BS 3G. 100-2.3.14: 1973

Specification for

General requirements for equipment for use in aircraft —

Part 2: All equipment —

Section 3: Environmental conditions —

Subsection 3.14: Acoustic vibration

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Contents

Foreword

This British Standard is part of a composite standard in the Aerospace Series of British Standards specifying general requirements for equipment in aircraft. An introduction to the complete British Standard is given in British Standard 3G. 100-0 Introduction.

This subsection of British Standard 3G. 100 gives details of an acoustic noise test for aircraft equipments and components. It includes appendices to provide a guide to assist in the selection of suitable chambers and noise sources. The tests described are designed to cater for severe noise environments in aircraft and rocket vehicles, e.g. from jet engine exhaust, boundary layer turbulence, etc.

Although, in general, other noise sources are negligible when compared to the above examples, the user should be aware that in some instances they may be significant, e.g. shock cell noise, gunfire etc. Furthermore, the principals of test could, where appropriate, be used to cover other acoustic environments.

The test is complementary to and does not replace the vibration test described in British Standard 3G. 100-2.3.1, Vibration. In this respect, it should be noted that vibration isolators do not necessarily isolate equipment from acoustically induced vibration.

This standard makes reference to the following British Standards:

BS 3G. 100, *General requirements for equipment in aircraft.*

BS 3G. 100-0, *Introduction.*

BS 3G. 100-2.3.0, *Standard test requirements.*

BS 661, *Glossary of acoustical terms.*

BS 2475, *Octave and one third octave band pass filters.*

BS 3593, *Preferred frequencies for acoustical measurements.*

BS 4197, *A precision sound level meter.*

Information concerning metric (SI) units is given in BS 350, Conversion factors and tables; BS 3763, The International System of units (SI), and PD 5686, The use of SI units.

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Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, pages 1 to 8 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.

1 Scope

This British Standard specifies details of tests to determine the ability of aircraft equipment and components to withstand four grades of acoustic environment.

This standard should also be read in conjunction with British Standard 3G. 100-0.

2 Definitions

For the purposes of this standard the definitions of BS 661 shall apply.

3 Conditions for testing

3.1 Standard test requirements. For the purposes of this test the appropriate requirements stated in British Standard 3G. 100-2.3.0 shall apply.

3.2 Mounting

3.2.1 The equipment under test, i.e. specimen, shall be mounted in a suitable chamber (as described in **3.3.1.1**) in such a manner that all appropriate external surfaces are exposed to the acoustic field. The principal surfaces of the specimen shall not be parallel to any surface of the test chamber.

3.2.2 Specimens should be suspended in the test chamber on an elastic suspension. The resonance frequency of the suspension system and specimen combined shall be less than 25 Hz, unless otherwise stated. Care must be exercised to ensure that no spurious acoustic or vibratory inputs are introduced.

Where the specimen is provided with specific means of mounting, the suspension system should be attached to the specimen in such a way that it does not interfere with the free movement of parts of the specimen which may move independently.

3.2.3 If cables, pipes etc., are required to be connected to the equipment during the test as prescribed in the relevant equipment specification, these should be arranged so as to add similar restraints and mass as in the normal installation.

3.3 Testing system

3.3.1 *Required characteristics*

3.3.1.1 *Test chamber*. The test chamber should be of such shape and construction as to produce as closely as possible a diffuse sound field. Appendix B and Appendix C give guidance concerning the choice and sizes of suitable chambers.

In general, a reverberant chamber is to be preferred. An irregular pentagonal chamber as illustrated in Figure 2 is recommended. The source opening should be small in relation to the total wall area.

Where possible the chamber should be of such a size that the volume occupied by the specimen does not exceed 10 % of the chamber volume.

As far as possible the specimen should be mounted centrally in the chamber. It should be noted that near to the source opening a direct sound field may exist.

In order that a measure of standardization of the test can be achieved, it is recommended that the chamber should be chosen from one of the three preferred sizes given in Table 2.

3.3.1.2 *Noise source*. The acoustic energy supplied to the test chamber should be of a random nature approximating to a normal distribution, with amplitudes up to a peak value not less than three times the root mean square (r.m.s.) value.

