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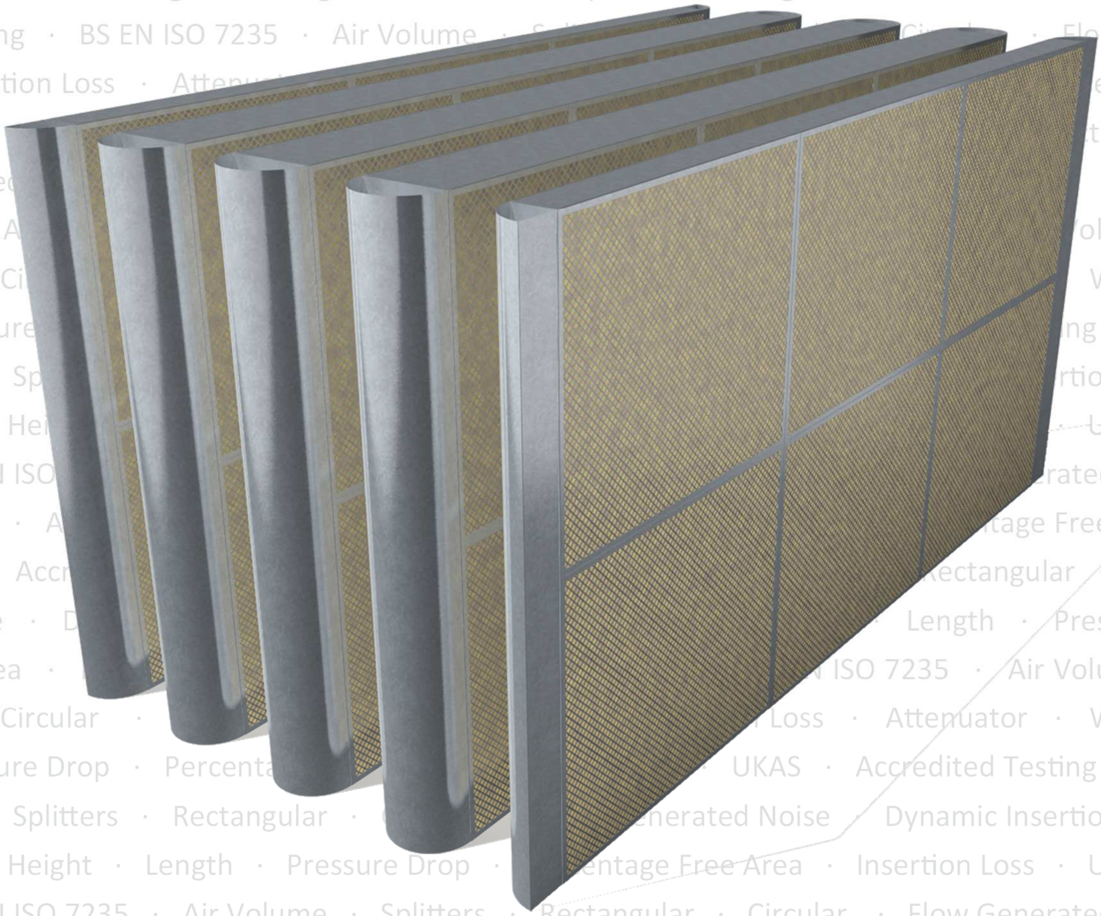


Attenuator Performance

BS EN ISO 7235 Attenuator Testing Laboratory

Test Facility Layout and Components

Attenuator Performance Properties

Attenuator Performance

ISO 7235 Attenuator Testing Laboratory

Attenuator testing is undertaken in the purpose built facility shown below, which is located in Sturminster Newton, Dorset, and operated by Lee Cunningham Partnership, the acoustic consultancy division of CAICE.

The facility is designed in accordance with BS EN ISO 7235: 2009 “Acoustics - Laboratory measurement procedures for ducted silencers and air terminal units - insertion loss, flow noise and total pressure loss”.

