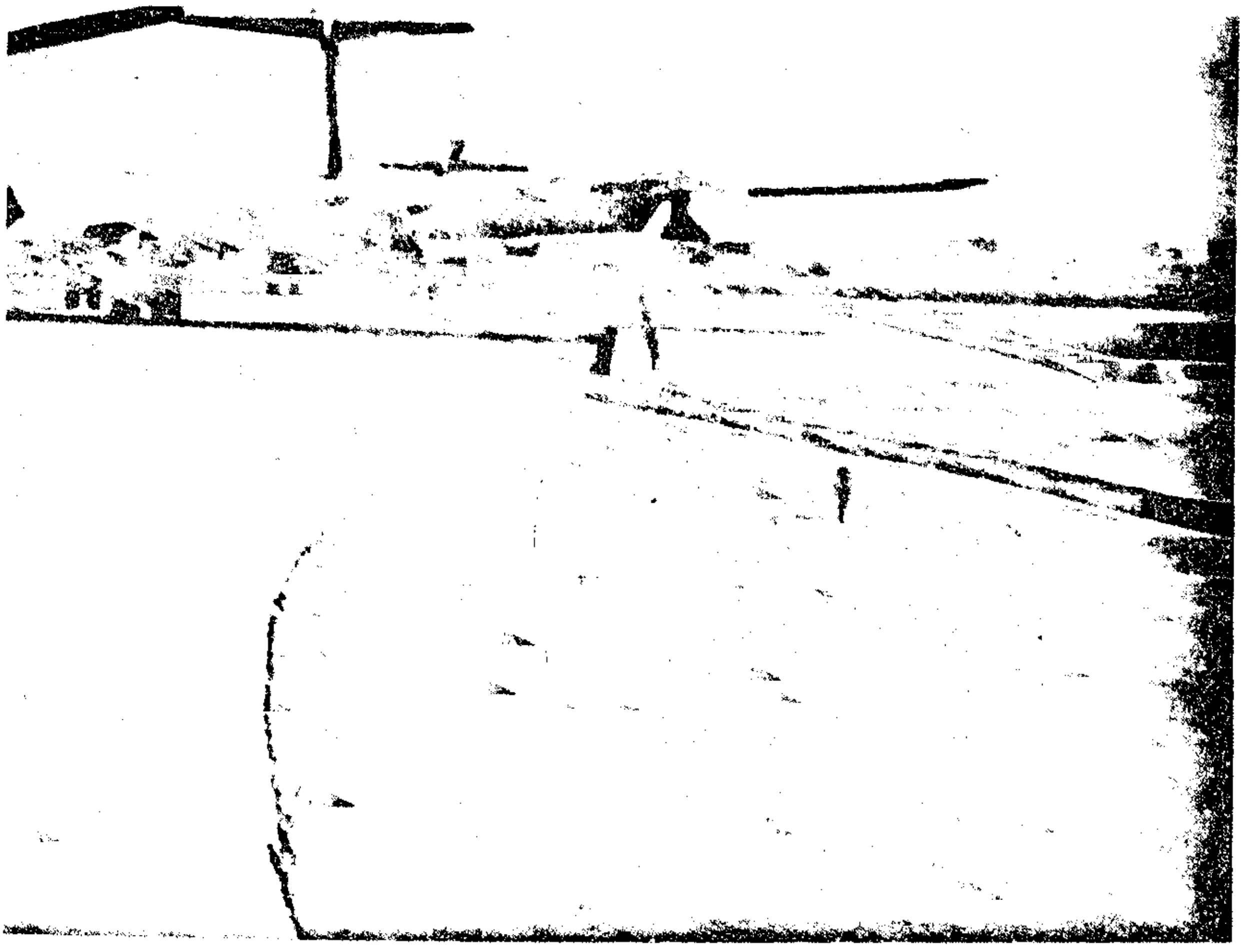


Figure 7-3. Minimum width taxiway bridge with positive edge protection, O'Hare Airport, Chicago, IL

