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Ground Proximity Warning Systems

1 Introduction

1.1 The CAA is introducing a requirement which will make the carriage of an approved ground proximity warning system[1] mandatory for certain categories of large transport aeroplanes.

1.2 At present the only class of GPWS which is commercially available is based on height above ground and rate Of closure, altitude rate, aeroplane configuration and ILS glideslope deviation. In the US the FAA have amended FAR to require the carriage of GPWS (Part 121.360), and a related amendment (Part 37.201) defines the equipment TSO (TSO-C92a) in terms of an RTCA specification (No. DO-161). A number of avionics equipment manufacturers are offering devices which meet these requirements.

1.3 This document states the technical requirements which must be complied with for approval of a GPWS in the United Kingdom.

1.4 For a GPWS to be effective in preventing accidents it must be such that pilots will react promptly to a warning, and this will only be the case if unnecessary alarms are kept to a minimum. This requirement, backed by analysis of operational flight data recordings has led CAA to specify the warning conditions or envelopes given in Appendix A. These differ from those adopted by RTCA as shown in the figures. Alternative, envelopes may also be approved where it can be shown that they are more suited to a particular operation.

1.5 The aeroplane may be deliberately flown in such a way as not to follow the glideslope for the ILS frequency selected, for example an approach on the "back beam", or a late transfer to a parallel runway. In these cases the ILS mode is liable to give a nuisance warning. CAA considers that the rate at which these might occur is such that a separate deactivation control for the ILS mode should be provided. Even with this provision it is considered unlikely that nuisance operation can be reduced to the level achievable by the other modes. Therefore, to avoid reducing the credibility of the other modes, the warning should be different and less compelling.

1.6 The effectiveness of GPWS will be greatly enhanced if there is rapid detection and correction of operational procedures or equipment faults which lead to nuisance warnings. It is therefore strongly recommended that installations should include provision for automatically logging the occurrence of a warning and, if possible, relating this directly to flight path parameters recorded on a flight data recorder, even though there is not a CAA requirement to this effect.

1. A ground proximity warning system (GPWS) provides warning to the crew of an aeroplane when the flight path is such that prompt action is required if collision with the ground is to be avoided.

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2 Requirements for Ground Proximity Warning Systems

2.1 General

CAA requirements for ground proximity warning systems are stated below in general terms. An appendix defines acceptable characteristics for a system making use of a radio altimeter, a pressure altimeter, landing gear and flap position, and deviation from the glideslope. An installation complying with these requirements and the appendix will be eligible for approval. The CAA does not wish to imply that this class of GPWS is the only one which will be approved, nor that the characteristics specified for this class of system are the only ones which will be found to be acceptable. The appendix material is an acceptable means of compliance and is not mandatory. However, any deviation from this must be shown to provide equivalent protection.

2.2 System Capability

(See Appendix A, paragraph A.1)

For a GPWS installation to be approved, the conditions under which it gives a warning shall be specified and shall be acceptable to the CAA.

NOTE: The design aim should be for the GPWS to provide maximum warning of terrain hazard consistent with attaining a low rate of unnecessary and unwanted warnings. Warning of the terrain hazard should be at least 20 seconds before ground collision would occur if no corrective action were taken, but the CAA accepts that this cannot be achieved in all circumstances, if acceptable freedom from nuisance warnings is to be achieved. However, it is considered likely that warning times less than 10 seconds could prove to be inadequate in many circumstances except those in which rapid crew response can be expected (e.g. final approach). In these circumstances 5 seconds may be adequate.

2.3 Warning (See Appendix A, paragraph A.1.4)

2.3.1 The warning shall include an aural signal and shall persist for as long as the hazard exists.

NOTE: This may be supplemented by suitable lights.

2.3.2 The aural warning shall include a voice giving appropriate advice to the crew.

2.3.3 The quality and level of the warnings shall be such as to ensure rapid perception by the crew, and will be the subject of assessment by CAA. It shall not be such as to interrupt communication between crew members.

2.3.4 The aural warning shall be provided by a loudspeaker on the flight deck and, where necessary, through the pilots' headsets.

2.4 Unwanted and Unnecessary Warnings (Nuisance Warnings) (See Appendix A paragraph A.2).

2.4.1 There shall be an acceptably low probability of a warning when the aeroplane is operating in accordance with permitted limitations and procedures, and the system is operating without failures.

2.4.2 Failures of the system which gives rise to a warning when no terrain hazard exists shall not have a probability exceeding 10^{-4} per hour.

NOTE: Failures in the system should normally inhibit the system without giving a terrain hazard warning.

2.5 Controls (See Appendix A, paragraph A.1.5)

There shall be provision for deactivating the GPWS or modifying its action so as to prevent an unwanted and unnecessary warning in any abnormal operation (e.g. abnormal configurations of the aeroplane).

2.6 **Serviceability** (See Appendix A, paragraph A.3)

There shall be a test facility which will enable the crew to determine the serviceability of the system before take-off. The predicted probability of the system becoming unserviceable during the subsequent flight shall be declared and shall be acceptable to the CAA.

2.7 **Stall Warning and Stall Identification**

The system shall be so designed that it cannot give a warning while a stall warning (stick shaker) or stall identification system (stick pusher) is operating.

2.8 **Power Supplies** (See Appendix A, paragraph A.4)

The sources of power shall be those that provide the maximum reliability for operation of the system without jeopardising service to essential or emergency loads.

2.9 **Environment**

Equipment comprising the system shall be shown to operate satisfactorily in the environmental conditions to which it will be subjected.

2.10 **Flight Manual**

The applicant for approval shall provide material suitable for incorporation into the Flight Manual for the aeroplane. This shall include a statement of the input sources which must be operating, and the procedures for operation (test, inhibit, the effect of abnormal aeroplane configurations on the system, etc.).

2.11 **Maintenance Manual** (See Appendix A, paragraph A.5)

The applicant for approval shall provide for inclusion in the Maintenance Manual for the aeroplane such material as is necessary for the maintenance of the system.

Appendix A

Ground Proximity Warnings System Based on Radio Altimeter, Pressure Height, ILS Signals and Aeroplane Configuration

A Ground Proximity Warning System having the characteristics described in this Appendix will be eligible for approval.

A.1 The System

A.1.1 Equipment

The system should consist of :

a) A ground proximity warning computer which accepts signals from the sources listed in b) to f) below, and generates a warning signal under conditions specified in paragraph A.1.2 below,

NOTE: GPWS computation may be carried out in a computer already fitted to the aeroplane for other purposes.

b) radio altimeter with failure signal[1].

c) vertical speed sensor with failure signal[1],

NOTE: A barometric altimeter may be used if the GPWS computer has the capability of deriving vertical speed from this input.

d) ILS glideslope receiver with failure signal[1],

e) switch activated when landing gear is down or selected down,

f) switch activated by any crew selection uniquely associated with final approach to landing.

NOTE: This should normally be when flaps are selected to a landing position, or are at a landing position.

g) aural warnings (see paragraph A.1.4 below),

h) deactivation controls (see paragraph A.1.5 below).

A.1.2 Operating Modes And Envelopes

A.1.2.1 The following operating modes should be provided. Figures 1 to 5 specify the normal warning envelopes for constant values of the appropriate input parameter e.g. barometric sink rate, closure rate to terrain, etc.

Mode 1: Excessive rate of descent with respect to terrain

Warning envelope to be in accordance with Figure A.1.

Mode 2: Excessive closure rate to terrain

Warning envelopes to be in accordance with Figures A2a and A2b.

Mode 3: Excessive altitude loss before acquiring 700 ft. terrain clearance after take-off or missed approach

Warning envelope to be in accordance with Figures A3.

1.It will not be necessary for a sensor to provide a failure signal where alternative means are used to inhibit the system in the event of sensor failure, e.g. multiple sensors with voting.

Mode 4: Flight into terrain with less than 500ft. terrain clearance and not in landing configuration

Warning envelope to be in accordance with Figures A4a and A4b. Mode 5: Excessive glideslope deviation.

Mode 5: Excessive glideslope deviation

Warning envelope to be in accordance with Figure 5: this or an equivalent mode should be implemented by October 1977.

NOTE: Information on acceptable tolerances is given in Appendix C.

A.1.2.2 The effect of varying input parameters should be declared e.g. increasing barometric sink rate, ILS deviation etc.

(See Appendix B, paragraph B.1.5)

NOTE: Flight testing will establish the installed characteristics of the total system, including the sensors.

(See Appendix B, paragraph B.2.k).

A.1.3 **Automatic Mode Selection**

The equipment should be so designed that it automatically selects Mode 3 for take-off or go-around below 500ft. and Mode k for landing without action by the flight crew. It should be such that when a go-around is made from any height there will be no nuisance warning due to flap or gear selection. Consideration should be given to reasonable variations in the timing of configuration changes and the rotation of the aeroplane to a climbing attitude.

A.1.4 **Warnings**

(See paragraph 2.3)

A.1.4.1 In the event that any of the envelopes for modes 1 to 4 is penetrated then an aural warning should operate which annunciates repeatedly "PULL UP" alternating with a distinctive audio tone.

NOTES: 1) If any test procedure operated by the flight crew activates the aural warning it is recommended that it should do so at reduced volume.

2) A reduction in the loudness of the warning after five seconds of operation would be accepted.

A.1.4.2 In the event that the envelope for mode 5 is penetrated then an aural warning should operate which annunciates repeatedly "GLIDE SLOPE".

A.1.4.3 The "PULL UP" warning for modes 1 to 4 should always take precedence over the "GLIDE SLOPE" warning for mode 5.

A.1.5 **Controls**

(See paragraph 2.5)

A.1.5.1 A means should be provided by which all modes of the system can be deactivated. The circuit breaker for the GPWS computer will normally be accepted for this purpose. If a separate switch is provided, it should be guarded.

NOTE: It is recommended that a guarded switch should be provided which will give a 'flaps-down' signal to the computer so that an approach to landing can be made in a configuration other than that normally used, without inhibiting the system. Alternatively, where a suitable discriminant is available this signal can be generated automatically.

A.1.5.2 A means should be provided by which mode 5 can be deactivated and reactivated at any time during the flight, including deactivation while the warning is operating. There should be a clear indication to the crew when the mode has been so deactivated. The mode should be reactivated automatically for the following flight, or there should be a crew procedure to ensure that it is reactivated when appropriate.

A.2 Unwanted and Unnecessary Warnings

(See paragraph 2.4)

A.2.1 Freedom from nuisance warnings for a system operating without failures will depend on the way in which the aeroplane is flown, as well as on the warning envelopes, tolerances and detailed dynamic characteristics of the system. If operational experience shows that a system is generating nuisance warnings at an unacceptable rate, changes may be required to the equipment or possibly to operational procedures.

