BRITISH STANDARD

BS G 152:1956

(Replacing, in part, BS G 110)

Specification for

A.C. Electrically-operated artificial horizons for aircraft

Confirmed January 2009

Foreword

BS G 110:1949, "*Artificial horizons for aircraft*," specified requirements for the general and detailed construction, and for the accuracy of both air-driven and electrically-driven instruments. This standard has been prepared to provide an up-to-date and separate specification for A.C. electrically-driven artificial horizons in the light of experience gained in the application of the relevant requirements of BS G 110, which it supersedes. Information has been added relating to the incidence of testing, and recommendations included in respect of tests to verify the serviceability of the instruments.

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Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, pages 1 to 6, an inside back cover and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

This British Standard, having been approved by the Aircraft Industry Standards Committee and endorsed by the Chairman of the Engineering Divisional Council, was published under the authority of the General Council of the Institution on 30 August 1956

The following BSI references relate to the work on this standard:—
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Amendments issued since publication

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Contents

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1 Scope

This British Standard specifies the general design requirements and test procedure for a.c. electrically-operated artificial horizons for aircraft.

2 Definition

For the purposes of this British Standard the following definition shall apply:—

artificial horizon

an instrument used on aircraft to indicate on a single dial the attitude of the aircraft in pitch and roll, by reference to a gyroscope coupled mechanically to an indicating system comprising a miniature aeroplane and an horizon line

Section 1. General requirements

3 Case size

The instrument case shall not be more than 4⅜ in. in diameter, and not more than 7 in. in overall depth.

4 Fixing holes

For 4⅜ in. diameter cases, attachment shall be effected by four fixing holes equally spaced on a 4¾ in. pitch circle diameter, with integral 2 B.A. stiff-nuts: otherwise the fixing holes should be in accordance with those specified for aircraft instrument cases in BS G 100, "*General requirements for electrical equipment and indicating instruments for aircraft*".

5 General construction

The instrument shall be sound and suitable for its purpose and its design and construction shall comply with the relevant requirements of BS G 100.

Section 2. Particular requirements

6 Construction

The instrument shall consist of an electrically-driven gyroscope spinning about an axis substantially vertical in both pitch and roll. The gyroscope shall be coupled mechanically to an indicating system comprising a miniature aeroplane and an horizon line, and the relative position of the miniature aeroplane to the horizon line shall be qualitatively the same as that of the real aircraft to the natural horizon. An indication of attitude shall be given for any combination of pitch and roll within the range ± 75° roll ± 60° pitch.

7 Electrical characteristics

a) *Supply*. The instrument shall be designed to operate satisfactorily on a three-phase supply of 103.5–126.5 volts, 380–420 cycles, and in addition the gyroscope shall be capable of erection to the vertical when the symmetrical supply voltage does not exceed 90 volts at 395–405 cycles. The maximum consumption shall be 30 VA and the power factor shall be 0.8 nominal.

b) *Phase sequence*. The phase sequence shall be such that the terminal voltages measured from an artificial star point shall reach their maxima in the order A, B, C (red, white and blue respectively), giving the clockwise rotation of the gyroscope when viewed from above.

c) *Earthing*. The supply to the instrument shall have the B (white) phase earthed, but no bonding shall be provided in the instrument.

d) *Erection supply*. Pins D and E shall give access to the erection supply for test purposes.

e) *Cable bonding*. A six-core screened cable 3 ft long, terminating in a suitable six-pin plug shall be provided from the instrument. The cable shall be screened overall and suitable detachable bonding provided between the screening of the cable and the instrument chassis.

f) *Cable connections*. The six-core screened cable shall enter the instrument body radially on the side of the rear end of the instrument. The entry shall be capable of being turned through 180° in steps of 45°. The colour coding is to be as follows:—

Socket pins:	A	B	C	D	E	F
Cable core colours:	Red	White	Blue	Green	Yellow	Black

8 Mechanical characteristics

a) *Freedom*. The gimbal shall be designed to give complete freedom in roll and a nominal ± 80° freedom in pitch. A resilient stop shall be fitted to the gimbal system to prevent damage to the instrument when the limits of freedom are exceeded.

b) *Gravity control*. The gyroscope movement shall be sufficiently pendulous to satisfy the requirements of Clause **12** b). The maximum pendulosity acceptable where the design requires a compensating side tilt shall be such that the tilt, calculated in accordance with *c* does not exceed 2° and shall be within ¼° of the calculated values.

c) *Turn error compensation*. Where the gyroscope axis is tilted slightly to compensate for errors experienced in flight, the amount of tilt to be applied, either forward or starboard, or in both directions, is to be obtained from the following:—

$$\text{Forward tilt } \alpha^\circ = \frac{R}{r} \times 57{\cdot}3$$

where R = erection rate in roll (Average 5°/min)

r = rate of turn.