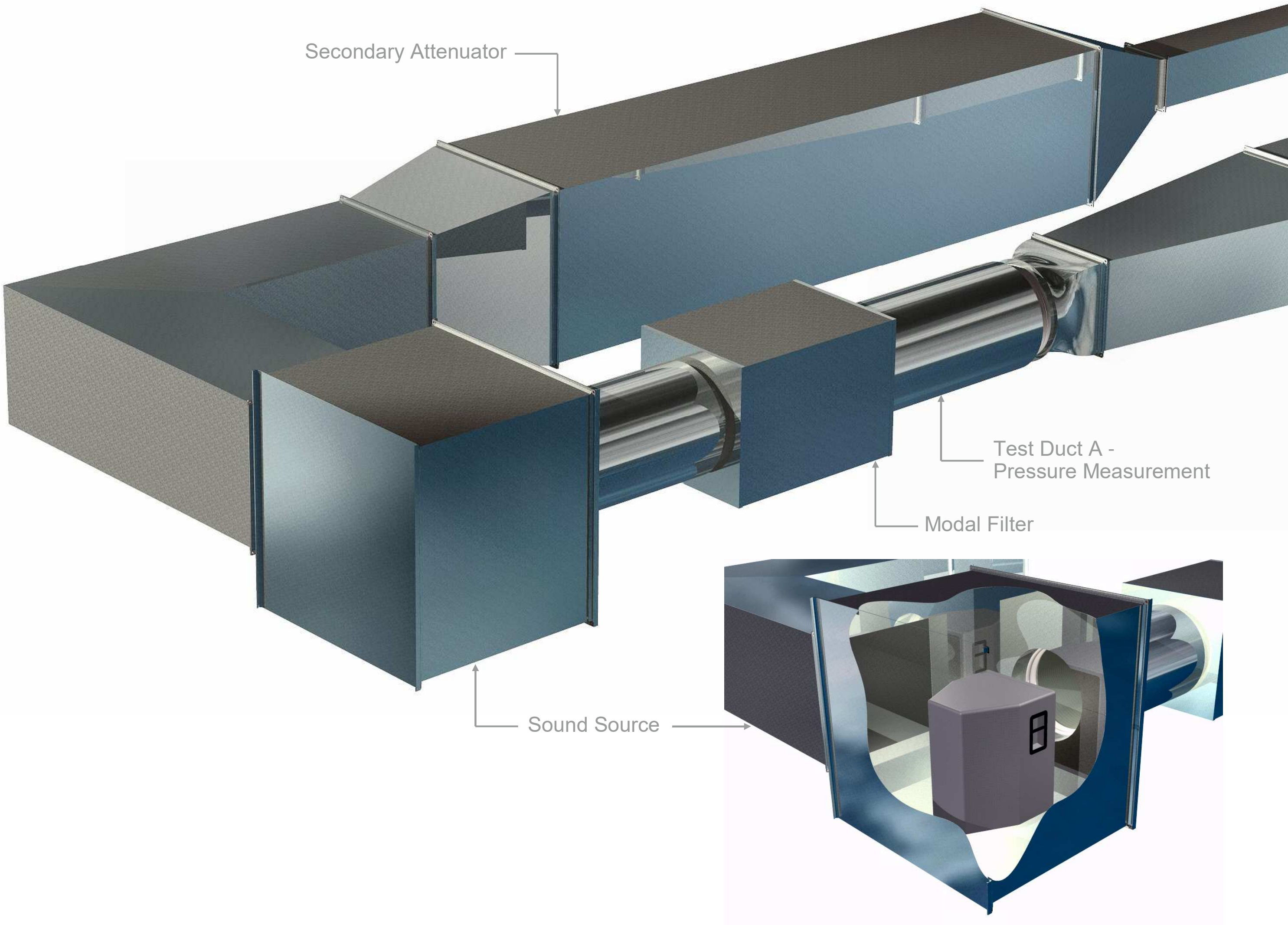
To underline our commitment to provide quality performance data, during the testing programme the facility was a UKAS accredited testing laboratory (No. 4241) for attenuator testing in accordance with ISO 7235: 2009.

