Appendix 1. WIND ANALYSIS

1. OBJECTIVE. This appendix provides guidance on the assembly and analysis of wind data to determine runway orientation. It also provides guidance on analyzing the operational impact of winds on existing runways.

a. A factor influencing runway orientation and number of runways is wind. Ideally a runway should be aligned with the prevailing wind. Wind conditions affect all airplanes in varying degrees. Generally, the smaller the airplane, the more it is affected by wind, particularly crosswind components (see figure A1-1). Crosswinds are often a contributing factor in small airplane accidents.

b. Airport planners and designers should make an accurate analysis of wind to determine the orientation and number of runways. In some cases, construction of two runways may be necessary to give the desired wind coverage (95 percent coverage). The proper application of the results of this analysis will add substantially to the safety and usefulness of the airport.

2. CROSSWINDS. The crosswind component of wind direction and velocity is the resultant vector which acts at a right angle to the runway. It is equal to the wind velocity multiplied by the trigonometric sine of the angle between the wind direction and the runway direction. Normally, these wind vector triangles are solved graphically. An example is shown in figure A1-1. From this diagram, one can also ascertain the headwind and tailwind component for combinations of wind velocities and directions. Refer to paragraph 203 for allowable crosswind components.

3. COVERAGE AND ORIENTATION OF RUNWAYS. The most desirable runway orientation based on wind is the one which has the largest wind coverage and minimum crosswind components. Wind coverage is that percent of time crosswind components are below an acceptable velocity. The desirable wind coverage for an airport is 95 percent, based on the total numbers of weather observations. This value of 95 percent takes into account various factors influencing operations and the economics of providing the coverage. The data collection should be with an understanding of the objective; i.e., to attain 95-percent usability. At many airports, airplane operations are almost nil after dark, and it may be desirable to analyze the wind data on less than a 24 -hour observation period. At airports where operations are predominantly seasonal, regard should be given to the wind data for the predominant-use period. At locations where provision of a crosswind runway is impractical due to severe terrain constraints, consideration may be given to increasing operational tolerance to crosswinds by upgrading the airport layout to the next higher airport reference code.

4. ASSEMBLING WIND DATA. The latest and best wind information should always be used to carry out a wind analysis. A record which covers the last 10 consecutive years of wind observations is preferred. Records of lesser duration may be acceptable on a case-by-case basis. In some instances, it may be highly desirable to obtain and assemble wind information for periods of particular significance; e.g., seasonal variations, instrument weather conditions, daytime versus nighttime, and regularly occurring gusts.

a. Data Source. The best source of wind information is the National Oceanic and Atmospheric Administration, National Climatic Data Center (NCDC). The NCDC is located at:

Climate Services Branch
National Climatic Data Center
151 Patton Avenue
Asheville, North Carolina 28801-5001
Tel: 828-271-4800/ Fax: 828-271-4876
Public Web Address: http://www.ncdc.noaa.gov/

The Center should be contacted directly to determine the availability of data for a particular site.

b. Data Costs. The EDS provides wind information at cost. The cost will vary, depending upon the complexity of the information desired, how the data are being stored, and whether the data have been assembled (summarized) previously. The wind summary for the airport site should be formatted with the standard 36 wind quadrants (the EDS standard for noting wind directions since January 1, 1964) and usual speed groupings (see figure A1-3). An existing wind summary of recent vintage is acceptable for analysis purposes if these standard wind direction and speed groupings are used. Figure A1-2 is an example of a typical EDS wind summary.

c. Data Not Available. In those instances when EDS data are not available for the site, it is permissible to develop composite wind data using wind information obtained from two or more nearby recording stations. Composite data are usually acceptable if the terrain between the stations and the site is level or only slightly rolling. If the terrain is hilly or mountainous, composite data may only have marginal validity. In extreme cases it may be necessary to obtain a minimum of 1 year of onsite wind observations. These meager records should be augmented with personal observations (wind-bent trees, interviews with the local populace, etc.) to ascertain if a discernible wind pattern can be established. Airport development should not proceed until adequate wind data are acquired.

5. **ANALYZING WIND DATA**. One wind analysis procedure uses a scaled graphical presentation of wind information known as a windrose.

a. **Drawing the Windrose**. The standard windrose (figure A1-3) is a series of concentric circles cut by radial lines. The perimeter of each concentric circle represents the division between successive wind speed groupings. Radial lines are drawn so that the area between each successive pair is centered on the direction of the reported wind.

b. **Plotting Wind Data**. Each segment of the windrose represents a wind direction and speed grouping corresponding to the wind direction and speed grouping on the EDS summary. The recorded directions and speeds of the wind summary are converted to a percentage of the total recorded observations. Computations are rounded to the nearest one-tenth of 1 percent and entered in the appropriate segment of the windrose. Figure A1-4 illustrates a completed windrose based on data from figure A1-2. Plus (+) symbols are used to indicate direction and speed combinations which occur less than one-tenth of 1 percent of the time.

c. **Crosswind Template**. A transparent crosswind template is a useful aid in carrying out the windrose analysis. The template is essentially a series of three parallel lines drawn to the same scale as the windrose circles. The allowable crosswind for the runway width establishes the physical distance between the outer parallel lines and the centerline. When analyzing the wind coverage for a runway orientation, the design crosswind limit lines can be drawn directly on the windrose. NOTE: EDS wind directions are recorded on the basis of true north.

d. **Analysis Procedure**. The purpose of the analysis is to determine the runway orientation which provides the greatest wind coverage within the allowable crosswind limits. This can be readily estimated by rotating the crosswind template about the windrose center point until the sum of the individual segment percentages appearing between the outer "crosswind limit" lines is maximized. It is accepted practice to total the percentages of the segments appearing outside the limit lines and to subtract this number from 100. For analyses purposes, winds are assumed to be uniformly distributed throughout each of the individual segments. Figures A1-5 and A1-6 illustrate the analysis procedure as it would be used in determining the wind coverage for a runway, oriented 105-285, intended to serve all types of airplanes. The wind information is from figure A1-2. Several trial orientations may be needed before the orientation which maximizes wind coverage is found.

6. **CONCLUSIONS**. The example wind analysis shows that the optimum wind coverage possible with a single runway and a 13 -knot crosswind is 97.28 percent. If the analysis had shown that it was not possible to obtain at least 95-percent wind coverage with a single runway, then consideration should be given to provide an additional (crosswind) runway oriented to bring the combined wind coverage of the two runways to at least 95 percent.

7. **ASSUMPTIONS**. The analysis procedures assume that winds are uniformly distributed over the area represented by each segment of the windrose. The larger the area, the less accurate is this presumption. Therefore, calculations made using nonstandard windrose directions or speeds result in a derivation of wind coverage (and its associated justification for a crosswind runway) which is questionable.

8. **WIND ANALYSIS TOOL**. A wind analysis tool is available on the Airports-GIS website:
http://airports-gis.faa.gov/public/.

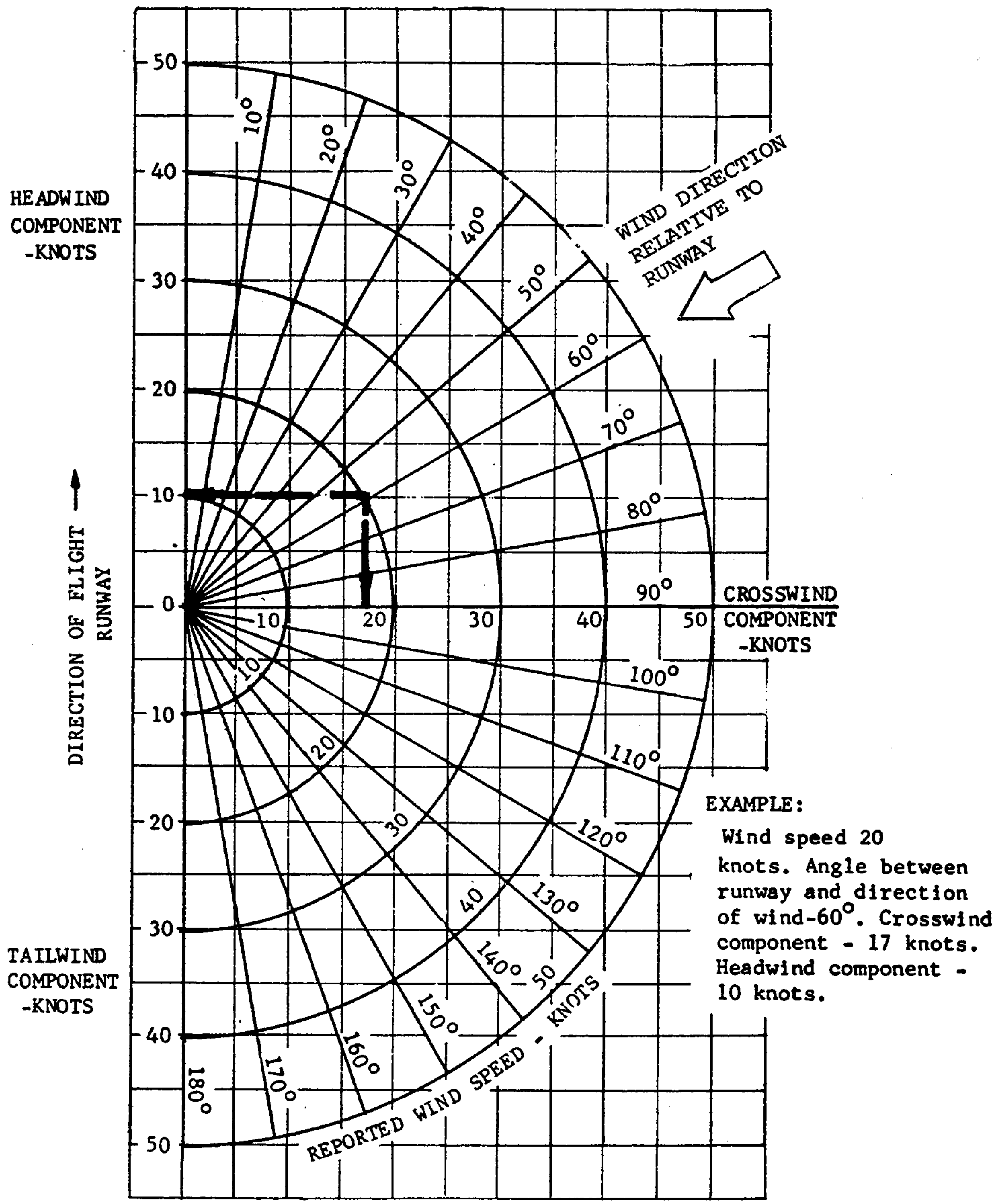


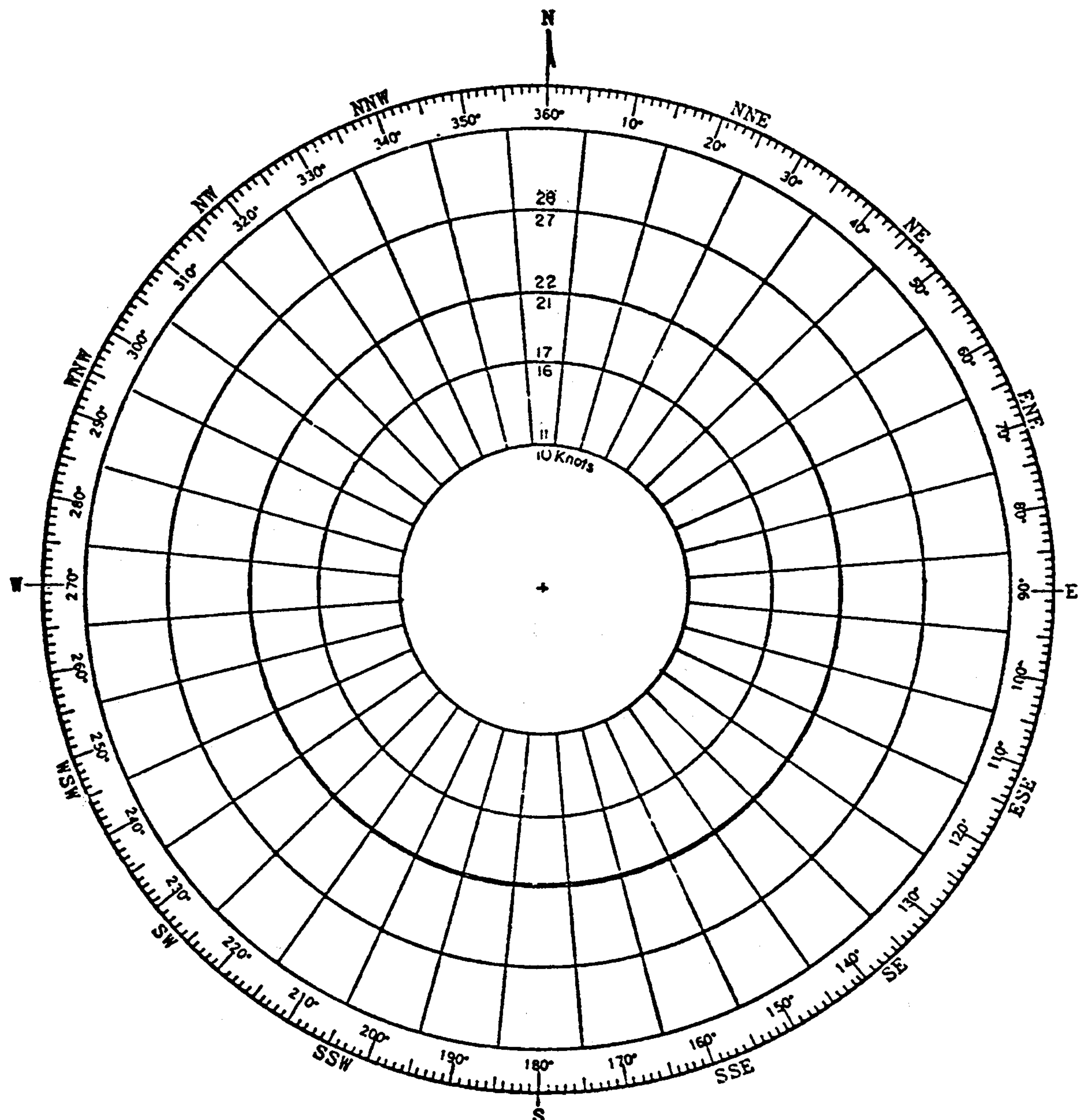
Figure A1-1. Wind vector diagram

WIND DIRECTION VERSUS WIND SPEED

STATION: Anywhere, USA   HOURS: 24 Observations/Day   PERIOD OF RECORD: 1964-1973

DIRECTION	HOURLY OBSERVATIONS OF WIND SPEED									TOTAL	AVERAGE SPEED	
	KNOTS 0-3	4-6	7-10	11-16	17-21	22-27	28-33	34-40	41 OVER		KNOTS	MPH
	MPH 0-3	4-7	8-12	13-18	19-24	25-31	32-38	39-46	47 OVER			
01	469	842	568	212						2091	6.2	7.1
02	568	1263	820	169						2820	6.0	6.9
03	294	775	519	73	9					1670	5.7	6.6
04	317	872	509	62	11					1771	5.7	6.6
05	268	861	437	106						1672	5.6	6.4
06	357	534	151	42	8					1092	4.9	5.6
07	369	403	273	84	36	10				1175	6.6	7.6
08	158	261	138	69	73	52	41	22		814	7.6	8.8
09	167	352	176	128	68	59	21			971	7.5	8.6
10	119	303	127	180	98	41	9			877	9.3	10.7
11	323	586	268	312	111	23	28			1651	7.9	9.1
12	618	1397	624	779	271	69	21			3779	8.3	9.6
13	472	1375	674	531	452	67				3571	8.4	9.7
14	647	1377	574	281	129					3008	6.2	7.1
15	338	1093	348	135	27					1941	5.6	6.4
16	560	1399	523	121	19					2622	5.5	6.3
17	587	883	469	128	12					2079	5.4	6.2
18	1046	1984	1068	297	83	18				4496	5.8	6.7
19	499	793	586	241	92					2211	6.2	7.1
20	371	946	615	243	64					2239	6.6	7.6
21	340	732	528	323	147	8				2078	7.6	8.8
22	479	768	603	231	115	38	19			2253	7.7	8.9
23	187	1008	915	413	192					2715	7.9	9.1
24	458	943	800	453	96	11	18			2779	7.2	8.2
25	351	899	752	297	102	21	9			2431	7.2	8.2
26	368	731	379	208	53					1739	6.3	7.2
27	411	748	469	232	118	19				1997	6.7	7.7
28	191	554	276	287	118					1426	7.3	8.4
29	271	642	548	479	143	17				2100	8.0	9.3
30	379	873	526	543	208	34				2563	8.0	9.3
31	299	643	597	618	222	19				2398	8.5	9.8
32	397	852	521	559	158	23				2510	7.9	9.1
33	236	721	324	238	48					1567	6.7	7.7
34	280	916	845	307	24					2372	6.9	7.9
35	252	931	918	487	23					2611	6.9	7.9
36	501	1568	1381	569	27					4046	7.0	8.0
00	7729									7729	0.0	0.0
TOTAL	21676	31828	19849	10437	3357	529	166	22		87864	6.9	7.9

Figure A1-2. Typical environmental data service wind summary



WIND SPEED DIVISIONS		RADIUS OF CIRCLE (KNOTS)
KNOTS	M.P.H.	
0 - 3.5	0 - 3.5	* 3.5 Units
3.5 - 6.5	3.5 - 7.5	* 6.5 "
6.5 - 10.5	7.5 - 12.5	10.5 - "
10.5 - 16.5	12.5 - 18.5	16.5 - "
16.5 - 21.5	18.5 - 24.5	21.5 - "
21.5 - 27.5	24.5 - 31.5	27.5 - "
27.5 - 33.5	31.5 - 38.5	*33.5 - "
33.5 - 40.5	38.5 - 46.5	*40.5 - "
40.5 - over	46.5 - over	

*May not be needed for most windrose analyses.