NOTE Forward tilt shall not exceed 2°.

$$\text{Side tilt } \beta^\circ = \frac{MV}{J} \times 57{\cdot}3$$

where M = pendulous moment due to bottom heaviness.

V = true air speed.

$J = I\omega$ angular moment of momentum.

The values selected for r and V shall be declared.

d) *Gyroscope erection*. Each instrument shall incorporate electrical means to erect the gyroscope automatically and to maintain it erect.

e) *Ventilation*. Where the instrument is not hermetically sealed, suitably screened and filtered ventilation holes shall be provided so that the requirements in respect of environmental pressure, temperature and humidity changes and self-heating conditions are satisfied.

f) *Lubrication*. The rotor and gimbal bearings shall be designed to give satisfactory performance throughout the operating life of the instrument without relubrication.

g) *Robustness*. The instrument shall be so designed that shock loads giving an acceleration of 50 *g* in any direction do not impair the performance.

h) *Moment of momentum*. The angular moment of momentum shall be as high as possible consistent with size.

j) *Balance*. The rotor shall be dynamically balanced about its axis of spin.

k) *Torque motors*. The design of torque motors shall be such that no serious overheating takes place if the erection rate is increased to 30° per minute for 15 seconds.

9 Marking

In addition to the marking required by BS G 100, instruments shall be marked with the rate of turn and true air speed selected for determining the tilt and turn error compensation.

Section 3. Tests

10 General

a) Tests shall be made to prove compliance with all the requirements of this British Standard. It is not intended or recommended that complete tests shall be made on every instrument supplied.

Two kinds of test, therefore, are specified as follows:—

A. *Type tests* (Clauses **11** to **21**), which shall be made on representative samples of each particular design.

B. *Production routine tests* (Clause **22**), which shall be made on every instrument manufactured in accordance with this British Standard.

The tests in Clauses **11**, **12**, **13** b), **14** a), **14** b), **14** d), and **18** shall be made at the relevant stage of construction before the instrument is cased.

b) Minimum tests recommended to verify the serviceability of instruments manufactured in compliance with this British Standard are indicated in Appendix A.

c) Unless otherwise specified the instrument shall be tested:—

i) at room temperature (15–20 °C);

ii) in the normal position (the normal position is that in which both the plane of the mounting face of the fixing flange is vertical and the centre line passing through the top fixing screw holes is horizontal and within 10 minutes of arc);

iii) stationary, on a three-phase test supply of 113–117 volts 395–405 c/s, and after the gyroscope has been running for at least half an hour.

A. Type tests

11 Rotor over-speed test[1)]

(This test has particular significance for sintered rotors but is applicable to all designs). With a power supply of 115 volts 500 cycles applied to the instrument the rotor shall be allowed to reach maximum speed for a duration of 5 minutes and then to coast to rest, after which the test shall be repeated with a supply of 115 volts at 475 cycles. Finally, with the normal test supply applied to the instrument the rotor shall be run for a duration of ten minutes.

[1)] In view of the possibly dangerous consequences of failure of the rotor, suitable precautions should be taken during the performance of this test.

12 Starting tests

a) With a supply of not more than 90 volts 395–405 cycles applied to the instrument, the rotor shall start to turn, in a clockwise direction when viewed from above, and continue to run at a speed of not less than 75 per cent of the nominal synchronous speed.

b) With the nominal test supply applied to the instrument the rotor shall run up from rest to at least 50 per cent of the nominal synchronous speed in not more than 1½ minutes and shall fulfil the requirements of Clause **14** c) within that time.

