Acoustics laboratory fire at the University of Sydney

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ABSTRACT

In October 2005, the University of Sydney's Acoustic Research Laboratory experienced a fire, which destroyed much of the facility through smoke and heat damage. This paper tells the story of the fire and its consequences. While the cause of the fire remains undetermined, it seems likely that it started in the lighting system of the anechoic room. The presence of some flammable material in the room, the high degree of thermal insulation, and a compressed air supply to the room established the fire in that room, with hot smoke filling the rest of the laboratory. Laboratory restoration is a slow process, and we report on how teaching and research has been affected. We also describe the features of the restored laboratory, including architectural modifications and a systems-based approach to equipment.

INTRODUCTION

On the evening of Friday 21st October 2005, fire took hold of the anechoic room in our acoustics laboratory at the University of Sydney. Although the flames were mainly restricted to one room, the entire laboratory suffered smoke and heat damage, with a large amount of equipment damaged. No-one was in the laboratory at the time and so, thankfully, nobody was hurt.

Reduced to minimal amounts of useable equipment and space, and with the total loss of the facility central to our acoustics teaching and research programs, we were left with the immediate problem of organising student laboratories while we worked towards the re-instatement. Some research students have had to suspend their study and we have had to rethink and reinvent hands-on activities for postgraduate coursework students. This loss occurred near the end of the academic year which gave us time before the next semester to have a selection of equipment cleaned and recalibrated, and to obtain the necessary portable field testing and bench-top measurement equipment to continue. Laboratory spaces around the Faculty, regardless of their designated function (eg lighting research), have become *de facto* acoustics laboratories for measurement, testing, teaching and storage.

This paper outlines major issues associated with the fire, including a description of the laboratory and its history, the fire itself, restoration of the laboratory and its envisaged improvement.

THE LABORATORY

Prior to the fire the laboratory consisted of an anechoic room with a useable volume of 56 m^3, and a reverberant room with a volume of 130 m^3 (which is smaller than standard). The anechoic room had a background noise (with the air conditioning operating) that was lower than the 1/3-octave band hearing threshold, as defined by ANSI S12.2-1995. These two specially designed rooms were isolated from the main building and separated by a control room with cable access to them for connection to noisy external measurement and control devices. Equipment was stored on shelving throughout the control room and in wooden cupboards below built-in benches. On the other side of the reverberant room there was also a large teaching and research area which had three impedance tube systems, portable recording devices and desktop analysers permanently set up ready to use. Six steel cupboards held the bulk of the current model hand-held analysers and their accessories. Joining on to the main lab area was a store room, in the form of a disused artificial sky consisting of a concrete dome (providing interesting acoustical conditions). This room housed three large multi deck shelves that stored all of the field measurement devices that had road cases along with large meters, amplifiers and speaker assemblies and test arrays. The general layout of the lab is shown in Figure 1.

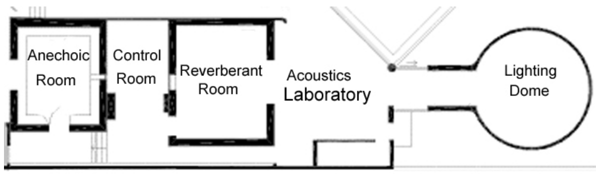

Figure 1. General layout of the laboratory

THE FIRE

The fire was mainly restricted to the anechoic room. While there is not much to burn in an anechoic room, at the time, our room had some samples of a synthetic porous absorber, which had a degree of flammability. Also in the room was a subwoofer and a dodecahedral loudspeaker, which ironically had been used about one week previously in a student project to qualify the room based on ISO 3745:2003. Figure 2 shows the inside of the anechoic chamber prior to the fire.