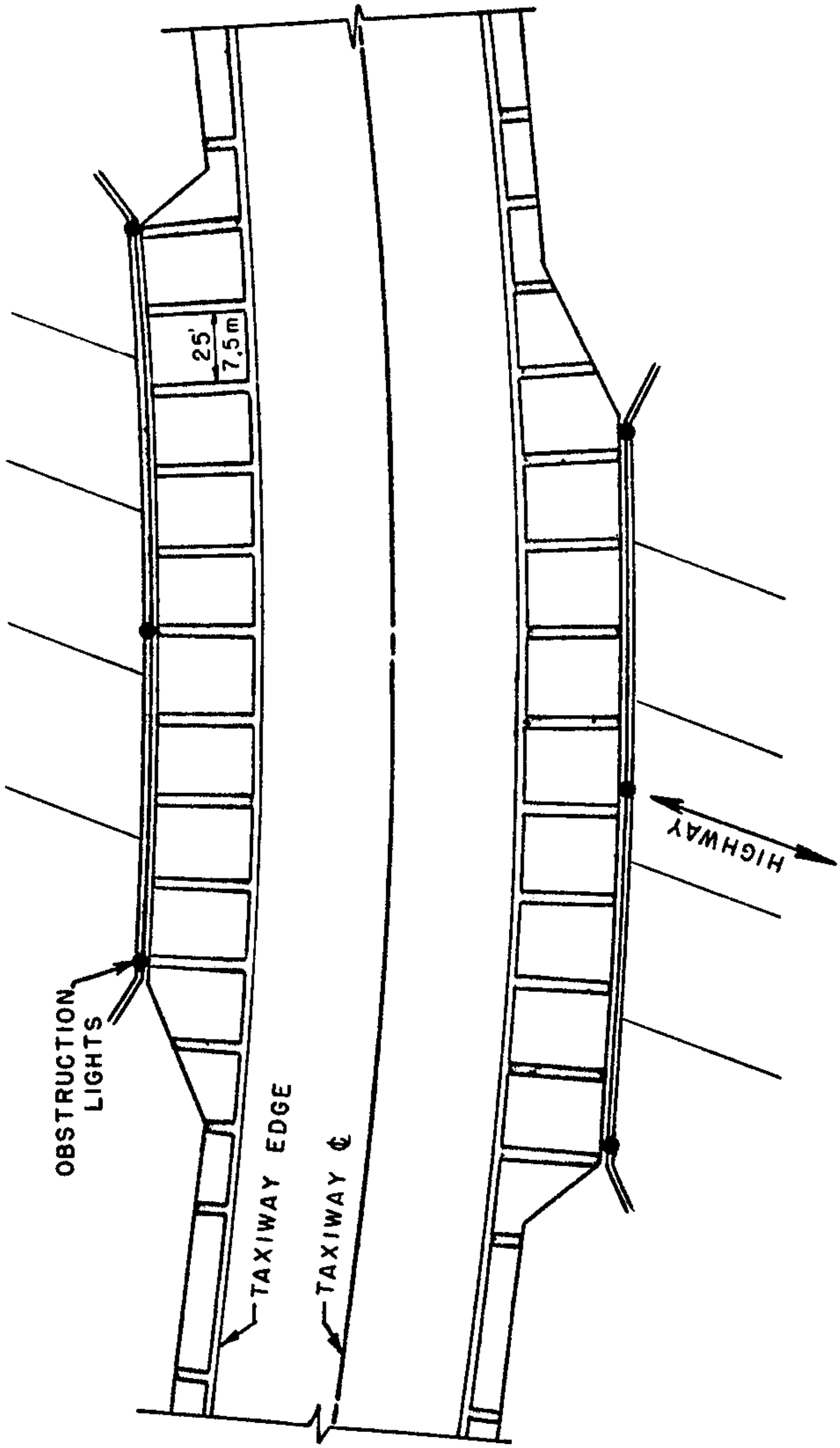


Figure 7-5. Suggested shoulder marking of minimum width taxiway bridge

c. Pavement Heating. Where freezing is a problem, in-pavement heating may be desirable on bridges which do not have sufficient earth cover to provide insulation. When in-pavement heating is used, the drainage system must be capable of accepting the melted runoff without refreezing or flooding the bridged surface mode.

d. Service Roads. Airport maintenance and service equipment may be permitted to use a runway or taxiway bridge if its presence does not interfere with airplane operations. If there is more than occasional use by these vehicles, a separate bridge should be provided. Figure 7-8 illustrates a multi-use bridge over a public roadway.

e. Blast Protection. Minimum width taxiway bridges require special features to protect the surface mode from jet blast. One alternative is nonload-bearing decks beyond the limits of the load-bearing shoulders.

f. Approach Aprons. Aprons, similar to those used in highway work, are normally needed to minimize the effects of differential settlement between the bridge proper and its approaches.

g. Tunnel Ventilation. The need for mechanical ventilation of the surface mode "tunnel" will depend upon its length (equal to the width of the air mode bridge). When mechanical ventilation is required, all aboveground components must be located so that they are not a hazard to aeronautical operations.

h. Tunnel Lighting. The need for artificial lighting of the surface mode tunnel will also depend upon its length. Emergency lighting and lane-control signals may also be needed. The American Association of State Highway Officials publication "Informational Guide for Roadway Lighting" has a section on lighting tunnels and underpasses. Copies of this publication are available through state highway offices. Surface-mode lighting in the approaches to a tunnel or underpass present special problems. Light supporting masts should not violate aeronautical surfaces and the light from the fixture should not cause glare or distract pilots or control tower personnel. Figures 7-4, 7-6, and 7-7 illustrate roadway lighting applications.

i. Drainage. Tunnels, especially those which are depressed to pass under a runway or taxiway, may lack natural drainage capability. Automatic, self-priming pumps are required in these instances.

51. PASSENGER AND BAGGAGE TUNNELS. Passenger and baggage tunnels are used to connect main and satellite terminals. In essence, they are merely smaller versions of runway and taxiway bridges and design considerations are the same. The tunnel may house a walkway, a moving sidewalk, a baggage conveyer belt, a subway-type car system, or a combination of these depending on the distance and the volume of passengers and baggage to be moved.

APPENDIX 1. TAXIWAY DESIGN RATIONALE

1. INTRODUCTION. An airport operator is occasionally faced with the problem of having to cope with unusual terrain or other local conditions or the need to accommodate a specific airplane without accommodating other more demanding airplanes in the same airplane design group. This appendix provides the reasoning behind the selection of the various widths, clearances, and separations related to airplane physical charactistics. This rationale is to be used, on a case-by-case basis, when local conditions or a specific airplane require modification of FAA airport design standards.

2. BACKGROUND AND RATIONALE. Taxiway system design is fixed by the minimum pavement widths, curve radii, and separations associated with airplane movement areas and airplane physical charactistics. Since the taxiway system is the transitional facility which supports airport operational capacity, the capability to maintain an average taxiing speed of at least 20 m.p.h. (30 km per hour) needs to be built into the system.

a. Separations. The parameters affecting separation criteria for taxiing airplanes, other than between a runway and its parallel taxiway, are wingspan and wingtip clearance. The need for ample wingtip clearance is driven by the fact that the pilots of most modern jets cannot see their airplanes' wingtips.

(1) Runway to taxiway separation is determined by the landing and takeoff flight path profiles and physical characteristics of airplanes. Flight safety prohibits any part of an aircraft (tail or wingtip) on a taxiway centerline from being within the runway safety area or penetrating the OFZ. For a detailed discussion on the OFZ, see AC 150/5300-4. Figure 2-3, herein, illustrates the OFZ for Aircraft Approach Category C and D airplanes.

(2) Runway to holding position separation is derived from landing and takeoff flight path profiles and the physical characteristics of airplanes. Flight safety also requires that holding aircraft not interfere with ILS localizer and glide slope operations.

(3) Taxiway to taxiway separation for two airplanes, each being on the centerline of a separate parallel taxiway, as shown in figure A1-1, is predicated on a minimum wingtip clearance of 0.25 times the wingspan of the most demanding airplane, plus 7 feet (2 m). However, this separation may have to be increased to accommodate minimum radius taxiway turns of 180 degrees, as shown in figure 4-7. The minimum acceptable radius is one which results in a maximum nosewheel steering angle (B) of 50 degrees. Nosewheel steering angle is discussed in paragraph 3e of appendix 2.

(4) Taxiway to obstacle separation, as shown in figures A1-2 and A1-3, is predicated on the wingtip clearances required for two taxiing airplanes. Thus, a minimum separation between a taxiway centerline and an obstacle of 0.75 times the wingspan of the critical airplane, plus 7 feet (2 m), is required.

