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PROVISIONAL ACCEPTABLE MEANS OF COMPLIANCE

TESTING OF PRESSURE-SENSITIVE ALTIMETERS

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FOREWORD

1. The Standards in Annex 8, Airworthiness of Aircraft, are of the nature of broad specifications stating objectives rather than the methods of realizing those objectives. In order to indicate by example the level of airworthiness intended by the Standards of that Annex, some specifications of a more detailed and quantitative nature have been included in the same volume under the title "Acceptable Means of Compliance". The Foreword of Annex 8 indicates the obligation under the Convention, resulting from the introduction of Acceptable Means of Compliance.

2. When the Annex was adopted on 13 June 1957, the Standards on the subjects: Aeroplane Performance, Strength under Flight Loads, Reciprocating Engines, Turbine Engines, Propellers, and Navigation Lights were supplemented by Acceptable Means of Compliance. The absence of provisions of that type pertaining to other subjects was considered either as recognition, by the Council, that the Standards in themselves defined a sufficiently accurate level of airworthiness, or as recognition, by the Council, that due to the technical developments going on in a subject at the time of adoption, it had not yet been possible to establish a more precise technical specification than that in the Standards themselves.

3. It is the essence of the Acceptable Means of Compliance that they permi variations in overall method as well as in detailed application. Therefore, Contracting States, in establishing national codes that will ensure compliance with the Standards, will sometimes need guidance as to the departures from Acceptable Means of Compliance that are suitable for the certification of aircraft other than those specified in their Range of Validity, and also as to the use of methods developed too recently to have behind them the suitable background of experience deemed necessary for introduction of an Acceptable Means of Compliance.

4. That type of guidance material is established by ICAO as "Provisional Acceptable Means of Compliance", a class of specification that does not impose any obligation under the Convention. The Provisional Acceptable Means of Compliance are not, like the Standards or the full-fledged Acceptable Means of Compliance, established by agreement between Contracting States; instead, they reflect an agreement reached by an international body of experts to the effect that a specification is worthy of trial.

5. Trial application of Provisional Acceptable Means of Compliance in national regulations or practices is intended to build up the amount of experience that, eventually, could lead to the introduction of an Acceptable Means of Compliance on the same subject.

6. The material included in the PAMC presented in the first edition of this Circular was proposed by the Panel on Vertical Separation of Aircraft, a body of experts authorized by the Council and functioning under the Air Navigation Commission. The Panel, at its First Meeting (February 1956), prepared a specification for test of pressure

altimeters, expressing the opinion that the specification should be used on a world-wide basis at the earliest possible date. The specification has been found generally acceptable and has been adopted by several States. At its Second Meeting (June 1957), the Panel reviewed the specifications and made only minor changes in the actual tests to be completed. The Air Navigation Commission recognized that the material was of the nature of an AMC illustrating the level of airworthiness intended in requiring an approval of altimeters in para. 8.1 of Part III of Annex 8. In order to submit the specifications to trial application, the Air Navigation Commission decided to issue them in the first edition of the Circular.

7. At the Eighth Meeting of its Forty-second Session (19 February 1963) the Air Navigation Commission directed the Airworthiness Committee, a body of experts authorized by the Council and functioning under the Commission, to revise the test procedures for Type I altimeters and develop test procedures for Type II and III altimeters. Accordingly, the Airworthiness Committee, as a result of discussion at its Sixth Meeting in June 1964, produced specifications which revised the test procedures for Type I altimeters and incorporated test procedures for Type II altimeters. The Air Navigation Commission, after satisfying itself that this PAMC is properly coordinated with the Standards, the AMC and other PAMCs, and that the policies of the Organization have been followed, authorized issue of this PAMC at the Eleventh Meeting of its Forty-eighth Session, on 2 March 1965, as the second edition of this Circular. It is to be noted that, in so doing, the Air Navigation Commission did not pass judgment on, or endorse, the technical contents recommended by the Airworthiness Committee.

8. States are invited to use these specifications and to notify ICAO of the extent to which they are being applied. Should any State find it desirable or necessary to adopt any significant variations from the specifications, that State is invited to notify the Organization of such differences.

INTRODUCTION

The Panel on Vertical Separation of Aircraft was created for the purpose of investigating ways and means of ensuring adequate vertical separation of aircraft at all heights. Having agreed that some minimum level of performance should be applied to all altimeters, the Panel developed the test procedure published as a PAMC in 1957 in Circular 53-AN/48. This has been revised by the Airworthiness Committee, making use of work done subsequently by the Vertical Separation Panel and by Contracting States, in order to ensure that the performance of all altimeters that are in use today and that are likely to be in use several years hence will be consistent with the tolerances specified herein. While these tolerances do not represent the best performance attainable at the present time by many instruments, they do represent a minimum which if applied will result in a considerable overall improvement.

The test procedures contained in this revised PAMC are limited to pressure altimeters, which are called TYPE IA, IB and II, ~~while test procedures for servo-driven altimeters or altimeters with equivalent correction facilities (TYPE III) are expected to be issued as soon as sufficient and dependable data are available.~~ The general description of Type IA, IB and II follows:

TYPE I - Pressure sensitive altimeter: A. - Test Range 0-6 000 m (20 000 ft).

B. - Test Range 0-9 000 m (30 000 ft).

This type of altimeter has been commonly used on reciprocating engined aircraft. It should not be used in aircraft to be flown at heights above 9 000 m (30 000 ft), although the scale range may be above that level. For aircraft not to be flown at heights above 6 000 m (20 000 ft), less stringent tolerances are acceptable than for those to be flown above that level.

TYPE II - Precision pressure altimeter: Test Range 0-15 000 m (50 000 ft)

This altimeter is a mechanical altimeter with improved performance above that of TYPE I. Altimeters of TYPE II are made by a number of instrument manufacturers.

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1. - DEFINITIONS

1. Diaphragm Error. The error in the indication of an altimeter due to the physical properties and construction of the aneroid and linkage system, which result in a variable response in diaphragm deflection for equal changes in atmospheric pressure at different heights.

2. Hysteresis Error. The error in the indication of an altimeter introduced during an increase or decrease in height, due to the imperfectly elastic properties of the aneroid material which prevents the aneroid from assuming its normal shape for any given atmospheric pressure.

3. Drift Error. The error in the indication of an altimeter due to the recovery effect which will occur with time when the instrument is exposed to a certain pressure.

   Note.- This is variously referred to as creep, lag, after-effect or time-effect.

4. Friction Error. The error in the indication given by an altimeter due to friction in the mechanism.

5. Temperature Error. The error in the indication of an altimeter due to the effect of temperature variation on its mechanism.

6. Backlash Error. The error in the indication of an altimeter due to lost motion in the gear transmission between the height scale and the pressure scale.

7. Instability Error. The change apparent in the indication of an altimeter following consecutive ascents and descents.

   Note.- This error, being additional to the errors 1-6 and 10-11 inclusive may occur any time after the original test of the instrument is completed and consequently is outside the limits specified in tolerance curves for diaphragm and drift tests. It may be due to the variable behaviour of the instrument mechanism during the changes in pressure on different occasions and/or inaccuracies in the method of testing.

8. Readability Error. The error due to parallax effects when reading the graduations on the height scale and the pressure scale.

9.* Static Pressure System Error. The error in the indication of an altimeter due to a static pressure source which applies to the instrument a pressure other than ambient atmospheric pressure.

10. Static Balance Error. The error in the indication of an altimeter due to changes in the state of static balance of the mechanism when it is rotated from the test position to other positions.

   Note.- This error is introduced when a pressure setting other than 1013.25 mb is used, since it is caused by the rotation of the altimeter mechanism. However, this error is only applicable to instruments so constructed that the mechanism of the altimeter turns when the pressure scale is moved to a setting other than 1013.25 mb.

* Does not apply to this test procedure.

11. Coordination Error. The error in the indication of an altimeter due to inability to obtain the correct relationship between the graduation of the pressure scale and the height scale.

Note.- This error does not occur in the instruments having a fixed pressure datum.

12.* Zero Setting Error. The error in the indication of an altimeter due to the displacement of the reference pressure datum from that used during test (1013.25 mb) to some other pressure.

Note.- The use of a setting other than 1013.25 mb has the effect of altering the diaphragm plus drift tolerance.

13.* Pressure Datum Error. The error in the indication of altitude provided by an altimeter due to variation in atmospheric pressure, in time and space.

14. Tolerance. The maximum permissible deviation from a stated reference datum adopted for a particular test, a positive tolerance being a permissible deviation above this datum and a negative tolerance, being a permissible deviation below this datum.

* Does not apply to this test procedure.

2. GENERAL

2.1 Standard Atmosphere

The ICAO Standard Atmosphere (ICAO Doc 7488) shall be the reference standard.

2.2 Reference Standard Barometer

The reference standard for atmospheric pressure shall be a Mercury Barometer which is certified at least once every two years by the competent authority of the State concerned, to be accurate, with corrections, to within ± 0.2 mb. A reference barometer newly introduced into service should be checked at intervals of approximately six months, until the stability of its calibration has been established.

Note:- It should be noted that unless extreme care is taken in reading the reference barometer, the error introduced may exceed some of the tolerances specified in this test procedure.

2.3 Temperature during Tests

Unless otherwise specified all tests should be carried out in a temperature of +20°C ± 5°C. When tests are conducted with temperatures substantially different from these values, a correction shall be made for the variation from the specified condition.

2.4 Pressure Datum during Tests

Unless otherwise specified all tests shall be carried out with the pressure-scale of the altimeter set to 1013.25 mb.

2.5 Rate of Pressure Change during Tests

Unless otherwise specified the minimum rate of change in pressure during all tests shall be such as to produce the following change in height indication:

with decreasing pressure -	- 3000 feet per minute - 1000 metres per minute;
with increasing pressure -	- 6000 feet per minute - 2000 metres per minute.

This rate shall be progressively reduced as the check points are approached to avoid passing the check point. The movement of the pointer during decreasing as well as increasing pressure shall be smooth and free from irregular motion when the pressure is changed uniformly.

Note:- These rates of change in pressure have been selected to exceed slightly those normally encountered in actual flight operations.

2.6 Reading

Unless otherwise specified, each reading shall be taken within 1 minute of the time the reference pressure is reached.

Note.- The period of 1 minute has been specified to reproduce as closely as possible conditions encountered in actual flight operations.

2.7 Vibration (to minimize friction)

Unless otherwise specified, all tests shall be made with the instrument subject to vibration.

Note.- This should be of the order of 0.2 g and is, for instance, attainable with a vibration of 0.04 mm total amplitude at a frequency of 50 cycles per second. A frequency less than 50 cycles per second is not recommended.

2.8 Tests to be completed

Note.- The several individual tests specified herein are intended to ensure that the several instrument errors mentioned will be within the tolerances given by the minimum performance curves contained in Figures 1 to 6. (See also discussion in Appendix A).

2.8.1 TYPE I instruments although with a scale range of 0 - 10 000 m (0 - 35 000 ft) or 0 - 15 000 m (0 - 50 000 ft), but not intended to be used above 9 000 m (30 000 ft), shall only be tested over the range 0 - 9 000 m (0 - 30 000 ft). If an altimeter is intended to be used below 6 000 m (20 000 ft) only, the tolerances specified for TYPE I-A are acceptable, but tolerances specified for TYPE I-B desirable. The test range may, however, not exceed 6 000 m (20 000 ft). TYPE II with a scale range of 0 - 15 000 m (0 - 50 000 ft) shall be tested over the entire range.