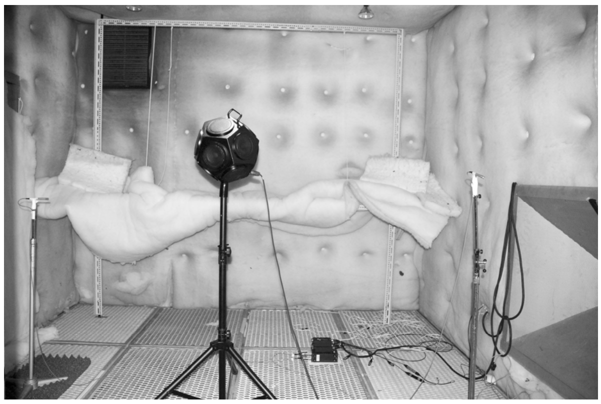

Figure 2. Anechoic Room prior the fire

At the time of the fire this equipment was disconnected from the power supply. The aluminium dodecahedral loudspeaker melted in the fire, so only small pieces of it were found afterwards. Various cables, including twelve loudspeaker leads, were fed into the room through small ports in the wall, and we understand that these were initially mistaken for high tension electrical supply cables by those investigating the fire (and considered to be a possible cause of the fire). The room also had a compressed air supply which, after the rubber hose melted, fed the flames with oxygen. Upon hearing the sound of this escaping gas, the fire fighters withdrew until the supply was stopped. The Fire Brigade investigation of the cause of the fire was inconclusive. It seems likely that the unusual nature of the room caused some confusion in the initial assessment, which could not be resolved later because material from the room had been removed. Figure 3 shows the anechoic room after the fire. The solid object front right is the charred remains of the subwoofer cabinet.

Figure 3. Anechoic Room after the fire

No matter where its location within the laboratory (even in the dome at the far end of the laboratory), only equipment sealed in airtight cases was saved from the hot corrosive smoke. Loudspeakers throughout the laboratory were damaged or destroyed, sometimes through the melting of their suspension, or else through corrosion. Most of the sensitive electronic equipment throughout the lab was damaged. About half of the microphones were damaged. The estimate for reinstatement (currently at AU$2.7M) is dominated by the equipment loss.

FIRE AFTERMATH

The University of Sydney is a very large organisation, which has advantages and disadvantages. A clear disadvantage of this has been seen in the protracted process of laboratory reinstatement. Having several extra-Faculty parties involved in this process (eg for loss assessment, risk management, reinstatement design, reinstatement planning, and so on) created a situation of dispersed responsibility, so that at the time of writing, work on rebuilding the laboratory has not commenced (nine months after the event). However, replacement of equipment has been faster, especially compact laboratory and field equipment essential for maintaining the graduate coursework in acoustics. In the mean time, the Faculty's photometric laboratory has been taken over by acoustics, to house the large amount of replacement or repaired equipment.

Some research students have been badly affected by the unavailability of a laboratory, and three have suspended their candidature for a year. By contrast, the graduate coursework program in audio and acoustics has continued to attract large student numbers, and we have accommodated their needs by changing the way in which we teach (with a greater emphasis on field work).

The Fire Department made the following recommendations:

- swipe card access be installed for the laboratory, so that access could be tracked by a security system;
- an automatic cut-off valve be installed on the building's compressed air supply, so that the supply is cut when a fire alarm is activated;
- master switches be installed for the power circuits in the laboratory (earth leakage protected); and
- low voltage lighting be used in the anechoic room.

These have been combined with other considerations in plans for the reinstatement, which are outlined in this paper.

ANECDOTAL HISTORY OF THE LABORATORY

The history of the acoustics laboratory dates from 1954 when Professor H. J. Cowan was appointed and the Department of Architectural Science was established in the Faculty of Architecture. A Master of Building Science degree was started in 1961. Initially it was mainly concerned with structural aspects of buildings but it was soon realized that there was a need for other aspects of building science such as lighting, thermal and acoustic design. These and other subjects were incorporated into the Master of Building Science degree and then, because of need and increased knowledge, became postgraduate degree courses in their own right. At the same time there was growing interest in undertaking postgraduate research degrees, especially in acoustics, and a need for acoustics courses in Architecture, Engineering, Physics and Music, all of which required access to an acoustical laboratory.

