

Running a Test in an Intensity Based Measuring Facility.

by

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Abstract

Intensity measurement has opened new prospects in many areas of diagnostic acoustics, but it is generally accompanied by the need for greater data gathering, strict discipline in measurement procedure, and involved data processing prior to result assessment. One consequence is the introduction of additional areas of potential error.

This paper presents the semi-automated procedures developed at the Centre for Building Studies to minimize user error in the running of a typical laboratory test. A Sound Transmission Loss measurement is used as an example.

An overview is also given of the new Intensity based measurement facility established at the Centre for Building Studies.

Résumé

Les mesures d'intensité ont ouvert de nouvelles avenues dans plusieurs domaines du diagnostique acoustique. Cependant, elles requièrent généralement une acquisition de données plus étendue, une très grande rigueur lors de la mesure et un traitement de données élaboré afin de produire quelque résultat que ce soit. Chacune de ces exigences entraîne de nouvelles possibilités d'erreur.

Cet article décrit les procédés semi-automatisés développés au Centre des études sur le bâtiment dans le but de minimiser les erreurs dues à l'utilisateur lors d'un test typique en laboratoire. Une mesure de perte dans la transmission du son sert d'exemple.

Suit un aperçu des nouvelles installations du Centre des études sur le bâtiment dédiées aux mesures d'intensité.

1. Introduction

The Centre for Building Studies was established in 1977 and at that time a two chamber test facility was constructed to support research activity in sound transmission.

The facility dimensions, Figure 1, were dictated by physical constraints and the choice was made to construct one medium sized chamber, Chamber A, and a relatively small chamber, Chamber B.

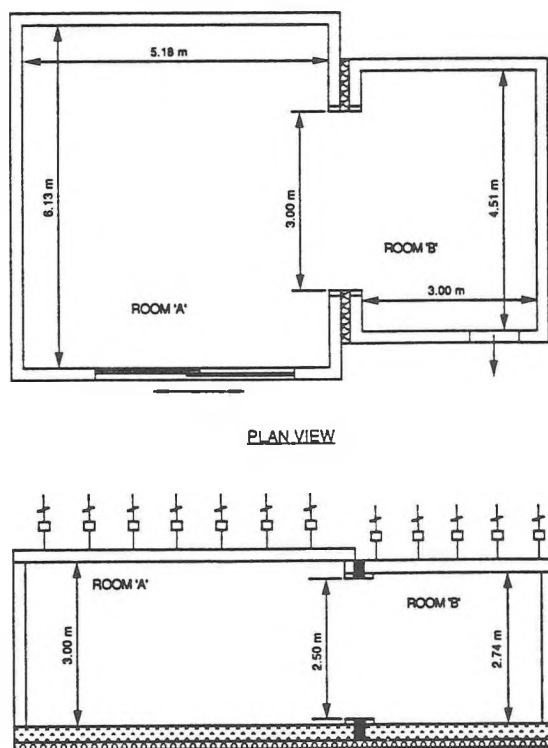


Figure 1. The Test Chambers at the Centre for Building Studies.

Chamber A has been qualified as a Reverberation Chamber in accordance with ANSI.S1.21, Reference 2, as such it is suitable for small source sound power measurements; it would also comply as a source room for sound transmission loss

measurements. However, because of the chamber B dimensions, the transmission suite formed by chambers A and B does not conform to standards for the purpose of sound transmission loss measurement. (See for example ASTM-E 90, Reference 1).

Over the past few years developments in instrumentation have been made which offer a solution to this chamber problem, namely developments in sound intensity measurement.

The laboratory measurement of sound transmission loss via sound intensity measurement typically requires just one reverberation chamber. The reverberation chamber is used to establish the source side intensity by sound pressure measurements, whilst the reception side intensity is measured directly.

Thus the decision was taken to refurbish the facility to better support an intensity measurement system and related measurement techniques.

The intensity measurement system employed at the Centre is the Bruel & Kjaer type 3360 in conjunction with a Multiplexer, B&K type 2811. The 3360 system is suited for a point to point measurement procedure. This allows subsequent generation of surface contour plots when used with a one dimensional probe, and the determination of intensity vectors when used with a three dimensional probe. Both attributes enable surface intensity assessment, fault location in construction or engineering elements, as well

as establishing source locations and directivity patterns.

However, it has been established, References 3 and 4, that strict criteria must be satisfied to ensure the correct use and end result of intensity systems employed for the measurement of sound power. Such criteria have yet to be formalised for the case of sound transmission loss measurements, but one may presume them to be similar and equally demanding.

As an example, reference 3 cites the need to measure both pressure and intensity at every point. The criterion resulting from this data assessment will indicate whether the intensity measurement is acceptable in relation to the reactivity of the sound field.

One consequence of such criteria is the need for a large data handling and processing capability. For example consider the typical data requirements of an intensity equivalent to an ASTM E 90 test (Reference 1), using the point to point system for reception surface intensity measurement, and a reverberant chamber as the source room:

16 Third Octaves (125 Hz to 4 kHz)

100 measurement points on the reception surface.

Sound Pressure Level measurement at each point.

Sound Intensity Level measurement at each point.

So far the need for 3200 data has been established and to this must be added source

room data gathering.

If one now includes the prospect of three axis intensity measurement together with multiple surface assessment, it becomes clear that automatic data gathering and processing is essential.

In order to satisfy data gathering requirements the probe must be held in position for a time satisfying the bandwidth and averaging time product $BT=400$, see for example Reference 3, (16 seconds for each measurement type for a spectrum ranging up from 125 Hz. on the B&K 3360). In consequence, automation of the probe placement is also desirable.

