Doc 9368
AN/911

Instrument Flight Procedures Construction Manual

Approved by the Secretary General
and published under his authority

Second Edition — 2002

International Civil Aviation Organization

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AMENDMENTS

The issue of amendments is announced regularly in the *ICAO Journal* and in the supplements to the *Catalogue of ICAO Publications and Audio-visual Training Aids*, which holders of this publication should consult. The space below is provided to keep a record of such amendments.

RECORD OF AMENDMENTS AND CORRIGENDA

AMENDMENTS					CORRIGENDA			
No.	Date applicable	Date entered	Entered by		No.	Date of issue	Date entered	Entered by

Table of Contents

Abbreviations

(used in this document)

AP	Autopilot		NDB	Non-directional radio beacon
Cat	Category		NM	Nautical mile
CRM	Collision risk model		non SI units	Non international system of units
DER	Departure end of the runway		OCA	Obstacle clearance altitude
DME	Distance measuring equipment		OCA/H	Obstacle clearance altitude/height
FAF	Final approach fix		OCH	Obstacle clearance height
FAP	Final approach point		OM	Outer marker
FD	Flight director		PANS-OPS	*Procedures for Air Navigation Services*
GP	Glide path			*— Aircraft Operations* (Doc 8168)
GS	Ground speed		PDG	Procedure design gradient
IAF	Initial approach fix		RSS	Root sum square
IAS	Indicated airspeed		RWY	Runway
IF	Intermediate approach fix		SI units	International system of units
ILS	Instrument landing system		SOC	Start of climb
km	Kilometre		SRE	Surveillance radar element
kt	Knots		TAS	True airspeed
LLZ	Localizer		THR	Threshold
MAPt	Missed approach point		TNA/H	Turn altitude/height
MHz	Megahertz		TP	Turning point
MM	Middle marker		UTM	Universal transverse mercator
MOC	Minimum obstacle clearance (required)		VOR	Very high frequency (VHF)
MSA	Minimum sector altitude			omnidirectional radio range
MSL	Mean sea level			

INSTRUMENT FLIGHT PROCEDURES
CONSTRUCTION MANUAL

PART I

GENERAL

Chapter 1

Introduction

1.1   The purpose of this manual is to assist in the implementation of the procedures defined in the *Procedures for Air Navigation Services — Aircraft Operations* (PANS-OPS, Doc 8168). It does this by breaking down each major procedure into a series of simple, easily understood steps, using examples to illustrate the main types of procedure. Some useful methods of simplifying mathematical aspects of procedure design are included in Attachment B2 to this manual, together with an illustration of the use of the collision risk model (CRM) in Attachment B5. Attachment B3 amplifies some items that are likely to be encountered in the procedure design. Attachment C1 illustrates methods of accounting for charting inaccuracies and includes one State's directive and codification system.

1.2   Three main principles apply to the design of all instrument approach procedures: they should be safe; they should be simple; they should be economic of both time and airspace. Safety is based on common sense and sound operational judgement. Simple procedures are essential at a time when pilot workload is high and the consequence of error can be fatal. Economic procedures are increasingly necessary — flight time is money and airspace is often in short supply.

1.3   It is recommended that both the plan view and the vertical profile of all procedures be accurately plotted on appropriate maps and graph paper. This forms a control that can reveal any significant error in calculation or obstacle location. In many cases the entire procedure can be devised by accurate plotting and with very little calculation.

1.4   It is recommended that worksheets used to record calculations be preserved for future work. Worksheets will speed up the design process, reduce errors and facilitate standardization, review and training.

1.5   It is recommended that the same units (SI units or non-SI units) be used throughout the design of a procedure (i.e. if all survey data or maps are metric, conversion to non-SI units should be the last step before rounding in procedure design). Where possible, this guide presents essential design information in both units.

1.6   The following conversion factors are used frequently throughout this document:

metres to feet:	multiply metres by 3.2808
feet to metres:	multiply feet by 0.3048
	(or divide by 3.2808)
NM to km:	multiply NM by 1.852
km to NM:	multiply km by 0.54
	(or divide by 1.852)

Chapter 2

Preparation for Procedure Design

2.1   INTRODUCTION

This chapter outlines the steps necessary before the process of procedure design can begin. Adequate preparation along the lines suggested should both simplify and speed up the task.

2.2   EQUIPMENT

The following equipment should be available:

a) rulers (various scales), protractors, compasses, flexible curves, etc.;

b) maps of appropriate scales;

c) a calculator with scientific functions and one or more memory function. Where a number of repetitive calculations are to be performed, a programmable calculator can be helpful; and

d) precalculated templates and tables of dimensions for the procedures to be designed (see 2.3).

2.3   PREPARATORY CALCULATIONS

2.3.1   The PANS-OPS caters to a wide variety of conditions in each segment of instrument procedures — departure as well as approach and missed approach. In States where many instrument procedures have to be designed, it is advisable to simplify procedure design by precalculating certain critical dimensions, area parameters and templates. These can then be used directly in most procedures, eliminating tedious and repetitive calculations.

Precalculated tables of dimensions and tolerances

2.3.2   The use of precalculated tables of dimensions/ tolerances is made possible because most of the departure,

final approach and missed approach area dimensions (MAPt, distance to SOC turn area dimensions, etc.) depend only on aerodrome elevation (IAS and wind speed are already defined and fixed). Fortunately, the variation of these dimensions with aerodrome elevation is relatively small. Thus, if the dimensions are calculated to cover a range of aerodrome elevations from, say, 0 to 3 000 ft, any "penalty" introduced is negligible. If the actual range of aerodrome elevations exceeds this, the aerodromes may be divided into two groups and separate sets of dimensions calculated; alternatively, one set (with slightly larger values) can be prepared to cover the extended range of aerodrome elevations.

Pre-calculated area transparencies

2.3.3   The following precalculated areas drawn on transparencies to map scale may be useful:

— intermediate approach within a reversal/racetrack area;

— final approach for off-aerodrome VOR or NDB;

— final approach/missed approach for on-aerodrome VOR or NDB;

— basic ILS surfaces; and

— departure.

Holding/racetrack/reversal procedure templates

2.3.4   Patterns for the areas required are published in the *Template Manual for Holding, Reversal and Racetrack Procedures* (Doc 9371). It should be noted that they are not templates for the whole area — this is obtained by locating such a template over the vertices of the associated fix tolerance area and tracing a composite boundary. In addition, the entry area (for racetracks and holdings)

requires further re-orientation of the TTT template and tracing to complete the entry areas. Precise instructions for use of the TTT templates are contained in Attachment B1, which should be studied closely.

Note 1.— It is always safe to use a template for an altitude higher than the minimum altitude specified for the procedure.

Note 2.— Simplified, rectangular areas may be calculated for any desired outbound time, TAS and wind speed, using the equations contained in Attachment B1, 3.5.

2.4   MAPS

Scales

2.4.1   It is necessary to select maps with scales appropriate to the procedure segment being designed. Suitable scales are:

— 1:1 000 000 and 1:500 000 for initial location of facilities in relation to airways and calculation of minimum sector altitudes;

— 1:250 000 for confirmation of minimum sector altitudes, plotting of standard arrival routes, racetrack and reversal areas, initial/intermediate areas and missed approach;

— 1:100 000 and 1:50 000 for detail checks within racetrack and reversal areas or intermediate areas, final approach area, detail checks in missed approach area; and

— 1:25 000 and 1:10 000 for check of the ILS precision segment and preparation of obstacle data for collision risk model (CRM).

Conversion between coordinate systems

2.4.2   In the design of procedures it is sometimes necessary to convert positions from one coordinate system to another. The most common conversions required are latitude/longitude to Universal Transverse Mercator (UTM) or national grid, and the inverse; and UTM or national grid to runway coordinates (x, y and z relative to threshold and final approach track).

2.4.3   For many purposes, conversions between latitude/longitude and UTM/national grid may be made by plotting, provided the appropriate scales are overprinted on the maps used. Where interpolation errors reduce accuracy, however, and in all cases where latitude/longitude is to be displayed on an arrival or approach chart, an accurate method must be used. Such methods are outside the scope of this manual and designers are referred to standard navigational texts (see the references at the end of this chapter). Note that on both arrival and approach charts latitude/longitude must be presented in degrees/minutes/seconds.

2.4.4   Conversion from UTM or national grid to runway x, y, z coordinates may be achieved by plotting, however, for precision procedures where survey data may be supplied in grid coordinates (or for convenience in calculating other procedures), an accurate calculation routine is included in Attachment B2 (Calculation Routine 4).

2.4.5   In 1989, the ICAO Council adopted the World Geodetic System — 1984 (WGS-84) as the standard geodetic reference system for international civil aviation. The publication of geographical coordinates shall be referenced to WGS-84 in aeronautical information publications (AIPs) and on aeronautical charts. It should be noted that the conversion to WGS-84 will not affect the standard routines of converting from one coordinate system to another as referred to in 2.4.2, 2.4.3 and 2.4.4 above. The only change will be to the actual numbers which make up the geographical coordinates (e.g. 050735N 0652542W may change to 050746N 0652533W).

2.5   OBSTACLE SURVEY

2.5.1   Most survey methods are based upon simple measurements of horizontal and vertical angles and distances, using triangulation to relate obstacle heights and locations to either a runway coordinate system or a grid system. A possible alternative is the use of photogrammetric methods, where heights and coordinates are measured by machine from aerial photographs. Whichever method is used, two principles are relevant:

a) all obstacles should be accounted for. This is relevant when using data from existing maps, since maps are frequently out of date by the time they are printed and many items (i.e. trees, heights of tall buildings) are not portrayed. Such items must be accounted for either by physical examination of the

site or by the addition of a suitable margin above the terrain contours; and

b) the accuracy of the vertical and horizontal data obtained (and hence the cost of the survey) may be adjusted by adding an amount equal to the specified survey error to the height of all measured obstructions and by making a corresponding adjustment for specified horizontal error.

Chapters 11 to 13 of Part II, Section 2 and Attachment B7 contain specific examples that account for charting tolerances. Attachment C1 includes one State's directives concerning chart tolerances and their application to procedure design. Detailed guidance on surveys is contained in the *Airport Services Manual* (Doc 9137), Part 6 — *Control of Obstacles* and in Annex 4 — *Aeronautical Charts*, Chapters 3, 4 and 5.

2.6   REFERENCES

Jackson, J.E. *Transverse Mercator Projection*. Survey Review XXIV, 188, April 1978.

Jordan-Eggert-Kneissl. *Handbuch der Vermessungskunde*, 10. Ausgabe. Band IV, zweite Halfte: Die geodatischen Berechnungen auf der Kugel und auf dem Ellipsoid.

Mailing, D.H. *Coordinate Systems and Map Projections*. London: George Philip and Son, 1973.

Richardus, P. and Adler, K. *Map Projections for Geodesists, Cartographers and Geographers*. London: North-Holland Publishing Company, Amsterdam, 1972.

U.S. Coast and Geodetic Survey, Special Publications.

INSTRUMENT FLIGHT PROCEDURES
CONSTRUCTION MANUAL

PART II

CONVENTIONAL PROCEDURES

**INSTRUMENT FLIGHT PROCEDURES
CONSTRUCTION MANUAL**

SECTION 1

DEPARTURE PROCEDURES

Chapter 1
Straight Departure

INTRODUCTION

Three straight departure areas are discussed along with the method of calculating the PDG (procedure design gradient) necessary to overfly the obstacles. They are:

— a straight departure along the extended runway centre line;

— a straight departure with track adjustment ≤15°; and

— a departure with a specified procedure design gradient to a height after which the normal climb gradient of 3.3 per cent will clear the remaining obstacles.

CASE 1.   STRAIGHT DEPARTURE ALONG THE RUNWAY CENTRE LINE
(See Figure II-1-1-1)

Two obstacles exist (both have been surveyed to accuracy code 2C or better) (see Attachment C1):

O_1 height 40 m (131 ft), on runway centre line, 2 km (1.08 NM) from DER.

O_2 height 250 m (820 ft), right of RWY centre line 1 325 m (4 347 ft), 5 500 m (2.97 NM) from DER.

STEP 1

Determine if obstacles are within the departure area
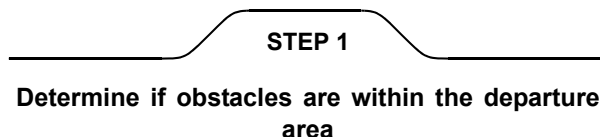
O_1 is on centre line and within the area.
O_2 is within the area.

Departure area ½W at O_2 = 150 + 5 500 tan 15° = 1 623.7 m (5 327 ft).

STEP 2

Determine OIS height at each obstacle

O_1 is below the OIS; OIS height = 5 + (2 000 × 0.025) = 55 m (180 ft).
O_2 penetrates the OIS; OIS height = 5 + (5 500 × 0.025) = 143 m (469 ft) (see Figure II-1-1-1).

STEP 3

Determine the PDG necessary to overfly O_2 with the MOC
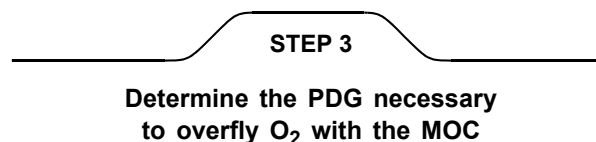
MOC at O_2 = 5 500 × 0.008 = 44 m (144 ft).
The RH (required height) at O_2 = O_2 height + MOC = 250 + 44 = 294 m (964 ft).

The PDG = $\dfrac{294 - 5}{5\ 500}$ = 0.0525 (5.3 per cent)

DEPARTURE PUBLICATION

A PDG of 5.3 per cent is required to a height (altitude) of 294 m (965 ft) to avoid a 250 m (820 ft) television tower bearing 14° right, 5 500 m (2.97 NM) from DER ...

CASE 2.   TRACK ADJUSTMENT TO AVOID OBSTACLE O_2
(See Figures II-1-1-2 and II-1-1-3)

STEP 1

Quick look to determine feasibility of track adjustment
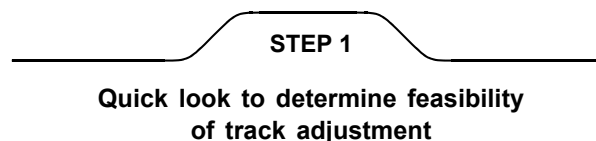
If O_2 is displaced from the runway centre line farther than the area one ½W (half width), a 15° track adjustment *is* feasible.

Area one $\frac{1}{2}W = 150 + 3\,500 \times \tan 15° = 1\,087.8$ m (3 569 ft).

Since O_2 is 1 325 m (4 347 ft) from the centre line, a track angle adjustment is feasible.

Note that the adjusted departure area accommodates a 15° track adjustment as early as the DER and as late as the end of Area 1 (see Figure II-1-1-2).

STEP 2

Determine the minimum track adjustment angle

In Step 1 a 15° track adjustment angle clearly avoids O_2. This calculation is simple because of the coincidence of the 15° splay of the area and the 15° permitted track adjustment angle.

Now the task is to reduce the track adjustment angle. The 15° angle can be reduced by the amount:

Minimum track adjustment angle =

$$15° - \tan^{-1}\frac{1\,325 - 1\,088}{5\,500 - 3\,500} = 15 - 6.75 = 8.24°$$

A track adjustment of 9° will avoid O_2 using a normal climb (see Figure II-1-1-3).

DEPARTURE PUBLICATION

After take-off **TURN LEFT 9° ...**

CASE 3.   CLIMB TO A HEIGHT AFTER WHICH A NORMAL CLIMB WILL PROVIDE THE MINIMUM OBSTACLE CLEARANCE
(See Figure II-1-1-4)

When several obstacles penetrate the OIS and no alternative track is possible to avoid them, the task is to specify *one* procedure design gradient (PDG) which can be used to a height (altitude) after which the normal climb (3.3 per cent) will provide the minimum obstacle clearance (MOC) over the remaining obstacles.

In this example, two obstacles penetrate the OIS (both are on the centre line and both have been surveyed to accuracy code 2C or better).

O_1 height 150 m (492 ft), 2 km (1.08 NM) from the DER
O_2 height 350 m (1 148 ft), 9 km (4.86 NM) from the DER

STEP 1

Determine the steepest PDG, considering the gradients, to reach the required height at both obstacles

Required height at $O_1 = 150 + (2\,000 \times 0.008)$ = 166 m (544 ft).

Required height at $O_2 = 350 + (9\,000 \times 0.008)$ = 422 m (1 384 ft).

$$\text{Gradient } O_1 = \frac{166 - 5}{2\,000} = 0.0805 \text{ (8.1 per cent)}$$

Gradient $O_2 = 0.46333$ (4.7 per cent)

PDG = 8.1 per cent.

Note.— It will be interesting to observe that the obstacle controlling the PDG can also be determined by comparing the gradient to the top *of each obstacle (see the worksheet below).*

STEP 2

Determine the height (altitude) to which the 8.1 per cent PDG is to be used to ensure that the normal 3.3 per cent gradient will clear obstacle O_2. (See Figure II-1-1-5)

The general method is to define the intersection of two lines that represent the climb profiles.

Line 1 is the PDG that originates 5 m (16 ft) above the DER.

Line 2 is the normal climb 3.3 per cent gradient that clears O_2 at the required height (obstacle height + MOC).

The formula for a sloping line is $z = sd + c$.

where: c = height at the origin (DER)
         d = distance from origin (DER)
         s = slope of the line (tan of the vertical angle)
         z = height at distance "d".

The formula for PDG 8.1 per cent gradient (line 1): $z = 0.081d + 5$.
The formula for normal 3.3 per cent gradient (line 2): $z = 0.033d + c$.

To be able to find the point where both lines intersect ($z = z$), a value for c in the formula for the normal climb must be found.

The normal climb gradient at O_2 must be at the required height of 422 m (1 384 ft) which is 9 km (4.86 NM) from DER ($z = 422$ m and $d = 9\ 000$ m).

Substitute $z = 422$ and $d = 9\ 000$ in the line 2 formula and find c.

$c = 422 - (0.033 \times 9\ 000)$; $c = 125$ m (410 ft)

The formula for line 2 (normal climb) is $z = 0.033d + 125$

The two formulae are: $z = 0.081d + 5$
$z = 0.033d + 125$

At the intersection of the two sloping lines $z = z$ and $d = d$.

Since $z = z$; $0.081d + 5 = 0.033d + 125$

Solve for d:

$0.081d - 0.033d = 125 - 5$
$0.048d = 120$
$d = 2\ 500$ m (8 202 ft)

The height at d is: $5 + 2\ 500 \times 0.081 = 207.5$ m (681 ft)

Consequently, a climb to an altitude at least 207.5 m (681 ft) above DER will provide the MOC at the obstacle O_2 .

A more direct solution is to realize that the climb profile can be defined as the PDG from 5 m (16 ft) at DER to a height h at a distance d and thereafter climbing normally at a 3.3 per cent gradient to the required height (RH) at the next obstacle, or:

$$RH_2 = 5 + d_{PDG} \times PDG + (d_{o2} - d_{PDG}) \times 0.033$$

$\uparrow$

Translated to find d_{PDG}; the distance the PDG must prevail

$\downarrow$

$$d_{PDG} = \frac{R0H_2 - 5 - 0.033 \times d_{0_2}}{PDG - 0.033}$$

Then the height (h) to climb at PDG is found with:

$$h = 5 + PDG \times d_{PDG}$$

DEPARTURE OBSTACLE ANALYSIS AND FORMULAE

Assign reference numbers to all obstacles beginning at DER (e.g. O_1, O_2 , O_3) (see Table II-1-1-1).

Determine if any obstacles penetrate the OIS. When obstacles penetrate the OIS, the obstacle with the steepest gradient will control the procedure design gradient (PDG) steeper than the normal 3.3 per cent gradient.

Table II-1-1-1.   Worksheet for departure obstacle analysis with formulae

No.	d_o* m (ft)	O_{ht}** above DER m (ft)	1 Gradient to obstacle top	2 MOC m (ft)	RH O_{ht} + MOC m (ft)	3 PDG	PDG rounded	4 d_{PDG} m (ft)	5 Ht_{min}

*   Obstacle distance (d_o) should be reduced by the horizontal chart accuracy margin.
** Obstacle height should include vertical margin for chart accuracy.

1.   Gradient = $(O_{ht} - 5)/d_o$, m; $(O_{ht} - 16)/d_o$, ft

2.   MOC = $0.008 \times d_o$

3.   PDG = $(RH - 5)/d_o$, m; $(RH - 16)/d_o$, ft

4. $d_{PDG} = \dfrac{RH - 5 \text{ m (16 ft)} - 0.33 \text{ d}}{PDG - 0.033}$

5. $Ht_{min} = 5$ m (16 ft) $+ d_{PDG} \times$ PDG (rounded)

Where: O_{ht} = obstacle height
$\quad\quad\quad\;\;$ d_o = obstacle distance
$\quad\quad\quad\;\;$ RH = required height
$\quad\quad\quad\;\;$ d_{PDG} = distance where PDG is applied
$\quad\quad\quad\;\;$ Ht_{min} = minimum height to which the PDG must prevail.

STEP 1

Calculate the gradient to each obstacle to see if the OIS is penetrated.
(See Table II-1-1-2 and Figure II-1-1-6)

Gradient = $(O_{ht} - 5)/d_o$ m, $(O_{ht} - 16)/d_o$ ft.

If the gradient is ≤0.025 for all obstacles, the OIS is clean and the job is finished.

If the OIS is penetrated, find CO_{stp} (controlling obstacle with steepest gradient).

STEP 2

Calculate the MOC for each obstacle penetrating the OIS. Start with CO_{stp}. (See Table II-1-1-3)

MOC = $0.008 \times d_o$

and then find the required height (RH) at each obstacle.

Table II-1-1-2. Worksheet for Step 1

No.	d_o m (ft)	O_{ht} above DER m (ft)	1 Gradient to obstacle top	2 MOC m (ft)	RH O_{ht} + MOC m (ft)	3 PDG	PDG rounded	4 d_{PDG} m (ft)	5 Ht_{min}
O_1	1 100 (3 609)	30 (98)	0.0227						
O_2*	2 475 (8 120)	105 (345)	0.0404*						
O_3	3 950 (12 959)	140 (559)	0.0342						
O_4	6 000 (19 685)	210 (689)	0.0342						
O_5	8 950 (29 363)	290 (951)	0.0318						

*CO_{stp}

Table II-1-1-3. Worksheet for Step 2

No.	d_o m (ft)	O_{ht} above DER m (ft)	1 Gradient to obstacle top	2 MOC m (ft)	RH O_{ht} + MOC m (ft)	3 PDG	PDG rounded	4 d_{PDG} m (ft)	5 Ht_{min}
O_1	1 100 (3 609)	30 (98)	0.0227	—	—				
O_2*	2 475 (8 120)	105 (345)	0.0404	20 (66)	125 (410)				
O_3	3 950 (12 959)	140 (559)	0.0342	31.6 (104)	172 (564)				
O_4	6 000 (19 685)	210 (689)	0.0342	48 (158)	258 (846)				
O_5	8 950 (29 363)	290 (951)	0.0318	71.6 (235)	362 (1 188)				

*CO_{stp}

STEP 3

Calculate PDG for CO_{stp}. (See Table II-1-1-4)

$PDG = (RH - 5)/d_o$

STEP 4

**Calculate d_{PDG} (the distance required for the PDG to be continued in order that all obstacles past CO_{stp} can be cleared with the normal 3.3 per cent climb gradient).
(See Figure II-1-1-7 and Table II-1-1-5)**

$$d_{PDG} = \frac{RH - 5 - 0.033\ d}{PDG - 0.033}$$

(RH and d are the required height and distance from DER

of each obstacle beyond the CO_{stp} and the PDG is the rounded value of the highest PDG, since it will be published in the procedure.)

STEP 5

The final question — to find the minimum height Ht_{min} at which the normal gradient of 3.3 per cent can be resumed — is simply a matter of finding the maximum d_{PDG} and multiplying it by PDG (rounded). (See Table II-1-1-5)

$Ht_{min} = 5\ m + d_{PDG} \times PDG$ (rounded).

For O_5; $Ht_{min} = 5\ m + 3\ 853 \times 0.049 = 194\ m$ (636 ft rounded up to a useful altitude).

Departure note: Climb 4.9 per cent to 640 ft (height) ...

Table II-1-1-4.   Worksheet for Step 3

No.	d_o m (ft)	O_{ht} above DER m (ft)	1 Gradient to obstacle top	2 MOC m (ft)	RH O_{ht} + MOC m (ft)	3 PDG	PDG rounded	4 d_{PDG} m (ft)	5 Ht_{min}
O_1	1 100 (3 609)	30 (98)	0.0227	—	—	—	—		
O_2*	2 475 (8 120)	105 (345)	0.0404	20 (66)	125 (240)	0.0485	0.049*		
O_3	3 950 (12 959)	140 (559)	0.0342	31.6 (104)	172 (564)	—	—		
O_4	6 000 (19 685)	210 (689)	0.0342	48 (158)	258 (846)	—	—		
O_5	8 950 (29 363)	290 (951)	0.0318	71.6 (235)	362 (1 188)	—	—		

*CO_{stp}

Table II-1-1-5.   Worksheet for Steps 4 and 5

No.	d_o m (ft)	O_{ht} above DER m (ft)	1 Gradient to obstacle top	2 MOC m (ft)	RH O_{ht} + MOC m (ft)	3 PDG	PDG rounded	4 d_{PDG} m (ft)	5 Ht_{min}
O_1	1 100 (3 609)	30 (98)	0.0227	—	—	—	—		
O_2	2 475 (8 120)	105 (345)	0.0404	20 (66)	125	0.0485	0.049	2 395 (7 858)	
O_3	3 950 (12 959)	140 (559)	0.0342	31.6 (104)	172	—	—	2 291 (7 516)	
O_4	6 000 (19 685)	210 (689)	0.0342	48 (158)	258	—	—	3 438 (11 279)	
O_5	8 950 (29 363)	290 (951)	0.0318	71.6 (235)	362	—	—	3 853 (12 641)	194 (636)
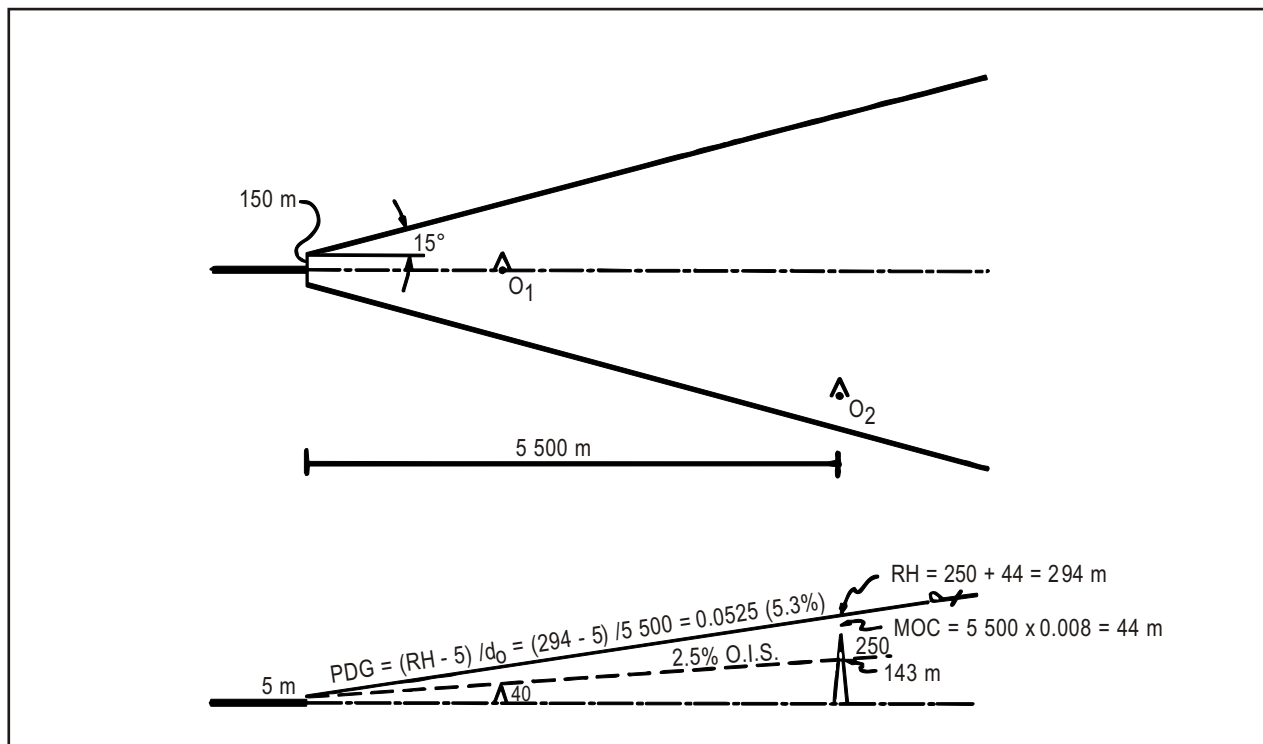
Figure II-1-1-1.   Straight departure
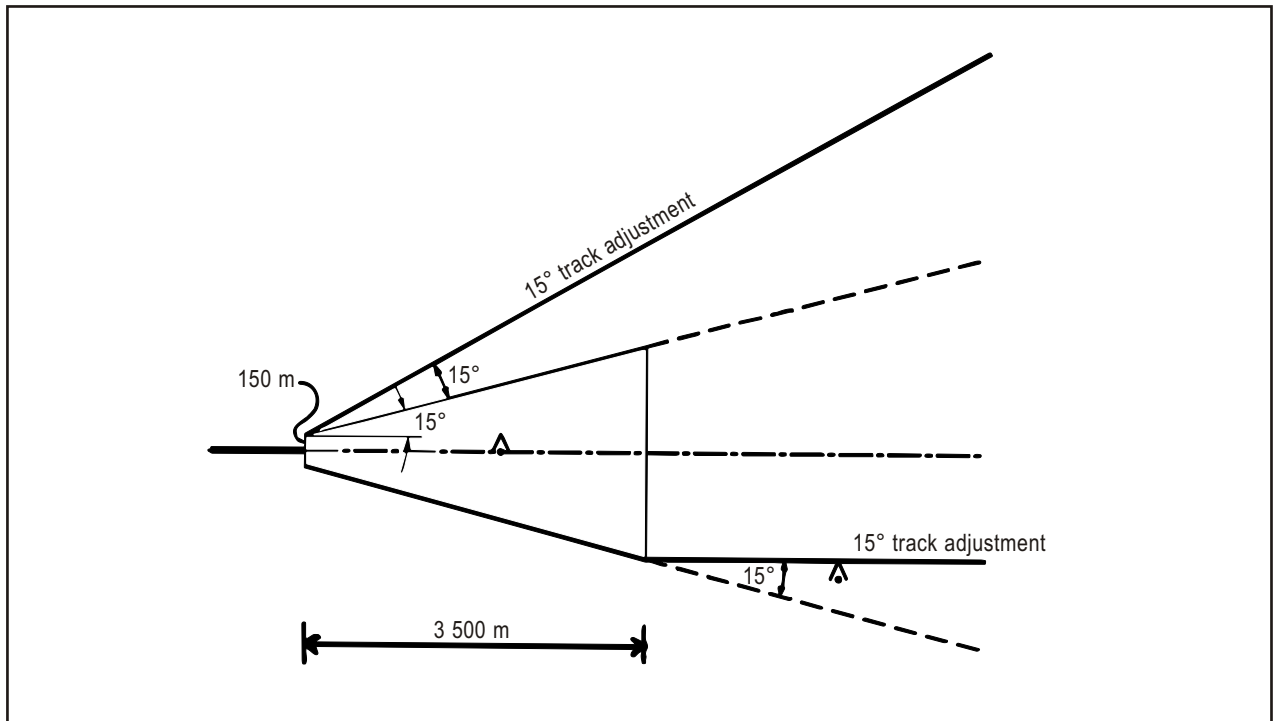
Figure II-1-1-2.   Departure with 15° track adjustment
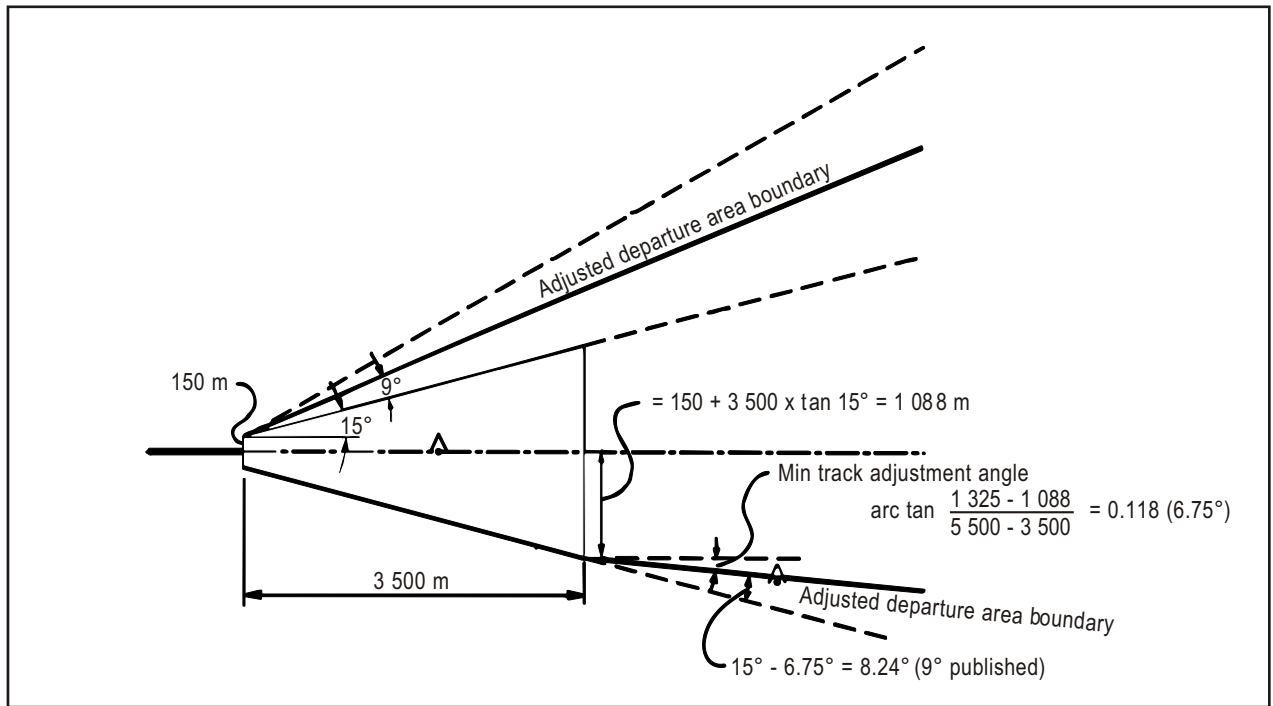
Figure II-1-1-3.   Departure with 9° track adjustment
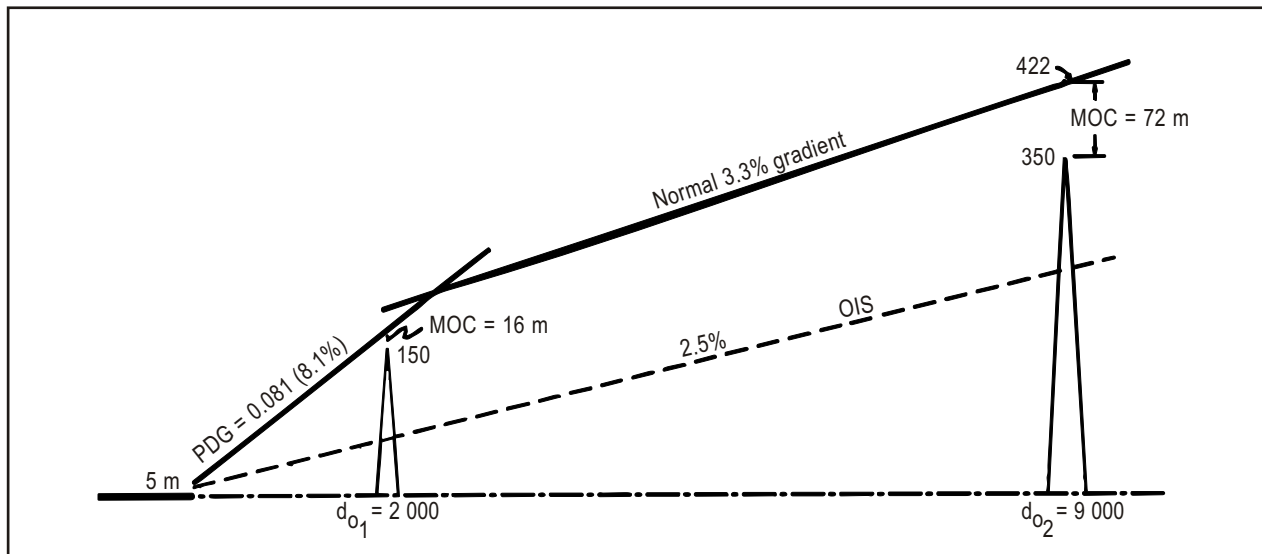
**Figure II-1-1-4.   Straight departure — Climb to a height (altitude)
after which a normal climb will clear remaining obstacles**
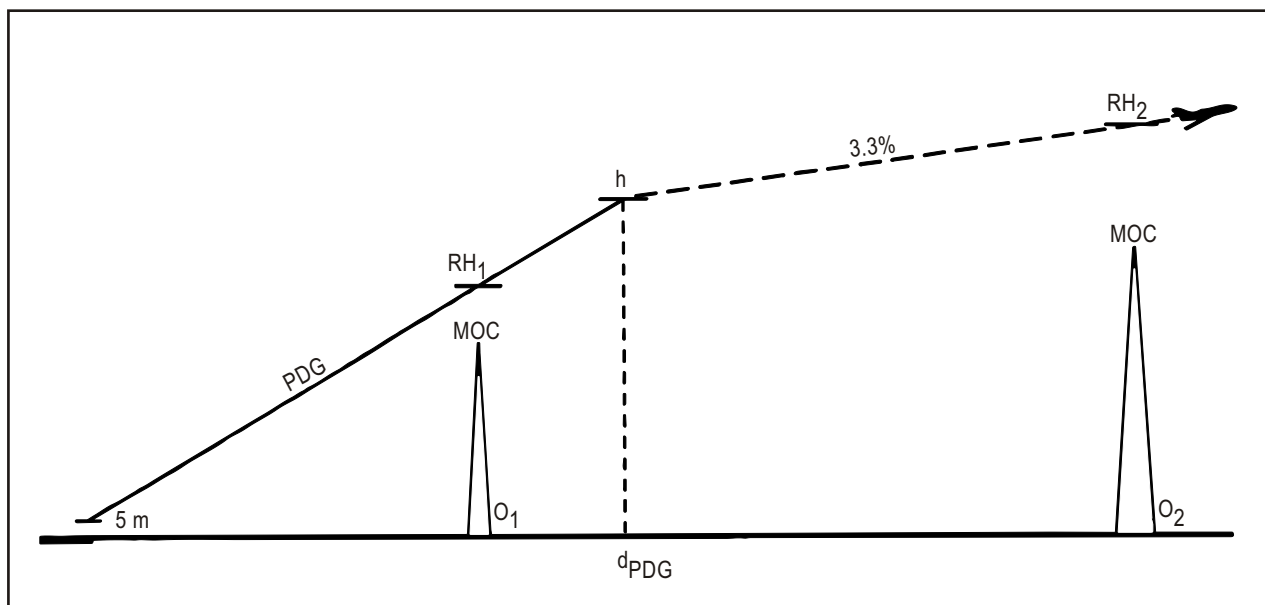
Figure II-1-1-5.   Fundamental departure climb profile
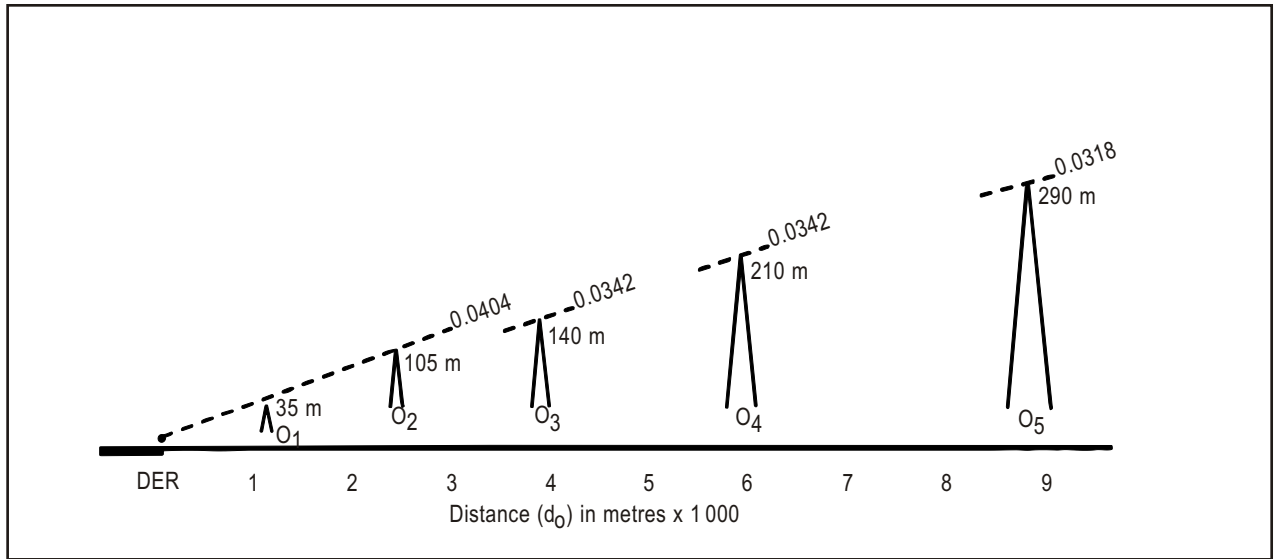
Figure II-1-1-6
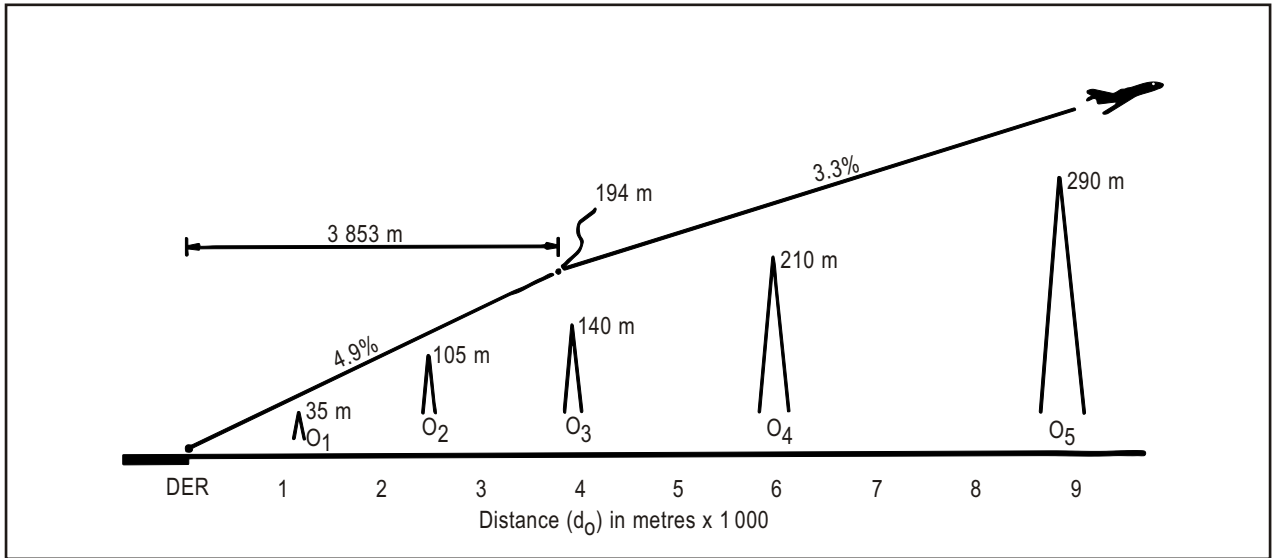
Figure II-1-1-7

Chapter 2
Turning Departure

INTRODUCTION

The turning departure utilizes the philosophies and criteria of the non-precision missed approach in PANS-OPS, Volume II, Part III, Chapter 7 with the following exceptions:

IAS = missed approach speeds + 10 per cent.

MOC = the greater of 90 m (295 ft), or 0.8 per cent of the distance DER to the obstacle.

Turning heights lower than 120 m (394 ft) are not accommodated.

Turns of 15° or less do not require a turn spiral boundary.

SITUATION
(See Figure II-1-2-1)

Obstacle O_1: height 800 m (2 624 ft), on centre line, 10.7 km (5.78 NM) from DER.
Obstacle O_2: height 500 m (1 640 ft), 7 km (3.78 NM) along centre line and 2 km (1.08 NM) to the left.
Obstacle O_3: height 256 m (839 ft), 9 km (4.86 NM) along centre line and 3.5 km (1.89 NM) to the right.
(All obstacles have been surveyed to accuracy code of 2C or better.)
Runway elevation at DER: 300 m (984 ft).

TASK
(See Figure II-1-2-2)

Identify the appropriate departure restrictions that may be required for each aircraft category.

Analysis: Obstacle O_1 on the centre line.

OIS = 10 700 m × 0.025 + 5 = 272.5 m (894 ft).

O_1 penetrates the OIS by 527.5 m (1 730 ft). A PDG is calculated.

MOC = 10 700 × 0.008 = 85.6 m (86 m), (282 ft).

The required height of the procedure at O_1 = 800 + 86 = 886 m (2 906 ft).

The PDG = $\dfrac{886 - 5}{10\ 700}$ = 0.0823 (8.3 per cent). Quite steep!

Assume a 90° right turn to avoid both obstacles O_1 and O_2.

A table similar to Tables III-7-3 and III-7-4 in PANS-OPS, Volume II, is developed using the appropriate aircraft category with missed approach speeds increased by 10 per cent. (See Table II-1-2-1.)

Using final missed approach speeds increased by 10 per cent, the four turning areas are drawn. It is apparent that while Categories A and B aircraft can avoid all obstacles, Category D must consider O_1 and O_3 and that Category C need only consider O_3.

O_1 can be avoided by restricting speeds to 490 km/h (264 kt) IAS for all aircraft.

O_3 must be considered with regard to the MOC required in the turn area.

MOC O_3 = 90 m (295 ft), since 0.008 × (3 500 + 6 006) = 76 m (249 ft)

The 256 m (840 ft) height of O_3 is unacceptable since it must be less than:

(3 500 + 6 006) × 0.033 + 5 − 90 = 229 m (751 ft).

An additional 27 m (89 ft) is required (256 − 229 = 27) [O_3 is 27 m (89 ft) too tall].

At least two alternatives exist:

1) Increase the climb gradient throughout the procedure to an altitude that provides the MOC at obstacle O_3.

The departure path at O_3 must be at least 90 m (295 ft) greater than O_3 [256 + 90 = 346 m (1 135 ft)].

The PDG for $O_3 = \dfrac{346 - 5}{3\,500 + 6\,006} = 0.0359$ (3.6 per cent)

Departure: "Climb straight ahead to 120 m (394 ft) (height) then turn right climbing 3.6 per cent to at least 346 m (1 135 ft) height ..." (rounded to a usable altitude).

or

2) Increase the climb gradient to a specified turn height (+27 m) (89 ft) at the end of Area 1 and assume a normal 3.3 per cent climb gradient after the turn.

The additional 27 m (89 ft) over the normal 120 m (394 ft) expected at the end of Area 1 requires a PDG:

$\dfrac{147 - 5}{3\,500} = 0.04057$ (4.1 per cent)

Departure: "Climb 4.1 per cent to 150 m (492 ft) (height), turn right ..."

Note.— The second alternative could be written to show the effect of a steep gradient on the length of Area 1, i.e. a 4.1 per cent gradient would see the 120 m (394 ft) height reached earlier than 3.5 km (1.89 NM) from DER; specifically (120 – 5)/0.041 = 2.805 km (1.53 NM).

Table II-1-2-1.   Turning departure parameters
(based on Tables III-7-3 and III-7-4 of PANS-OPS, Volume II, with IAS increased 10 per cent)

IAS	TAS 600 m (2 000 ft)	c 6 seconds $TAS + 56(30) \times \dfrac{6}{3\,600}$	R $\dfrac{542}{TAS}$ (293)	r $\dfrac{TAS}{62.8R}$	E $\dfrac{1.4}{R}$ (0.75)
km/h (kt)	km/h (kt)	km (NM)	deg/s	km (NM)	km (NM)
A					
226 (122)	239 (129)	0.49 (0.27)	2.27	1.68 (0.90)	0.62 (0.33)
B					
308 (166)	325 (176)	0.64 (0.34)	1.67	3.11 (1.66)	0.84 (0.45)
380 (205)	401 (217)	0.76 (0.41)	1.35	4.72 (2.56)	1.04 (0.56)
440 (236)	465 (249)	0.87 (0.47)	1.17	6.35 (3.36)	1.2 (0.64)
C					
490 (265)	518 (280)	0.96 (0.52)	1.05	7.88 (4.25)	1.34 (0.71)
D					
539 (291)	569 (308)	1.04 (0.56)	0.95	9.51 (5.16)	1.47 (0.79)

Turning Departure Situation

7 000 m

500 m

O_2

800 m

O_1

10 700 m

256 m

9 000 m

O_3

Figure II-1-2-1. Turning departure situation

Turning Departure Area with Bounding Circles for Cat. A, B, C, D.

800 m

o_1

Cat D

15°
Cat B
490 IAS
(264 kts)

500 m

o_2

256 m

o_3

15°
Cat B

15°
Cat A

do_3 6 006 m

Cat B

"C"

D 1.04

C .96

B .64

A .49

3.11

1.68

7.88

9.51

Area 1
3 500 m

Inner turn boundary if turn not
accommodated before DER

Inner
boundary
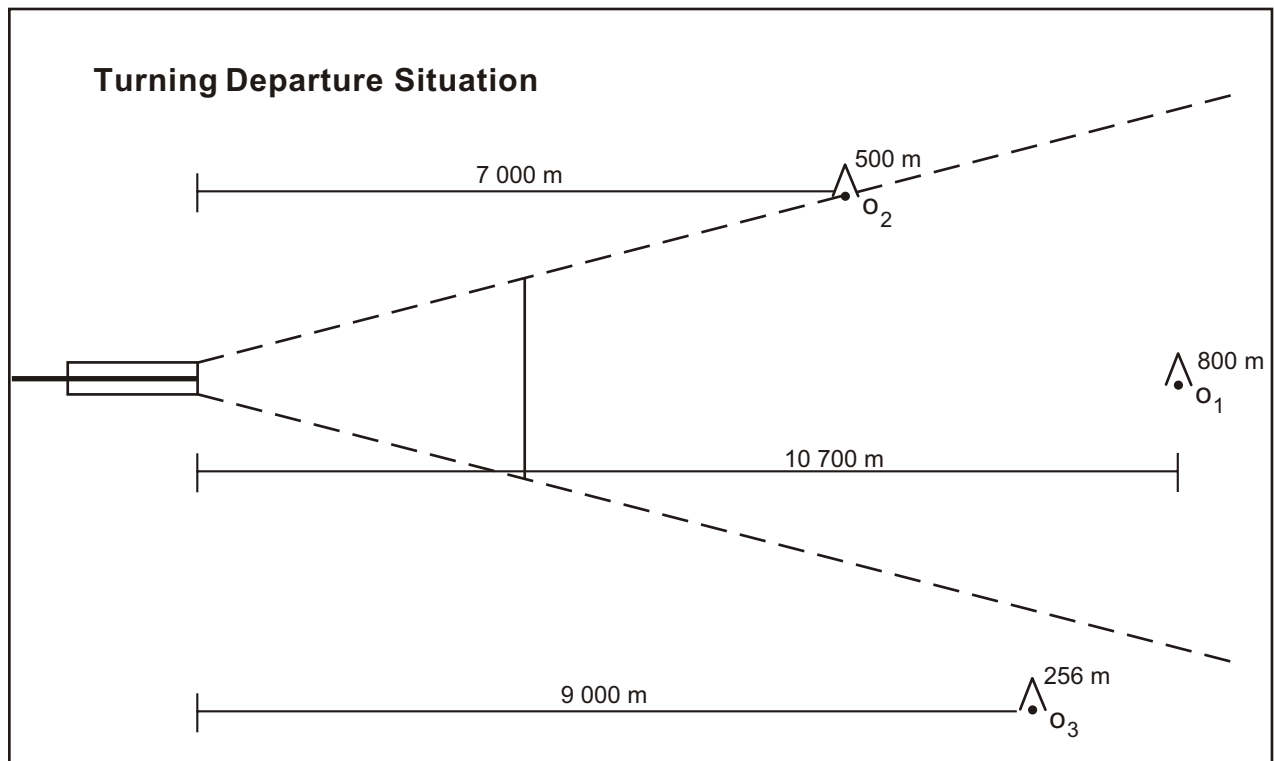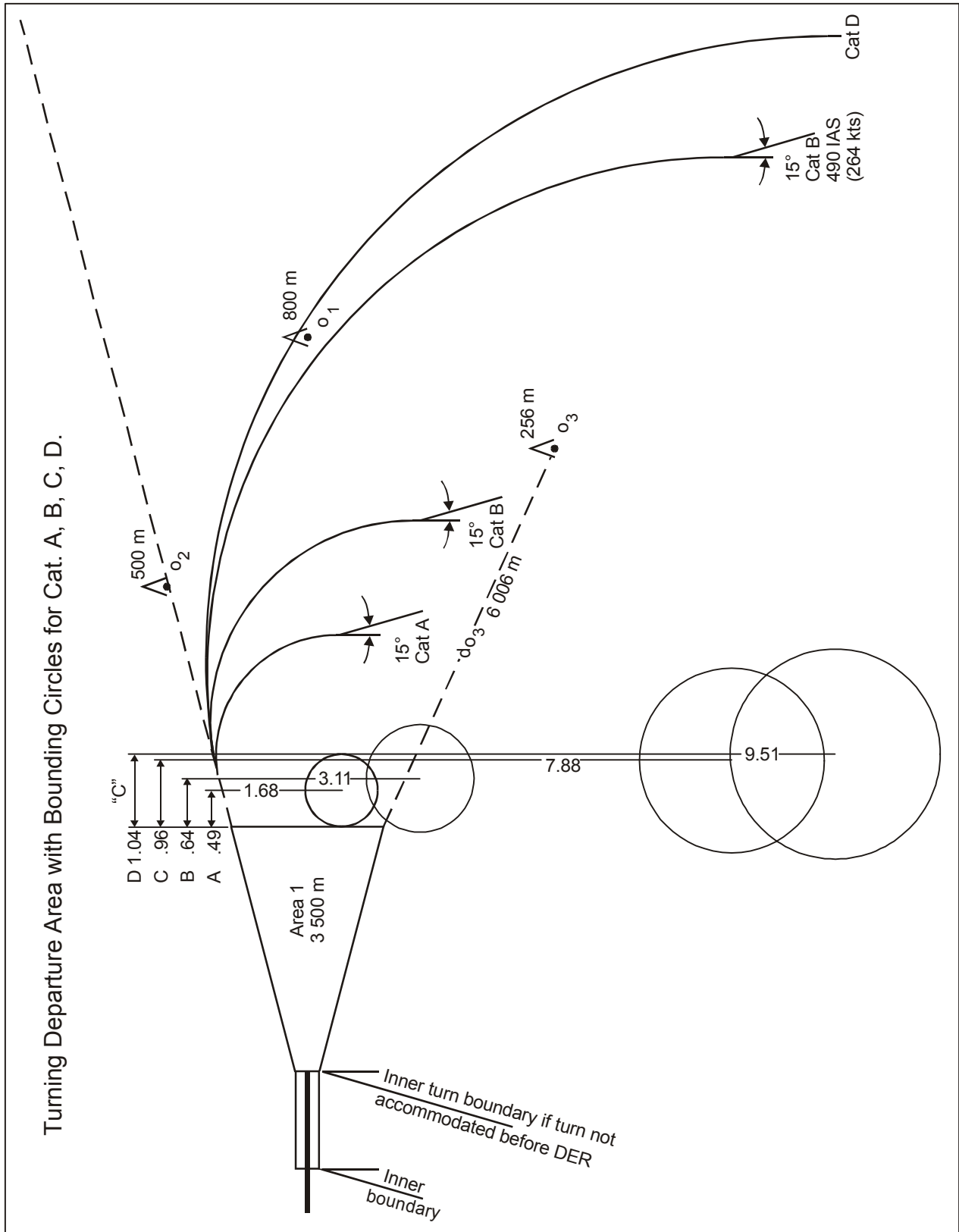
Figure II-1-2-2. Turning area with bounding circle turn spirals for Categories A, B, C and D

Chapter 3

Multiple Departures from One Aerodrome
(using non-standard units of measurement)

INTRODUCTION

This example explores a situation where all the departures must proceed to a common facility prior to departing en-route.

To facilitate the presentation, only Category B aircraft speeds are used since these slower speeds make it possible to plot the areas on a single sheet of A4 graph paper. The solutions and considerations are equally applicable to the other aircraft categories.

Obstacle locations are listed as north or south of RWY 09/29 and east or west of the DERs (measured along the RWY centre line).

Runway 09/27, elevation 1 000 ft, length 6 000 ft.

VOR site is 1.62 NM (9 843 ft) north of RWY centre line, 7.83 NM (47 576 ft) east of 09 DER.
(See Table II-1-3-1 and Figure II-1-3-1.)

Discussion RWY 09 departure

Runway 09 departures can proceed directly to the VOR with a track adjustment of less than 15°.

Runway 09

A track adjustment angle of 12° left to a VOR R-258 is feasible. The R-258 is only 270 ft south of the centre line at the 09 DER. (See Figure II-1-3-2.)

Tan 12° × 47 576 ft = 10 113 ft; 10 113 – 9 843 = 270 ft

Effect of O_1

d = 19 687 ft, Ht = 1 745 – 1 000 = 745 ft

OIS = 19 687 × 0.025 + 16 = 508 ft [O_1 penetrates the OIS]
MOC = 19 687 × 0.008 = 157 ft
RH_{01} = 745 + 157 = 902 ft

$$PDG = \frac{(902 - 16)}{19\ 687} = 0.045 \text{ (4.5 per cent)}$$

Effect of O_2

d = 36 092 ft, Ht = 2 292 – 1 000 = 1 292 ft

OIS = 36 092 × 0.025 + 16 = 918 ft
(O_2 penetrates the OIS, but secondary area MOC can apply)

Primary area MOC = 36 092 × 0.008 = 289 ft

Table II-1-3-1

Obstacle	Elevation (height)	North/south of RWY centre line	West of 27 DER	East of 09 DER
O_1	1 745 ft (745 ft)	N 0.27 NM (1 640 ft)	—	3.24 NM (19 687 ft)
O_2	2 292 ft (1 292 ft)	N 0.27 NM (1 640 ft)	—	5.94 NM (36 092 ft)
O_3	1 132 ft (132 ft)	On RWY centre line	1.89 NM (11 484 ft)	—
O_4	1 985 ft (985 ft)	N 1.35 NM (8 203 ft)	2.7 NM (16 405 ft)	—
O_5	1 263 ft (263 ft)	S 1.08 NM (6 562 ft)	1.62 NM (9 843 ft)	—
O_6	1 755 ft (755 ft)	S 2.7 NM (19 687 ft)	Equally distant from both DERs	

Secondary area calculations at the point at O_2:

VOR area at O_2 = 6 076.1 + tan 7.8° × 13 000 = 7 857 ft
O_2 is 5 580 ft from the VOR R-258

$$\text{Secondary} = \frac{7\ 857 - 5\ 580}{(7\ 857/2)} \times 289 = 167.5\ (168\ \text{ft})$$

RH_{02} = 1 292 + 168 = 1 460 ft

$$\text{PDG} = \frac{(1\ 460 - 16)}{36\ 092} = 0.04\ (4\ \text{per cent})$$

PDG = 4.5 per cent (demanded by O_1) to a height of 1 460 ft (demanded by O_2)

$$d_{PDG} = \frac{RH_2 - 16 - 0.033 \times d_{0_2}}{\text{PDG} - 0.033}$$

$$= \frac{1\ 460 - 16 - 0.033 \times 36\ 092}{0.045 - 0.033} = 21\ 080\ \text{ft}$$

The required height (altitude) for the RWY 09 departure must be at least:

16 + (21 080 × 0.045) = 965 ft
[1 000 + 965 = 1 965 (2 000 ft MSL)]

Departure 09: track 078° direct to VOR (R-258), climb 4.5 per cent to 2 000 ft to avoid an obstacle 3.25 NM from DER, elevation 1 745 ft.

Discussion RWY 27 departure

A Runway 27 departure must climb to an altitude (no fix available) and reverse track to the VOR. Obstacle O_4 will force a left turn.

Construct the turn area outer boundary

(See Figure II-1-3-3.)

The Category B turning departure IAS is 150 kt × 110 per cent = 165 kt. The TAS at altitude 300 m above aerodrome is 165 × 1.0567 = 174 kt. The latest TP is (174 + 30) × (6/3 600) = 0.34 NM beyond the nominal TP.

Bounding circles are constructed from both the left and right sides of Area 1 at the latest TP. A bounding circle with more than 180° of turn is needed from the left side of Area 1 to describe the turn back toward the VOR.

The earliest possible turn point will influence the southern boundary of the turn area. Bounding circles of approximately 235° are drawn from a point only 3 s (0.17 NM) beyond the 600 m earliest turn point.

In this example the area provides for not specifying a VOR inbound track or radial to follow. The area is drawn assuming that the pilot will choose and fly the VOR radial tangent to the worst position on the turning area boundary. At that point, the area splays 15° from the VOR radial until the VOR area is encountered.

The boundary on the north should provide for the same assumption. The area splays 15° from the VOR radial drawn to the latest turn point. An argument could be developed based on the still air track minus the wind effect describing the worst possible northern turn position, but this is not used anywhere in PANS-OPS except in the holding area construction.

Runway 27 obstacle analysis

Obstacle O_3; Ht 132 ft and d = 11 484 ft is in Area 1 and must be considered from two points of view.

1) it must be considered against the straight ahead OIS; and

2) it must be considered against the turn height (altitude).

OIS at O_3 = 16 + (11 484 × 0.025) = 303 [OIS not penetrated].

The turn height (altitude) must be 295 ft (90 m) above O_3.

Minimum turn height is 132 + 295 = 427 ft.

The distance necessary to gain height 427 ft is d_r (This is the minimum possible turn height. The associated d_r is used to evaluate obstacles in the subsequent turn area.)

$$d_r = \frac{427 - 16}{0.033} = 12\ 455\ \text{ft}$$

The remaining obstacles are considered using a four-step process for each obstacle in the turn area:

1) determine the d_o, the distance available for height gain (Hg) after the turn is commenced;

2) determine MOC [the greater of 295 ft, or $(d_r + d_o) \times 0.008$];

3) determine the required height (RH) at the obstacle; and

4) determine the minimum turn height relative to that obstacle by subtracting the potential height gain (Hg) from the RH (climbing 3.3 per cent).

Obstacle O_5 is in the turn area, 6 562 ft abeam the centre line, 9 843 ft from the DER.

Step 1) The distance (d_o) that is available for a height gain (Hg) from the turn initiation area boundary (Area 1) is:

Area 1: ½W = 9 843 × tan 15° + 492 = 3 129 ft
d_o = cos 15° (6 562 – 3 129) = 3 316 ft (shortest distance to O_5).

Step 2) The MOC is 295 ft since (10 701 + 3 316) × 0.008 = 112 ft.

Note.— In this case d_r* is used. It is 9 843 + 3 316 × sin 15° = 10 701.

Step 3) The required height (RH) is 263 + 295 = 558 ft.

Step 4) The minimum turn height for O_5 is 558 – (3 316 × 0.033) = 449 ft.

Obstacle O_6 is also in the turn area. It is 19 687 ft south of the runway midpoint.

Step 1) d_o = 19 687 – 492 = 19 195 ft [shortest distance from early turn boundary area].

Step 2) The MOC is 295 ft since (0 + 19 195) × 0.008 = 154 ft. (d_r* = zero).

Step 3) The RH at O_6 = 755 + 295 = 1 050 ft.

Step 4) The minimum turn height for O_6 is 1 050 – (19 195 × 0.033) = 417 ft.

Obstacles O_1 and O_2 must also be considered. The shortest distances d_o are measured from the earliest possible turn point 600 m (1 968 ft) from the beginning point of the runway available for take-off.

Obstacle O_1 is 3.24 NM east of the beginning point of RWY 27.

Step 1) d_o = 1 968 + 19 657 = 21 625 ft.

Step 2) The MOC is 295 ft since (0 + 21 625) × 0.008 = 273 ft. (d_r* = zero).

Step 3) The RH at O_1 = 745 + 295 = 1 040 ft.

Step 4) The minimum turn height for O_1 is 1 040 – (21 625 × 0.033) = 326 ft.

Obstacle O_2 is 5.94 NM east of the beginning point of RWY 27.

Step 1) d_o = 1 968 + 36 092 = 38 060 ft.

Step 2) The MOC is 304 ft since (0 + 38 060) × 0.008 = 304 ft. (d_r* = zero).

Step 3) The RH at O_2 = 1 292 + 304 = 1 596 ft.

Step 4) The minimum turn height for O_2 is 1 596 – (38 060 × 0.033) = 340 ft.

The controlling obstacle in the turn area is O_5.

Summary minimum turn heights:

O_1 = 326 ft
O_2 = 304 ft
O_3 = 427 ft
O_4 not in turn area
O_5 = 449 ft
O_6 = 417 ft

The turn height must be at least 449 ft (required by O_5).

Note.— At this point an operationally useful turn altitude MUST be established for use on the departure chart or in the narrative which describes the departure procedure (SID). Historical use seems to require that turn altitude be stated in 100 ft increments.

The turn altitude (TNA) is (1 000 + 449) = 1 449 ft (rounded to 1 500 ft MSL).

The nominal turn point needed to plot the turning areas must use the turn height relative to 1 500 ft MSL.

TNH = 1 500 – 1 000 = 500 ft.

The nominal TP = d_r = $\dfrac{(500 - 16)}{0.033}$ = 14 667 ft

Note that all the previous analyses of obstacles in the turn area used d_r = 12 455 ft. These were conservative analyses based on the minimum possible turn heights. There will be no adverse consequences in this case by climbing higher before turning using the greater d_r of 14 667 ft.

Departure 27: climb straight ahead to 1 500 ft. Turn left to VOR climbing to 3 000 ft.
(See Figure II-1-3-4.)

For complete reference, refer to Annex 4 — *Aeronautical Charts*, Chapter 9, Standard Departure Chart — Instrument (SID) — ICAO and to the *Aeronautical Chart Manual* (Doc 8697), Chapter 7.
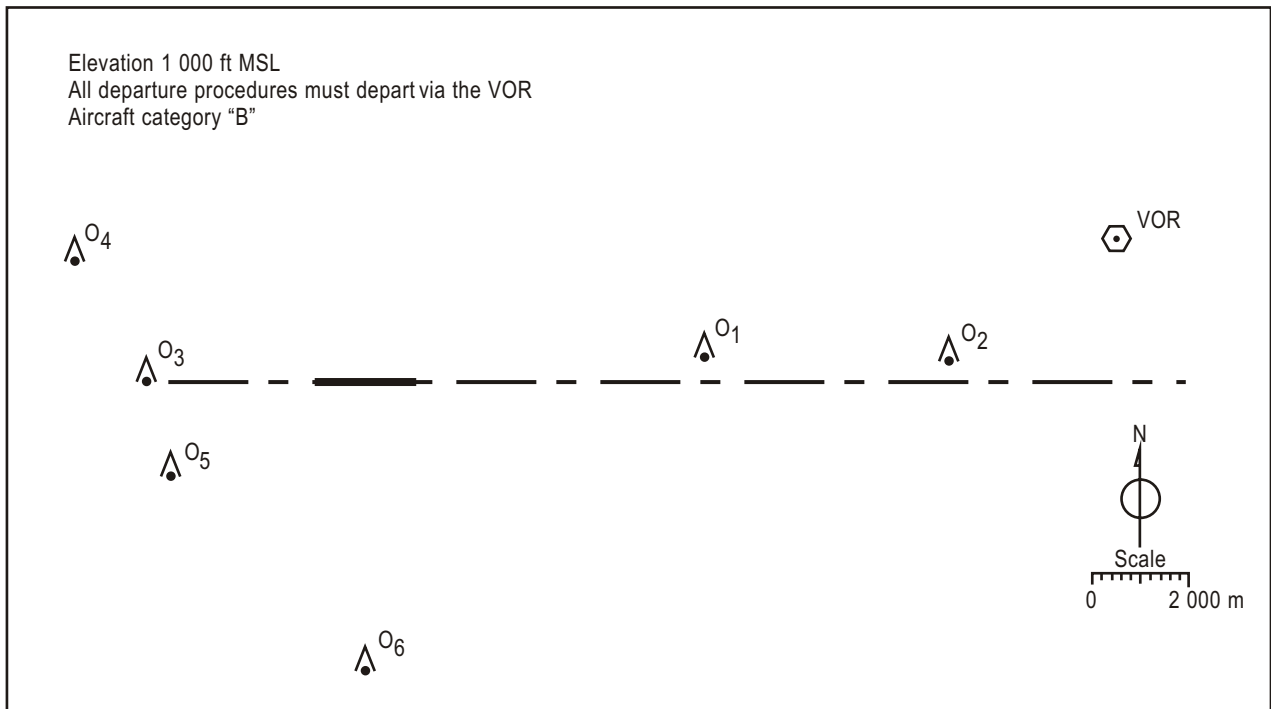
Figure II-1-3-1.   Multiple departure layout plan
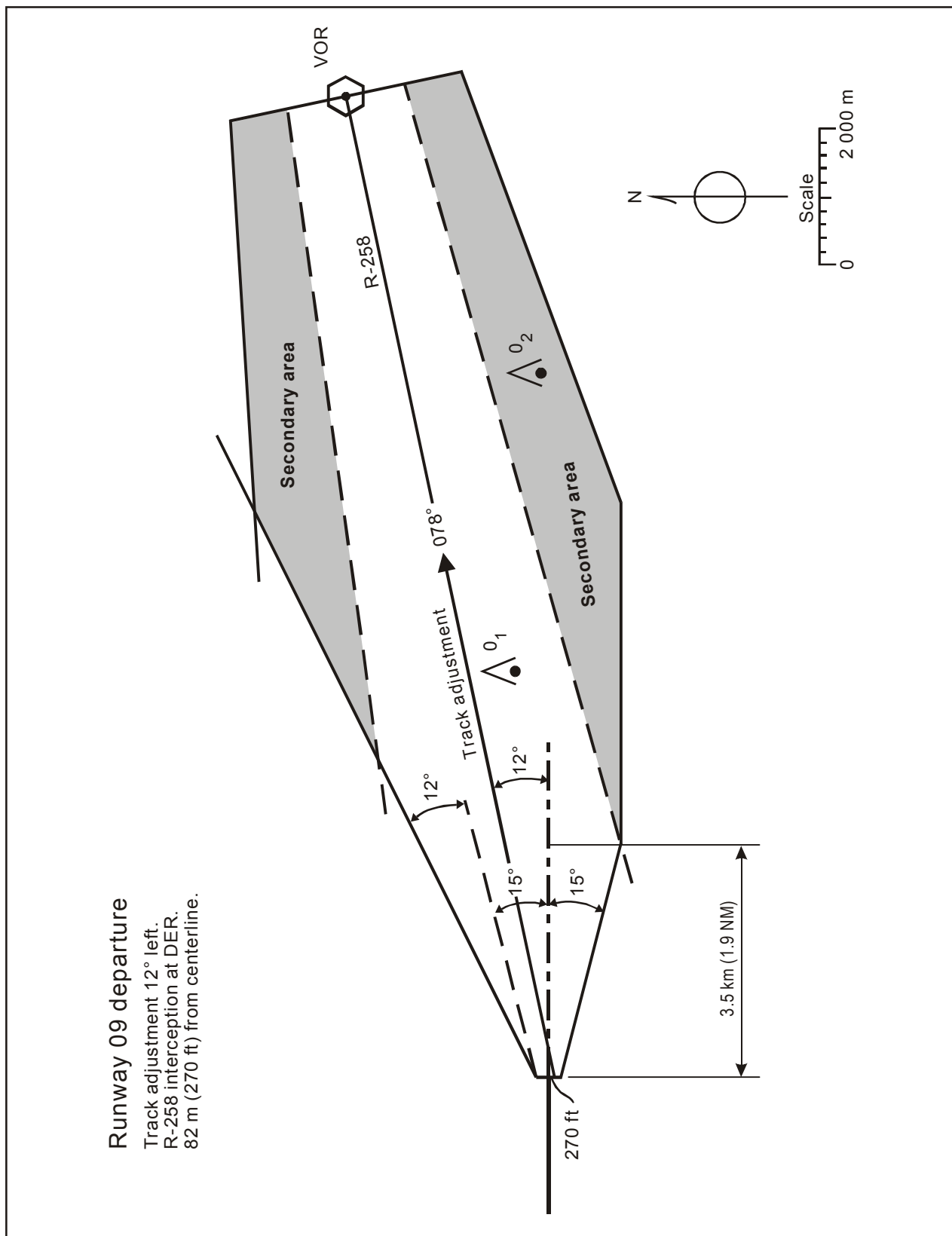
Figure II-1-3-2.   Runway 09 departure with track adjustment and climb restriction

Nautical miles

Table of turn parameters at 2 000 ft MSL.

Acft	IAS	TAS	r	E	c
Cat B	165	174	1.65	0.45	0.34

Detail A

$$3\ 316 = 3\ 433\ \cos 15°$$
$$3\ 129 = 9\ 843 \times \tan 15° + 492$$
$$d_r{}^* = 9\ 843 + 3\ 316 \times \sin 15° = 10\ 701$$

Figure II-1-3-3

STANDARD DEPARTURE CHART-
INSTRUMENT (SID) - ICAO

TRANSITION ALTITUDE
5 000 FT

TWR 118.1
APP 119.1
ACC 120.3

CITY/Aerodrome
RWY 09/27

VAR 4°W

BEARINGS, TRACKS AND
RADIALS ARE MAGNETIC

ALTITUDES AND ELEVATIONS
ARE IN FEET

DISTANCES IN NM

MSA 25 NM
from RESTON VOR

RESTON
VOR 123.0 RTN

DEPARTURE RWY 09 RADIAL 078° DIRECT TO
VOR CLIMB 4.5 PERCENT TO 2 000 FT TO AVOID
OBSTACLE 3.25 NM FROM DER ELEVATION 1 745 FT.

DEPARTURE RWY 27 CLIMB STRAIGHT AHEAD
ON RWY HEADING TO 1 500 FT TURN LEFT TO
VOR CLIMBING TO 3 000 FT.

kilometres

nautical miles

DATE OF AERONAUTICAL
INFORMATION

PRODUCING ORGANIZATION

REFERENCE NUMBER

Figure II-1-3-4

INSTRUMENT FLIGHT PROCEDURES
CONSTRUCTION MANUAL

SECTION 2

ARRIVAL AND APPROACH PROCEDURES

Chapter 1

NDB or VOR Off-aerodrome Procedure —
Categories C/D Aircraft

3.1 INTRODUCTION

As an example, it has been decided that an instrument approach procedure, off-aerodrome NDB, is to be designed for Runway 11 on DONLON/Slipton aerodrome. A major part of the design study will be to determine an optimum area in which the facility should be positioned, leading to selection of a precise location depending upon the actual terrain characteristics within the area selected. It is best to start the design with the final and intermediate approach phases of the procedure, as it is normally the obstacle situation in the relevant areas which will affect the location of the facility.

3.2 EXAMPLE OF PROCEDURE DESIGN

Data

Runway: 11/29, length = 2 000 m
  Threshold 11 elevation = 53 m (174 ft)
  Aerodrome elevation = 54 m (178 ft)
  Magnetic bearing = 105°/285°

Magnetic variation: 1°W

Type of facility: NDB
Ident: SCN

Aircraft: Procedure calculated for Categories C/D (for Categories A/B, see Chapter 2 of this section)

In an instrument approach procedure an aircraft has to reduce height from initial altitude down to the threshold elevation. The amount of height to be reduced depends on the obstacle situation in the vicinity of the aerodrome and may also depend on the type of entry into the procedure, which may be either by omnidirectional entry into a racetrack or by a standard arrival route. Many States use the highest of the minimum sector altitudes as the initial altitude. This method is applied herein.

STEP 1

Profile of final approach
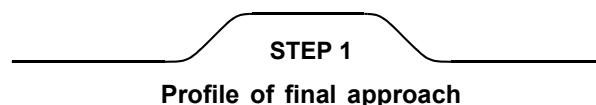
Draw a profile on graph paper using suitable dimensions such as horizontal scale: 10 mm = 1 000 m, vertical scale: 10 mm = 100 m. Indicate the runway as in Figure II-2-1-1.

From a point 15 m above the threshold, draw the optimum final descent path (gradient 5 per cent).

STEP 2

Preliminary location of the facility (FAF)
(in the example, an NDB)
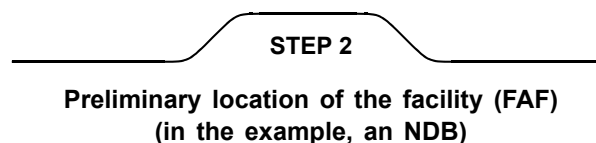
Locate the runway on a suitable map and draw the extended runway centre line in both directions. Select a provisional location for the NDB facility between 5 and 7 km from the threshold, if possible on the extended runway centre line. Lakes, swamps and other unsuitable terrain for location of equipment should be avoided. Indicate the facility with a vertical line on the graph paper profile begun in Step 1 (in the example, 6 000 m from the threshold).

  Note.— Electrical power lines, telephone cables, metallic fences and roofs and similar obstacles in the vicinity of the antenna will interfere with the function of the beacon — obtain technical advice.

STEP 3

Obstacle situation in the intermediate area
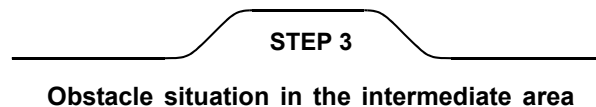
It is always preferable to locate a facility on the extended runway centre line. For an illustration of an offset track, see Chapter 4 of this section, Step 1.

Draw on a map (suitable scale 1:250 000 or larger) the limits of the intermediate area, aligned with the extended runway centre line and FAF. Dimensions: 2.5 NM wide at the facility and expanding uniformly to 10 NM at the 15 NM point, opposite the inbound direction. Draw the final approach area 2.5 NM at the facility expanding both sides of the area at 10.3° (see Figure II-2-1-2). Indicate primary and secondary areas (or place a transparent contour template) on the map, centred on the preliminary FAF location and aligned with the final approach track. The highest value after adding MOC 150 m (reduced in secondary areas) to obstacle elevations in the area indicates the lowest possible altitude before passing FAF inbound. In the example there is an obstacle in the primary area with its top at 275 m. The lowest altitude at FAF is 275 + 150 = 425 m (1 394 ft which rounds up to 1 400 ft). Draw a short horizontal line through the final descent path on altitude 425 m. The intersection indicates the closest distance to the threshold for location of FAF, graphically about 7 150 m, if the optimum descent gradient of 5 per cent in the final approach is not to be exceeded. The distance is calculated as follows:

$$\frac{425 - 15 - 53}{0.05} = 7\ 140\ \text{m}$$

where 15 is descent path height above the threshold and 53 is threshold elevation.

After studying the chart and actual conditions at the site, a suitable location 7 800 m from the threshold on the extended runway centre line is confirmed. The maximum altitude at the FAF (within the optimum 5 per cent gradient) is then calculated:

Threshold elevation = 53 m
Descent path height above threshold = 15 m
Descent gradient of 5 per cent = 0.05

(7 800 × 0.05) + 15 + 53 = 458 m MSL (1 503 ft MSL)

The altitude specified at the FAF must therefore be 1 500 ft or less to be within the 5 per cent optimum descent gradient.

STEP 4

Minimum sector altitudes (MSA)

It is recommended that the minimum sector altitudes be based on a facility with a range of at least 46 km (25 NM). The site of the facility in the example is preliminary: initially it is assumed to be 7 to 8 km from the threshold on the extended runway centre line. A transparent template with quadrants and 5 NM buffer areas should be constructed to map scale. This template is centred on the assumed location of the NDB. The highest of the obstacles in each of the quadrants including the buffer areas, plus 300 m (984 ft if the elevations are expressed in feet), rounded up to the next higher 30 m (100 ft) increment, is the MSA in each sector (see Figure II-2-1-3). As these obstacles seldom appear on the instrument approach chart, which covers a smaller area, it is necessary to indicate them on a separate chart for record purposes. Figure II-2-1-3 is an example. The following MSA have been calculated:

Sector NE = 2 900 ft, Sector SE = 2 400 ft, Sector SW = 2 900 ft, Sector NW = 3 000 ft MSL.

STEP 5

Descent during the outbound and inbound track in the racetrack

The altitude from which the procedure design shall be started, determined in Step 4, is the highest of the four MSA, 3 000 ft (or 914 m) MSL. In Step 3 the optimum and minimum altitudes at the FAF were determined to be 1 500 ft and 1 400 ft MSL respectively. Taking the maximum height at the FAF (1 500 ft MSL), the height to be reduced during the outbound and inbound manoeuvring is 3 000 – 1 500 = 1 500 ft. In this step, we shall determine outbound nominal time required in the procedure.

Maximum descent to be specified on a reversal or racetrack procedure
(extract from PANS-OPS, Volume II, Table III-4-1)

Track	Outbound track		Inbound track	
Aircraft category	*CAT A/B*	*CAT C/D/E*	*CAT A/B*	*CAT C/D/E*
Maximum descent for 1 minute nominal outbound time	245 m (804 ft)	365 m (1 197 ft)	200 m (655 ft)	305 m (1 000 ft)

The NDB is indicated as a vertical line, altitudes are indicated vertically and the time outbound is indicated horizontally (see Figure II-2-1-4).

Maximum descent for Categories C/D during 1 minute from 914 m gives 914 – 365 = 549 m MSL. During 1 minute inbound, maximum 305 m shall be reduced to 458 m MSL at FAF, starting from 458 + 305 = 763 m MSL. Indicate the four altitudes as in Figure II-2-1-4 and draw maximum descent lines. The two lines should intersect earlier than 1 minute outbound; if so, 1 minute outbound can be adopted into the procedure.

Note 1.— Calculations for Categories A/B aircraft indicate that 1 min 30 s outbound time is required.

Note 2.— According to PANS-OPS, Volume II, Part III, 4.4.5.1, separate instrument approach charts must be published when outbound times or headings are specified for different categories of aircraft. Calculations for Categories A/B are shown separately in Chapter 2 of this section.

STEP 6

The use of racetrack area templates

It is always safe to use a template for a higher altitude than that at which initial operations will take place, because true airspeeds are higher and, as a consequence, outer limits are wider. The limits of an area can be drawn either by using one of the precalculated templates contained in the *Template Manual for Holding, Reversal and Racetrack Procedures* (Doc 9371) or by using the "Simplified area construction method for reversal and racetrack procedures" presented in Attachment B1. Examples of such areas are shown in Figures II-2-1-5 and II-2-1-6 below.

STEP 7

Obstacle situation in the racetrack area — minimum racetrack altitude

The purpose of this step is to establish whether straight-in alignment between the racetrack axis and final approach is still possible, and to determine the lowest possible altitude/height before descent in the intermediate phase. Develop a racetrack area template, incorporating fix error,

omnidirectional entry and secondary areas. As the initial altitude is 3 000 ft MSL, use a template for this or the next higher altitude for the following data:

Categories C/D use 250 kt, 3 000 ft, 1 minute outbound. A suitable scale for both chart and template is 1:250 000.

Place the template on the chart, centred on the FAF and aligned with the inbound track (in the example, the extended runway centre line) and for right-hand turns. In the example the highest obstacle is a mast, elevation 405 m, situated in the secondary area. The distance from the outer limit is 14.5 mm. The whole width of the secondary area is 18.5 mm, measured with a ruler (see the note below).

Reduced MOC is:

$$\frac{14.5}{18.5} \times 300 = 235 \text{ m}$$

The lowest possible altitude before beginning of descent in the intermediate area is 405 + 235 = 640 m MSL (2 100 ft MSL).

See again Figure II-2-1-4. Indicate the point corresponding to 1 minute nominal outbound time and 2 100 ft. This lies within the acceptable descent limits (both outbound and inbound). One minute outbound is therefore accepted for the procedure for Categories C/D aircraft.

Note.— If the chart scale is 1:250 000, the width of the secondary area can be calculated as follows (2.5 NM = 4 630 m):

$$\frac{4 630}{250 000} = 0.0185 \text{ m} = 18.5 \text{ mm}$$

STEP 8

Final approach OCA/H

OCA/H is determined by obstacles either in the final approach area or in the missed approach area. If the distance FAF to THR does not exceed 6 NM, MOC is reduced to 75 m (246 ft) in the secondary areas of the final approach area and the initial missed approach area. If the distance FAF to THR exceeds 6 NM, MOC shall be increased at the rate of 1.5 m (5 ft) for each one-tenth of a nautical mile over 6 NM. The final approach area terminates at the missed approach point (MAPt) which is normally located at the threshold in procedures of this type (MAPt will be discussed in Step 9).

Examine the obstacle situation in the final approach area. In the example (Figure II-2-1-7), two obstacles are indicated: a mast with elevation 63 m MSL in the primary area and a hill 80 m MSL in the secondary area. As the distance FAF to THR does not exceed 11.1 km (6 NM), MOC in the primary area is 75 m. The obstacle is situated 25.5 mm from the outer limit of the secondary area on the map and the whole width of the secondary area is 30.5 mm.

Reduced MOC is:

$$\frac{25.5}{30.5} \times 75 = 63 \text{ m}$$

The OCA and OCH are:

OCA (exact)	OCH (exact)
Mast: 63 + 75 = 138 m	OCA – 54 m = 84 m
Hill: 80 + 63 = 143 m	OCA – 54 m = 89 m

The critical obstacle is thus the hill. The OCA/H is rounded up to the nearest 5 m giving OCA/H 145 (90) m (or OCA/H 470 (300) ft), provided that no obstacles in the initial missed approach area will affect this value. The initial missed approach area is the area between MAPt and start of climb (SOC). The size of this area is calculated in Step 10. Regarding MOC and how to deal with obstacles situated within this area, see Chapter 6 of this section, Step 3.

STEP 9

Missed approach point (MAPt)

Preferably the MAPt should be defined by a navigational facility or fix (if a VOR or NDB facility is so located that it can serve as MAPt, the tolerance is 0 km (NM)). A 75 MHz marker beacon is acceptable as MAPt only in the case of procedure LLZ ONLY (ILS with GP inoperative). See Chapter 6 of this section. The MAPt must not be after the threshold; it should be located at the threshold whenever possible. It may, however, be located earlier if obstacles in the intermediate missed approach area are so high that OCA/H becomes higher than that for the final approach area. In this case it should not be moved so far back as to affect the final approach gradient, nor so far that the chances of seeing the approach lights/aerodrome are reduced too far (see also Chapter 6). Another method of avoiding obstacles in the missed approach is to prescribe turning missed approach as presented in Chapters 9 and 10 of this section or to prescribe an early turn. Figure III-7-17 in PANS-OPS, Volume II, shows a turn <15°. There is no illustration of a turn as soon as practicable for non-precision procedures but in principle the turn could be based on SOC. The distance from FAF to MAPt as well as a table of times to fly the distance with different ground speeds shall be published in the instrument approach chart (provided that DME is not available in the procedure). See Step 14.

Note.— In on-aerodrome procedures, the MAPt can be located at the facility beyond the THR (see, in this section, Chapter 3, Step 8 and Chapter 9, Step 1).

STEP 10

Longitudinal tolerance of MAPt area

The MAPt tolerance area is calculated for Category D aircraft in accordance with PANS-OPS, Volume II (*Longitudinal tolerance of MAPt defined by a distance* and *Calculation of SOC when MAPt is defined by a distance*). Note that the earliest MAPt is needed only in the case of a turn. In the first part of this example the values have been calculated to the nearest metre to facilitate the checking of computer calculation routines. Note that differences of 1 m may arise due to differing rounding methods.

The fix is an NDB with a crossing altitude of 460 m MSL (see Step 3). The elevation of the NDB is 40 m MSL. The height above the NDB is thus 460 – 40 or 420 m. The NDB cone of ambiguity is 40 degrees. Thus, using the terminology of Attachment B6 and calculating in SI units:

b = distance from the FAF to the latest point of the FAF tolerance
    = $420 \times \tan 40°$
    = 352 m
D = distance FAF to MAPt
    = 7 800 m

Category D maximum IAS is 345 km/h
Category D minimum IAS is 240 km/h
Aerodrome elevation is 54 m (used as value H for speed calculation)
IAS/TAS conversion factor = $171\,233 \times [(288 + \text{VAR}) - 0.006496 \times \text{H}]^{0.5}$ / $(288 - 0.006496 \times \text{H})^{2.628}$

Minimum value (ISA – 10) = 0.9850
Maximum value (ISA + 15) = 1.0285
TASMIN (Category D)   = 240 × 0.985
                    = 236.4 km/h
TASMAX (Category D) = 345 × 1.0285
                    = 354.8 km/h

Distance FAF to MAPt   = 7.8 km
Wind   = 56 km/h

Calculation of latest MAPt (calculated in km and km/h):

$$X3 = [b^2 + (TASMIN \times 13/3\ 600)^2 + (56 \times D/TASMIN)^2]^{0.5}$$
$$= [(0.352)^2 + (236.4 \times 13/3\ 600)^2 + (56 \times 7.8/236.4)^2]^{0.5}$$
$$= [0.352^2 + 0.8537^2 + 1.2311^2]^{0.5}$$
$$= 1.5389 \text{ km}$$

$$X4 = [b^2 + (TASMAX \times 13/3\ 600)^2 + (56 \times D/TASMAX)^2]^{0.5}$$
$$= [(0.352)^2 + (354.8 \times 13/3\ 600)^2 + (56 \times 7.8/354.8)^2]^{0.5}$$
$$= [0.352^2 + 1.2812^2 + 1.2311^2]^{0.5}$$
$$= 1.811$$

Latest MAPt tolerance =   max[X3;X4]
                      =   1.81 km

$$X5 = X3 + 15 \times (TASMIN + 19)/3\ 600$$
$$= 1.5389 + 15 \times (236.4 + 19)/3\ 600)$$
$$= 2.603 \text{ km}$$

$$X6 = X4 + 15 \times (TASMAX + 19)/3\ 600$$
$$= 1.811 + 15 \times (354.8 + 19)/3\ 600$$
$$= 3.368 \text{ km}$$

MAPt to SOC distance   = max[X5;X6]
                        = 3.368 km

Note.— X5 may be greater than X6, depending on the FAF to MAPt distance and aircraft category.

As a check, the approximate calculation is shown using the graph of "*MAPt defined by a distance – graph of nominal MAPt to SOC distance vs. nominal FAF to nominal MAPt distance*" as follows:

Nominal FAF to MAPt distance = 7 800 m

Nominal FAF to latest MAPt   = max[2 463;
                                0.1562D + 1 908]
                              = max[2 463; 1 238]
                              = 2 463 m

Nominal FAF to MAPt distance = max[0.0495D + 4 153;
                                0.2055D + 2 073]
                              = max[386 + 4 135;
                                1 602 + 2 073]
                              = max[4 521;3 675]
                              = 4 521 m

Note that the simplified equations are based on linear interpolation between extreme values up to 4 000 m (13 000 ft) and are conservative at intermediate values. In the case shown the simplified solution increases the MAPt to SOC distance by 1.15 km. In many locations this may not be important; however where missed approach obstacles are present, the more accurate method may be used. In this case a computer or spreadsheet calculation is preferred to avoid human calculation errors.

Since the aerodrome is below 600 m elevation, the tables "Distance d" and "Distances of transitional tolerance" from PANS-OPS, Volume II, may be used. This is illustrated for Category C aircraft:

For Category C aircraft with speed 160 kt IAS, 164 kt TAS, value 0.98 NM = 1 800 m is calculated. The value for the transitional tolerance (X) from PANS-OPS, Volume II, Table III-7-2 (metric) for Category C is 1 380 m. Similarly, the distance MAPt to SOC = 1 810 + 1 380 = 3 190 m (rounded to 3 200 m).

Note.— The values in PANS-OPS, Volume II, Table III-7-2 are valid for 600 m above MSL. A more accurate value can be obtained if TAS is calculated for the actual altitude.

The formula for X is:

$$X = \frac{(TAS + 10) \times 15}{3\ 600}$$

TAS is given in knots. If 10 is changed to 19, the formula is valid for km/h.

The formula for d is:

$$d = \frac{(TAS + 10) \times 3}{3\ 600}$$

STEP 11

Intermediate and final missed approach areas

After line SOC is drawn (see Figure II-2-1-8), the effect of obstacles in the intermediate and final missed approach areas must be checked. This is done with the following formula:

$$OCA = OE - (d_o \times \tan Z) + MOC$$

where: d_o is distance from SOC to the obstacle
OE is obstacle elevation
tan Z is climb gradient (exact value) in percentage

(See Figure II-2-1-9.)

In the example it is assumed that an obstacle is situated in the primary area, distance 6 500 m from the threshold, elevation 240 m. SOC distance from the MAPt for Category D aircraft is 3 400 m. The distance available for height gain from SOC is 6 500 – 3 400 = 3 100 m.

The OCA missed approach for Category D aircraft is calculated for climb gradient as follows:
240 – (3 100 × 0.025) + 30 = 192.5 m = 632 ft, rounded up to 195 m or 640 ft.

Similarly, the distance obstacle to SOC for Category C is 6 500 – 3 200 = 3 300 m.

OCA = 240 – (3 300 × 0.025) + 30 = 187.5 = 615 ft, rounded up to 190 m or 620 ft.

Both values are higher than final approach OCA (see Step 8) and, therefore, OCA/H for the procedure to be published on the instrument approach chart would be:

Category C: 620 (450) ft
Category D: 640 (470) ft

The difference in altitude between the aerodrome elevation (178 ft) and the threshold elevation (174 ft) is only 4 ft. As this is a non-precision procedure, the aerodrome elevation is a reference datum for OCH. Other climb gradients calculated for Category D aircraft are:

240 – (3 100 × 0.030) + 30 = 177 m = 581 ft
Higher than final approach OCA/H

240 – (3 100 × 0.040) + 30 = 146 m = 479 ft

240 – (3 100 × 0.045) + 30 = 130.5 m = 428 ft
Lower than final approach OCA/H

OCA/H values associated with climb gradients steeper than 2.5 per cent may be published as an additional minima to provide an operational benefit for aircraft capable of steeper missed approach climbs.

It is up to the appropriate authority to decide when additional value(s) are published.

Note.— This example is calculated with a straight missed approach. For a turning missed approach, see Chapters 9 and 10 of this section.

Discussion Step 11

The values of OCH obtained appear operationally restrictive; therefore, ways of reducing them should be examined. The most obvious remedy is to introduce a turn in the missed approach — this is covered in detail in Chapters 9 and 10 of this section. The option examined here is the adjustment of the MAPt which moves SOC back and so reduces OCA for missed approach obstacles. The PANS-OPS favours locating the MAPt at the runway threshold. It may be moved toward the FAF but not further than the point calculated as follows:

$$D = \frac{\text{OCH final approach} - 15}{0.05}$$

where 15 is descent path height above THR
D = distance THR to MAPt and 0.05 is 5 per cent.

Note.— The MAPt is not intended to mark the ideal point where the pilot should see the runway. It is the point where the pilot MUST commence the missed approach because of obstacle considerations.

In the example, OCH is 89 m.

$$\frac{89 - 15}{0.05} = 1\,480 \text{ m}$$

which is the maximum MAPt distance from THR and should be considered when establishing visibility limits for the approach.

The revised distance FAF to MAPt is
7 800 – 1 480 = 6 320 m (3.41 NM).

The latest MAPt tolerance (d_2) is again calculated for Category D aircraft:

Distance "b" = 0.19 NM

$$\frac{13 \times 190}{3\,600} = 0.69 \text{ NM}$$

$$\frac{3.4 \times 30}{190} = 0.54 \text{ NM}$$

RSS = $[0.19^2 + 0.69^2 + 0.54^2]^{0.5}$ = 0.90 NM = 1 670 m

Distance MAPt to SOC is 1 670 + 1 600 = 3 270 m

(See Figure II-2-1-10.)

Similar calculations for Category C aircraft give the distance 3 010 m. For the calculation of OCA it is necessary to know the distance SOC to the obstacle. Thus, the distance THR to obstacle is 6 500 m. From FAF it is 7 800 + 6 500 = 14 300 m.

Category D is calculated distance FAF to SOC:

6 320 + 3 270 = 9 590 m

Distance obstacle to SOC is 14 300 – 9 590 = 4 710 m
Similarly for Category C, the distance is

14 300 – (6 320 + 3 010) = 4 970 m

OCA Category D is calculated:

240 – (4 710 × 0.025) + 30 = 152.3 m = 500 ft

and for Category C:

240 – (4 970 × 0.025) + 30 = 145.8 m = 478 ft

OCA/H to be published:

Category C: 480 (300) ft
Category D: 500 (330) ft

Summary

In the example, a preliminary procedure is based on an assumed location of an NDB as FAF. The next step is to indicate on a detailed chart (1:20 000 to 1:100 000) an area of the terrain that can be explored for a suitable physical location for the equipment. A line indicating the closest acceptable location to the threshold is drawn. Only after the location of the NDB has been decided can a final procedure be designed. Options that were available but not required in this example are as follows:

1) Rotate the racetrack and intermediate areas clockwise around FAF until obstacle 405 is outside the area. A left turn must then be performed after passing FAF inbound in the case of a VOR or an NDB approach.

2) Reverse the direction of the procedure and re-examine the obstacle situation.

3) Apply a reversal procedure instead of a racetrack. Reversal procedures have differently shaped areas, however, entry into the procedure has to be from a track within ±30° of the outbound track of the reversal procedure and this will involve additional manoeuvring and delays within an associated hold procedure.

4) Restrict the speed within the racetrack or reversal procedure, which will reduce the size of the area. Such a restriction shall be indicated on the instrument approach chart. The minimum speed which still permits Category D operations is 185 kt.

5) Increase the height at the FAF by using the maximum (6.5 per cent) final approach gradient.

STEP 12

Radius of visual manoeuvring (circling) area

Figure II-2-1-11 is an example of a chart with areas for four categories of aircraft drawn. Note that a short runway, not to be used by Categories C and D aircraft, shall not affect the limits of the corresponding areas. The chart on which drawings have been made should be retained as a permanent record.

Radii (see Table II-2-1-1) calculated for the IAS specified for visual manoeuvring calculations in Table III-1-2 of PANS-OPS, Volume II at ISA + 15° using the relationship:

radius (NM) = [2 (TAS + 25)] [the greater of (1/60 π or (TAS + 25)/68 620 tan 20)] + the constant for a straight segment from Table III-8-2 of PANS-OPS, Volume II.

Radii (see Table II-2-1-2) calculated for the IAS specified for visual manoeuvring calculations in Table III-1-1 of PANS-OPS, Volume II at ISA + 15° using the relationship:

radius (km) = [2 (TAS + 46)] [the greater of (1/60 π) or (TAS + 46)/127 094 tan 20)] + the constant for a straight segment from Table III-8-1 of PANS-OPS, Volume II.

Table II-2-1-1

Aerodrome elevation (ft)	Radius in NM (km)				
	Cat A	Cat B	Cat C	Cat D	Cat E
0	1.65 (3.06)	2.54 (4.70)	4.02 (7.44)	5.03 (9.32)	6.59 (12.21)
1 000	1.67 (3.09)	2.59 (4.81)	4.11 (7.62)	5.15 (9.54)	6.75 (12.50)
2 000	1.69 (3.12)	2.65 (4.91)	4.21 (7.80)	5.28 (9.77)	6.92 (12.82)
3 000	1.70 (3.16)	2.71 (6.03)	4.31 (7.98)	5.40 (10.01)	7.09 (13.13)
4 000	1.74 (3.22)	2.77 (5.13)	4.41 (8.17)	5.54 (10.25)	7.27 (13.46)
5 000	1.77 (3.28)	2.83 (5.25)	4.52 (8.37)	5.67 (10.51)	7.45 (13.80)
6 000	1.81 (3.35)	2.90 (5.37)	4.63 (8.58)	5.82 (10.77)	7.65 (14.17)
7 000	1.85 (3.42)	2.97 (5.49)	4.75 (8.79)	5.96 (11.05)	7.85 (14.54)
8 000	1.89 (3.50)	3.04 (5.62)	4.87 (9.02)	6.12 (11.33)	8.05 (14.91)
9 000	1.93 (3.58)	3.11 (5.76)	4.99 (9.25)	6.28 (11.63)	8.27 (15.32)
10 000	1.97 (3.66)	3.18 (5.90)	5.12 (9.49)	6.44 (11.93)	8.49 (15.72)
11 000	2.02 (3.74)	3.26 (6.04)	5.26 (9.73)	6.62 (12.25)	8.73 (16.17)
12 000	2.07 (3.83)	3.34 (6.19)	5.40 (9.99)	6.79 (12.58)	8.97 (16.61)

Note.— Given that users of non-SI units frequently use maps with metric scales, metric equivalents are included in parentheses.