Figure A1-3. Windrose blank showing direction and divisions

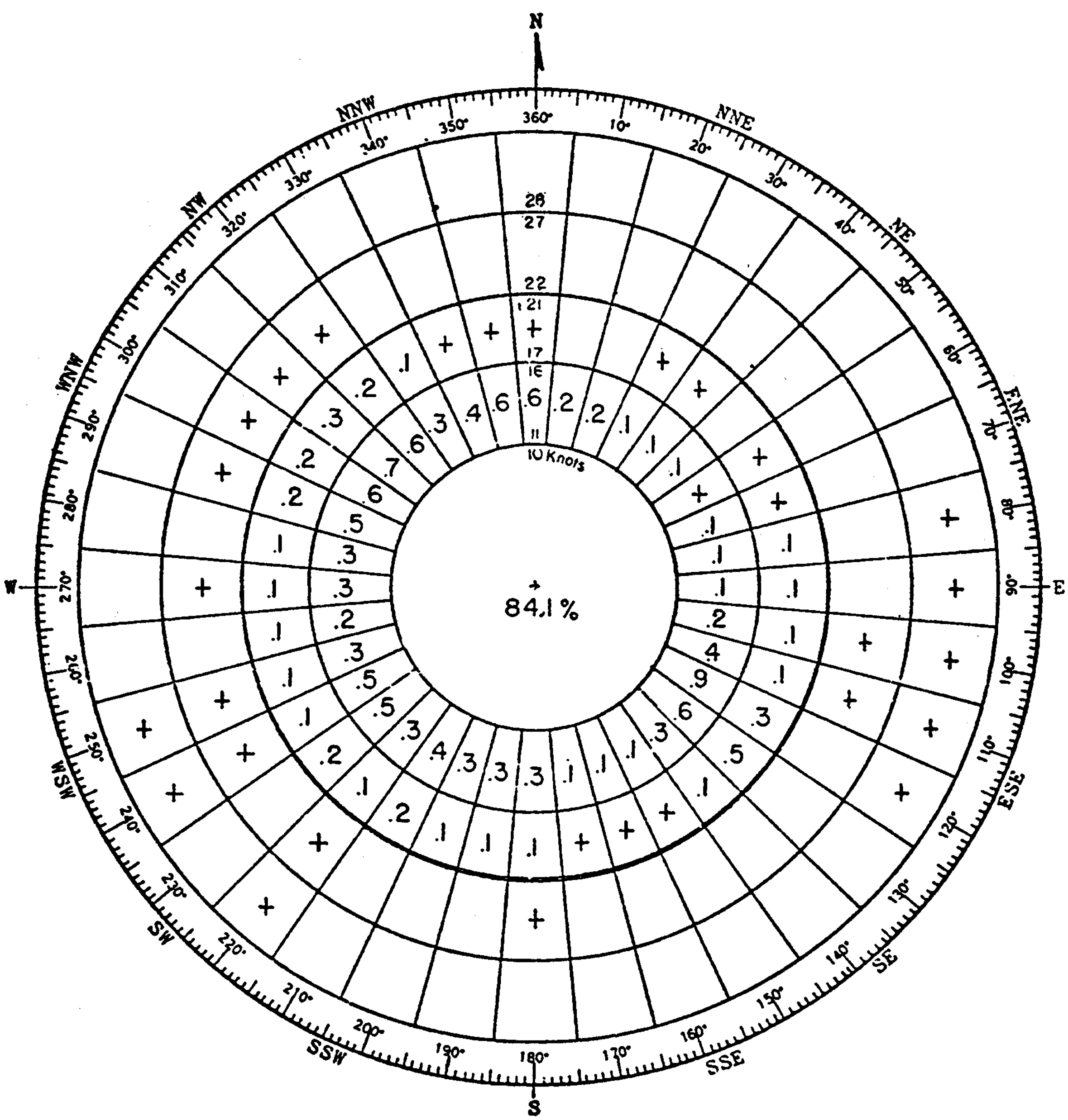
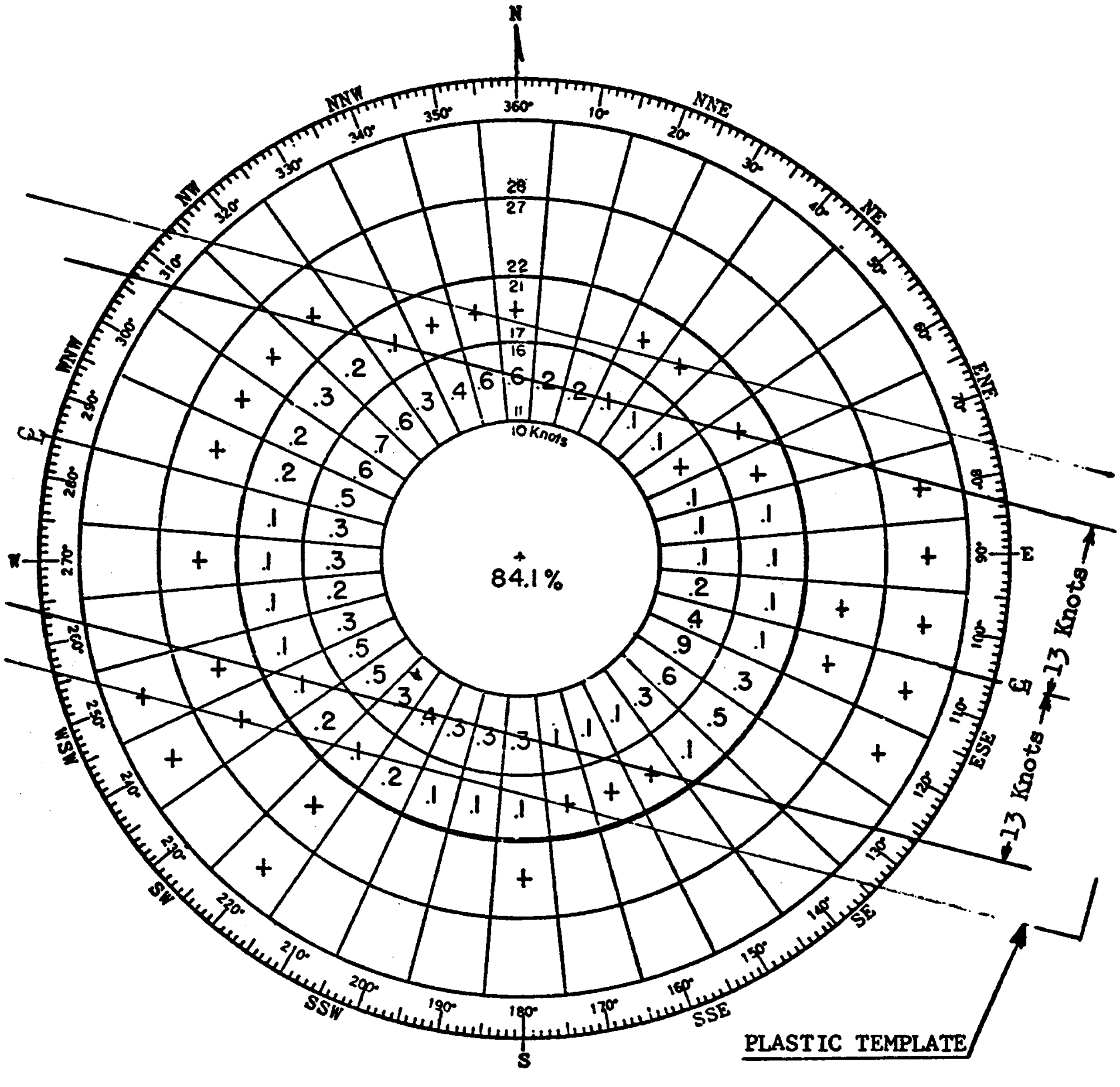


Figure A1-4. Completed windrose using figure A1-2 data



A runway oriented 105°-285° (true) would have 2.72% of the winds exceeding the design crosswind/crosswind component of 13 knots.

Figure A1-5. Windrose analysis

DIRECTION	ESTIMATED AREA NOT INCLUDED 11-16	17-21	22-27	28+
10	.12			
20	.12			
30	.05	+		
40	.04	+		
50	.01			
60		+		
70				
80			.01	+
90				
100				
110				
120				
130			.01	
140		.01		
150		+		
160	.01	+		
170	.04	+		
180	.14	.10	+	
190	.16	.10		
200	.16	.10		
210	.20	.20	+	
220	.11	.10	+	+
230	.03	.19		
240		.05	+	+
250		.01	+	+
260				
270				
280				
290				
300				
310				
320		.01	+	
330		.05		
340	.04	+		
350	.25	+		
360	.30	+		
SUM	1.78	.92	.02	+

1.78
.92
.02
2.72

100.00
2.72
97.28

100.00 - SUM = Coverage

100.00 - 2.72 =97.28% Coverage

Figure A1-6. Windrose analysis--estimating area not included

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Appendix 2. RUNWAY END SITING REQUIREMENTS

1. **PURPOSE**. This appendix contains guidance on siting thresholds to meet approach obstacle clearance requirements and departure obstacle clearance requirements.

2. **APPLICATION**.

a. The threshold should be located at the beginning of the full-strength runway pavement or runway surface. However, displacement of the threshold may be required when an object that obstructs the airspace required for landing and/or departing airplanes is beyond the airport owner's power to remove, relocate, or lower. Thresholds may also be displaced for environmental considerations, such as noise abatement, or to provide the standard RSA and ROFA lengths.

b. When a hazard to air navigation exists, the amount of displacement of the threshold or reduction of the TODA should be based on the operational requirements of the most demanding airplanes. The standards in this appendix minimize the loss of operational use of the established runway and reflect the FAA policy of maximum utilization and retention of existing paved areas on airports.

c. Displacement of a threshold reduces the length of runway available for landings. Depending on the reason for displacement of the threshold, the portion of the runway behind a displaced threshold may be available for takeoffs in either direction and landings from the opposite direction. Refer to Appendix 14, Declared Distances, for additional information.

d. Where specifically noted, the Glidepath Angle (GPA) and Threshold Crossing Height (TCH) of a vertically guided approach may be altered (usually increased) rather than displacing the threshold. Examples of approaches with positive vertical guidance include Instrument Landing System (ILS), Microwave Landing System (MLS), Localizer Performance with Vertical Guidance (LPV), Lateral Navigation/Vertical Navigation (LNAV/VNAV), and required navigation performance (RNP). Alternatively, a combination of threshold displacement and altering of the Glidepath Angle/ Threshold Crossing Height (GPA/TCH) may also be accomplished. Guidelines for maximum and minimum values of TCH and GPA are contained in FAA Order 8260.3, *United States Standard for Terminal Instrument Procedures (TERPS)*. The tradeoff between threshold displacement, TCH, and GPA is complex, but can be analyzed by applying formula contained in the order. Contact the appropriate FAA Airports Regional or District Office for assistance on the specific requirements and effects of GPA and TCH changes.

3. **LIMITATIONS**.

a. These standards should not be interpreted as an FAA blanket endorsement of the alternative to displace or relocate a runway threshold. Threshold displacement or relocation should be undertaken only after a full evaluation reveals that displacement or relocation is the only practical alternative.

b. The standards in this appendix are applicable for identifying objects affecting navigable airspace. See Title 14 Code of Federal Regulations Part 77, Safe, Efficient Use, and Preservation of the Navigable Airspace.

4. **EVALUATION CONSIDERATIONS**.

a. **Possible Actions**. When a penetration to a threshold siting surface defined in paragraph 5 exists, one or more of the following actions are required:

(1) **Approach Surfaces**.

(a) The object is removed or lowered to preclude penetration of applicable threshold siting surfaces;

(b) The threshold is displaced to preclude object penetration of applicable threshold siting surfaces, with a resulting shorter landing distance; or

(c) The GPA and/or TCH is/are modified, or a combination of threshold displacement and GPA/TCH increase is accomplished.

(d) Visibility minimums are raised.

(e) Night operations are prohibited unless the obstruction is lighted or an approved Visual Glide Slope Indicator (VGSI) is used.

(2) **Departure Surfaces for Designated Runways**. The applicability of the surface defined in Table A2-1 is dependant on the designation of primary runway(s) for departure. The Airport Sponsor, through the Airports District Office to the Regional Airspace Procedures Team (RAPT), will identify runway end(s) intended primarily for instrument departures. The determination of primary runway(s) for departure does not prohibit or negate the use of other runways. It only identifies the applicability of the surface in Table A2-1 to the runway end(s).

(a) Remove, relocate, or lower (or both relocate and lower) the object to preclude penetration of applicable siting surfaces unless it is fixed by function and/or designated impracticable. Within 6000' of the Table A2-1 surface origin, objects less than or equal to an elevation determined by application of the formula below are allowable.

E + (0.025 x D)

Where:
E = DER elevation
D = Distance from OCS origin to object in feet

(b) Decrease the Takeoff Distance Available (TODA) to preclude object penetration of applicable siting surfaces, with a resulting shorter takeoff distance (the Departure End of the Runway (DER) is coincident with the end of the TODA where a clearway is not in effect); or

(c) Modify instrument departures. Contact the Flight Procedures Office (FPO) for guidance. Objects penetrating by < 35 feet may not require actions (a) or (b); however, they will impact departure minimums/climb gradients or departure procedures.

b. **Relevant Factors for Evaluation**.

(1) Types of airplanes that will use the runway and their performance characteristics.

(2) Operational disadvantages associated with accepting higher landing/ takeoff minimums.

(3) Cost of removing, relocating, or lowering the object.

(4) Effect of the reduced available landing/takeoff length when the runway is wet or icy.

(5) Cost of extending the runway if insufficient runway length would remain as a result of displacing the threshold. The environmental aspects of a runway extension need to also be evaluated under this consideration.

(6) Cost and feasibility of relocating visual and electronic approach aids, such as threshold lights, visual glide slope indicator, runway end identification lights, localizer, glide slope (to provide a threshold crossing height of not more than 60 feet (18 m)), approach lighting system, and runway markings.

(7) Effect of the threshold change on noise abatement.

5. **CLEARANCE REQUIREMENTS**. The standard shape, dimensions, and slope of the surface used for locating a threshold are dependent upon the type of aircraft operations currently conducted or forecasted, the landing visibility minimums desired, and the types of instrumentation available or planned for that runway end.

a. **Approaches with Vertical Guidance**. Table A2-1 and Figure A2-1 describe the clearance surfaces required for instrument approach procedures with vertical guidance.

The Glidepath Qualification Surface (GQS) limits the height of obstructions between Decision Altitude (DA) and runway threshold (RWT). When obstacles exceed the height of the GQS, an approach procedure with vertical guidance (ILS, PAR, MLS, TLS, LPV, LNAV/VNAV, etc.) is not authorized. Further information can be found in the appropriate TERPS criterion.

b. **Instrument Approach Procedures Aligned with the Runway Centerline**. Table A2-1 and Figure A2-1 describe the minimum clearance surfaces required for instrument approach procedures aligned with the runway centerline.

c. **Procedures Not Aligned with the Runway Centerline**. To accommodate for offset procedures, follow the steps in Figure A2-2 to determine the offset boundary. The surface slope is as specified in the applicable paragraph, according to Table A2-1.

d. **Locating or Determining the DER**. The standard shape, dimensions, and slope of the departure surface used for determining the DER, as defined in TERPS, is only dependent upon whether or not instrument departures are being used or planned for that runway end. See Table A2-1 and Figures A2-1 and A2-2 for dimensions.

Subparagraph 5d(2) applies only to runways supporting Air Carrier departures and is not to be considered a clearance surface.

(1) For Departure Ends at Designated Runways.

(a) No object should penetrate a surface beginning at the elevation of the runway at the DER or end of clearway, and slopes at 40:1. Penetrations by existing obstacles of 35 feet or less would not require TODA reduction or other mitigations found in paragraph 4; however, they may affect new or existing departure procedures.

(2) Departure Runway Ends Supporting Air Carrier Operations.

(a) Objects should be identified that penetrate a one-engine inoperative (OEI) obstacle identification surface (OIS) starting at the DER and at the elevation of the runway at that point, and slopes upward at 62.5:1. See Figure A2-4. **Note:** This surface is provided for information only and does not take effect until January 1, 2012.

Table A2-1. Approach/Departure Requirements Table

	Runway Type	DIMENSIONAL STANDARDS* Feet					Slope/ OCS
		A	B	C	D	E	
1	Approach end of runways expected to serve small airplanes with approach speeds less than 50 knots. (Visual runways only, day/night)	0	60	150	500	2,500	15:1
2	Approach end of runways expected to serve small airplanes with approach speeds of 50 knots or more. (Visual runways only, day/night)	0	125	350	2,250	2,750	20:1
3	Approach end of runways expected to serve large airplanes (Visual day/night); or instrument minimums ≥ 1 statute mile (day only).	0	200	500	1,500	8,500	20:1
4	Approach end of runways expected to support instrument night operations, serving approach category A and B aircraft only. [1]	200	200	1,900	10,000 [2]	0	20:1
5	Approach end of runways expected to support instrument night operations serving greater than approach category B aircraft. [1]	200	400	1,900	10,000 [2]	0	20:1
6	Approach end of runways expected to accommodate instrument approaches having visibility minimums ≥ 3/4 but < 1 statute mile, day or night.	200	400	1,900	10,000 [2]	0	20:1
7	Approach end of runways expected to accommodate instrument approaches having visibility minimums < 3/4 statute mile or precision approach (ILS, GLS, or MLS), day or night.	200	400	1,900	10,000 [2]	0	34:1
8	Approach runway ends having Category II approach minimums or greater.	The criteria are set forth in TERPS, Order 8260.3.					
9	Approach end of runways expected to accommodate approaches with vertical guidance [Glideslope Qualification Surface (GQS).]	0	1/2 width runway +100	760	10,000 [2]	0	30:1
10	Departure runway ends for all instrument operations.	0[4]	See Figure A2-3				40:1
11	Departure runway ends supporting Air Carrier operations. [5]	0[4]	See Figure A2-4				62.5:1

* The letters are keyed to those shown in Figure A2-1.

Notes:
1. Marking & Lighting of obstacle penetrations to this surface or the use of a VGSI, as defined by the TERPS order, may avoid displacing the threshold.
2. 10,000 feet is a nominal value for planning purposes. The actual length of these areas is dependent upon the visual descent point position for 20:1 and 34:1 and Decision Altitude point for the 30:1.
3. When obstacles exceed the height of the GQS, an approach procedure with vertical guidance (ILS, PAR MLS, TLS, LPV, LNAV/VNAV, etc.) is not authorized. No vertical approaches will be authorized until the penetration(s) is/are removed except obstacles fixed by function and/or allowable grading (paragraphs 305 and 308).
4. Dimension A is measured relative to Departure End of Runway (DER) or TODA (to include clearway).
5. Data Collected regarding penetrations to this surface are provided for information and use by the air carriers operating from the airport. These requirements do not take effect until January 1, 2012.

6. Surface dimensions/Obstacle Clearance Surface (OCS) slope represent a nominal approach with 3 degree GPA, 50'TCH, <500' HATh. For specific cases refer to TERPS. The Obstacle Clearance Surface slope (30:1) supports a nominal approach of 3 degrees (also known as the Glide Path Angle). This assumes a threshold crossing height of 50 feet. Three degrees is commonly used for ILS systems and VGSI aiming angles. This approximates a 30:1 approach angle that is between the 34:1 and the 20:1 notice surfaces of Part 77. Surfaces cleared to 34:1 should accommodate a 30:1 approach without any obstacle clearance problems.
7. For runways with vertically guided approaches the criteria in Row 9 is in addition to the basic criteria established within the table, to ensure the protection of the Glidepath Qualification Surface (GQS).
8. For planning purposes, sponsors and consultants determine a tentative Decision Altitude based on a 3° Glidepath angle and a 50-foot Threshold Crossing Height.