A.2.2 Component failures, or combination of failures in the system (GPWS computer or sensors) which give rise to terrain hazard warnings when no such hazard exists should not occur more frequently than 1 in every 10,000 flying hours. This may be demonstrated by a suitable analysis of the equipment, paying particular attention to the following:

a) sensor failures which are not accompanied by a failure signal,

b) sensor failures which are accompanied by a failure signal but the GPWS computer fails to prevent a warning,

c) failures in the GPWS computer which result in a warning even though none of the sensors is indicating a hazardous flight path.

A.3 Serviceability

(See paragraph 2.6)

The system should not on average be unserviceable more often than on 1 in every 1000 hours. In assessing this, account should be taken of the reliability of the sensors. It should also be shown by analysis that there are no dormant faults, or combinations of faults, which can elude the pre-flight test, or else additional maintenance checks should be specified to detect such faults. In that case the frequency with which these checks are to be carried out should be shown to be appropriate to the probability of occurrence of the faults.

A.4 Power Supplies

(See paragraph 2.8)

Failures or interruptions of the power supply should be taken into account in assessing the reliability of the system and its freedom from nuisance warnings. It should also be shown that interruptions of the power supply do not cause inappropriate mode switching.

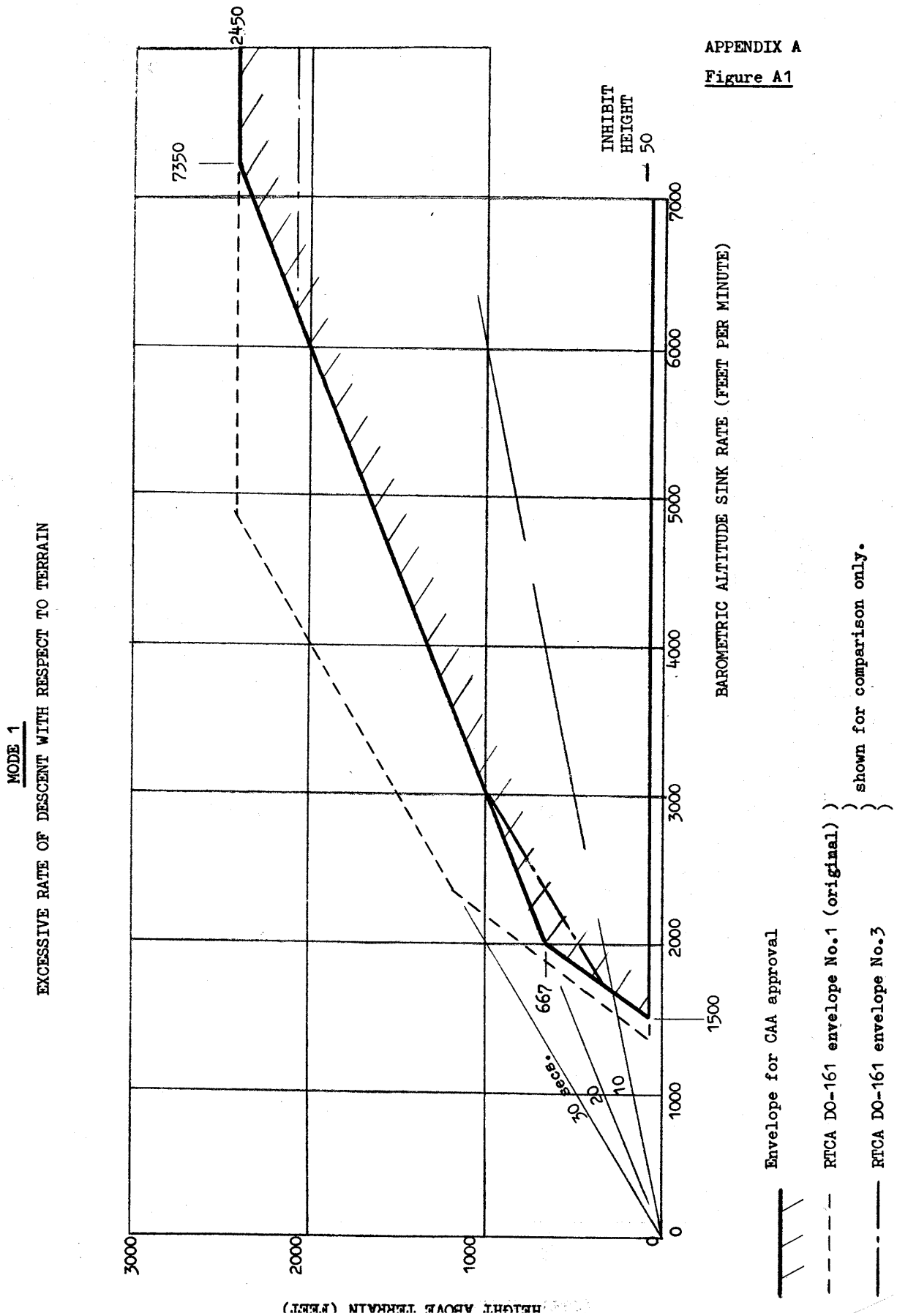
A.5 Maintenance Manual

(See paragraph 2.11)

The checks necessary to satisfy paragraph A.3 above, and their frequency should be specified in the Maintenance Manual.