Last but not least, the accuracy of an intensity measurement is dependent upon a number of factors, some inherent to the system and some to the environment within which the measurement is undertaken.

The optimum measurement environment is quiet and free field. This requirement is approximated within the laboratory by taking measurements in an anechoic chamber. In addition, if such a reception side is created, then greater sensitivity and choice of measurement position with respect to intensity vector determination is also realised.

Measurement system accuracy is assessed by calibration. In the case of intensity measurement, somewhat greater user participation and discipline is required for the calibration procedure as

compared, for example, with sound pressure calibration.

Thus, given the complexities of calibration, measurement procedure, and result assessment, additional areas of concern arise, namely the correct sequencing of events and user responses.

This paper will introduce programmes which prompt the user and operate equipment during a test procedure. They are written with respect to the measurement system at the Centre for Building Studies, however the general objectives may be transcribed to other systems; namely to ensure correct test sequencing, instrument calibration, instrumentation settings, and maximum dynamic range for a spectrum read result.

2. The Test Facility

The new facility configuration is shown in Figure 2, and by comparison with Figure 1 it can be seen that most changes have been made to chamber B.

The surfaces of chamber B are lined with acoustic wedges. The wedges are in-house constructed and have a cut-off frequency of 125 Hz. They are approximately 0.5m deep from base to wedge tip and line the chambers back wall, side walls, and ceiling. Additional wedges on portable frames in modules of .5 x .6 m face area line the floor.

Room B also houses the probe traverse mechanism. This consists of a vertical framework on either side of the test

aperture which acts as a guide to a horizontal member. The horizontal member can traverse up and down over the aperture height driven by a stepper motor. A probe holding carriage also stepper motor driven, may be maneuvered to any position across the aperture width. The net result is a probe placement system capable of scanning over the 3 x 2.5 m test aperture to any location with an accuracy of 0.5mm.

The probe may be oriented towards the aperture, as in the case of a sound transmission loss test, or towards room B for sound power measurement. All subsequent probe placements, data gathering, and processing can now be under software control.

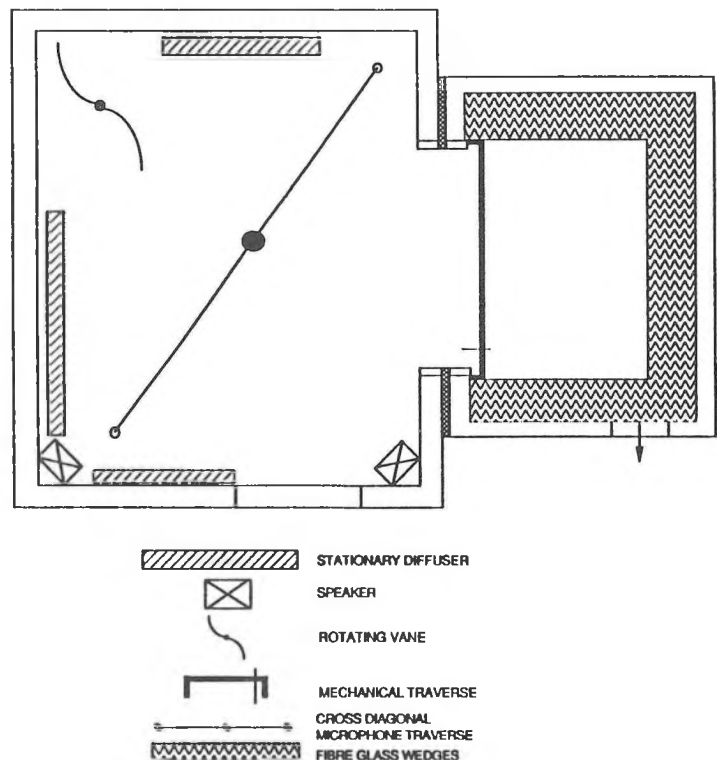


Figure 2. The Room Arrangement to Support Intensity Tests.

The automated system developed at the Centre for Building Studies to support both data gathering and probe placement is shown diagrammatically in Figure 3.