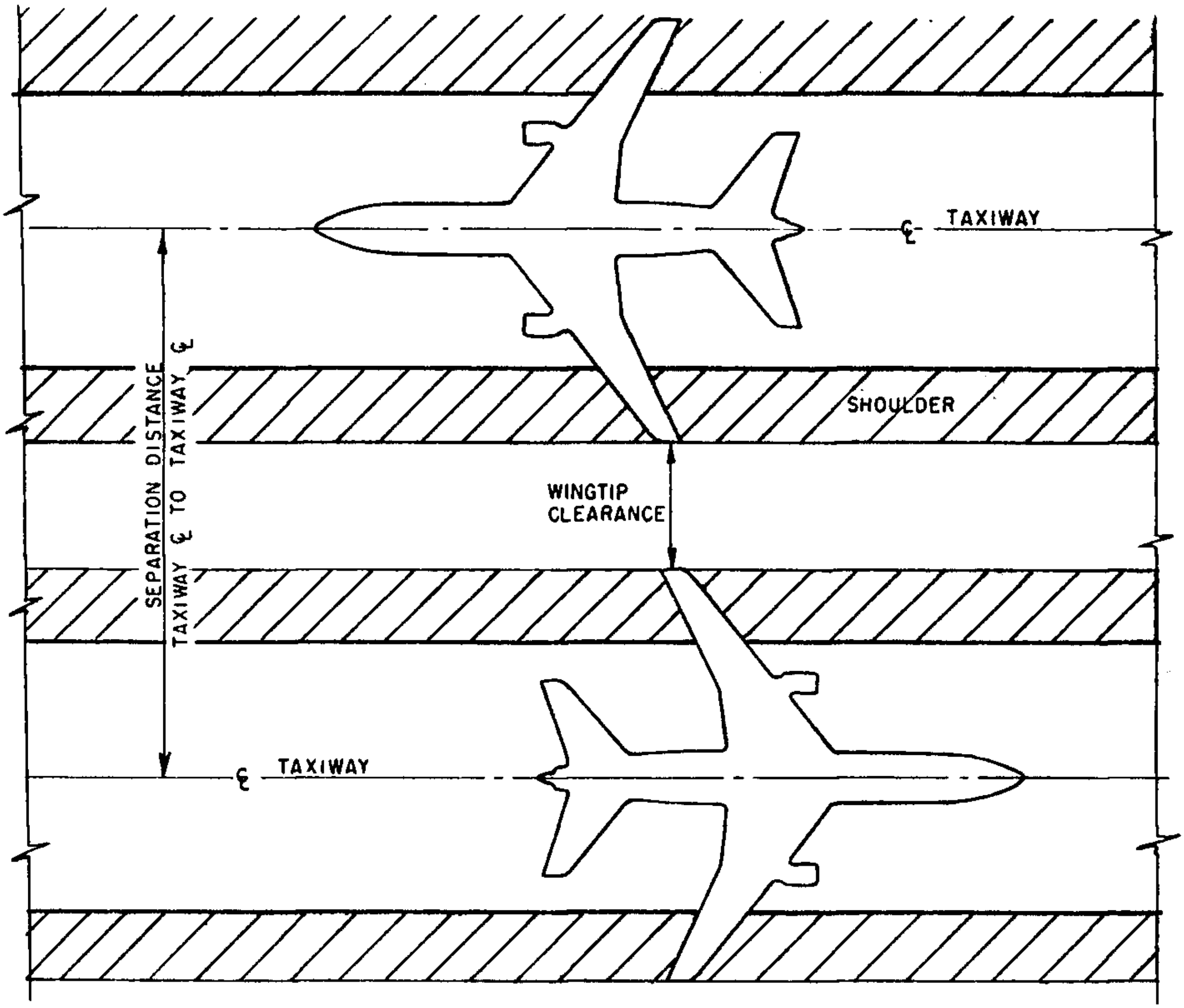


Figure A1-1. Wingtip clearance - parallel taxiways

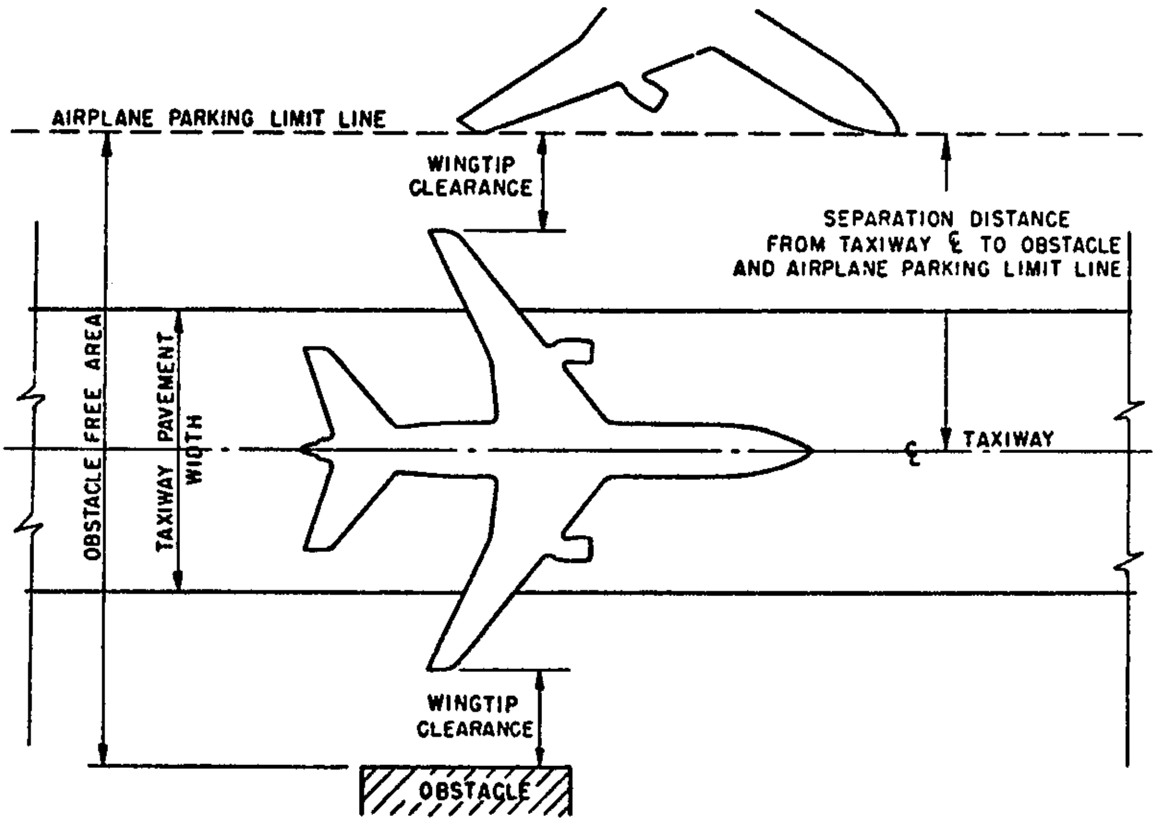


Figure A1-2. Wingtip clearance from taxiway

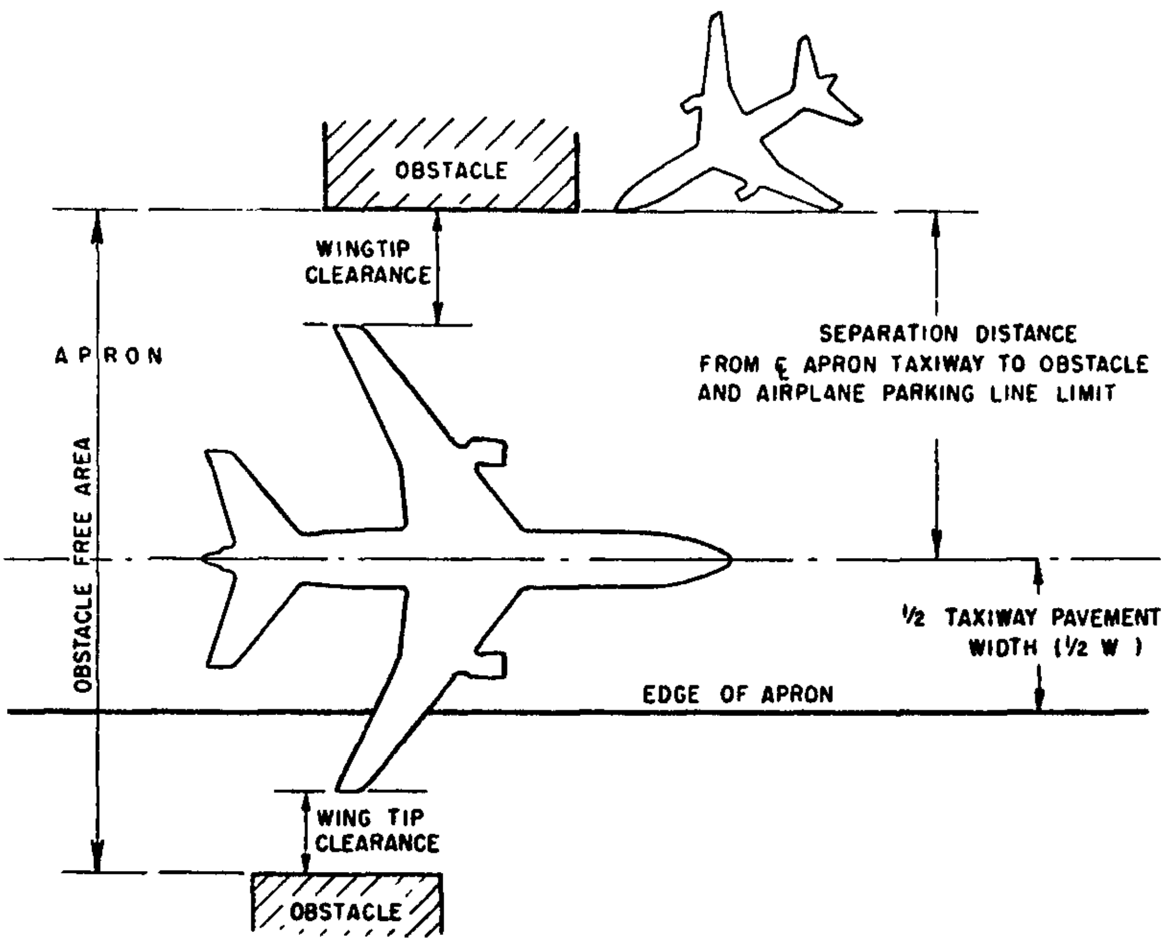


Figure A1-3. Wingtip clearance from apron taxiway

(5) The taxilane to obstacle separations are predicated on a wingtip clearance of approximately one-half of that required for an apron taxiway. These reduced clearances are acceptable because taxiing speed is very slow in this area, taxiing is precise, and special operator guidance techniques and devices are provided. Wingtip clearance dictates a minimum separation between a taxilane centerline and an obstacle of 0.63 times the wingspan of the most demanding airplane plus 7 feet (2 m).

b. Taxiway Width. For a taxiway system to function safely and efficiently, the taxiway pavement must be of sufficient width to provide adequate clearance between the outside wheel and the pavement edge. This clearance must permit normal deviations from the taxiway centerline or the intended path while taxiing at 20 mph (30 km per hour).

(1) Since taxiway widths are related to the physical characteristics of airplanes, a small high-performance jet airplane with narrow undercarriage, which requires a long runway for takeoff or landing, may operate on a relatively narrow taxiway. Conversely, a large airplane with short takeoff and landing capability, but with wide undercarriage, requires a wider taxiway.

(2) The clearance to be provided on tangents and curves, as illustrated in figure A1-4, is specified in table 4-1 under taxiway edge safety margin. A minimum acceptable taxiway width, based on fillet requirement, is specified in appendix 2.

c. Curves and Fillets. Taxiing around turns is difficult for pilots of airplanes with long wheelbases or when the cockpit is high and in front of the nosewheel. Table A1-1 lists the appropriate curve radii for taxiing speeds of transport airplanes. Detailed fillet design is covered in appendix 2.

d. Taxiway Shoulders. Design considerations for taxiway shoulders are discussed in chapter 6.

e. Taxiway Safety Area. To provide room for firefighting and rescue operations, the taxiway safety area width must be at least equal to the wingspan of the most demanding airplane.

