Transport Canada Transports Canada

Advisory Circular

Subject:	**Flight Management System (FMS) Barometric Vertical Navigation (VNAV) Temperature Compensation**

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1.0 Introduction

(1) This Advisory Circular (AC) is provided for information and guidance purposes. It describes an example of an acceptable means, but not the only means, of demonstrating compliance with regulations and standards. This AC on its own does not change, create, amend or permit deviations from regulatory requirements, nor does it establish minimum standards.

1.1 Purpose

(1) The purpose of this AC is to provide National Aircraft Certification personnel, delegates and industry with guidance on the criteria for incorporation of temperature compensation in new or updated Flight Management System (FMS) designs for barometric Vertical Navigation (VNAV) approach procedures.

1.2 Applicability

(1) This document is applicable to all Transport Canada Civil Aviation (TCCA) employees, to individuals and organizations when they are exercising privileges granted to them under an External Ministerial Delegation of Authority. This information is also available to the aviation industry for information purposes.

1.3 Description of changes

(1) This document, formerly AC 500-020 Issue 03, has been reissued as AC 500-020 Issue 04. A discrepancy was identified in the correction equation in Section 4.8 between Issue 02 of this AC and the source International Civil Aviation Organization (ICAO) document. Issue 03 brought the AC into alignment, however it was subsequently discovered that the ICAO document is incorrect. In addition the forms of the simplified and accurate equations have been revised for consistent definition of variables.

(2) The qualifier “to the MDA”, where MDA means Minimum Decent Altitude, was added to the sentence “… the constant angle vertical path can be intercepted and flown like an ILS”, where ILS means Instrument Landing System, in paragraph 3.0(3).

(3) Issue 04 corrects the error introduced in Issue 03 and incorporates the clarification sought by Flight Standards.

(4) Issue 04 refers to updated versions AC 20-138, Document 8168-OPS/611 and DO-236.

(5) In item 5 of section 3.0, the Obstacle Clearance Panel (OCP) is now called the Instrument Flight Procedure Panel (IFPP).

(6) Section 4.6 was updated to indicate only the simplified method is included in Transport Canada publication (TP) 14371.

(7) Section 5.0(1) added the case where the temperature compensation does not correct for MDA/ Decision Altitude (DA).

2.0 References and requirements

2.1 Reference documents

(1) It is intended that the following reference materials be used in conjunction with this document:

(a) Chapter 523 of the Airworthiness Manual (AWM)—Normal, Utility, Aerobatic and Commuter Category Aeroplanes;

(b) Chapter 525 of the AWM—Transport Category Aeroplanes;

(c) Chapter 527 of the AWM—Normal Category Rotorcraft;

(d) Chapter 529 of the AWM—Transport Category Rotorcraft;

(e) Advisory Circular (AC) 803-001, Issue 15, 2025-04-01 - Transport Canada Publication (TP) 308/GPH209 – Change 9.1 —Criteria For the Development of Instrument Procedures;

(f) AC 700-028, Issue 01, 2013-04-22 — Vertical Path Control on Non-Precision Approaches;

(g) TP 14371—Aeronautical Information Manual;

(h) Nav Canada Publication Number CAP GEN—Canada Air Pilot, General Pages;

(i) Federal Aviation Administration Advisory Circular (FAA AC) 20-138D—Airworthiness Approval of Positioning and Navigation Systems;

(j) International Civil Aviation Organization (ICAO) Document 8168-OPS/611—Procedures for Air Navigation Services, Aircraft Operations, Volume I, Sixth Edition (2018) Amendment 11; and

(k) Radio Technical Commission for Aeronautics (RTCA) Inc. Document DO-236D—Minimum Aviation System Performance Standards: Required Navigation Performance for Area Navigation;.

(l) International Civil Aviation Organization (ICAO) Document 8168 — Procedures for Air Navigation Services, Aircraft Operations, Volume II, Seventh Edition (2020) Amendment 10; and

(m) International Civil Aviation Organization (ICAO) Document 8168 — Procedures for Air Navigation Services, Aircraft Operations, Volume III, First Edition (2018) Amendment 3.

2.2 Cancelled documents

(1) Not applicable.

(2) By default, it is understood that the publication of a new issue of a document automatically renders any earlier issues of the same document null and void

2.3 Definitions and abbreviations

(1) The following **abbreviations** are used in this document:

(a) **CAP GEN:** Canada Air Pilot General Pages.

(b) **CFIT:** Controlled Flight into Terrain.

(c) **DA:** Decision Altitude.

(d) **FAF:** Final Approach Fix.