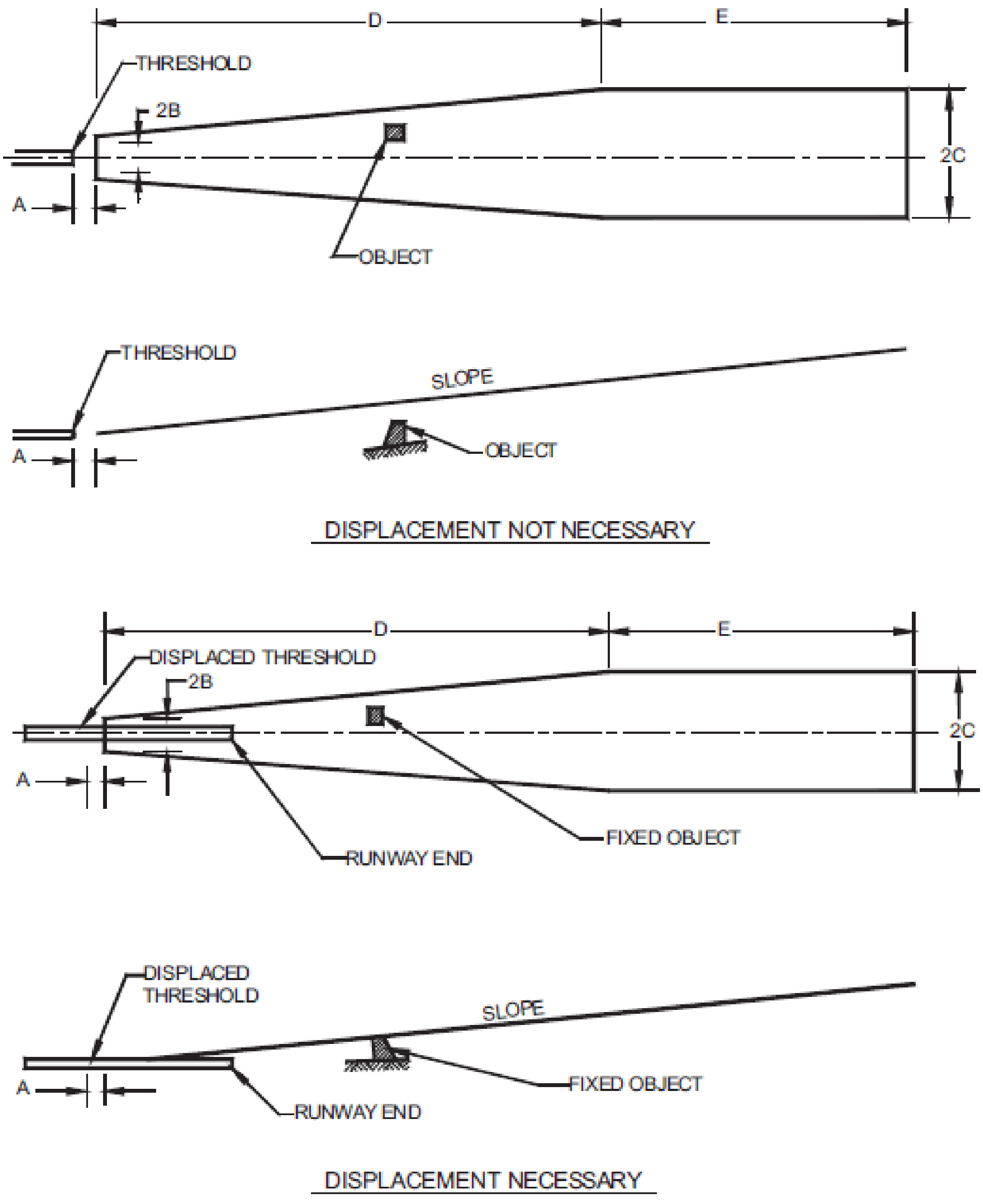


Figure A2-1. Approach slopes

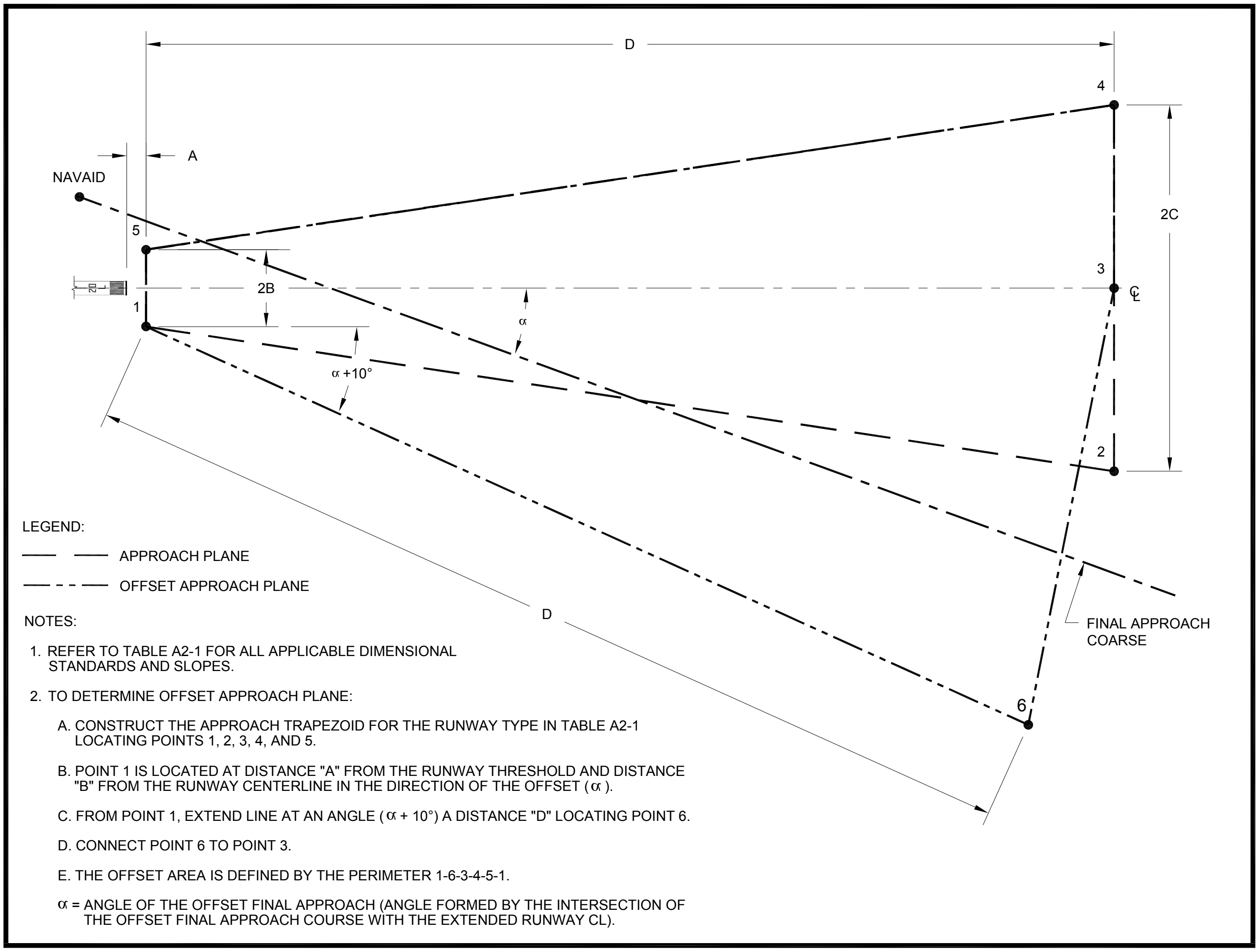


Figure A2-2. Offset Approach Course

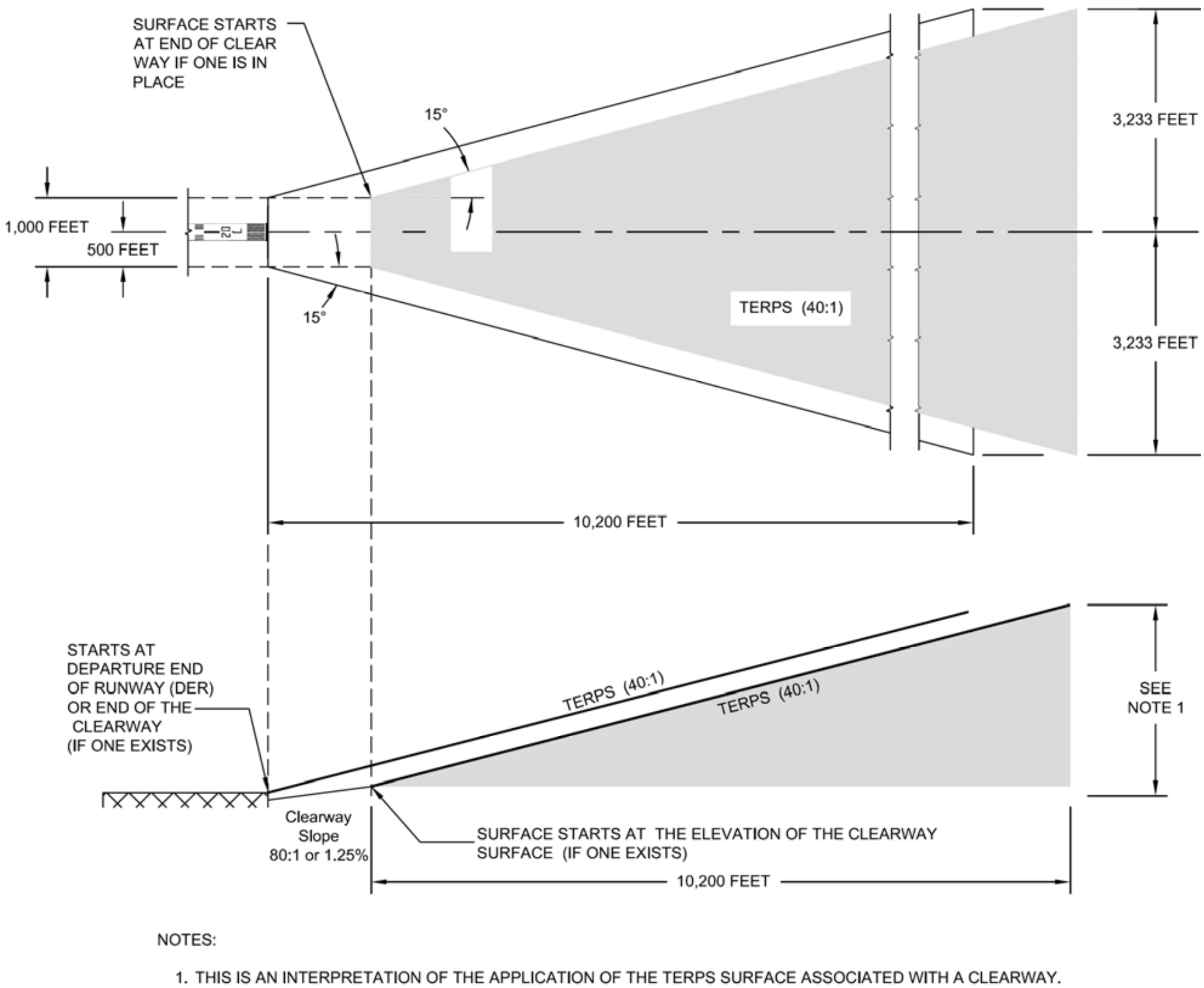


Figure A2-3. Departure surface for Instrument Runways TERPS (40:1)

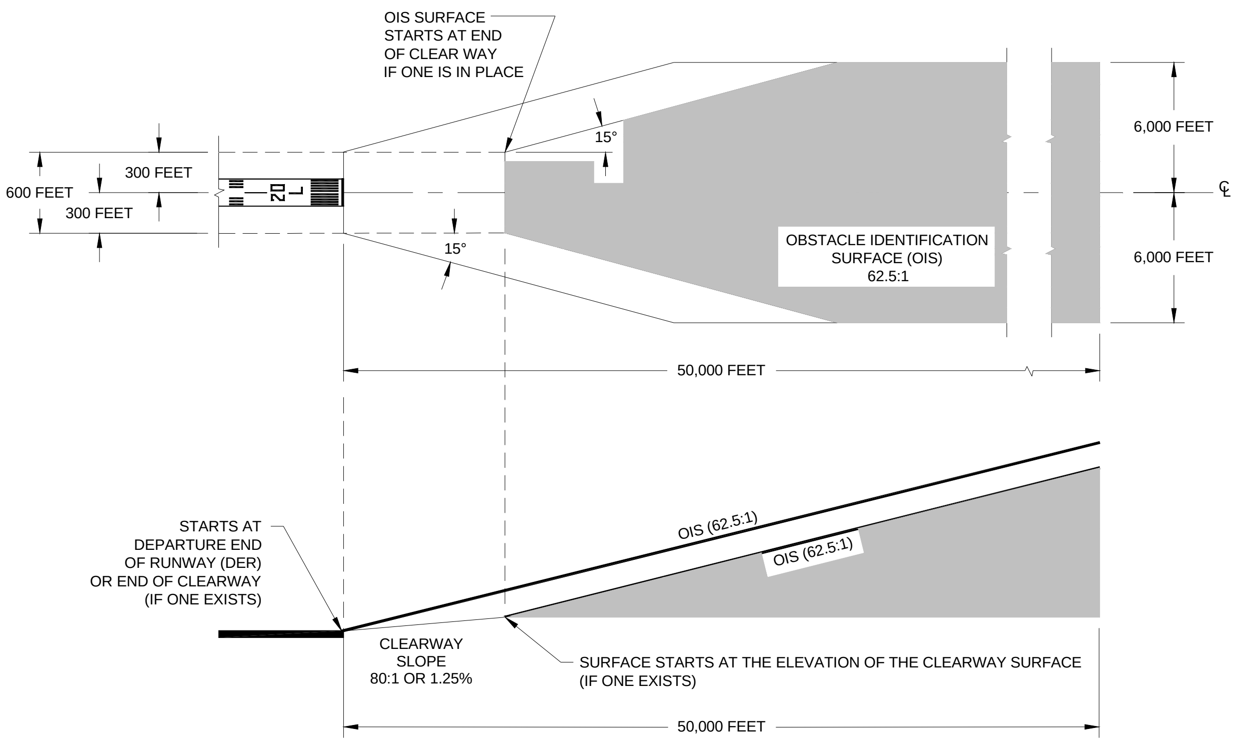


Figure A2-4. One-Engine Inoperative (OEI) Obstacle Identification Surface (62.5:1)

Appendix 3. AIRPORT REFERENCE POINT

1. DISCUSSION.

a. The airport reference point (ARP) geographically locates the airport horizontally. The ARP is normally not monumented or physically marked on the ground. The computation of this point uses only runway length.

b. Meaningful airport reference point computations use the ultimate runway lengths proposed for development. These computations do not use closed or abandoned areas. The FAA approved airport layout plan shows the ultimate development. If there is no airport layout plan, the ultimate runway lengths are the existing runways plus those that have airspace approval, less closed or abandoned areas.

c. The ARP is computed or recomputed as infrequently as possible. The only time that a recomputation is needed is when the proposed ultimate development is changed.

2. SAMPLE COMPUTATION. The following procedure determines the location of the airport reference point used in FAR Part 77 studies.

a. Establish two base lines perpendicular to each other as shown in Figure A3-1. Let the northerly base line be known as B and the westerly as A.

b. Establish the midpoint of each runway.

c. Determine the perpendicular distance from the base lines to the midpoints.

d. Calculate the moment of areas for each base line as shown in Figure A3-2.

e. Divide each moment of area by the sum of areas to determine distance of the ARP from each base line.

f. The location is converted into latitude and longitude.

3. ACCURACY. The latitude and longitude should be to the nearest second. Installation of navigational aids may need coordinates to the nearest tenth of a second. Coordinate with the appropriate FAA Airway Facilities field office to ascertain the need for accuracy closer than the nearest second.

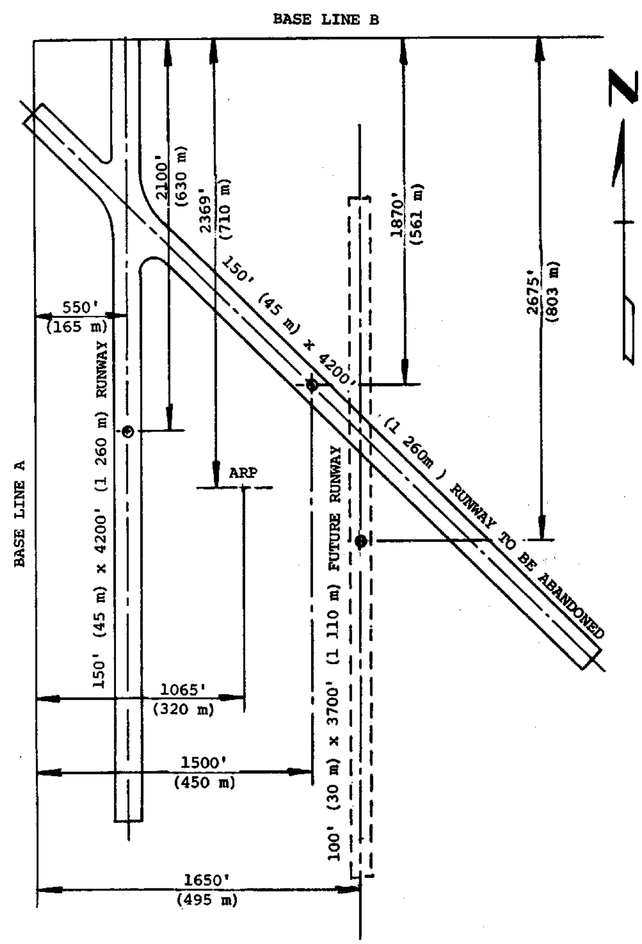


Figure A3-1. Sample layout

U.S. Customary Units

BASE LINE A:

4,200	x	550	=	2,310,000
3,700	x	1,650	=	6,105,000
7,900				8,415,000

$$= \frac{8,415,000}{7,900} = 1,065'$$

BASE LINE B:

4,200	x	2,100	=	8,820,000
3,700	x	2,675	=	9,897,500
7,900				18,717,500

$$= \frac{18,717,500}{7,900} = 2,369'$$

Metric Units

BASE LINE A:

1 266	x	165	=	207 900
1 110	x	495	=	549 450
2 370				757 350

$$= \frac{757\ 350}{2\ 370} = 320 \text{ m}$$

BASE LINE B:

1 266	x	630	=	793 800
1 110	x	803	=	891 330
2 370				1 685 130

$$= \frac{1\ 685\ 130}{2\ 370} = 710 \text{ m}$$

Note: Since the diagonal runway is to be abandoned, it is not used in the computation.

Figure A3-2. Sample computation – airport reference point

Appendix 4. COMPASS CALIBRATION PAD

1. PURPOSE. This appendix provides guidelines for the design, location and construction of a compass calibration pad and basic information concerning its use in determining the deviation error in an aircraft magnetic compass.

2. BACKGROUND.

a. An aircraft magnetic compass is a navigation instrument with certain inherent errors resulting from the nature of its construction. All types of magnetic compasses indicate direction with respect to the earth's magnetic field. This is true even for the gyro-stabilized and/or fluxgate compasses. Aircraft navigation is based on applying the appropriate angular corrections to the magnetic reading in order to obtain the true heading.

b. The aircraft magnetic compass should be checked following pertinent aircraft modifications and on a frequent, routine schedule. One method of calibrating the compass is to use a compass calibration pad to align the aircraft on known magnetic headings and make adjustments to the compass and/or placard markings to indicate the required corrections. There are other methods available for calibrating a magnetic compass, but for small aircraft the method outlined herein is normally used.

3. APPLICATION.

a. The process of aligning an aircraft on known magnetic headings for the purpose of determining the degree of error in the magnetic compass is commonly referred to as "swinging the compass." The technique which should be used is as follows:

(1) Place the aircraft on a compass calibration pad.

(2) Place the aircraft in level flying position.

(3) Remove compensating magnets from chambers or reset the fixed compensating magnets to neutral position, whichever is applicable, before swinging.

(4) Check indicator for fluid level and cleanliness. If fluid is required, the compass is defective.

(5) Check the pivot friction of the indicator by deflecting the card with a small magnet. The card should rotate freely in a horizontal plane.

(6) If a radio is used in the aircraft, there should be corrections noted for "radio on" and "radio off" conditions.

(7) Align the aircraft with the north magnetic heading and make the indicated reading correspond to the actual magnetic reading by use of the compensating magnets. Repeat for the east magnetic heading. Then place on south and west magnetic headings and remove half of indicated error by adjusting compensators. Engine(s) should be running.

(8) Turn the aircraft on successive 30-degree headings through 360 degrees. Placards should be marked to indicate correction at each 30-degree heading showing "radio on" and "radio off" corrections.

b. Calibration and adjustment of remote indicating gyro compasses, polar path compasses, and other systems of this type should be by a qualified instrument technician.