Table A1-1. Taxiing speeds and curve radii

SPEED	RADIUS OF CURVE	SPEED	RADIUS OF CURVE
10 m.p.h.	50 feet	20 km per hour	24 m
20 m.p.h.	200 feet	30 km per hour	54 m
30 m.p.h.	450 feet	40 km per hour	96 m
40 m.p.h.	800 feet	50 km per hour	150 m
50 m.p.h.	1250 feet	60 km per hour	216 m
60 m.p.h.	1800 feet	70 km per hour	294 m
		80 km per hour	384 m
		90 km per hour	486 m
		100 km per hour	600 m

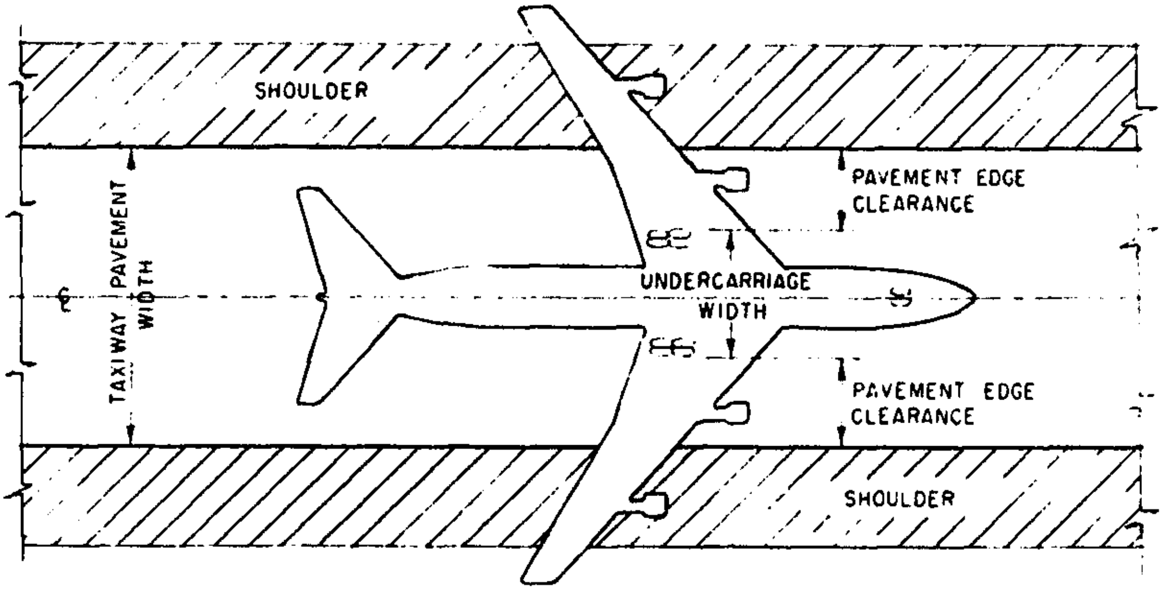


Figure A1-4. Pavement edge clearance on tangent

APPENDIX 2. TAXIWAY FILLET DESIGN

1. INTRODUCTION. This appendix details the methodology for the design of fillets for airport taxiways.

a. Types of taxiway fillets. Based on the requirements of airport users, airport authorities may use either "judgmental oversteering" or "maintaining-cockpit-over-centerline" type of pavement fillets.

b. Taxiway Markings. Judgmental oversteering intersections are marked with straight-through markings. Maintaining-cockpit-over-centerline intersections are marked with centerline markings describing a curve through the taxiway turn.

2. APPLICATION. Dimensions for recommended taxiway fillet designs are presented in table A2-1. Figures A2-1 and A2-2 show those taxiway fillet designs which provide an acceptable taxiway edge safety margin for a range of wheelbase and undercarriage width combinations. When airplanes do not have the minimum taxiway safety margin with a standard taxiway fillet, or when space limitations require other than the recommended radius of taxiway turn, the pavement fillet may be custom designed, using the equations in paragraph 3, to provide an acceptable taxiway edge safety margin. Examples on the use of the equations for designing pavement fillets are illustrated in paragraphs 4 and 5.

Table A2-1. Taxiway fillet dimensions

ITEM	DIM 2/	AIRPLANE DESIGN GROUP 1/					
		I	II	III 3/	IV	V	VI
Radius of Taxiway Turn	R	75 ft 22.5 m	75 ft 22.5 m	100 ft 30 m	150 ft 45 m	150 ft 45 m	170 ft 51 m
Length of Lead-in to Fillet	L	50 ft 15 m	50 ft 15 m	150 ft 45 m	250 ft 75 m	250 ft 75 m	250 ft 75 m
Fillet Radius for Judgmental Oversteering Symmetrical Widening	F	62.5 ft 18.75 m	57.5 ft 17.25 m	68 ft 20.4 m	105 ft 31.5 m	105 ft 31.5 m	110 ft 33 m
Fillet Radius for Judgmental Oversteering One Side Widening	F	62.5 ft 18.75 m	57.5 ft 17.25 m	60 ft 18 m	97 ft 29 m	97 ft 29 m	100 ft 30 m
Fillet Radius for Tracking Centerline	F	60 ft 18 m	55 ft 16.5 m	55 ft 16.5 m	85 ft 25.5 m	85 ft 25.5 m	85 ft 25.5 m

1/ Airplane design groups are keyed to those of table 1-1.

2/ Letters are keyed to those shown as dimensions on figures A2-3 and A2-4.

3/ For Airplane Design Group III taxiways intended to be used by airplanes with a wheelbase equal or greater than 60 feet (18m), a fillet radius of 50 feet (15 m) should be used.