3.3.1.3 *Measuring system*. The measuring and indicating instruments used with the microphones and the microphones themselves shall be capable of handling random noise as defined in **3.3.1.2**. The measuring system shall give the r.m.s. value of the sound pressure when measuring a random noise.

3.3.1.4 *Microphones*. The microphones sued shall be calibrated for random incidence.

3.3.1.5 *Spectrum measurements*. The sound pressure level (SPL) shall be measured in octave bands with centre frequencies and band-widths in accordance with the requirements of BS 3593.

3.3.2 *Tolerances*

3.3.2.1 *Acoustic measuring system*. The accuracy of the measuring system should correspond to the precision grade for sound level meters, given in BS 4197, and for octave band filters, given in BS 2475. The indications obtained in this manner may be compared directly with the levels (and tolerances) in Figure 1 without further allowance for instrumentation errors.

3.3.2.2 *Tolerances on sound pressure level and spectrum*. The spectrum of the sound field shall be initially adjusted with the specimen and its suspension removed from the chamber.

The overall sound pressure level, determined from Table 1, shall be produced in the chamber, conforming with the octave band spectra given in Figure 1. Measuring equipment capable of resolution better than one octave may be used but the appropriate reductions should be made to the octave band sound pressure levels in Figure 1 to give the required overall sound pressure level. Measurements shall be made by using one microphone (or more if desired) placed in the area to be occupied by the test specimen.

The test item shall be mounted in the chamber as specified in **3.2.2** and the overall sound pressure level re-established and monitored by not less than three microphones. A microphone should be located in proximity to each major dissimilar face of the test item at a distance of 0.5 m from the face or half the distance to the nearest chamber wall, whichever is the lesser. Where the chamber is provided with a single noise injection point, one microphone is to be placed between the test item and the chamber wall furthest from the injection point.

The overall sound pressure level shall be adjusted until the average of the sound level at each of the monitoring points is within + 4 dB to – 2 dB of the specified level and until the overall sound pressure level at each monitoring point is also within + 4 dB to – 2 dB. For large or irregularly shaped test items where it is impracticable to meet the latter requirement, its tolerance may be relaxed to ± 6 dB. When the spread of readings at the measuring positions does not exceed 5 dB a simple arithmetic average of the decibel readings may be used. For spreads exceeding 5 dB an r.m.s. summation of the individual sound pressures (not decibel values) shall be used. The performance achieved shall be noted in the test report.

4 Severities

An acoustic severity is defined by a combination of the following three parameters.

4.1 Acoustic level. The equipment under test shall be graded in accordance with Table 1, where the overall sound pressure level is expressed in decibels relative to a sound pressure of 2×10^{-5} Pa. The equipment specification shall state the relevant grade.

4.2 Frequency range. The standardized frequency range for the test is that given in Figure 1 unless otherwise prescribed by the relevant equipment specification.

4.3 Endurance duration. Equipment in aircraft is exposed to acoustic noise environments of varying amplitude during the course of its life. The most severe levels arise during take-off and the application of reheat, and occur only for a small proportion of the life of the equipment. Lower levels invariably persist for long periods. The cumulative damage caused by the varying environments can, where there is an established relationship between stress and cycles to failure, be simulated by a test of reduced duration applied at a level representative of the most severe condition.

Unless otherwise stated in the relevant equipment specification the test duration shall be 10 h.

NOTE It is not normally necessary to exceed 10^7 stress reversals within the component. When a demonstration of performance only is required during the test, the test duration shall be 30 min.

5 Testing procedure

5.1 Initial inspection and tests. The specimen shall be visually inspected and electrically and mechanically checked as required by the relevant equipment specification.

5.2 Conditioning. The specimen shall be subjected to the acoustic level prescribed by the relevant equipment specification. The relevant equipment specification shall also state the circumstances in which electrical and/or mechanical functioning is required and any performance checks to be carried out.

Table 1 — Severity grades

Grade	Typical region	Nominal test overall SPL
		dB
A	Civil and military transport aircraft — locations not close to jet exhausts.	130
B	Civil and military transport aircraft — internal equipment bays close to jet exhaust. High performance military and civil aircraft — locations not close to jet exhaust.	140
C	High performance military and civil aircraft — internal equipment bays close to jet exhausts.	150
D	High performance military and civil aircraft — special applications (e.g. equipment bays close to reheat exhausts, gun muzzles etc.).	160

5.3 Final inspection and tests. The specimen shall be visually inspected, and electrically and mechanically checked, as required by the relevant equipment specification.