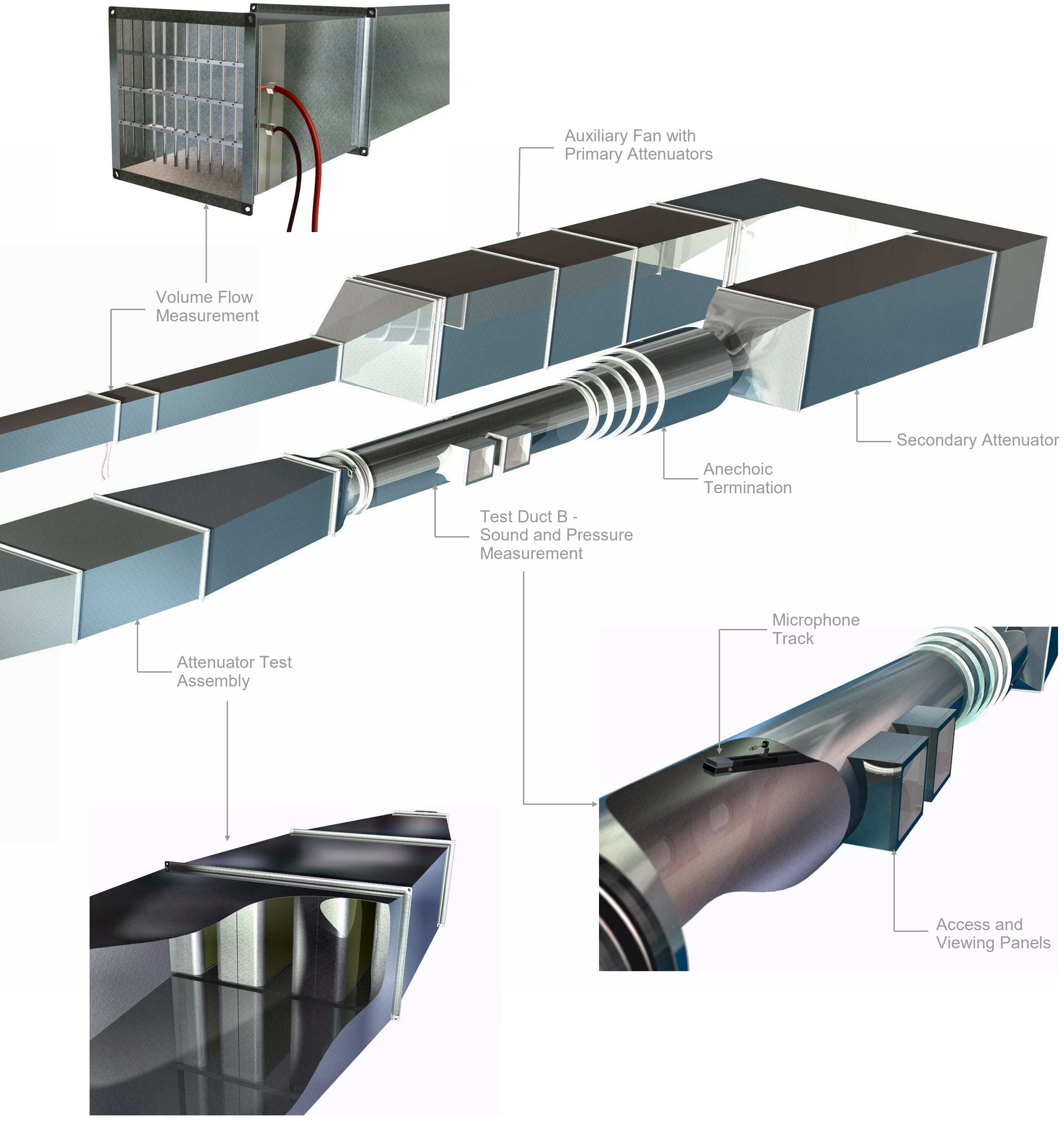
A range of attenuator performance properties can be determined within the facility.