Note.- Instruments tested only partly over the scale range shall be labelled in front of the scale with the performed test range.

2.8.2 All of the tests specified in 3.1 to 3.7 inclusive shall be completed at regular time intervals once an instrument has been introduced into service or placed in storage.

Note 1.- This interval may vary according to the overhaul schedule adopted by an operator and the performance of a particular type of instrument. New instruments will probably require more frequent testing than instruments which have been in service for some time. In relation to the maximum time interval between tests for stored instruments, the operator should be guided by the recommendation of the manufacturers.

Note 2.- The tests specified in 3.1 to 3.7 inclusive may be completed within a period of approximately one hour.

2.8.3 All of the tests specified in 3.1 to 3.8 inclusive shall be carried out:

a) by an operator as a delivery test, unless they have been completed by the manufacturer before delivery of the instrument;

b) after the diaphragm has been replaced in an instrument;

c) after an instrument has been in service for a period not exceeding five years;

d) when a comprehensive calibration curve for an instrument is to be prepared.

2.8.4 The test specified in 3.9 shall be completed by an operator as a delivery test, unless it has been completed by the manufacturer, and when any of the parts of the temperature compensating mechanism have been replaced or adjusted.

2.9 Sequence of Tests

The sequence of the tests listed is considered to be the best for testing.

3. - TEST PROCEDURE

3.1 Case Leak Test

Adjust pressure to the instrument to obtain a height indication of 5 000 metres (16 000 feet), and seal off the instrument case. The change in height indication shall not exceed 30 metres (100 feet) in a period of one minute. Turn the pressure scale knob 90° and repeat the test. Complete four tests for four positions of the knob, 90° apart.

3.2 Static Balance Test

Read the instrument when in its normal position. Rotate the instrument mechanism 90° about its longitudinal axis and take a second reading. The difference between these two readings shall not exceed 6 metres, for a metric altimeter or 20 feet, for a foot altimeter. Repeat test after rotating instrument mechanism 90° from its normal position in the opposite direction.

3.3 Setting Mark Test (where applicable)

Start the test with the pressure scale set to approximately 1020 mb then turn the pressure-scale knob to a setting of exactly 1013.25 mb and read the height indicated by the triangular setting-mark. Repeat the test starting at approximately 1000 mb. In both cases the height indicated by the triangular setting-mark shall be 0 plus or minus 5 metres (15 feet) when the pressure-scale is set to 1013.25 mb.

Note.- This test applies only to instruments in which the triangular zero setting markers are positively geared to the pressure-scale adjustment.

3.4 Co-ordination Test (See Table 1)

Position the instrument so that its face is in a horizontal plane.

Apply to the instrument a pressure of 1013.25 mb.

Adjust the pressure scale to obtain the values shown in Column 1 and read the resulting height indications. Instrument reading shall be within the range shown in Column 2 [tolerance ± 8 metres (± 25 feet)].

TABLE 1

Pressure Scale Setting mb	Instrument Reading		Pressure Scale Setting in. Hg	Instrument Reading	
	Metres	Feet		Metres	Feet
1	2	2	1	2	2
1050	+310 to +294	+1014 to +964	31.0	+307 to +292	+1008 to +958
1013.25	+8 to -8	+25 to -25	29.92	+8 to -8	+25 to -25
930	-709 to -725	-2328 to -2378	29.4	-140 to -156	-461 to -511
850	-1449 to -1465	-4756 to -4806	28.2	-490 to -505	-1605 to -1655

3. 5 Backlash Test

This test shall be made without vibration.

Turn the pressure-scale knob in a clockwise direction to change the setting a few millibars and note the height indication. Slowly turn the knob in an anti-clockwise direction 0. 5 mb and observe whether or not the height indicator also moves. This change of setting 0. 5 mb on the pressure scale shall result in a noticeable movement of the height indicator.

3. 6 Friction Test

3. 6. 1 Friction Test No. 1 (See Table 2)

Adjust pressure to the value corresponding to the first height shown in Column 1 of Table 2. Read the instrument. Then decrease pressure to provide a change in indication of 500 metres for metric altimeters(1 000 feet for foot altimeters) and then immediately increase the pressure to its initial value. The instrument shall then be read a second time. The difference in height indication between these two readings shall not exceed the figures specified in Column 2. The pressure shall be set without any overshoot of the barometer mercury column. Repeat this procedure for each of the check points shown in Column 1.

TABLE 2

Altimeter graduated in			
Metres		Feet	
Height in metres Standard Atmosphere	Maximum deviation in metres	Height in feet Standard Atmosphere	Maximum deviation in feet
1	2	1	2
0	5	0	20
3 000	10	10 000	30
6 000	15	20 000	50
9 000	20	30 000	70
12 000	30	40 000	100
15 000	45	50 000	150

Hold pressure at top level. This level shall be used as starting point for the following test in paragraph 3. 6. 2.

3.6.2 Friction Test No. 2 (See Table 3)

Part of this test is carried out without vibrating the instrument. With no vibration applied, adjust the pressure until it has reached a value corresponding to the first height shown in Column 1. Read the instrument. Apply vibration and take a second reading. Repeat this procedure for each of the heights shown in Column 1. The difference between the two height indications, before and after vibration, is a measure of the friction between aneroids and height indicators, and shall not exceed the figures listed in Column 2, Table 3.

TABLE 3

Altimeters graduated in					
Metres			Feet		
Height in metres Standard Atmosphere	Maximum deviation in metres TYPE I	TYPE II	Height in feet Standard Atmosphere	Maximum deviation in feet TYPE I	TYPE II
1	2		1	2	
15 000	-	75	50 000	-	250
12 000	-	55	40 000	-	180
9 000	55	40	30 000	180	130
6 000	40	30	20 000	125	100
3 000	30	25	10 000	100	80
0	20	20	0	70	70

3.7 Diaphragm Test (See Tables 4-A and 4-B)

Starting with a height indication of -600 m (-2 000 ft) the pressure shall be decreased and consecutive height readings taken at pressures corresponding to each of the height check points shown in Column 1. The pressure shall be applied without overshoot of the barometer mercury column.

The instrument reading shall be within the range specified in columns 2, 3 or 4, whichever is applicable.

When the test is completed and the pressure is increasing no readings shall be taken but the movement of the height indicators shall be checked for smooth operation.

TABLE 4-A

Altimeters graduated in metres			
Height in Standard Atmosphere	TYPE I-A	TYPE I-B	TYPE II
1	2	3	4
-600(x)	No reading	No reading	No reading
0	-20 to 0	-15 to 0	-12 to 0
300	280 to 300	285 to 300	285 to 305
900	875 to 900	885 to 900	885 to 310
1 800	1 770 to 1 800	1 780 to 1 800	1 780 to 1 810
3 000	2 955 to 3 000	2 970 to 3 000	2 975 to 3 010
4 500	4 430 to 4 500	4 455 to 4 500	4 470 to 4 510
6 000	5 910 to 6 010	5 940 to 6 010	5 960 to 6 010
9 000	- -	8 910 to 9 050	8 945 to 9 025
12 000	- -	- -	11 930 to 12 040
15 000	- -	- -	14 915 to 15 055
-600(x)	No reading	No reading	No reading
-150	-150 to -170	-150 to -165	-150 to -162
0	-20 to 0	-15 to 0	-12 to 0

(x) These check points apply only to altimeters to be used in pressurized aircraft. For altimeters to be used in non-pressurized aircraft -600 metres should be changed to -300 metres.

TABLE 4-B

Altimeters graduated in feet			
Height in Standard Atmosphere	TYPE I-A	TYPE I-B	TYPE II
1	2	3	4
-2 000(x)	No reading	No reading	No reading
0	-65 to 0	-50 to 0	-40 to 0
1 000	935 to 1 000	950 to 1 000	960 to 1 010
3 000	2 915 to 3 000	2 950 to 3 000	2 955 to 3 025
6 000	5 890 to 6 000	5 935 to 6 000	5 940 to 6 025
10 000	9 850 to 10 000	9 900 to 10 000	9 920 to 10 025
15 000	14 775 to 15 000	14 850 to 15 000	14 895 to 15 025
20 000	19 700 to 20 025	19 800 to 20 020	19 870 to 20 030
30 000	- -	29 700 to 30 125	29 820 to 30 080
40 000	- -	- -	39 770 to 40 130
50 000	- -	- -	49 720 to 50 180
-2 000(x)	No reading	No reading	No reading
-500	-500 to -565	-500 to -550	-500 to -540
0	-65 to 0	-50 to 0	-40 to 0

(x) These check points apply only to altimeters to be used in pressurized aircraft. For altimeters to be used in non-pressurized aircraft -2 000 feet should be changed to -1 000 feet.

3.8 Drift Test (including Hysteresis) (See Tables 5-A, 5-B and 5-C)

Adjust pressure in accordance with 2.5 to a value equivalent to the height (Standard Atmosphere) shown in Column 2 for check point Number 1. Read the height indication within the prescribed 1 minute period and then reduce pressure to that called for at check point Number 2. Continue and obtain readings for check points 3 and 4. Hold the pressure for check point 4 for a period of 4 hours and then take a second reading (check point 5). Continue to hold the pressure for check point 4 for an additional two hours (total period 6 hours) and then take a third reading (check point 6). Between check points 4 and 5 and between 5 and 6, the pressure shall be maintained at the prescribed value as closely as is practicable but the variation in pressure shall not exceed the equivalent of ±300 m (±1 000 feet) in height. Before taking readings at check points 5 and 6, the pressure shall be adjusted to the prescribed test value by reducing pressure and not by increasing it. Increase pressure and take readings at check points 7 and 8 within the prescribed 1 minute period.

The difference in height indications obtained for the same pressure shall not exceed the values shown in Column 3 of Table 5.

TABLE 5-A (TYPE I-A)

Check Point Number and Time Interval	Height Standard Atmosphere Metres	Feet	Maximum deviation between two height indications obtained for same atmospheric pressure
1	2		3
1 (1 Minute)	-600(x)	-2 000(x)	
2 (1 Minute)	0	0	
3 (1 Minute)	3 000	10 000	20 m (65 ft)
4 (1 Minute)	6 000	20 000	45 m (150 ft); 45 m (150 ft)
5 (4 hours)(xx)	6 000	20 000	20 m (65 ft)
6 (2 hours)	6 000	20 000	
7 (1 Minute)	3 000	10 000	
8 (1 Minute)	0	0	

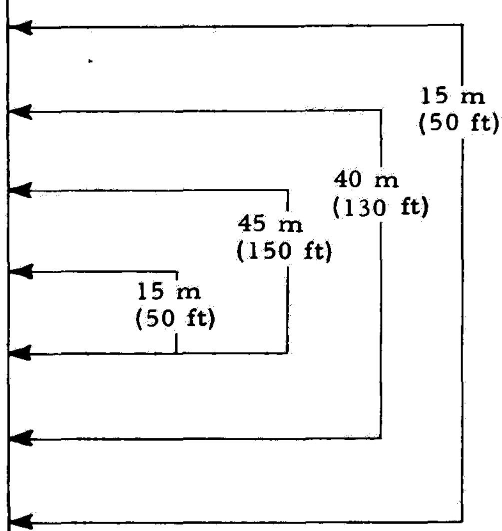
Note.- The time interval shown after each check point number is the time the test pressure should be held before it is changed to that of the next check point.

