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Abbreviations
(used in this document)

AP   Autopilot
Cat  Category
CRM  Collision risk model
DER  Departure end of the runway
DME  Distance measuring equipment
FAF  Final approach fix
FAP  Final approach point
FD   Flight director
GP   Glide path
GS   Ground speed
IAF  Initial approach fix
IAS  Indicated airspeed
IF   Intermediate approach fix
ILS  Instrument landing system
km   Kilometre
kt   Knots
LLZ  Localizer
MAPt Missed approach point
MHz  Megahertz
MM   Middle marker
MOC  Minimum obstacle clearance (required)
MSA  Minimum sector altitude
MSL  Mean sea level

NDB  Non-directional radio beacon
NM   Nautical mile
non SI units Non international system of units
OCA  Obstacle clearance altitude
OCA/H Obstacle clearance altitude/height
OCH  Obstacle clearance height
OM   Outer marker
PANS-OPS Procedures for Air Navigation Services
— Aircraft Operations (Doc 8168)
PDG  Procedure design gradient
RSS  Root sum square
R Wy Runway
SI units International system of units
SOC  Start of climb
SRE  Surveillance radar element
TAS  True airspeed
THR  Threshold
TNA/H Turn altitude/height
TP   Turning point
UTM  Universal transverse mercator
VOR Very high frequency (VHF)
onomidirectional radio range
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
Part I. General
Chapter 2. Preparation for Procedure Design

2.6 REFERENCES


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

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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.
PART II
CONVENTIONAL PROCEDURES
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):

O₁ height 40 m (131 ft), on runway centre line, 2 km (1.08 NM) from DER.
O₂ height 250 m (820 ft), right of RWY centre line 1 325 m (4 347 ft), 5 500 m (2.97 NM) from DER.

Determine if obstacles are within the departure area

O₁ is on centre line and within the area.
O₂ is within the area.

Departure area ½W at O₂ = 150 + 5 500 tan 15° = 1 623.7 m (5 327 ft).

Determine OIS height at each obstacle

O₁ is below the OIS; OIS height = 5 + (2 000 × 0.025) = 55 m (180 ft).
O₂ penetrates the OIS; OIS height = 5 + (5 500 × 0.025) = 143 m (469 ft) (see Figure II-1-1-1).

Determine the PDG necessary to overfly O₂ with the MOC

MOC at O₂ = 5 500 × 0.008 = 44 m (144 ft).
The RH (required height) at O₂ = O₂ height + MOC = 250 + 44 = 294 m (964 ft).
The PDG = \frac{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 O₂
(See Figures II-1-1-2 and II-1-1-3)

Quick look to determine feasibility of track adjustment
If O₂ is displaced from the runway centre line farther than the area one ½W (half width), a 15° track adjustment is feasible.
Area one \( \frac{1}{2}W = 150 + 3500 \times \tan 15^\circ = 1087.8 \text{ m} \) (3569 ft).

Since \( O_2 \) is 1325 m (4347 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:

\[
\text{Minimum track adjustment angle} = 15^\circ - \tan^{-1} \frac{1325 - 1088}{5500 - 3500} = 15 - 6.75 = 8.24^\circ
\]

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 (1148 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 + (2000 \times 0.008) = 166 m (544 ft).

Required height at \( O_2 \) = 350 + (9000 \times 0.008) = 422 m (1384 ft).

Gradient \( O_1 \) = \( \frac{166 - 5}{2000} \) = 0.0805 (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 O2 must be at the required height of 422 m (1 384 ft) which is 9 km (4.86 NM) from DER \((z = 422 \text{ m} \text{ and } d = 9 000 \text{ m})\).

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

\[ c = 422 - (0.033 \times 9 000); c = 125 \text{ m} (410 \text{ ft}) \]

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 \(d\):
\[ 0.081d - 0.033d = 125 - 5 \]
\[ 0.048d = 120 \]
\[ d = 2 500 \text{ m} (8 202 \text{ ft}) \]

The height at \(d\) is: \(5 + 2 500 \times 0.081 = 207.5 \text{ m} (681 \text{ ft})\) Consequently, a climb to an altitude at least 207.5 m (681 ft) above DER will provide the MOC at the obstacle O2.

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:

\[ \text{RH} = 5 + d_{PDG} \times \text{PDG} + (d_{O2} - d_{PDG}) \times 0.033 \]

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

\[ d_{PDG} = \frac{\text{RH} - 5 - 0.033 \times d_{O2}}{\text{PDG} - 0.033} \]

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

\[ h = 5 + \text{PDG} \times d_{PDG} \]

**DEPARTURE OBSTACLE ANALYSIS AND FORMULAE**

Assign reference numbers to all obstacles beginning at DER (e.g. O1, O2, O3) (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

<table>
<thead>
<tr>
<th>No.</th>
<th>(d_o^*) (\text{m (ft)})</th>
<th>(O_{ht}^{**}) above DER (\text{m (ft)})</th>
<th>1 Gradient to obstacle top</th>
<th>2 MOC (\text{m (ft)})</th>
<th>RH (O_{ht} + \text{MOC}) (\text{m (ft)})</th>
<th>3 PDG</th>
<th>4 (d_{PDG}) (\text{m (ft)})</th>
<th>5 (H_{min})</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Obstacle distance \((d_o)\) should be reduced by the horizontal chart accuracy margin.

** Obstacle height should include vertical margin for chart accuracy.

1. Gradient = \((O_{ht} - 5)/d_o\); \((O_{ht} - 16)/d_o\), ft
2. MOC = \(0.008 \times d_o\)
3. PDG = \((RH - 5)/d_o\); \((RH - 16)/d_o\), ft
4. \(d_{PDG} = \frac{RH - 5 \text{ m (16 ft)} - 0.33 d}{PDG - 0.033}\)
5. \(H_{min} = 5 \text{ m (16 ft)} + d_{PDG} \times \text{PDG (rounded)}\)

Where:

- \(O_{ht}\) = obstacle height
- \(d_o\) = obstacle distance
- \(RH\) = required height
- \(d_{PDG}\) = distance where PDG is applied
- \(H_{min}\) = minimum height to which the PDG must prevail.
Part II. Conventional Procedures
Section 1, Chapter 1. Straight Departure

II-1-1-5

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 = \((O_{ht} - 5)/d_{o}, \ (O_{ht} - 16)/d_{o}\) ft.

If the gradient is \(\leq 0.025\) for all obstacles, the OIS is clean and the job is finished.

If the OIS is penetrated, find COstp (controlling obstacle with steepest gradient).

Calculate the MOC for each obstacle penetrating the OIS. Start with COstp. (See Table II-1-1-3)

\[ \text{MOC} = 0.008 \times d_{o} \]

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

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

<table>
<thead>
<tr>
<th>No.</th>
<th>(d_{o}) m (ft)</th>
<th>(O_{ht}) above DER m (ft)</th>
<th>Gradient to obstacle top</th>
<th>(2) MOC m (ft)</th>
<th>(3) PDG</th>
<th>(4) (d_{PDG}) m (ft)</th>
<th>(5) H(_{\text{min}})</th>
</tr>
</thead>
<tbody>
<tr>
<td>O(_{1})</td>
<td>1 100 (3 609)</td>
<td>30 (98)</td>
<td>0.0227</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>O(_{2})*</td>
<td>2 475 (8 120)</td>
<td>105 (345)</td>
<td>0.0404*</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>O(_{3})</td>
<td>3 950 (12 959)</td>
<td>140 (559)</td>
<td>0.0342</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>O(_{4})</td>
<td>6 000 (19 685)</td>
<td>210 (689)</td>
<td>0.0342</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>O(_{5})</td>
<td>8 950 (29 363)</td>
<td>290 (951)</td>
<td>0.0318</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*CO\(_{ap}\)

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

<table>
<thead>
<tr>
<th>No.</th>
<th>(d_{o}) m (ft)</th>
<th>(O_{ht}) above DER m (ft)</th>
<th>Gradient to obstacle top</th>
<th>(2) MOC m (ft)</th>
<th>(3) PDG</th>
<th>(4) (d_{PDG}) m (ft)</th>
<th>(5) H(_{\text{min}})</th>
</tr>
</thead>
<tbody>
<tr>
<td>O(_{1})</td>
<td>1 100 (3 609)</td>
<td>30 (98)</td>
<td>0.0227</td>
<td>—</td>
<td>—</td>
<td></td>
<td></td>
</tr>
<tr>
<td>O(_{2})*</td>
<td>2 475 (8 120)</td>
<td>105 (345)</td>
<td>0.0404</td>
<td>20 (66)</td>
<td>125 (410)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>O(_{3})</td>
<td>3 950 (12 959)</td>
<td>140 (559)</td>
<td>0.0342</td>
<td>31.6 (104)</td>
<td>172 (564)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>O(_{4})</td>
<td>6 000 (19 685)</td>
<td>210 (689)</td>
<td>0.0342</td>
<td>48 (158)</td>
<td>258 (846)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>O(_{5})</td>
<td>8 950 (29 363)</td>
<td>290 (951)</td>
<td>0.0318</td>
<td>71.6 (235)</td>
<td>362 (1 188)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*CO\(_{ap}\)
Calculate PDG for CO\textsubscript{stp} (See Table II-1-1-4)

\[ PDG = \frac{RH - 5}{d_o} \]

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)

\[ d_{PDG} = \frac{RH - 5 - 0.033 \cdot d}{PDG - 0.033} \]

(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.)

The final question — to find the minimum height \( H_{t_{min}} \) 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)

\[ H_{t_{min}} = 5 + d_{PDG} \times PDG \text{ (rounded)}. \]

For \( O_5 \): \( H_{t_{min}} = 5 + 3.853 \times 0.049 = 194 \text{ m} \) (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

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

*\( CO_{stp} \)
### Table II-1-1-5. Worksheet for Steps 4 and 5

<table>
<thead>
<tr>
<th>No.</th>
<th>(d_o) m (ft)</th>
<th>(O_{ht}) above DER m (ft)</th>
<th>1 Gradient to obstacle top</th>
<th>2 MOC m (ft)</th>
<th>RH (O_{ht}) + MOC m (ft)</th>
<th>3 PDG</th>
<th>PDG rounded</th>
<th>4 (d_{PDG}) m (ft)</th>
<th>5 (H_{min})</th>
</tr>
</thead>
<tbody>
<tr>
<td>O₁</td>
<td>1 100 (3 609)</td>
<td>30 (98)</td>
<td>0.0227</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>2 395</td>
<td>(7 858)</td>
</tr>
<tr>
<td>O₂</td>
<td>2 475 (8 120)</td>
<td>105 (345)</td>
<td>0.0404</td>
<td>20 (66)</td>
<td>125</td>
<td>0.0485</td>
<td>0.049</td>
<td>2 291</td>
<td>(7 516)</td>
</tr>
<tr>
<td>O₃</td>
<td>3 950 (12 959)</td>
<td>140 (559)</td>
<td>0.0342</td>
<td>31.6 (104)</td>
<td>172</td>
<td>—</td>
<td>—</td>
<td>3 438</td>
<td>(11 279)</td>
</tr>
<tr>
<td>O₄</td>
<td>6 000 (19 685)</td>
<td>210 (689)</td>
<td>0.0342</td>
<td>48 (158)</td>
<td>258</td>
<td>—</td>
<td>—</td>
<td>3 853</td>
<td>(12 641)</td>
</tr>
<tr>
<td>O₅</td>
<td>8 950 (29 363)</td>
<td>290 (951)</td>
<td>0.0318</td>
<td>71.6 (235)</td>
<td>362</td>
<td>—</td>
<td>—</td>
<td>194</td>
<td>(636)</td>
</tr>
</tbody>
</table>

### 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.
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 O₁: height 800 m (2 624 ft), on centre line, 10.7 km (5.78 NM) from DER.
Obstacle O₂: height 500 m (1 640 ft), 7 km (3.78 NM) along centre line and 2 km (1.08 NM) to the left.
Obstacle O₃: 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 O₁ on the centre line.

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

O₁ 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 O₁ = 800 + 86 = 886 m (2 906 ft).

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

Assume a 90° right turn to avoid both obstacles O₁ and O₂.

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 O₁ and O₃ and that Category C need only consider O₃.

O₁ can be avoided by restricting speeds to 490 km/h (264 kt) IAS for all aircraft.

O₂ must be considered with regard to the MOC required in the turn area.

MOC O₃ = 90 m (295 ft), since 0.008 × (3 500 + 6 006) = 76 m (249 ft)

The 256 m (840 ft) height of O₃ 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) [O₃ 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 O₃.

The departure path at O₃ must be at least 90 m (295 ft) greater than O₃ [256 + 90 = 346 m (1 135 ft)].
The PDG for $O_3 = \frac{346 - 5}{3500 + 6006} = 0.0359$ (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 (1135 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:

$$\frac{147 - 5}{3500} = 0.04057$$ (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)

<table>
<thead>
<tr>
<th>IAS (km/h)</th>
<th>TAS 600 m (600 m)</th>
<th>c (km/h)</th>
<th>6 seconds</th>
<th>R (deg/s)</th>
<th>r (km)</th>
<th>E (km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>km/h (kt)</td>
<td>(2 000 ft)</td>
<td>km (NM)</td>
<td>6 360</td>
<td>542R (293)</td>
<td>62.8R</td>
<td>1.4 (0.75)</td>
</tr>
<tr>
<td>A 226</td>
<td>239</td>
<td>0.49</td>
<td></td>
<td></td>
<td>1.68</td>
<td>0.62</td>
</tr>
<tr>
<td>(122)</td>
<td>(129)</td>
<td>(0.27)</td>
<td></td>
<td></td>
<td>(0.90)</td>
<td>(0.33)</td>
</tr>
<tr>
<td>B 308</td>
<td>325</td>
<td>0.64</td>
<td></td>
<td></td>
<td>3.11</td>
<td>0.84</td>
</tr>
<tr>
<td>(166)</td>
<td>(176)</td>
<td>(0.34)</td>
<td></td>
<td></td>
<td>(1.66)</td>
<td>(0.45)</td>
</tr>
<tr>
<td>380</td>
<td>401</td>
<td>0.76</td>
<td></td>
<td></td>
<td>4.72</td>
<td>1.04</td>
</tr>
<tr>
<td>(205)</td>
<td>(217)</td>
<td>(0.41)</td>
<td></td>
<td></td>
<td>(2.56)</td>
<td>(0.56)</td>
</tr>
<tr>
<td>440</td>
<td>465</td>
<td>0.87</td>
<td></td>
<td></td>
<td>6.35</td>
<td>1.2</td>
</tr>
<tr>
<td>(236)</td>
<td>(249)</td>
<td>(0.47)</td>
<td></td>
<td></td>
<td>(3.36)</td>
<td>(0.64)</td>
</tr>
<tr>
<td>C 490</td>
<td>518</td>
<td>0.96</td>
<td></td>
<td></td>
<td>7.88</td>
<td>1.34</td>
</tr>
<tr>
<td>(265)</td>
<td>(280)</td>
<td>(0.52)</td>
<td></td>
<td></td>
<td>(4.25)</td>
<td>(0.71)</td>
</tr>
<tr>
<td>D 539</td>
<td>569</td>
<td>1.04</td>
<td></td>
<td></td>
<td>9.51</td>
<td>1.47</td>
</tr>
<tr>
<td>(291)</td>
<td>(308)</td>
<td>(0.56)</td>
<td></td>
<td></td>
<td>(5.16)</td>
<td>(0.79)</td>
</tr>
</tbody>
</table>
Figure II-1-2-1. Turning departure situation
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.)

\[
\tan 12° \times 47 576 \text{ ft} = 10 113 \text{ ft}; 10 113 - 9 843 = 270 \text{ ft}
\]

Effect of O1

\[
d = 19 687 \text{ ft}, Ht = 1 745 - 1 000 = 745 \text{ ft}
\]

OIS = 19 687 × 0.025 + 16 = 508 ft [O1 penetrates the OIS]

MOC = 19 687 × 0.008 = 157 ft

RH_{O1} = 745 + 157 = 902 \text{ ft}

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

Effect of O2

\[
d = 36 092 \text{ ft}, Ht = 2 292 - 1 000 = 1 292 \text{ ft}
\]

OIS = 36 092 × 0.025 + 16 = 918 ft

(O2 penetrates the OIS, but secondary area MOC can apply)

Primary area MOC = 36 092 × 0.008 = 289 ft

Table II-1-3-1

<table>
<thead>
<tr>
<th>Obstacle</th>
<th>Elevation (height)</th>
<th>North/south of RWY centre line</th>
<th>West of 27 DER</th>
<th>East of 09 DER</th>
</tr>
</thead>
<tbody>
<tr>
<td>O₁</td>
<td>1 745 ft (745 ft)</td>
<td>N 0.27 NM (1 640 ft)</td>
<td>—</td>
<td>3.24 NM (19 687 ft)</td>
</tr>
<tr>
<td>O₂</td>
<td>2 292 ft (1 292 ft)</td>
<td>N 0.27 NM (1 640 ft)</td>
<td>—</td>
<td>5.94 NM (36 092 ft)</td>
</tr>
<tr>
<td>O₃</td>
<td>1 132 ft (132 ft)</td>
<td>On RWY centre line</td>
<td>1.89 NM (11 484 ft)</td>
<td>—</td>
</tr>
<tr>
<td>O₄</td>
<td>1 985 ft (985 ft)</td>
<td>N 1.35 NM (8 203 ft)</td>
<td>2.7 NM (16 405 ft)</td>
<td>—</td>
</tr>
<tr>
<td>O₅</td>
<td>1 263 ft (263 ft)</td>
<td>S 1.08 NM (6 562 ft)</td>
<td>1.62 NM (9 843 ft)</td>
<td>—</td>
</tr>
<tr>
<td>O₆</td>
<td>1 755 ft (755 ft)</td>
<td>S 2.7 NM (19 687 ft)</td>
<td>Equally distant from both DERs</td>
<td></td>
</tr>
</tbody>
</table>

II-1-3-1
Secondary area calculations at the point at O₂:

VOR area at O₂ = 6 076.1 + tan 7.8° × 13 000 = 7 857 ft
O₂ is 5 580 ft from the VOR R-258

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

\[
\text{RH}_{02} = 1 292 + 168 = 1 460 \text{ ft}
\]

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

\[
\text{d}_{\text{PDG}} = \frac{\text{RH}_2 - 16 - 0.033 \times d_{O₂}}{\text{PDG} - 0.033}
= \frac{1 460 - 16 - 0.033 \times 36 092}{0.045 - 0.033} = 21 080 \text{ ft}
\]

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

\[
16 + (21 080 \times 0.045) = 965 \text{ ft}
\]

[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 O₄ 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 O₃; 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 O₃ = 16 + (11 484 × 0.025) = 303 [OIS not penetrated].