- Static insertion losses
- Dynamic insertion losses in forward or reverse flow
- Forward or reverse flow generated sound power levels
- Total pressure loss

Insertion loss and flow generated data can be provided in octave bands from 63 to 8000Hz, or in one third octave bands from 50 to 10000Hz.

Rectangular attenuators can be tested between 280 and 1200mm square with a maximum length of 4800mm, and circular attenuators from 300 to 1200mm diameter.




Auxiliary Fan with
Primary Attenuators
Volume Flow
Measurement
Secondary Attenuator
Anechoic
Termination
Test Duct B -
Sound and Pressure
Measurement
Microphone
Track
Attenuator Test
Assembly
Access and
Viewing Panels

Attenuator Performance

Test Facility Layout and Components

The test facility is essentially a closed loop ductwork system constructed from galvanised sheet steel, with a number of integral components. The main Test Duct sections A and B, are 630mm diameter, and the total length of the loop is over 50m.

Attenuator Test Assembly

This consists of two transitions and the test object - which is either the test attenuator or an identically sized substitution duct, that replaces the attenuator.

Sound Source and Test Duct A

Random noise is generated by a speaker that is located within the sound source chamber. The modal filter exists to damp any higher order modes generated within the sound source chamber thus creating a plane wave sound field within Test Duct A. Pressure and temperature measurement stations are also located within this section.

Test Duct B

A microphone is automatically moved along a diagonal track within Test Duct B to measure the noise level in five different positions, which determines the average sound pressure level.

An anechoic termination helps to reduce noise reflections back down the duct that could interfere with the noise measurements.

Another pressure measurement station is located in this section.

Auxiliary Fan and Volume Flow Measurement

An auxiliary fan system is located within the ductwork loop to provide airflow up to $2m^3/s$.

High performance primary and secondary attenuators are installed on both sides of the fan to minimise noise transmission to the microphone position.

The fan can be rotated through 180 degrees, which enables air to be moved across the test object in either forward or reverse flow modes.

The volume flow measurement section uses a Wilson Flow Grid to measure the airflow that is generated by the auxiliary fan. Further pressure and measurement stations are also located within this section.

Test Data Acquisition

All data is gathered at a control station and recorded using an in-house software programme, which automatically produces a comprehensive Attenuator Test Report for each test object.

Attenuator Performance Properties

In order to explain attenuator performance properties, it is helpful to understand the basic testing procedures.

The same test procedures must be carried out firstly on the attenuator itself and then secondly on an empty replacement or substitution duct. The substitution duct has exactly the same geometric properties as the test attenuator and both are referred to as the test object when under test.

Static Insertion Loss

This is determined by subtracting the noise levels measured with an attenuator installed from the noise levels measured with the substitution duct installed. It is referred to as static because there is no air passing through the test object.

Dynamic Insertion Loss

Again this is determined by subtracting the noise levels measured with an attenuator installed from the noise levels measured with the substitution duct installed. However it is referred to as dynamic as there is air passing through the test object.

Dynamic insertion losses can be measured with either forward or reverse airflow across the test object, and with up to five different airflow rates for each direction.

Flow Generated Sound Power Levels

When air passes through an attenuator it generates noise. This is defined as attenuator flow generated noise, regenerated noise or self-noise.

Attenuator flow generated sound power levels can be determined with either forward or reverse airflow across the test object, and again with up to five different airflow rates for each direction.

Noise levels also need to be measured under the same conditions with the substitution duct installed to ensure that flow noise generated through the ductwork loop itself is not additive to the attenuator flow generated noise.

Total Pressure Loss

This is determined by subtracting the differential pressure across the attenuator from the differential pressure across the substitution duct.

A total pressure loss coefficient is calculated for each attenuator by measuring the total pressure loss at five different airflow rates.