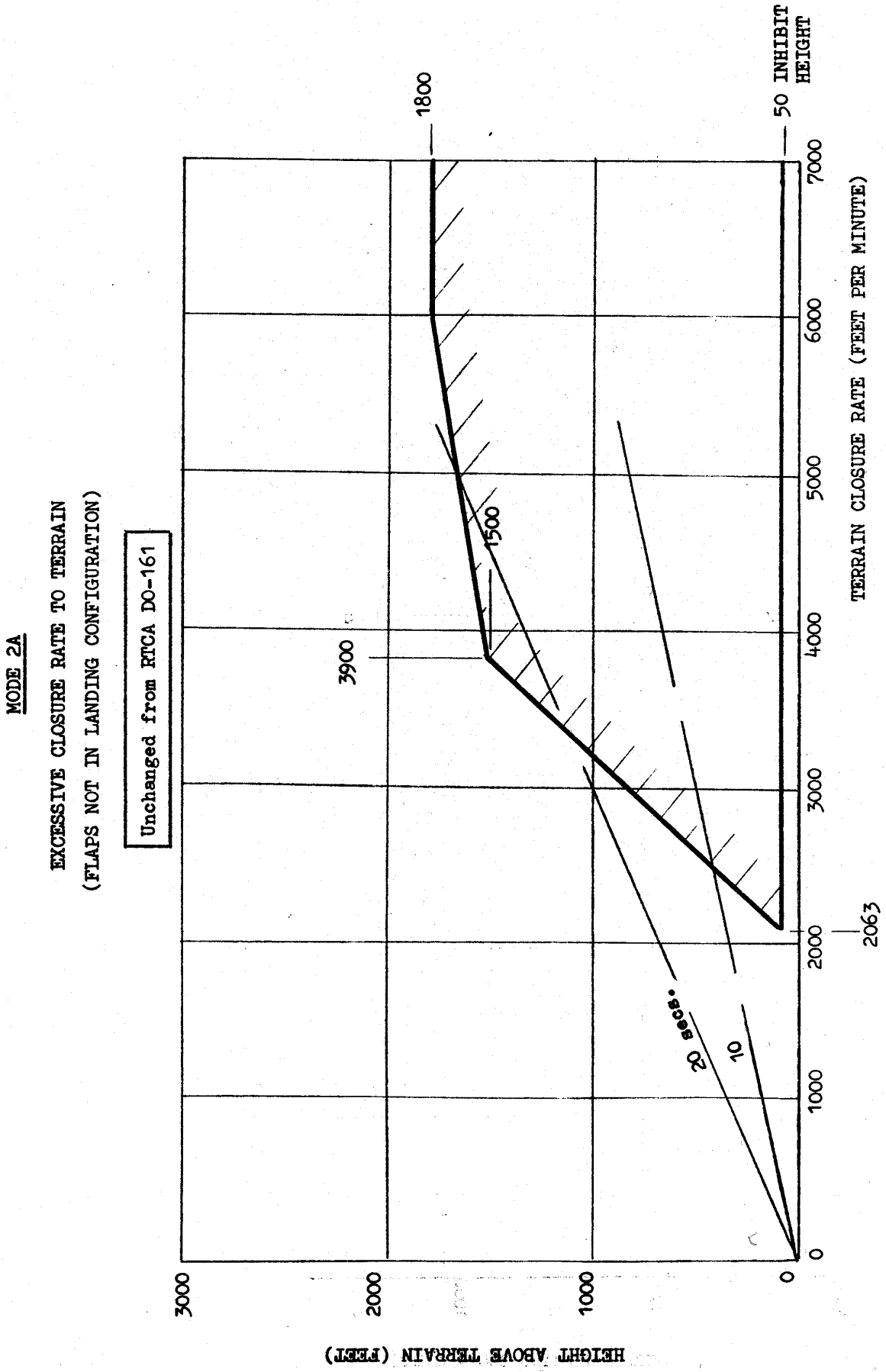
APPENDIX A

Figure A1



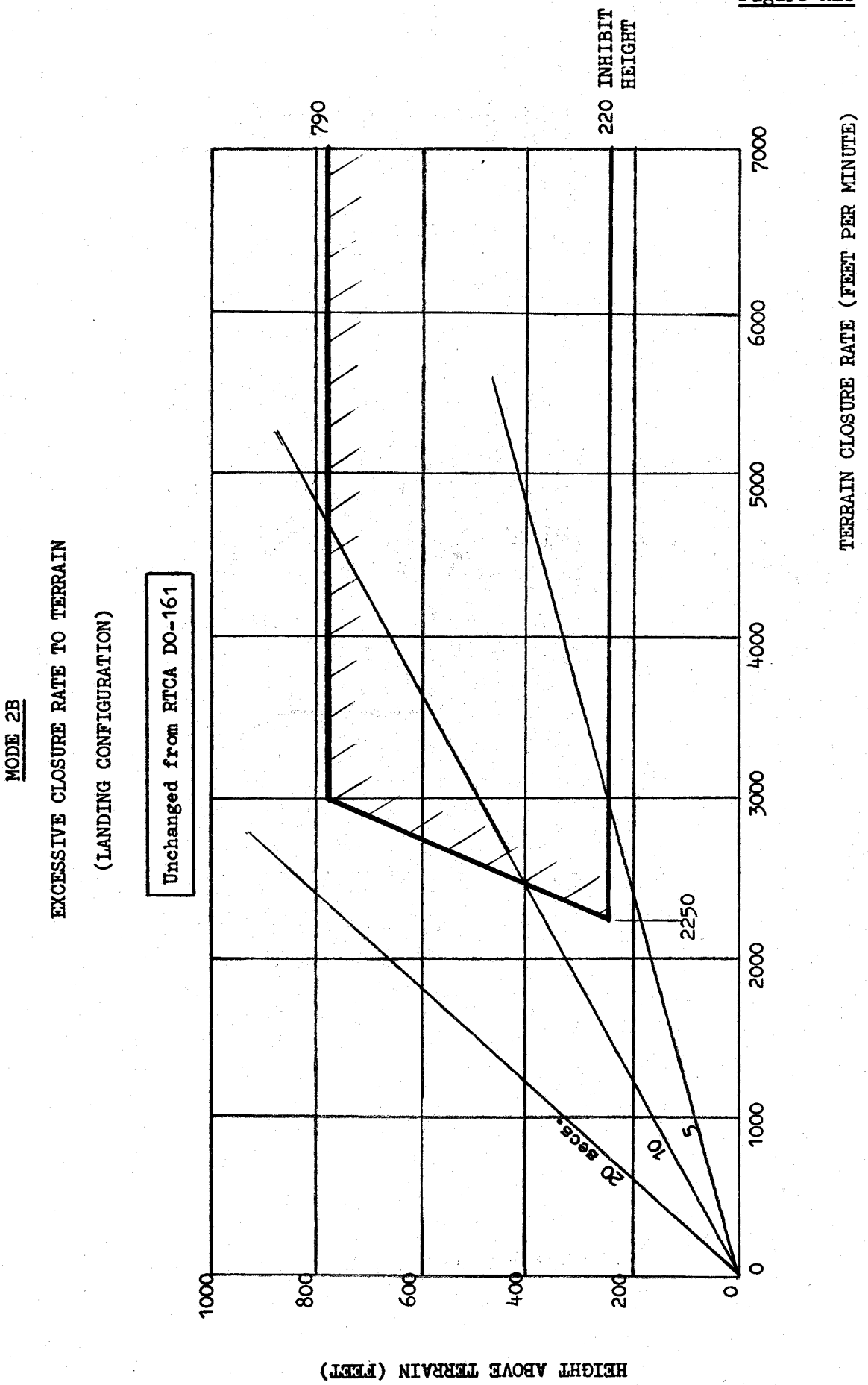
APPENDIX A

Figure A2a



APPENDIX A

Figure A2b

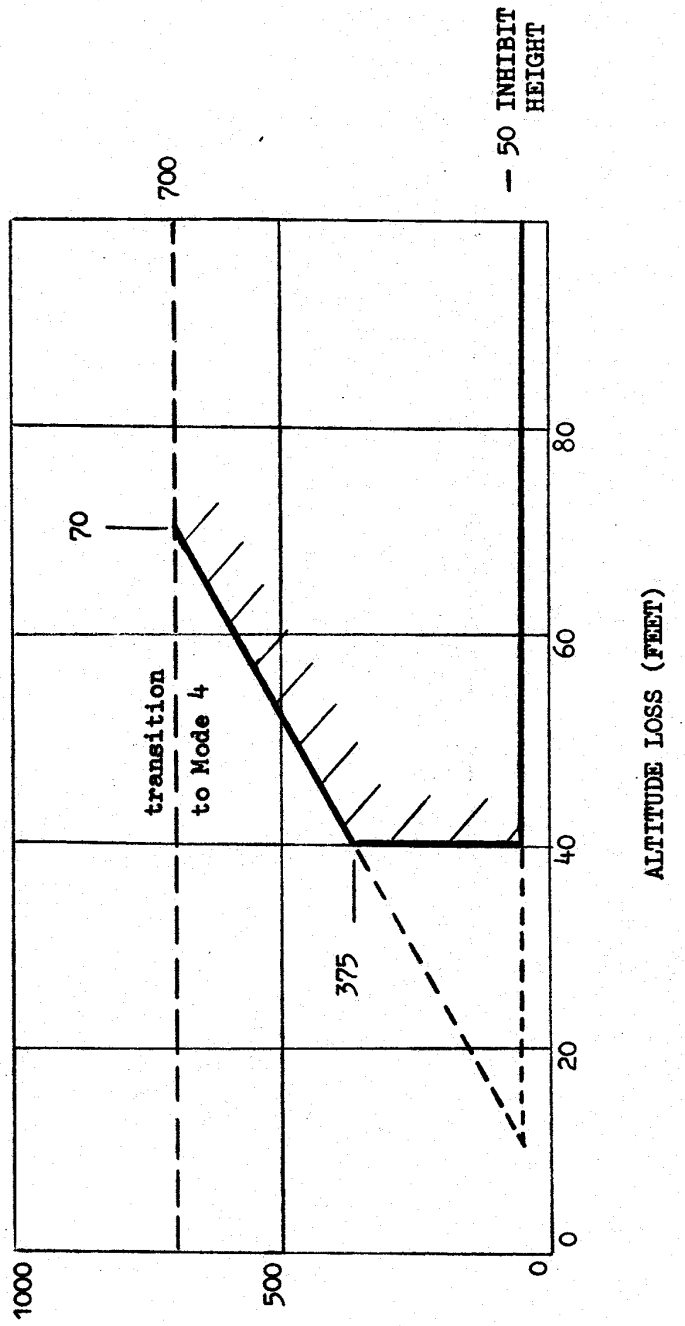


APPENDIX A

Figure A3

MODE 3

ALTITUDE LOSS AFTER TAKE-OFF OR GO-AROUND

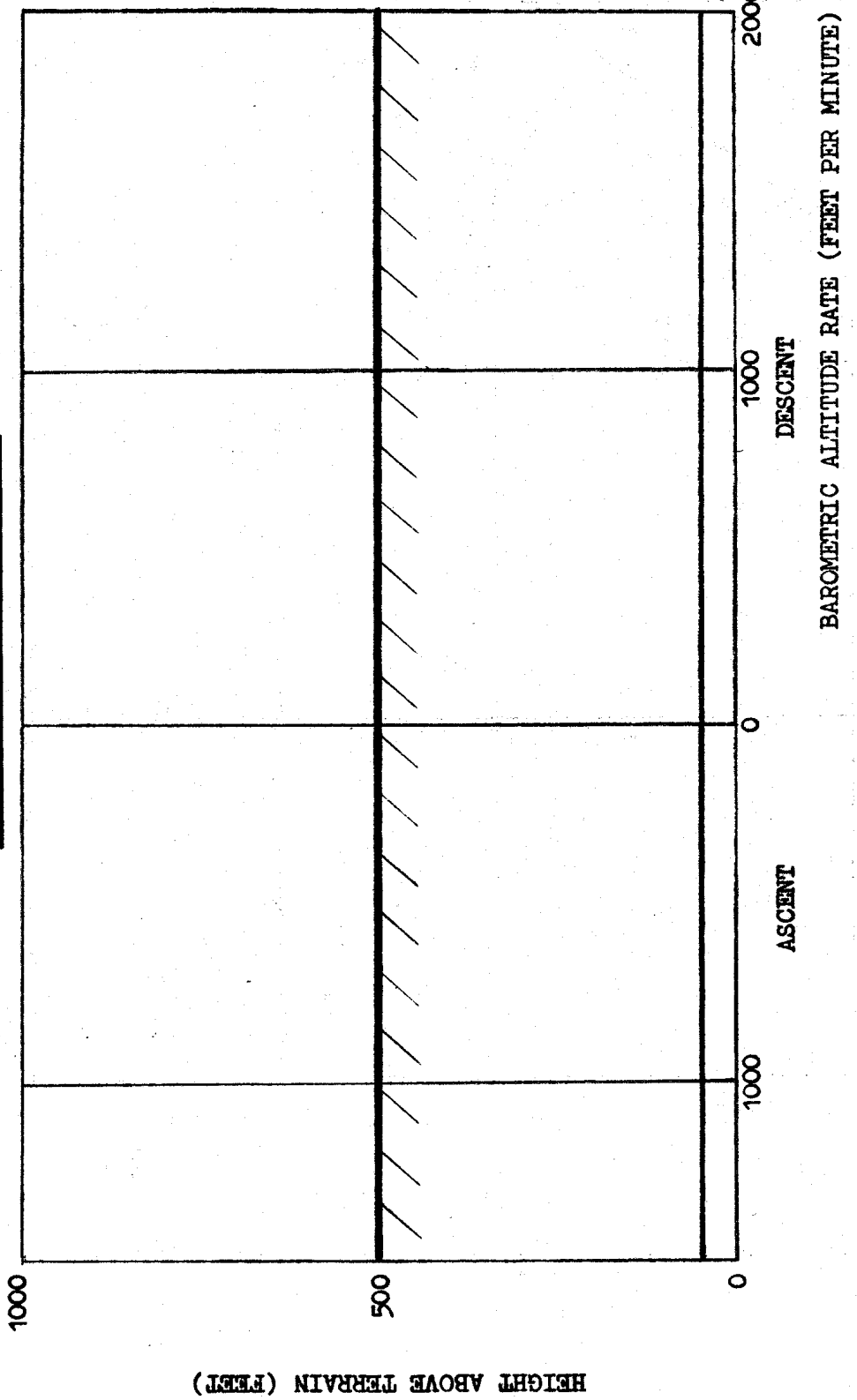


APPENDIX A
Figure A4a

MODE 4A

FLIGHT INTO TERRAIN WITH LESS THAN 500 FEET TERRAIN CLEARANCE AND LANDING GEAR UP

Unchanged from RTCA DO-161



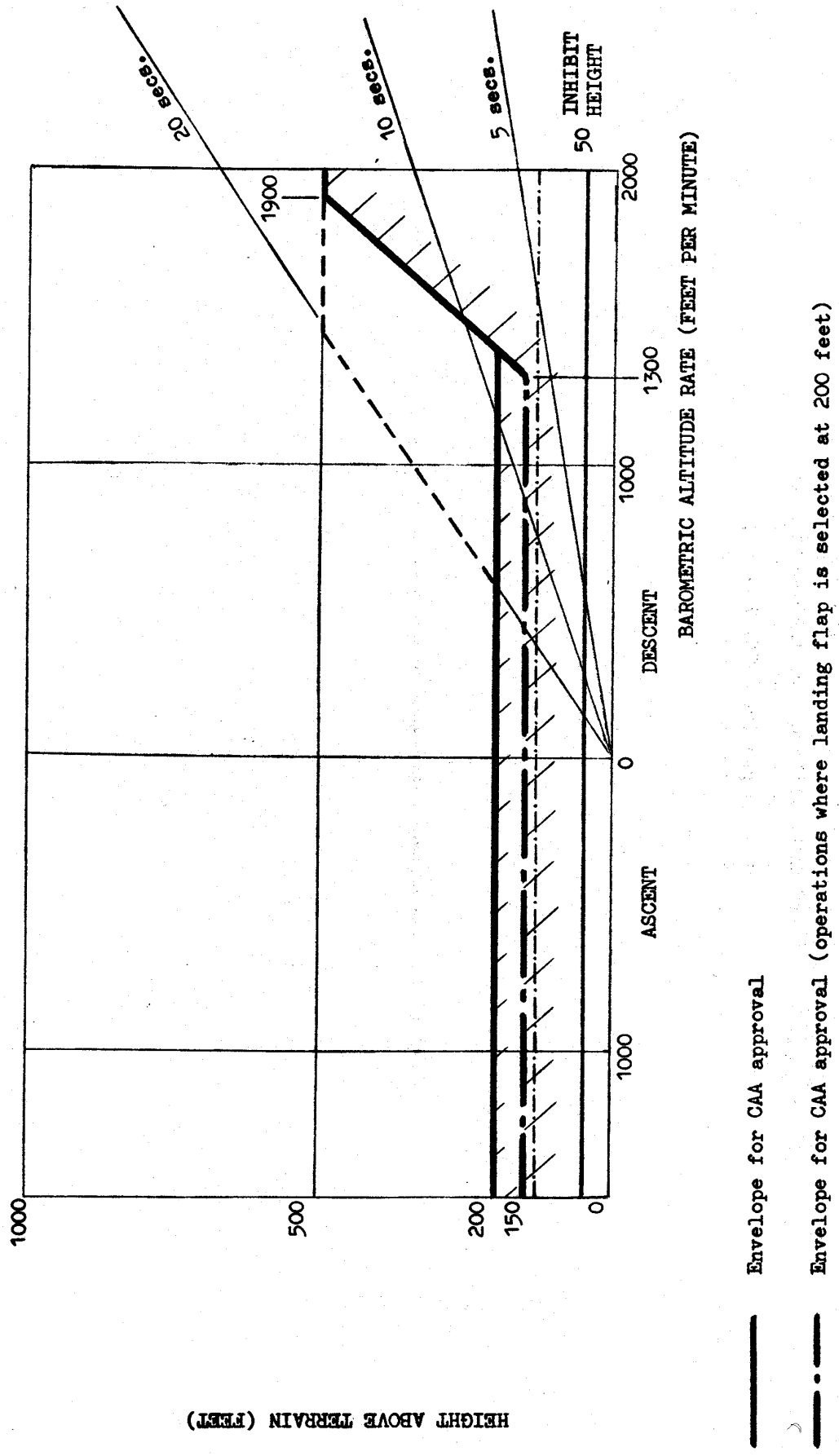
APPENDIX A

Figure A4b

MODE 4B

FLIGHT INTO TERRAIN WITH LESS THAN 500 FEET

TERRAIN CLEARANCE AND FLAPS NOT IN THE LANDING CONFIGURATION

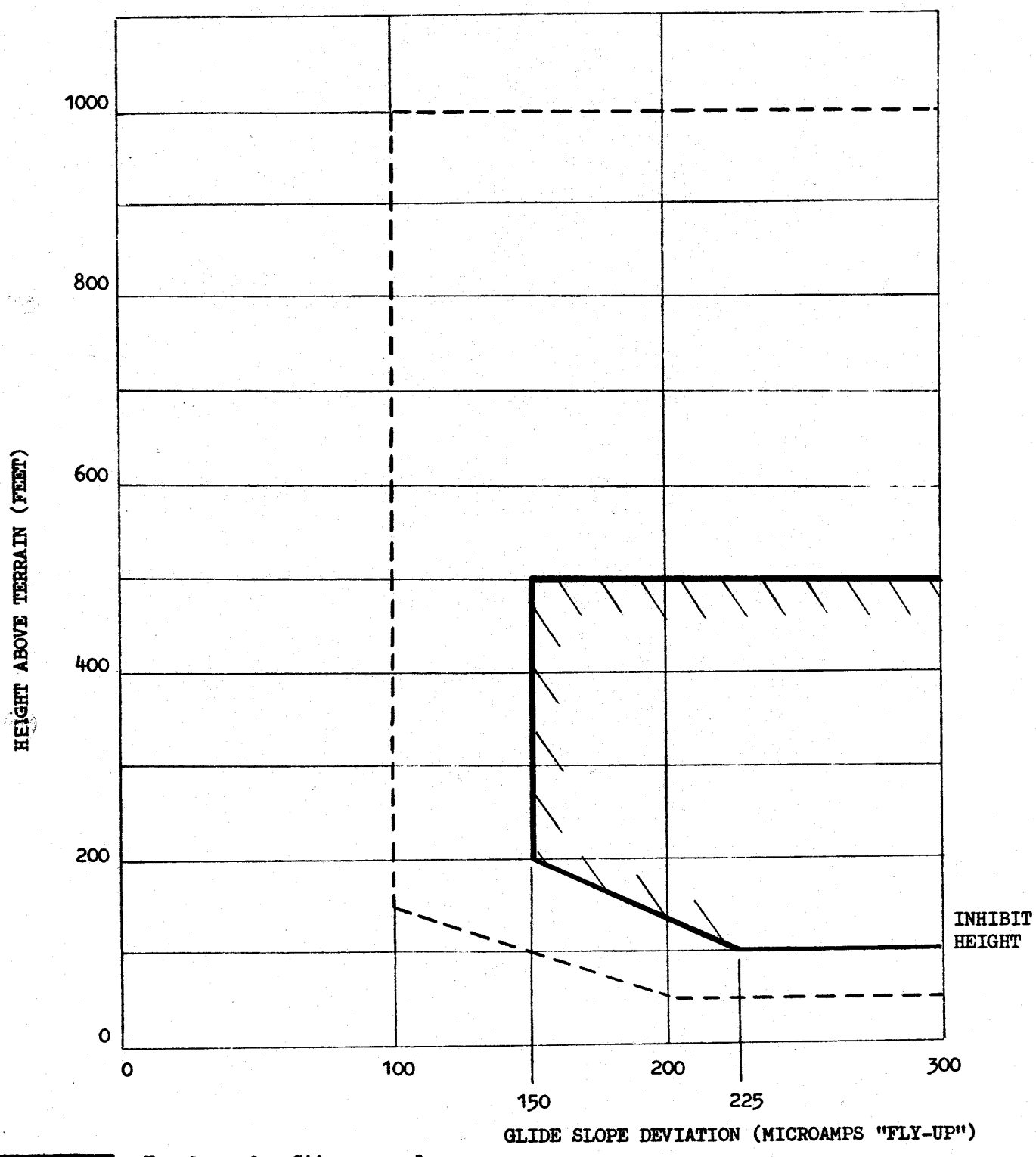


APPENDIX A

Figure A5

MODE 5

EXCESSIVE GLIDESLOPE DEVIATION



Appendix B

Approval Procedure for GPWS Equipment and Installations

NOTE: The procedures of this Appendix are principally directed at GPWS of the type considered in Appendix A. These procedures may be applicable to other acceptable types of GPWS or they may be extended when the characteristics of these other systems are known.

B.1 Equipment Approval

B.1.1 The items of equipment forming a GPWS should be approved using appropriate CAA approval procedures. Unless otherwise permitted by these procedures, the approval of each item will be against an Equipment Specification issued by its Manufacturer, or an applicable technical standard, which provides a sufficient definition of equipment characteristics and which shows it to be compatible with the requirements of this Specification.

B.1.2 This Specification defines the required reliability and integrity of the total system. It does not define the reliability and integrity required of each item of the system but such information derived either practically or theoretically will be needed in order to demonstrate that a complete GPWS complies with this Specification.

B.1.3 Ground Proximity Warning computers of a type suitable for use in the system described by Appendix A, should have their performance characteristics defined in terms of :-

a) warning envelopes and the flight conditions and aircraft configurations to which these envelopes apply.

b) the detailed test procedures and permitted test tolerances which are applicable to these envelopes.

B.1.4 The warning envelopes and tolerances of Appendix C and the related test procedures of Appendix D are an acceptable means of achieving the equipment definition specified in B.1.3 above.

B.1.5 In addition to evaluating equipment performance under simulated steady flight conditions (see Note B of Appendix C), the effects on equipment performance of a varying terrain closure rate and a varying barometric sink rate shall be evaluated and the results declared.

B.2 Approval of GPWS Installations

B.2.1 **General**

For the design of a GPWS installation to qualify for CAA approval, it should be subjected to sufficient analysis and testing to demonstrate compliance with the requirements of this Specification.