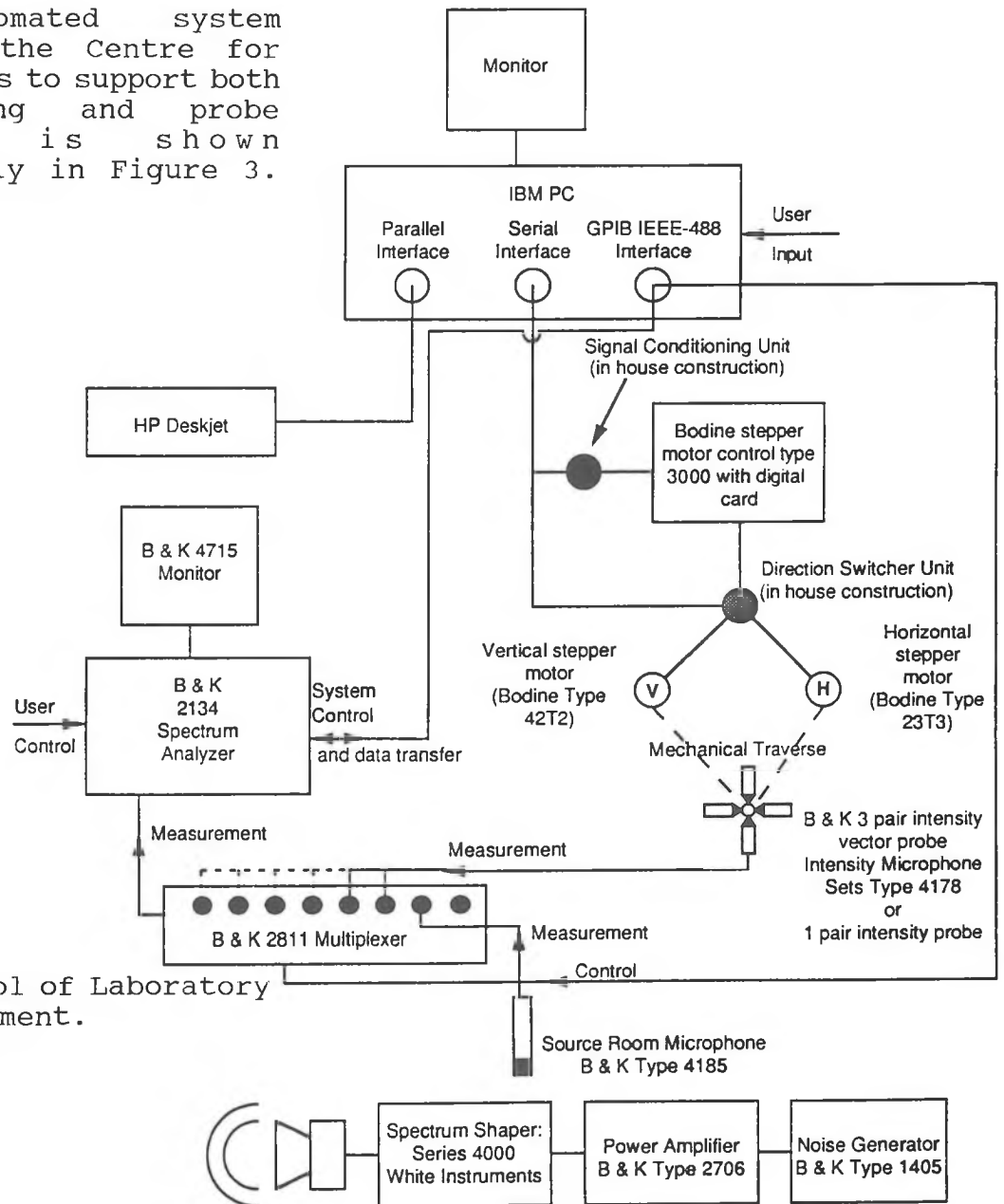


Figure 3. Control of Laboratory Equipment.

3. The Procedure

A test may be considered in three stages:

Stage 1. Instrumentation set-up, calibration, and test settings.

Stage 2. Data acquisition and test monitoring.

Stage 3. Data processing, result evaluation, and output.

Stage 1:

Several programmes have been developed during the course of the present work, each specific to a particular application and probe arrangement. However all

involve transducer and system calibration, and most require the use of a multiplexer, so that an outline for the determination of sound transmission loss and surface intensity contour plots, will serve as a representative example.

The sound transmission loss is given by the formulation (Reference 5):-

$$TL = L_p - L_r - 6 + L_{wh} + L_a - L_c$$

where

TL is the Sound Transmission Loss.

L_p is the Sound Pressure Level in the Source Room.

L_r is the Average Intensity Level on the Reception Side.

L_{wh} is the Waterhouse correction

L_a is a Reception side measurement to test area correction.

L_c is a calibration correction

A measurement of the source room sound pressure level to the requirements of ASTM E 90, and the measurement of the sound intensity level plus sound pressure level at each grid point across the reception surface will now be required.

It may be noted in passing that employing an anechoic reception room will eliminate the need for corrections associated with absorption of the test panel surface in the presence of a reflective field, see for example Reference 7.

An overview of stage 1 elements is shown in Figure 4.

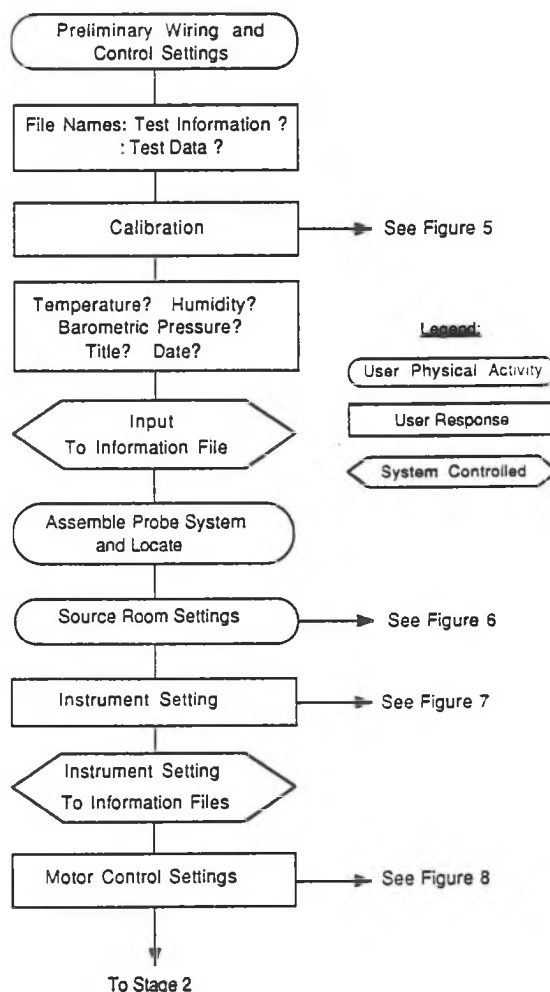


Figure 4. Overview of Stage 1. Instrument Set-up, Calibration, and Test Settings.