(x) This check point applies only altimeters to be used in pressurized aircraft. For altimeters to be used in non-pressurized aircraft only, starting point shall be 300 metres (1 000 feet).

(xx) If a maximum deviation of 45 metres (150 feet) has not been exceeded in 4 hours and no significant change has occurred during the last 30 minutes check point 6 may be omitted.

TABLE 5-B (TYPE I-B)

Check Point Number and Time Interval	Height Standard Atmosphere Metres	Feet	Maximum deviation between two height indications obtained for same atmospheric pressure
1	2		3
1 (1 Minute)	-600(x)	-2 000(x)	
2 (1 Minute)	0	0	
3 (1 Minute)	4 500	15 000	
4 (1 Minute)	9 000	30 000	
5 (4 hours)(xx)	9 000	30 000	
6 (2 hours)	9 000	30 000	
7 (1 Minute)	4 500	15 000	
8 (1 Minute)	0	0	



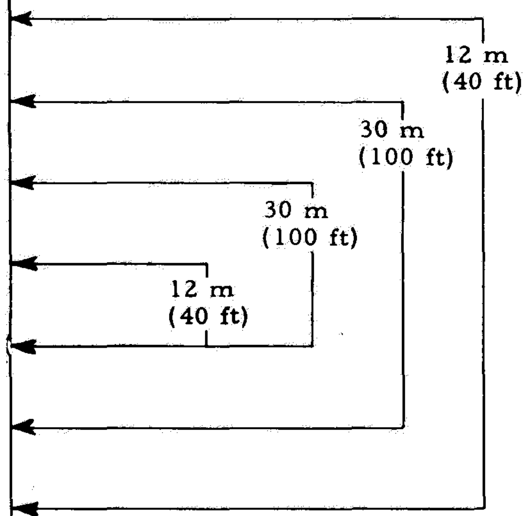
Note.- The time interval shown after each check point number is the time the test pressure should be held before it is changed to that of the next check point.

(x) This check point applies only to altimeters to be used in pressurized aircraft. For altimeters made to be used in non-pressurized aircraft only, starting point shall be 300 metres (1 000 feet).

(xx) If a maximum deviation of 45 metres (150 feet) has not been exceeded in 4 hours and no significant change has occurred during the last 30 minutes check point 6 may be omitted.

TABLE 5-C (TYPE II)

Check Point Number and Time Interval	Height Standard Atmosphere Metres	Feet	Maximum deviation between two height indications obtained for same atmospheric pressure
1	2		3
1 (1 Minute)	-600	-2 000	
2 (1 Minute)	0	0	
3 (1 Minute)	7 500	25 000	
4 (1 Minute)	15 000	50 000(x)	
5 (4 hours)(xx)	15 000	50 000	
6 (2 hours)	15 000	50 000	
7 (1 Minute)	7 500	25 000	
8 (1 Minute)	0	0	



Note.- The time interval shown after each check point number is the time the test pressure should be held before it is changed to that of the next check point.

(x) If the altimeter is not used above 13 500 metres (45 000 feet), check points 4, 5 and 6 may be taken at 13 500 metres (45 000 feet) instead of 15 000 metres (50 000 feet).

(xx) If a maximum deviation of 30 metres (100 feet) has not been exceeded in 4 hours and no significant change has occurred during the last 30 minutes, check point 6 may be omitted.

3.9 Temperature Test (See Tables 6-A and 6-B)

3.9.1 Low Temperature Test

Repeat the diaphragm test specified in 3.7, except that the temperature of the altimeter during this test shall be -30° C. The test points shall be in accordance with Table 6-A or 6-B. The instrument reading shall be within the range specified in columns 2, 3 or 4, whichever is applicable.

TABLE 6-A

Altimeters graduated in metres			
Height in metres Standard Atmosphere	TYPE I-A	TYPE I-B	TYPE II
1	2	3	4
0	-35 to 15	-30 to 15	-25 to 10
3 000	2 710 to 3 045	2 945 to 3 020	2 960 to 3 025
6 000	5 820 to 6 100	5 895 to 6 055	5 930 to 6 040
9 000		8 840 to 9 120	8 900 to 9 070
12 000			11 870 to 12 100
15 000			14 840 to 15 130

TABLE 6-B

Altimeters graduated in feet			
Height in feet Standard Atmosphere	TYPE I-A	TYPE I-B	TYPE II
1	2	3	4
0	-115 to 50	-100 to 50	-70 to 30
10 000	9 700 to 10 150	9 825 to 10 075	9 870 to 10 075
20 000	19 400 to 20 325	19 650 to 20 170	19 770 to 20 130
30 000		29 475 to 30 350	29 670 to 30 230
40 000			39 570 to 40 330
50 000			49 470 to 50 430

3.9.2 High Temperature Test

Record the height indications and place the altimeter in a temperature test chamber. Adjust and maintain the temperature at +60°C. After a period of one hour check the height indication. The difference in reading shall not exceed 6 metres (20 feet).

Note.- This test is a maintenance check of the compensation stability and need be applied only during the period between consecutive low temperature tests.

3.10 Pre-flight Operational Test

The following test shall be carried out in an aircraft by flight crew members prior to the commencement of a flight.

3.10.1 Flight crews shall be advised of the purpose of the test and the manner in which it shall be carried out and shall be given specific instructions on the action to be taken in accordance with the results of the test.

3.10.2 QNH Setting

With the aircraft at a known elevation on the aerodrome, set the altimeter pressure scale to the current QNH setting. Vibrate the instrument by tapping unless mechanical vibration is provided. A serviceable altimeter will indicate the elevation of the point selected, plus the height of the altimeter above this point, within a tolerance of plus or minus 20 metres or 60 feet (± 2.0 mb) for altimeters with a test range of 0 to 9 000 metres and 0 to 30 000 feet and plus or minus 25 metres or 80 feet for altimeters with a test range of 0 to 15 000 metres and 0 to 50 000 feet.

3.10.3 QFE Setting

With the aircraft at a known elevation on the aerodrome set altimeter pressure-scale to the current QFE. Vibrate the instrument by tapping unless mechanical vibration is provided. A serviceable altimeter will indicate the height of the altimeter in relation to the QFE reference point, within a tolerance of plus or minus 20 metres or 60 feet (± 2.0 mb) for altimeters with a test range of 0 to 9 000 metres and 0 to 30 000 feet and plus or minus 25 metres or 80 feet for altimeters with a test range of 0 to 15 000 metres and 0 to 50 000 feet.

Note 1.- When the altimeter does not indicate the reference elevation or height exactly, but is within the specified tolerances, no adjustment of this indication should be made either by means of the pressure adjustment knob or other adjustment on the altimeter at any stage of a flight. Furthermore, any error that is within tolerance noted during pre-flight check on the ground should be ignored by the pilot during flight.

Note 2.- The tolerance of 20 metres or 60 feet (± 2.0 mb) for altimeters with a test range of 0 to 9 000 metres (0 to 30 000 feet) is considered acceptable for aerodromes having elevations up to 1 100 metres (3 600 feet) (Standard atmospheric pressure). Table 7-A indicates the permissible range for aerodromes having different elevations, when the atmospheric pressure at an aerodrome is lower than standard, i.e. when the QNH setting is as low as 950 mb.

Note 3.- The tolerance of 25 metres (80 feet) (±2.0 mb) for altimeters with a test range of 0 to 15 000 metres (0 to 50 000 feet) is considered acceptable for aerodromes having elevation up to 1 100 metres (3 600 feet) (Standard atmospheric pressure). Table 7-B indicates the permissible range for aerodromes having different elevations, when the atmospheric pressure at an aerodrome is lower than standard, i.e. when the QNH setting is as low as 950 mb.

TABLE 7-A

Elevation of the aerodrome (metres)	Permissible range	Elevation of the aerodrome (feet)	Permissible range
600	581.5 to 618.5	2 000	1 940 to 2 060
900	878.5 to 921.5	3 000	2 930 to 3 070
1 200	1 177 to 1 223	4 000	3 925 to 4 075
1 500	1 475.5 to 1 524.5	5 000	4 920 to 5 080
1 850	1 824 to 1 876	6 000	5 915 to 6 085
2 150	2 121 to 2 179	7 000	6 905 to 7 095
2 450	2 418 to 2 482	8 000	7 895 to 8 105
2 750	2 715 to 2 785	9 000	8 885 to 9 115
3 050	3 012 to 3 088	10 000	9 875 to 10 125
3 350	3 309 to 3 391	11 000	10 865 to 11 135
3 650	3 606 to 3 694	12 000	11 855 to 12 145
3 950	3 903 to 3 997	13 000	12 845 to 13 155
4 250	4 199.5 to 4 300.5	14 000	13 835 to 14 165
4 550	4 496.5 to 4 603.5	15 000	14 825 to 15 175

TABLE 7-B

Elevation of the aerodrome (metres)	Permissible range	Elevation of the aerodrome (feet)	Permissible range
600	569.5 to 630.5	2 000	1 900 to 2 100
900	868 to 932	3 000	2 895 to 3 105
1 200	1 165 to 1 235	4 000	3 885 to 4 115
1 500	1 462 to 1 538	5 000	4 875 to 5 125
1 850	1 809 to 1 891	6 000	5 865 to 6 135
2 150	2 106 to 2 194	7 000	6 855 to 7 145
2 450	2 403 to 2 497	8 000	7 845 to 8 155
2 750	2 699.5 to 2 800.5	9 000	8 835 to 9 165
3 050	2 996.5 to 3 103.5	10 000	9 825 to 10 175
3 350	3 293.5 to 3 406.5	11 000	10 815 to 11 185
3 650	3 590.5 to 3 709.5	12 000	11 805 to 12 195
3 950	3 887.5 to 4 012.5	13 000	12 795 to 13 205
4 250	4 184.5 to 4 315.5	14 000	13 785 to 14 215
4 550	4 481.5 to 4 618.5	15 000	14 775 to 15 225

FIGURE 1

MINIMUM PERFORMANCE CURVES

ALTIMETER TYPE I-A (METRES)

Ordinates AB - Maximum tolerance during decreasing pressure.

Ordinates AC - Maximum tolerance during increasing pressure subsequent to a decrease i.e. the total permissible tolerances including hysteresis and drift.