Table II-2-1-2

Alt (m)/MSL	Radius in km				
	A	B	C	D	E
0	3.06	4.69	7.49	9.32	12.22
500	3.11	4.86	7.78	9.69	12.71
1 000	3.16	5.04	8.09	10.07	13.24
1 500	3.27	5.23	8.41	10.49	13.80
2 000	3.38	5.43	8.76	10.93	14.39
2 500	3.51	5.64	9.12	11.39	15.01
3 000	3.63	5.86	9.51	11.89	15.68
3 500	3.77	6.1	9.93	12.41	16.39
4 000	3.92	6.35	10.37	12.97	17.15

STEP 13

Holding

A one-minute holding, based on NDB, is designed to coincide with the racetrack. Check the obstacle situation with the appropriate template and confirm the minimum height.

STEP 14

Instrument approach chart tables

The "time to fly distance FAF to MAPt" table

This table is calculated with the following formula:

$$\frac{3\ 600 \times D}{GS} = T \text{ (in seconds)}$$

where D = distance FAF to MAPt and GS = ground speed.

In Discussion Step 11, the distance FAF to MAPt was determined to be 6 320 m or 3.41 NM. With non-SI units the following value for 120 kt is calculated:

$$\frac{3\ 600 \times 3.41}{120} = 102.3 \text{ s} = 1 \text{ min } 42 \text{ s}$$

120 kt = 222 km/h

With SI units the following is calculated:

$$\frac{3\ 600 \times 6.32}{222} = 102.49 \text{ s} = 1 \text{ min } 42 \text{ s}$$

The "rate of descent" table

This table is calculated with the following formula:

$$\frac{GS \times 1\ 000 \times \text{descent gradient (or tan angle)}}{3\ 600} = \text{m/s}$$

where GS is ground speed in km/h.

For 222 km/h and descent gradient 5 per cent (or tan angle) the following is calculated:

$$\frac{222 \times 1\ 000 \times 0.05}{3\ 600} = 3.08 \text{ m/s}$$

Feet per minute is calculated with the following formula:

$$\frac{GS \times 6\ 076.1 \times \text{descent gradient (or tan angle)}}{60}$$

Example: For 120 kt and descent 5 per cent:

$$\frac{120 \times 6\ 076.1 \times 0.05}{60} = 608 \text{ ft/min}$$
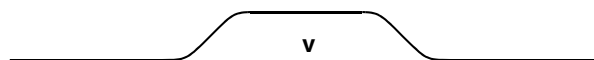
Production of the instrument approach chart

The specifications for the instrument approach chart layout are contained in Annex 4 and the *Aeronautical Chart Manual* (Doc 8697). Two instrument approach charts designed in this chapter, one based on standard units, one on non-standard units, are presented in Figures II-2-1-12 and II-2-1-13.

Figure II-2-1-1

Figure II-2-1-2

MINIMUM SECTOR ALTITUDE   Aerodrome: DONLON/Slipton

Scale 1 : 1 000 000

Centered on: NDB SCN	Position: 562630N042130E	Elevation: 65 M MSL
SECTOR 000° – 090°	Obstacle elevation 560 M 1 840 FT	MNM SECT ALT 2 900 FT MSL
SECTOR 090° – 180°	Obstacle elevation 445 M 1 380 FT	MNM SECT ALT 2 400 FT MSL
SECTOR 180° – 270°	Obstacle elevation 575 M 1 887 FT	MNM SECT ALT 2 900 FT MSL
SECTOR 270° – 360°	Obstacle elevation 585 M 1 920 FT	MNM SECT ALT 3 000 FT MSL

**Figure II-2-1-3.   Map elevations in metres. Spot elevations indicated on the map
are ground elevations. A margin of 25 m for vegetation has been added.
The SE quadrant is dominated by a mast.**

Figure II-2-1-4. Calculation of turn altitude.

Figure II-2-1-5

Figure II-2-1-6

Secondary area

Primary area

Obstacle clearance 75 m

Runway

0   1   2 km

Final approach area

10.3°

FAF

NDB

2.3 km (1.25 NM)   2.3 km (1.25 NM)

63

80

25.5 mm

30.5 mm

Figure II-2-1-7

Figure II-2-1-8

Figure II-2-1-9

$d_o =$
Cat A 5 120 m
Cat B 5 090
Cat C 4 970
Cat D 5 120

Start of climb

Cat A 1 980
Cat B 1 720
Cat C 1 630
Cat D 1 670

A 890
B 1 140
C 1 380
D 1 600

1:40
2.5%

SOC

6 320 m

FAF

NDB

MAPt

Runway

SOC

d_2

x

1:40
2.5%

A 2 870
B 2 660
C 3 010
D 3 270

Start of climb

Figure II-2-1-10

Figure II-2-1-11

INSTRUMENT
APPROACH
CHART - ICAO

AERODROME ELEV 54 m
HEIGHT RELATED TO
THR RWY 11 R - ELEV 53 m

DONLON CONTROL 125.05
SLIPTON TWR 118.70

DONLON/Slipton
NDB 11 Cat C/D

MNM SECT ALT
900   46 km

MNM SECT ALT
870   46 km

BEARING ARE MAGNETIC
ALTITUDES, ELEVATIONS
AND HEIGHTS IN METRES

VAR 1° W 1990

04° 10'   04° 20'   04° 30'

180°   18.5 km

56° 30' N   56° 30'

FAF
360 SCN

270°

275
(221)   105°

090°   HOLDING
MNM 640

285°   80
(26)

RACETRACK 1 MIN   240
(186)

56° 20'   56° 20'

405
(351)

MNM SECT ALT
900   46 km

360°

MNM SECT ALT
720   46 km

04° 10' E   04° 20'   04° 30'

TRANSITION ALTITUDE 1 400 m MSL

FAF
SCN

MSA or above

1 MIN

Climb straight ahead
to 720 (670)

640
(590)

405
(351)

105°

460
(410)

5.0%

MAPt

240
(186)

275
(221)

80
(26)

ELEV 54 m   VASIS 5.0%

20 km   15   10   ←6.3 km→   0   5   10

OCA(H)			Distance SCN - MAPt 6.3 km							
Cat of ACFT	Cat C	Cat D	Speed	km/h	200	225	250	275	300	325	350
Straight-in	150 (100)	155 (105)	Time	min:s	1:53	1:41	1:31	1:22	1:16	1:10	1:05
Circling	360 (310)	435 (385)	Rate of descent / GS	m/s	2.8	3.1	3.5	3.8	4.2	4.5	4.9

Figure II-2-1-12

INSTRUMENT APPROACH CHART - ICAO

AERODROME ELEV 178 FT
HEIGHT RELATED TO
THR RWY 11 R - ELEV 174 FT

DONLON CONTROL 125.05
SLIPTON TWR 118.70

DONLON/Slipton
NDB 11 Cat C/D

MNM SECT ALT
3000   25 NM

MNM SECT ALT
2900   25 NM

BEARING ARE MAGNETIC
ALTITUDES, ELEVATIONS
AND HEIGHTS IN METRES

VAR 1° W 1990

04° 10'   04° 20'   04° 30'

180°   10 NM

56° 30' N   56° 30'

FAF
360 SCN

1034
(856)

903
(725)   105°   270°

HOLDING
MNM 2100

090°

263
(85)

RACETRACK 1 MIN   285°

788
(610)

56° 20'   56° 20'

1329
(1151)

MNM SECT ALT
2900   25 NM

MNM SECT ALT
2400   25 NM

360°

04° 10' E   04° 20'   04° 30'

TRANSITION ALTITUDE 4500 FT MSL

FAF
SCN

MSA or above

1 MIN

Climb straight ahead
to 2400 (2230)

2100
(1930)

1329
(1151)

105°

903
(725)

1500
(1330)

5.0%

MAPt

788
(610)

ELEV 178 FT   VASIS 5.0%

263
(85)

NM   10   5   3.4 NM   0   5   NM

OCA(H)			Distance SCN - MAPt 3.4 NM										
Cat of ACFT	Cat C	Cat D	Speed	KT	110	120	130	140	150	160	170	180	190
Straight-in	480 (300)	500 (330)	Time	min:s	1:51	1:42	1:34	1:27	1:22	1:17	1:12	1:08	1:04
Circling	1190 (1010)	1430 (1250)	Rate of descent / GS	ft/min	556	610	660	710	760	810	860	910	960

Figure II-2-1-13

Chapter 2

NDB or VOR Off-aerodrome Procedure — Categories A/B Aircraft

Using the example from Chapter 1 of this section, DONLON/Slipton Runway 11 shall be completed with a procedure for Categories A/B aircraft.

STEP 1

See Chapter 1 of this section, Steps 1 and 2.

STEP 2

Intermediate approach area, time outbound in racetrack

The lateral boundary of the intermediate approach area is the same as in Chapter 1 of this section, Step 4 but the length of the area is possibly smaller, depending on the size of the racetrack template used. The size of the racetrack area depends on the nominal outbound time. This time is determined in the same way as in Chapter 1 of this section, Step 5. Construct the same diagram as in Chapter 1 of this section, Figure II-2-1-4. Mark the initial altitude at the altitude at the FAF on the vertical axis as shown in Figure II-2-2-1 below. Plot 1 min descent for Categories A/B and draw maximum descent lines outbound and inbound. With turn altitude at 2 100 ft (640 m) MSL (the same as for Categories C/D), it is necessary to increase the nominal outbound time to 1 min 30 s to remain within the maximum permitted descent limits.

Note.— When different outbound times have been specified, separate instrument approach charts shall be published.

STEP 3

Racetrack area

Note that the racetrack area for 1 min 30 s Categories A/B, (see Figure II-2-2-2) 3 000 ft is contained within the Categories C/D template already used (Chapter 1 of this section). The same minimum outbound height may therefore be specified. Note that it is highly desirable for the heights to be the same for Categories A/B and C/D groups.

STEP 4

Final approach

When the end of the initial missed approach segment (SOC) has been calculated (Step 6), the OCA/H for final approach may be calculated as in Chapter 1 of this section, Step 8.

STEP 5

Missed approach point (MAPt)

It is highly desirable to have a common MAPt for all aircraft categories. The FAF to MAPt distance has already been calculated (Chapter 1 of this section) as 6.32 km (3.41 NM).

STEP 6

Longitudinal tolerance of MAPt area

MAPt longitudinal area is calculated as follows.

Category A aircraft:

Speed = 100 kt IAS. TAS on 1 000 ft MSL is 104 kt

Distance "b" = 0.2 NM

$$\frac{13 \times 104}{3\ 600} = 0.38 \text{ NM}$$

$$\frac{3.4 \times 30}{104} = 0.98 \text{ NM}$$

RSS = $[0.2^2 + 0.38^2 + 0.98^2]^{0.5}$ = 1.07 NM = 1 980 m

X = 0.48 NM = 890 m

The distance MAPt to SOC = 1 980 + 890 = 2 870 m.

SOC distance from FAF is 6 320 + 2 870 = 9 190 m.

Category B aircraft:

Speed = 130 kt. TAS on 1 000 ft MSL is 133 kt.

Distance "b" = 0.2 NM

$$\frac{13 \times 133}{3\ 600} = 0.48 \text{ NM}$$

$$\frac{3.4 \times 30}{133} = 0.77 \text{ NM}$$

RSS = $[0.2^2 + 0.48^2 + 0.77^2]^{0.5}$ = 0.93 NM = 1 720 m

X = 0.61 NM = 1 140 m

The distance MAPt to SOC = 1 720 + 1 140 = 2 860 m (see note below).

SOC distance from FAF is 6 320 + 2 860 = 9 180 for Category B.

Note.— The Category A value is more critical than the Category B value. Although the difference is small in this example, it increases significantly for large FAF to MAPt distances, and the effect is amplified if the minimum as well as the maximum speeds within each category are considered. This is particularly relevant if the procedure is to be used by slow aircraft.

STEP 7

Missed approach area

As in Chapter 1 of this section, Discussion Step 11, the exact values of OCA are calculated:

Category A: 240 – (5 110 × 0.025) + 30 = 142.3 m = 467 ft
Category B: 240 – (5 120 × 0.025) + 30 = 142.0 m = 466 ft

The OCA/H published for Category A/B then becomes 470 m (290 ft), which is the same as final approach OCA/H.

STEP 8

Holding area

The same holding area as Categories C/D applies (see Chapter 1 of this section).

STEP 9

Circling minima

Circling OCA/H have been calculated in Chapter 1 of this section, Figure II-2-1-11.

STEP 10

Instrument approach charts

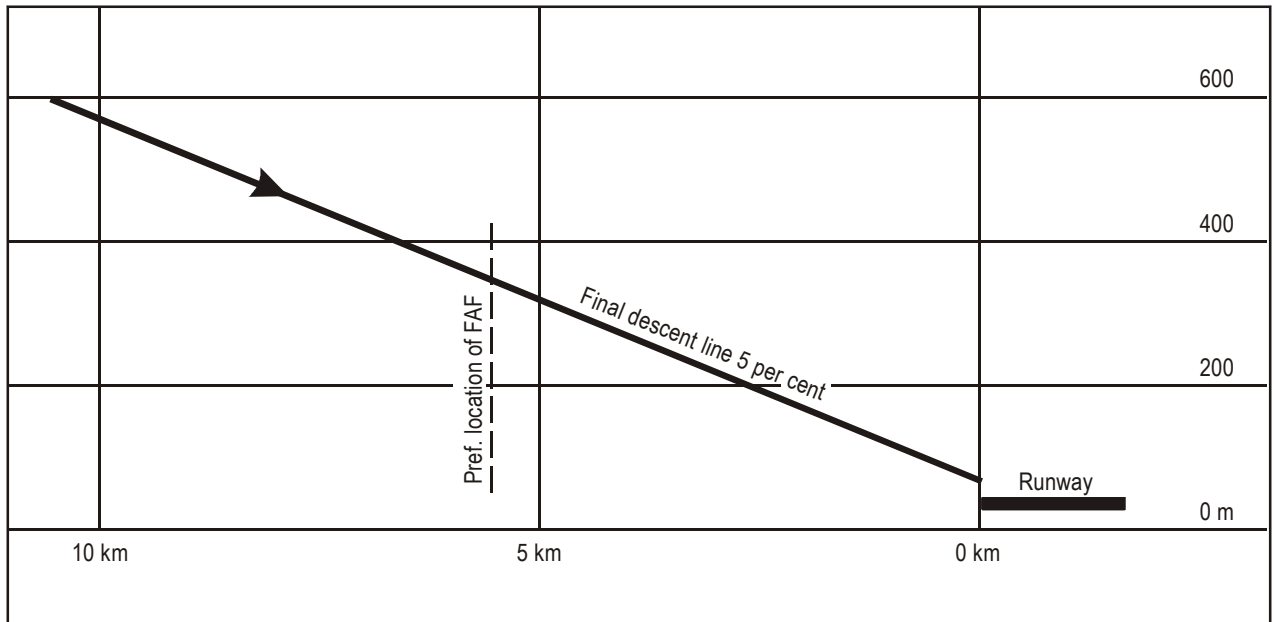Two instrument approach charts designed in this chapter, one based on standard units, one on non-standard units, are presented at the end of the chapter. (See Figures II-2-2-3 and II-2-2-4.)
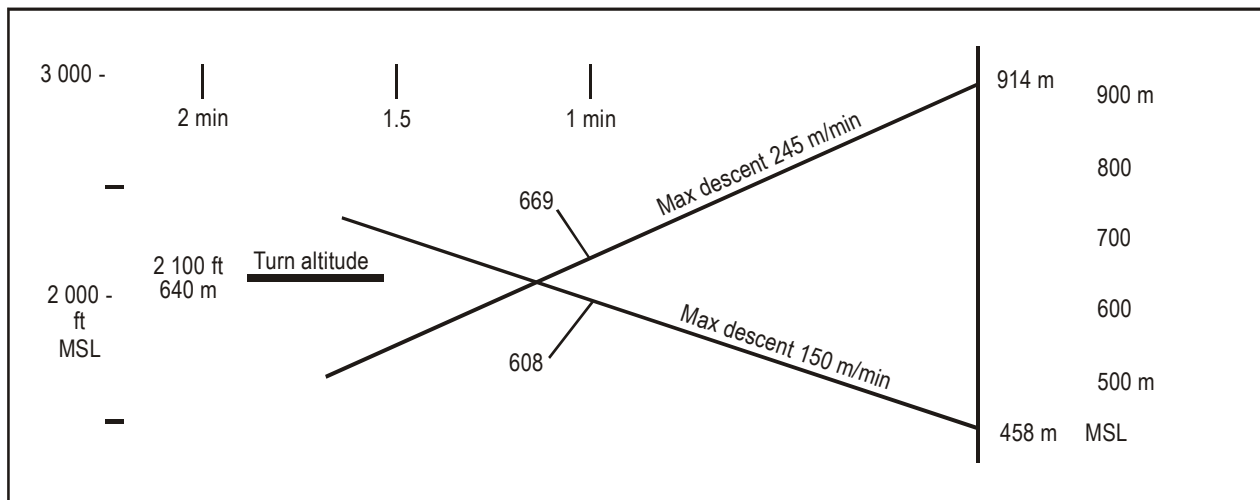
Figure II-2-2-1

Figure II-2-2-2

INSTRUMENT
APPROACH
CHART - ICAO

AERODROME ELEV 54 m
HEIGHT RELATED TO
THR RWY 11 R - ELEV 53 m

DONLON CONTROL 125.05
SLIPTON TWR 118.70

DONLON/Slipton
NDB 11 Cat A/B

MNM SECT ALT
900   46 km

MNM SECT ALT
870   46 km

04° 10'   04° 20'   04° 30'

180°   18.5 km

VAR 1° W 1990

BEARING ARE MAGNETIC
ALTITUDES, ELEVATIONS
AND HEIGHTS IN METRES

56° 30' N   56° 30'

FAF
360 SCN

140
(86)

275
(221)*   105°

270°

090°   HOLDING
MNM 640

RACETRACK 1MIN 30 SEC   ←285°   80
(26)   240
(186)

56° 20'   56° 20'

405
(351)

MNM SECT ALT
900   46 km   360°   MNM SECT ALT
720   46 km

04° 10' E   04° 20'   04° 30'

TRANSITION ALTITUDE 1 400 m MSL

FAF
SCN

MSA or above

1 MIN 30 SEC

Climb straight ahead
to 720 (670)

640
(590)

405
(351)

105°

460
(410)

5.0%

MAPt

240
(186)

275
(221)

80
(26)

ELEV 54 m   VASIS 5.0%

20 km   15   10   ←—8.3 km—→   0   5   10

Distance SCN - MAPt 6.3 km

OCA(H)									
Cat of ACFT	Cat A	Cat B	Speed	km/h	125	150	175	200	225	250
Straight-in	145 (90)	145 (90)	Time	min:s	3:01	2:32	2:10	1:54	1:41	1:31
Circling	230 (180)	330 (280)	Rate of descent / GS	m/s	1.7	2.1	2.4	2.8	3.1	3.5

Figure II-2-2-3

Figure II-2-2-4

Chapter 3

NDB or VOR On-aerodrome Procedure — On-aerodrome Facility (VOR or NDB)

3.1   INTRODUCTION

BROMBURG aerodrome is situated in a mountainous area. There is need for an NDB for en-route navigation and instrument approach. Electric power is available on the aerodrome but it is deemed too expensive to locate an NDB at a distance from the runway. Thus, an on-aerodrome procedure shall be designed. (See Figure II-2-3-4).

The NDB shall be located on an extended runway centre line, if possible, either before or after the runway. With respect to the wind diagram for the aerodrome, Runway 09 is preferable.

3.2   EXAMPLE OF PROCEDURE DESIGN

Data

Runway: 09/27, length = 1 100 m
Aerodrome elevation = 363 m (1 190 ft) MSL
Threshold elevation = 362 m (1 187 ft)
Magnetic bearing = 092°/272°

Magnetic variation: 3°W

Aircraft: Categories A and B only

The following question arises. With regard to the obstacle situation, is it possible to make an on-aerodrome procedure to Runway 09 or 27 or a circling procedure only? The most critical part of this procedure is the large descent necessary in the racetrack/reversal procedure.

STEP 1

Final approach
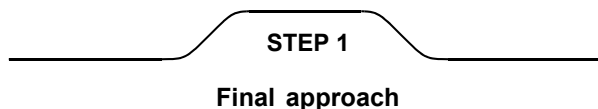
An on-aerodrome facility is one located within 1 NM of the nearest portion of the usable landing surface. This means that on a given runway the facility may be located up to 1 NM before the threshold or 1 NM plus runway length beyond the threshold. These examples represent the two extremes.

In this example it is assumed that the facility, an NDB if possible, be located on the extended runway centre line not closer to the threshold than is possible with regard to the Annex 14 surfaces. This is a runway code letter C. The take-off climb surface has a slope of 2 per cent as this runway is a main take-off runway. Assuming a height of 15 m for the NDB antenna, the facility should not be located closer to the threshold than:

$$\frac{15}{0.02} + 60 = 810 \text{ m}$$

provided that the ground surface is not higher than threshold elevation.

60 m is the distance THR to the line where the Annex 14 surface begins to slope.

If a location of 850 m before the threshold is assumed, an altitude at NDB, followed by a height reduction from NDB to THR with descent gradient 5 per cent to a point 15 m above THR, is calculated:

$850 \times 0.05 + 15 + 362 = 419.5$ m

STEP 2

Minimum sector altitudes
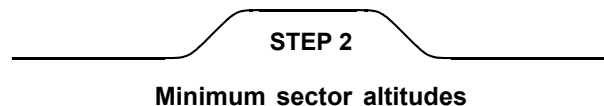
In this example the following MSA, centred on the aerodrome, have been determined (compare with Chapter 1 of this section, Step 4).

Sector NE 4 400 ft, Sector SE 2 600 ft, Sector SW 3 200 ft, Sector NW 5 100 ft MSL.

Discussion

The minimum sector altitudes indicate that the terrain surrounding the aerodrome is high and much height has to be reduced in the procedure. It remains to be seen what time outbound can be applied with regard to the size of the racetrack area.

STEP 3

Descent during the outbound and inbound track in the racetrack
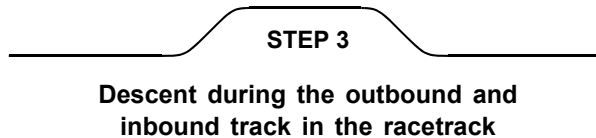
Now a diagram for descent during the outbound and inbound track can be constructed (see Figure II-2-3-1). The NDB is indicated with a vertical line. Outbound descents are indicated for four minimum sector altitudes. Inbound descent is indicated down to 420 m MSL (calculated in Step 1).

The intersection between the outbound descent line from 5 100 ft MSL and the maximum descent inbound line indicates that aircraft approaching the NDB from the NW sector need 3 min outbound, turn altitude 2 700 ft and utilize almost maximum permitted descent. Before determination of time outbound it is necessary to investigate the obstacle situation within the racetrack area with respect to the lowest possible altitude in a turn before the final descent.

STEP 4
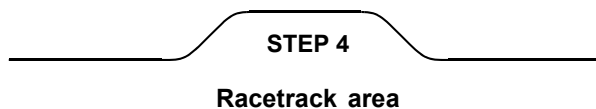
Racetrack area

Develop a template for Categories A/B, 2.0 min outbound, altitude 6 000 ft MSL. A suitable chart scale for this work is 1:100 000 to 1:250 000. Figure II-2-3-2 shows the racetrack area together with the final approach area and straight missed approach area. With this template it is possible to study the effect of obstacles on turn altitude/height as well as OCA/H in the final approach area.

Indicate all significant obstacles around the aerodrome with elevations above MSL (m). Place a template on the chart and examine the obstacles. An NDB location 850 m before the threshold on the extended runway centre line was selected and it was confirmed that the antenna mast did not penetrate the Annex 14 approach surface and take-off climb surface.

A check of the MSA, now centred on the NDB, shall be done.

See Figure II-2-3-2. Two obstacles are indicated. Obstacle 398 is the controlling one. With the addition of MOC 300, the minimum turn altitude becomes 698 (which rounds up to 2 300 ft MSL). Obstacle 600 is located in the secondary area 3.5 mm from the outer limit.

Reduced MOC obstacle 600 is:

$$\frac{3.5}{18.5} \times 300 = 57 \text{ m}$$

Turn altitude is 600 + 57 = 657 m (which rounds up to 2 200 ft MSL).

Obstacle 398 determines the lowest possible turn altitude 2 300 ft MSL.

STEP 5

Determination of time outbound
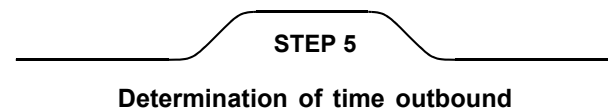
See Figure II-2-3-1. Two turn heights are indicated, 2 700 and 2 300 ft MSL. If turn altitude 2 700 ft MSL is selected, a check with a template for 3 min outbound shall be done. If no obstacles raise the turn altitude height, then the time outbound will be 3 min for aircraft arriving from all directions. BROMBURG aerodrome is so located that most arrivals come from the SW and SE quadrants at or below 3 200 ft. Therefore, 2 min outbound and turn altitude 2 300 ft is preferable. Aircraft arriving from NW and NE must reduce height in an extra hold orbit to 2 300 ft before entering the racetrack. Aircraft arriving from the SE and SW need not more than 2 min outbound in racetrack.

Discussion

In the example the NDB was located on the extended RWY centre line. For an illustration of an offset track, see Chapter 4 of this section, Step 1.

In Step 2 it was mentioned that an NDB may also be located after THR. This is illustrated in the following example.

Assume that an on-aerodrome procedure is to be designed to RWY 27 on BROMBURG aerodrome, utilizing NDB BB. The distance THR to NDB is 1 100 + 850 = 1 950 m

after THR 27. As the horizontal axis in Figure II-2-3-1 indicates time, compensation for the distance 1 950 m must be converted to time (see Figure II-2-3-3).

Speed outbound in Category A is 110 kt IAS or 118 kt TAS or 1.97 NM/min = 3.05 km per min.

The distance 1 950 m is flown in:

$$\frac{1.95}{3.05} = 0.64 \text{ min}$$

One minute is needed to compensate for the distance THR to NDB flown by the slowest category aircraft. From a point 15 m above THR the maximum descent inbound line is drawn and from NW MSA altitude 5 100 ft MSL, the maximum descent outbound line. When indicating the lowest available turn altitude, 2 400 ft MSL, it is apparent that if the maximum descent inbound time shall not be exceeded, a time outbound of 3 min 30 s is required, and to this point maximum descent outbound from 5 100 m MSL is required.

According to the PANS-OPS, extension of outbound timing beyond 3 min must only be considered in exceptional circumstances.

A racetrack template for 3 min 30 s has to be constructed to check for obstacles.

The alternative is instrument approach to RWY 09, followed by circling to RWY 27.

STEP 6

Alignment
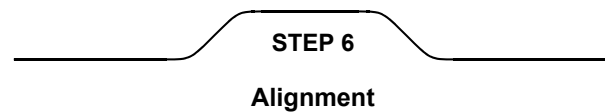
The extended runway centre line is the inbound track, magnetic bearing 092°.

STEP 7

Final approach area — OCA/H
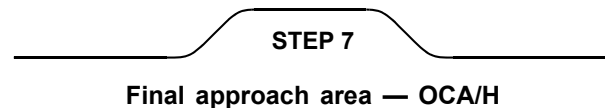
See Figure II-2-3-2. MOC in the final approach area is 90 m (295 ft), reduced in secondary areas. Obstacle 398 determines OCA which becomes 398 + 90 = 488 m. This gives an exact value of 1 601 ft, which rounds to an OCA of 1 610 ft. OCH is 488 − 363 = 125 m (410 ft). This is already a "rounded" increment.

STEP 8

Missed approach

See Figure II-2-3-2. The missed approach point (MAPt) is located at the NDB. The fix tolerance is 0 m. The distance MAPt to SOC is d + X for Categories A and B, where the d and the X values are obtained from the PANS-OPS (see Chapter 1 of this section, Step 10):

Category A: 0.1 + 0.48 = 0.58 NM = 1.1 km
Category B: 0.12 + 0.61 = 0.73 NM = 1.4 km

It is assumed that no objects affect the missed approach. Therefore, final approach OCA/H = procedure OCA/H.

STEP 9
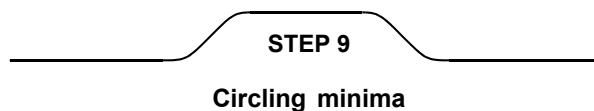
Circling minima

The following circling minima have been determined (see Chapter 1 of this section, Step 12):

Category A: 1 580 (383). Category B: 1 620 (423) ft; however, they shall not be published lower than the straight-in OCA/H.

STEP 10

Holding

The holding procedure coincides with the racetrack and has already been checked.

STEP 11

Instrument approach chart tables

No tables, except OCA/H, are required for this type of procedure.
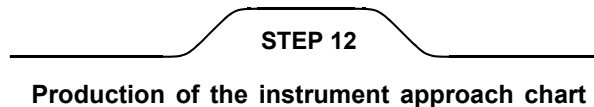
STEP 12

Production of the instrument approach chart

Two instrument approach charts designed in this chapter, one based on standard units, one on non-standard units, are presented in Figures II-2-3-4 and II-2-3-5.
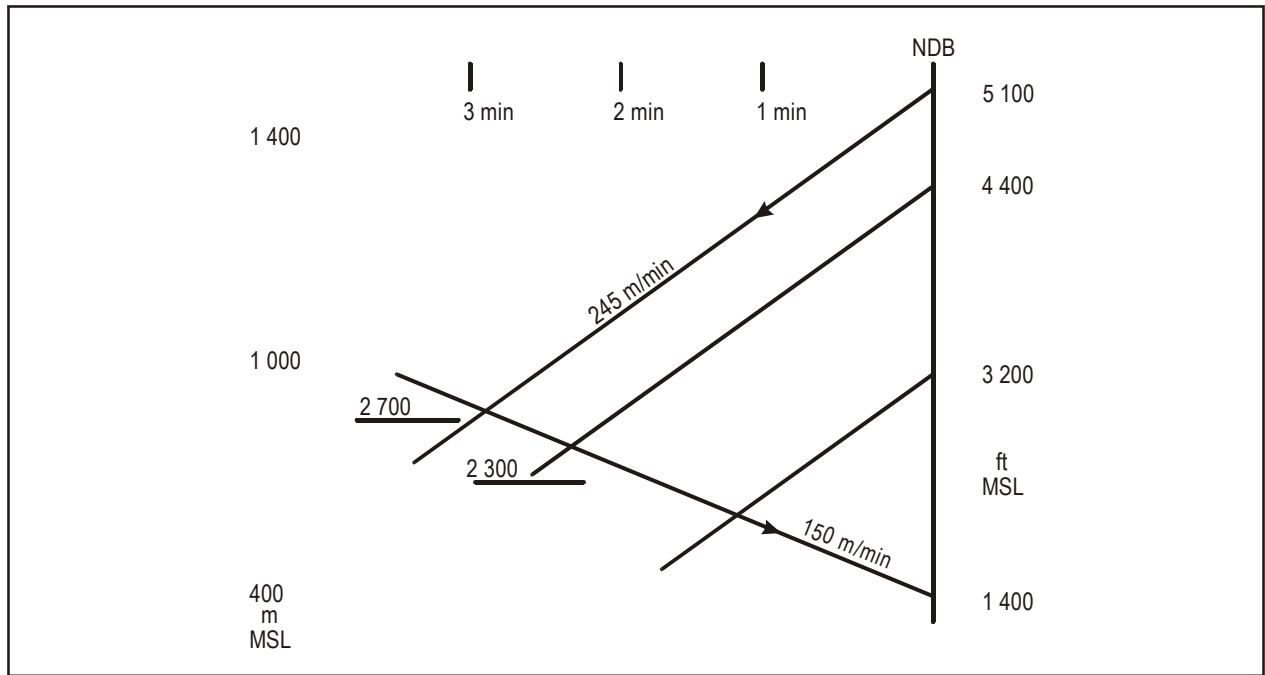
Figure II-2-3-1
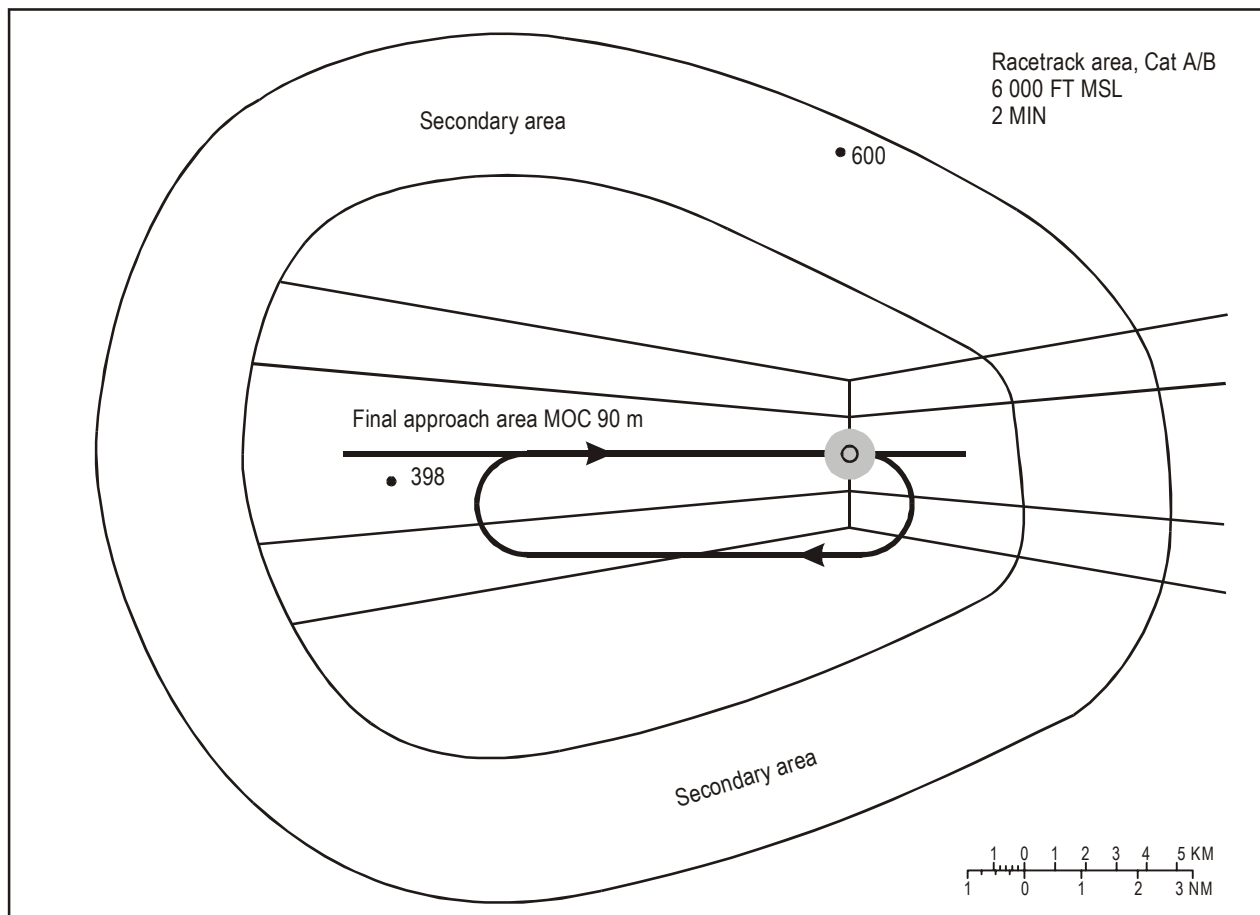
Figure II-2-3-2

Figure II-2-3-3

INSTRUMENT
APPROACH
CHART - ICAO

AERODROME ELEV 363 m
HEIGHT RELATED TO
THR RWY 09 - ELEV 362 m

BROMBURG TWR 118.10
BROMBURG APP 124.50

BROMBURG
NDB 09

MNM SECT ALT
1560   46 km

05° 00'

05° 10'

05° 20'

MNM SECT ALT
1350   46 km

VAR 3° W 1990

BEARING ARE MAGNETIC
ALTITUDES, ELEVATIONS
AND HEIGHTS IN METRES

180°

18.5 km

60° 30' N

• 600
(237)

60° 30'

• 405
(42)

• 403
(40)

NDB
360 BB

270°

090°

092°

HOLDING
MNM 700

• 391
(28)

• 398
(35)

272°

RACETRACK 2 MIN

60° 20'

60° 20'

MNM SECT ALT
970   46 km

360°

MNM SECT ALT
780   46 km

05° 00' E

05° 10'

05° 20'

TRANSITION ALTITUDE 1 700 m MSL

Arrival from NE and NW sector descending in hold

BB

MSA or above (except from NE and NW)

2 MIN

700
(340)

Climb to 780 (420)
return to BB

398
(35)

092°

ELEV 363 m

15 km   10   5   0   5   10   15 km

OCA(H)		
Cat of ACFT	Cat A	Cat B
Straight-in	490 (125)	
Circling	490 (125)	515 (150)

Figure II-2-3-4

INSTRUMENT APPROACH CHART - ICAO

AERODROME ELEV 1191 m
HEIGHT RELATED TO
THR RWY 09 - ELEV 1188 m

BROMBURG TWR 118.10
BROMBURG APP 124.50

BROMBURG
NDB 09

MNM SECT ALT
5100   25 km

MNM SECT ALT
4400   25 km

BEARING ARE MAGNETIC
ALTITUDES, ELEVATIONS
AND HEIGHTS IN METRES

VAR 3° W 1990

05° 00'   05° 10'   05° 20'

180°   10 NM

•1969
(778)

60° 30' N   60° 30'

1329
(138)

•1323
(132)

NDB
360 BB

092°   270°

090°
1306 •
(115)

HOLDING
MNM 2300

•1283
(92)

← 272°

RACETRACK 2 MIN

60° 20'   60° 20'

MNM SECT ALT
3200   25 NM

MNM SECT ALT
2600   25 NM

360°

05° 00' E   05° 10'   05° 20'

TRANSITION ALTITUDE 5500 ft MSL

Arrival from NE and NW sector
descending in hold

BB

MSA or above (except from NE and NW)

2300
(1110)

2 MIN

Climb to 2600
(1410)
return to BB

1306
(115)

092°

ELEV 1191 FT

| NM | 10 | 5 | 0 | 5 | 10 | NM |

OCA(H)		
Cat of ACFT	Cat A	Cat B
Straight-in	1610 (410)	
Circling	1610 (410)	1690 (500)

Figure II-2-3-5

Chapter 4

VOR/DME Procedure

4.1   INTRODUCTION

A VOR/DME is to be installed on SIRPA aerodrome. In this example an instrument approach procedure to Runway 09 will be designed, comprising a racetrack and a standard arrival route from airway Amber 5.

Because of technical considerations, the VOR/DME equipment must be located north of the runway centre line.

Note.— Normally a location of the facility on the runway extended centre line is preferable.

4.2   EXAMPLE OF PROCEDURE DESIGN

Data

Runway: 09/27, length = 2 000 m
           Threshold elevation = 460 m (1 510 ft)
           Aerodrome elevation = 466.3 m (1 530 ft)
           Magnetic bearing = 087°/267°

Magnetic variation: 1°W

Aircraft: Categories A to D

The VOR/DME facilities are co-located 950 m after THR 09 and 300 m north of the centre line (see Figure II-2-4-1).

Racetrack

The racetrack is to be designed as an "on-aerodrome" procedure as presented in Chapter 3 of this section and shall be published on a separate instrument approach chart. This procedure is not designed here.

Arrival Route

Airway Amber 5 is centred on radial R-220 DON. An arrival route shall be designed using a DME arc without a reversal/racetrack procedure.

The intermediate approach fix (IF) shall be located at the extended final approach track.

The initial approach fix (IAF) shall be located on the airway centre line.

The lowest available altitude in the airway is 5 000 ft.

STEP 1

Inbound track — alignment

The FAF is a DME fix on final approach. Distance from the threshold depends on the obstacle situation in the intermediate area and has to be assessed.

The final approach track should intercept the runway centre line inside the visibility limit (normally 1 600 m). The intercept point distance to threshold must be based on operational judgement. However, it shall not intersect the runway centre line closer than 1 400 m to the threshold.

The following factors are considered:

a)   OCA/H — the need to identify runway before turn;

b)   aircraft size — larger/faster aircraft require a longer distance for turn, etc.

In this example, a distance of 1 400 m before the threshold to the intercept angle is selected and calculated:

$$\text{Tan intercept angle} = \frac{300}{1\,400 + 950} = 0.1277$$

Thus, intercept angle = 7.2°

Thus, radial 260 would make a suitable final approach track.

Considering the altitude next, aircraft on the nominal 5 per cent approach gradient would be $(1\,100 \times 0.05) + 15 = 55$ m above threshold. Therefore an OCH higher than 55 m is satisfactory with respect to a) above.

STEP 2

Profile on final approach
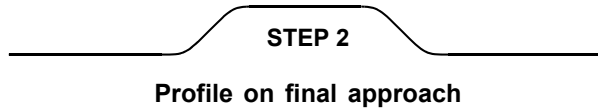
See Chapter 1 of this section, Step 1 and Figure II-2-4-2.

STEP 3

Intermediate and final approach segment
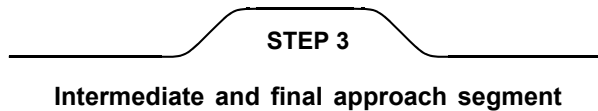
Draw the preliminary boundaries of the final and intermediate areas symmetrically along radial R-260, as is done in Figure II-2-4-3, beginning at the VOR (semi-width 1 NM at VOR, splay 7.8°). Indicate secondary areas. Examine the obstacle situation. Indicate two obstacles in the profile by "poles", as is done in Figure II-2-4-2, the highest of which is 650 m at a distance 10 800 m from the threshold. A FAF can be located either after the obstacle (between the obstacle and THR) or before, depending on the lowest possible turn altitude/height in the turn before the inbound track. The closest DME distance before passing obstacle 650 is 7 DME.

Estimate a provisional FAF location at 7 NM. Indicate this distance on the inbound track on the chart. See Figure II-2-4-2. Descent must begin at or before a distance of 7 DME (12 964 m) if a nominal descent of 5 per cent is not to be exceeded.

Within the final approach area are two obstacles, the highest of which is 650 m MSL, situated at approximately 6 NM (12 km) before the VOR (see Figure II-2-4-2). This obstacle determines OCA/H as follows:

Distance FAF to THR =
12 964 – 950 = 12 014 m = 6.5 NM.

For each one-tenth of a mile over 6 NM, 1.5 m shall be added to MOC 75 m. MOC = 75 + 8 = 83 m. OCA = 650 + 83 = 733 m, which rounds to 2 410 ft. Corresponding OCH values are 460 m (900 ft).

STEP 4

Stepdown fix — final approach OCA/H
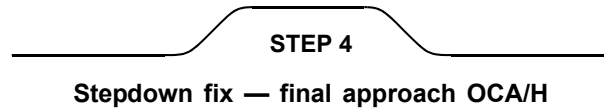
The obstacle 650 can, however, be overcome with a stepdown fix, located closer to the THR. The simplest solution is a graphical one. Lowest permissible altitude above the obstacle is 650 + 83 = 733 m. Draw a horizontal line at 733 m MSL to cross the descent line (which is done at about range 6 500 m from DME). Four DME (7 408 m) is more distant, is suitably located as a stepdown fix and gives an acceptable gradient to a point 15 m above the threshold.

Indicate the fix as is done in Figure II-2-4-2.

The obstacle after 4 DME has an elevation of 510 m: OCA/H if the 7 DME fix is received now reduces to 510 + 75 = 585 (125) m or 1 920 (400) ft.

Altitude at FAF is 1 050 m (3 400 ft) and gives an overall final approach gradient of 4.8 per cent.

The distance from threshold to the point on the nominal descent path, where OCA/H is attained, is calculated as follows (see Step 1 b)):

$$\frac{125 - 15}{0.048} = 2\,292 \text{ m}$$

Note.— The slant effect on DME fixes, close to the DME location, should be checked. Ground elevation at the DME facility has been measured to be 60 m MSL.

DME altitude is 1 050 m. 1 050 – 60 = 990. 7 DME = 12 960 m (hypotenuse in the following calculation):

$$[12\,960^2 - 990^2]^{0.5} = 12\,922$$

12 960 – 12 922 = 38 m. The slant effect is negligible.

STEP 5

DME distances versus altitude/height
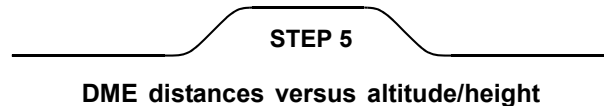
In the example, the stepdown fix is located so that an overall gradient of 0.048 will satisfy the stepdown fix and the descent to threshold +15 m. Where the stepdown fix has to be located close to the runway and a steeper gradient is necessary in the last stages of the approach, the advisory altitudes/heights adjust accordingly.

For the table on the instrument approach chart the following values are calculated.

1) DME is too close to the threshold.

2) DME is 3 704 – 950 = 2 754 m from the threshold. The nominal descent path height above the threshold is (2 754 × 0.048) + 15 = 147 m or 483 ft, altitude 607 m or 1 993 ft.

3) DME: [(2 754 + 1 852) × 0.048] + 15 = 236 m or 774 ft, altitude 696 m or 2 284 ft.

4) DME: (6 458 × 0.048) + 15 = 325 m or 1 066 ft, altitude 785 m or 2 576 ft.

5) DME: (8 310 × 0.048) + 15 = 414 m or 1 358 ft, altitude 874 m or 2 868 ft.

6) DME: (10 162 × 0.048) + 15 = 503 m or 1 650 ft, altitude 963 m or 3 159 ft.

STEP 6

Intermediate approach segment

See PANS-OPS, Volume II, Figure III-26-1. The lower figure is applied.

The length of the intermediate area shall not be less than 5 NM, therefore, IF shall be located at the inbound track at a distance of 12 DME.

The DME arc ends at IF. The radius of the DME arc is therefore 12 DME. A lead radial can be calculated as follows:

See PANS-OPS, Volume II, Figure III-4-1. Two NM of lead, divided by the distance from the DME location gives a tangent of 2/12 = 0.167, which corresponds to 10°.

See Figure II-2-4-4. The lead radial shall be 260 – 10 = 250 or R-250.

The DME arc joins a radial from a VOR, co-located with DME. In the case where the arc joins an ILS course line, centred on the RWY centre line, the angle may exceed 90°.

STEP 7

Initial approach segment

The radius of the DME arc shall be 12 NM. The turn initiation distance on the airway must exceed at least 2 NM to permit a comfortable turn. This is based on operational judgement. Fourteen DME is a suitable distance.

STEP 8

The obstacle situation in the initial and intermediate approach areas

On a map, scale 1:100 000 to 1:250 000, draw primary and secondary areas for the initial and intermediate areas. Check obstacles in the primary and secondary areas. Descent from the lowest en-route altitude in the airway can be made to a suitable altitude in the initial arrival segment, in this case 1 050 m MSL (3 500 ft MSL) if no obstacle exists.

STEP 9

Minimum sector altitudes (MSA)

It is assumed that the following MSA, centred on the VOR, have been determined:

Sector NE 4 000 ft, Sector SE 4 000 ft, Sector SW 4 400 ft (4 000 ft within 10 DME), Sector NW 4 800 ft MSL.

Note.— Sector SW utilizes two MSA values. Here it is assumed that the obstacle controlling the 4 400 ft MSA is at least 5 NM beyond the 10 DME arc.

STEP 10

Holding

Holding should be specified at the IAF or it could coincide with the racetrack, or both.

STEP 11

**MAPt, longitudinal tolerance
of MAPt area, etc.**

See Chapter 10 of this section, Turning Missed Approach –
Non-Precision.

STEP 12

Circling minima

Circling minima shall be calculated as in Chapter 1 of this
section, Step 12. Minima presented on the instrument
approach chart in Figures II-2-4-4 and II-2-4-5.

*Note.— The missed approach procedure in Chapter 9 of
this section is a continuation of the procedure presented in
this chapter.*

STEP 13

Instrument approach chart

Tables "Final approach distance/altitude (height)" (see Step 6)
and "Rate of descent/GS" shall be published on the
instrument approach chart (see Figures II-2-4-4 and II-2-4-5).
Regarding calculation of the rate of descent, see Chapter 1 of
this section, Step 14. The OCA/H values shown on the chart
are determined by missed approach obstacles (see Chapter 9
of this section).

Figure II-2-4-1

Figure II-2-4-2

VOR/
DME

R-260

FAF 7 DME

Secondary area

Primary area
MOC 150 m

Secondary area

MOC 300 m

Secondary area

ARC 12 DME

IAF 14 DME

MOC 300 m

IF 12 DME

MOC 300 m

MOC 300 m

Secondary area

Primary area

Primary area

Secondary area

R-250
Lead radial

1 0 1 2 3 4 5 km

1 0 1 2 3 NM

Figure II-2-4-3

INSTRUMENT
APPROACH
CHART - ICAO

AERODROME ELEV 466 m
HEIGHT RELATED TO
THR RWY 08 - ELEV 460 m

SIRPA CONTROL 126.05
SIRPA TOWER 118.10

SIRPA
VOR/DME 09

06° 20'   06° 30'   06° 40'

VAR 1° W 1990

MNM SECT ALT
1470   46 km

720
(260)

BEARING ARE MAGNETIC
ALTITUDES, ELEVATIONS
AND HEIGHTS IN METRES
DME DISTANCE ARE
RELATED TO DON DME

MNM SECT ALT
1230   46 km

R-360

R-270

13.0 km

650
(190)

510
(50)

VOR/DME
DONLON
114.6 DON
93X

R-090

R-260

22.2 km

R-260

IF

FAF

56 25.0 N
006 20.5 E

HOLDING
MNM 1050

659
(199)

280°

680
(220)

805
(345)

60° 30'

R-250

ARC 22.2 km

56° 20' N

Inbound track offset 8°
from RWY centreline

56°
20'

18.5 km

25.9 km

IAF

MNM SECT ALT
1350   46 km
1200 within 18 km

R-220

HOLDING
MNM 1550

220°

MNM SECT ALT
1230   46 km

AWY AMBER 5

R-180

56° 10'   05° 00' E   06° 20   06° 30   06° 40

56°
10'

TRANSITION ALTITUDE 1500 m MSL

VOR/DME
DON

Missed approach speed restricted
to 340 km/h max until after turn.
Climb straight ahead to 830 (370)
turn right to 170° and continue
climb to MSA.

1550

1050 (590)

720
(260)

650
(190)

785
(325)

4.8%

IAF 25.9 km

IF 22.2 km

FAF 13.0 km

7.4 km

ELEV 460 m   VASIS 4.8%

25 KM   20   15   10   5   0   5   10   15 km

OCA(H)				Distance	11.1 km	9.3 km	7.4 km	5.6 km	
Cat of ACFT	Cat A	Cat B	Cat C	Cat D	Altitude (height)	965 (505)	875 (415)	785 (325)	700 (240)
Straight-in	610 (150)	615 (155)	625 (165)	630 (170)	Speed	km/h	100	150	200	250	300	350
Circling	750 (290)	770 (310)	925 (465)	925 (465)	Rate of descent/GS	m/s	1.3	2.0	2.7	3.3	4.0	4.7

Figure II-2-4-4

INSTRUMENT APPROACH CHART - ICAO

AERODROME ELEV 1530 ft
HEIGHT RELATED TO
THR RWY 08 - ELEV 1510 ft

SIRPA CONTROL 126.05
SIRPA TOWER 118.10

SIRPA
VOR/DME 09

VAR 1° W 1990

MNM SECT ALT
4800   25 NM

BEARING ARE MAGNETIC
ALTITUDES, ELEVATIONS
AND HEIGHTS IN FEET
DME DISTANCE ARE
RELATED TO DON DME

06° 20'
• 2263 (853)

06° 30'

06° 40'

R-360

MNM SECT ALT
4000   25 NM

R-270

7 DME

• 2133 (623)

• 1674 (164)

VOR/DME
DONLON
114.6 DON
93X

R-090

12 DME

R-260

R-260

IF

FAF
56 25.0 N
006 20.5 E

HOLDING
MNM 3500

• 2162 (652)

2641 (1131)

60° 30'

280°

• 2231 (721)

R-250

ARC 12 DME

56° 20' N

Inbound track offset 8°
from RWY centreline

56° 20'

10 km

14 DME

IAF

MNM SECT ALT
4400   25 NM
4000 within 10 NM

R-220

HOLDING
MNM 1550

220°

MNM SECT ALT
4000   25 NM

AWY AMBER 5

R-180

56° 10'

56° 10'

05° 00' E

06° 20'

06° 30'

06° 40'

TRANSITION ALTITUDE 5000 ft MSL

VOR/DME
DON

Missed approach speed restricted
to 185 kt max until after turn.
Climb straight ahead to 2730 (1220)
turn right to 170° and continue
climb to MSA.

5 000

3500 (1990)

IAF 14 DME

IF 12 DME

2363 (853)

FAF 7 DME

2133 (623)

2580 (1070)

4 DME

4.8%

ELEV 1510 ft

VASIS 4.8%

NM   10   5   0   10

OCA(H)				Distance	6 DME	5 DME		4 DME	3 DME
Cat of ACFT	Cat A	Cat B	Cat C	Cat D	Altitude (height)	3160 (1650)	2870 (1360)		2580 (1070)	2290 (780)
Straight-in	1990 (480)	2020 (510)	2060 (550)	2060 (550)	Speed	kt	70	100	130	160	190
Circling	2460 (950)	2530 (1020)	3040 (1530)	3040 (1530)	Rate of descent/GS	m/s	340	485	630	780	925

Figure II-2-4-5

Chapter 5

ILS

5.1 INTRODUCTION

The planning of an ILS installation requires careful preparation involving the design of a full ILS procedure. It is important to get information about instrument approach minima in case installation of the equipment involves costs for extra facilities, etc.

The first ILS approach procedure to be designed will normally be a preliminary one.

AROM aerodrome Runway 22 shall be completed with ILS Categories I and II.

A VOR/DME is located 7 300 m SW of THR 04 on the extended runway centre line and serves as a basic facility for VOR/DME procedures to Runway 04/22. Entry into the ILS procedure shall make use of 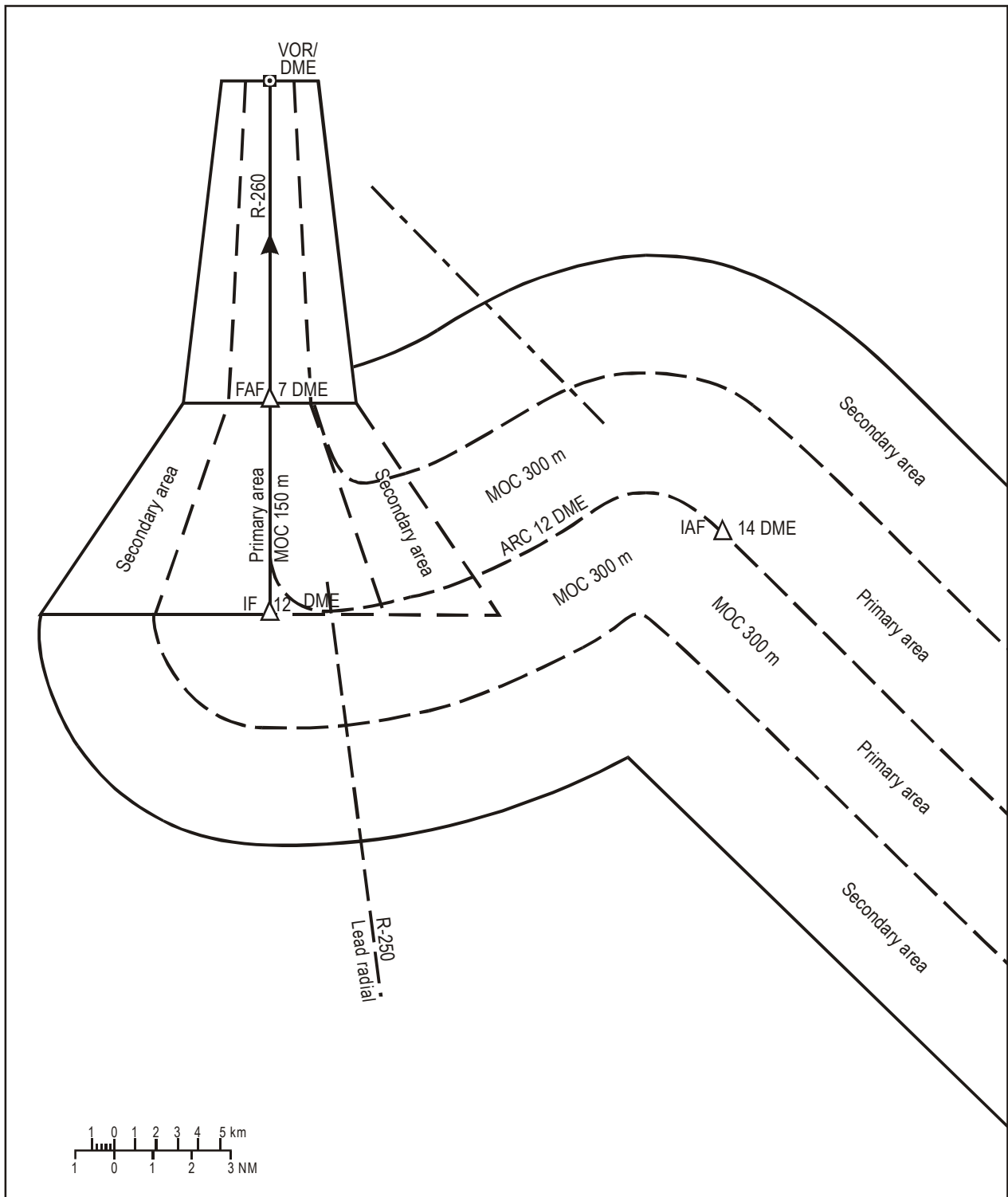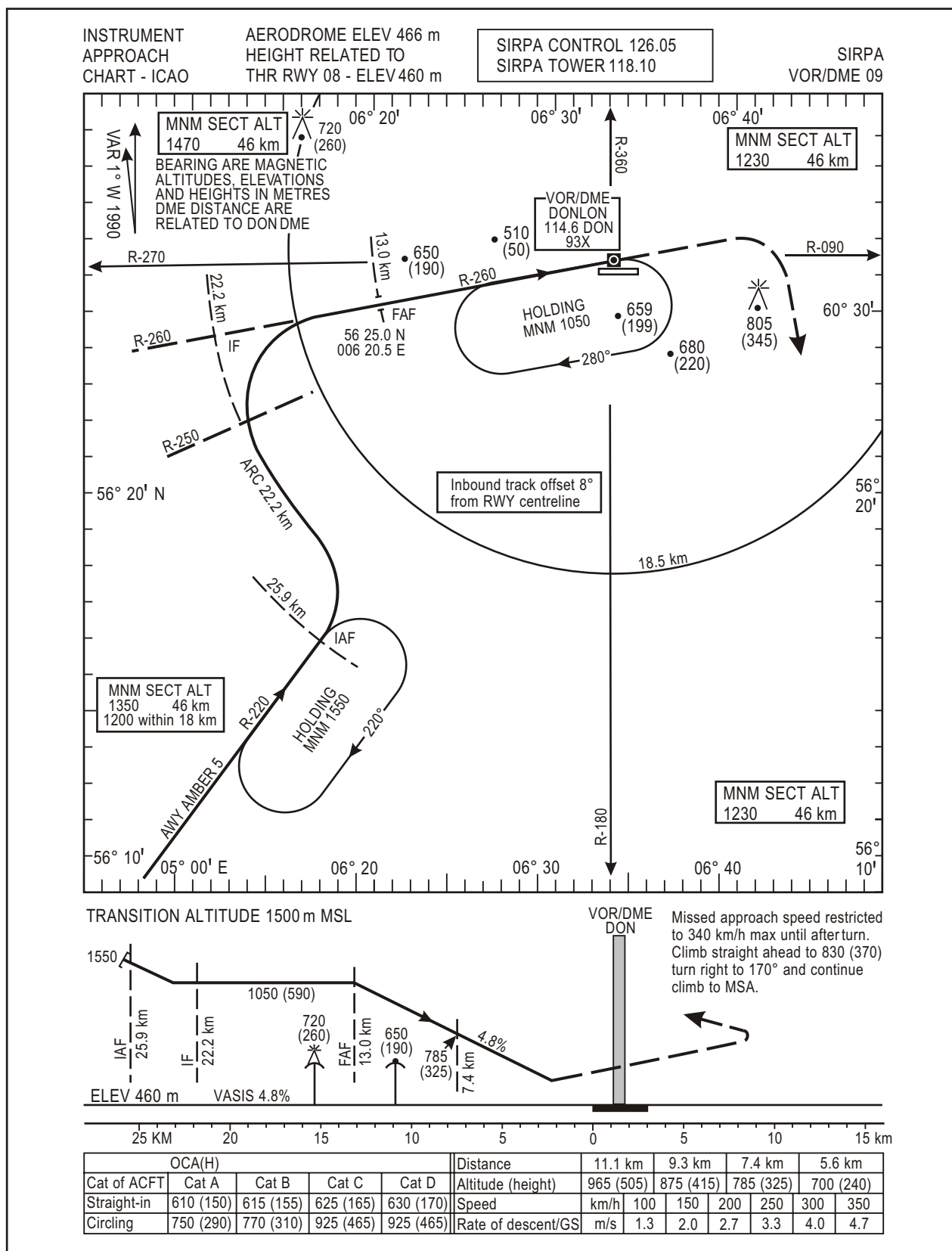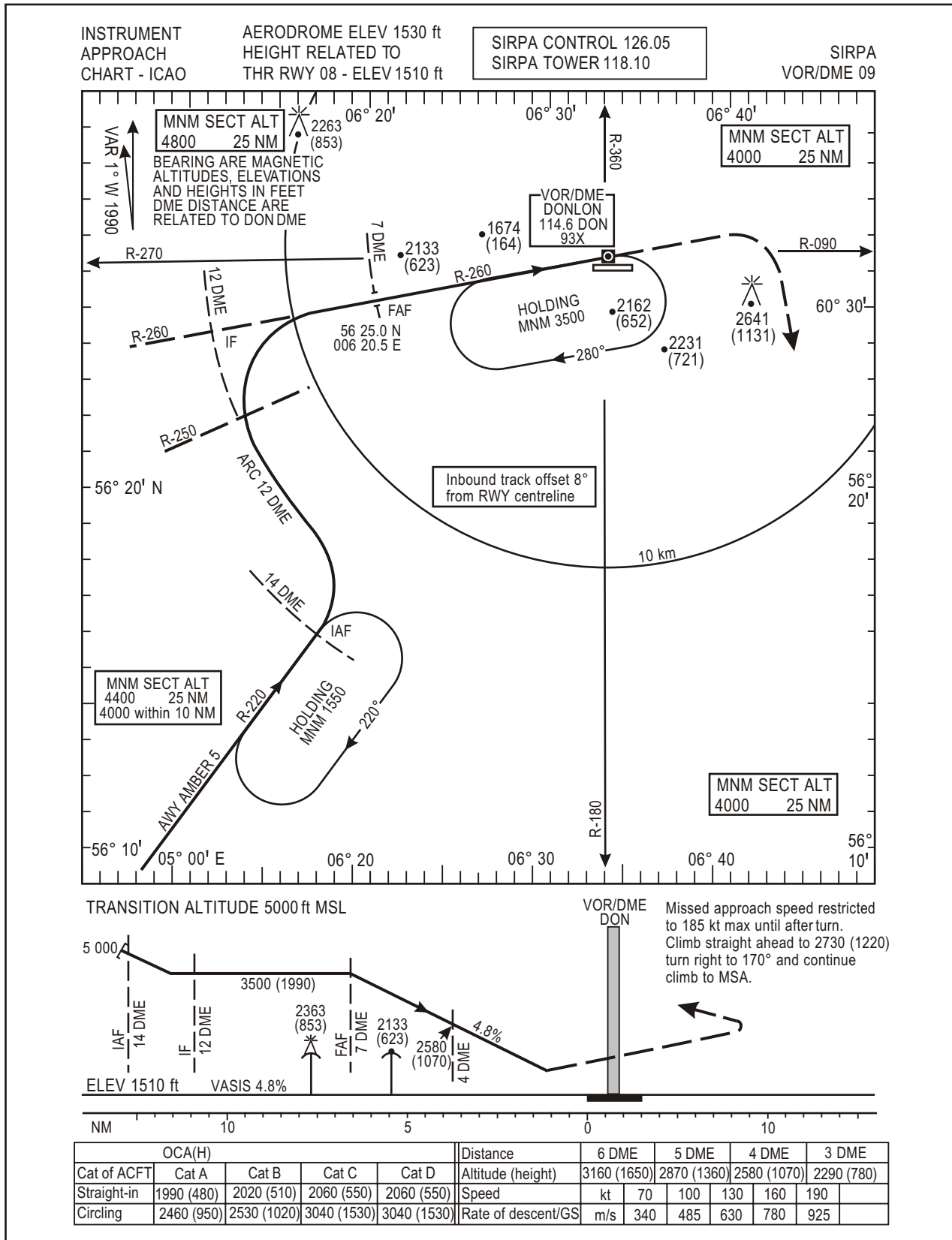four standard routes. A racetrack shall enable omnidirectional entry into the procedure. An NDB shall be located so that it will give optimal benefit in the procedure.

The final approach is executed in a valley. A hill rises to the left and may affect the glide path.

5.2 EXAMPLE OF PROCEDURE DESIGN

Data

Runway: Length = 2 000 m

Threshold elevation = 34 m (110 ft)

Aerodrome elevation = 39.7 m (130 ft)

Magnetic bearing = 040°/220°

Magnetic variation: 1°W

Aircraft: Categories A to D, standard size, 2.5 per cent missed approach gradient, Category I, Category II FD and AP

ILS reference datum height (RDH): 15 m (50 ft)

Proposed GP angle 3° and distance THR – LLZ = 2 400 m

Existing facilities in the vicinity: VOR KAVRAN, VOR TECHO, NDB PARKES

The design of an ILS procedure is divided into four main steps:

1) investigation of the effect of obstacles on ILS basic surfaces;

2) investigation of the effect of obstacles on OAS;

3) requisition of a CRM calculation;

4) design of the procedure as a whole.

PANS-OPS presents three methods of calculating OCA/H: 1) to 3) above. The advantages and disadvantages of these methods are summarized in Table II-2-5-1.

All three methods require careful investigation of the obstacle situation. For obstacles on the aerodrome, a chart on a scale of 1:10 000 to 1:25 000 is required. For more distant obstacles, 1:25 000 to 1:50 000. Contours with 5 or 10 m equidistance are helpful. An allowance for vegetation shall be added to the contours, provided that vegetation exists.

5.3 PRECISION SEGMENT OBSTACLES

Initially it is necessary to estimate a final approach point (FAP) and the termination range of the precision segment.

An initial examination of the obstacles indicates the following.

The GP antenna and holding aircraft may constitute potential obstacles. A small hill is located on the extended runway centre line about 650 m from threshold 22 and

another hill about 500 m north of threshold 22 (see Table II-2-5-2). The slope of a large hill about 3 km northeast of threshold 22 is located below the inbound track. This may affect the glide path angle.

All obstacles have been surveyed and meet ILS accuracy requirements.

After initial examination of the charts, make a list of the obstacles to be investigated. It is preferable to refer all obstacle heights to runway threshold elevation.

Each obstacle should have its own serial number for identification.

x coordinates are positive before the threshold and negative after the threshold.

y values are negative to the left of the inbound track and positive to the right of the inbound track.

In this example, each obstacle shall be regarded as a single obstacle making y_1 and y_2 an equal distance from the inbound track. Heights should be corrected to threshold elevation, which is 34 m MSL. The allowance for vegetation is 15 m.

One of the requirements on which ILS procedures are developed is that for Category II and Category III operations, the Annex 14 inner approach, inner transitional and balked landing surfaces shall not be penetrated.

STEP 1

Annex 14 inner approach, inner transitional and balked landing surfaces

The first step is to draw the basic ILS surfaces on the map as shown in Figure II-2-5-1 and to prepare a list of obstacles to be investigated (see Table II-2-5-2, List of obstacles).

Obstacle 23 is a holding aircraft 120 m from the runway centre line.

The slope of the inner transitional surfaces is 33.3 per cent. Distance from the runway centre line is 60 m.

Obstacle distance is 120 m.

$(120 - 60) \times 0.333 = 20$ m.

The holding aircraft does not penetrate.

Table II-2-5-1.   Methods of calculating OCA/H

Application	Advantages	Disadvantages
Basic ILS surfaces		
Detailed aerodrome planning. Safeguarding for proposed new constructions. Calculation of OCA/H.	Survey can be linked to Annex 14 surfaces. Development unrestricted below the surfaces (but may affect other criteria, i.e. circling). Can be used to identify obstacles which must be checked.	Produces pessimistic values of OCA/H compared with OAS and CRM. Does not reflect adjustment of GP, RDH, missed approach gradient or aircraft geometry. Probably identifies more obstacles than OAS.
OAS		
Quick-look assessment of new facilities (e.g. for cost-benefit studies). Calculation of OCA/H.	Small surfaces, hence fewer obstacles. Accounts for variation in GP, RDH, aircraft geometry, missed approach gradient.	Does not consider the density of obstacles below the OAS. Large number of repetitive calculations, better suited to computer data handling.
CRM		
Calculation of OCA/H when main aerodrome layout is finalized and obstacle data confirmed.	Produces the most accurate and lowest OCA/H meeting the required level of safety.	Requires processing by computer.

Obstacle 24 is the GP antenna at facility height 17 m. The distance from the runway centre line is the same as for obstacle 23, which does not penetrate.

PANS-OPS, Volume II, Table III-21-2 indicates that the GP antenna and aircraft in holding bays at a distance 120 m from the runway centre line, and aircraft between threshold and –250 m may be ignored. No portion of the GP antenna penetrates. Distance from the RWY centre line is 120 m. Both obstacles can be ignored when the ILS sector width is 210 m and the ILS Category I DH is at least 60 m (30 m for ILS Category II).

STEP 2

The first method — basic ILS surfaces

The basic ILS surfaces are illustrated in PANS-OPS, Volume II, Figure III-21-6. Where these surfaces are free from penetrations, the OCA/H for Category I and Category II is defined by aircraft category margins (Table III-21-4) and there are no restrictions to Category III operations.

The side of the hill has been represented as a series of regularly spaced poles (see also the figure entitled "Example 4 (Page 2)" in Part I, Appendix D, of the *Manual on the Use of the Collision Risk Model (CRM) for ILS Operations* (Doc 9274).

The height of the basic ILS surfaces over each obstacle is calculated using the equations presented in PANS-OPS, Volume II, Figure III-21-7.

Obstacle O_1 is situated in an area where the formula $z = 0.025 \, x - 16.5$ applies.

The distance from the threshold is 3 300 m

$$z = (0.025 \times 3\,300) - 16.5 = 66$$

Table II-2-5-2. List of obstacles

Number	Description	x (metres)	y_1 and y_2 (metres)	z metres above THR	Cat I Height of W surface	Cat I Height of X surface	Cat II Height of W surface	Cat II Height of X surface
1	Tree	3 300	−50	71	86.0		112.0	
2	Tree	3 300	−150	85		97.7		125.8
3	Tree	3 300	−250	97		115.2		148.5
4	Tree	3 300	−350	105		132.8		171.2
5	Tree	3 100	−50	79	80.3		104.8	
6	Tree	3 100	−150	93		92.5		119.0
7	Tree	3 100	−250	96		110.0		
8	Tree	3 100	−350	108		127.5		164.3
9	Tree	2 900	−50	70	74.6		97.6	
10	Tree	2 900	−150	85		87.2		121.1
11	Tree	2 900	−250	93		104.7		134.8
12	Tree	2 900	−350	102		122.1		157.5
13	Tree	2 700	−50	69	68.9		90.5	
14	Tree	2 700	−150	81		81.9		105.3
15	Tree	2 700	−250	89		99.3		128.0
16	Tree	2 700	−350	103		116.8		150.7
17	Tree	2 500	−50	63	63.2		83.3	
18	Tree	2 500	−150	72		76.5		98.5
19	Tree	2 500	−250	81		94.0		121.2
20	Tree	2 500	−350	91		111.5		143.9
21	Hill	650	0	16	10.5		17.1	
22	Hill	450	−180	25		27.4		35.3
23	Holding A/C	−170	120	12	*			
24	GP	−260	−120	17	*			
25	LLZ	−2 393	0	0				

* These obstacles are excluded on the basis that decision heights below 200 ft Category I or 100 ft Category II will not be

Obstacle height is 71 m, therefore it penetrates.

Obstacle 17 is situated in an area where the equation $z = 0.02 \, x - 1.2$ applies:

$z = (0.02 \times 2 \, 500) - 1.2 = 48.8$

Obstacle height is 63 m; it penetrates.

It is apparent that a more sophisticated method must be used to obtain a satisfactory OCH. The next step, then, is to use the OAS method.

STEP 3

The second method — Category I obstacle assessment surfaces (OAS)

In order to define the system of obstacle assessment surfaces, indicate the surfaces on a suitable chart, for instance, scale 1:50 000 or 1:100 000. A scale of 1:10 000 to 1:25 000 is recommended for examining obstacles close to the runway (see also Figure II-2-5-2).

The runway length is 2 000 m. Distance LLZ to THR is 2 400 m. Glide path angle is proposed to be 3°.

Annex 10, Volume I, 3.1.5 contains the following recommendation:

"**Recommendation.—** *The ILS glide path angle should be 3 degrees. ILS glide path angles in excess of 3 degrees should not be used except where alternative means of satisfying obstruction clearance requirements are impracticable.*"

The table of constants for the calculation of OAS surfaces shown in Table II-2-5-3 is reproduced from PANS-OPS, Volume II, Attachment I to Part III.

The height equation

$z = Ax + By + C$

is used to calculate the OAS height (z) at any location (x, y) relative to threshold elevation. x and y are the runway coordinates, z is the height above threshold, values A, B and C are taken from Table II-2-5-3. When an obstacle is situated close to an intersection between two surfaces it is necessary to calculate using equations for both surfaces. The highest of the two surfaces is the height of the OAS.

Note.— If any OAS surface height is above the height of the obstacle, the obstacle does not penetrate inside the OAS area.

OAS penetration is checked as follows (see Figure II-2-5-3):

Obstacle O_1. Category I Table:

W surface:
$(0.0285 \times 3 \, 300) - 8.01 = 86.0$ m

X surface:
$(0.026534 \times 3 \, 300) + (0.174940 \times 50) - 16.03 = 80.3$ m
Obstacle O_1 does not penetrate.

Note that the y coordinate is always counted as positive in OAS calculations.

Obstacle O_2:

X surface:
$(0.026534 \times 3 \, 300) + (0.174940 \times 150) - 16.03 = 97.8$ m
Obstacle O_2 does not penetrate.

Obstacle O_5:

W surface:
$(0.0285 \times 3 \, 100) - 8.01 = 80.3$ m
The obstacle reaches 79 m. Obstacle O_5 does not penetrate.

Obstacle 21:

W surface:
$(0.0285 \times 650) - 8.01 = 10.5$ m
This obstacle is 16 m and penetrates.

Does it penetrate Category II W surface?

$(0.0358 \times 650) - 6.19 = 17.1$ m
It does not penetrate.

The remaining values are presented in Table II-2-5-2, List of obstacles. The result of the use of OAS is that at least three obstacles penetrate, numbers 6, 13 and 21.

Obstacles 23 and 24 are considered in Step 1. At least two of the "poles" representing the hill penetrate the OAS and the remainder are only just below the OAS.

PANS-OPS, Volume II, Part III, 21.1.5.4 indicates that the third method, CRM, should be employed when the obstacle density below the OAS is considered to be excessive. This appears possible in this example.

Table II-2-5-3

ILS OAS DATA GLIDEPATH ANGLE 3.00 LLZ/THR DISTANCE 2400.

ILS OAS CONSTANTS

OAS CONSTANTS
MODIFIED FOR

	CAT I			CAT II			CAT II AUTOPILOT		
	A	B	C	A	B	C	A	B	C
W	.028500	.000000	−8.01	.035800	.000000	−6.19	.035800	.000000	−6.19
W*							.042000	.000000	−12.39
X	.026534	.174940	−16.03	.034123	.226993	−20.88	.039585	.263324	−24.23
Y 5.0P	.016841	.240476	−27.65	.024373	.348029	−40.01	.024373	.348029	−40.01
Z	−.050000	.000000	−45.00	−.050000	.000000	−45.00	−.050000	.000000	−45.00
Y 4.0P	.019083	.225321	−24.96	.026860	.317157	−35.13	.026860	.317157	−35.13
Z	−.040000	.000000	−36.00	−.040000	.000000	−36.00	−.040000	.000000	−36.00
Y 3.OP	.021466	.209207	−22.10	.029359	.286135	−30.23	.029359	.286135	−30.23
Z	−.030000	.000000	−27.00	−.030000	.000000	−27.00	−.030000	.000000	−27.00
Y 2.5P	.022813	.200100	−20.49	.030710	.269368	−27.58	.030710	.269368	−27.58
Z	.025000	.000000	−22.50	−.025000	.000000	−22.50	−.025000	.000000	−22.50
Y 2.0P	.024215	.190618	−18.81	.032072	.252461	−24.91	.032072	.252461	−24.91
Z	−.020000	.000000	−18.00	−.020000	.000000	−18.00	−.020000	.000000	−18.00

OAS TEMPLATE COORDINATES −M

THRESHOLD ELEVATION

	CAT I		CAT II		CAT II AUTOPILOT	
	X	Y	X	Y	X	Y
C	281	49	173	66	173	66
D	−286	135	−286	135	−286	135
E 5.OP	−900	178	−900	178	−900	178
4.OP	−900	187	−900	187	−900	187
3.OP	−900	198	−900	198	−900	198
2.5P	−900	205	−900	205	−900	205
2.0P	−900	213	−900	213	−900	213

	300M HEIGHT CAT I		150M HEIGHT CAT II		150M HEIGHT** CAT II AUTOPILOT	
	X	Y	X	Y	X	Y
C"	10807	167	4362	96	3866	80
C""					1000	54
D"5.0P	5438	981	2576	365	1440	445
E"	−6900	1845	−3900	819	−3900	819
D"4.OP	5438	981	2576	365	1187	483
E"	−8400	2153	−4650	977	−4650	977
D"3.OP	5438	981	2576	365	665	561
E"	−10900	2658	−5900	1235	−5900	1235
D"2.5P	5438	981	2576	365	65	651
E"	−12900	3072	−6900	1445	−6900	1445
D"2.0P	5438	981	2576	365	−1338	862
E"	−15900	3692	−8400	1759	−8400	1759

P = PERCENTAGE
** NOTE ,
C"" COORDINATES APPLY TO TEMPLATE AT 29.6M HEIGHT
I.E. AT THE INTERSECTION OF THE W AND W* SURFACES(CAT II AUTOPILOT ONLY)

So far the heights of all obstacles have been estimated from contours on a chart and 15 m have been added for vegetation. It is normal practice to obtain more accurate and reliable (surveyed) data, certified by a qualified expert, before calculating OCA/Hs to be published for precision procedures. Various methods are presented in the *Airport Services Manual*, Part 6 — *Control of Obstacles* (Doc 9137).

STEP 4

The second method — Category II obstacle assessment surfaces (OAS)

Check obstacles O_1 to O_{20} with regard to Category II surfaces. None of them penetrate.

Obstacle 21:

W values:

$(0.0358 \times 650) - 6.19 = 17.1$ m

Obstacle 21 does not penetrate the W surface and need not be considered.

Obstacle 22:

Situated below the X surface
Flight director: $(0.034123 \times 450) + (0.226993 \times 180) - 20.88 = 35.3$ m
Autopilot: $(0.039585 \times 450) + (0.263324 \times 180) - 24.23 = 41.0$ m

Obstacle 22 does not penetrate.

A study of the list of obstacles indicates that no obstacles penetrate either set of the Category II OAS surfaces. The minimum separation between the surfaces and the obstacles on the big hill is about 20 m. The most critical obstacle is number 21, one metre below the OAS.

Note regarding OAS Category II.— Two tables have been published for Category II OAS, the left one for Category II flight director, the right one for Category II autopilot. Differences between the two tables are:

a) *different A and B values for X surfaces; and*

b) *the same A and B values for W surfaces plus an extra value (W*) for Category II autopilot. This means that two W surfaces exist for the autopilot case. The W* surface is steeper than the W surface (the A value is the tangent of the angle between the*

W surface and the horizontal plane) and the two surfaces intersect 1 000 m from the threshold (see Figure II-2-5-4).

STEP 5

Division between approach and missed approach obstacles and OCH calculation

It is assumed that no obstacles affect the missed approach segment of the procedure. Instead the following comments regarding ILS missed approach can be studied (see also "Training in calculation of OAS surfaces" at the end of this chapter and in Attachment B7).

Obstacles penetrating the OAS (or basic ILS surfaces) are divided into two classes (approach and missed approach obstacles) when calculating OCH. There are two ways of partitioning these obstacles — a simple partition by range (before/after the –900 m) (see Figures II-2-5-5 and II-2-5-6) and a more complex method which allows greater benefit. This latter partition is relative to a plane surface originating at –900 m and sloping upwards into the approach area parallel to the plane of the glide path.

When using either the basic ILS surfaces or the OAS, the OCH for approach/missed approach obstacles is obtained as follows:

a) Convert the height of all missed approach obstacles (h_{ma}) to the height of "equivalent" approach obstacles (h_a) using the equation (see Figure II-2-5-5):

$$h_a = \frac{h_{ma} \cot Z + (900 + X)}{\cot Z + \cot \theta}$$

b) Determine the highest value h_a or approach obstacle height and add the appropriate HL values from PANS-OPS, Volume II, Table III-21-4 to obtain OCH.

Note that the highest value h_a obtained in b) above is also the height of SOC and is used in subsequent calculations for obstacles after the precision segment.

STEP 6

The third method — collision risk model (CRM)

Instructions for the preparation of a request for a CRM calculation are published in the *Manual on the Use of the Collision Risk Model (CRM) for ILS Operations* (Doc 9274).

In the example it is assumed that all obstacles have been surveyed accurately, resulting in revised heights. A request for a CRM calculation was made and submitted to ICAO. Copies of the request and of the result are published in Attachment B5 to this manual.

The measured heights indicate that several obstacles are higher than shown in Table II-2-5-2, List of Obstacles, and penetrate the surfaces. Obstacle 13 with height 71 m penetrates the W surface by 2 m. In spite of this fact the risk is not more than $6.3 \times ^{-10}$. The explanation is that the CRM 10^{-7} probability contour has a curved surface and is above the geometric obstacle assessment surfaces at that point. When the obstacle situation is critical, as in the present example, it is always preferable to use the CRM calculation.

STEP 7

Precision segment OCA/H

The result of the CRM calculation (see Attachment B5) has given the following Category I OCA/H.

Category A OCH 168 ft (51 m)
Category B   174 ft (53 m)
Category C   183 ft (56 m)
Category D   193 ft (59 m)

The design of preceding and subsequent segments

In Step 1 of the precision segment, obstacles were examined. OCA/H was determined by the use of OAS and CRM. However, the precision segment begins at the point where the descent on glide path begins at final approach point (FAP). The altitude and distance from the threshold of this point has not yet been precisely determined. The extension of the precision segment in the approach segment, higher than 300 m above the threshold elevation, also has to be calculated.

STEP 8

Location of the outer marker (OM) and the middle marker (MM)

The outer marker (OM) and the middle marker (MM) should, if possible, be located at distances according to Annex 10. The assumed locations are OM 7 200 m from THR, MM 1 050 m from THR.

Note.— If an approach is made over water or unsuitable terrain and the OM cannot be installed, a DME fix may replace the OM.

STEP 9

Glide path height above OM and MM

Glide path angle is 3.0°

Tan 3.0° = 0.0524 which corresponds to descent gradient 5.2 per cent.

The glide path height overhead OM is:

15 + (7 200 × tan 3.0°) = 392.3 m = 1 287 ft

Altitude 426.3 m MSL, 1 399 ft MSL

The glide path height overhead MM is:

15 + (1 050 × tan 3.0°) = 70 m = 230 ft

altitude 104 m = 340 ft MSL.

STEP 10

Alignment

LLZ course line is centred on the runway centre line, magnetic bearing 220°.

STEP 11 a)

Planning of the initial and intermediate segments

The PANS-OPS states that the intermediate segment shall be aligned with the localizer course. The optimum length is 5 NM. A shorter distance should only be used if usable airspace is restricted and, if so, the distance indicated in Table III-21-1 shall apply. There should be sufficient distance to damp the LLZ join errors before reaching glide path descent (FAP).

It is planned that four arrival routes shall, in initial segments, join the localizer course.

A racetrack has minor importance but enables omnidirectional entry.

It is intended to locate an NDB, if possible, at the FAP. This facility shall be the base for a racetrack. Furthermore, it shall be the centre for minimum sector altitudes. At the FAP the aircraft joins the glide path and the precision segment commences. If the aerodrome is situated in an area with significant obstacles, careful initial preparation is necessary.

Begin by drawing boundaries for the precision segment on a chart with scale 1:250 000. Indicate the runway and the extended centre line in both directions and plot location of all radio navigation facilities mentioned above as is done in Figure II-2-5-8. Draw preliminary limits of the precision segment as is done in Figure II-2-5-9. The approach in the intermediate segment shall, if possible, be level flight on a height above THR from which a descent can be made, long enough to enable a descent check at OM and to stabilize aircraft.

In this example, it is assumed that an intermediate altitude of 760 m (2 500 ft) MSL will suit. Note that the selection of intermediate segment height and FAP location are interdependent and, in difficult locations, an iterative process may be necessary.
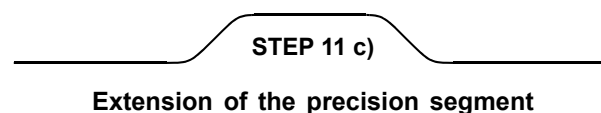

STEP 11 b)

Final approach point (FAP)

Distance FAP to THR is calculated:

$$\frac{760 - 34 - 15}{\tan 3°} = 13\ 567 \text{ m}$$

where 34 is threshold elevation and 15 is ILS reference datum height (glide path height above the threshold).

Distance LESTRA VOR/DME to FAP = 7 300 + 2 000 + 13 567 = 22 867 m = 12.3 NM.

STEP 11 c)

Extension of the precision segment

The X and W surfaces extend above 300 m contour into the intermediate segment as shown in PANS-OPS, Volume II,

Figures III-21-2 and III-21-3. In this example, an NDB has been located at FAP which makes Figure II-2-5-10 applicable. The extension of this portion of the precision segment is calculated as follows.

The width of the whole area at FAP elevation may be calculated or obtained by plotting from the Category I OAS template coordinates (see Table II-2-5-3). The height of FAP above the threshold is 760 – 34 = 726 m (34 = threshold RWY 22 elevation). Since the edge of the Category I X surface is in the plane of the glide path, the precise width at the FAP altitude may also be obtained by calculation using the OAS X surface equation:

$$\underset{726}{z} = \underset{0.026534}{A} \times \underset{13\ 567}{x} + \underset{0.17494}{B} \ \underset{y}{} - \underset{16.03}{C}$$

$$y = \frac{726 - (0.026534 \times 13\ 567) + 16.03}{0.17494} = 2\ 184 \text{ m}$$

Thus, the semi-width at FAP at altitude 760 m MSL is 2 184 m.

The semi-width of the precision segment at a height of 576 m (150 m below FAP) is calculated with the same equation. Result: 1 326 m. The gradient of the W surface is indicated in the table of ILS OAS constants (Table II-2-5-3) as 0.0285 or 2.85 per cent. Using these values, a profile and plan view as in Figure II-2-5-7 can be drawn for this procedure.

STEP 11 d)

Intermediate approach segment
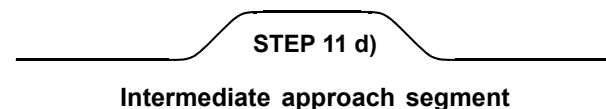
As was mentioned in Step 11 a), the nominal length of the intermediate segment should be 5 NM. As FAP DME distance is 12.3 NM, IF shall be defined with 17 DME. Thus, the extension of the intermediate approach segment is adopted.

The intermediate area within the racetrack area (arrival from PRK) is drawn according to PANS-OPS, Volume II, Part III, 21.3.4, the 28 km (15 NM) distance being measured from the LLZ.

STEP 12

Location of the NDB — racetrack and holding

An NDB shall be so located that it will give optimal service in the procedure in conjunction with the DME at LES. The

NDB will also serve as a fix in procedure ILS with glide path unserviceable (see Chapter 6 of this section). Annex 10 indicates that the outer marker should be located at 3.9 NM from the threshold except where, for topographical or operational reasons, this distance is not practicable, etc. Because of the requirements of a procedure for ILS with GP unserviceable, it is desirable for the NDB to be located at or before the FAP. As DME is available and suitably located, a DME fix can serve as FAF (see the note below).

In this example, the NDB will be located at the FAP. As in Chapter 1 of this section, the terrain itself shall be explored in order to find a suitable spot for the NDB equipment. The nominal length of the intermediate approach segment is 5 NM. The FAP is situated at distance 12.3 NM from LESTRA DME so a suitable location of the IF is at 17 DME. The racetrack, presented on the instrument approach charts at the end of this chapter, shall be designed in accordance with Chapter 1 of this section except that no descent shall be executed.

A one-minute holding based on the NDB shall coincide with the racetrack of which the inbound track is an intermediate approach. Check the obstacle situation with the appropriate template, remembering the buffer area is 5 NM wide (see Figure II-2-5-9a)).

Note.— Other possible bases for racetrack area fix 12 DME combined with LLZ course line or radial R-040 LES, or intersection R-040 LES and R-165 KAV entry along radials.

STEP 13

Minimum sector altitudes

In this example, it is assumed that the following MSA, centred on the NDB, have been determined (compare with Chapter 1 of this section, Step 1).

Sector NE 2 500 ft MSL, Sector SE 3 200 ft MSL, Sector SW 2 300 ft MSL, Sector NW 2 300 ft MSL.

Arrival routes

See specimen chart, Arrival Routes RWY 22, Figure II-2-5-10. Arrival routes from VOR TEC, NDB PRK and VOR KAV.

On a map with suitable scale (for instance 1:250 000), indicate the aerodrome and all radio navigation facilities involved (see Figure II-2-5-8).

STEP 14

Initial approach segments from KAV and TEC

VOR KAV and VOR TEC are identified as IAF and consequently the segments KAV to IF and TEC to IF are initial approach segments. The initial approaches are drawn on Figure II-2-5-9. The angle of interception between the initial approach track and the intermediate fix is an intersection of radials from the two VORs and the localizer course.

Indicate IF at 17 DME. The angle KAV-IF does exceed 70° which makes a lead radial necessary from VOR LES. Lead radial is calculated as in Chapter 4 of this section, Step 6:

$$\frac{2}{17} = 0.118 \text{ which corresponds to angle } 7°$$

Lead radial is R-033 from LES.

STEP 15

Arrival route from PARKES

Initial approach fix (IAF) in this procedure in NDB OS. The arrival route from PARKES is defined as a Sector 1 entry into the racetrack at OS (see Figure II-2-5-9a)).

Summary

In the example, it is assumed that obstacles are not high enough to affect the initial and intermediate segments' altitude in arrival routes. Otherwise, the FAP height must be raised and consequently the FAP moved outward from the aerodrome. The intermediate segment will also be moved accordingly and the angle of intersection increased.

STEP 16

Circling minima

It is assumed that the following circling OCA/H have been determined for this procedure:

Category A 265 (225) m
Category B 265 (225) m
Category C 295 (255) m
Category D 295 (255) m

<hr>

STEP 17

Tables on the instrument approach chart

For the procedure "ILS UNSERVICEABLE", a table, "Time to fly FAF to MAPt" (here FAF to MM) and "Rate of descent/GS" shall be published.

<hr>

STEP 18

Production of the instrument approach chart and the standard arrival chart

An Arrival Route Chart RWY 22 is presented in Figure II-2-5-10. Two instrument approach charts for ILS 22 are presented in Figures II-2-5-12 and II-2-5-13.

Training in calculation of OAS surfaces

The upper figure in Figure II-2-5-11 is constructed with values calculated as follows.

The width of the precision segment at distance –3 900 m is calculated by using the height equation with the values in the table of constants for calculations of OAS (Table II-2-5-3).

$300 = (–3\ 900 \times 0.0228) + (y \times 0.2001) – 20.49$
$y = 2\ 047$

The width at the threshold is calculated:

$300 = 0.2\ 001y – 20.49$
$y = 1\ 601.6$ m

Z surface height at $x = –3\ 900$ m is calculated:

$–0.025\ (–3\ 900) – 22.5 = 75$ m

The Y surface y-coordinate at $z = 75$ is calculated with the height equation:

$y = 922$ m

What angle does the intersection Y surface/Z surface splay?

See Table II-2-5-3. The width of the precision segment at E" is 3 072 m and at E, 205 m.

Distance between E and E" is 12 900 – 900 = 12 000 m.

The tangent value for the splay is:

$\dfrac{3\ 072 – 205}{12\ 000} = 0.2389$ which corresponds to angle 13.4°
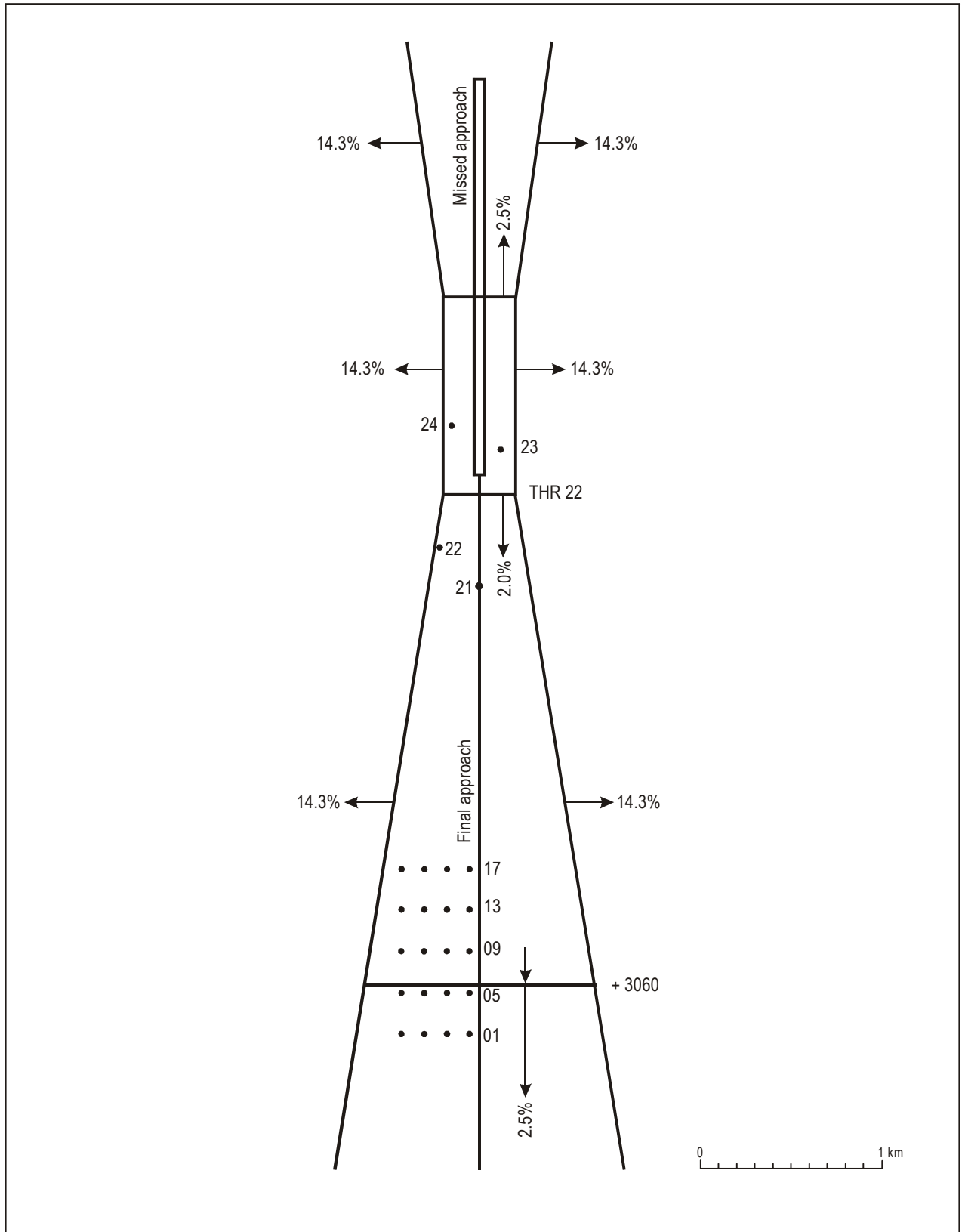
(See Figure II-2-5-14).

Figure II-2-5-1

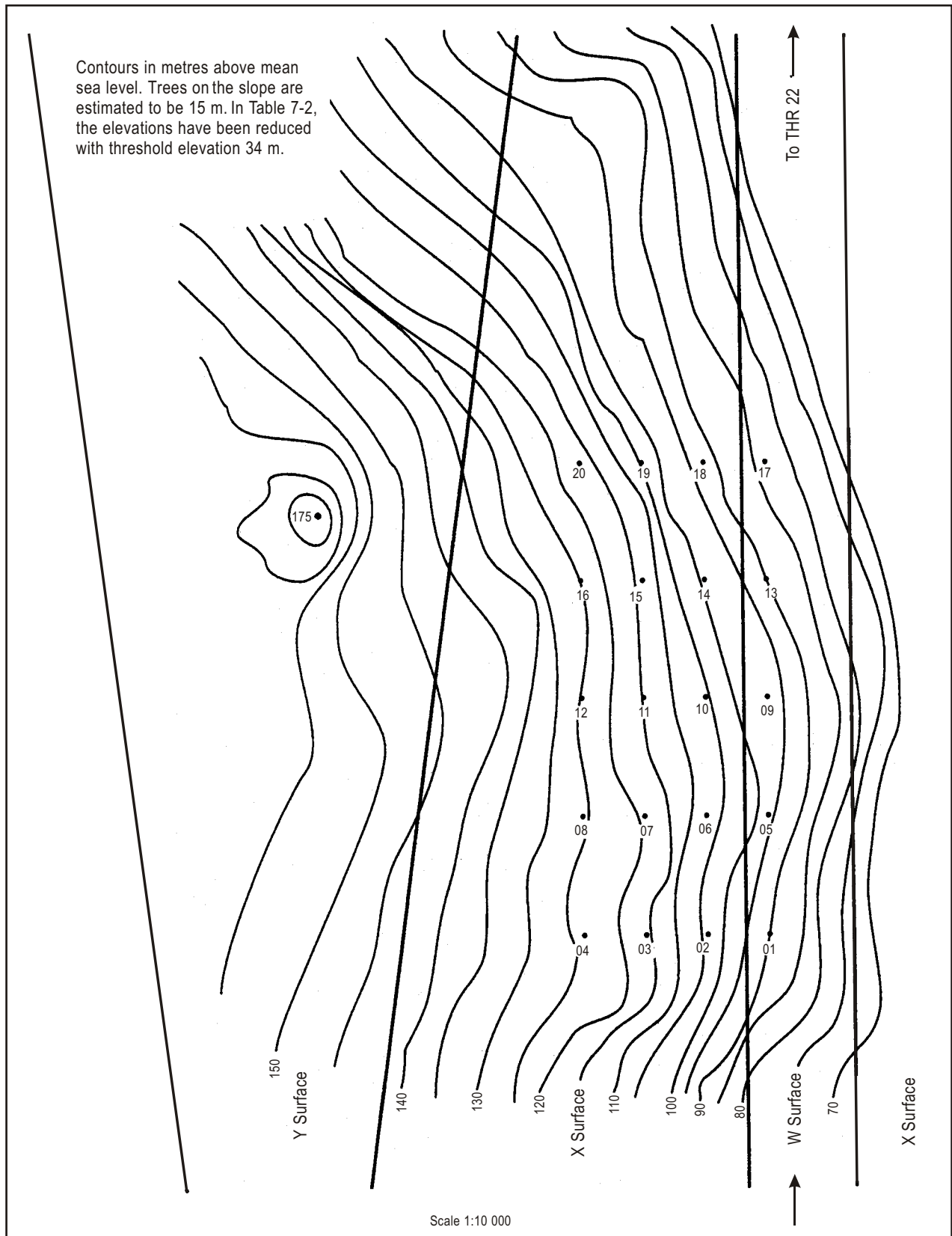Contours in metres above mean sea level. Trees on the slope are estimated to be 15 m. In Table 7-2, the elevations have been reduced with threshold elevation 34 m.