Three types of activity are represented, A User Physical Activity, A User Response, and A System Controlled Event.

Each user involved activity is accompanied by full instruction or necessary description on the visual display monitor and the next step is not encountered until prompted by the user; the system controlled events are accompanied by some visual display message or output to

assure the user that something actually is happening, and to allow full test monitoring.

For convenience, stage 1 is further subdivided to:

- a). The Calibration Sequence.
- b). Source Room Management.
- c). Instrument Settings.
- d). Measurement Grid Set-up.

a). The Calibration Sequence

The calibration sequence is shown in Figure 5, and it can be seen to involve three types; pressure calibration, pressure-intensity index evaluation, and probe pair reversal.

The pressure-intensity index will subsequently be used as part of the measurement error estimate and in consequence is stored to file for later retrieval.

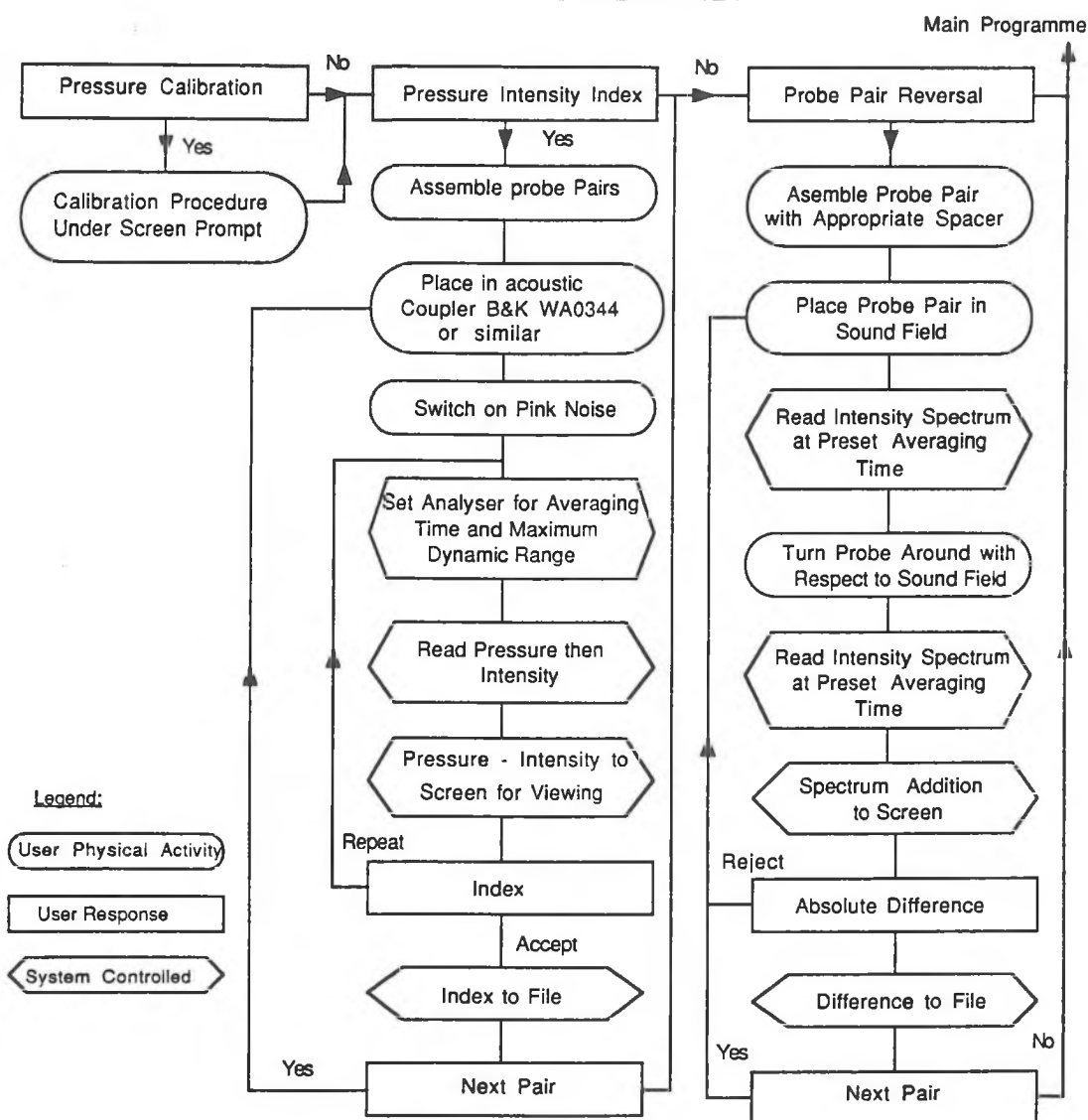


Figure 5. Calibration Sequence.

The probe pair reversal test serves the dual purpose of checking the probe consistency in use as well as identifying channel orientation for intensity direction sensing.

It involves sensing the intensity at each frequency band of interest with the probe oriented at 0, then 180 degrees to the source whilst maintaining the same acoustic centre. One should find the same absolute intensity measurement with the direction reversed. In the present laboratory procedure, this test is undertaken in approximate free field conditions with a broad band noise source.

b). Source Room Management

The source room management sequence is shown diagrammatically in Figure 6.