6 Information required in the relevant equipment specification

When this test is included in a relevant specification the following details shall be given, as far as they are applicable.

	Relevant clause
Method of mounting	**3.2**
Testing system	**3.3**
Severity grade	**4.1** and Table 1
Frequency range	**4.2**
Endurance duration	**4.3**
Initial checks	**5.1**
Functional tests	**5.2**
Final checks	**5.3**

Appendix A Choice of test spectra

The test spectrum given in Figure 1 was derived from consideration of the following factors.

1) The external exhaust overall noise level can range from 130 dB to 165 dB when both jet and rocket noise are considered. Below this range acoustic prolems are unlikely, whilst above this range special attention is necessary.

2) The maximum band level occurs in the frequency range 200 Hz to 1 000 Hz with a 6 dB per octave roll off at higher and lower frequencies.

3) The attenuation by the skin etc. below 1 000 Hz is of the order of 10 dB. Above 1 000 Hz the attenuation can increase at a rate of 6 dB per octave, giving up to 30 dB attenuation at high frequencies. However, these figures are only generalizations since many factors may be involved.

4) Depending on the type of vehicle, maximum boundary layer noise will normally be in the region of 145 dB to 155 dB, with a spectrum closer to white than that for jet noise.

5) When exhaust and boundary layer spectra are combined, and skin attenuation is taken into account, the result is similar to the external spectrum for jet noise only.

Where a particular test specification requires restrictions on the bandwidth, it is recommended that the cut-off frequencies should correspond to the appropriate octave bands spaced at the preferred octave intervals stated in BS 3593.

Although the preferred signal should be random, reverberation conditions may modify the amplitude distribution giving misleading distribution measurements in the reverberation chamber.

These considerations give rise to a general purpose test, but should one particular type of noise predominate, a special test may be required.

Appendix B Some considerations in the selection of a test facility

B.1 Choice of test chamber. The test is based on conditions arising primarily with aircraft equipment which operate in an enclosed compartment. Hence the first characteristic of the normal environment is that of an enclosed space.

The greater part of the acoustic field in such enclosed compartments is usually due to secondary radiation of sound from vibration of the surrounding structure. Thus the sound radiating source can comprise a large area of the compartment.

A combination of enclosed space, reflective surfaces and a relatively large radiating area, will result in sound waves being reflected and transmitted in random directions to build up a diffuse field. This is closely simulated in a reverberation chamber. Other types of chamber that may be considered would not give the same correlation of pressures over the specimen, and would therefore not excite specimen resonances in quite the same way.

B.2 Realism in the choice of test chamber size. The class of equipment and components to be dealt with is to be confined to the airborne type, although some conclusions may have more general applications.

Much airborne equipment will be in the form of "black boxes", which will generally be the largest items to be tested. They will seldom approach 1 m^3 in volume, a more realistic limit being in the order of 0.1 m^3. In general, components will be enclosed inside the black boxes so that, for the component, the environment is enclosed in the box (or whatever equipment the component operates in).

The volume of operating space for equipment cannot be specified, although some generalizations may be permissible. The largest volumes are usually passenger and crew compartments where an overall noise level of less than 120 dB makes noise problems unlikely. Crew compartments of small military aircraft have a relatively small volume (8 m^3 or less), but noise levels up to 135 dB are possible. Generally, airborne equipment subject to intense noise environments will be operating in small compartments in the nose, tail, wings and underfloor compartments. Possible exceptions are where aircraft have large underfloor cargo spaces, or in the case of military aircraft where electronic equipment may be carried in large bomb bays.

It is unlikely to find equipment operating in volumes of the order of 500 m^3, and even more unlikely that such equipment will require an acoustic test. Components will operate in an environment formed by the casing of the equipment and can therefore be tested in a small test chamber.

B.3 Standardization of test conditions. Standardization of test conditions is needed if different establishments are to obtain similar results with the same type of specimen. In addition, if the cataloguing of equipment as complying with a specification is to have meaning, the conditions need to be related to some standard conditions. These conditions would include frequency spectra, sound pressure levels and type or pattern of acoustic field.