To THR 22

175●

●20 ●19 ●18 ●17

●16 ●15 ●14 ●13

●12 ●11 ●10 ●09

●08 ●07 ●06 ●05

●04 ●03 ●02 ●01

150
Y Surface
140
130
120
X Surface
110
100
90
80
W Surface
70
X Surface
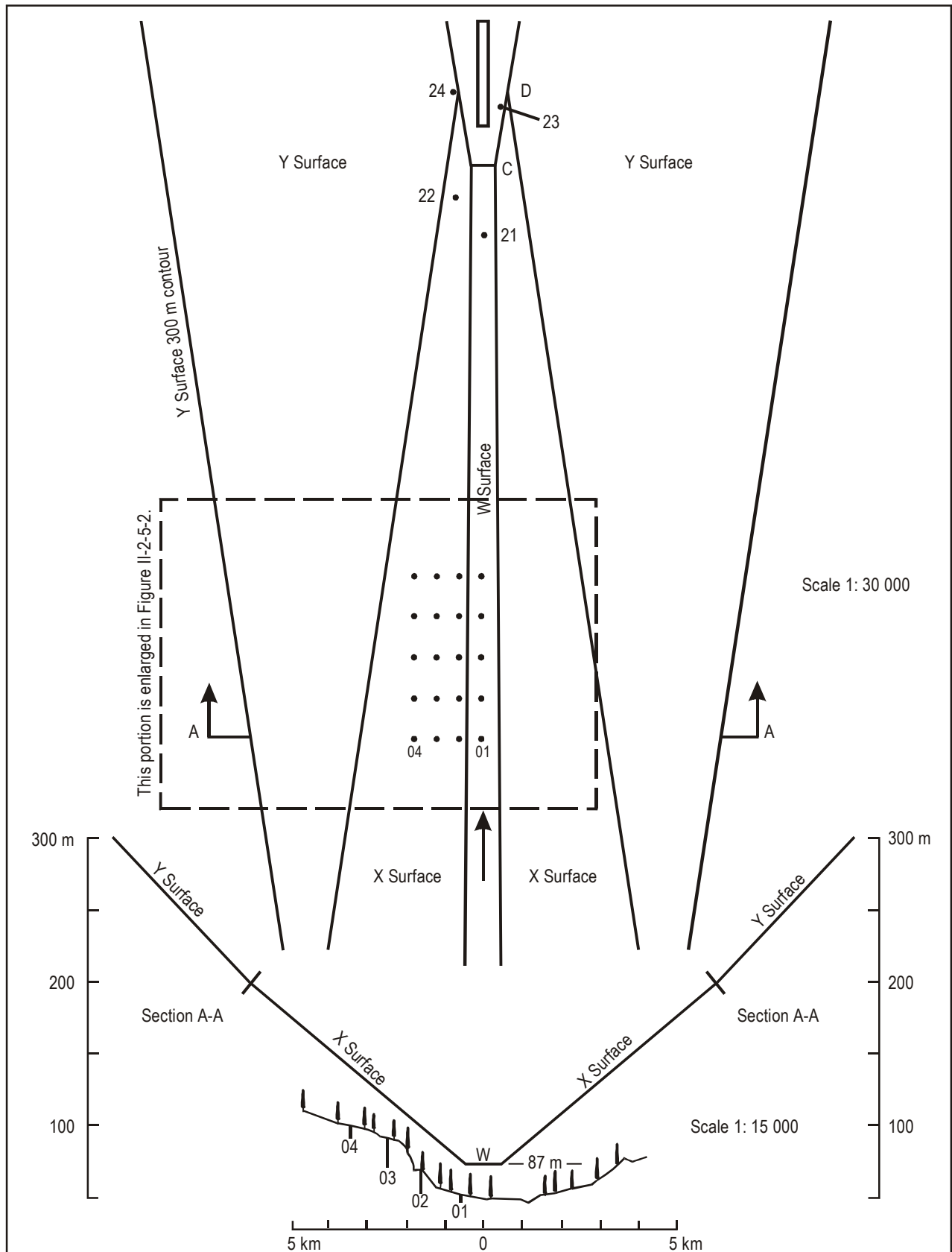
Scale 1:10 000

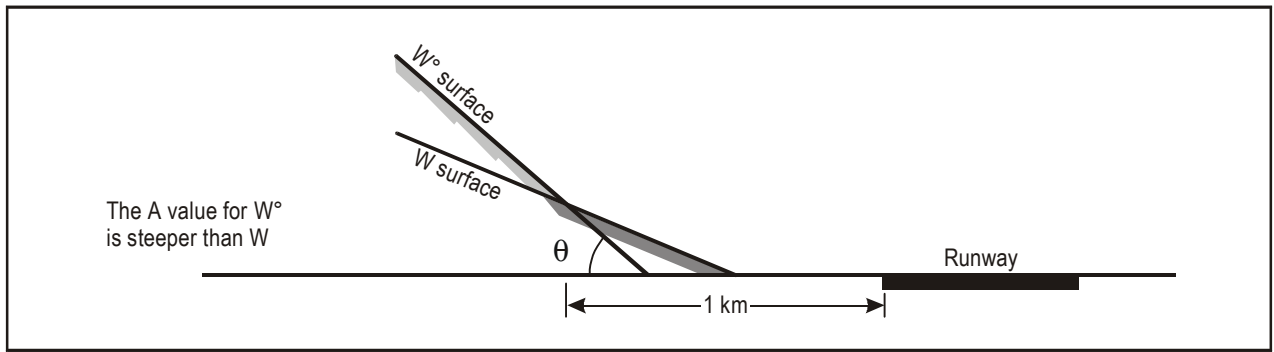**Figure II-2-5-2**

Figure II-2-5-3

Figure II-2-5-4

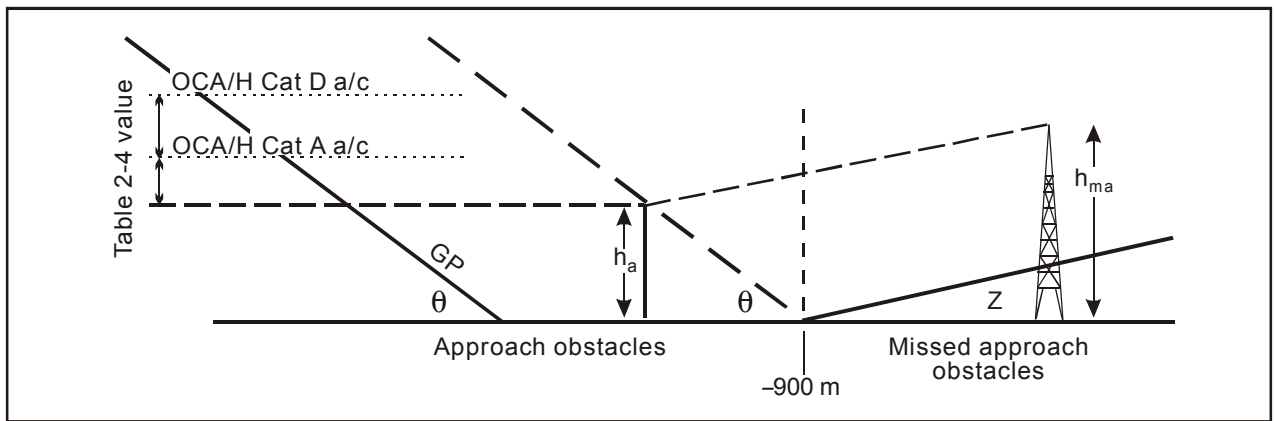**Figure II-2-5-5. Missed approach obstacle after range –900 m**

Figure II-2-5-6. Missed approach obstacle before range –900 m

Fix tolerance area

760 m MSL

150 m (492 ft)

300 m (984 ft) MOC

610 m MSL

"X"

Nominal glidepath

15%

Obstacle assessment surfaces

W surface

34 m MSL

OM or DME distance

Intermediate segment

Precision segment

IF

FAP & descent fix

Slope gradient 2.85%

Secondary area

Primary area
150 m (492 ft) MOC

15%

X surface

W surface

X surface
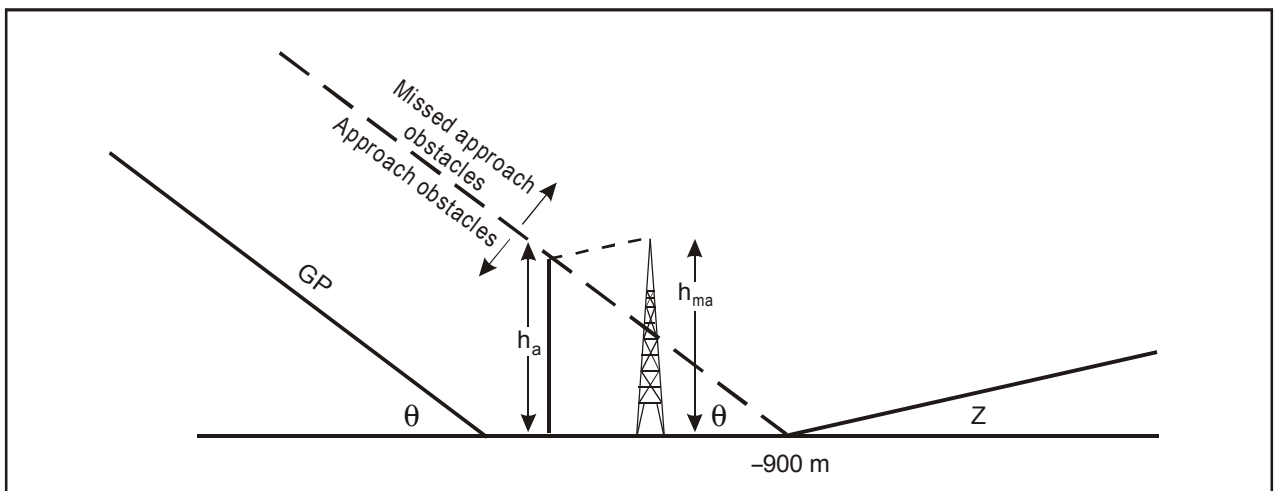
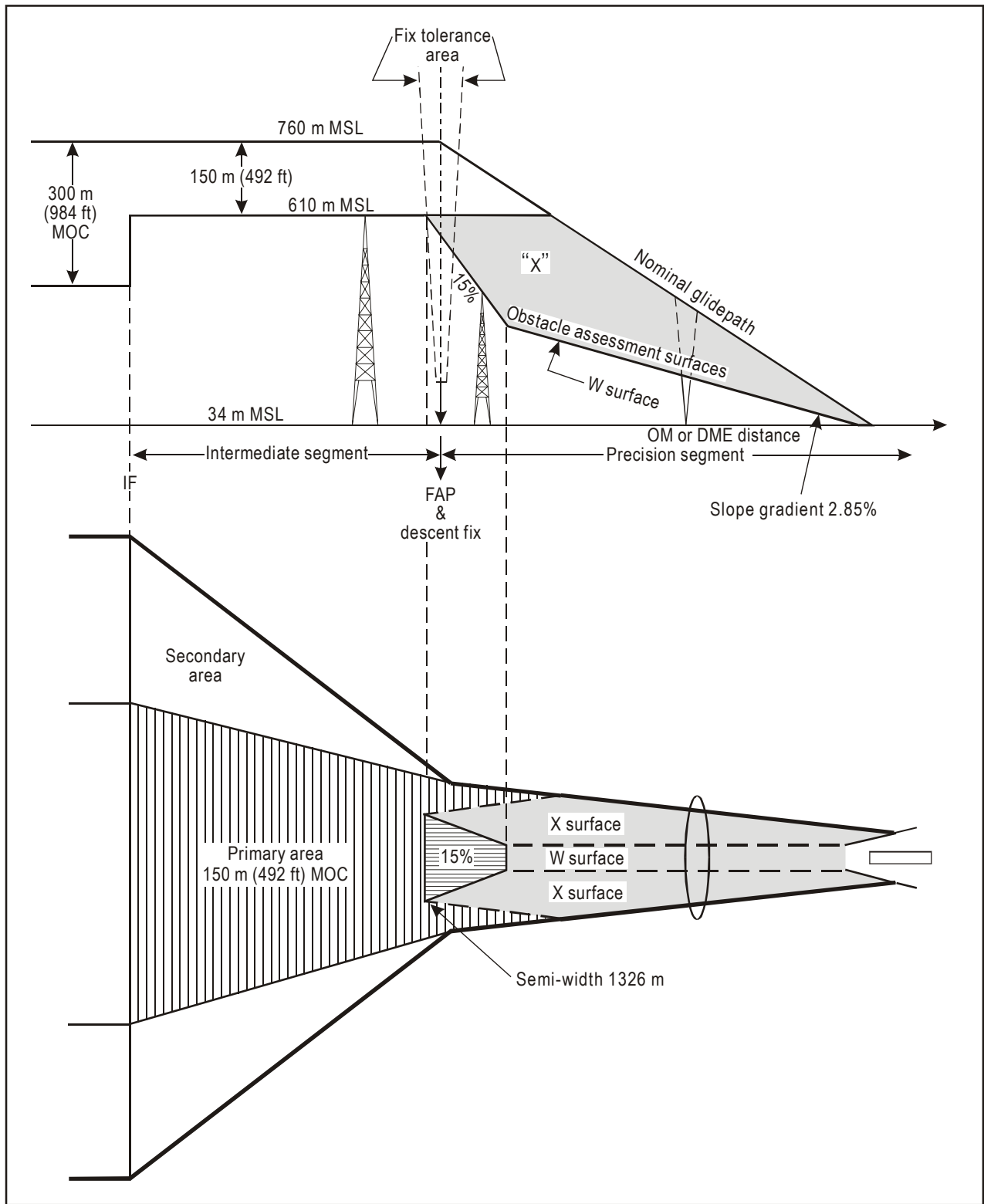Semi-width 1326 m

Figure II-2-5-7.   Final approach fix defined by descent fix located at final approach point
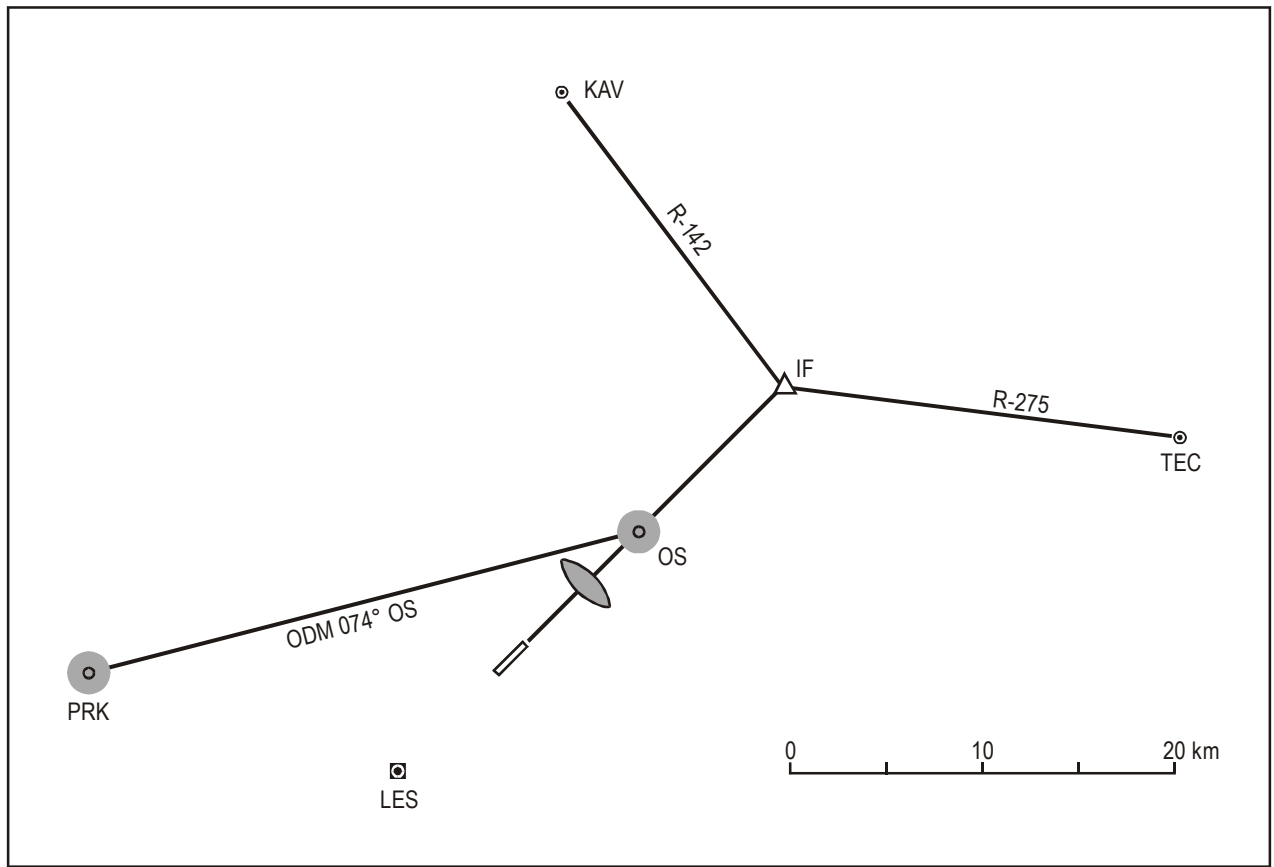
Figure II-2-5-8
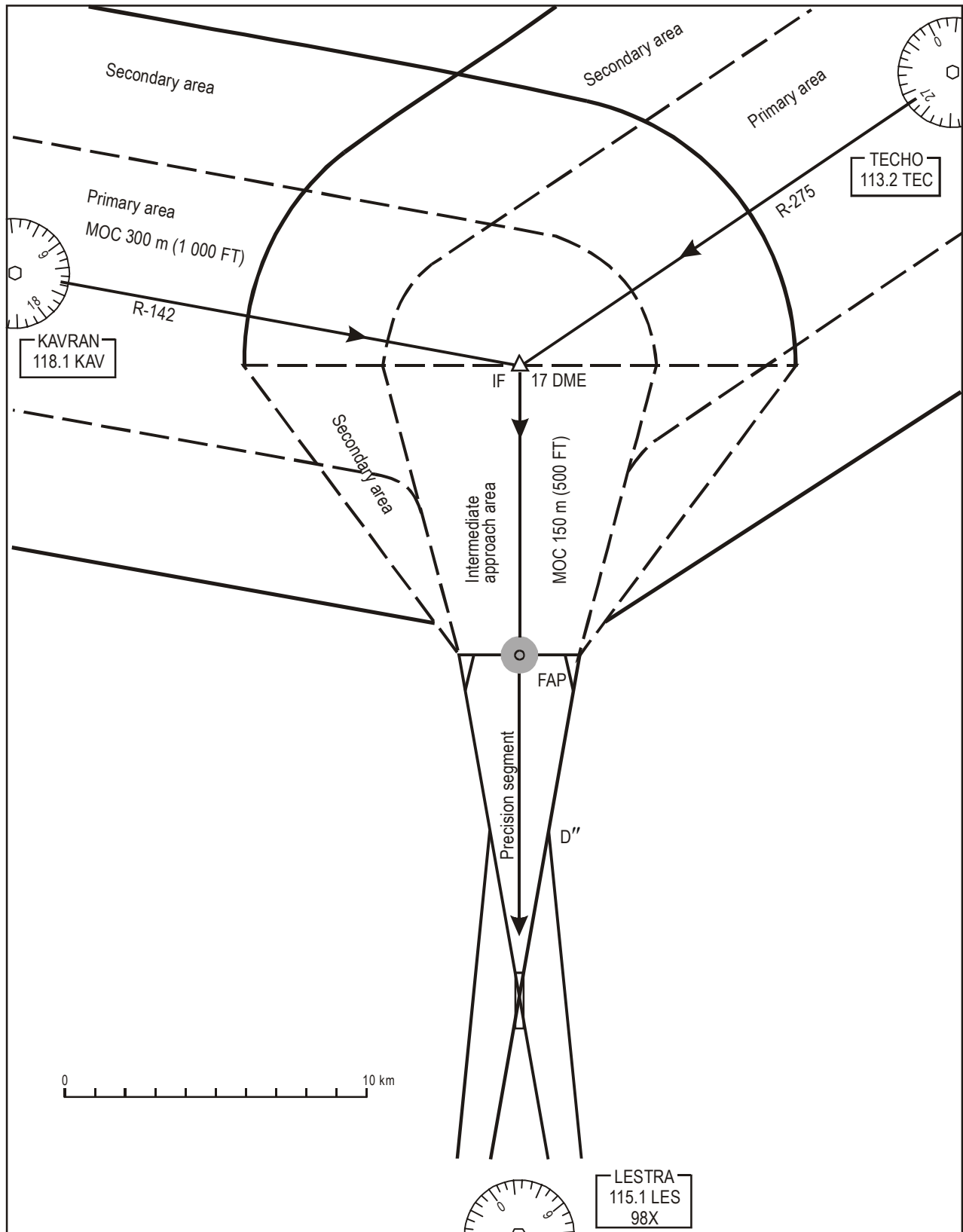
Figure II-2-5-9

Figure II-2-5-9 a)

ARRIVAL ROUTES RWY 22

AROM

Figure II-2-5-10

A
A

x = -3 900
y = 922 m
y = 2 047 m

13.4°

Y Surface 300 m contour

E
x = -900

D

x = 0 m
y = 1 600 m

300 m
300 m

Y Surface
Y Surface

200 m
200 m

Extension of ILS
LLZ courseline

100 m
100 m

Z Surface
75 m
y = 922 m

Threshold elevation

1 km
0
1 km

Section A-A
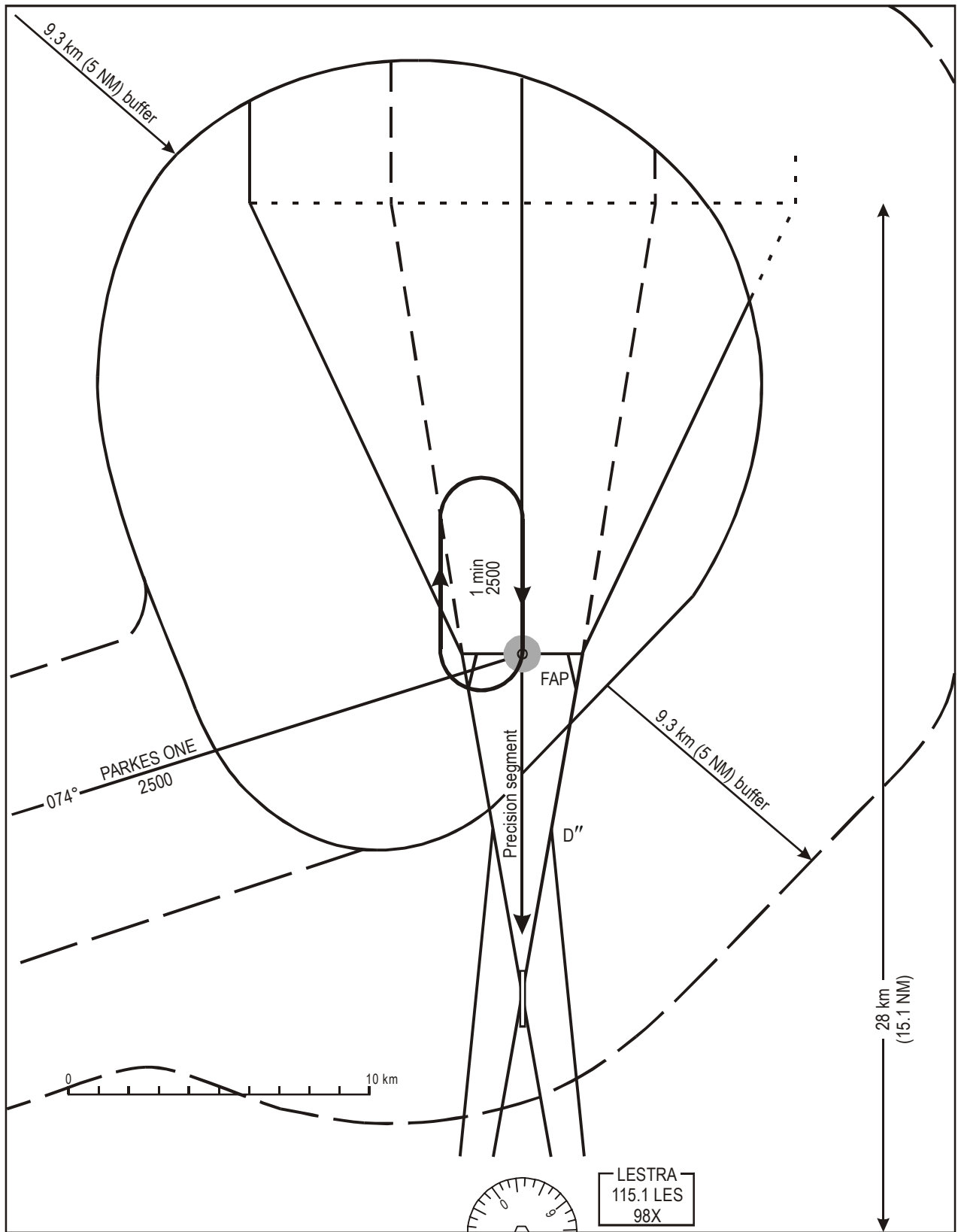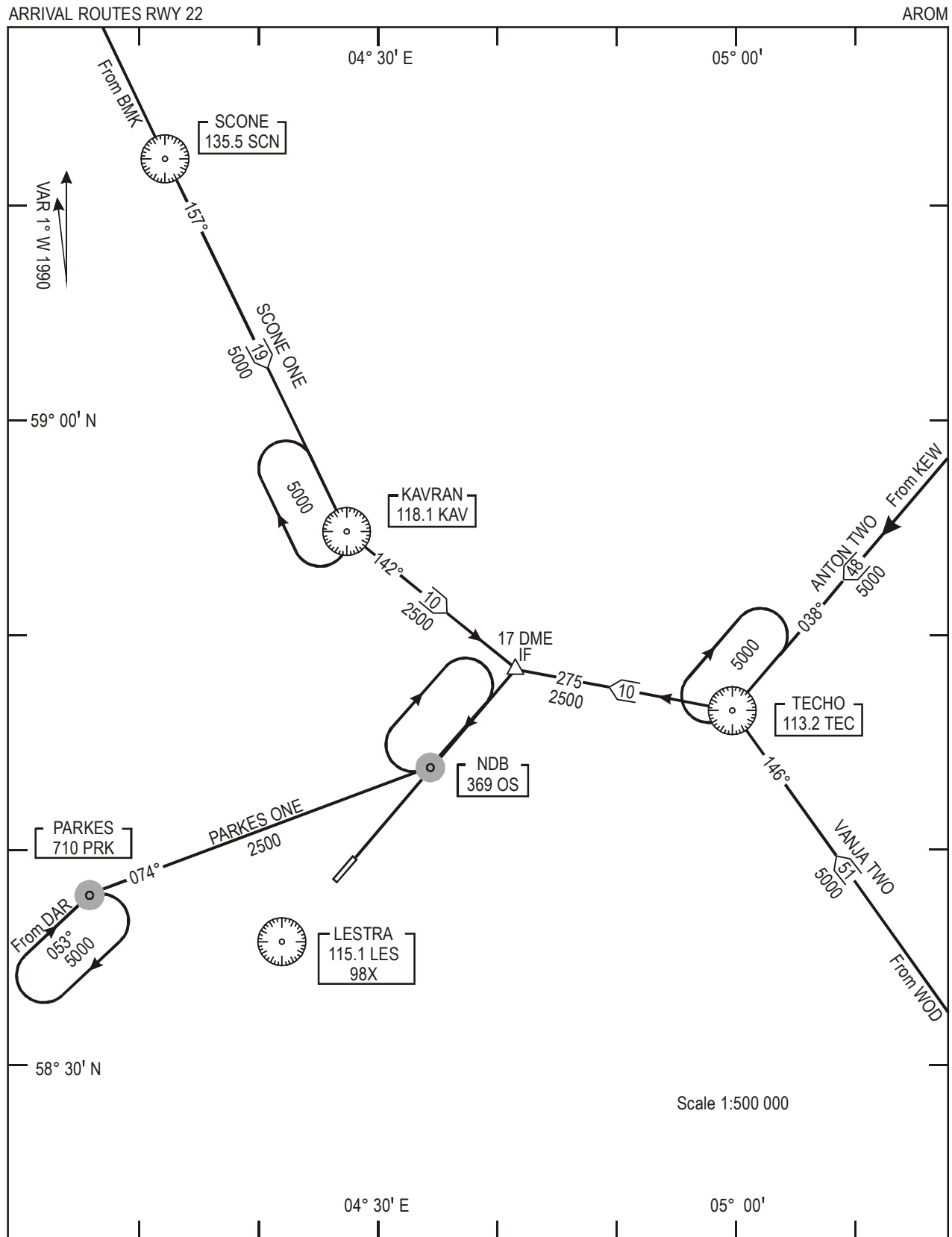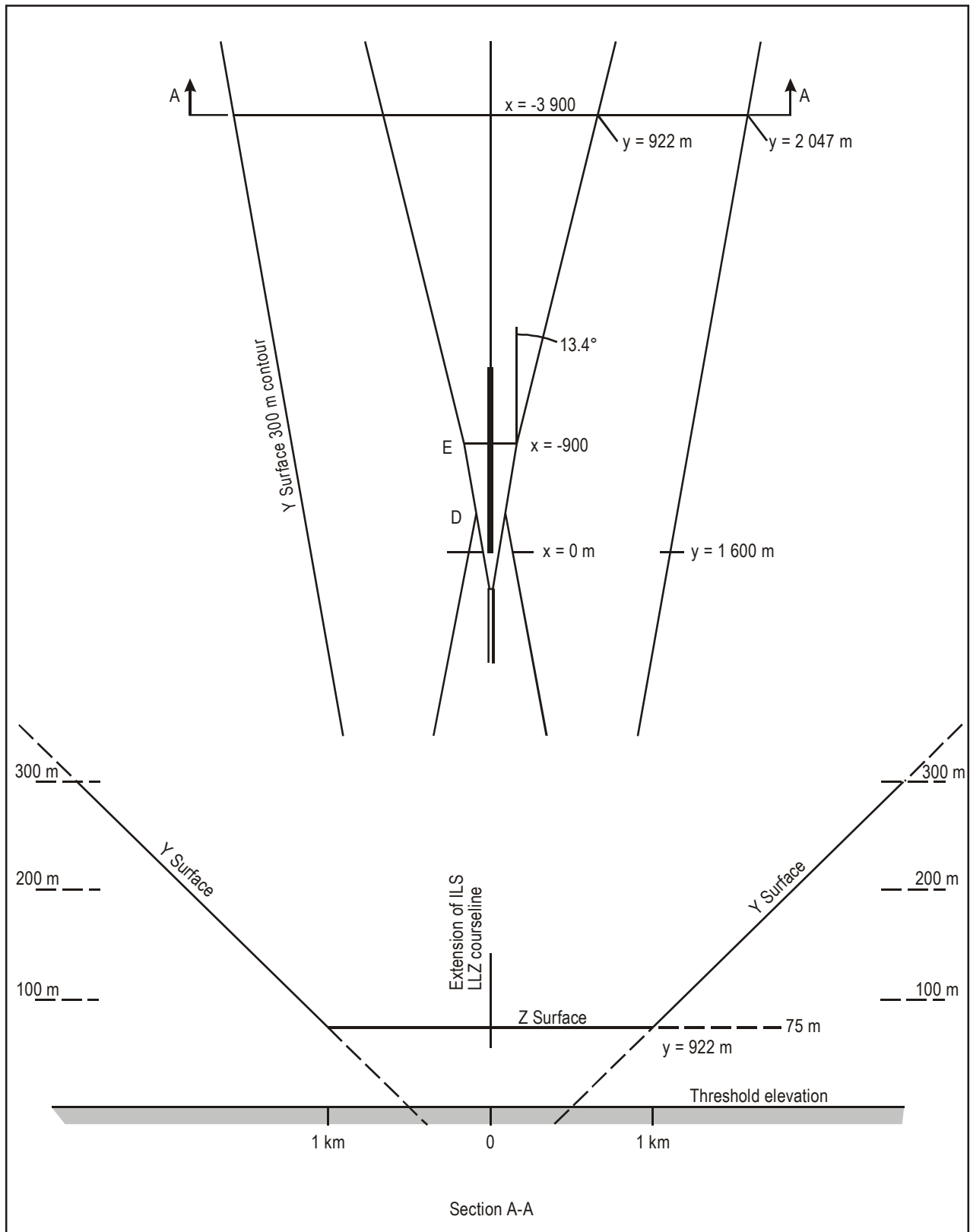
Figure II-2-5-11

Figure II-2-5-12

INSTRUMENT APPROACH CHART - ICAO

AERODROME ELEV 130 FT
HEIGHTS RELATED TO
THR RWY 22 - ELEV 110 FT

AROM TWR 116.10
AROM APP 118.50

AROM
ILS 22

MNM SECT ALT
2300   25 NM

04° 25'

180°

04° 40'

10 NM

MNM SECT ALT
2500   25 NM

BEARINGS ARE MAGNETIC
ALTITUDES, ELEVATIONS
AND HEIGHTS IN FEET

R-142 KAV
2500 (2390)

R-033 LES

58°
50' N

VAR 1° W 1990

58°
50'

SEE STAR CHART

B

17 DME LES

Y

R-275 TEC
2500 (2390)

RACETRACK 1MIN
040°

HOLDING
MNM 2500

220°

270°

090°

Parkes one arrival
QDM 074° OS 2500 (2390)

FAP
369 OS
58 44.9 N
04 36.0 E

58°
40'

164
(54)

575
(465)

58°
40'

to OS

LZZ
110.30 MK

360°

VOR/DME
LESTRA
115.10 LES
98X

MNM SECT ALT
2300   25 NM

04° 25'

E
04° 40'

MNM SECT ALT
3200   25 NM

TRANSITION ALTITUDE 5000 FT MSL

(FAF GP INOP) SEE STAR CHART

LES

PARKES ONE ARR

(MAPt GP INOP)
MM

OM

FAP
OS

From
KAVRAN
TECHO

IF

RACETRACK

2500(2390)

2500 (2390)

17 DME
LES

Climb to LES
turn right to
OS climbing
to 2500 (2390)

340
(230)

GP 3.0°
220°

1400
(1290)

ILS RDH 50 FT

Elevation 110 FT

VASIS 3.0°

3.89 NM

NM   5   0   5   10   15 km

OCA(H)				Distance OS-MM 6.76 NM							
Cat of ACFT	Cat A	Cat B	Cat C	Cat D	Speed	KT	80	100	120	140	180	220
Straight-in Cat I	278 (168)	284 (174)	293 (183)	303 (193)	Time	min:s	5:04	4:03	3:23	2:54	2:32	2:15
Straight-in Cat II	152 (42)	169 (59)	181 (71)	195 (85)	Rate of descent / GS	ft/min	425	530	635	740	850	956
GP INOP	850 (740)											
Circling	870 (760)	870 (760)	970 (860)	970 (860)								

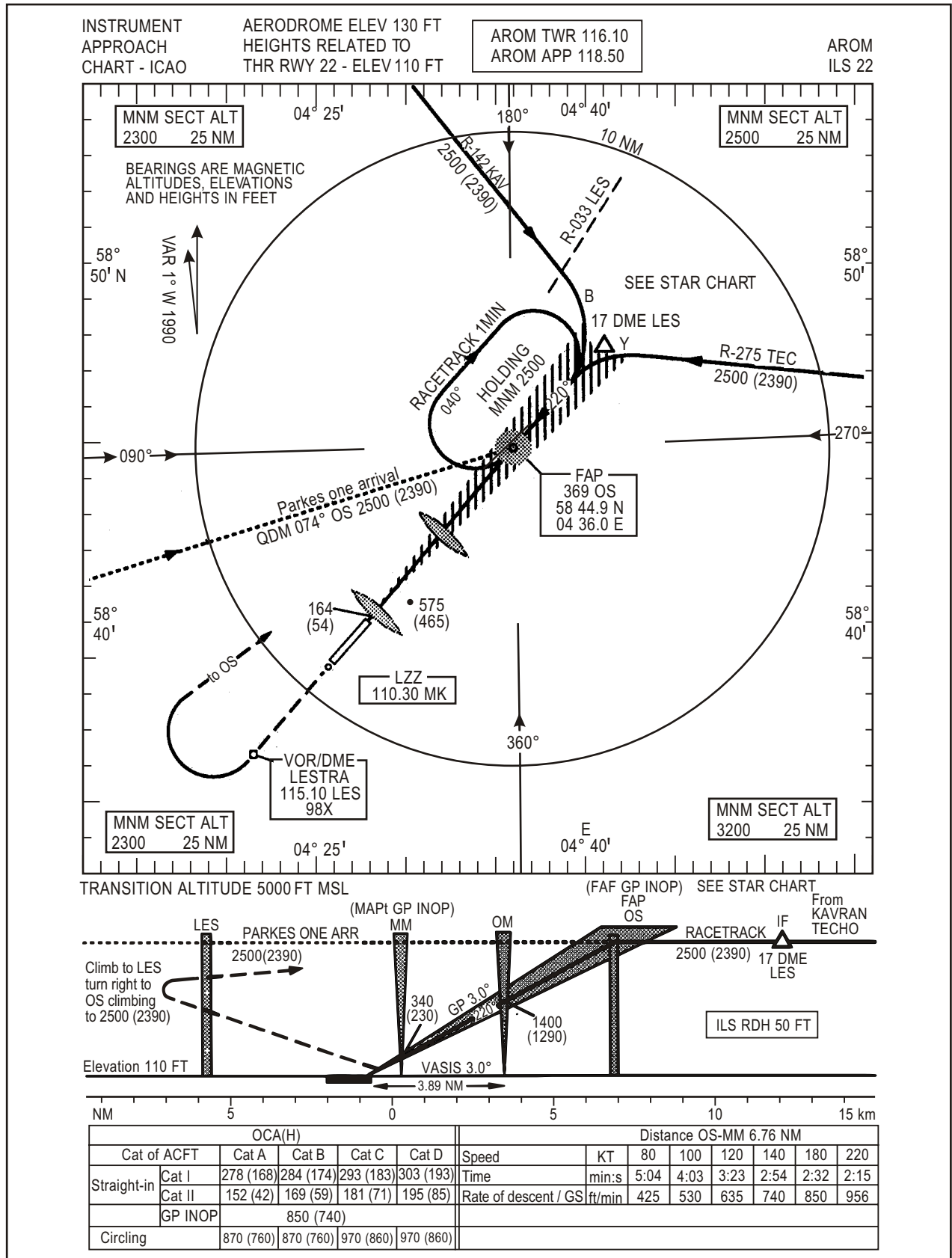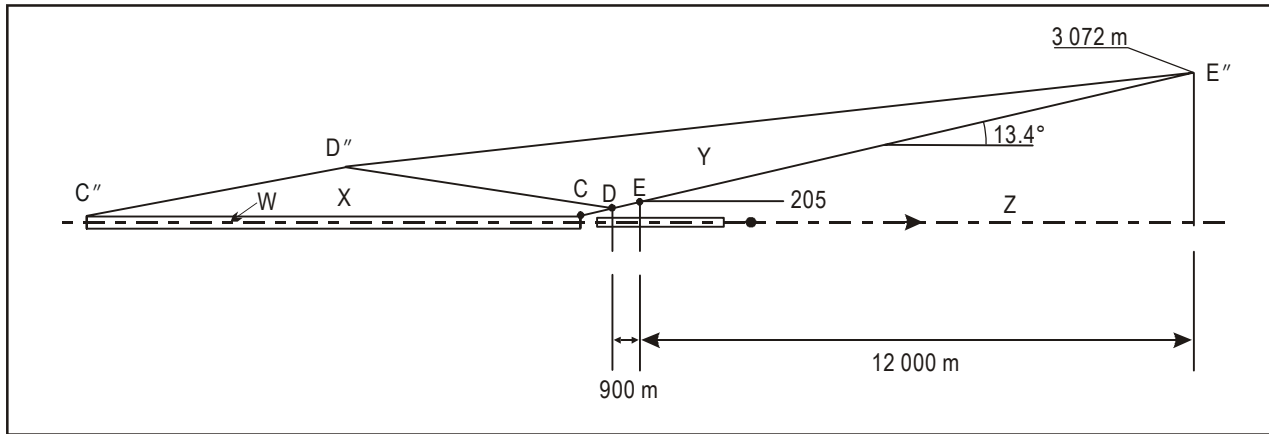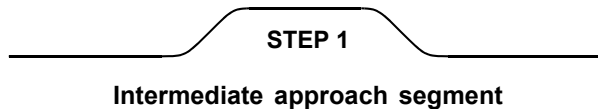**Figure II-2-5-13**

Figure II-2-5-14

Chapter 6

Localizer Only

ILS procedure on AROM aerodrome Runway 22 is to be completed with a procedure for ILS with GP inoperative.

Entry into the procedure, making use of standard arrival routes and the racetrack area, is as in Chapter 5 of this section.

Data

See Chapter 5 of this section.

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_____╱   STEP 1   ╲_____
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Intermediate approach segment

The intermediate approach segment is not always the same as in full ILS (see Chapter 5 of this section). NDB OS is located at the FAP position and in this procedure functions as the FAF. Chapter 5 of this section, Figure II-2-6-9 applies.

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        ╱‾‾‾‾‾‾‾‾‾‾‾╲
_____╱   STEP 2   ╲_____
```

Final approach segment
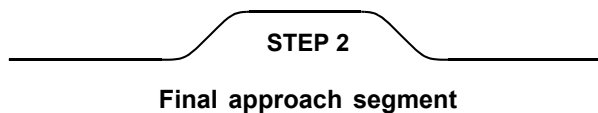
The final approach descent begins at the FAF, with the descent gradient calculated as 5.2 per cent. The outer boundaries for the final approach area and the straight missed approach area are defined by the OAS 300 m contours for Category I, plus the extension of line D-D".

Coordinates for D, E, D" and E" are attained from the tables in Attachment I to Part III for 2 400 m LLZ/THR, 3° GP. MOC is 94 m (increased due to excessive length of final approach, PANS-OPS, Volume II, Part III, 6.4.6 b)), reduced in secondary areas (see the example in Figure II-2-6-1).

See Chapter 5 of this section, Figure II-2-5-2. A check is made whether Obstacle 175 penetrates the Y surface (coordinates x = 2 600 m, y = 800 m):
(2 600 × 0.0228) + (800 × 0.2001) − 20.5 = 198.9 m.

The Y surface is not penetrated by any part of the hill. Therefore, the top 175 m can be disregarded. The highest contour of the hill below the X surface is 150 m MSL. Add 15 m for vegetation. Add MOC 94 m. OCA/H is therefore 260 (230) m or 860 (750) ft.

Can obstacle 165 be eliminated by a stepdown fix? LES DME is a possible solution:

Distance LES to THR 22 is 7 300 + 2 000 = 9 300 m.

Obstacle 165 distance from THR 22 is 2 900 (about the same as obstacle 12 in the list of obstacles).

Distance from DME is 9 300 + 2 900 = 12 200 m = 6.59 NM.

Thus, 6 DME is the earliest range at which the stepdown fix can be located. Will this procedure have an acceptable final approach gradient?

Distance 6 DME to THR is 11 100 m.

Distance from THR 22 is 11 100 − 9 300 = 1 800 m.

Lowest altitude over obstacle 165 is 165 + 75 = 240 m MSL or 206 m above THR 22. Descent gradient to a point 15 m above THR is:

$$\frac{200 - 15}{1\ 800} = 0.1 = 10\%$$

This gradient exceeds the maximum descent gradient (6.5 per cent).
The obstacle cannot be eliminated with 6 DME as stepdown fix.
OCA/H final approach is therefore 860 (750) ft.

STEP 3

Initial missed approach area — calculation of MOC

Note.— As a training exercise, a separate example is introduced in this step.

MOC in the initial missed approach area is 30 m from the SOC and increases linearly in the opposite direction to the inbound track (see PANS-OPS, Volume II, Figure III-7-3). Compare with Figure II-2-6-2. MOC increases along line AC from 30 to 75 m in the primary area.

MOC in the primary area is calculated as follows:

In the triangle ABC

$$\frac{AB}{BC} = \tan z, \tan z = \text{climb gradient}$$

Thus, $BC = \dfrac{AB}{\text{climb gradient}}$

In this example, $BC = \dfrac{45}{0.025} = 1\ 800$ m

An obstacle with elevation 205 m is assumed to be situated at coordinates x = 550, y = 1 050 m. A check with the height equation for the Y surface indicates that the surface is penetrated and the obstacle cannot be disregarded.

Distance MAPt to obstacle 205 is 500 m.

For Category C aircraft d + X = 280 + 1 380 = 1 660 m (no overhead fix tolerance).
Therefore, distance SOC to the obstacle is 1 660 – 500 = 1 160 m.

MOC in primary area is now calculated

$$\frac{1\ 160}{1\ 800} \times 45 + 30 = 59 \text{ m}$$

For Category B aircraft, the corresponding value is 52 m and for Category A, 45 m.

Obstacle 205 penetrates the Y surface and secondary area obstacle clearance reductions can be applied.

Category C MOC at Obstacle 205 is $\dfrac{400}{1\ 200} \times 59 = 19.6$ (20 m)

OCA for Category C aircraft in initial missed approach area = 205 + 20 = 225 m.

Corresponding calculations for Categories B and A give:

Category B = 205 + 18 = 223 m
Category A = 205 + 15 = 220 m.

Note 1.— In the whole final approach area MOC 75 m is applied in the primary area.

Note 2.— When distance FAF to the nearest landing surface exceeds 6 NM, MOC in the final approach area shall be increased. This increased value shall be used in the calculations above (the length of line BC is affected).

STEP 4

Intermediate and final missed approach

It is assumed that no obstacles affect the intermediate and final missed approach. Regarding turning missed approach, see Chapters 9 and 10 of this section.

Summary

Normally the FAP is located before the OM. This means that if the OM is used as FAF and if no facility is available at the FAP and there is no DME facility, the altitude/height of the intermediate segment may have to be reduced to the overhead altitude/height at the OM, if the maximum descent gradient is not to be exceeded. If a steeper gradient must be accepted, PANS-OPS, Volume II, Part III, 26.4.5 applies (i.e. the procedure must be restricted to circling OCA/H).
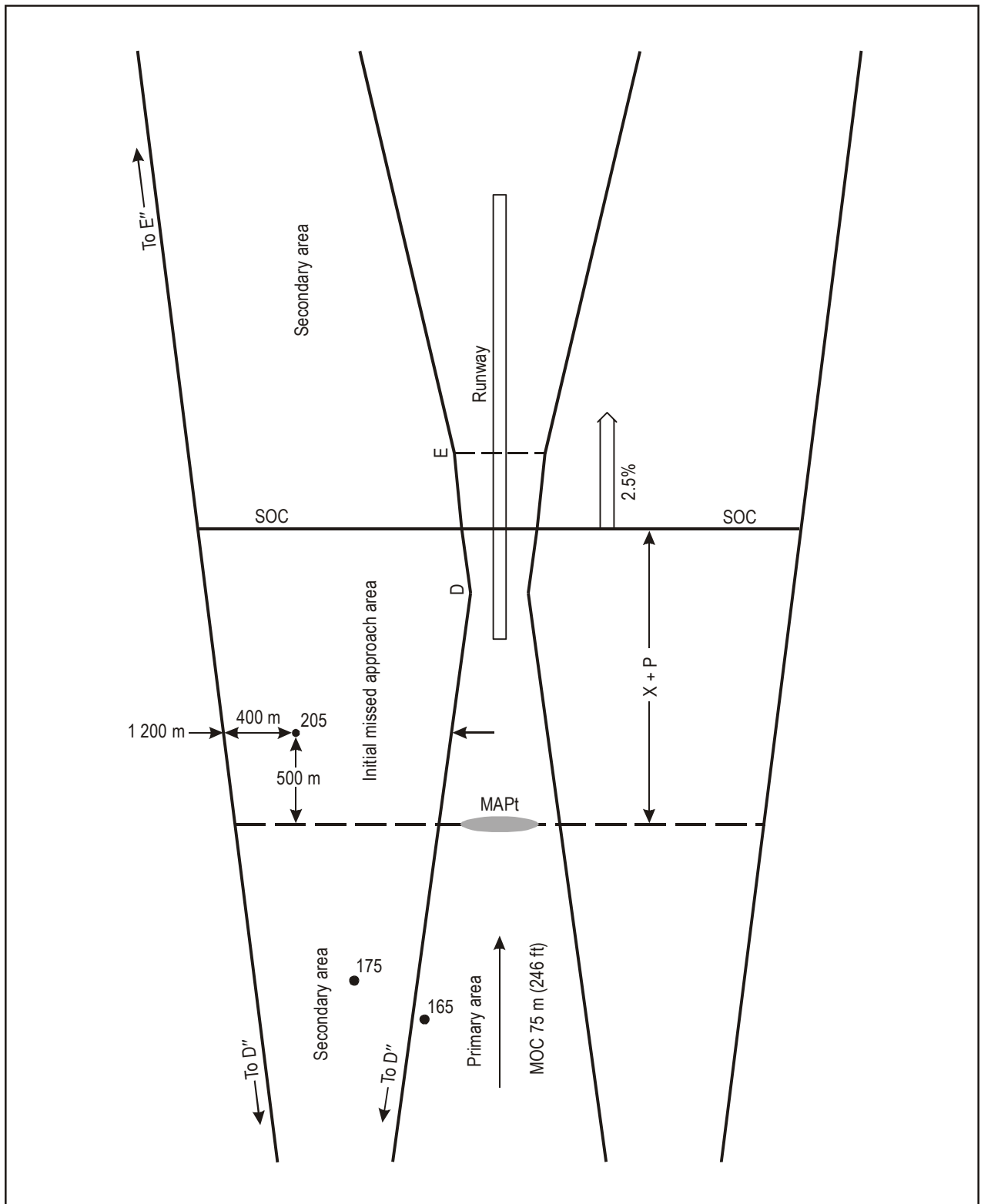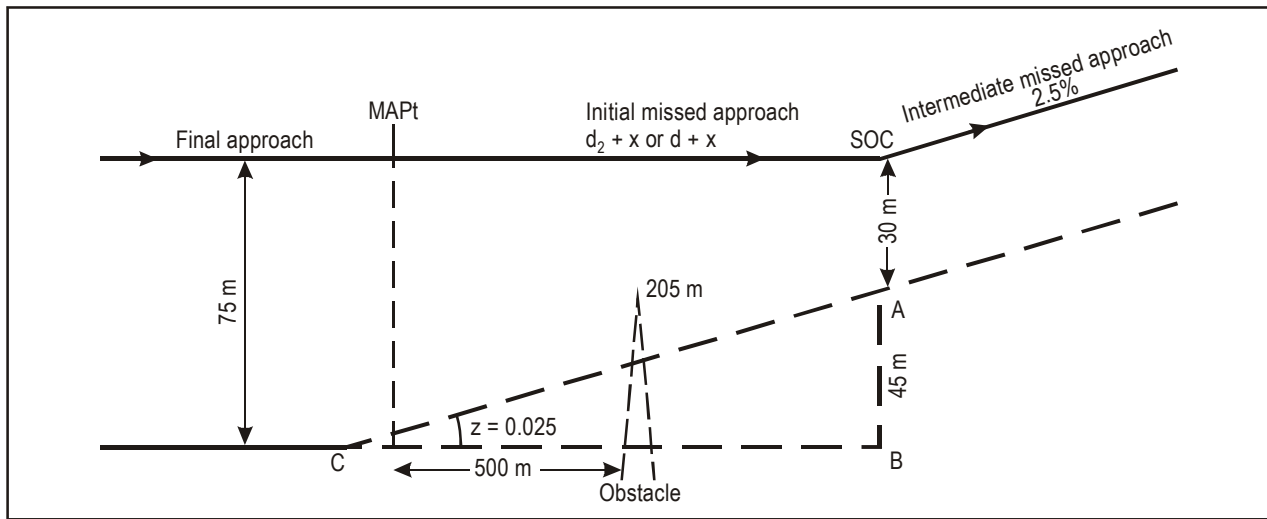
Figure II-2-6-1

**Figure II-2-6-2. d_2 + the transitional tolerance X is valid when timing from a FAF is applied.
d + the transitional tolerance X is valid when MAPt is defined by a fix.**

Chapter 7

Surveillance Radar

The Surveillance Radar Element (SRE) straight-in procedure using terminal area radar shall be designed for DONLON/Slipton Runway 11.

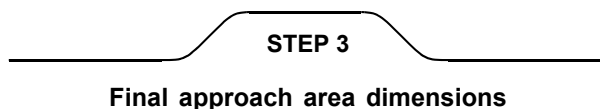### Data

See Chapter 1 of this section.

The radar antenna location is 14 NM at a bearing of 301° from ARP (located at the intersection of two runways).

STEP 1

Minimum sector altitudes (MSA)
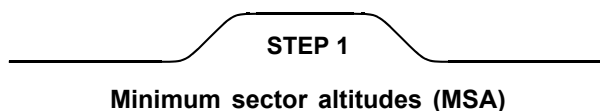
When a suitable radio navigation facility is available, the use of minimum sector altitudes is recommended. Minimum sector altitudes are calculated in Chapter 1 of this section, Step 4.

STEP 2

Final approach descent line, profile
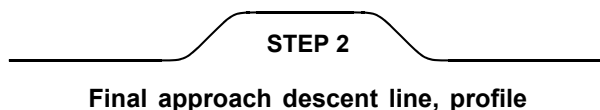
Draw a profile as in Chapter 1 of this section, Step 2, using a descent gradient of 5 per cent.

STEP 3

Final approach area dimensions

The final approach track shall coincide with the extended runway centre line. According to PANS-OPS, Volume II, Part III, 24.2.5, the MAPt is located at the point where the radar approach terminates, either 2 NM before the threshold or, when approved by the appropriate authority, closer to the threshold when the accuracy of the radar permits. In the example, a location of MAPt 2 NM before the threshold is assumed. The minimum length of the final approach is 3 NM. The obstacle situation in the intermediate and final approach area shall be examined for determination of FAF location. Assume a FAF at 4 NM from MAPt or 6 NM (11.1 km) from the threshold. The width for the area at FAF is calculated as follows.

Draw the extended runway centre line on a suitable map. Indicate MAPt 2 NM and preliminary FAF 6 NM from the threshold. Indicate radar antenna position. Measure with a ruler the distance from antenna to FAF = 15 000 m (8.3 NM) and antenna to MAPt = 17 800 m (9.6 NM).

Calculate the half-width of each:

at FAF: $1 + (0.1 \times 8.3) = 1.83$ NM = 3.4 km
at MAPt: $1 + (0.1 \times 9.6) = 1.96$ NM = 3.6 km

STEP 4

Intermediate area dimensions
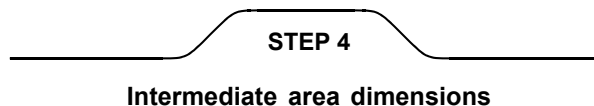
If the intermediate track differs from final track (max 30°) it shall intersect the extended runway centre line at a distance from the point where final approach descent begins. If the obstacle situation does not necessitate such a different track, a straight-in approach is preferable, at an optimum length of 5 NM.

See Figure II-2-7-1. The boundaries for the intermediate, final and missed approach areas shall be drawn. The width of the segment at IF is 3 + 3 NM at distances from the radar antenna up to 20 NM from the antenna.

Examine the obstacle situation in the intermediate area. This segment should, if possible, be flat. If obstacles tend to raise this segment to a height making descent gradient from FAF to THR steeper than 5 per cent, the FAF should be moved outwards to a maximum of 6 NM from the MAPt. If this is not enough, a steeper final gradient can be accepted; however, it must not exceed 6.5 per cent.

Note.— Assume all obstacles meet accuracy requirements for SRE approaches.

STEP 5

Initial segment

The initial segment is either centred on a predetermined track or on an area for tactical vectoring. In the first case, the semi-width of the sector is 3 NM up to 20 NM from the radar antenna and 5 NM at greater distances. The segment begins where the aircraft has been identified for a radar approach. The aircraft shall be vectored along the track or tactically vectored to the IF. Within the sector or the whole area, MOC is 300 m (985 ft).

STEP 6

Final approach OCA/H – MAPt

If the obstacle situation in the intermediate segment area does not necessitate moving the FAF outwards, OCA/H can be determined. The highest obstacle within the whole area plus 75 m applies. Secondary areas are not authorized for radar approaches.

PANS-OPS, Volume II, Part III, 2.8.4 regarding obstacles close to a final approach fix applies (see also Chapter 4 of this section, Figure II-2-4-2). Radar fix accuracy is 0.8 NM (terminal area radar). If the highest obstacle in the final approach area is 115 m MSL, OCA/H in this segment is 115 + 75 = 190 (137) m.

Altitude at FAF, when calculated for a gradient of 5 per cent from 15 m above THR, is (6 NM = 11 100 m):

11 100 × 0.05 + 15 + 53 = 623 m = 2 044 ft

See Figures II-2-7-2 and II-2-7-3. MAPt is situated 2 NM before THR. What height is the descent path at this distance?

15 + (0.05 × 3 704) = 200.2 m or altitude 254 m MSL

This value is higher than final approach OCH 137 m or OCA 190 m. This means that an aircraft will reach MAPt before final approach OCA/H.

To enable aircraft to reach OCA/H at MAPt, the descent path shall be calculated from altitude 190 m at 2 NM distance from the THR. Altitude at FAF is calculated:

190 + 0.05 × 7 408 = 560.4 m = 1 839 ft rounded up to 1 900 ft

which increases the descent gradient to 0.053.

A check of the obstacle situation in the initial and intermediate approach areas confirms that this height is acceptable. If the obstacle situation would not permit a height reduction, either the FAF must be moved to 7 NM from the THR or the descent gradient must be increased (maximum 6.5 per cent).

The descent gradient from MAPt on 190 m to THR is calculated:

$$\frac{190 - 53 - 15}{3\ 074} = 0.0396 = 3.9\%$$

STEP 7

Missed approach OCA/H
(Figures II-2-7-2 and II-2-7-3)

Missed approach area begins at MAPt (2 NM before THR) and widens from there with splay 15°.

Distance MAPt to SOC is calculated with fix accuracy + d + X values for Category D aircraft:

0.8 + 0.17 + 0.86 = 1.83 NM = 3 389 m

SOC begins 2.0 – 1.83 = 0.17 NM = 315 m before THR

An obstacle, elevation 200 m, is situated 0.85 NM after THR or 0.85 + 0.17 = 1.02 NM = 1 890 m from SOC. OCA is calculated:

200 – 1 890 × 0.025 + 30 = 182.8 m, which is below final approach OCA.

A check of another obstacle in the missed approach area, elevation 305 m, at distance 3.35 NM from THR, indicates that it does not affect OCA/H.

Regarding turning missed approach, see Chapters 9 and 10 of this section.

STEP 8

Circling minima

A circling OCA/H is determined in accordance with PANS-OPS, Volume II, Part III, Chapter 8 (see Chapter 1 of this section, Step 12).

An SRE approach procedure can also be designed as a circling procedure.

STEP 9

Calculation of altitude/height on points at the final descent path

Altitudes/heights through which the aircraft should pass to maintain the required descent path in the final approach phase should be computed for each 1 or 1/2 NM from touchdown, assuming a 15-m height at the runway threshold. Touchdown point is located:

$$\frac{15}{0.05} = 300 \text{ m after the threshold.}$$

In the example, descent path is calculated between FAF (altitude 1 900 ft = 579.5 m) and a point 2 NM before THR (altitude = OCA = 190 m). Height to be reduced is 579.5 – 190 = 389.5 m on distance 4 NM.

Descent gradient is:

$$\frac{389.5}{7\ 408} = 0.053$$

As descent path is not directed to touchdown point, distances after FAF are related to THR in this example. With gradient 0.049, altitudes at 3, 4 and 5 NM from THR are calculated:

3 NM: 190 + 1 852 × 0.053 = 288 m = 945 ft
4 NM: 190 + 3 704 × 0.053 = 386 m = 1 267 ft
5 NM: 190 + 5 556 × 0.053 = 484 m = 1 589 ft.

All values shall be rounded up to the next 10 ft increment.

The pre-computed altitudes/heights should be readily available to the radar controller and should be published in the Aeronautical Information Publication (AIP). An example is presented in the next step.

STEP 10

Publishing of the instrument approach procedure

This procedure may be presented in the AIP as a table (see Table II-2-7-1) or as an instrument approach chart (see the end of this chapter).

Table II-2-7-1

Aerodrome	RWY number	Aerodrome elevation ft m	Inbound track degrees magnetic	Intermediate approach altitude ft m	IF range from THR NM km	FAF range from THR NM km	MAPt range from THR NM km	OCA/H ft m
DONLON/	11	178	105	1 900	11	6	2.0	630 (450)
Slipton		54		580	20.4	11.1	3.7	190 (140)

Missed approach procedure feet m	Circling OCA/H feet m			
	Cat A	Cat B	Cat C	Cat D
Climb straight ahead to 2 400 (2 230)	760 (580)	1 090 (910)	1 190 (1 010)	1 430 (1 250)
720 (670)	230 (180)	330 (280)	360 (310)	435 (385)

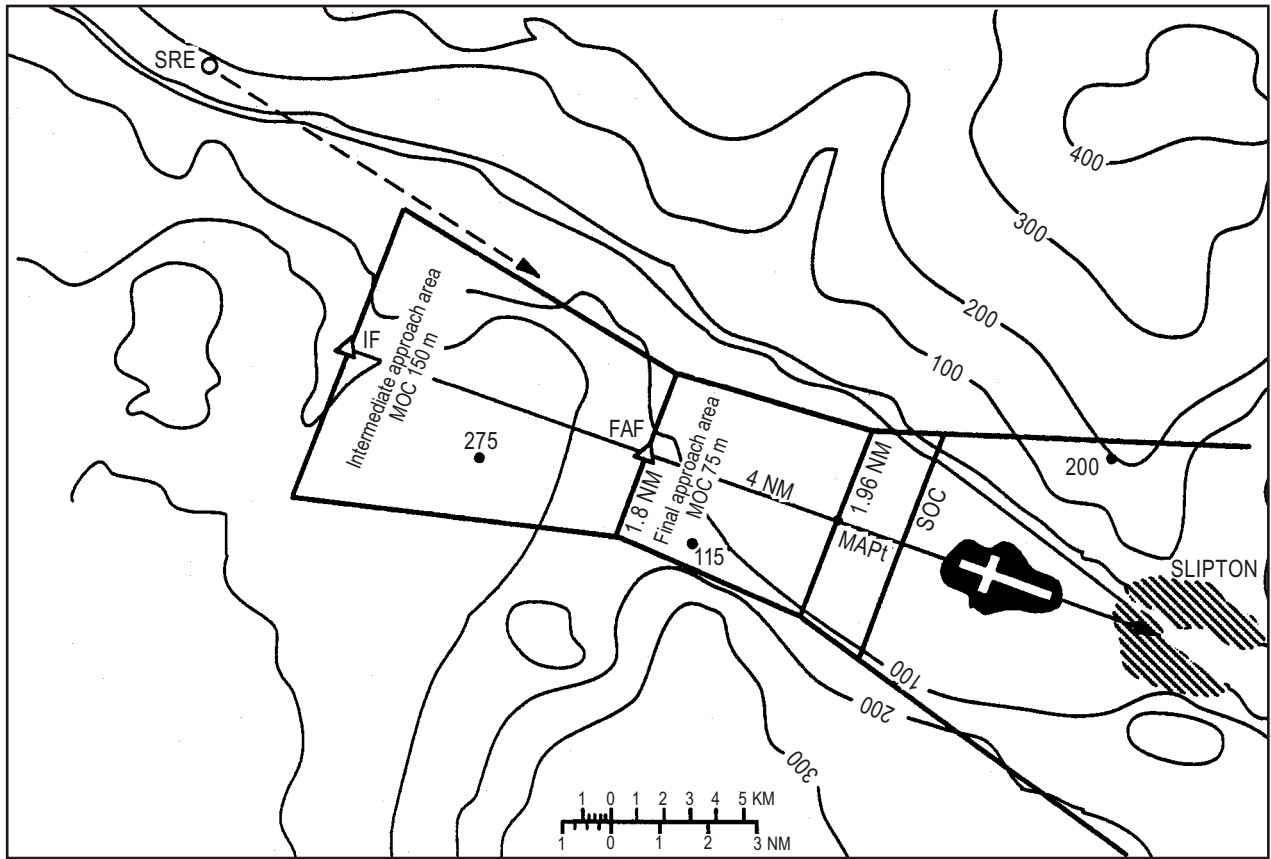| Distance from THR NM KM	2 3.7	3 5.6	4 7.4	5 9.3
Altitude/height: ft	630 (450)	950 (770)	1 270 (1 090)	1 590 (1 420)
m	190 (140)	290 (235)	390 (335)	485 (430)

Figure II-2-7-1.   SRE straight-in procedure — plan view
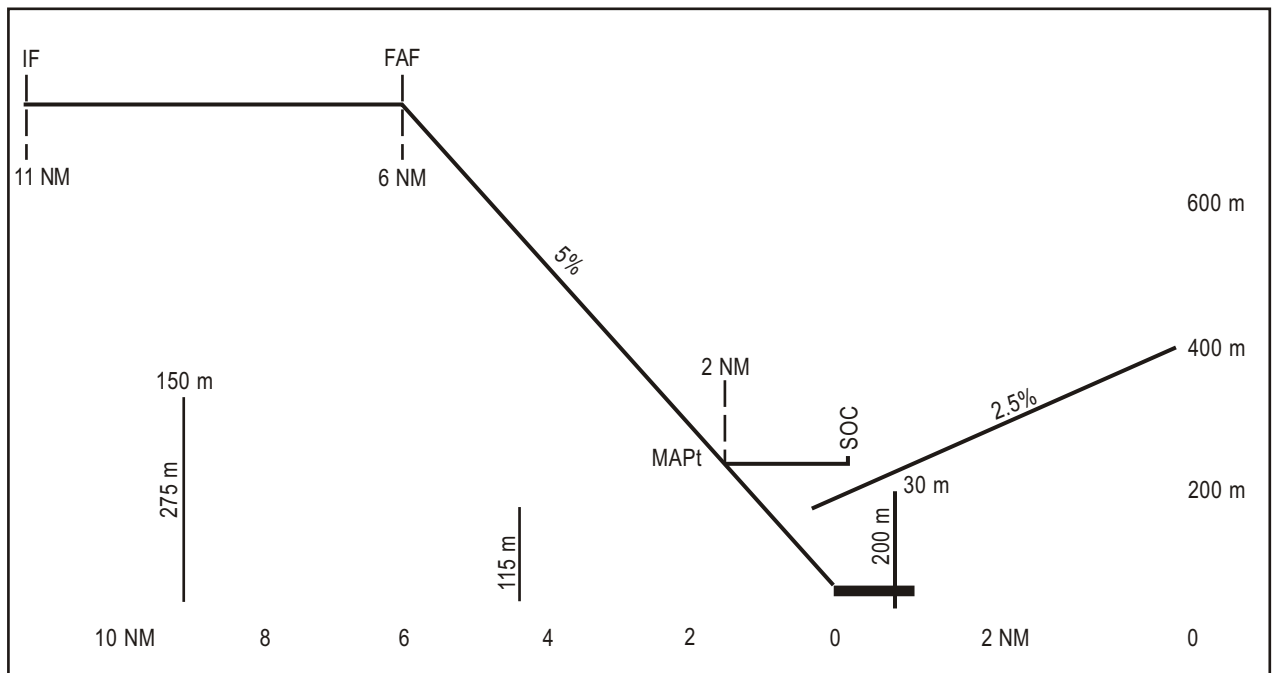
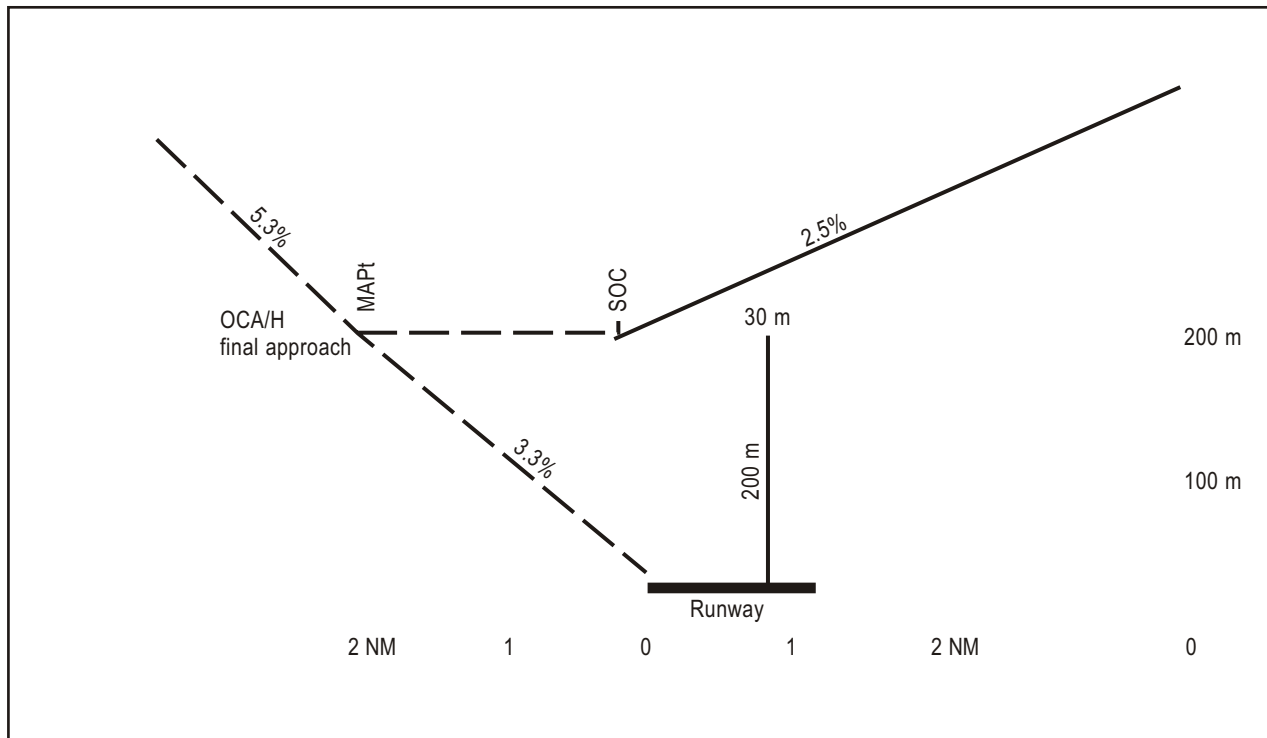**Figure II-2-7-2.   SRE straight-in procedure — vertical profile**

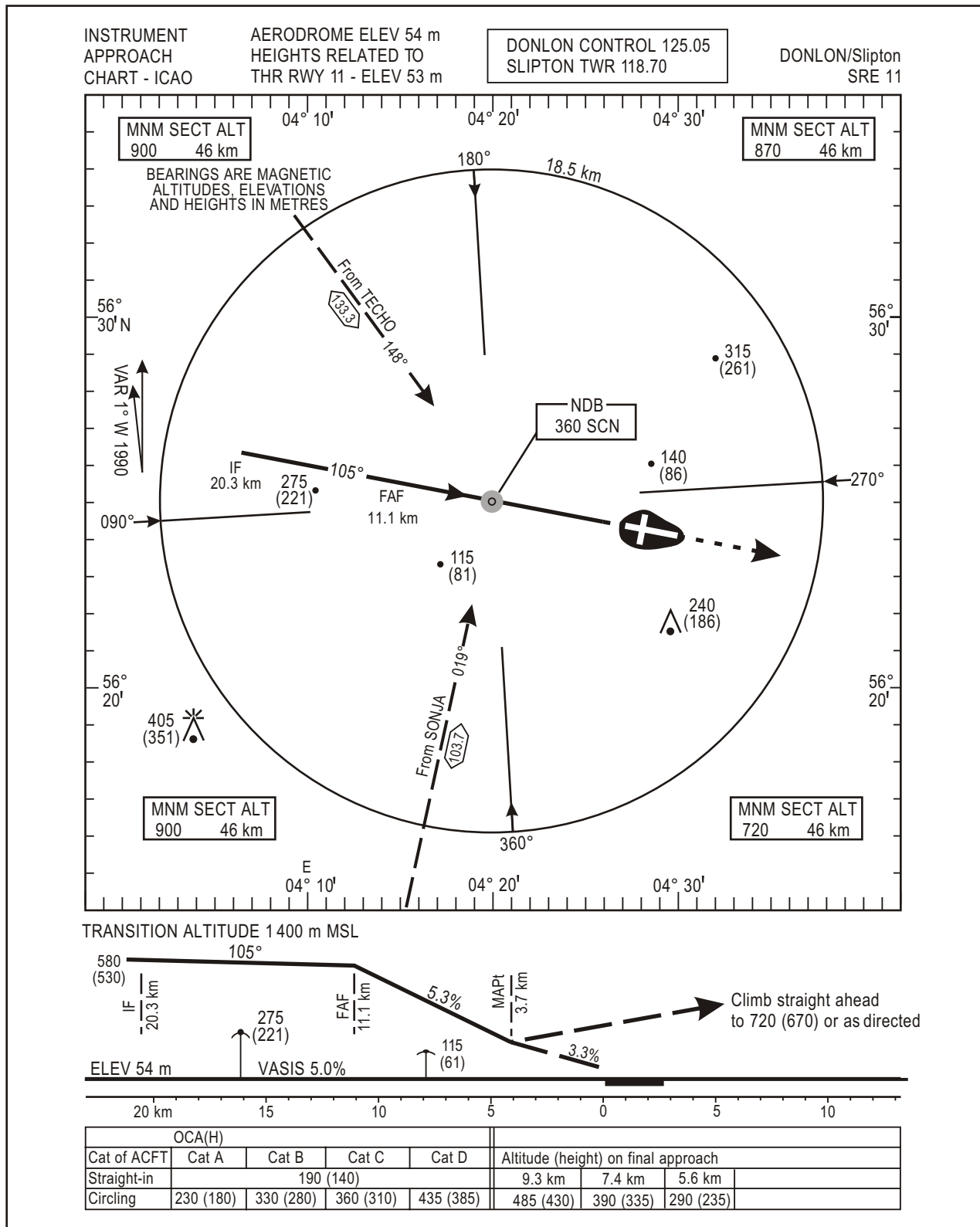**Figure II-2-7-3.   SRE straight-in procedure — missed approach**

Figure II-2-7-4

INSTRUMENT
APPROACH
CHART - ICAO

AERODROME ELEV 178 FT
HEIGHTS RELATED TO
THR RWY 11 - ELEV 174 FT

DONLON CONTROL 125.05
SLIPTON TWR 118.70

DONLON/Slipton
SRE 11

MNM SECT ALT
3000   25 NM

MNM SECT ALT
2900   25 NM

04° 10'   04° 20'   04° 30'

180°   10 NM

BEARINGS ARE MAGNETIC
ALTITUDES, ELEVATIONS
AND HEIGHTS IN FEET

From TECHO
72
148°

56°
30' N

56°
30'

1034
(856)

VAR 1° W 1990

NDB
360 SCN

460
(282)

270°

IF
11 NM   903
(725)   105°

FAF
6 NM

090°

378
(200)

788
(610)

56°
20'

1329
(1151)

56°
20'

From SONJA   019°

56

MNM SECT ALT
2900   25 NM

MNM SECT ALT
2400   25 NM

360°

E
04° 10'   04° 20'   04° 30'

TRANSITION ALTITUDE 4 500 FT MSL

1900
(1730)   105°

IF
11 NM

903
(725)

FAF
6 NM   5.3%

MAPt
2 NM

Climb straight ahead
to 2400 (2230) or as
directed

378
(200)   3.3%

ELEV 178 FT   VASIS 5.0%

NM   10   5   0   5   NM

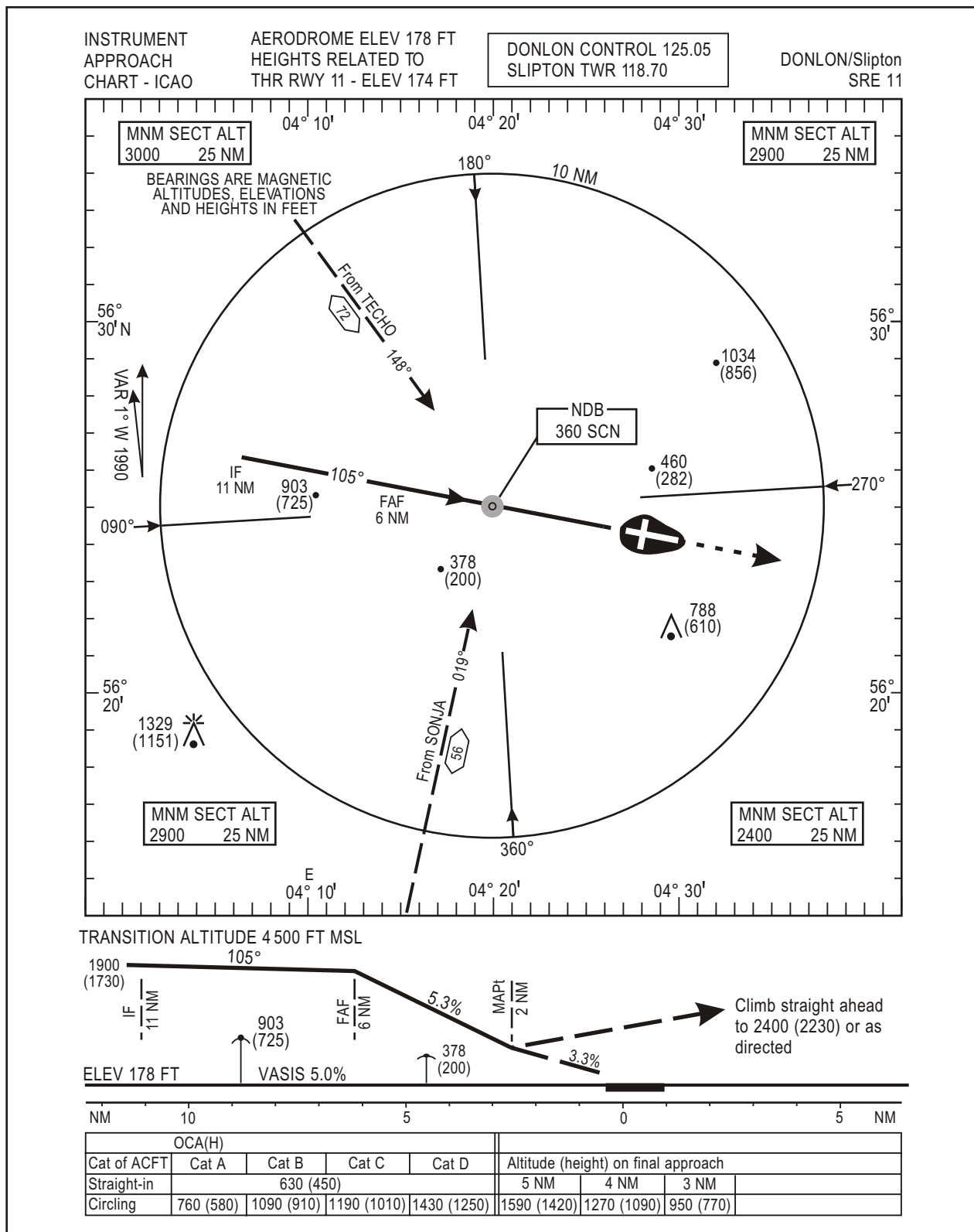| Cat of ACFT	OCA(H)				Altitude (height) on final approach			
	Cat A	Cat B	Cat C	Cat D				
Straight-in		630 (450)			5 NM	4 NM	3 NM	
Circling	760 (580)	1090 (910)	1190 (1010)	1430 (1250)	1590 (1420)	1270 (1090)	950 (770)	

Figure II-2-7-5

Chapter 8

Direction Finding (DF) Facility

8.1 INTRODUCTION

In principle, a direction finding facility functions as an NDB. By homing, it is possible to navigate towards the DF location and to determine the overhead facility. Given sufficient altitude, homing may be possible from distances up to 25 NM or more. Therefore, the use of minimum sector altitudes is recommended. Where one (high) MSA makes it difficult to plan the necessary descent, it is suggested that a 10 NM radius circle (300 m MOC) be established over the facility to enable aircraft to manoeuvre onto the outbound leg.

8.2 DATA

See Chapter 3 of this section. The DF equipment is located on the airfield, 200 m north of threshold 09.

8.3 REQUIREMENT

A DF instrument approach procedure shall be designed for BROMBURG aerodrome Runway 09. If a straight-in approach is possible to RWY 09 it is preferable, otherwise a circling procedure is sufficient.

Aircraft: Categories A and B.

8.4 THE PROCEDURE

The DF procedure is principally a base turn. Approach into the procedure should be executed at the highest MSA to enable the aircraft to manoeuvre after the first overhead into the procedure from a track within ±30° of the outbound track.

The lowest possible altitude during the last turn before the inbound track is 300 m (1 000 ft) above the highest

obstacle in the area (drawn on Figure II-2-8-1). The design begins with establishing MSA and thereafter examining the obstacle situation in the final approach area.

STEP 1

Minimum sector altitudes (MSA)
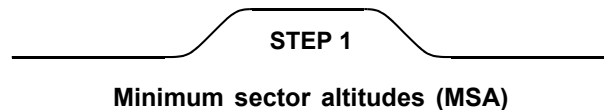
Minimum sector altitudes have been established for an on-aerodrome NDB procedure in Chapter 3 of this section, Step 2. A check confirms that moving the centre of the MSA to the DF location does not change the MSA.

STEP 2
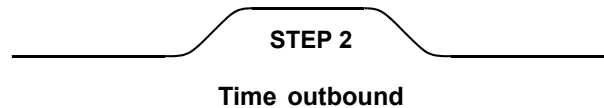
Time outbound

A diagram for determining the time outbound for an on-aerodrome NDB procedure to RWY 09 is shown in Chapter 3 of this section, Step 1 (Figure II-2-3-1). Aircraft arriving from the NW sector will need 3 min outbound using maximum descent gradients to reduce height down to THR. A holding is not available for aircraft using a DF procedure. Aircraft arriving from the NW can reduce height in the two southern MSAs to 3 400 ft MSL, manoeuvring after the first overhead for another overhead on the outbound track. The turn altitude will be 2 400 ft MSL.

Another solution is to define the lowest possible altitude using 300 m MOC over the highest obstacle within a circular area of 10 NM radius around the DF facility. This area shall be available for height reduction when manoeuvring for another overhead towards the outbound track.

The type of height reduction to be utilized shall be indicated on the instrument approach chart.

Time outbound will be 2 min 30 s.

STEP 3

Final approach area — alignment

The final approach area has a total width of 3 NM at the facility. The splay angle is 10° (see Figure II-2-8-2).

The length of the area is D + 2 NM where D is calculated with the following formula:

$$D = \left(\frac{V}{60} + 1\right) t + 1.5$$

where D is the radius in NM. V = TAS in knots and T outbound time in minutes.

$$D = \left(\frac{139}{60} + 1\right) \times 2.5 + 1.5 = 9.79 \text{ NM}$$

The length of the area is 9.79 + 2 = 11.79 NM = 21.8 km.

The final approach area and the straight missed approach area are drawn on Figure II-2-8-1. The DF facility is located off the centre line (see Chapter 4 of this section, Step 1).

If the inbound track intercepts the extended runway centre line at 1 000 m from the THR, the intercept angle is calculated:

$$\tan (\text{intercept angle}) = \frac{200}{1\ 000} = 0.2$$

Corresponding angle is 11°

As the runway magnetic bearing is 092°, the inbound track should be 081° or, better, 080°.

Check the obstacle situation in the final approach area with this track. Obstacle 398 is the highest one in the area.

OCA = 398 + 90 = 488 m MSL or 1 600 ft MSL. OCH is 440 ft.

STEP 4

Initial approach area

The distance D was calculated in Step 3. The angle between the outbound and the inbound track is 36/t.

In the example 36/2.5 = 14.4°. With these values Figure II-2-8-2 is drawn. Overhead tolerance is included in the limits of the area.

The highest obstacle within the area (no secondary areas) is 405 m. Add MOC 300 m. This makes the lowest possible turn altitude 705 m for obstacle reasons. This is safely below the proposed turn altitude 732 m or 2 400 ft MSL as was indicated in Step 2.

For comparison, see Figure II-2-8-1.

STEP 5

Missed approach

The missed approach point (MAPt) is located at the facility. The missed approach area begins to splay 15° 1 NM before the facility (see Figure II-2-8-2).

Distance MAPt to SOC is d + X (see Chapter 1 of this section, Step 10).

It is assumed that no objects affect in the missed approach area.

Regarding the turning missed approach, see Chapters 9 and 10 of this section.

STEP 6

Circling minima

The circling minima, determined in Chapter 3 of this section, apply. However, the circling OCA/H must not be lower than the OCA/H for the final approach OCA/H. Therefore, the OCA/H Category A circling shall be raised (see the instrument approach chart at the end of this chapter).

STEP 7

Holding

Holding shall not be presented (see the introduction to this chapter).

STEP 8

Tables

Only OCA/H tables shall be presented on the instrument approach chart.

STEP 9

Production of the instrument approach chart

Instrument approach charts, based on the procedure designed, are presented in Figures II-2-8-3 and II-2-8-4.
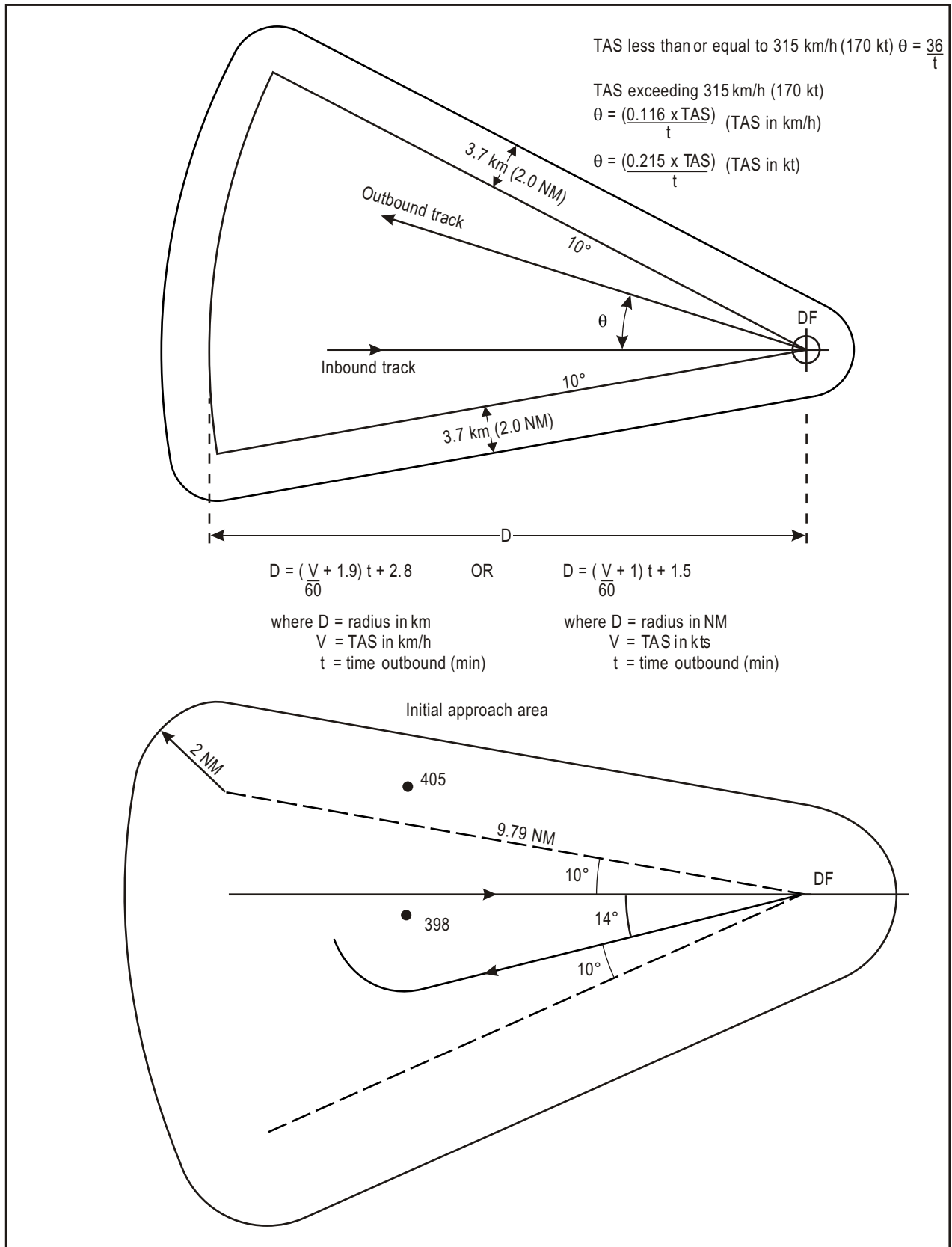
TAS less than or equal to 315 km/h (170 kt) $\theta = \dfrac{36}{t}$

TAS exceeding 315 km/h (170 kt)

$\theta = \dfrac{(0.116 \times TAS)}{t}$ (TAS in km/h)

$\theta = \dfrac{(0.215 \times TAS)}{t}$ (TAS in kt)

3.7 km (2.0 NM)

Outbound track

10°

θ

DF

Inbound track

10°

3.7 km (2.0 NM)

D

$D = \left(\dfrac{V}{60} + 1.9\right) t + 2.8$ OR $D = \left(\dfrac{V}{60} + 1\right) t + 1.5$

where D = radius in km   where D = radius in NM
      V = TAS in km/h   V = TAS in kts
      t = time outbound (min)   t = time outbound (min)

Initial approach area

2 NM

● 405

9.79 NM

10°

DF

● 398

14°

10°

Figure II-2-8-1.   Area for the calculation of turn altitude
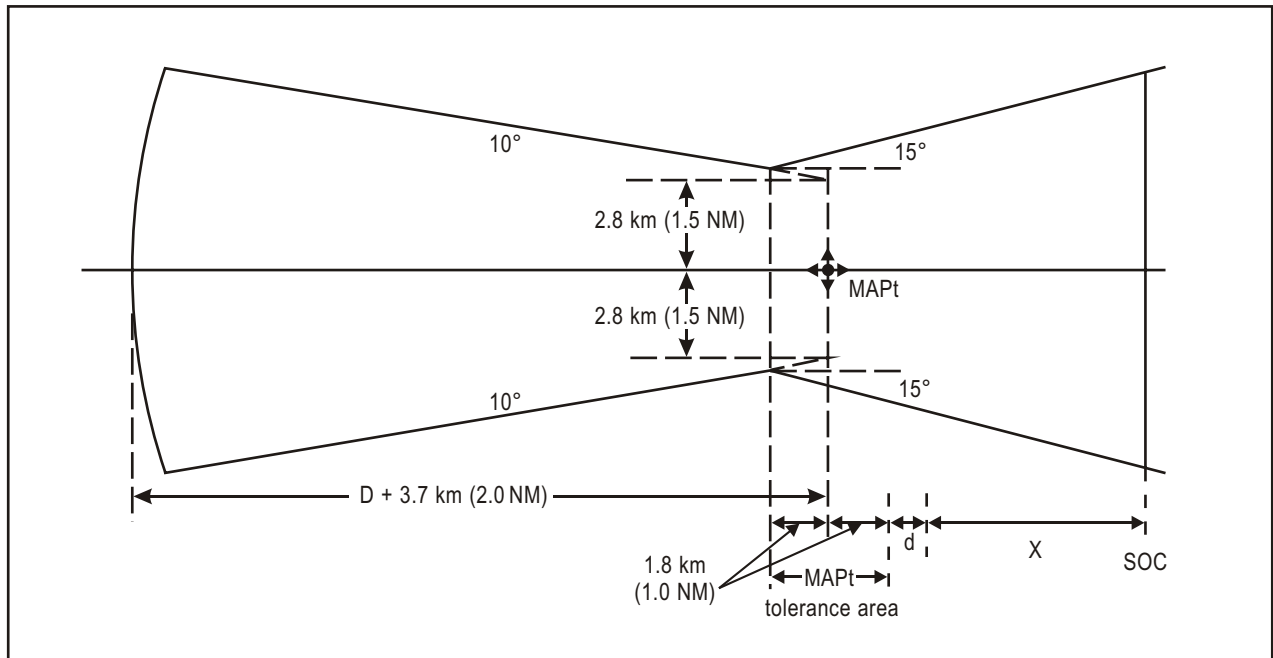
Figure II-2-8-2.   Final approach area

INSTRUMENT APPROACH CHART - ICAO

AERODROME ELEV 363 m
HEIGHTS RELATED TO
THR RWY 09 - ELEV 362 m

BROMBURG TWR 118.10
BROMBURG APP 124.50

BROMBURG
NDB 09

MNM SECT ALT
1560   46 km

05° 00'   05° 10'   05° 20'

MNM SECT ALT
1350   46 km

BEARINGS ARE MAGNETIC
ALTITUDES, ELEVATIONS
AND HEIGHTS IN METRES

180°   18.5 km

VAR 3° W 1990

60°
30' N

60°
30'

• 405
(42)

• 403
(40)

DF

270°

090°   080°   • 391
(28)

398 •
(35)

246°
2 MIN 30 SEC

Note.– Inbound track is offset 12°
from runway bearing 092°

60°
20'

60°
20'

MNM SECT ALT
970   46 km

360°

MNM SECT ALT
780   46 km

E
05° 00'   05° 10'   05° 20'

TRANSITION ALTITUDE 1 700 m MSL

Arrival from NW sector
descending in SE or SW sector

2 MIN 30 SEC
246°

DF

MSA (except from NW)

720
(360)

Climb to 780 (420)

398
(35)

080°

ELEV 363 m

15 km   10   5   0   5   10   15 km

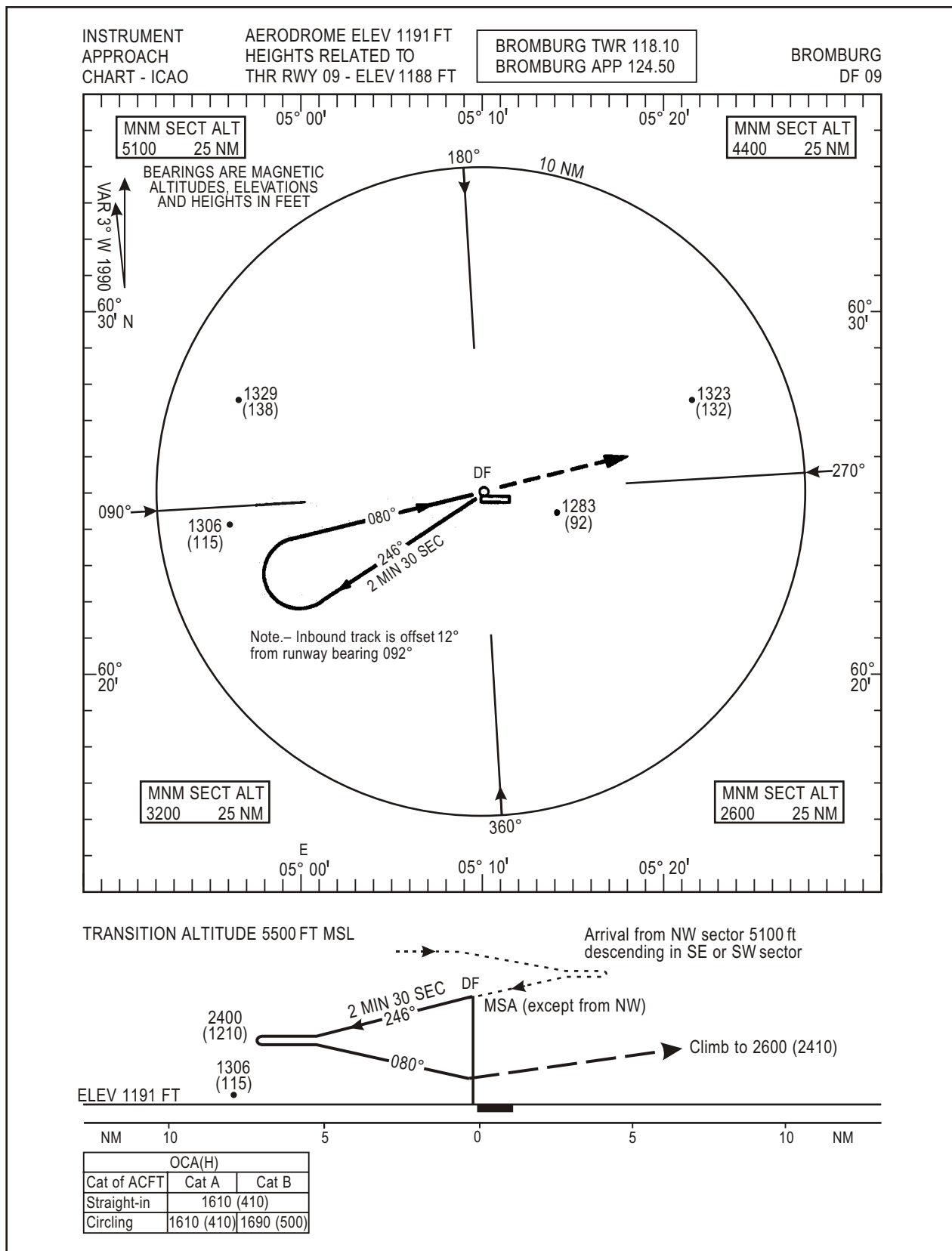| OCA(H)		
Cat of ACFT	Cat A	Cat B
Straight-in	490 (125)	
Circling	490 (125)	515 (150)

Figure II-2-8-3.   Bromburg NDB 09

Figure II-2-8-4. Bromburg DF 09

Chapter 9

Turning Missed Approach — Non-precision — Turn at a Designated Altitude/height

Note.— A complete outline of the fundamentals of the missed approach segment can be found in Attachment B7 along with additional examples.

This example is a continuation of Chapter 4 of this section, VOR/DME 09 using additional circumstances.

High obstacles straight ahead at a distance of 14 to 15 km from the VOR make a turning missed approach necessary. Hills also rise on both sides of the missed approach area. If possible, a turn 90° to the right should be executed. The OCH for this procedure is obtained by subtracting the threshold elevation from OCA (and rounding to the next 10-ft increment). Note that threshold elevation is used in this case rather than aerodrome elevation because the threshold elevation is more than 7 ft below aerodrome elevation.

Note.— Obstacle locations and heights are assumed to meet the chart accuracy tolerances for this procedure. See Chapters 11 to 13 of this section and Attachment C1 for specific examples applying charting tolerances to procedure construction.

STEP 1

Missed approach point (MAPt), SOC
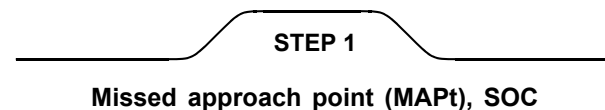
In this example the VOR is the MAPt. SOC is drawn at a distance d + X from VOR (see Chapter 1 of this section, Step 10) as shown on Figure II-2-9-1:

Category C: 0.15 + 0.75 = 0.90 NM = 1 670 m

where 0.15 is longitudinal (d) and 0.75 transitional (X) tolerance of the MAPt.

Category D: 0.17 + 0.86 = 1.03 NM = 1 910 m

Also, indicate the earliest MAPt tolerance.

STEP 2

Turn boundary construction
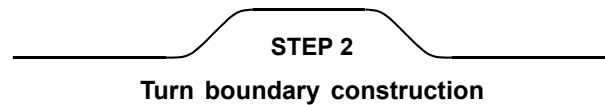
Examination of the distance available before O_1 and the large turn radius associated with the final missed approach speeds suggests that it would be impossible to exclude O_1 from the turn area. However, if the speed is restricted to the intermediate missed approach speed for Category D (185 kt), the smaller radius of turn can make the procedure feasible.
See Figure II-2-9-1.

The values r and E at 3 000 MSL shall be calculated with formulae presented in PANS-OPS, Volume II, Tables III-7-3 and III-7-4. IAS 185: TAS = 198 kt, calculated with temperature ISA + 15°.

R = 1.48°/sec r = 2.13 NM = 3 950 m   E = 0.51 NM = 940 m

Radius of bounding circle is:

$[2.13^2 + 0.51^2]^{0.5}$ = 2.19 NM = 4 060 m.

With the calculated values above and as shown in Figure II-2-9-1, draw a bounding circle to avoid obstacle O_1, first by indicating radius r from the left corner of the straight missed approach area, by drawing a line E parallel with straight missed approach and finally by drawing a limiting circle with radius 4 060 m.

Locate TP at distance c before the start of the turn boundary.

Distance c is calculated with formula presented in PANS-OPS, Volume II, Table III-7-4, with speed 198 kt TAS.

c = 0.38 NM = 700 m

This is the end of the turn initiation area.

As the turn can be initiated as early as at the VOR, an inner limit shall be drawn from the earliest left corner of the turn initiation area with an angle of 15° to the perpendicular through VOR to the straight missed approach track as is done in Figure II-2-9-1.

A profile is presented in Figure II-2-9-2.

Note.— The speed restriction shall be annotated in the missed approach procedure.

STEP 3

### Obstacles in the straight missed approach area
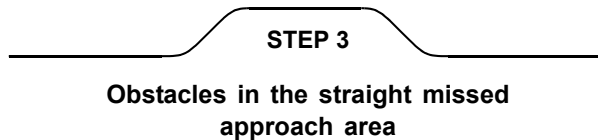
Before calculating the turning points and the turn altitude/height, it is necessary to check if obstacles in the straight missed approach area will give an OCA/H higher than the final approach OCA/H.

The straight missed approach criteria apply up to the TP. Indicate significant obstacles by points and elevations in metres MSL. Draw a profile as in Figure II-2-9-2. Indicate obstacles with vertical lines.

Draw a sloping surface at 2.5 per cent, touching the top of only one of the obstacles and not drawing through any of the others. One obstacle (765) is situated in the primary area. This obstacle gives

$$OCA = 765 - 6\,700 \times 0.025 + 30 = 627.5 \text{ m MSL.}$$

The OCA/H is highest at 630 (170) m.

## STEP 4

Obstacles in the turn initiation area
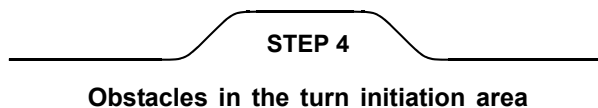
Measure distance SOC to TP (8 000 m). Calculate the height of the TP as follows:

$$\text{Height turning point} = OCA + 8\,000 \times 0.025 = 630 + 200 = 830 \text{ m.}$$

The highest obstacle in the turn initiation area has an elevation of 765 m MSL. The PANS-OPS states that the obstacle/height in the turn initiation area shall be less than TA/H – 50 m.

The turn altitude must therefore be above $765 + 50 = 815$ m.

This obstacle is therefore acceptable.

STEP 5

Obstacles in the turn area
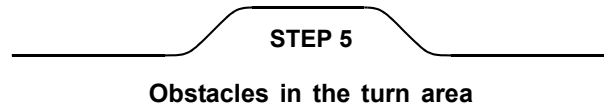
The preliminary boundaries of the turn area have been drawn and it is possible to check the obstacle situation. See Figure II-2-9-1. Obstacle O_1, which shall be avoided, is situated close to the border. Indicate the highest point just inside the border: O_2, elevation 910 m.

The distance from TP to O_2 is 6 100 m.

The influence of this obstacle shall be calculated with the formula in PANS-OPS, Volume II, Part III, 7.3.4.4.1 b) which reads "Obstacle elevation/height in the turn area and subsequently shall be less than TNA/H + d_o tan Z – MOC ..."

In this example TNA = 830 m (see Step 4), tan Z = 0.025, MOC = 50 m and the distance d_o is obstacle O_2 distance from TP = 6 100 m. The following is calculated:

$$830 + (6\,100 \times 0.025) - 50 = 932.5 \text{ m}$$

As the O_2 elevation is 910 m, the ridge does not affect.

Obstacle O_3 distance from the straight missed approach area boundary is 1 600 m and the elevation is 805 m. A calculation with the formula above indicates that obstacle O_3 does not affect.

The preliminary calculated missed approach procedure can be accepted, OCA/H for the procedure, climb gradient 2.5 per cent can be accepted namely 630 m (596). It is this value that shall be published on the instrument approach chart SIRPA VOR/DME 09, Chapter 4 of this section.

The turn altitude may also be confirmed as 830 m.

"Climb straight ahead to 830 m, turn right to 170°. Missed approach turn limited to 185 kt max."

Note.— If obstacles in the turn initiation and turn area make it necessary to increase the turn height, there are two options available:

a) *increase both the turn height and the OCA/H by the amount necessary to obtain clearance;*

b) *increase the turn height only by the amount necessary to obtain clearance, calculate the new position of TP and re-draw the turn area boundaries. This option avoids an increase of the OCA/H but may not always be practicable for certain obstacle situations.*

Note that in some cases it may be possible to re-locate the MAPt and hence change the maximum permissible obstacle heights.

Discussion Step 5

Assume that obstacle O_4, elevation 1 100 m, affects the missed approach. A check is made as follows:

$$830 + 12\ 000 \times 0.025 - 50 = 1\ 080 \text{ m}.$$

The obstacle exceeds the acceptable elevation by 20 m. One way to overcome the problem is to raise the turn altitude/height by 20 m to 850 (390) m. As a consequence, the latest TP must be moved

$$\frac{20}{0.25} = 800 \text{ m}$$

outwards in the direction of obstacle O_1, which shall be avoided. A possibility for avoiding O_1 in this situation is to reduce the extension of the turn area by specifying reduced speed, if not already done.

If, however, obstacle O_1 begins to affect the missed approach after this action, still another possibility remaining is to save height by moving MAPt from VOR to the final approach descent line. The position of SOC is then determined by calculating $d_2 + X$ as in Chapter 1 of this section, Step 10. The OCA/H missed approach is then calculated as in Chapter 1 of this section, Step 11 (see also Figure II-2-1-8).

The distance FAF — MAPt shall be indicated by a distance in the profile on the instrument approach chart, the table in the right bottom being replaced by final approach distance/altitude (height). (See the instrument approach chart in Chapter 4 of this section.)