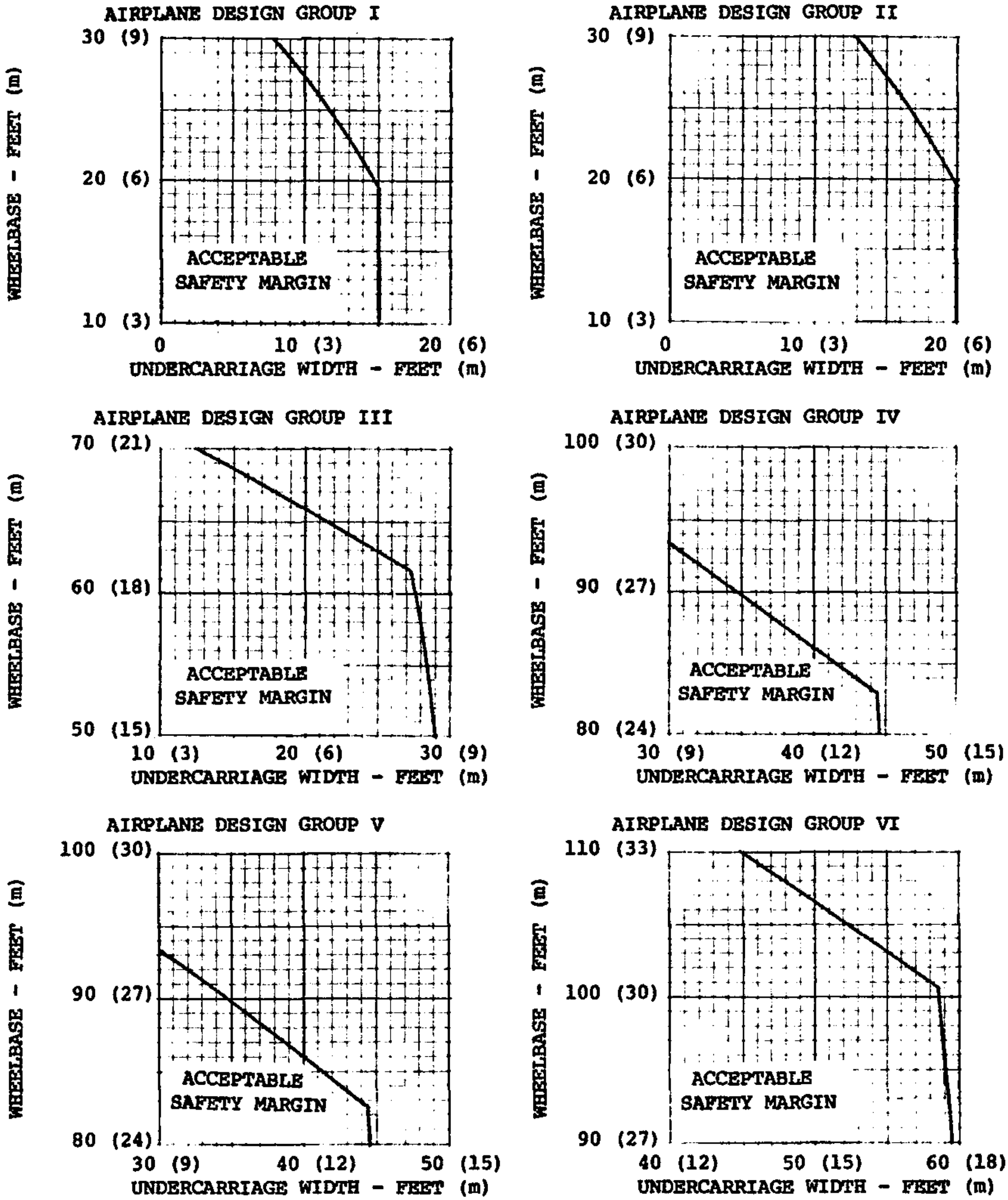


Figure A2-1. Judgmental oversteering

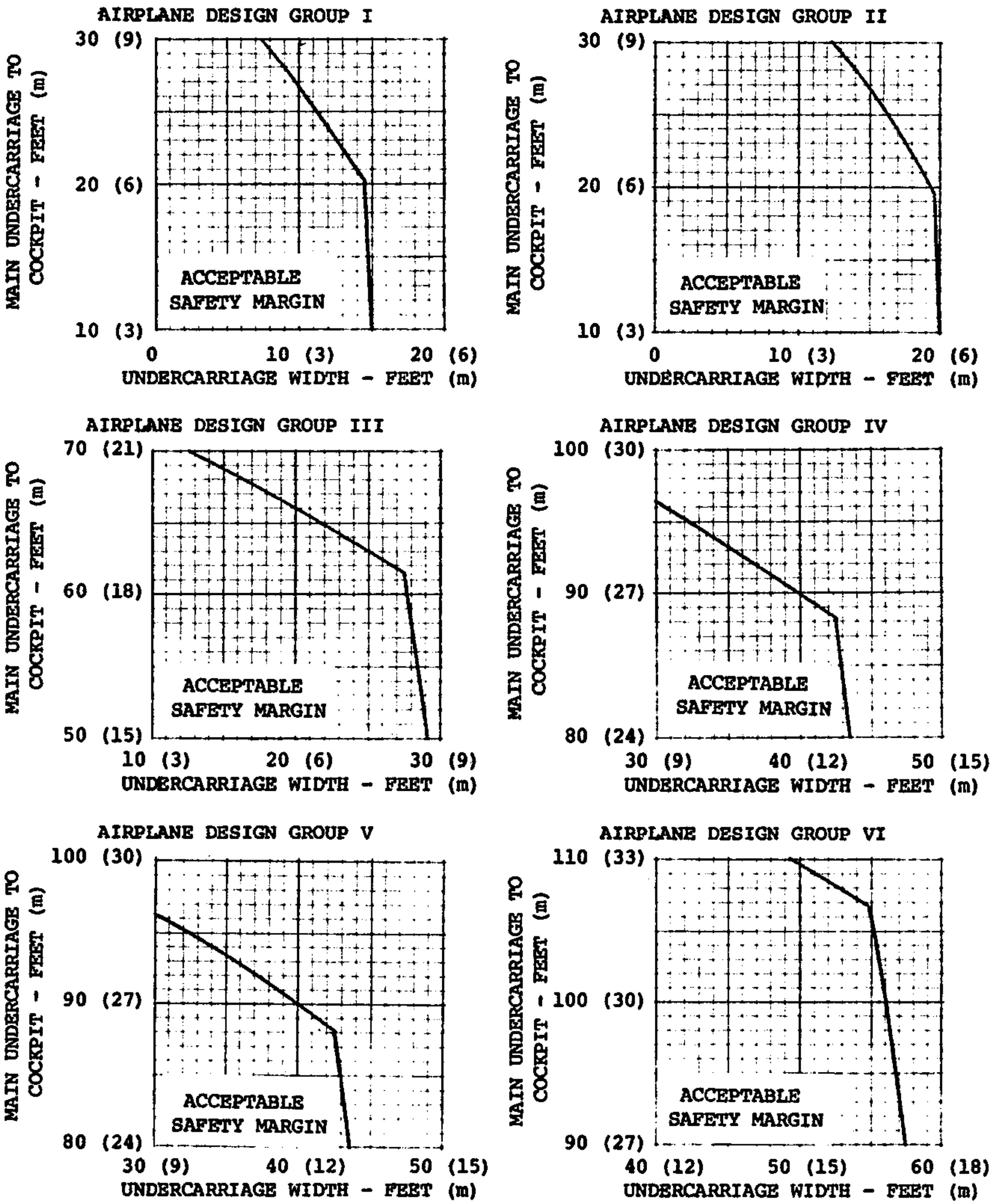


Figure A2-2. Maintaining cockpit over centerline

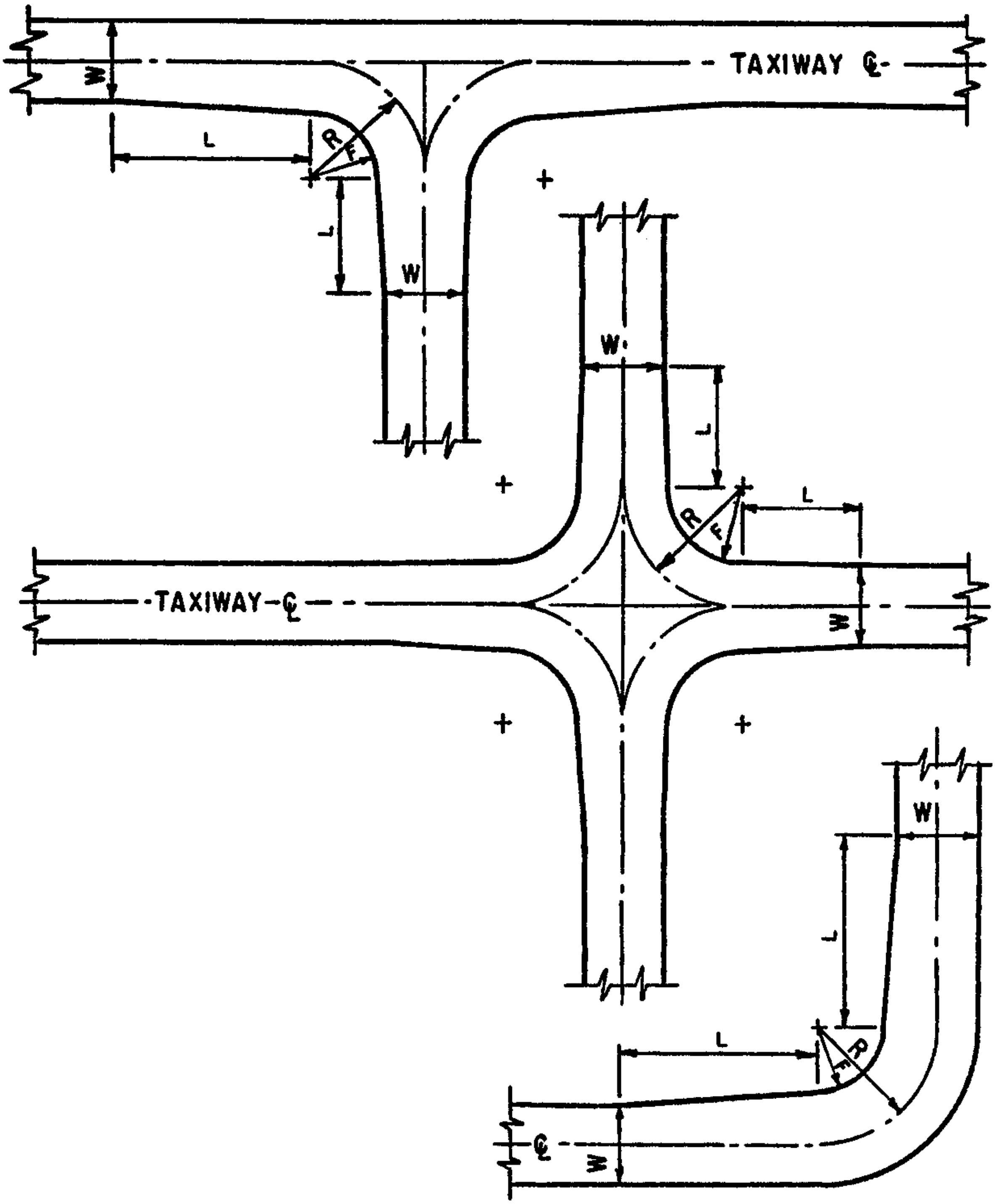


Figure A2-3. Taxiway intersection details