The attention of applicants is particularly drawn to the fact that CAA will accept data derived from tests and analyses of previous similar installations or evidence of their satisfactory in-service operation or results obtained from tests on the items of equipment being employed to assist in satisfying this requirement.

B.2.2 **Installation Design and Analysis**

The following should be included in the design activity of an Organisation seeking approval of a GPWS installation :

a) It shall be shown that the units forming the system are mutually compatible and approved for use in the environmental conditions-to which they will be subjected.

b) It shall be shown by analysis that the system is able to satisfy the Serviceability requirement of paragraph 2.6 of this Specification.

c) The preparation of the Maintenance Manual material required by paragraph 2.11; this should take account of the findings of the Serviceability analysis of b) above.

d) It shall be shown by analysis that the GPWS working either with or without failures does not significantly affect the airworthiness of those systems and equipment to which it is connected.

e) The aircraft's electrical load analysis shall be suitably amended.

f) The preparation of ground and flight test schedules for proving the initial installation and a test schedule for subsequent installations.

g) The preparation of the Flight Manual material required by paragraph 2.10.

B.2.3 **Ground Testing**

B.2.3.1 **Purpose**

Ground testing, to a scale which adequately complements prior experience in the use of the system or its component parts, should be carried out on each design of installation for the purpose of :

a) Minimising flight testing.

b) Proving that when subjected to an appropriate range of simulated flight conditions, it achieves the performance required by this Specification.

c) Exercising the system to allow design faults to be identified and corrected.

d) Confirming that the system does not interfere with other systems or equipment in the aircraft.

e) Showing that power supply interruptions such as those the installation is likely to experience in service, do not cause spurious, Mode switching or spurious warnings.

f) Confirming that the electrical performance and the mechanical settings of undercarriage switches are correct.

g) Confirming, to the extent that practicable ground testing will allow, that the radio altimeter is a suitable source of height information which is accurate and reliable throughout the range 0 to 2,500 feet and when above this height this information will not fluctuate in a manner likely to cause false warnings (its antennae being located and bonded such as to assist in avoiding this happening), and that the installed radio altimeter including antennae, feeder and connectors are fully serviceable and can be expected to remain so by application of the declared maintenance procedures.

h) Examine system operation when sensor self-test devices are activated and in the, presence of intermittent sensor faults which have been identified as being of significance by an agreed analysis to confirm that false warnings are avoided under these conditions and that the system is not inhibited for an excessive period thereafter.