Establishing the base level for maximum dynamic range is accomplished under software control on the 3360 by switching the analyzer to Octave Filter Bandwidth and sensing the overall sound pressure level. A simple iterative manipulation of the input attenuation setting will then allow the maximum dynamic range to be established. The source room base level need only be established at the start of the test because of the spectrum's general stability.

In the case of sound transmission loss, a complication can arise with respect to the selection of the source spectrum, Pink or White. Most panels will yield low transmission loss at low frequency with high transmission

loss at high frequency. On the reception side, low frequency intensity will dominate the measured spectrum and to avoid instrument overload the high frequency bands may be forced below measurement range. This prospect can be alleviated by employing White Noise as the source spectrum.

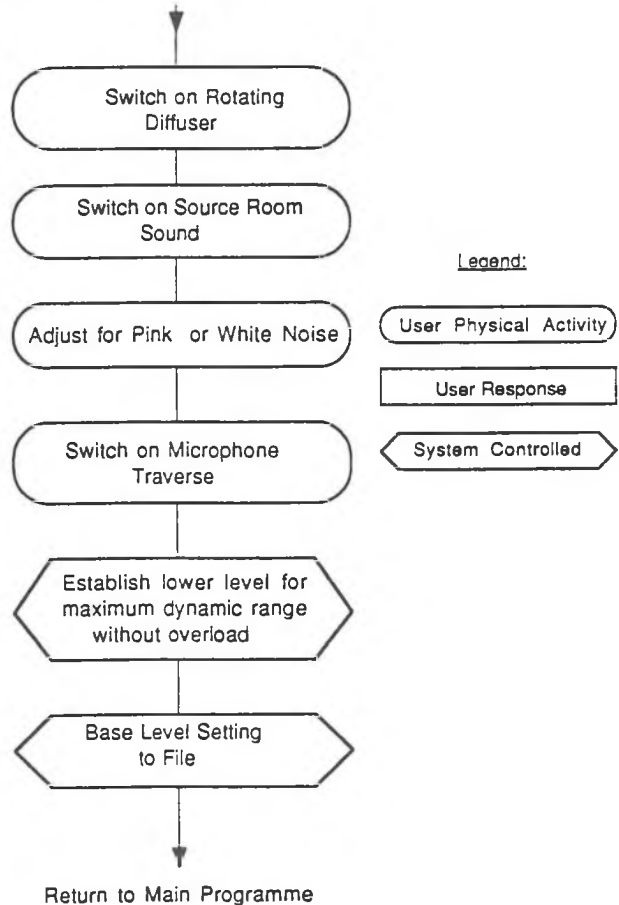


Figure 6. Source Room Management.

c). Instrument Setting

The instrument setting routine is shown in Figure 7. The settings will primarily depend upon the frequency bandwidth analysis required together with the frequency range.

Of great importance in the matter of the frequency range is selection of the appropriate microphone type and probe spacing. As can be seen, the user is stepped through the required decision making process and when automated analyzer setting is not possible, the user is prompted to manually select.

d) Measurement Grid Set-up

The measurement grid set-up procedure is shown diagrammatically in Figure 8. The grid usually consists of a two dimensional point array over a vertical plane as set by the traversing mechanism installed in Chamber B, see Figure 2.

In the case of sound transmission loss measurement the panel under test is treated as a noise source on the transmission side, and a procedure similar to that of sound power measurement may be employed to determine the average surface intensity.

One of two surface measurement schemes have been employed by experimenters so far (References 5 and 8), they are:

1. A single plane parallel to the test panel and located within a niche or at the interface of the niche and receiving room. (See Figure 9a).

2. A major plane parallel to the test panel, with a secondary surface scan for 'leakage' across the open edges to the reception room formed between the major plane and the test panel. (See Figure 9b).

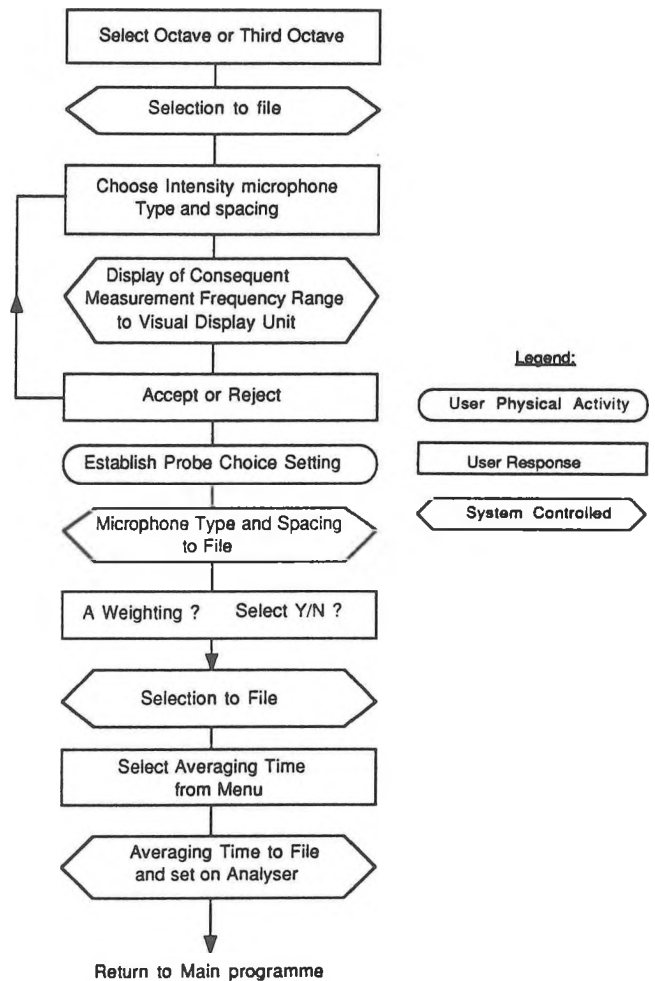


Figure 7. Instrument Setting.