4. DESIGN OF COMPASS CALIBRATION PAD. The design details shown in this appendix should be considered as guidance only and variations of these designs are acceptable provided the general requirements are met.

a. The compass calibration pad provides a series of 12 radials, either painted on with nonmetallic paint or inlaid in the surface of the calibration pad, extending toward predetermined magnetic directions every 30 degrees beginning with magnetic north. Each radial should be marked with three separate magnetic headings; one at the end of the radial indicating the direction along which each line lies; and one on each side of the line which indicates the magnetic heading of the aircraft when it is oriented at 90 degrees to the radial. Markings facing the pilot must correspond to the airplane's heading when traveling in that direction. The markings must be large enough to be easily read from the aircraft cockpit as the radial is being approached. The last zero may be dropped from the heading designation. Figure A4-1 shows a layout of markings.

b. Figures A4-2 and A4-3 depict suggested types of calibration pads. Type I, as shown in figure A4-2, can be either rigid or flexible pavement construction. Type II, as shown in figure A4-3, is applicable only to rigid pavements. The pavement thickness of either type shall be as required to support the user aircraft in a critical area in accordance with AC 150/5320-6. The concrete pavements, joint type, and spacing shall conform to standard practices, without no magnetic materials. Therefore, dowels (where required) shall be of aluminum, brass, or bronze, rather than steel.

c. Make the size of the calibration pad compatible with the requirements of the user aircraft. For small airplanes make the radius of the pad 50 feet (15 m); for basic transports make the radius 60 feet (18 m); for large two- and three-engine jets, other than basic transports, and all large propeller-driven airplanes make the radius 80 feet (24 m); and for large four-engine jets, other than basic transports, make the radius 110 feet (33 m). For aircraft over 300,000 pounds (136 000 kg), an analysis of the turning area required for the aircraft will be necessary to determine adaptability to the dimensions specified herein.

d. The Type II compass calibration pad shown in figure A4-3 provides wheel slots to assist in true alignment of aircraft normal to each radial. It may be desirable to construct a special device for use in obtaining true alignment for the calibration pad shown in figure A4-2. One method of establishing control points consists of hollow shell non-magnetic inserts along each radial. A wooden block with aluminum or bronze bolts to fit into the center hole of the brass insert can then be used to provide an accurate alignment of the aircraft wheels. Figure A4-1 shows design details of this system.

e. There are many satisfactory ways of providing a device to wheelblock an aircraft to obtain the required alignment, and the exact method is left to the discretion of the design engineer. The method detailed in Figure A4-1 is one suggestion. One alternative which comes to mind is the possibility of forming holes in the concrete with some form of removable dowel, rather than constructing the specially built brass inserts.

5. <u>LOCATION OF COMPASS CALIBRATION PAD</u>. The requirements specified herein have been determined through consultation with instrument calibration specialists, fixed base operators, and persons in the Geological Survey with considerable experience in performing surveys of compass calibration pads.

a. Locate the site at least 300 feet (90 m) from power and communication cables (both above and below ground) and from other aircraft. Locate the site at least 600 feet (180 m) from large magnetic objects such as buildings, railroad tracks, high voltage electrical transmission lines, or cables carrying direct current (either above or below ground). In order to prevent interference with electronic navigational aid facilities located on the airport, make sure that the required clearances are maintained as specified in chapter 6. Control cables, runway and taxiway light bases or sign fixtures, pipelines, ducts, grates for drainage, distance remaining signs, and aircraft arresting gear should be avoided when they contain ferrous materials.

b. The compass calibration pad must be located off the side of a taxiway or runway a sufficient distance to satisfy the runway and taxiway clearances applicable to the airport on which it is located.

c. After tentative selection of a site through visual application of appropriate criteria contained herein, make a thorough magnetic survey of the site. Many sites which meet all visually applied criteria regarding distances from structures, etc., still are unsatisfactory because of locally generated or natural magnetic anomalies. At locations near heavy industrial areas, intermittent magnetic variations may be experienced and sufficient surveys at various periods of time are necessary to ascertain if this situation exists.

d. The difference between magnetic and true north must be uniform in the vicinity of the site. Make sufficient surveys to determine that the angular difference between true and magnetic north measured at any point does not differ from the angular difference measured at any other point by more than one-half degree within a space between 2 and 10 feet (0.6 and 3 m) above the surface of the base and extending over an area within a 250-foot (75 m) radius from the center.

6. <u>CONSTRUCTION OF COMPASS CALIBRATION PAD</u>. For pavement construction, the applicable portions of AC 150/5320-6 should be used. The following additional information is important:

a. Do not use magnetic materials, such as reinforcing steel or ferrous aggregate, in the construction of the calibration pad or of any pavement within a 300-foot (90 m) radius of the center of the site. If a drainage pipe is required within 300 feet (90 m) of the center of the site, use a nonmetallic or aluminum culvert.

b. Each of the radials is oriented within one minute of the magnetic bearing indicated by its markings.

c. Mark the date of observation and any annual change in direction of magnetic north durably and legibly on the surface of the calibration pad near the magnetic north mark. It would be well to establish a permanent monument at some remote location on the true north radial for future reference.

d. The U.S. Geological Survey of the Department of Interior is available to conduct the necessary surveys to determine the difference between true and magnetic north and the uniformity of this difference. The cost for this service is that necessary to cover the expense to the U.S. Geological Survey. Requests for this service should be made to the following:

National Geometric Information Center
U.S. Geomagnetic Survey
Box 25046 MS 968
Denver, Colorado 80225-0046 USA
Tel: 1(303)273-8486 Fax: 1(303)273-8450
Public Web Site: http://geomag.usgs.gov

There are also many other competent registered surveyors or engineers who are capable of performing these surveys. It is recommended that a qualified engineer be employed to lay out the work in the field and to design the pavement for the critical aircraft that can reasonably be expected to use the pad.

e. After all construction work on the compass pad is completed, it is advisable to have the pad magnetically resurveyed to guard against the possibility of objectionable magnetic materials being introduced during the construction.

f. Magnetic surveys of existing compass calibration pads should be performed at regular intervals of 5 years or less. Additional surveys should be performed after major construction of utility lines, buildings, or any other structures within 600 feet (180 m) of the center of the pad.

7. VOR CHECKPOINT. At some airports, it may be advantageous to collocate a VOR checkpoint with the compass calibration pad. In such instances, the requirements presented in paragraph 201.3212 of FAA Handbook OA P 8200.1, United States Standard Flight Inspection Manual, should be followed.

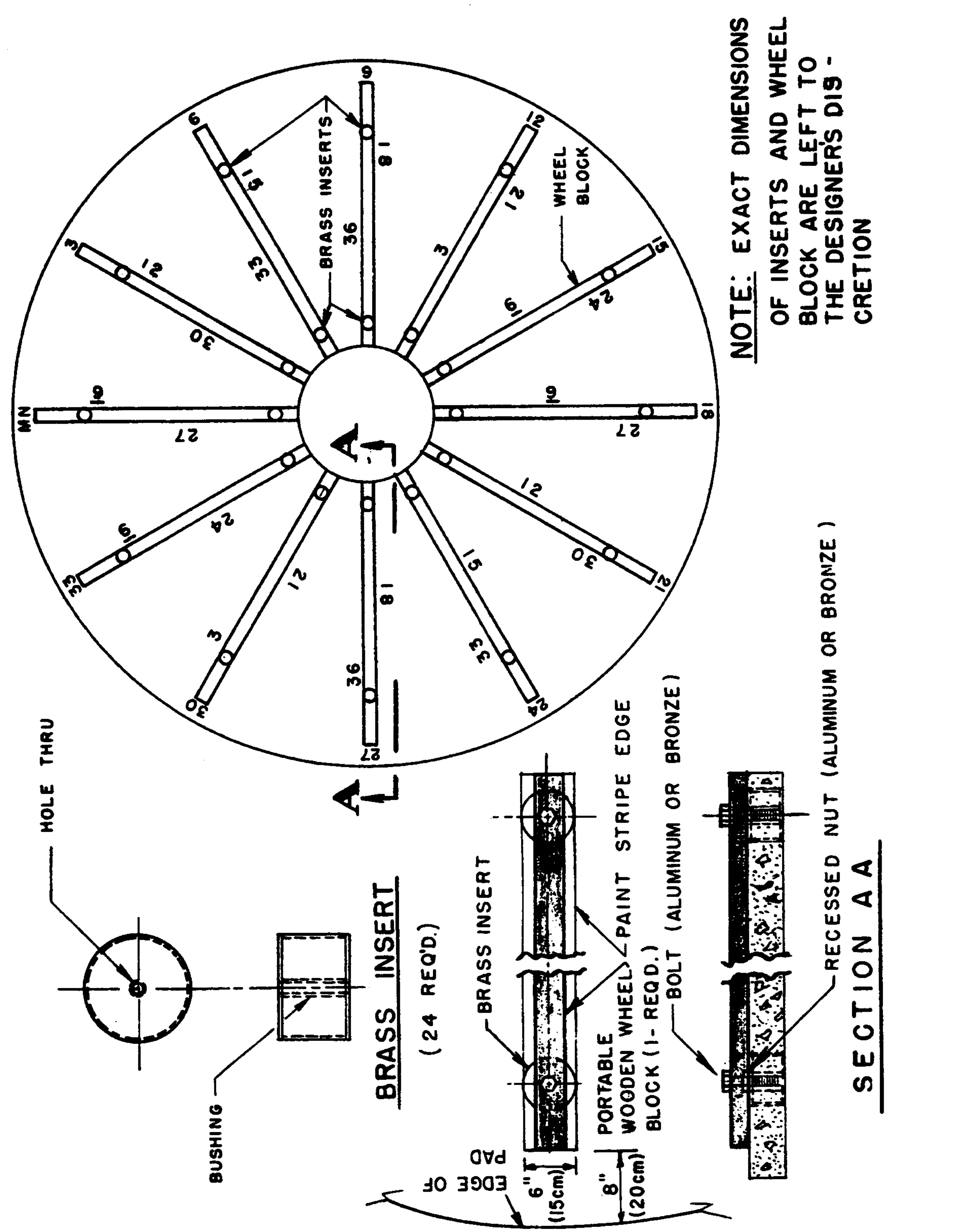


Figure A4-1. Marking layout and details of wheel block

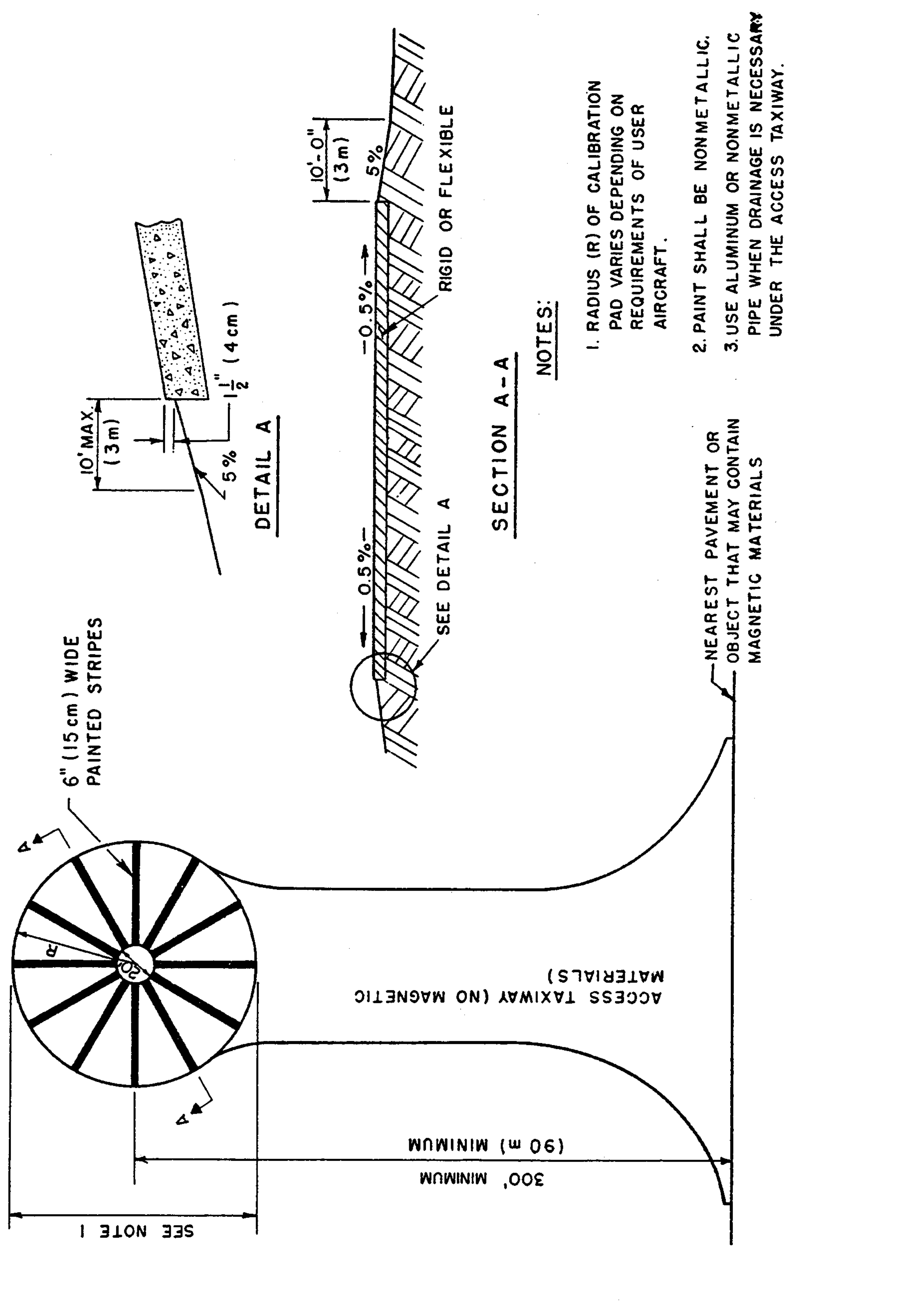


Figure A4-2. Type I. compass calibration pad

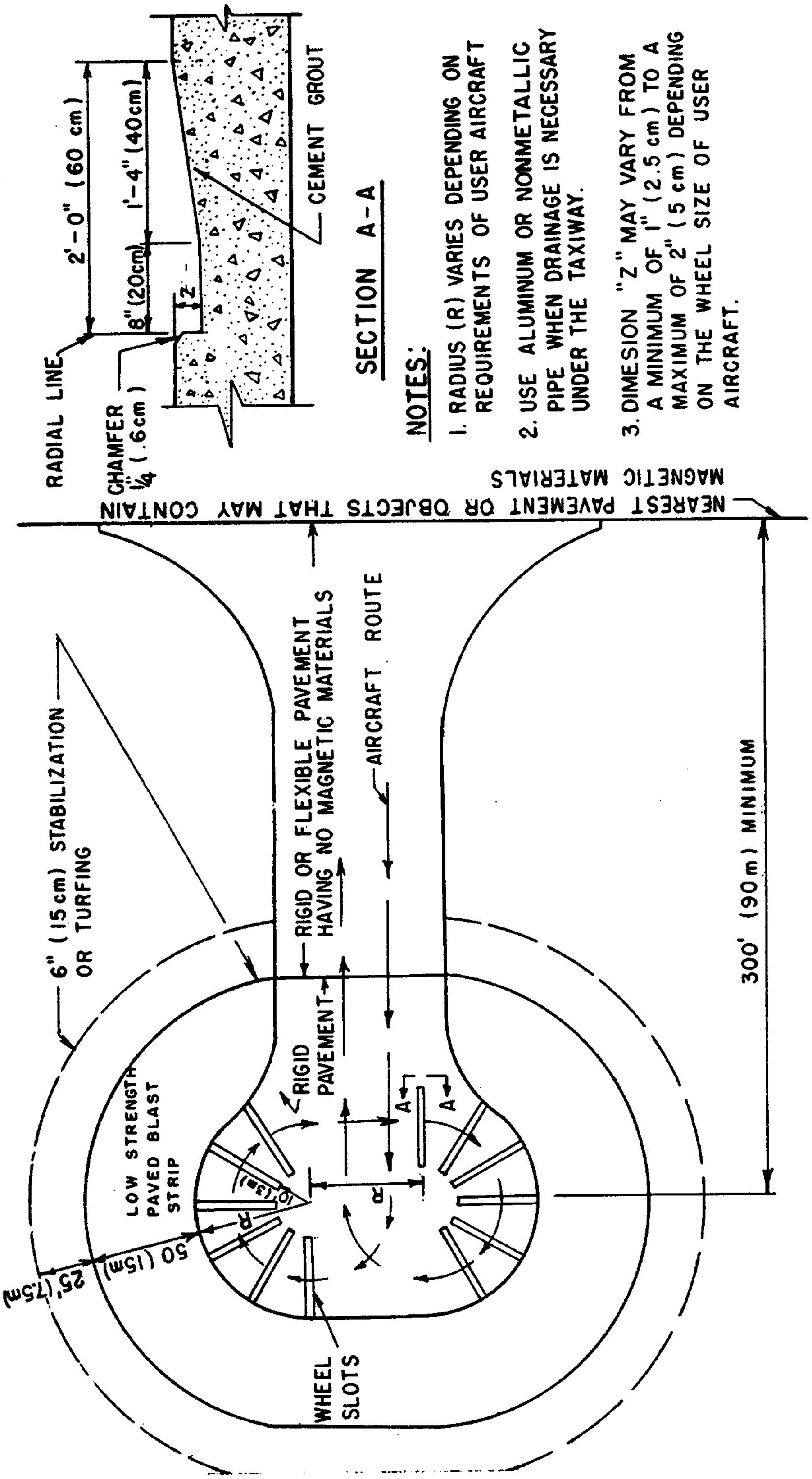


Figure A4-3. Type II. compass calibration pad

Appendix 5. SMALL AIRPORT BUILDINGS, AIRPLANE PARKING, AND TIEDOWNS

1. GENERAL. This chapter provides guidelines on airport buildings, airplane parking, and tiedowns at small airports. Airport buildings fulfill the needs of specific aviation activities. The fixed base operator's (FBO) building usually provides space for the commercial activities, maintenance and repair of aircraft, air charter, and the like. The administration building accommodates the public, pilots, passengers, visitors and also the airport manager's office. Constructed small airplane hangars generally house only airplanes.

a. Figure A5-1 illustrates a typical layout for the building area of a small airport. Siting the FBO building adjacent to the airplane parking apron offers both convenience for local and itinerate pilots. Apron frontage is a premium airport space and should be judiciously utilized. Most hangaring is essentially a garaging operation which usually does not require direct apron front access. The administration building should be near the FBO but sufficiently separated to preclude conflict between airplanes operating from these areas. Storage hangars are often T-hangars, grouped in multiunits in a separate area.

b. Other aviation-oriented buildings may be necessary on the airport. The function(s) of such a building in relation to other aviation activities helps determine its optimum location.

c. An airport master planning study indicates the number of based and transient airplanes expected to utilize the airport. This information will assist in the layout and design of the airplane parking apron(s) and tiedown area(s).

d. AC 150/5360-13 contains guidance on the planning and design of airport terminal buildings and related access facilities at large airports.