Scope of Attenuator Testing

The full extent of performance data that can be provided for a single test attenuator is therefore as follows:

- Static insertion loss
- Dynamic insertion loss at 5 forward flow rates
- Dynamic insertion losses at 5 reverse flow rates
- Flow generated sound power level at 5 forward flow rates
- Flow generated sound power level at 5 reverse flow rates
- Total pressure loss coefficient

A total of 43 tests would be required to obtain this data for a single attenuator, and each test requires noise levels to be obtained in five measurement positions. This is a total of 215 measurement sets, which takes about 4 hours to complete.

Although not all tests have been undertaken in this detail, CAICE have tested over 200 different attenuators in order to establish performance data for their range, which further underlines our investment and commitment to quality data.

Repeatability of Test Data

UKAS required periodic audits to take place to check repeatability of test data. The following tables show typical performance data from a number of re-tests that have been undertaken on the same specimen attenuator to monitor consistency of results.

Static Insertion Loss repeatability

Test	(dB) in each Octave Band centre frequency (Hz)							
	63	125	250	500	1k	2k	4k	8k
1	8.5	11.1	19.2	37.2	47.9	46.0	34.0	26.8
2	8.6	11.0	19.0	36.9	47.9	46.1	34.3	27.0
3	7.7	11.0	19.2	37.5	47.8	45.3	33.4	27.1
Diff	**0.9**	**0.1**	**0.2**	**0.6**	**0.1**	**0.8**	**0.9**	**0.3**

Dynamic Insertion Loss repeatability

Test	(dB) in each Octave Band centre frequency (Hz)							
	63	125	250	500	1k	2k	4k	8k
1	2.9	10.0	17.9	34.4	43.9	44.6	32.6	29.3
2	2.5	10.9	18.6	34.7	43.2	44.6	32.8	29.0
3	2.7	10.4	17.9	34.2	42.7	44.8	32.8	29.1
Diff	**0.4**	**0.9**	**0.7**	**0.5**	**1.2**	**0.2**	**0.2**	**0.3**

Flow Generated Sound Power Level repeatability

Test	(dB) in each Octave Band centre frequency (Hz)							
	63	125	250	500	1k	2k	4k	8k
1	52.0	46.8	44.0	43.7	44.7	39.3	30.8	16.0
2	51.6	47.8	43.8	44.0	44.5	38.5	30.1	16.1
3	51.1	47.6	43.6	43.4	44.5	38.4	29.7	15.2
Diff	**0.9**	**1.0**	**0.4**	**0.6**	**0.2**	**0.9**	**1.1**	**0.9**

It can be seen that the test data is remarkably consistent, and in particular static insertion loss never varies by more than 0.9dB in any octave band.

Whilst this shows good repeatability of results, we also need to consider the accuracy of the test data.

Measurement Uncertainty of Test Data

ISO 7235 makes the statement that “exact information on the precision achievable cannot be given at this time”. However it does provide the following estimates for insertion losses only:

ISO 7235 Estimates	50 to 100 Hz	125 to 500 Hz	630 to 1250 Hz	1600 to 10000 Hz
Standard deviation of reproducibility (dB)	1.5	1.0	2.0	3.0
Expanded measurement uncertainty (dB)	3.0	2.0	4.0	6.0

The **standard deviation of reproducibility** is the maximum amount of variance expected if the same specimen attenuator was tested across a number of different ISO 7235 laboratories. Their estimate is made based on a range of tests undertaken on a 1m long attenuator.

The **expanded measurement uncertainty** is for a coverage probability of 95% and this takes into account the huge variety of attenuator types and sizes that could be tested within an ISO 7235 facility. In the absence of more specific data their estimate is taken as twice the standard deviation of reproducibility.

How Accurate is the Test Data?

When the standard itself only provides estimates of accuracy, this does not particularly promote confidence.

However it must be understood that there are only a handful of ISO 7235 laboratories in the world, and most of these are operated by attenuator manufacturers who do not provide access to their confidential test data. It is therefore difficult to make definitive statements on accuracy.