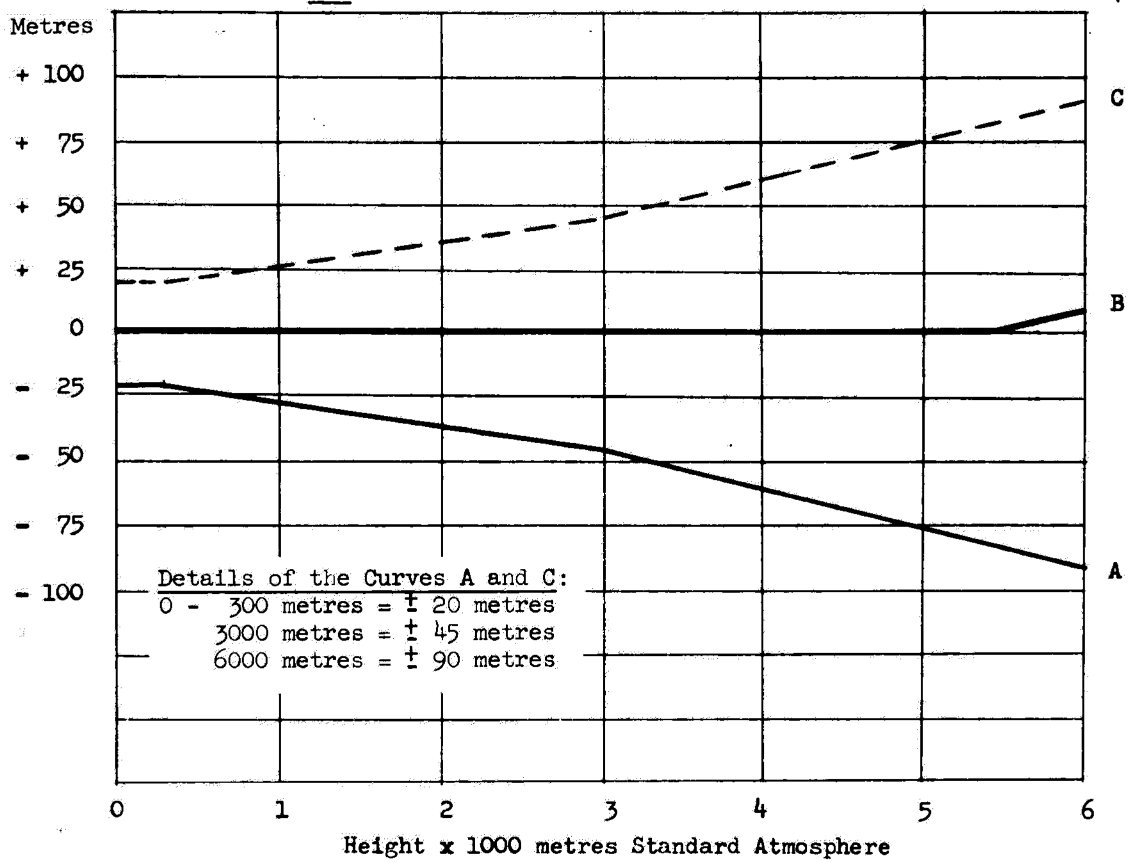


FIGURE 2

MINIMUM PERFORMANCE CURVES

ALTIMETER TYPE I-A (FEET)

Ordinates AB - Maximum tolerance during decreasing pressure.

Ordinates AC - Maximum tolerance during increasing pressure subsequent to a decrease i.e. the total permissible tolerances, including hysteresis and drift.

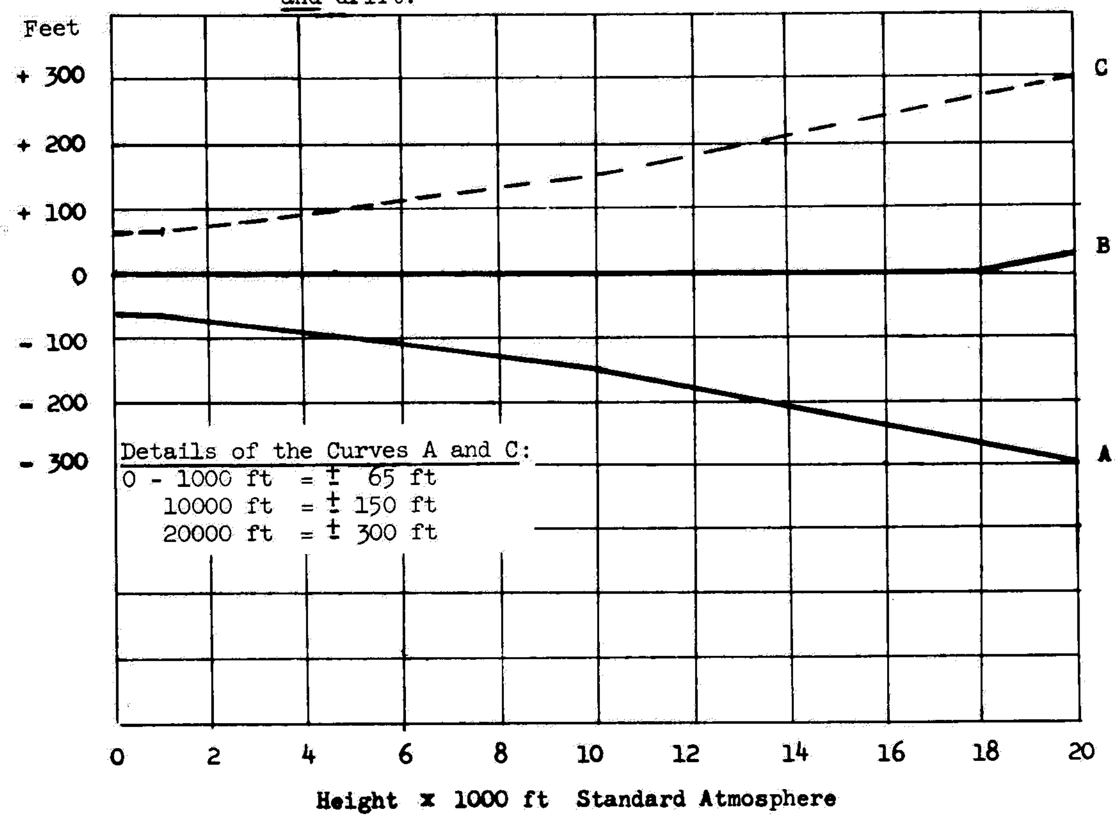


FIGURE 3

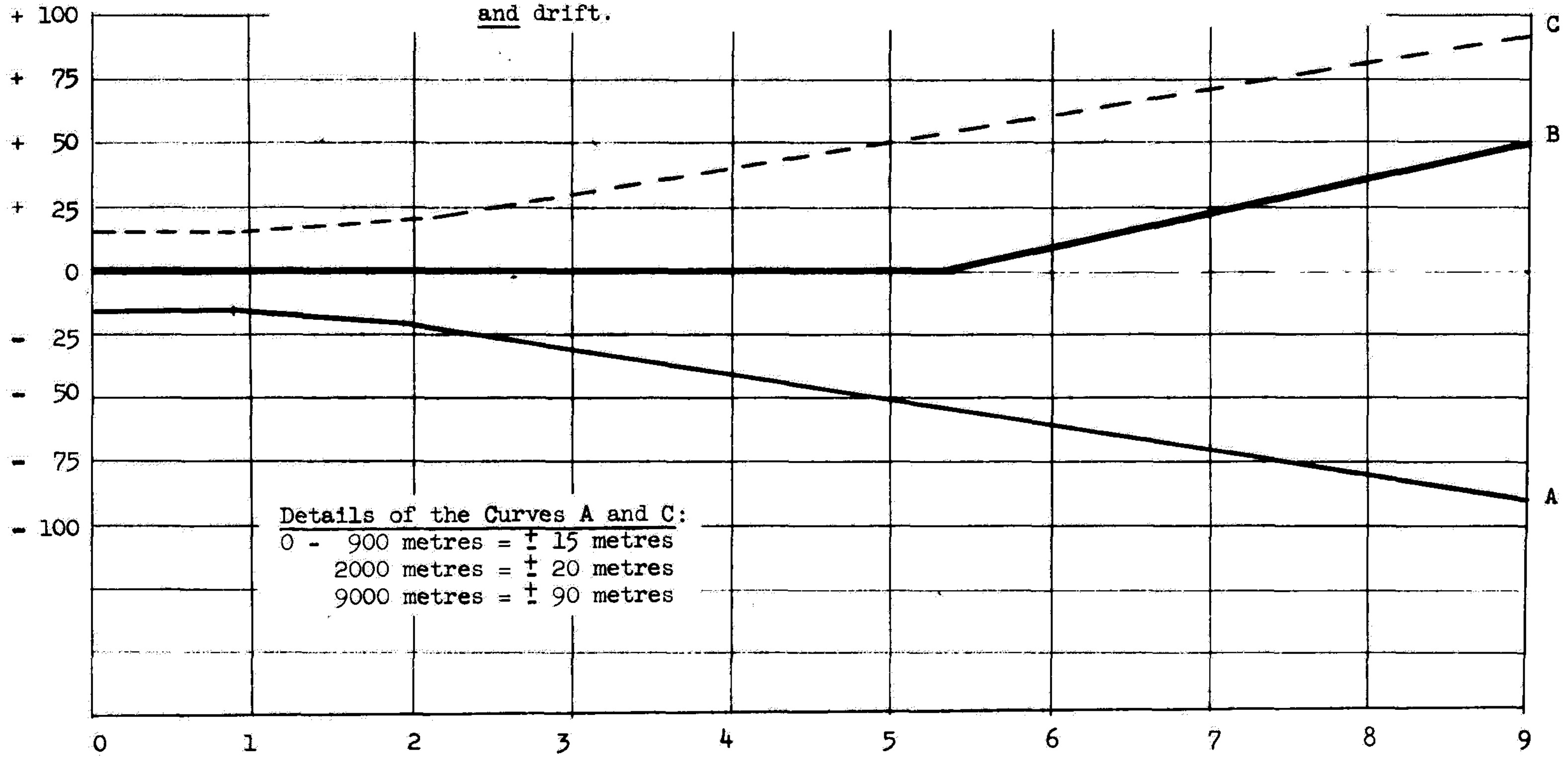
MINIMUM PERFORMANCE CURVES

ALTIMETER TYPE I-B (METRES)

Ordinates AB-Maximum tolerance during decreasing pressure.

Ordinates AC-Maximum tolerance during increasing pressure subsequent to a decrease i.e. total permissible tolerances including hysteresis and drift.

Metres



Height x 1000 metres Standard Atmosphere

FIGURE 4

MINIMUM PERFORMANCE CURVES

ALTIMETER TYPE I-B (FEET)

Ordinates AB - Maximum tolerance during decreasing pressure.

Ordinates AC - Maximum tolerance during increasing pressure subsequent to a decrease i.e. the total permissible tolerances, including hysteresis and drift.