B.2.3.2 **Tests**

a) Ground testing shall be carried out to the extent and for the purpose given in B.2.3.1. Tests should be made on a complete GPWS installation to the extent that this is practicable.

b) For a system of the type defined in Appendix A, the performance tests may be based upon the Test Procedures contained in Appendix C, extended to include the following tests :

i) **Audio Output Test**

The quality and volume of the warning shall be assessed.

ii) **Stall Warning and Stall Identification**

When the GPWS is installed in an aircraft fitted with either stall warning (stick shaker) or stall identification (stick pusher) systems, it should be confirmed by test that for the duration of any warnings provided by either or both of these, GPWS warnings are inhibited.

iii) **Controls**

Test to confirm the effectiveness of controls for manually de-activating the GPWS or for modifying its action so as to prevent unwanted and unnecessary warning in any abnormal operation.

The additional 5% tolerance band permitted by Note B of Appendix C, may be exploited when examining system performance.

B.2.4 **Flight Testing**

B.2.4.1 For each installation evidence should be provided by the applicant to show that the function and performance of the system in flight complies with the requirements of this specification. The CAA will accept evidence from ground testing where appropriate, and also that flight test evidence from one aeroplane type may in many instances be read across to another. The following paragraphs give guidance.

B.2.4.1.1 **Function**

a) For aeroplanes of the same type and model fitted with the same system (GPWS computer and associated sensors), only one flight test would be needed.

b) The same evidence may be accepted for other aeroplanes of the same type, but a different model, fitted with the same system, where it can be shown that the difference cannot affect the functioning of the ground proximity warning system.

c) In other cases a flight test of system function will normally be required.

B.2.4.1.2 **Performance**

Flight test evidence will be required to confirm the performance of the system. This will be acceptable from flight test of another aeroplane or aeroplane type if it can be shown that the differences will not significantly affect the performance of the system. Where the sensors used in the flight test differ from those in the subject installation, it will be necessary to show by testing or analysis that the characteristics of the sensors do not adversely affect the performance of the system, or a flight test may be called for.

B.2.4.2 **Functional Testing**

For a system of the class considered in Appendix A (i.e. one based on radio altimeter, pressure height, ILS signals and aeroplane configuration), the flight test programme should include a demonstration of the following characteristics and functions, unless adequately covered by ground testing.

B.2.4.2.1 **Warning**

a) quality of voice warning

b) level of warning during flight with high ambient noise and low ambient noise.

B.2.4.2.2 **Controls**[1]

a) suitability of de-activation controls.

b) operation of Mode 5 de-activation control before and during operation of the warning.

c) automatic reactivation of Mode 5 for flight following one on which it has been de-activated.

B.2.4.2.3 **Unwanted and Unnecessary Warnings (Nuisance Warnings)**

a) no nuisance warnings as a consequence of a sensor failure.

b) no nuisance warning as a consequence of power supply transients, switching or interruptions (either caused directly, or because the computer switches to an inappropriate mode).

c) no nuisance warnings during go-around as a consequence of reasonable variations in the timing of configuration changes and the rotation of the aeroplane to a climbing attitude.

B.2.4.2.4 **Automatic Mode Selection and Switching**

a) Switching from Mode 2A to Mode 2B when landing configuration selected.

b) Selection of Mode 3 for take-off.

c) Switching from Mode 4A to Mode 4B when landing gear selected down.

d) Inhibition of Mode 4 when landing gear and landing flap are selected down.

e) Switching from Mode 4 to Mode 3 for go-around.

B.2.4.3 **Performance**

For a system of the class considered in Appendix A (i.e. one based on radio altimeter, pressure height, ILS signals and aeroplane configuration), the flight test programme should include measurement[2] of the start of warning, the flight path and other relevant parameters sufficient to establish satisfactory performance in the modes to be- tested. The test programme should be agreed in advance with the CAA, and for example, the following test conditions would normally constitute a satisfactory programme.

B.2.4.3.1 **Mode 1**

a) Descent at or exceeding 3000 fpm to warning.

b) Descent between 1500 and 2000 fpm to warning.

NOTE: It is more important to maintain a constant descent rate than to achieve a precise target value.

B.2.4.3.2 **Mode 2A**

a) Penetration of the warning envelope with gear and flaps up.

b) Penetration of the warning envelope with gear down and flaps up, using similar flight path to a) above.

NOTE: It would be acceptable if this were done by suppression of Mode 1 and descent over flat terrain.

1.It is expected that these tests could normally be satisfactorily accomplished during ground testing of the installation.
2.Normally with a flight data recorder

B.2.4.3.3 **Mode 3**

a) Descent from 300 feet to warning during take-off or go-around.

b) Descent from 600 feet to warning during take-off or go-around.

B.2.4.3.4 **Mode 4**

a) Descent with landing gear and flaps up to warning.

b) Descent at 600 fpm with landing gear down and flaps not in the landing position to warning.

c) Descent at 1500 fpm with landing gear down and flaps not in landing position to warning.

B.2.4.3.5 **Mode 5**

a) Excursion to more than full scale below glide slope at 800 feet : no warning.

b) Excursion below glide slope below 500 feet to warning.

Appendix C

Envelopes of Conditions for Warning and Tolerance for Airborne Ground Proximity Warning Equipment

NOTES: a) This Appendix C and the complementary Appendix D are derived from RTCA DO-161A, Appendices A and B respectively, and include the minimum of changes to take account of differences in warning and alert envelopes.

b) The curves of this Appendix C specify the performance required of the Ground Proximity Warning equipment on the bench when it is supplied with laboratory-source inputs of barometric data, radio height data and glide slope deviation, and tested using the procedures of Appendix D or their equivalents.

If these curves are used as references for stabilized descent-rate flight tests of the equipment, an additional tolerance band below the lower tolerance limit of each bench test curve is necessary to accommodate the integration of the equipment into the aircraft. Five percent of nominal curve values has been used for this additional tolerance band.

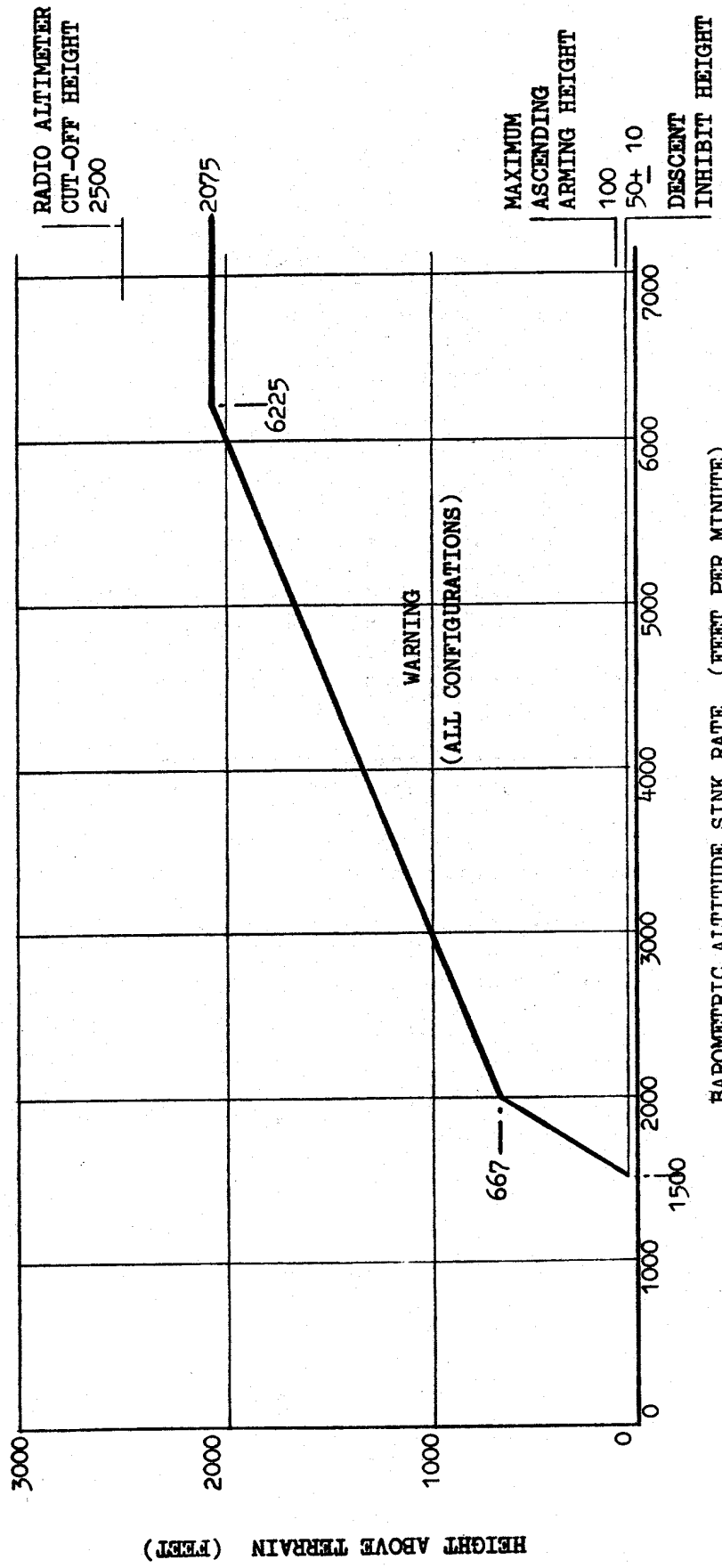
Smoothing of the input data is necessary in the Ground Proximity Warning equipment to minimize nuisance warnings. The test procedures of Appendix D specify constant rate inputs, and are designed to ensure that delays to warning onset resulting from such smoothing are not such that the equipment fails to provide warnings before the lower tolerance limits of the warning envelopes are reached. The curves of this Appendix C are not applicable to increasing rates, and additional delays to warning onset will be experienced if increasing rates are used.