The first acoustics laboratory was constructed in the late 1960s, partly in an abandoned chocolate factory and partly in a disused ladder factory. It consisted of a large reverberation room, an instrument room/electronic workshop and a small anechoic room. The instrument room contained little more than a reel-to-reel tape recorder, a couple of sound level meters, a calibrator, a measuring amplifier, a couple of frequency filters, a standing wave tube with frequency generator and power amplifier, a white noise generator, paper chart recorder, a couple of condenser microphones and a few loudspeakers. The reverberation room was a very basic 200 m^3 concrete block construction that was mainly used as a venue for parties. The anechoic room could be best described as a large broom cupboard, the walls and ceiling of which had been sprayed with asbestos. The floor had also been sprayed with asbestos, upon which had been laid steel reinforcing mesh for a concrete slab.

Despite these limited resources some important research was undertaken, such as the first survey of aircraft noise problems in Australia (Mather 1971) and on the propagation of sound in urban areas (Bullen 1978) before the anechoic room was permanently sealed up because of the danger it posed to students and staff, and the reverberation room (and the building it was in) were demolished as the building was in danger of collapsing if the white-ants decided to move out.

A temporary acoustics laboratory was established on the fifth level of the first stage of the existing Architecture building. A small reverberant room (approx 80 m^3), an even smaller hemi-anechoic room (approx 35 m^3) and an instrument room were fitted out using existing spaces. By this time there was considerably more instrumentation and, because most of the work at this stage involved field measurements, such as measuring sound transmission in buildings (Lim, 1982), much time and effort was spent in carrying equipment up and down four flights of stairs, there being no lift.

In 1984 the acoustics lab moved into the newly constructed and purpose designed facility (space limitations however were a major constraint on the design) that was largely destroyed by the fire in October 2005. Studies involving subjective assessments in anechoic conditions could be carried out for the first time. Before the fire both the anechoic and reverberant rooms were heavily used for research (eg Madry (1990), Wu (1991), Jeon (1994), Wendolowski (1995), Field (1998), Jeong (1998), Cabrera (2001) and Xu (2005)), teaching (especially after the audio and acoustics postgraduate coursework program started in 1995) and for final year and honours year projects carried out by students from Physics, Psychology, Mechanical Engineering and Electrical Engineering. Nineteen PhD students and seventeen Masters students completed their degrees in the period 1984 to 2005 and over 150 journal and conference papers were published. Since the laboratory did not have a transmission suite and the reverberant room was not full size, commercial work in the facility was not routine, tending to be of a specialist nature.

Many items of equipment were specifically made for research and teaching activities, eg an airflow resistance rig, two microphone impedance tube, Kundt's tube, computer operated positioning apparatus which could position hot-wire anemometer probes and microphones to 0.5 mm accuracy and specialised loudspeakers. The first computer was introduced into the lab in 1986 and by 2005 most measurement, analysis and recording was undertaken digitally.

Many memorable activities have been undertaken over the years, not the least of which were yelling competitions in the reverberant room on University open days (throat lozenges were freely available for the overzealous participants).

OPTIMISING THE RECONSTRUCTED LABORATORY

Anechoic lining

One of the issues that needed to be addressed in reconstructing the acoustics laboratory was the performance of the anechoic room lining. The original room had flat layers of "graded-density", fibrous, lining. The design was determined using the work undertaken by the CSIRO (Davern 1980) which involved extensive trial and error testing in an impedance tube. Information on the materials in the three layers and thicknesses of the layers in the destroyed room was lost but the resultant room lining had a low frequency cut-off of approximately 315 Hz.

The flat layer graded density (or more correctly graded flow resistance) type construction is far less costly than the anechoic wedge construction and, for a given thickness (length of wedge) can be made anechoic to a lower frequency than the wedge linings. In the past the difficulty with this type of construction has been to determine the optimum airflow resistance and thicknesses of the layers of sound absorbing material to achieve a required cut-off frequency. While it was known that the layer of material nearest the wall had to have the highest airflow resistance and the layer on the room side the least airflow resistance, the thickness of the layers, the airflow resistance values of them and the number of layers was largely a matter of experimentation. There was also another constraint; the limited materials available and their thicknesses.