```
         STEP 6
```

Calculation of OCA/H for climb gradients other than 2.5 per cent

A missed approach procedure for 2.5 per cent climb gradient has been designed. Aircraft with better climb gradients may utilize other OCA/Hs and other boundaries.

As an example, a calculation for a climb gradient of 3.5 per cent follows.

The OCA/H is calculated (compare with Step 3):

$$765 - 6\ 700 \times 0.035 + 30 = 560.5$$

$$695 - 4\ 700 \times 0.035 + 30 = 560.5 \text{ m}$$

The OCA/H straight missed approach is 561 (105) m (3.5%).

However, final approach OCA/H is higher: 585 (125) m, see Chapter 4 of this section, Step 4.

This value shall be used for the following calculations.

Turn altitude is still 830 m MSL.

The difference in altitude between turn altitude and SOC altitude is $830 - 585 = 245$ m.

The distance to climb the 245 m at 3.5 per cent is:

$$\frac{245}{0.035} = 7\ 000 \text{ m}$$

Compare with the calculations in Step 4.

The distance SOC to latest TP is 7 000 m. This means that the whole turn area will be moved closer to the SOC.

Note that these OCA/H are not normally published. They are only computed and used when the appropriate authority considers the aircraft performance justifies higher gradients.

Note.— When calculating with climb gradients other than 2.5 per cent the turn altitude/height can be changed, as well, the distance SOC to TP can be shortened, which may make full missed approach calculations necessary for every different climb gradient.
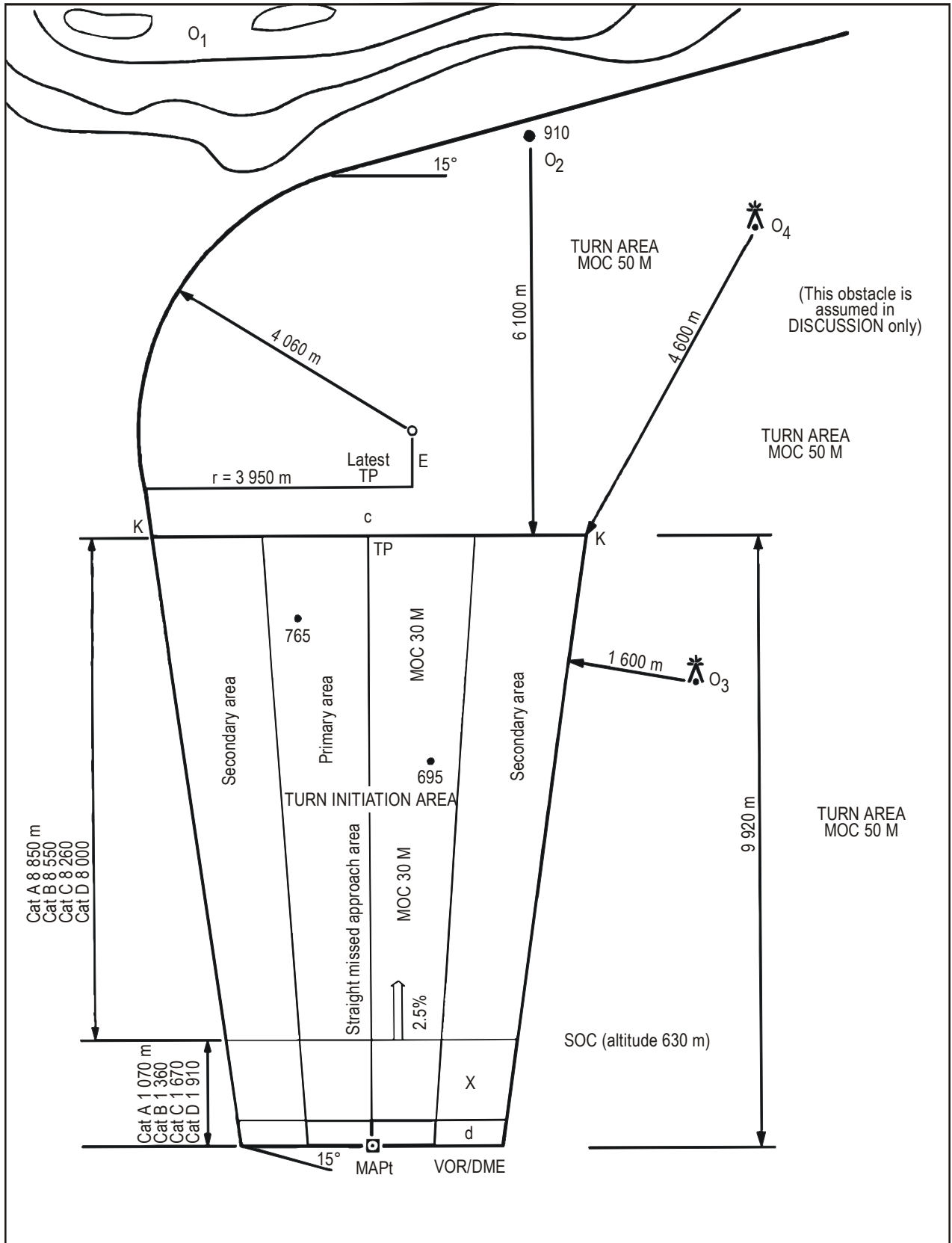
Figure II-2-9-1

VOR

830 m

TP

MOC 50 m

800

1:40

2.5%

600

OCA 630

695 m

765 m

Runway

400 m

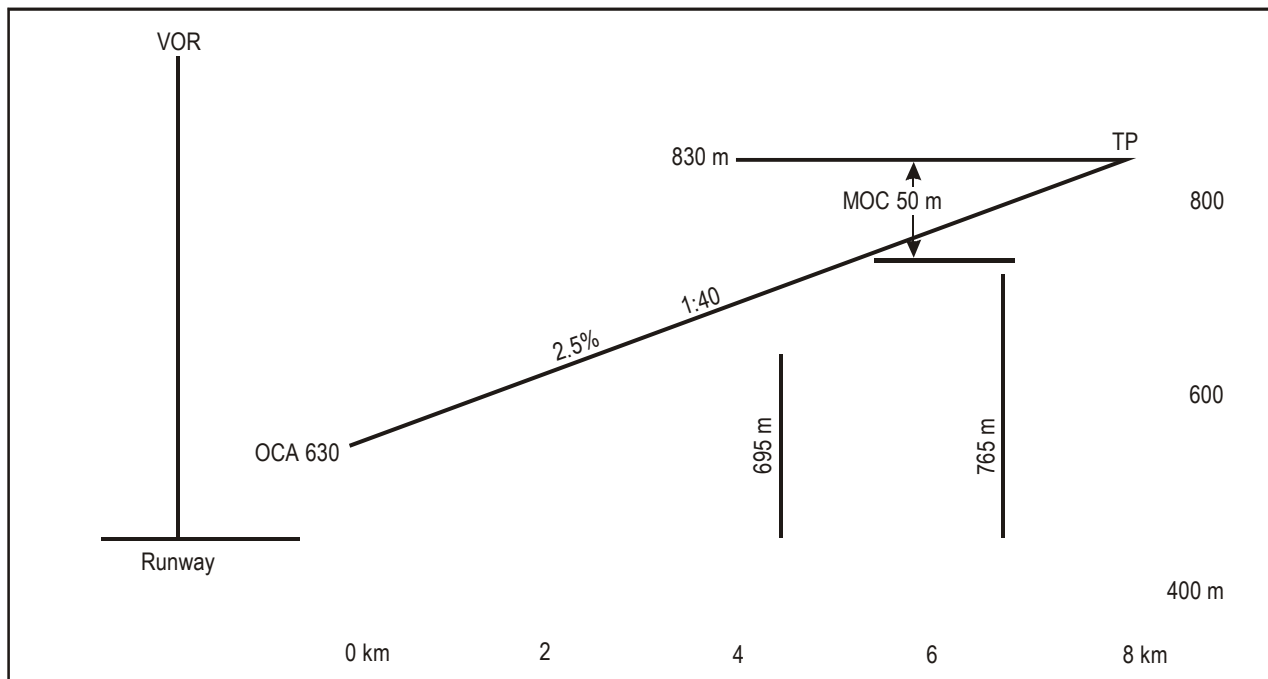0 km   2   4   6   8 km

Figure II-2-9-2

Chapter 10

Turning Missed Approach — Non-precision — Turn at a Designated Turning Point (Fix)

This example is a continuation of Chapter 4 of this section, VOR/DME 09 using additional circumstances.

High obstacles (O_1) straight ahead at a distance of 14 to 15 km from the VOR make a turning missed approach necessary. It is decided to specify a return to the facility in the missed approach procedure because of the obstacle environment. Because of this, the procedure will have a speed restriction of 185 kt IAS max, which shall be annotated the missed approach procedure.

Note.— A complete discussion of the fundamentals of the missed approach segment can be found in Attachment B7 along with additional examples.

STEP 1

Missed approach point (MAPt)

See Chapter 9 of this section, Step 1.

STEP 2

Outer boundary construction

Draw boundaries of the straight missed approach area as a continuation of the VOR final area.

To construct the turn boundary, calculate the following values using PANS-OPS, Volume II, Tables III-7-3 or III-7-4 formulae for 4 566 ft MSL (aerodrome elevation + 10 per cent of 5 NM).

Maximum speed Category D = 185 kt IAS
Altitude 466.3 m + 926 m (4 566 ft)
TAS = 203 k
c = 0.39 NM = 722 m
R = 1.44°/sec

r = 2.24 NM = 4 148 m
E = 0.52 NM = 963 m

$[r^2 + E^2]^{0.5}$ = 2.29 NM = 4 241 m
r + E = 2.76 NM = 5 111 m
r + 2E = 3.28 NM = 6 075 m

At a point 0.31 NM (574 m) from 5 DME towards the SOC (DME fix tolerance), draw a line perpendicular to the missed approach track indicating the earliest TP, line K-K.

Construct the remainder of the turn area as shown in Figure II-2-10-1.

The distance from SOC to line K-K is:

5 NM – 0.3125 NM – 1.03 NM = 3.657 NM = 6 774 m, where 1.03 is SOC distance from MAPt (see Chapter 9 of this section, Step 1).

The straight missed approach criteria apply out to line K-K with MOC 30 m, reduced in secondary areas (see Chapter 1 of this section, Step 11). The left secondary area in Figure II-2-10-1 is extended out into the turn area where MOC 50 m (165 ft) may be reduced.

STEP 3

Turn area obstacles

In this procedure the area between MAPt and line K-K is not a turn initiation area. Turns are initiated earliest at line K-K and therefore the shortest distance d_o from an obstacle in the turn area to line K-K plus range SOC to line K-K (d_z) shall be used when the effect on OCA/H of a turn area obstacle is calculated.

Obstacle O_2 distance from line K-K is 4 700 m, elevation 805 m. The OCA/H necessary to avoid O_2 is calculated:

805 – [(4 700 + 6 774) × 0.025] + 50 = 568 m MSL.

As OCA/H final approach is 585 m (125), obstacle O_2 does not affect. The effect of obstacles O_3 and O_4 is checked with the same calculation.

The missed approach procedure is specified as:

"Missed approach speed restricted to max 185 kt until after turn. Climb straight ahead to 5 DME, turn right to DON climbing to 3 500 m (1 990)."
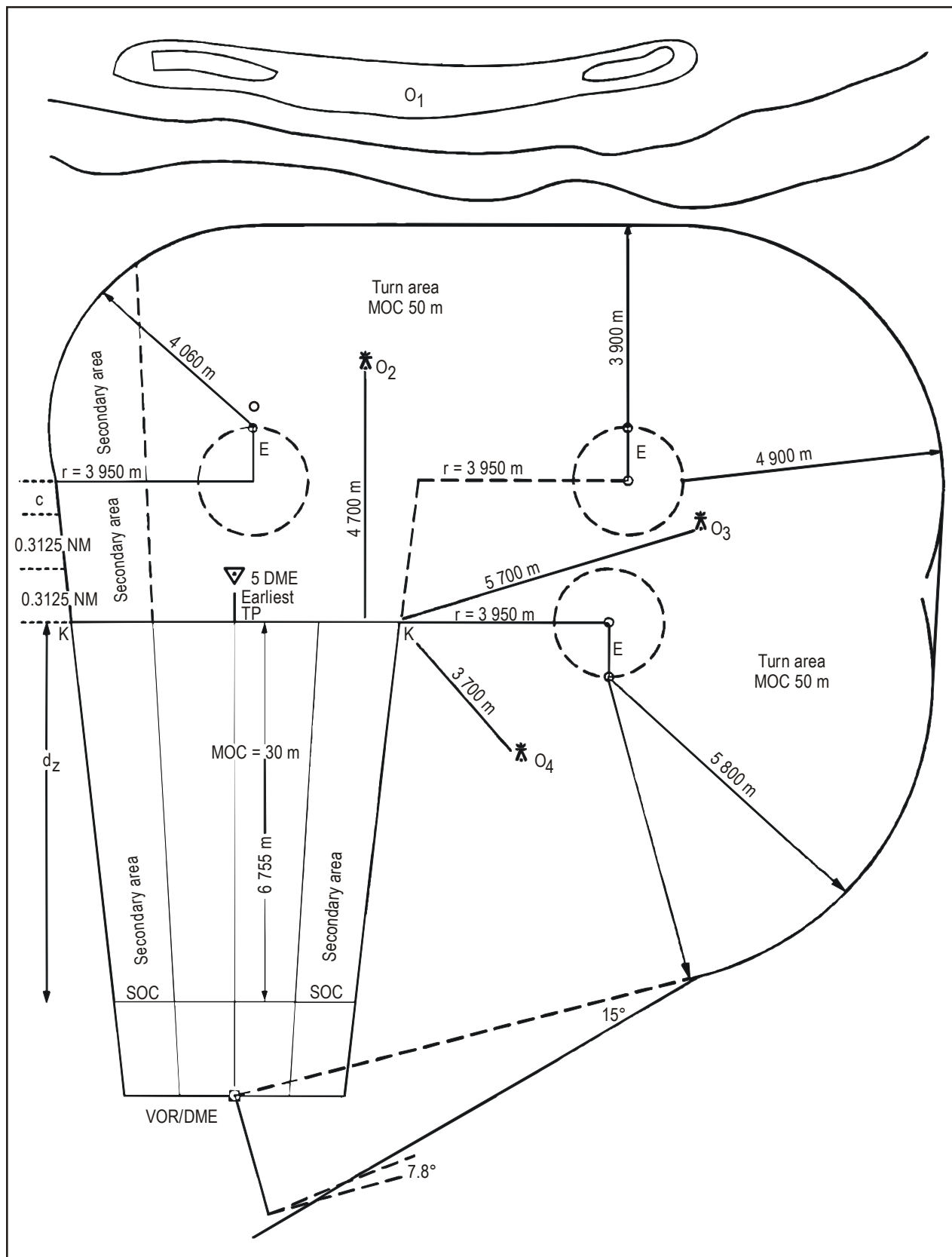
Figure II-2-10-1

Chapter 11

Precision — Straight Missed Approach

INTRODUCTION

This is a straight ILS missed approach procedure. This example is not associated with any previous example.

The glide path is 3°, LLZ-THR is 3 000 m and other parameters are standard so that the corresponding table in Attachment I to Part III of PANS-OPS, Volume II can be used.

There are no obstacles that penetrate the OAS approach surfaces X and Y. One obstacle, O_1, (chart tolerance code 1A contained in Attachment B) penetrates the Z surface. Its location coordinates (referenced to the runway threshold) are (see Figure II-2-11-1):

    x = –8 100 m
    y = –1 700 m
    z = 195 m

STEP 1

Identify the MAPt
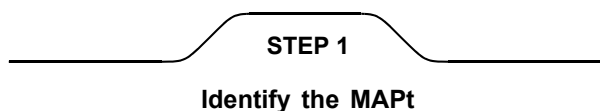
The MAPt will be on the glide path (θ) at the start of climb height (SOC_z) plus a height equal to the height loss for each category of aeroplane.

STEP 2

Start of climb coordinates (SOC_x and SOC_z)
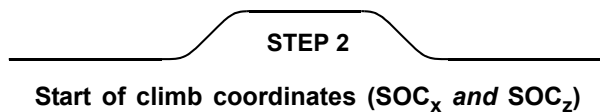
The SOC is at a height equal to the controlling approach obstacle or the equivalent height of the controlling missed approach obstacle, whichever is higher. It is located on line GP' which originates at $x = –900$ and is parallel to the glide path. (see Figure II-2-11-2).

Find SOC_z.

The height of the start of climb (SOC_z) is the same as the equivalent height (h_a) of the missed approach obstacle (O_1).

Formula:

$$h_a = \frac{h_{ma} \times \cot Z + 900 + x}{\cot Z + \cot \theta} = SOC_z$$

$$h_a = \frac{195 \times 40 + 900 + (–8\ 100)}{40 + 19.08} = 10.156\ m = SOC_z$$

(See Figure II-2-11-3.)

Find SOC_x.

$$SOC_x = SOC_z/\tan \theta – 900$$

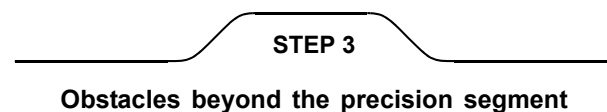$$SOC_x = 10.156/\tan 3° – 900$$

$$SOC_x = 193.8\ m – 900 = –706.2\ m$$

Proof: Height gain (HG) from SOC should equal height of O_1 (195 m).

$$HG = (8\ 100 – 900 + 193.8) \times 0.025 = 184.84\ m$$

$$SOC_z + HG = 10.156 + 184.84 = 195\ m$$

The OCH, then, is simply SOC_z + height loss (HL).

	A	B	C	D
OCH ILS Category I	51	54	57	60
OCH ILS Category II	24	29	33	37

STEP 3

Obstacles beyond the precision segment

Assume that an obstacle (O_2, code 2A) is located beyond the precision segment and appears to penetrate an extension of the 2.5 per cent Z surface. The coordinates of O_2 are:

x = –15 000 m
y = –3 200 m
z = 365 m

The task is to determine if O_2 will change SOC_z adversely and raise the OCA/H. (See Figure II-2-11-4.)

O_2 is evaluated in two steps.

1) Determine whether O_2 is located within the missed approach area which splays 15° from both sides of the end of the precision segment at points E"–E".

2) Determine whether the h_a of O_2 is higher than that of O_1.

The half-width of the missed approach area beyond the precision segment is:

½W = tan 15° × ($|x_{0_2}| - |x_{E''}|$) + $|y_{E''}|$

½W = tan 15° × (15 000 – 12 900) + 3 001 = 3 564 m

Find that O_2 lies within the continued missed approach area.

The equivalent height (h_a) of O_2 is:

$$h_a = \frac{365 \times 40 + 900 - 15\ 000}{40 + 19.08} = 8.46 \text{ m} = SOC_z$$

(See Figure II-2-11-5.)

Conclusion: Obstacle O_2 will not affect the OCA/H. The missed approach is controlled by O_1 in the precision segment with an h_a (SOC_z) at 10.156 m (11 m) which is more demanding than the h_a of O_2 at 8.46 m.

The OCA/H values remain:

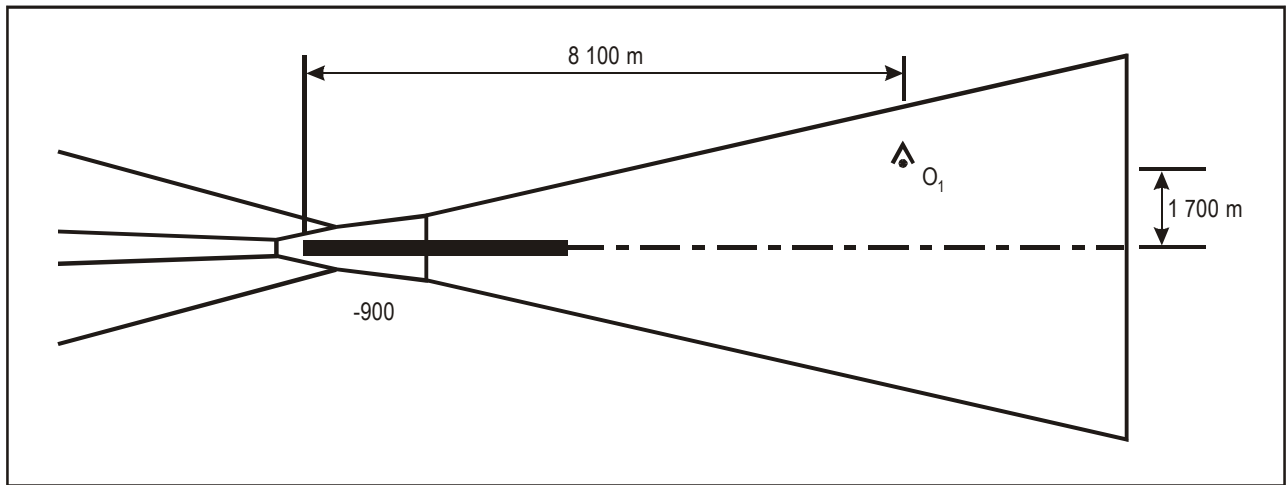|	A	B	C	D
OCH ILS Category I	51	54	57	60
OCH ILS Category II	24	29	33	37

Figure II-2-11-1
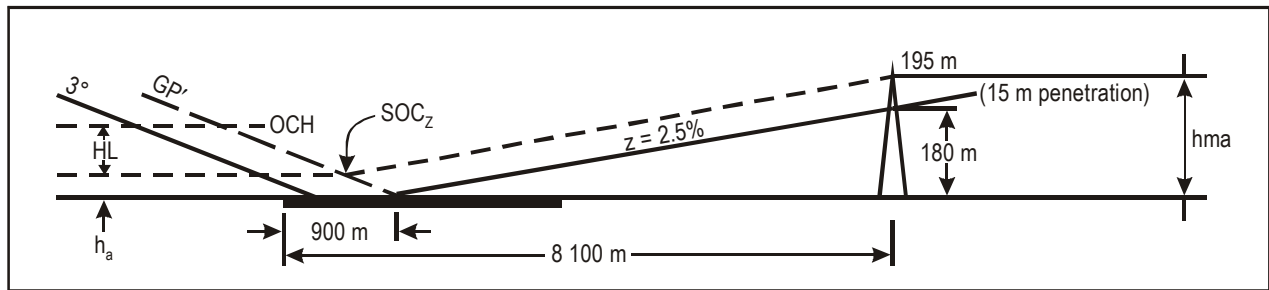
Figure II-2-11-2

Figure II-2-11-3

15 000 m

E″

15°

O₂

3 200 m

O₁

-900

E″

15°

ILS MISSED APPROACH
(Obstacle beyond the precision segment)

$\begin{pmatrix} x = -12\ 900 \\ y = 3\ 001 \end{pmatrix}$

Figure II-2-11-4

300 m Contour

Gp,

10.156

OCH

8.46

HL

3°

z = 2.5%

O₁

O₂

900 m

h_a

15 000 m
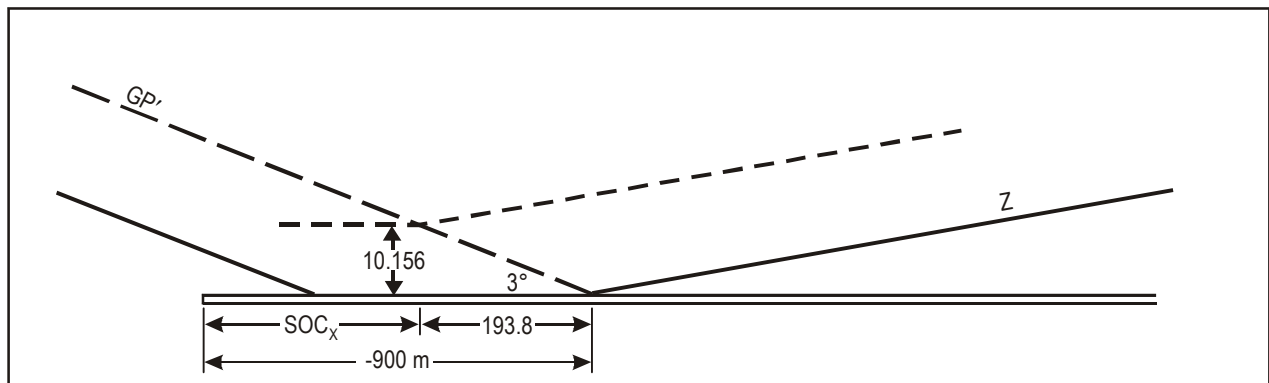
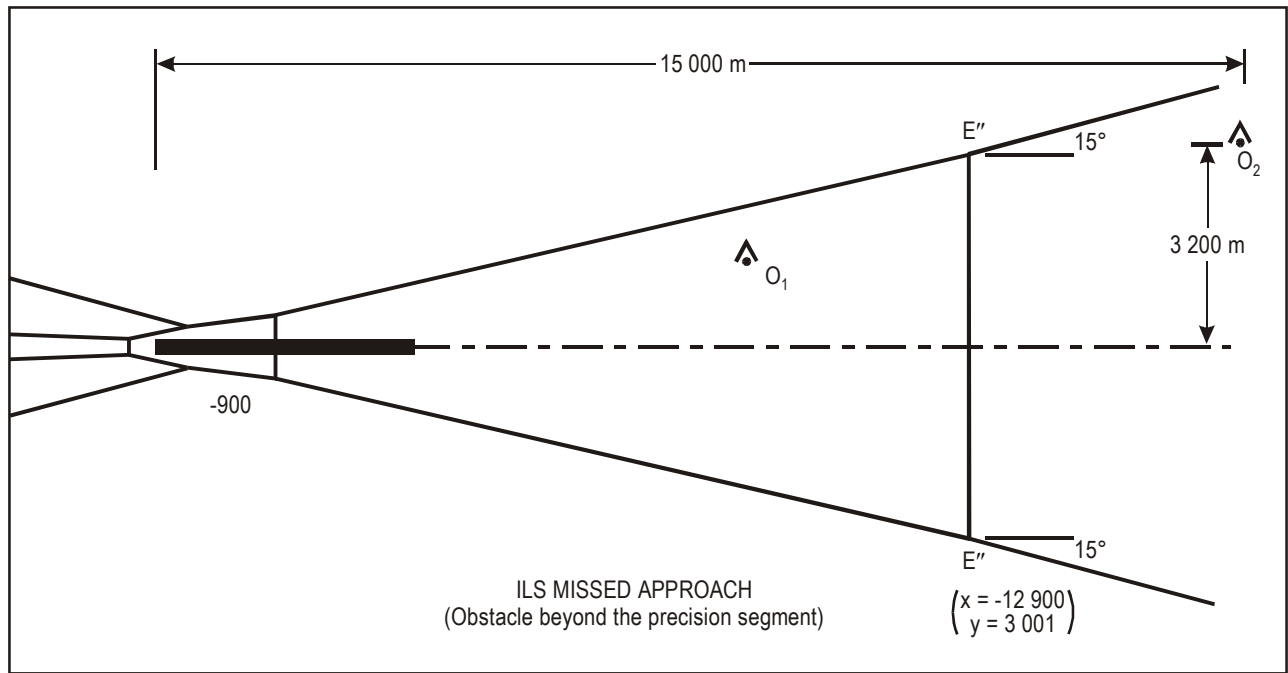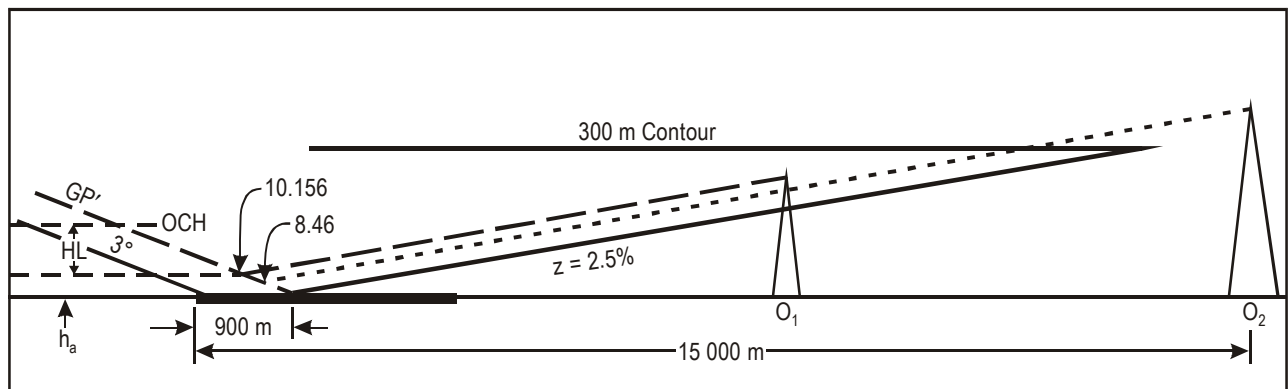**Figure II-2-11-5**

Chapter 12

Precision — Turning Missed Approach
Turn at an Altitude

INTRODUCTION

The glide path is 3°, LLZ-THR is 3 000 m and the other parameters are standard. The corresponding table in Attachment I to Part III of PANS-OPS, Volume II applies.

Runway threshold elevation = 300 m (984 ft).

There are four obstacles. Obstacles O_1, O_2 and O_3 (all chart tolerance codes 1A*) are on the runway centre line. Obstacles O_1 and O_2 penetrate both the ILS Categories I and II OAS surfaces. Obstacle O_4 (code 6C) is outside of the precision surface area and will be of concern during the turning missed approach. The location coordinates (referenced to the runway threshold) are:

	x	y	z		code*
O_1	750	0	22	penetrates W surface	1A
O_2	−4 500	0	100	penetrates Z surface	1A
O_3	−15 000	0	1 000		1A
O_4	−5 000	6 000	255		6C**

 * Refer to Attachment C1 to this document.

** Code C (6 m) is acceptable but code 6 (300 m) must be accommodated.

All ILS coordinates are in metres and all calculations are accomplished as heights above the threshold in metres. The conversion to feet is accomplished after the critical calculations are complete.

Airspace constraints demand either a straight ahead or a RIGHT turning missed approach.

Draw the precision approach segment outline using the threshold and 300 m contour coordinates of the corresponding table in Attachment I to Part III.

Obstacle O_3 precludes a straight ahead missed approach. No fix is available to mark a TP and a turn at an altitude is the solution. (See Figure II-2-12-1.)

Determine the SOC for the precision segment

Compare the height of O_1 to the equivalent height of O_2. The higher of the two will equal SOC_z. (See Figure II-2-12-2.)

O_1 height is 22 m

The h_a of $O_2 = \dfrac{(100 \times 40) + 900 - 4\,500}{40 + 19.08} = 6.8$ m

$SOC_z = 22$ m for the precision segment.

Find the location of the start of climb (SOC_x).

$SOC_x = SOC_z/\tan \theta - 900$

$SOC_x = 22/\tan 3° - 900 = -480$ m

$SOC_x = -480$ m.

STEP 3

Identify the lowest usable turn height (TNH) that will clear O_2 in the turn initiation area and provide the MOC over O_4 in the turn area

The lowest TNH for O_2 = 100 + 50 = 150 m.

The lowest TNH for O_4 = (O_4 height + MOC) – height gain (HG) along the shortest distance (d_{o_4}) from the 300 m contour to O_4.

The distance d_{o_4} can be measured carefully on a chart or calculated after finding the splay angle of the 300 m contour. (See Figure II-2-12-3.)

The 300 m contour splay angle (α) is:

$$\alpha = \tan^{-1} \frac{y_{E''} - y_{D''}}{y_{D''} + |x_{E''}|} = \frac{3\,001 - 910}{5\,438 + 12\,900} = 6.5°$$

The y coordinate of the 300 m contour at the range of O_4 is found by solving for y in the formula $z = Ax + By + C$ for the Y surfaces where x = the x coordinate of O_4 (–5 000) and z = 300 m.

$$y = \frac{z - Ax - C}{B} = \frac{300 - (0.023948 \times -5\,000) - (-21.51)}{0.210054} = 2\,101 \text{ m}$$

The distance $d_{o_4} = (|y_{o_4}| - \text{chart tolerance} - |y_{Y300}|) \times \cos \alpha$

$$d_{o_4} = (6\,000 - 300 - 2\,101) \times \cos 6.5° = 3\,576 \text{ m}$$

The lowest TNH that will ensure the MOC at O_4 is:

$$\text{TNH}_{o_4} = (255 + 50) - (3\,576 \times 0.025) = 215.6 \text{ m}.$$

The lowest operationally useful turn altitude (TNA) must consider the turn height (TNH) plus the threshold elevation and probably a rounded value in 100 ft increments.

$$\text{TNA} = 215.6 + 300 \text{ m} = 515.6 \times 3.2808 = 1\,692 \text{ ft}$$
(1 700 ft rounded).

The associated TNH that must be used in calculations is:

$$\text{TNH} = \frac{(1\,700 - 984)}{3.2808} = 218 \text{ m}$$

STEP 4

Determine the nominal TP, realizing that the TNH must be at least 218 m and that operators will want both the lowest OCA/H as well as an unrestricted turning IAS, if possible

The TP must be located prior to O_3 at a distance at least equal to the charting tolerance (300 m) plus $c + E + [r^2 + E^2]^{0.5}$

Calculate the turn area requirements based on the bounding circle method and unrestricted IAS at a 2 000 ft elevation (see PANS-OPS, Tables III-7-3 and III-7-4) in km (NM). (See Table II-2-12-1.)

If the nominal TP must be at least 9.67 km prior to O_3, the distance d_z available for height gain after SOC is:

$$d_z = 15\,000 - 9\,670 - 480 = 4\,850 \text{ m}$$

The nominal height (NH) at the TP = SOC_z of the precision segment + HG.

$$\text{NH} = 22 + (4\,850 \times 0.025) = 143.25 \text{ (which is insufficient). (See Figure II-2-12-4.)}$$

Table II-2-12-1

Category	c +	E +	$[r^2 + E^2]^{0.5}$ +	Chart tolerance	=	Required turn area	at TAS km/h (kt)
A	0.46	0.6	$[1.38^2 + 0.56^2]^{0.5}$	0.3		2.85 (1.53 NM)	217 (116 kt)
B	0.59	0.76	$[2.57^2 + 0.76^2]^{0.5}$	0.3		4.33 (2.34 NM)	296 (159 kt)
C	0.88	1.21	$[6.49^2 + 1.21^2]^{0.5}$	0.3		8.99 (4.86 NM)	470 (254 kt)
D	0.91	1.27	$[7.08^2 + 1.27^2]^{0.5}$	0.3		9.67 (5.22 NM)	491 (265 kt)

Restrict the turning IAS in order to reduce the turning area requirement.

Note.— Simply increasing the climb gradient is not sufficient. The procedure must specify an OCA/H appropriate to the nominal 2.5 per cent missed approach climb. Special minima can be published in addition to, but not instead of, the nominal OCA/H based on 2.5 per cent.

At this point discussions are needed with the operators or the approving officials to decide the slowest speeds that are operationally acceptable. The PANS-OPS allows turning speeds equal to the fastest final approach speeds. However, operational considerations may require higher speeds.

Assume that the following speeds have been accepted:

Category A: 100 kt IAS; 116 kt TAS (no change)
Category B: 150 kt IAS; 159 kt TAS (no change)
Category C: 185 kt IAS; 195 kt TAS (no change)
Category D: 200 kt IAS; 211 kt TAS

The adjusted turning area requirements calculated in km (including chart tolerance) are now:

Category A: 2.85 (1.53 NM)
Category B: 4.33 (2.34 NM)
Category C: 5.94 (3.21 NM)
             (when c = 0.7 km, r = 3.89 km, E = 0.94 km)
Category D: 6.65 (3.59 NM)
             (when c = 0.75 km, r = 4.49 km,
             E = 1.0 km)

Draw the turning areas from the latest TP (distance 'c') beyond the nominal TP.

Adjust the SOC to provide sufficient climb distance d_z to the TP.

The SOC_z can be calculated with the h_a formula when:

h_{ma} = TNH and x = the coordinate of the TP

$$SOC_z = h_a = \frac{218 \times 40 + 900 - (15\,000 - \text{turn area requirement})}{40 + 19.08}$$

Category A SOC_z =

$$\frac{218 \times 40 + 900 - (15\,000 - 2\,850)}{40 + 19.08} = -43 \text{ m (use 22 m)}$$

Category B SOC_z =

$$\frac{218 \times 40 + 900 - (15\,000 - 4\,330)}{40 + 19.08} = -18 \text{ m (use 22 m)}$$

Category C SOC_z =

$$\frac{218 \times 40 + 900 - (15\,000 - 5\,940)}{40 + 19.08} = 9.5 \text{ m (use 22 m)}$$

Category D SOC_z =

$$\frac{218 \times 40 + 900 - (15\,000 - 6\,650)}{40 + 19.08} = 21.5 \text{ m (use 22 m)}$$

(See Figure II-2-12-5.)

STEP 5

Calculate the OCA/H based on the adjusted SOC_z to ensure that the TNA will be achieved at the point where each category of aeroplane must begin to turn in order to avoid the obstacle O_3 straight ahead.

The OCA/H then is simply the adjusted SOC_z + appropriate height loss (HL) for each category of aeroplane.

	A	B	C	D
OCH ILS Category I	62	65	68	71
OCH ILS Category II	35	40	44	48

Missed approach instruction: Climb straight ahead to 1 700 ft, turn right ... (90°) ... missed approach turn limited to 200 kt IAS max.

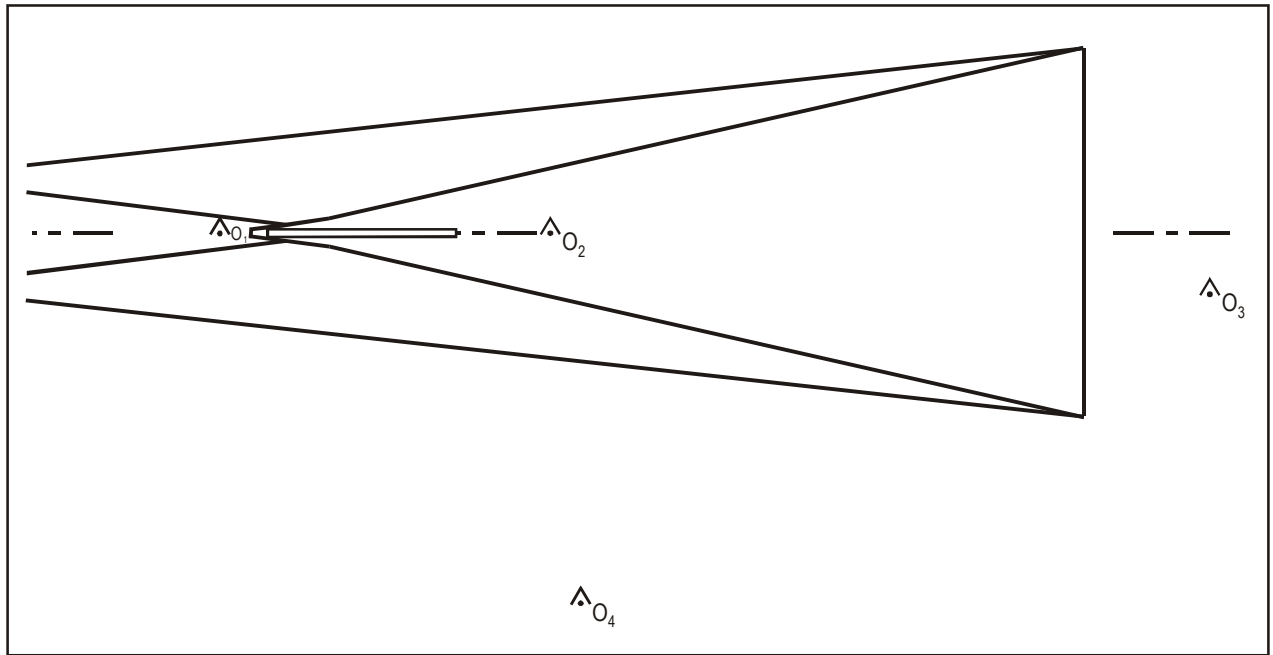*Note.— Although the Category C operators agreed to a 185 kt IAS, the 200 kt IAS is safe.*
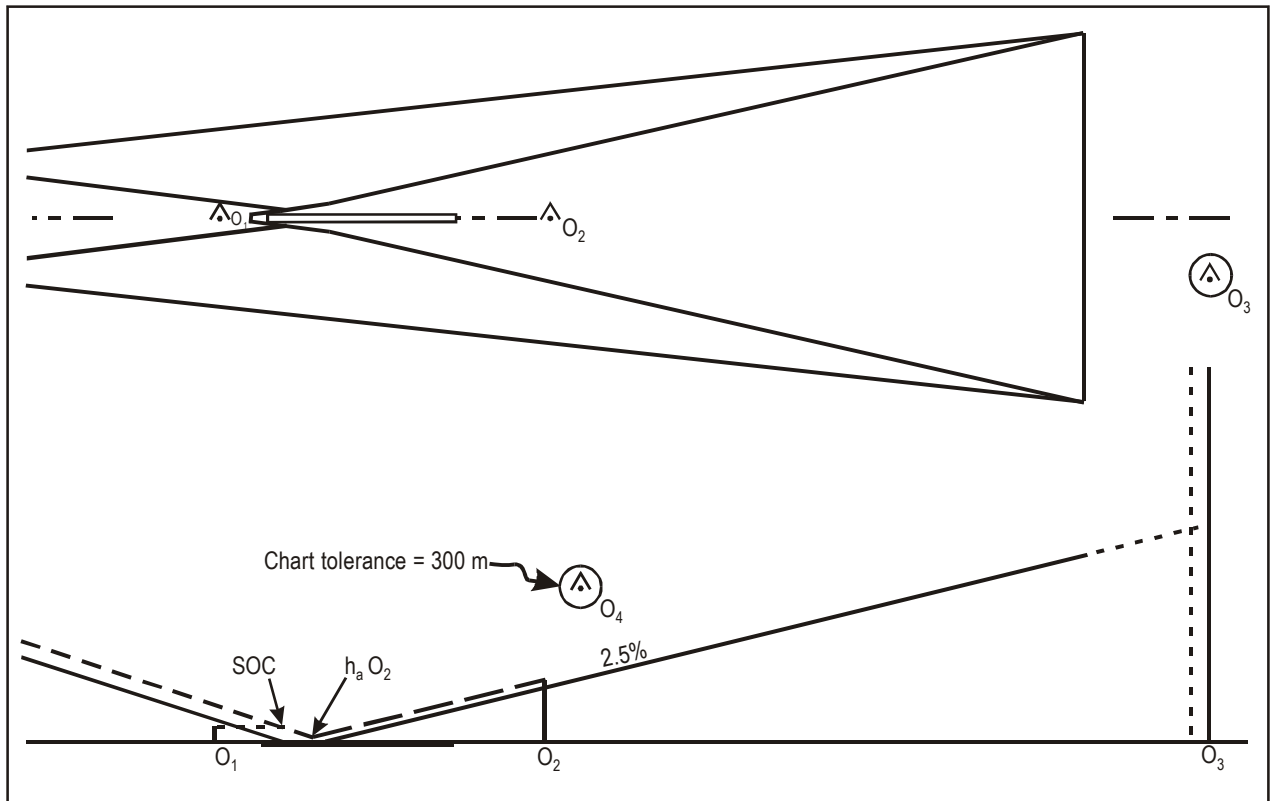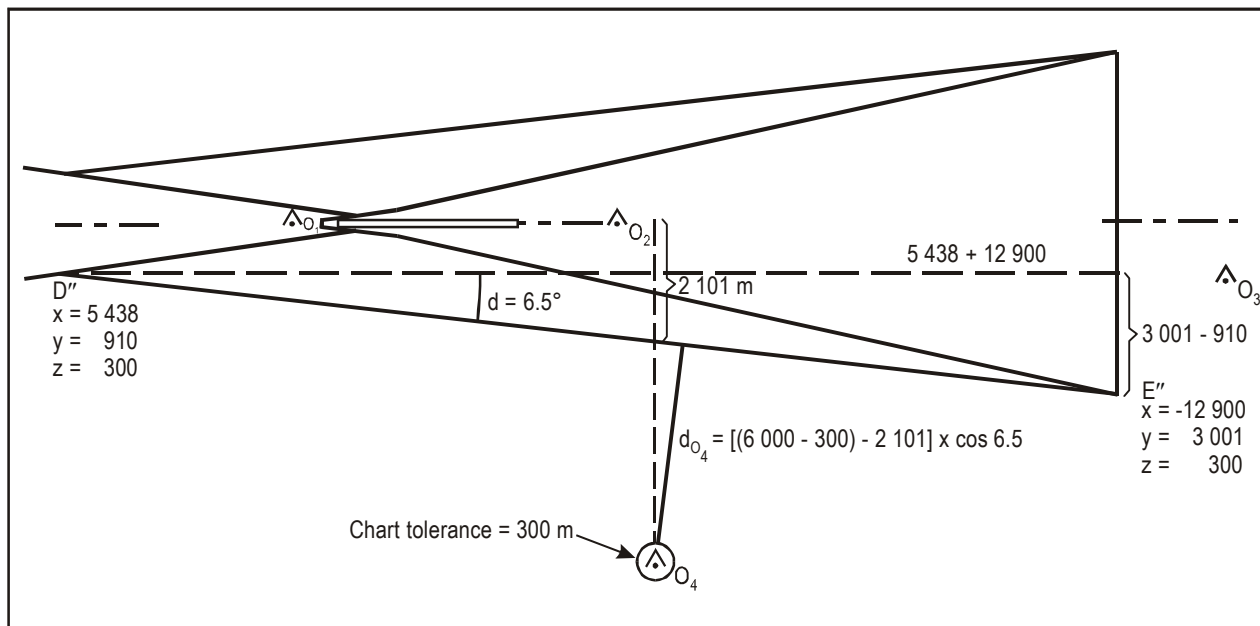
Figure II-2-12-1

Figure II-2-12-2
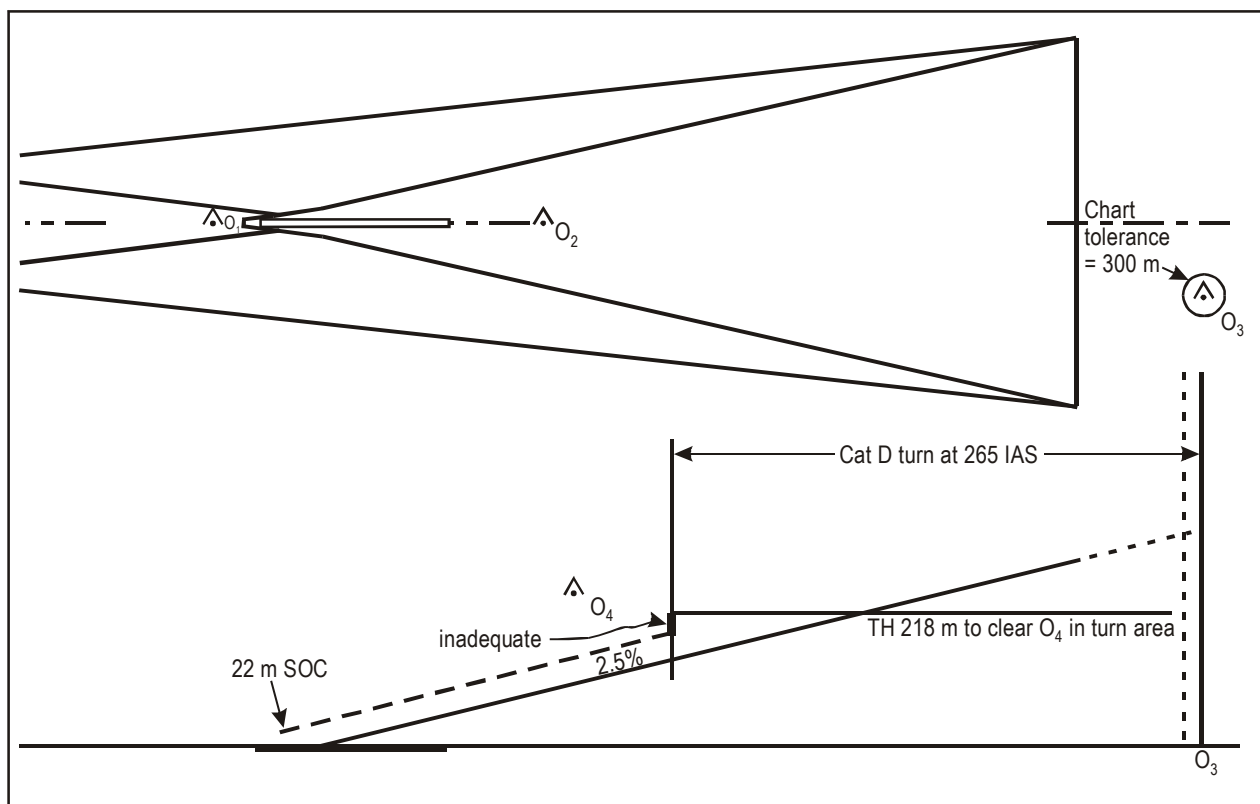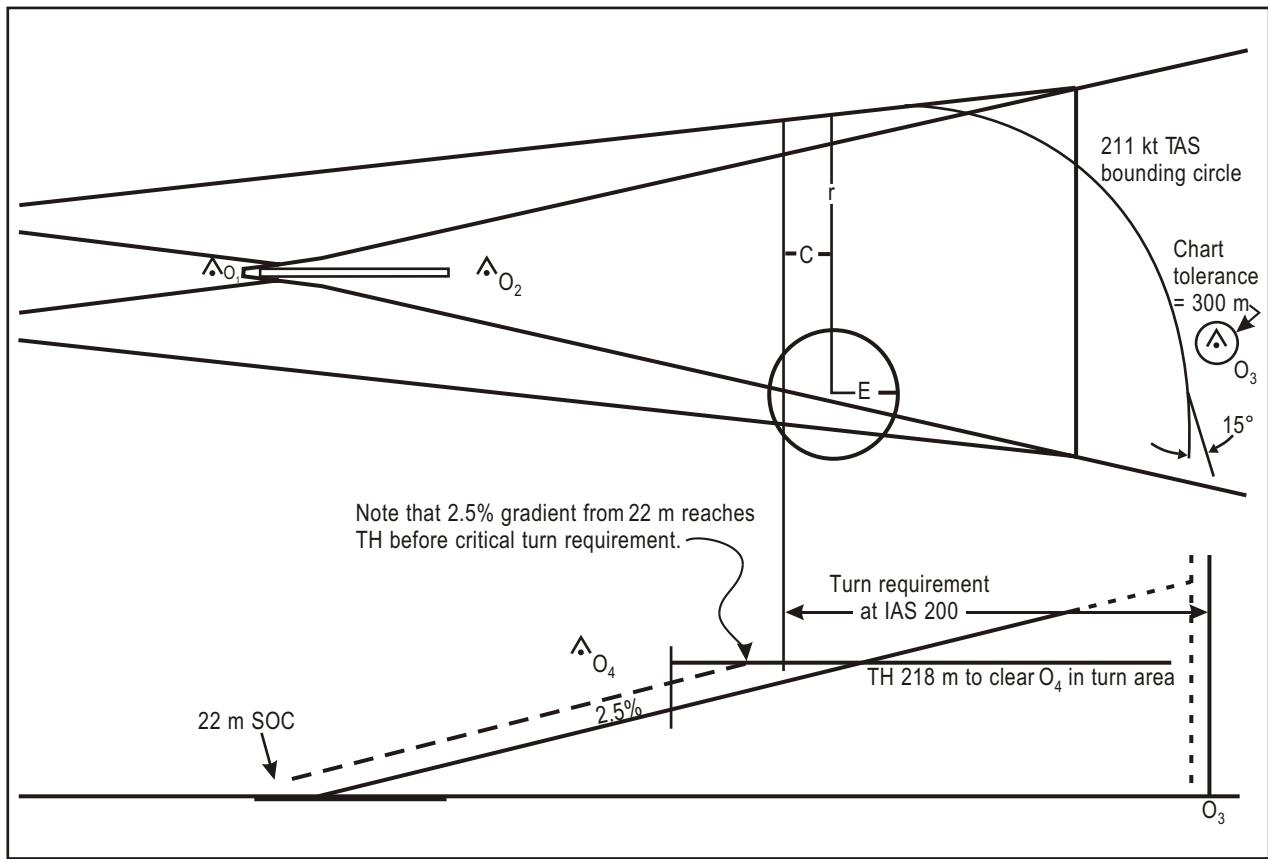
Figure II-2-12-3

Figure II-2-12-4

Figure II-2-12-5

Chapter 13

Precision — Turning Missed Approach
Turn at a Fix
(within the precision segment)

INTRODUCTION

Using the same circumstances as in Chapter 12 of this section, the problem remains to develop a turning fix to avoid the obstacle O_3 straight ahead at x = –15 000 m. Working backwards to the TP, assume that the DME site is at the GP antenna where x = –286 m.

Note.— DME tolerance is ±0.46 km (0.25 NM) + 1.25 per cent of the distance to the antenna.

The most critical aeroplane is Category D using an IAS of 200 kt.

Unless separate procedures are developed, all aeroplanes will use the same DME fix as the turning point (TP). The latest TP (six seconds 'c' beyond the DME fix tolerance) must accommodate the turning requirements for Category D as calculated in Chapter 12 of this section, Step 4, a value of 6.65 km (3.59 NM).

The nominal TP can be stated in tenths of an NM but must be at least 0.25 NM + 1.25 per cent of distance to the antenna closer to the DME than the latest TP.

The earliest TP identifies line K-K.

The distance SOC to K-K is d_z from which the distance d_o in the turn area to O_4 is measured.

The distance available for height gain is $d_z + d_o$.

The 200 kt (211 TAS) turning area requirements are 6.65 km (3.59 NM). See Chapter 12 of this section, Step 4.

The latest TP fix tolerance is then at
x = –15 000 + 6 650 = –8 350 m.

The DME reading at this point is

$$\frac{(8\ 350 - 286)}{1\ 852} = 4.354 \text{ NM}$$

The nominal TP must be at least 0.25 + (0.0125 × 4.354) NM prior to the latest point and will be published as 4.354 – 0.3 = 4.0 DME.

The earliest TP is line K-K at DME 4.0 – 0.3 = 3.7; where x = –7 138 m. (Note the DME site is at the G/P antenna where x = –286.) (See Figure II-2-13-1.)

STEP 2

Determine d_z to be SOC to line K-K
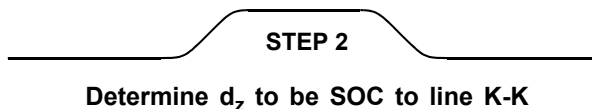
Therefore

d_z = 7 138 – 480 (SOC_x) = 6 658 m.

STEP 3

Determine d_o, the distance from K-K to O_4
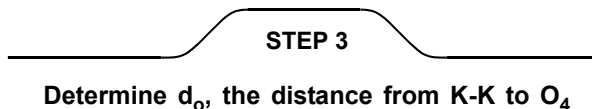
The y coordinate of point 'K' on the 300 m contour at the earliest TP is found by solving for y in the formula z = Ax + By + C for the Y surfaces, where x = the x coordinate of 'K' (–7 138) and z = 300 m.

STEP 1

Identify the latest TP

The latest TP fix tolerance must occur prior to O_3 at a distance at least equal to the charting tolerance (code 6C) plus $c + E + [r^2 + E^2]^{0.5}$.

$$y = \frac{z - Ax - C}{B} =$$

$$\frac{300 - (0.023948 \times -7\,138) - (-21.51)}{0.210054} = 2\,344 \text{ m}$$

The distance d_{o_4} is the hypotenuse of the right angle triangle minus the chart tolerance (KAd_{o_4}).

$$d_{o_4} = [(6\,000 - 2\,344)^2 + (7\,138 - 5\,000)^2]^{0.5} - 300 = 3\,935 \text{ m}.$$

The nominal altitude (NA) = aerodrome elevation + start of climb (SOC_z) + height gain [($d_z + d_o$) × 0.025].

The required altitude (RA) = obstacle elevation (OE) + minimum obstacle clearance (MOC)

$$NA_{o_4} = 300 + 22 + [(6\,658 + 3\,935) \times 0.025] = 586.8 \text{ m}.$$

$$RA_{o_4} = 300 + 255 + 50 = 605 \text{ m}.$$

The NA is inadequate by 18.2 m. The SOC must be adjusted to ensure that the RA of 605 m (305 ft) will be met.

Since the shortest path to the obstacle is defined as $d_z + d_o$, the equivalent height h_a formula can be used to find the SOC_z where:

$$h_a = SOC_z$$

$$h_{ma} = RA - 300 = 305 \text{ m}$$

$$x = SOC_x + d_z + d_o \; ; \; -480 + (-6\,658) + (-3\,935) = -11\,073 \text{ m}$$

$$h_a = \frac{(305 \times 40) + 900 - 11\,073}{40 + 19.08} = 34.3 \text{ m} = SOC_z$$

This is not the best result. A turn to avoid the obstacle O_4 should be developed, if possible.

STEP 4

A major advantage of turning at a fix is that the inner boundary is drawn from the earliest TP fix tolerance. The obstacle O_4 may be completely avoided IF the turn angle is such that O_4 is outside of the turn area.

Since the angle of turn must be nearly 90° to avoid O_3 , the inner turn boundary will be drawn from point K on the far side of the precision segment.

The angle from the far side point K to O_4 is:

$$\tan^{-1} \frac{|x_K| - |x_{o_4}| - \text{chart tolerance}}{|y_{o_4}| + |y_K|} \; ;$$

$$\tan^{-1} \frac{7\,138 - 5\,000 - 300}{6\,000 + 2\,344} = 12.4°$$

This means that the procedure can ignore O_4 if the turn of the missed approach can be established at 89° or less. See Figure II-2-13-2.

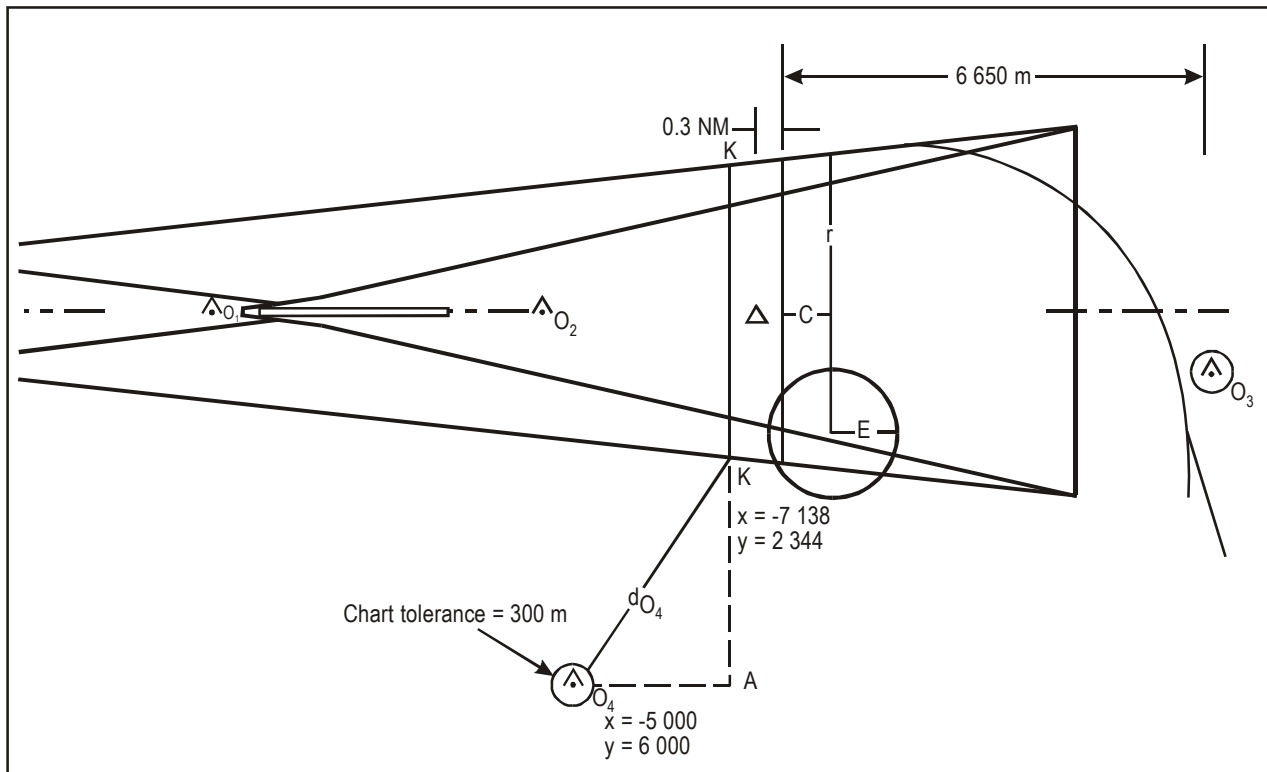**Figure II-2-13-1.   Turning missed approach (90 degrees or more)**
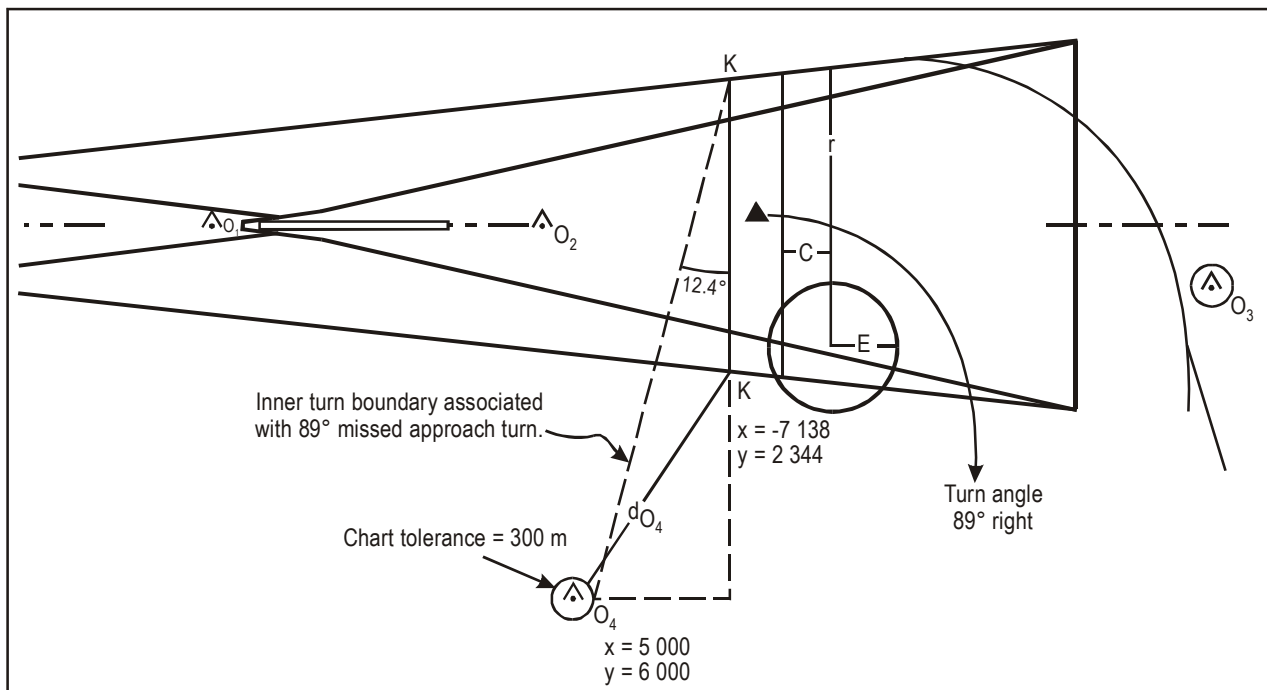
Figure II-2-13-2.   Turning missed approach (less than 90 degrees)

Chapter 14

Safeguarding of Early Turns in an ILS Missed Approach

INTRODUCTION

(Reference PANS-OPS, Attachment J to Part III)

The basic ILS/MLS criteria protect for a turning missed approach from the point where the glide path descends below 300 m (1 000 ft) above the threshold. Obstacles immediately outside the turn initiation area become of interest as soon as a missed approach turn is specified. The distance to climb from the turn initiation area is measured by the shortest possible vector perpendicular to the turn area boundary *regardless* of the prescribed track after the turn.

These criteria present an iterative method of assessing obstacles in the turn area, taking into consideration:

— the track specified after the turn (+15° of drift);

— the actual turn height contour as the turn area boundary; and

— the lowest possible height of the aeroplane when it is necessary to assess an obstacle before the aeroplane has descended on the glide path to the turn height.

The main advantage of this method occurs when the turn angle is less than 75°. That advantage is significant. The specific example discussed here develops two situations:

1) provide the greatest possible climb distance (d_o) with a minimum turn angle from the lowest possible turn height; and

2) modify the solution to provide the highest possible turn height while preserving the OCA/H found in 1) above.

CONDITIONS

Three obstacles are considered (all surveyed accurately):

Obstacle	x	y	z
O_1	−10 000	−1 050	400 m
O_2	−5 200	4 800	225 m
O_3	−500	200	40 m

ILS Category I, 3°, 3 000 m LLZ-THR, 2.5 per cent missed approach, Aircraft Category C.

STEP 1

Draw the OAS 300 m contour plan view including the approach area W and X surface outlines

See Figures II-2-14-1 and II-2-14-2.

STEP 2

Find the start of climb SOC_X and SOC_Z

The obstacle O_3 penetrates the OAS surfaces. It can be treated as a missed approach obstacle because it penetrates GP'. An equivalent height (h_a) is computed.

$$h_a = \frac{40 \times 40 + 900 - 500}{40 + 19.08} = 33.85 \ (34 \ m) = SOC_z$$

$SOC_X = -900 + (34/\tan 3°) = -251 \ m \ [OCH = 80 \ m]$

STEP 3

Determine the turn height (TNH)

TNH = obstacle elevation + MOC = 40 + 50 m = 90 m.

Note.— A MOC of 30 m is permitted when the turn angle is 15° or less. In this case a 90 m turn height seems appropriate.

STEP 4

Construct the 90 m contour
(see Attachment B7, 5.2)

The coordinate points of C", D" and E" for the 90 m contour are:

$E''_{90} : x = \dfrac{90}{300} \times (-12\,900 + 900) - 900 = -4\,500$

$E''_{90} : y = \dfrac{90}{300} \times (3\,001 - 205) + 205 = 1\,045$

$D''_{90} : x = \dfrac{90}{300} \times (5\,438 + 286) - 286 = 1\,431$

$D''_{90} : y = \dfrac{90}{300} \times (910 - 135) + 135 = 368$

$C''_{90} : x = \dfrac{90}{300} \times (10\,807 - 281) + 281 = 3\,439$

$C''_{90} : y = \dfrac{90}{300} \times (96 - 49) + 49 = 63$

STEP 5

The dimension DT is found with the formula:

DT = (HL – RDH) Cot θ + 900 = (46 – 15) Cot 3° + 900 = 1 492 m

DT is plotted from D" along the 300 m contour toward the threshold and a line is drawn from DT parallel to the line DD" and describes the area which an aeroplane will use during the recovery from "on glide path" to the point where a missed approach climb gradient is established. It is of no consequence in this case.

STEP 6

The bounding circle turn area is plotted from the latest TP six seconds beyond E"$_{90}$

The turn parameters are found in PANS-OPS, Table III-7-3 as:

c = 0.88 km, r = 6.49 km and E = 1.21 km

STEP 7

Determine the minimum turn necessary to avoid O$_1$ straight ahead (see Attachment B7, 5.3)

Find that a missed approach turn of 15° will avoid O_1.

STEP 8

The turn area inner boundary, the dividing boundaries of Areas 2 and 3, as well as the direction of the distance vector d$_o$, which determines the height gain, are all plotted from their respective points with a splay angle of 15° + 15° = 30°

STEP 9

Determine the height that can be gained along the 30° line d$_o$ measured from the obstacle O$_1$ back to the 90 m contour of the OAS. Find, by careful measurement, that d$_o$ = 9 000 m

STEP 10

In Area 3 the obstacle height shall be less than:

TNH + (d$_o$ × tan Z) – MOC [30 m with 15° turn]
90 + (9 000 × 0.025) – 30 = 285 m