2. TRANSIENT APRON. Aprons provide parking for airplanes, access to the terminal facilities, fueling, and surface transportation. A determination on the total amount of apron area needed cannot be developed by formula or empirical relationship since local conditions often vary significantly from one airport to another. The ideal solution is conducting an onsite survey during typical busy days and counting the airplanes on the ground periodically during the day. This approach, however, is impossible for new airports and likely impractical for many airports without a manager. Below is a method which includes factors that affect the determination of the area needed for transient parking and analyzes and estimates the demand for the transient airplane.

a. Calculate the total annual operations (local plus itinerant) from the best available source. Where specific data are not available, the following data, which reflect local plus itinerant operations, may be used: Non-NPIAS Public Use - 538/based aircraft; Reliever - 492/based aircraft; Other General Aviation -637/based aircraft; and Primary - 700/based aircraft.

b. Obtain the record of aviation gas sales for the year for the airport.

c. Correlate gas sales with annual operations on a monthly basis.

d. Calculate the average daily operations for the most active month.

e. Assume the busy day is 10 percent more active than the average day.

f. Assume that a certain portion of the transient airplanes will be on the apron during the busy day. Consider fifty percent as a reasonable figure.

g. Allow an area of 360 square yards per transient airplane.

h. Adjust the calculated amount to accommodate expansion for at least the next 2-year period. A minimum suggested increase is 10 percent.

3. APRON FOR BASED AIRPLANES. The apron used for based airplanes should be separate from the transient airplanes. The area needed for parking based airplanes should be smaller per airplane than for transient. This is due to knowledge of the specific type of based airplanes and closer clearance allowed between airplanes. The following considerations apply in determining the total apron area required for based airplanes:

a. The total number of based airplanes.

b. The number of airplanes now hangared or expected to be within 2 years.

c. The number of airplane owners who will continue to tie down their airplane in a turfed (unpaved) area. At many general aviation airports a certain percentage of airplane owners will prefer to tie down in the most inexpensive area.

d. An area of 300 square yards (250 m^2) per airplane. This should be adequate for all single engine and light twin engine airplanes, such as the Cessna 310, which has a wingspan of 37 feet (11 m) and a length of 27 feet (8 m).

e. An increase in total area to accommodate expansion for at least the next 2-year period. A minimum suggested increase is 10 percent.

4. **TIEDOWNS**. Tiedown locations for based airplanes will vary with local preference. The purpose of a tiedown layout is to park the maximum number of airplanes while satisfying taxilane object free area width criteria. Figure A5-2 illustrates two tiedown layouts for small airplanes in Airplane Design Group I. General information on tiedown techniques and procedures is contained in AC 20-35.

5. **OTHER CONSIDERATIONS**.

a. As airport activity increases, the demand for an area to load and unload airplanes will increase. This activity may be in the form of charter, air taxi, business, or personal airplane operations. Generally, the area should be large enough to accommodate two airplanes in front of the terminal building. Also, investigate requirements for possible local air mail service.

b. At small general aviation airports, a gas pump facility is usually the most economical method of airplane fueling. A fueling area should be near the terminal building. Some larger general aviation airports use fuel truck operations. Such an operation eliminates the need for gas pump areas and allows more area for airplane parking. In either case, appropriate static grounding capability must be provided.

c. In summary, the apron design should allow for flexibility and expandability. The design should use empirical relationships only when field data are not available. Arrangement of tiedown installation should allow apron area alterations as needed. Keeping both ends of the apron free of structures will enhance future expansion.

6. **HANGARS**. Figure A5-3 illustrates typical layouts of hangar areas for different types of hangars. As noted, the recommended clearance between T-hangars is 75 feet (23 m) for one-way traffic and 125 feet (38 m) for two-way traffic. These clearances will accommodate most twin engine general aviation airplanes.

a. Prefabricated T-hangars are available in various sizes and lengths. Details on their erection and cost may be obtained from any of several manufacturers throughout the country.

b. The number of T-hangars depends upon local demand. However, expect a greater demand for protection from weather in the more severe climate areas.

7. **ADMINISTRATION BUILDING**. The necessity of an administration building is a managerial question answered on the weight of at least the following two factors. First, operationally, the chief factor is whether the airport can take care of present and anticipated airplane activity. Second, economically, the chief factor is the kind of community the airport serves and how well this community can support general aviation activity. Note that lower activity airports may not initially justify the construction of either an FBO or administration building. In many cases, the initial airport building is a small maintenance hangar with an attached office. Prior to the construction of an administrative type of building on a general aviation airport, the following basic questions should receive consideration:

a. Are there a minimum of 10 airplane departures and arrivals, not including touch and go, during the peak hours of a typically busy day during the year?

b. Is there at least one active fixed base operator on the airport?

c. Is airplane fuel available on the airport?

d. Is a hangar with repair facilities in operation on the airport?

e. Is a full-time airport manager on duty during the normal day?

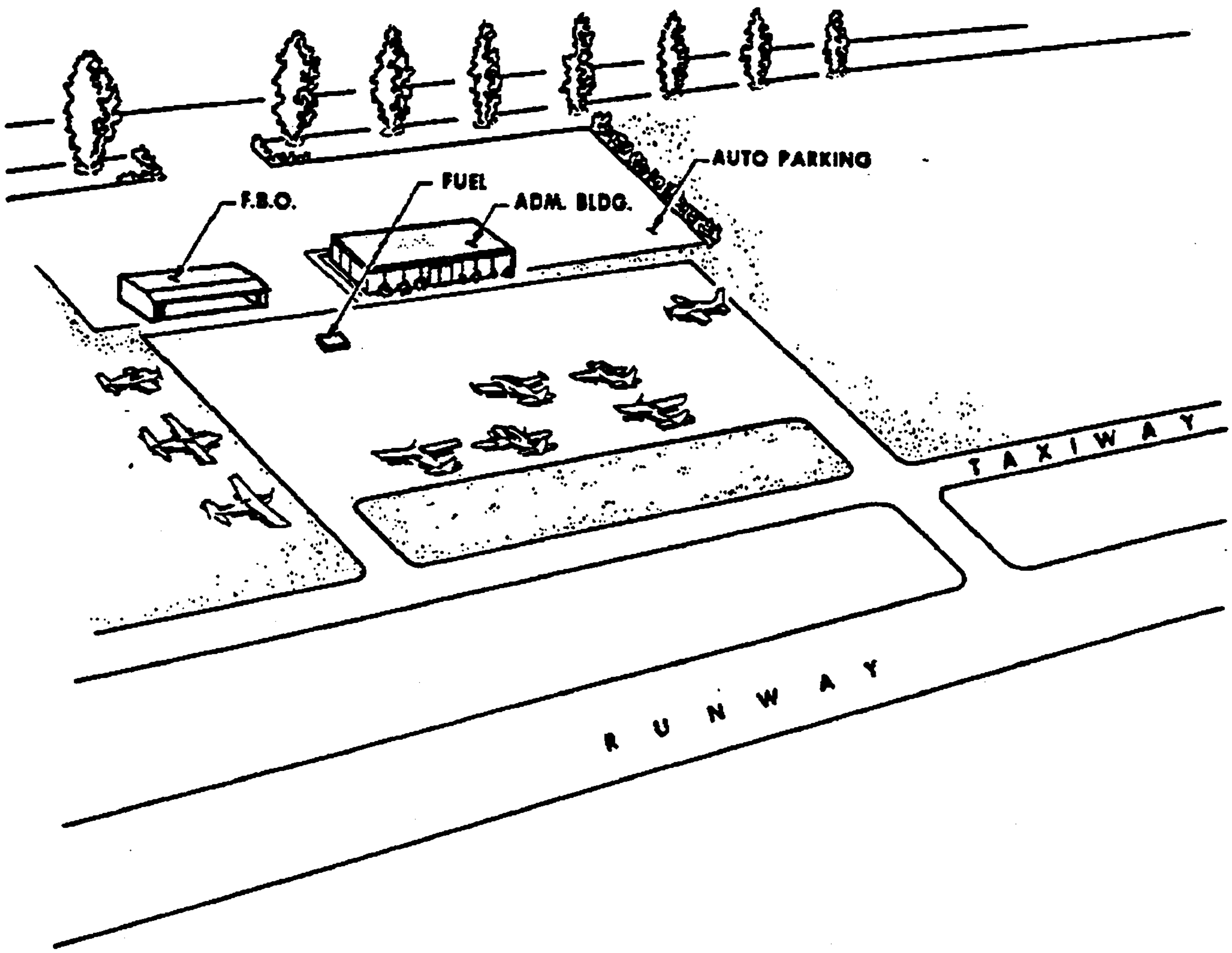
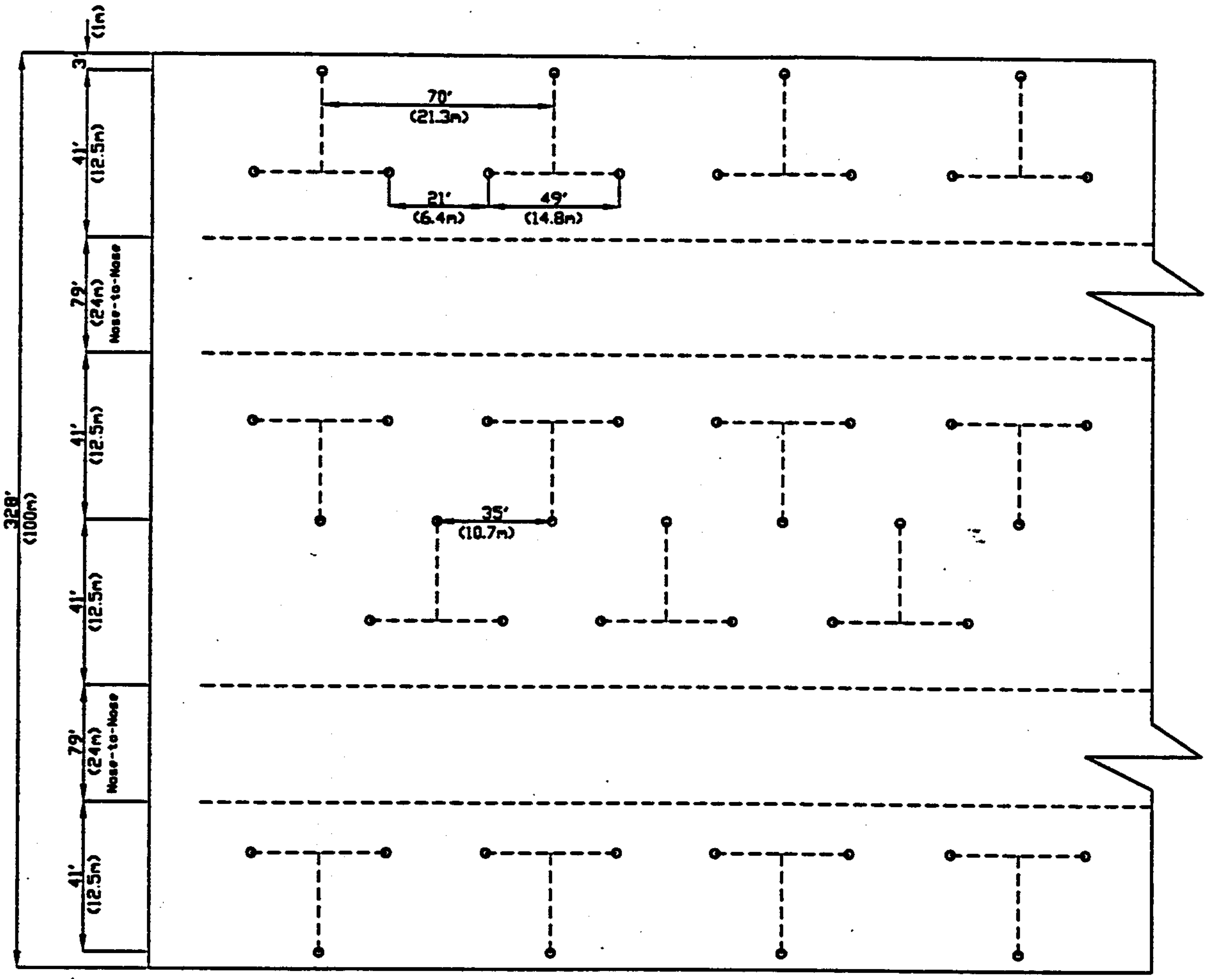


Figure A5-1. Parking apron area



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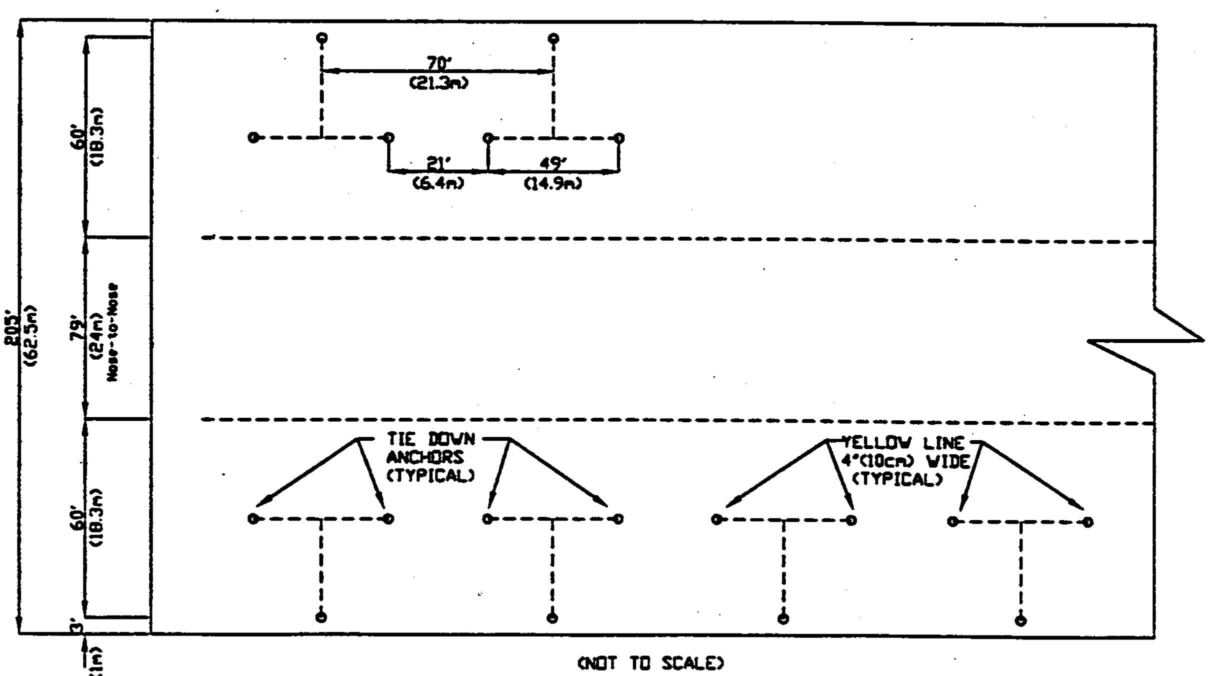

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Figure A5-2. Tiedown layouts

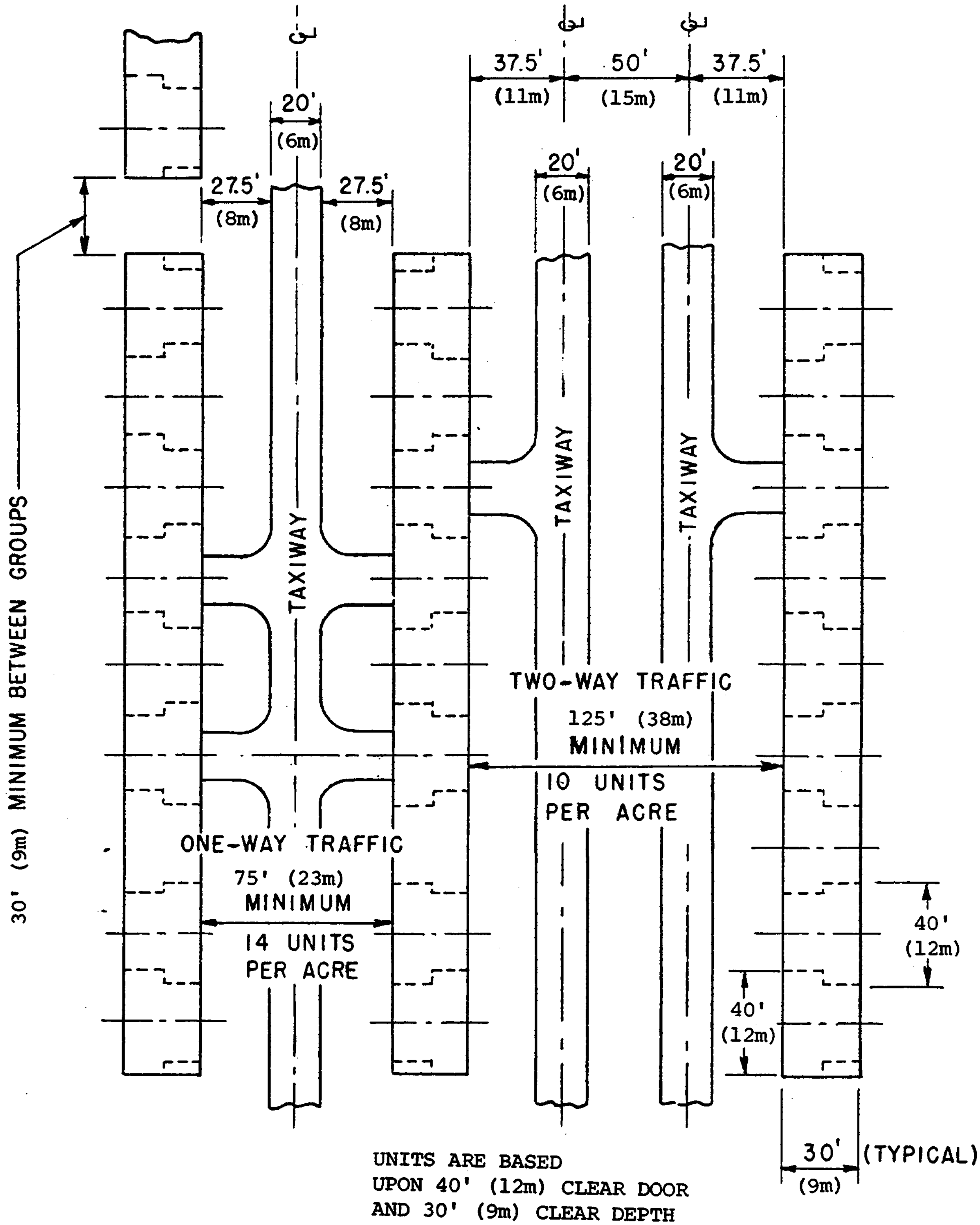

Figure A5-3. T-hanger layout

f. Are public waiting areas and restrooms already available in hangars or other buildings on the airport?

g. Is a public telephone available 24 hours a day for closing flight plans or requesting fuel or transportation to town?

8. AIRPORT SURVEY. A survey of an airport's aviation activity should precede the planning of an administration building. For survey purpose, "airport aviation activity" includes the number of active-based airplanes, the number of airplane operations (local and itinerant), and the number of pilots and passengers at the airport on a typically busy day.

a. A survey of current activity at the airport can determine what functional requirements need accommodating by and the total area of the administration building. Also surveys of other airports with similar aviation activity characteristics which already have administration buildings provide additional valuable data. The airport manager or a fixed base operator can gather the information on several typically busy days over a period of several weeks during the most active season. At many small airports, weekends are usually the busiest days and are a good time to measure peak activity. A Pilots Register is also useful in making a traffic count.

b. With respect to passengers, an airport manager obtains data on the two or three days in the week of the season historically known to be the busiest. This record of the plateau of high activity in terms of peak-hour operations and peak-hour passengers determines the typically busy hour by averaging the hourly activity for three or four of the busiest hours.

9. BUILDING PLAN. The specialized interior requirements of a small administration building are few and should reflect a basic simplicity by providing direct functional relationships between rooms and facilities.

a. The arrangement of elements within the building should address the airfield configuration, future building expansion, and the passenger and service driveways. In determining the details of space relations and requirements, the experienced general aviation airport manager is in the best position to assist in tailoring detailed building needs to actual aviation activity and should be a participant in the early planning conferences.

b. The building components should provide:

(1) Short and direct pedestrian routes from parking areas to public waiting areas or airport offices, and to the loading apron or tiedown areas; and

(2) A view of the airfield operations from the manager's office, the waiting room, and any eating facilities.