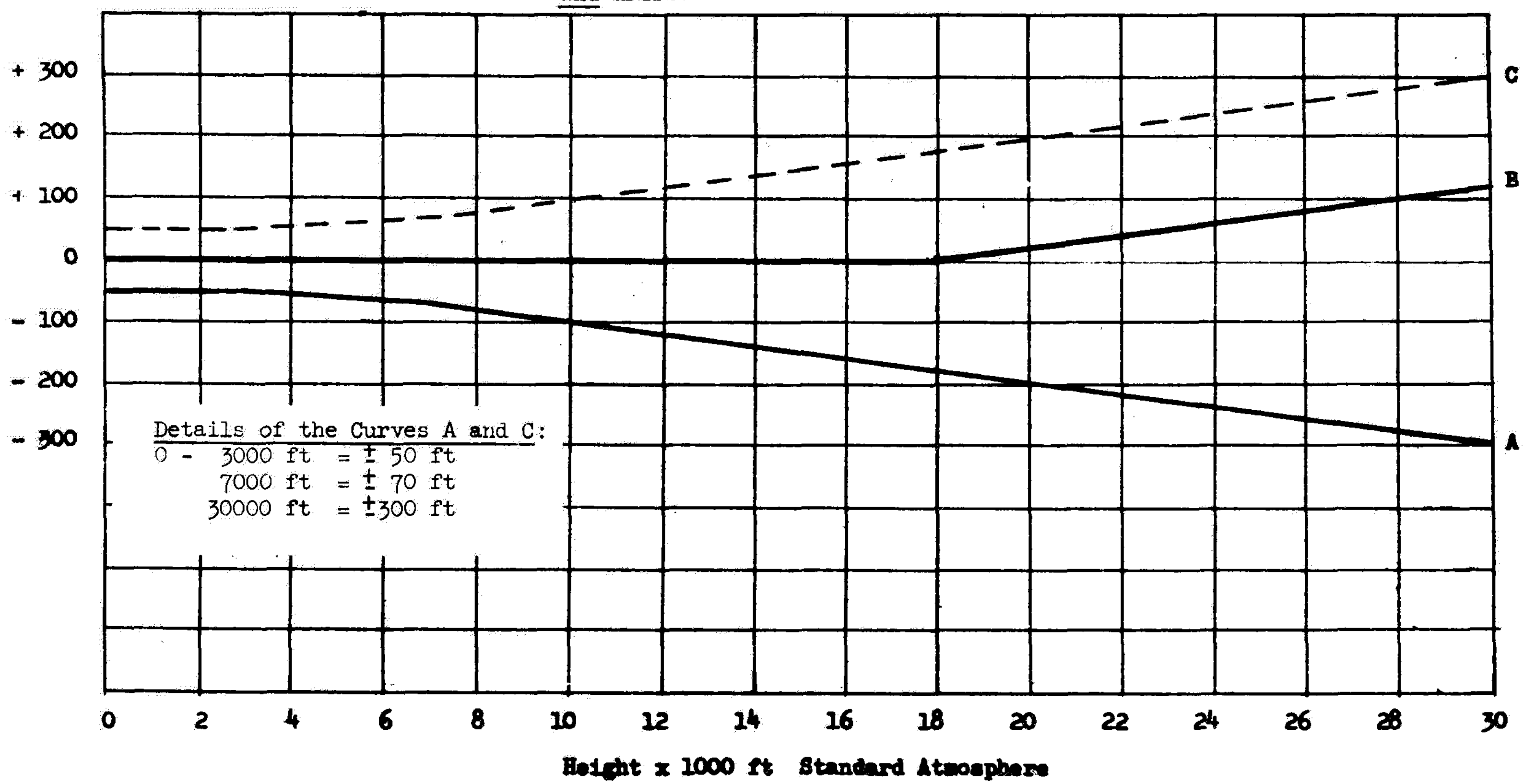


FIGURE 5

MINIMUM PERFORMANCE CURVES

ALTIMETER TYPE II (METRES)

Ordinates AB - Maximum tolerance during decreasing pressure.

Ordinates AC - Maximum tolerance during increasing pressure subsequent to a decrease i.e. the total permissible tolerances including hysteresis and drift.

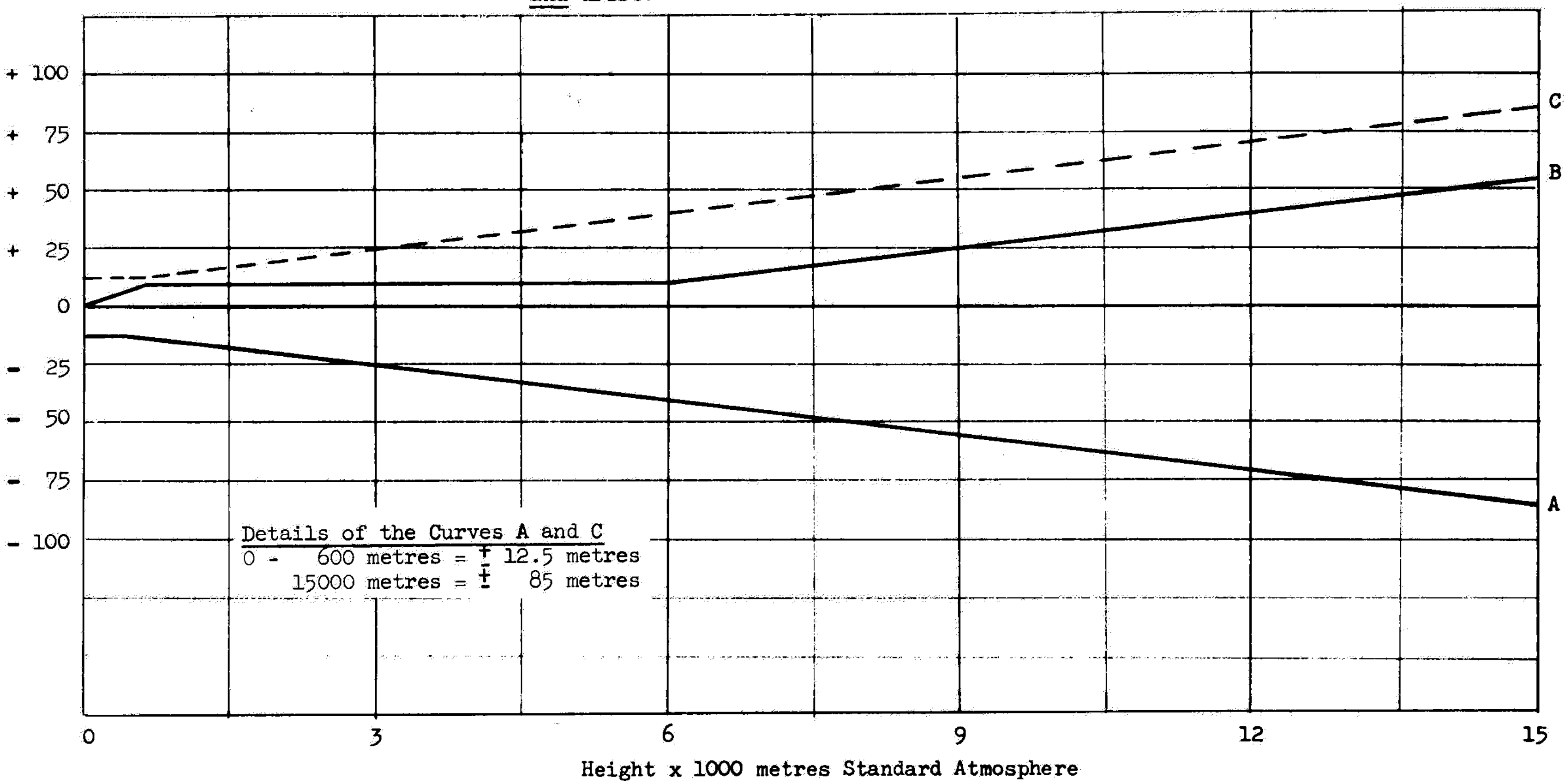


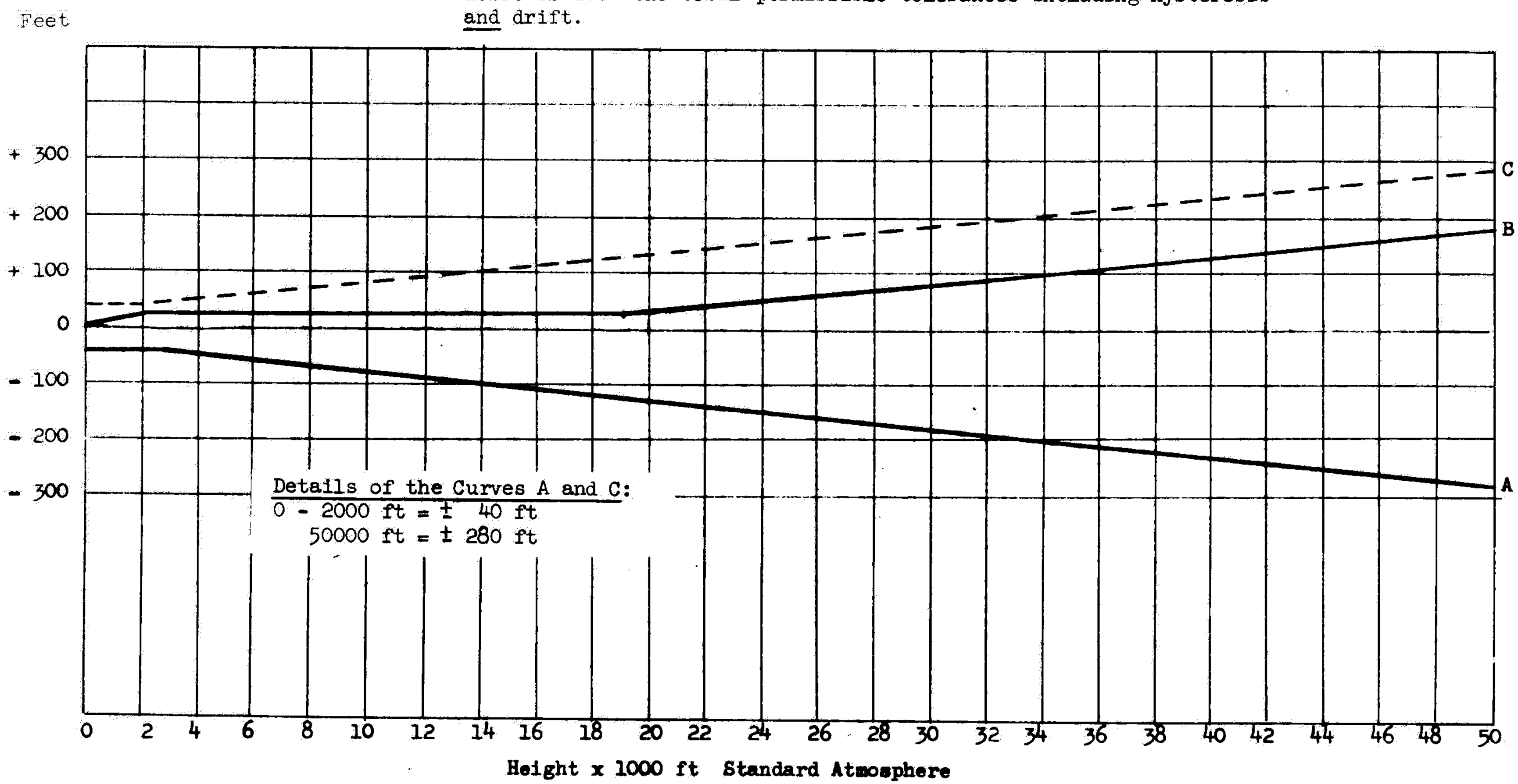
FIGURE 6

MINIMUM PERFORMANCE CURVES

ALTIMETER TYPE II (FEET)

Ordinates AB - Maximum tolerance during decreasing pressure.

Ordinates AC - Maximum tolerance during increasing pressure subsequent to a decrease i.e. the total permissible tolerances including hysteresis and drift.



APPENDIX A

Calibration Curves

Preparation of Calibration Curve (See Figure A-1)

1. When a high degree of accuracy is required in the height indication of an altimeter, e. g., when an altimeter is to be used for obtaining D-values* a calibration curve may be prepared indicating the actual diaphragm and drift errors for a particular instrument which in turn may be used to prepare a correction table for use in flight.