13 Electrical tests

a) *Normal current*. When steady conditions have been reached the current in each phase shall be measured and shall not exceed 0.2 amp. on any phase.

b) *High voltage test*. The instrument shall be subjected to a high voltage test at the conclusion of a functioning test [e.g. Clause **14** f)]. The supply shall be 1 000 volts r.m.s.) at 50 c/s applied for a total of 1 minute between the terminals A, B and C grouped together at the plug and the chassis of the instrument.

c) *Routine insulation test*. A routine insulation resistance test shall be carried out on all instruments within 1 minute after completing a functioning test [e.g. Clause **14** f)]. The test shall be carried out with a 500 volt d.c. supply applied between the 3 pins A, B and C grouped together on the plug and the chassis of the instrument. The insulation resistance shall be not less than 20 megohms.

14 Mechanical tests

a) *Gimbal freedom*. The gimbal freedom shall be checked over the whole freedom range, which shall not be less than 78° in pitch (both dive and climb) and complete freedom in roll, with the gyroscope running.

b) *Horizon bar clearances*. With the gyroscope stationary the horizon bar shall be offset, in pitch 75° each way separately and in these positions the outer gimbal shall be rotated through a complete revolution to check clearances between bars and chassis.

c) *Settling*. The datum positions of the horizon bar and roll indicator shall be within 1° (indicated) of their zero positions when the instrument is in the normal position [see Clause **10** c) ii)] and with the gyroscope running. The zero position is that at which the associated fixed and moving indicators are in alignment.

d) *Bottom heaviness* (if embodied). The following tests shall be made to determine that the pendulous moment due to bottom heaviness complies with the agreed figures:—

i) An appropriate weight or weights shall be applied to the gimbals of the gyroscope to counterbalance the designed pendulous moment. The test shall be successively performed with the instrument dial down and in its normal position, i.e. with the longitudinal axis of the case horizontal, the gyroscope axis being swung to the horizontal in both cases (in the latter position the gyroscope axis will lie transversely). With the rotor stationary, the gyroscope axis shall be moved to various angles from the horizontal and the instrument gently tapped to ensure that the gyroscope axis remains stationary, indicating that the bottom heaviness has been removed.

ii) With the counterbalance weight specified in i) removed and with the gyroscope rotor stationary, the gimbals shall be tilted in both the longitudinal and transverse axes 25° from the vertical and when released without initial velocity the gyroscope shall settle to within 20° of the vertical in both pitch and roll.

e) *Gyroscope axis inclination* (if embodied).

i) *Instruments with inclination in both pitch and roll*. The inclination of the gyroscope axis in both pitch and roll shall be determined by the following method and the top end of the gyroscope spindle shall be inclined to within ¼° of the calculated values forward:—

A. The instrument shall be mounted on a table capable of rapid rotation about an axis truly vertical to within 0.1°. With the gyroscope running, five minutes shall be allowed for stable conditions to be reached and then the position of the roll indicator shall be noted.

B. The erection control only shall be switched off and the instrument rotated quickly through 180° about the vertical axis. The horizon bar shall move to indicate a “dive” condition. The angular displacement of the roll indicator from position A shall be counter-clockwise and twice the angular amount of the required roll tilt.

C. With the instrument returned to position A the erection shall again be applied, the instrument allowed to re-erect and the position of the roll indicator noted.

D. The erection control shall be switched off and the instrument rotated quickly through 90° in a clockwise direction as viewed from above. The angular displacement of the roll indicator from position C shall be counter-clockwise and equal to the sum of the pitch and roll tilts.

E. With the erection still switched off, the instrument shall be rotated through 180° and the angular displacement of the roll indicator noted. The algebraic difference between the readings obtained during D and E shall be counter-clockwise and twice the angular amount of the required pitch tilt.

ii) *Instruments with inclination in pitch*. The inclination of the gyroscope axis in pitch shall be determined by the following method and the top end of the gyroscope spindle shall be inclined to within ¼° of the calculated values:—

A. The instrument shall be mounted on a table capable of rapid rotation about an axis truly vertical to within 0.1°. With the gyroscope running, five minutes shall be allowed for stable conditions to be reached and then the position of the roll indicator shall be noted.