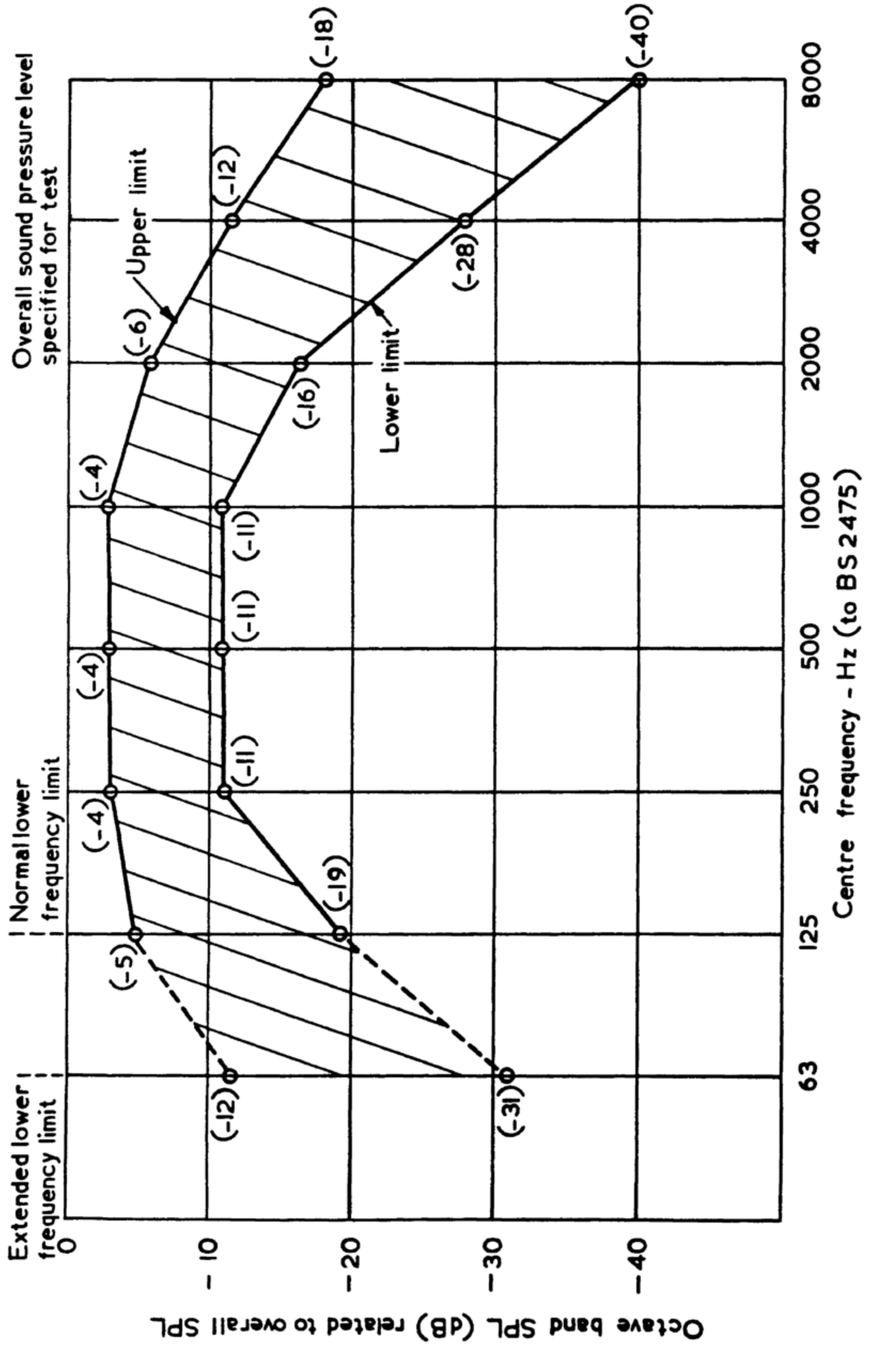

Figure 1 — Octave band spectrum

B.4 The preferred test chambers. The best available means of achieving a representative test is to obtain standardization by testing in standard forms of chamber, and to obtain realism by having these forms of realistic size. A range of three test chamber sizes has been chosen to cover most likely cases.