The turn height (altitude) must be 295 ft (90 m) above O₃.

Minimum turn height is 132 + 295 = 427 ft.

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

\[
dₜ = \frac{427 - 16}{0.033} = 12 455 \text{ ft}
\]

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

1) determine the dₜ, 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 (\(H_g\)) from the RH (climbing 3.3 per cent).

Obstacle O5 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 (\(H_g\)) from the turn initiation area boundary (Area 1) is:

\[
\text{Area 1: } \frac{1}{2}W = 9 843 \times \tan 15^\circ + 492 = 3 129 \text{ ft}
\]

\[
d_o = \cos 15^\circ (6 562 - 3 129) = 3 316 \text{ ft (shortest distance to O5).}
\]

Step 2) The MOC is 295 ft since \((10 701 + 3 316) \times 0.008 = 112 \text{ ft.}\)

Note.— In this case \(d_r^*\) is used. It is \(9 843 + 3 316 \times \sin 15^\circ = 10 701.\)

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

Step 4) The minimum turn height for O5 is 558 – \((3 316 \times 0.033) = 449 \text{ ft.}\)

Obstacle O6 is also in the turn area. It is 19 687 ft south of the runway midpoint.

Step 1) \(d_o = 1 968 + 19 657 = 21 625 \text{ ft.}\) [shortest distance from early turn boundary area].

Step 2) The MOC is 295 ft since \((0 + 19 657) \times 0.008 = 154 \text{ ft.} \quad (d_r^* = \text{zero}).\)

Step 3) The RH at O6 = 755 + 295 = 1 050 ft.

Step 4) The minimum turn height for O6 is 1 050 – \((19 195 \times 0.033) = 417 \text{ ft.}\)

Obstacles O1 and O2 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 O1 is 3.24 NM east of the beginning point of RWY 27.

Obstacle O2 is 5.94 NM east of the beginning point of RWY 27.

Obstacle O3 is in the turn area, 1 562 ft abeam the centre line, 1 360 ft from the DER.

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

\[
\text{Area 1: } \frac{1}{2}W = 1 360 \times \tan 15^\circ + 492 = 605 \text{ ft}
\]

\[
d_o = \cos 15^\circ (1 562 - 605) = 857 \text{ ft (shortest distance to O3).}
\]

Step 2) The MOC is 295 ft since \((0 + 1 562) \times 0.008 = 125 \text{ ft.} \quad (d_r^* = \text{zero}).\)

Step 3) The RH at O3 = 745 + 295 = 1 040 ft.

Step 4) The minimum turn height for O3 is 1 040 – \((21 625 \times 0.033) = 326 \text{ ft.}\)

Obstacles O4 and O5 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 O4 is 0.64 NM east of the beginning point of RWY 27.

Obstacle O4 is also in the turn area. It is 19 687 ft south of the runway midpoint.

Step 1) \(d_o = 1 968 + 19 657 = 21 625 \text{ ft.}\) [shortest distance from early turn boundary area].

Step 2) The MOC is 295 ft since \((0 + 19 657) \times 0.008 = 154 \text{ ft.} \quad (d_r^* = \text{zero}).\)

Step 3) The RH at O4 = 755 + 295 = 1 050 ft.

Step 4) The minimum turn height for O4 is 1 050 – \((19 195 \times 0.033) = 417 \text{ ft.}\)

Obstacles O1 and O2 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 O1 is 3.24 NM east of the beginning point of RWY 27.

Obstacle O2 is 5.94 NM east of the beginning point of RWY 27.

Obstacle O3 is also in the turn area. It is 19 687 ft south of the runway midpoint.

Step 1) \(d_o = 1 968 + 19 657 = 21 625 \text{ ft.}\) [shortest distance from early turn boundary area].

Step 2) The MOC is 295 ft since \((0 + 19 657) \times 0.008 = 154 \text{ ft.} \quad (d_r^* = \text{zero}).\)

Step 3) The RH at O3 = 745 + 295 = 1 040 ft.

Step 4) The minimum turn height for O3 is 1 040 – \((21 625 \times 0.033) = 326 \text{ ft.}\)

Obstacle O4 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 (\(H_g\)) from the turn initiation area boundary (Area 1) is:

\[
\text{Area 1: } \frac{1}{2}W = 9 843 \times \tan 15^\circ + 492 = 3 129 \text{ ft}
\]

\[
d_o = \cos 15^\circ (6 562 - 3 129) = 3 316 \text{ ft (shortest distance to O5).}
\]

Step 2) The MOC is 295 ft since \((10 701 + 3 316) \times 0.008 = 112 \text{ ft.}\)

Note.— In this case \(d_r^*\) is used. It is \(9 843 + 3 316 \times \sin 15^\circ = 10 701.\)

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

Step 4) The minimum turn height for O5 is 558 – \((3 316 \times 0.033) = 449 \text{ ft.}\)

Obstacle O6 is also in the turn area. It is 19 687 ft south of the runway midpoint.

Step 1) \(d_o = 1 968 + 19 657 = 21 625 \text{ ft.}\) [shortest distance from early turn boundary area].

Step 2) The MOC is 295 ft since \((0 + 19 657) \times 0.008 = 154 \text{ ft.} \quad (d_r^* = \text{zero}).\)

Step 3) The RH at O6 = 755 + 295 = 1 050 ft.

Step 4) The minimum turn height for O6 is 1 050 – \((19 195 \times 0.033) = 417 \text{ ft.}\)

The controlling obstacle in the turn area is O5.

Summary minimum turn heights:

\[
O_1 = 326 \text{ ft}
\]
\[
O_2 = 304 \text{ ft}
\]
\[
O_3 = 427 \text{ ft}
\]
\[
O_4 \text{ not in turn area}
\]
\[
O_5 = 449 \text{ ft}
\]
\[
O_6 = 417 \text{ ft}
\]

The turn height must be at least 449 ft (required by O5).

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 \((1 000 + 449) = 1 449 \text{ ft (rounded to 1 500 ft MSL).}\)

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

\[
\text{TNH} = 1 500 - 1 000 = 500 \text{ ft.}
\]
The nominal TP = $d_r = \frac{(500 - 16)}{0.033} = 14,667$ 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.)


Figure II-1-3-1. Multiple departure layout plan
Runway 09 departure

Track adjustment 12° left.
R-258 interception at DER.
82 m (270 ft) from centerline.

Figure II-1-3-2. Runway 09 departure with track adjustment and climb restriction
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

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.

Figure II-1-3-4
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.

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).

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.

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:

\[
\text{Threshold elevation} = 53 \text{ m} \\
\text{Descent path height above threshold} = 15 \text{ m} \\
\text{Descent gradient of 5 per cent} = 0.05
\]

\[(7 800 \times 0.05) + 15 + 53 = 458 \text{ m MSL (1 503 ft MSL)}\]

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

---

**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.

---

**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)

<table>
<thead>
<tr>
<th>Track</th>
<th>Outbound track</th>
<th>Inbound track</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aircraft category</td>
<td>CAT A/B</td>
<td>CAT C/D/E</td>
</tr>
<tr>
<td>Maximum descent for 1 minute nominal outbound time</td>
<td>245 m (804 ft)</td>
<td>365 m (1 197 ft)</td>
</tr>
</tbody>
</table>
Part II. Conventional Procedures
Section 2, Chapter 1. NDB or VOR Off-aerodrome Procedure — Categories C/D Aircraft

II-2-1-3

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.

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.

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):

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

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:

<table>
<thead>
<tr>
<th>Obstacle</th>
<th>OCA (exact)</th>
<th>OCH (exact)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mast</td>
<td>63 + 75 = 138 m</td>
<td>OCA – 54 m = 84 m</td>
</tr>
<tr>
<td>Hill</td>
<td>80 + 63 = 143 m</td>
<td>OCA – 54 m = 89 m</td>
</tr>
</tbody>
</table>

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.

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:

\[
b = \text{distance from the FAF to the latest point of the FAF tolerance} = 420 \times \tan 40^\circ = 352 \text{ m}
\]

\[
D = \text{distance FAF to MAPt} = 7800 \text{ m}
\]

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 = \[
171233 \times [(288 + \text{VAR}) - 0.006496 \times H]^{0.5} / (288 - 0.006496 \times H)^{2.628}
\]

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

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

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

\[ X_3 = \left( \frac{b^2 + (TAS_{MIN} \times 13/3 \, 600)^2 + (56 \times D/TAS_{MIN})^2}{0.5} \right) \]
\[ = \left( (0.352)^2 + (236.4 \times 13/3 \, 600)^2 + (56 \times 7.8/236.4)^2 \right)^{0.5} \]
\[ = 1.5389 \text{ km} \]

\[ X_4 = \left( \frac{b^2 + (TAS_{MAX} \times 13/3 \, 600)^2 + (56 \times D/TAS_{MAX})^2}{0.5} \right) \]
\[ = \left( (0.352)^2 + (354.8 \times 13/3 \, 600)^2 + (56 \times 7.8/354.8)^2 \right)^{0.5} \]
\[ = 1.811 \text{ km} \]

Latest MAPt tolerance = \text{max}[X_3;X_4] = 1.81 km

X_5 = X_3 + 15 \times (TAS_{MIN} + 19)/3 \, 600
\[ = 1.5389 + 15 \times (236.4 + 19)/3 \, 600 \]
\[ = 2.603 \text{ km} \]

X_6 = X_4 + 15 \times (TAS_{MAX} + 19)/3 \, 600
\[ = 1.811 + 15 \times (354.8 + 19)/3 \, 600 \]
\[ = 3.368 \text{ km} \]

MAPt to SOC distance = \text{max}[X_5;X_6] = 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:

\[ d = \frac{(TAS + 10) \times 3}{3 \, 600} \]

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:

\[ OCA = OE - (d_0 \times \tan Z) + MOC \]
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:

\[
D = \frac{\text{OCA final approach} - 15}{0.05}
\]

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

\[
\frac{13 	imes 190}{3 600} = 0.69 \text{ NM}
\]

\[
\frac{3.4 	imes 30}{190} = 0.54 \text{ NM}
\]

\[
\text{RSS} = (0.19^2 + 0.69^2 + 0.54^2)^{0.5} = 0.90 \text{ NM} = 1 670 \text{ m}
\]
Part II. Conventional Procedures
Section 2, Chapter I. NDB or VOR Off-aerodrome Procedure — Categories C/D Aircraft

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:

$240 - (4\,710 \times 0.025) + 30 = 152.3\,m = 500\,ft$

and for Category C:

$240 - (4\,970 \times 0.025) + 30 = 145.8\,m = 478\,ft$

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 $\pm 30^\circ$ 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:

$$\text{radius (NM)} = \left[2 \left(\text{TAS} + 25\right)\right] \left[\text{the greater of} \left(\frac{1}{60} \pi \text{ or} \left(\frac{\text{TAS} + 25}{68\,620 \tan 20}\right)\right)\right] + \text{the constant for a straight segment from Table III-8-2 of PANS-OPS, Volume II.}$$

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:

$$\text{radius (km)} = \left[2 \left(\text{TAS} + 46\right)\right] \left[\text{the greater of} \left(\frac{1}{60} \pi \text{ or} \left(\frac{\text{TAS} + 46}{127\,094 \tan 20}\right)\right)\right] + \text{the constant for a straight segment from Table III-8-1 of PANS-OPS, Volume II.}$$
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.

**Table II-2-1-1**

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

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**

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

**STEP 13**

**STEP 14**

Instrument approach chart tables

The “time to fly distance FAF to MAPt” table

This table is calculated with the following formula:

\[
\frac{3600 \times D}{GS} = T \text{ (in seconds)}
\]
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:

\[
\frac{GS \times 6\ 076.1 \times \text{descent gradient (or tan angle)}}{60} = \text{ft/min}
\]

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
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.
Part II. Conventional Procedures
Section 2, Chapter 1. NDB or VOR Off-aerodrome Procedure — Categories C/D Aircraft

Figure II-2-1-5

Racetrack area
240 KT IAS
4 000 FT MSL
1 MIN

1 0 1 2 3 4 5 KM
1 0 1 2 3 4 5 NM

Lake Slip
ton
SLIPTON

Secondary Area

18.5 mm
14.5 mm

405

Secondary Area

Racetrack

275

100
Figure II-2-1-6

Lake Slipton

X = -7.32 NMMIN

440

250 KT IAS

3000 FT MSL

1 MIN

Y = 7.99 NMMAX

Secondary Area

405

X = 14.44 NMMAX

Y = -7.44 NMMIN

Secondary Area

250 KT IAS

3000 FT MSL

1 MIN

Secondary Area

X_{MAX} = 14.44 NM

Y_{MIN} = 7.99 NM

0 1 2 3 4 5 KM

1 2 3 4 5 NM

Figure II-2-1-6
Part II. Conventional Procedures
Section 2, Chapter 1. NDB or VOR Off-aerodrome Procedure — Categories C/D Aircraft

Figure II-2-1-7
Figure II-2-1-8

Figure II-2-1-9
Part II. Conventional Procedures
Section 2, Chapter 1. NDB or VOR Off-aerodrome Procedure — Categories C/D Aircraft

Figure II-2-1-10

- Cat A 5 120 m
- Cat B 5 090
- Cat C 4 970
- Cat D 5 120

- FAF
- NDB

- SOC

- Start of climb

- d = 6 320 m

- 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

- Runway

- Start of climb
Figure II-2-1-11
Part II. Conventional Procedures
Section 2, Chapter 1. NDB or VOR Off-aerodrome Procedure — Categories C/D Aircraft

Figure II-2-1-12

<table>
<thead>
<tr>
<th>OCA(H)</th>
<th>Distance SCN - MAPt 6.3 km</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cat of ACFT</td>
<td>Cat C</td>
</tr>
<tr>
<td>Straight-in</td>
<td>150 (100)</td>
</tr>
<tr>
<td>Circling</td>
<td>360 (310)</td>
</tr>
</tbody>
</table>
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” = \( \frac{13 \times 104}{3 600} = 0.38 \text{ NM} \)
\[
\frac{3.4 \times 30}{104} = 0.98 \text{ NM}
\]

\[
\text{RSS} = \left[0.2^2 + 0.38^2 + 0.98^2\right]^{0.5} = 1.07 \text{ NM} = 1,980 \text{ m}
\]

\[
X = 0.48 \text{ NM} = 890 \text{ m}
\]

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

\[
\frac{13 \times 133}{3,600} = 0.48 \text{ NM}
\]

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

\[
\text{RSS} = \left[0.2^2 + 0.48^2 + 0.77^2\right]^{0.5} = 0.93 \text{ NM} = 1,720 \text{ m}
\]

\[
X = 0.61 \text{ NM} = 1,140 \text{ m}
\]

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 EAF 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.)
Part II. Conventional Procedures

Section 2, Chapter 2. NDB or VOR Off-aerodrome Procedure — Categories A/B Aircraft

II-2-2-3

Figure II-2-2-1

Figure II-2-2-2
Figure II-2-2-3

<table>
<thead>
<tr>
<th>OCA (H)</th>
<th>Distance SCN - MAPt 6.3 km</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cat of ACFT</td>
<td>Cat A</td>
</tr>
<tr>
<td>Straight-in</td>
<td>145 (90)</td>
</tr>
<tr>
<td>Circling</td>
<td>230 (180)</td>
</tr>
</tbody>
</table>
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.