B. The erection control shall be switched off and the instrument rotated quickly through 90° in a clockwise direction as viewed from above. The angular displacement of the roll indicator counter-clockwise from position A shall be the pitch tilt.

iii) *Instruments with inclination in roll*. The inclination of the gyroscope axis in roll shall be determined by the following method and the top end of the gyroscope spindle shall be inclined to within ¼° of the calculated values:—

A. The instrument shall be mounted on a table capable of rapid rotation about an axis truly vertical to within 0.1°. With the gyroscope running, five minutes shall be allowed for stable conditions to be reached and then the position of the roll indicator shall be noted.

B. The erection control only shall be switched off and the instrument rotated quickly through 180° about the vertical axis. The angular displacement of the roll indicator counter-clockwise from position A shall be twice the roll tilt.

f) *Gyroscope erection*:—

i) The normal erection rates from opposite directions in each axis shall be equal to each other to within 1 minute, the rates being obtained as specified in ii) and iii).

ii) The horizon bar shall be set to a 30° climb position and the roll indicator set to the datum position with the instrument in its normal position. The time required for the horizon bar to reach 5° from the datum position shall be between 4 min 10 sec and 5 min 50 sec. This test shall be repeated with the horizon bar erecting from a 30° dive position. During each test the roll indicator shall not deviate from the datum position by more than the values shown in Table 1 appropriate to the design.

iii) The roll indicator shall be set to 30° right bank position, and the horizon bar set to the datum position, with the instrument in its normal position. The time required for the roll indicator to reach 5° from the datum position shall be between 4 min 10 sec and 5 min 50 sec. This test shall be repeated with the roll indicator erecting from a 30° left bank position. During each test the horizon bar shall not deviate in the pitch axis by more than the values shown in Table 1 appropriate to the design.

Table 1 — Direction and acceptable amount of deviation in the quadrature axis during erection

Erection from —	Friction (maximum 1°)	Pendulosity (maximum 3°)
Bar down	Clockwise roll	Counter-clockwise roll
Bar up	Counter-clockwise roll	Clockwise roll
Right bank	Bar down	Bar up
Left bank	Bar up	Bar down

NOTE The following method may be employed to topple the gyroscope for the above tests:—

i) Remove the instrument from the stand and tilt in pitch until the gimbal stop is reached. A slight sideways movement of the instrument in this position will usually cause the gyroscope to topple slightly.

ii) Return the instrument to a level position, replace it on the stand and rotate the table until the roll pointer or horizon bar reads zero, depending upon whether erection is being measured in pitch or roll respectively.

iii) If the pointer of the axis under test reads more than 30° proceed with the test. If necessary, repeat i) until pointer exceeds 30°.

g) *Roll, pitch and yaw test*. The instrument shall be mounted on a gyroscope test table and subjected to a roll, pitch and yaw test at an amplitude of ± 7½°. (overall 15°) and from 5 to 7 oscillations per minute. Whilst running, the table shall be reversed at 1-minute intervals. After 10 minutes the table shall be levelled to the horizontal stop. The amount of deviation in both pitch and roll shall not exceed 1°.

h) *Free wander rate*. After the instrument has been running and is fully erected the erection control supply shall be switched off and the instrument subjected to rocking conditions of 5° total movement at from 5–7 oscillations a minute. The amount of wander in both pitch and roll shall not exceed 3° in four minutes. The direction of rocking shall be such that both gimbal axes are equally exercised. During this test pins D and E shall be isolated.

15 Vibration, acceleration and climatic tests

The instrument shall be subjected to the tests specified in BS G 100 appropriate to its declared grades of vibration, acceleration, and climatic performance. During these tests the accuracy tolerances specified in Clause **14** c) shall not be exceeded.

After these tests it shall be verified that the instrument still complies with the requirements of Clauses **14** f) and h).

16 Temperature rise

The temperature rise of the stator windings shall be determined after the instrument has been running for 1 hour.

The temperature rise shall not exceed 40 Centigrade degrees when computed from the change in the resistance of the windings.

17 Compass interference

The compass safe distance shall be not more than 12 inches when measured in accordance with BS G 100.