```
┌─────────────────────┐
│      STEP 11        │
└─────────────────────┘
```

Conclusion: Obstacle O_2 will be avoided with a 60-m extra margin.

SECOND SOLUTION

Conditions: Assume that operational considerations require that the turn height be raised. It appears reasonable since the 15° turn provided 60 m of extra obstacle clearance. Climbing to a higher altitude before turning will place the TP closer to O_1 and will require a greater turn angle, which will affect the distance to climb. You will find that d_o is shortened significantly.

There appears to be no direct method of calculating the solution. It can be found by trial and error that a climb to a height of 155 m followed by a turn of 30° will provide the required 50 m MOC plus a 12 m extra margin. See Figure II-2-14-3.

The parameters used to find the solution presented in Figure II-2-14-3 are:

OCH	80 m
Turn height	155 m, $TP_x = -5\ 091$ m
Indicated airspeed	445 km/h (240 kt)
MAP turn	30° right

155 m contour coordinates are:

E''_{155}; x = –7 100, y = 1 650
D''_{155}; x = 2 671, y = 535
C''_{155}; x = 5 719, y = 73

The results are:

d_o = 5 300 m
MOC = 50 m

The allowable obstacle height at this point is:

155 + (5 300 × 0.025) – 50 = 237.5 m

O_2 height is 225 m.

Conclusion: Obstacle O_2 is avoided and an extra 12.5-m margin is provided.

$\triangle \bullet O_1$ (400)

$\triangle \bullet O_2$ (225)

$\triangle \bullet O_3$ (40)
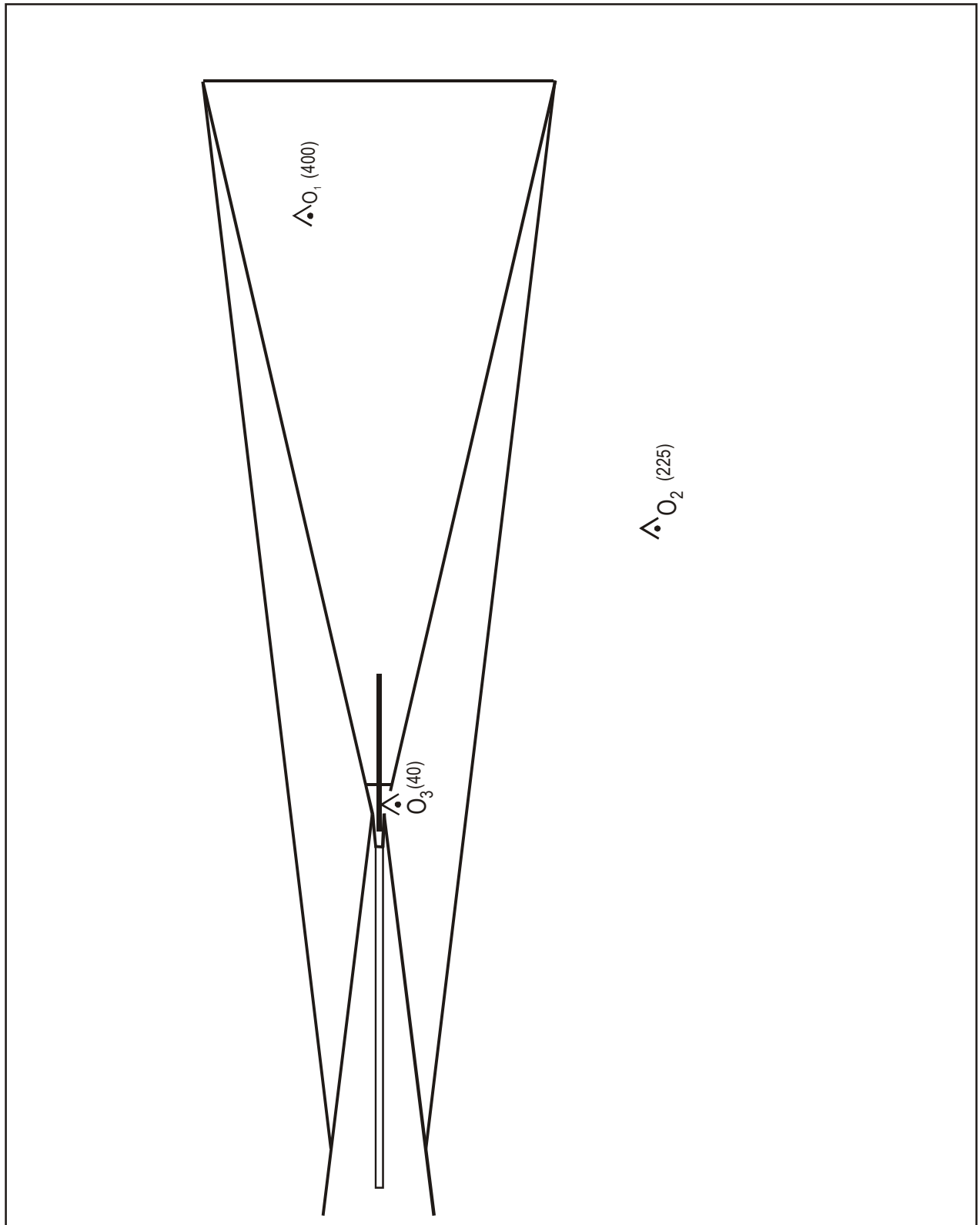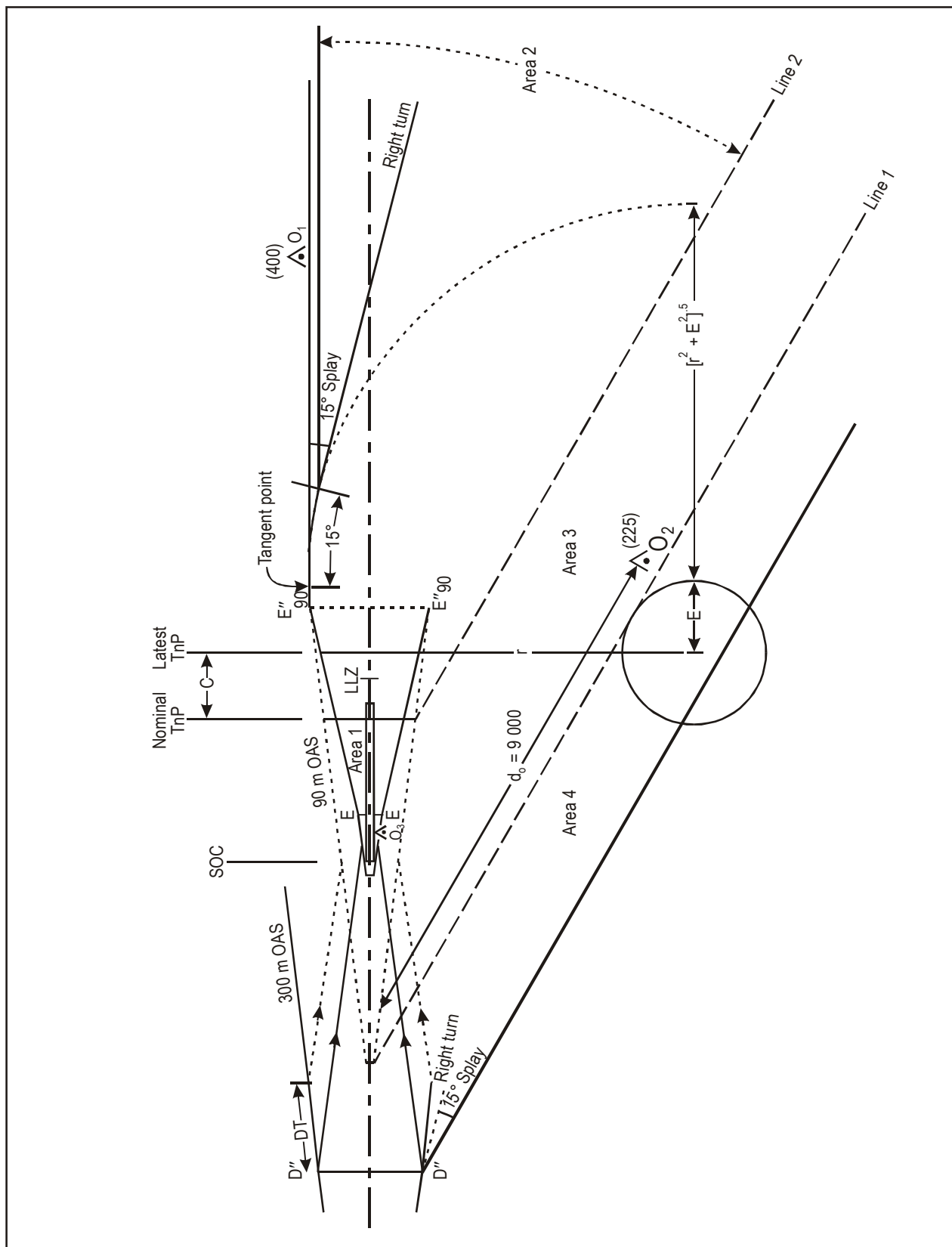
Figure II-2-14-1

Figure II-2-14-2
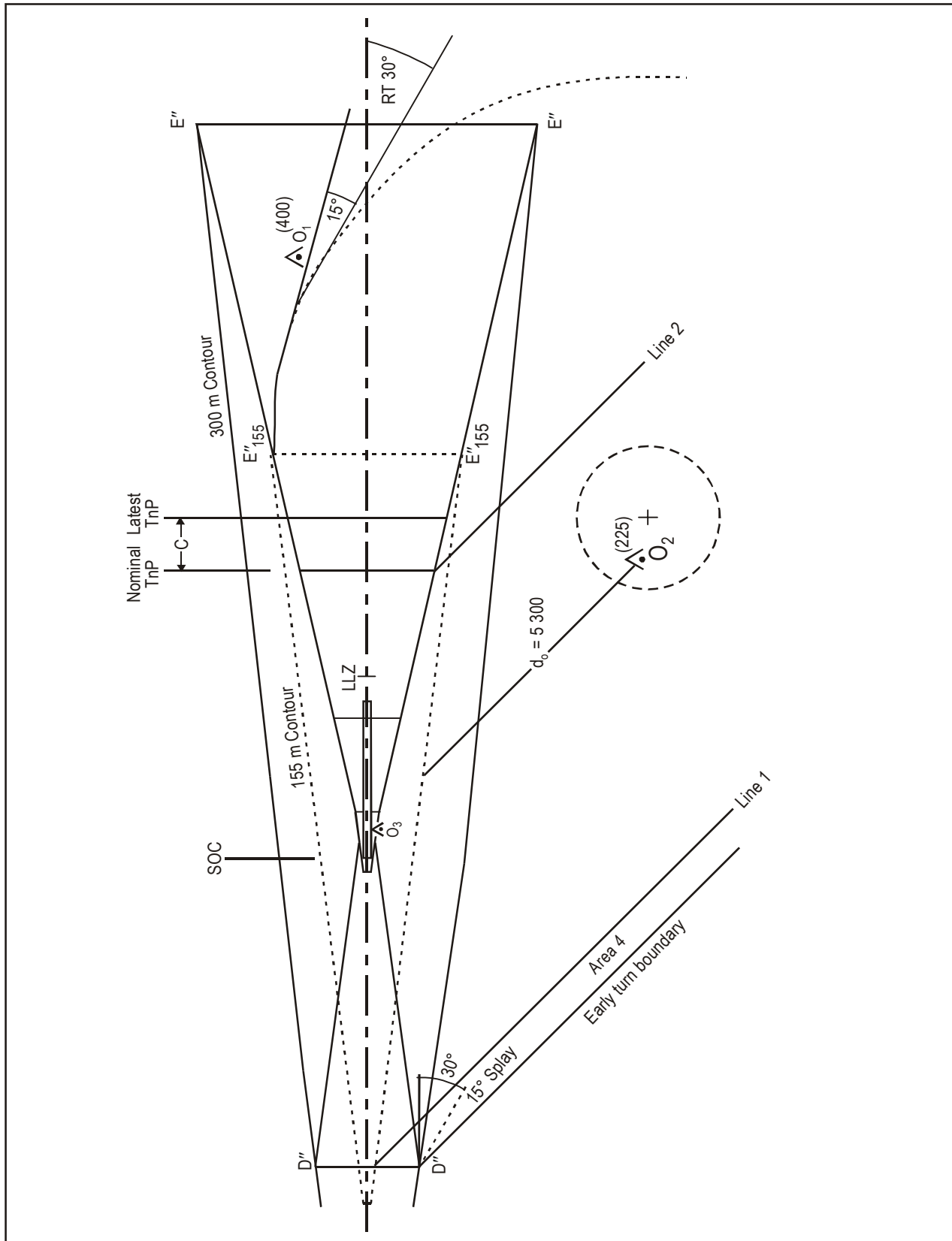
Figure II-2-14-3

INSTRUMENT FLIGHT PROCEDURES
CONSTRUCTION MANUAL

PART III

RNAV PROCEDURES AND SATELLITE-BASED PROCEDURES

Part III

RNAV procedures and satellite-based procedures

(To be developed)

Attachment A

CONVERSION TABLES

Attachment A1

Percentage Gradient to Slope

Percentage gradient	Slope		
	m/km	*m/NM*	*ft/NM*
0.5	5	9.3	30
1.0	10	18.5	61
1.5	15	27.8	91
2.0	20	37.0	122
2.5	25	46.3	152
3.0	30	55.6	182
3.5	35	64.8	213
4.0	40	74.1	243
4.5	45	83.3	273
5.0	50	92.6	304
5.5	55	101.9	334
6.0	60	111.1	365
6.5	65	120.4	395
7.0	70	129.6	425
7.5	75	138.9	456
8.0	80	148.2	486
8.5	85	157.4	516
9.0	90	166.7	547
9.5	95	175.9	577
10.0	100	185.2	608

Attachment A2
Metres and Feet

ft	0	1	2	3	4	5	6	7	8	9
					Feet to metres					
0	0	0.30	0.61	0.91	1.22	1.52	1.83	2.13	2.44	2.74
10	3.05	3.35	3.66	3.96	4.27	4.57	4.88	5.18	5.49	5.79
20	6.10	6.40	6.71	7.01	7.32	7.62	7.92	8.23	8.53	8.84
30	9.14	9.45	9.75	10.06	10.36	10.67	10.97	11.28	11.58	11.89
40	12.19	12.50	12.80	13.11	13.41	13.72	14.02	14.33	14.63	14.94
50	15.24	15.54	15.85	16.15	16.46	16.76	17.07	17.37	17.68	17.98
60	18.29	18.59	18.90	19.20	19.51	19.81	20.12	20.42	20.73	21.03
70	21.34	21.64	21.95	22.25	22.56	22.86	23.16	23.47	23.77	24.08
80	24.38	24.69	24.99	25.30	25.60	25.91	26.21	26.52	26.82	27.13
90	27.43	27.74	28.04	28.35	28.65	28.96	29.26	29.57	29.87	30.18
	0	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**
100	30.48	33.53	36.58	39.62	42.67	45.72	48.77	51.82	54.86	57.91
200	60.96	64.01	67.06	70.10	73.15	76.20	79.25	82.30	85.34	88.39
300	91.44	94.49	97.54	100.58	103.63	106.68	109.73	112.78	115.82	118.87
400	121.92	124.97	128.02	131.06	134.11	137.16	140.21	143.26	146.30	149.35
500	152.40	155.45	158.50	161.54	164.59	167.64	170.69	173.74	176.78	179.83
600	182.88	185.93	188.98	192.02	195.07	198.12	201.17	204.22	207.26	210.31
700	213.36	216.41	219.46	222.50	225.55	228.60	231.65	234.70	237.74	240.79
800	243.84	246.89	249.94	252.98	256.03	259.08	262.13	265.18	268.22	271.27
900	274.32	277.37	280.42	283.46	286.51	289.56	292.61	295.66	298.70	301.75
	0	**100**	**200**	**300**	**400**	**500**	**600**	**700**	**800**	**900**
1 000	304.80	335.28	365.76	396.24	426.72	457.20	487.68	518.16	548.64	579.12
2 000	609.60	640.08	670.56	701.04	731.52	762.00	792.48	822.96	853.44	883.92
3 000	914.40	944.88	975.36	1 005.8	1 036.3	1 066.8	1 097.3	1 127.8	1 158.2	1 188.7
4 000	1 219.2	1 249.7	1 280.2	1 310.6	1 341.1	1 371.6	1 402.1	1 432.6	1 463.0	1 493.5
5 000	1 524.0	1 554.5	1 585.0	1 615.4	11 645.9	1 676.4	1 706.9	1 737.4	1 767.8	1 798.3
6 000	1 828.8	1 859.3	1 889.8	1 920.2	1 950.7	1 981.2	2 011.7	2 042.2	2 072.6	2 103.1
7 000	2 133.6	2 164.1	2 194.6	2 225.0	2 255.5	2 286.0	2 316.5	2 347.0	2 377.4	2 407.9
8 000	2 438.4	2 468.9	2 499.4	2 529.8	2 560.3	2 590.8	2 621.3	2 651.8	2 682.2	2 712.7
9 000	2 743.2	2 773.7	2 804.2	2 834.6	2 865.1	2 895.6	2 926.1	2 956.6	2 987.0	3 017.5
	0	**1 000**	**2 000**	**3 000**	**4 000**	**5 000**	**6 000**	**7 000**	**8 000**	**9 000**
10 000	3 048.0	3 352.8	3 657.6	13 962.4	4 267.2	4 572.0	4 876.8	5 181.6	5 486.4	5 791.2
20 000	6 096.0	6 400.8	6 705.6	7 010.4	7 315.2	7 620.0	7 924.8	8 229.6	8 534.4	8 839.2
30 000	9 144.0	9 448.8	9 753.6	10 058	10 363	10 668	10 973	11 278	11 582	11 887
40 000	12 192	12 497	12 802	13 106	13 411	13 716	14 021	14 326	14 630	14 935
50 000	15 240	15 545	15 850	16 154	16 459	16 764	17 069	17 374	17 678	17 983

Metres to feet

m	0	1	2	3	4	5	6	7	8	9
0	0	3.28	6.56	9.84	13.12	16.40	19.68	22.97	26.25	29.53
10	32.81	36.09	39.37	42.65	45.93	49.21	52.49	55.77	59.05	62.34
20	65.62	68.90	72.18	75.46	78.74	82.02	85.30	88.58	91.86	95.14
30	98.42	101.70	104.99	108.27	111.55	114.83	118.11	121.39	124.67	127.95
40	131.23	134.51	137.79	141.07	144.36	147.64	150.92	154.20	157.48	160.76
50	164.04	167.32	170.60	173.88	177.16	180.44	183.72	187.01	190.29	193.57
60	196.85	200.13	203.41	206.69	209.97	213.25	216.53	219.81	223.09	226.38
70	229.66	232.94	236.22	239.50	242.78	246.06	249.34	252.62	255.90	259.18
80	262.46	265.74	269.03	272.31	275.59	278.87	282.15	285.43	288.71	291.99
90	295.27	298.55	301.83	305.11	308.40	311.68	314.96	318.24	321.52	324.80

	0	10	20	30	40	50	60	70	80	90
100	328.08	360.89	393.70	426.50	459.31	492.12	524.93	557.74	590.54	623.35
200	656.16	688.97	721.78	754.58	787.39	820.20	853.01	885.82	918.62	951.43
300	984.24	1 017.0	1 049.9	1 082.7	1 115.5	1 148.3	1 181.1	1 213.9	1 246.7	1 279.5
400	1 312.3	1 345.1	1 377.9	1 410.7	1 143.6	1 476.4	1 509.2	1 542.0	1 574.8	1 607.6
500	1 640.4	1 673.2	1 706.0	1 738.8	1 771.6	1 804.4	1 837.2	1 870.1	1 902.9	1 935.7
600	1 968.5	2 001.3	2 034.1	2 066.9	2 099.7	2 132.5	2 165.3	2 198.1	2 230.9	2 263.8
700	2 296.6	2 329.4	2 362.2	2 395.0	2 427.8	2 460.6	2 493.4	2 526.2	2 559.0	2 591.8
800	2 624.6	2 657.4	2 690.3	2 723.1	2 755.9	2 788.7	2 821.5	2 854.3	2 887.1	2 919.9
900	2 952.7	2 985.5	3 018.3	3 051.1	3 084.0	3 116.8	3 149.6	3 182.4	3 215.2	3 248.0

	0	100	200	300	400	500	600	700	800	900
1 000	3 280.8	3 608.9	3 937.0	4 265.0	4 593.1	4 921.2	5 249.3	5 577.4	5 905.4	6 233.5
2 000	6 561.6	6 889.7	7 217.8	7 545.8	7 873.9	8 202.0	8 530.1	8 858.2	9 186.2	9 514.3
3 000	9 842.4	10 170	10 499	10 827	11 155	11 483	11 811	12 139	12 467	12 795
4 000	13 123	13 451	13 779	14 107	14 436	14 764	15 092	15 420	15 748	16 076
5 000	16 404	16 732	17 060	17 388	17 716	18 044	18 372	18 701	19 029	19 357
6 000	19 685	20 013	20 341	20 669	20 997	21 325	21 653	21 981	22 309	22 638
7 000	22 966	23 294	23 622	23 950	24 278	24 606	24 934	25 262	25 590	25 918
8 000	26 246	26 574	26 903	27 231	27 559	27 887	28 215	28 543	28 871	29 199
9 000	29 527	29 855	30 183	30 511	30 840	31 168	31 496	31 824	32 152	32 480

Attachment B

CONSTRUCTION AND CALCULATION

Attachment B1

Construction of Obstacle Clearance
Areas for Reversal Procedures

1.   INTRODUCTION

The construction of obstacle clearance areas for reversal procedures (PANS-OPS, Volume II, Part III, 4.6) is based on the direct application of the tolerance criteria specified in PANS-OPS, Volume II, Part III, Chapter 2. These may be applied either on an additive tolerance basis, or using statistical methods.

2.   STATISTICAL AREA CONSTRUCTION

If statistical methods are used to combine the variables, and then to extrapolate distributions to develop areas, the probability level associated with that extrapolation should meet an acceptable level of safety.

3.   ADDITIVE TOLERANCE AREA
CONSTRUCTION

A variety of methods may be used; whichever method is used, the criteria and parameters given in PANS-OPS, Volume II, Part III, 4.5 and 4.6 apply. The method described in this attachment is the template tracing technique (TTT).

3.1   Protection area of a base turn

3.1.1   *General*

The primary area of a base turn can be drawn either by applying the construction method of the template specified in 3.1.2 of this attachment or by using one of the precalculated templates contained in the *Template Manual for Holding, Reversal and Racetrack Procedures* (Doc 9371) for the appropriate timing, speed and altitude. This template caters for all factors which can cause an

aircraft to deviate from the nominal track; tolerances of the navigational facility, flight technical tolerances and wind effect; so that it represents the primary area of the base turn.

3.1.2   *Construction of the base turn template*
(Table B1-1 and Diagram B1-1)

3.1.2.1   Draw a line representing the axis of the procedure and locate point "a" on the fix — draw the nominal outbound leg and inbound turn:

   — *angle between outbound leg and procedure axis:* ϕ (Table B1-l, line 10);

   — *outbound leg length:* L (Table B1-1, line 13);

   — *radius of turn:* r (Table B1-l, line 5).

3.1.2.2   *Protection of the outbound leg.* From "a" draw two lines at an angle of 5.2° for a VOR and 6.9° for an NDB on each side of the nominal outbound leg. Locate points bl, b2, b3 and b4 on these lines (Table B1-1, lines 14 and 15). These points determine the area containing the beginning of the inbound turn.

3.1.2.3   *Protection of the inbound turn*

3.1.2.3.1   With a centre on c2 at a distance r from b2 on the perpendicular to the nominal outbound leg and a radius r, draw an arc beginning at b2. Locate points d and e after 50 and 100 degrees of turn after b2. Similarly, draw an arc beginning at b4 and locate point f after 100 degrees of turn after b4 and draw an arc beginning at b3 and locate points i and j after 190 and 235 degrees of turn after b3.

3.1.2.3.2   *Influence of the wind*

   a)   The wind effect is calculated for each point of the turn by multiplying E, the wind effect during one degree, by the number of degrees of turn;

b) draw arcs with centres d, e, f, i and j and radii W_d, W_e, W_f, W_i and W_j (Table B1-1, lines 16 to 19). The arc centred on f is called arc f;

c) draw a line tangent to the arc centred on e (or f if more conservative) making an angle d (Table B1-1, line 20) with the perpendicular to the inbound track and locate point k at its intersection with the inbound track. With a centre on C5 at a distance r from k on the nominal inbound track, and a radius r, draw an arc beginning at k. Locate points g and h after 50 and 100 degrees of turn after k; and

d) draw arcs with centres g and h and radii W_g and W_h (Table B1-1, lines 16 and 17).

3.1.2.4 *Drawing of the protection area of the base turn.* The outline of the protection area is composed of:

a) the spiral envelope of the arcs centred on "d" and "e";

b) the spiral envelope of the arcs centred on "g" and "h";

c) the spiral envelope of the arcs centred on "i" and "j";

d) the tangent to the spiral a) passing through "a";

e) the tangent to the spirals a) and b) or the tangent to the spiral a) and arc f, a portion of arc f, and the tangent to arc f and b);

f) the tangent to the spirals b) and c); and

g) the tangent to the spiral c) passing through "a".

Note.— If point "a" lies within spiral c), the outbound time should be increased.

3.1.2.5 *Protection of the entry*

3.1.2.5.1 *Entry along a straight segment (see 3.2.5)*

3.1.2.5.2 *Entry along a holding or racetrack procedure (see Diagram B1-2)*

3.1.2.5.2.1 Let ϕ be the angle between the inbound track of the holding or racetrack procedure and the outbound track of the base turn, From "a", draw line E making an angle α

from the nominal outbound track and draw the position fix tolerance area with reference to that line, as described in 3.3.2.2.4.4 for a VOR and 3.3.2.2.4.5 for an NDB.

3.1.2.5.2.2 Draw line E' parallel to E passing through V_3 (respectively N_3) and locate point *l* (Table B1-1, line 21). Draw an arc of 100° with a radius r tangent to line E' at *l* and locate points m and n after 50° and 100° of turn from *l*. Draw arcs with centres *l*, m and n and radii W_l, W_m and W_n (Table B1-1, lines 22, 23 and 24).

3.1.2.5.2.3 Draw the spiral envelope of the arcs centred on *l*, m and n and its tangent from V_3 (respectively N_3).

3.1.2.5.2.4 Draw the tangent between the entry spiral above and the protection area of the base turn.

3.1.3 **Secondary area**

Draw the secondary area limit at a distance of 4.6 km (2.5 NM) from the boundary of the primary area.

Note.— See PANS-OPS, Volume II, Attachment K to Part III for a possible reduction of the width of the secondary area.

3.2   Protection area of a procedure turn

3.2.1 **General**

The construction of the protection area of a procedure is made in two steps.

— The first one is to construct a procedure turn template (see 3.2.2 or 3.2.3) or to use one of the precalculated templates contained in the *Template Manual for Holding, Reversal and Racetrack Procedures* (Doc 9371) for the appropriate speed and altitude. This template caters for all factors which can cause an aircraft to deviate from the nominal track, except those which define the tolerance area of the beginning of the outbound track.

— The second step is then to draw the protection area of the procedure turn by moving the template point "a" around the tolerance area of the beginning of the outbound turn as described in 3.2.4 of this attachment.

3.2.2   ***Construction of the 45° — 180° procedure turn template***
(Table B1-2 and Diagram B1-3)

3.2.2.1   *Nominal track.* Draw a line representing the axis of the procedure and locate points "a" and "b" on it (Table B1-2, line 10). Beginning at "b" and ending at "c", draw the nominal outbound turn of 45°. Draw between "c" and "d" the nominal outbound leg and beginning at "d" the nominal inbound turn of 180°;

— *radius of the turns*: r (Table B1-2, line 5);
— *outbound leg length*: cd (Table B1-2, line 11).

3.2.2.2   *Influence of the flight technical tolerances*

a) From "c" draw two lines at 5 degrees on each side of the nominal outbound leg;

b) locate points "d1", "d2", "d3" and "d4" on these lines (Table B1-2, lines 12 and 13); and

c) with a centre on "e2" at a distance r from "d2" on the perpendicular line to the nominal outbound leg (line passing through d2 and d4), and a radius r, draw the inbound turn beginning at "d2". Locate points "f" and "g" after 50 and 100 degrees of turn from "d2". With centres on "e3" and "e4", draw the corresponding arcs beginning at "d3" and "d4". Locate points "h", "i" and "j" after 100, 150 and 200 degrees from "d4" and points "k" and "l" after 200 and 250 degrees of turn from "d3".

3.2.2.3   *Influence of the wind*

a) The wind effect is calculated for each point by multiplying the wind speed w by the flying time from point "a";

b) draw arcs with centres "c", "d2", "f", "g", "h", "i", "j", "k" and "l" and radii Wc, Wd2, Wf, Wg, Wh, Wi, Wj, Wk and Wl (Table B1-2, lines 14 to 21).

3.2.2.4   *Drawing of the outline of the template.* The outline of the template is composed of:

a) the tangent passing through "a" to the arc centred on "c";

b) the common tangent to the arcs centred on "c" and "d2";

c) the spiral envelope of the arcs centred on "d2", "f" and "g";

d) the spiral envelope of the arcs centred on "h", "i" and "j";

e) the spiral envelope of the arcs centred on "k" and "l";

f) the common tangent to the spirals c) and d);

g) the common tangent to the spirals d) and e); and

h) the tangent passing through "a" to the spiral e).

3.2.3   ***Construction of the 80° — 260° procedure turn template***
(Table B1-3 and Diagram B1-4)

3.2.3.1   *Nominal track.* Draw a line representing the axis of the procedure and locate points "a" and "b" on it (Table B1-3, line 10). With a centre "c" at a distance r (Table B1-3, line 5) from "b" on the perpendicular line to the procedure axis passing through "b", draw the nominal outbound turn of 80° and locate point "d" at the end of this turn. From "d" draw the tangent to the nominal outbound turn and locate point "e" on this tangent (Table B1-3, line 11). With a centre on "f" and a radius r, draw the nominal inbound turn of 260° beginning at "e".

3.2.3.2   *Influence of the flight technical tolerances*

a) On the nominal outbound turn, locate points "d1" and "d2" after 75 and 85 degrees of turn from "b";

b) from "d1" and "d2", draw the tangents to the outbound turn and locate points "e1" and "e2" on these tangents (Table B1-3, line 11);

c) with a centre on "f2" at a distance r from "e2" on the perpendicular line to d2e2, draw the inbound turn at "e2". Locate points "g", "h", "i" and "j" after 45, 90, 135 and 180 degrees of turn from "e2"; and

d) with a centre on "f1", draw the inbound turn beginning at "e1" and locate points "k", "l" and "m" after 180, 225 and 270 degrees of turn from "e1".

3.2.3.3   *Influence of the wind*

a) The wind effect is calculated for each point by multiplying the wind speed w by the flying time from the point "a", to the beginning of the turn; and

b) draw arcs with centres "e2", "g", "h", "i", "j", "k", "l" and "m" and radii We2, Wg, Wh, Wi, Wj, Wk, Wl and Wm (Table B1-3, lines 12 to 19).

3.2.3.4 *Drawing of the outline of the template.* The outline of the template is composed of:

a) the spiral envelope of the arcs centred on "e2", "g", "h", "i" and "j";

b) the spiral envelope of the arcs centred on "k", "l" and "m";

c) the common tangent to the spirals a) and b);

d) the tangent passing through "a" to the spiral a); and

e) the tangent passing through "a" to the spiral b).

3.2.4 ***Drawing of the protection area of the procedure turn***
(Diagram B1-5)

3.2.4.1 *Tolerance area of the beginning of the outbound turn*

3.2.4.1.1 From the facility, point 0, draw the radial of the procedure and its two protection lines. These lines make an angle of 6.9° if the facility is NDB, 5.2°, if the facility is a VOR, or 2.4° if the facility is a localizer, on each side of the radial.

3.2.4.1.2 Locate point A on the nominal beginning of the outbound turn.

3.2.4.1.3 According to the type of facility at 0 and eventually at A or 0, draw the tolerance area of point A Al A2 A3 A4 as described on the Figures B1-1 to B1-5.

Note.— Units in following formulas:

	SI units	Non-SI units
t	= s	s
v and w'	= km/s	NM/s
distances	= km	NM

The values of v, w' and h are given by Table B1-1 (lines 3, 8 and 6 respectively). D is the specified DME distance expressed in km (NM) and d1 is the tolerance of this DME indication:

$$d1 = 0.46 \text{ km } (0.25 \text{ NM}) + 0.0125 \text{ D}$$

3.2.4.2 *Primary area*

a) Place the template point "a" on "Al", with the template procedure axis parallel to the inbound track, and draw the curve "l" (part of the outline of the template);

b) in the same manner, place the template point "a" successively on "A2", "A3" and "A4" to draw curves "2", "3" and "4"; and

c) draw the common tangents to curves "1" and "2", "2" and "4", "3" and "4" and the tangent from "0" to curve "l" and from "0" to curve "3".

3.2.4.3 *Secondary area.* Draw the secondary area limit at a distance of 4.6 km (2.5 NM) from the boundary of the primary area.

3.2.5 ***Interface between initial segment area and base and procedure turn areas***

3.2.5.1 *General.* The primary area of the initial segment, the boundaries of which are 4.6 km (2.5 NM) apart from the nominal path, shall be blended with the primary area of the turn procedure, which is described above in 3.1.2 (base turn) and 3.2.4 (procedure turn). The secondary areas of the two phases of the procedure shall be blended so that a constant width of 4.6 km (2.5 NM) is respected.

3.2.5.2 *Construction of the secondary area outer boundary (see Figures B1-6 and B1-7).* On one side of the initial segment path the outer boundaries of the two secondary areas will intersect. On the other side of the initial segment path, the outer boundary of the secondary area consists of an arc of circle, 9.2 km (5 NM) from the facility, and the tangent to that circle and the outer boundary of the secondary area of the turn.

3.2.5.3 *Construction of the primary area boundary.* The boundary of the primary area is drawn in 4.6 km (2.5 NM) from the outer boundary of the secondary area.

3.3 Protection area of racetrack and holding procedures

3.3.1 ***General***

Note.— The methods described in this paragraph are related to right turn procedures. For left turn procedures, the corresponding areas are symmetrical with respect to the inbound track.

3.3.1.1   The protection area of a racetrack procedure consists of a primary area and a secondary area; the protection area of a holding procedure consists of an area and a buffer area. Since the construction of the primary area of a racetrack and of the area of a holding is the same, they are referred to by the same term hereafter — *the basic area of the procedure.*

3.3.1.2   The construction of the basic area of the procedure is made in two steps.

3.3.1.2.1   The first step is to construct a template or to take a precalculated one from the *Template Manual for Holding, Reversal and Racetrack Procedures* (Doc 9371), for the appropriate time, speed and altitude. This template caters for all factors which can cause an aircraft to deviate from the nominal pattern except those related to the fix tolerance area. It is applicable to all types of procedures including VOR or NDB overhead, intersection of VOR radials, VOR/DME and their entries.

3.3.1.2.2   The second step is to draw the basic area of the procedure by moving the template-origin around the fix tolerance area for procedures overhead a facility or at the intersection of VOR radials, or by using it as described in 3.3.4 for VOR/DME procedures, and by adding areas to protect entries as required.

3.3.1.3   Finally, a secondary area of 4.6 km (2.5 NM) is added around the basic area for a racetrack, and a buffer area of 9.3 km (5.0 NM) is added around the basic area for a holding.

3.3.2   *First step: construction of the template* *(Table B1-4 and Diagram B1-6)*

3.3.2.1   The parameters used in the construction of the template are contained in PANS-OPS, Volume II, Part III, 4.6.2 for the racetrack and in PANS-OPS, Volume II, Part IV, 1.3 for the holding procedures.

3.3.2.2   After completion of the calculations indicated in Table B1-4, the template is constructed as follows.

3.3.2.2.1   Draw a line representing the axis of the procedure and the nominal pattern. Locate point "a" at the procedure fix. (The radius of turn r is given at line 5 and the outbound length L is given at line 11 of Table B1-4.)

3.3.2.2.2   *Influence of the navigation tolerances*

3.3.2.2.2.1   Locate points "b" and "c" on the procedure axis (Table B1-4, lines 12 and 13); "b" and "c" represent the earliest (5 s after "a") and the latest (11 s after "a") still air positions of the beginning of the outbound turn.

3.3.2.2.2.2   Draw an arc of 180° with a radius r tangent to the procedure axis at "c", which represents the latest still air outbound turn. Locate points "d", "e", "f" and "g" after 45, 90, 135 and 180° of turn from "c".

3.3.2.2.2.3   Draw an arc of 270° with a radius r tangent to the procedure axis at "b", which represents the earliest still air outbound turn. Locate points "h", "o" and "p" after 180, 225 and 270° of turn from "b".

3.3.2.2.2.4   From "g" draw two lines at 5° on each side of the nominal outbound leg. Locate points "il", "i2", "i3" and "i4" on these lines (Table B1-4, lines 14 and 15). "i1" and "i3" are plotted (60T − 5) seconds after "g"; "i2" and "i4" should be (60T + 15) seconds after "h", but for the sake of simplification they are plotted (60T + 21) seconds after "g". il i2 i3 i4 determine the area containing the still air position of the beginning of the inbound turn.

3.3.2.2.2.5   With a centre at a distance r below "i2" on the perpendicular line to the nominal outbound leg, and a radius r draw an arc of 180° beginning at "i2" and ending at "n2". Locate points "j" and "k" after 45 and 90° of turn from "i2". Draw the corresponding arc beginning at "i4" and ending at "n4". Locate points "1" and "m" after 90 and 135° of turn from "i4".

3.3.2.2.2.6   The end of the inbound turn in still air conditions is contained in the area nl n2 n3 n4 reduced from il i2 i3 i4 by a translation of one diameter of nominal turn.

3.3.2.2.3   *Influence of the wind*

3.3.2.2.3.1   The wind effect is calculated for each point by multiplying the wind speed (Table B1-4, line 7) with the flying time from "a" to the point.

3.3.2.2.3.2   *Influence of the wind during the outbound turn.* Draw arcs with centres "b", "c", "d", ''e" and "f" and radii Wb, Wc, Wd, We and Wf (Table B1-4, lines 16 to 20).

3.3.2.2.3.3   The area containing the end of the outbound turn is determined by two arcs with centres "g" and "h" and radii Wg and Wh (Table B1-4, lines 21 and 22) and their common tangents.

3.3.2.2.3.4   The area containing the beginning of the inbound turn is determined by the four arcs with the centres

"i1", "i2", "i3" and "i4" and radii Wi1, Wi2, Wi3 and Wi4 (Table B1-4, lines 25 and 26) and their four common tangents.

3.3.2.2.3.5 *Influence of the wind during the inbound turn.* Draw arcs with centres "j", "k", "l", "m", "n4" and "n3" and radii Wj, Wk, Wl, Wm, Wn4 and Wn3 (Table B1-4, lines 27 to 31).

3.3.2.2.3.6 Draw arcs with centres "o" and "p" and radii Wo and Wp (Table B1-4, lines 23 and 24).

3.3.2.2.4 *Drawing of the template*

3.3.2.2.4.1 The outline of the template is composed of:

a) the spiral envelope of the arcs centred on "c", "d", "e", "f" and "g";

b) the arc centred on "i1" and the common tangent to this arc and the spiral drawn in a);

c) the common tangent to the arcs centred on "i1" and "i2";

d) the spiral envelope of the arcs centred on "i2", "j" and "k", the spiral envelope of the arc centred on "l", "m" and "n4" and their common tangent;

e) the arcs centred on "n3" and "n4" and their common tangent; and

f) the tangent to the arc centred on "n3" and to the spiral drawn in a).

3.3.2.2.4.2 The protection of the outbound leg in the direction of the D axis is represented by the common tangents to the arcs centred on "g", "i3" and "i4", called line "3" (see Diagrams B1-6, B1-7 and B1-8).

3.3.2.2.4.3 The protection of a turn of more than 180° is represented by:

a) the spiral envelope of the arcs centred on "c", "d", "e", "f" and "g" and the tangent to this spiral passing through "a"; and

b) the spiral envelope of the arcs centred on "h", "o" and "p" and the tangent to this spiral and to the area drawn in 3.3.2.2.3.3.

3.3.2.2.4.4 *VOR position fix tolerance area*

a) *Manual construction.* The VOR position fix tolerance area Vl V2 V3 V4 is determined as follows (see Figure B1-8):

1) draw a circle with centre on the VOR and a radius of zV:

$$zV = h \tan \alpha$$

where α is 50° or a lesser value, as determined by the appropriate authority (see PANS-OPS, Volume II, Part III, 2.6.5.1), corresponding to the cone effect;

2) draw two lines 5° from the perpendicular to the inbound track;

3) draw two lines perpendicular to the lines drawn in 2) at a distance qV on each side of the inbound track:

$qV = 0.2 \ h$ (h in km and qV in km)

$qV = 0.033 \ h$ (h in thousands of feet and qV in NM); and

4) locate points Vl, V2, V3, V4 at the four intersections of the lines drawn in 3) with the circle drawn in 1).

b) *Use of template.* See the *Template Manual for Holding, Reversal and Racetrack Procedures* (Doc 9371).

3.3.2.2.4.5 *NDB position fix tolerance area*

a) *Manual construction.* The NDB position fix tolerance area Nl N2 N3 N4 is determined as follows (see Figure B1-9):

1) draw a circle with centre on the NDB (point "a") and a radius zN = h tan 40° to obtain the cone effect area;

2) draw the parallel lines at a distance qN = zN sin 15° on each side of the inbound track;

3) draw two lines making an angle of 5° with the precedents on the points "N2" and "N4"; and

4) locate points "Nl" and "N3" at the intersections of the lines drawn in 3) and the circle drawn in 1).

b) *Use of template.* See the *Template Manual for Holding, Reversal and Racetrack Procedures* (Doc 9371).

3.3.2.2.4.6   *Point "R".* This point is used to determine the lowest position of the limiting radial, so that this radial does not cross the area containing the end of the outbound turn. It is located as follows:

a) draw the tangent to the area containing the end of the outbound turn passing through the intersection point of the outline of the template with the C axis;

b) locate point "R" at the intersection of this tangent with the curve drawn in 3.3.2.2.4.3 b).

3.3.2.2.4.7   *Point "E".* This point is used to determine the omnidirectional entry area in the direction of the C and D axis. It is located by its coordinates XE and YE from the outline of the template:

a) draw a line perpendicular to the inbound track at a distance XE (Table B1-4, line 32) from the extreme position of the outline of the template in the direction of the C axis (common tangent to the circles centred on "k" and "l");

b) draw a line parallel to the inbound track at a distance YE (Table B1-4, line 33) from the extreme position of the outline of the template in the direction of the D axis (circle centred on "N4"); and

c) locate point "E" at the intersection of these two lines.

Explanation:

XE is the greatest displacement along the C axis of an aeroplane making an entry procedure. This occurs for a sector 3 entry at an angle of 90° with the procedure axis and a wind along the C axis (see Figure B1-10).

The maximum displacement along the C axis due to wind effect occurs at point E_{max}, after that portion of turn corresponding to the drift angle. For simplicity this angle has a value of 15° in the formula.

$$XE = 2r + (t + 15)v + (11 + 90/R + t + 15 + 105/R)w'$$

YE is the greatest displacement along the D axis of an aeroplane making an entry procedure. This occurs for a sector 1 entry at an angle of 70° with the procedure axis and a wind along the D axis (see Figure B1-11).

The maximum displacement along the D axis due to wind effect occurs at point E_{max}, after that portion of turn corresponding to the drift angle. For simplicity, this angle has a value of 15° in the formula.

$$YE = llv \cos 20° + r \sin 20° + r + (t + 15)v \tan 5°$$
$$+ (11 + 20/R + 90/R + t + 15 + 15/R)w'$$

3.3.3   ***Second step: construction of the basic area and the associated omnidirectional entry area overhead a VOR or NDB or at the intersection of VOR radials***

3.3.3.1   *Construction of the basic area (Diagram B1-9)*

3.3.3.1.1   *Procedure fix tolerance area*

3.3.3.1.1.1   *Procedure overhead a VOR*

a) Locate point "A" on the VOR; and

b) draw around "A" the position fix tolerance area of the VOR given by the template (area Vl V2 V3 V4) and locate points "Al", "A2", "A3" and "A4" on the four corners of this area.

3.3.3.1.1.2   *Procedure overhead an NDB*

a) Locate point "A" on the NDB; and

b) draw around "A" the position fix tolerance area of the NDB given by the template (area Nl N2 N3 N4) and locate points "Al", "A2", "A3" and "A4" on the four corners of this area.

3.3.3.1.1.3   *Procedure at the intersection of VOR radials*

a) Locate point "A" at the intersection of the homing and intersecting radials; and

b) draw around "A" the position fix tolerance area determined by the tolerances of the homing and intersecting radials (PANS-OPS, Volume II, Part III, 2.6) and locate points "Al", "A2", "A3" and "A4" on the four corners of this area.

3.3.3.1.2   *Construction of the procedure area*

3.3.3.1.2.1   Place the template point "a" on A3, with the template procedure axis parallel to the inbound track, and

draw the curve "3" (part of the outline of the template) and the line "3" (protection of the outbound leg in the direction of the D axis).

3.3.3.1.2.2   Place the template point "a" successively on "Al", "A2" and "A4" to draw curves "l", "2" and "4".

3.3.3.1.2.3   Draw the common tangents to curves "l" and "2", "2" and "4", "3" and "4", "3" and "1".

3.3.3.2   *Construction of the entry area*

3.3.3.2.1   *Construction of the entry area assuming omnidirectional entry overhead a VOR or an NDB (Diagrams B1-10, B1-11 and B1-12)*

3.3.3.2.1.1   Draw the circle centred on "A" passing through "Al" and "A3".

3.3.3.2.1.2   Locate point "E" on a series of points along this circle (with the template axis parallel to the inbound track) and for each point draw a curve at the outer limit of the template in the direction of the C and D axis; curve "5" is the envelope of these curves.

3.3.3.2.1.3   Draw the limit of the entry sectors 1 and 3 (line making an angle of 70° with the inbound track). With the template axis on this line, draw the entry fix tolerance area El E2 E3 E4 given by the template for the VOR or the NDB.

3.3.3.2.1.4   Place the template point "a" on El and E3 (with the template axis parallel to the separating line of the sectors 1 and 3) and draw curves "6" and "7" and their common tangent.

3.3.3.2.1.5   With a centre on "A", draw the arc tangent to curve "6" until intersecting curve "1".

3.3.3.2.1.6   Line 8 is the symmetric of lines 6 and 7 about the 70° dividing line. Draw common tangents to curves "5", "6", "7" and "8" as appropriate.

3.3.3.2.2   *Construction of the entry area assuming entries along the homing and intersecting radial in the case of a procedure based on the intersection of VOR radials (Diagram B1-14)*

3.3.3.2.2.1   *Protection of the entry along the reciprocal of the inbound track.* Place the template point "E" on "A2" and "A4" (with the template axis parallel to the inbound track) and draw curves "5" and "6" (parts of the outline of the template) and their common tangent.

3.3.3.2.2.2   *Protection of the entries along the intersecting radial.* In addition to the area provided by the curves "5" and "6" above, if the intersecting VOR is located in sector 2 or in the part of sector 3 opposite to sector 2 the protection area is determined as follows.

3.3.3.2.2.2.1   Determine the entry fix tolerance area El E2 E3 E4 by applying the tolerance for a homing VOR (PANS-OPS, Volume II, Part III, 2.6.2.1) to the intersecting radial and the tolerance for an intersecting VOR (PANS-OPS, Volume II, Part III, 2.6.3.1) to the homing radial.

3.3.3.2.2.2.2   Place the template point "a" on E3 and E4 (with the template axis parallel to the intersecting radial) and draw curves "7" and "8" (protection of a turn of more than 180°: inner curve of the template) and their common tangent.

3.3.3.3   *Area reduction for a procedure overhead a facility when entries from Sector 1 are not permitted (Diagram B1-13)*

3.3.3.3.1   If the aircraft intercepts the procedure radial before the end of the outbound leg, the pilot is assumed to follow the indications of this radial without drifting any further from the procedure axis, so the following applies.

3.3.3.3.2   If line 3 intersects the protection line of the procedure axis (VOR or NDB along track errors) the area may be reduced as shown on Diagram B1-13; rotate the template 180° and place point "a" on the protection line of the procedure axis, tangent to the area in the direction of the C axis; draw a parallel line to the protection line, tangent to the entry curve. The area under that parallel, in the direction of D axis, may be eliminated.

3.3.3.3.3   This reduction is allowed only when entries from Sector 1 are not permitted.

3.3.4   **Construction of the basic area and the associated along-the-radial entry area for VOR/DME procedure**

3.3.4.1   *Procedure towards the station (Diagram B1-15)*

3.3.4.1.1   *Construction of the basic area*

3.3.4.1.1.1   *Selection and calculation of the distance parameters (see Figure B1-12).* The distance parameters are chosen and calculated in the following sequence:

a) choice of the nominal distance: D

D is the slant range between the VOR/DME facility and the procedure point at the specified altitude;

b) choice of the outbound distance: ds

ds is the horizontal length of the outbound leg; ds should conform to the relationship ds $\geq$ vt, where t is the outbound timing, as specified in PANS-OPS, Volume II, Part III, 4.5.5 for racetrack procedures and in PANS-OPS, Volume II, Part IV, 1.3.2.2 for holding procedures;

c) calculation of the horizontal distance: Ds

Ds is the distance between the VOR/DME facility (S) and the projection of the procedure point on the horizontal plane passing through S (point A)

$$Ds = \sqrt{D^2 - hl^2}$$
(Ds, D and hl in km); or

$$DS = \sqrt{D^2 - 0.027 \ hl^2}$$
(Ds and D in NM and hl in thousands of feet);

d) calculation of the limiting outbound distance: DL

DL is the slant range between the VOR/DME facility and the end of the outbound track at the specified altitude

$$DL = \sqrt{(Ds + ds)^2 + 4r^2 + hl^2}$$
(DL, Ds, ds, r, hl in km); or

$$DL = \sqrt{(Ds + ds)^2 + 4r^2 + 0.027 \ hl^2}$$
(DL, Ds, ds, r in NM and hl in thousands of feet).

DL is then rounded to the next higher km (or NM), unless:

the decimal part is less than 0.25 km (or NM) in the case of a procedure at or below 4 250 m (or 14 000 ft) or 0.5 km (or NM) in the case of a procedure above 4 250 m (or 14 000 ft), in which case it is rounded to the next lower km (or NM); and

e) calculation of the horizontal limiting outbound distance: DLs

DLs is the distance between the VOR/DME facility and the vertical projection of the end of the outbound track onto the horizontal plane passing through S

$$DLs = \sqrt{DL^2 - hl^2}$$
(DLS, hl in km); or

$$DLs = \sqrt{DL^2 - 0.027 \ hl^2}$$
(DLs, DL in NM and hl in thousands of feet).

3.3.4.1.1.2 *Fix tolerance area and limiting
                outbound distance*

a) Draw from S the procedure radial "RP" and two lines "RP1" and "RP2" making an angle α (tolerance for a homing VOR, PANS-OPS, Volume II, Part III, 2.6.2.1) with RP on each side of it;

b) with a centre on S, draw arcs "Ds" with a radius Ds, "Dl" with a radius Ds – dl, "D2" with a radius Ds + dl, "DLs", "DL1" and "DL2" with radii DLs, DLs – d2 and DLs + d2

where dl and d2 are the DME tolerance associated with D and DL:

dl is 0.46 km (0.25 NM) + 0.0125 D;

d2 is 0.46 km (0.25NM) + 0.0125 DL; and

c) locate points "A" at the intersection of RP and Ds, "Al" and "A2" at the intersections of RP1 with Dl and D2, "A3" and "A4" at the intersections of RP2 with D1 and D2.

3.3.4.1.1.3 *Protection of the outbound turn
                and outbound leg*

a) Place racetrack template point "a" on Al, with axis parallel to the inbound track, and draw curve "1" (part of the outline of the template);

b) place template point "a" on A3, with axis parallel to the inbound track, and draw curve "2" (part of the outline of the template) and line "3" (protection of the outbound leg on the non-manoeuvring side); and

c) draw the common tangent to curves "1" and "2" and extend the straight part of curve "1" and the line "3" in the direction of the outbound end.

3.3.4.1.1.4   *Area containing the end of the outbound leg*

a) Locate points Cl and C'3 at the intersection of the extension of curve "l" with the arcs DL1 and DL2;

b) locate point C2 between Cl and C'3 at a distance (dl + d2 − 1.8) km or (dl + d2 − 1) NM from C'3;

c) draw a parallel line to the inbound track through C2 and locate points C3 at the intersection of this line with arc DL2;

d) do the same thing as in a), b) and c) with the line "3" instead of curve "l" and points C4, C'6, C5 and C6 instead of Cl, C'3, C2 and C3 (see Figure B1-13 a); and

e) if the aircraft intercepts the VOR radial before reaching the limiting outbound distance, the pilot is assumed to follow the indications of the VOR without drifting any further from the procedure axis, so:

where C5 and C6 are further from the procedure axis than RP2 (see Figure B1-13 b), replace C5 and C6 by the intersections of RP2 with line "3" and DL2, and the end of the outbound leg is contained in the area Cl, C2, C3, C4, C5 and C6;

where C4, C5 and C6 are further from the procedure axis than RP2 (see Figure B1-13 c), replace C4 and C6 by the intersections of RP2 with DL1 and DL2, and the end of the outbound leg is contained in the area Cl, C2, C3, C4 and C6.

3.3.4.1.1.5   *Protection of the inbound turn.* Rotate the template 180°, then:

a) place template point "a" on C2 and C3, with axis parallel to the inbound track, and draw curves "4" and "5" (part of the protection line of a turn of more than 180°) and their common tangent;

b) move the template point "a" along arc DL2 from C3 to C6 (with axis parallel and opposite to the inbound track) and draw curve "6";

c) place template point "a" on C6, C4 and eventually on C5 and draw curves "7", "8" and eventually "9" and their common tangent; and

d) draw the tangent to curves "8" and "2".

3.3.4.1.2   *Construction of the entry areas*

3.3.4.1.2.1   Arrival to a VOR/DME holding pattern may be:

— along the axis of the inbound track;

— along a published track;

— by radar vectoring, when aircraft must be established on prescribed protected flight paths;

and the entry point may be either:

a) the holding fix; or

b) the fix at the end of the outbound leg.

When the entry point is at the holding fix, two cases may be considered:

Case 1.1 — arrival via the VOR radial for the inbound leg;

Case 1.2 — arrival via the DME arc defining the holding fix.

When the entry point is at the fix at the end of the outbound leg, the only case is arrival via the VOR radial passing through the fix at the end of the outbound leg.

3.3.4.1.2.2   It is also possible to make use of guidance from another radio facility (e.g. NDB); in that case, protection of the entry should be the subject of a special study based on general criteria.

3.3.4.1.2.3   The radius of a DME arc used as guidance for arrival at a VOR/DME holding should be not less than 18.5 km (10 NM).

3.3.4.1.2.4   The minimum length for the last segment of the arrival track terminating at the entry point is a function of the angle (θ) between the penultimate segment or radar path and the last segment. The values are shown in the following table:

q	0° to 70°	71° to 90°	91° to 105°	106° to 120°
Minimum distance km (NM)	7.5 (4)	9.5 (5)	13 (7)	16.5 (9)

3.3.4.1.2.5 *Method of arrival at a VOR/DME holding and the corresponding entry procedures.* The methods are described in more detail as follows.

Case 1 — entry at the holding fix.

Case 1.1 — entry at the holding fix via a radial forming the fix.

a) Arrival on the VOR radial for the inbound leg, on the same heading as the inbound track. The arrival path (or last segment thereof) is aligned with the inbound track and follows the same heading. The entry consists of following the holding pattern (see Figure B1-14 a).

Protection of the entry: The entry is protected by the holding protection area.

b) Arrival on the VOR radial for the inbound leg, on a heading reciprocal to the inbound track.

On arrival over the holding fix, the aircraft turns onto the holding side on a track making an angle of 30° with the reciprocal of the inbound track, until reaching the DME outbound limiting distance, at which point it turns to intercept the inbound track. In the case of a VOR/DME holding entry away from the facility with a limiting radial, if the aircraft encounters the radial ahead of the DME distance, it must turn and follow it until reaching the DME outbound limiting distance, at which point it turns to join the inbound track. (See Figure B1-14 b).

Case 1.2 — entry at the holding fix via the DME arc forming the fix.

a) Arrival on the DME arc defining the holding fix, from the holding side. On arrival over the holding fix, the aircraft turns and follows a track parallel to and reciprocal to the inbound track, until reaching the DME limiting outbound distance, at which point it turns to intercept the inbound track (see Figure B1-14 c).

b) Arrival on the DME arc defining the holding fix, from the non-holding side. On arrival over the holding fix, the aircraft turns and follows a track parallel to and on the same heading as the outbound track, until reaching the DME outbound limiting distance, at which point it turns to intercept the inbound track (see Figure B1-14 d).

An arrival track leading to a Case 1.2 a) entry should not be specified unless absolutely necessary, particularly in a VOR/DME holding procedure away from the facility. If an appropriate DME distance is chosen, this type of arrival can actually be replaced by one on a DME arc terminating in the extension of the inbound track (see Figures B1-14 e and f).

Case 2 — entry at the fix at the end of the outbound leg via a radial forming the limiting fix:

a) outbound from the facility;

b) inbound from the facility.

On arrival over the fix at the end of the outbound leg, the aircraft turns and follows the holding pattern.

3.3.4.1.2.6 *The sector 1 entry along the DME arc is protected as follows:*

a) take a tracing of the template, turn it over and place point "a" on A3 with axis on the line Al, A3 to draw curve "13";

b) draw the line "14" parallel to line "3" (used in the construction of the basic area) and tangent to curve "13", and locate point C10 at the intersection of this line with arc DL2; and

c) place point "a" of the tracing on C10, with axis parallel and opposite to the inbound track and move it along DL2 up to the intersection of DL2 and RP1 to draw curve "15".

3.3.4.1.2.7 *Protection of sector 2 entry procedure*

3.3.4.1.2.7.1 It is assumed that having passed the fix, the pilot makes good (± 5° error) a track making an angle of 30° with the inbound track on the manoeuvring side and reaching the limiting outbound distance, turns inbound. In addition, the flying time on the 30° offset track is limited to 1 min 30 s after which the pilot is expected to turn to a heading parallel to the outbound track until reaching the limiting outbound distance, where the pilot turns inbound.

3.3.4.1.2.7.2 For a procedure with outbound of more than 1 min 30 s the protection of sector 2 entry procedure is assured by the basic area.

3.3.4.1.2.7.3 For a procedure with outbound of 1 min or 1 min 30 s, the protection area of sector 2 entry is drawn as follows:

a) from Al draw a line making an angle of 30° + 5° with RP and locate C7 at its intersection with DL2;

b) from A4 draw a line making an angle of 30° – 5° with RP and locate C8 at its intersection with DL2;

c) place template point "a" on C7 and move it along DL2 to C8, with axis making an angle of 30° with RP, to draw curve "11"; and

d) draw the common tangents to the curves "10" and "11" and to the basic area.

3.3.4.1.3   *Construction of the entry area for a reciprocal direct entry to a secondary point (Diagram B1-16)*

3.3.4.1.3.1   It is assumed that reciprocal direct entries are made along the entry radial (RE) joining the VOR/DME station (S) to the secondary point (I) where the turn to inbound is initiated.

3.3.4.1.3.2   This direct entry area is drawn as follows.

3.3.4.1.3.2.1   Measure the angle made by the procedure radial (RP) and the radial joining the VOR/DME station to the end of the nominal outbound leg (line SC) and round its value to the nearest entire degree to obtain the entry radial (RE) to be published.

3.3.4.1.3.2.2   Locate point "I" at the intersection of RE and DLs.

3.3.4.1.3.2.3   From S draw the lines "RE1" and "RE2" making an angle α (tolerance for· homing VOR; PANS-OPS, Volume II, Part III, 2.6.2.1) with RE on each side of it.

3.3.4.1.3.2.4   Locate points "I1" and "I2" at the intersections of RE1 with DL1 and DL2 and points "I3" and "I4" at the intersections of RE2 with DL1 and DL2.

3.3.4.1.3.2.5   Place template point "a" on I2, with axis parallel to RE and move it along DL2 from I2 to I4 to draw curve "13".

3.3.4.2   *Procedure away from the station (Diagram B1-17)*

3.3.4.2.1   *Construction of the basic area*

3.3.4.2.1.1   *Selection and calculation of the distance parameters (see Figure B1-15)*. The distance parameters are chosen and calculated in the following sequence:

a) choice of the nominal distance: D

D is the slant range between VOR/DME facility and the procedure point at the specified altitude;

b) choice of the outbound distance: ds

ds is the horizontal length of the outbound leg

ds should conform to the relationship ds ≥ vt, where t is the outbound timing, as specified in PANS-OPS, Volume II, Part III, 4.5.5 for racetrack procedures and in PANS-OPS, Volume II, Part IV, 1.3.2.2 for holding procedures;

c) calculation of the horizontal distance: Ds

Ds is the distance between the VOR/DME facility (S) and the vertical projection of the procedure point on the horizontal plane through S

$Ds = \sqrt{D^2 - hl^2}$
(Ds, D and hl in km); or

$Ds = \sqrt{D^2 - 0.027\ hl^2}$
(Ds and D in NM and hl in thousands of feet);

d) calculation of the limiting outbound distance: DL

DL is the slant range between the VOR/DME facility and the end of the outbound track at the specified altitude

$DL = \sqrt{(Ds - ds)^2 + 4r^2 + hl^2}$
(DL, Ds, ds, r, hl in km); or

$DL = \sqrt{(Ds - ds)^2 + 4r^2 + 0.027\ hl^2}$
(DL, Ds, ds, r in NM and hl in thousands of feet).

DL is then rounded to the next lower km or NM, unless: the decimal part is greater than 0.75 km or NM in the case of a procedure at or below 4 250 m (or 14 000 ft) or 0.5 km or NM in the case of a procedure above 4 250 m (or 14 000 ft), in which case it is rounded to the next higher km or NM; and

e) calculation of the horizontal limiting outbound distance: DLs

DLs is the distance between the VOR/DME facility and the vertical projection of the end of the outbound track onto the horizontal plane passing through S

$DLs = \sqrt{DL^2 - hl^2}$
(DL, hl in km); or

$DLs = \sqrt{DL^2 - 0.027\ hl^2}$
(DLs, DL in NM and hl in thousands of feet).

3.3.4.2.1.2   *Fix tolerance area and limiting
                outbound distance*

a) Draw from S the procedure radial "RP" and two
    lines, "RP1" and "RP2", making an angle α
    (tolerance for a homing VOR, PANS-OPS,
    Volume II, Part III, 2.6.2.1) with RP on each side
    of it;

b) with a centre on S, draw arcs "Ds" with a radius Ds,
    "Dl" with a radius Ds + dl, "D2" with a radius Ds
    – dl, "DLs", "DL1" and "DL2" with radii DLs, DLs
    + d2 and DLs – d2;

    where dl and d2 are the DME tolerances associated
    with D and DL:

    dl is 0.46 km (0.25 NM) + 0.125 D

    d2 is 0.46 km (0.25 NM) + 0.0125 DL; and

c) locate points "A" at the intersection of RP and Ds,
    "Al" and "A2" at the intersections of RP1 with Dl
    and D2, "A3" and "A4" at the intersections of RP2
    with Dl and D2.

3.3.4.2.1.3   *Protection of the outbound turn
                and outbound leg*

a) Place template point "a" on Al, with axis parallel to
    the inbound track, and draw curve "l" (part of the
    outline of the template);

b) place template point "a" on A3, with axis parallel to
    the inbound track, and draw curve "2" (part of the
    outline of the template) and line "3" (protection of
    the outbound leg in the direction of the non-
    manoeuvring side); and

c) draw the common tangent to curves "l" and "2" and
    extend the straight part of curve "l" and the line "3"
    in the direction of the outbound end.

3.3.4.2.1.4   *Area containing the end of the outbound leg*

a) Locate points Cl and C'3 at the intersections of the
    extensions of curve "l" with the arcs DL1 and DL2.

If no intersection occurs a limiting radial shall be
specified (see 3.3.4.3 of this attachment);

b) locate point C2 between Cl and C'3 at a distance
    (dl + d2 – 1.8) km or (dl + d2 – 1*)* NM from C'3;

c) draw a parallel line to the inbound track through C2
    and locate point C3 at the intersection of this line
    with arc DL2;

d) do the same thing as in a), b) and c) above, with the
    line "3" instead of curve "l" and points C4, C'6, C5
    and C6 instead of Cl, C'3, C2 and C3 (see Figure
    B1-16 a); and

e) if the aeroplane intercepts the VOR radial before
    reaching the limiting outbound distance, the pilot is
    assumed to follow the indications of the VOR
    without drifting any further from the procedure
    axis, so:

    where C5 and C6 are further from the procedure
    axis than RP2 (see Figure B1-16 b), replace C5 and
    C6 by the intersections of RP2 with line "3" and
    DL2, and the end of the outbound leg is contained
    in the area Cl C2 C3 C4 C5 C6;

    where C4, C5 and C6 are further from the
    procedure axis than RP2 (see Figure B1-16 c),
    replace C4 and C6 by the intersections of RP2 with
    DL1 and DL2, and the end of the outbound leg is
    contained in the area Cl C2 C3 C4 C6.

3.3.4.2.1.5   *Protection of the inbound turn.* Rotate the
template 180°, then:

a) place template point "a" on C2 and C3, with axis
    parallel to the inbound track, and draw curves "4"
    and "5" (part of the protection line of a turn of more
    than 180°) and their common tangent;

b) move the template point "a" along arc DL2 from
    C3 to C6, with axis parallel to the inbound track,
    and draw curve "6";

c) place template point "a" on C6, C4 and eventually
    on C5 and draw curves "7", "8" and eventually "9"
    and their common tangents; and

d) draw the tangent to curves "8" and "2".

3.3.4.2.2   *Construction of the entry area.* It is assumed
that all entries are executed along the VOR radial or the
DME arc defining the fix. The entries made along the radial

inbound to the fix or along the DME arc from the non-manoeuvring side are protected by the basic area. The protection of the entries made along the reciprocal to inbound or along the DME arc from the manoeuvring side needs, in addition to the basic area, the area constructed as follows. The entry along the DME arc from the manoeuvring side is a sector 1 entry procedure. As the reciprocal to the inbound track is the dividing line between entry sectors 1 and 2, it is assumed that both sector 1 and sector 2 entry procedures may be executed when entering along the reciprocal to inbound.

3.3.4.2.2.1   *Protection of sector 1 entry procedure.* When entering along the DME arc, it is assumed that having passed the fix the aircraft turns and follows a track parallel to the inbound track and on reaching the DME limiting outbound distance, turns inbound onto the manoeuvring side. For entries along the DME arc, the entry area is drawn as follows:

   a)   take a tracing of the template, turn it over and place point "a" on A3 with axis on the line Al A3 to draw curve "14";

   b)   draw the line "15" parallel to line "3" (used in the construction of the basic area) and tangent to curve "14", and locate point C10 at the intersection of this line with arc DL2; and

      Note.— If no intersection occurs, either the specified DME distances should be adjusted or the sector 1 entry along the DME arc shall not be allowed.

   c)   place point "a" of the tracing on C10, with axis parallel and opposite to the inbound track, and move it along DL2 up to the intersection of DL2 and RP1 to draw curve "16".

3.3.4.2.2.2   *Protection of sector 2 entry procedure.* It is assumed that having passed the fix, the pilot makes good (with ± 5° error) a track making an angle of 30° with the inbound track on the manoeuvring side and reaching the limiting outbound distance, turns inbound. In addition, the flying time on the 30° offset track is limited to 1 min 30 s after which the pilot is expected to turn to a heading parallel to the outbound track until reaching the limiting outbound distance, where the pilot turns inbound.

3.3.4.2.2.2.1   For a procedure with outbound of more than 1 min 30 s the protection of sector 2 entry procedure is assured by the basic area.

3.3.4.2.2.2.2   For a procedure with outbound of 1 min or 1 min 30 s, the protection area of sector 2 entry is drawn as follows:

   a)   from Al draw a line making an angle of 30° + 5° with RP and locate C7 at its intersection with DL2. If no intersection occurs, a limiting radial must be specified according to 3.3.4.3;

   b)   from A4 draw a line making an angle of 30° – 5° with RP and locate C8 at its intersection with DL2;

   c)   place template point "a" on C7 and move it along DL2 to C8, with axis making an angle of 30° with RP, to draw curve "10"; and

   d)   draw the common tangents to the curve "10" and to the basic area.

3.3.4.2.3   *Construction of the entry area for a reciprocal direct entry to a secondary point (Diagram B1-18)*

3.3.4.2.3.1   The reciprocal direct entry is made along the entry radial (RE) joining the VOR/DME station (S) to the secondary point (I) where the turn to inbound is initiated.

3.3.4.2.3.2   The protection of this entry procedure is assured by the basic area.

3.3.4.2.3.3   The entry radial is determined as follows: Measure the angle made by the procedure radial (RP) and the radial joining the VOR/DME station to the end of the nominal outbound leg (line SC) and round its value to the nearest entire degree to obtain the entry radial (RE) to be published.

3.3.4.3   *Procedure away from the station with a limiting radial (Diagram B1-19)*

3.3.4.3.1   *Construction of the basic area*

3.3.4.3.1.1   *Selection and calculation of the distance parameters (see Figure B1-15).* The distance parameters are chosen and calculated in the same manner as in 3.3.4.2.1.1 above.

3.3.4.3.1.2   *Fix tolerance area, limiting outbound distance and limiting radial*

   a)   The fix tolerance area and the limiting outbound distance are drawn in the same manner as in 3.3.4.2.1.2;

b) place template point "a" on A2 and locate the point "R" given by the template;

c) measure the angle between the line joining R and S and RP, add β (tolerance for an intersecting VOR, see PANS-OPS, Volume II, Part III, 2.6.3.1) and round the result to the next higher degree; and

d) from S draw line RL making an angle of the rounded value of c) with RP and line RL2 making the angle β with RL.

3.3.4.3.1.3   *Protection of the outbound turn and outbound leg*. Protection of the outbound turn and outbound leg is drawn in the same manner as in 3.3.4.2.1.3 above.

3.3.4.3.1.4   *Area containing the end of the outbound leg*

a) If the intersection of extension of curve 1 and RL2 is nearer to Al than the intersection of extension of curve 1 and DL1 (case of Diagram B1-19), locate point Cl at the intersection of extension of curve 1 with line RL2 and C2 and C3 at the intersections of RL2 with DL1 and DL2;

b) if the intersection of extension of curve 1 and RL2 is between the intersections of the same extension with DL1 and DL2, locate points Cl and C2 at the intersections of the extension of curve 1 with arc DL1 and line RL2 and point C3 at the intersection of RL2 with DL2;

c) if the intersection of extension of curve 1 and RL2 is further from Al than the intersection of the same extension with DL2, do the same as in 3.3.4.2.1.4 a), b) and c); and

d) locate points C4, C6 and eventually C5 in the same manner as explained in 3.3.4.2.1.4 d) and e).

3.3.4.3.1.5   *Protection of the inbound turn.* Rotate the template 180°, then:

a) place the template point "a" on Cl, C2 and C3, with axis parallel to the inbound track, and draw curves "4", "5" and "6" (part of the protection line of a turn of more than 180°) and their common tangents;

b) move template point "a" along arc DL2 from C3 to C6, with axis parallel to the inbound track, and draw curve "7";

c) place template point "a" on C6, C4 and eventually on C5, with axis parallel to the inbound track, and

draw curves "8", "9" and eventually "10" and their common tangents; and

d) draw the tangent to curves "9" and "2".

3.3.4.3.2   *Construction of the entry area*

3.3.4.3.2.1   *Protection of sector 1 entry procedures*. For the protection of sector 1 entry procedure see 3.3.4.2.2.1 above.

3.3.4.3.2.2   *Protection of sector 2 entry procedures*. It is assumed that having passed the fix, the pilot makes good a track (with ± 5° error) making an angle of 30° with the inbound track on the manoeuvring side and reaching the limiting outbound distance, turns inbound. In addition, the flying time on the 30° offset track is limited to 1 min 30 s after which the pilot is expected to turn a heading parallel to the inbound track until reaching the limiting outbound distance, where the pilot turns inbound.

3.3.4.3.2.2.1   For a procedure with outbound of more than 1 min 30 s the protection of sector 2 entry procedure is assured by the basic area.

3.3.4.3.2.2.2   For a procedure with outbound of 1 min or 1 min 30 s, the protection area of sector 2 entry is drawn as follows:

a) from Al draw a line making an angle of 30° + 5° with RP and locate C7 at its intersection with DL2 or RL2, whichever is the nearer to Al;

b) from A4 draw a line making an angle of 30° − 5° with RP and locate C8 at its intersection with DL2;

c) place template point "a" on C7, with axis making an angle of 30° with RP, and draw curve "11" (part of the protection line of a turn of more than 180°);

d) move template point "a" from C7 to C8 along arc DL2, or along line RL2 and then arc DL2 if C7 is on RL2, keeping the axis of the template making an angle of 30° with RP, to draw curve "12"; and

e) draw the common tangents to the curves "11" and "12" and to the basic area.

3.4   Area reduction for holding and racetrack procedures

3.4.1   *Area reduction by use of DME or limiting radial/ bearing*. If a DME distance or an intersection of radial or

bearing is used to limit the outbound leg of a procedure, the area may be reduced by applying the racetrack or holding template for the altitude in question in the following way:

a) construct the protection area in accordance with 3.3;

b) with the centre on S (= position of the DME station) draw arcs "DL" and "DL2" on the end of the outbound leg. The radius DL is the distance from S to the end of the nominal outbound legs. The radius DL2 is DL plus DME tolerance d2; d2 is 0.46 km (0.25 NM) + 0.0125 DL;

c) from S (= position of VOR or NDB) draw line "RL" through the end of the nominal outbound leg representing the intersecting radial or bearing. Draw line "RL2" by adding the respective tolerance of the intersecting facility (PANS-OPS, Volume II, Part III, 2.6.3); and

d) place template point "a" on the intersection of "DL2" or "RL2" with the boundary of the protection area obstructed in a).

The axis of the template has to be parallel to the nominal outbound track. Move template point "a" along "DL2" or "RL2" respectively drawing curve "R". The area between curve "R" and the outbound end of the area protected in accordance with a) can be deleted (see Figure B1-17).

3.4.2 *Area reduction for racetrack or holding procedures by limitation of entry routes.* If entry to a procedure is restricted to entry along the inbound radial, the basic area may be used without the additional areas required for omnidirectional entry (see examples in Figures B1-18 and B1-19).

3.5 Simplified area construction method for reversal and racetrack procedures

3.5.1 *General.* Reversal and racetrack procedure areas may be defined by simple rectangles. The dimensions of the rectangle for each type of procedure may easily be calculated from the equations given in this section. The rectangle will, in all cases, include or be slightly larger than the area constructed using the more detailed TTT method. The TTT method should be used to obtain maximum benefit wherever airspace is critical.

3.5.2 *Frame of reference.* The dimensions of the rectangles are related to a conventional x, y coordinate system, with its origin at the facility (see Figure B1-20). The x axis is parallel to the inbound track. Negative values of x are measured

from the facility in the direction of the inbound track, positive values are measured from the facility against the direction of the inbound track. Positive values of y are measured on that side of the x axis containing the outbound track or manoeuvre of the reversal procedure/ racetrack. The y axis is at right angles to the x axis.

3.5.3 *Area calculation*

a) Decide the values of IAS and height for the reversal/racetrack procedure. Calculate the TAS at ISA + 15°C for the specified height (PANS-OPS, Volume II, Part III, Attachment F). Calculate the wind speed (ICAO or statistical wind for the height specified).

b) Decide the type of procedure required:

Procedure turn (45/180) — Table B1-5 a)
Procedure turn (80/260) — Table B1-5 b)
Base turn   — Table B1-5 c)
Racetrack   — Table B1-5 d).

c) Note the equations from Table B1-5.

d) Substitute the values of TAS and wind speed calculated in a) above into the equations and calculate the required x and y values.

e) Adjust the values to account for fix tolerance.

f) Plot the area rectangle to the scale required.

g) Add the appropriate buffer area.

3.6 Protection area of RNAV holding procedures based on VOR/DME

3.6.1 *General.* Criteria described in 3.3 of the attachment apply only with the following modifications.

3.6.2 *First step.* Construction of the RNAV template (see Figure B1-21).

1) Choose the outbound distance: D is the length of the outbound leg; D shall be at least equal to one diameter of turn (PANS-OPS, Volume II, Part IV, 2.2.2) rounded to the next higher km (NM);

