Basic Studio Acoustics And Design

By

Rupert Neve

Studio Sound

October 1980

Basic studio acoustics and design

Rupert Neve (Broadcast Training and Services Ltd)

The purpose of this article is to give a brief outline of the principal acoustic requirements for recording and broadcast studios, together with some practical suggestions as to how such requirements may be achieved especially when converting an existing building. The emphasis is on the minimum standards, but these give useful guidelines for studio construction.

A STUDIO has to be an ideal environment enabling creative work to be carried out with a minimum of frustration or disturbance. The qualities which contribute to such an environment are:

(a) Isolation—the attenuation of *outside* sounds which would otherwise interrupt work, and attenuation of *inside* sounds, eg monitoring, music recording, etc, so that you don't offend your neighbours;

(b) Controlled acoustics—giving a much greater freedom especially in the production of music and drama.

Generally, one should aim for a working environment which gives a high degree of comfort and permanence to reduce fatigue and ensure repeatability.

A studio can mean anything from a small voice booth to a large complex of studios and control rooms with multitrack music recording, stage and lighting facilities. The cost can vary enormously and it is very important to define the type of work to be undertaken in order to meet the standards required. In addition to the studio itself, an adjacent control room is required with a soundproof window between. The control room will contain mixing and effects units and high quality sound monitoring equipment, plus recorders and various other electronic equipment. Additionally, voice communication must be provided between the control room and the studio.

In a busy situation it makes sense to have one or more additional rooms suitably equipped for mixing, programme assembly and editing so that these operations can proceed without tying up the main studio/control room.

Isolation

Studios and control rooms must be designed to have high isolation from the outside world and from each other. The reverberation time must be designed to suit the type of work to be undertaken and must be controlled over as wide a range of frequencies as possible. The acoustics of the control room are as important as those of the studio. Also noise in the studio due to ventilation or other services must be kept very low.

If top performance is required it will be necessary to employ an acoustics consultant capable of a full design and supervision service. He will ensure that the right materials and methods have been used and undertake proof of performance measurements. A compromise design is usually not advisable for a busy commercial studio where efficient utilization of facilities is important and where effective use of invested capital is a factor.

There are many kinds of studios. For example music recording, multitrack studios, mixdown studios, disc mastering, broadcast, film sound, and video. They all fulfil the primary purpose of providing the right working environment for the user. They vary only in specification details which are required to achieve the optimum for the specialist.

There are three fairly clearly defined classifications:

(a) Full broadcast or top quality recording standard where isolation is in excess of 55dB for both airborne and structure borne noise which usually requires a floating structure decoupled from the rest of the building. Reverberation time is maintained over a wide frequency spectrum.

(b) Intermediate standard where isolation may be of the order of 35 to 50dB. A floating structure would only be necessary in the presence of heavy city traffic or underground trains nearby. The acoustic treatment may be less effective and the reverberation time not so closely controlled especially at low frequencies.

(c) Practical production room standard where isolation is less than 35dB and acoustic treatment is limited to that which is necessary to achieve a pleasant sound.

There is a cost factor of about three times between each classification. For instance if (a) costs around £90/sq ft (b) costs around £30/sq ft and (c) may cost as little as £10/sq ft. These figures cannot be taken as indicators of actual cost as obviously location, country and inflation will vary greatly.

The ratios reflect the very large cost of achieving high standards where extensive structural work may be required but they also reveal the attractive possibilities of a relatively low cost studio which has been carefully sited.