Attenuator Performance

What we do know is that ISO 7235 has gone to extraordinary lengths to ensure that every element of the test facility complies with very stringent requirements. All sound, temperature, pressure and airflow measurement instrumentation has to perform to the highest standards of precision, and carried UKAS accredited calibration certificates. There are also numerous commissioning procedures that have to be undertaken to ensure various components fully meet the performance requirements of the standard.

The previous attenuator test standard was BS 4718 and this contained very few stringent requirements. The current American standard ASTM E477 is more detailed than BS 4718, but it is still far less stringent than ISO 7235.

Through our extensive knowledge of ISO 7235 and the close scrutiny of UKAS during the accreditation process we are confident that the test data is more accurate than the estimates given within ISO 7235. This is supported by the excellent repeatability that we have seen across a vast testing programme and a variety of different attenuator types and sizes. Our estimated measurement uncertainties are shown below:

CAICE Estimates of Expanded Measurement Uncertainty	(dB) in each Octave Band centre frequency (Hz)							
	63	125	250	500	1k	2k	4k	8k
Static insertion loss	2	2	2	2	3	3	3	3
Dynamic insertion loss	2	2	2	2	3	3	3	3
Flow generated Lw	3	3	3	3	4	4	4	4
Total pressure loss	Within 5 Pa							

Test Attenuator Quality

The single most important factor in obtaining good test data is the constructional quality of the attenuator being tested.

A highly sophisticated ISO 7235 test facility is completely undermined unless the dimensional tolerances of the test attenuator are closely controlled. All test attenuator casings, splitter widths and airway widths are therefore constructed to a tolerance of +/- 1mm.

This constructional accuracy ensures that when the test data is subsequently extrapolated to provide data for the range, the expanded data remains accurate.

There are three other constructional factors that must also be closely controlled and inspected.

Gaps between the splitters and casing - can dramatically reduce mid and high frequency insertion loss. Our high build quality ensures that all splitters fit tightly into the casing and gaps are therefore minimised.

Inconsistently packed splitter infill - can again undermine performance. If it is under packed then the mineral wool infill can settle leaving gaps at the top of the splitter, which will reduce mid to high frequency insertion loss. If it is excessively over packed it will actually increase performance. It could also cause the splitter facing to bulge thereby reducing the airway and increasing pressure loss and flow generated noise. Mineral wool slabs must therefore be pre-cut to the correct size before packing, to ensure consistency and to avoid settlement or over packing.

Splitter facing deformation - can cause large variations in airway width along the length of the splitter. This will cause inconsistencies with insertion loss, flow generated noise and pressure loss test data. We provide channel stiffeners that are fixed to the rear of the expanded steel mesh splitter facings. These are fitted at pre-determined centres to minimise splitter facing deformation.

Deriving Performance for the Entire Range

The SG splitter attenuator with 30mm flanges has 18 standard lengths, uses 5 different centre splitter widths and each width of splitter can be provided in 17 standard free area configurations from 20 to 60% in 2.5% increments. This one model therefore has 1530 standard permutations, although we often deviate from these and there are also numerous models in the CAICE range.

Consequently the attenuator configuration permutations across the entire range are almost limitless.

This provides tremendous flexibility in terms of selection options, but it does mean that it is impossible to test every possible permutation of attenuator within the range.

CAICE have therefore devised a sophisticated technique that for a particular splitter width can accurately predict the full range of static insertion loss performance from a relatively small set of sample tests.

Hence it is imperative that test attenuators are constructed to the highest standards otherwise expanded data will not be accurate.

The table below illustrates the principle of the prediction technique where we test three different attenuator lengths, and for each length we test a range of three free areas.

The Range of Sample Tests

Attenuator Length	% Free Area				
	20.0	27.5	37.5	45.0	50.0
1	✓		✓		✓
2	✓	?	✓	?	✓
3	✓		✓		✓

We also test two random attenuators, shown in the table by the ? and compare the test data to the predicted data. Typical results are shown below that highlight the accuracy of this technique.