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:

\[
850 \times 0.05 + 15 + 362 = 419.5 \text{ m}
\]

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.

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 5100 ft MSL and the maximum descent inbound line indicates that aircraft approaching the NDB from the NW sector need 3 min outbound, turn altitude 2700 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.

Racetrack area

Develop a template for Categories A/B, 2.0 min outbound, altitude 6000 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 2300 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 2200 ft MSL).

Obstacle 398 determines the lowest possible turn altitude 2300 ft MSL.

Determination of time outbound

See Figure II-2-3-1. Two turn heights are indicated, 2700 and 2300 ft MSL. If turn altitude 2700 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 3200 ft. Therefore, 2 min outbound and turn altitude 2300 ft is preferable. Aircraft arriving from NW and NE must reduce height in an extra hold orbit to 2300 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 1100 + 850 = 1950 m
Part II. Conventional Procedures  
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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
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Figure II-2-3-2

Figure II-2-3-3
Transit altitude 1700 m MSL

Arrival from NE and NW sector descending in hold

MSA or above (except from NE and NW)

Climb to 780 (420) return to BB

OCA(H)

Cat of ACFT
Straight-in
Circling

Cat A
490 (125)

Cat B
515 (150)

Figure II-2-3-4
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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/fastest 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 \((1100 \times 0.05) + 15 = 55\) m above threshold. Therefore an OCH higher than 55 m is satisfactory with respect to a) above.

**Profile on final approach**

See Chapter 1 of this section, Step 1 and Figure II-2-4-2.

**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:

\[
\text{Distance FAF to THR} = 12964 - 950 = 12014 \text{ m} = 6.5 \text{ NM.}
\]

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).

**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):

\[
[12960^2 - 990^2]^{0.5} = 12 922
\]

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

**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 $(2 \, 754 \times 0.048) + 15 = 147$ m or 483 ft, altitude 607 m or 1,993 ft.

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

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

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

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

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°.

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.

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.

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.

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.

**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).
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Figure II-2-4-1

Figure II-2-4-2
Figure II-2-4-3
Part II. Conventional Procedures

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Figure II-2-4-4
Inbound track offset 8° from RWY centreline
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.

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

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

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 O₁ is situated in an area where the formula \( z = 0.025 \times 3300 - 16.5 \) applies.

The distance from the threshold is 3300 m

\[ z = (0.025 \times 3300) - 16.5 = 66 \]

<table>
<thead>
<tr>
<th>Number</th>
<th>Description</th>
<th>( x ) (metres)</th>
<th>( y_1 ) and ( y_2 ) (metres)</th>
<th>( z ) metres above THR</th>
<th>Cat I Height of W surface</th>
<th>X surface</th>
<th>Cat II Height of W surface</th>
<th>X surface</th>
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</thead>
<tbody>
<tr>
<td>1</td>
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<td>3300</td>
<td>–50</td>
<td>71</td>
<td>86.0</td>
<td>112.0</td>
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<td>85</td>
<td>97.7</td>
<td>125.8</td>
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* 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:

\[
z = (0.02 \times 2500) - 1.2 = 48.8
\]

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 O₁. Category I Table:

W surface:

\[
(0.0285 \times 3300) - 8.01 = 86.0 \text{ m}
\]

Obstacle O₁ does not penetrate.

X surface:

\[
(0.026534 \times 3300) + (0.174940 \times 50) - 16.03 = 80.3 \text{ m}
\]

Obstacle O₁ does not penetrate.

Obstacle O₂:

X surface:

\[
(0.026534 \times 3300) + (0.174940 \times 150) - 16.03 = 97.8 \text{ m}
\]

Obstacle O₂ does not penetrate.

Obstacle O₅:

W surface:

\[
(0.0285 \times 3100) - 8.01 = 80.3 \text{ m}
\]

The obstacle reaches 79 m. Obstacle O₅ does not penetrate.

Obstacle 21:

W surface:

\[
(0.0285 \times 650) - 8.01 = 10.5 \text{ m}
\]

This obstacle is 16 m and penetrates.

Does it penetrate Category II W surface?

\[
(0.0358 \times 650) - 6.19 = 17.1 \text{ m}
\]

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.**

<table>
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**OAS TEMPLATE COORDINATES -M**

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**300M HEIGHT**

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**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 O₁ to O₂₀ with regard to Category II surfaces. None of them penetrate.

Obstacle 21:

W values:

\[(0.0358 \times 650) - 6.19 = 17.1 \text{ m}\]

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

Obstacle 22:

Situated below the X surface

Flight director: \[(0.034123 \times 450) + (0.226993 \times 180) - 20.88 = 35.3 \text{ m}\]

Autopilot: \[(0.039585 \times 450) + (0.263324 \times 180) - 24.23 = 41.0 \text{ m}\]

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 (hₘₐ) to the height of “equivalent” approach obstacles (hₐ) using the equation (see Figure II-2-5-5):

\[ hₐ = \frac{hₘₐ \cot Z + (900 + X)}{\cot Z + \cot θ} \]

b) Determine the highest value hₐ 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 hₐ 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 $6.3 \times 10^{-10}$. 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.

**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 $3.0^\circ$

$\tan 3.0^\circ = 0.0524$ which corresponds to descent gradient 5.2 per cent.

The glide path height overhead OM is:

$15 + (7200 \times \tan 3.0^\circ) = 392.3 \text{ m} = 1287 \text{ ft}$

Altitude 426.3 m MSL, 1399 ft MSL

The glide path height overhead MM is:

$15 + (1050 \times \tan 3.0^\circ) = 70 \text{ m} = 230 \text{ ft}$

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.

**Final approach point (FAP)**

Distance FAP to THR is calculated:

\[
\frac{760 - 34 - 15}{\tan 3^\circ} = 13 \, 567 \, m
\]

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.

**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:

\[
z = A \times x + B \times C
\]

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

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.

**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.

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

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).

\[ 300 = (-3 \times 900 \times 0.0228) + (y \times 0.2001) - 20.49 \]
\[ y = 2.047 \]

The width at the threshold is calculated:

\[ 300 = 0.2 \times 0.001y - 20.49 \]
\[ y = 1.601.6 \text{ m} \]

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

\[ -0.025 \times (-3 \times 900) - 22.5 = 75 \text{ m} \]

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

\[ y = 922 \text{ m} \]

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:

\[ \frac{3 \times 072 - 205}{12 \times 000} = 0.2389 \text{ which corresponds to angle 13.4°} \]

(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.
This portion is enlarged in Figure II-2-5-2.
Figure II-2-5-4

The A value for $W^n$ is steeper than $W$

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

Figure II-2-5-6. Missed approach obstacle before range –900 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)
Figure II-2-5-11
Figure II-2-5-12

Part II. Conventional Procedures
Section 2, Chapter 5. ILS
**Figure II-2-5-13**

**Instruments Flight Procedures Construction Manual**

- **AROM TWR 116.10**
- **AROM APP 118.50**
- **LES**
- **VOR/DME**
- **LESTRA**

**Table: Category of Aircraft Speed**

<table>
<thead>
<tr>
<th>Cat of ACFT</th>
<th>Speed</th>
<th>Rate of Descent / GS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cat A</td>
<td>278 (168)</td>
<td>80</td>
</tr>
<tr>
<td>Cat B</td>
<td>284 (174)</td>
<td>100</td>
</tr>
<tr>
<td>Cat C</td>
<td>293 (183)</td>
<td>120</td>
</tr>
<tr>
<td>Cat D</td>
<td>303 (193)</td>
<td>140</td>
</tr>
<tr>
<td>Cat I</td>
<td>164 (94)</td>
<td>180</td>
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<tr>
<td>Cat II</td>
<td>178 (109)</td>
<td>220</td>
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<tr>
<td>Cat III</td>
<td>195 (115)</td>
<td>250</td>
</tr>
<tr>
<td>Cat IV</td>
<td>215 (135)</td>
<td>300</td>
</tr>
</tbody>
</table>

**Horizontal Range (km) and CAT:**

<table>
<thead>
<tr>
<th>Horizontal Range (km)</th>
<th>CAT A</th>
<th>CAT B</th>
<th>CAT C</th>
<th>CAT D</th>
</tr>
</thead>
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<tr>
<td>10</td>
<td>5.5</td>
<td>7.5</td>
<td>10.0</td>
<td>12.5</td>
</tr>
<tr>
<td>15</td>
<td>8.0</td>
<td>12.0</td>
<td>15.0</td>
<td>17.5</td>
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<tr>
<td>20</td>
<td>10.0</td>
<td>15.0</td>
<td>20.0</td>
<td>25.0</td>
</tr>
<tr>
<td>25</td>
<td>12.5</td>
<td>20.0</td>
<td>30.0</td>
<td>37.5</td>
</tr>
<tr>
<td>30</td>
<td>15.0</td>
<td>30.0</td>
<td>50.0</td>
<td>67.5</td>
</tr>
</tbody>
</table>

**Transiton Altitude:**

- **5000 FT MSL**

**LEGIONS:**

- **LES**
- **VOR/DME**
- **LESTRA**

**MNM SECT ALT:**

- **2300** 25 NM
- **2500** 25 NM
- **3200** 25 NM

**VOR/DME LES:**

- **115.10 LES**
- **98X**

**LES:**

- **110.30 MK**
- **LES PARKES ONE ARR**

**ILS RDH 50 FT:**

- **From KAVRAN TECHO**

**OCA(H):**

- **3.89 NM**

**Distance OS-MM 6.76 NM:**

<table>
<thead>
<tr>
<th>Distance OS-MM 6.76 NM</th>
<th>5</th>
<th>10</th>
<th>15</th>
<th>20</th>
<th>25</th>
<th>30</th>
<th>35</th>
<th>40</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speed (KT)</td>
<td>80</td>
<td>100</td>
<td>120</td>
<td>140</td>
<td>180</td>
<td>220</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time (min)</td>
<td>5.04</td>
<td>4.03</td>
<td>3.23</td>
<td>2.54</td>
<td>2.32</td>
<td>2.15</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rate of descent / GS (ft/min)</td>
<td>425</td>
<td>530</td>
<td>635</td>
<td>740</td>
<td>850</td>
<td>956</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Part II. Conventional Procedures
Section 2, Chapter 5. ILS

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.

---

**STEP 1**

**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.

---

**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 \times 0.0228) + (800 \times 0.2001) – 20.5 = 198.9 \text{ 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.
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

\[
\frac{AB}{BC} = \tan z, \quad \tan z = \text{climb gradient}
\]

Thus, \[BC = \frac{AB}{\text{climb gradient}}\]

In this example, \[BC = \frac{45}{0.025} = 1800 \text{ m}\]

An obstacle with elevation 205 m is assumed to be situated at coordinates \(x = 550, y = 1050\) 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 \(d + X = 280 + 1380 = 1660 \text{ m}\) (no overhead fix tolerance).

Therefore, distance SOC to the obstacle is \(1660 - 500 = 1160 \text{ m}\).

MOC in primary area is now calculated

\[
\frac{1160}{1800} \times 45 + 30 = 59 \text{ m}
\]

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 \[
\frac{400}{1200} \times 59 = 19.6 \text{ (20 m)}
\]

OCA for Category C aircraft in initial missed approach area \(= 205 + 20 = 225 \text{ m}\).

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).

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

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.

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.

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

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):

$$11 100 \times 0.05 + 15 + 53 = 623 \text{ m} = 2 044 \text{ ft}$$

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?

$$15 + (0.05 \times 7 004) = 200.2 \text{ m or altitude 254 m MSL}$$

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:

$$190 + 0.05 \times 7 408 = 560.4 \text{ m} = 1 839 \text{ ft}$$

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:

$$0.8 + 0.17 + 0.86 = 1.83 \text{ NM} = 3 389 \text{ m}$$

SOC begins $2.0 - 1.83 = 0.17 \text{ NM} = 315 \text{ m}$ before THR

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

$$200 - 1 890 \times 0.025 + 30 = 182.8 \text{ m}, \text{which is below final approach OCA}.$$

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.
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Section 2, Chapter 7. Surveillance Radar Element (SRE) II-2-7-3

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: \(190 + 1 852 \times 0.053 = 288 \text{ m} = 945 \text{ ft}\)
4 NM: \(190 + 3 704 \times 0.053 = 386 \text{ m} = 1 267 \text{ ft}\)
5 NM: \(190 + 5 556 \times 0.053 = 484 \text{ m} = 1 589 \text{ ft}\).

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>
<thead>
<tr>
<th>Aerodrome</th>
<th>RWY number</th>
<th>Aerodrome elevation ft</th>
<th>Inbound track degrees magnetic</th>
<th>Intermediate approach altitude ft</th>
<th>IF range from THR NM</th>
<th>FAF range from THR NM</th>
<th>MAPt range from THR NM</th>
<th>OCA/H ft</th>
</tr>
</thead>
<tbody>
<tr>
<td>DONLON/ Slipinton</td>
<td>11</td>
<td>178</td>
<td>105</td>
<td>1 900</td>
<td>11</td>
<td>6</td>
<td>2.0</td>
<td>630 (450)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Missed approach procedure feet</th>
<th>Circling OCA/H feet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cat A</td>
<td>Cat B</td>
</tr>
<tr>
<td>Climb straight ahead to 2 400 (2 230) 720 (670)</td>
<td>760 (580)</td>
</tr>
<tr>
<td></td>
<td>230 (180)</td>
</tr>
</tbody>
</table>

Distance from THR

<table>
<thead>
<tr>
<th>NM KM</th>
<th>Altitude/height: ft m</th>
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</thead>
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<tr>
<td>2 3.7</td>
<td>630 (450) 190 (140)</td>
</tr>
<tr>
<td>3 5.6</td>
<td>950 (770) 290 (235)</td>
</tr>
<tr>
<td>4 7.4</td>
<td>1 270 (1 090) 390 (335)</td>
</tr>
<tr>
<td>5 9.3</td>
<td>1 590 (1 420) 485 (430)</td>
</tr>
</tbody>
</table>
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
Climb straight ahead to 720 (670) or as directed.
Part II. Conventional Procedures  
Section 2, Chapter 7. Surveillance Radar Element (SRE)  

**Figure II-2-7-5**

- **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**

**Bearings are magnetic altitudes, elevations and heights in feet**

**Transition Altitude 4500 FT MSL**

<table>
<thead>
<tr>
<th>NM</th>
<th>0</th>
<th>5</th>
<th>10</th>
<th>15</th>
<th>20</th>
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</thead>
<tbody>
<tr>
<td>OCA(H)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cat of ACFT</td>
<td>Cat A</td>
<td>Cat B</td>
<td>Cat C</td>
<td>Cat D</td>
<td>Altitude (height) on final approach</td>
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<tr>
<td>Straight-in</td>
<td>1900 (1730)</td>
<td>903 (725)</td>
<td>378 (200)</td>
<td>2400 (2230)</td>
<td>5 NM</td>
</tr>
<tr>
<td>Circling</td>
<td>760 (580)</td>
<td>1090 (910)</td>
<td>1190 (1010)</td>
<td>1430 (1250)</td>
<td>1590 (1420)</td>
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</tbody>
</table>

<table>
<thead>
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<th>0</th>
<th>5</th>
<th>10</th>
<th>15</th>
<th>20</th>
</tr>
</thead>
<tbody>
<tr>
<td>Altitude (height) on final approach</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cat D</td>
<td>1270 (1090)</td>
<td>950 (770)</td>
<td>5.3%</td>
<td>3.3%</td>
<td></td>
</tr>
</tbody>
</table>

**Climb straight ahead to 2400 (2230) or as directed**
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.

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.

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.
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:

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

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:

\[
\tan (\text{intercept angle}) = \frac{200}{1000} = 0.2
\]

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.

\[
\text{OCA} = 398 + 90 = 488 \text{ m MSL or 1 600 ft MSL. OCH is 440 ft.}
\]

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.

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).

Holding shall not be presented (see the introduction to this chapter).
Only OCA/H tables shall be presented on 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.
Figure II-2-8-1. Area for the calculation of turn altitude

\[
\text{TAS less than or equal to 315 km/h (170 kt)} \quad \theta = \frac{36}{t}
\]

\[
\text{TAS exceeding 315 km/h (170 kt)} \quad \theta = \frac{(0.116 \times \text{TAS})}{t} \quad (\text{TAS in km/h})
\]

\[
\theta = \frac{(0.215 \times \text{TAS})}{t} \quad (\text{TAS in kt})
\]

\[
D = \frac{(V + 1.9) t + 2.8}{60}
\]

\[
D = \frac{(V + 1) t + 1.5}{60}
\]

where \(D\) = radius in km
\(V\) = TAS in km/h
\(t\) = time outbound (min)

where \(D\) = radius in NM
\(V\) = TAS in kt
\(t\) = time outbound (min)
Figure II-2-8-2. Final approach area
Figure II-2-8-3. Bromburg NDB 09

Note.– Inbound track is offset 12° from runway bearing 092° E.
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 O1 and the large turn radius associated with the final missed approach speeds suggests that it would be impossible to exclude O1 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 O1, 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.