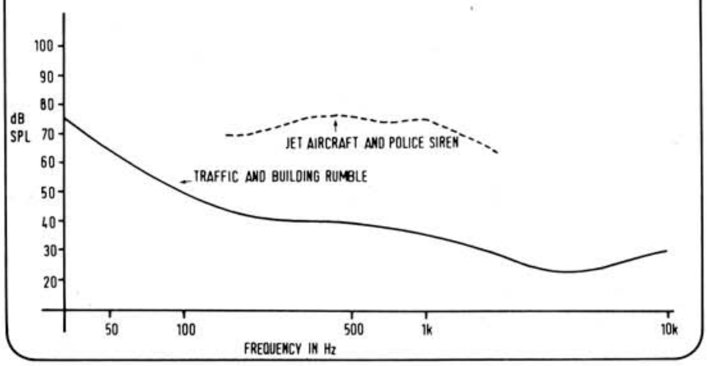
Where does one start? The correct starting point is at the *concept* stage, so this is where we must ask some pointed questions. Firstly, what is the main use to which the studio is to be put? Is it music recording, drama, entertainment, documentary programmes, etc. The answer is frequently "a bit of everything". If so, then the cost will be higher or the results inadequate for some uses. Quite often a studio does get used for a wide variety of purposes, but this inevitably means a more comprehensive design so that several functions can be covered. Secondly, we need to ask how much usage will the studio get? If recordings are only made for two or three hours each day, but you have to stop once or twice because of a jet aircraft overhead, or because of a fire engine siren in the street, it would be arguable that you should not spend large amounts of money on expensive sound isolation. But if a busy main road nearby has heavy trucks passing every few minutes then a high degree of isolation is needed. Considering isolation, therefore, we must ask what is the environmental noise level like and how does it vary throughout the day?

The main sources of outdoor noise in towns are road and rail traffic, children playing, service deliveries, road repairs and building operations and, of course, aircraft are a potential hazard almost anywhere.

Sources of indoor noise, if the studio is in a shared building, are hi-fi equipment, radio and TV receivers, banging doors, heavy footsteps on wooden or concrete floors, lifts, air conditioning and other such machinery. These need to be measured and their probable effect assessed before trying to make decisions. **Fig 1** shows typical residual noise in a 'quiet' location, illustrating the need for adequate isolation. The best defence against any form of interfering noise is distance but one is not often in the happy position of being able to choose a truly remote location and an appropriate degree of isolation is always necessary, even if only to exclude birdsong!

A survey of the site before going ahead with a studio must be fairly thorough and must take account of seasonal activities (ie school holidays might lead you to forget that the next door building is a school!). Local planners need to be consulted about proposed new roads or other developments as well as the nearest airport, including details of present or projected aircraft flight paths. An alternative site would almost certainly be cheaper than trying to

FIG.1 BASIC STUDIO DESIGN RESIDUAL NOISE



exclude the sound of frequent low flying jets. Avoid busy main or trunk roads which carry continuous heavy traffic. Similarly avoid schools, railways (including underground) churches, convents or public clocks with bells or chimes. Beware of nearby factories with heavy machinery, high power transformers and high voltage electricity power lines. Watch out for high power radio and radar installations closer than a mile.

A third factor is the question of whether the studio you are planning is likely to cause any kind of nuisance to neighbours.

It is all very well to conclude that you have found a quiet residential area, which will enable you to convert a building for use as a studio, but what about the noise you will be making? Sound from the studio must not leak out sufficiently to be audible under quiet conditions, say late at night. It is also necessary to consider car parking and the noise created by groups of people arriving or departing.

It is usually necessary to provide a reception area, rest rooms, coffee and refreshment facilities and so on. Normally these factors would be taken care of by an architect and they will certainly be considered by the local planning authorities before granting permission. You can obviously save time and money by taking such factors into consideration yourself before making formal planning applications and incurring professional fees.

The next important question is whether to build from scratch or convert an existing building? A new building enables all the important parameters to be designed in at the start. It is only necessary to agree the specification and if you have the right professional advice, full facilities and acoustic performance will be achieved. An existing building may merely make use of existing rooms modestly adapted to classification (c) performance or it can be entirely remodelled inside retaining only the outer shell to achieve a studio complex to full classification (a) standards. In the latter case, an architect will do as much work as for a new building, but if you are adapting a building to provide a more modest standard you can save professional fees by assessing some of the features yourself.