APPENDIX C

Page 1

MODE 1

EXCESSIVE RATE OF DESCENT WITH RESPECT TO TERRAIN



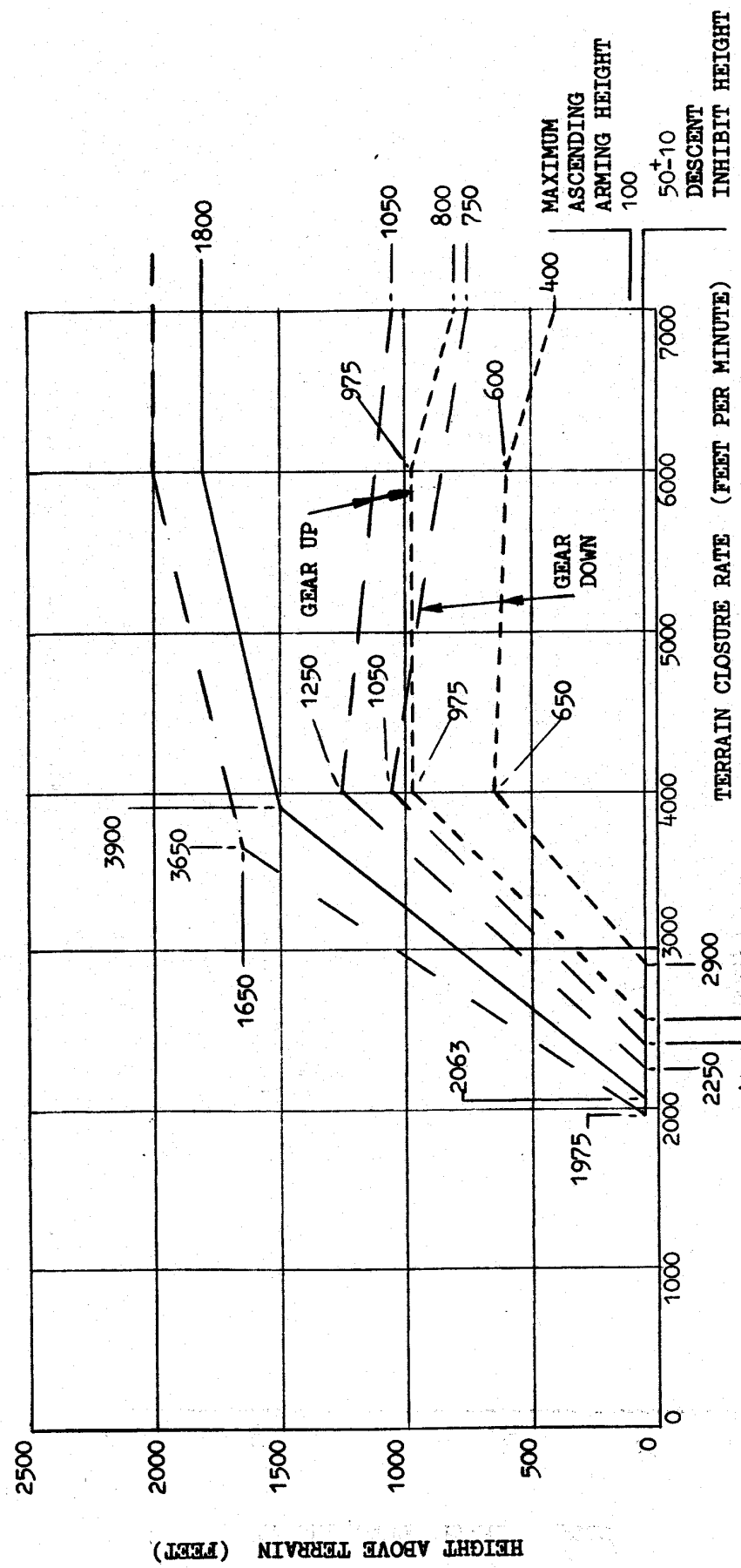
Solid line is lower tolerance limit. Manufacturer shall define selected position for nominal envelope above this line and declare upper tolerance limit (recognizing the need to minimize nuisance warnings) before applying test procedure T-1 of Appendix B.

MODE 1 IS FUNCTIONAL AT ALL TIMES

MODE 2A

EXCESSIVE CLOSURE RATE TO TERRAIN

(FLAPS NOT IN LANDING CONFIGURATION)



Solid lines are nominal values

Dashed lines indicate tolerance limits when initiating test from 2450 feet

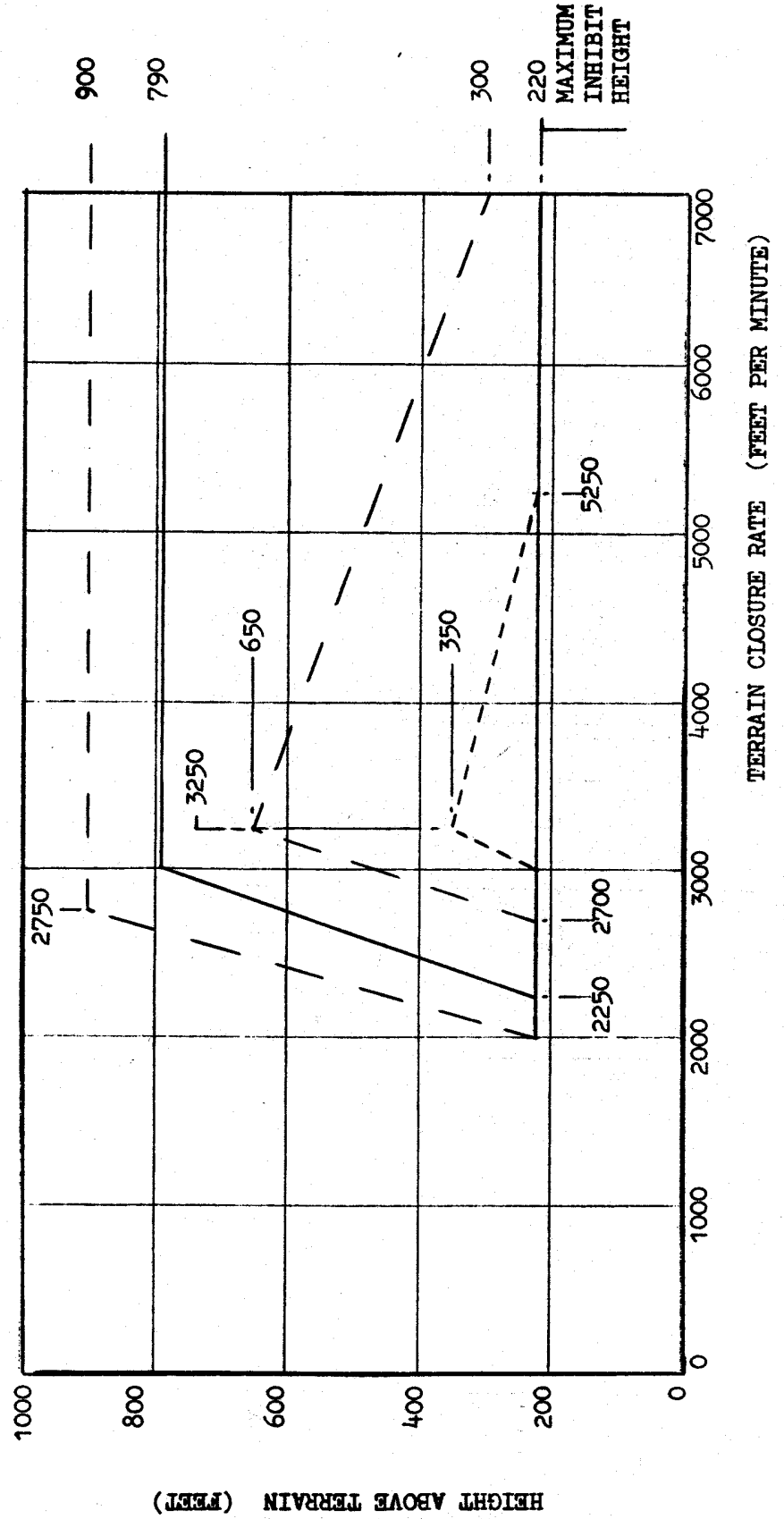
Dotted lines indicate tolerance limits when initiating test from the nominal envelope

MODE 2A IS FUNCTIONAL AT ALL TIMES FLAPS ARE NOT IN LANDING CONFIGURATION

MODE 2B

EXCESSIVE CLOSURE RATE TO TERRAIN

(LANDING CONFIGURATION)

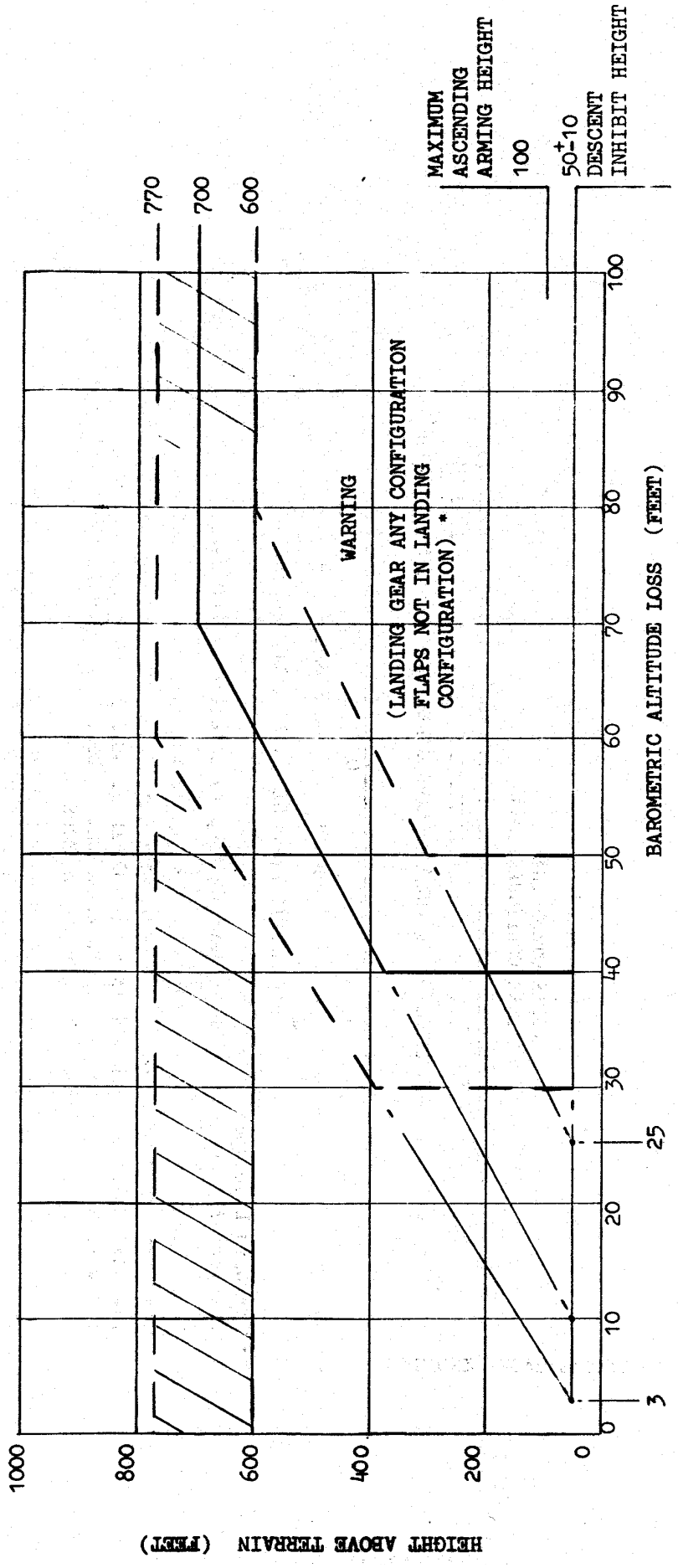


Solid lines are nominal values

Dashed lines indicate tolerance limits when initiating test from 2450 feet

Dotted lines indicate tolerance limits when initiating test from 1500 feet

MODE 2B IS FUNCTIONAL AT ALL TIMES FLAPS ARE IN LANDING CONFIGURATION AND IRRESPECTIVE OF LANDING GEAR POSITION.