Fortuitously, work on this topic had recently been successfully completed for a PhD dissertation at Sydney University (Xu 2006a). The theory, which involved an optimisation technique using evolutionary algorithms, was published (Xu 2004), used in a design (Xu 2006b) and evaluated (Xu 2006c) in an anechoic room at the University of Western Sydney, with a low cut-off frequency of 250 Hz (300 mm lining thickness). Another semi-anechoic room, in the School of Electrical and Information Enginnering at Sydney University, has also been designed, contructed and successfully tested, with an anechoic cut-off frequency of 100 Hz (790 mm lining thickness). This research has established that there is little performance advantage to be gained using more than three different layers of absorbing material, and that optimised designs can be achieved using unmodified commercially available materials. The envisaged anechoic lining of the restored laboratory has a low cut-off frequency of 200 Hz (thickness of 430 mm).

Other improvements

Further improvement to the anechoic performance of the room is to be achieved by a better selection of expanded metal raised floor (which has been shown not to compromise anechoic conditions in the room at the University of Western Sydney). The observation window is to be removed, to be replaced by closed circuit television monitoring – which has a much smaller acoustic impact on the room. The luminaires (which were bare Par-38 sources) are to be replaced with much smaller tungsten-halogen light sources, again reducing acoustic impact. This is also supported by the Fire Department's recommendations, since lighting was a possible cause of the fire. Rather than a pair of doors separated by an air gap, the new anechoic room will have a single door, which will permit a continuous anechoic lining when closed due to the door being outward opening. While this will reduce the sound insulation (an STC 50 door has been specified), on balance this is an improvement. A sound absorptive booth around the outside of the single door will shield it from at least some external noise. A secondary doorway will be replaced with a wall, which will both increase the sound isolation from an adjacent corridor and allow for better anechoic performance (the pre-existing doors had perforated metal facings).

Beyond the anechoic room changes to the laboratory are minor, such as bench reconfigurations, changes to fire escape routes, and improvement of the electrical system and other cabling. We considered the possibility of expanding the reverberant room to 200 m^3, but this was considered to be too expensive, since it probably would involve raising the roof of the concrete shell that encapsulates the laboratory.

EQUIPMENT

The evolution of equipment needs

Fifteen years ago, much research would be done with simple sound level meters, and we would be doing well to get two phase related microphones (apart from the sound intensity probe) working on the Kundt's tube in the acoustics laboratory. A single microphone was enough to measure the speed of sound and the cut-off frequency for tube modes, but we wanted to observe wave effects in ducting because this was being researched at the time. More measurement microphones were always being acquired for research and to enable more simultaneous laboratory exercises to be performed and acoustic demonstrations to be conveniently left set up. The graduate audio coursework program, which began in 1995, was built on the foundation of the resident acoustic knowledge and facilities. The scope of research and number of researchers soon expanded to incorporate audio (eg loudspeaker design and measurement, and audio systems) and room and building acoustics studies and the associated equipment inventory grew as a result. More and more channels were needed for measurement systems, as well as higher resolution computer-based instrumentation (eg for impulse response measurements). In the late 1990s we began making binaural measurements and reproductions, and soon afterwards we were making measurements involving audio recordings of up to 24 channels (for research on room acoustics and opera singer vocal directivity). These are just some instances of how the laboratory's capability expanded rapidly over the years, with researchers always wanting to push the limits of the equipment capability. The result was that, prior to the fire, ambitious measurement systems were often improvised, and involved a great deal of preparation to use. One of our aims in recovering from the fire has been to have a more systematic approach to equipping the laboratory to allow for more efficient work.