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

\[ \text{OCA} = 765 - 6 \times 700 \times 0.025 + 30 = 627.5 \text{ m MSL}. \]

The OCA/H is highest at 630 (170) m.

Obstacles in the turn initiation area

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.

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 O1, which shall be avoided, is situated close to the border. Indicate the highest point just inside the border: O2, elevation 910 m.

The distance from TP to O2 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 + do tan Z – MOC ...”

In this example TNA = 830 m (see Step 4), tan Z = 0.025, MOC = 50 m and the distance do is obstacle O2 distance from TP = 6 100 m. The following is calculated:

\[ 830 + (6 \times 100 \times 0.025) - 50 = 932.5 \text{ m} \]

As the O2 elevation is 910 m, the ridge does not affect.

Obstacle O3 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 O3 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 O₄, elevation 1 100 m, affects the missed approach. A check is made as follows:

$$830 + 12\,000 \times 0.025 - 50 = 1\,080\,m.$$  

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

$$\frac{20}{0.25} = 800\,m$$

outwards in the direction of obstacle O₁, which shall be avoided. A possibility for avoiding O₁ in this situation is to reduce the extension of the turn area by specifying reduced speed, if not already done.

If, however, obstacle O₁ 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 $$d₂ + X$$ as in Chapter 1 of this section, Step 10. The OCA/H 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.)
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 (O₁) 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.

Missed approach point (MAPt)

See Chapter 9 of this section, Step 1.

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
\( c = 0.39 \text{ NM} = 722 \text{ m} \)
\( R = 1.44^\circ/\text{sec} \)

\[ r = 2.24 \text{ NM} = 4 148 \text{ m} \]
\[ E = 0.52 \text{ NM} = 963 \text{ m} \]

\[ r + E = 2.76 \text{ NM} = 5 111 \text{ m} \]
\[ r + 2E = 3.28 \text{ NM} = 6 075 \text{ m} \]

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:

\[ 5 \text{ NM} - 0.3125 \text{ NM} - 1.03 \text{ NM} = 3.657 \text{ NM} = 6 774 \text{ m} \]

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.

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 (\( d_o \)) shall be used when the effect on OCA/H of a turn area obstacle is calculated.

Obstacle O₂ distance from line K-K is 4 700 m, elevation 805 m. The OCA/H necessary to avoid O₂ is calculated:
805 – [(4 700 + 6 774) × 0.025] + 50 = 568 m MSL.

As OCA/H final approach is 585 m (125), obstacle O2 does not affect. The effect of obstacles O3 and O4 is checked with the same calculation.

The missed approach procedure is specified as:

“The 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).”
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):

\[
\begin{align*}
x &= -8 100 \\
y &= -1 700 \\
z &= 195
\end{align*}
\]

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.

\[
\text{Formula:}
\begin{align*}
\text{SOC}_z &= \frac{\text{h}_{\text{ma}} \times \cot Z + 900 + x}{\cot Z + \cot \theta} \\
\text{SOC}_z &= \frac{195 \times 40 + 900 + (-8 100)}{40 + 19.08} = 10.156 \text{ m} = \text{SOC}_z
\end{align*}
\]

(See Figure II-2-11-3.)

Find SOC_x

\[
\begin{align*}
\text{SOC}_x &= \text{SOC}_z \tan \theta - 900 \\
\text{SOC}_x &= 10.156 \tan 3^\circ - 900 \\
\text{SOC}_x &= 193.8 \text{ m} - 900 = -706.2 \text{ m}
\end{align*}
\]

Proof: Height gain (HG) from SOC should equal height of O_1 (195 m).

\[
\begin{align*}
\text{HG} &= (8 100 - 900 + 193.8) \times 0.025 = 184.84 \text{ m} \\
\text{SOC}_z + \text{HG} &= 10.156 + 184.84 = 195 \text{ m}
\end{align*}
\]

The OCH, then, is simply \( \text{SOC}_z + \text{height loss (HL)} \).

<table>
<thead>
<tr>
<th>OCH ILS Category</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>51</td>
<td>54</td>
<td>57</td>
<td>60</td>
</tr>
<tr>
<td>II</td>
<td>24</td>
<td>29</td>
<td>33</td>
<td>37</td>
</tr>
</tbody>
</table>

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:

\[
\begin{align*}
x &= -8 100 \\
y &= -1 700 \\
z &= 195
\end{align*}
\]
The task is to determine if \( O_2 \) will change \( \text{SOC}_z \) 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 \( 15^\circ \) 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:

\[
\frac{1}{2}W = \tan 15^\circ \times (|x_{O_2}| - |x_{E^{"}}|) + |y_{E^{"}}|
\]

\[
\frac{1}{2}W = \tan 15^\circ \times (15,000 - 12,900) + 3,001 = 3,564 \text{ m}
\]

Find that \( O_2 \) lies within the continued missed approach area.

The equivalent height (\( h_a \)) of \( O_2 \) is:

\[
\frac{1}{2}W = \tan 15^\circ \times (15,000 - 12,900) + 3,001 = 3,564 \text{ m}
\]

\[
h_a = \frac{365 \times 40 + 900 - 15,000}{40 + 19.08} = 8.46 \text{ m} = \text{SOC}_z
\]

(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) 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:

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>OCH ILS Category I</td>
<td>51</td>
<td>54</td>
<td>57</td>
<td>60</td>
</tr>
<tr>
<td>OCH ILS Category II</td>
<td>24</td>
<td>29</td>
<td>33</td>
<td>37</td>
</tr>
</tbody>
</table>
ILS MISSED APPROACH
(Obstacle beyond the precision segment)

Figure II-2-11-4

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 O₁, O₂ and O₃ (all chart tolerance codes 1A*) are on the runway centre line. Obstacles O₁ and O₂ penetrate both the ILS Categories I and II OAS surfaces. Obstacle O₄ (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:

<table>
<thead>
<tr>
<th>x</th>
<th>y</th>
<th>z</th>
<th>code*</th>
</tr>
</thead>
<tbody>
<tr>
<td>O₁</td>
<td>750</td>
<td>0</td>
<td>22</td>
</tr>
<tr>
<td>O₂</td>
<td>−4500</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>O₃</td>
<td>−15000</td>
<td>0</td>
<td>1000</td>
</tr>
<tr>
<td>O₄</td>
<td>−5000</td>
<td>6000</td>
<td>255</td>
</tr>
</tbody>
</table>

* 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.

STEP 1

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 O₃ 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.)

STEP 2

Determine the SOC for the precision segment

Compare the height of O₁ to the equivalent height of O₂. The higher of the two will equal SOCz. (See Figure II-2-12-2.)

O₁ height is 22 m

The \( h_a \) of O₂ = \( \frac{(100 \times 40) + 900 - 4500}{40 + 19.08} \) = 6.8 m

SOC₂ = 22 m for the precision segment.

Find the location of the start of climb (SOCₓ).

SOCₓ = SOC₂/tan \( \theta \) – 900

SOCₓ = 22/tan 3° – 900 = −480 m

SOCₓ = −480 m.
**STEP 3**

Identify the lowest usable turn height (TNH) that will clear O₂ in the turn initiation area and provide the MOC over O₄ in the turn area.

The lowest TNH for O₂ = 100 + 50 = 150 m.

The lowest TNH for O₄ = (O₄ height + MOC) – height gain (HG) along the shortest distance (dₒ₄) from the 300 m contour to O₄.

The distance dₒ₄ 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:

\[ \alpha = \tan^{-1} \frac{y_{D''} - y_{E''}}{x_{E''} + |x_{E'}|} = \frac{3 001 - 910}{5 438 + 12 900} = 6.5° \]

The y coordinate of the 300 m contour at the range of O₄ is found by solving for y in the formula z = Ax + By + C for the Y surfaces where x = the x coordinate of O₄ (-5 000) and z = 300 m.

\[ y = \frac{z - Ax - C}{B} = \frac{300 - (0.023948 \times -5 000) - (-21.51)}{0.210054} = 2 101 m \]

The distance dₒ₄ = (|yₒ₄| - chart tolerance - |y₃₀₀|) × cos α

\[ dₒ₄ = (6 000 - 300 - 2 101) \times \cos 6.5° = 3 576 m \]

The lowest TNH that will ensure the MOC at O₄ is:

\[ \text{TNH}_{O₄} = (255 + 50) - (3 576 \times 0.025) = 215.6 m. \]

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.

\[ \text{TNA} = 215.6 + 300 = 515.6\text{ m} = 1 692 \text{ ft} \]

(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 O₃ 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 O₃, the distance dₓ available for height gain after SOC is:

\[ dₓ = 15 000 - 9 670 - 480 = 4 850 m \]

The nominal height (NH) at the TP = SOCₓ 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**

<table>
<thead>
<tr>
<th>Category</th>
<th>c +</th>
<th>E +</th>
<th>[ r^2 + E^2 ]^{0.5} +</th>
<th>Chart tolerance</th>
<th>Required turn area at TAS km/h (kt)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0.46</td>
<td>0.6</td>
<td>[ 1.38^2 + 0.56^2 ]^{0.5}</td>
<td>0.3</td>
<td>2.85 (1.53 NM)</td>
</tr>
<tr>
<td>B</td>
<td>0.59</td>
<td>0.76</td>
<td>[ 2.57^2 + 0.76^2 ]^{0.5}</td>
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</tr>
<tr>
<td>C</td>
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<td>1.21</td>
<td>[ 6.49^2 + 1.21^2 ]^{0.5}</td>
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<td>8.99 (4.86 NM)</td>
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<tr>
<td>D</td>
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<td>1.27</td>
<td>[ 7.08^2 + 1.27^2 ]^{0.5}</td>
<td>0.3</td>
<td>9.67 (5.22 NM)</td>
</tr>
</tbody>
</table>
Part II. Conventional Procedures  
Section 2, Chapter 12. Precision — Turning Missed Approach — Turn at an Altitude

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)  
Category D: 6.65 (3.59 NM)

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

$SOC_z = h_a = \frac{218 \times 40 + 900 - (15000 - \text{turn area requirement})}{40 + 19.08}$

Category A $SOC_z = \frac{218 \times 40 + 900 - (15000 - 2850)}{40 + 19.08} = -43$ m (use 22 m)

Category B $SOC_z = \frac{218 \times 40 + 900 - (15000 - 4330)}{40 + 19.08} = -18$ m (use 22 m)

Category C $SOC_z = \frac{218 \times 40 + 900 - (15000 - 5940)}{40 + 19.08} = 9.5$ m (use 22 m)

Category D $SOC_z = \frac{218 \times 40 + 900 - (15000 - 6650)}{40 + 19.08} = 21.5$ 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.

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<th>C</th>
<th>D</th>
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<tr>
<td>OCH ILS Category II</td>
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</table>

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
Part II. Conventional Procedures
Section 2, Chapter 12. Precision — Turning Missed Approach — Turn at an Altitude

Figure II-2-12-3

Figure II-2-12-4
Note that 2.5% gradient from 22 m reaches TH before critical turn requirement.

Turn requirement at IAS 200

TH 218 m to clear O₄ in turn area

Chart tolerance = 300 m

211 kt TAS bounding circle

15°

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 O3 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 dz from which the distance do in the turn area to O4 is measured.

The distance available for height gain is dz + do.

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 \times 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 1

Identify the latest TP

The latest TP fix tolerance must occur prior to O3 at a distance at least equal to the charting tolerance (code 6C) plus c + E + \(\sqrt{r^2 + E^2}\)0.5.

STEP 2

Determine dz to be SOC to line K-K

Therefore

\[d_z = 7 138 – 480 \text{ (SOC}_x\text{)} = 6 658 \text{ m.}\]

STEP 3

Determine do, the distance from K-K to O4

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.
The distance $d_{o4}$ is the hypotenuse of the right angle triangle minus the chart tolerance ($KAd_{o4}$).

$$d_{o4} = \sqrt{(6000 - 2344)^2 + (7138 - 5000)^2} - 300 = 3935 \text{ m}.$$  

The nominal altitude (NA) = aerodrome elevation + start of climb (SOCz) + height gain \[[d_z + d_o] \times 0.025\].

The required altitude (RA) = obstacle elevation (OE) + minimum obstacle clearance (MOC)

NA$_{o4}$ = 300 + 22 + \[(6658 + 3935) \times 0.025\] = 586.8 m.

RA$_{o4}$ = 300 + 255 + 50 = 605 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:

$$h_a = \text{SOC}_z$$

$$h_{ma} = \text{RA} - 300 = 305 \text{ m}$$

$$x = \text{SOC}_x + d_z + d_o; \quad -480 + (-6658) + (-3935) = -11073 \text{ m}$$

$$h_a = \frac{(305 \times 40) + (900 - 11073)}{40 + 19.08} = 34.3 \text{ m} = \text{SOC}_z$$

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:

$$\tan^{-1} \left( \frac{|x_K| - |x_{o4}| - \text{chart tolerance}}{|y_{o4}| + |y_K|} \right);$$

$$\tan^{-1} \left( \frac{7138 - 5000 - 300}{6000 + 2344} \right) = 12.4^\circ$$

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 \( (d_a) \) 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):

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<th>Obstacle</th>
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<th>y</th>
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<td>-1 050</td>
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<td>-5 200</td>
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<tr>
<td>O₃</td>
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<td>40 m</td>
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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.

\[
h_a = \frac{40 \times 40 + 900 - 500}{40 + 19.08} = \frac{3385}{59.08} = 57.37 \text{ (34 m)} = SOC_z
\]

\[SOC_x = -900 + (34/\tan 3°) = -251 \text{ m} \quad \text{[OCH = 80 m]}\]

II-2-14-1
Determine the turn height (TNH)

\[
TNH = \text{obstacle elevation} + \text{MOC} = 40 + 50\ m = 90\ m.
\]

*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.*

Construct the 90 m contour (see Attachment B7, 5.2)

The coordinate points of C", D" and E" for the 90 m contour are:

\[
\begin{align*}
E"_{90} : x &= \frac{90}{300} \times (-12\ 900 + 900) - 900 = -4\ 500 \\
E"_{90} : y &= \frac{90}{300} \times (3\ 001 - 205) + 205 = 1\ 045 \\
D"_{90} : x &= \frac{90}{300} \times (5\ 438 + 286) - 286 = 1\ 431 \\
D"_{90} : y &= \frac{90}{300} \times (910 - 135) + 135 = 368 \\
C"_{90} : x &= \frac{90}{300} \times (10\ 807 - 281) + 281 = 3\ 439 \\
C"_{90} : y &= \frac{90}{300} \times (96 - 49) + 49 = 63
\end{align*}
\]

The dimension DT is found with the formula:

\[
DT = (HL - RDH) \cot 3° + 900 = 1\ 492\ m
\]

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.

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:

\[
c = 0.88\ km, r = 6.49\ km\ and\ E = 1.21\ km
\]

Determine the minimum turn necessary to avoid O₁ straight ahead (see Attachment B7, 5.3)

Find that a missed approach turn of 15° will avoid O₁.

The turn area inner boundary, the dividing boundaries of Areas 2 and 3, as well as the direction of the distance vector d₀, which determines the height gain, are all plotted from their respective points with a splay angle of 15° + 15° = 30°

Determine the height that can be gained along the 30° line d₀ measured from the obstacle O₁ back to the 90 m contour of the OAS. Find, by careful measurement, that d₀ = 9 000 m

In Area 3 the obstacle height shall be less than:

\[
TNH + (d₀ \times \tan Z) - \text{MOC [30 m with 15° turn]} = 90 + (9\ 000 \times 0.025) - 30 = 285\ m
\]
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 O1 and will require a greater turn angle, which will affect the distance to climb. You will find that do 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:

\[ E_{155}; x = -7100, \ y = 1650 \]
\[ D_{155}; x = 2671, \ y = 535 \]
\[ C_{155}; x = 5719, \ y = 73 \]

The results are:

- \( d_o = 5300 \) m
- MOC = 50 m

The allowable obstacle height at this point is:

\[ 155 + (5300 \times 0.025) - 50 = 237.5 \] m

O2 height is 225 m.

**Conclusion:** Obstacle O2 is avoided and an extra 12.5-m margin is provided.
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**

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## Attachment A2

Metres and Feet

### Feet to metres

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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: $\phi$ (Table B1-1, line 10);
- outbound leg length: L (Table B1-1, line 13);
- radius of turn: r (Table B1-1, 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 b1, 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 \( \phi \) 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 \( \alpha \) 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 We, 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 “dl” and “d2” after 75 and 85 degrees of turn from “b”; and

b) from “dl” and “d2”, draw the tangents to the outbound turn and locate points “el” 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 “fl”, draw the inbound turn beginning at “el” and locate points “k”, “l” and “m” after 180, 225 and 270 degrees of turn from “el”.