10. EXPANSION.

a. Identification of future expansion of the administration building should be from the outset. This is particularly important at a general aviation airport where it is difficult to accurately forecast and assess initial construction cost when based on actual measurable activity.

b. Normally, with the air field side of the building fixed, building expansion occurs only on the off-field side and the ends. When drives and walks resist expansion on the off-field side, all major expansion should proceed on the ends of the building.

11. CIRCULATION. The waiting room is the hub from which circulation routes radiate. Usually, an open plan with only the minimum essential partitioning allows better circulation and a more spacious building interior. The following items are important in assuring a satisfactory circulation of traffic through the building:

a. Short and direct routes from the entrance of the off-field side of the building to the exit on the field side.

b. Wide doorways at the main entry and exits.

c. Public corridors, as necessary, wide enough for comfortable traffic flow, but not excessive to raise initial and maintenance costs.

d. Adequate circulation aisles within the waiting area to assure free movement and comfort for the room occupants.

12. WAITING ROOM. As the central meeting and waiting space for passengers, visitors, pilots, and airport employees, the waiting room is the focal point of the building. It should merge with such other required spaces as the manager's office, eating facilities, and public restrooms. The closer this relationship, the more economical the building. Additional recommendations follow:

a. A view of airfield activities. The public enjoys seeing airplanes and their operations. Do not put utility rooms, restrooms, and other service facilities on the field side of the building if possible.

b. A comfortable seating arrangement. Comfortable seating need not be fixed seats or stereotyped. Such an arrangement at a small airport is especially good to promote the waiting room informality usually associated with small airport operations.

c. Concession items such as coin-operated parcel lockers and small item dispensing machines.

d. A bulletin board for information of interest to private pilots and the aviation public; for example, weather reports, notices to airmen, and FAA information.

e. Space for the mounting of aeronautical charts.

f. A folding partition to provide dual space use. This flexible arrangement conserves building space and makes it possible to hold meetings in the administration building without disturbing the essential business routine.

g. A public phone for closing flight plans, weather briefings, calling public transportation, etc.

13. MANAGER'S OFFICE. Expect variation in the room space for management use at a particular airport. Determining the local management's space requirements should follow after an analysis of the management equipment, furnishings, and personnel space needs. As a general planning guide, the minimum office size sufficient for the furnishings and functions of an office for a manager and one secretary should be about 180 square feet (17 m^2).

14. EATING FACILITIES. Normally, some provision for food services is in the administration building for the comfort and convenience of airport users. The scope of the eating facilities in the building varies with local and itinerant aviation activity. There may be dispenser items, a snack bar, a coffee shop, a dining room, or a combination of these. Frequently, the airport eating facility attracts additional patrons because of its convenient location, its unusual cuisine, or the interest which the patrons have in aviation activity.

a. Food and drink dispensers are usually enough to satisfy initial needs at general aviation airports. Dispenser service requires little attention to operate. Grouped dispensers can better be seen from the main circulation route between the waiting area and the operation/management office.

b. Usually a concessionaire operates the coffee shop or dining room service. It is important to select the concessionaire early enough to receive concessionaire input in planning that part of the administration building. Computing the required size of space should proceed in terms of seated patrons and the kind and amount of food service and preparation equipment. Additional recommended planning considerations are:

(1) Direct relation with the waiting room;

(2) Convenient route from public entrances;

(3) Direct access from the food preparation area to the outside service drive;

(4) View of the airfield activity from the seating area; and

(5) Compliance with public health agency requirements.

15. PUBLIC RESTROOMS. Restrooms should be immediately accessible from the waiting room and meet federal, state, and local requirements for the handicap impaired.

16. ROADS AND AUTO PARKING. Establishing roads and parking areas directly related to the administration building should follow after arranging the configuration of the building, including passenger entrances/exits and service entries. Other important considerations are as follows:

a. Location of short-limit parking or stopping spaces should be close to the main off-field public entrance with enough distance left between building and parking spaces for any future building expansion planned toward these parking spaces.

b. Consolidation of public and employee parking spaces should be into one centrally located parking area when both an administration building and a hangar area are contemplated. This plan is feasible when a convenient relation is established from the outset between the administration building and the hangars.

c. For special events, there should be one or more well-drained turfed areas, located beside the airport access roads for overflow parking.

d. Additional parking areas should exist if the administration building contains eating facilities which outside customers regularly patronized.

e. There should be separate service drives for kitchens from public drives and parking. However, the service drive may often be adjacent to the apron access drive. This requires preventive measures to prohibit restaurant vehicles from inadvertently driving onto the apron.

f. Designated parking spaces for the handicap impaired are required to comply with applicable federal, state, and local requirements

Appendix 6. METRIC CONVERSION AND TYPICAL AIRPORT LAYOUT PLAN

This appendix was cancelled by AC 150/5070-6, Airport Master Plans. Please replace pages 125–130.

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Appendix 7. AIRPORT LAYOUT PLAN COMPONENTS AND PREPARATION

This appendix was cancelled by AC 150/5070-6, Airport Master Plans. Please replace pages 131–138.

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Appendix 8. RUNWAY DESIGN RATIONALE

1. SEPARATIONS. Dimensions shown in tables 2-1, 2-2, 3-1, 3-2, and 3-3 may vary slightly due to rounding off.

a. **Runway to holdline separation** is derived from landing and takeoff flight path profiles and the physical characteristics of airplanes. The runway to holdline standard satisfies the requirement that no part of an airplane (nose, wingtip, tail, etc.) holding at a holdline penetrates the obstacle free zone (OFZ). Additionally, the holdline standard keeps the nose of the airplane outside the runway safety area (RSA) when holding prior to entering the runway. When the airplane exiting the runway is beyond the standard holdline, the tail of the airplane is also clear of the RSA. Additional holdlines may be required to prevent airplane, from interfering with the ILS localizer and glide slope operations.

b. **Runway to parallel taxiway/taxilane separation** is determined by the landing and takeoff flight path profiles and physical characteristics of airplanes. The runway to parallel taxiway/taxilane standard precludes any part of an airplane (tail, wingtip, nose, etc.) on a parallel taxiway/taxilane centerline from being within the runway safety area or penetrating the OFZ.

c. **Runway to airplane parking areas** is determined by the landing and takeoff flight path profiles and physical characteristics of airplanes. The runway to parking area standard precludes any part of a parked airplane (tail, wingtip, nose, etc.) from being within the runway object free area or penetrating the OFZ.

2. OBSTACLE FREE ZONE (OFZ). The portion of the OFZ within 200 feet (60 m) of the runway centerline is required for departure clearance. The additional OFZ, beyond 200 feet (60 m) from runway centerline, is required to provide an acceptable accumulative target level of safety without having to adjust minimums. The level of safety for precision instrument operations is determined by the collision risk model. The collision risk model is a computer program developed from observed approaches and missed approaches. It provides the probability of an airplane passing through any given area along the flight path of the airplane. To obtain an acceptable accumulative target level of safety with objects in the OFZ, operating minimums may have to be adjusted.

3. RUNWAY SAFETY AREA.

a. **Historical Development.** 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. Figure A8-1 depicts the approximate percentage of airplanes undershooting and overrunning the runway which stay within a specified distance from the runway end. The runway safety area is depicted in figure 3-1 and its dimensions are given in tables 3-1, 3-2, and 3-3.

b. **Recent Changes.** FAA recognizes that incremental improvements inside standard RSA dimensions can enhance the margin of safety for aircraft. This is a significant change from the earlier concept where the RSA was deemed to end at the point it was no longer graded and constructed to standards. Previously, a modification to standards could be issued if the actual, graded and constructed RSA did not meet dimensional standards as long as an acceptable level of safety was provided. Today, modifications to standards no longer apply to runway safety areas. (See paragraph 6) Instead, FAA airport regional division offices are required to maintain a written determination of the best practicable alternative for improving non-standard RSAs. They must continually analyze the non-standard RSA with respect to operational, environmental, and technological changes and revise the determination as appropriate. Incremental improvements are included in the determination if they are practicable and they will enhance the margin of safety.

4. RUNWAY OBJECT FREE AREA (ROFA). The ROFA is a result of an agreement that a minimum 400-foot (120 m) separation from runway centerline is required for equipment shelters, other than localizer equipment shelters. The aircraft parking limit line no longer exists as a separate design standard. Instead, the separations required for parked aircraft and the building restriction line from the runway centerline are determined by object clearing criteria.

5. RUNWAY SHOULDERS AND BLAST PADS. Chapter 8 contains the design considerations for runway shoulders and blast pads.

6. CLEARWAY. The use of a clearway for takeoff computations requires compliance with the clearway definition of 14 CFR Part 1.

7. STOPWAY. The use of a stopway for takeoff computations requires compliance with the stopway definition of 14 CFR Part 1.

8. RUNWAY PROTECTION ZONE (RPZ). Approach protection zones were originally established to define land areas underneath aircraft approach paths in which control by the airport operator was highly desirable to prevent the creation of airport hazards. Subsequently, a 1952 report by the President's Airport Commission (chaired by James Doolittle), entitled "The Airport and Its Neighbors," recommended the establishment of clear areas beyond runway ends. Provision of these clear areas was not only to preclude obstructions potentially hazardous to aircraft, but also to control building construction as a protection from nuisance and hazard to people on the ground. The Department of Commerce concurred with the recommendation on the basis that this area was "primarily for the purpose of safety and convenience to people on the ground." The FAA adopted "Clear Zones" with dimensional standards to implement the Doolittle Commission's recommendation. Guidelines were developed recommending that clear zones be kept free of structures and any development which would create a place of public assembly.

In conjunction with the introduction of the RPZ as a replacement term for clear zone, the RPZ was divided into "object free" and "controlled activity" areas. The RPZ function is to enhance the protection of people and property on the ground. Where practical, airport owners should own the property under the runway approach and departure areas to at least the limits of the RPZ. It is desirable to clear the entire RPZ of all aboveground objects. Where this is impractical, airport owners, as a minimum, shall maintain the RPZ clear of all facilities supporting incompatible activities. Incompatible activities include, but are not limited to, those which lead to an assembly of people.

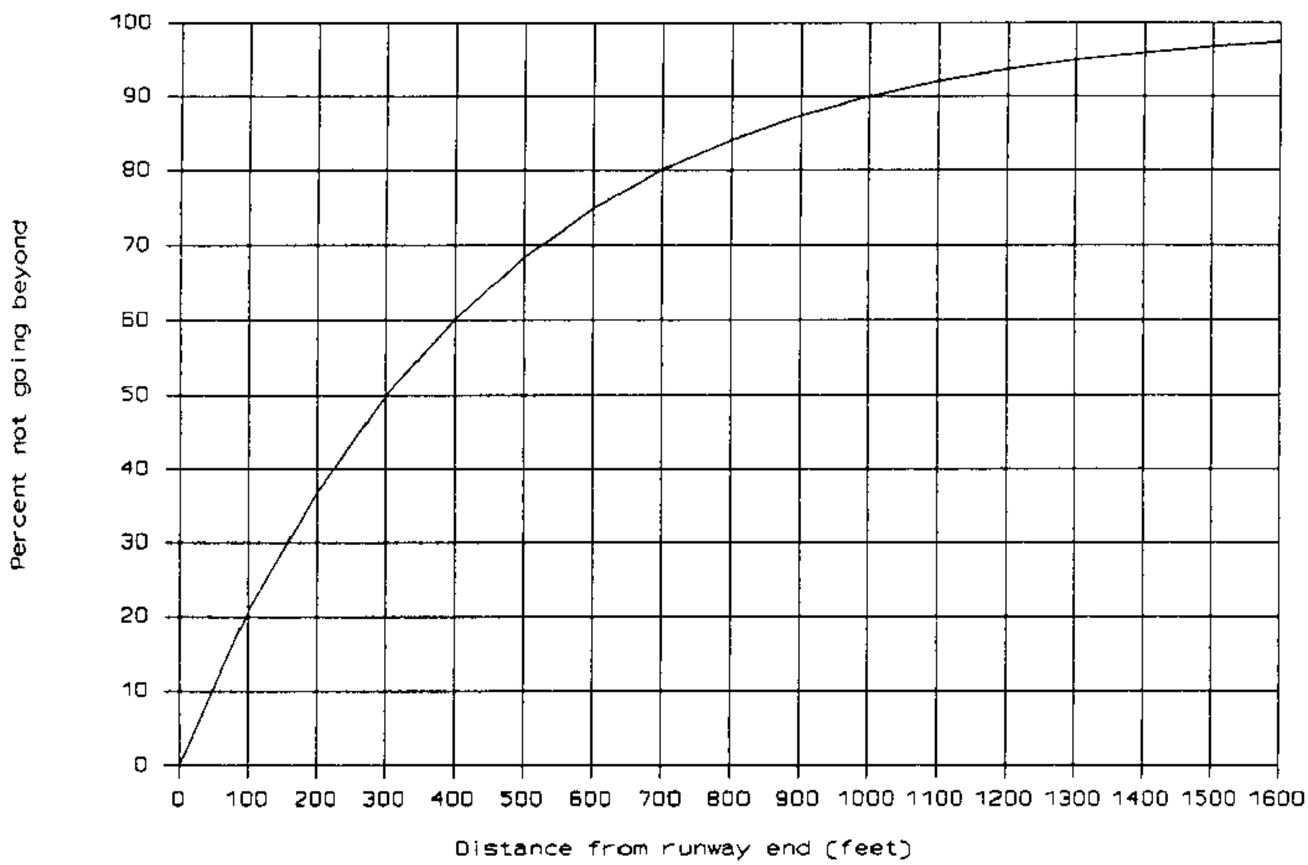

Figure A8-1. Approximate distance airplanes undershoot and overrun the runway end

Appendix 9. TAXIWAY AND TAXILANE DESIGN RATIONALE

1. INTRODUCTION. An airport operator is occasionally faced with the problem of having to cope with unusual terrain, 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 characteristics. This rationale is usable, on a case-by-case basis, when local conditions or a specific airplane require modification of FAA airport design standards.

2. BACKGROUND AND RATIONALE. The minimum pavement widths, curve radii, and separations associated with airplane movement areas and airplane physical characteristics establish the taxiway system. 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 airplane's wingtips.

(1) Taxiway to taxiway centerline separation, as shown in figure A9-1, is equal to 1.20 times the wingspan of the most demanding airplane plus 10 feet (3 m). This gives a wingtip clearance of 0.20 times the wingspan plus 10 feet (3 m). However, this separation may require an increase to accommodate minimum radius taxiway turns of 180 degrees, as shown in figure 4-10. The minimum acceptable radius is one which results in a maximum nosewheel steering angle (B) of 50 degrees. Appendix 10 discusses nosewheel steering angles.

(2) Taxiway centerline to object separation, as shown in figures A9-2 and A9-3, has the same wingtip clearances as taxiway to taxiway centerline separation. Thus, a minimum separation between a taxiway centerline and an object is 0.70 times the wingspan of the most demanding airplane, plus 10 feet (3 m).

(3) Taxiway object free area width is equal to twice the taxiway centerline to object separation.

(4) Taxilane centerline to object separation, as shown in figure A9-4, is equal to 0.60 times the wingspan of the most demanding airplane plus 10 feet (3 m). This gives a wingtip clearance of 0.10 times the wingspan plus 10 feet (3 m). This gives a wingtip clearance of one-half of that for an apron taxiway plus 5 feet (1.5 m). Reduced clearances are acceptable because taxi speed is very slow outside the movement area, taxiing is precise, and special operator guidance techniques and devices are normally present.

(5) Taxilane object free area width is twice the taxilane to object separation for a single lane width and 2.30 times the wingspan of the most demanding airplane plus 30 feet (9 m) for a dual lane width.

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

(1) Taxiway widths relate to the physical characteristics of airplanes. For example, a small high-performance jet airplane with long takeoff and landing requirement and a narrow undercarriage may operate on a relatively narrow taxiway. Conversely, a large airplane with short takeoff and landing capability, but with a wide undercarriage, requires a wider taxiway. Consequently, taxiway width is independent of runway length. The taxiway width should be at least equal to the sum of the undercarriage width plus two times the acceptable taxiway edge safety margin of the most demanding airplane.

(2) Table 4-1 specifies the clearance for tangents and curves, illustrated in figure A9-5, as taxiway edge safety margin.

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. Appendix 10 covers detailed fillet design.

d. Taxiway Shoulders. Chapter 8 contains the design considerations for taxiway shoulders.

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

3. EXIT TAXIWAY LOCATION. Table A9-1 presents cumulative percentages of airplanes observed exiting existing runways at specific exit taxiway locations. In general, each 100-foot (30 m) reduction of the distance from the threshold to the exit taxiway reduces the runway occupancy time by approximately 3/4 of a second for each airplane using the exit. Conversely, the runway occupancy time of each additional airplane now overrunning the new exit location is increased by approximately 3/4 of a second for each 100 feet (30 m) from the old location to the next available exit.

For example, the percent of airplanes exiting at or before an exit located 4,000 feet (1220 m) from the threshold are:

a. When the runway is wet, 100 percent of A, 80 percent of B, 1 percent of C, and 0 percent of D airplanes;

b. When the runway is dry and the exit is right angled, 100 percent of A, 98 percent of B, 8 percent of C, and 0 percent of D airplanes; and

c. When the runway is dry and the exit is acute angled, 100 percent of A, 98 percent of B, 26 percent of C, and 3 percent of D airplanes.

When selecting the location and type of exit both the wet and dry runway conditions along with a balance between increases and decreases in runway occupancy time should be considered.