Pre-existing equipment

As an architectural acoustics laboratory we had equipment that could test many facets of building acoustics for compliance with appropriate building standards. The laboratory also supports a postgraduate audio and acoustics program for which measurements of audio transducers, digital signal processing, and sound reinforcement combine with room acoustics and psychoacoustics. We were set up to take this level of accuracy into the field to obtain airborne and impact sound insulation ratings, vibration measurements, traffic noise, reverberation times as well as high resolution spatial and binaural recordings of acoustic spaces such as auditoria. The laboratory was also set up for sound-field simulations, so that, for example, acoustic environments measured in the field could be brought into the laboratory through a calibrated multi-channel audio system. The equipment spanned many generations of technology from the latest back to equipment some 40 years old. Much equipment regardless of its age was of the highest quality and kept to specification performance by NATA registered laboratory or factory calibration. Keeping up with change is an ongoing process in a research laboratory as measurement techniques vary and increases in processing power deliver greater precision, accuracy and reliability. Included with this were equipment donations from other government laboratories, that had ceased operations or upgraded, leaving us extremely well endowed in many areas of building acoustics and environmental noise measurement. Well constructed precision equipment has a very long life, especially in the sheltered (except for fire) confines of a laboratory.

Saving equipment

In the first three working days after the fire some 1312 items were tagged, boxed and removed from the laboratory to humidy-controlled storage to minimise any further deteriation by the corrosive nature of the smoke silt. A technical cleaning group then assesed the equipment deciding what was worth cleaning and what should be written off. Much of the equipment is irreplaceable and much had been custom built for research or was no longer available comercially. The process of having equipment dismantled, cleaned and calibrated is fraught with hazards. Most devices being sensitive acoustical equipment, the cleaners inadvertantly mishandled some of it causing direct damage, for example, to speaker diaphragms and liquid crystal displays and conceivably misalignments to internal assemblies. After cleaning the equipment was sent to the agents' technical laboratories for testing and calibration. The quote from the agent would invariably include the cost of sending the equipment back overseas to the manufacturer for testing and calibration. In one case, an analyser went to Lichtenstein for a calibration check, and then to the Isle of Wight for factory repair to the digital circuits. Not much scientific equipment is held on shelves in Australia so there is a four to eight week delay in ordering anything new. The turn-around time for repaired equipment has typically been three to six months. It should also be noted that some equipment is so sensitive that it cannot be cost-effectively restored because there is so much that can be corroded by the smoke, but we and the assessors have had to learn this through failed attempts at recovering certain items. The smoke corrodes plastic as well as metal and after cleaning the smell of the smoke can still be strong, or worse, the cleaning agent and smoke can combine with cloth materials of headphones and speaker cones to make a sickly 'new' smell. Smell, therefore, is an important aspect of having equipment that is fit for use, which is required in addition to meeting the manufacturer's specifications. Loudspeakers, sound level meters, analysers and preamplifiers did not recover from exposure even when inside bags and cases other than airtight cases. How expensive the equipment, its construction, sensitivity and exposure level were the guiding factors in whether to employ a clean, test and calibrate procedure rather than replace. If the cleaning procedure itself was more than half the cost of replacement then it was a poor option as the total cost of repair could soon become more than the cost of a new device. The other hazard with cleaning is the administration time involved for which there is no compensation.

Replacing equipment

The replacement of the existing equipment damaged by the fire with new equipment is constrained by the principle of "like for like". In practice, sometimes a great deal of interpretation is required for this, because some items are irreplacable, and in some cases it is useless to simply replace an item because it can only be used effectively in conjuction with other items that cannot be replaced. Nevertheless, some manufacturers still supply exactly the same equipment as they did twenty or thirty years ago, making for a straightforward replacement. For common laboratory devices such as cathode ray oscilloscopes it is simple to replace on specification (eg whether analog or digital, how many channels, computer interfacing and printing protocols, the measurement bandwidth, sensitivity, time base, triggering and whether it has X-Y mode functionality for phase shift measurement). In more complex situations, the principle has been to replace the functionality of the equipment (whether it be an individual item or a group of items forming a system) rather than to literally replace item for item. This process has allowed us to plan for a better organised laboratory.

Systems approach

In reinstating the laboratory's equipment, we have decided to take a systems-based approach. That is, we have tried to organise the equipment into a collection of relatively independent systems designed for particular types of applications. Some of these systems will be set up in the laboratory ready to use at any time, without the need to borrow components from other systems. Other systems will normally be stored, but ready to use with a relatively short setup time. The alternative to this approach could have been to replace each item of damaged equipment from the old laboratory, which would have cost substantially more but led to a less effective outcome. Apart from cost, new equipment tends to be more compact than old equivalent equipment, giving us the space to have more systems set up at a time. The ethernet connections in current devices means that there is less reason to move equipment.