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:

<table>
<thead>
<tr>
<th>SI units</th>
<th>Non-SI units</th>
</tr>
</thead>
<tbody>
<tr>
<td>$t$</td>
<td>$s$</td>
</tr>
<tr>
<td>$v$ and $w'$</td>
<td>km/s</td>
</tr>
<tr>
<td>distances</td>
<td>km</td>
</tr>
</tbody>
</table>

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:

$$d1 = 0.46 \text{ km (0.25 NM)} + 0.0125 \text{ D}$$

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 “i1”, “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”. “i1” “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 “l” 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 n1 n2 n3 n4 reduced from “i1” “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 V1 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 \( \alpha \) 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:

\[ qV = 0.2 h \quad (h \text{ in km and } qV \text{ in km}) \]

\[ qV = 0.033 h \quad (h \text{ in thousands of feet and } qV \text{ in NM}) \]; and

4) locate points V1, 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 N1 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 “N1” 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).

3.3.2.4.6 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 3.3.2.4.3 b).

3.3.2.4.7 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 V1 V2 V3 V4) and locate points “A1”, “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 N1 N2 N3 N4) and locate points “A1”, “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 “A1”, “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)

3.3.3.2.2.2 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 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).
3.3.4.1.4  Area containing the end of the outbound leg

a) Locate points C1 and C3 at the intersection of the extension of curve “l” with the arcs DL1 and DL2;

b) locate point C2 between C1 and C3 at a distance \((d_l + d_2 - 1.8)\) km or \((d_l + d_2 - 1)\) NM from C3;

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, C6, C5 and C6 instead of C1, C3, 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 C1, 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 C1, C2, C3, C4 and C6.

3.3.4.1.5  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:

<table>
<thead>
<tr>
<th>q</th>
<th>0° to 70°</th>
<th>71° to 90°</th>
<th>91° to 105°</th>
<th>106° to 120°</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>km (NM)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0°</td>
<td>7.5 (4)</td>
<td>9.5 (5)</td>
<td>13 (7)</td>
<td>16.5 (9)</td>
</tr>
</tbody>
</table>
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 A1, 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 $30^\circ + 5^\circ$ with RP and locate C7 at its intersection with DL2;
b) from A4 draw a line making an angle of $30^\circ - 5^\circ$ 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 $30^\circ$ 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 $\alpha$ (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 $ds \geq vt$, 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: $D_s$

$D_s$ is the distance between the VOR/DME facility (S) and the vertical projection of the procedure point on the horizontal plane through S

$D_s = \sqrt{D^2 - h_l^2}$

$(D_s, D$ and $h_l$ in km); or

$D_s = \sqrt{D^2 - 0.027 \cdot h_l^2}$

$(D_s$ and $D$ in NM and $h_l$ 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

$DL = \sqrt{(D_s - ds)^2 + r^2 + h_l^2}$

$(DL, D_s, ds, r, h_l$ in km); or

$DL = \sqrt{(D_s - ds)^2 + 4r^2 + h_l^2}$

$(DL, D_s, ds, r$ in NM and $h_l$ 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: $D_{Ls}$

$D_{Ls}$ 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

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 $\alpha$ (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:

$dl = 0.46 \text{ km} (0.25 \text{ NM}) + 0.125 \text{ D}$

$d2 = 0.46 \text{ km} (0.25 \text{ NM}) + 0.0125 \text{ DL};$

c) locate points “A” at the intersection of RP and Ds, “A1” 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 A1, 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-maneuuvring 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 C1 and C3 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 C1 and C3 at a distance ($dl + d2 - 1.8$) km or ($dl + d2 - 1$) NM from C3;

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, C6, C5 and C6 instead of C1, C3, 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 C1 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 C1 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 are 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.

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 \( \beta \) (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 \( \beta \) 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 C1, 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 \( \pm 5° \) 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.

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.

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:

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Table</th>
</tr>
</thead>
<tbody>
<tr>
<td>Procedure turn (45/180)</td>
<td>B1-5 a</td>
</tr>
<tr>
<td>Procedure turn (80/260)</td>
<td>B1-5 b</td>
</tr>
<tr>
<td>Base turn</td>
<td>B1-5 c</td>
</tr>
<tr>
<td>Racetrack</td>
<td>B1-5 d</td>
</tr>
</tbody>
</table>

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;
Attachment B1. Construction of Obstacle Clearance Areas for Reversal Procedure

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):

\[
XE = 2r + D + 11v + \left(11 + \frac{90}{R} + 11 + \frac{105}{R}\right)W'
\]

\[
YE = 11v \cdot \cos 20° + r \cdot \sin 20° + r' + \left(11 + \frac{20}{R} + \frac{90}{R} + 11 + \frac{15}{R}\right)W'
\]

(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 \(1.414 \times d3\) 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:

\[
\text{RNP} + 3.7 \text{ km (2.0 NM)}
\]

\[
9.3 \text{ km (5.0 NM)}
\]
### Table B1-1. Calculations associated with the construction of the base turn template

<table>
<thead>
<tr>
<th>DATA</th>
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</tr>
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<tbody>
<tr>
<td>IAS</td>
<td>260 km/h</td>
<td>140 kt</td>
</tr>
<tr>
<td>Altitude</td>
<td>1 850 m</td>
<td>6 000 ft</td>
</tr>
<tr>
<td>T</td>
<td>2 min</td>
<td>2 min</td>
</tr>
<tr>
<td>NDB</td>
<td>at 0 m</td>
<td>at 0 ft</td>
</tr>
<tr>
<td>Temperature</td>
<td>ISA + 15°C</td>
<td>ISA + 15°C</td>
</tr>
</tbody>
</table>

#### CALCULATIONS USING SI UNITS

<table>
<thead>
<tr>
<th>Line</th>
<th>Parameter</th>
<th>Formula</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>K</td>
<td>Conversion factor for 1 850 m and ISA + 15°C (see PANS-OPS, Volume II, Attachment F to Part III)</td>
<td>1.1244</td>
</tr>
<tr>
<td>2</td>
<td>V</td>
<td>$V = K \times IAS$</td>
<td>292.34 km/h</td>
</tr>
<tr>
<td>3</td>
<td>v</td>
<td>$v = \frac{V}{3600}$</td>
<td>0.0812 km/s</td>
</tr>
<tr>
<td>4</td>
<td>R</td>
<td>$R = \frac{943.27}{V}$, or $3^\circ/s$, whichever is less</td>
<td>(3.23)</td>
</tr>
<tr>
<td>5</td>
<td>r</td>
<td>$r = \frac{V}{62.83}$</td>
<td>1.55 km</td>
</tr>
<tr>
<td>6</td>
<td>h</td>
<td>in thousands of metres</td>
<td>1.85</td>
</tr>
<tr>
<td>7</td>
<td>w</td>
<td>$w = 12h + 87$</td>
<td>109.2 km/h</td>
</tr>
<tr>
<td>8</td>
<td>w'</td>
<td>$w' = \frac{w}{3600}$</td>
<td>0.03 km/s</td>
</tr>
<tr>
<td>9</td>
<td>E</td>
<td>$E = w' + R$</td>
<td>0.01 km/°</td>
</tr>
<tr>
<td>10</td>
<td>f</td>
<td>for $V \leq 315$ km/h: $\phi = \frac{36}{T}$, for $V &gt; 315$ km/h: $\phi = \frac{0.116 V}{T}$</td>
<td>18°</td>
</tr>
<tr>
<td>11</td>
<td>zN</td>
<td>$zN = h \tan 40^\circ$</td>
<td>1.55 km</td>
</tr>
<tr>
<td>12</td>
<td>t</td>
<td>$t = 60T$</td>
<td>120 s</td>
</tr>
<tr>
<td>13</td>
<td>L</td>
<td>$L = vt$</td>
<td>9.74 km</td>
</tr>
<tr>
<td>14</td>
<td>ab1 = ab3</td>
<td>$ab1 = ab3 = (t - 5)(v - w') - zN$</td>
<td>4.34 km</td>
</tr>
</tbody>
</table>

#### CALCULATIONS USING NON-SI UNITS

<table>
<thead>
<tr>
<th>Line</th>
<th>Parameter</th>
<th>Formula</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>K</td>
<td>Conversion factor for 6 000 ft and ISA + 15°C (see PANS-OPS, Volume II, Attachment F to Part III)</td>
<td>1.1231</td>
</tr>
<tr>
<td>2</td>
<td>V</td>
<td>$V = K \times IAS$</td>
<td>157.23 kt</td>
</tr>
<tr>
<td>3</td>
<td>v</td>
<td>$v = \frac{V}{3600}$</td>
<td>0.0437 NM/s</td>
</tr>
<tr>
<td>4</td>
<td>R</td>
<td>$R = \frac{509.26}{V}$, or $3^\circ/s$, whichever is less</td>
<td>(3.24)</td>
</tr>
<tr>
<td>5</td>
<td>r</td>
<td>$r = \frac{V}{62.83}$</td>
<td>0.83 NM</td>
</tr>
<tr>
<td>6</td>
<td>h</td>
<td>in thousands of feet</td>
<td>6</td>
</tr>
<tr>
<td>7</td>
<td>w</td>
<td>$w = 2h + 47$</td>
<td>59 kt</td>
</tr>
<tr>
<td>8</td>
<td>w'</td>
<td>$w' = \frac{w}{3600}$</td>
<td>0.0164 NM/s</td>
</tr>
<tr>
<td>9</td>
<td>E</td>
<td>$E = w' + R$</td>
<td>0.00546 NM/°</td>
</tr>
<tr>
<td>10</td>
<td>f</td>
<td>for $V \leq 170$ kt: $\phi = \frac{36}{T}$, for $V &gt; 170$ kt: $\phi = \frac{0.215 V}{T}$</td>
<td>18°</td>
</tr>
<tr>
<td>11</td>
<td>zN</td>
<td>$zN = 0.164 h \tan 40^\circ$</td>
<td>0.83 NM</td>
</tr>
<tr>
<td>12</td>
<td>t</td>
<td>$t = 60T$</td>
<td>120 s</td>
</tr>
<tr>
<td>13</td>
<td>L</td>
<td>$L = vt$</td>
<td>5.24 NM</td>
</tr>
<tr>
<td>14</td>
<td>ab1 = ab3</td>
<td>$ab1 = ab3 = (t - 5)(v - w') - zN$</td>
<td>2.31 NM</td>
</tr>
</tbody>
</table>
## Attachment B1. Construction of Obstacle Clearance Areas for Reversal Procedure

### CALCULATIONS USING SI UNITS

<table>
<thead>
<tr>
<th>Line</th>
<th>Parameter</th>
<th>Formula</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td>ab2 = ab4</td>
<td>***ab2 = ab4 = (t + 21)(v + w') + zN</td>
<td>17.23 km</td>
</tr>
<tr>
<td>16</td>
<td>Wd = We</td>
<td>(W_d = W_e = 50) E</td>
<td>0.5 km</td>
</tr>
<tr>
<td>17</td>
<td>We = Wf = Wh</td>
<td>(W_e = W_f = W_h = 100) E</td>
<td>1.0 km</td>
</tr>
<tr>
<td>18</td>
<td>Wi</td>
<td>(W_i = 190) E</td>
<td>1.9 km</td>
</tr>
<tr>
<td>19</td>
<td>Wj</td>
<td>(W_j = 235) E</td>
<td>2.35 km</td>
</tr>
<tr>
<td>20</td>
<td>drift angle d</td>
<td>d = (\text{arc sin}\ (w / V))</td>
<td>23°</td>
</tr>
<tr>
<td>21</td>
<td>Nj/J</td>
<td>(N_j = 11\ v)</td>
<td>0.9 km</td>
</tr>
<tr>
<td>22</td>
<td>Wj</td>
<td>(W_j = 11\ w')</td>
<td>0.33 km</td>
</tr>
<tr>
<td>23</td>
<td>Wm</td>
<td>(W_m = W_j + 50) E</td>
<td>0.83 km</td>
</tr>
<tr>
<td>24</td>
<td>Wn</td>
<td>(W_n = W_j + 100) E</td>
<td>1.33 km</td>
</tr>
</tbody>
</table>

### CALCULATIONS USING NON-SI UNITS

<table>
<thead>
<tr>
<th>Line</th>
<th>Parameter</th>
<th>Formula</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td>ab2 = ab4</td>
<td>***ab2 = ab4 = (t + 21)(v + w') + zN</td>
<td>9.30 NM</td>
</tr>
<tr>
<td>16</td>
<td>Wd = We</td>
<td>(W_d = W_e = 50) E</td>
<td>0.27 NM</td>
</tr>
<tr>
<td>17</td>
<td>We = Wf = Wh</td>
<td>(W_e = W_f = W_h = 100) E</td>
<td>0.55 NM</td>
</tr>
<tr>
<td>18</td>
<td>Wi</td>
<td>(W_i = 190) E</td>
<td>1.04 NM</td>
</tr>
<tr>
<td>19</td>
<td>Wj</td>
<td>(W_j = 235) E</td>
<td>1.28 NM</td>
</tr>
<tr>
<td>20</td>
<td>drift angle d</td>
<td>d = (\text{arc sin}\ (w / V))</td>
<td>23°</td>
</tr>
<tr>
<td>21</td>
<td>Nj/J</td>
<td>(N_j = 11\ v)</td>
<td>0.48 NM</td>
</tr>
<tr>
<td>22</td>
<td>Wj</td>
<td>(W_j = 11\ w')</td>
<td>0.18 NM</td>
</tr>
<tr>
<td>23</td>
<td>Wm</td>
<td>(W_m = W_j + 50) E</td>
<td>0.45 NM</td>
</tr>
<tr>
<td>24</td>
<td>Wn</td>
<td>(W_n = W_j + 100) E</td>
<td>0.73 NM</td>
</tr>
</tbody>
</table>

* In case of a VOR base turn, line 11 reads \(zV = h \tan 50°\).
** In case of a VOR base turn, line 11 reads \(zV = 0.164h \tan 50°\).
*** 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:

\[
\begin{align*}
ab1 &= ab3 = D - d1 + 5(v - w') \\
ab2 &= ab4 = D + d1 + 11(v + w')
\end{align*}
\]

In case of a VOR base turn, lines 14 and 15 read:

\[
\begin{align*}
ab1 &= ab3 = (t - 5)(v - w') - zV \\
ab2 &= ab4 = (t + 21)(v + w') + zV
\end{align*}
\]
### Table B1-2. Calculations associated with the construction of the 45°-180° procedure turn template

<table>
<thead>
<tr>
<th>DATA</th>
<th>SI UNITS</th>
<th>NON-SI UNITS</th>
</tr>
</thead>
<tbody>
<tr>
<td>IAS</td>
<td>260 km/h</td>
<td>140 kt</td>
</tr>
<tr>
<td>Altitude</td>
<td>1 850 m</td>
<td>6 000 ft</td>
</tr>
<tr>
<td>T</td>
<td>1.25 min for Cat C, D and E</td>
<td>1.25 min for Cat C, D and E</td>
</tr>
<tr>
<td>Temperature</td>
<td>ISA + 15°C</td>
<td>ISA + 15°C</td>
</tr>
</tbody>
</table>

#### CALCULATIONS USING SI UNITS

<table>
<thead>
<tr>
<th>Line</th>
<th>Parameter</th>
<th>Formula</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>K</td>
<td>Conversion factor for 1 850 m and ISA + 15°C (see PANS-OPS, Volume II, Attachment F to Part III)</td>
<td>1.1244</td>
</tr>
<tr>
<td>2</td>
<td>V</td>
<td>V = K × IAS</td>
<td>292.34 km/h</td>
</tr>
<tr>
<td>3</td>
<td>v</td>
<td>v = V ÷ 3 600</td>
<td>0.0812 km/s</td>
</tr>
<tr>
<td>4</td>
<td>R</td>
<td>R = 943.27 ÷ V, or 3°/s, whichever is less</td>
<td>(3.23) 3°/s</td>
</tr>
<tr>
<td>5</td>
<td>r</td>
<td>r = V ÷ 62.83 R</td>
<td>1.55 km</td>
</tr>
<tr>
<td>6</td>
<td>h</td>
<td>in thousands of metres</td>
<td>1.85</td>
</tr>
<tr>
<td>7</td>
<td>w</td>
<td>w = 12h + 87</td>
<td>109.2 km/h</td>
</tr>
<tr>
<td>8</td>
<td>w’</td>
<td>w’ = w ÷ 3 600</td>
<td>0.03 km/s</td>
</tr>
<tr>
<td>9</td>
<td>E</td>
<td>E = w’ ÷ R</td>
<td>0.01 km/°</td>
</tr>
<tr>
<td>10</td>
<td>ab</td>
<td>ab = 5v</td>
<td>0.41 km</td>
</tr>
<tr>
<td>11</td>
<td>cd</td>
<td>cd = (t – 5 – 45 ÷ R) v</td>
<td>3.25 km</td>
</tr>
<tr>
<td>12</td>
<td>cd1, cd3</td>
<td>cd1 = cd3 = cd – 5v</td>
<td>2.84 km</td>
</tr>
<tr>
<td>13</td>
<td>cd2, cd4</td>
<td>cd2 = cd4 = cd + 15v</td>
<td>4.47 km</td>
</tr>
<tr>
<td>14</td>
<td>W_e</td>
<td>W_e = 5w’ + 45 E</td>
<td>0.60 km</td>
</tr>
<tr>
<td>15</td>
<td>W_d2, W_d4</td>
<td>W_d2 = W_d4 = (t + 15) w’</td>
<td>2.25 km</td>
</tr>
<tr>
<td>16</td>
<td>W_r</td>
<td>W_r = W_d2 + 50 E</td>
<td>2.75 km</td>
</tr>
</tbody>
</table>