1) A small test chamber suitable for component testing.

2) A medium sized chamber to cater for a wide range of equipment.

3) A large chamber to provide for cases needing larger volume.

The size and shape of the chambers have been chosen to meet an effective compromise between technical and economic considerations.

B.5 Acoustic noise generators: requirements and types available. For the acoustic test, a source should be capable of delivering controllable random noise at high power; controllable in that the shape of the spectrum can be changed without altering the randomness of the output. A high efficiency is also desirable, although this tends to take second place to the first mentioned requirement.

At the present time, the most suitable devices are those which are electromagnetic in operation: loudspeakers and electromagnetic air modulators. The only other suitable device is the random siren, although this is of doubtful value due to control problems. No available noise generator is entirely satisfactory from power output, spectral range, or controllability points of view.

More details of these generators should be obtained from current literature.

Appendix C Preferred chamber and guide to suitable sources

C.1 Test chambers

C.1.1 The preferred test chamber is an uneven pentagon as shown in Figure 2, and in order that a measure of standardization of the test can be achieved it is recommended that the size of the chamber be chosen from one of three sizes having the following dimensional constants:

$n = 0.5$ m

$n = 1.25$ m

$n = 3$ m

The mean absorption coefficient ($\bar{\alpha}$) should be between 0.03 and 0.04.

C.1.2 Material suitable for the test chamber include painted brickwork, smoothed concrete, or steel or aluminium plate. Vibration damping of the wall and horns coupling the sources to the chamber is of importance if high absorption, due to mechanical resonance, is to be avoided. Absorption coefficients for these materials commonly range from 0.02 to 0.05; with adequate vibration damping the figure is closer to 0.02 than 0.05.

Brick and concrete may also give figures of less than 0.02, although this should normally be avoided. The recommended range for $\bar{\alpha}$ is a compromise between power requirements, diffusion and smoothness of frequency response. Absorption coefficients, when tending to be high, may sometimes be reduced by coating the appropriate surfaces with an epoxy paint.

The sound source opening and the specimen are also absorbers of acoustic energy. Initially it may be found best to assume the absorption coefficient of the sound source opening to be unity ($\bar{\alpha} = 1$).

Absorption by the specimen would normally be low, as the specimen would have a similar absorption coefficient range to those materials quoted above. If however, the specimen to be tested has non-metallic or highly resonant surfaces, special consideration should be given to the absorption by the specimen.

C.2 Acoustic power requirements. The basic power requirement may be initially estimated from:

PWL $= \text{SPL} - 10 \log_{10}\left(\frac{4}{R}\right)$ dB referred to 10^{-12} watt

where PWL $= 10 \log_{10} W + 120$ dB

and W is the acoustic power in watts;

SPL is the sound pressure level in decibels referred to 2×10^{-5} Pa;

R is the room constant in m^2.

$$R = \frac{S\bar{\alpha}}{1 - \bar{\alpha}}$$

where S is the total surface area absorbing acoustic energy in m^2;

$\bar{\alpha}$ is the mean absorption coefficient of the surface area.

Most sound sources deliver their power unevenly through the spectrum, so that spectrum shaping may be accomplished by reducing the power output in the most efficient part of the output spectrum of the source. Additional power may therefore be required to allow for the inefficiency of the source in parts of its output spectrum.

For the test chambers recommended in **C.1.1** the higher absorbtion coefficient ($\bar{\alpha} = 0.04$) should be assumed in initial calculations.

C.3 Source requirements. An indication of power requirements and of the type of source which may be associated with the recommended test chambers, is given in Table 2.

Acoustic powers, as calculated by the method in **C.2**, have been increased to allow for spectrum shaping and other uncertainties.

Input power for loudspeakers and pressure drive units is given in electrical watts, all other power being given in acoustic watts. In the table these are shown as watts (E) and watts (A) respectively.

Any individual device may not necessarily cover the whole of the frequency range required.

The air modulators referred to are not necessarily commercially available in the intermediate sizes, but represent types which are feasible and would be suitable. A 2 kW (A) modulator is available and could be used in the absence of intermediate sizes.

The use of a large number of sources should be avoided where possible. Since the source area is absorbent to sound, the addition of extra sources will increase the absorption and a state may be reached where the SPL falls when more sources are added. Thus one high powered source is in general more effective than a number of low powered sources.