In this section we briefly describe how we have organised the equipment into systems, also giving some sense of the capabilities of the laboratory. First we describe the systems that are to be installed in the laboratory.

For the reverberant room, we have a system for measuring reverberation time (for sound power, absorption and diffusion measurements) using a signal generator, powerful loudspeakers, and so on. Complementing this system, we have a set of equipment for measuring the sound power in the free field, diffuse field using the source substitution method (with a reference power source) and intensity method (including intensity mapping). Also, as mentioned in the previous section, we have tubes for measuring the impedance, absorption, transmission and flow resistivity of small samples of material.

We have a system for measuring electroacoustic components, including frequency response, impedance, efficiency, directivity and distortion using steady state analysis, impulse response and other techniques. This includes a remotely controlled turntable and a simple laser Doppler vibrometer. Electroacoustic components are a important area of study and research in our laboratory, and the demonstration of several complementary techniques is a key aspect of teaching in this area.

Another system in the laboratory is for sound-field simulation. At the time of writing we are considering how to reconfigure this, but prior to the fire it consisted of 16-channels, including 12 dual-concentric loudspeakers (Tannoy System 800, which are no longer available) and four channels for subwoofers (Whise 319A). Apart from its use in sound-field simulation, this system has been key to our research in auditory localisation and spatial impression (eg Ferguson and Cabrera (2005)). Normally this equipment is used in the anechoic room. On a larger scale, the new hemi-anechoic room in the School of Electrical and Information Engineering houses a sound-field simulation system with 76 loudspeakers.

There is a large space saving with the new systems compared to the old as so much processing can be done inside the computer in real time rather than having all the data conditioned in some manner before being processed by the analyser. It is anticipated that these systems will be able to be left set up for teaching without congesting the laboratory.

All of these new systems are comprised of a personal computer, software and hardware. The mechanical hardware of the new systems is comparable if not better than the old systems and is expected that it will also have a long life. The electronic hardware is continually changing as analog to digital convertors, sampling resolution and noise immunity are improved.

The field-oriented equipment of the laboratory includes a system for building acoustics testing (for background noise, airborne sound insulation, and impact sound insulation). This includes sound sources, impact sources, sound level meters and Field-oriented systems of the laboratory also include one for noise monitoring (including for outdoor measurements) and for one for vibrometry.

An important aspect of sound-field simulation is the ability to record sound-fields in the field. Our system for this consists of a 24-channel hard disc recorder and associated transducers (dummy head microphones, an ambisonic (B-format) microphone, and multiple single channel microphones). We also use a variety of loudspeakers for this task, depending on the purpose of a measurement (including subwoofers, omnidirectional loudspeakers, and directional loudspeakers, and special loudspeakers such as a speech simulator and a 12-channel dodecahedral loudspeaker).

Prior to the fire, we had begun to organise a number of kits for field measurements. Since each type of kit is carried in a different colour case, we refer to them in that way. The 'yellow boxes' (of which we have eight) are an environmental studies field unit consisting of an anenometer, temperature and humidity meter, basic sound level meter, illuminance meter, laser distance measurer, tape measure and a compass. These are used by students across the Faculty (architectural students, lighting students, and audio/acoustics students) to profile spaces in terms of their measureable environmental qualities.

The 'orange boxes' (of which we have five) contain a laptop computer with a 2-channel USB audio interface, and audio measurement software. These are frequently used for impulse response measurements of audio systems and for room acoustical measurements.

Prior to the fire, the laboratory was equipped with several 'blue boxes' which were custom-built integrated multi-function electroacoustic measurement devices. These are being replaced as kits of discrete components (which will be kept in blue cases for sentimental reasons).

The laboratory also has some 'black boxes' which contain very sensitive field equipment (eg the sound intensity kit and head and torso simulator).