#### CALCULATIONS USING NON-SI UNITS

<table>
<thead>
<tr>
<th>Formula</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>V = K × IAS</td>
<td>157.23 kt</td>
</tr>
<tr>
<td>v = V ÷ 3 600</td>
<td>0.0437 NM/s</td>
</tr>
<tr>
<td>R = 509.26 ÷ V, or 3°/s, whichever is less</td>
<td>(3.24) 3°/s</td>
</tr>
<tr>
<td>r = V ÷ 62.83 R</td>
<td>0.83 NM</td>
</tr>
<tr>
<td>w = 2h + 47</td>
<td>59 kt</td>
</tr>
<tr>
<td>w’ = w ÷ 3 600</td>
<td>0.0164 NM/s</td>
</tr>
<tr>
<td>E = w’ ÷ R</td>
<td>0.00546 NM/°</td>
</tr>
<tr>
<td>ab = 5v</td>
<td>0.22 NM</td>
</tr>
<tr>
<td>cd = (t – 5 – 45 ÷ R) v</td>
<td>1.75 NM</td>
</tr>
<tr>
<td>cd1 = cd3 = cd – 5v</td>
<td>1.53 NM</td>
</tr>
<tr>
<td>cd2 = cd4 = cd + 15v</td>
<td>2.41 NM</td>
</tr>
<tr>
<td>W_e = 5w’ + 45 E</td>
<td>0.33 NM</td>
</tr>
<tr>
<td>W_d2 = W_d4 = (t + 15) w’</td>
<td>1.23 NM</td>
</tr>
<tr>
<td>W_r = W_d2 + 50 E</td>
<td>1.50 NM</td>
</tr>
<tr>
<td>Line</td>
<td>Parameter</td>
</tr>
<tr>
<td>------</td>
<td>-----------</td>
</tr>
<tr>
<td>17</td>
<td>$W_g, W_h$</td>
</tr>
<tr>
<td>18</td>
<td>$W_i$</td>
</tr>
<tr>
<td>19</td>
<td>$W_j$</td>
</tr>
<tr>
<td>20</td>
<td>$W_k$</td>
</tr>
<tr>
<td>21</td>
<td>$W_l$</td>
</tr>
</tbody>
</table>
Table B1-3. Calculations associated with the construction of the 80°-260° procedure turn template

<table>
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<tbody>
<tr>
<td><strong>SI UNITS</strong></td>
</tr>
<tr>
<td>IAS</td>
</tr>
<tr>
<td>Altitude</td>
</tr>
<tr>
<td>Temperature</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>CALCULATIONS USING SI UNITS</th>
<th>CALCULATIONS USING NON-SI UNITS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Line</strong></td>
<td><strong>Parameter</strong></td>
</tr>
<tr>
<td>1</td>
<td>K</td>
</tr>
<tr>
<td>2</td>
<td>V</td>
</tr>
<tr>
<td>3</td>
<td>( v )</td>
</tr>
<tr>
<td>4</td>
<td>R</td>
</tr>
<tr>
<td>5</td>
<td>r</td>
</tr>
<tr>
<td>6</td>
<td>h</td>
</tr>
<tr>
<td>7</td>
<td>w</td>
</tr>
<tr>
<td>8</td>
<td>( w' )</td>
</tr>
<tr>
<td>9</td>
<td>E</td>
</tr>
<tr>
<td>10</td>
<td>ab</td>
</tr>
<tr>
<td>11</td>
<td>( d_e, d_{2e1}, d_{2e2} )</td>
</tr>
<tr>
<td>12</td>
<td>( W_{e2} )</td>
</tr>
<tr>
<td>13</td>
<td>( W_g )</td>
</tr>
<tr>
<td>14</td>
<td>( W_h )</td>
</tr>
<tr>
<td>15</td>
<td>( W_i )</td>
</tr>
<tr>
<td>16</td>
<td>( W_j )</td>
</tr>
</tbody>
</table>
### CALCULATIONS USING SI UNITS

<table>
<thead>
<tr>
<th>Line</th>
<th>Parameter</th>
<th>Formula</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>17</td>
<td>( W_k )</td>
<td>( W_k = 15w' + 255 \text{ E} )</td>
<td>4.15 km</td>
</tr>
<tr>
<td>18</td>
<td>( W_l )</td>
<td>( W_l = 15w' + 300 \text{ E} )</td>
<td>4.80 km</td>
</tr>
<tr>
<td>19</td>
<td>( W_m )</td>
<td>( W_m = 15w' + 345 \text{ E} )</td>
<td>5.45 km</td>
</tr>
</tbody>
</table>

### CALCULATIONS USING NON-SI UNITS

<table>
<thead>
<tr>
<th>Line</th>
<th>Parameter</th>
<th>Formula</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>( W_k = 15w' + 255 \text{ E} )</td>
<td>2.28 NM</td>
</tr>
<tr>
<td></td>
<td></td>
<td>( W_l = 15w' + 300 \text{ E} )</td>
<td>2.63 NM</td>
</tr>
<tr>
<td></td>
<td></td>
<td>( W_m = 15w' + 345 \text{ E} )</td>
<td>2.99 NM</td>
</tr>
</tbody>
</table>
Table B1-4. Calculations associated with the construction of the holding and racetrack template

<table>
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<th>SI UNITS</th>
<th>NON-SI UNITS</th>
</tr>
</thead>
<tbody>
<tr>
<td>IAS</td>
<td>405 km/h</td>
<td>220 kt</td>
</tr>
<tr>
<td>Altitude</td>
<td>3 050 m</td>
<td>10 000 ft</td>
</tr>
<tr>
<td>T</td>
<td>1 min</td>
<td>1 min</td>
</tr>
<tr>
<td>Temperature</td>
<td>ISA + 15°C</td>
<td>ISA + 15°C</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>CALCULATIONS USING SI UNITS</th>
<th>CALCULATIONS USING NON-SI UNITS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Line</td>
<td>Parameter</td>
</tr>
<tr>
<td>1</td>
<td>K</td>
</tr>
<tr>
<td>2</td>
<td>V</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>v</td>
</tr>
<tr>
<td>4</td>
<td>R</td>
</tr>
<tr>
<td>5</td>
<td>r</td>
</tr>
<tr>
<td>6</td>
<td>h</td>
</tr>
<tr>
<td>7</td>
<td>w</td>
</tr>
<tr>
<td>8</td>
<td>w'</td>
</tr>
<tr>
<td>9</td>
<td>( E_{45} )</td>
</tr>
<tr>
<td>10</td>
<td>t</td>
</tr>
<tr>
<td>11</td>
<td>L</td>
</tr>
<tr>
<td>12</td>
<td>ab</td>
</tr>
<tr>
<td>13</td>
<td>ac</td>
</tr>
<tr>
<td>14</td>
<td>( g_{i1} = g_{i3} )</td>
</tr>
<tr>
<td>15</td>
<td>( g_{i2} = g_{i4} )</td>
</tr>
<tr>
<td>Line</td>
<td>Parameter</td>
</tr>
<tr>
<td>------</td>
<td>-----------</td>
</tr>
<tr>
<td>16</td>
<td>$W_b$</td>
</tr>
<tr>
<td>17</td>
<td>$W_c$</td>
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<tr>
<td>18</td>
<td>$W_d$</td>
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<tr>
<td>19</td>
<td>$W_e$</td>
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<tr>
<td>20</td>
<td>$W_f$</td>
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<tr>
<td>21</td>
<td>$W_g$</td>
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<td>22</td>
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<tr>
<td>23</td>
<td>$W_i$</td>
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<tr>
<td>24</td>
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<tr>
<td>25</td>
<td>$W_k = W_{i3}$</td>
</tr>
<tr>
<td>26</td>
<td>$W_{i2} = W_{i4}$</td>
</tr>
<tr>
<td>27</td>
<td>$W_j$</td>
</tr>
<tr>
<td>28</td>
<td>$W_k = W_f$</td>
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<tr>
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<td>$W_o$</td>
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<tr>
<td>32</td>
<td>XE</td>
</tr>
<tr>
<td>33</td>
<td>YE</td>
</tr>
</tbody>
</table>
**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.

<table>
<thead>
<tr>
<th></th>
<th><strong>SI UNITS</strong> (distances in km; speeds in km/h; time in minutes)</th>
<th><strong>NON-SI UNITS</strong> (distances in NM; speeds in kt; time in minutes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>a) equations for 45/180 procedure turn</td>
<td>$x_{\text{max}} = \text{TAS}(0.0165t + 0.0431) + W(0.0165t + 0.0278) + 3.4$</td>
<td>$x_{\text{max}} = \text{TAS}(0.0165t + 0.0431) + W(0.0165t + 0.0278) + 1.8$</td>
</tr>
<tr>
<td></td>
<td>$y_{\text{max}} = \text{TAS}(0.002t + 0.022) + W(0.002t + 0.0333) – 0.74$</td>
<td>$y_{\text{max}} = \text{TAS}(0.002t + 0.022) + W(0.002t + 0.0333) – 0.4$</td>
</tr>
<tr>
<td></td>
<td>$y_{\text{min}} = \text{TAS}(-0.002t – 0.0137) + W(-0.002t – 0.0594) + 1.67$</td>
<td>$y_{\text{min}} = \text{TAS}(-0.002t – 0.0137) + W(-0.002t – 0.0594) + 0.9$</td>
</tr>
<tr>
<td>b) equations for 80/260 procedure turn</td>
<td>$x_{\text{max}} = \text{TAS}(0.0165t + 0.0421) + W(0.0165t + 0.0489) – 3.34$</td>
<td>$x_{\text{max}} = \text{TAS}(0.0165t + 0.0421) + W(0.0165t + 0.0489) – 1.8$</td>
</tr>
<tr>
<td></td>
<td>$y_{\text{max}} = \text{TAS}(0.002t + 0.0263) + W(0.002t + 0.0322) – 1.85$</td>
<td>$y_{\text{max}} = \text{TAS}(0.002t + 0.0263) + W(0.002t + 0.0322) – 1.0$</td>
</tr>
<tr>
<td></td>
<td>$y_{\text{min}} = \text{TAS}(-0.002t – 0.01) + W(-0.002t – 0.0591) + 1.3$</td>
<td>$y_{\text{min}} = \text{TAS}(-0.002t – 0.01) + W(-0.002t – 0.0591) + 0.7$</td>
</tr>
<tr>
<td>c) equations for base turn</td>
<td>$x_{\text{max}} = \text{TAS}(0.0173t + 0.0181) + W(0.0166t + 0.0209) – 0.93$</td>
<td>$x_{\text{max}} = \text{TAS}(0.0173t + 0.0181) + W(0.0166t + 0.0209) – 0.5$</td>
</tr>
<tr>
<td></td>
<td>$y_{\text{max}} = \text{TAS}(-0.0004t + 0.0373) + W(-0.0072t + 0.0404) + 0.164t – 3.15$</td>
<td>$y_{\text{max}} = \text{TAS}(-0.0004t + 0.0373) + W(-0.0072t + 0.0404) + 0.0887t – 1.7$</td>
</tr>
<tr>
<td></td>
<td>$y_{\text{min}} = \text{TAS}(-0.0122) + W(0.0151t – 0.0639) – 0.1845t + 1.48$</td>
<td>$y_{\text{min}} = \text{TAS}(-0.0122) + W(0.0151t – 0.0639) – 0.0996t + 0.8$</td>
</tr>
<tr>
<td>d) equations for racetrack</td>
<td>$x_{\text{max}} = \text{TAS}(0.0167t + 0.0297) + W(0.0167t + 0.0381) – 1.67$</td>
<td>$x_{\text{max}} = \text{TAS}(0.0167t + 0.0297) + W(0.0167t + 0.0381) – 0.9$</td>
</tr>
<tr>
<td></td>
<td>$x_{\text{min}} = \text{TAS}(-0.0241) + W(-0.0373) + 2.04$</td>
<td>$x_{\text{min}} = \text{TAS}(-0.0241) + W(-0.0373) + 1.1$</td>
</tr>
<tr>
<td></td>
<td>$y_{\text{max}} = \text{TAS}(0.0012t + 0.0266) + W(0.0158t + 0.0368) + 0.843t – 5.37$</td>
<td>$y_{\text{max}} = \text{TAS}(0.0012t + 0.0266) + W(0.0158t + 0.0368) + 0.455t – 2.9$</td>
</tr>
<tr>
<td></td>
<td>$y_{\text{min}} = \text{TAS}(-0.0015t – 0.0202) + W(-0.0167t – 0.027) + 1.3$</td>
<td>$y_{\text{min}} = \text{TAS}(-0.0015t – 0.0202) + W(-0.0167t – 0.027) + 0.7$</td>
</tr>
</tbody>
</table>

**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 = $260 \times 1.1243 = 292$ km/h
- W = $12 \times 1.85 + 87 = 109$ km/h
- Fix error = $1.85 \times \tan 50 = 2.20$ km

*Calculation (equations from c) above):*

- $x_{\text{max}} = 292(0.0173t + 0.0181) + W(0.0166t + 0.0209) – 0.93 = 20.36$ km/h
- $y_{\text{max}} = 292(-0.0004t + 0.0373) + W(-0.0072t + 0.0404) + 0.164t – 3.15 = 10.67$ km/h
- $y_{\text{min}} = 292(-0.0122) + W(0.0151t – 0.0639) – 0.1845t + 1.48 = –6.12$ km/h

*Template plotting values (including addition for fix error of 2.20 km):*

- $x_{\text{max}} = 22.6$ km
- $y_{\text{max}} = 12.9$ km
- $y_{\text{min}} = –8.3$ 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 = $140 \times 1.1231 = 157$ kt
- W = $2 \times 6 + 47 = 59$ kt
- Fix error = $0.164 \times 6 \tan 40 = 0.83$ NM

*Calculation (equations from a) above):*

- $x_{\text{max}} = 157(0.0165 \times 1 + 0.0431) + 59(0.0165 \times 1 + 0.0278) + 1.8 = 13.77$ NM
- $y_{\text{max}} = 157(0.002t \times 1 + 0.022) + 59(0.002t \times 1 + 0.0333) – 0.4 = 5.45$ NM
- $y_{\text{min}} = 157(-0.002t \times 1 – 0.0137) + 59(-0.002t \times 1 – 0.0594) + 0.9 = –5.19$ NM

*Template plotting values (including addition of fix error of 0.83 NM):*

- $x_{\text{max}} = 14.6$ NM
- $y_{\text{max}} = 6.3$ NM
- $y_{\text{min}} = –6.0$ NM
Figure B1-1. VOR or NDB at 0 — time from 0 to A

\[ \alpha = 5.2^\circ \text{ (VOR); } 6.9^\circ \text{ (NDB)} \]

\[ O \ A = v t \]

\[ O \ A1 = O \ A3 = (v-w') (t-10) - a \]

\[ O \ A2 = O \ A4 = (v+w') (t+10)+a \]

\( a = \text{fix tolerance of the facility at 0 (see Chapter 2, 2.6.5 of the PANS-OPS, Volume II)} \)

Figure B1-2. VOR/DME at 0

\[ O \ A = D \]

\[ O \ A1 = O \ A3 = D-d1 \]

\[ O \ A2 = O \ A4 = D+d1 \]

\[ A2 \ A'2 = A4 \ A'4 = 6 (v+w') \]

Figure B1-3. VOR at 0 and VOR at 0'

\[ A2 \ A'2 = A4 \ A'4 = 6 (v+w') \]
Figure B1-4. VOR at 0 and NDB or locator at A

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
Figure B1-14
Figure B1-15

Figure B1-16
Attachment B1. Construction of Obstacle Clearance Areas for Reversal Procedure

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.
Altitude: 3 050 m (10 000 ft)
IAS: 405 km/h (220 kt)
Outbound distance: 7.7 km (4.2 NM)

Figure B1-21. RNAV template
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
Figure B1-25. RNAV holding area including protection of entry procedures

RNAV tolerance of the holding point
Buffer area width =
Greater of:

\[ X + 3.7 \text{ km (2.0 NM)} \]
\[ 9.3 \text{ km (5.0 NM)} \]

\[ d_3 = \text{RNP} = X \]

\[ d_4 \]

\[ 1.414 X \]
\[ (\approx 1.414 d_3) \]

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

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)

Diagram B1-4. 80° — 360° procedure turn template
Diagram B1-5. VOR 45° — 180° procedure turn
Diagram B1-6. Holding/racetrack template with associated construction points

Procedure protected for:
Altitude: 3,050 m (10,000 ft)
IAS: 450 km/h (220 kt)
Outbound time: 1 min