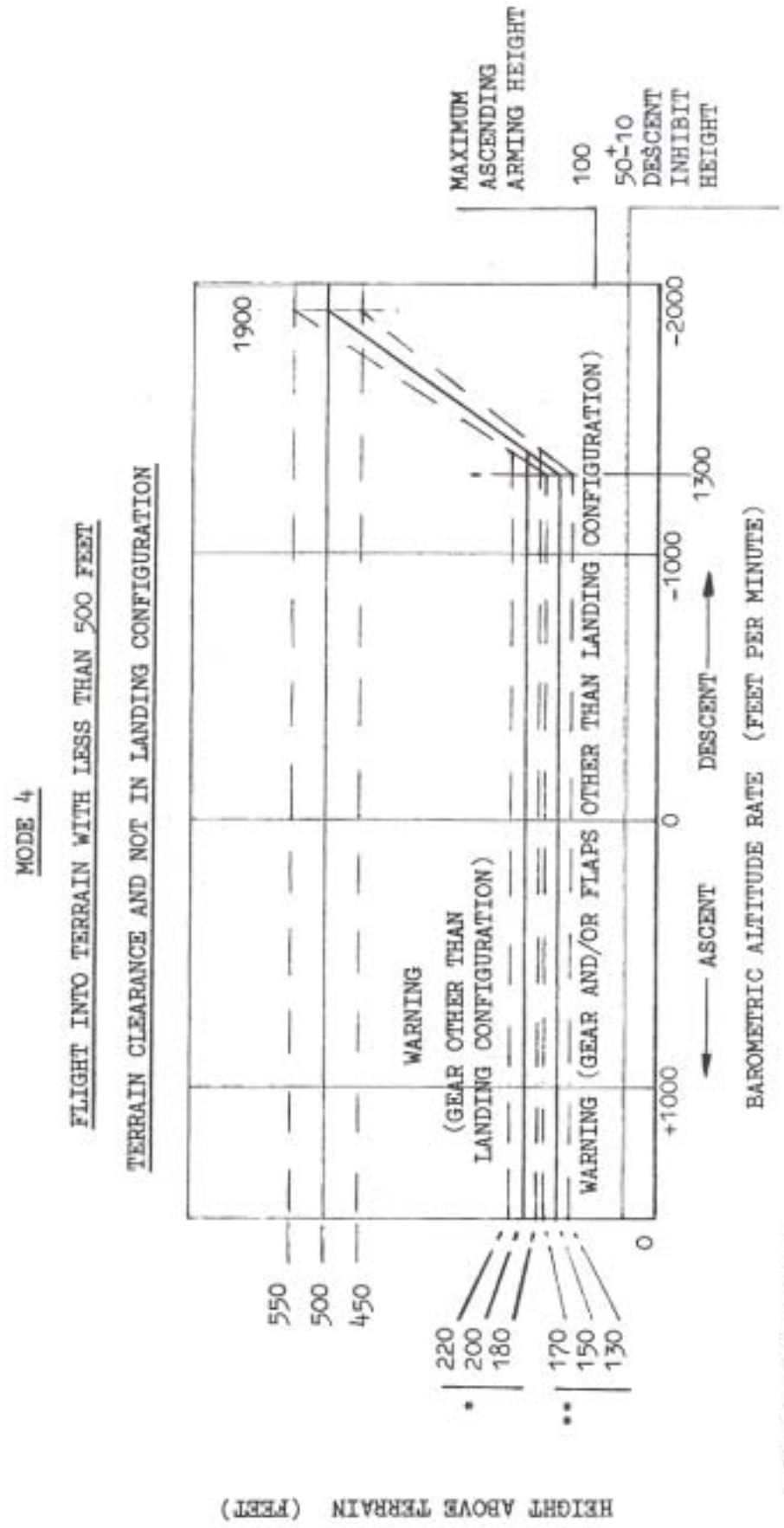


Solid lines are nominal values

Dashed lines indicate tolerance limits

MODE 3 IS FUNCTIONAL DURING TAKE-OFF OR MISSED APPROACH WHEN MODE 4 IS DISABLED.

*OPTIONALLY, ALL CONFIGURATIONS EXCEPT GEAR AND FLAPS IN LANDING CONFIGURATION.
TRANSITION TO MODE 4 BETWEEN 600 AND 770 FEET.



* Standard Envelope

** Envelope for operations where landing flap is selected at 200 feet.

Solid lines are nominal values. Dashed lines indicate tolerance limits.

AUTOMATIC TRANSFER FROM MODE 4 TO MODE 3 MUST OCCUR WITHIN 2 TO 3 SECONDS UPON CHANGING AIRCRAFT CONFIGURATION WITHIN AREA BOUNDED BY GEAR AND/OR FLAPS OTHER THAN LANDING CONFIGURATION WHEN EXECUTING MISSED APPROACH. ABOVE THIS BOUNDARY AIRCRAFT CONFIGURATION CHANGE SHALL NOT CAUSE TRANSFER OUT OF MODE 4.

OPTIONALLY, AUTOMATIC TRANSFER FROM MODE 4 TO MODE 3 MAY OCCUR WITHIN 2 TO 3 SECONDS UPON CHANGING AIRCRAFT CONFIGURATION WITHIN AREA BOUNDED BY GEAR AND/OR FLAPS OTHER THAN LANDING CONFIGURATION ENVELOPE AND GEAR OTHER THAN LANDING CONFIGURATION ENVELOPE WHEN EXECUTING MISSED APPROACH.
ABOVE 500+50 FEET, AIRCRAFT CONFIGURATION SHALL NOT CAUSE TRANSFER OUT OF MODE 4.

APPENDIX C

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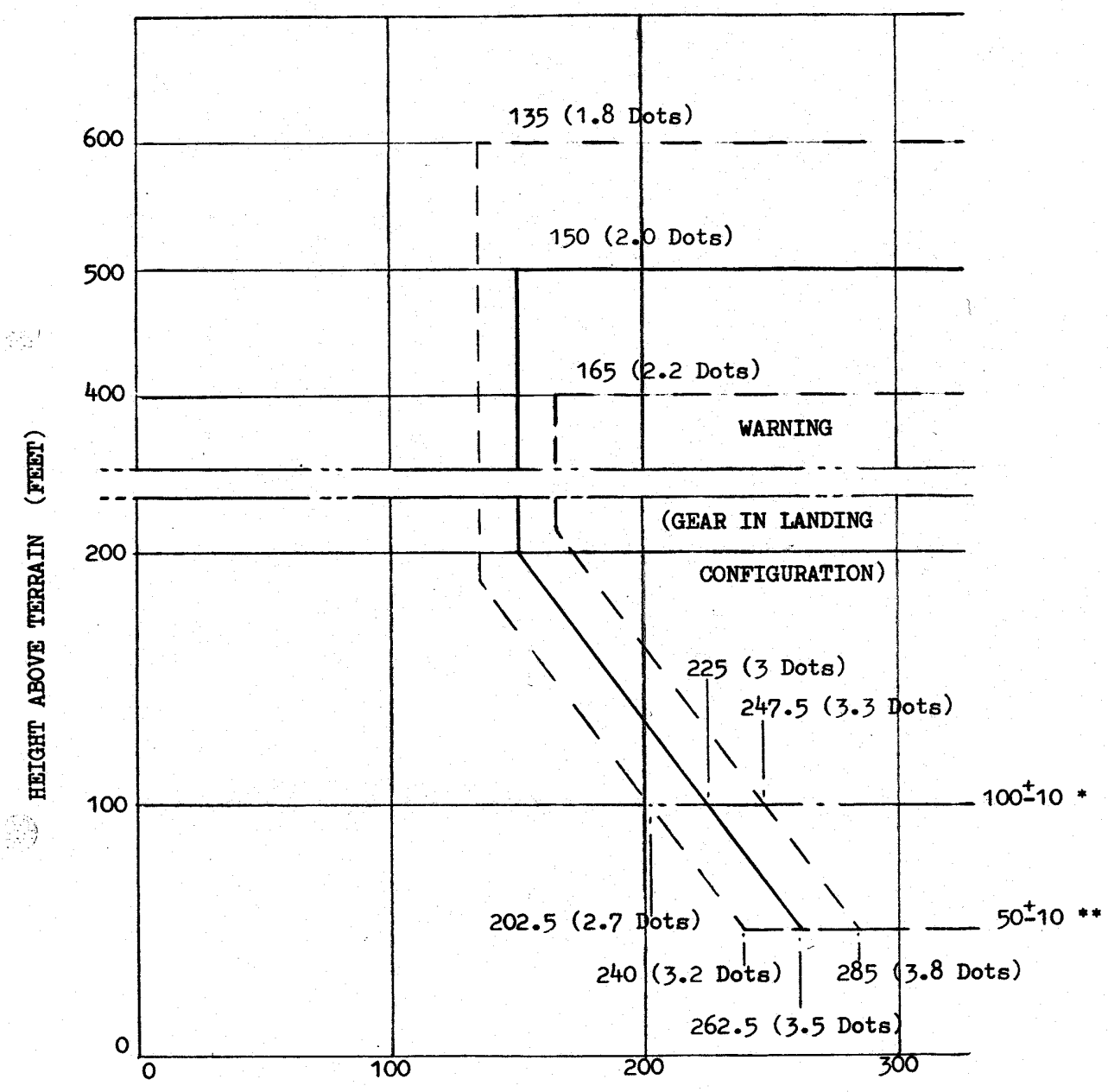
MODE 5

EXCESSIVE GLIDE SLOPE DEVIATION



Solid lines are nominal values

Dashed lines indicate tolerance limits

*** Automatic Inhibit Height Upper Limit**

**** Automatic Inhibit Height Lower Limit**

Appendix D

Test Procedures for Airborne Ground Proximity Warning Equipment

NOTES: a) See Note a) of Appendix C.

b) The test procedures set forth in this Appendix are satisfactory for use in determining the performance of airborne Ground Proximity Warning equipment when the input data is simulating stabilised decent-rate or closure-rate flight conditions. **Test procedures which provide equivalent information may be used**.