Table A9-1. Exit taxiway cumulative utilization percentages

DISTANCE THRESHOLD TO EXIT	WET RUNWAYS				DRY RUNWAYS							
	RIGHT & ACUTE ANGLED EXITS				RIGHT ANGLED EXITS				ACUTE ANGLED EXITS			
	A	B	C	D	A	B	C	D	A	B	C	D
0 ft (0 m)	0	0	0	0	0	0	0	0	0	0	0	0
500 ft (152)	0	0	0	0	0	0	0	0	1	0	0	0
1000 ft (305 m)	4	0	0	0	6	0	0	0	13	0	0	0
1500 ft (457 m)	23	0	0	0	39	0	0	0	53	0	0	0
2000 ft (610 m)	60	0	0	0	84	1	0	0	90	1	0	0
2500 ft (762 m)	84	1	0	0	99	10	0	0	99	10	0	0
3000 ft (914 m)	96	10	0	0	100	39	0	0	100	40	0	0
3500 ft (1067 m)	99	41	0	0	100	81	2	0	100	82	9	0
4000 ft (1219 m)	100	80	1	0	100	98	8	0	100	98	26	3
4500 ft (1372 m)	100	97	4	0	100	100	24	2	100	100	51	19
5000 ft (1524 m)	100	100	12	0	100	100	49	9	100	100	76	55
5500 ft (1676 m)	100	100	27	0	100	100	75	24	100	100	92	81
6000 ft (1829 m)	100	100	48	10	100	100	92	71	100	100	98	95
6500 ft (1981 m)	100	100	71	35	100	100	98	90	100	100	100	99
7000 ft (2134 m)	100	100	88	64	100	100	100	98	100	100	100	100
7500 ft (2686 m)	100	100	97	84	100	100	100	100	100	100	100	100
8000 ft (2438 m)	100	100	100	93	100	100	100	100	100	100	100	100
8500 ft (2591 m)	100	100	100	99	100	100	100	100	100	100	100	100
9000 ft (2743 m)	100	100	100	100	100	100	100	100	100	100	100	100

A - Small, single engine 12,500 lbs (5 700 kg) or less
B - Small, twin engine 12,500 lbs (5 700 kg) or less
C - Large 12,500 lbs (5 700 kg) to 300,000 lbs (136 000 kg)
D - Heavy 300,000 lbs (136 000 kg)

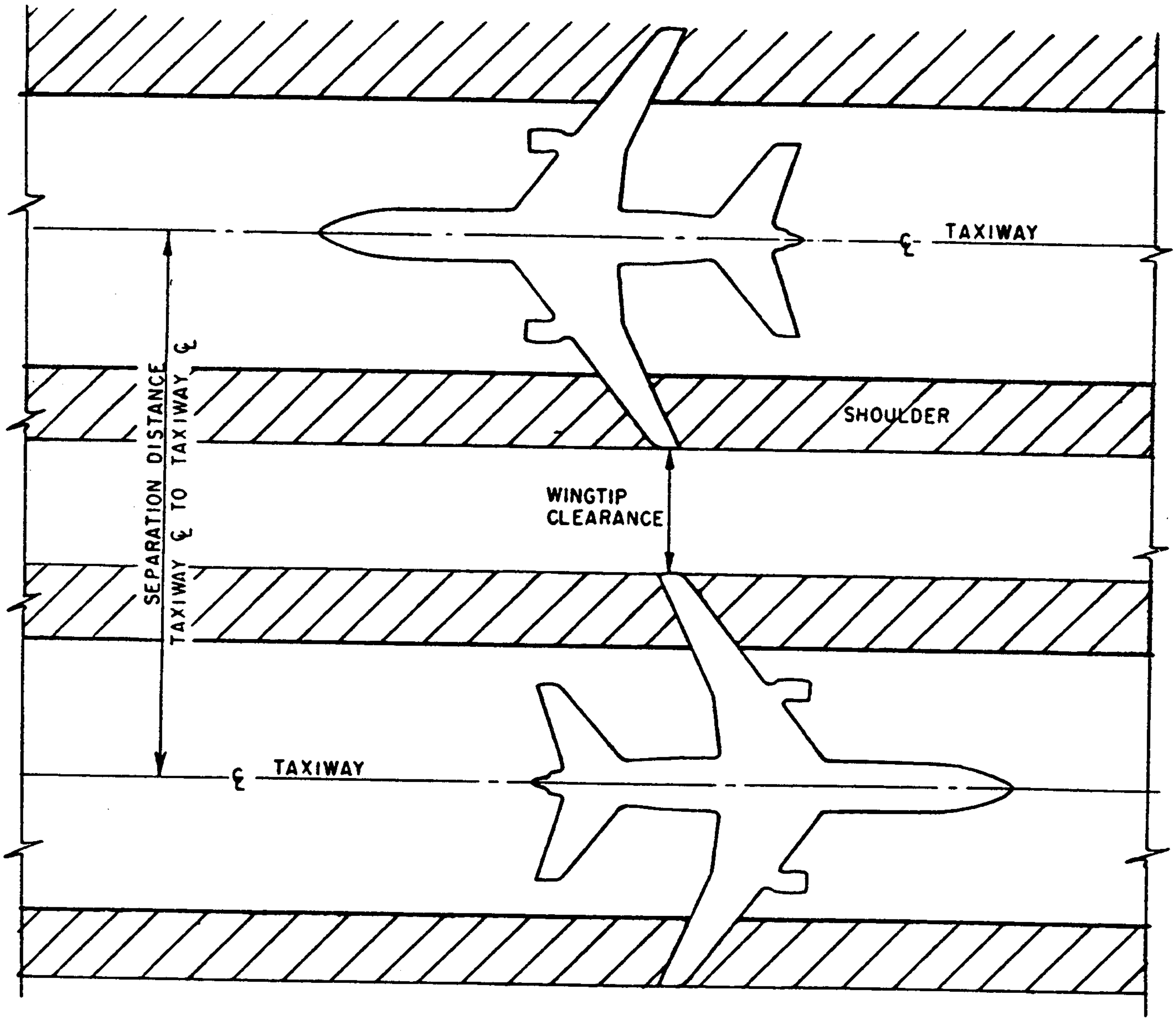

Figure A9-1. Wingtip clearance - parallel taxiways

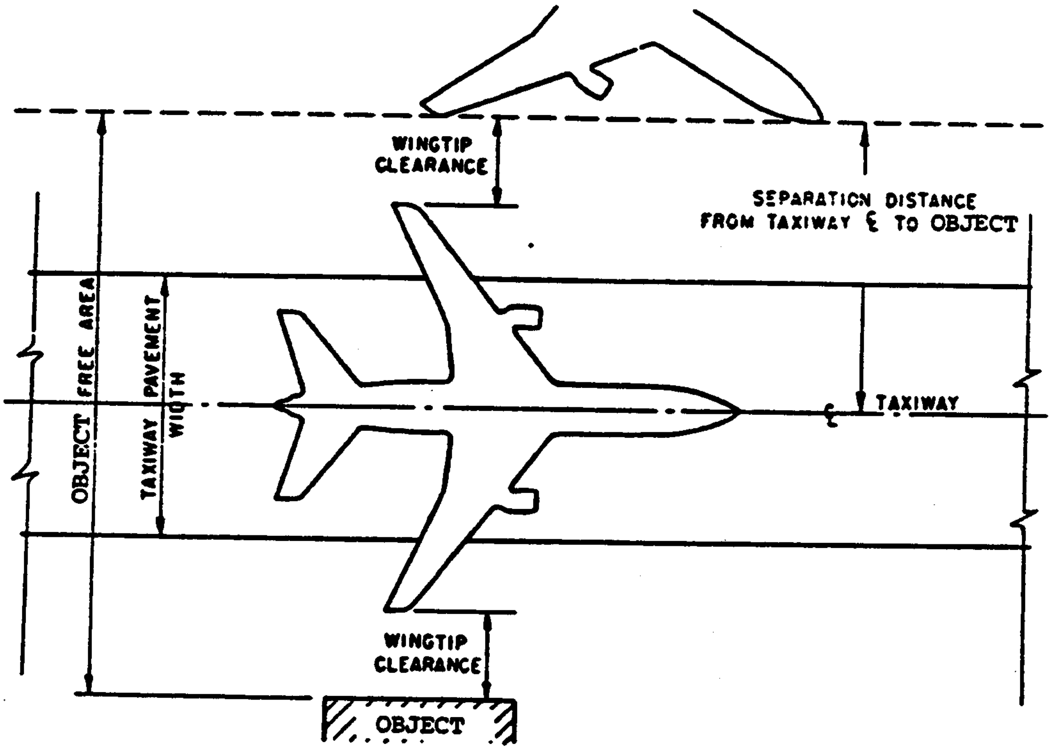

Figure A9-2. Wingtip clearance from taxiway

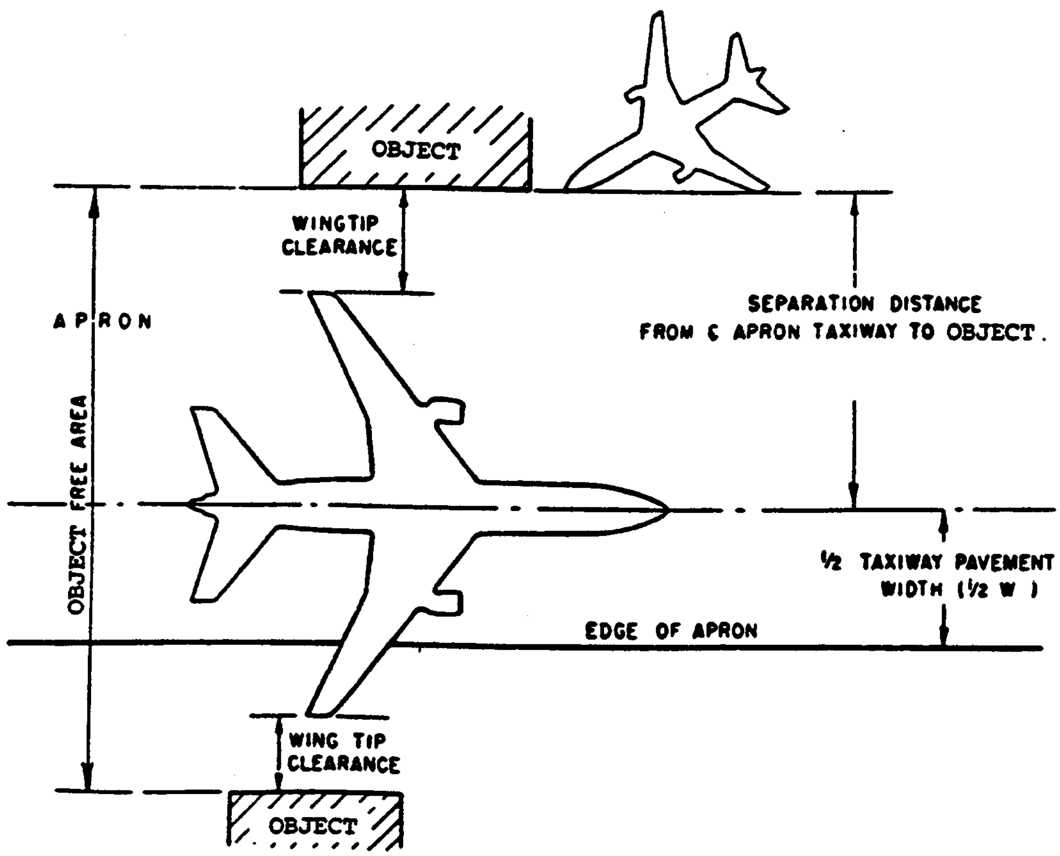

Figure A9-3. Wingtip clearance from apron taxiway

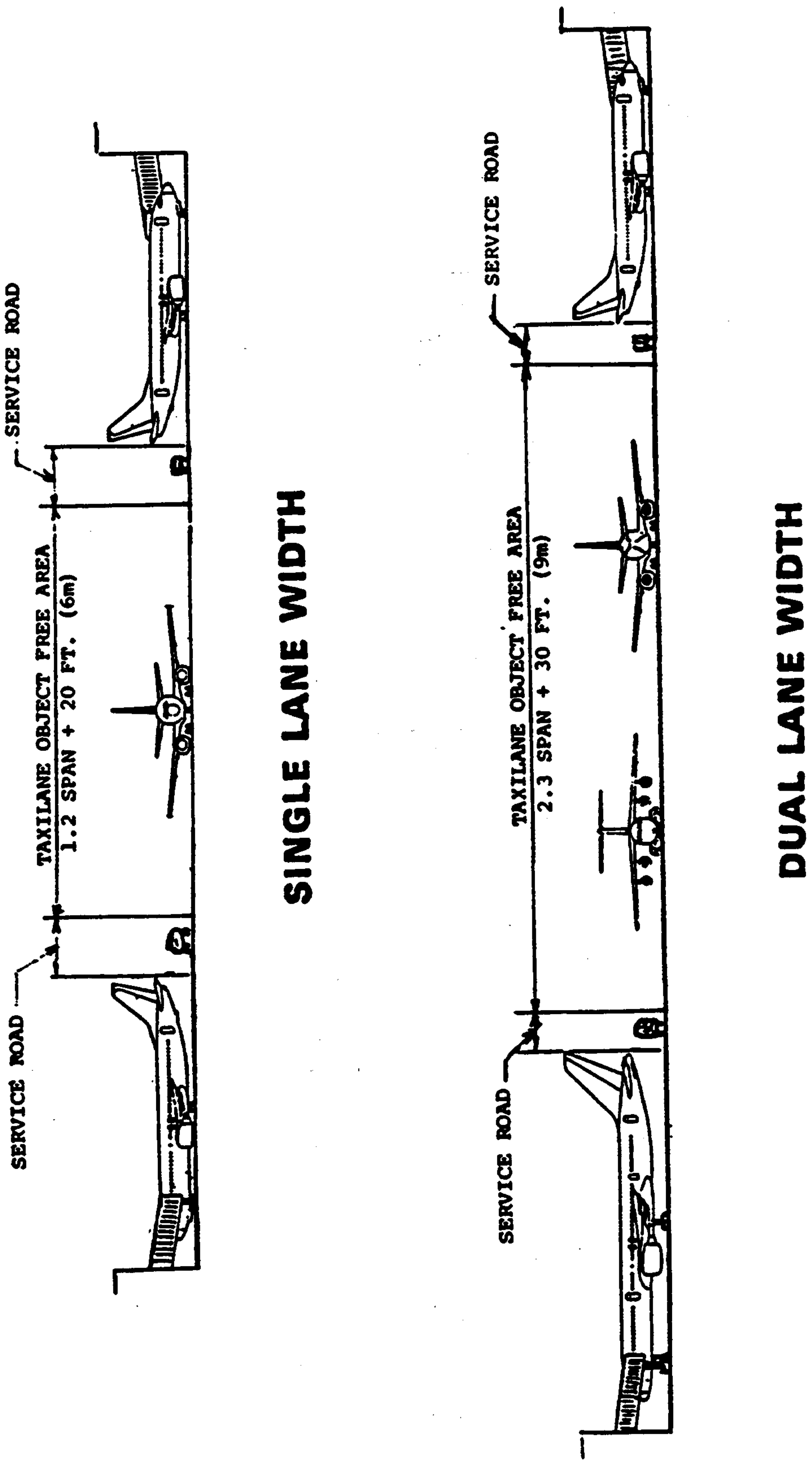

Figure A9-4. Wingtip clearance from taxilane

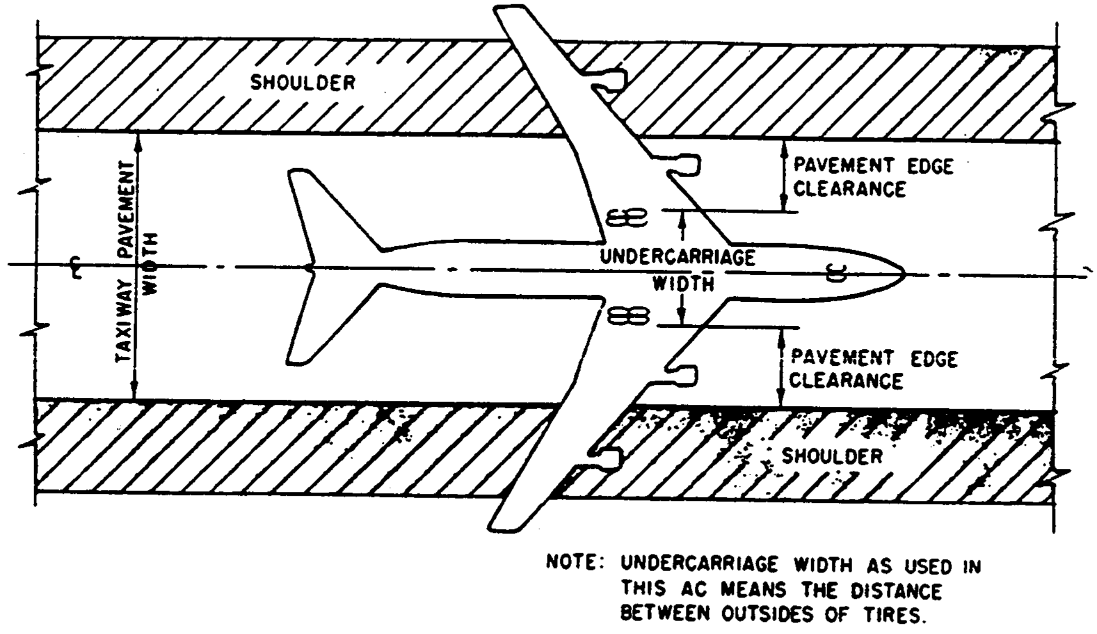

Figure A9-5. Pavement edge clearance on tangent

4. <u>WINGTIP TRACE</u>. The following equations calculate the rectangular coordinates of points on the wingtip trace.

$x = x_c - t \cos(A - B) \pm .5s \sin(A - B)$

$y = y_c + t \sin(A - B) \pm .5s \cos(A - B)$

x_c and y_c are the rectangular coordinates of a selected point on the centerline pavement markings. One centerline point is required for each trace point.

A is the angle formed by the tangent to the centerline pavement markings and the longitudinal axis of the airplane at the selected point. Appendix 10 provides instructions for obtaining this angle.

B is the angle direction of the centerline pavement markings at the select centerline point.

t is the longitudinal distance from the center of airplane cockpit to the airplane wingtip.

s is the airplane wingspan.

To obtain the wingtip clearance trace, add the wingtip clearance to the wingtip trace.

a. The airport design computer program described in appendix 11 provides the OFA clearance fillet requirement directly.

(1) Figure A9-6 depicts the McDonnell-Douglas MD-88 wingtip clearance traces for a 100-foot (30.5 m) radius of turn with centerline pavement markings.

(2) Figure A9-7 depicts the McDonnell-Douglas MD-88 wingtip clearance trace for a 100-foot (30.5 m) radius of turn with offset centerline pavement markings located on a 120-foot (30.5 m) radius arc.

(3) Figure A9-8 depicts the Boeing 727-200 wingtip clearance trace for a 100-foot (30.5 m) radius of turn with offset centerline pavement markings located on a 120-foot (30.5 m) radius arc.

(4) Figure A9-9 depicts the Boeing 727-100 wingtip clearance trace for a 100-foot (30.5 m) radius of turn with offset centerline pavement markings located on a 120-foot (30.5 m) radius arc.

b. The computer program treats the offset taxilane pavement markings arcs as five sections:

(1) A tangent section;

(2) A circular section comprised of a $\pm\cos^{-1}$(turn radius/offset radius) degree angle (same sign as the intersection angle) and a 0-foot radius;

(3) the offset arc (a circular section comprised of the intersection angle and the offset radius);

(4) A circular section comprised of a $\pm\cos^{-1}$(turn radius/offset radius) degree angle (apposite sign as the intersection angle) and a 0-foot radius; and

(5) A tangent section.