2. Such a calibration curve may be produced by carrying out the tests specified in 3. 7, diaphragm test, and 3. 8, drift test or some suitable combination of these two tests. The greater the number of check points, the more complete will be the curve. A curve may be produced from readings taken both during decreasing pressure and increasing pressure or from readings taken only during decreasing pressure, the former providing the more accurate curve.

3. When a curve is based on both increasing pressure and decreasing pressure, that part of the curve drawn during decreasing pressure may resemble that shown as "A" in Figure A-1. During the time the pressure is held at 9 000 m (30 000 ft) (Standard Atmosphere) this curve will rise vertically to the origin of Curve B which represents the type of curve which may be obtained during increasing pressure. Since, in flight, there is no way of knowing for sure which of these two curves should be used at a particular time, the best reference obtainable is a mean of Curves A and B. In actual operation, the altimeter indications tend to lie in the vicinity of this mean curve, hence its use is considered quite acceptable.

4. When a calibration curve is based only on decreasing pressure and only Curve A is obtained, a useful approximation of Curve B may be derived by adding 1/2 the positive tolerance shown to Curve A to produce Curve C. For example at 9 000 m, 1/2 of 90 m (45 m) [30 000 ft, 1/2 of 300 ft (150 ft)] is added to 30 m (100 ft) on Curve A to produce 75 m (250 ft) a point on Curve C; at 4 800 m (16 000 ft), 1/2 of 48 m (24 m) [160 ft (80 ft)] is added to -30 m (-100 ft) to produce -6m (-20 ft) another point on Curve C. In this instance the mean curve will be the mean between Curves A and C.

---

* D-Value - "The amount (positive or negative) by which the altitude (Z) of a point on an isobaric surface differs from the altitude(Z_p) of the same isobaric surface in the ICAO standard atmosphere (i.e. D-value = $Z - Z_p$)." (Annex 3)

Use of Calibration Curves

1. In order that the information provided by a calibration curve may be readily usable by flight crews, it must be converted into either an altimeter correction curve or correction table. Such a curve or table will indicate the numerical value to be added algebraically to the altimeter indication, and it should be noted that the corrections to be added to the altimeter indication will be opposite in sign to the errors taken from the mean calibration curve.

2. Such a correction curve or table might well also incorporate additional corrections to account for other known errors such as those introduced by the static pressure system.

Figure A-1

PREPARATION OF CALIBRATION CURVE

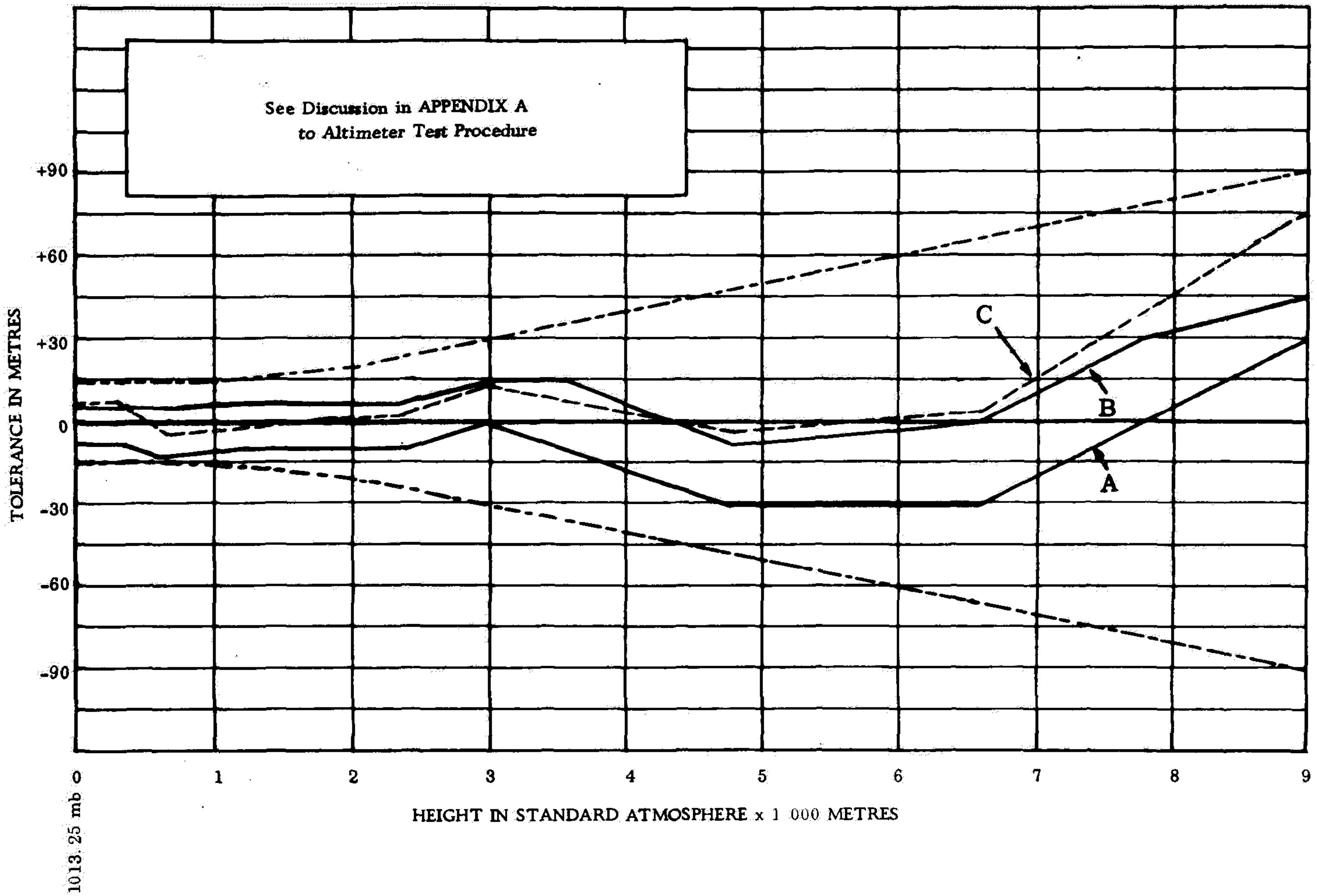
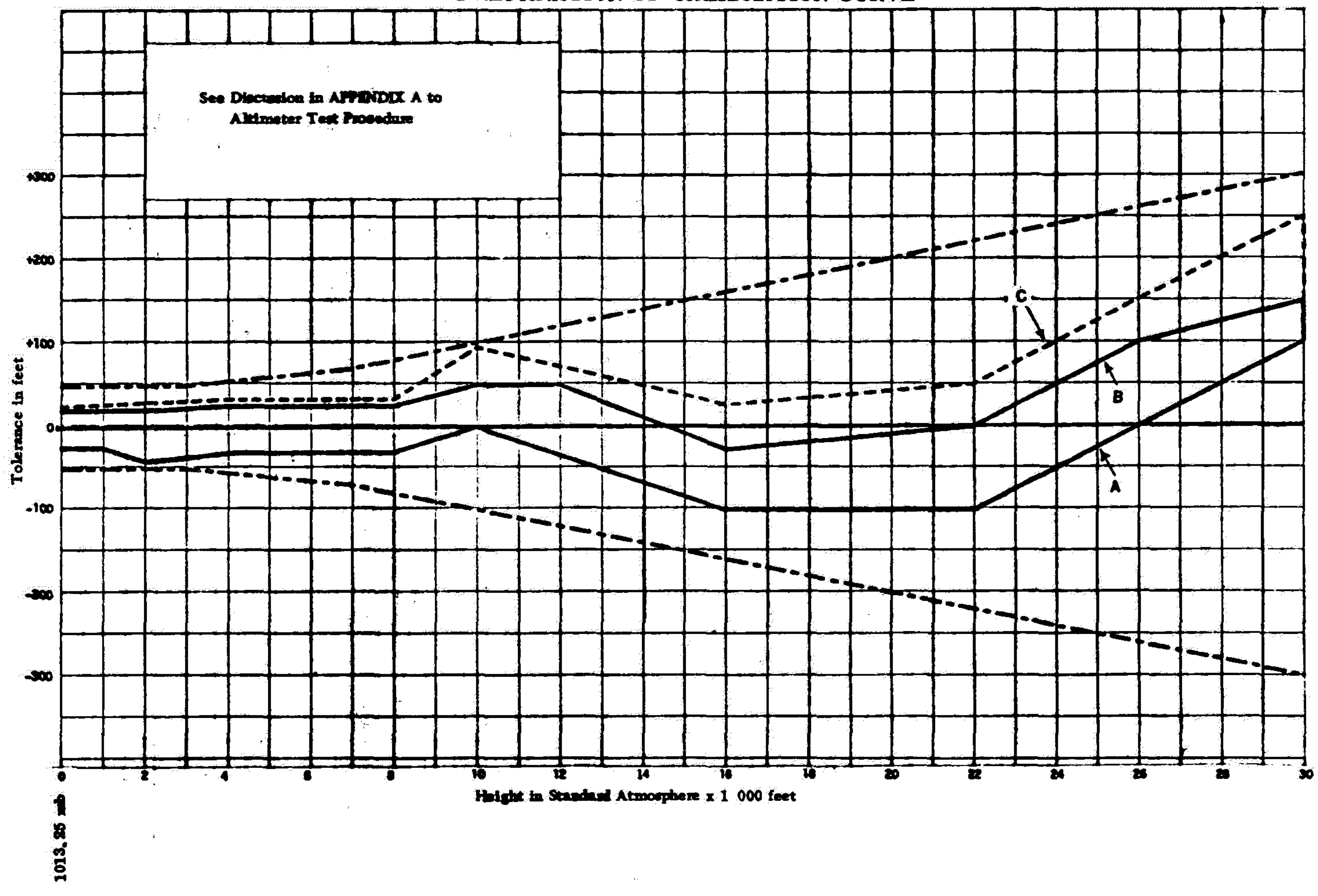


Figure A-1

PREPARATION OF CALIBRATION CURVE



APPENDIX B

1. The particular tests specified in this procedure are intended to ensure that, as far as is possible, in actual flight operations a symmetrical distribution of instrument errors will be obtained for decreasing and increasing pressure, i.e. that such errors will fall within the symmetrical minimum performance curves given in Figures 1-6 of the test procedure.

2. This is achieved by using a non-symmetrical minimum performance curve for the diaphragm test during decreasing pressure. In this regard it will be noted that in the diaphragm test specified in 3.7, the tolerances for the lower heights during decreasing pressure are negative hence the resulting minimum performance curve for this test will be non-symmetrical.

3. Figure B-1 illustrates the calibration curves obtained when this principle is applied, Curve A being that obtained during decreasing pressure and Curve B that obtained during increasing pressure. It will be noted that Curve A starts with a negative error of -9 m (-30 ft), the curve is completed by reducing pressure to the point equivalent to 9 000 m (30 000 ft). On reaching this point the pressure is immediately increased and Curve B is the calibration curve obtained during increasing pressure. It will be noted that both Curves A and B are within the minimum performance curves specified and that Curve B, in reaching the pressure of 1013.25 mb, indicates an error of +6 m (+20 ft).