A random siren is a possible alternative to the air modulator where very high acoustic powers are required. With this type of device, however, spectrum shaping is very difficult to achieve. In addition, special care should be taken to ensure that the output is random under all conditions of use.

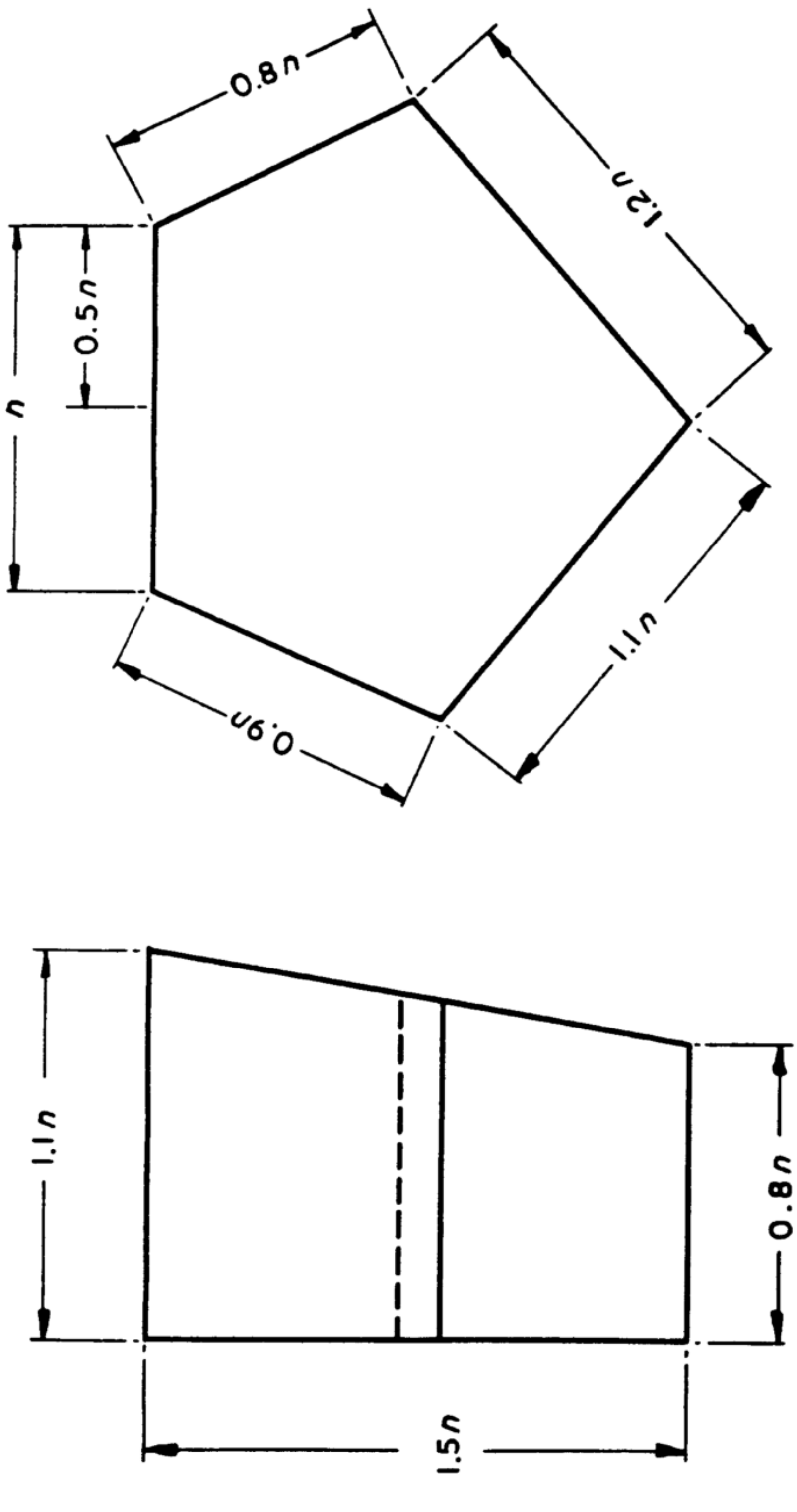

Figure 2 — Reverberation test chamber shape

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