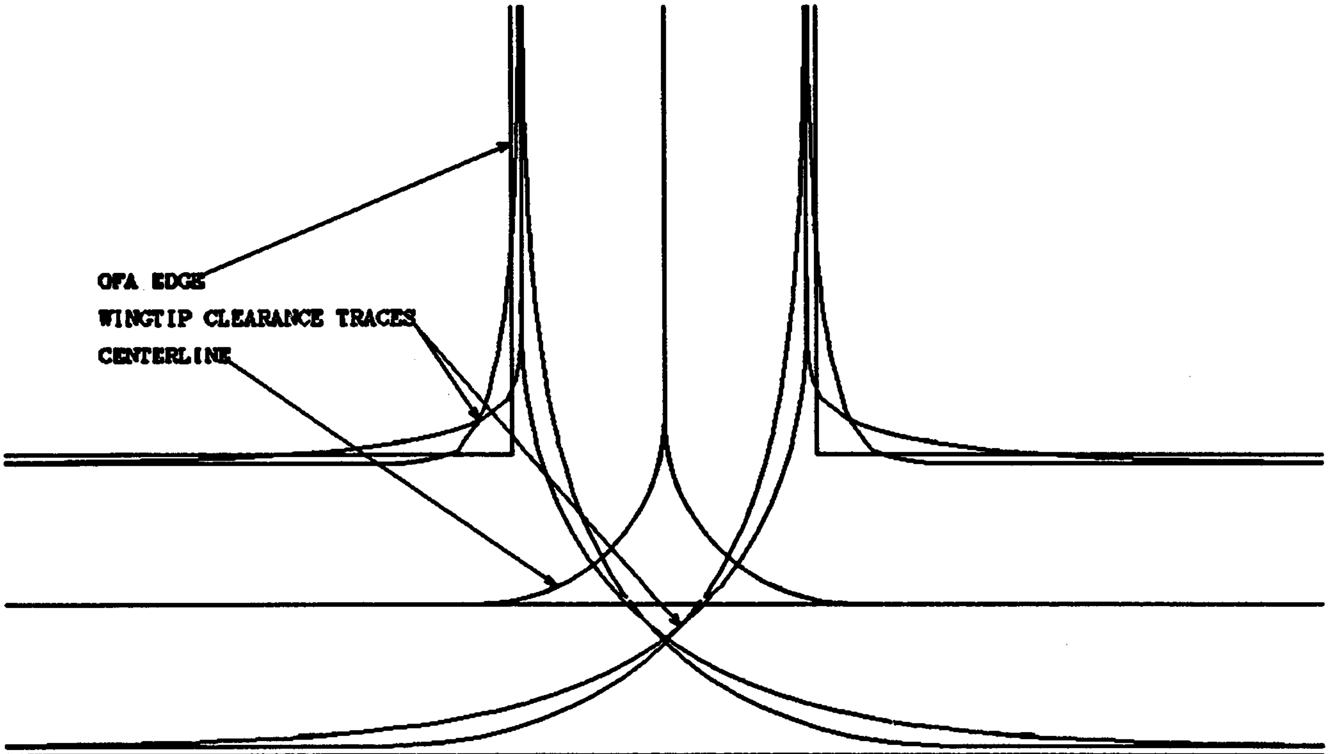

Figure A9-6. McDonnell-Douglas MD-88 wingtip clearance trace for a 100-foot (30.5 m) radius centerline

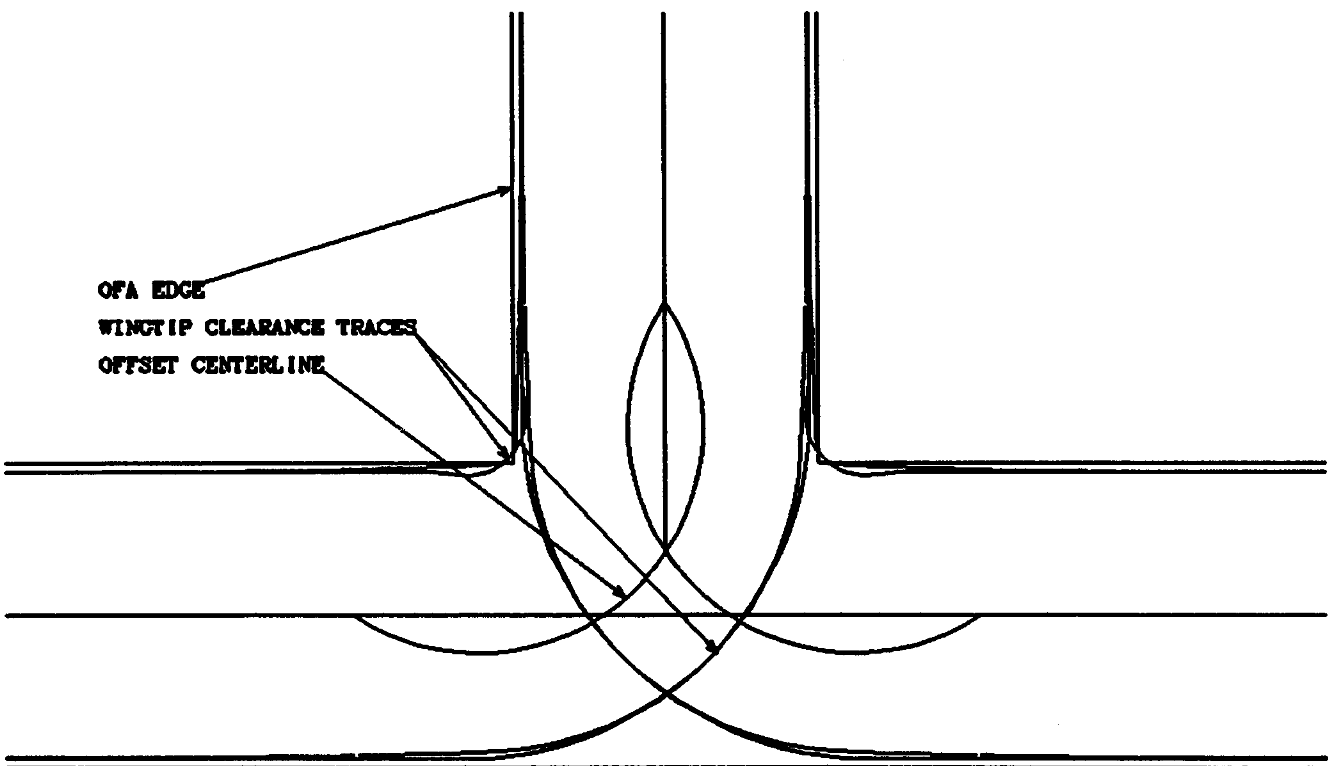

Figure A9-7. McDonnell-Douglas MD-88 wingtip clearance trace for a 120-foot (36.5 m) radius offset centerline

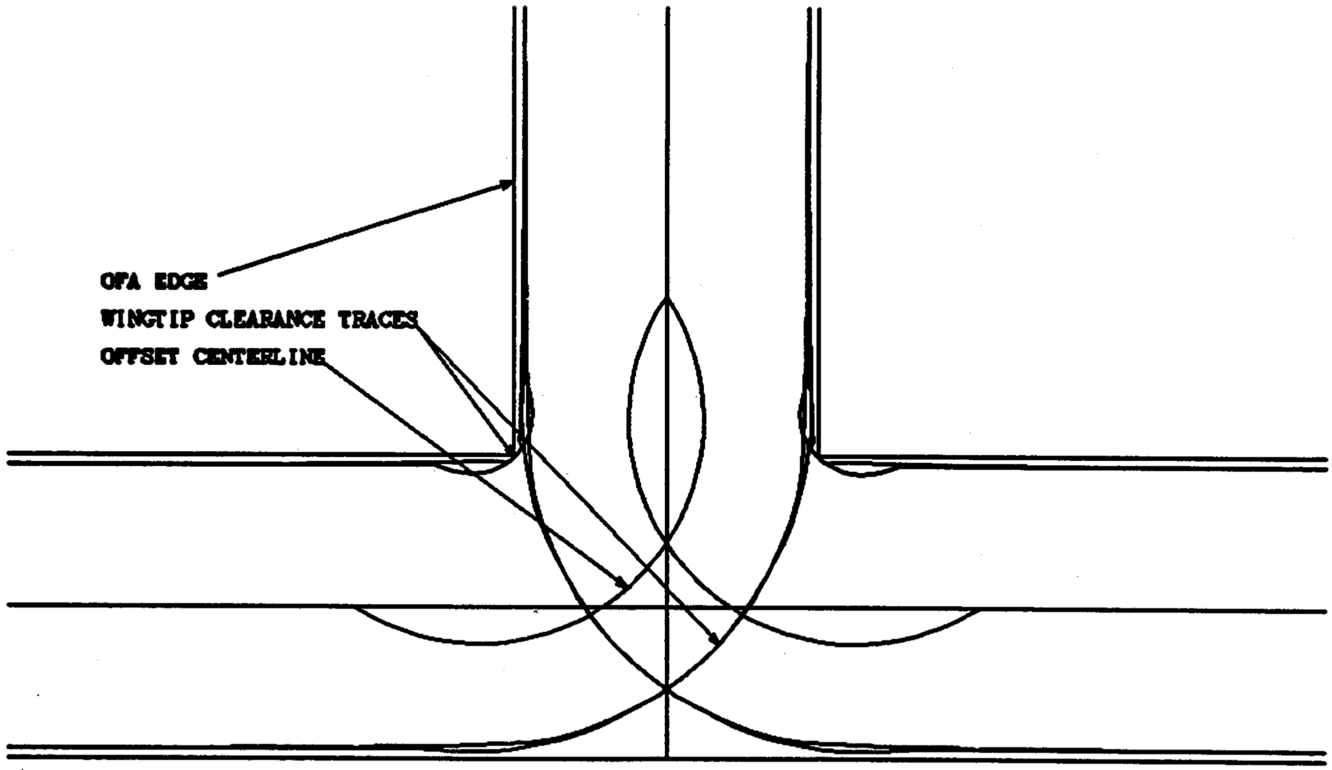

Figure A9-8. Boeing 727-200 wingtip clearance trace for a 120-foot (36.5 m) radius offset centerline

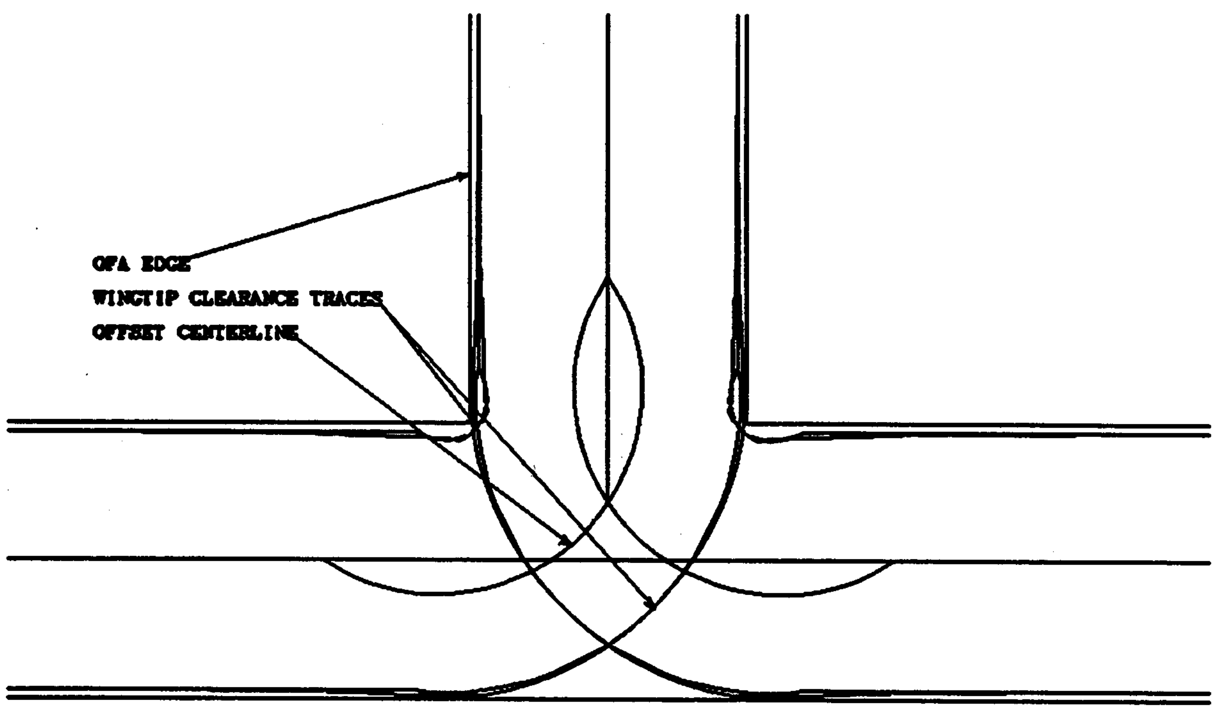

Figure A9-9. Boeing 727-100 wingtip clearance trace for a 120-foot (36.5 m) radius offset centerline

Appendix 10. TAXIWAY FILLET DESIGN

1. INTRODUCTION. This appendix details the methodology for the design of fillets for airport taxiways. This methodology is equally applicable for either the judgmental oversteering and the maintaining cockpit over centerline method of fillet design. The computer program cited in Appendix 11 computes these fillet dimensions for the maintaining cockpit over centerline method of fillet design. Figures A10-1 and A10-2 illustrate the terms and symbols used in the following equations:

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 equal to 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 (0). 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.

(a) Widening on only one side:

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

(b) 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.

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

2. 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 Amax = 27.3 degrees (27.2 degrees)

Step 3 - Calculate Bmax = 32.2 degrees (32.6 degrees)

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

3. 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)

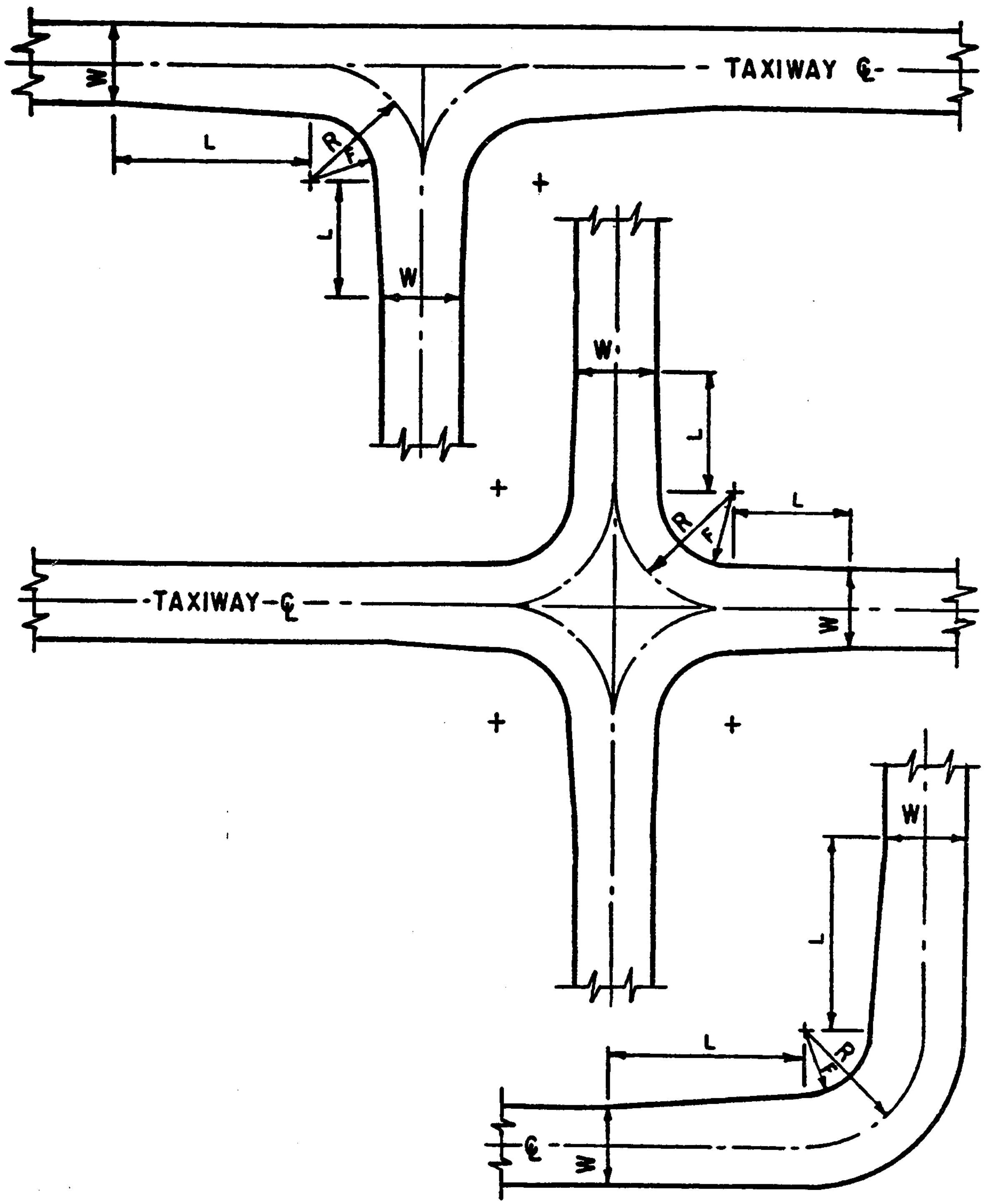

Figure A10-1. Taxiway intersection details

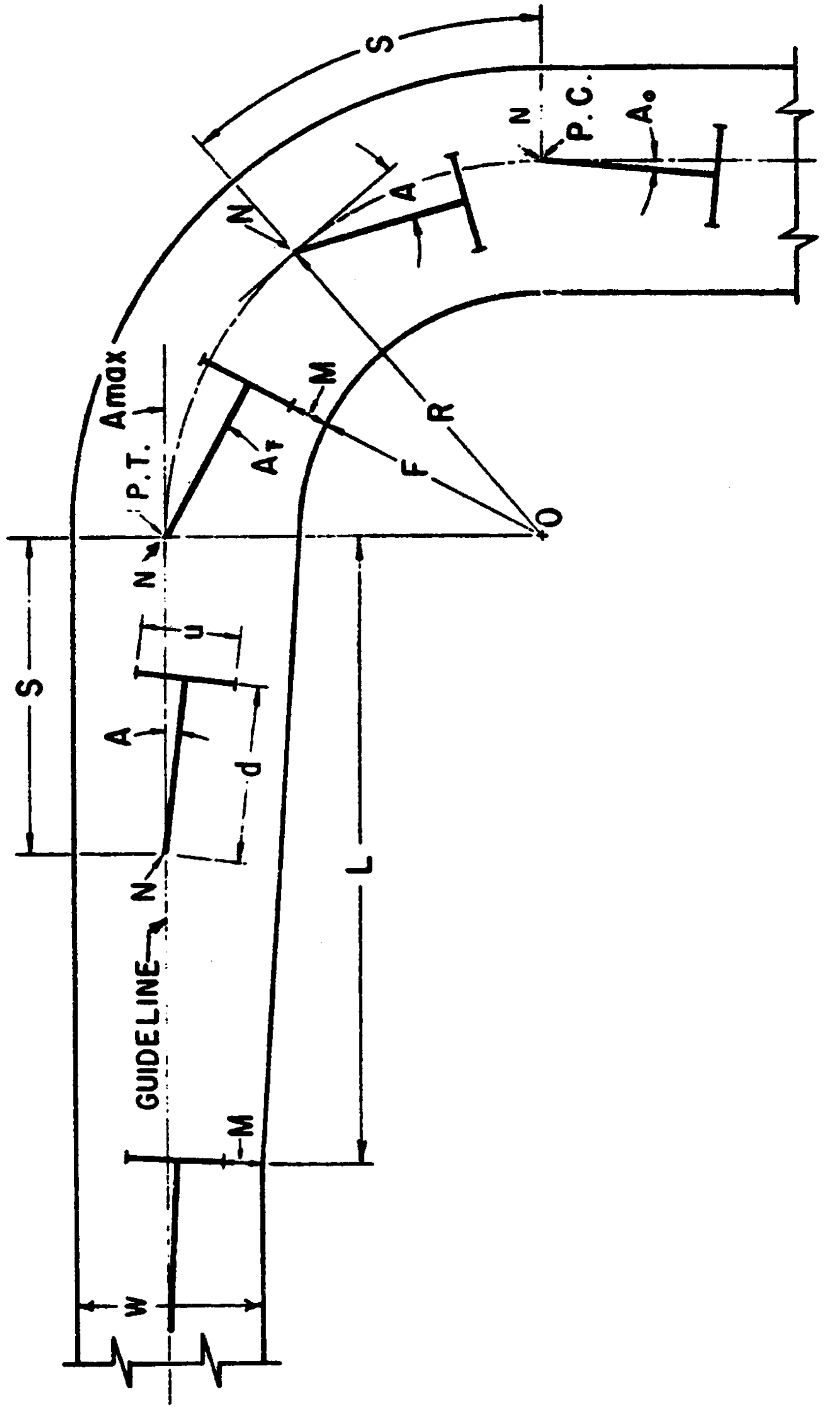

Figure A10-2. Depiction of symbols

Appendix 11. COMPUTER PROGRAM

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