(e) **IAF:** Initial Approach Fix.

(f) **ICAO:** International Civil Aviation Organization.

(g) **IFR:** Instrument Flight Rules.

(h) **ILS:** Instrument Landing System.

(i) **ISA:** International Standard Atmosphere.

(j) **MAHP:** Missed Approach Holding Point.

(k) **MAP:** Missed Approach Point.

(l) **MDA:** Minimum Descent Altitude.

(m) **RNAV:** Area Navigation.

3.0 Background

(1) Barometric altimeters are calibrated to indicate true altitude only under International Standard Atmosphere (ISA) conditions of temperature and sea level pressure. In cases where the temperature is higher than ISA, the true altitude will be higher than the altitude indicated by the altimeter. Conversely, when the temperature is lower than ISA, the true altitude will be lower than indicated.

(2) The effects of cold temperature on published instrument approach procedure altitudes have long been recognized in Canada. Although non-precision approach procedures in Canada are designed using Transport Canada TP 308, Criteria for the Development of Instrument Procedures, these criteria do not consider off standard temperatures, TCCA has provided a procedure to manually correct minimum Instrument Flight Rules (IFR) altitudes specified in approach procedures when the approach airport temperature is below 0°C. The procedure is described in Canada Air Pilot General Pages (CAP GEN). The procedure, however, is quite cumbersome, requiring a pilot to use a table to manually calculate the correction for each of the minimum IFR altitudes of the approach procedure.

(3) FMS that provide VNAV capability for non-precision approaches may incorporate both extended constant angle vertical path for the final approach course as well as providing point-to-point vertical navigation between waypoints in the approach procedure. With the extended constant angle vertical path feature it is not necessary to follow the vertical profile defined by the minimum IFR altitudes of the approach procedure waypoints: the constant angle vertical path can be intercepted and flown like an ILS to the MDA. This is a feature that is being advocated by various aviation groups in the interest of prevention of Controlled Flight into Terrain (CFIT). These two barometric VNAV descent profiles are illustrated in Figure 1.

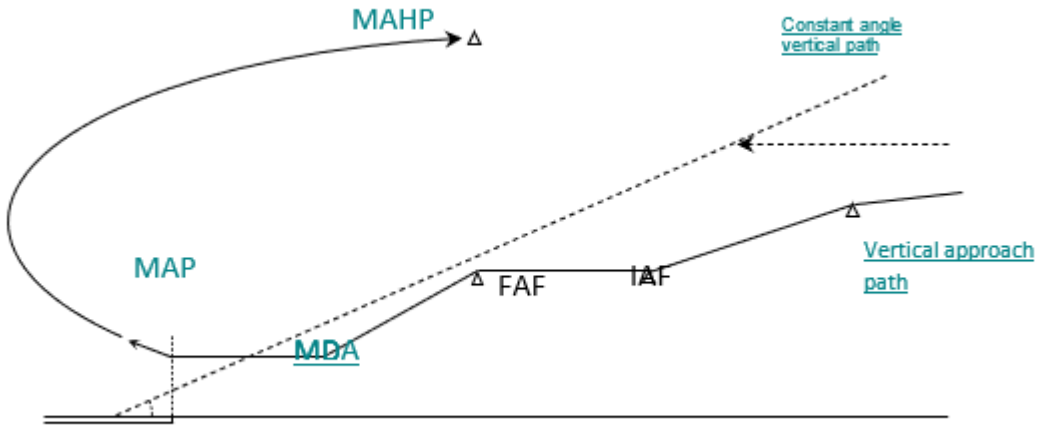

Figure 1: FMS VNAV Vertical Approach

Note: For definition of these abbreviations see section 2.3.

(4) Both of the illustrated FMS vertical paths are defined by barometric altimetry. Consequently, the vertical paths would only be at the published procedure altitudes when ISA conditions exist. In below ISA conditions, the constant angle vertical path would be at a shallower angle than for ISA conditions. Likewise, the vertical profile defined by the waypoint altitudes would also be lower. In such cases expected terrain and obstacle clearance during approaches would not be maintained if the aircraft were flown at minimum IFR altitudes, nor would pilots be made aware of this condition. Clearly there is a safety consideration to be addressed for FMS barometric VNAV terrain and obstacle clearance margin.

(5) The need for an FMS to provide a capability to correct the published approach altitudes for below ISA temperature has been recognized and discussed by various groups including ICAO Instrument Flight Procedure Panel, and Special Committee SC-181 Working Group for RTCA DO-236B.