Naturally, the laboratory also houses many other discrete devices, such as sound level meters, loudspeakers, amplifiers – and many other miscellaneous items too numerous to detail here.

Old versus new

New equipment is, in some respects, much better than old equipment. Nevertheless, equipment from some decades ago had a number of advantages over current equipment. A large 1/3-octave filter set with a prominent rotary knob on its face to switch between filters presents much better to a group of students than the complexity and compactness of its modern equivalents. Sometimes exploratory experimental work is facilitated by simple equipment – a characteristic of older analogue devices. Certainly the simplicity of old equipment was supportive of teaching the acoustical concepts, rather than getting bogged down in how to use software. Some older measurement techniques are easy to understand by observation (eg reverberation time measurement through the interrupted noise method, or measurement of absorption coefficients using a pure tone standing wave pattern), and have been replaced by obscure but more powerful techniques in new equipment. Analogue equipment can have a very long usable life, especially since it does not rely on personal computers (which have a short life) for its operation.

Old equipment has disadvantages too. It tends to be large and heavy, often requiring several discrete components to be connected to make a measurement. Data may be difficult to move onto a computer for storage or further analysis. The equipment tends to be very expensive to maintain and repair. Older acoustics measurement equipment is not necessarily compatible with audio devices (eg for sound recording), and may also have compatibility problems with new transducers and peripheral devices.

New equipment provides powerful processing, a high degree of compatibility (including with audio devices), is cheaper and compact. When computers are used, the ability to project the screen output is very useful for teaching. However, a disadvantage of being dependent on personal computers is a vulnerability to the vagaries of operating systems. Software and licence maintenance is not a trivial task.

A case in point here is the standing wave apparatus or impedance tube system that was used by Jingfeng Xu in his research papers on anechoic room linings referred to in this paper. For initial data and final validation, his measurements required looking at various acoustic materials combined in systems and these were sometimes far too thick to mount in the off-the-shelf test apparatus. An extension pipe and holding brackets were manufactured in the faculty's on-site technical service centre (ATSC). This allowed for measurements on layered materials up to 800 mm thick. There are two usual means of measuring absorption coeficient of porous absorbers, the standing wave method (ISO 10534-1:1996) and the two microphone intensity method (ISO 10534-2:1998). We had three separate sets of equipment allowing us to use the first of these methods. Therefore we adapted one of our standing wave tubes to accept the two microphones and deploy it in conjunction with a suitably programmed computer controlled analyser and appropriate microphones to be able to confidently use this method as well. Figure 4 shows the modified tube and the extension pipe.

Figure 4. The modified standing wave tube (rear) for transfer function measurements of impedance, with the extension tube and retaining strap extensions in front.

In the fire we lost the frequency analysers used to measure the absorption coefficient directly and will need to rebuild systems to demonstrate the standing wave pressure maxim and minima (the tubework was not affected by the fire). These analysers are no longer available and so we have replaced the standing wave absorption coefficient measuring system with the new off-the-shelf impedance tube kit shown in Figure 5, which employs the two microphone technique exclusively but cannot display the standing wave principle (which had been an effective teaching tool).

Figure 5. Impedance tube using the transfer function method.

The new system uses a computer controlled data acquisition unit with an inbuilt noise generator and the manufacturer's software package to run the system and organise the data and will be how we will obtain absorption coefficients of porous materials from now on. This device has the added advantage of measuring a continuous transfer function. The length of this pipe can be increased in 200mm steps using extensions designed to allow for increased air gaps, but it is yet to be seen if this can be built up to allow for 800mm samples.

CONCLUSION

We hope that in the long term the laboratory fire makes a positive contribution to its colourful history, through the opportunity to improve the anechoic room and reorganise the equipment. The redesign of the anechoic room allows us to take advantage of research previously underaken in the laboratory concerned with anechoic lining design. Nevertheless, we can say that a laboratory fire is far better avoided than experienced, because short term costs are enormous. While the Fire Department's report was inconclusive as to the cause of the fire, its recommendations should reduce the risk of future fire, and to some extent these might be applicable to other laboratories.

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