2) draw the nominal trajectory; locate point "i" at the end of the outbound leg;

3) draw the protection of a turn of more than 180° as for a conventional template (see Diagram B1-6);

4) draw a parallel to the outbound track tangent to line (2);

5) from "i", draw a perpendicular to the outbound track;

6) lines (3) and (4) intercept at i1;

7) place conventional template point "a" on "i", then on "i1", with axis parallel to the outbound leg and, in both cases, draw the protection of a turn of more than 180°; draw the tangent T to these protections;

8) draw the tangent T1 between line (6) and line (2);

9) draw the tangent T2 between line (2) and (6); and

10) locate point E on the template (see 3.3.2.2.4.7 of this Attachment) and use the following formulas for XE and YE (which are different from those in 3.3.2.2.4.7):

$$XE = 2r + D + 11v + \left(11 + \frac{90}{R} + 11 + \frac{105}{R}\right)W'$$

$$YE = 11v.\cos20° + r.\sin20° + r + \left(11 + \frac{20}{R} + \frac{90}{R} + 11 + \frac{15}{R}\right)W'$$

(see Figures B1-22A and B1-22B.)

3.6.3 *Second step.* Construction of the basic area (one way-point holding case).

3.6.3.1 *Holding point tolerance area.* Draw around the holding point A the RNAV tolerance associated with this point (see PANS-OPS, Volume II, Part III, Chapter 31, Appendix — Calculation of cross-track and along-track tolerances of way-points). (see Figure B1-23)

3.6.3.2 *Construction of the basic area (see Figure B1-24).* Move the RNAV template origin "a" around the RNAV tolerance area of the holding point "A".

3.6.4.   *Construction of the entry area (see Figure B1-25).* Draw the circle centred on "A" passing through A1 and A3; apply the same method as explained in 3.3.3.2.

3.7   Obstacle clearance area for RNP holdings

See Figure B1-26. The holding area includes the basic holding area and the additional protection for entries from Sector 4 (see PANS-OPS, Volume II, Attachment C to Part IV).

A value (d3) equal to the RNP is applied around the maximum track defined on PANS-OPS, Volume II, Part IV, Figure IV-3-1 for the straight segments. A value equal to 1.414 × d3 is applied around the maximum track defined on this figure for the circular parts of the holding, until the limit reaches the limit defined for straight segments (See Figure B1-26).

For obstacle clearance, a buffer area is applied around the holding area. The width of the buffer area is the greater of:

RNP + 3.7 km (2.0 NM)

9.3 km (5.0 NM)

**Table B1-1.   Calculations associated with the construction of
the base turn template**

DATA		
	SI UNITS	*NON-SI UNITS*
IAS	260 km/h	140 kt
Altitude	1 850 m	6 000 ft
T	2 min	2 min
NDB	at 0 m	at 0 ft
Temperature	ISA + 15°C	ISA + 15°C

		CALCULATIONS USING SI UNITS		*CALCULATIONS USING NON-SI UNITS*	
Line	*Parameter*	*Formula*	*Value*	*Formula*	*Value*
1	K	Conversion factor for 1 850 m and ISA + 15°C (see PANS-OPS, Volume II, Attachment F to Part III)	1.1244	Conversion factor for 6 000 ft and ISA + 15°C (see PANS-OPS, Volume II, Attachment F to Part III)	1.1231
2	V	$V = K \times IAS$	292.34 km/h	$V = K \times IAS$	157.23 kt
3	v	$v = V \div 3\,600$	0.0812 km/s	$v = V \div 3\,600$	0.0437 NM/s
4	R	$R = 943.27 \div V$, or 3°/s, whichever is less	(3.23) 3°/s	$R = 509.26 \div V$, or 3°/s, whichever is less	(3.24) 3°/s
5	r	$r = V \div 62.83\,R$	1.55 km	$r = V \div 62.83\,R$	0.83 NM
6	h	in thousands of metres	1.85	in thousands of feet	6
7	w	$w = 12h + 87$	109.2 km/h	$w = 2h + 47$	59 kt
8	w′	$w' = w \div 3\,600$	0.03 km/s	$w' = w \div 3\,600$	0.0164 NM/s
9	E	$E = w' \div R$	0.01 km/°	$E = w' \div R$	0.00546 NM/°
10	f	for V ≤ 315 km/h: $\phi = 36 \div T$ for V > 315 km/h: $\phi = 0.116\,V \div T$	18°	for V ≤ 170 kt: $\phi = 36 \div T$ for V > 170 kt: $\phi = 0.215\,V \div T$	18°
11	zN	*$zN = h \tan 40°$	1.55 km	**$zN = 0.164\,h \tan 40°$	0.83 NM
12	t	$t = 60T$	120 s	$t = 60T$	120 s
13	L	$L = vt$	9.74 km	$L = vt$	5.24 NM
14	ab1 = ab3	***ab1 = ab3 = $(t - 5)(v - w') - zN$	4.34 km	***ab1 = ab3 = $(t - 5)(v - w') - zN$	2.31 NM

		CALCULATIONS USING SI UNITS		CALCULATIONS USING NON-SI UNITS	
Line	*Parameter*	*Formula*	*Value*	*Formula*	*Value*
15	ab2 = ab4	***ab2 = ab4 = $(t + 21)(v + w') + zN$	17.23 km	***ab2 = ab4 = $(t + 21)(v + w') + zN$	9.30 NM
16	$W_d = W_g$	$W_d = W_g = 50\ E$	0.5 km	$W_d = W_g = 50\ E$	0.27 NM
17	$W_e = W_f = W_h$	$W_e = W_f = W_h = 100\ E$	1.0 km	$W_e = W_f = W_h = 100\ E$	0.55 NM
18	W_i	$W_i = 190\ E$	1.9 km	$W_i = 190\ E$	1.04 NM
19	W_j	$W_j = 235\ E$	2.35 km	$W_j = 235\ E$	1.28 NM
20	drift angle d	$d = \arcsin (w \div V)$	23°	$d = \arcsin (w \div V)$	23°
21	N_{3l}	$N_{3l} = 11\ v$	0.9 km	$N_{3l} = 11\ v$	0.48 NM
22	W_l	$W_l = 11\ w'$	0.33 km	$W_l = 11\ w'$	0.18 NM
23	W_m	$W_m = W_l + 50\ E$	0.83 km	$W_m = W_l + 50\ E$	0.45 NM
24	W_n	$W_n = W_l + 100\ E$	1.33 km	$W_n = W_l + 100\ E$	0.73 NM

*   In case of a VOR base turn, line 11 reads $zV = h \tan 50°$.

**   In case of a VOR base turn, line 11 reads $zV = 0.164\ h \tan 50°$.

*** In case of VOR/DME base turn, where D is the specified DME distance limiting the outbound leg and d1 is the tolerance of the DME indication (d1 is 0.46 km (0.25 NM) + 0.0125 D), lines 14 and 15 read:

  $ab1 = ab3 = D - d1 + 5\ (v - w')$
  $ab2 = ab4 = D + d1 + 11\ (v + w')$

In case of a VOR base turn, lines 14 and 15 read:

  $ab1 = ab3 = (t - 5)\ (v - w') - zV$
  $ab2 = ab4 = (t + 21)\ (v + w') + zV$

**Table B1-2.   Calculations associated with the construction of
the 45°-180° procedure turn template**

DATA		
	SI UNITS	*NON-SI UNITS*
IAS	260 km/h	140 kt
Altitude	1 850 m	6 000 ft
T	60 s (1 min for Cat A and B;	60 s (1 min for Cat A and B;
	1.25 min for Cat C, D and E)	1.25 min for Cat C, D and E)
Temperature	ISA + 15°C	ISA + 15°C

Line	Parameter	CALCULATIONS USING SI UNITS		CALCULATIONS USING NON-SI UNITS	
		Formula	*Value*	*Formula*	*Value*
1	K	Conversion factor for 1 850 m and ISA + 15°C (see PANS-OPS, Volume II, Attachment F to Part III)	1.1244	Conversion factor for 6 000 ft and ISA + 15°C (see PANS-OPS, Volume II, Attachment F to Part III)	1.1231
2	V	$V = K \times IAS$	292.34 km/h	$V = K \times IAS$	157.23 kt
3	v	$v = V \div 3\ 600$	0.0812 km/s	$v = V \div 3\ 600$	0.0437 NM/s
4	R	$R = 943.27 \div V$, or 3°/s, whichever is less	(3.23) 3°/s	$R = 509.26 \div V$, or 3°/s, whichever is less	(3.24) 3°/s
5	r	$r = V \div 62.83\ R$	1.55 km	$r = V \div 62.83\ R$	0.83 NM
6	h	in thousands of metres	1.85	in thousands of feet	6
7	w	$w = 12h + 87$	109.2 km/h	$w = 2h + 47$	59 kt
8	w′	$w' = w \div 3\ 600$	0.03 km/s	$w' = w \div 3\ 600$	0.0164 NM/s
9	E	$E = w' \div R$	0.01 km/°	$E = w' \div R$	0.00546 NM/°
10	ab	$ab = 5v$	0.41 km	$ab = 5v$	0.22 NM
11	cd	$cd = (t - 5 - 45 \div R)\ v$	3.25 km	$cd = (t - 5 - 45 \div R)\ v$	1.75 NM
12	cd1, cd3	$cd1 = cd3 = cd - 5v$	2.84 km	$cd1 = cd3 = cd - 5v$	1.53 NM
13	cd2, cd4	$cd2 = cd4 = cd + 15v$	4.47 km	$cd2 = cd4 = cd + 15v$	2.41 NM
14	W_c	$W_c = 5w' + 45\ E$	0.60 km	$W_c = 5w' + 45\ E$	0.33 NM
15	W_{d2}, W_{d4}	$W_{d2} = W_{d4} = (t + 15)\ w'$	2.25 km	$W_{d2} = W_{d4} = (t + 15)\ w'$	1.23 NM
16	W_f	$W_f = W_{d2} + 50\ E$	2.75 km	$W_f = W_{d2} + 50\ E$	1.50 NM

		CALCULATIONS USING SI UNITS		*CALCULATIONS USING NON-SI UNITS*	
Line	*Parameter*	*Formula*	*Value*	*Formula*	*Value*
17	W_g, W_h	$W_g = W_h = W_{d2} + 100\ E$	3.25 km	$W_g = W_h = W_{d2} + 100\ E$	1.78 NM
18	W_i	$W_i = W_{d2} + 150\ E$	3.75 km	$W_i = W_{d2} + 150\ E$	2.05 NM
19	W_j	$W_j = W_{d2} + 200\ E$	4.25 km	$W_j = W_{d2} + 200\ E$	2.32 NM
20	W_k	$W_k = (t - 5)w' + 200\ E$	3.65 km	$W_k = (t - 5)w' + 200\ E$	1.99 NM
21	W_l	$W_l = W_k + 50\ E$	4.15 km	$W_l = W_k + 50\ E$	2.27 NM

**Table B1-3.   Calculations associated with the construction of
the 80°-260° procedure turn template**

DATA		
	SI UNITS	*NON-SI UNITS*
IAS	405 km/h	220 kt
Altitude	1 850 m	6 000 ft
Temperature	ISA + 15°C	ISA + 15°C

		CALCULATIONS USING SI UNITS		*CALCULATIONS USING NON-SI UNITS*	
Line	*Parameter*	*Formula*	*Value*	*Formula*	*Value*
1	K	Conversion factor for 1 850 m and ISA + 15°C (see PANS-OPS, Volume II, Attachment F to Part III)	1.1244	Conversion factor for 6 000 ft and ISA + 15°C (see PANS-OPS, Volume II, Attachment F to Part III)	1.1231
2	V	$V = K \times IAS$	455.38 km/h	$V = K \times IAS$	247.08 kt
3	v	$v = V \div 3\,600$	0.1265 km/s	$v = V \div 3\,600$	0.0686 NM/s
4	R	$R = 943.27 \div V$, or 3°/s, whichever is less	2.07°/s	$R = 509.26 \div V$, or 3°/s, whichever is less	2.06°/s
5	r	$r = V \div 62.83\,R$	3.5 km	$r = V \div 62.83\,R$	1.91 NM
6	h	in thousands of metres	1.85	in thousands of feet	6
7	w	$w = 12h + 87$	109.2 km/h	$w = 2h + 47$	59 kt
8	w′	$w' = w \div 3\,600$	0.03 km/s	$w' = w \div 3\,600$	0.0164 NM/s
9	E	$E = w' \div R$	0.0145 km/°	$E = w' \div R$	0.00796 NM/°
10	ab	$ab = 5v$	0.63 km	$ab = 5v$	0.34 NM
11	d_e, d_{1e1}, d_{2e2}	$d_e = d_{1e1} = d_{2e2} = 10v$	1.27 km	$d_e = d_{1e1} = d_{2e2} = 10v$	0.69 NM
12	W_{e2}	$W_{e2} = 15w' + 85\,E$	1.68 km	$W_{e2} = 15w' + 85\,E$	0.92 NM
13	W_g	$W_g = 15w' + 130\,E$	2.34 km	$W_g = 15w' + 130\,E$	1.28 NM
14	W_h	$W_h = 15w' + 175\,E$	2.99 km	$W_h = 15w' + 175\,E$	1.64 NM
15	W_i	$W_i = 15w' + 220\,E$	3.64 km	$W_i = 15w' + 220\,E$	2.00 NM
16	W_j	$W_j = 15w' + 265\,E$	4.29 km	$W_j = 15w' + 265\,E$	2.36 NM

		CALCULATIONS USING SI UNITS		CALCULATIONS USING NON-SI UNITS	
Line	*Parameter*	*Formula*	*Value*	*Formula*	*Value*
17	W_k	$W_k = 15w' + 255\ E$	4.15 km	$W_k = 15w' + 255\ E$	2.28 NM
18	W_l	$W_l = 15w' + 300\ E$	4.80 km	$W_l = 15w' + 300\ E$	2.63 NM
19	W_m	$W_m = 15w' + 345\ E$	5.45 km	$W_m = 15w' + 345\ E$	2.99 NM

**Table B1-4. Calculations associated with the construction of
the holding and racetrack template**

DATA		
	SI UNITS	*NON-SI UNITS*
IAS	405 km/h	220 kt
Altitude	3 050 m	10 000 ft
T	1 min	1 min
Temperature	ISA + 15°C	ISA + 15°C

		CALCULATIONS USING SI UNITS		*CALCULATIONS USING NON-SI UNITS*	
Line	*Parameter*	*Formula*	*Value*	*Formula*	*Value*
1	K	Conversion factor for 3 050 m and ISA + 15°C (see PANS-OPS, Volume II, Attachment F to Part III)	1.1960	Conversion factor for 10 000 ft and ISA + 15°C (see PANS-OPS, Volume II, Attachment F to Part III)	1.1958
2	V	$V = K \times IAS*$	484.38 km/h	$V = K \times IAS*$	263.08 kt
		* The true airspeed may also be deduced from PANS-OPS, Volume II, Attachment A to Part IV, paragraph 5.		* The true airspeed may also be deduced from PANS-OPS, Volume II, Attachment A to Part IV, paragraph 5.	
3	v	$v = V \div 3\ 600$	0.1346 km/s	$v = V \div 3\ 600$	0.07308 NM/s
4	R	$R = 943.27 \div V$, or 3°/s, whichever is less	1.95°/s	$R = 509.26 \div V$, or 3°/s, whichever is less	1.94°/s
5	r	$r = V \div 62.83\ R$	3.96 km	$r = V \div 62.83\ R$	2.16 NM
6	h	in thousands of metres	3.05	in thousands of feet	10
7	w	$w = 12h + 87$	123.6 km/h	$w = 2h + 47$	67 kt
8	w′	$w' = w \div 3\ 600$	0.03433 km/s	$w' = w \div 3\ 600$	0.0186 NM/s
9	E_{45}	$E_{45} = 45w' \div R$	0.792 km	$E_{45} = 45w' \div R$	0.431 NM
10	t	$t = 60T$	60 s	$t = 60T$	60 s
11	L	$L = v\ t$	8.08 km	$L = v\ t$	4.38 NM
12	ab	$ab = 5v$	0.67 km	$ab = 5v$	0.37 NM
13	ac	$ac = 11v$	1.48 km	$ac = 11v$	0.80 NM
14	$g_{i1} = g_{i3}$	$g_{i1} = g_{i3} = (t - 5)v$	7.40 km	$g_{i1} = g_{i3} = (t - 5)v$	4.02 NM
15	$g_{i2} = g_{i4}$	$g_{i2} = g_{i4} = (t + 21)v$	10.90 km	$g_{i2} = g_{i4} = (t + 21)v$	5.92 NM

		CALCULATIONS USING SI UNITS		CALCULATIONS USING NON-SI UNITS	
Line	*Parameter*	*Formula*	*Value*	*Formula*	*Value*
16	W_b	$W_b = 5w'$	0.17 km	$W_b = 5w'$	0.09 NM
17	W_c	$W_c = 11w'$	0.38 km	$W_c = 11w'$	0.20 NM
18	W_d	$W_d = W_c + E_{45}$	1.17 km	$W_d = W_c + E_{45}$	0.64 NM
19	W_e	$W_e = W_c + 2E_{45}$	1.96 km	$W_e = W_c + 2E_{45}$	1.07 NM
20	W_f	$W_f = W_c + 3E_{45}$	2.75 km	$W_f = W_c + 3E_{45}$	1.50 NM
21	W_g	$W_g = W_c + 4E_{45}$	3.55 km	$W_g = W_c + 4E_{45}$	1.93 NM
22	W_h	$W_h = W_b + 4E_{45}$	3.34 km	$W_h = W_b + 4E_{45}$	1.82 NM
23	W_o	$W_o = W_b + 5E_{45}$	4.13 km	$W_o = W_b + 5E_{45}$	2.25 NM
24	W_p	$W_p = W_b + 6E_{45}$	4.92 km	$W_p = W_b + 6E_{45}$	2.69 NM
25	$W_{i1} = W_{i3}$	$W_{i1} = W_{i3} = (t + 6)w' +$ $4E_{45}$	5.43 km	$W_{i1} = W_{i3} = (t + 6)w' +$ $4E_{45}$	2.96 NM
26	$W_{i2} = W_{i4}$	$W_{i2} = W_{i4} = W_{i1} + 14w'$	5.91 km	$W_{i2} = W_{i4} = W_{i1} + 14w'$	3.22 NM
27	W_j	$W_j = W_{i2} + E_{45}$	6.71 km	$W_j = W_{i2} + E_{45}$	3.65 NM
28	$W_k = W_l$	$W_k = W_l = W_{i2} + 2E_{45}$	7.50 km	$W_k = W_l = W_{i2} + 2E_{45}$	4.08 NM
29	W_m	$W_m = W_{i2} + 3E_{45}$	8.29 km	$W_m = W_{i2} + 3E_{45}$	4.51 NM
30	W_{n3}	$W_{n3} = W_{i1} + 4E_{45}$	8.60 km	$W_{n3} = W_{i1} + 4E_{45}$	4.68 NM
31	W_{n4}	$W_{n4} = W_{i2} + 4E_{45}$	9.08 km	$W_{n4} = W_{i2} + 4E_{45}$	4.94 NM
32	XE	$XE = 2r + (t + 15)v +$ $(t + 26 + 195 \div R)w'$	24.38 km	$XE = 2r + (t + 15)v +$ $(t + 26 + 195 \div R)w'$	13.27 NM
33	YE	$YE = 11\ v \cos 20° +$ $r(1 + \sin 20°) +$ $(t + 15)v \tan 5° +$ $(t + 26 + 125 \div R)w'$	12.73 km	$YE = 11\ v \cos 20° +$ $r(1 + \sin 20°) +$ $(t + 15)v \tan 5° +$ $(t + 26 + 125 \div R)w'$	6.93 NM

Table B1-5.   Rectangle equations

WARNING: *This table is based on a range of TAS values from 165 to 540 km/h (90 to 290 kt), wind speeds up to 120 km/h (65 kt), and for nominal outbound timing between 1 and 3 minutes. This table should not be used outside these ranges.*

	SI UNITS *(distances in km; speeds in km/h; time in minutes)*	*NON-SI UNITS* *(distances in NM; speeds in kt; time in minutes)*
a) equations for 45/180 procedure turn		
x_{max}	TAS(0.0165t + 0.0431) + W(0.0165t + 0.0278) + 3.4	TAS(0.0165t + 0.0431) + W(0.0165t + 0.0278) + 1.8
y_{max}	TAS(0.002t + 0.022) + W(0.002t + 0.0333) − 0.74	TAS(0.002t + 0.022) + W(0.002t + 0.0333) − 0.4
y_{min}	TAS(−0.002t − 0.0137) + W(−0.002t − 0.0594) + 1.67	TAS(−0.002t − 0.0137) + W(−0.002t − 0.0594) + 0.9
b) equations for 80/260 procedure turn		
x_{max}	TAS(0.0165t + 0.0421) + W(0.0165t + 0.0489) − 3.34	TAS(0.0165t + 0.0421) + W(0.0165t + 0.0489) − 1.8
y_{max}	TAS(0.002t + 0.0263) + W(0.002t + 0.0322) − 1.85	TAS(0.002t + 0.0263) + W(0.002t + 0.0322) − 1.0
y_{min}	TAS(−0.002t − 0.01) + W(−0.002t − 0.0591) + 1.3	TAS(−0.002t − 0.01) + W(−0.002t − 0.0591) + 0.7
c) equations for base turn		
x_{max}	TAS(0.0173t + 0.0181) + W(0.0166t + 0.0209) − 0.93	TAS(0.0173t + 0.0181) + W(0.0166t + 0.0209) − 0.5
y_{max}	TAS(−0.0004t + 0.0373) + W(−0.0072t + 0.0404) + 0.164t − 3.15	TAS(−0.0004t + 0.0373) + W(−0.0072t + 0.0404) + 0.0887t − 1.7
y_{min}	TAS(−0.0122) + W(0.0151t − 0.0639) − 0.1845t + 1.48	TAS(−0.0122) + W(0.0151t − 0.0639) − 0.0996t + 0.8
d) equations for racetrack		
x_{max}	TAS(0.0167t + 0.0297) + W(0.0167t + 0.0381) − 1.67	TAS(0.0167t + 0.0297) + W(0.0167t + 0.0381) − 0.9
x_{min}	TAS(−0.0241) + W(−0.037) + 2.04	TAS(−0.0241) + W(−0.037) + 1.1
y_{max}	TAS(0.0012t + 0.0266) + W(0.0158t + 0.0368) + 0.843t − 5.37	TAS(0.0012t + 0.0266) + W(0.0158t + 0.0368) + 0.455t − 2.9
y_{min}	TAS(−0.0015t − 0.0202) + W(−0.0167t − 0.027) + 1.3	TAS(−0.0015t − 0.0202) + W(−0.0167t − 0.027) + 0.7

EXAMPLE (SI UNITS)

Specification: 2 min base turn for 260 km/h IAS, altitude 1 850 m, ICAO wind, VOR facility with a cone of ambiguity of 50°:

TAS = 260 × 1.1243 = 292 km/h
W = 12 × 1.85 + 87 = 109 km/h
Fix error = 1.85 × tan 50 = 2.20 km

Calculation (equations from c) above):

x_{max} = 292(0.0173 × 2 + 0.0181) + 109(0.0166 × 2 + 0.0209) − 0.93 = 20.36 km/h
y_{max} = 292(−0.0004 × 2 + 0.0373) + 109(−0.0072 × 2 + 0.0404) + 0.164 × 2 − 3.15 = 10.67 km/h
y_{min} = 292(−0.0122) + 109(0.0151 × 2 − 0.0639) − 0.1845 × 2 + 1.48 = −6.12 km

Template plotting values (including addition for fix error of 2.20 km):

x_{max} = 22.6 km
y_{max} = 12.9 km
y_{min} = −8.3 km

EXAMPLE (NON-SI UNITS):

Specification: 1 min 45/180 procedure turn for 140 kt IAS, altitude 6 000 ft, ICAO wind, NDB facility.

TAS = 140 × 1.1231 = 157 kt
W = 2 × 6 + 47 = 59 kt
Fix error = 0.164 × 6 tan 40 = 0.83 NM

Calculation (equations from a) above):

x_{max} = 157(0.0165 × 1 + 0.0431) + 59(0.0165 × 1 + 0.0278) + 1.8 = 13.77 NM
y_{max} = 157(0.002 × 1 + 0.022) + 59(0.002 × 1 + 0.0333) − 0.4 = 5.45 NM
y_{min} = 157(−0.002 × 1 − 0.0137) + 59(−0.002 × 1 − 0.0594) + 0.9 = −5.19 NM

Template plotting values (including addition of fix error of 0.83 NM):

x_{max} = 14.6 NM
y_{max} = 6.3 NM
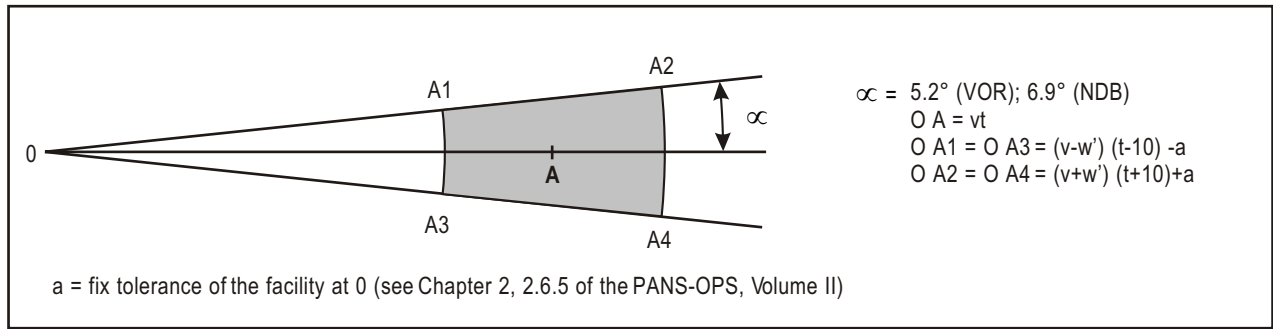y_{min} = −6.0 NM

Figure B1-1.   VOR or NDB at 0 — time from 0 to A

Figure B1-2.   VOR/DME at 0
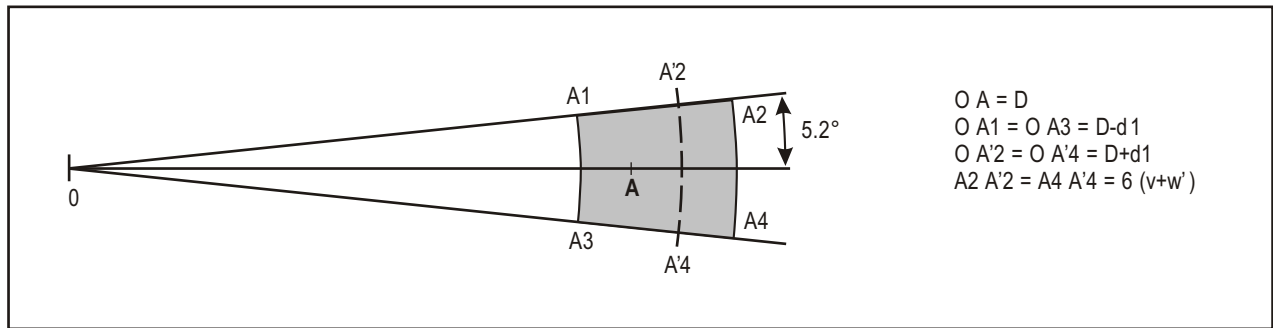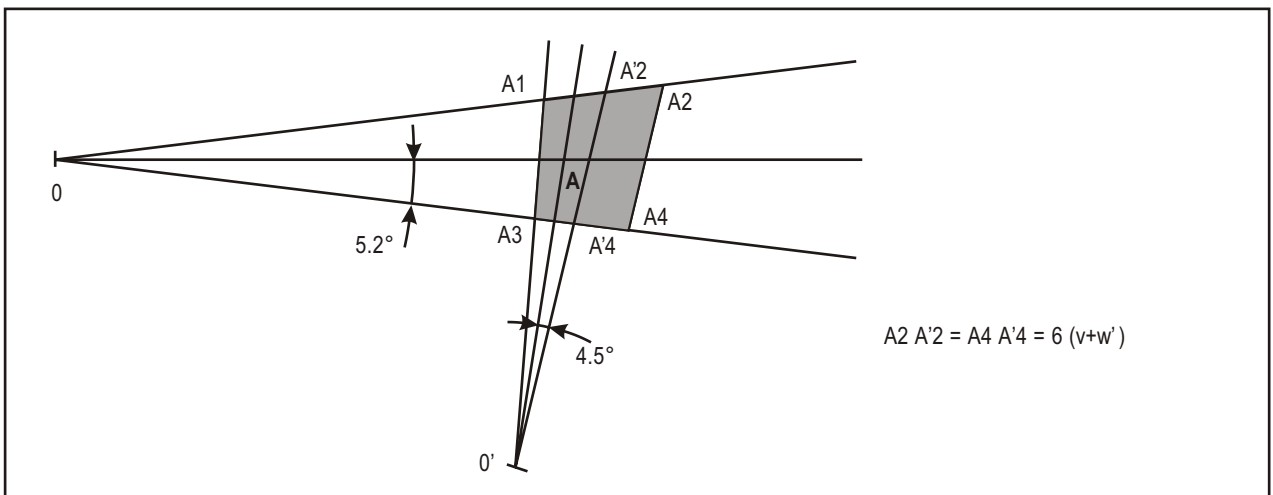

Figure B1-3. VOR at 0 and VOR at 0'

A2 A'2 = A4 A'4 = 6 (v+w')

zN = h x tan 40°

or:
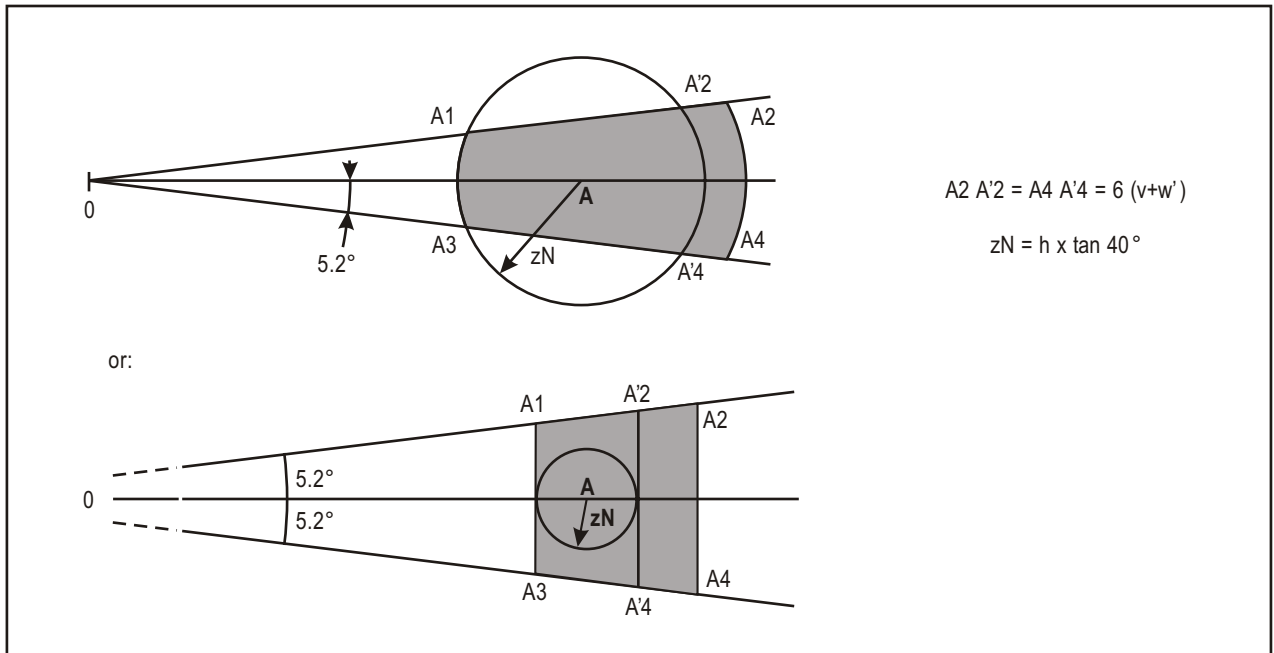
Figure B1-4.   VOR at 0 and NDB or locator at A

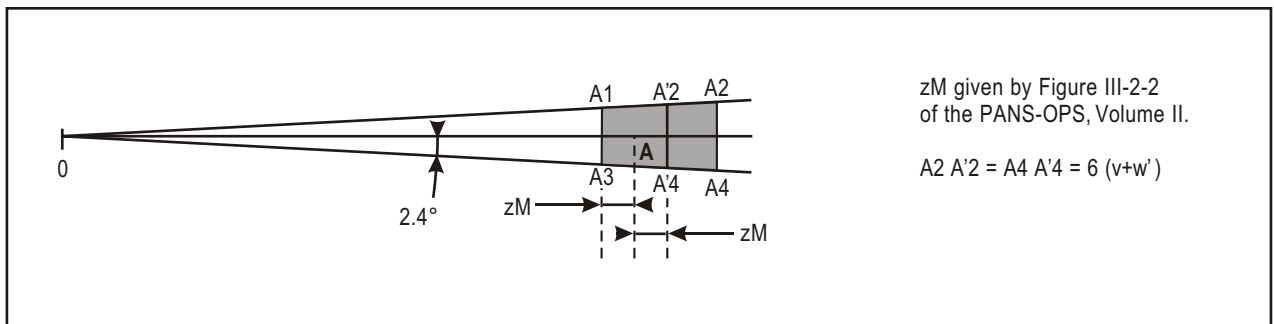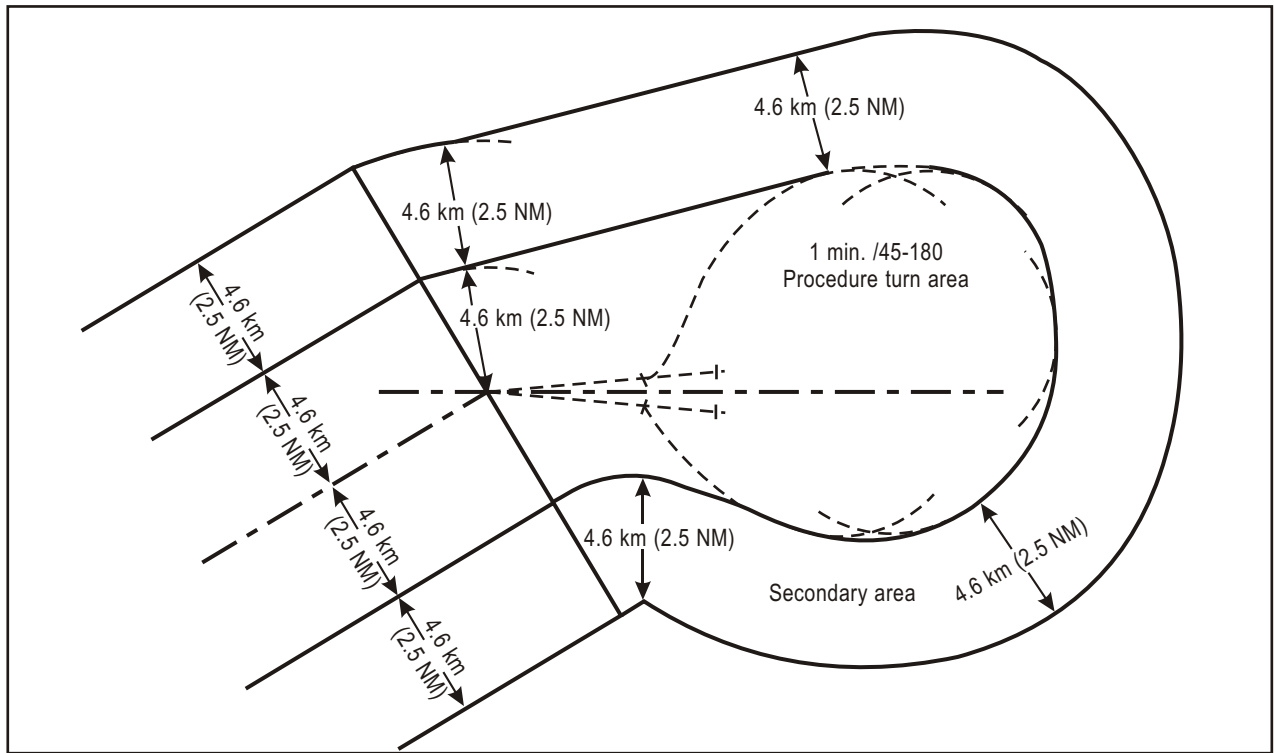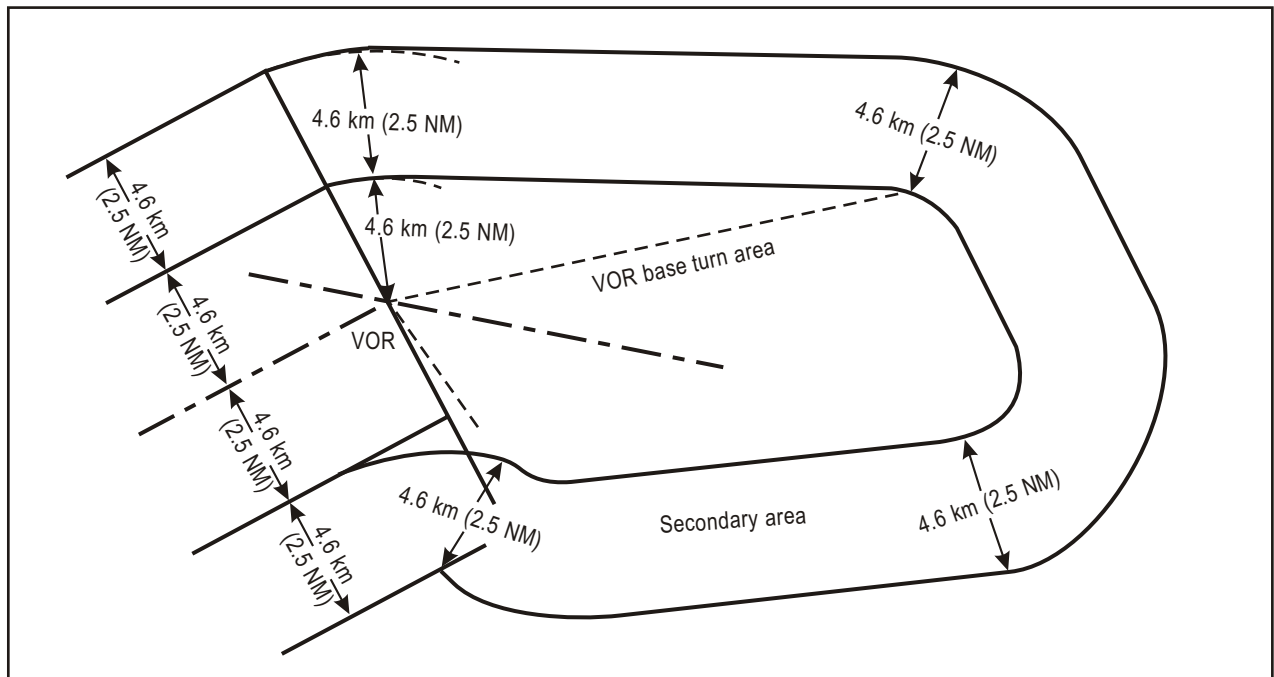zM given by Figure III-2-2
of the PANS-OPS, Volume II.

A2 A'2 = A4 A'4 = 6 (v+w')

Figure B1-5.   Localizer at 0 and marker at A

**Figure B1-6.   Interface between initial segment areas
and procedure turn areas**

**Figure B1-7.   Interface between initial segment areas
and base turn areas**
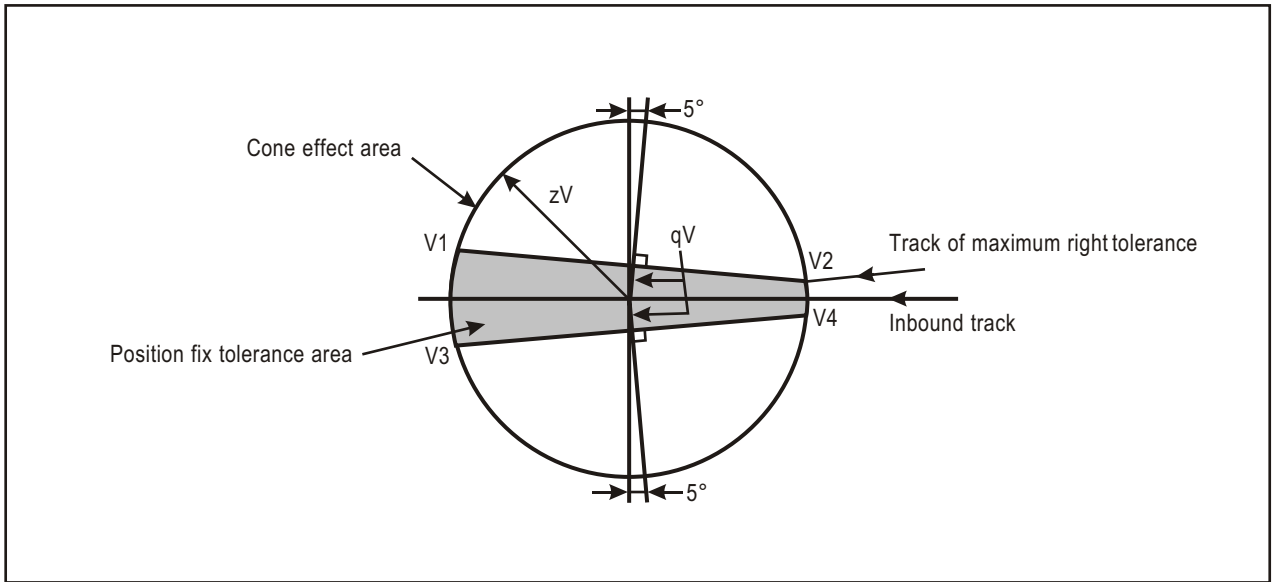
Figure B1-8
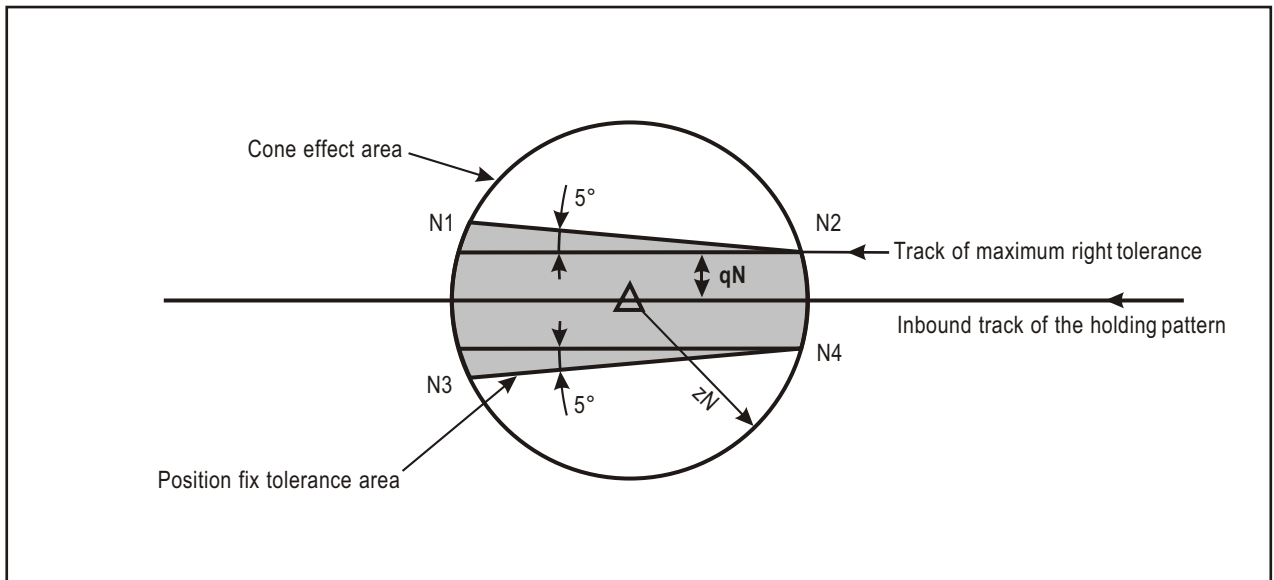
Figure B1-9
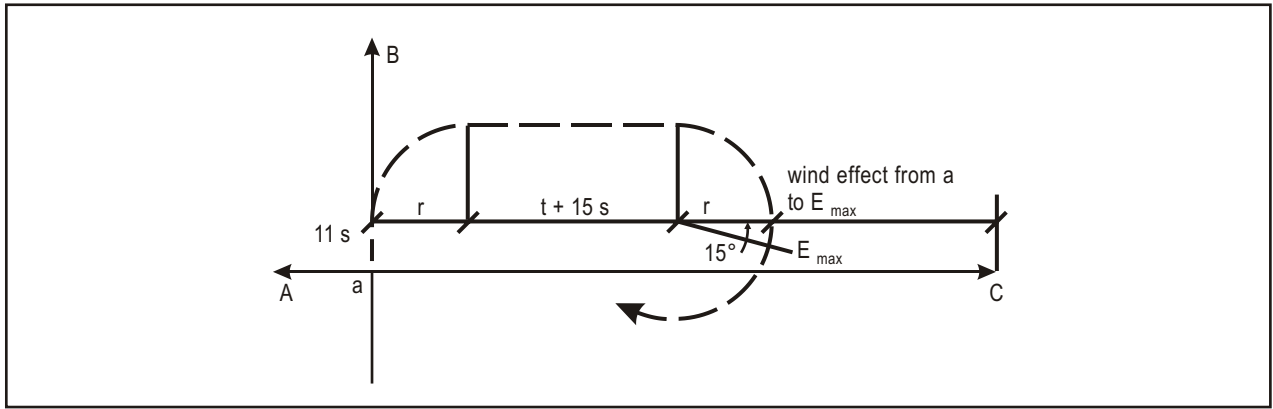
Figure B1-10
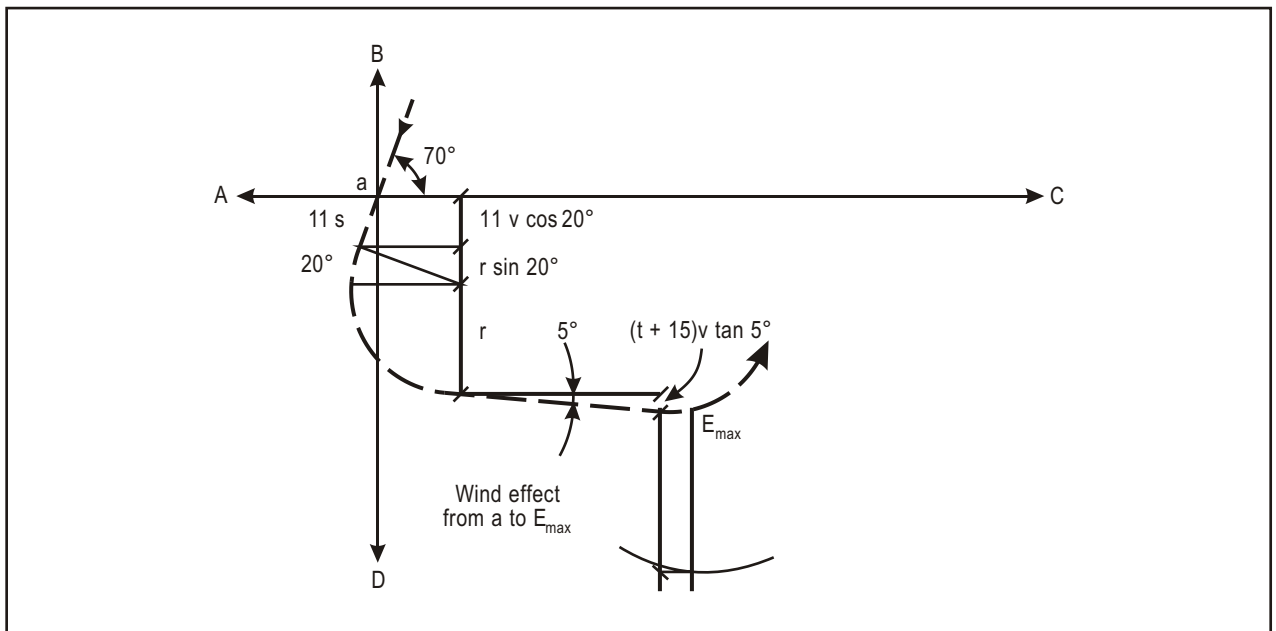
Figure B1-11

Figure B1-12

Figure B1-13

A

Minimum distance

θ

Arrivals

Holding fix,
entry point

B

Limiting radial

DME outbound
limiting distance

VOR/DME

Arrival

30°

Holding fix, entry point

C

DME outbound
limiting distance

Holding fix,
entry point

D

DME outbound
limiting distance

Holding fix,
entry point

E

VOR

TP

Holding fix,
entry point

VOR/DME holding
towards the facility

F

TP

VOR

Holding fix,
entry point

VOR/DME holding away
from the facility

Figure B1-14
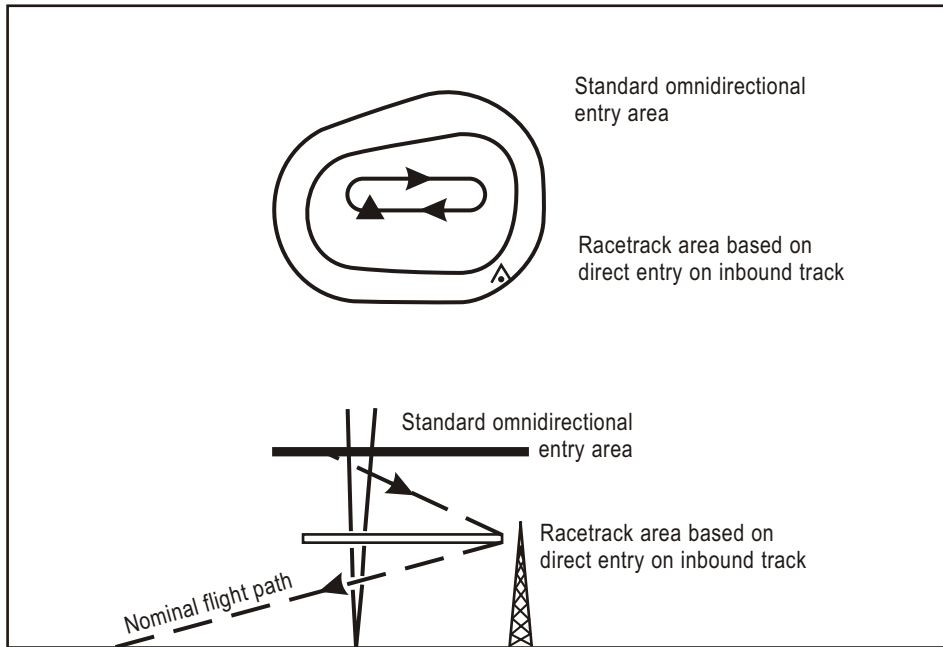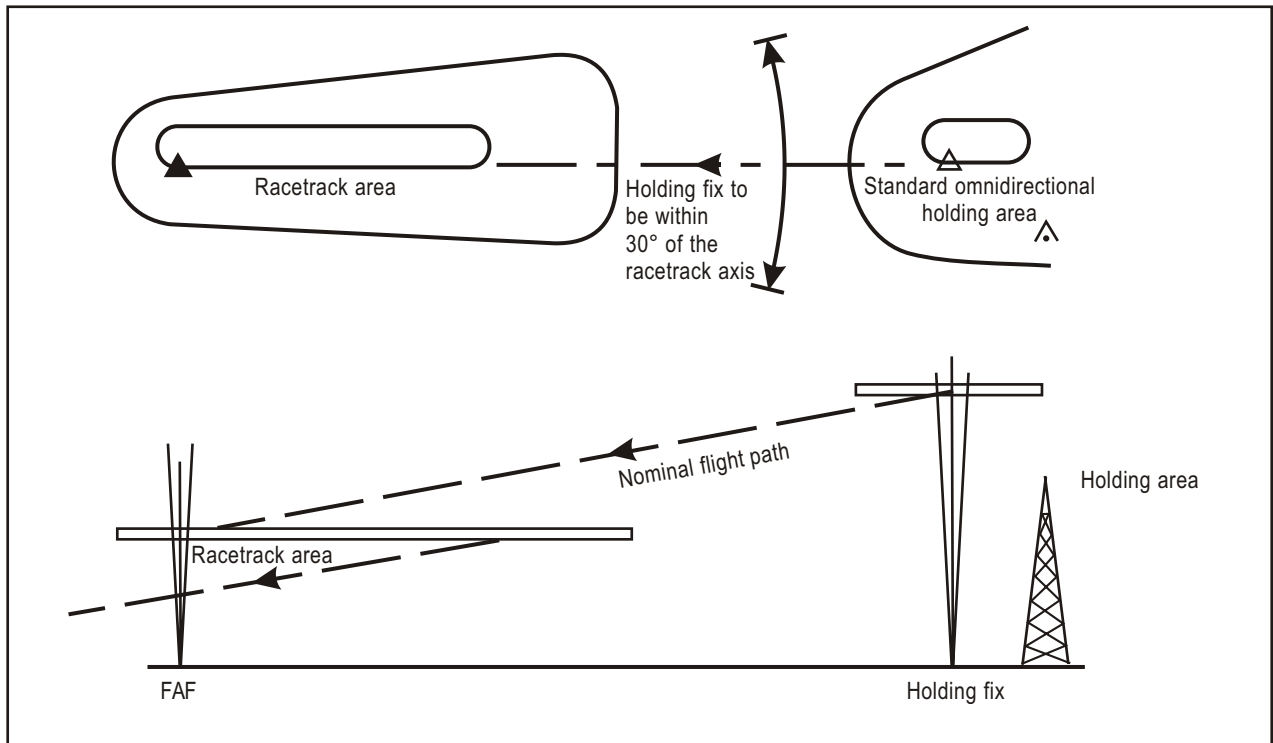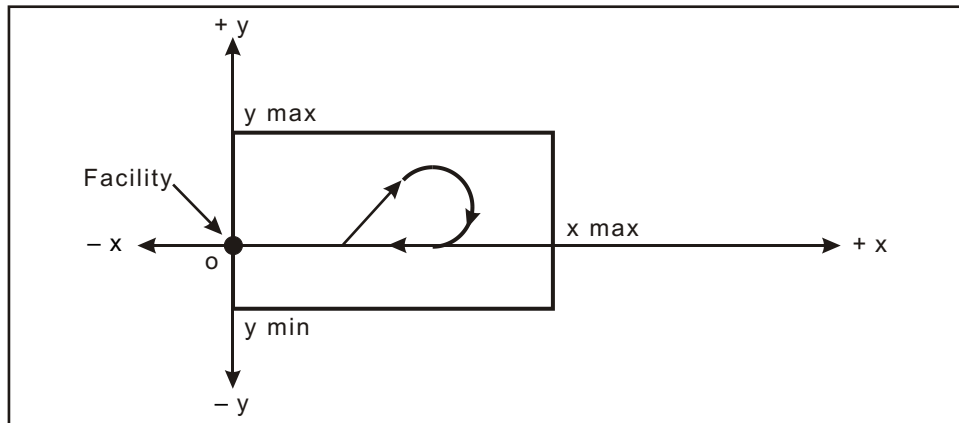
Figure B1-15

Figure B1-16
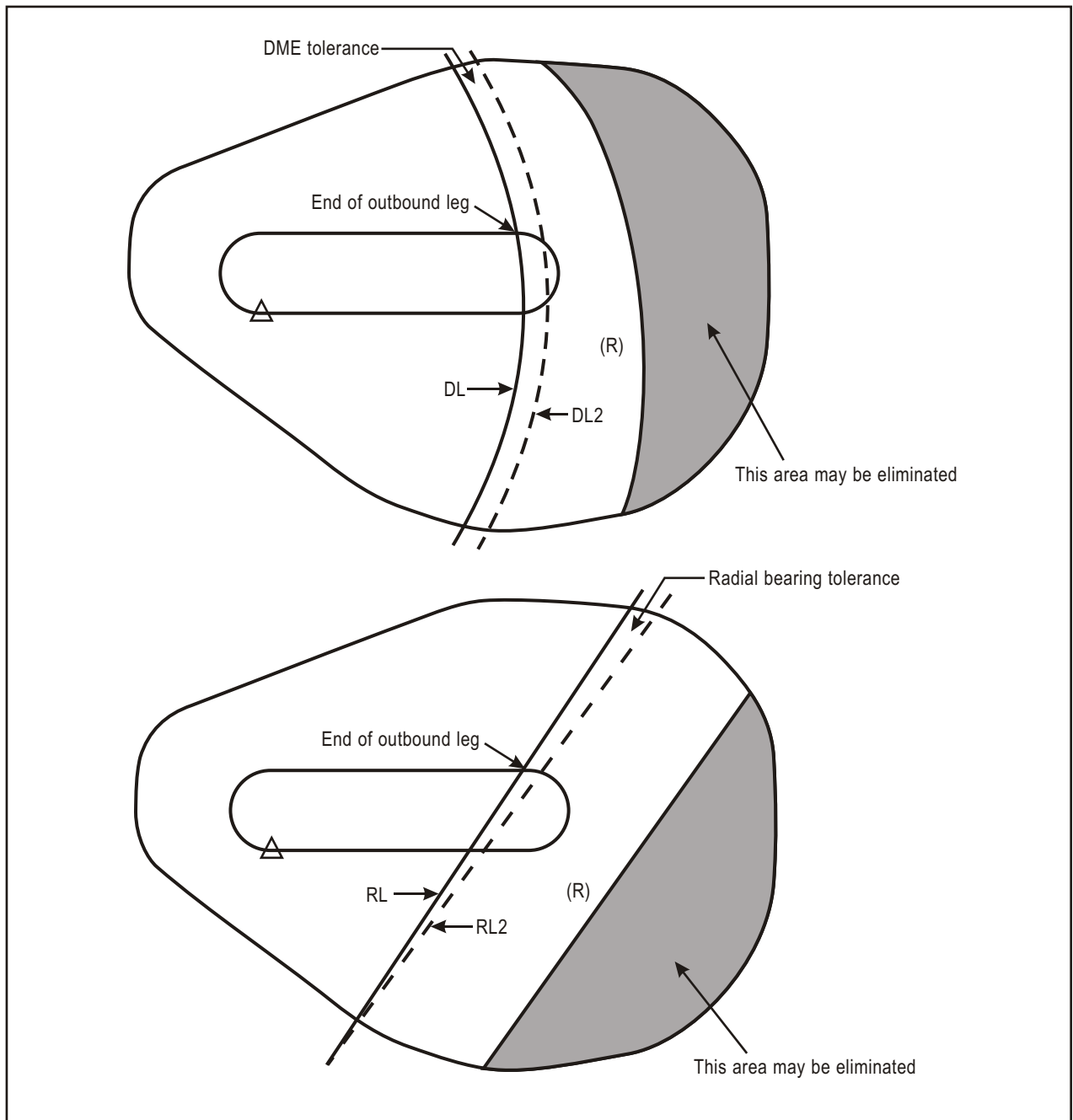
Figure B1-17. Example for area reduction using DME or intersecting radial or bearing

**Figure B1-18. Example of racetrack entry via standard/omnidirectional entry
at higher altitude (racetrack area reduced for "on axis" entry)**

**Figure B1-19. Example of restricted racetrack entry via restricted or
specified track(s) (racetrack area reduced for "on axis" entry)**

**Figure B1-20.   Construction of simplified area —
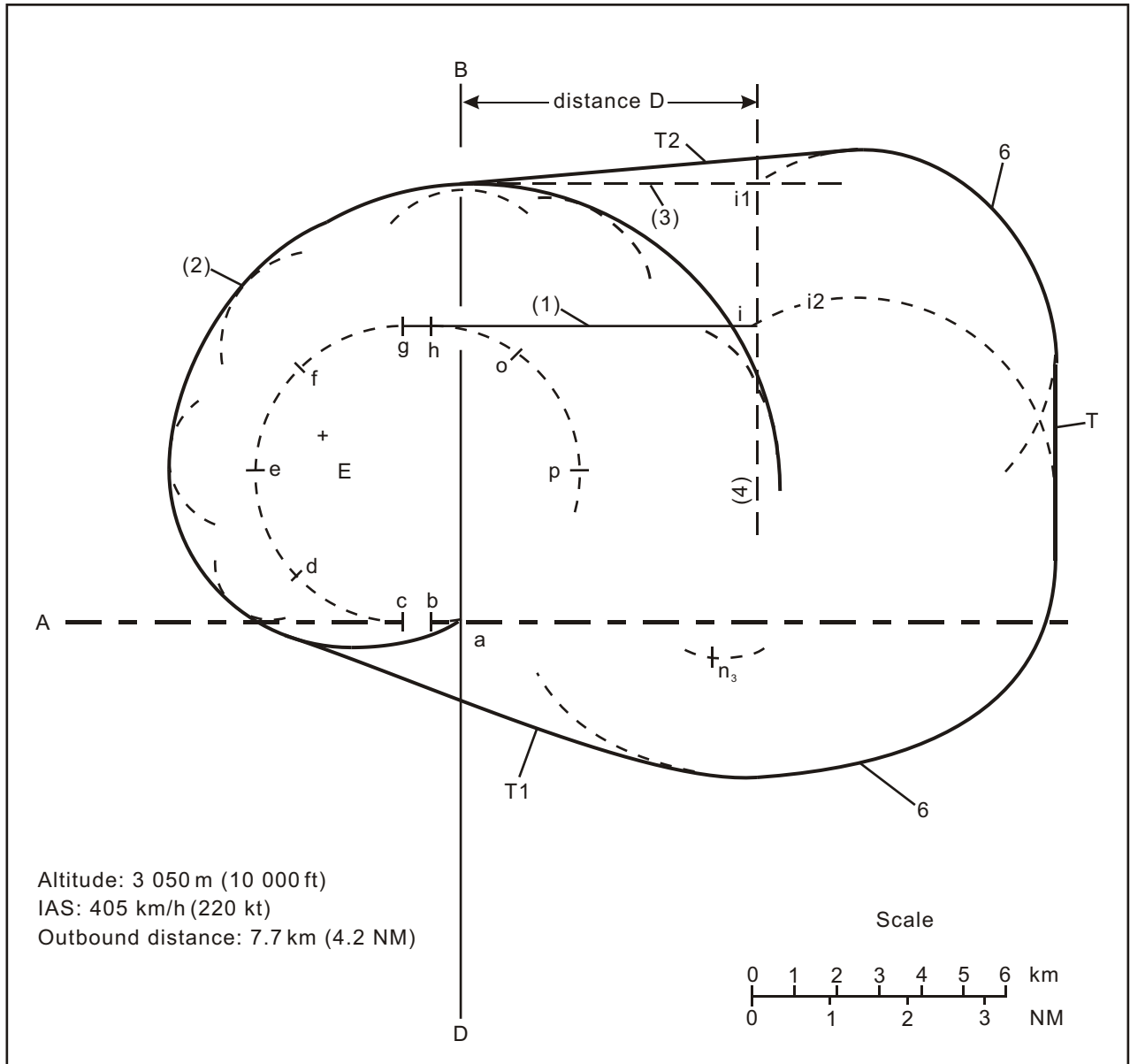example showing rectangle for procedure turn**

Figure B1-21. RNAV template

Altitude: 3 050 m (10 000 ft)
IAS: 405 km/h (220 kt)
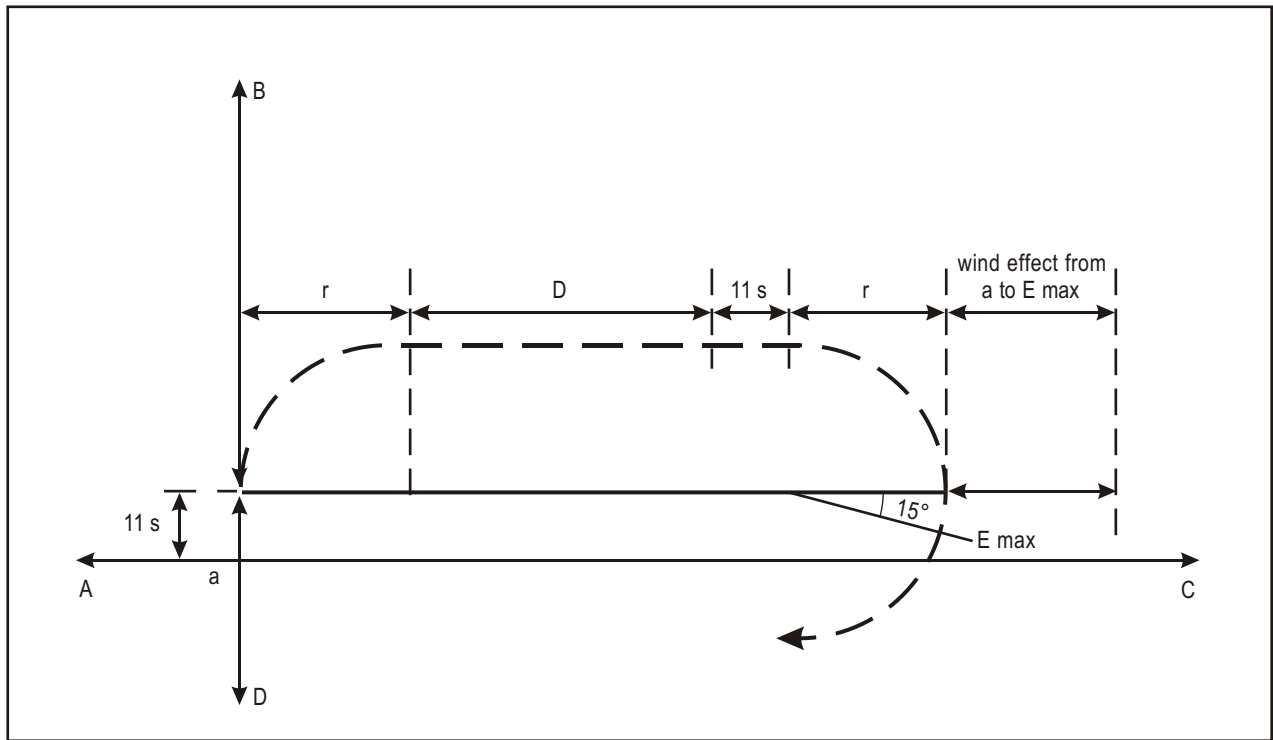Outbound distance: 7.7 km (4.2 NM)

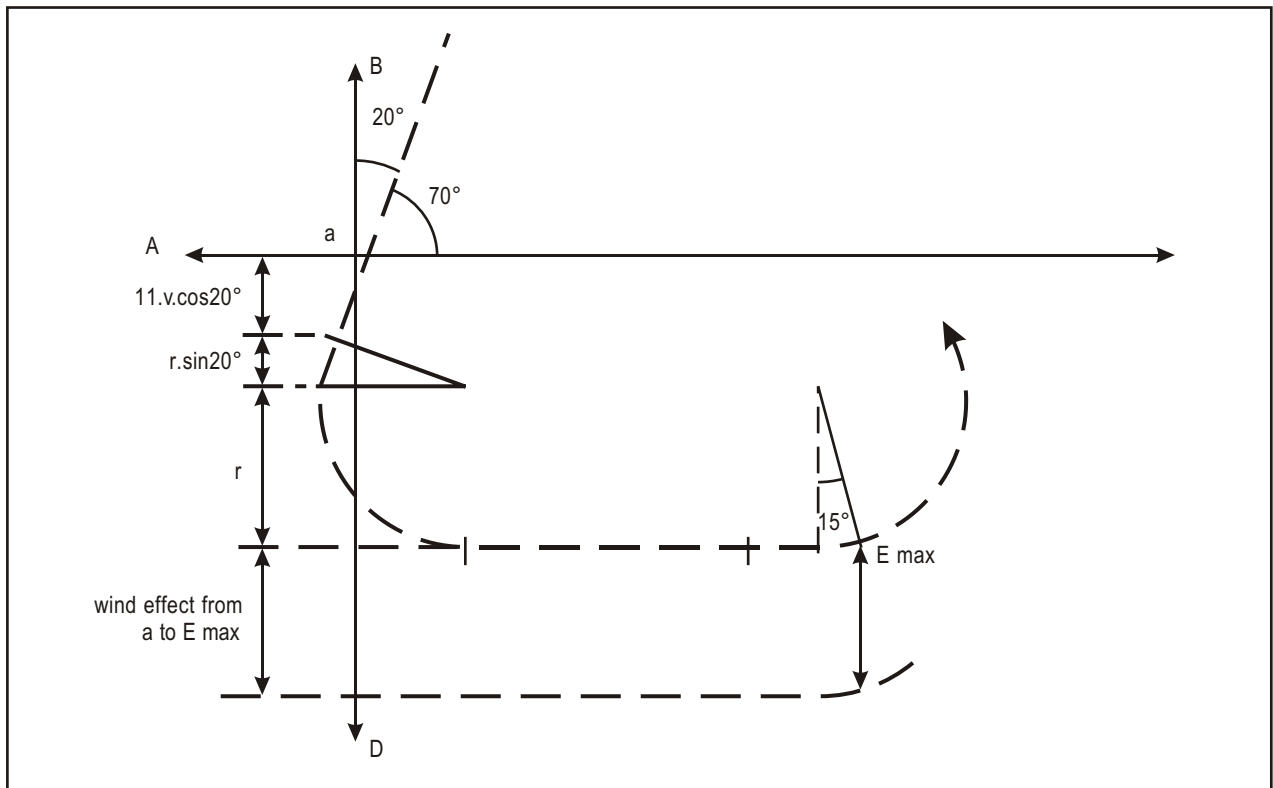**Figure B1-22A.   RNAV holding: XE calculation**

Figure B1-22B.   RNAV holding: YE calculation
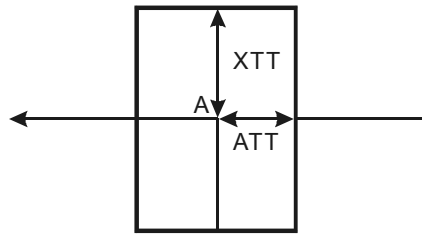
Figure B1-23.   Holding point tolerance area
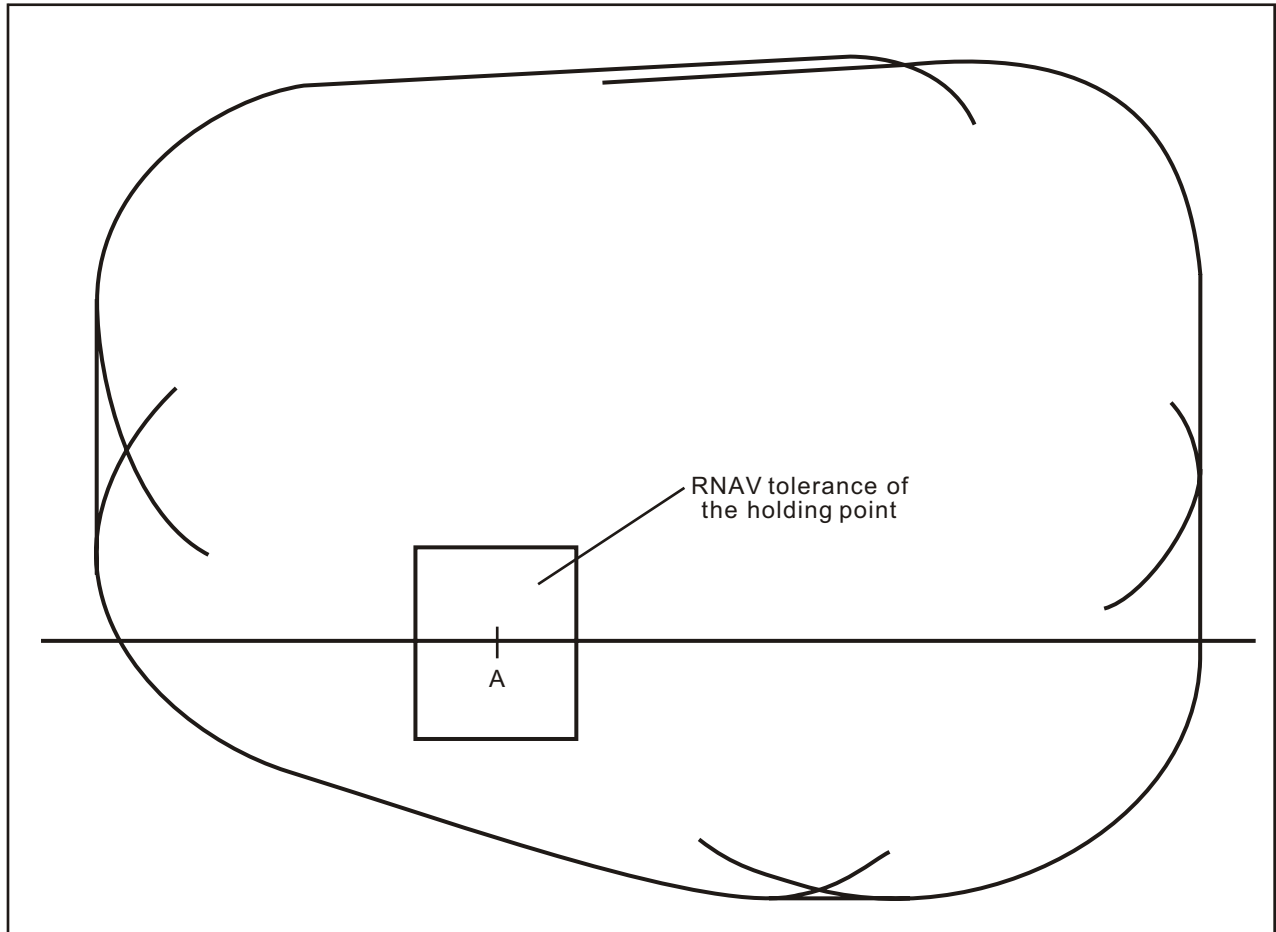
Figure B1-24.   RNAV basic area

RNAV tolerance of
the holding point

A
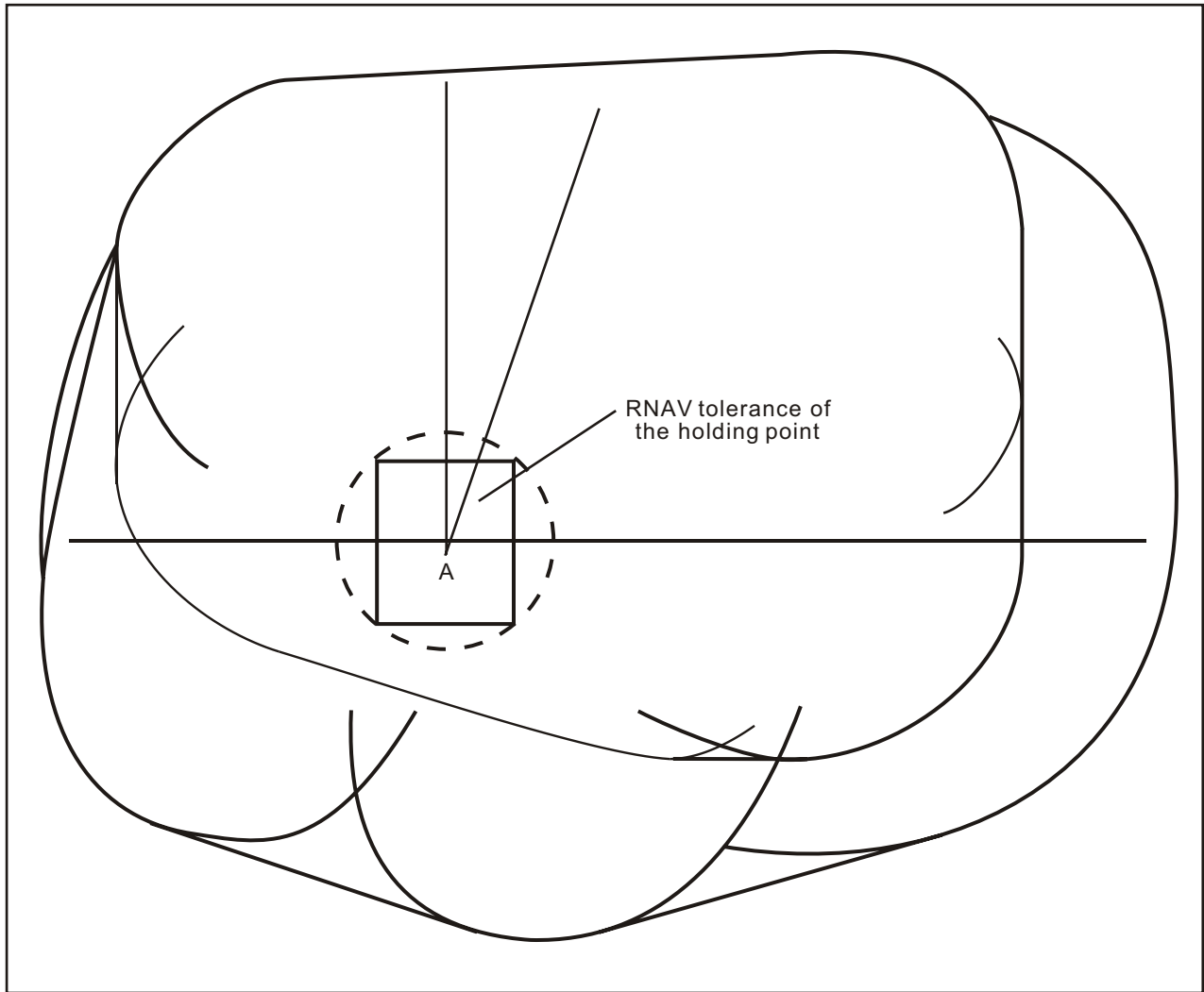
Figure B1-25.   RNAV holding area including protection of entry procedures
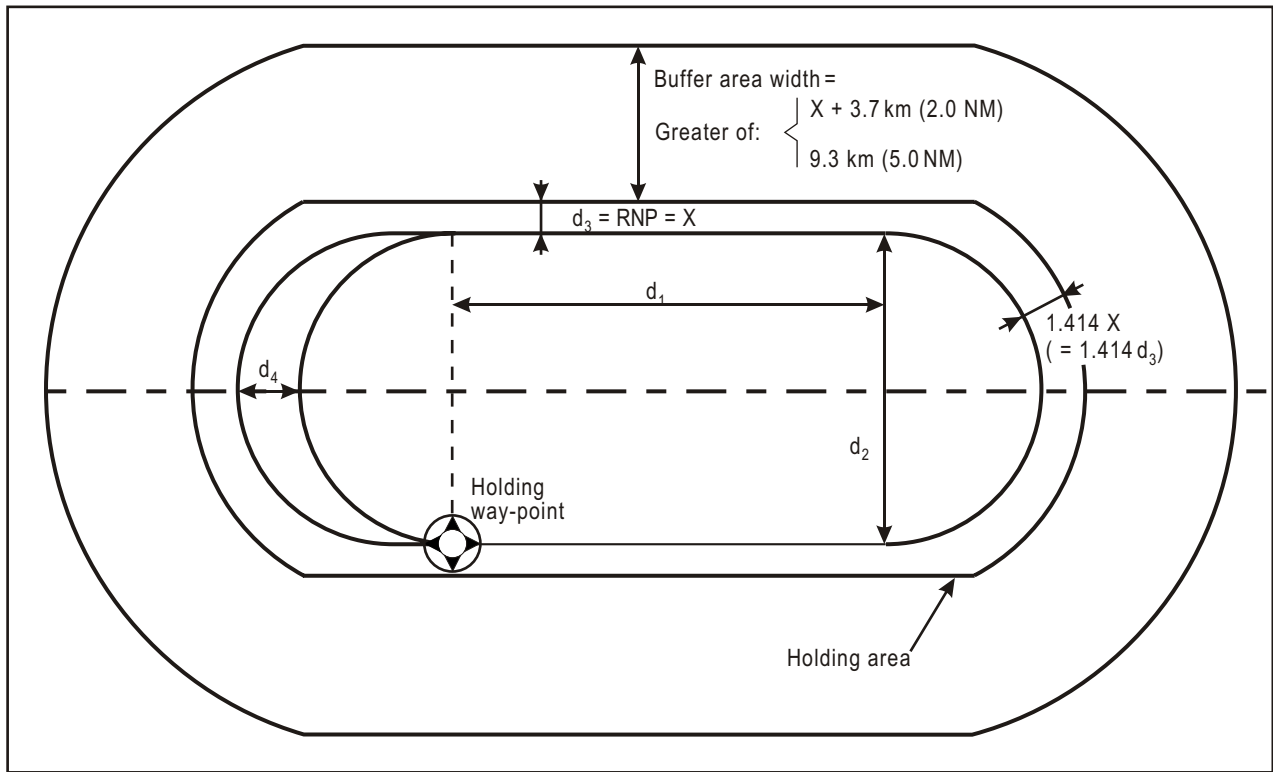
Figure B1-26. RNP holding area — obstacle clearance area

NDB base turn protected for:

Altitude: 1 850 m (6 000 ft)
IAS: 260 km/h (140 kt)
Outbound time: 2 min

See Diagram B1-2

Primary area

Secondary area

4.6 km
2.5 NM

Scale

0	1	2	3	4	5	6 km
0		1		2		3 NM
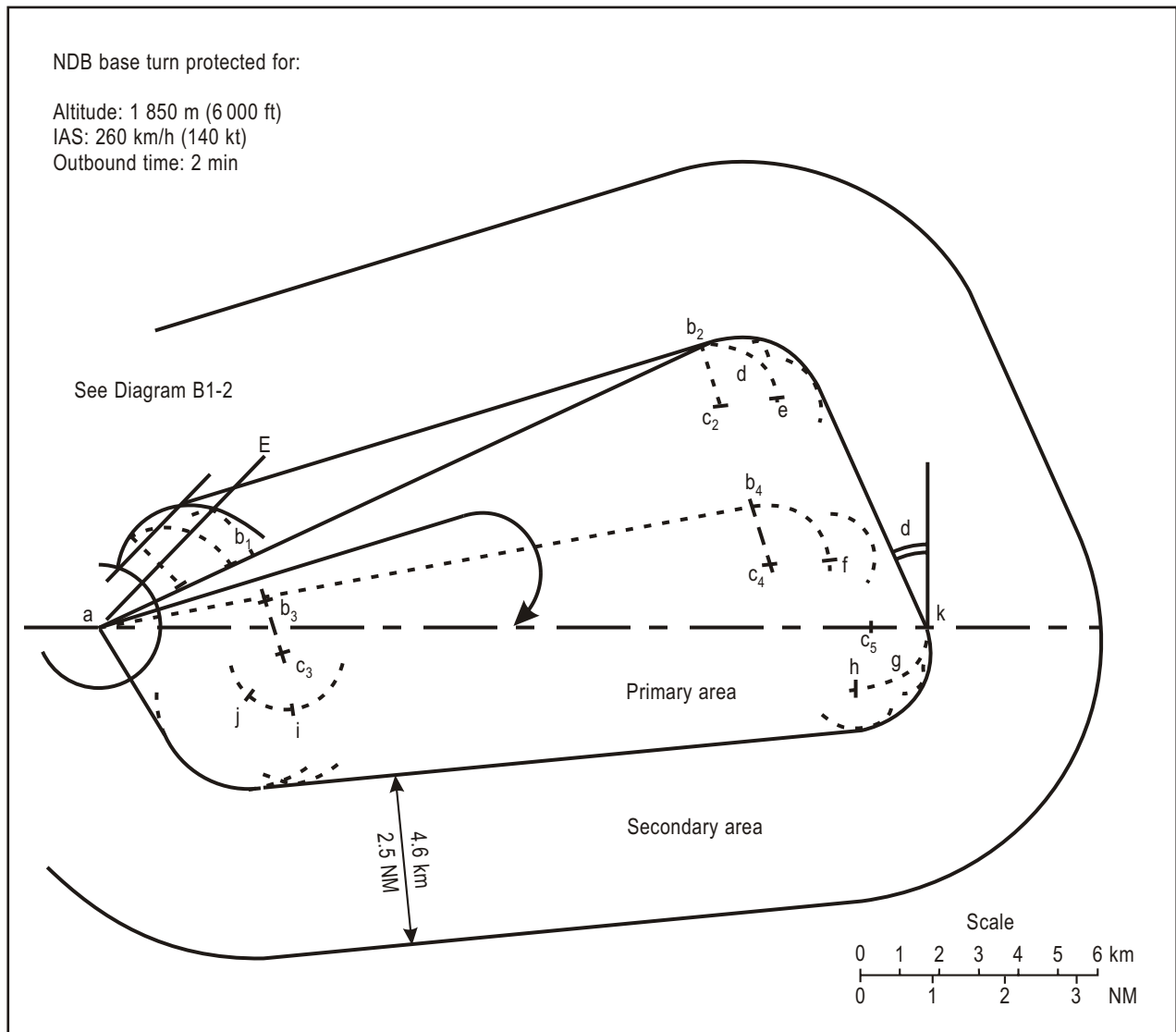
Diagram B1-1.   NDB base turn area
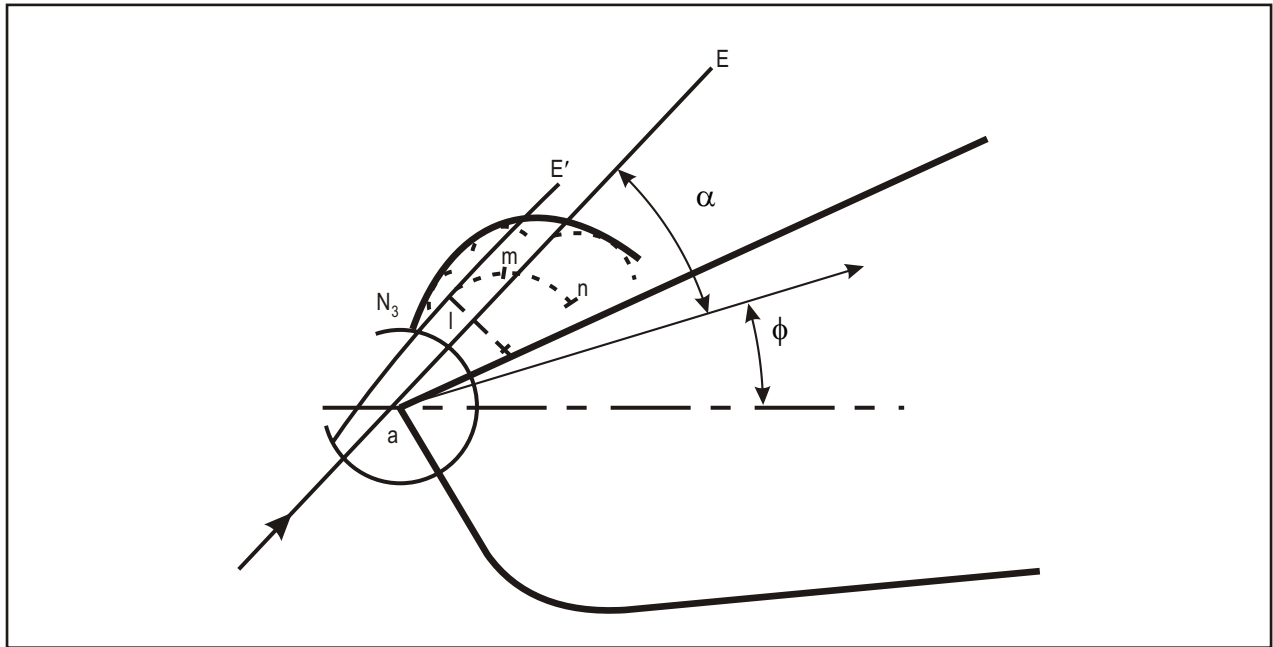
Diagram B1-2.   Protection of the entry to a base turn

45° — 180° procedure turn protected for:

Altitude: 1 850 m (6 000 ft)
IAS: 260 km/h (140 kt)
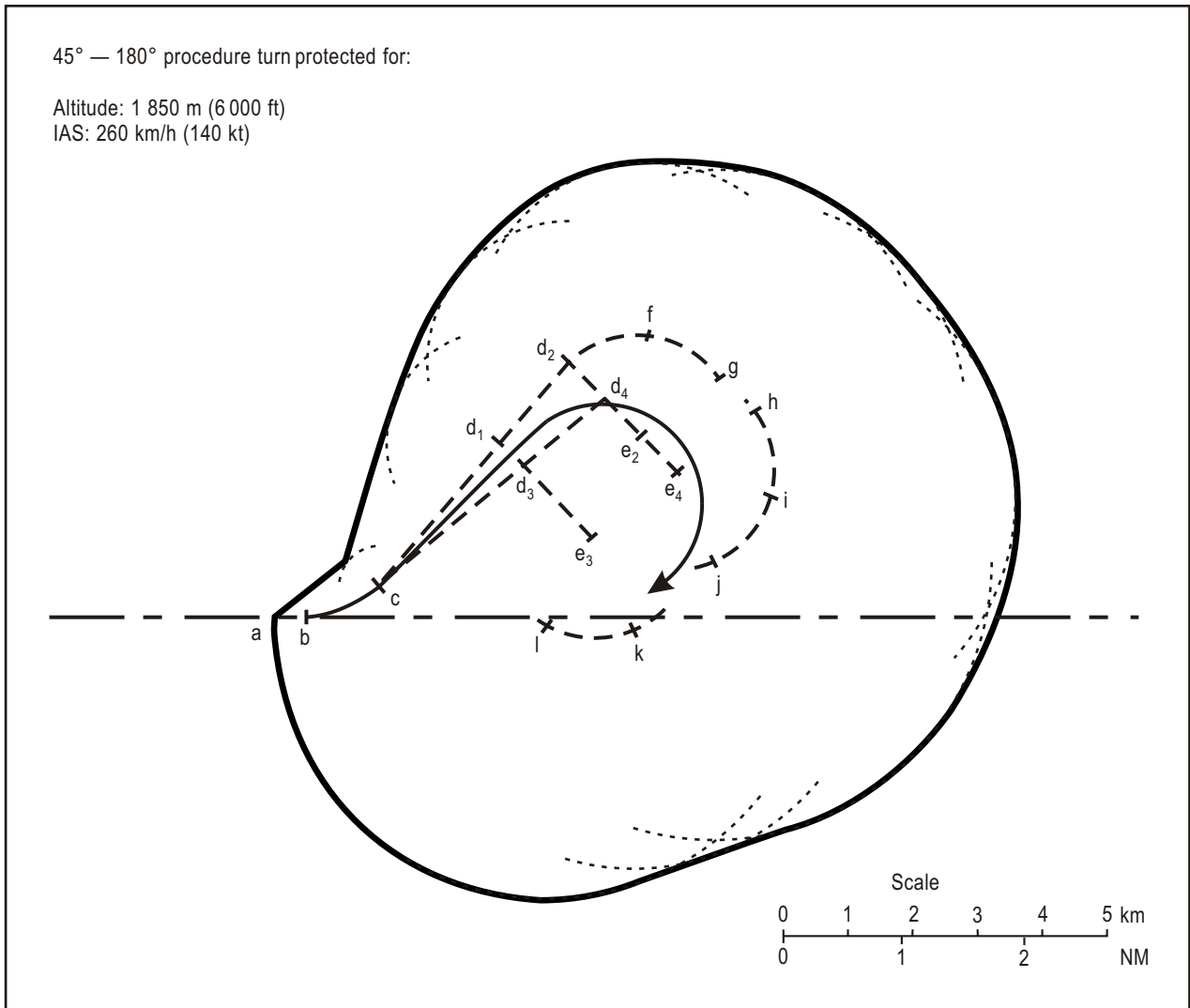
Diagram B1-3. 45° — 180° procedure turn template

Turn protected for:

Altitude: 1 850 m (6 000 ft)
IAS: 405 km/h (220 kt)

g

h

e2
e
e1
d2
d
d1

c

f2
f
f1

i

j

k

a   b

m   l

Scale

0	1	2	3	4	5 km
0		1		2	NM
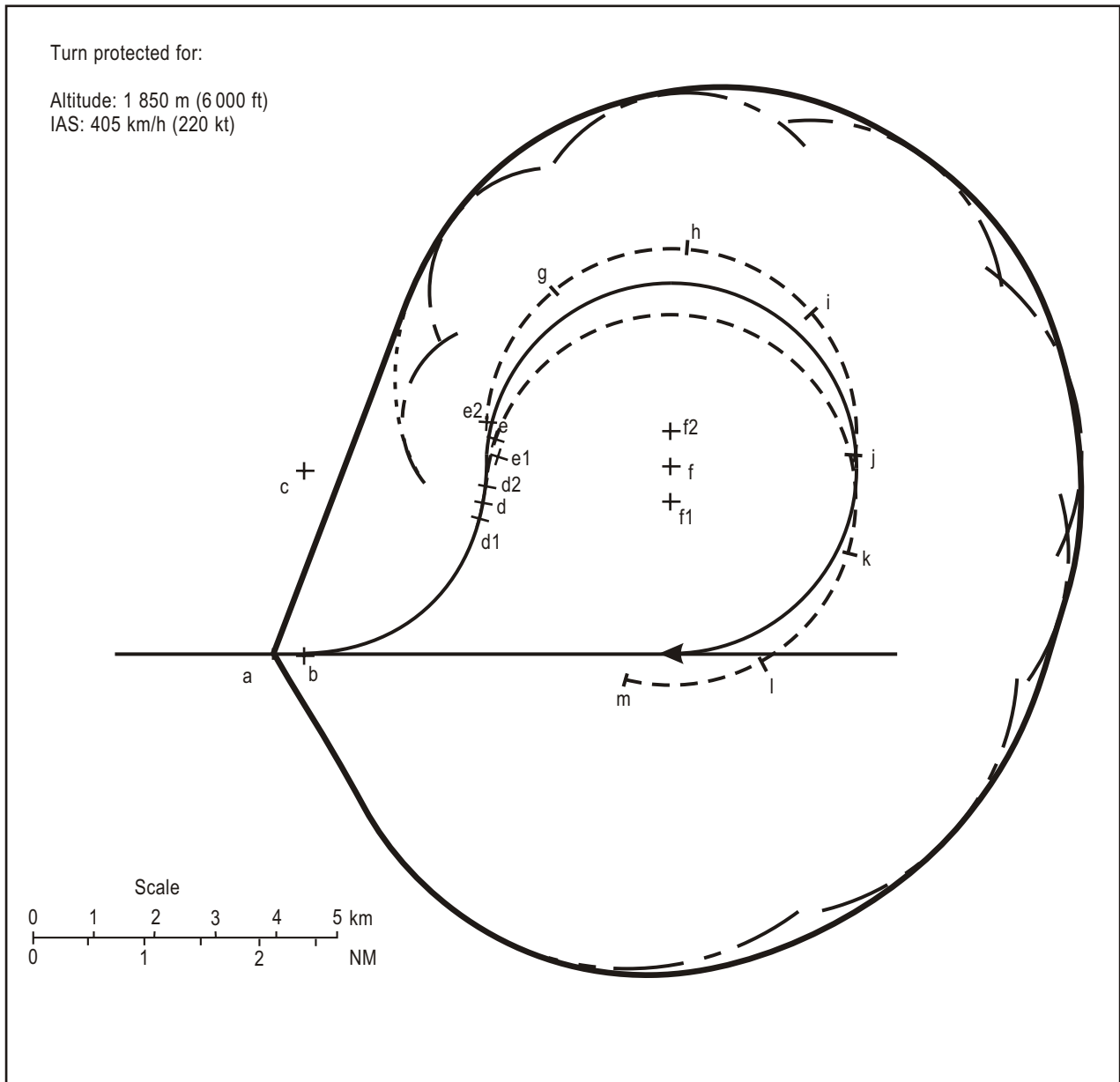
Diagram B1-4.   80° — 260° procedure turn template

Turn protected for:

Altitude: 1 850 m (6 000 ft)
IAS: 260 km/h (140 kt)
OA : 1 minute

4.6 km
(2.5 NM)

A1

A2

A

A3

A4

0

1

2

3

4

Primary area

Secondary area

Not to scale
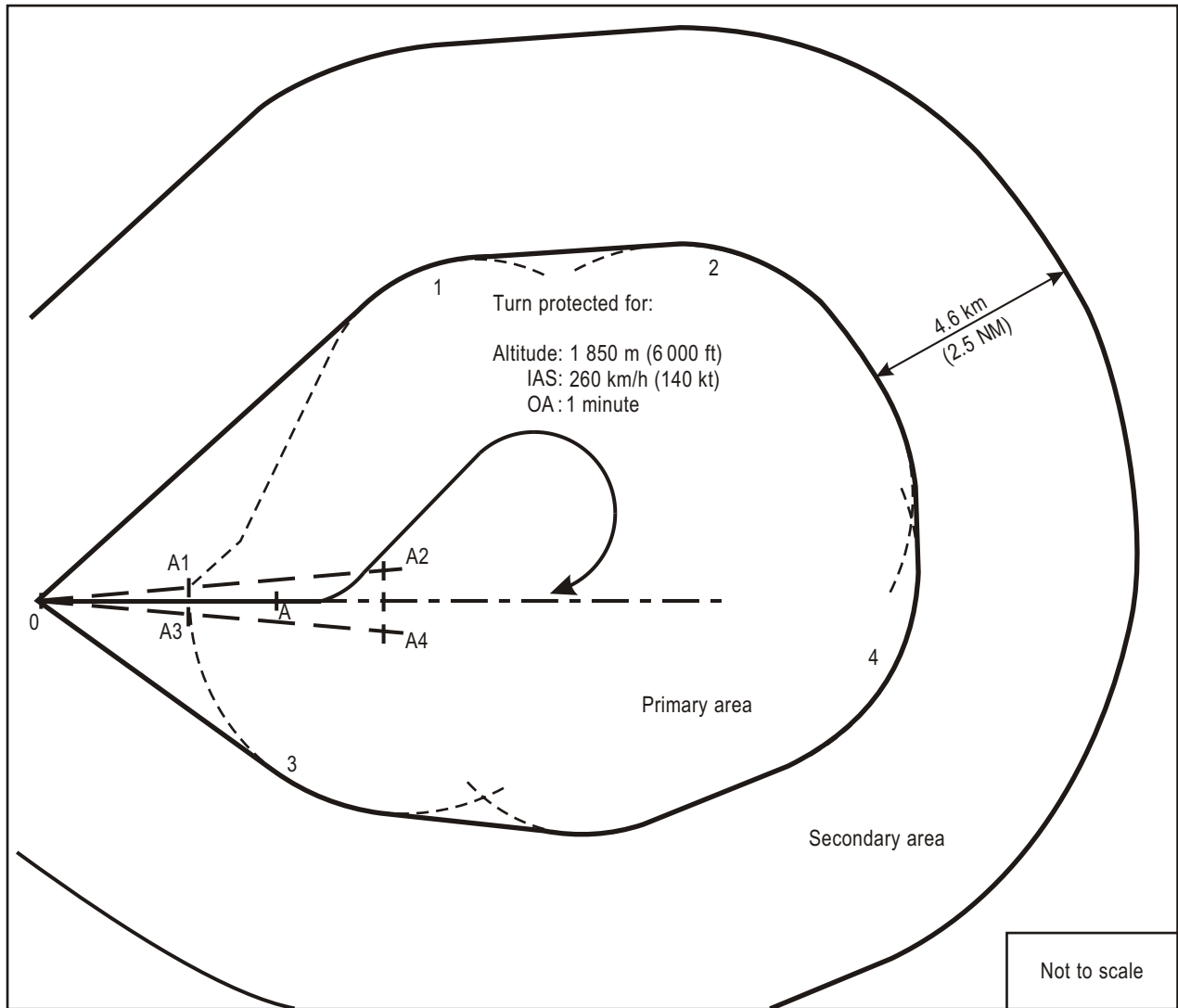
Diagram B1-5.   VOR 45° — 180° procedure turn

B

R

i₁

i₂

j

g h

o

i₃

i₄

f

k

e

p

l

E

d

Line 3

A

c b

a

m

D

n₃

n₄

C

Procedure protected for:

Altitude: 3 050 m (10 000 ft)
IAS: 450 km/h (220 kt)
Outbound time: 1 min

Scale

0 1 2 3 4 5 6 km

0 1 2 3 NM
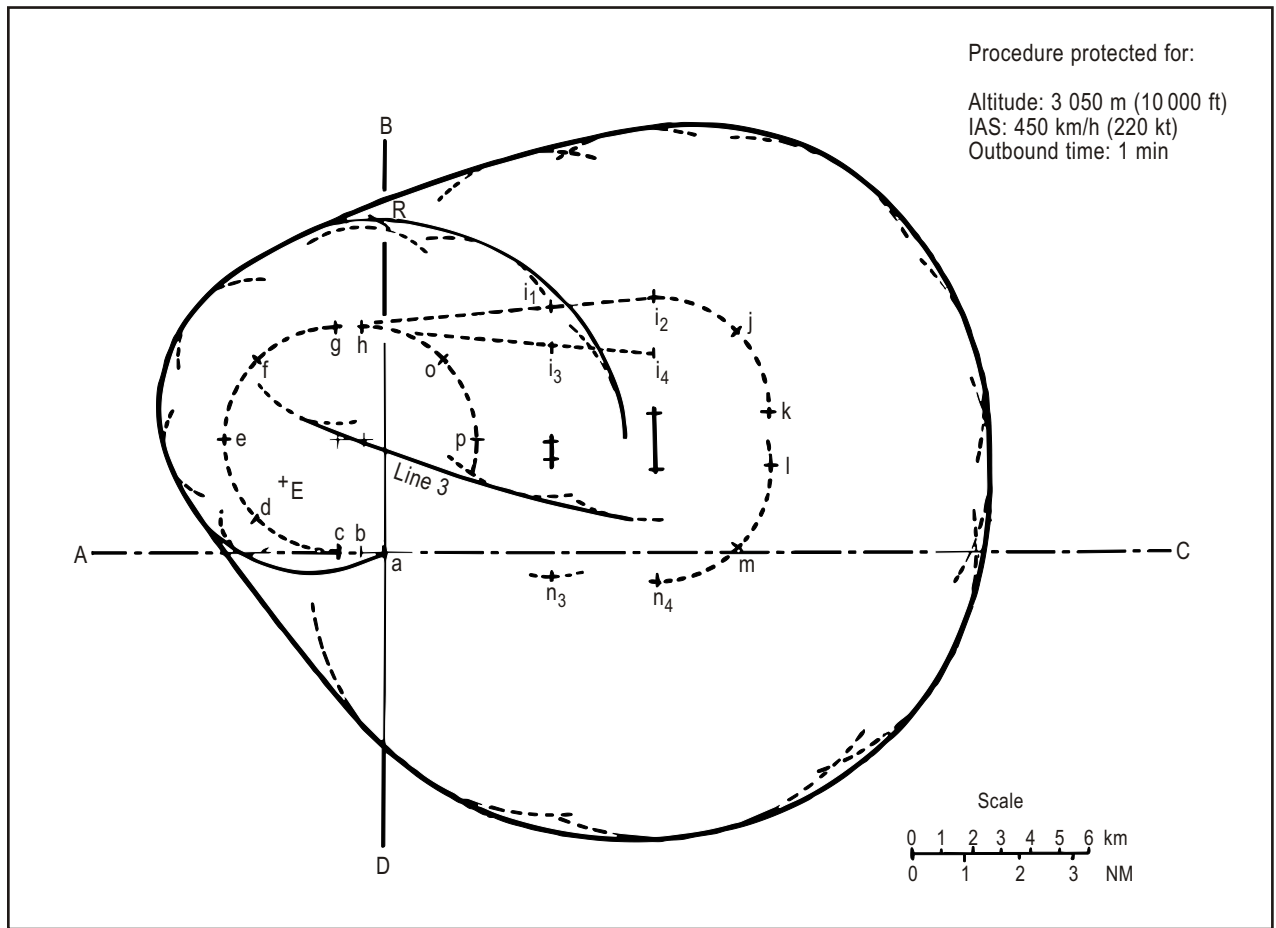
Diagram B1-6.   Holding/racetrack template with associated construction points

425 km/h (230 kt)
3 050 m (10 000 ft)
1 min

NDB

VOR

1/ 250 000

| 0 | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 | 45 | km |
| 0 | | 5 | | 10 | | 15 | | 20 | | 25 | NM |
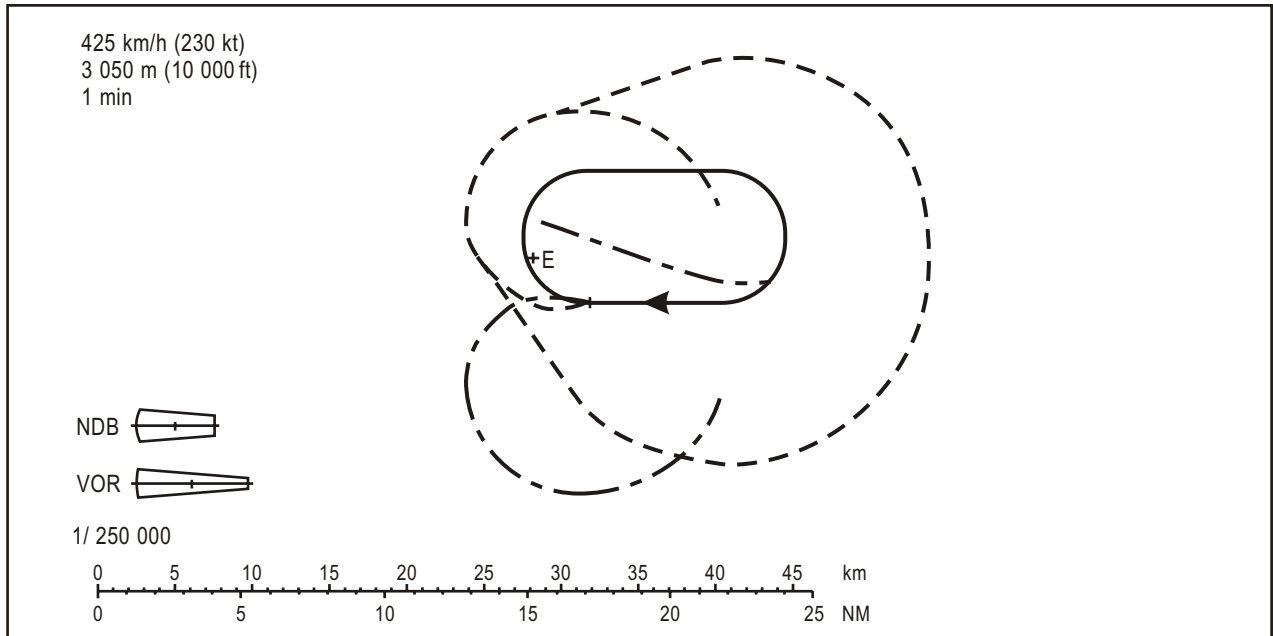
Diagram B1-7.   Holding template extracted from the *Template Manual for Holding, Reversal and Racetrack Procedures* **(Doc 9371)**

405 km/h (220 kt)
3 050 m (10 000 ft)
1 min

NDB

VOR

CAUTION: DO NOT USE THIS REPRODUCTION FOR ACTUAL AREA DESIGN

| 0 | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 | 45 | km |
| 0 | | 5 | | 10 | | 15 | | 20 | | 25 | NM |
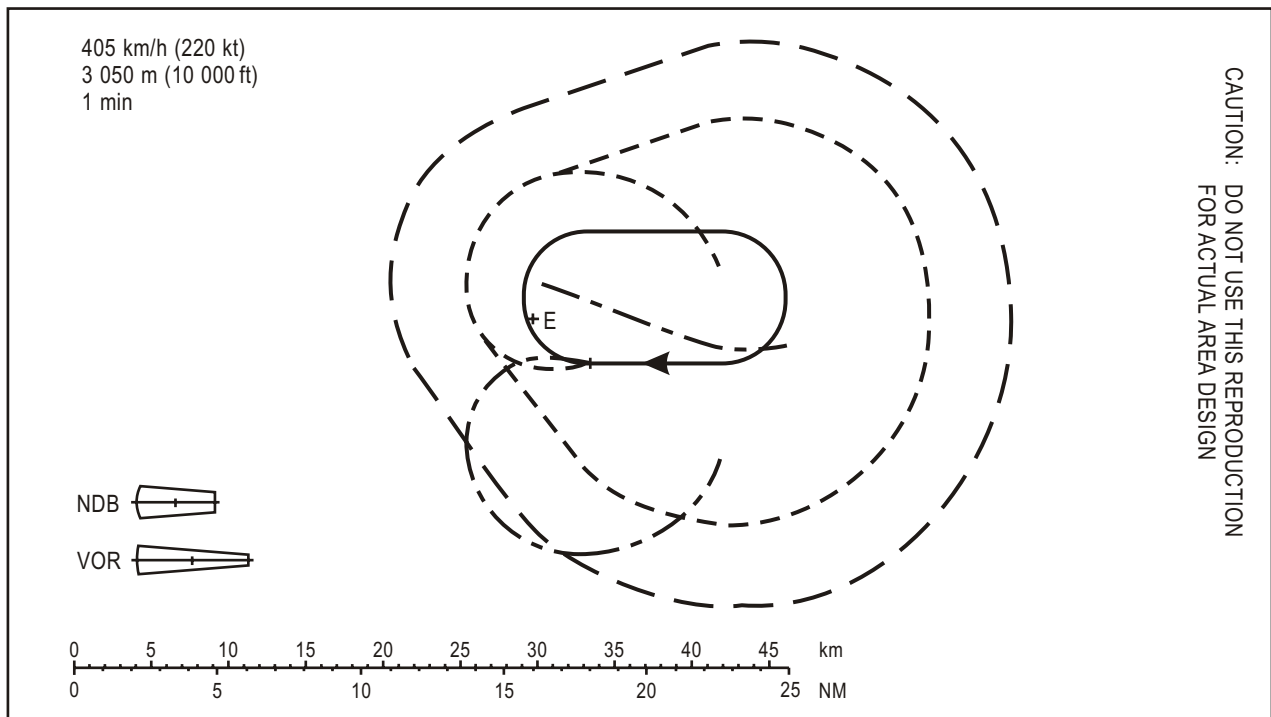
Diagram B1-8.   Racetrack template extracted from the *Template Manual for Holding, Reversal and Racetrack Procedures* **(Doc 9371)**
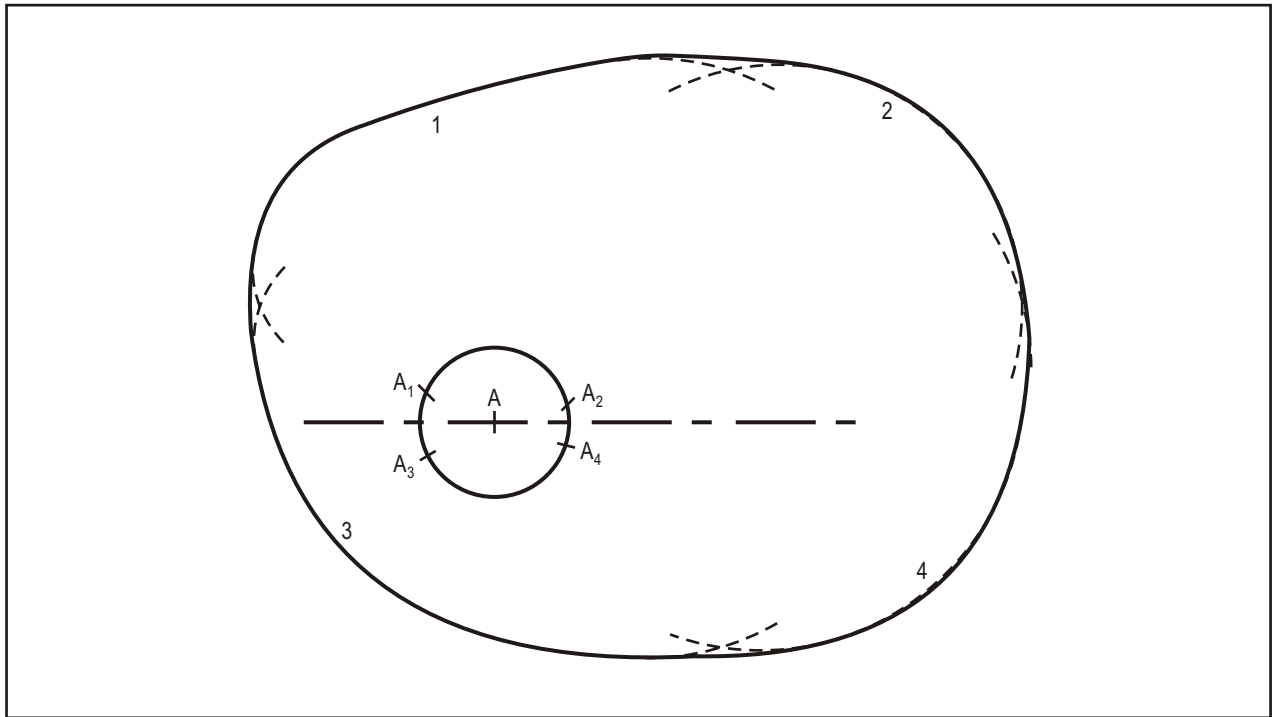
Diagram B1-9.   Construction of the basic area
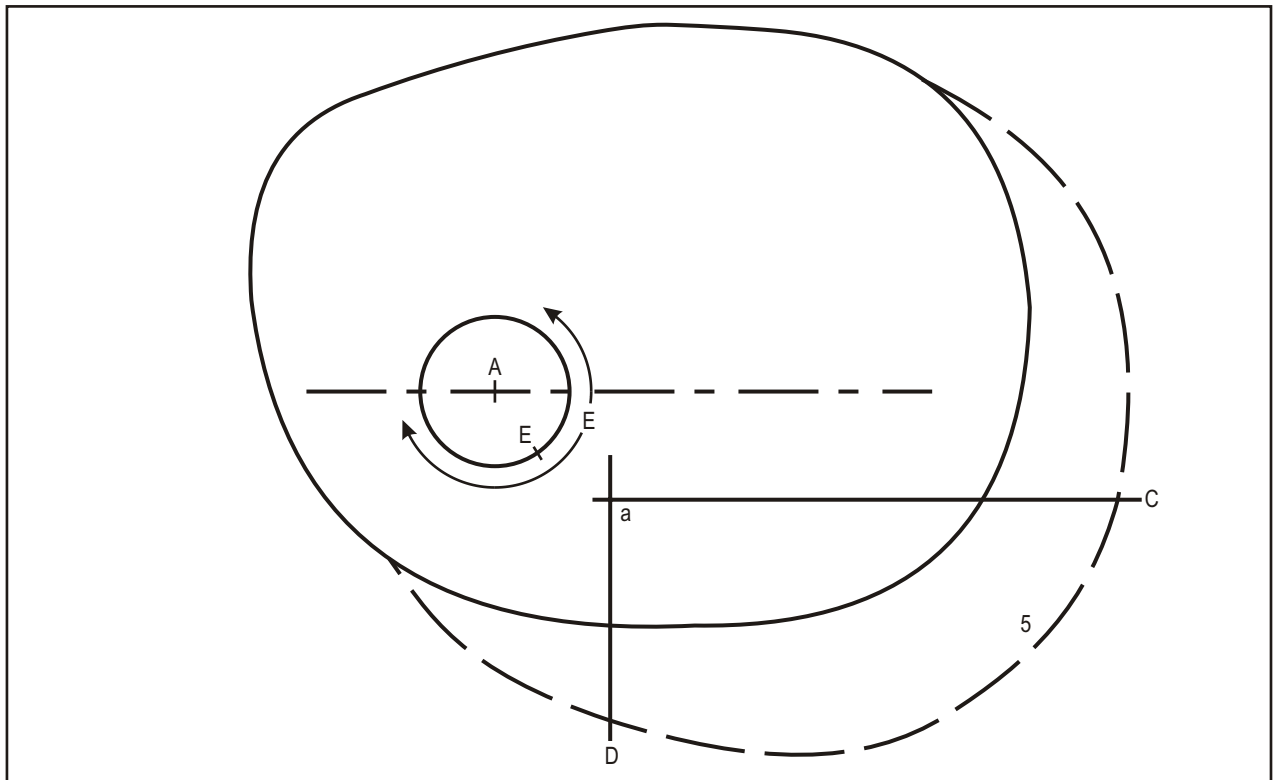
**Diagram B1-10.   Construction of the entry area; use of point E,
the axis of the template being parallel to the procedure axis**
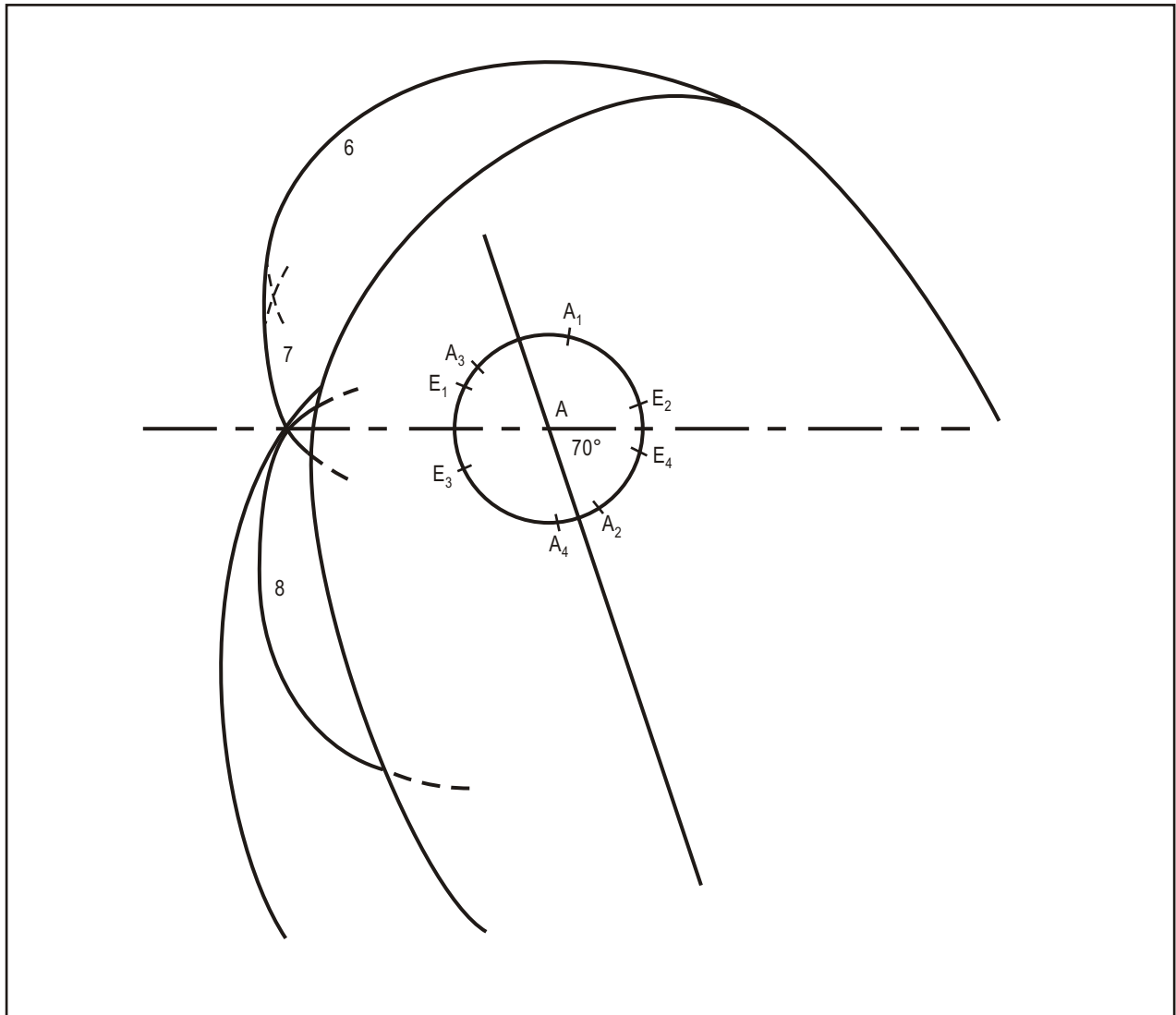
**Diagram B1-11.   Construction of the entry area; the axis of the template
making an angle of 70° with the procedure axis**
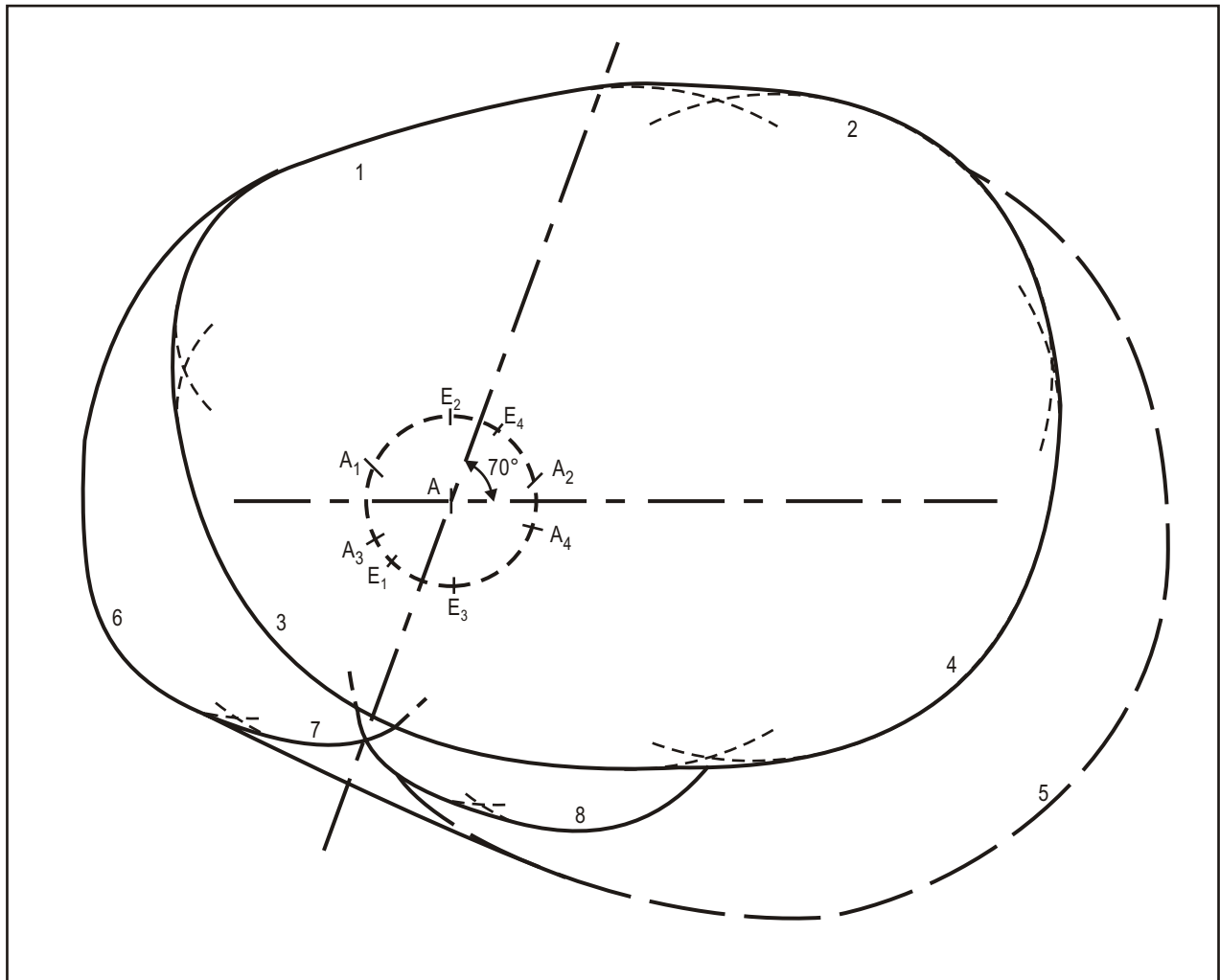
Diagram B1-12. Basic area with omnidirectional entry areas; procedure overhead a facility

Entries from Sector 1
not permitted

A

6.9°

Parallel lines

a
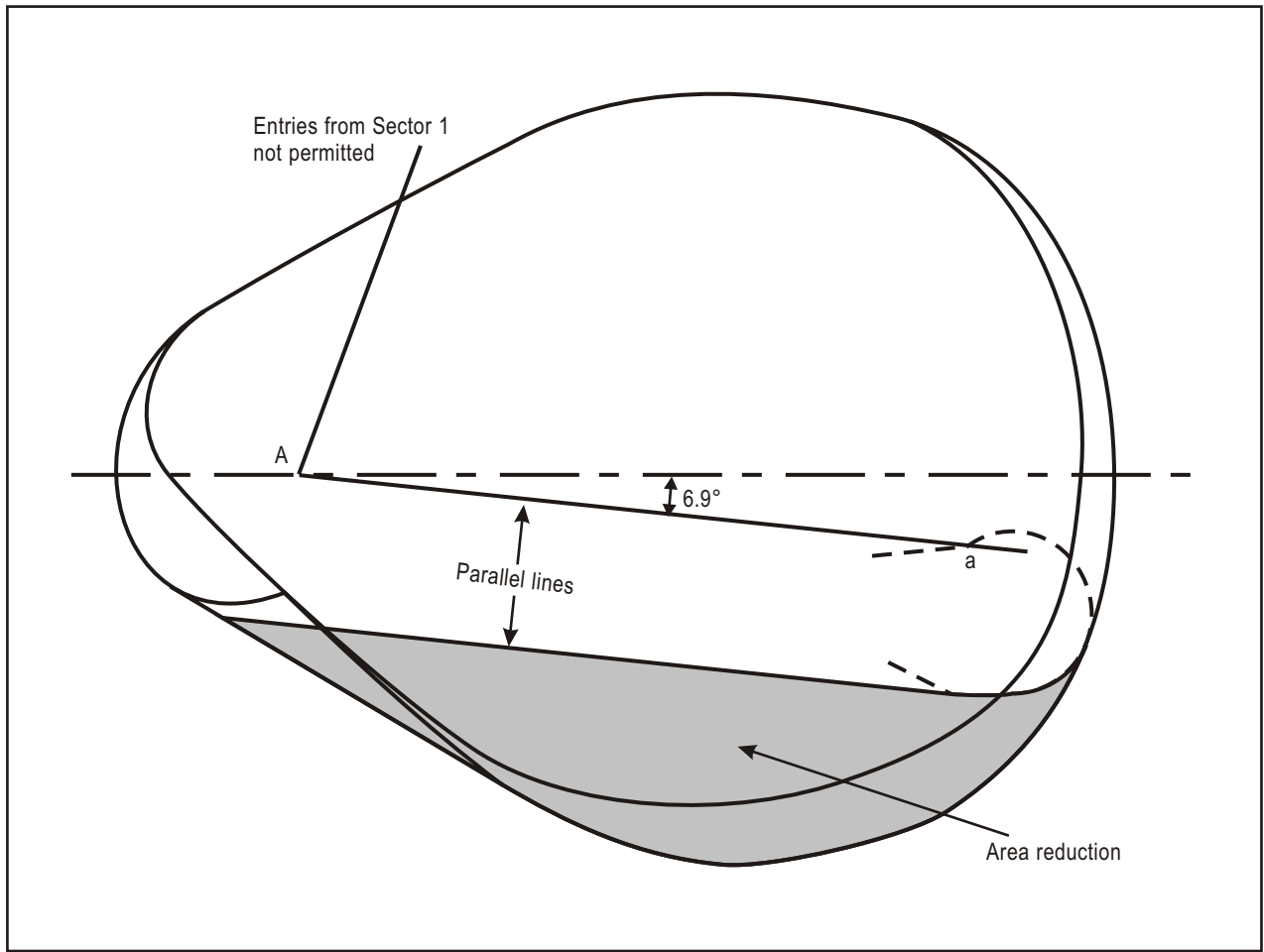
Area reduction

**Diagram B1-13.   Area reduction for a procedure overhead an NDB when
entries from Sector 1 are not permitted**

PROCEDURE AT THE INTERSECTION OF VOR RADIALS
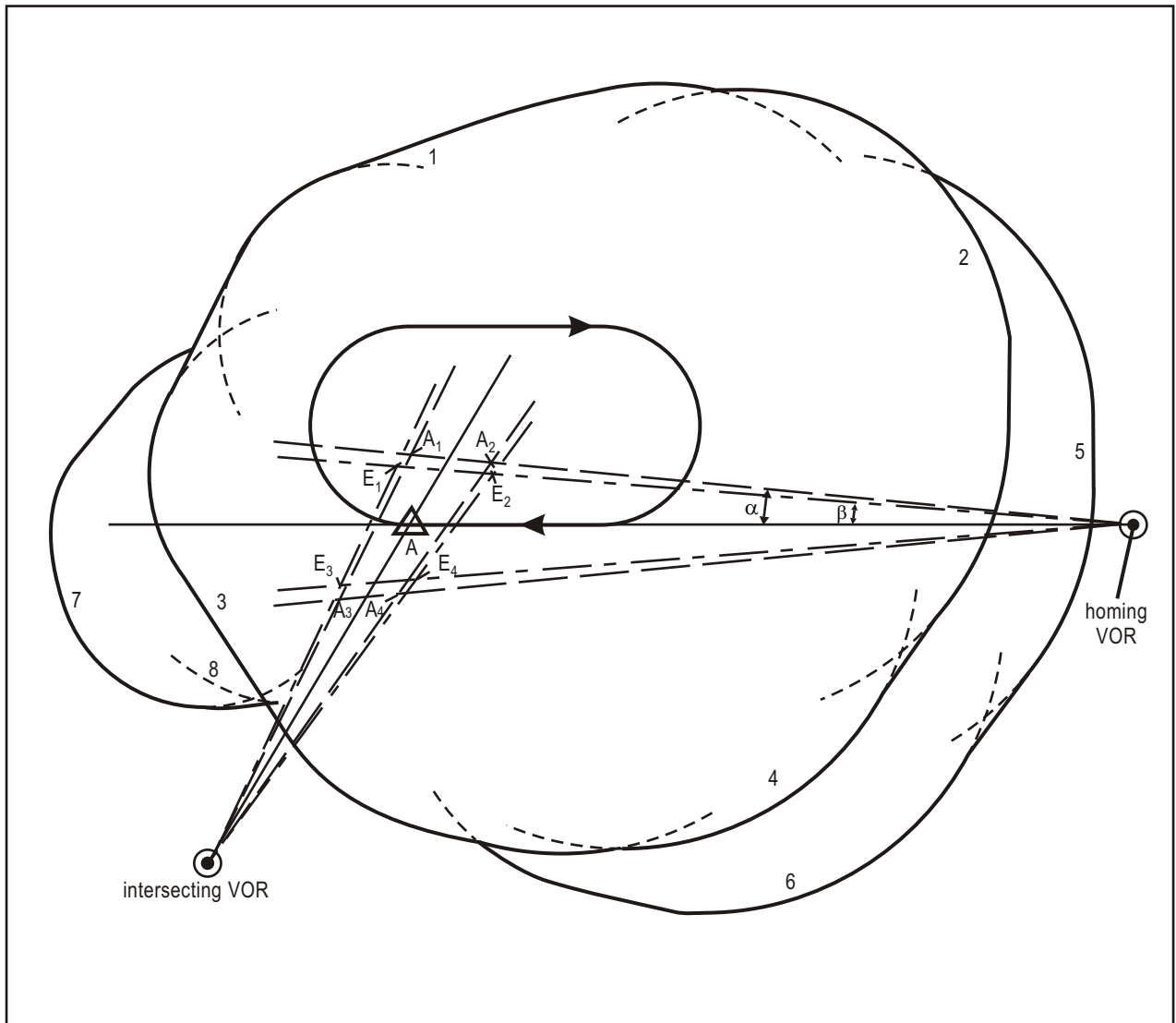
**Diagram B1-14.   Basic area and the associated entry area assuming
entries along the procedure track and intersecting radial**

Procedure protected for:

Altitude: 4 250 m (14 000 ft)
IAS: 405 km/h (220 kt)
Nominal distance: 55 km (30 NM)
Limiting distance: 65 km (35 NM)

Protection of
sector 1 entry

Protection of
sector 2 entry

C'3

C2

C3

C1

4

5

1

C7

A2

A1

RP1

DL1

DLs

DL2

D1

Ds

D2

6

11

RP

A

C

B

2

3

RP2

C4

C5

C6

C'6

A3

A4

13

14

C10

15

8

9

7

Scale:

0   1   2   3   4   5 NM

1 2 3 4 5 6 7 8 9 km

**Diagram B1-15.   VOR/DME procedure towards the facility —
basic area and associated area for entries**

Procedure protected for:

Altitude: 4 250 m (14 000 ft)
IAS: 405 km/h (220 kt)
Nominal distance: 55 km (30 NM)
Limiting distance: 65 km (35 NM)
Angle between RE and RP: 8°

Scale:

0   1   2   3   4   5 NM
1   2   3   4   5   6   7   8   9   km

**Diagram B1-16.   VOR/DME procedure towards the facility — basic area and
associated area for reciprocal direct entry to the secondary point**

Procedure protected for:

Altitude: 4 250 m (14 000 ft)
IAS: 405 km/h (220 kt)
Nominal distance: 55 km (30 NM)
Limiting distance: 48 km (26 NM)

C'3
C2
C1
C3
4
5
1
C7
A1
A2
RP1
6
10
D1
Ds
D2
DL1
DLs
DL2
RP
2
A
3
C8
RP2
C4
C5
C6
A3
A4
14
8
15
7
16
Scale:
9
C10

0   1   2   3   4   5 NM
1 2 3 4 5 6 7 8 9 km
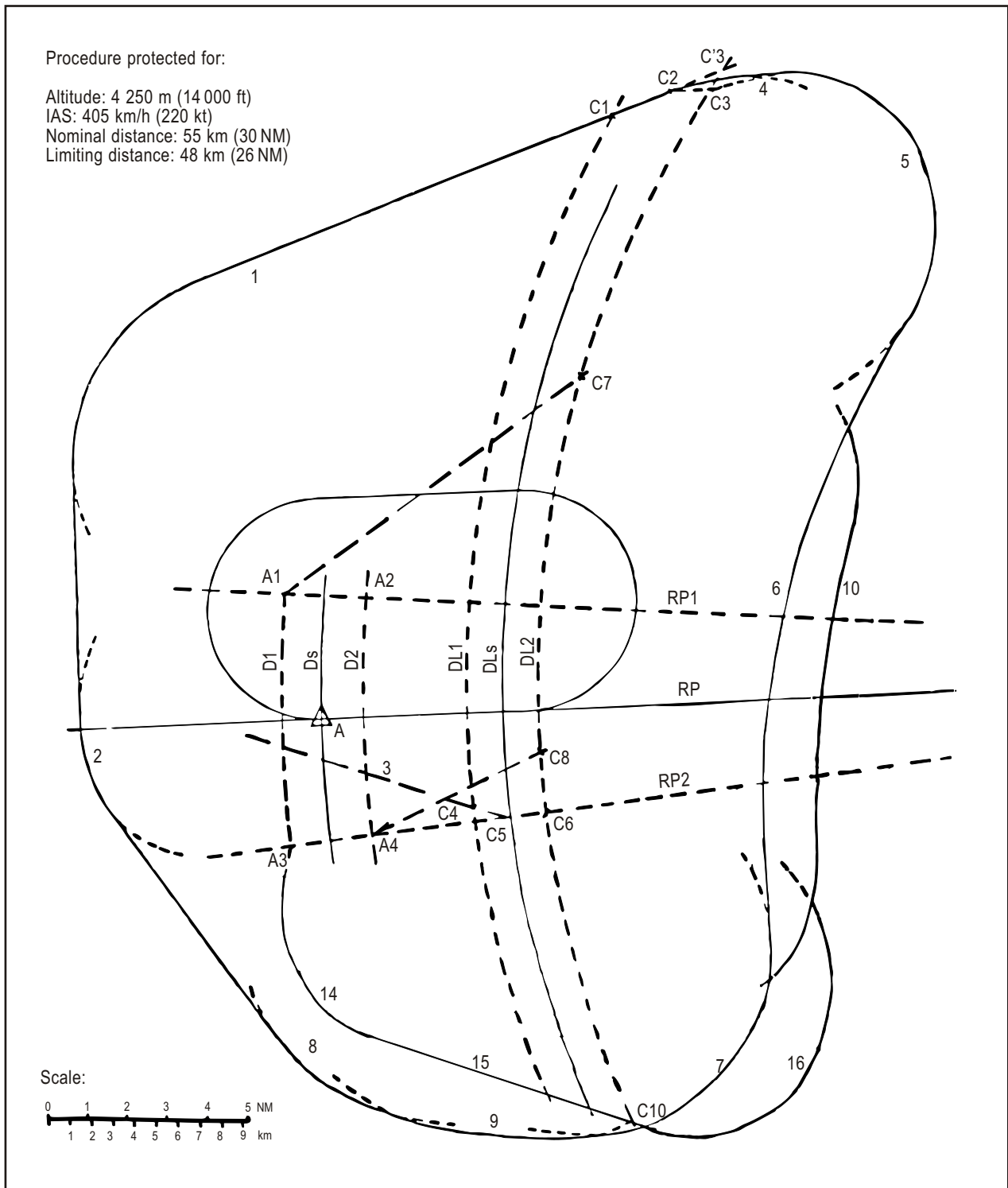
**Diagram B1-17.   VOR/DME procedure away from the facility — basic
area and associated area for entries**

Procedure protected for:

Altitude: 4 250 m (14 000 ft)
IAS: 405 km/h (220 kt)
Nominal distance: 55 km (30 NM)
Limiting distance: 48 km (26 NM)
Angle between RE and RP: 12°

Scale:

0   1   2   3   4   5 NM
1 2 3 4 5 6 7 8 9 km
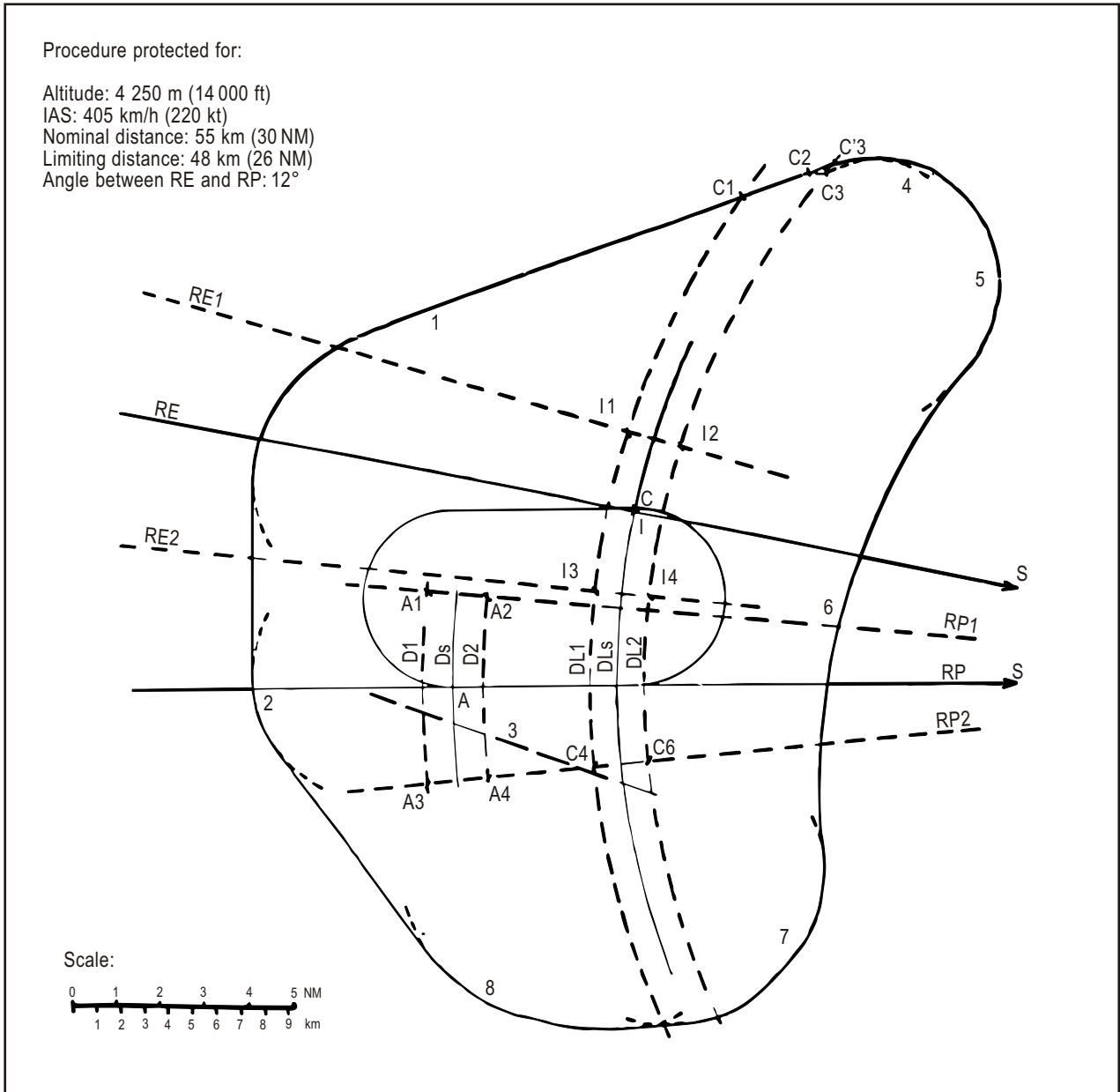
**Diagram B1-18.   VOR/DME procedure from the facility — basic area
and the associated area for reciprocal direct entry to the secondary point**

Procedure protected for:

Altitude: 4 250 m (14 000 ft)
IAS: 405 km/h (220 kt)
Nominal distance: 55 km (30 NM)
Limiting distance: 48 km (26 NM)
Angle between RP and RL: 25°

Scale:

0   1   2   3   4   5 NM
1 2 3 4 5 6 7 8 9 km
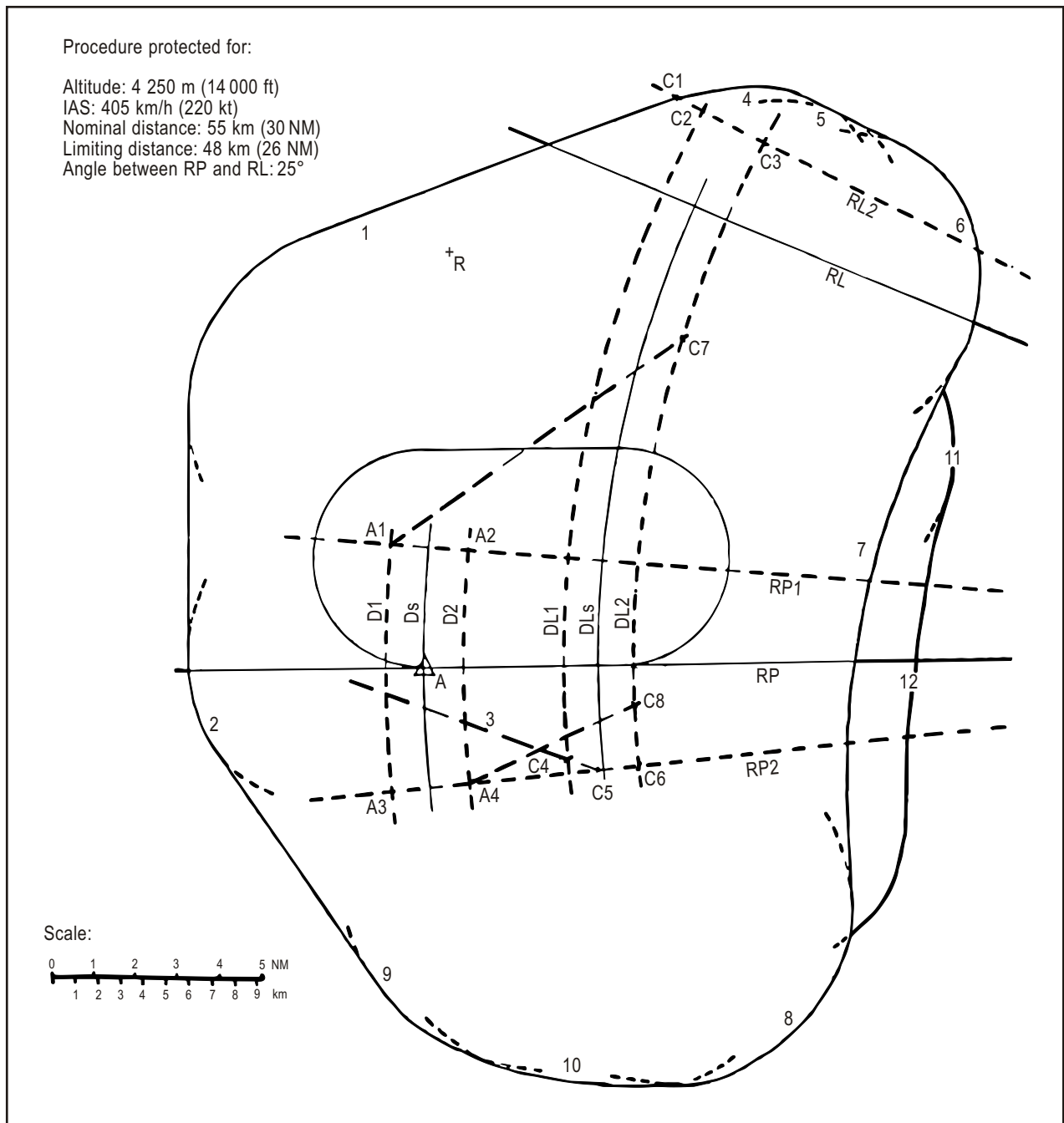
**Diagram B1-19.   VOR/DME procedure away from the facility with a
limiting radial — basic area and associated area for entries**

Attachment B2

Calculation Routines

This Attachment contains a selection of routines designed to simplify the mathematical calculations involved in certain aspects of procedure design. Some of the routines may be used for manual calculations using nothing more than a relatively simple scientific calculator, others are more suited to programmable calculators or micro-computers. In all cases where repetitive calculations are necessary, the use of a programmable machine is preferable since data entry errors may be reduced by standard programming safeguards (printout of all data entered, checks for acceptable range and sign of input, etc.).

These routines require an adequate understanding of mathematics (and simple programming for the more complex routines). If necessary, suitably qualified assistance should be obtained.

Calculation Routine 1

Application of the ILS OAS and Obstacle Height Equations

1. *Introduction.* This routine presents examples of the use of the OAS and h_a/h_{ma} equations given in PANS-OPS, Volume II, Part III, 21.4.8.8.2 and Attachment I.

2. *Implementation*

2.1 *OAS equations.* The OAS equations may be used to calculate a number of useful dimensions in addition to the height of the surfaces at a location (x, y) as illustrated in Attachment C1. Examples are:

a) *Plotting of OAS contours.* Take the A, B and C coefficients for the appropriate surface and calculate the semi-width (y') of the surface contour for height (z') at range (x') for X and Y surfaces as follows:

$$y' = \frac{(C - Ax')}{B}$$

Similarly, for the W, W* and Z surfaces, the range (x') of contour (z') may be calculated:

$$x' = \frac{(z' - C)}{A}$$

b) *Plotting of areas.* The point of intersection of two adjacent OAS heights (z') may be calculated from the equations of the adjacent surfaces:

Surface 1 coefficients: A1, B1, C1

Surface 2 coefficients: A2, B2, C2

Point of intersection at height z' is (x, y):

$$x = \frac{(z'(B2 - B1) - C1*B2 + C2*B1)}{A1*B2 - A2*B1}$$

$$y = \frac{(z*B2 - C1*B1 - A1*A2*x)}{B1*B2}$$

c) *Alternative plotting techniques.* Note that the area may also be obtained by plotting directly from the OAS template coordinates given in PANS-OPS, Volume II, Attachment I to Part III. Contours within each area may be obtained by suitably subdividing and joining points on the intersection lines C-C", D-D", and E-E". There are a number of items worth noting:

1) the autopilot W and W* surfaces always intersect 1 000 m before the threshold. The height at this range is noted at the bottom of each page (C"" COORDINATES APPLY TO TEMPLATE AT — M HEIGHT);

2) when uncertain which OAS is above obstacle locations (x, y), calculate the height of *both* surfaces; the surface above the obstacle is that with the greater height;

3) when plotting the autopilot templates, it may be found that in some cases the line of intersection

between the x and y surfaces rotate in the direction of flight so that D" lies *after* D. This is not an error — it is because the autopilot X surfaces are narrower than those for the flight director whilst the Y surfaces are the same; and

4) the intersection between the X and Y surfaces is only designed to lie in the plane of the glide path for the Category II flight director case. For Category I, there may be small discrepancies and as mentioned in c) above, there are major differences for the autopilot OAS. These discrepancies are intentional and are necessary to ensure logical compatibility between the various surfaces (e.g. that Category I OAS enclose those for Category II in all cases).

2.2   *The h_a/h_{ma} equation.* The geometry associated with the h_a/h_{ma} equation (PANS-OPS, Volume II, Part III, 21.4.8.8.2) is shown in Figure III-21-16 of PANS-OPS. The equation enables the height of an approach obstacle (h_a) equivalent to the height of a given missed approach obstacle (h_{ma}) to be calculated. Use of this equation avoids the need to calculate the range of SOC and the associated geometry. For obstacles in the precision segment, and in any subsequent *straight* missed approach area, the equation is used as given:

$$h_a = \frac{h_{ma} \times \text{Cot } Z + (900 + x)}{\text{Cot } Z + \text{Cot } \theta}$$

However, the equation may be adopted for use in calculating turn criteria as follows:

a) *Calculation of turn height.* For a turn at an altitude, the turn altitude necessary to correspond with a pre-determined TP may be calculated. In this case, h_a becomes the height of SOC (for ILS, OCH − HL) and x gives the distance from threshold to the TP. In this case, the equation may be re-arranged as follows:

$$h_{ma} = \frac{(h_a \, (\text{Cot } Z + \text{Cot } \theta) - 900 - x)}{\text{Cot } Z}$$

where h_{ma} = height of the turn altitude
x = range of desired TP relative to threshold

b) *OCH for turn area obstacles.* The OCH due to obstacles in the turn area may be calculated as follows:

1) *Turn at fix.* Calculate SOC height from:

$$h_a = \frac{h_{ma} \times \text{Cot } Z + (900 + x)}{\text{Cot } Z + \text{Cot } \theta}$$

where:

h_a = height of SOC (for ILS OCH − HL)
h_{ma} = height of turn area obstacle
$x = - (d_z + d_o)$
d_z = distance from threshold to line K-K
d_o = distance from line K-K to obstacle
MOC = 50 m

2) *Turn at altitude.* Obstacles in the turn initiation area are first checked against the turn height:

TNH < obstacle height + MOC

If the turn height has to be increased because of these obstacles, there are two options. A turn height is re-calculated to clear obstacles in both the turn area and the turn initiation area, and the area is re-drawn. In this case, the new range of the TP may be obtained using the equation in a) above. However, this may not exclude the obstacle or may introduce new obstacles. In that event, the alternative solution is to keep the same TP but raise turn height by increasing SOC height (and hence OCH). This may be achieved by:

$$h_a = \frac{h_{ma} \times \text{Cot } Z + (900 + x)}{\text{Cot } Z + \text{Cot } \theta}$$

where:

h_a = new height of SOC
h_{ma} = increased turn height
x = desired range of TP relative to threshold

Calculation Routine 2

**Selection of Minimum Outbound Height
and Nominal Outbound Time for Reversal Procedures**

1.   *Introduction.* The selection of minimum outbound height and nominal outbound time is best done graphically. Two graphical solutions are presented, the first for use when the facility location is already fixed, the second for use when the facility location is selected by the procedure designer.

2. *Facility location fixed*

2.1   Plot points on the vertical axis corresponding to procedure start height (top) and height at FAF (bottom) (see Figure B2-1). From the top point construct two lines representing Categories A/B and C/D outbound descent limits: gradients of –245 m/min (–804 ft/min) and –365 m/min (–1 197 ft/min). From the bottom point construct two lines representing Categories A/B and C/D inbound descent limits: gradients of +150 m/min (+492 ft/min) and +230 m/min (+755 ft/min).

2.2   Indicate the "acceptable" envelope of height/time as illustrated.

2.3   Select suitable values of nominal outbound time/minimum outbound height within the "acceptable" Categories A/B envelope (if you select a time for which pre-calculated area templates are available, you will save much work). Make a note of the maximum value of the "minimum outbound height" corresponding to the selected time.

2.4   For the minimum outbound height selected in 2.3 above, select a suitable value of nominal outbound time within the "acceptable" Categories C/D envelope. Whilst the same time outbound *may* be specified for both A/B and C/D groups, the calculation suggested will both reduce the airspace required and reduce procedure time for the faster aircraft.

Note.— For a procedure turn (45/180 variant only), the outbound time used in this calculation is taken as 1 min longer *than the outbound time specified for the procedure (i.e. if the procedure is restricted to "45/180 procedure turn only, time 2 min," then 3 minutes is used to calculate the maximum permitted descent).*

3. *Facility location to be selected*

3.1   Select a large sheet of graph paper and mark range from threshold from zero to 19 km (10 NM). Mark also 11 km (6 NM), which is the distance beyond which the final approach MOC has to be increased [PANS-OPS, Volume II, Part III, 6.4.6 b)]. Mark the vertical axis with height above MSL at 50 m (100 ft) intervals from zero up to the maximum likely start height for the procedure to be designed.

3.2   Construct two transparent templates as shown in Figures B2-2 and B2-3, one for descent outbound, the other for descent inbound. The vertical dimensions indicated must be to the same scale as the vertical scale used on the graph paper in 3.1 above. The horizontal scale may be any convenient dimension divided into three and suitably subdivided for nominal outbound times from one to three minutes.

3.3   To use, first draw a horizontal line on the graph at the procedure start height. Next mark a point 15 m (50 ft) above threshold altitude elevation. From this point, plot the optimum 5 per cent (and maximum 6.5 per cent) final approach gradients towards the FAF. Take the transparencies and locate their vertical axes at the proposed FAF range before the threshold. Slide the "outbound" transparency vertically to locate its origin at the procedure start height. Slide the "inbound" transparency vertically to locate its origin at the next 50-m (100-ft) increment below the final approach gradient line (optimum or maximum as required). The transparencies will then show the acceptable envelopes of nominal outbound time and minimum height outbound (see Figure B2-4). When a check of obstacles within the racetrack/reversal area has been made, the minimum outbound height can be confirmed or adjusted. The effect of changing the facility/FAF location may be reviewed by adjusting the transparencies.

Note.— If the procedure is restricted to circling minima, the origin of the final approach line is plotted from the circling altitude instead of 15 m (50 ft) from the surface (PANS-OPS, Volume II, Part III, 26.4.5).

Calculation Routine 3

Calculation of OCH for Final Approach and Straight Missed Approach

1.   *Introduction.* The calculation of OCH for the final approach and straight missed approach is relatively simple when the OCH is clearly dependent on one obvious obstacle. However, where there are a number of obstacles in secondary areas and also obstacles in the interface between final approach and missed approach, it is not easy to identify the critical obstacle by inspection. This means OCH has to be calculated separately for a number of obstacles. A routine is presented to simplify the calculations involved.

2.   *Calculation.* The calculation of OCH involves five steps:

   a)   identify the range of the nominal MAPt, the SOC and the obstacle;

   b)   establish the primary area MOC at the obstacle range;

    Note.— Within the initial missed approach segment (between MAPt and SOC), the primary area MOC progressively reduces from that for final approach to that for missed approach. However, for on-aerodrome procedures (with fix error over-heading a facility presumed as zero), there may be a step change in MOC at the MAPt. See PANS-OPS, Part III, 7.1.7 and Figure III-7-3.

c) establish the semi-width of the area, and the reduction in MOC if the obstacle is within the secondary area at the obstacle location;

d) add the MOC calculated above the height of the obstacle;

e) if the obstacle is after the SOC, subtract d_o x tan Z, where d_o is the difference between the obstacle and SOC ranges, and tan Z is the tangent of the missed approach surface (nominal value 0.025).

3. *Implementation*

a) The positions of obstacles SOC and MAPt are related to a conventional x, y, z coordinate system with its origin at the facility. The x axis is parallel to the final approach track, positive x being measured before the facility and negative x being measured after the facility. The y axis is at right angles to the x axis.

b) Establish:

lx, ly, lz: obstacle location and height
$MAPt_x$: range of MAPt
SOC_x: range of SOC
MOC_f: MOC specified for final approach
MOC_{ma}: MOC specified for missed approach
SWFAC: semi-width of the area at the facility
SPLAY: splay of the area associated with the facility
Tan Z: tangent of the missed approach surface (gradient per cent/100)

c) Calculate:

$A = \max \{MOC_{ma}; \tan Z (lx - SOC_x) + MOC_{ma}\}$

$B = \min \{A; MOC_f\}$

If $lx < MAPt_x$, $B = MOC_f$

$MOC_x = \min \{B; 2B(l-|ly|/(SWFAC + |lx| \tan SPLAY))\}$

If $MOC_x < 0$, the obstacle is OUTSIDE the area and can be disregarded (but if a turn at an altitude is specified in the missed approach, refer to PANS-OPS, Volume II, Part III, 7.3.4.6 regarding provision for safeguarding early turns).

$D = \max \{0; SOC_x - lx\}$
$OCH = lz + MOC_x - D \times \tan Z$

Standard values for the parameters are:

MOC_f: with FAF 75 m (246 ft)
          without FAF 90 m (295 ft)

MOC_{ma}: straight missed approach 30 m (98 ft)
          turning missed approach 50 m (164 ft)

SWFAC: 1.85 km (1 NM) for VOR
          2.3 km (1.25 NM) for NDB

SPLAY: VOR 7.8° (tan SPLAY = 0.136983)
          NDB 10.3° (tan SPLAY = 0.181731)

3. *Example.* Off-aerodrome NDB procedure, distance from FAF to MAPt 6 340 m, distance from FAF to SOC 9 620 m, for Category D 2.5 per cent missed approach gradient.

$MAPt_x = -6\ 340$
$SOC_x = 9\ 620$
$MOC_f = 75$
$MOC_{ma} = 30$
$SWFAC = 10.3°$
$\tan Z = 0.025$

x	y	z	OCH
−6 000	0	10	85
−9 000	0	40	86
−9 000	3 000	60	82
−10 000	0	60	80.5
−10 000	3 500	80	79.5

Calculation Routine 4

Grid/xyz Conversion

1. *Introduction.* It is frequently convenient to collate and record obstacle position information in the form of grid

coordinates. Whilst this may be converted to the xyz, Cartesian conversions are readily made by calculator or computer using the following routine.

2.   *Implementation*

   a) *Frame of reference.* Positions of obstacles (in grid coordinates) are to be converted to a conventional xyz coordinate system with origin at threshold (facility), the direction of flight. The y axis is at right angles to the x axis, negative values of y being measured to the left of the aircraft.

   b) *Calculation*

   Given:

   DATEAST = grid easting of datum (threshold or facility) (m)

   DATNRTH = grid northing of datum (threshold or facility) (m)

   OBSEAST = grid easting of obstacle (m)

   OBSNRTH = grid northing of obstacle (m)
   FAB = final approach (or desired centre line) bearing (° grid)

   Calculate:

   A = sin (FAB + 180)
   B = cos (FAB + 180)

DIFFEAST = OBSEAST – DATEAST
DIFFNRTH = OBSNRTH – DATNRTH

x = A × DIFFEAST + B × DIFFNRTH
y = A × DIFFNRTH + B × DIFFEAST

3.   *Example.* Threshold location 378356, 381378. Final approach bearing (magnetic 060°, variation 9.4°W, convergence angle 0.2°E obstacle location 379571, 371115.

FAB (grid) = magnetic bearing – variation + convergence angle = 060° – 9.3° – 0.2° = 51.5°
DATEAST = 378357
DATNRTH = 391378
OBSEAST = 379571
OBSNRTH = 371115
FAB = 51.5°

A = SIN (51.5 + 180) = –0.792608
B = COS (51.5 + 180) = –0.622515

DIFFEAST = 379571 – 738357 = 1214
DIFFNRTH = 371115 – 391378 = –10263

x = –0.782608 × 1 214 + (–0.622515) × (–10263)
y = –0.782608 × (–10263) – (–0.622515) × 1214

x = + 5 439
y = + 8 788

In runway coordinates, the obstacle is 5 439 m before the threshold and 8 788 m from the final approach track (on the right-hand side as seen from an aircraft on approach).
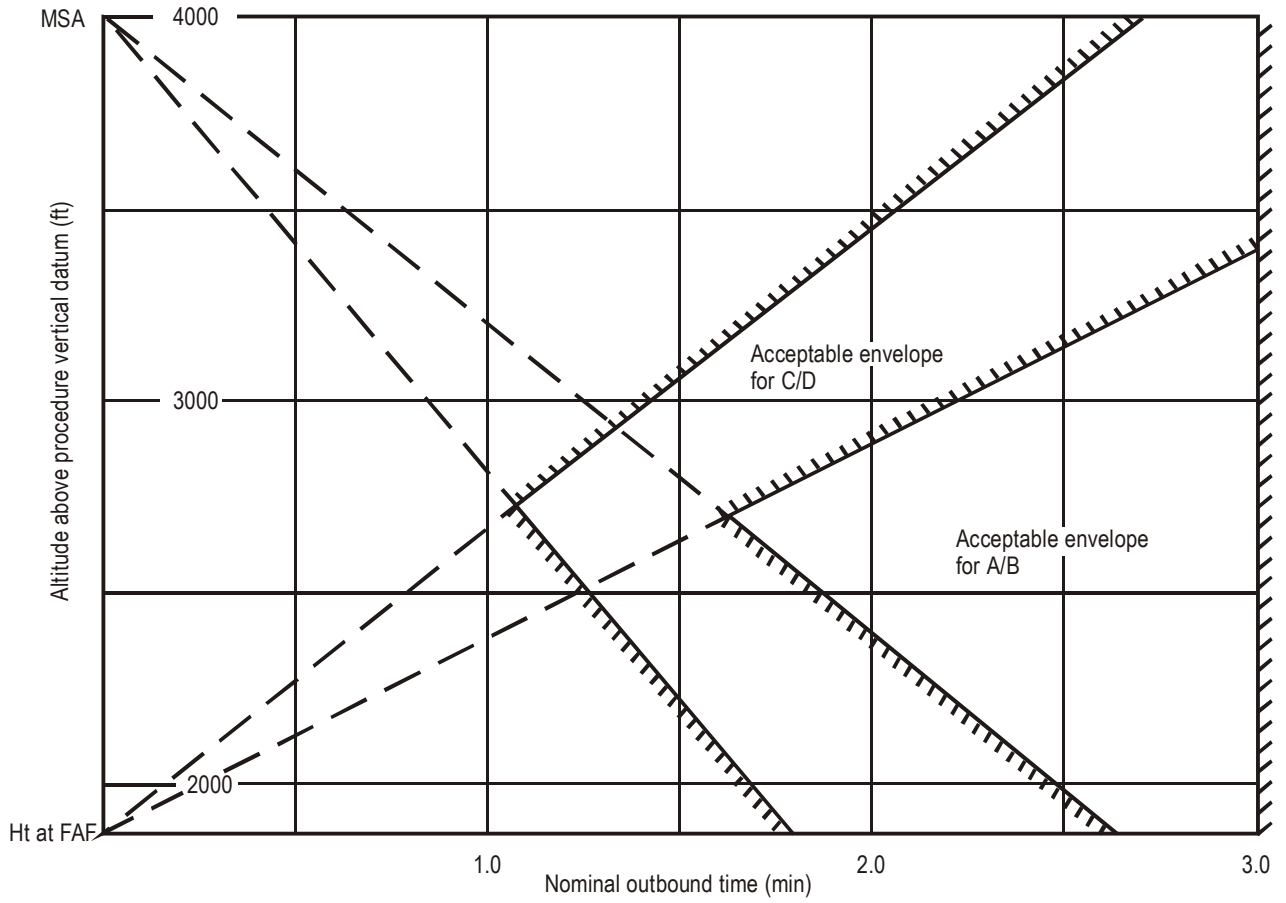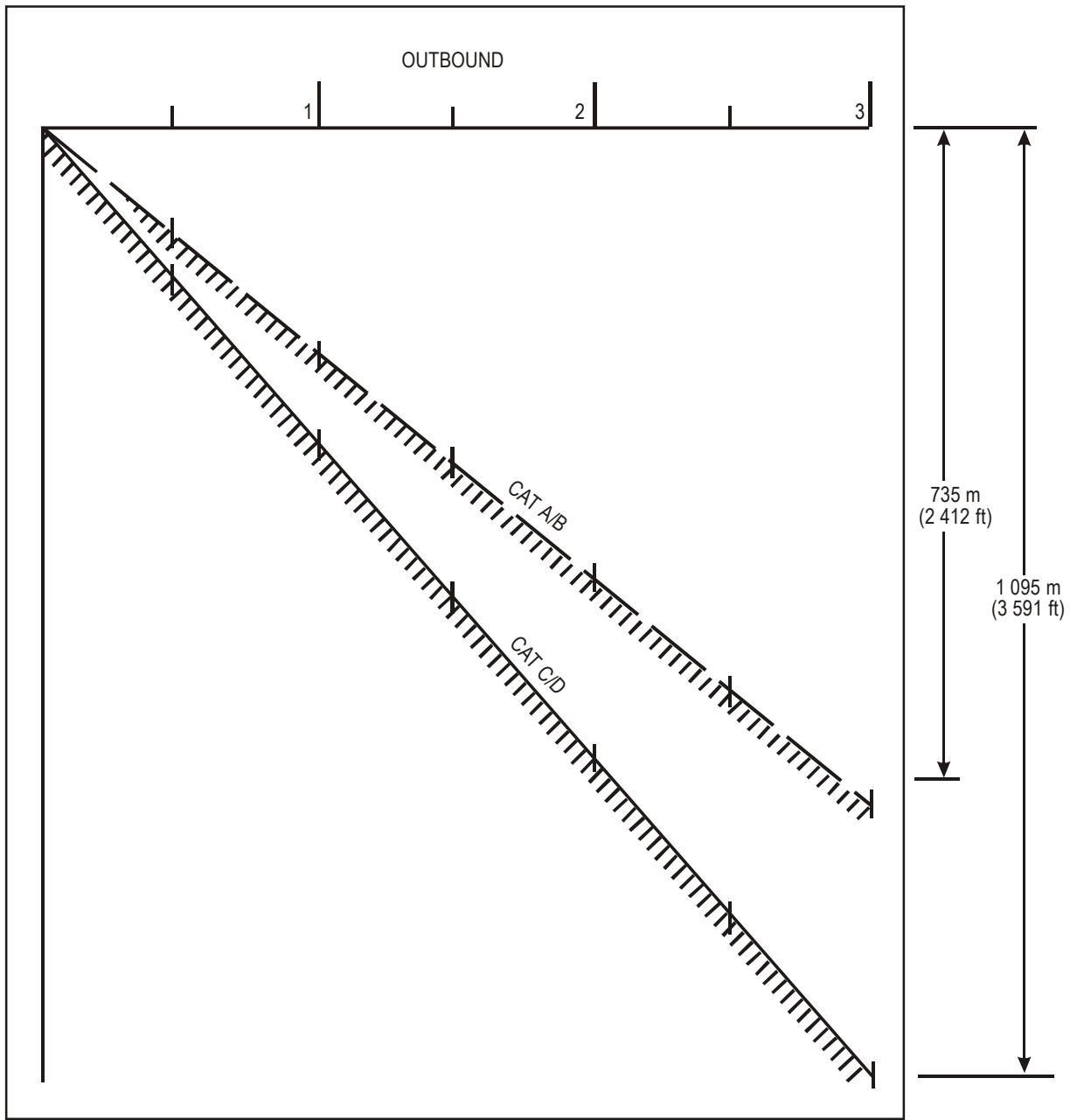
Figure B2-1

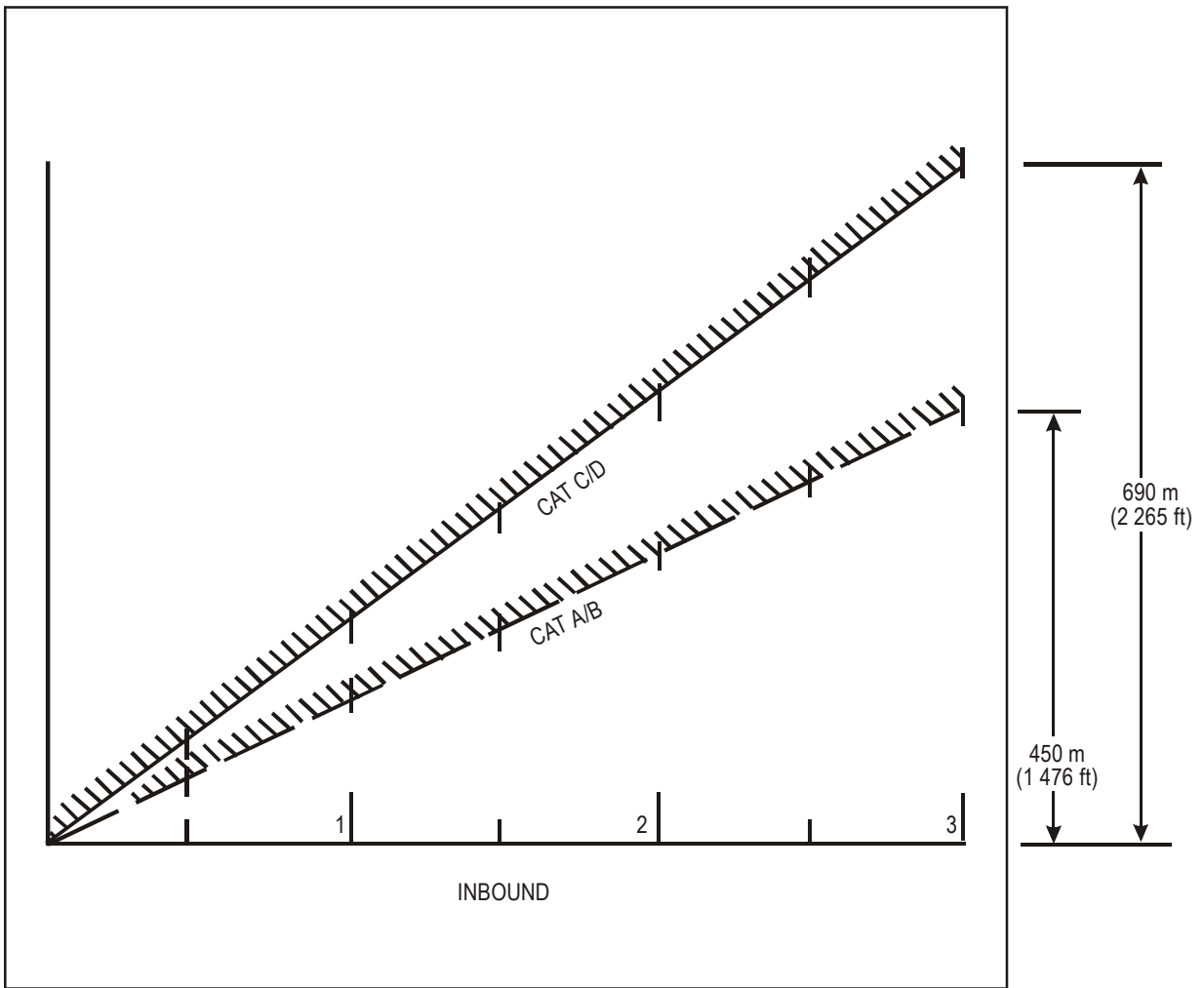**Figure B2-2.   Outbound template**
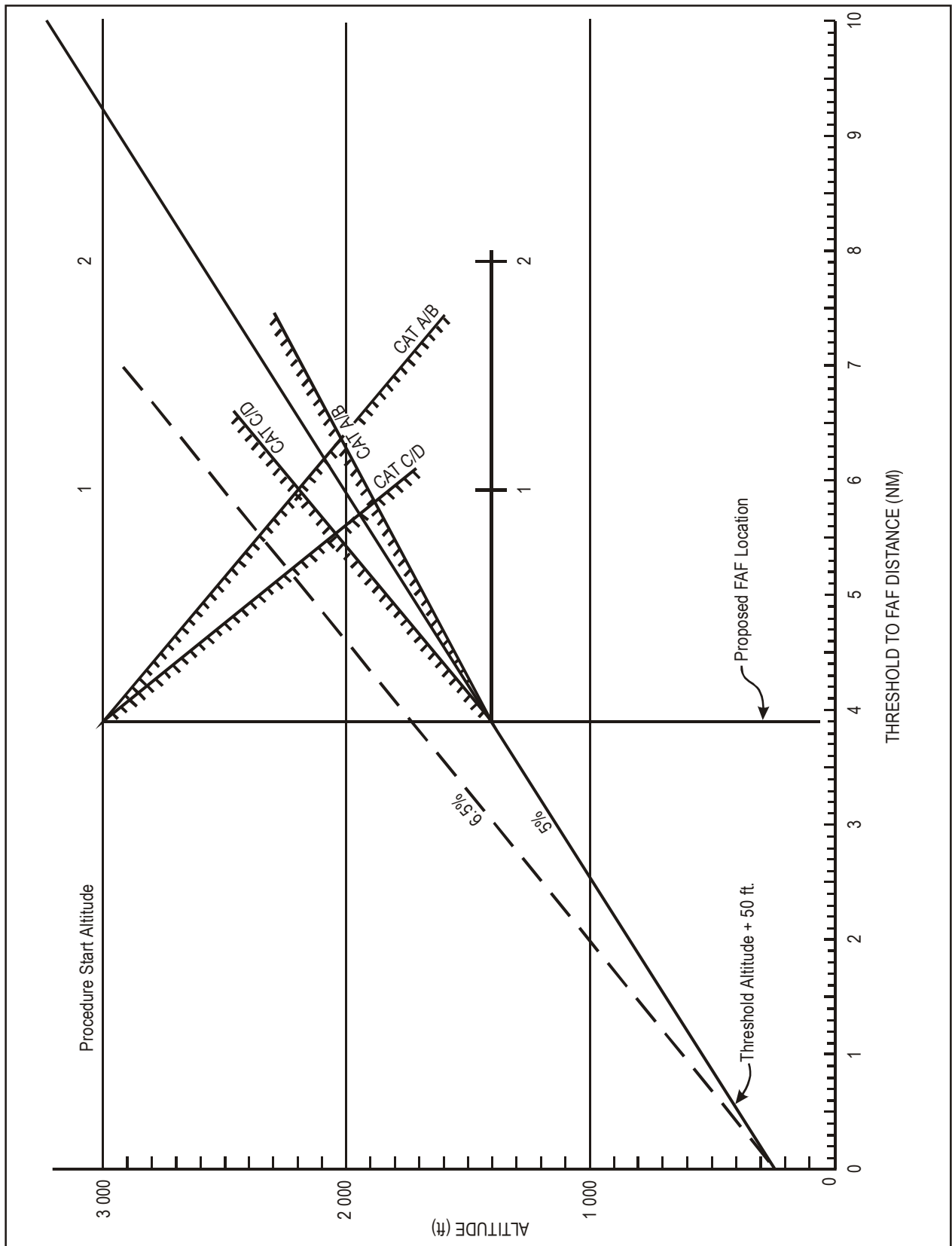
Figure B2-3.   Inbound template

Figure B2-4. Use of descent planning transparencies

Attachment B3

Amplification of Certain Details Related to Procedures Design

The PANS-OPS is a concise document. This Attachment expands and amplifies some of the more complex criteria. The material in this Attachment is based on and in no way supersedes the criteria in the PANS-OPS.

1. *Stepdown-fix calculations.* It has not always been appreciated that the 15 per cent surface effectively increases the MOC within the fix tolerance area before the fix. In addition, where the fix is a facility, the dimensions of its tolerance area vary with altitude — which complicates the calculations. See Figure B3-1 for a method of avoiding calculation by trial and error (PANS-OPS, Volume II, Part III, 2.8.2, 2.8.3 and 2.8.4).

2. *TTT areas for slow aircraft.* For racetrack and for holding procedures, the area should be calculated and drawn for the fastest aircraft to be accommodated. Although the area based on the slow speed (i.e. 90 kt) aircraft in strong winds may in some places be larger than the area so constructed, it is considered that the normal operational adjustments made by pilots are such that the aircraft will be contained. However, for base and procedure turns, the area for 90 kt should be checked in addition to that for the fastest category; for this purpose, an additional 90 kt template has been incorporated in the *Template Manual for Holding, Reversal and Racetrack Procedures* (Doc 9371).

3. *Requirement for separate instrument approach charts.* To obtain the minimum possible value of OCA/H, a procedure designer may wish to specify a different MAPt for one category (or group of categories). This may arise when the OCA/H is determined by a missed approach obstacle, and there is a considerable difference between SOC locations for different categories. Although not stated in Annex 4 or PANS-OPS, it is suggested that separate approach charts be produced in these cases.

4. *Reduction of MOC in initial missed approach area.* Note that the reduction in MOC projected back into the initial missed approach segment before SOC should not be projected back before the MAPt (see Figure B3-2). PANS-OPS, Volume II, Part III, 7.1.7 refers.

5. *MAPt defined by timing over a specified distance.* Note that the illustration of the RSS method contained in the PANS-OPS shows the calculation for one aircraft speed (the maximum TAS); however, because of wind effect, slower aircraft may be more critical in some cases (PANS-OPS, Volume II, Part III, 7.1.9.3).

6. *Turn at the FAF.* If a turn is specified at the FAF, the parameters required to calculate the area are not specified. It is suggested that the areas are calculated on the basis of the fastest "final approach IAS" from PANS-OPS, Volume II, Part III, Table III-1-1 appropriate to the procedure, corrected to TAS for aerodrome elevation at ISA + 15, and the standard omnidirectional wind for the height (PANS-OPS, Volume II, Part III, 5.3).

7. *Reduction in area widths — Attachment K.* The significance of the inclusion of criteria for "possible reduction of the width of the initial approach area" as an attachment instead of in the main text is not explained. This material was so placed to indicate that it represents an option. Additional material relating to use of this criteria in constructing initial/intermediate areas is illustrated in Figure B3-3.

8. *Termination of ILS precision segment.* The definition of the termination of the precision segment contained in PANS-OPS, Volume II, Part III, 21.4.6 appears to be in conflict with PANS-OPS, Volume II, Part III, 21.5.2.1. It is intended that the precision segment terminates before the point where the Z surface reaches 300 m only when a turn TP (turn at fix) or TP (turn at altitude).

9. *Use of OCH based on radio altimeter*

9.1   The OCH promulgated on instrument approach charts for precision approach is a height above runway threshold.

9.2 At locations where the OCH is based on radio altimeter height loss values, PANS-OPS, Volume II, Part III, 21.4.8.8.3.3 requires that the terrain/surface conditions be operationally suitable to provide repeatable information in the area where radio altimeter heights are to be used. Operators are expected to make appropriate allowances for the profile and transverse slope of the surface.

9.3 The allowance for the difference in the OCH and the radio altimeter height is a part of the "operational considerations" referred to in PANS-OPS, Volume II, Part III, Figure III-6-1.

10. *On-aerodrome procedure — landing threshold.* It is suggested that if the landing threshold is located more than 1 NM before the facility (although the facility is within 1 NM of the aerodrome), this distance should be accounted for by increasing the outbound time beyond that necessary to achieve the required descent (PANS-OPS, Volume II, Part III, Chapter 25).

11. *On-aerodrome procedure — calculation of maximum permitted descent.* Maximum permitted descent/outbound nominal times are calculated using the criteria in PANS-OPS, Volume II, Part III, 4.7.1, Table III-4-1. However, the lower datum to be used in the calculations is unspecified. It is intended that descent be calculated to:

a) an elevation 15 m above threshold for straight-in approaches; and

b) an altitude/height of circling OCA/H for circling approaches.

(PANS-OPS, Volume II, Part III, 25.5)

12. *Standard conditions for ILS procedures — Glide path antenna/wheel dimension.** The PANS-OPS specifies standard assumptions upon which the ILS procedures are based and states that adjustments are mandatory when conditions differ adversely from those specified. One of these assumptions concerns the maximum aircraft dimensions. The maximum semi-span (30 m) is adequate for all current civil transport aircraft, but the glide path antenna/wheel dimension (6 m) is exceeded at present by approximately six aircraft, the most adverse value being about 10 m (list of typical values in Table B3-1). Since these aeroplanes represent a significant proportion of current civil air traffic, it is desirable that a common method of deriving and publishing appropriate OCA/H values for them be used. The OCA/H values published on instrument approach charts are based on the "standard" dimensions. Occasionally, the larger glide path antenna/wheel dimension will require an increased OCA/H. Therefore, OCA/H values should also be calculated based on the largest current glide path antenna/wheel dimension (10 m) and when these OCA/H values exceed those for the "standard" dimensions:

a) the approach chart should be annotated:

"increased OCA/H values apply to aeroplanes exceeding a 6 m glide path antenna wheel dimension;" and

b) the increased OCA/H values should also be shown for use by operators of such aeroplanes.

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* The vertical distance between the flight paths of the wheels and the GP antenna.

Table B3-1

Aeroplane type	Glide path antenna to wheel distance
B-707	4 to 7 m
B-727	4 to 7 m
B-747	4 to 7 m
DC-8	4 to 7 m
DC-10	9 m
DHC-4	8 m
IL-18	7 m
IL-6Z	5 to 9 m
L-1011	7 to 10 m

Note.— These values may vary between aeroplanes of the same type.
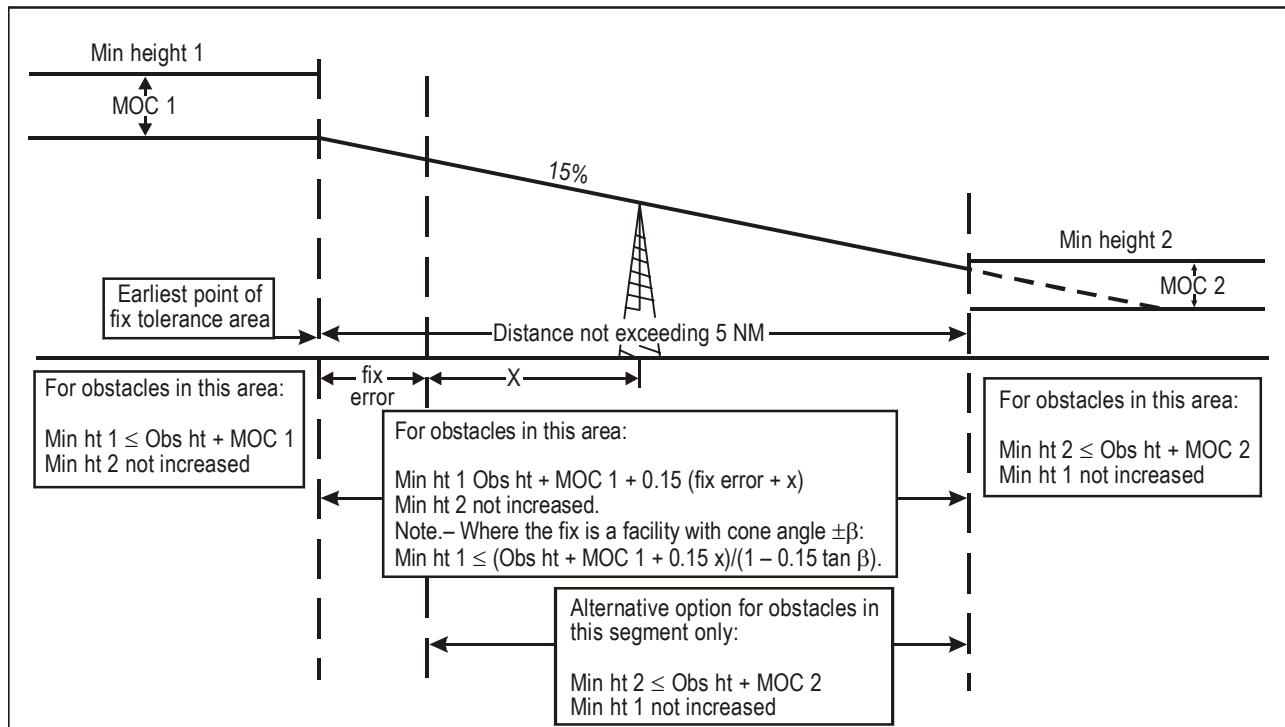
Figure B3-1.   Stepdown fix — calculation of minimum heights

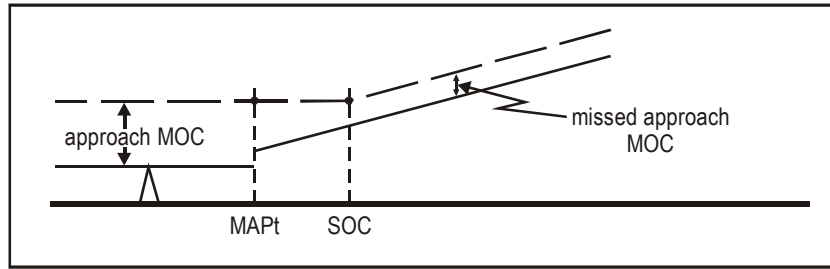**Figure B3-2.   MOC in initial missed approach area**
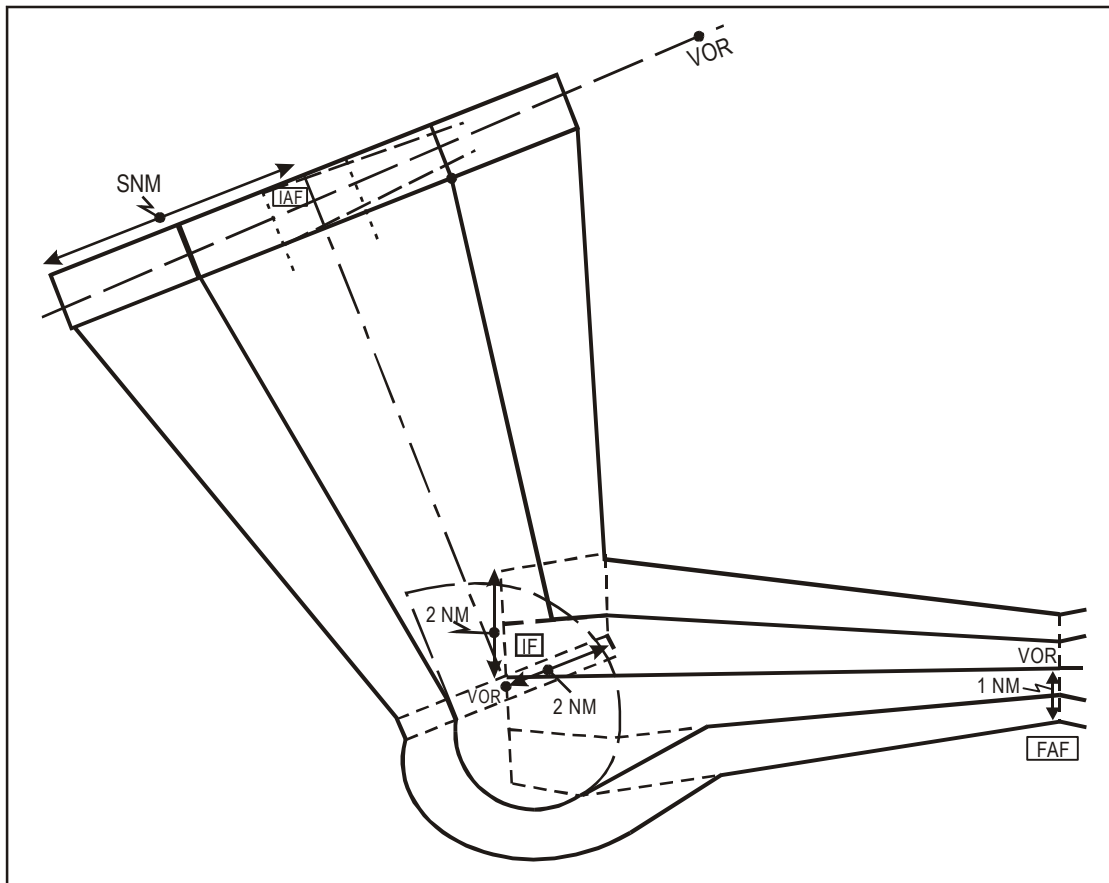

**Figure B3-3.   Reduction in area widths — initial segment
joined to intermediate segment by a turn**

Attachment B4

EXAMPLES OF OAS CALCULATIONS

1.   INTRODUCTION

This attachment contains the following examples:

— paragraph 4: Calculation of OAS height equations
— paragraph 5: Calculation of OAS templates
— paragraph 6: adjustment of OAS for:
   1 — ILS reference datum at threshold
   2 — aircraft size
   3 — autopilot operation in Category II
— paragraph 7: Step by step obstacle assessment (Category II)
— paragraph 8: Calculation of the required glide path angle to provide OAS that is above a defined obstacle.

2.   BASIC INFORMATION

2.1   *Description of tables.* The tables with OAS data are given in PANS-OPS, Volume II, Attachment I to Part III for small steps in glide path angle and localizer-threshold distance and must be entered with the known glide path angle and localizer-threshold distance. A commonly used page of Attachment I to Part III (for 3° glide path angle and 3 000 m localizer-threshold distance) is reproduced in Table III-21-3 of PANS-OPS, Volume II. All example calculations in this attachment are in metres. For use of feet see Part I, Chapter 3 of PANS-OPS, Volume II.

2.2   *OAS height equations.* The A, B and C coefficients are given for all surfaces in the Category I and the Category II cases (flight director; autopilot). For the Y and Z surfaces the results are partitioned for the different missed approach climb gradients (2, 2.5, 3, 4 and 5 per cent).

2.3   *OAS template coordinates at threshold level.* The x and y coordinates of the templates at threshold elevation are given in metres for Category I and II approaches. The position of point E (Figure B4-1) is specified for different climb gradients.

2.4   *OAS template coordinates at specified heights.* The x and y coordinates at 300 m for Category I and at 150 m for Category II are specified. Furthermore the coordinates are given for point C"", which determines the intersection between the W and W* (autopilot only) surfaces. The height at which these surfaces intersect is given at the bottom of the tables.
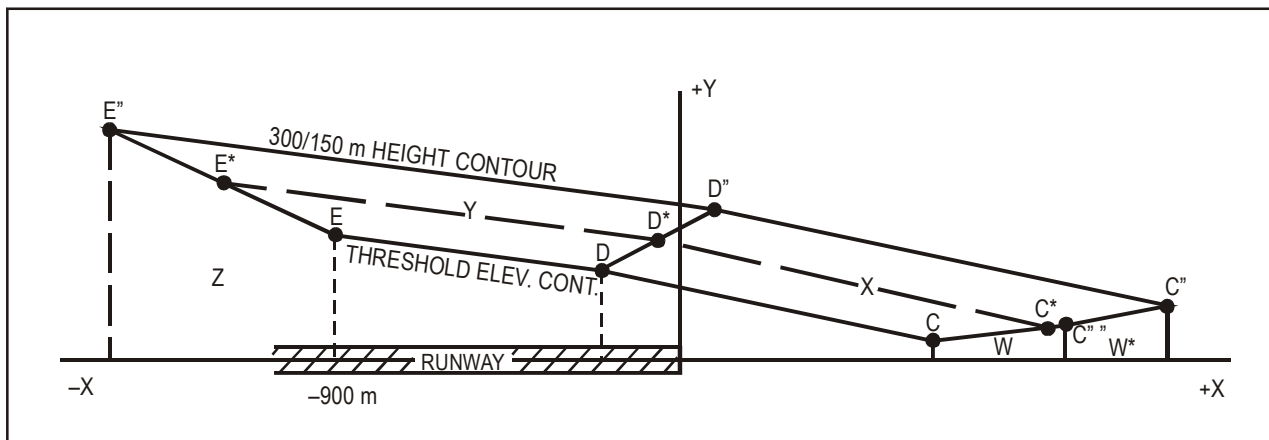

Figure B4-1.   OAS templates

3. EXAMPLE PARTICULARS

3.1 *Equipment definition*

a) ILS A: Category I
    glide path angle: $3°$
    LLZ threshold distance: 3 000 m
    ILS sector width at threshold: 210 m
    ILS reference datum height (RDH): 18 m

b) ILS B: Category II
    glide path angle: $3°$
    LLZ threshold distance: 3 000 m

3.2 *Aircraft definition (missed approach climb gradient 2.5 per cent)* For explanation of dimensions see PANS-OPS, Volume II, Part III, Chapter 21, 21.1.3 and 21.4.8.7.2.

a) aircraft 1: Standard size

$$s = 30 \text{ m}$$
$$t = 6 \text{ m}$$

b) aircraft 2:

$$s = 32 \text{ m}$$
$$t = 9 \text{ m.}$$

3.3 *Obstacle environment*

Table B4-1. Obstacle example

Obstacle	x coordinate (m)	y coordinate (m)	Height above threshold (m)
1	160	45	1.5
2	400	180	37.0
3	800	350	50.0
4	8 000	2 500	140.0
5	–450	200	6.0

3.4 *Threshold elevation*. 152 m. This value will be considered in OCA/H calculations.

4. CALCULATION OF OAS HEIGHT EQUATIONS (NO ADJUSTMENTS)

4.1 *ILS A*. The equations for the unadjusted OAS, pertinent to ILS A, can be obtained using Table III-21-3 of PANS-OPS, Volume II:

W surface: $z = 0.028500 \, x - 8.01$
X surface: $z = 0.027681 \, x + 0.182500 \, y - 16.72$
Y surface: $z = 0.023948 \, x + 0.210054 \, y - 21.51$
Z surface: $z = -0.02500 \, x - 22.50$

4.2 *ILS B*. The OAS height equations for ILS B can be obtained using Table III-21-3 of PANS-OPS, Volume II:

W surface: $z = 0.035800 \, x - 6.19$
X surface: $z = 0.035282 \, x + 0.234700 \, y - 21.59$
Y surface: $z = 0.031955 \, x + 0.280291 \, y - 28.70$
Z surface: $z = -0.02500 \, x - 22.50$

5. CALCULATION OF OAS TEMPLATES

ILS A:

a) *Threshold contour* (see Figure B4-1). From Table III-21-3 of PANS-OPS, Volume II, the following coordinates can be obtained:

Table B4-2. Template coordinates at threshold elevation

Point	x coordinate (m)	y coordinate (m)
C	281	49
D	–286	135
E	–900	205

b) *300 m contour*. In Table III-21-3 of PANS-OPS, Volume II, the coordinates of the 300 m contour are given.

Table B4-3. Template coordinates at 300 m

Point	x coordinate (m)	y coordinate (m)
C"	10 807	96
D"	5 438	910
E"	–12 900	3 001

c) *Contour at arbitrary height*. The position coordinates of the points C*, D* and E* (Figure B4-1) of the template at a specific height (not being the threshold elevation or the 300 m height for Category I and 150 m for Category II) can be calculated by solving the equations for the two

adjacent surfaces, which contain two unknowns (x, y). The equations for these surfaces are derived from Table III-21-3 of PANS-OPS, Volume II, and given in 4.1.

Table B4-4.   Template points and surface equations to be used

Required point of template	Surfaces for which equations are to be solved
C*	W; X
D*	X; Y
E*	Y; Z

As an example the position coordinates of point D* will be calculated at 140 m height for ILS A and aircraft 1.

According to Table B4-4 the equations for the X and Y surfaces have to be used to find the x and y coordinates of point D*.

From 4.1 and after substitution of z = 140 the following set of equations is found:

X surface: 140 = 0.027681 x + 0.182500 y – 16.72
Y surface: 140 = 0.023948 x + 0.210054 y – 21.51

or after rearrangement:

X surface: 156.72 = 0.027681 x + 0.182500 y
Y surface: 161.51 = 0.023948 x + 0.210054 y

The solution of this set of two equations in two unknowns is basic algebra and only the result will be given:

D*: x coordinate   2 385 m
    y coordinate   497 m

6.   ADJUSTMENT OF OAS

(No accumulation of the adjustments in these examples; the A and B coefficients given in 4.1 are rounded to four decimal points.)

6.1   *ILS reference datum height at threshold.* The physical properties of ILS A would permit an adjustment to the W, X and Y surfaces because of the difference between the RDH (18 m) and the standard height of 15 m.

$$C_{corr} = C + (RDH - 15)$$
$$C_{corr} = C + 3$$

The OAS height equations for ILS A, using the corrected C coefficient, are:

W surface: z = 0.0285 x – 5.01
X surface: z = 0.0277 x + 0.1825 y – 13.72
Y surface: z = 0.0239 x + 0.2101 y – 18.51
Z surface: unchanged

6.2   *Aircraft size.* The adjustment for aircraft size will be explained in an example for ILS B and aircraft 2:

One of the factors required for the adjustment of the X and Y surfaces is: "P".

$$P = \max \left\{ \frac{t}{B_x}; \ s + \frac{t-3}{B_x} \right\} - \max \left\{ \frac{6}{B_x}; \ 30 + \frac{3}{B_x} \right\}$$

$$P = \max \left\{ \frac{9}{0.2347}; \ 32 + \frac{6}{0.2347} \right\}$$

$$- \max \left\{ \frac{6}{0.2347}; \ 30 + \frac{3}{0.2347} \right\}$$

$$P = \max \{38.3 \ ; \ 57.6\} - \max \{25.6 \ 42.8\}$$

$$P = 57.6 - 42.8 = 14.8$$

The correction to the height equations is done by an adjustment of the coefficient C:

$$C_{corr} = C - B \ P$$

In this formula, B stands for the B coefficient of either the X or Y surface height equation.

W surface:

The surface calculated in 4.2 is:

$$z = 0.0358 \ x - 6.19$$

The adjusted height equation for the W surface becomes:

z = 0.0358 x + [–6.19 – (9 – 6)]
z = 0.0358 x – 9.19

X surface:

The unadjusted height equation is:

$$z = 0.0353 \ x + 0.2347 \ y - 21.59$$

Using the above-mentioned formula the adjusted equation is:

z = 0.0353 x + 0.2347 y + [–21.59 – (0.2347) (14.8)]
z = 0.0353 x + 0.2347 y – 25.09

Y surface:

The unadjusted height equation is:

$$z = 0.0320\ x + 0.2803\ y - 28.70$$

The adjusted height equation is:

$$z = 0.0320\ x + 0.2803\ y + [-28.70 - (0.2803)\ (14.8)]$$
$$z = 0.0320\ x + 0.2803\ y - 32.85$$

6.3   *Autopilot operation in Category II.* In the Category II ILS for the autopilot operation a different set of surfaces is given in Table III-21-3 of PANS-OPS, Volume II. An additional surface W* intersects the W surface at 1 000 m before threshold and extends in a downwind direction. The calculation of the height equations follows the same procedure as explained in paragraph 4. The last three columns at the top of the tables have to be used. The template for the threshold contour is identical with the standard (flight director) case (identical calculations as in paragraph 5). The template at 150 m can be calculated from the last two columns at the bottom of the tables. In addition the coordinates of point C'''' are given at the height at which the W and W* surfaces intersect. This height is given in the note of each table.

7.   STEP-BY-STEP OBSTACLE ASSESSMENT (CATEGORY II)

The assessment of an obstacle environment (without the use of the collision risk model) is a step-by-step process,

which can best be illustrated by an example. The obstacles are defined in 3.3. The ILS is Category II and defined as ILS B in 3.1. The aircraft considered in the example has the standard size. The OAS height equations as determined in 4.1 for the Category I ILS and in 4.2 for the Category II ILS are:

Category I ILS:

W surface: $z = 0.0285\ x - 8.01$
X surface: $z = 0.0277\ x + 0.1825\ y - 16.72$
Y surface: $z = 0.0239\ x + 0.2101\ y - 21.51$
Z surface: $z = -0.025\ x - 22.50$

Category II ILS:

W surface: $z = 0.0358\ x - 6.19$
X surface: $z = 0.0353\ x + 0.2347\ y - 21.59$
Y surface: $z = 0.0320\ x + 0.2803\ y - 28.70$
Z surface: $z = -0.025\ x - 22.50$

a)   *Use of Annex 14 surfaces and extensions:* In Table B4-5 the height of the appropriate basic ILS surfaces are given in the columns. If the obstacle is outside the underlying area the surface is labelled: "Not applicable" (NA).

b)   *Use of OAS*: The obstacles which penetrate the above-mentioned basic ILS surfaces have to be further assessed by the OAS. It should be noted that wherever the OAS height, which is determined from either W (W*), X, Y and Z surface is less than

Table B4-5.   Height (m) of basic ILS surfaces at the position of the defined obstacles

Obstacles	Obstacle height (m)	Inner approach surface	Inner transitional surface (1:3)	Approach surface section 1	Approach surface section 2	Runway strip	Transitional surface (1:7)	Extended transitional surfaces (1:7)	Missed approach surface	Penetration YES/NO
1	1.5	2	NA	2	NA	NA	NA	NA	NA	NO*
2	37.0	NA	NA	6.8	NA	NA	NA	NA	NA	YES
3	50.0	NA	NA	NA	NA	NA	28.6	NA	NA	YES
4	140.0	NA	NA	NA	NA	NA	NA	NA	NA	NO
5	6.0	NA	NA	NA	NA	NA	7	NA	NA	NO

* Provided lightweight and frangible

the Annex 14 surface height, the last mentioned height prevails as the OAS height.

In the OAS assessment the obstacles 2 and 3 are further treated. None of the obstacles is higher than 150 m, which would require a first assessment against the OAS for Category I ILS. If the obstacle coordinates are substituted in the Category II height equations, the following table results:

Table B4-6.   Height of OAS over defined obstacles

| | *Height OAS (m)* | | | |
Obstacle	*W surface*	*X surface*	*Y surface*	*Z surface*
2	8.1	<u>34.8</u>	34.6	−32.5
3	22.5	88.8	<u>95.0</u>	−42.5

From Tables B4-5 and B4-6 the following conclusions can be drawn:

— As the OAS over an obstacle is the highest value of the subsequent OAS *and* Annex 14 surfaces, the underlined values are *the* OAS heights over the respective obstacles.

— Comparison of these OAS heights and the obstacle heights only shows a penetration of the X surface by obstacle 2.

c) *Determination of OCA/H*: The different *OCA/H* values for this approach which have to be promulgated by the State, using the height loss/ altimeter margins of Table III-21-4 of PANS-OPS, Volume II, for the different aircraft categories are:

Table B4-7.   Height loss/altimeter margins and promulgated *OCA/H*
(Use of radio altimeter assumed)

Aircraft category	*Height loss/ altimeter margin (m)*	*Promulgated* OCH (m)*	*Promulgated* OCA (m)*
A	13	50	202
B	18	55	207
C	22	59	211
D	26	63	215

*   Prior to promulgation of these values operational checks shall have confirmed the repeatability of radio altimeter information (see PANS-OPS, Volume II, Part III, 21.4.9.3).

An extension of this runway for Category III operations is not possible because the *OCA/H* is above the height at which the Annex 14 obstacle limitation surfaces for Category II approaches terminate (45 m). However, if Category III operations are required, they may be promulgated provided the inner approach, the inner transitional and the baulked landing surfaces are enlarged to the height of the *OCA/H* for the appropriate aircraft category (see Figure III-21-6 of PANS-OPS, Volume II).

8.   CALCULATION OF THE REQUIRED GLIDE PATH ANGLE TO PROVIDE OAS THAT ARE ABOVE A DEFINED OBSTACLE

This problem cannot be resolved directly as the glide path angle is contained implicitly in the tabulated data. However, it can be resolved by an iterative method in which the data in Attachment I to Part III of PANS-OPS, Volume II, are used to obtain the desired glide path angle by means of bracketing. The glide path angle selected will be the higher of the bracketed values.

Attachment B5

Collision Risk Model

Example of CRM Calculation Request and Results based on Data from Chapter 7

On the basis of Chapter 5, Table II-2-5-2, "List of obstacles", the following CRM calculation has been made. After physical measurement of the height of obstacles O_{1-25}, the elevations (Z) have been revised and entered in the CRM. For the calculation, use is made of CD-101 "PANS-OPS Software". The results of the calculation can be found in this attachment. For the interpretation of the result, see the *Manual on the Use of the Collision Risk Model (CRM) for ILS Operations* (Doc 9274).

The PANS-OPS_Software comprises several computer programmes including the ICAO Collision Risk Model (CRM). ICAO, Infolution inc. and/or any other parties involved in the creation or distribution of these programmes take no responsibility whatsoever for damages, direct or indirect losses and/or for the correctness, accuracy or validity of the data entered into these programmes and/or for the applicability of these programmes to any specific case or data generated by said programmes. It is the responsibility of the user to verify all data used by these programmes for the specific cases and ensure the conformity to the proper norms and standards.

AERODROME DATA

IDENT AROM   Name   AROM RW22 ILS   A/D Elev.   34 m

Rwy   22   THR.   Elev.   34 m   Opp. Rwy   Elev.   0 m

Cat. I

Ref.——— Coordinates		Ref.——— Coordinates	
WGS84	Lat. N 56° 00' 00".0000	WGS84	Lat.
	Long. E 04° 28' 00".0000		Long.

NAVAID DATA

GP IDENT   MK   Name   AROM 22 GP

Ref.——— Coordinates		
WGS84	Lat.	Approved for: Cat. I
	Long.	GP antenna (°) 3
		ILS RDH 15 m

IDENT LLZ MK   Name   AROM 22 LOC

Ref.——— Coordinates		
WGS84	Lat. N 55° 58' 59".6857	Approved for: Cat. I
	Long. E 04° 26' 32".8909	LLZ THR Dist 2393.02 m
		LLZ course width at THR 210 m

GROUND DATA

Dist. from earliest point of FIX tolerance area to THR   12442 m

Standard termination of precision segment   ☑

If No then :

   A. Termination point before THR   ☐

   B. Distance from termination point to THR   0 m

AEROPLANE DATA

M/App CG (%)

2.5

CAT	STD	Wing S/Span	G/P Wheel
☑ A	☑	30	6
☑ B	☑	30	6
☑ C	☑	30	6
☑ D	☑	30	6

REQUESTED CASE

ILS APPROACH CATEGORY	Category I
OCA/OCH SELECTED	OCH (ABOVE THRESHOLD)
UNIT OF MEASUREMENT FOR OCA/H :	m

SPEED CATEGORY	RISK FOR SPECIFIED OCA/H REQUESTED? IF YES THEN OCA/H	MINIMUM ACCEPTABLE OCA/H REQUESTED
A	☐ 0	☑
B	☐ 0	☑
C	☐ 0	☑
D	☐ 0	☑

OBSTACLE DATA IN GEOGRAPHICAL COORDINATE SYSTEM   OBSTACLE IN CRM RUNWAY COORDINATE SYSTEM

Ident	Type	Latitude	Longitude	ASL (M)	X (M)	Y1 (M)	Y2 (M)	Z (M)	Description
2002M1407	Navaid	N 55° 58' 59".6857	E 04° 26' 32".8909	38.00	-2393.03	0.00	0.00	4.00 √	
2002M1422	Aircraft	N 55° 59' 58".1579	E 04° 27' 48".4031	46.00	-170.00	120.00	120.00	12.00 √	
2002M1423	Pole	N 55° 59' 51".0043	E 04° 27' 55".9444	51.00	-260.00	-120.00	-120.00	17.00 √	
2002N28	Tree	N 56° 01' 17".1153	E 04° 29' 55".0975	115.00	3100.00	-50.00	-50.00	81.00 √	
2002N29	Tree	N 56° 01' 15".0798	E 04° 29' 59".6048	130.00	3100.01	-150.00	-150.00	96.00 √	
2002N30	Tree	N 56° 01' 13".0442	E 04° 30' 04".1120	133.00	3100.00	-250.00	-250.00	99.00 √	
2002N31	Tree	N 56° 01' 11".0087	E 04° 30' 08".6193	146.00	3100.00	-350.00	-350.00	112.00 √	
2002N32	Tree	N 56° 01' 12".0745	E 04° 29' 47".8173	108.00	2900.01	-50.00	-50.00	74.00 √	
2002N33	Tree	N 56° 01' 10".0389	E 04° 29' 52".3245	121.00	2900.00	-150.00	-150.00	87.00 √	
2002N34	Tree	N 56° 01' 08".0034	E 04° 29' 56".8318	132.00	2900.00	-250.00	-250.00	98.00 √	
2002N35	Tree	N 56° 01' 05".9679	E 04° 30' 01".3390	144.00	2900.01	-350.00	-350.00	110.00 √	
2002N36	Tree	N 56° 01' 07".0336	E 04° 29' 40".5370	105.00	2700.00	-50.00	-50.00	71.00 √	
2002N37	Tree	N 56° 01' 04".9981	E 04° 29' 45".0443	117.00	2700.00	-150.00	-150.00	83.00 √	
2002N38	Tree	N 56° 01' 02".9626	E 04° 29' 49".5515	126.00	2700.00	-250.00	-250.00	92.00 √	
2002N39	Tree	N 56° 01' 00".9270	E 04° 29' 54".0588	140.00	2700.00	-350.00	-350.00	106.00 √	
2002N40	Tree	N 56° 01' 01".9928	E 04° 29' 33".2568	98.00	2500.00	-50.00	-50.00	64.00 √	
2002N41	Tree	N 56° 00' 59".9572	E 04° 29' 37".7640	108.00	2500.00	-150.00	-150.00	74.00 √	
2002N42	Tree	N 56° 00' 57".9217	E 04° 29' 42".2713	119.00	2500.00	-250.00	-250.00	85.00 √	
2002N43	Tree	N 56° 00' 55".8862	E 04° 29' 46".7785	130.00	2500.00	-350.00	-350.00	96.00 √	
2002N44	Spot height	N 56° 00' 16".3827	E 04° 28' 23".6608	50.00	650.00	0.00	0.00	16.00 √	OFZ PENETRATED?
2002N45	Spot height	N 56° 00' 07".6779	E 04° 28' 24".4936	59.00	450.00	-180.00	-180.00	25.00 √	
2002N46	Tree	N 56° 01' 22".1562	E 04° 30' 02".3778	110.00	3300.01	-50.00	-50.00	76.00 √	
2002N47	Tree	N 56° 01' 20".1206	E 04° 30' 06".8850	124.00	3300.00	-150.00	-150.00	90.00 √	
2002N48	Tree	N 56° 01' 18".0851	E 04° 30' 11".3923	132.00	3300.01	-250.00	-250.00	98.00 √	
2002N49	Tree	N 56° 01' 16".0496	E 04° 30' 15".8995	143.00	3300.01	-350.00	-350.00	109.00 √	