(6) As part of the ICAO CFIT project, the ICAO Instrument Flight Procedure Panel is interested in the design and presentation of all types of non-precision approach procedures, in particular by considering the stabilized approach technique when defining a vertical profile to be followed for an approach with a minimum 5% gradient (3° glide path). Recognizing the safety concern with respect to terrain and obstacle clearance below ISA conditions, this working group has introduced the concept of procedural altitudes to address stabilized approaches.

(7) SC-181 Working Group has concluded its mandate with the publication of RTCA DO-236B. While this document recognizes that not all states are agreed upon all the elements of temperature compensation, its Appendix H, Temperature Compensation Information, presents recommendations for implementation of below ISA temperature compensation. Application of temperature compensation to the final approach vertical path angle as well as the waypoint altitudes associated with approach waypoints is addressed.

(8) The information in the following paragraphs is consistent with the criteria included in RTCA Inc. document DO-236D with respect to below ISA conditions.

4.0 New or updated FMS designs

(1) Originally, the policy called for “all temperature” compensation that is for both above and below ISA. This AC requires that the final approach course vertical path angle and the waypoint altitudes associated with the approach procedure be compensated for below ISA conditions only. While off-standard temperature conditions result in indicated altitudes different than true, TCCA is especially concerned with compensating altitudes in below ISA temperature conditions. TCCA considers that FMS that do not include a means to compensate below ISA conditions create an unacceptable loss of terrain and obstacle clearance when conducting VNAV approach operations.

4.1 New/Updated FMS Designs Incorporating Barometric VNAV Approach Capability

(1) New or updated FMS designs shall provide a means for an aircraft to fly the true vertical path angle for final approach segment, as defined in the resident navigation database, in below ISA temperature conditions. The FMS equipment shall also provide the capability to temperature compensate all waypoints from the Initial Approach Fix (IAF) to the Missed Approach Holding Point (MAHP) (known as the Missed Approach Holding Waypoint for Area Navigation (RNAV) procedures) inclusive, as coded in the navigation database. The FMS shall also provide a means for determining a temperature compensated MDA/DA, when the MDA/DA is entered by the pilot.

(2) Temperature compensation may be applied for airport temperatures “below ISA” or “below 0°C”. The latter has been included to be consistent with the existing Nav Canada operational procedures as described in CAP GEN.

4.2 Enabling Temperature Compensation

(1) TCCA recognizes that some ICAO States do not require application of temperature compensation. While TCCA requires that new or updated FMS include the capability to temperature compensate constant angle vertical path and minimum IFR approach altitudes for below ISA conditions, employment of this capability is not mandatory nor is there a requirement to preclude the FMS from providing a vertical path or barometric VNAV descent profile if temperature compensation is not applied.

4.3 Prevention of Incorrect Temperature Selection

(1) It is important that the vertical path and minimum IFR altitudes are compensated for below ISA temperatures correctly. For example, an incorrectly entered sign for temperature in below ISA conditions would lower the vertical path and indicated waypoint altitudes, when in fact they should be raised.

(2) Where an FMS design requires manual input of temperature to enable temperature compensation the FMS shall provide a means for the pilot to confirm the intended input. FMS temperature compensation algorithms must provide indications for pilots to interpret how the vertical path and altitudes have been corrected.

4.4 Manually Entered Waypoint Altitudes

(1) FMS designs usually include the ability to enter or edit waypoint altitudes. This ability allows pilots to enter altitudes assigned by air traffic control. Normally, air traffic control expects that assigned altitudes will not be temperature compensated. For this reason, it shall be possible for waypoint altitudes to be manually entered or edited without automatically applying temperature compensation.

4.5 Annunciation and Indication

(1) Temperature compensated altitudes displayed by the FMS shall be clearly differentiated from uncompensated altitudes. In addition, the altitudes being used for FMS guidance, compensated or uncompensated, shall be clearly annunciated.

4.6 Means of Temperature Correction for Barometric Altitude

(1) The basis for correcting altitudes for off-standard temperature has been presented in ICAO Procedures for Air Navigation Services Aircraft Operations (PANS OPS) Doc 8168. Two correction methods are presented in this document, the “Simplified Method” as described in section 4.7 and “Accurate Method” as described in section 4.8. Both methods are acceptable to TCCA and are summarized herein. Note that the parameter definitions are specific to each method, in keeping with presentation in ICAO PAN OPS Doc 8168. The simplified method is also reflected in section RAC 9.17.1 of Transport Canada publication (TP) 14371 – Aeronautical Information Manual.