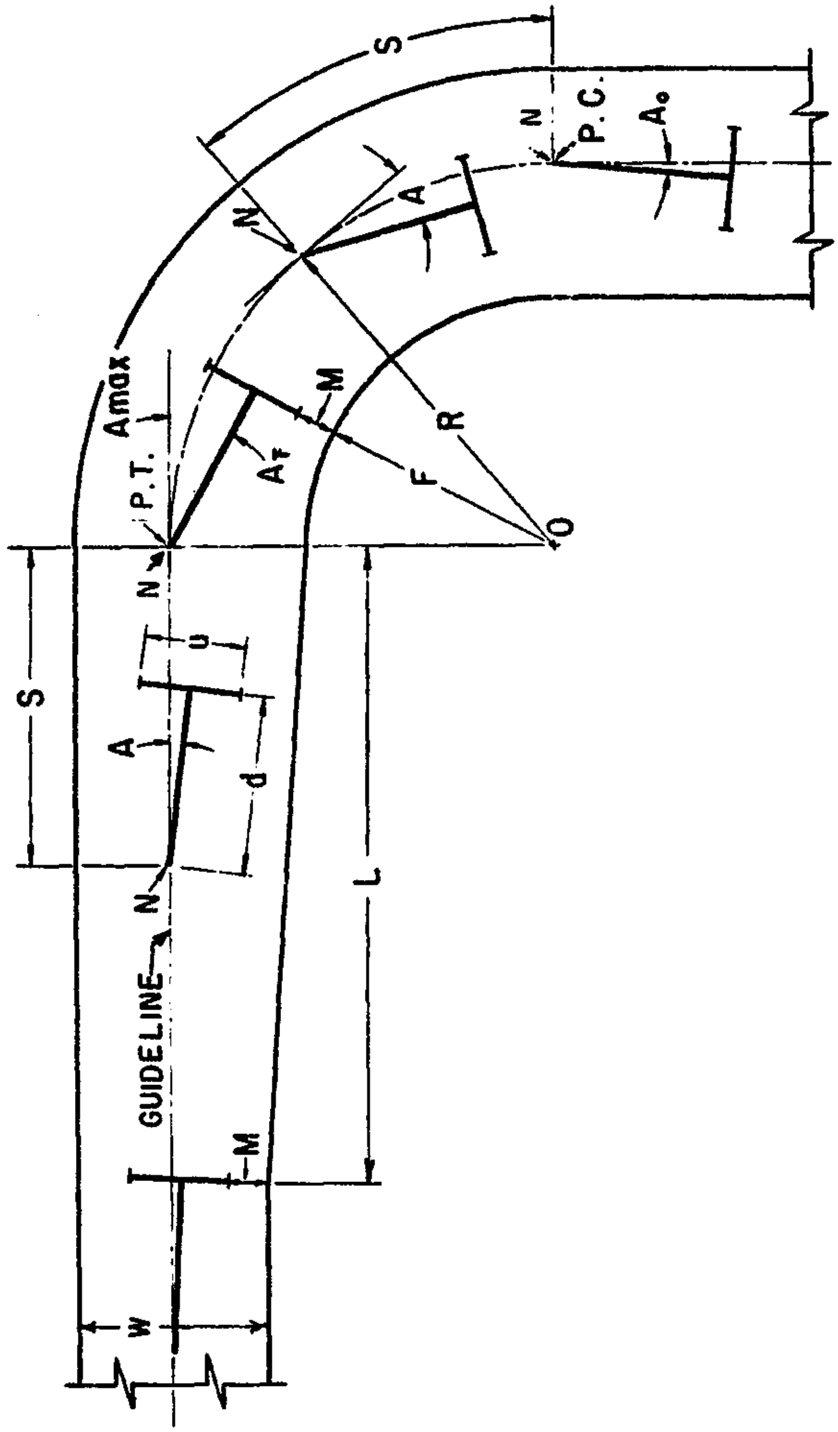


Figure A2-4. Depiction of symbols

3. EQUATIONS. The methodology used in the two types of fillet design is presented below. The terms and symbols used in the equations are illustrated in figure A2-4.