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
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
Diagram B1-15. VOR/DME procedure towards the facility — basic area and associated area for entries
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: 65 km (35 NM)
Angle between RE and RP: 8°
Diagram B1-17. VOR/DME procedure away from the facility — basic area and associated area for entries
Diagram B1-18. VOR/DME procedure from the facility — basic area and the associated area for reciprocal direct entry to the secondary point.
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 microcomputers. 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<sub>a</sub>/h<sub>ma</sub> 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<sup>′</sup>) of the surface contour for height (z<sup>′</sup>) at range (x<sup>′</sup>) for X and Y surfaces as follows:

\[ y' = \frac{(C - Ax')}{B} \]

Similarly, for the W, W* and Z surfaces, the range (x<sup>′</sup>) of contour (z<sup>′</sup>) may be calculated:

\[ x' = \frac{(z' - C)}{A} \]

b) Plotting of areas. The point of intersection of two adjacent OAS heights (z<sup>′</sup>) 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:

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

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:

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

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:

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

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:

$$TNH < \text{obstacle height} + \text{MOC}$$

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:

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

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 (–1197 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 inbound 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 \( d_o \times \tan Z \), 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:

\[ \begin{align*}
&l_x, l_y, l_z: \text{obstacle location and height} \\
&\text{MAPt}_x: \text{range of MAPt} \\
&\text{SOC}_x: \text{range of SOC} \\
&MOC_f: \text{MOC specified for final approach} \\
&MOC_{ma}: \text{MOC specified for missed approach} \\
&\text{SWFAC}: \text{semi-width of the area at the facility} \\
&\text{SPLAY}: \text{splay of the area associated with the facility} \\
&Tan Z: \text{tangent of the missed approach surface (gradient per cent/100)}
\end{align*} \]

c) Calculate:

\[ \begin{align*}
&A = \max \{MOC_{ma}; \tan Z (l_x - SOC_x) + MOC_{ma}\} \\
&B = \min \{A; MOC_f\}
\end{align*} \]

If \( l_x < \text{MAPt}_x \), \( B = MOC_f \)

\[ \text{MOC}_x = \min \{B; 2B(1 - |l_y|/|l_x| \tan \text{SPLAY})\} \]

If \( \text{MOC}_x < 0 \), 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).

\[ \begin{align*}
&D = \max \{0; \text{SOC}_x - l_x\} \\
&OCH = l_z + \text{MOC}_x - D \times \tan Z
\end{align*} \]

Standard values for the parameters are:

\[ \begin{align*}
&MOC_f: \text{with FAF 75 m (246 ft)} \\
&\text{without FAF 90 m (295 ft)} \\
&MOC_{ma}: \text{straight missed approach 30 m (98 ft)} \\
&\text{turning missed approach 50 m (164 ft)} \\
&\text{SWFAC}: 1.85 \text{ km (1 NM) for VOR} \\
&\text{2.3 km (1.25 NM) for NDB} \\
&SPLAY: \text{VOR 7.8° (tan SPLAY = 0.136983)} \\
&\text{NDB 10.3° (tan SPLAY = 0.181731)}
\end{align*} \]

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.

\[ \begin{align*}
&\text{MAPt}_x = -6 \ 340 \\
&\text{SOC}_x = 9 \ 620 \\
&MOC_f = 75 \\
&MOC_{ma} = 30 \\
&\text{SWFAC} = 10.3^\circ \\
&Tan Z = 0.025
\end{align*} \]

\[ \begin{array}{cccc}
&x & y & z & \text{OCH} \\
-6000 & 0 & 10 & 85 \\
-9000 & 0 & 40 & 86 \\
-9000 & 3000 & 60 & 82 \\
-10000 & 0 & 60 & 80.5 \\
-10000 & 3500 & 80 & 79.5
\end{array} \]

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:

\[
\begin{align*}
\text{DATEAST} & = \text{grid easting of datum (threshold or facility)} \ (\text{m}) \\
\text{DATNRTH} & = \text{grid northing of datum (threshold or facility)} \ (\text{m}) \\
\text{OBSEAST} & = \text{grid easting of obstacle} \ (\text{m}) \\
\text{OBSNRTH} & = \text{grid northing of obstacle} \ (\text{m}) \\
\text{FAB} & = \text{final approach (or desired centre line) bearing (° grid)}
\end{align*}
\]

Calculate:

\[
\begin{align*}
A & = \sin (\text{FAB} + 180) \\
B & = \cos (\text{FAB} + 180)
\end{align*}
\]

\[
\begin{align*}
\text{DIFFEAST} & = \text{OBSEAST} – \text{DATEAST} \\
\text{DIFFNRTH} & = \text{OBSNRTH} – \text{DATNRTH}
\end{align*}
\]

\[
\begin{align*}
x & = A \times \text{DIFFEAST} + B \times \text{DIFFNRTH} \\
y & = A \times \text{DIFFNRTH} + B \times \text{DIFFEAST}
\end{align*}
\]

3. Example. Threshold location 378356, 381378. Final approach bearing (magnetic 060°, variation 9.4°W, convergence angle 0.2°E obstacle location 379571, 371115.

\[
\begin{align*}
\text{FAB (grid)} & = \text{magnetic bearing} – \text{variation} + \text{convergence angle} = 060° – 9.3° – 0.2° = 51.5° \\
\text{DATEAST} & = 378357 \\
\text{DATNRTH} & = 391378 \\
\text{OBSEAST} & = 379571 \\
\text{OBSNRTH} & = 371115 \\
\text{FAB} & = 51.5°
\end{align*}
\]

\[
\begin{align*}
A & = \sin (51.5 + 180) = –0.792608 \\
B & = \cos (51.5 + 180) = –0.622515
\end{align*}
\]

\[
\begin{align*}
\text{DIFFEAST} & = 379571 – 38357 = 1214 \\
\text{DIFFNRTH} & = 371115 – 391378 = –10263
\end{align*}
\]

\[
\begin{align*}
x & = –0.782608 \times 1214 + (–0.622515) \times (–10263) \\
y & = –0.782608 \times (–10263) – (–0.622515) \times 1214
\end{align*}
\]

\[
\begin{align*}
x & = + 5 \ 439 \\
y & = + 8 \ 788
\end{align*}
\]

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

Acceptable envelope for C/D
Acceptable envelope for A/B
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 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.

   * The vertical distance between the flight paths of the wheels and the GP antenna.

<table>
<thead>
<tr>
<th>Aeroplane type</th>
<th>Glide path antenna to wheel distance</th>
</tr>
</thead>
<tbody>
<tr>
<td>B-707</td>
<td>4 to 7 m</td>
</tr>
<tr>
<td>B-727</td>
<td>4 to 7 m</td>
</tr>
<tr>
<td>B-747</td>
<td>4 to 7 m</td>
</tr>
<tr>
<td>DC-8</td>
<td>4 to 7 m</td>
</tr>
<tr>
<td>DC-10</td>
<td>9 m</td>
</tr>
<tr>
<td>DHC-4</td>
<td>8 m</td>
</tr>
<tr>
<td>IL-18</td>
<td>7 m</td>
</tr>
<tr>
<td>IL-6Z</td>
<td>5 to 9 m</td>
</tr>
<tr>
<td>L-1011</td>
<td>7 to 10 m</td>
</tr>
</tbody>
</table>

*Note.— These values may vary between aeroplanes of the same type.*
Figure B3-1. Stepdown fix — calculation of minimum heights

For obstacles in this area:
Min ht 1 ≤ Obs ht + MOC 1
Min ht 2 not increased

For obstacles in this area:
Min ht 1 Obs ht + MOC 1 + 0.15 (fix error + x)
Min ht 2 not increased.
Note.— Where the fix is a facility with cone angle ±β:
Min ht 1 ≤ (Obs ht + MOC 1 + 0.15 x)/(1 – 0.15 tan β).

Alternative option for obstacles in this segment only:
Min ht 2 ≤ Obs ht + MOC 2
Min ht 1 not increased
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\(^\circ\) 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 m
   - t = 6 m

b) Aircraft 2:
   - s = 32 m
   - t = 9 m.

3.3 Obstacle environment

Table B4-1. Obstacle example

<table>
<thead>
<tr>
<th>Obstacle</th>
<th>x coordinate (m)</th>
<th>y coordinate (m)</th>
<th>Height above threshold (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>160</td>
<td>45</td>
<td>1.5</td>
</tr>
<tr>
<td>2</td>
<td>400</td>
<td>180</td>
<td>37.0</td>
</tr>
<tr>
<td>3</td>
<td>800</td>
<td>350</td>
<td>50.0</td>
</tr>
<tr>
<td>4</td>
<td>8 000</td>
<td>2 500</td>
<td>140.0</td>
</tr>
<tr>
<td>5</td>
<td>–450</td>
<td>200</td>
<td>6.0</td>
</tr>
</tbody>
</table>

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: \( z = 0.028500 \times -8.01 \)

X surface: \( z = 0.0227681 \times +0.182500 \times -16.72 \)

Y surface: \( z = 0.023948 \times +0.210054 \times -21.51 \)

Z surface: \( z = -0.02500 \times -22.50 \)

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: \( z = 0.035800 \times -6.19 \)

X surface: \( z = 0.035282 \times +0.234700 \times -21.59 \)

Y surface: \( z = 0.031955 \times +0.280291 \times -28.70 \)

Z surface: \( z = -0.02500 \times -22.50 \)

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

<table>
<thead>
<tr>
<th>Point</th>
<th>x coordinate (m)</th>
<th>y coordinate (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>281</td>
<td>49</td>
</tr>
<tr>
<td>D</td>
<td>–286</td>
<td>135</td>
</tr>
<tr>
<td>E</td>
<td>–900</td>
<td>205</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Point</th>
<th>x coordinate (m)</th>
<th>y coordinate (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C&quot;</td>
<td>10 807</td>
<td>96</td>
</tr>
<tr>
<td>D&quot;</td>
<td>5 438</td>
<td>910</td>
</tr>
<tr>
<td>E&quot;</td>
<td>–12 900</td>
<td>3 001</td>
</tr>
</tbody>
</table>

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**

<table>
<thead>
<tr>
<th>Required point of template</th>
<th>Surfaces for which equations are to be solved</th>
</tr>
</thead>
<tbody>
<tr>
<td>C*</td>
<td>W; X</td>
</tr>
<tr>
<td>D*</td>
<td>X; Y</td>
</tr>
<tr>
<td>E*</td>
<td>Y; Z</td>
</tr>
</tbody>
</table>

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 2385 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”.

\[
P = \max \left\{ \frac{L}{B_x} ; \frac{s - 3}{B_x} \right\} - \max \left\{ \frac{6}{B_x} ; \frac{30 + \frac{3}{B_x}}{0.2347} \right\}
\]

\[
P = \max \left\{ \frac{9}{0.2347} ; \frac{9}{0.2347} - \frac{3}{0.2347} \right\}
\]

\[
P = \max \left\{ \frac{6}{0.2347} ; \frac{6}{0.2347} + \frac{3}{0.2347} \right\}
\]

\[
P = \max \{38.3 ; 57.6\} - \max \{25.6 ; 42.8\}
\]

\[
P = 57.6 - 42.8 = 14.8
\]

The correction to the height equations is done by an adjustment of the coefficient \(C\):

\[
C_{corr} = C - B \cdot P
\]

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:

\[
z = 0.0353 x + 0.2347 y + [-21.59 - (0.2347) (14.8)]
\]

\[
z = 0.0353 x + 0.2347 y - 25.09
\]
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:**

\[ W \text{ surface: } z = 0.0285 x - 8.01 \]
\[ X \text{ surface: } z = 0.0277 x + 0.1825 y - 16.72 \]
\[ Y \text{ surface: } z = 0.0239 x + 0.2101 y - 21.51 \]
\[ Z \text{ surface: } z = -0.025 x - 22.50 \]

**Category II ILS:**

\[ W \text{ surface: } z = 0.0358 x - 6.19 \]
\[ X \text{ surface: } z = 0.0353 x + 0.2347 y - 21.59 \]
\[ Y \text{ surface: } z = 0.0320 x + 0.2803 y - 28.70 \]
\[ Z \text{ surface: } z = -0.025 x - 22.50 \]

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

<table>
<thead>
<tr>
<th>Obstacles</th>
<th>Obstacle height (m)</th>
<th>Inner approach surface</th>
<th>Inner transitional surface (1:3)</th>
<th>Approach surface section 1</th>
<th>Approach surface section 2</th>
<th>Runway strip</th>
<th>Transitional surface (1:7)</th>
<th>Extended transitional surfaces (1:7)</th>
<th>Missed approach surface</th>
<th>Penetration YES/NO</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.5</td>
<td>2</td>
<td>NA</td>
<td>2</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NO*</td>
</tr>
<tr>
<td>2</td>
<td>37.0</td>
<td>NA</td>
<td>NA</td>
<td>6.8</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>YES</td>
</tr>
<tr>
<td>3</td>
<td>50.0</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>28.6</td>
<td>NA</td>
<td>NA</td>
<td>YES</td>
</tr>
<tr>
<td>4</td>
<td>140.0</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
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* 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>
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<tr>
<th>Obstacle</th>
<th>W surface</th>
<th>X surface</th>
<th>Y surface</th>
<th>Z surface</th>
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<tr>
<td>2</td>
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<td>95.0</td>
<td>-42.5</td>
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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)

<table>
<thead>
<tr>
<th>Aircraft category</th>
<th>Height loss/altimeter margin (m)</th>
<th>Promulgated* OCH (m)</th>
<th>Promulgated* OCA (m)</th>
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<tr>
<td>A</td>
<td>13</td>
<td>50</td>
<td>202</td>
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<td>B</td>
<td>18</td>
<td>55</td>
<td>207</td>
</tr>
<tr>
<td>C</td>
<td>22</td>
<td>59</td>
<td>211</td>
</tr>
<tr>
<td>D</td>
<td>26</td>
<td>63</td>
<td>215</td>
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</table>

* 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 O₁₂₅, 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

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ILS Category I OCH (ABOVE THRESHOLD)  
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

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<th>X metres</th>
<th>Y1 metres</th>
<th>Y2 metres</th>
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* 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

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* 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

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* REPRESENTS A RISK LESS THAN 1.0E-15
Attachment B5. Collision Risk Model

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

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* REPRESENTS A RISK LESS THAN 1.0E-15
Errors and warnings list:
OFZ PENETRATED?
## PRELIMINARY RESULTS FOR ILS Category I

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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

\[
X_1 = a^2 + (\text{TASMIN} \times 10/3 \times 600)^2 + (56 \times D/\text{TASMIN})^2
\]

\[
X_2 = a^2 + (\text{TASMAX} \times 10/3 \times 600)^2 + (56 \times D/\text{TASMAX})^2
\]

\[
X_1 = a^2 + (\text{TASMIN} \times 10/3 \times 600)^2 + (30 \times D/\text{TASMIN})^2
\]

\[
X_2 = a^2 + (\text{TASMAX} \times 10/3 \times 600)^2 + (30 \times D/\text{TASMAX})^2
\]

Earliest MAPt tolerance = max {X1; X2}

2.3.2 Latest MAPt

\[
X_3 = b^2 + (\text{TASMIN} \times 13/3 \times 600)^2 + (56 \times D/\text{TASMIN})^2
\]

\[
X_4 = b^2 + (\text{TASMAX} \times 13/3 \times 600)^2 + (56 \times D/\text{TASMAX})^2
\]

\[
X_3 = b^2 + (\text{TASMIN} \times 13/3 \times 600)^2 + (30 \times D/\text{TASMIN})^2
\]

\[
X_4 = b^2 + (\text{TASMAX} \times 13/3 \times 600)^2 + (30 \times D/\text{TASMAX})^2
\]

Latest MAPt tolerance = max {X3; X4}
2.3.3 *MAPt to SOC distance*

\[
X_5 = (b^2 + (TASMIN \times 13/3 \ 600)^2
+ (66 \times D/TASMIN)^2)^{0.5}
+ 15 \times (TASMIN + 19)/3 \ 600
\]

\[
X_6 = (b^2 + (TASMAX \times 13/3 \ 600)^2
+ (66 \times D/TASMAX)^2)^{0.5}
+ 15 \times (TASMAX + 19)/3 \ 600
\]

\[
X_5 = (b^2 + (TASMIN \times 13/3 \ 600)^2
+ (30 \times D/TASMIN)^2)^{0.5}
+ 15 \times (TASMIN + 10)/3 \ 600
\]

\[
X_6 = (b^2 + (TASMAX \times 13/3 \ 600)^2
+ (30 \times D/TASMAX)^2)^{0.5}
+ 15 \times (TASMAX + 10)/3 \ 600
\]

MAPt to SOC distance = max \{X_5; X_6\}.
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/Hf).
b) Locate MAPt.
c) Determine MAPt tolerance area.
d) Calculate transitional tolerance X and locate SOC.
e) Measure do: distance SOC to obstacle O.
f) Calculate height gained (HG) over distance do.

\[ \text{HG(do)} = \text{do} \tan Z \]

(tan Z is the missed approach climb gradient; normally \( \tan Z = \frac{1}{40} = 0.025 = 2.5 \text{ per cent} \))
g) Calculate nominal altitude over obstacle O: NA(O).

\[ \text{NA(O)} = \text{OCA}_f + \text{HG(do)} \]
h) Calculate required altitude over obstacle O: RA(O).

\[ \text{RA(O)} = \text{OE} + \text{MOC} \]

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 OCAf 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 = OCAf + RA(O) – NA(O);

2) Move the missed approach point further from the threshold. This will increase do (and consequently HG(do) 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.

\[ 18 \times \frac{(TAS + 10)}{3600} \]

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 \(TAS_{\text{min}} = IAS_{\text{min}} \times \) cold day correction factor and \(TAS_{\text{max}} = IAS_{\text{max}} \times \) hot day correction factor.

e) Calculate or carefully draw the \(a\) and \(b\) values of the FAF tolerance.