```
ILS  Category I OCH (ABOVE THRESHOLD)              Speed CAT. A
Minimum acceptable OCH (ABOVE THRESHOLD)       51  Metres



Total risk for this approach      9.5E-08
Risk of hitting the ground plane 2.4E-10

Obstacle with highest individual risk
2002N44    #21 hill            650.00       0.00        0.00     16.00  8.8E-08

Ident      Description       X metres Y1 metres Y2 metres Z metres     RISK
2002N46    #1 tree            3300.01     -50.00      -50.00     76.00  2.6E-11
2002N48    #3 tree            3300.01    -250.00     -250.00     98.00  7.3E-13
2002N49    #4 tree            3300.01    -350.00     -350.00    109.00  1.5E-14
2002N47    #2 tree            3300.00    -150.00     -150.00     90.00  1.2E-11
2002N29    #6 tree            3100.01    -150.00     -150.00     96.00  3.5E-10
2002N31    #8 tree            3100.00    -350.00     -350.00    112.00  1.0E-13
2002N28    #5 tree            3100.00     -50.00      -50.00     81.00  3.7E-10
2002N30    #7 tree            3100.00    -250.00     -250.00     99.00  3.7E-12
2002N35    #12 tree           2900.01    -350.00     -350.00    110.00  1.7E-13
2002N32    #9 tree            2900.01     -50.00      -50.00     74.00  2.6E-10
2002N33    #10 tree           2900.00    -150.00     -150.00     87.00  1.2E-10
2002N34    #11 tree           2900.00    -250.00     -250.00     98.00  1.1E-11
2002N39    #16 tree           2700.00    -350.00     -350.00    106.00  1.6E-13
2002N38    #15 tree           2700.00    -250.00     -250.00     92.00  7.5E-12
2002N36    #13 tree           2700.00     -50.00      -50.00     71.00  6.3E-10
2002N37    #14 tree           2700.00    -150.00     -150.00     83.00  2.1E-10
2002N43    #20 tree           2500.00    -350.00     -350.00     96.00  3.1E-14
2002N42    #19 tree           2500.00    -250.00     -250.00     85.00  3.3E-12
2002N40    #17 tree           2500.00     -50.00      -50.00     64.00  4.4E-10
2002N41    #18 tree           2500.00    -150.00     -150.00     74.00  6.5E-11
2002N44    #21 hill            650.00       0.00        0.00     16.00  8.8E-08
2002N45    #22 hill            450.00    -180.00     -180.00     25.00  9.7E-12
2002M1422  #23 aircraft h     -170.00     120.00      120.00     12.00  6.2E-10
2002M1423  AROM 22 GP         -260.00    -120.00     -120.00     17.00  3.2E-09
2002M1407  AROM 22 LOC       -2393.03       0.00        0.00      4.00  0.0E+00
* REPRESENTS A RISK LESS THAN 1.0E-15
```

```
ILS  Category I OCH (ABOVE THRESHOLD)                Speed CAT. B
Minimum acceptable OCH (ABOVE THRESHOLD)        54  Metres



Total risk for this approach      5.9E-08
Risk of hitting the ground plane 2.4E-10
Obstacle with highest individual risk
2002N44    #21 hill          650.00       0.00       0.00      16.00   5.1E-08

Ident      Description     X metres Y1 metres Y2 metres Z metres      RISK
2002N46    #1 tree          3300.01    -50.00     -50.00     76.00   2.6E-11
2002N48    #3 tree          3300.01   -250.00    -250.00     98.00   7.3E-13
2002N49    #4 tree          3300.01   -350.00    -350.00    109.00   1.5E-14
2002N47    #2 tree          3300.00   -150.00    -150.00     90.00   1.2E-11
2002N29    #6 tree          3100.01   -150.00    -150.00     96.00   3.5E-10
2002N31    #8 tree          3100.00   -350.00    -350.00    112.00   1.0E-13
2002N28    #5 tree          3100.00    -50.00     -50.00     81.00   3.7E-10
2002N30    #7 tree          3100.00   -250.00    -250.00     99.00   3.7E-12
2002N35    #12 tree         2900.01   -350.00    -350.00    110.00   1.7E-13
2002N32    #9 tree          2900.01    -50.00     -50.00     74.00   2.6E-10
2002N33    #10 tree         2900.00   -150.00    -150.00     87.00   1.2E-10
2002N34    #11 tree         2900.00   -250.00    -250.00     98.00   1.1E-11
2002N39    #16 tree         2700.00   -350.00    -350.00    106.00   1.6E-13
2002N38    #15 tree         2700.00   -250.00    -250.00     92.00   7.5E-12
2002N36    #13 tree         2700.00    -50.00     -50.00     71.00   6.3E-10
2002N37    #14 tree         2700.00   -150.00    -150.00     83.00   2.1E-10
2002N43    #20 tree         2500.00   -350.00    -350.00     96.00   3.1E-14
2002N42    #19 tree         2500.00   -250.00    -250.00     85.00   3.3E-12
2002N40    #17 tree         2500.00    -50.00     -50.00     64.00   4.4E-10
2002N41    #18 tree         2500.00   -150.00    -150.00     74.00   6.5E-11
2002N44    #21 hill          650.00      0.00       0.00     16.00   5.1E-08
2002N45    #22 hill          450.00   -180.00    -180.00     25.00   8.5E-12
2002M1422  #23 aircraft h   -170.00    120.00     120.00     12.00   8.5E-10
2002M1423  AROM 22 GP       -260.00   -120.00    -120.00     17.00   4.2E-09
2002M1407  AROM 22 LOC     -2393.03      0.00       0.00      4.00   0.0E+00
* REPRESENTS A RISK LESS THAN 1.0E-15
```

```
ILS  Category I OCH (ABOVE THRESHOLD)              Speed CAT. C
Minimum acceptable OCH (ABOVE THRESHOLD)      56  Metres


Total risk for this approach     8.3E-08
Risk of hitting the ground plane 2.3E-10
Obstacle with highest individual risk
2002N44    #21 hill          650.00      0.00      0.00    16.00  6.8E-08
```

Ident	Description	X metres	Y1 metres	Y2 metres	Z metres	RISK
2002N46	#1 tree	3300.01	-50.00	-50.00	76.00	2.6E-11
2002N48	#3 tree	3300.01	-250.00	-250.00	98.00	7.3E-13
2002N49	#4 tree	3300.01	-350.00	-350.00	109.00	1.5E-14
2002N47	#2 tree	3300.00	-150.00	-150.00	90.00	1.2E-11
2002N29	#6 tree	3100.01	-150.00	-150.00	96.00	3.5E-10
2002N31	#8 tree	3100.00	-350.00	-350.00	112.00	1.0E-13
2002N28	#5 tree	3100.00	-50.00	-50.00	81.00	3.7E-10
2002N30	#7 tree	3100.00	-250.00	-250.00	99.00	3.7E-12
2002N35	#12 tree	2900.01	-350.00	-350.00	110.00	1.7E-13
2002N32	#9 tree	2900.01	-50.00	-50.00	74.00	2.6E-10
2002N33	#10 tree	2900.00	-150.00	-150.00	87.00	1.2E-10
2002N34	#11 tree	2900.00	-250.00	-250.00	98.00	1.1E-11
2002N39	#16 tree	2700.00	-350.00	-350.00	106.00	1.6E-13
2002N38	#15 tree	2700.00	-250.00	-250.00	92.00	7.5E-12
2002N36	#13 tree	2700.00	-50.00	-50.00	71.00	6.3E-10
2002N37	#14 tree	2700.00	-150.00	-150.00	83.00	2.1E-10
2002N43	#20 tree	2500.00	-350.00	-350.00	96.00	3.1E-14
2002N42	#19 tree	2500.00	-250.00	-250.00	85.00	3.3E-12
2002N40	#17 tree	2500.00	-50.00	-50.00	64.00	4.4E-10
2002N41	#18 tree	2500.00	-150.00	-150.00	74.00	6.5E-11
2002N44	#21 hill	650.00	0.00	0.00	16.00	6.8E-08
2002N45	#22 hill	450.00	-180.00	-180.00	25.00	1.2E-11
2002M1422	#23 aircraft h	-170.00	120.00	120.00	12.00	1.6E-09
2002M1423	AROM 22 GP	-260.00	-120.00	-120.00	17.00	1.1E-08
2002M1407	AROM 22 LOC	-2393.03	0.00	0.00	4.00	0.0E+00