Both surface schemes would typically require the main plane to be relatively close to the test panel in order to allow the development of surface intensity contours or to avoid adverse surface pressure-intensity ratios in a reverberant reception field. However, whilst the closest distance will be dictated by surface proximity measurement errors, (See Reference 6), problems of measurement interpretation can arise as a result of being within the panels near field.

Surface scheme 1 offers the advantage of a single plane scan, and this is preferable provided that the niche does not have dimensions which may influence the test result (Reference 9).

Assuming the single plane measurement pattern for the present example, the set grid will now form the basis for monitoring and progressing the test proper. In the case of automatic traversing the pattern will also establish the stepper motor controls and sequencing.

As can be seen from Figure 8, the rectangular grid requires the minimum data input of measurement plane height and width, together with the number of measurement rows and columns. In the case of an irregular spaced grid, the coordinates of all points must be input.

Once the pattern is established a scale representation of all points is presented to the user on the viewing monitor; this serves as a check prior to starting the measurement procedure and as a progress guide during the test.

Stage 2:

The data acquisition sequence is shown diagrammatically in Figure 10, and whilst the probe movement may be under manual or automatic control, once the probe is located the measurement sequence will be automatic.

The actual order of data gathering is not significant provided each is preceded by

appropriate dynamic range fixing.

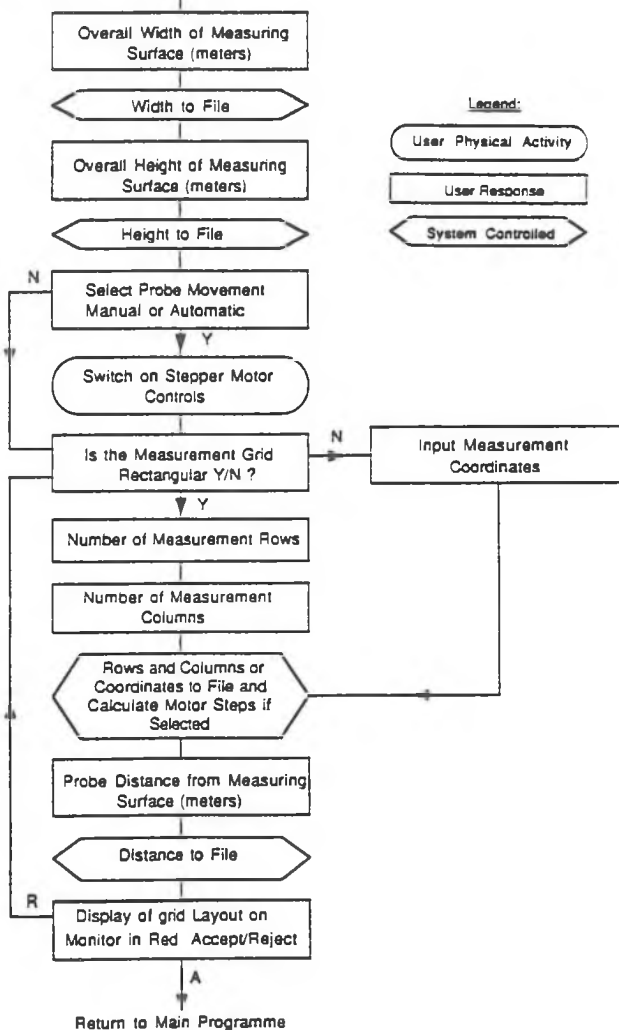


Figure 8. Measurement Grid Set-up.

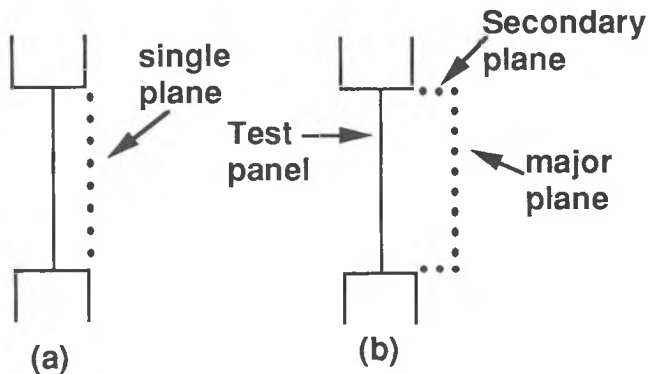


Figure 9. Surface Measurement Schemes.

Progress monitoring is achieved at this stage by the use of a colour code system for the grid points shown on the visual display monitor. If the point has not been measured then it is displayed in red, if measurements are taking place at the point then it is displayed in green, and completed points are blue.

In addition, during a point measurement sequence, the actual measurement type, the actual measurement type and the required multiplexer channels are shown underneath the grid display.

The spectrum reading is simultaneously shown on the analyzers display unit. Under probe automatic movement control, the full test sequence will be completed without further user intervention.

The vertical and horizontal bars on which the probe carriage is mounted have preset movement limit switches to avoid accidents to the probe resulting from incorrect input data; if tripped the movement system is put to neutral and an audible signal is generated. At the end of a test the probes last position is maintained to allow visual confirmation of correct overall movements.