Figure B-1

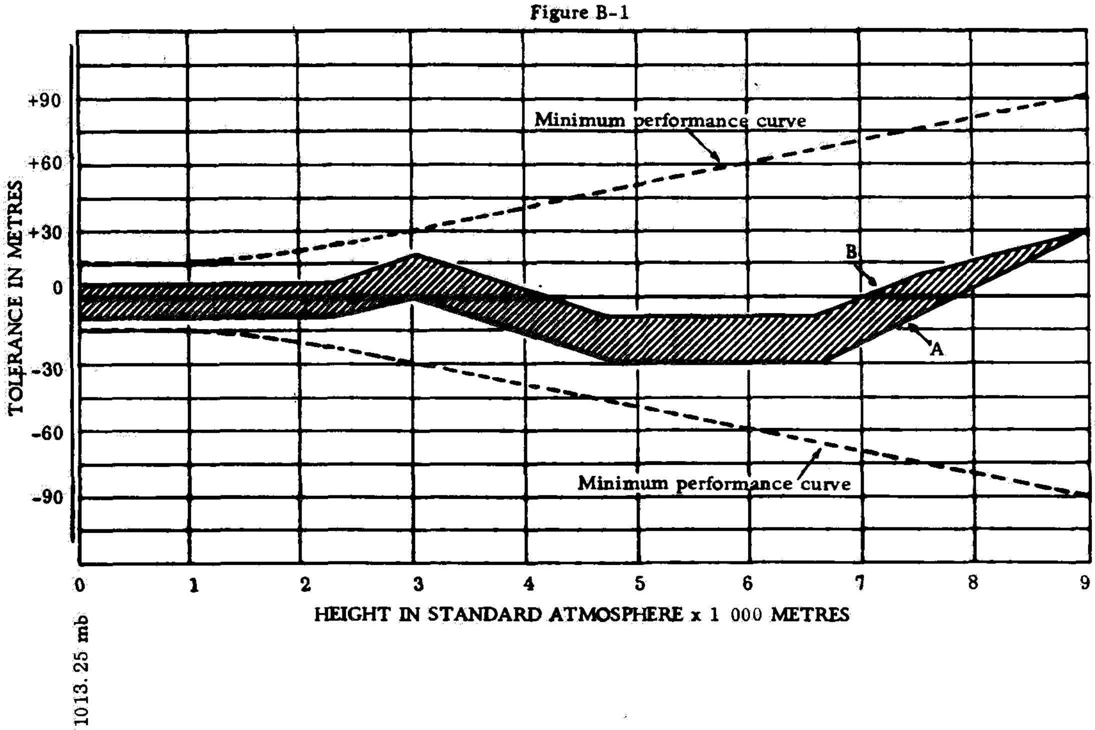
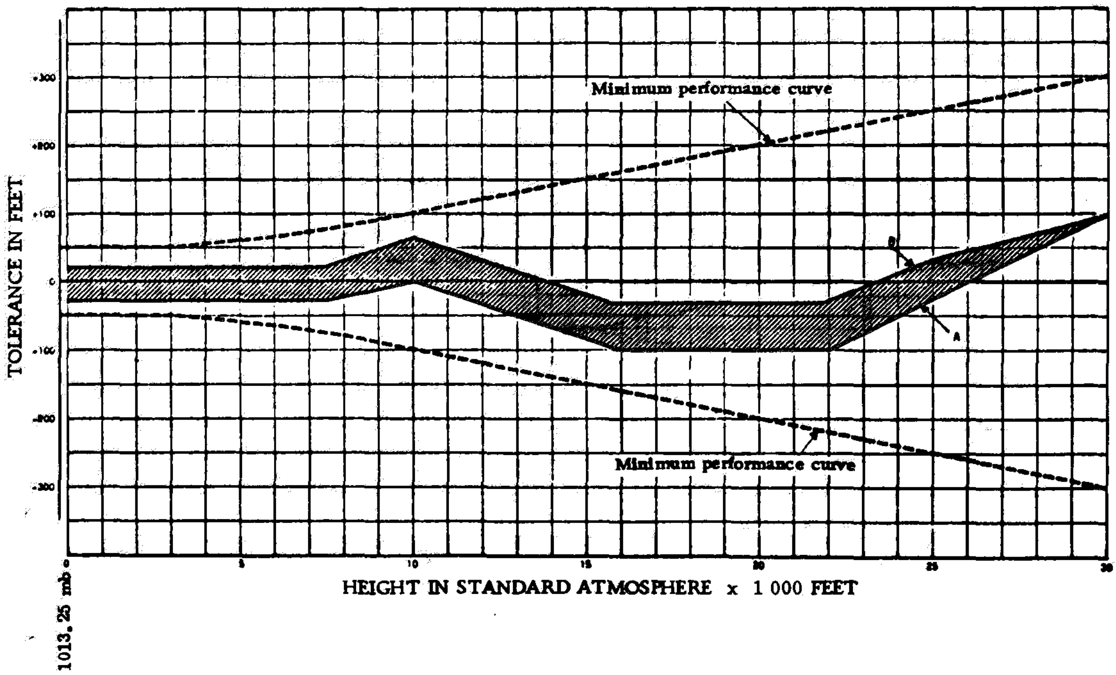


Figure B-1



4. Figure B-2 illustrates the type of calibration curves obtained when completing exactly the same test, except that the tolerances permitted in the diaphragm test are plus and minus and in this example it has been assumed that Curve A starts with an error of +6 m (+20 ft). Curve A is obtained in the same manner by decreasing pressure and Curve B with increasing pressure, but in this instance it will be noted that on returning to a pressure of 1013.25 mb, Curve B indicates an error of +21 m (+70 ft), i.e. the altimeter indication will be 21 m (70 ft) too high.

5. The difference between the Curves A and B in Figure B-1 and B-2 is due to hysteresis and possibly friction in the temperature compensating pins.

Test Procedure to Determine Drift

6. Figures B-1 andB-2 illustrate why negative tolerances are specified for the diaphragm test and Figures B-3 and B-4 indicate why neither of these tests, in itself, reflects actual operating conditions, in view of the fact that during normal operations an aircraft will not climb to a cruising altitude and then immediately descend, as indicated in Figures B-1 and B-2, but will cruise at the top for a considerable period of time. This should be reflected in the test procedure.

7. In Figure B-3, which is comparable with Figure B-1, Curve A is obtained during decreasing pressure in the same manner. However, on reaching the pressure corresponding to 9 000 m (30 000 ft), the pressure is maintained at this value for a period of 6 hours and as indicated in Figure B-3, during this time the recovery of the diaphragm results in drift in the direction of the positive tolerance curve. At the end of the 6 hour period the pressure is increased to obtain the calibration Curve B which terminates at a pressure of 1013.25 mb with an error of +6 m (20 ft). In this instance it will be noted that both Curves A and B are within the minimum performance curves specified for increasing and decreasing pressure.