FIG. 2 BASIC STUDIO DESIGN REVERBERATION TIME RT_{60}

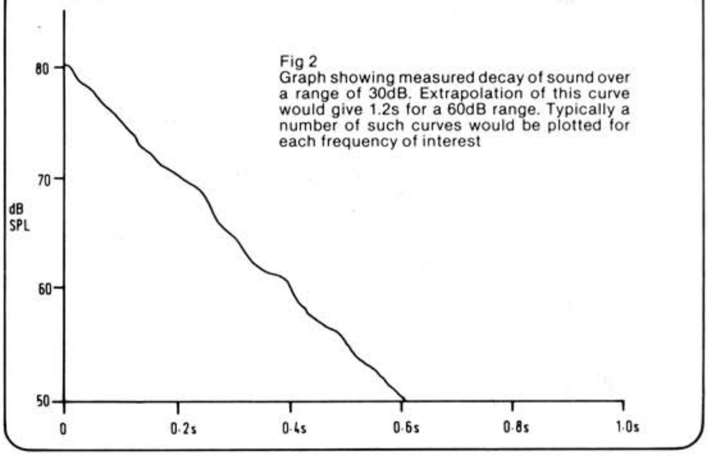


Fig 2
Graph showing measured decay of sound over a range of 30dB. Extrapolation of this curve would give 1.2s for a 60dB range. Typically a number of such curves would be plotted for each frequency of interest

A building must be well built and have a solid 'feel' about it. Unfortunately not many very modern buildings achieve this. However, in older buildings typically the lounge and dining room are ideal for conversion to a studio and control room. Depending on the layout of the rooms you will need sound resistant doors to an entrance hall. Alternatively the studio door can be bricked up and access made from the control room. You will also need to fit a window between the control room and studio. Doors and windows of advanced design are available from specialist suppliers complete with their frames to build in.

If the hall is likely to sustain noise of people coming and going, etc, during recording, then the doors and walls between hall and studio and control room have to be well insulated for sound and this could mean expensive double doors. It is probably cheaper to make a new entrance to the building and block off the hall, using it as a sound buffer area which can be used for storage of tapes, archives, books, etc. Watch out for toilets and water pipes which can be heard in these rooms when taps are opened.

You will find a second audition room very useful, where you can have semi-control room acoustics, for editing and listening. The amount of insulation from this audition room to the others must be fairly good, but is usually easy to achieve as it is likely to be the other side of the entrance hall. The audition room does not itself need very high isolation from the rest of the building.

It is very important to establish that the walls are heavy enough to give the isolation required. Single partitions of lath or plasterboard are not usually satisfactory. Either a double 4½in wall or a single wall of 9in thickness is required. Apart from visual inspection there are no really definitive tests possible at this stage because doors and windows are likely to be the weakest link.

Unless you are certain that isolation of less than 30dB is enough for your purpose, it will be necessary to fit fully designed acoustic doors and windows which typically have isolation around 35 to 40dB. Walls, floors and ceilings can be strengthened acoustically by additional construction which may take the form of standard building materials (wet work) or special isolation panels containing lead (dry work). Although the initial cost of dry materials is higher, their convenience may well outweigh their cost.

So much for lateral isolation. Now you need to check isolation from above and below. Get someone to walk around in ordinary shoes and speak in a good audible voice, as if on the telephone, in the rooms above. Hard noises such as leather heels, on bare floor boards are fairly easy to get rid of. Place a strip of a few yards of good foam rubber-backed carpet on the floor above and walk on it. The footstep noises should be greatly reduced but watch our for heavy low frequency thumps still audible when your tester walks on the carpet. If the floor shakes and transmits these thumps you may need a more expensive treatment either to the floor above or to the ceiling of the studio. This will mean that you need sufficient height in the studio to fit a suspended ceiling. However, this all depends upon what you use the upstairs rooms for. Noise from below is unlikely to affect you but check that conversations elsewhere can't be heard in the studio and that the floor does not thump or creak as you walk about. You should aim to find a building that requires only carpet on the floors. If a sound level meter is available having a flat response position noise level tests will be of great value to assessment.

Once the ground work has been done you will be likely to need measuring equipment and professional advice from an acoustic engineer who understands your objectives and who can, therefore, respond efficiently and can brief your architect. He will also estimate the weight of new or modified structures and at this stage your architect will say whether an existing building can take it.

The big lesson to be learned is that you must be clear in your own mind of your objectives.

An objectively prepared brief which provides answers to the questions is a remarkably helpful document which saves time and money in the long run.

Controlled acoustics

A studio must be free from objectionable reverberations, echoes and acoustic resonances. As with isolation, the degree of perfection necessary varies with the use to which the studio will be put.