With an averaging time of 16 seconds per measurement type, two 8 second dynamic base settings per point, an array of 100 points, stepper motor controlling and signal lull times, full data gathering under automatic control for a sound transmission loss and surface intensity contour test will take approximately 2 hours.

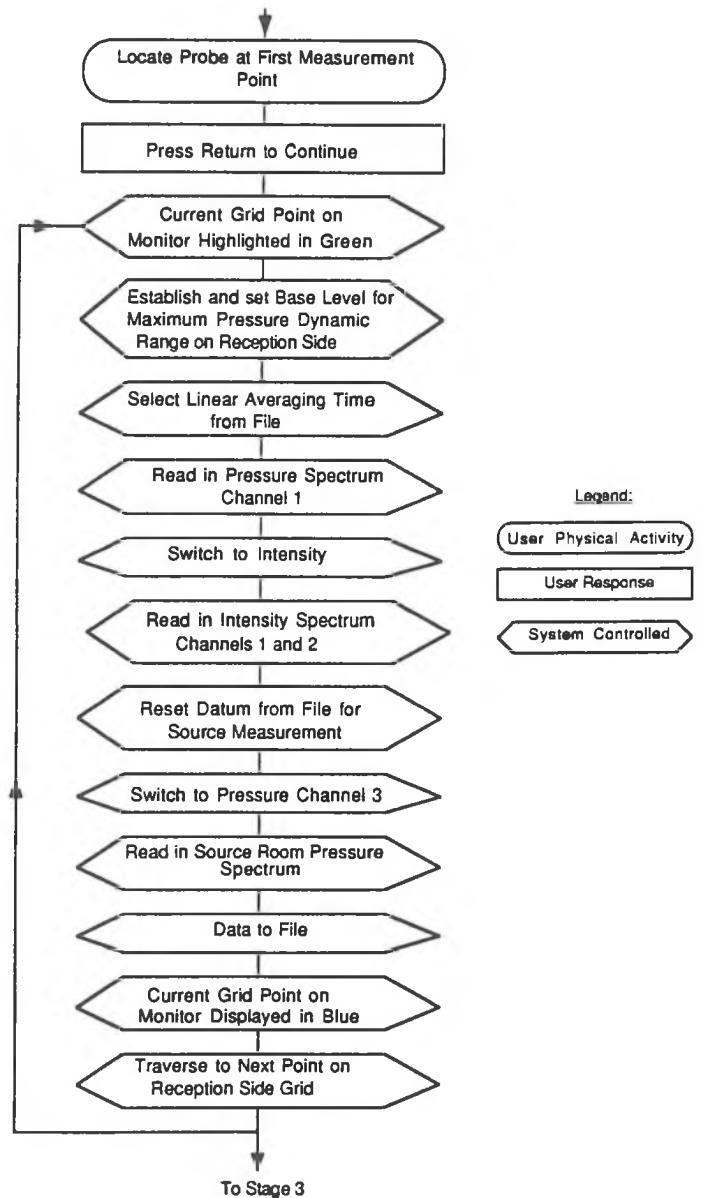


Figure 10. Stage 2, Automatic Probe Movement and Measurement.

Stage 3:

Stage 3 of the test sequence is concerned with data processing and its nature will depend upon the particular test requirements.

In the present example of

a transmission loss test the primary output could be similar to that of an ASTM E 90 test together with field indicators and test descriptors. However much greater insight into the transmission process is now possible.

The advantage of the current intensity based, point to point measurement system over a standard reverberant chamber test result may be considered under three headings:-

- a) Product Development.
 - b) Fault Location.
 - c) Examination of Phenomena.
- a) Product Development

Consider the surface profile of transmitted intensity for a given window shown in Figures 11 and 12.

The system tested was a Vertically sliding window set within an aluminum frame.

The two vertical sliders (top and bottom), are arranged to seal within the tracks of the frame and against each other across the centre of the window.

Figure 11 displays the transmitted intensity at 250 Hz, whilst Figure 12 shows the result at 2000 Hz.

At low frequency, maximum intensity can be seen emanating from the sides of the window, or from the frame track. Three dimensional intensity vector measurement would probably clarify this point.

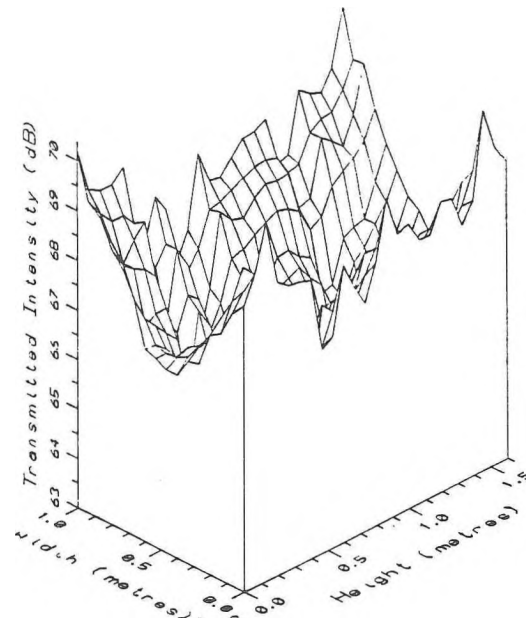


Figure 11. Transmitted Intensity for a Vertical Sliding Window at 250 Hz.