18 Temperature tests

a) The instrument performance shall comply with the requirements of the tests in b) and c) after subjection to the low and high temperature conditions for the periods specified.

b) *Functioning tests*. The instrument shall function satisfactorily at – 20 °C and + 50 °C as follows:—

i) The instrument shall be subjected to a temperature of – 20 °C for a period of 1 hour with the gyroscope stationary. At the end of that period and at that temperature the gyroscope shall be set in operation and allowed 15 minutes to run up to speed. It shall then comply with Clause **14** c) and be tested in accordance with Clause **14** f) but the erection rate from opposite directions in each axis shall be equal to each other to within 1 minute 20 seconds and the erection rates from 30° to 5° shall be from 4 to 6 minutes.

ii) The instrument shall then be subjected to a temperature of 50 °C for 1 hour with the gyroscope running and shall at that temperature comply with the requirements of i) above.

c) *Derangement tests*. The instrument shall operate at – 40 °C and + 70 °C as follows:—

i) The instrument shall be subjected to a temperature of – 40 °C for a period of 1 hour with the gyroscope stationary. At the end of that period the supply shall be introduced and the gyroscope shall start to rotate and continue to increase in speed. After running for ½ hour the instrument shall comply with Clauses **14** c) and **16**. The instrument shall be returned to normal temperature (15–20 °C) conditions and, after 1 hour shall comply with all the requirements of Clauses **13** and **14**.

ii) The instrument shall be subjected to the test described in i) above but at a temperature of + 70 °C and with the gyroscope running it shall comply with the requirements of Clauses **14** c) and **16** at the temperature of + 70 °C and with all the requirements of Clauses **13** and **14** for 1 hour after return to normal temperature (15–20 °C).

19 Radio interference

The instrument shall comply with the requirements of BS G 100 in respect of interference with radio.

20 Power consumption

The total power consumption under steady conditions shall be measured and shall not exceed 30 VA at a lagging power factor of 0.80 ± 0.05.

21 Endurance test

The instrument shall be mounted on a combined rocking and vibration table subjected to rocking in accordance with Clause **14** h) and to vibration in accordance with Clause **15** and run for 1 000 hours at normal temperature (15–20 °C) with the normal supply and without further lubrication or adjustment, after which it shall comply with the tests in Appendix A.

During this test the instrument shall comply with the requirements of Clauses **13** a) and **14** c), and at the conclusion of the endurance test shall comply with Clauses **13** b) and c) and with Clauses **14** d), f), g) and h).

B. Routine production tests

[As defined in Clause **10** a)]

22 Each instrument shall comply with the requirements of the tests specified in the following Clauses of this British Standard:—

Clause **11**	Rotor over-speed test.
12	Starting test.
13 a)	Normal current test.
13 c)	Routine insulation test.
14 a)	Gimbal freedom test.
14 c)	Settling accuracy test.
14 f)	Gyroscope erection test.
14 g)	Roll, pitch and yaw test.
14 h)	Free wander rate test.

Appendix A Serviceability tests

The minimum tests recommended to verify the serviceability of instruments manufactured in compliance with this British Standard are as follows with the tolerances amended where appropriate:—

a) *Conditions of test*. Unless otherwise stated, as in Clause **10** c).

b) *Functioning tests*.

i) *Exercise*. The instrument shall be mounted in a vertical panel on a gyroscope test table set at a roll, pitch and yaw of 7½° (overall 15°) and oscillated at a frequency of between 5 and 7 oscillations per minute. The instrument shall be exercised for 20 minutes.

ii) *Starting test*. Clause **12** a).

iii) *Settling test*. With the instrument mounted in a vertical panel and the gyroscope rotor at rest, the normal 3-phase power supply shall be applied. The instrument shall settle to within 1° of zero within a period of 5 minutes.

iv) *Erection tests*.

1. *Pitch*. The time of the return of the horizon bar from ⅞in. (30°) to within $^{5}/_{32}$ in.(5°) of the datum position shall be within 3½ and 7 minutes. During this test the roll pointer shall not depart from zero by more than $^{3}/_{64}$ in. The test shall be repeated with the gyroscope erecting from the opposite direction.
2. *Roll*. The time of the return of the roll indicator from 30° bank to 5° shall be between 3½ and 7 minutes. During this test the horizon bar shall not rise or fall more than $^{3}/_{64}$ in. from the datum position. The test shall be repeated with the gyroscope erecting from the opposite direction.
3. *Time*. The times obtained in b) iv) 1 and b) iv) 2 should not differ by more than 1½minutes in each case.

v) *Insulation resistance test*. Clause **13** c).

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