4.7 Simplified Method

(1) The simplified method provides a correction that is within 5% of the accurate method for airfield elevations up to 10,000 ft (3 000 m) and for heights up to 5,000 ft (1 500 m) above that airfield elevation.

$\text{Correction} = \text{H}\left[\frac{(15\ -\ \text{t}_0)}{273 + \text{t}_0\ -\ 0.5\ \text{L}_0\ (\text{H} + \text{H}_{SS})}\right]$ (See note below)				
Where:				
	H	=	Minimum height above the altimeter setting source (setting source is normally the aerodrome unless otherwise specified)	ft
	t_0	=	$t_{aerodrome} + L_0 * H_{aerodrome}$ which is the aerodrome (or specified temperature reporting point) temperature adjusted to sea level	°C
	L_0	=	0.0019812 °C/ft or 0.0065 °C/m. *Standard temperature lapse rate with pressure altitude in the first layer (sea level to tropopause) of the ISA.*	°C/ft
	H_{ss}	=	Altimeter setting source elevation	ft
	$t_{aerodrome}$	=	Aerodrome (or specified temperature reporting point) temperature	°C
	$H_{aerodrome}$	=	Aerodrome (or specified temperature reporting point) elevation	ft

Table 1. Simplified Method for Temperature Correction

Note: Correction values in this formula are to be added to published minimum IFR altitudes.

4.8 Accurate Method

(1) The accurate method is more complex than the simplified method in that an iterative method must be used to determine the altitude correction. This method is valid to 36,000 ft (11 000 m).

$$\text{Correction} = \Delta h_{P\text{aircraft}} - \Delta h_{G\text{aircraft}} = \frac{\Delta t_{std}}{L_0} \text{Ln}\left[1 - \frac{L_0\, \Delta h_{P\text{aircraft}}}{273 + t_{std} - L_0\, h_{P\text{aerodrome}}}\right]$$

(See note (a) and (b) below)

Where:				
	$\Delta h_{P\text{aircraft}}$	=	*Aircraft height above aerodrome (pressure)*	ft
	$\Delta h_{G\text{aircraft}}$	=	*Aircraft height above aerodrome (geopotential)*	ft
	Δt_{std}	=	*Temperature deviation from the ISA temperature*	°C
	L_0	=	0.0019812 °C/ft or 0.0065 °C/m *Standard temperature lapse rate with pressure altitude in the first layer (sea level to tropopause) of the ISA.*	°C/ft
	t_{std}	=	*Standard temperature at sea level*	°C
	$h_{P\text{aerodrome}}$	=	Aerodrome height (pressure)	ft

Table 2. Accurate Method for Temperature Correction

(a) Correction values in this formula are to be added to published minimum IFR altitudes.

(b) It is acknowledged that this equation is not consistent with ICAO Document 8168 — Procedures for Air Navigation Services, Aircraft Operations, Volume III, First Edition (2018). This is the preferred equation and is based on ICAO Document 8168, Volume II, Seventh Edition (2020).

5.0 Installation of existing FMS without temperature compensation

(1) While implementation of temperature compensation procedures is an operational responsibility, TCCA has a responsibility to ensure that the end users are aware of the limitations of installed systems. TCCA recognizes that FMS installations exist which include a barometric VNAV approach capability, but do not include a temperature compensation function. For these installations, the following note shall be included in the Aircraft Flight Manual “Limitations” section for the FMS:

(2) "Barometric VNAV guidance during approach including the approach transition, final approach segment, and the missed approach procedure is not temperature compensated. Unless a temperature limitation is reflected on the approach chart, operating at uncompensated minimum IFR altitudes will not provide expected terrain and obstacle clearance for temperatures below ISA".

(3) Some installations with temperature compensation do not correct for MDA/DA. For these installations, the pilot may need to manually apply temperature corrections to the MDA/DA.

6.0 Information management

(1) Not applicable.

7.0 Document history

(1) AC 500-020, Issue **03**, 8511380 (english), SGDDI 8514635 (french), dated 2013-07-22 — Flight Management System (FMS) Barometric Vertical Navigation (VNAV) Temperature Compensation:

(2) AC 500-020, Issue **02**, 3698255 (english), SGDDI 3698283 (french),dated 2008-01-07 — Flight Management System (FMS) Barometric Vertical Navigation (VNAV) Temperature Compensation:

(3) AC 500-020, Issue **01**, 1441506 (english), SGDDI 1596458 (french), dated 2006-02-10 — Flight Management System (FMS) Barometric Vertical Navigation (VNAV) Temperature Compensation:

8.0 Contact us

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