Test procedures which provide information on the performance of airborne Ground Proximity Warning equipment when the input data is simulating non-stabilised flight conditions should also be used and the results declared. (See B.2.3.2c)).

Part I

Definitions of Terms and Conditions of Test

The following definitions of terms and conditions of test are applicable to the test procedures specified herein:

a) **Power Input Voltage - Direct Current**

Unless otherwise specified, when the Ground Proximity Warning equipment is designed for operation from a direct current power source, all measurements shall be conducted with the voltage input to the equipment adjusted to 27.5 V, ± 2% for 24-28 V equipment. The input voltage shall be measured at the equipment power input terminals.

b) **Power Input Voltage - Alternating Current**

Unless otherwise specified, when the equipment is designed for operation from an alternating current power source, all tests shall be conducted with the power input voltage adjusted to design voltage ± 2%. In the case of equipment designed for operation from a power source of essentially constant frequency (e.g. 400 Hz) the input frequency shall be adjusted to design frequency ± 2%. In the case of equipment designed for operation from a power source of variable frequency (e.g. 350 to 1000 Hz), tests shall be conducted with the input frequency adjusted to within 5% of a selected frequency within the range for which the equipment is designed.

c) **Adjustment Of Equipment**

The circuits of the equipment under test shall be properly aligned and otherwise adjusted in accordance with the manufacturer's recommended practices, prior to the application of the specified tests.

d) **Test Instrument Precautions**

Due precautions shall be taken during the conduct of the tests to prevent the introduction of errors resulting from the improper sensor system simulators, oscilloscopes and other test instruments.

e) **Ambient Conditions**

Unless otherwise specified, all tests shall be conducted under conditions of ambient room temperature, pressure, and humidity. However, the room temperature shall be not lower than 10°C.

f) **Warm-up Period**

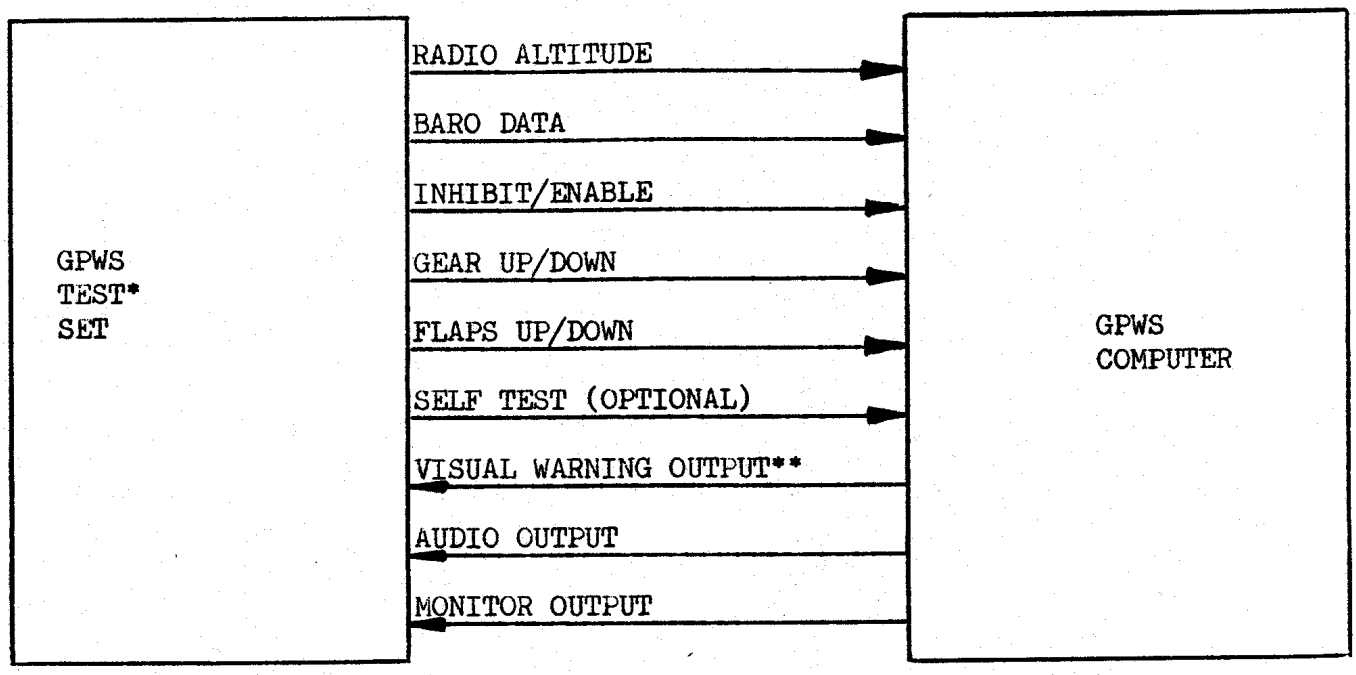
Unless otherwise specified, all tests shall be conducted after a warm-up period of not less than 15 minutes.

g) **Connected Loads**

Unless otherwise specified, all tests shall be performed with the equipment connected to loads having the impedance value for which it is designed.

h) **Special Purpose Test Set**

The Special Purpose Ground Proximity Warning equipment test set shown in Figure 1 may be used to facilitate testing. Equivalent test sets or arrangements of discrete test-equipment may be used.



*SUNDSTRAND - P/N 951-0090-001
BENDIX - CPT-83A
COLLINS - 971T-1

EDO - GPW 1501TD
LITTON - MODEL GPWS-STC
IDC - 28400-001

** MODES 1 THROUGH 4 ONLY

FIG. 1 SPECIAL PURPOSE GROUND PROXIMITY WARNING TEST EQUIPMENT

Part II

Detailed Test Procedures

General

Special purpose Ground Proximity Warning System (GPWS) test equipment described in Part I, or equivalent, is used for all test procedures. For all tests T-1 through T-4 at least two points shall be established for each segment of each warning envelope.

T-1 Mode 1

The initial test altitude shall be 2600 feet height above terrain. Attach GPWS test equipment, Figure 1, and determine that warning outputs are provided within the envelope specified for Mode 1 in Appendix C. Each measurement shall be made with a selected barometric altimeter sink rate and the corresponding rate of decrease of height above the terrain. The warning outputs shall occur at an altitude within the Manufacturer's prescribed limits. Demonstrate that Mode 1 is functional with the gear and flaps in the landing configuration.

T-2 Mode 2

Attach GPWS test equipment, Figure 1, and determine that warning outputs are provided within the envelopes specified by Modes 2A and 2B in Appendix C, for each of the applicable aircraft configurations. Demonstrate that Mode 2A is functional at heights within Mode 4 envelope.

Mode 2a

a) Apply a uniformly decreasing rate of change of the height above terrain signal starting from a height of 2450 feet. The warning outputs shall occur within the limits prescribed by the dashed lines for Mode 2A in Appendix C, for each of the two applicable aircraft configurations.

b) Apply a uniformly decreasing rate of change of the height above terrain signal starting from the nominal warning envelope. The warning outputs shall occur within the limits prescribed by the dotted lines for Mode 2A in Appendix C, for each of the two applicable aircraft configurations.

Mode 2b

a) Apply a uniformly decreasing rate of change of the height above terrain signal starting from a height of 2450 feet. The warning outputs shall occur at a height not lower than the limits prescribed by the dashed lines for Mode 2B in Appendix C.

b) Apply a uniformly decreasing rate of change of the height above terrain signal starting from a height of 1500 feet. The warning outputs shall occur at a height not lower than the limits prescribed by the dotted lines for Mode 2B in Appendix C.

T-3 Mode 3

a) Attach GPWS test equipment, Figure 1, and determine that warning outputs are provided within the envelope specified by Mode 3 in Appendix C. Starting with an initial height above terrain of less than 600 feet, set the test equipment to generate an altitude loss using either a sink rate of 300 feet/minute and time, or altitude directly. The warning outputs shall occur within the limits prescribed by the dashed lines of Mode 3 in Appendix C. The terrain height shall be increased to 770 feet and the barometric-altitude sink rate increased to 1000 ft per minute or equivalent altitude loss of 100 feet to verify that the Mode is inhibited. The height

above terrain shall then be reduced to verify that the Mode 4 envelope is armed. The maximum ascending arming height shall be verified by increasing the radio height signal to 100 feet, and then providing a barometric altitude sink rate signal of 200 feet/minute or an altitude loss in excess of 50 feet.

T-4 Mode 4

a) Attach GPWS test equipment, Figure 1, and determine that warning outputs are provided within the envelope(s) for Mode 4, selected from those set forth for this Mode in Appendix C for each of the applicable aircraft configurations. Apply a constant barometric altitude rate and the selected rate of decrease of height above terrain signal starting from a height of 1000 feet. The warning outputs shall occur within the limits prescribed by the dashed lines for Mode 4 in Appendix C, for each of the applicable aircraft configurations.

b) Attach GPWS test equipment, Figure 1, and set the barometric altitude rate signal to zero rate. With gear selected in landing configuration, and flaps set in other than landing configuration, apply a terrain height signal of 300 feet. Select gear not in landing configuration and verify that no warning occurs. Change the terrain height signal to 1000 feet to re-arm Mode 4, then lower the height signal to 300 feet. Verify that warning occurs. Select landing gear in landing configuration and, verify that the warnings cease. Apply a sink rate of 1700 feet/minute and verify that Mode 4 provides warnings. Where the optional Mode 3/Mode 4 changeover logic is used, apply a barometric altitude loss of 90 feet and verify that Mode 3 provides warnings.

c) Attach GPWS test equipment, Figure 1, and set the barometric altitude rate signal to zero rate. With gear and flaps selected in landing configuration, apply a terrain height signal of 100 feet. Select flaps not in landing configuration and verify that no warnings occur. Apply a barometric altitude loss of 50 feet to verify that Mode 3 provides warnings.

T-5 Inhibit Altitude Test

Attach GPWS test equipment, Figure 1, and adjust height above terrain to a value less than the inhibit height. Determine that the GPW function is inhibited in each Mode.

T-6 Mode 5

Attach GPWS equipment, Figure 1, and arm Mode 5, including selecting the landing gear to the landing configuration.

a) Set the test equipment height above terrain signal to 700 feet and increase the deviation below glide slope signal from zero to 300 au (4 dots) and verify that no warning occurs.

Set the test equipment height above terrain signal to 100 feet and two values between 200 feet and 400 feet. Verify that, in each case, the warning is provided as specified by Mode 5 in Appendix C.

b) Verify that the alert specified in the envelope defined for Mode 5 in Appendix C, is inhibited by the momentary closure of a switch.

c) While in the alert mode specified for Mode 5 in Appendix C, verify that Mode 5 is de-activated by changing either the landing gear or the flaps from a landing configuration to a non-landing configuration.

d) Means to re-arm Mode 5 shall be demonstrated.