Figure B-2

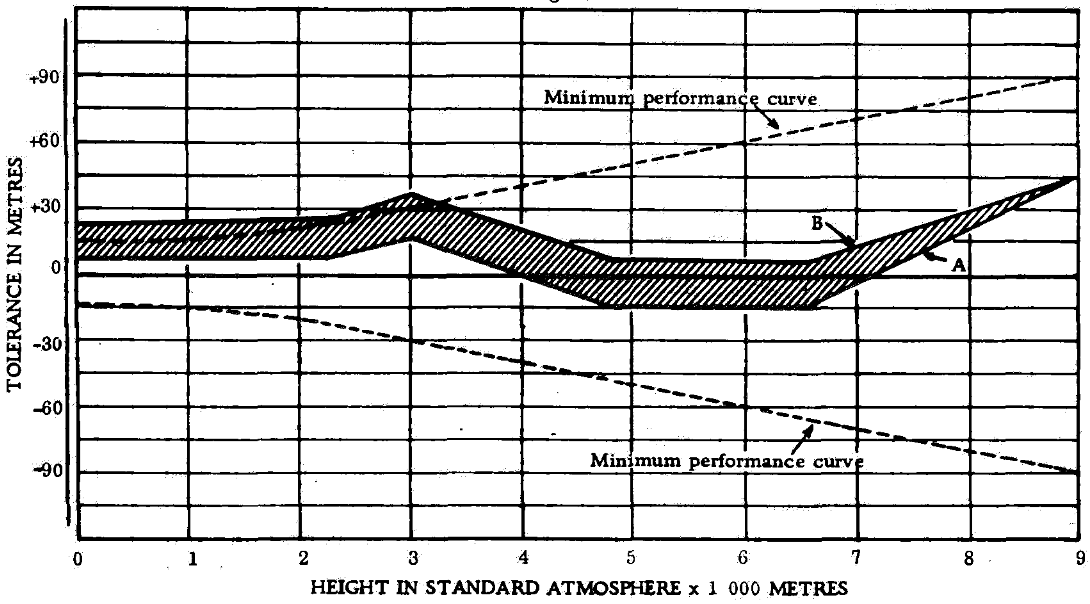


Figure B-2

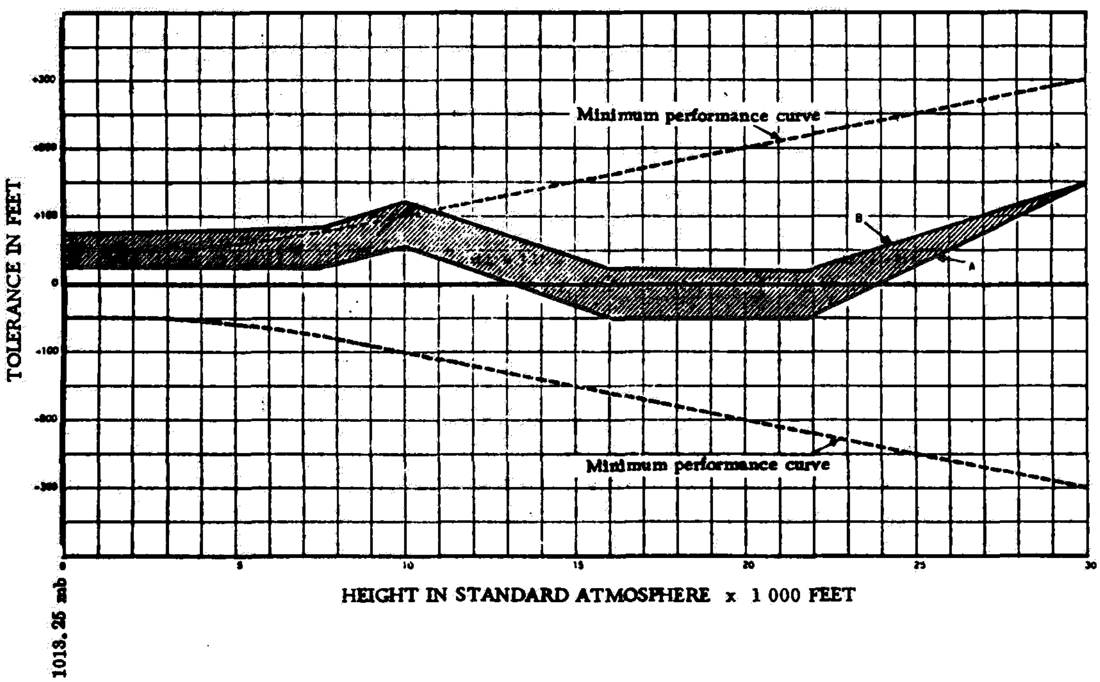


Figure B-3

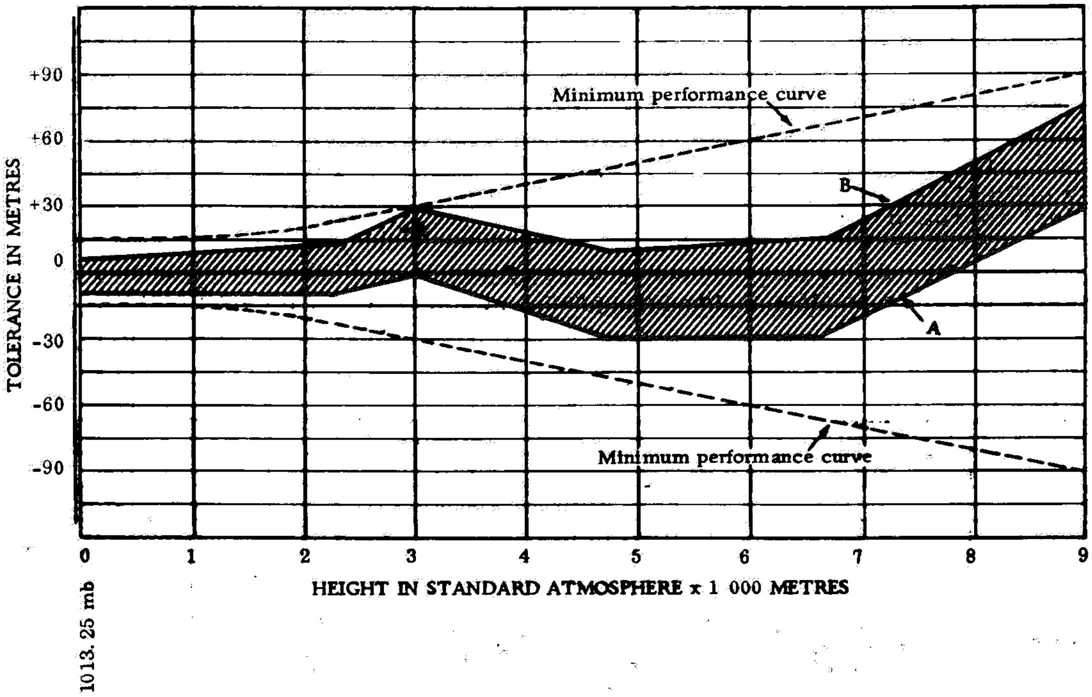
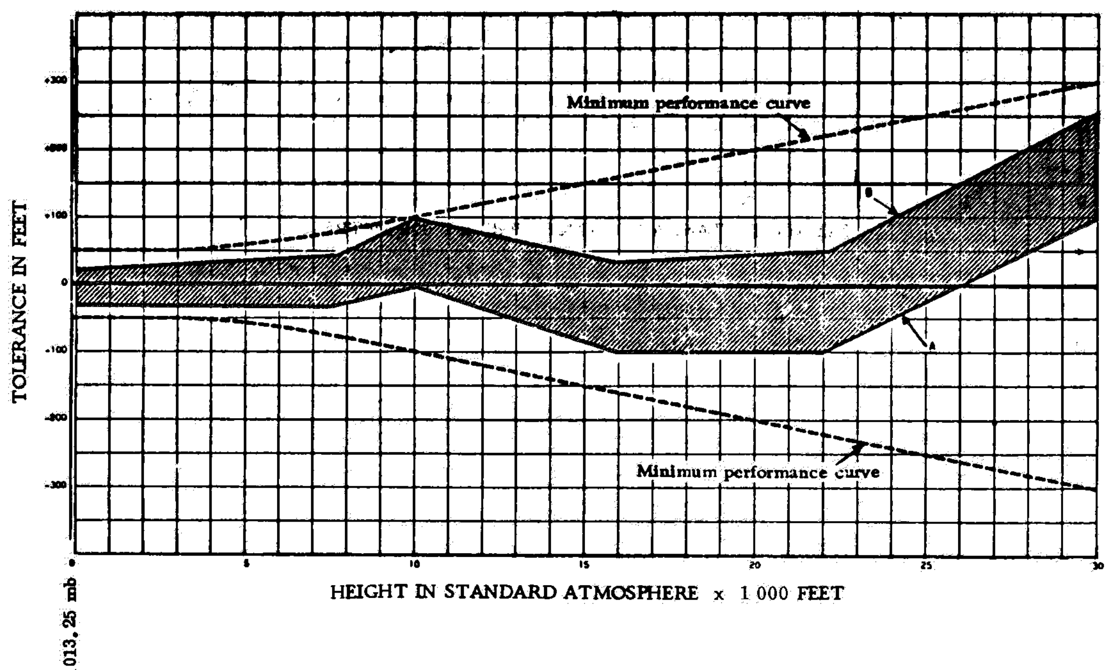


Figure B-3



8. Figure B-4 is comparable with Figure B-2 except that the drift test carried out in Figure B-3 has also been incorporated. As in the case of Figure B-2 Curve A starts with an error of +6 m (+20 ft). The pressure is decreased to complete Curve A, is then held for 6 hours during which time the instrument indication drifts as illustrated. Then Curve B is obtained with increasing pressure in the normal manner. In this instance it will be noted that the calibration Curve B goes outside the minimum performance curves which have been specified for both decreasing and increasing pressure. It will also be noted that Curve B terminates with an altimeter indication of +21 m (+70 ft) as compared with +6 m (+20 ft) in Figure B-3, the former being less acceptable for final approach and landing operations.

9. The difference between Curves A and B in Figure B-3 and B-4 is due to hysteresis, possible friction in the temperature compensating pins plus drift.

Figure B-4

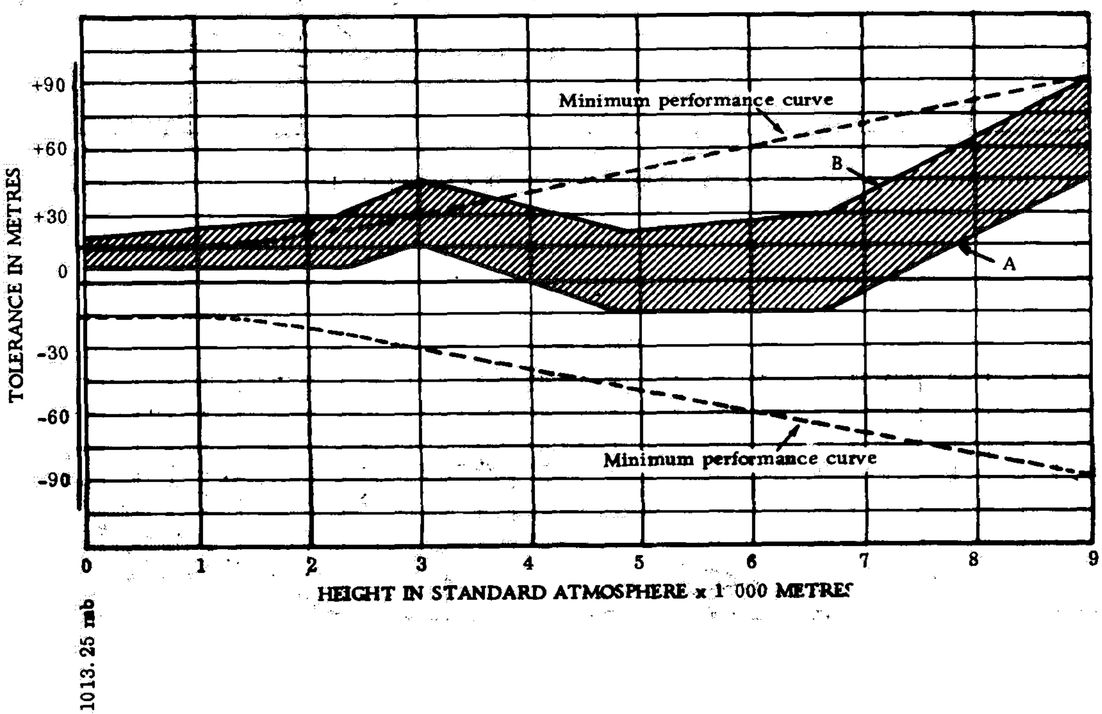
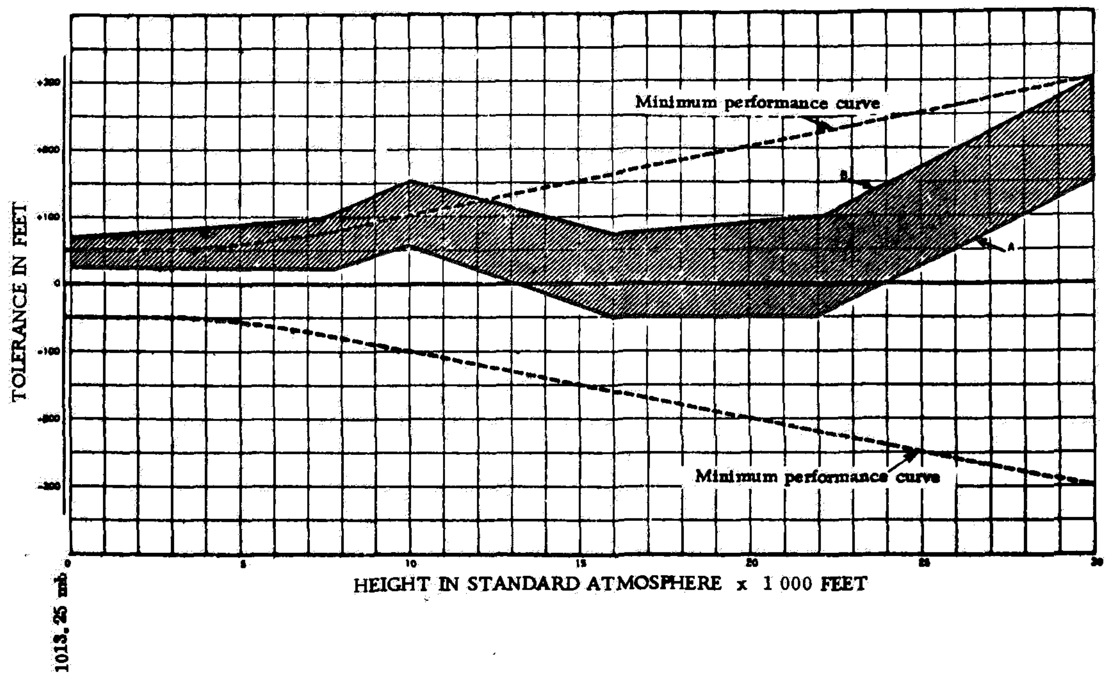


Figure B-4



10. As stated in 2.8.3 of the test procedure it is not necessary to make a drift test each time an altimeter is tested. Experience has shown that if the drift test specified in 3.8 is made at the intervals specified in 2.8.3 only the diaphragm test (3.7) and the friction test (3.6.1) are required. If the instrument is within the tolerances specified in 3.7 and 3.6.1, the errors in the instrument during actual operations, during decreasing pressure, will never exceed the positive tolerances specified in the minimum performance curves found in Figures 1-6 of the test procedure.

- END -

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