a. Angle A. The angle formed by the tangent to the guideline and the longitudinal axis of airplane at point N.

(1) For R less than d:

$$A = 2\ \tan^{-1}[x\ \tan(\tan^{-1}((\tan(.5A_o) - R/d)/x) + 28.648xS/R) + R/d]$$

(2) For R equals d:

$$A = 2\ \tan^{-1}[1/(1/(\tan(.5A_o) - 1) - .5S/R) + 1]$$

(3) For R greater than d:

$$A = 2\ \tan^{-1}[y(2/(1 - z) - 1) + R/d]$$

(4) For tangent section:

$$A = 2\ \tan^{-1}[\tan(.5A_t)/2.7183^{S/d}]$$

b. Angle A_{max}. Angle A with point N at the point of tangency (P.T.) or at the point of change of curvature (P.C.C.). At the end of a long curve:

$$A_{max} = \sin^{-1}(d/R)$$

c. Angle A_o. Angle A with point N at the point of curvature (P.C.). The angle A_o at the end of a long tangent section is zero (0) degrees.

d. Angle A_t. Angle A with point N at the point of tangency (P.T.).

e. Nosewheel Steering Angle (B). The angle the nosewheel makes with the longitudinal axis of the airplane. In the design of pavement fillets, check to ensure that the nosewheel steering angle does not exceed 50 degrees. If exceeded, choose a larger radius of arc (R).

$$B = \tan^{-1}(w/d\ \tan A)$$

$$B_{max} = \tan^{-1}(w/d\ \tan A_{max})$$

f. Airplane Datum Length (d). The distance between point N and the center of the main undercarriage.

g. Radius of Fillet Arc (F). The radius of the fillet measured from the center of the taxiway longitudinal curvature (O). To provide an acceptable taxiway edge safety margin (M), the radius of fillet should be equal to or less than:

$$F = (R^2 + d^2 - 2Rd\ \sin A_{max})^{.5} - .5u - M$$

h. Length of Lead-in to Fillet (L). The distance from the P.T. to the end of the fillet. To provide an acceptable taxiway edge safety margin (M), the length of lead-in to the fillet should be equal to or greater than:

$$L = d \ln(4d \tan(.5A_t)/(W - u - 2M)) - d$$

i. Taxiway Edge Safety Margin (M). The minimum distance between the outside of the airplane wheels and the pavement edge. The minimum acceptable taxiway edge safety margin is given in table 4-1.

j. Point N. The point beneath the longitudinal axis of the airplane which tracks the guideline on the ground. Point N is located:

(1) For judgmental oversteering, beneath the longitudinal axis of the airplane at a distance from the center of the main undercarriage equal to the following. This distance provides a safety margin to compensate for the lack of positive guidance.

(i) Widening on only one side.

$$d = (R^2 - (R + .5W - 2M)^2 + w^2)^{.5}$$

(ii) Widening symmetrical.

$$d = (R^2 - (2R - F - 2M)^2 + w^2)^{.5}$$

(2) For cockpit over centerline, beneath the cockpit of the airplane.

k. Radius of Arc (R). The radius of the arc at point N measured from center of curvature (O) to the point N.

l. Distance S. The distance from the P.C. to the point N along the arc for arc sections and from the P.T. to the point N along the tangent for tangent sections.

m. Undercarriage Width (u). The distance between the airplane's outer main wheels, including the width of the wheels. For airport design purposes, when the dimension "u" is not available, assume "u" to be 1.15 times the airplane's main gear track.

n. Wheelbase (w). The distance between the nosewheel and the center of the main undercarriage.

o. Taxiway Width (W). The taxiway pavement width on the tangent section. The taxiway width should be greater than the sum of the undercarriage width plus two times the acceptable taxiway edge safety margin (M).

p. Symbol x.

$$x = (1 - (R/d)^2)^{.5}$$

q Symbol y.

$$y = ((R/d)^2 - 1)^{.5}$$

r. Symbol z.

$$z = 2.7183^{yS/R}(R/d + y - \tan(.5A_O))/(R/d - y - \tan(.5A_O))$$

4. EXAMPLE NO. 1, JUDGMENTAL OVERSTEERING. Given: Airplane wingspan 196 feet (59.7 m), wheelbase 84 feet (25.6 m), undercarriage width 41 feet (12.5 m), and R = 150 feet (45 m) for 180 degree turn. Taxiway width is 75 feet (23 m), fillet radius, widening on only one side, is 97 feet (29 m), and lead-in to fillet is 250 feet (75 m).

Step 1 - Acceptable M = 15.0 feet (4.5 m)

Step 2 - Calculate A_{max} = 27.3 degrees (27.2 degrees)

Step 3 - Calculate B_{max} = 32.2 degrees (32.6 degrees)

Step 4 - Calculate provided M = 15.8 feet (4.8 m)

5. EXAMPLE NO. 2, MAINTAINING COCKPIT OVER CENTERLINE. Given: Airplane wingspan 196 feet (59.7 m), wheelbase 84 feet (25.6 m), distance between main undercarriage and cockpit 90 feet (27.4 m), undercarriage width 41 feet (12.5 m), and cockpit following R = 150 feet (45 m) for 180 degree turn. Taxiway width is 75 feet (22 m).

Step 1 - Acceptable M = 15.0 feet (4.5 m)

Step 2 - Calculate A_{max} = 36.4 degrees (37.0 degrees)

Step 3 - Calculate B_{max} = 34.5 degrees (35.1 degrees)

Step 4 - Calculate F_{max} = 85.2 feet (25.2 m)

Step 5 - Calculate L_{min} = 215 feet (60.2 m)

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