Static Insertion Loss at 27.5%FA

	(dB) in each Octave Band centre frequency (Hz)							
	63	125	250	500	1k	2k	4k	8k
Predicted	6.4	9.4	17.1	34.7	49.2	38.2	23.9	18.8
Measured	5.7	9.2	16.9	35.6	50.0	39.3	24.2	19.4
Diff	**0.7**	**0.2**	**0.2**	**-0.9**	**-0.8**	**-1.1**	**-0.3**	**-0.6**

Static Insertion Loss at 45.0%FA

	(dB) in each Octave Band centre frequency (Hz)							
	63	125	250	500	1k	2k	4k	8k
Predicted	4.5	5.7	11.7	25.9	32.6	19.1	12.4	9.3
Measured	3.9	5.5	11.8	26.2	32.4	18.8	13.6	9.7
Diff	**0.6**	**0.2**	**-0.1**	**-0.3**	**0.2**	**0.3**	**-1.2**	**-0.4**

Performance Data you can Trust

Attenuator performance is an immensely complex topic and CAICE are very much on the leading edge of development work in this field of acoustics.

Our research work is ongoing as we constantly look to improve our methods and accuracy of performance data.

We hope that this again underlines our position as the leading UK attenuator manufacturer and helps to provide our clients with performance data that you can trust.

Attenuator Performance in the Real World

Attenuator testing to ISO 7235 provides performance data that is achieved in ideal laboratory conditions.

How is this performance data affected when attenuators are installed in non-ideal conditions?

Dynamic Insertion Loss is meant to account for the change in performance that occurs as the airflow increases through an attenuator.

However ISO 7235 states that where the airway velocity falls short of 20m/s airflow will hardly have an effect on the insertion loss. Therefore up to this velocity the difference between Static Insertion Loss and Dynamic Insertion Loss is negligible, and this has been proven during our test programme.

An airway velocity of 20m/s would correspond to an attenuator pressure loss of between 100 to 200Pa, depending on the free area of the attenuator.

Attenuators are generally selected to a maximum pressure loss of 50Pa, and therefore Dynamic Insertion Losses are of little use for day to day attenuator applications.

CAICE have therefore adopted a policy to use Static Insertion Losses for selection of attenuators, although we can provide Dynamic Insertion Losses if required.

Two other problems exist with Dynamic Insertion Losses:

1. Dynamic Insertion Losses are determined in the laboratory under ideal airflow conditions. What happens when the attenuator is subjected to the sort of turbulent airflow conditions that often exist on site? ISO 7235 points out that a design airway velocity of 10 to 15m/s may give you 20m/s on site due to non-uniform airflow distribution. It is impossible to predict how evenly the air will flow through the attenuator on site, which again makes Dynamic Insertion Losses questionable.

2. Even if attenuator manufacturers can provide Dynamic Insertion Losses, how accurate are they? CAICE are currently the only attenuator manufacturer in the UK that can provide both Static and Dynamic Insertion Losses in accordance with ISO 7235: 2009 and our latest very stringent test procedures provide good accuracy. We would seriously question data derived from other, older test standards, or where manufacturers have not ensured that the test attenuators are constructed to the highest standards.

Attenuator pressure loss and flow generated noise can be adversely affected by poor airflow conditions on site. Attenuators should therefore be installed as far away as possible from bends, change of sections, fan discharges, etc, to ensure that airflow is uniformly distributed across the attenuator.

Where poor airflow conditions do exist across attenuators, the site pressure loss can be up to two or three times the expected laboratory pressure loss. Flow generated noise through the attenuator will also increase considerably.

If In Doubt Test It

We hope that this section of the brochure has provided a good overview of the complexities of Attenuator Performance.

However if you have any doubts at all over attenuators that are required for a particular project then we would be pleased to provide further advice accordingly.

The CAICE Attenuator Testing Laboratory is also available to our clients to substantiate performance data where required, and our advice would generally be that if you have any doubt at all then test it.

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