```
* REPRESENTS A RISK LESS THAN 1.0E-15
```

ILS Category I OCH (ABOVE THRESHOLD)   Speed CAT. D
Minimum acceptable OCH (ABOVE THRESHOLD)   59   Metres

Total risk for this approach   9.0E-08
Risk of hitting the ground plane 2.4E-10
Obstacle with highest individual risk

Ident	Description	X metres	Y1 metres	Y2 metres	Z metres	RISK
2002N44	#21 hill	650.00	0.00	0.00	16.00	6.3E-08
2002N46	#1 tree	3300.01	-50.00	-50.00	76.00	2.6E-11
2002N48	#3 tree	3300.01	-250.00	-250.00	98.00	7.3E-13
2002N49	#4 tree	3300.01	-350.00	-350.00	109.00	1.5E-14
2002N47	#2 tree	3300.00	-150.00	-150.00	90.00	1.2E-11
2002N29	#6 tree	3100.01	-150.00	-150.00	96.00	3.5E-10
2002N31	#8 tree	3100.00	-350.00	-350.00	112.00	1.0E-13
2002N28	#5 tree	3100.00	-50.00	-50.00	81.00	3.7E-10
2002N30	#7 tree	3100.00	-250.00	-250.00	99.00	3.7E-12
2002N35	#12 tree	2900.01	-350.00	-350.00	110.00	1.7E-13
2002N32	#9 tree	2900.01	-50.00	-50.00	74.00	2.6E-10
2002N33	#10 tree	2900.00	-150.00	-150.00	87.00	1.2E-10
2002N34	#11 tree	2900.00	-250.00	-250.00	98.00	1.1E-11
2002N39	#16 tree	2700.00	-350.00	-350.00	106.00	1.6E-13
2002N38	#15 tree	2700.00	-250.00	-250.00	92.00	7.5E-12
2002N36	#13 tree	2700.00	-50.00	-50.00	71.00	6.3E-10
2002N37	#14 tree	2700.00	-150.00	-150.00	83.00	2.2E-10
2002N43	#20 tree	2500.00	-350.00	-350.00	96.00	3.1E-14
2002N42	#19 tree	2500.00	-250.00	-250.00	85.00	3.3E-12
2002N40	#17 tree	2500.00	-50.00	-50.00	64.00	4.4E-10
2002N41	#18 tree	2500.00	-150.00	-150.00	74.00	6.5E-11
2002N44	#21 hill	650.00	0.00	0.00	16.00	6.3E-08
2002N45	#22 hill	450.00	-180.00	-180.00	25.00	1.5E-11
2002M1422	#23 aircraft h	-170.00	120.00	120.00	12.00	1.7E-09
2002M1423	AROM 22 GP	-260.00	-120.00	-120.00	17.00	2.2E-08
2002M1407	AROM 22 LOC	-2393.03	0.00	0.00	4.00	0.0E+00

* REPRESENTS A RISK LESS THAN 1.0E-15

Errors and warnings list :

OFZ PENETRATED?

PRELIMINARY RESULTS FOR ILS Category I

Speed CAT.	Type of report	OCA/H (M)	Total risk	Highest risk obstacle Ident	Description	Risk
A	Minimum OCH	51	9.5E-08	2002N44	#21 hill	8.8E-08
B	Minimum OCH	54	5.9E-08	2002N44	#21 hill	5.1E-08
C	Minimum OCH	56	8.3E-08	2002N44	#21 hill	6.8E-08
D	Minimum OCH	59	9.0E-08	2002N44	#21 hill	6.3E-08

Attachment B6

Calculation of MAPt Tolerance and MAPt to SOC Distance for a Missed Approach Point Defined by a Distance from the FAF

(see PANS-OPS, Volume II, Part III, 7.1.9.3 and 7.1.9.4)

1. INTRODUCTION

1.1   This attachment contains information on calculation of the MAPt tolerance and MAPt to SOC distance in a procedure where MAPt is determined by a distance (i.e. timing) from the FAF.

1.2   The criteria contained in PANS-OPS, Volume II, 7.1.9.3 and 7.1.9.4 are conservative in certain cases. To overcome this conservatism, distances may be calculated precisely using the formulae in this attachment.

2. CALCULATION

2.1 General

The calculation of each of the relevant distances is done in two steps, using the maximum and minimum final approach speeds for the category of aircraft. Thence, the considered distance is the higher of the two found.

2.2 Parameters

a = distance from the earliest point of the FAF tolerance to the FAF;

b = distance from the FAF to the latest point of the FAF tolerance;

D = distance from FAF to MAPT;

TASMIN = slowest final approach IAS for the relevant aircraft category (Tables III-1-1 and III-1-2 of PANS-OPS, Volume II) converted to TAS, allowing for aerodrome elevation and temperature ISA − 10;

TASMAX = fastest final approach IAS for the relevant aircraft category (Tables III-1-1 and III-1-2 of PANS-OPS, Volume II) converted to TAS, allowing for aerodrome elevation and temperature ISA + 15.

2.3 MAPt tolerance

2.3.1 *Earliest MAPt*

$$X1 = (a^2 + (\text{TASMIN} \times 10/3\ 600)^2 + (56 \times D/\text{TASMIN})^2)^{0.5}$$

$$X2 = (a^2 + (\text{TASMAX} \times 10/3\ 600)^2 + (56 \times D/\text{TASMAX})^2)^{0.5}$$

SI units

$$X1 = (a^2 + (\text{TASMIN} \times 10/3\ 600)^2 + (30 \times D/\text{TASMIN})^2)^{0.5}$$

$$X2 = (a^2 + (\text{TASMAX} \times 10/3\ 600)^2 + (30 \times D/\text{TASMAX})^2)^{0.5}$$

non-SI units

Earliest MAPT tolerance = max {X1; X2}

2.3.2 *Latest MAPt*

$$X3 = (b^2 + (\text{TASMIN} \times 13/3\ 600)^2 + (56 \times D/\text{TASMIN})^2)^{0.5}$$

$$X4 = (b^2 + (\text{TASMAX} \times 13/3\ 600)^2 + (56 \times D/\text{TASMAX})^2)^{0.5}$$

SI units

$$X3 = (b^2 + (\text{TASMIN} \times 13/3\ 600)^2 + (30 \times D/\text{TASMIN})^2)^{0.5}$$

$$X4 = (b^2 + (\text{TASMAX} \times 13/3\ 600)^2 + (30 \times D/\text{TASMAX})^2)^{0.5}$$

non-SI units

Latest MAPt tolerance = max {X3; X4}

2.3.3   *MAPt to SOC distance*

$$X5 = (b^2 + (TASMIN \times 13/3\ 600)^2$$
$$+ (56 \times D/TASMIN)^2)^{0.5}$$
$$+ 15 \times (TASMIN + 19)/3\ 600$$

$$X6 = (b^2 + (TASMAX \times 13/3\ 600)^2$$
$$+ (56 \times D/TASMAX)^2)^{0.5}$$
$$+ 15 \times (TASMAX + 19)/3\ 600$$

SI units

$$X5 = (b^2 + (TASMIN \times 13/3\ 600)^2$$
$$+ (30 \times D/TASMIN)^2)^{0.5}$$
$$+ 15 \times (TASMIN + 10)/3\ 600$$

$$X6 = (b^2 + (TASMAX \times 13/3\ 600)^2$$
$$+ (30 \times D/TASMAX)^2)^{0.5}$$
$$+ 15 \times (TASMAX + 10)/3\ 600$$

non-SI units

MAPt to SOC distance = max {X5; X6}.

Attachment B7

Fundamentals of the Missed Approach

The following fundamental steps are necessary for the proper calculation of OCA/H with regard to obstacles in the missed approach. The material presented herein is divided into two sections:

1) missed approach associated with non-precision procedures; and

2) missed approach associated with precision procedures.

Each section is further subdivided into straight and turning missed approach cases. The fundamentals that must be applied to each situation are first discussed and then actual examples of each situation, complete with calculations, are presented.

1. FUNDAMENTALS OF THE NON-PRECISION MISSED APPROACH

1.1 Steps of a straight missed approach calculation

a) Determine OCA/H on final (OCA/H_f).

b) Locate MAPt.

c) Determine MAPt tolerance area.

d) Calculate transitional tolerance X and locate SOC.

e) Measure d_o: distance SOC to obstacle O.

f) Calculate height gained (HG) over distance d_o.

$HG(d_o) = d_o \tan Z$

(tan Z is the missed approach climb gradient;

normally $\tan Z = \dfrac{1}{40} = 0.025 = 2.5$ per cent)

g) Calculate nominal altitude over obstacle O: NA(O).

$NA(O) = OCA_f + HG(d_o)$

h) Calculate required altitude over obstacle O: RA(O).

$RA(O) = OE + MOC$ where OE is obstacle O elevation and MOC is 30 m (98 ft) in the missed approach primary area.

i) If NA(O) is higher than RA(O) or equal to RA(O), obstacle O is not a factor (which means that it is compatible with OCA_f for the final segment and with the MAPt location). Check the other obstacles in the missed approach area (return to e) above).

j) If NA(O) is smaller than RA(O), NA(O) must be increased to at least equal RA(O). This can be achieved by two means:

1) Increase OCA by the amount of altitude which is missing over obstacle O: new OCA = OCA_f + RA(O) – NA(O);

2) Move the missed approach point further from the threshold. This will increase d_o (and consequently $HG(d_o)$ and NA(O)). For a one-nautical mile MAPt displacement from threshold (which might be considered as a maximum), a 152-ft increase in NA(O) is obtained.

   Note.— If both of these solutions prove impractical or result in an unacceptable operational penalty, a turning missed approach must be designed in order to exclude obstacle O from the missed approach area.

1.2 MAPt tolerance area when MAPt is defined by a fix

a) Draw the fix tolerance area. (See Figures B7-1 to B7-4.)

b) SOC calculations. (See Figure B7-5.)

Locate SOC at 18 s of flight (3 s pilot reaction time plus 15 s transitional tolerance) after the latest point of the fix tolerance area.

$$\frac{18 \times (TAS + 10)}{3\ 600}$$

TAS = IAS (maximum final approach speed) × conversion factor (aerodrome altitude, ISA + 15).

Note.— When the MAPt fix is a facility there is no fix tolerance. So the SOC is located 18 s of flight after the nominal facility.

1.3   MAPt defined by a distance D from the FAF (no MAPt fix)

a) Calculate d_1 and d_2. (See Figure B7-6.)

b) Find the maximum and minimum final approach speeds for the category considered.

c) Find the "cold day" correction factor (aerodrome elevation, ISA − 10) and the "hot day" correction factor (aerodrome elevation, ISA + 15).

d) Calculate TAS min = IAS min × cold day correction factor and TAS max = IAS max × hot day correction factor.

e) Calculate or carefully draw the a and b values of the FAF tolerance.

a = distance measured along the nominal track between the earliest point of FAF tolerance area and FAF;

b = distance measured along the nominal track between the FAF and the latest point of FAF tolerance area.

f) Calculation of d_1 and d_2. (See PANS-OPS, Volume II, Attachment L to Part III and Table B7-1.)

1) Calculation for each category of aeroplane is necessary for d_1, d_2 and particularly for the SOC in order to get the best operational advantage for each group. Both the fastest and the slowest TAS must be used in the calculations to determine which will most adversely affect the size of the fix tolerance and the location of the SOC. Frequently, the slowest TAS develops the largest d value due to the extra time exposed to wind effect.

The earliest and the latest MAPt tolerance values are the maximum value of the root sum square total (RSS) of the two solutions calculated.

2) The formulae for the above calculations are presented in PANS-OPS, Volume II, Attachment L to Part III and are shown as:

The EARLIEST MAPt tolerance = max of the {TAS max; TAS min}

TAS min: $[a^2 + (TAS\ min \times 10/3\ 600)^2$ | SI
$+ (56 \times D/TAS\ min)^2]^{0.5}$ | units
TAS max: $[a^2 + (TAS\ max \times 10/3\ 600)^2$
$+ (56 \times D/TAS\ max)^2]^{0.5}$

Table B7-1

	Earliest MAPt tolerance		Latest MAPt tolerance	
	d_1		d_2	
	TAS min	TAS max	TAS min	TAS max
FAF fix	a	b	a	b
Timing	$10 \times \dfrac{TAS\ min}{3\ 600}$	$10 \times \dfrac{TAS\ max}{3\ 600}$	$13 \times \dfrac{TAS\ min}{3\ 600}$	$13 \times \dfrac{TAS\ max}{3\ 600}$
30 kt wind effect	$\dfrac{D}{TAS\ min} \times 30$	$\dfrac{D}{TAS\ max} \times 30$	$\dfrac{D}{TAS\ min} \times 30$	$\dfrac{D}{TAS\ max} \times 30$
	RSS total	RSS total	RSS total	RSS total

TAS min: $[a^2 + (\text{TAS min} \times 10/3\ 600)^2\ |\text{non-SI}$
$+ (30 \times D/\text{TAS min})^2]^{0.5}$ $|\text{units}$
TAS max: $[a^2 + (\text{TAS max} \times 10/3\ 600)^2$
$+ (30 \times D/\text{TAS max})^2]^{0.5}$

where:

   a = distance from the earliest point of the FAF
   b = distance from the latest point of the FAF

and

   D = distance from FAF to MAPt

   The LATEST MAPt tolerance = max of the {TAS max; TAS min}

   TAS min: $[b^2 + (\text{TAS min} \times 13/3\ 600)^2\ |\text{SI}$
   $+ (56 \times D/\text{TAS min})^2]^{0.5}$ $|\text{units}$
   TAS max: $[b^2 + (\text{TAS max} \times 13/3\ 600)^2$
   $+ (56 \times D/\text{TAS max})^2]^{0.5}$

   TAS min: $[b^2 + (\text{TAS min} \times 13/3\ 600)^2\ |\text{non-SI}$
   $+ (30 \times D/\text{TAS min})^2]^{0.5}$ $|\text{units}$
   TAS max: $[b^2 + (\text{TAS max} \times 13/3\ 600)^2$
   $+ (30 \times D/\text{TAS max})^2]^{0.5}$

g)   Determine the MAPt to SOC distance.

   1)   The SOC is determined by adding the transitional tolerance 'X' equal to 15 s of flight with a tailwind of 10 kt.

   Note.— When the greatest MAPt tolerance is created by the slowest final approach speed, it is mutually exclusive to use the fastest final approach speed for the transitional tolerance. Consequently, both speeds must be evaluated with the latest MAPt tolerance to determine which circumstance develops the most pessimistic MAPt to SOC distance.

   2)   The formulae are similar and are shown in PANS-OPS, Volume II, Attachment L as: the MAPt to SOC tolerance = max of the {TAS max; TAS min}.

   TAS min: $[b^2 + (\text{TAS min} \times 13/3\ 600)^2\ |\text{SI units}$
   $+ (56 \times D/\text{TAS min})^2]^{0.5}$
   $+ 15 \times (\text{TAS min} + 19)/3\ 600$ units

   TAS max: $[b^2 + (\text{TAS max} \times 13/3\ 600)^2\ |\text{SI units}$
   $+ (56 \times D/\text{TAS max})^2]^{0.5}$
   $+ 15 \times (\text{TAS max} + 19)/3\ 600$

   TAS min: $[b^2 + (\text{TAS min} \times 13/3\ 600)^2\ |\text{non-SI}$
   $+ (30 \times D/\text{TAS min})^2]^{0.5}$ $|\text{units}$
   $+ 15 \times (\text{TAS min} + 10)/3\ 600$

TAS max: $[b^2 + (\text{TAS max} \times 13/3\ 600)^2\ |\text{non-SI}$
$+ (30 \times D/\text{TAS max})^2]^{0.5}$ $|\text{units}$
$+ 15 \times (\text{TAS max} + 10)/3\ 600$

h)   *Simplified method.* The MAPt tolerance graphs in PANS-OPS, Figure III-7-6 may be used to determine the earliest and the latest MAPt tolerance values. They are shown to be equal because the graph assumes that the MAPt tolerance is the largest of the two possibilities and that the FAF tolerance is ±1 NM. A similar graph is also available as Figure III-7-9 for the MAPt to SOC distance. The results are equally conservative since the curves are based on a FAF tolerance of ±1 NM.

1.4   Comparisons of the required altitude/height to the nominal altitude/height

a)   The required altitude/height is always the elevation/height of the obstacle plus the minimum obstacle clearance (including any allowances necessary for mountainous terrain and charting tolerances).

   RA/H = OE + MOC + chart and precipitous terrain allowances, etc.

b)   The nominal altitude/height must always equal or exceed the RA/H. The nominal altitude is calculated by adding the height gained (HG) from the point where the missed approach climb is started (SOC) to the location of the obstacle via the shortest distance.

c)   In straight missed approaches, the shortest distance is d_z:

   d_z = SOC_x to the obstacle location (less chart tolerances) measured along the missed approach track. (See Figure B7-7.)

d)   In a turn at an altitude situation, the shortest distance is $d_z + d_o$:

   d_z is measured to the *nominal* turn point (TP) along the straight missed approach track, and

   d_o is measured along the shortest distance to the *turn area boundary* (less any charting tolerances).

   Alternatively, the NA can be determined from the turn altitude adding HG from the turn altitude to find the NA at the obstacle, i.e. NA = TNA + $d_o \times 0.025$.

e)   In a turn at a FIX situation, the climb is calculated from the OCA/H_f and the shortest distance is $d_z + d_o$:

d_z is measured to the *earliest* turn point along the straight missed approach track, and

d_o is measured along the shortest distance from line K-K to the obstacle (less any charting tolerances).

$$NA/H = SOC_z + HG$$

where:

$SOC_z = OCA_f$ for non-precision approaches, and
$SOC_z = OCA_f -$ height loss for precision approaches

$HG = d_z \times 0.025$ (straight missed approaches)
$HG = (d_z + d_o) \times 0.025$ (turning missed approaches)

1.5   Calculation of the distance d_o

a) The distance d_o after the turn to an obstacle is measured differently depending on whether the turn is specified to be commenced at an altitude or at a fix.

b) Turn at an altitude. (See Figures B7-8 and B7-10).

$$d_o = \cos \alpha \times (y_o - \tfrac{1}{2}W) - \text{chart tolerance}$$

where $\alpha =$ splay of missed approach area.

VOR: 7.8°; NDB: 10.3°, etc.
(see Chapters 12 and 13 of Part II, Section 2, for ILS splay calculation)

$y_o =$ distance of obstacle from the MAPt track at range of obstacle

$\tfrac{1}{2}W =$ half-width of missed approach area at range of obstacle

c) Turn at a fix. (See Figures B7-9 and B7-11)

$$d_o = [(y_o - y_K)^2 + (d')^2]^{0.5} - \text{chart tolerance}$$
where:

$y_o =$ distance of obstacle (O) from the MAPt track at range of (O)
$y_K =$ half-width of missed approach area at range of point K
$d' =$ distance between K and (O) measured parallel to the MAPt track

1.6   Turning altitude/height considerations and calculations

a) Turn at an altitude. (See Figure B7-12.)

The turning altitude, when used as the prime method of designating the turn point (TP), should be rounded to an operationally acceptable altitude increment of 100 ft or 50 m. (The PANS-OPS does not specify this as a criterion, but past practices seem to require it.)

The nominal TP is plotted at the point where the 2.5 per cent climb gradient reaches the turn altitude (TNA).

The latest TP is the point where the bounding circle(s) area is constructed. It occurs 6 s (c) after the nominal TP.

Obstacles straight ahead are avoided when the bounding circle area excludes the obstacle (including any charting tolerance).

The distance from the nominal TP to the critical obstacle that demands the turn is calculated using the parameters described in the PANS-OPS, Volume II, Part III, Tables II-7-3 and III-7-4 and is the sum of:

$$c + E + [r^2 + E^2]^{0.5} + \text{chart tolerance}$$

b) Turn at a fix. (See Figure B7-13.)

The turn fix, when used as the prime method of designating the turn point (TP), uses the exact altitude/height reached at the earliest fix tolerance of the TP fix. This is called line K-K.

The latest TP remains the point where the bounding circle(s) is constructed. It occurs 6 s (c) after the latest fix tolerance of the TP fix.

The distance from the latest fix tolerance to the critical obstacle that demands the turn is calculated using the parameters described in Tables III-7-3 and III-7-4 of the PANS-OPS and is the sum of:

$$c + E + [r^2 + E^2]^{0.5} + \text{chart tolerance}$$

1.7   MAPt adjustments to meet turn altitude/height requirements

a) Turn altitude is the focus point when obstacles in the turn area after the turn point (TP) control the OCA/H. The procedure must climb straight ahead to an adequate altitude before turning when obstacles after the turn are critical.

1) Determine the turn height that will ensure that the height gain from the edge of the turn initiation area

will meet the required altitude (RA) at the obstacle in the turn area (see Figure B7-14).

2) Round that value to an operationally acceptable "Turn at_____" value (see Figure B7-15).

3) Adjust the SOC position (SOC_x) and the SOC height (SOC_z) to ensure that the "turn altitude" can be achieved with a 2.5 per cent climb from the SOC to the turn point (TP) (see Figure B7-16).

b) Precision approach adjustments of OCA/H are more complex. Any adjustment vertically has a consequence horizontally since the MAPt occurs on the glide path. Furthermore, the MOC in the precision approach segment is completely involved in the height loss (HL) consideration for each aeroplane category.

1) The formula for determining the equivalent height of missed approach obstacles is very useful when a particular turn height (TNH) must be achieved at a particular turn point (TP) distance.

2) The x coordinate of the TP is the point where the TNH (h_{ma}) must be achieved. The formula is:

$$SOC_z = h_a = \frac{TNH \times Cot\ Z + 900 + x}{Cot\ Z + Cot\ \theta}$$

(See Figure B7-17.)

3) The SOC_x where the missed approach climb will start is found on line G/P' with the formula:

$$SOC_x = SOC_z/Tan\ \theta - 900$$

(See Figure B7-18.)

4) The OCA/H (adjusted for the new SOC) is:
$OCA/H = SOC_z + HL$.
(See Figure B7-19.)

2.   FUNDAMENTALS OF THE PRECISION APPROACH WITH A STRAIGHT MISSED APPROACH

2.1   Plot the basic ILS surfaces.

2.2   Identify obstacles penetrating basic surfaces.

2.3   Analyse obstacles using either:

CRM using all obstacles; or

OAS using the highest approach (equivalent missed approach).

2.4   OCA/H.

Note.— These steps are demonstrated in Chapter 11.

3.   FUNDAMENTALS OF THE PRECISION APPROACH WITH A TURN AT AN ALTITUDE MISSED APPROACH

3.1   Straight portion.

3.2   Lowest acceptable turn height.
Turn initiation area.
Turn area.

3.3   Lowest acceptable turn altitude.

3.4   Start of climb based on precision segment (SOC_{ps}).

3.5   Turn point (TP) adjustments.

3.6   SOC adjustments to accommodate TP requirement.

3.7   OCA/H.

Note.— These steps are demonstrated in Chapter 12.

4.   FUNDAMENTALS OF THE PRECISION APPROACH WITH A TURN AT A FIX MISSED APPROACH

4.1   Straight portion.

4.2   Lowest acceptable turn height.
Turn initiation area.
Turn area.

4.3   Lowest acceptable turn altitude.

4.4   Start of climb based on precision segment (SOC_{ps}).

4.5   Turn point (TP) adjustments.

4.6   SOC adjustments to accommodate TP requirement.

4.7   OCA/H.

Note.— These steps are demonstrated in Chapter 13.

5.   MINIMIZED TURN ANGLE AND TURN INITIATION AREA BOUNDARY REVISED DISTANCE TO OBSTACLE (d_o) CALCULATIONS

5.1   *Introduction.* The main advantage of this method occurs when the turn angle is less than 75°. That advantage is significant. The discussions found here amplify that of PANS-OPS, Volume II, Attachment J to Part III for turns less than 75°. The general text of the PANS-OPS is adequate where turns more than 75° are used. The method is nearly the same as is described elsewhere in this manual and in the PANS-OPS with the following exceptions:

a) The revised boundary of the turn initiation area is based on the contour of the actual turn height, not the 300 m contour.

b) The distance d_o to obstacles in the turn area is based on the heading specified after the turn (+15°), not the perpendicular distance to the 300 m contour.

c) Obstacles in the turn area, which can be overflown only when the aeroplane has initiated the missed approach turn before descending to the turn height, are appropriately considered.

5.2   *Turn initiation area boundary revisions (see PANS-OPS, Volume II, Attachment J to Part III)*

a) *Width of the turn initiation area (Y surface) based on specified turn height (TNH) contour.* At any x coordinate, the y coordinate of the area boundary (distance from centre line) can be found with the formula:

$y_{TNH} = \dfrac{TNH - Ax - C}{B}$: (y coordinate of the Y surface at the turn height)

(See Figure B7-20.)

b) The new coordinate points of C", D" and E" for the turn height (TNH) are:

E"$_{TNH}$ = the new x and y coordinate at the TNH
D"$_{TNH}$ = the new x and y coordinate at the TNH
C"$_{TNH}$ = the new x and y coordinate at the TNH

The exact value for these points are calculated with:

E"$_{TNH}$: x = TNH/300 × (E"$_x$ − E$_x$) + E$_x$
E"$_{TNH}$: y = TNH/300 × (E"$_y$ − E$_y$) + E$_y$

D"$_{TNH}$: x = TNH/300 × (D"$_x$ − D$_x$) + D$_x$
D"$_{TNH}$: y = TNH/300 × (D"$_y$ − D$_y$) + D$_y$

C"$_{TNH}$: x = TNH/300 × (C"$_x$ − C$_x$) + C$_x$
C"$_{TNH}$: y = TNH/300 × (C"$_y$ − C$_y$) + C$_y$

For example:

Find the 500 ft (152 m) turn height coordinates for point E"$_{TNH}$

x = 152/300 (−12 900 + 900) − 900 = −6 980 m
y = 152/300 (3 001 − 205) + 205 = 1 622 m

Note.— The y coordinate is always counted positive in OAS calculations.

5.3   *Turn angle considerations.* The minimum turn angle necessary to avoid an obstacle is found by:

a) establishing the lowest allowable (acceptable) turn altitude/height (TNA/H);

b) plotting a line from the obstacle in question back towards the MAPt so that it is tangent to the bounding circle of the turn area; and

c) selecting a turn angle "α" for the MAPt track which is at least 15° beyond the tangent point found above (see Figure B7-21).

5.4   *Distance to obstacles d_o in turn areas.* The turning area for obstacle clearance considerations is divided into four areas as shown in Figure B7-22. The boundary of Areas 2, 3, and 4 is divided by lines which diverge α + 15° from the localizer approach track.

a) The distance d_o considered available to gain height from the turning altitude/height (TNA/H) is measured from the TNA/H contour in Areas 2 and 3. The distance d_o in Area 4 is measured from the edge of the "W" surface and from the height of the "W" surface at that point (see Figure B7-23).

Intersection case:
Draw the fix tolerance area and
measure a and b on the map.

Figure B7-1

Draw two straight lines starting from VOR 1 and diverging at 5.2° from the nominal track.
Then draw two other straight lines starting from VOR 2 and diverging at 4.5° from the
intersecting radial; the intersection of these 4 lines gives the fix tolerance area.

Note.— Drawing a 5.2° angle should not be done with a protractor.

Figure B7-2

VOR case:

a = b = h tan 50°
h is the height of the nominal flight
path above the VOR site.

NDB case:

Same method but a = b = h tan 40°.

a   b

h

50° (or flight checked value)

Figure B7-3

VOR intersection case

7.8°

5.2°

X

d

SOC

4.5°

Figure B7-4

VOR/DME case

(DME tolerance: ±0.46 km (0.25 NM) plus
1.25% of DME distance.)

5.2°

d

X

SOC

Figure B7-5

d_1 d_2 X

MAPt   SOC

D

Figure B7-6

Figure B7-7

Figure B7-8
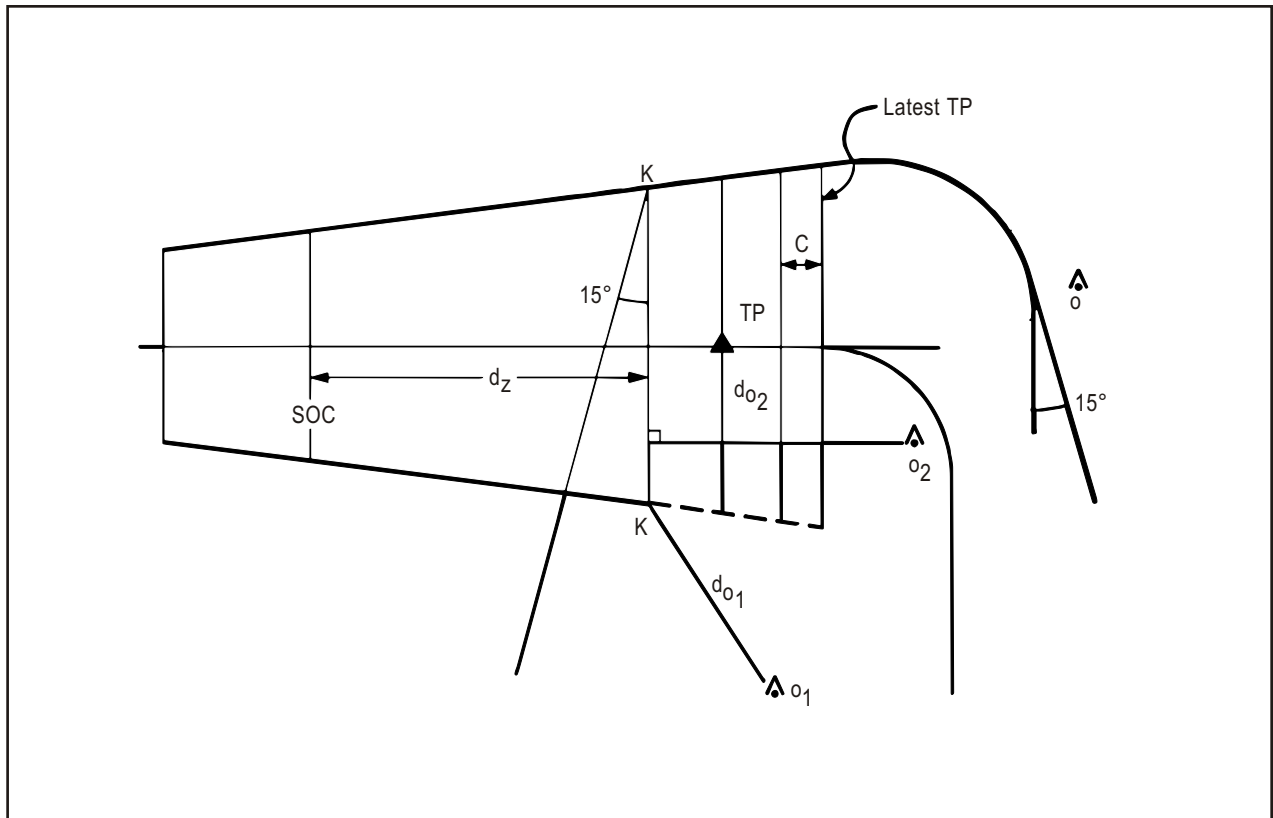
Figure B7-9
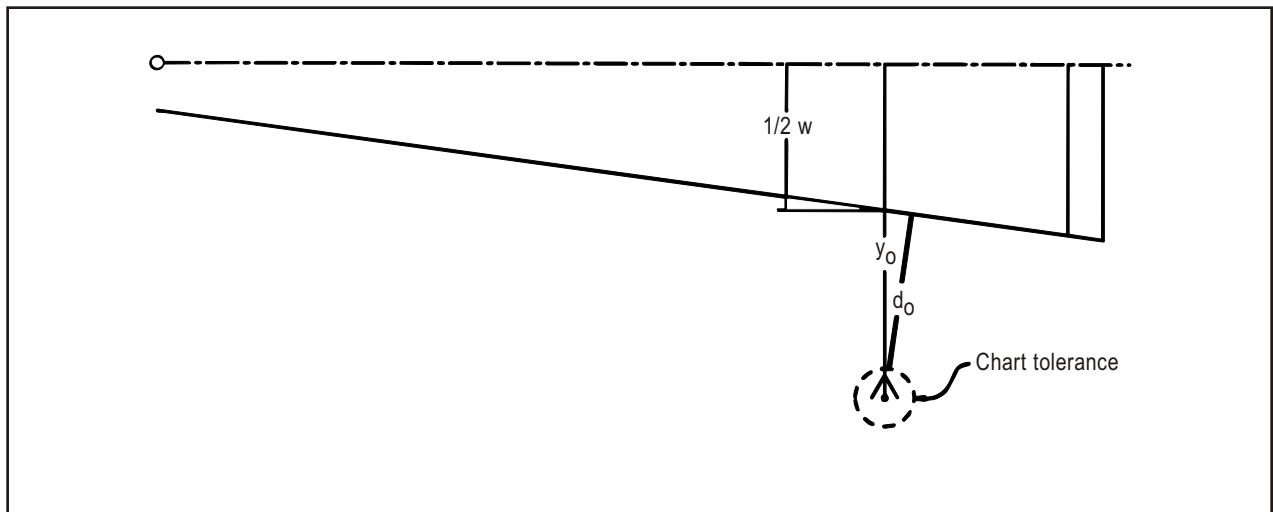
Figure B7-10

Figure B7-11

Figure B7-12

Turn height ⸱ ⸱ ⸱ ⸱ ⸱ ⸱ ⸱ ⸱ ⸱ ⸱ ⸱ ⸱ Altitude (rounded value)

TP

Fix tolerance →

C

K

$[r^2 + E^2]^{0.5}$

r

$c + E + [r^2 + E^2]^{0.5}$

K

E

Chart tolerance

Figure B7-13

Required height

MOC

Min turn height

2.5%

Turn initiation area

Figure B7-14

Nominal TP

Operational turn altitude

Minimum turn height

Optimum

MAPt   SOC

Figure B7-15

5%

Adjusted MAPt

Adjusted SOC

Adjusted OCA/H

Required to reach Turn Altitude at TP

2.5% missed approach gradient

Original OCA/H$_f$

MOC final

15 m

Max distance visibility consideration
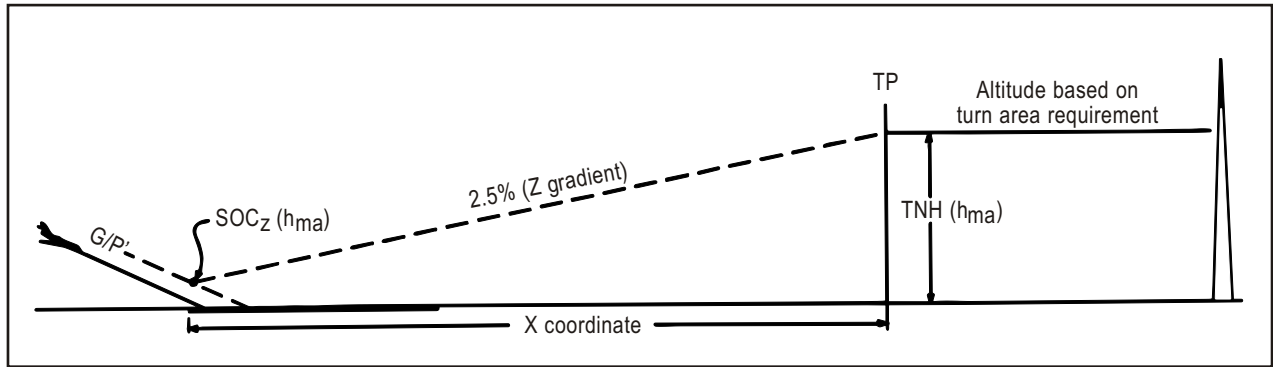
Figure B7-16
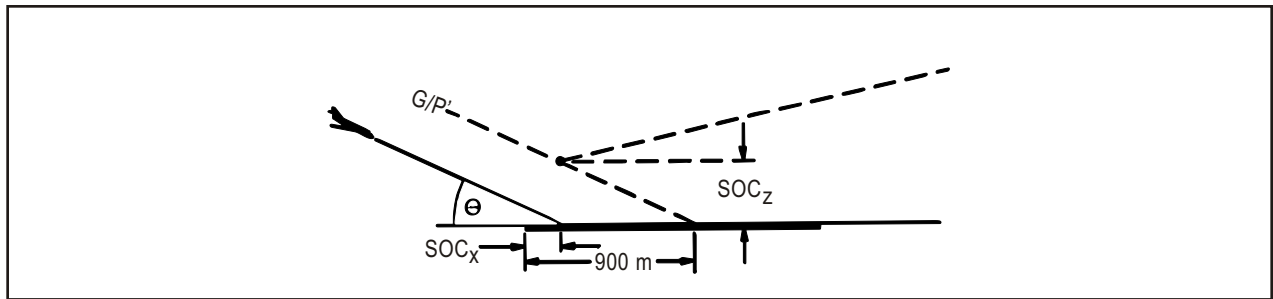
Figure B7-17

Figure B7-18
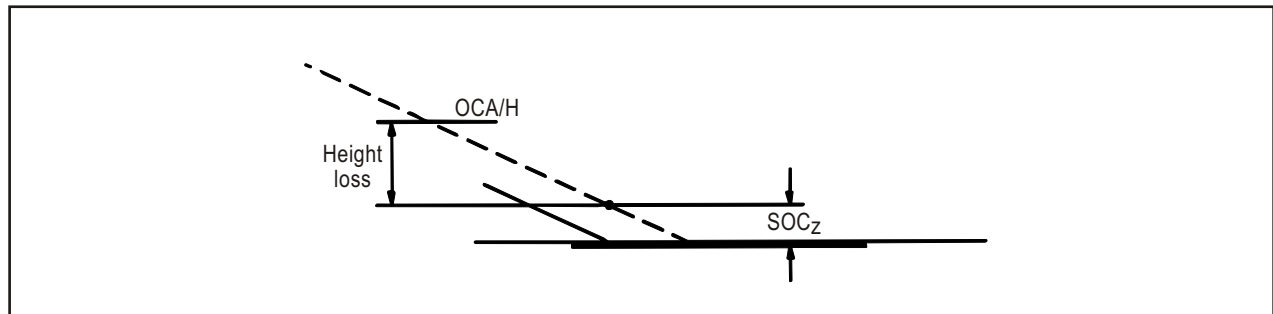
Figure B7-19
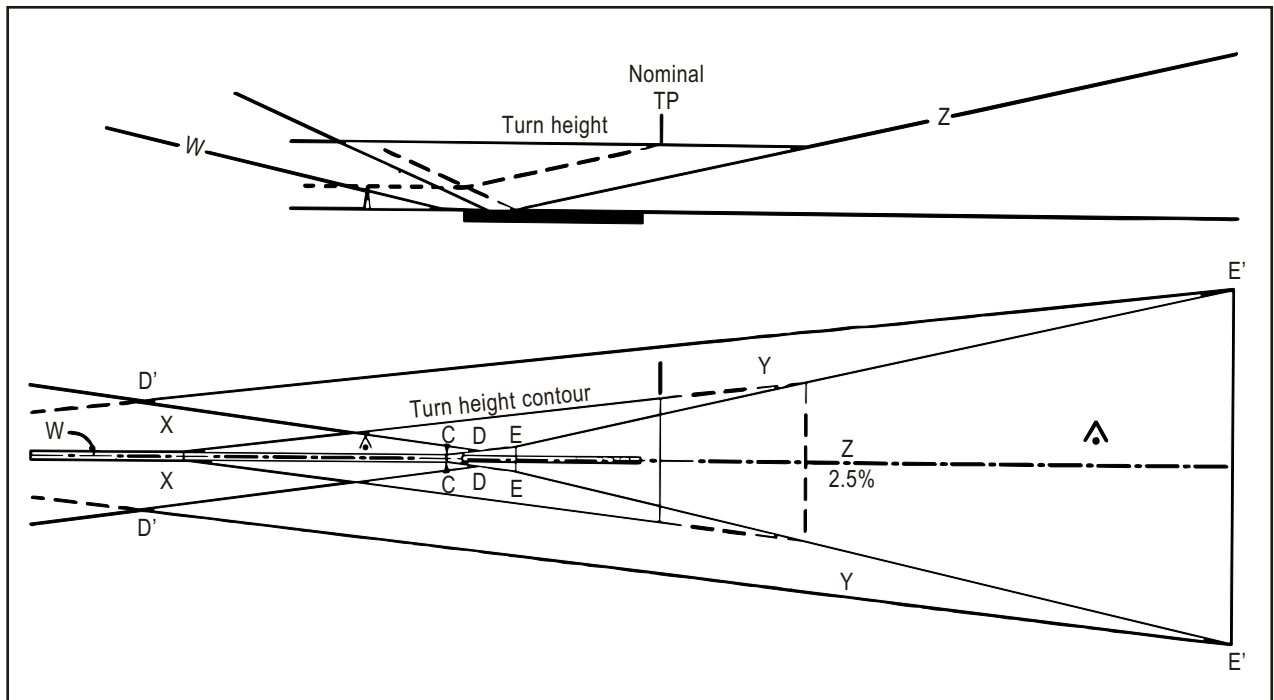
Figure B7-20.   Contour of the turn height
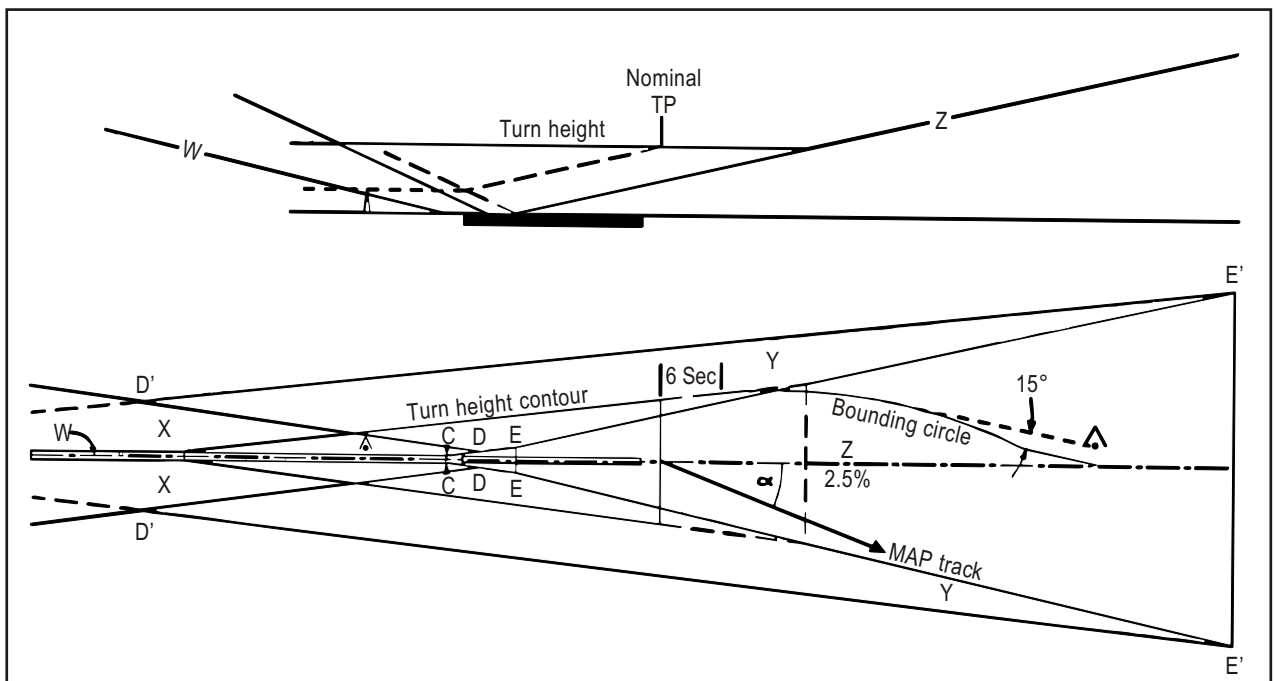
Figure B7-21
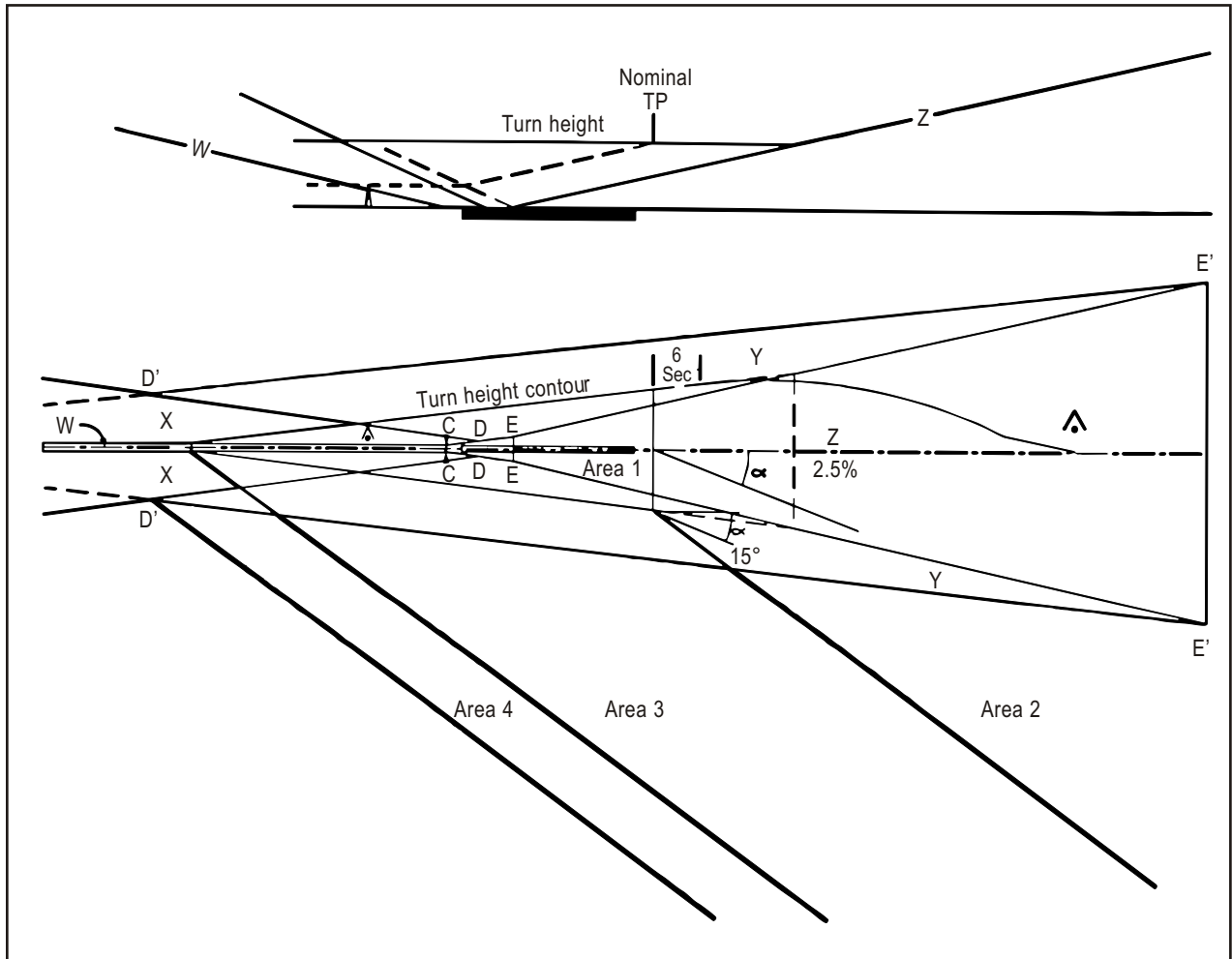
Figure B7-22.   Turning missed approach areas

Figure B7-23

Attachment C

QUALITY ASSURANCE

Attachment C1

Accounting for Charting Inaccuracy

INTRODUCTION

Reference: PANS-OPS, Volume II, Part II, 2.6 and Part III, 1.14.

The procedure designer must take cognizance of and compensate for the fact that charts are not absolutely accurate.

Charting standards allow certain latitude to the cartographer when illustrating the position of an object on a chart. These standards differ according to the type of results needed and often no pure engineering data are available on which the features of a chart are drawn. Some specific examples of possible inaccuracies exist where artificial features are depicted. Frequently, the position is distorted or exaggerated to best show the relationship of one object to another. Contour lines drawn to illustrate sloping surfaces normally have no hard survey data that can be applied to each level. Most cartographic authorities will claim an accuracy of only one-half the value of the contour interval, i.e. 50 ft where the contour lines are shown at 100 ft intervals.

The information presented in this Attachment corresponds to one State that has quantified the accuracy of the various aeronautical charts, the types of surveys, fly-by techniques and other sources of obstacle data into a simple code of horizontal and vertical tolerances. That State has also developed acceptable tolerances for the various segments of approach and departure procedures. Excerpts from that State's directives are included at the end of this Attachment. An abstract from these directives is included herein.

Application of these tolerances are explained in this Attachment using the excerpt of the Obstacle Accuracy Standards, Codes and Sources.

Further examples applying charting tolerances to ensure that the MOC is provided are shown in the context of developing a procedure in Attachment B7 and in Part II, Section 1 and in Chapters 11 to 14 of Part II, Section 2.

ABSTRACT OF THE OBSTACLE ACCURACY STANDARDS USED BY ONE STATE

Code	Horizontal	Code	Vertical
1	5 m (15 ft)	A	1 m (3 ft)
2	15 m (50 ft)	B	3 m (10 ft)
3	33 m (100 ft)	C	6 m (20 ft)
4	75 m (250 ft)	D	15 m (50 ft)
5	150 m (500 ft)	E	38 m (125 ft)
6	300 m (1 000 ft)	F	75 m (250 ft)
7	900 m (0.5 NM)	G	150 m (500 ft)
8	1 800 m (1 NM)	H	300 m (1 000 ft)

DATA SOURCE CODE

Obstacle Charts

1A   OC (ICAO types A and B) charts along flight path < 2 NM

1B   OC (ICAO type B) chart horizontal surfaces

2C   OC (ICAO types A and B) charts along flight path > 2 NM

2C   OC (ICAO type B) chart conical surfaces

WAC, Sectional and VFR Charts

7G   WAC
6F   Sectional
5F   VFR
Spot heights: Vertical = A (1 m, 3 ft)
Double the horizontal code for artificial features
Contour lines: 1/2 contour line interval

DOD Charts

4D   Digitized terrain data
5E   All other charts and files

DOT Charts

1A   Airways facilities field survey
2C   Field inspection (with theodolite) and topographic charts 1:24 000
4D   Obstruction evaluation data and flight inspection fly-by, topographic charts 1:62 500
4-8D National oceanic survey verified hazards
6E   Department of interior magnetic tape data, topographic charts 1:250 000
7G   Airport owner estimates

ACCEPTABLE LIMITS OF CHART/SURVEY ACCURACY IN PROCEDURE DESIGN

ILS/MLS final   1A
Non-precision final   2C
Missed approach and circling   2C
Departure within 2 NM from DER   2C
Departure over 2 NM from DER   4D
Intermediate   4D
Initial   6F

APPLICATION OF ACCURACY CODES

1. *Compensating obstacle data which does not meet the accuracy requirement of 1A in an ILS approach procedure*

(See Figure C1-1)

1.1 *Obstacle chart coordinates*

  x = 1 000 m
  y = –200 m
  z = 45 m

  Obstacle data source: topographic chart 1:24 000 Code 2C

  Code 2 = 15 m (50 ft) horizontally
  Code C = 6 m (20 ft) vertically

1.2 *Adjusted obstacle coordinate (for use in CRM or OAS calculations)*

  x = 1 000 – 15 = 985 m (adjusted toward RWY threshold)
  y = –200 + 15 = –185 m (adjusted toward RWY centre line)
  z = 45 + 6 = 51 m (adjusted higher)

1.3 *OAS surface calculations*

(Standard ILS Category I conditions with 3° GP and LLZ-THR at 3 000 m)

At the chart coordinates	Adjusted coordinates
W surface: 20.49 m	20.06 m
X surface: 47.46 m	44.31 m
Y surface: 44.45 m	40.94 m

1.4 The obstacle lies under the X surface in both situations because the OAS calculations show it to be the highest surface.

1.4.1 However, the adjusted coordinates of the obstacle (including the height) combine to show that the obstacle now penetrates the OAS and an operational penalty will need to be imposed by applying height loss to the 51 m height unless better (more accurate) survey data proves the obstacle to be located nearer to the point where the raw data showed it to be.

2. *Compensating for a missed approach obstacle which does not meet the accuracy requirement of 2C in the turning area*

2.1 An obstacle is shown on a topographic chart, scale 1:250 000, near the runway centre line beyond the termination of the precision segment and must be avoided by a 90° turn.

  Note.— The principals demonstrated here are appropriate to the non-precision situation as well.

2.2 The accuracy code of the chart and the obstacle is 6E.

2.3 The turn point must be established so that the bounding circle of the area can avoid the horizontal chart tolerance of 300 m around the obstacle. See Figure C1-2.

2.4 *Sloping terrain considerations*

2.4.1 The problem presented here is to determine the closest point on the up-sloping terrain of the ridge that must be avoided by the turn boundary of the missed approach procedure.

2.4.2 A ridge on the extended runway centre line is shown on a 1:250 000 chart as a spot height 13 000 m from the runway threshold.

2.4.3 Contour lines at 100 m intervals show a steep incline facing the aerodrome. The procedure will incorporate a turn to avoid the ridge.

2.5   *Tolerances.* As a spot the vertical accuracy is "A" 1 m (3 ft). The horizontal accuracy, however, is a "6" 300 m (1 000 ft). The contour lines of the slope have a vertical accuracy of half the 30 m (100 ft) interval or 15 m (50 ft).

2.6   Plot a buffer along the sloping surface that will account for both the 300 m horizontal chart tolerance as well as the vertical tolerance of 50 m.

2.7   Plot the 2.5 per cent missed approach gradient from the SOC to find the point at which the gradient will encounter the up-slope of the ridge, including the chart tolerance buffer.

2.7.1   Since the slope of the ridge must be avoided by the MOC of 50 m, a line 50 m below the 2.5 per cent missed approach plane is used as the critical surface to determine the limits of the turn area. See Figure C1-3.

3.   *Compensating for an obstacle in the initial/ intermediate segments*

3.1   This obstacle is located in the base turn and the associated intermediate approach areas. It is shown on a sectional chart at a scale of 1:250 000.

3.1.1   The accuracy is determined to be 6E.

3.2   The obstacle has an elevation of 290 m (951 ft) and is located 5 NM from the VOR (the FAF) and 2 NM to the right of the inbound intermediate track.

3.3   The 6E accuracy is acceptable in the initial approach and the location will be as is shown for determining initial approach procedure minimum altitudes. The base turn altitude can be as low as 290 + 300 m (2 000 ft).

3.3.1   However, the 6E accuracy is NOT acceptable in the intermediate approach and the obstacle coordinates must be adjusted 300 m (1 000 ft) horizontally and 38 m (125 ft) vertically when determining the intermediate approach procedure altitudes.

3.3.2   Plot the adjusted obstacle position against the intermediate approach area and determine the applicable MOC.

The adjusted position is:

5 NM − 300 m (0.16 NM) = 4.84 NM from the VOR;

2 NM − 300 m (0.16 NM) = 1.84 NM from the intermediate track; and

290 m + 38 m = 328 m adjusted elevation.

3.3.3   The MOC in the primary intermediate area is 150 m.

3.3.4   Plot the adjusted obstacle position and determine whether the primary or secondary area MOC applies.

3.3.4.1   The intermediate area half-width 4.84 NM from the VOR is:

½W = 1 + (4/15 × 4.84) = 2.29 NM

The MOC is [(2.29 − 1.84)/(2.29/2)] × 150 m = 59 m

The lowest intermediate altitude is 328 + 59 = 387 m (1 300 ft)

EXTRACT FROM A DOCUMENT USED BY ONE STATE

Note.— See the end of this appendix for a list of abbreviations used in this extract.

SECTION 11.   OBSTACLE DATA ACCURACY

270.   GENERAL

The primary purpose of obstacle evaluation is to determine how an object will impact instrument flight procedures. The evaluations can provide accurate, consistent, and meaningful results and determinations only if FIFO and regional flight procedures specialists apply the same rules, criteria, and processes during development, review, and revision phases. This section establishes the minimum accuracy standards for obstacle data and its application in the development, review or revision of instrument procedures, and provides information on the application of the minimum accuracy standards. The minimum standards are to be applied by regional and FIFO specialists in all instrument procedures obstacle evaluations.

271.   OBSTACLE DATA ACCURACY STANDARDS FOR INSTRUMENT PROCEDURES

This paragraph identifies the MINIMUM requirement for accuracy of obstacle data used in the development of instrument procedures, and provides minimum accuracy standards for each instrument procedure segment.

a) *Concept.* Obstacle data accuracy is not absolute, and the accuracy depends on the data source. The magnitude of the error does not preclude the use of these data, provided it is identified and accounted for. In some cases, upgrading obstacle accuracy can provide relief from operational restrictions in an instrument procedure. This will allow expenditure of funds for obstacle surveys in areas where benefit to the aviation community would result. In no case, however, will the application of obstacle data accuracy preempt the requirement for the flight check of an instrument procedure for discrepancies. For sources of obstacle data accuracy, see Appendix 2.

b) *Standards.* The minimum accuracy standards contained herein are for use in the development, review, and revision of instrument procedures. They shall be applied to all new procedures and to existing procedures at the next revision or annual review, whichever occurs first.

The minimum accuracy standards are listed in (1) through (5) below. ADJUST the location/elevation data of the segment controlling obstacle by the amount indicated by the assigned accuracy code ONLY if that assigned code does not meet or exceed the following standards. For example, if the non-precision final segment controlling obstacle has an assigned accuracy code 4D, adjust its location data by +250' laterally, and its elevation data by +50' vertically; this is because 4D does not meet or exceed the minimum accuracy requirement of +50' horizontal and +20' vertical (2C) applicable to the non-precision final segment.

1) *+15' horizontal and +3' vertical accuracy.* Precision final segment.

2) *+50' horizontal and +20' vertical accuracy.* Non-precision final segment; missed approach area; circling areas. For departures and SIDs: Zone 1/Section 1 and first 2 NM of departure route.

3) *+250' horizontal and +50' vertical accuracy.* Intermediate segment. For departures and SIDs: Zones 2 and 3; Section 2; and beyond first 2 NM of departure route.

4) *+500' horizontal and +125' vertical accuracy; (1 000' ROC and Special ROC); (non-mountainous).* Initial segments; feeder segments; en-route areas; missed approach

holding; MSA; ESA; MVA; EOVM; MIA; DF Vector Areas. For SIDs: level route portion.

5) *+1 000' horizontal and +250' vertical accuracy; (2 000' ROC) mountainous).* Feeder segments; En-route areas; ESAs, DF Vector Areas. For SIDs: level route portion.

6) *In all cases,* if it is determined that the horizontal and/or vertical uncertainty adjustment associated with the controlling obstacle must be applied, *application should be in the most critical direction;* e.g. applied in the horizontal and/or vertical direction which most adversely affects the procedure.

7) If the controlling obstacle elevation plus accuracy code adjustments *affects a minimum altitude or gradient,* and a higher order of accuracy could reduce an adverse operational effect, then take action to have the accuracy improved; or adjust the procedure accordingly. See paragraph 272.

8) *Take no further action* if the controlling obstacle elevation plus accuracy code adjustment does not affect a SIAP minimum altitude or gradient.

9) *The FPB shall,* in coordination with air traffic, determine the accuracy standard to apply in the evaluation of a proposed obstruction. The FPB shall provide the FIFO with the accuracy standard to be applied in the development/ revision of any affected procedures.

c) *IAPA database.* The IAPA obstruction base file (OBS1) contains obstacle location and elevation data as provided to the Office of Aviation System Standards by the National Ocean Service. The data contains both verified and unverified obstacles. Obstacles identified in the development, review, and revision of instrument procedures which are not contained within the IAPA database shall be entered into the OBS1 file by the FIFO in accordance with the following:

1) *Graph table terrain entries* shall be for terrain elevation only. When between contour lines, the next higher contour elevation minus 1 foot shall be used. For example, if the map contour interval is 20 feet and the basic elevation is 100 feet, then the entry would be 119 feet. Surveyed spot elevations shall be entered as stated on the map.

2) *Manually entered obstacles* such as natural growth and artificial objects shall be entered in the OBS1 file. The MSL and AGL values shall be included with the other available data entries.

3) *The accuracy standards in paragraph 271 b)* above shall be included in IAPA obstruction data entries made by the FIFO. When entering obstructions manually via the alphanumeric keyboard, enter the appropriate horizontal and vertical accuracy errors in feet on OBS1, items 6 and 7.

272. APPLICATION

The instrument procedure shall be adjusted to meet the requirements of the minimum accuracy standards. When an altitude adjustment is required which would affect the procedure, the FIFO shall notify the FPB of the nature, magnitude, and rationale for the adjustment. The FPB will first review records to identify an existing source validating a higher level of accuracy and advise the FIFO of this data. If no data is found, the FPB will notify the public/proponent of the impact on the procedure and alternatives available. FIFOs shall not delay further processing of affected procedures pending receipt of higher level accuracy data from the FPB unless otherwise agreed by the FPB.

a) *Manual.* When manually developing the procedure, depict all obstacles identified on FAA Form 8260-9 in coordinates to the second, and assign the highest order of accuracy known for the data source. See paragraph 909.

b) *IAPA.* When using IAPA to develop the procedure, apply the accuracy standards as follows:

1) *Obstacle accuracy standards* shall be considered when determining the altitude(s) to be charted. This is accomplished on the applicable segment menu; e.g. FINAL, CIRCLING, etc.

2) *If segment altitude adjustments are made* to meet the requirements of the minimum accuracy standards, state the reason for the adjustment on the applicable menu or in the remarks section (RMKS).

c) *Evaluation Sequence.* In either a) or b) above, first determine the controlling obstacle using raw obstacle data. Then add horizontal/vertical accuracy

code adjustments to the raw values to determine the obstacle's most adverse location and elevation. Accuracy code adjustment is not applied to obstacles evaluated relative to TERPS, paragraphs 289 or 332.

d) *"Controlling obstacle"* has the following definitions for the purpose of application and documentation:

1) *For precision* SIAP final segments, that obstacle which, having penetrated the obstacle clearance or transitional surface, causes the most adverse adjustment to DH. Where there are multiple penetrations, first determine the required DH adjustment for each obstacle using raw obstacle data. Then, having determined the controlling obstacle, recalculate the required DH ad-justment using accuracy code adjusted data.

2) *For non-precision* final segments, intermediate, initials, holding, feeders, etc., the obstacle in the primary area (or secondary area equivalent) which has the highest elevation.

3) *For missed approach* segments, that obstacle which, having penetrated a missed approach obstacle clearance surface, causes the most adverse adjustment to DH/MDA or MAP relocation.

4) *For departure/SIDs,* that obstacle which, having penetrated the 40:1 Obstacle Identification Surface (OIS), causes the most adverse climb gradient and/or ceiling and visibility to be published.

List of Abbreviations

AGL	Above ground level
DF	Direction finding
DH	Decision height
ESA	Emergency safe altitude
EOVM	Emergency obstacle video map
FAA	Federal Aviation Administration
FIFO	Flight inspection field office
FPB	Flight Inspection Branch
IAPA	Instrument approach procedure automation
MAP	Missed approach point
MDA	Minimum descent altitude
MIA	Minimum IFR altitude

MSA   Minimum safe altitude
MVA   Minimum vector altitude
OBS1   Obstruction base file
RMKS   Remarks
ROC   Required obstacle clearance

SIAP   Standard instrument approach procedure
SID   Standard instrument departure
TERPS   United States Standard for terminal and en-
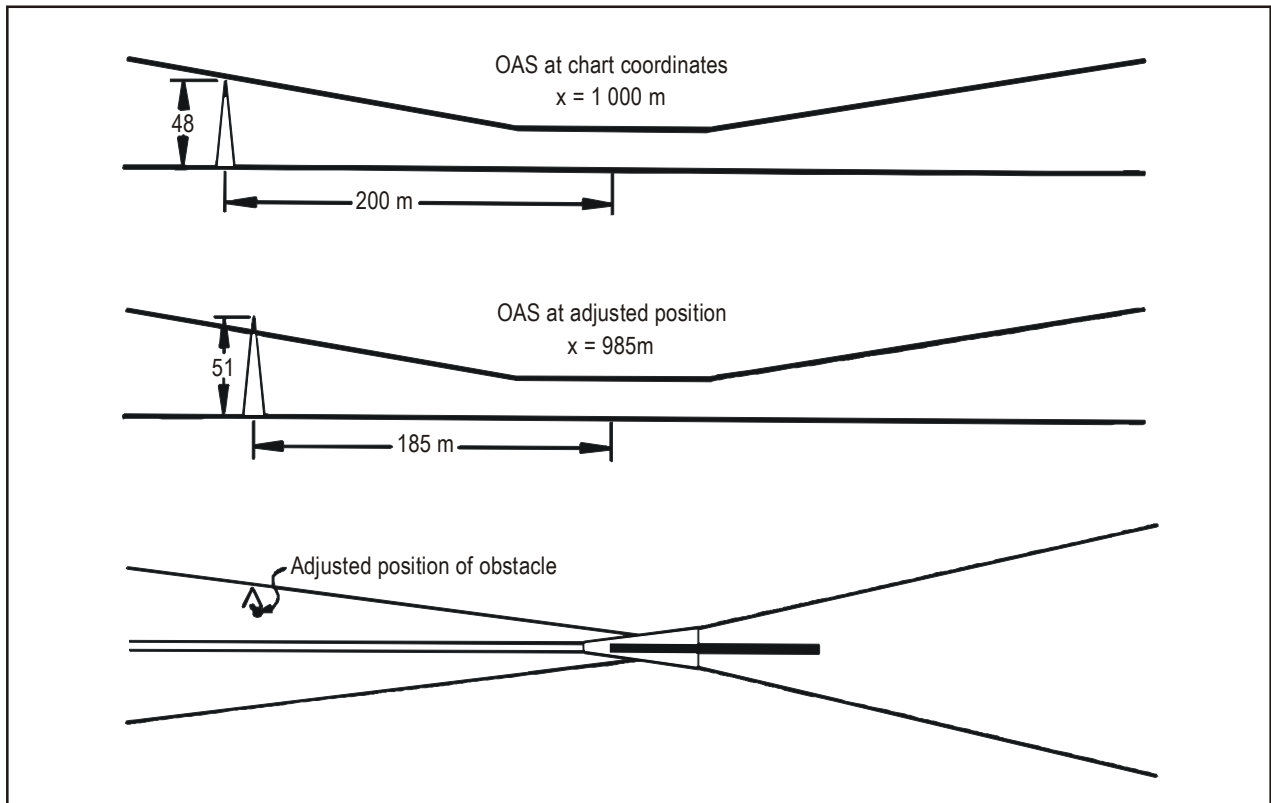   route procedures
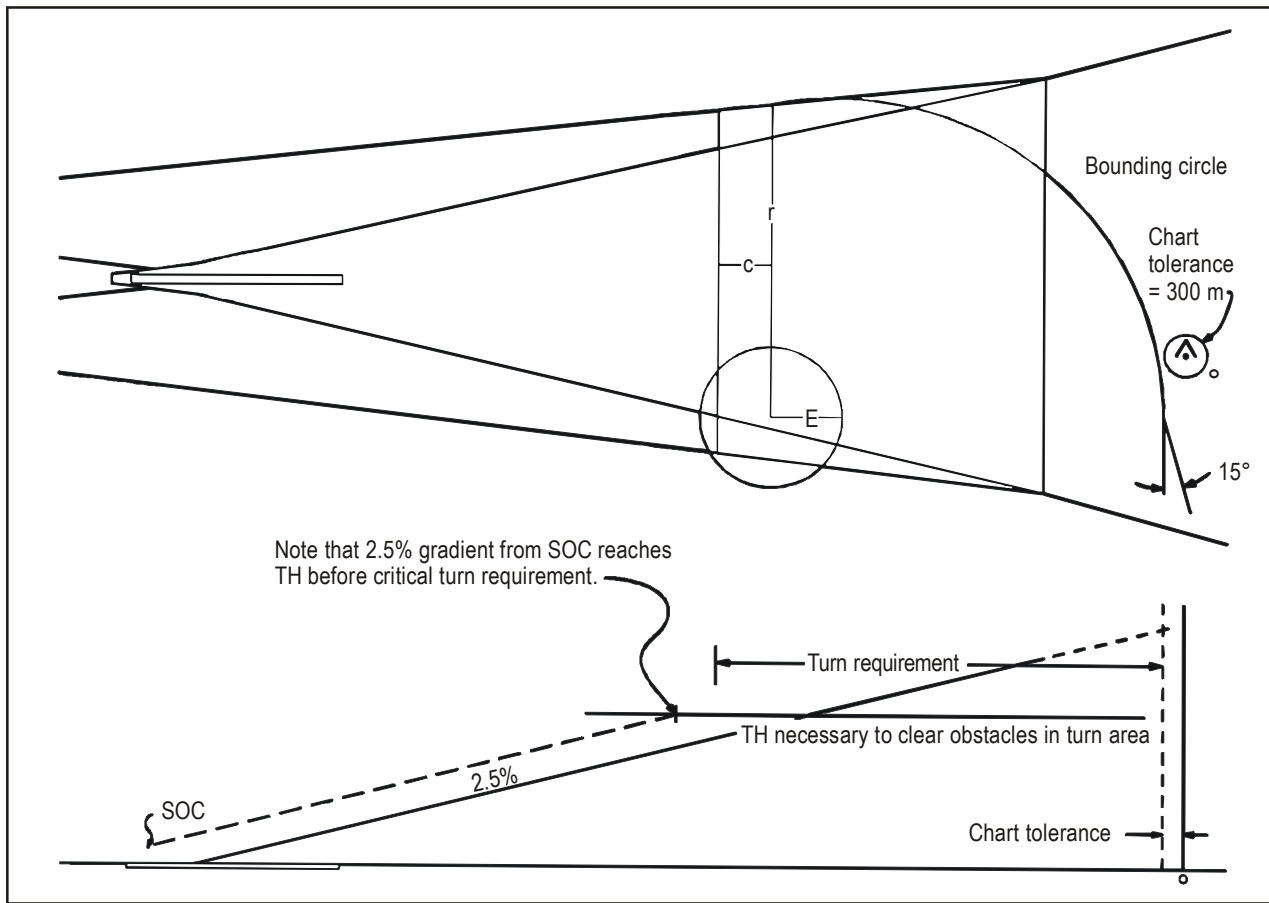

Figure C1-1.   Affect of chart tolerance on ILS

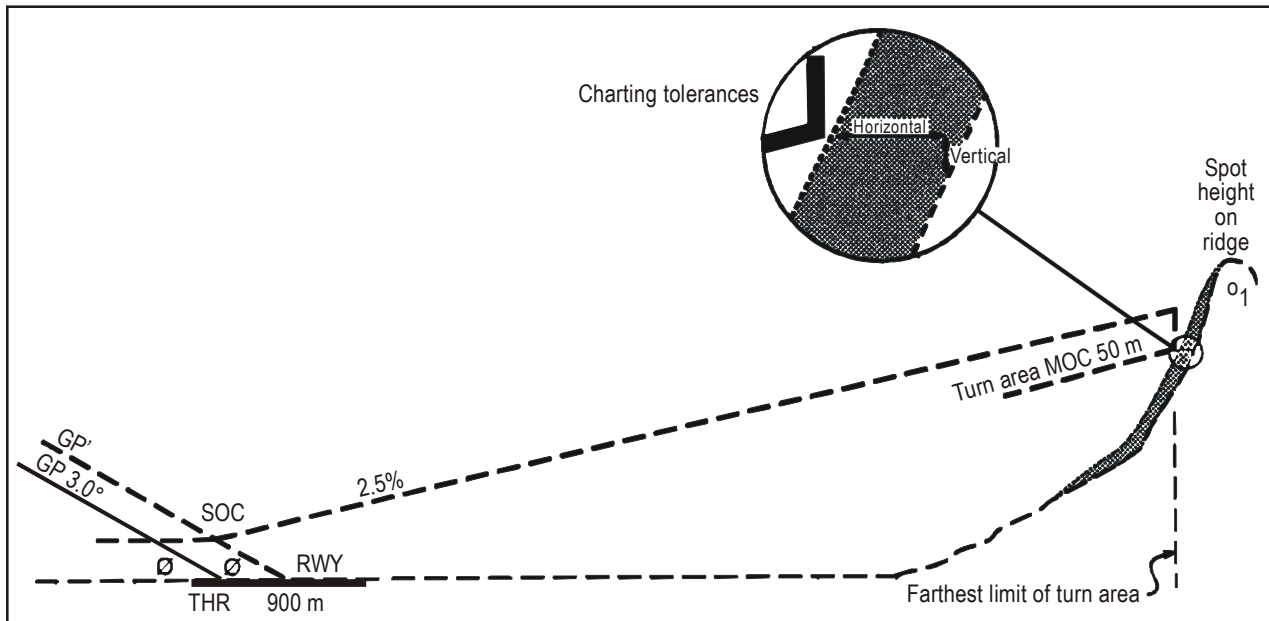**Figure C1-2.   Chart tolerance application to a turning missed approach**

Figure C1-3.   Chart tolerance applied to an obstacle with a sloping surface

Adjusted position

0   5   10   15   20   25   30 km

0   5   10   15 NM
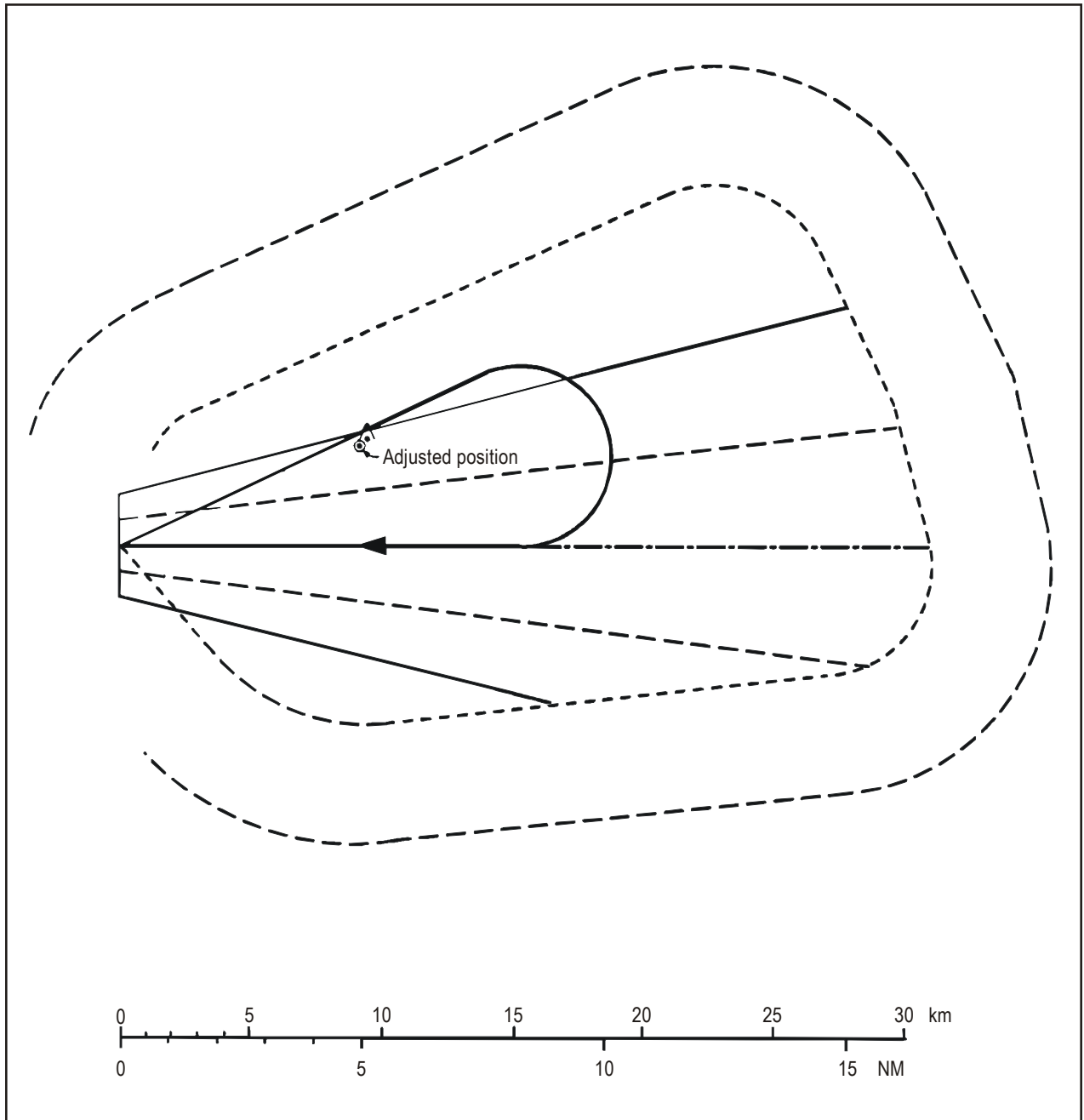
Figure C1-4

Attachment C2

Documentation Record

The forms included in this Attachment and called "checklists" are examples of how a record can be kept of the essential results of calculations involved in the process of developing an instrument approach procedure.

Two different forms are proposed, one for non-precision and the other for precision procedures. For each segment, the controlling obstacle, the MOC applied and the resulting minimum altitude is listed. At the end of the form, the OCA/H for the procedure is recorded.

It is suggested that these checklists be retained as a part of the permanent file along with the terrain charts and other documents which support the procedure.

PROCEDURE CHECKLIST NON-PRECISION

Threshold elevation:

INITIAL 1	A	B	C	D
Type: straight (S) racetrack (RT) reversal (R)				
Obstacle elevation				
Location of obstacle primary (P) secondary (S)				
MOC applied				
Required altitude				
Nominal altitude				
Speed restriction: no (N) yes (Y) value				
Comments				

INITIAL 2	A	B	C	D
Type: straight (S) racetrack (RT) reversal (R)				
Obstacle elevation				
Location of obstacle primary (P) secondary (S)				
MOC applied				
Required altitude				
Nominal altitude				
Speed restriction: no (N) yes (Y) value				
Comments				

INTERMEDIATE: yes (Y) no (N)	A	B	C	D
Length (L) or time (T) value				
Alignment with final: straight (S) angle				
Obstacle elevation				
Primary (P) or secondary (S) area				
MOC applied				
Required altitude				
Nominal altitude				
Gradient (G) rate of descent (R) value				
Comments				

FINAL	A	B	C	D
On- or off-aerodrome facility				
Length (L) time (T) value				
Obstacle elevation				
Primary (P) secondary (S) area				
Stepdown fix: yes (Y) or no (N) MOC applied				
OCA (final)				
Comments		Threshold elevation		

MISSED APPROACH	A	B	C	D
MAPt: facility (F) fix (FIX) distance/FAF (D) value				
Straight missed approach				
Obstacle elevation				
Primary (P) secondary (S)				
MOC applied (full MOC = 30 m)				
Required altitude				
OCA missed approach				
Comments (non standard gradient)				

TURNING MISSED APPROACH	A	B	C	D
Fix (F) altitude (A) distance (D)				
Obstacle elevation in turn initiation area (if turn at an altitude)				
Minimum turn altitude (MOC = 50 m)				
Obstacle elevation in turn area				
Resulting turn altitude				
OCA (missed approach)				
Restricted speed: no (N) yes (Y) value				
Comments				

RESULTS	A	B	C	D
Resulting OCA for the procedure				
Gradient (G) rate of descent (R) value on final				
Level acceleration segment height				
Comments Threshold elevation				

PROCEDURE CHECKLIST PRECISION

INITIAL 1	A	B	C	D
Type: straight (S) racetrack (RT) reversal (R)				
Obstacle elevation				
Location of obstacle primary (P) secondary (S)				
MOC applied				
Required altitude				
Nominal altitude				
Speed restriction: no (N) yes (Y) value				
Comments				

INITIAL 2	A	B	C	D
Type: straight (S) racetrack (RT) reversal (R)				
Obstacle elevation				
Location of obstacle primary (P) secondary (S)				
MOC applied				
Required altitude				
Nominal altitude				
Speed restriction: no (N) yes (Y) value				
Comments				

INTERMEDIATE: yes (Y) no (N)	A	B	C	D
Length (L) or time (T) value				
Alignment with final: straight (S) angle				
Obstacle elevation				
Primary (P) or secondary (S) area				
MOC applied				
Required altitude				
Nominal altitude				
Gradient (G) rate of descent (R) value				
Comments				

PRECISION SEGMENT	A	B	C	D
Distance FAP/threshold				
OAS penetrated no (N) yes (Y) surface				
Obstacle height				
HL applied				
OCHps (precision segment) applied				
OCHps CRM				
Comments				

STRAIGHT MISSED APPROACH AFTER PS	A	B	C	D
Obstacle height				
SOC height				
HL applied				
OCHm (missed approach)				
Comments				

TURNING MISSED APPROACH	A	B	C	D
Fix (F) or height (H)				
Obstacle height in turn initiation area (if turn at a height)				
Minimum T height (MOC = 50 m)				
Obstacle height in turn area				
Resulting T height				
dz (minimum 1 200 m)				
SOC height				
HL applied				
OCHm (missed approach)				
Comments				

RESULTS	A	B	C	D
Resulting OCH for the procedure				
Level acceleration segment height				
Comments				

GP INOPERATIVE	A	B	C	D
FAF: fix (FIX) facility (F) name				
Obstacle height				
MOC applied				
OCHf (final)				
MAPt: facility (F) fix (FIX) distance/FAF (D) value				
Missed approach: straight (S) turn (T)				
If obstacle height in turn initiation (T) area Minimum T height (MOC = 50 m)				
Obstacle height				
Required height				
OCHm (missed approach)				
Resulting OCH				
Comments				

CIRCLING	A	B	C	D
Obstacle elevation				
MOC applied				
OCA (check minimum values)				
Comments				

Attachment C3

Calculation of Way-point Coordinates

INTRODUCTION

An international standard is required for selecting the information to be used in the calculation of way-point positions defining routes of flight and establishing course directions for RNAV procedures. This standard method of calculation is critically important for RNP operations to ensure repeatability of navigation performance. The aviation industry has developed recognized methods (rules) of way-point coordinate calculation that satisfy the requirements of RNP operations. Instrument procedure designers are encouraged to utilize these methods, together with computer geodetic computation software, in developing RNAV instrument procedures.

CALCULATION OF MISSED APPROACH POINT (MAPt) COORDINATES

Example 1 — Where the MAPt is located at the runway threshold, use the coordinates of the designated centre of the landing threshold as the MAPt coordinates. See example 1 in Figure C3-1.

Example 2 — Where the MAPt is located on the runway centre line extended, use the reciprocal of the landing runway true bearing, threshold coordinates and intended distance from the threshold to the MAPt for calculating the coordinates. See example 2 in Figure C3-1.

Example 3 — Where the final approach course is offset from the runway centre line extended and the MAPt is located prior to the runway threshold, use the threshold coordinates and the true bearing and intended distance from the threshold to the MAPt for calculating the MAPt coordinates. See example 3 in Figure C3-1.

CALCULATION OF FINAL APPROACH FIX COORDINATES

Example 1 — Where the FAF is on the extended runway centre line, use the reciprocal of the landing runway true bearing, landing runway threshold coordinates and the intended distance from the landing runway threshold to the FAF for calculating the FAF coordinates. The MAPt may or may not be located at the landing runway threshold. See Figure C3-2.

Example 2 — Where a continuous geodesic course includes the FAF and the MAPt but does not pass through the threshold, calculate the FAF coordinates using the MAPt coordinates and the true bearing and the intended distance from the MAPt to the FAF. See Figure C3-3.

CALCULATION OF INTERMEDIATE FIX COORDINATES

Example 1 — Where the IF, FAF and MAPt are located on the extended runway centre line, use the threshold coordinates, the reciprocal of the landing runway true bearing, and the distance from the threshold to the IF for calculating the IF coordinates. The MAPt may or may not be located at the landing runway threshold. See Figure C3-4.

Example 2 — Where a continuous geodesic course includes the IF, FAF and MAPt but does not pass through the threshold, calculate the IF coordinates using the MAPt coordinates and the true bearing and distance from the MAPt to the IF. See Figure C3-5.

Example 3 — Where the IF is not on a continuous geodesic course that includes both the FAF and MAPt, use the FAF coordinates and the true bearing and distance from the FAF to the IF for calculating the IF coordinates. See Figure C3-6.

CALCULATION OF INITIAL APPROACH FIX (IAF) COORDINATES

Example 1 — Where the IAF, IF, FAF and MAPt are located on the runway centre line extended, use the landing runway threshold coordinates, the reciprocal of the landing runway true bearing and distance from the threshold to the IAF for calculating the IAF coordinates. The MAPt may or may not be located at the threshold. See Figure C3-7.

Example 2 — Where a continuous geodesic course includes the IAF, IF, FAF and MAPt but does not pass through the threshold, calculate the IAF coordinates using the MAPt coordinates and the true bearing and distance from the MAPt to the IAF. See Figure C3-8.

Example 3 — Where the IAF is not on a continuous geodesic course that includes the IF, FAF and MAPt, use the IF or FAF coordinates and the true bearing and distance from the IF or FAF to calculate the IAF coordinates. See Figure C3-9.

CALCULATING RNAV INSTRUMENT DEPARTURE TURN POINTS

Departure turn points should normally be established on an extension of the departure runway extended centre line. To establish the lateral position for the turn point, apply the true bearing of the departure runway and a distance from the beginning of the authorized take-off run to the desired position of the turn point. Note that the runway length is included as part of the distance.

To establish the coordinates of a turn way-point on a departure from Runway 31, apply the departure runway true bearing and the distance from the position of authorized take-off roll to the fix/way-point. See Figure C3-10.

Example — Calculate the coordinates of the departure turn way-point, given: RWY 31 threshold coordinates = N 35 23 21.99 W 097 35 50.72; Distance threshold to turn way-point = 12.964 km (7 NM) (includes runway length); RWY 31 true bearing = 315.07°T; Calculated turn way-point coordinates = N 35 28 19.65 W 097 41 53.88
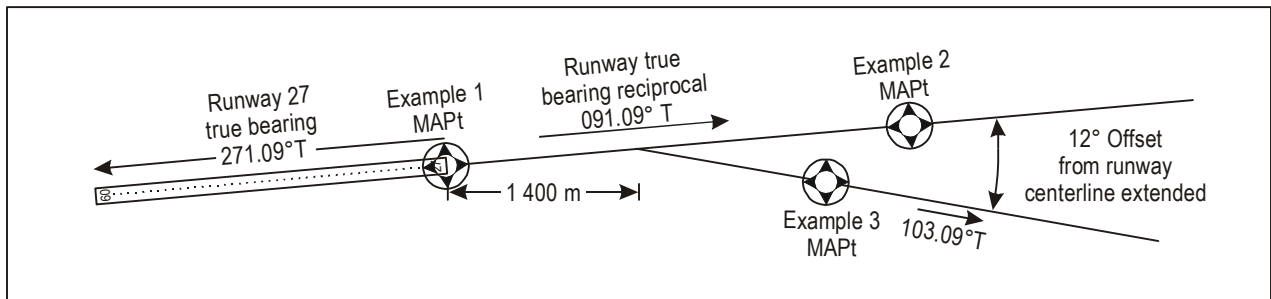
Figure C3-1
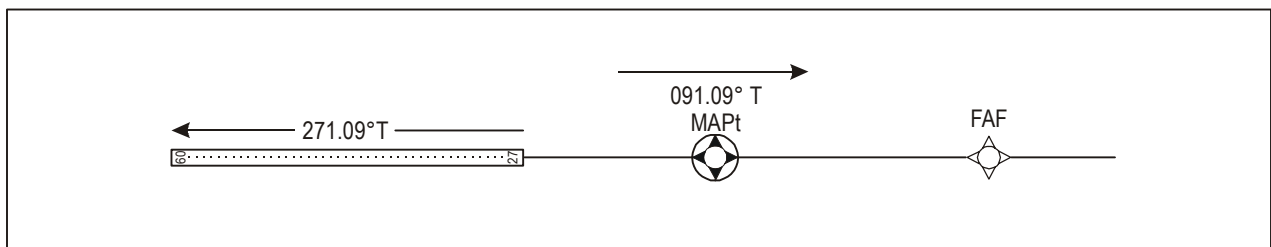
Figure C3-2
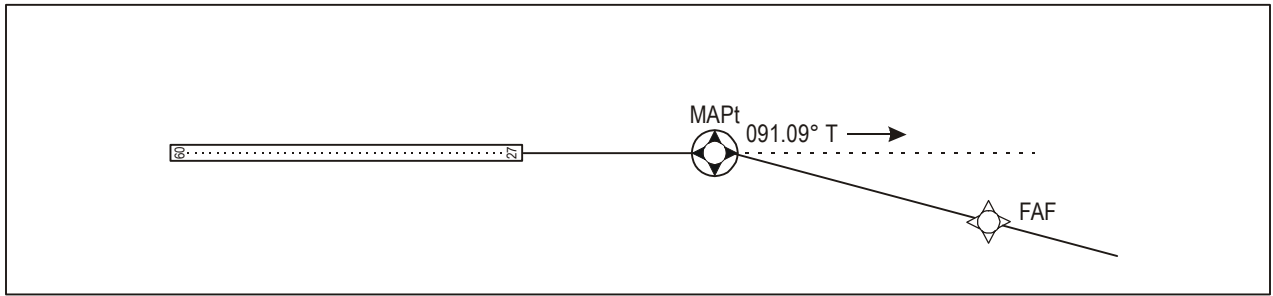
Figure C3-3
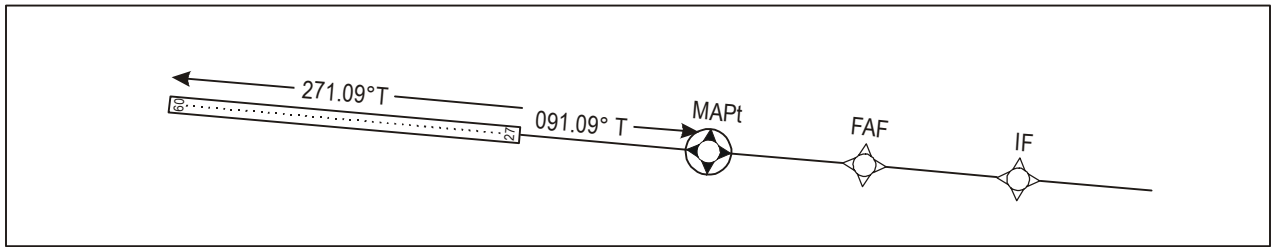
Figure C3-4
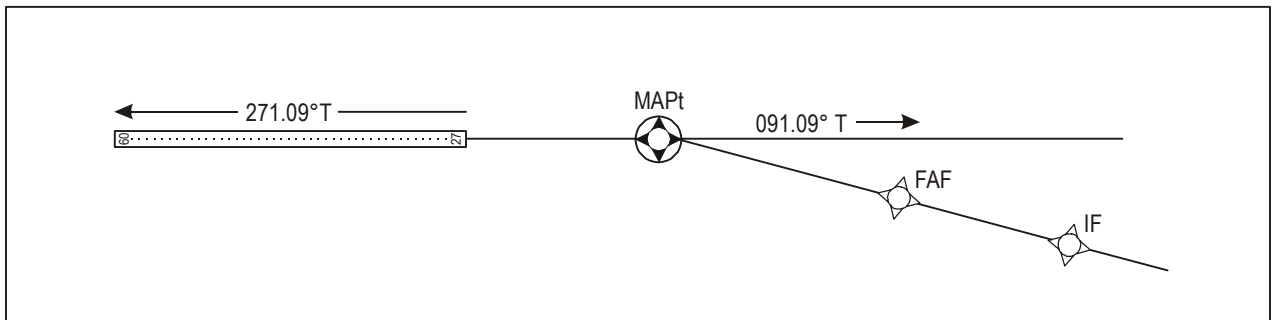
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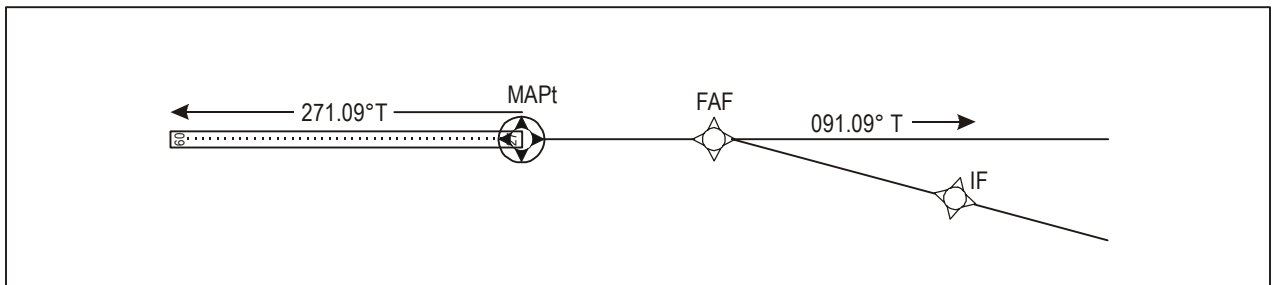
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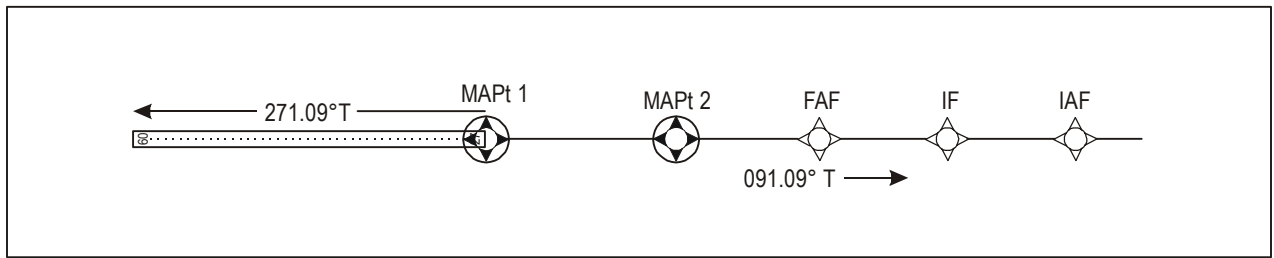
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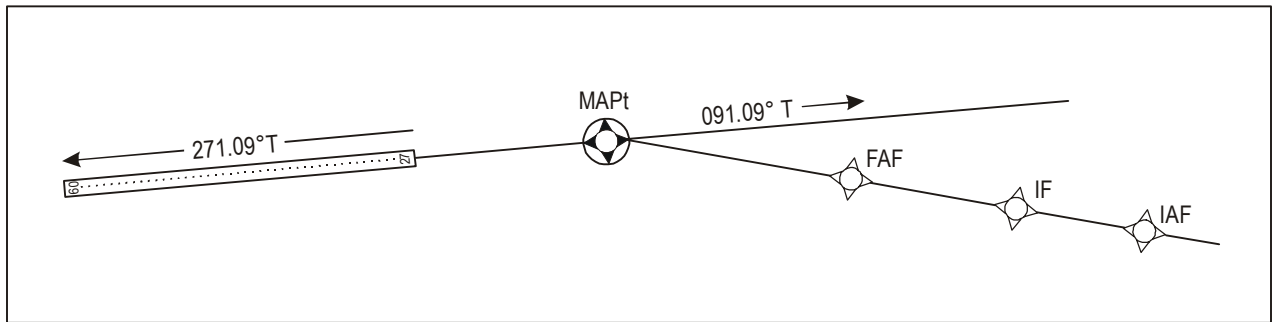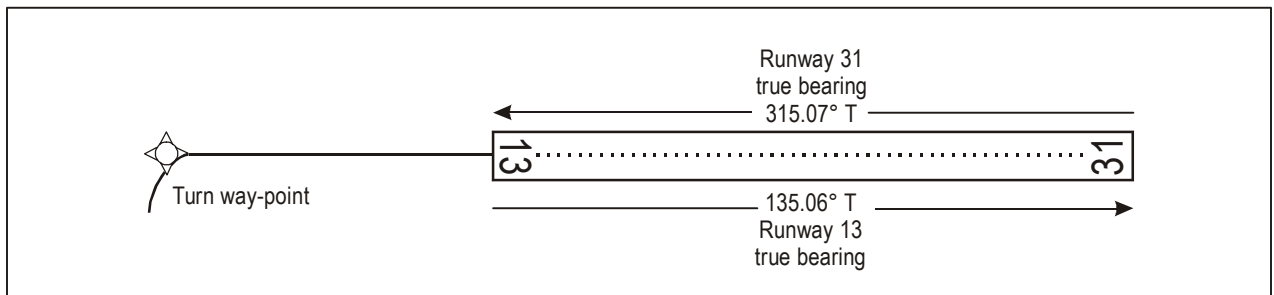

Figure C3-8
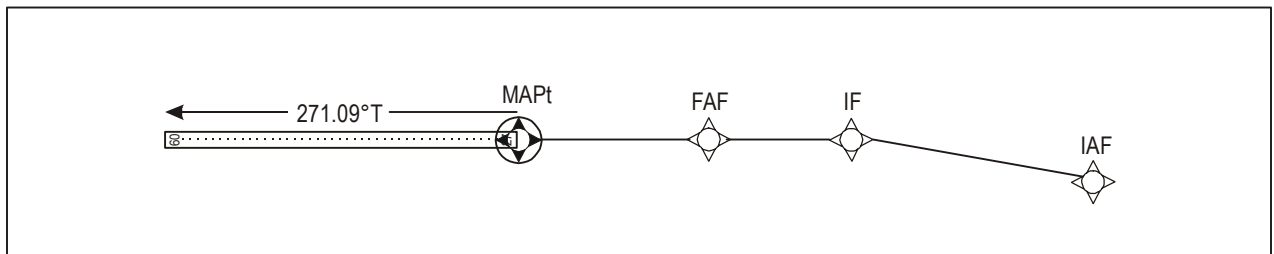
Figure C3-9

Figure C3-10

Attachment C4

Aeronautical Data Quality Management

1. INTRODUCTION

1.1 *Cyclic redundancy check (CRC).* A mathematical algorithm applied to the digital expression of data that provides a level of assurance against loss or alteration of data.

1.2 The intent of this attachment is to familiarize procedure designers with the CRC methodology and to define the application of a CRC that is specific to the precision approach path points. The integrity of aeronautical data, produced by surveyors and procedure designers, becomes progressively more important as this data is used on an onboard navigation database to define more precisely the procedure to be flown by the aircraft.

1.3 Aeronautical data integrity requirements are based upon the potential risk resulting from the alteration or loss of data during the use of that data. Responsibility for the integrity of the data starts with the originator, such as the surveyor or procedure designer. Thereafter, as the data is stored, reformatted and transferred between different organizations, the data integrity can be ensured using validation and verification checks and, where necessary, a cyclic redundancy check (CRC). Traditional instrument procedure design does not require this high level of integrity due to the fact that the procedure is based upon a specific conventional navigation aid that is regularly flight checked. With the introduction of RNAV, maintenance of aeronautical data integrity becomes crucial.

1.4 It is important to understand that the CRC only provides a level of assurance against loss or alteration of data during the electronic transmission of this data but does not assure the correctness or accuracy of the original data input itself. While the CRC may form part of the data during transmission, it is not intended to publish the CRC on aeronautical charts.

2. CLASSIFICATION OF DATA FOR RNP

2.1 Aeronautical data can be divided into the following three integrity categories, which have been adopted from the ICAO *World Geodetic System — 1984 (WGS-84) Manual* (Doc 9674):

Critical data: There is a high probability when trying to use altered or lost critical data that an aircraft would be placed in a life threatening situation. The required level of integrity is 1×10^{-8} or better;

Essential data: There is a low probability when trying to use altered or lost essential data that an aircraft would be placed in a life threatening situation. The required level of integrity is 1×10^{-5} or better.

Routine data: There is a very low probability when trying to use altered or lost routine data that an aircraft would be placed in a life threatening situation. The required level of integrity is 1×10^{-3} or better.

2.2 Aeronautical data integrity requirements depend upon the intended use of the data. For example, data concerning a VOR designed for RNAV in terminal airspace is classified essential while data concerning a VOR supporting en-route RNP 5 RNAV is classified routine. Data should be classified such that its highest integrity requirement corresponds to its most critical use.

2.3 The integrity of critical aeronautical data is achieved by using a 32-bit CRC algorithm.[1] Examples of critical data include:

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1. An 8-bit CRC algorithm will provide a 3.9×10^{-3} level of integrity protection; a 16-bit algorithm will provide a 1.5×10^{-5} level of integrity protection; a 24-bit algorithm will provide a 6.0×10^{-8} level of integrity protection; and a 32-bit CRC algorithm will provide a 2.3×10^{-10} level of integrity protection.

a) precision RNAV runway landing threshold point and flight path alignment point used in precision RNP RNAV procedures;

b) WGS-84 ellipsoid height at the landing threshold point;

c) WGS-84 ellipsoid height CAT I/II/III runway end and threshold points;

d) CAT I/II/III runway end and threshold;

e) threshold crossing height or runway datum height; and

f) precision RNP RNAV approach path point angle.

2.4   The integrity of essential data can be achieved through the implementation of an appropriate quality assurance system as detailed in RTCA DO200A/ EUROCAE ED-76. Examples of essential data include:

a) latitude and longitude of most terminal and en-route navaids;

b) all instrument approach procedure fixes/way-points;

c) obstacles in the approach, departure and missed approach paths;

d) non-precision runway ends and landing thresholds;

e) elevation data of most navaids;

f) non-precision instrument approach procedure altitudes; and

g) IRU update latitude and longitude position coordinates.

2.5   Routine data integrity requirements can be achieved using existing quality assurance methods. Examples of routine data include:

a) all other obstacles;

b) airspace boundaries;

c) aerodrome reference points;

d) aircraft stands/gates (when not used as IRU update positions);

e) elevation data of most en-route navaids;

f) elevation data of ILS, MLS, GBAS antenna;

g) airway segments;

h) NDB navaid magnetic variation;

i) fixes/way-point other than those in instrument approach and departure procedures;

j) ILS glide slope angles;

k) MLS elevation beam width;

l) ILS beam width; and

m) MLS azimuth limits.

2.6   It should be noted that routine data are elements of aeronautical information that are currently being utilized in today's operations. The normal data quality assurance checks in place today should continue to meet the requirements of data integrity. The essential data include RNAV way-points used in terminal airspace and runway thresholds used for non-precision RNAV approaches. It is necessary that all organizations involved in producing and handling essential data meet the quality assurance requirements laid down in RTCA DO200A/EUROCAE ED76. Critical data includes data associated with precision path points and requires the surveyor, the procedure designer and all subsequent data processors to use a 32-bit CRC to ensure data integrity for such operations.

3.   QUALITY MANAGEMENT OF NUMERICAL AERONAUTICAL DATA

RNAV-based instrument procedures should be developed with the aid of computer technology. Critical navigation data must be created in an electronic format with an associated CRC value so that the integrity can be electronically monitored at all stages of the various production processes. The CRC check is applied to a specific binary pattern and a CRC value has to be regenerated every time the data format changes. The format of the data fields to be protected by a CRC in the airborne navigation database is still being developed. It is anticipated that guidance on the format to be protected by the designer, and the CRC algorithm to be used, will be provided in the near future. In the interim, the designer should ensure that any critical data is protected and that the format and CRC algorithm used is published with the data set. The following table provides an example of this:

Data item name	Data item
Airport identifier	EGCC
Runway number	24R
Operation type	GLS RNP0.1
Landing threshold point latitude	532140.76N
Landing threshold point longitude	0021533.39W
Landing threshold point height	249
Landing threshold point undulation	50
Threshold crossing height	50
Flight path alignment point latitude	532051.18N
Flight path alignment point longitude	0021715.98W
Flight path alignment point height	211
CRC value (hexadecimal representation)	52AF07D5
Format — ASCII CRC Algorithm — CRC-32Q	

4.   ATTRIBUTES OF COMPUTATION SOFTWARE, QUALITY ASSURANCE AND INTEGRITY TOOLS

Various computer software are available on the commercial market to aid the instrument procedure designer in developing RNAV-based procedures as well as ensuring data quality and integrity. Some of the attributes of this software may include, but are not limited to:

a)   a cyclic redundancy check (CRC) tool;

b)   datum transformation and map projections;

c)   geodetic computations to include distance and azimuth direct and inverse calculations, long line intersections between geodesics and geodetic and small circles, and slant ranges;

d)   collinearity checks;

e)   location checks within a geographic area;

f)   a convenient method of storing, tracking and retrieving data files; and

g)   user manual, data integrity guidance material, user training and software programme updates.

References — Industry Requirements for Aeronautical Information. Draft RTCA DO-201A/EUROCAE ED-77 (Final Draft, 3 May 1999)

Attachment C5

Path Terminators

1. INTRODUCTION

1.1 This attachment contains information and guidance material on the aviation industry's navigation database requirements necessary to support operational airborne navigation system software. To achieve the objectives of the ICAO FANS working group, future navigation systems must compute flight paths that are consistent and flown in the same manner by all aircraft. To accomplish this, the flight paths must be accurate, reliable and repeatable. It is necessary, therefore, that all future navigation systems perform certain flight path functions in the same manner.

1.2 A route of flight (airway, air route, SID, STAR, approach or departure procedure), appropriately designed in terms of its usability in navigation databases, provides for consistent aircraft performance on the required flight path.

2. PATH TERMINATORS

2.1 The aviation industry applies a "path and terminator concept" for transforming arrival, departure and approach procedures into coded flight paths that can be interpreted and used by a computer-based navigation system. The path and terminator concept includes a set of defined codes referred to as "path terminators". A path terminator instructs an aircraft to navigate from a starting point along a defined path to a specific point or terminating condition. A sequence of path terminators defines the intended route from take-off, through each departure segment, to a point on the en-route airway, or from the en-route airway through each arrival segment and approach segment, to the missed approach point, landing runway end point or the missed approach hold point.

2.2 The path and terminator concept used is a set of two alphabetic characters, each of which has meaning when describing a flight manoeuvre to a computer. The first character indicates the type of flight path to be flown and the second character indicates where the route segment terminates. For example, a direct track from one explicit fix to another would be coded with a "TF" path terminator.

The "T" represents the type of flight path to be flown (a track in this case) and the "F" indicates that the segment terminates at a fix.

2.3 There are 23 different path and terminator sets used by the aviation industry to accommodate the coding of procedure route segments for RNAV. The 23 different path terminator sets are shown in the table below and explained in the following sections. Only 9 of the 23 path terminator sets are usable in defining RNP procedures and airspace. These are indicated in Table C5-1 as "used for RNP procedures."

3. ROUTE SEGMENTS TO BE USED IN RNP PROCEDURES

3.1 Only two types of route segments, a straight path or a curved path between defined points, can be used unconditionally in procedure design in RNP airspace, especially airspace to be designated RNP 4 or less. Using these two route types ensures that the flight path is reliable, repeatable and predictable.

3.2 The first of these route segments is a track between two way-points. The track will be coded as a track to a fix or a TF leg (see Figure C5-1) by the database agency. If the track is the beginning route segment of a flight path an initial fix or IF leg is used to code or define the beginning point (see Figure C5-2). Otherwise, the first fix (or way-point) is the termination fix/way-point of the previous segment.
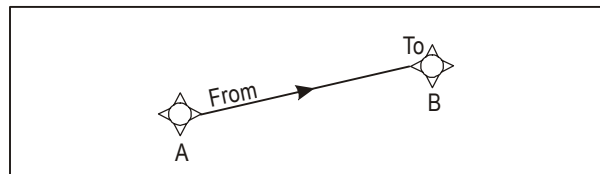

Figure C5-1. TF leg. Track to fix

The "TF" leg, track to fix, yields a path that is the great circle track between two defined way-points. Since the

Table C5-1

Leg types	Description	Used for conventional procedures	Used for RNAV procedures	Used for RNP procedures
IF	Initial fix	Yes	Yes (preferred)	Yes (preferred)
TF	Track to fix	Yes	Yes (preferred)	Yes (preferred)
RF	Radius to fix	No	No	Yes (preferred)
DF	Direct to fix	Yes	Yes	Yes (discouraged)
FA	Fix to altitude	Yes	Yes	Yes (discouraged)
CF	Course to fix	Yes	Yes	Yes (to be phased out)
HF	Hold to fix (and exit)	Yes	Yes	Yes (new RNP hold criteria)
HA	Hold to altitude (climb)	Yes	Yes	Yes (new RNP hold criteria)
HM	Hold for clearance	Yes	Yes	Yes (new RNP hold criteria)
PI	Procedure turn to intercept	Yes	No	No
CA	Course to altitude (climb)	Yes	No	No
CI	Course to intercept	Yes	No	No
CD	Course to DME arc	Yes	No	No
CR	Course to VOR radial	Yes	No	No
FC	Course from fix	Yes	No	No
FD	Fix to DME arc	Yes	No	No
FM	Vectors from fix	Yes	No	No
AF	DME arc to fix	Yes	No	No
VD	Heading to DME arc	Yes	No	No
VA	Heading to altitude (climb)	Yes	No	No
VM	Heading (vectors)	Yes	No	No
VI	Heading to intercept	Yes	No	No
VR	Heading to VOR radial	Yes	No	No

course is calculated on the basis of the latitudes and longitudes of the defining way-points, true courses, rather than magnetic courses, will result. The FMS's magnetic variation model adjusts the desired course to display magnetic course information on the pilot's instruments, but it will have no influence on the aircraft's path over the earth's surface. The TF leg, from the FMS designer's standpoint, is probably the easiest to implement. Database requirements are minimal in that only the coordinates of the defining way-points are needed. Since the end points of a TF leg are defined by their coordinates, this leg type results in the most precisely defined path over the ground. The TF leg is used in the construction of all RNAV procedures.
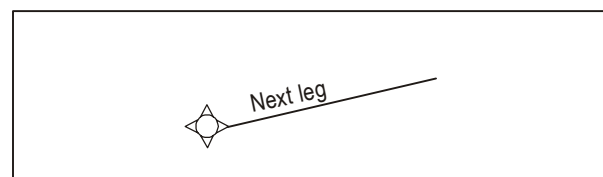
Figure C5-2.   IF leg. Initial fix

The "IF" leg, initial fix, is the point where a flight path begins. An IF leg is not a route segment and does not define a desired track in or of itself. It is used in conjunction with other leg types, such as the TF leg, in order to define the beginning of the desired route.

3.3   The second route segment that will ensure RNP containment is a curved path route segment about a defined turn centre (point B in Figure C5-3). A curved path route segment is used where a course change is required and will be coded as a radius to a fix, or RF leg. The curved path segment begins at the terminating fix/way-point of the previous segment (point A in Figure C5-3) and ends at the terminating fix/way-point (point C in Figure C5-3). Both entry and exit paths should be tangential to the arc of the curved path, and the termination fix/way-point for the previous segment should lie on the arc. The curved path itself is calculated by the avionics system using the termination fix/way-point, the turn direction of the segment and the centre of the arc, all of which are defined in the navigation database. The radius is computed as the distance from the turn centre to the termination fix/way-point. The procedure should be developed by providing all required data including:

a)   the geographic location of the arc centre;

b)   the geographic location of the radius termination fix/way-point; and

c)   the geographic location of the previous segment termination fix/way-point.
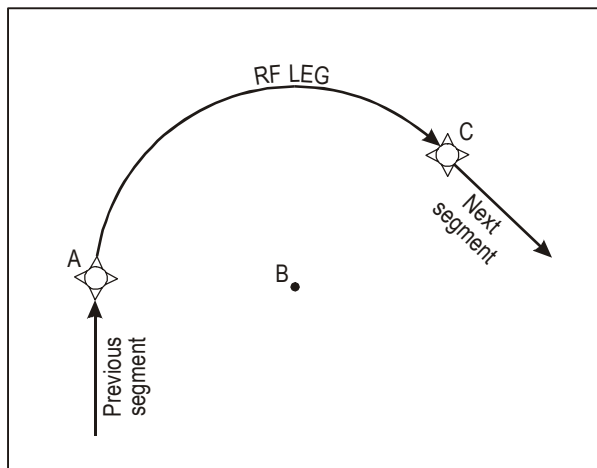
Figure C5-3.   RF leg. Radius to a fix

The "RF" leg, radius to a fix, is referred to as the precision arc leg. Its primary application is curved-path procedures. It permits resolution of the arc radius to 0.001 NM. It does not require a navaid at the arc origin. In the aircraft navigation database ARINC 424 record, the description of this leg type is overdefined to permit some inherent error checking capability. The RF leg will generally be preceded and followed by TF legs that are tangential to the arc.

4.   HOLDING AREAS FOR RNP AIRSPACE

4.1   The protected airspace for holding areas within RNP airspace for RNAV and FMS-equipped aircraft will be significantly different from the protected area for traditional holds. RNP RNAV holds are defined to take advantage of fixed path flight with a predetermined level of expected system accuracy. Some of the significant differences between RNP RNAV holds and the non-RNP RNAV holds are:

a)   RNP RNAV holds eliminate the requirement to overfly the hold fix upon entry, allowing a reduction of required holding airspace on the non-holding side of the hold fix; and

b)   the holding area for RNP RNAV holds is based upon a "racetrack" defined path in lieu of an airmass path (based upon maximum bank angle).

4.2   The design of holding patterns for RNP RNAV will permit navigation systems to maintain containment while holding in the RNP airspace. Once the holding pattern has been entered, there are three types of holding terminations that are described by the path and terminator defined below.

4.3   A hold to fix (HF) route segment is a holding pattern path that terminates at the first crossing of the hold fix/way-point after the holding entry procedure is performed. HF legs are commonly used for course reversals on instrument approach procedures. A hold to altitude (HA) route segment is a climbing holding pattern that automatically terminates at the next crossing of the hold fix/way-point after the aircraft reaches the specified altitude. A hold to manual termination (HM) route segment is a holding pattern path that is manually terminated by the pilot, often used while expecting further ATC clearance. See Figure C5-4.
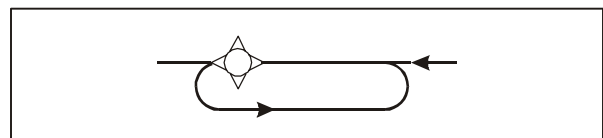
**Figure C5-4.   HF, HA and HM legs.
Hold to fix, hold to altitude and
hold to manual termination**

The "HA" leg, hold to an altitude, is provided for a climb in the holding pattern. Upon reaching the terminating altitude, the FMS will provide guidance across the holding

fix then sequence legs to proceed on course to the next way-point in the flight plan. The "HM" leg, hold to a manual termination, does exactly as the name implies. Leg sequencing requires the pilot's manual intervention.
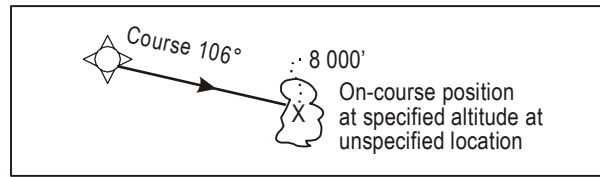

Figure C5-6.   FA leg. Fix to altitude

5.   ROUTE SEGMENTS THAT ARE DISCOURAGED IN THE DESIGN OF RNP PROCEDURES

5.1   The route segments described below cannot uniquely specify the intended aircraft track under all circumstances and are therefore inconsistent with the objective of RNP. These route segments, however, can achieve limited compatibility with RNP.

5.2   A direct to fix (DF) route segment is one that proceeds from an unspecified position direct to a specified fix/way-point (see Figure C5-5). The path flown by the aircraft for the DF leg is determined by the aircraft position after becoming established on an inbound track to the defined fix/way-point.
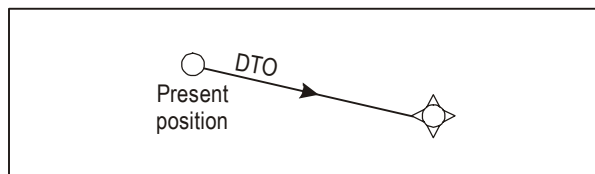
Figure C5-5.   DF leg. Direct to fix

The "DF" leg, direct to fix, is the route segment (geodesic path) that begins from an aircraft's present position (at the time of the direct entry made by the pilot), or an unspecified position from the aircraft's present track, direct to a specified fix. The system calculates a great circle route defined between that direct entry and the specified "to" way-point.

5.3   A course from a fix to an altitude (FA) is used to define a climbing route segment (geodesic path) that begins at a fix and terminates at the point when the aircraft reaches the specified altitude (see Figure C5-6). No position is specified for the altitude point. The FA route segment is acceptable but undesirable for RNP operations because it can be highly variable in the along-track dimension due to the unknown termination point.

6.   ROUTE SEGMENT TO BE AVOIDED AFTER THE TRANSITION TO RNP

A course to a fix (CF) route segment is used in many existing approach procedures. The route is defined as a magnetic course that terminates at a fix (see Figure C5-7). The inbound course to the termination fix is provided by the navigation database. Because of difficulties with respect to the application of magnetic variations, the CF route segment will be used in RNP procedures only during a transitional period. Eventually, it is expected that this route type segment will be avoided in RNP procedure development and replaced by a track to a fix (TF) route segment.


Figure C5-7.   CF leg. Course to fix

A "CF" leg, course to fix, specifies an inbound course to a defined location. The route is defined as a geodesic path that terminates at a location that can be identified by its latitude and longitude. The inbound course to the termination fix is provided by the navigation database.

7.   ROUTE SEGMENTS TO BE USED ONLY IN THE DESIGN OF NON-RNP PROCEDURES

7.1   Aeronautical database coding specifications are designed to accommodate RNAV systems operating in RNP and non-RNP (RNAV and conventionally designed) airspace. As the world navigation system makes the transition to a total RNP environment, RNAV and FMS systems will continue to be utilized to emulate, as closely as possible, non-RNAV instrument procedures.

7.2   The following route segments are currently being used by the aviation industry and describe various path terminator sets. It has been suggested that instrument procedure design that requires the use of the following path terminator sets should be avoided:

a)   A procedure turn (PI) leg to intercept the final approach track defines the outbound portion of a reversal procedure (see Figure C5-8). The turn to intercept is normally only constrained by a "turn within distance" thus allowing the computer navigation system or the pilot to choose the point of turn. The beginning point, the outbound track and the turn direction of the procedure turn manoeuvre are coded as a PI leg.
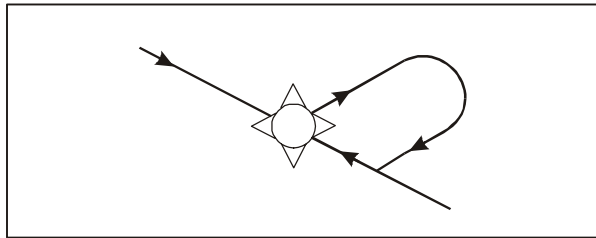
Figure C5-8.   PI leg. Procedure turn to intercept

The "PI" leg, procedure turn to intercept, provides the course reversal for an instrument approach procedure. A CF leg follows it to the FAF. When a holding pattern is used in lieu of a procedure turn, the HF leg will be used. When a teardrop course reversal is used, it would typically be constructed with an FC leg followed by a CF leg.

b)   A course to an altitude (CA) leg is a climbing route segment that begins at an unspecified position and terminates at an unspecified position upon attaining the specified altitude (see Figure C5-9).
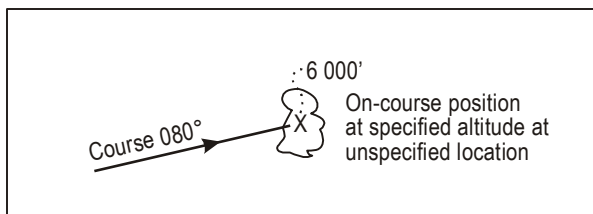
Figure C5-9.   CA leg. Course to altitude

The "CA" leg, course to altitude, will result in the aircraft flying a specified track until reaching the terminating altitude. The difference between the VA leg and the CA leg can be readily seen in a cross-wind situation. On a VA leg, slower aircraft will have a longer exposure to the *cross-wind, and thus a greater displacement, than faster aircraft. On a CA leg, the crab angle is adjusted so that all aircraft will fly the same track over the ground. On a CA leg, the terminator is still at an undefined location. Although the track is defined, the point at which the aircraft will reach the terminating altitude is not. The along-track distance of the leg termination will be a function of aircraft performance and environmental conditions.*

c)   A course to intercept (CI) leg is used to define a route segment that begins at an unspecified point and intersects a following segment where no intercept point or turn point has been defined (see Figure C5-10).
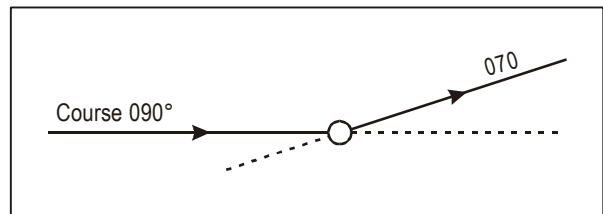
Figure C5-10.   CI leg. Course to next leg intercept

A "CI" leg, course to intercept the next segment, is used to define a route segment that intersects a following segment where no intercept point or turn point has been defined.

d)   A course to a DME distance (CD) leg is a route segment that begins at an unspecified point and terminates at a DME distance from a navaid (see Figure C5-11).
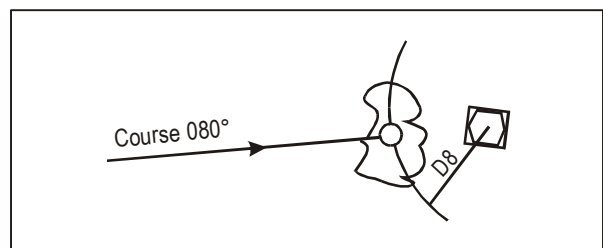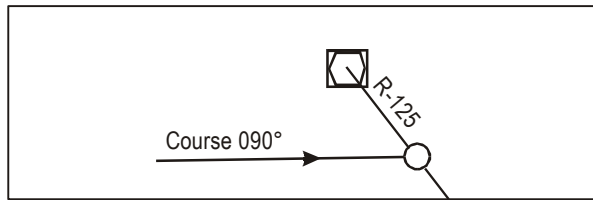

Figure C5-11.   CD leg. Course to a DME termination

A "CD" leg, course to a DME distance, is a route segment that terminates at a DME distance from a navaid other than the one providing course guidance.

e)   A course to VOR radial (CR) leg is a route segment that begins at an unspecified point and terminates at a crossing radial where an intercept point has not been defined (see Figure C5-12).

Figure C5-12.   CR leg. Course to a radial intercept

A "CR" leg, a course to a VOR radial, is a route segment that terminates at a crossing radial where the intercept point has not been defined.
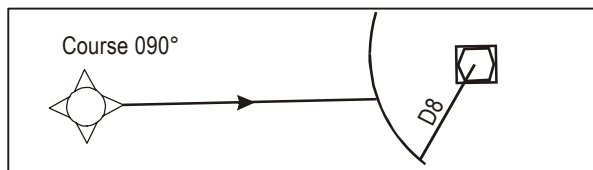
 f) A course from a fix to a distance (FC) leg is a route segment from a fix/way-point to a specified distance. The position of the end point is uncertain because the geodesic definition and the magnetic reference for the track are subject to error (see Figure C5-13).
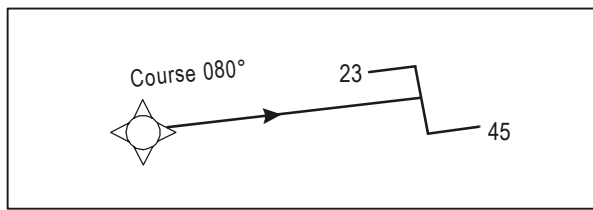
Figure C5-13.   FC leg. Fix to a distance on course

An "FC" leg, course from a fix to a distance, is a route segment from a fix to a specified distance with an unspecified position. There need not be a DME fix. The distance is calculated so the originating fix could be a VOR, or an intersection, or any fix/way-point provided in the aircraft's navigation database.

 g) A course from a fix to a DME distance (FD) leg is a route segment that begins at a fix and terminates at a DME distance from a navaid (see Figure C5-14).

Figure C5-14.   FD leg. Fix to a DME termination

An "FD" leg, a course from a fix to a DME distance, is a route segment that begins at a fix and terminates at a DME distance from the navaid other than the one providing course guidance. The terminating DME distance need not be the reference fix and it need not lie on the track.

 h) A course from a fix to a manual termination (FM) leg is used when a route segment is expected to be terminated by radar vectors (see Figure C5-15).
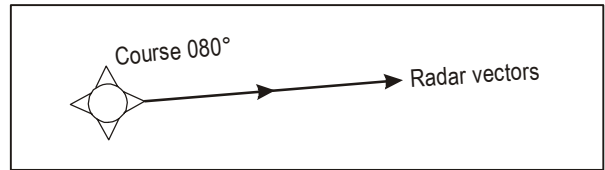
Figure C5-15.   FM leg. Fix to a manual termination

An "FM" leg, a course from a fix to a manual termination, is used when a route segment is expected to be terminated for radar vectors. This leg type will not provide an automatic leg sequence.

 i) A DME arc to a fix (AF) leg is an arc route segment that can begin at any unspecified point along the arc but terminates at a specified fix/way-point (see Figure C5-16).
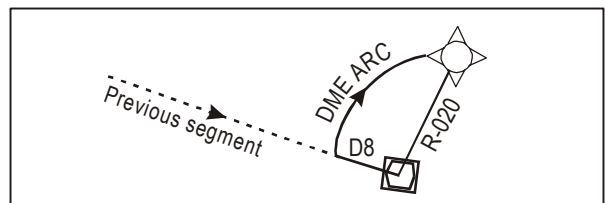
Figure C5-16.   AF leg. Arc to a fix

The "AF" leg, a DME arc to a fix, is an arc route segment that can begin at any unspecified point along the arc but terminates at a specified fix. A navaid must be at the origin of the arc and a minimum radius of 4.0 NM is specified. The resolution of the arc radius is 0.1 NM. The terminator is defined by a terminating radial from the reference VOR.

 j) A heading to a DME distance (VD) leg is a departure or missed approach route segment where a heading rather than a track has been specified for climb (see Figure C5-17). The position of the intercepted DME distance will vary around an arc depending on the winds.
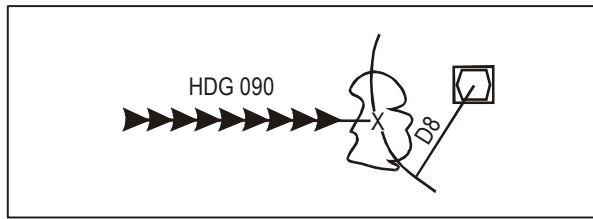
Figure C5-17.   VD leg. Heading to DME distance

The "VD" leg, "heading to a DME distance", is similar to the VA leg, except that the terminator is a DME distance instead of an altitude. Like the VA leg, it terminates at an unspecified position, this time on the DME arc. The FMS need not have an interface with the DME to implement this leg type. The location of the DME is contained in the database, so the system simply calculates its distance from the facility.

k) A heading to an altitude (VA) leg is a departure route segment where a heading rather than a track has been specified for the climb (see Figure C5-18). The segment terminates at a specified altitude without a terminating position.
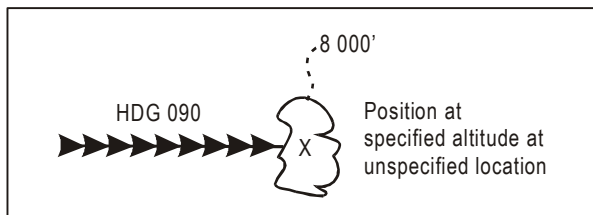

Figure C5-18.   VA leg. Heading to altitude

A "fly runway heading to 8 000 ft" would be coded in the database as a "Heading-to-altitude" leg described as a "VA" leg. "V" is used as in "Vector" since the letter "H" is used to describe a hold leg. As the leg is implemented in the Flight Management System (FMS), the system reads the compass heading and provides the autopilot or flight director with a steering command that will null out any deviation from the desired heading. The FMS will also be monitoring its baro-altitude input (QNH), then sequence the legs when the terminating altitude has been reached. Two inputs are required for the VA leg — a compass input and altimeter input. When light aircraft installations are considered, the availability of a compass input cannot be assumed. In most light aircraft, the compass system is a simple vacuum-driven gyro that is not capable of providing heading data to any external output capabilities. Compass and altitude data typically originate from AC synchro signals. This implies the requirement for an inverter which is absent from most single-engine and light twin-engine

aircraft. Since altitude is the terminator of the VA leg, it terminates at a position on the surface of the earth that cannot be defined. The wind effect on the aircraft's track is unknown, as is the climb gradient. Although this is not a problem in itself, it does place some constraints on the connectivity with subsequent leg types. The VA leg is typically used as the first leg of an instrument departure. Departures are usually coded with a leg that flies runway heading to 400 ft AGL. This procedure coding technique precludes undesirable manoeuvring at low altitudes.

l) A heading to a manual termination (VM) route segment is very commonly used to address heading segments in procedure design. These segments also generally occur where radar vectoring is planned by ATC (see Figure C5-19).
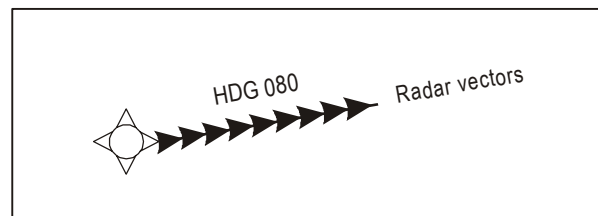
Figure C5-19.   VM leg. Heading to manual termination

The "VM" leg, heading to a manual termination, will require manual intervention to sequence the next leg. This leg permits the pilot to respond to ATC vectors while leaving the FMS displayed on the instruments and coupled to the flight control system.

m) A heading to intercept the next segment (VI) leg is a route segment to an unspecified intercept point on the following fixed route segment (see Figure C5-20).
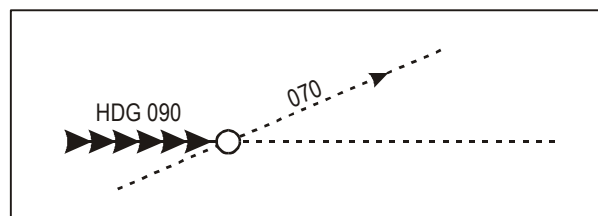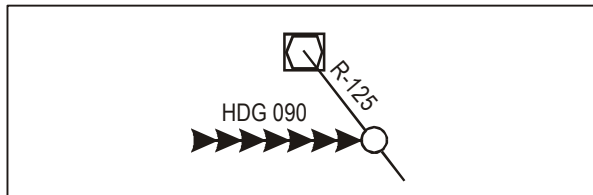

Figure C5-20.   VI leg. Heading to next leg intercept

The "VI" leg, heading to a next leg intercept, is terminated by intercepting the next leg to be flown, typically a VOR radial. As with all the heading-path legs, the terminator is an unspecified position since the leg does not specify the aircraft's track. Another aspect of the FMS's capability to

use these data is highlighted in this leg type. The course to be intercepted is expressed as a magnetic course. The bearings that result from a position computation are true bearings. To convert these to magnetic, the FMS must have some mathematical model of the earth's magnetic variation, which it uses to calculate the magnetic variation at a specific latitude and longitude. Without this capability, the FMS cannot fly a VI leg. Any errors in the magnetic variation model would be reflected in the intercept. Since the magnetic variation at any point will vary over time, the model should be dynamic, i.e., adjusting the variation for the date. Some systems use a fixed epoch-year variation model which results in the calculated magnetic variation getting better for a few years, then gradually degrading. Some systems shortcut the computations by using fewer coefficients to simplify the calculations, which compromises accuracy. The worse case for magnetic variation modelling occurs in northern latitudes owing to the proximity of the North magnetic pole. Most systems have some cut-off latitude for their magnetic variation model after which manual variation entries into the FMS are required.

n) A heading to a VOR radial (VR) leg is a route segment that terminates at a crossing radial where an intercept point has not been defined (see Figure C5-21).

Figure C5-21.   VR leg. Heading to radial termination

The "VR" leg, heading to radial termination, initially appears to be similar to the VI leg. However on the VI leg, the intercept forms the subsequent leg. On the VR leg, there are several choices. For example, a VA leg for the next segment of a climb could follow it. More database capabilities come into play on the VR leg. The FMS needs to know the coordinates of the VOR facility. Local magnetic variation is not an issue here, but the database must know the station declination of the VOR.

8.   CODING TURN AND DISTANCE FIELDS

The path and terminator concept must accommodate the performance capabilities of various aircraft types. In order to accomplish this requirement, ARINC Specification 424 establishes certain values for coding the path terminators. These values have been established by the aviation industry to allow database suppliers to code turn and distance fields to a single set of rules. If the official procedure source information provides values other than the values listed below, then the source values will be used.

a) *Speed*. A speed of 210 knots, ground speed, will be used to compute distance based on time (3.5 NM per minute). On course reversal Path Terminators, if no time or distance is specified by the source information, a minimum distance of 4.3 NM will be used prior to turning inbound;

b) *Bank angle*. A maximum bank angle of 25° will be used to compute turn radii. A full 180° turn would require a minimum of 4 NM in diameter;

c) *Climb rate*. A climb rate of 500 ft per nautical mile will be used for computations. For missed approach, the climb rate will begin at the missed approach point. For departure procedures, the climb rate will begin at the take-off end of the runway unless specified otherwise by the source information;

d) *Tear drop procedures*. If no distance limit is provided in the source information, or if a time only is given, database suppliers will use Table C5-2 to determine the length of the outbound leg; and

Table C5-2.   Tear drop procedures

Angle of divergence	NM	Outbound time
18	10.5	2:45
20	9.5	2:30
22	8.6	2:15
24	7.9	2:00
26	7.3	1:55
28	6.8	1:45
30	6.3	1:40
32	5.9	1:30
34	5.6	1:28
36	5.3	1:23
38	5.0	1:18
40	4.7	1:14
42	4.5	1:10
44	4.3	1:07

Note. — This table is based on a speed of 210 knots and a density altitude of 5 000 ft. Any procedure that does not fall within this table would not be coded.

e) *Intercept angles*. When the source information does not specify an intercept angle on a procedure, the following angles will be used:

1) 30° on approach transitions to intercept the localizer approach path;

2) 30° to 45° on all other procedures; and

3) a VI path terminator and 30° to 45° intercept if there is a fix termination in the current leg followed by a 3 NM or greater gap between a start of a turn and the track in the leg to be intercepted.

9.   REFERENCES

Navigation System Data Base ARINC Specification 424-13, Published 31 December 1995

Industry Requirements for Aeronautical Information, Draft RTCA DO-201A/EUROCAE ED-77 (Final Draft 3 May 1999)

Air Traffic Control Association Symposium, Alexandria, Virginia, 16 December 1997, Universal Avionics Systems Corporation FMS Implementing Free Flight Briefing.

— **END** —

ICAO TECHNICAL PUBLICATIONS

The following summary gives the status, and also describes in general terms the contents of the various series of technical publications issued by the International Civil Aviation Organization. It does not include specialized publications that do not fall specifically within one of the series, such as the Aeronautical Chart Catalogue *or the* Meteorological Tables for International Air Navigation.

International Standards and Recommended Practices are adopted by the Council in accordance with Articles 54, 37 and 90 of the Convention on International Civil Aviation and are designated, for convenience, as Annexes to the Convention. The uniform application by Contracting States of the specifications contained in the International Standards is recognized as necessary for the safety or regularity of international air navigation while the uniform application of the specifications in the Recommended Practices is regarded as desirable in the interest of safety, regularity or efficiency of international air navigation. Knowledge of any differences between the national regulations or practices of a State and those established by an International Standard is essential to the safety or regularity of international air navigation. In the event of non-compliance with an International Standard, a State has, in fact, an obligation, under Article 38 of the Convention, to notify the Council of any differences. Knowledge of differences from Recommended Practices may also be important for the safety of air navigation and, although the Convention does not impose any obligation with regard thereto, the Council has invited Contracting States to notify such differences in addition to those relating to International Standards.

Procedures for Air Navigation Services (PANS) are approved by the Council for worldwide application. They contain, for the most part, operating procedures regarded as not yet having attained a sufficient degree of maturity for adoption as International Standards and Recommended Practices, as well as material of a more permanent character which is considered too detailed for incorporation in an Annex, or is susceptible to frequent amendment, for which the processes of the Convention would be too cumbersome.

Regional Supplementary Procedures (SUPPS) have a status similar to that of PANS in that they are approved by the Council, but only for application in the respective regions. They are prepared in consolidated form, since certain of the procedures apply to overlapping regions or are common to two or more regions.

The following publications are prepared by authority of the Secretary General in accordance with the principles and policies approved by the Council.

Technical Manuals provide guidance and information in amplification of the International Standards, Recommended Practices and PANS, the implementation of which they are designed to facilitate.

Air Navigation Plans detail requirements for facilities and services for international air navigation in the respective ICAO Air Navigation Regions. They are prepared on the authority of the Secretary General on the basis of recommendations of regional air navigation meetings and of the Council action thereon. The plans are amended periodically to reflect changes in requirements and in the status of implementation of the recommended facilities and services.

ICAO Circulars make available specialized information of interest to Contracting States. This includes studies on technical subjects.