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:

\[
\text{The EARLIEST MAPt tolerance} = \max \{TAS_{\text{max}}; TAS_{\text{min}}\}
\]

\[
TAS_{\text{min}}: [a^2 + (TAS_{\text{min}} \times 10/3600)^2]^{0.5} \quad \text{SI units}
\]

\[
TAS_{\text{max}}: [a^2 + (TAS_{\text{max}} \times 10/3600)^2 + (56 \times D/TAS_{\text{max}})^2]^{0.5}
\]

Table B7-1

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</tr>
<tr>
<td>10 \times TAS_{\text{min}} \div 3600</td>
<td>13 \times TAS_{\text{min}} \div 3600</td>
</tr>
<tr>
<td>10 \times TAS_{\text{max}} \div 3600</td>
<td>13 \times TAS_{\text{max}} \div 3600</td>
</tr>
<tr>
<td>30 kt wind effect</td>
<td></td>
</tr>
<tr>
<td>(D \times 30) \div TAS_{\text{min}}</td>
<td>(D \times 30) \div TAS_{\text{max}}</td>
</tr>
<tr>
<td>(D \times 30) \div TAS_{\text{min}}</td>
<td>(D \times 30) \div TAS_{\text{max}}</td>
</tr>
<tr>
<td>RSS total</td>
<td>RSS total</td>
</tr>
</tbody>
</table>
where:

\[ a = \text{distance from the earliest point of the FAF} \]

\[ b = \text{distance from the latest point of the FAF} \]

and

\[ D = \text{distance from FAF to MAPt} \]

The LATEST MAPt tolerance = max of the \{TAS max; TAS min\}

\[
\begin{align*}
\text{TAS min: } & [a^2 + (\text{TAS min} \times 13/3 \, 600)^2]^{0.5} \\
& + (56 \times D/\text{TAS min})^{0.5} \\
\text{TAS max: } & [b^2 + (\text{TAS max} \times 13/3 \, 600)^2]^{0.5} \\
& + (56 \times D/\text{TAS max})^{0.5}
\end{align*}
\]

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).

\[ \text{RA/H} = \text{OE} + \text{MOC} + \text{chart and precipitous terrain allowances, etc.} \]

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 \( d_z \):

\[ d_z = \text{SOC}_z \times \text{to the obstacle location (less chart tolerances) measured along the missed approach track. (See Figure B7-7.)} \]

d) In a turn at an altitude situation, the shortest distance is \( d_z + d_o \):

\[ d_z \text{ is measured to the } \text{nominal} \text{ turn point (TP) along the straight missed approach track, and} \]

\[ d_o \text{ is measured along the shortest distance to the turn area boundary (less any charting tolerances).} \]

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. \[ \text{NA} = \text{TNA} + d_o \times 0.025. \]

e) In a turn at a FIX situation, the climb is calculated from the OCA/H_f and the shortest distance is \( d_z + d_o \) :
\[ d_z \text{ is measured to the } \text{earliest} \text{ turn point along the straight missed approach track, and} \]
\[ d_o \text{ is measured along the shortest distance from line K-K to the obstacle (less any charting tolerances).} \]

\[ NA/H = SOC_z + HG \]

where:
\[ SOC_z = OCA_f \text{ for non-precision approaches, and} \]
\[ SOC_z = OCA_f - \text{height loss for precision approaches} \]
\[ HG = d_z \times 0.025 \text{ (straight missed approaches)} \]
\[ HG = (d_z + d_o) \times 0.025 \text{ (turning missed approaches)} \]

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).
\[ d_o = \cos \alpha \times (y_o - \frac{1}{2}W) - \text{chart tolerance} \]
where \( \alpha = \text{splay of missed approach area.} \)
VOR: 7.8°; NDB: 10.3°, etc.
(see Chapters 12 and 13 of Part II, Section 2, for ILS splay calculation)
\[ y_o = \text{distance of obstacle from the MAPt track at range of obstacle} \]
\[ \frac{1}{2}W = \text{half-width of missed approach area at range of obstacle} \]

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:
\[ y_o = \text{distance of obstacle (O) from the MAPt track at range of (O)} \]
\[ y_K = \text{half-width of missed approach area at range of point K} \]
\[ d' = \text{distance between K and (O) measured parallel to the MAPt track} \]

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_z) 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 (hma) must be achieved. The formula is:

   \[ SOC_z = \frac{TNH \times \cot Z + 900 + x}{\cot Z + \cot \theta} \]

   (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.)

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.

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

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:

\[
Y_{TNH} = \frac{TNH - Ax - C}{B} \quad \text{(y coordinate of the Y surface at the turn height)}
\]

(See Figure B7-20.)

b) The new coordinate points of C", D" and E" for the turn height (TNH) are:

\[
E''_{TNH} = \text{the new } x \text{ and } y \text{ coordinate at the TNH}
\]

\[
D''_{TNH} = \text{the new } x \text{ and } y \text{ coordinate at the TNH}
\]

\[
C''_{TNH} = \text{the new } x \text{ and } y \text{ coordinate at the TNH}
\]

The exact value for these points are calculated with:

\[
E''_{TNH}: x = \frac{TNH}{300} \times (E''_x - E_x) + E_x
\]

\[
E''_{TNH}: y = \frac{TNH}{300} \times (E''_y - E_y) + E_y
\]

\[
D''_{TNH}: x = \frac{TNH}{300} \times (D''_x - D_x) + D_x
\]

\[
D''_{TNH}: y = \frac{TNH}{300} \times (D''_y - D_y) + D_y
\]

\[
C''_{TNH}: x = \frac{TNH}{300} \times (C''_x - C_x) + C_x
\]

\[
C''_{TNH}: y = \frac{TNH}{300} \times (C''_y - C_y) + C_y
\]

For example:

Find the 500 ft (152 m) turn height coordinates for point \(E''_{TNH}\)

\[
x = \frac{152}{300} (-12 900 + 900) - 900 = -6 980 m
\]

\[
y = \frac{152}{300} (3 001 - 205) + 205 = 1 622 m
\]

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 “\(\alpha\)” 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 \(\alpha + 15°\) 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:
\[ a = b = h \tan 50^\circ \]
h is the height of the nominal flight path above the VOR site.

NDB case:
Same method but \[ a = b = h \tan 40^\circ \].

---

VOR intersection case

---

Figure B7-3

Figure B7-4
VOR/DME case

(DME tolerance: ±0.46 km (0.25 NM) plus 1.25% of DME distance.)

Figure B7-5

Figure B7-6
Figure B7-7

Figure B7-8
Figure B7-11

Figure B7-12
Figure B7-13

Figure B7-14
Figure B7-15

Nominal TP

Minimum turn height

Optimum

MAPt

SOC

Operational turn altitude

Figure B7-16

5% Adjusted MAPt Adjusted SOC

Required to reach Turn Altitude at TP

2.5% missed approach gradient

Original OCA/Hf

Adjusted OCA/H

MOC final

Max distance visibility consideration

15 m
Altitude based on turn area requirement

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


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

<table>
<thead>
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<th>Code</th>
<th>Horizontal</th>
<th>Code</th>
<th>Vertical</th>
</tr>
</thead>
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<tr>
<td>1</td>
<td>5 m (15 ft)</td>
<td>A</td>
<td>1 m (3 ft)</td>
</tr>
<tr>
<td>2</td>
<td>15 m (50 ft)</td>
<td>B</td>
<td>3 m (10 ft)</td>
</tr>
<tr>
<td>3</td>
<td>33 m (100 ft)</td>
<td>C</td>
<td>6 m (20 ft)</td>
</tr>
<tr>
<td>4</td>
<td>75 m (250 ft)</td>
<td>D</td>
<td>15 m (50 ft)</td>
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<td>150 m (500 ft)</td>
<td>E</td>
<td>38 m (125 ft)</td>
</tr>
<tr>
<td>6</td>
<td>300 m (1 000 ft)</td>
<td>F</td>
<td>75 m (250 ft)</td>
</tr>
<tr>
<td>7</td>
<td>900 m (0.5 NM)</td>
<td>G</td>
<td>150 m (500 ft)</td>
</tr>
<tr>
<td>8</td>
<td>1 800 m (1 NM)</td>
<td>H</td>
<td>300 m (1 000 ft)</td>
</tr>
</tbody>
</table>

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

1A ILS/MLS final
2C Non-precision final
2C Missed approach and circling
2C Departure within 2 NM from DER
2C Departure over 2 NM from DER
4D Intermediate
6F Initial

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

\[ x = 1\,000\,\text{m} \]
\[ y = -200\,\text{m} \]
\[ z = 45\,\text{m} \]

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)

\[ x = 1\,000 - 15 = 985\,\text{m} \] (adjusted toward RWY threshold)
\[ y = -200 + 15 = -185\,\text{m} \] (adjusted toward RWY centre line)
\[ z = 45 + 6 = 51\,\text{m} \] (adjusted higher)

1.3 OAS surface calculations

(Standard ILS Category I conditions with 3° GP and LLZ-THR at 3 000 m)

<table>
<thead>
<tr>
<th>At the chart coordinates</th>
<th>Adjusted coordinates</th>
</tr>
</thead>
<tbody>
<tr>
<td>W surface: 20.49 m</td>
<td>20.06 m</td>
</tr>
<tr>
<td>X surface: 47.46 m</td>
<td>44.31 m</td>
</tr>
<tr>
<td>Y surface: 44.45 m</td>
<td>40.94 m</td>
</tr>
</tbody>
</table>

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:

\[
\frac{1}{2}W = 1 + \frac{4}{15} \times 4.84 = 2.29 \text{ NM}
\]

The MOC is \([2.29 - 1.84]/(2.29/2)] \times 150 \text{ m} = 59 \text{ 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 adjustment 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

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Definition</th>
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<tbody>
<tr>
<td>AGL</td>
<td>Above ground level</td>
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<tr>
<td>DF</td>
<td>Direction finding</td>
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<tr>
<td>DH</td>
<td>Decision height</td>
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<td>ESA</td>
<td>Emergency safe altitude</td>
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<td>EOVM</td>
<td>Emergency obstacle video map</td>
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<td>FAA</td>
<td>Federal Aviation Administration</td>
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<td>FIFO</td>
<td>Flight inspection field office</td>
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<td>FPB</td>
<td>Flight Inspection Branch</td>
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<td>IAPA</td>
<td>Instrument approach procedure automation</td>
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<td>MAP</td>
<td>Missed approach point</td>
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<td>MDA</td>
<td>Minimum descent altitude</td>
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<td>MIA</td>
<td>Minimum IFR altitude</td>
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<td>Abbreviation</td>
<td>Description</td>
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<td>MSA</td>
<td>Minimum safe altitude</td>
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<td>MVA</td>
<td>Minimum vector altitude</td>
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<td>OBS1</td>
<td>Obstruction base file</td>
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<td>Remarks</td>
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<td>Required obstacle clearance</td>
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<td>SIAP</td>
<td>Standard instrument approach procedure</td>
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<td>SID</td>
<td>Standard instrument departure</td>
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<td>TERPS</td>
<td>United States Standard for terminal and en-route procedures</td>
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**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
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.
Threshold elevation:

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### MISSED APPROACH

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Straight missed approach

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### TURNING MISSED APPROACH

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<th>Resulting turn altitude</th>
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### RESULTS

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## PROCEDURE CHECKLIST PRECISION

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<tr>
<td>Obstacle elevation</td>
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<td>Location of obstacle primary (P) secondary (S)</td>
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<td>Nominal altitude</td>
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<td>Length (L) or time (T) value</td>
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<td>Alignment with final: straight (S) angle</td>
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### TURNING MISSED APPROACH

<table>
<thead>
<tr>
<th></th>
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<td>Fix (F) or height (H)</td>
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</tr>
<tr>
<td>Obstacle height in turn initiation area (if turn at a height)</td>
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<td>Minimum T height (MOC = 50 m)</td>
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<td>Obstacle height in turn area</td>
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<tr>
<td>Resulting T height</td>
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</tr>
<tr>
<td>dz (minimum 1 200 m)</td>
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<td></td>
<td></td>
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</tr>
<tr>
<td>SOC height</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HL applied</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>OCHm (missed approach)</td>
<td></td>
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### RESULTS

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<td>Level acceleration segment height</td>
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### GP INOPERATIVE

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<tr>
<td>FAF: fix (FIX) facility (F) name</td>
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</tr>
<tr>
<td>Obstacle height</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MOC applied</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OCHf (final)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MAP: facility (F) fix (FIX) distance/FAF (D) value</td>
<td></td>
<td></td>
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<td>Missed approach: straight (S) turn (T)</td>
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<td></td>
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<td></td>
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<tr>
<td>If obstacle height in turn initiation (T) area</td>
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</tr>
<tr>
<td>Minimum T height (MOC = 50 m)</td>
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<tr>
<td>Obstacle height</td>
<td></td>
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</tr>
<tr>
<td>Required height</td>
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<td></td>
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<tr>
<td>OCHm (missed approach)</td>
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<td></td>
</tr>
<tr>
<td>Resulting OCH</td>
<td></td>
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### CIRCLING

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<td>OCA (check minimum values)</td>
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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 C3-7

Figure C3-8

Figure C3-9

Figure C3-10
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 $1 \times 10^{-8}$ 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 $1 \times 10^{-5}$ 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 $1 \times 10^{-3}$ 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. Examples of critical data include:

- An 8-bit CRC algorithm will provide a $3.9 \times 10^{-3}$ level of integrity protection; a 16-bit algorithm will provide a $1.5 \times 10^{-5}$ level of integrity protection; a 24-bit algorithm will provide a $6.0 \times 10^{-8}$ level of integrity protection; and a 32-bit CRC algorithm will provide a $2.3 \times 10^{-10}$ level of integrity protection.
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:
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)
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
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.

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<th>Leg types</th>
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<th>Used for RNAV procedures</th>
<th>Used for RNP procedures</th>
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<td>Yes (preferred)</td>
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<td>TF</td>
<td>Track to fix</td>
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<td>Yes (preferred)</td>
<td>Yes (preferred)</td>
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<td>RF</td>
<td>Radius to fix</td>
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<td>No</td>
<td>Yes (preferred)</td>
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<td>DF</td>
<td>Direct to fix</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes (discouraged)</td>
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<td>FA</td>
<td>Fix to altitude</td>
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<td>Yes</td>
<td>Yes (discouraged)</td>
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<td>CF</td>
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<td>Yes</td>
<td>Yes (to be phased out)</td>
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<td>Yes</td>
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<td>Hold to altitude (climb)</td>
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<td>Yes</td>
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<td>Yes</td>
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<td>CA</td>
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<td>No</td>
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<tr>
<td>CI</td>
<td>Course to intercept</td>
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<td>VR</td>
<td>Heading to VOR radial</td>
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</table>

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.

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 C5-3. 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.

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.

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.

A “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.

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.

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.

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](image)

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](image)

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](image)

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 leg and terminates at a DME distance from a navaid (see Figure C5-11).

![Figure C5-11. CD leg. Course to a DME termination](image)

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).
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).

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).

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).

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).

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.
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.

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).

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).

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>
<thead>
<tr>
<th>Angle of divergence</th>
<th>NM</th>
<th>Outbound time</th>
</tr>
</thead>
<tbody>
<tr>
<td>18</td>
<td>10.5</td>
<td>2:45</td>
</tr>
<tr>
<td>20</td>
<td>9.5</td>
<td>2:30</td>
</tr>
<tr>
<td>22</td>
<td>8.6</td>
<td>2:15</td>
</tr>
<tr>
<td>24</td>
<td>7.9</td>
<td>2:00</td>
</tr>
<tr>
<td>26</td>
<td>7.3</td>
<td>1:55</td>
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<tr>
<td>28</td>
<td>6.8</td>
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<tr>
<td>30</td>
<td>6.3</td>
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<td>5.9</td>
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</tr>
<tr>
<td>44</td>
<td>4.3</td>
<td>1:07</td>
</tr>
</tbody>
</table>

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


*Industry Requirements for Aeronautical Information*, Draft RTCA DO-201A/EUROCAE ED-77 (Final Draft 3 May 1999)


— END —
ICALO 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.