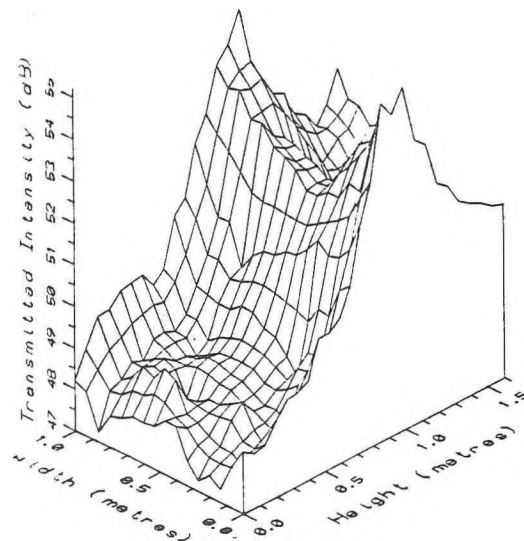


Figure 12. Transmitted Intensity for a Vertical Sliding Window at 2000 Hz.

At higher frequencies, maximum intensity is measured at and about the horizontal junction of the sliding panes. In addition, more energy is

transmitted from the top of the window system compared to the bottom.

Such information may now be further processed to yield detailed design suggestions.

b) Fault Location

The identification of unexpected or untoward sound transmission paths can be used to confirm the correct installation or integrity of a test specimen.

Figure 13, (Reference 10), displays the results of two transmission loss tests. The lower transmission loss curve, shown dashed, was obtained after purposely removing some of the edge sealing between the test panel and containing wall. The result, if viewed in isolation, would probably be accepted as a true indication of the panel's performance. The upper curve of Figure 13 shows the panel performance prior to introducing the fault.

Figure 14 displays a contour plot of transmitted intensity at 1600 Hz after introduction of the fault. The fault location at the left hand side of the panel can clearly be seen. Thus the surface intensity scans will give confidence to the installation integrity.

c) Transmission Phenomena

The examination of sound transmission phenomena can be undertaken in much greater detail than hitherto possible.

For example, Figure 15 displays the transmitted surface

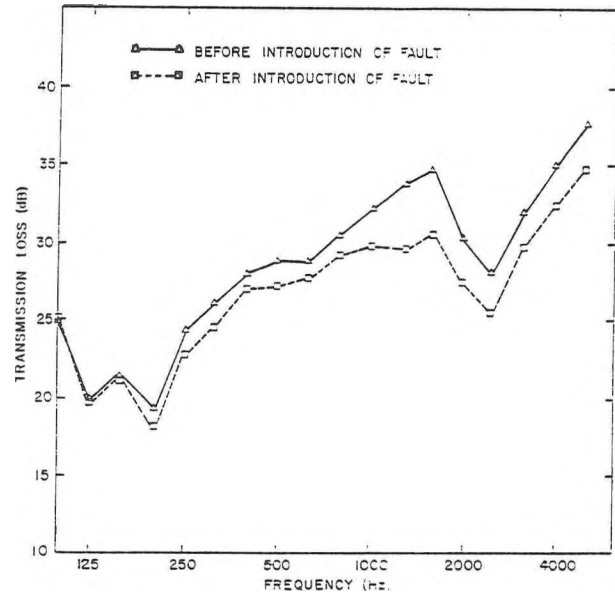


Figure 13. Comparison of Transmission Loss before and after introduction of a fault. 1.14 m x 1.14 m panel.



Figure 14. Transmitted Intensity at 1600 Hz after introduction of a fault. 1.14 m x 1.14 m panel

intensity profile at 400 Hz of a standard double glazed window consisting of two 3mm. glass panes separated by an air gap of approximately 10 mm.

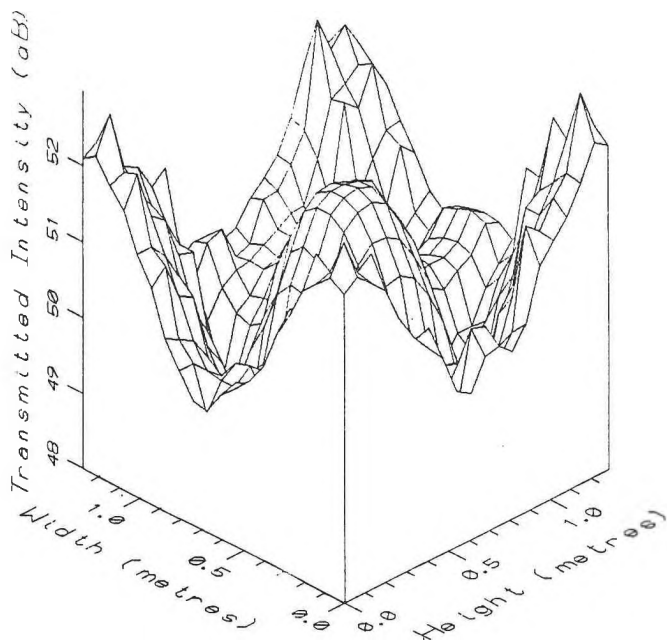


Figure 15. Transmitted Intensity at 400 Hz for a double glazed window.

The profile displayed may be interpreted as the fundamental mass-spring-mass resonance of this system which occurs within the 400 Hz third octave band.

The surface plots presented here are achieved by use of 'Surfer', a programme developed by Golden Software, Inc.

Conclusion

Much care and attention is required to successfully complete a sound intensity based test. However with the aid of the ubiquitous PC the user can avoid many pitfalls and realise an end result far superior to that obtained by other measurement techniques.

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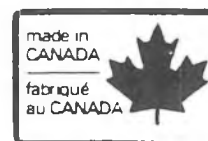
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