Anyone who has viewed an empty building knows that echoes abound, footsteps and noises sound louder and sound is often hard. By contrast a well furnished room with heavy carpet, upholstered chairs and book-lined walls sounds quiet and gives an air of intimacy. This is because the higher frequencies are readily absorbed by such furnishing.

Sound is reflected off hard surfaces such as bricks and concrete. If walls are left bare, sounds will continue to be reflected from wall to wall after the original sound has ceased. The time taken for the sound pressure to fall by 1000 times its original value (or 60dB) is called the reverberation time (or RT_{60}). Reverberation time can be reduced by using absorbent materials in a room. Sound is not reflected equally well at all frequencies and a wall or floor covering which absorbs well at high frequencies is usually ineffective at low frequencies. This gives the room a characteristically tubby or even a boomy sound.

A large room or hall can be allowed to have a longer reverberation time than a small room, but whether the RT_{60} is long or short it is necessary that it should be the same value (or as near as practical considerations allow) at all the frequencies of interest. It is also necessary to ensure that the sound dies away at an even rate (see **fig 2**). Some buildings have naturally good acoustics either

46 ▶

Studio design

because of careful design or due to a favourable disposition of dimensions and materials.

Small rooms ar often more difficult to deal with as the natural RT increases more quickly at middle and low frequencies.

A purpose built studio can be correctly designed from the outset and once the specification has been drawn up it is simply a matter of correct design and construction to ensure that the specification is met.

Adapting an existing building is obviously easier if isolation and reverberation are already good but even if this appears to be so it is essential to consult an experienced acoustics engineer at the start. Such measures as curtains (used on their own) egg boxes, peg board and even so called acoustic tiles are not effective — they may absorb the wrong frequencies and can actually worsen an otherwise useable room. Extensive use of fibreglass quilting produces too much absorption at high frequencies and needs to be balanced with other materials for even response.

Design values of reverberation time will vary quite considerably depending on the intended use of the studio, **fig 3**.

A small speech studio requires a short RT_{60} of about 0.2 to 0.5s. A multitrack studio is also given a short RT_{60} but for different reasons. Music groups, especially strings and choirs, need a somewhat longer RT_{60}, say around 0.5 to 1s. Large orchestras may need even longer RT_{60}.

It is very useful if the studio is large enough so that one end can be made dry (short RT_{60}) and the other end fairly live (long RT_{60}). This is of particular benefit for drama. If a studio is too dry musicians complain that they cannot hear themselves or each other. Careful use of directional microphones can produce a high definition sound even if the musicians are placed near the live end of the studio. As stated previously, RT_{60} should be reasonably even with frequency and, broadly speaking should be maintained over the range of frequencies being produced in the studio.

Design of the studio building

(a) Isolation

Sound travels through liquids and solids. Air is a liquid and very small apertures in a studio construction can completely wreck an otherwise good design. Doors and windows are the most obvious points of weakness.

Inadequate air seals will let sound through. Electrical fittings, ceiling and floor cavities, ducts and holes in walls which have been hidden but not filled are common offenders.

Sound travels through solids such as a wall or a door by causing it to vibrate and so creating a new sound wave on the other side. If the wall or door can't move then it can't create the new sound. So to prevent all transmission of sound, a wall or door must either be infinitely rigid or infinitely massive (see **table 1**). Therefore, a brick wall is very much better than a timber frame clad with building board and filled with fibreglass. This is often incorrectly specified. A door may have to be constructed with sheets of lead internally, alternatively it may be filled with sand or concrete. The weight makes it difficult to hang and to obtain a good seal, therefore, design is important. More than one door may be used with a space between, but the total weight must still be large. Similarly windows need to be double-glazed and of thick glass and framed in such a way as to prevent structure or airborne leaks around them.

Where walls, floors and ceilings are inadequate from an isolation point of view, special panels containing lead have to be used. Sometimes the required isolation can only be obtained by building a floating structure within the main room to isolate all structure-borne noise. The great weight often required for good studio design needs a very strong building and an architect must look carefully into the effect of adding such weights to the building structure.

The isolation provided by a door or window can be no better than that of the wall in which it is located and there is obviously no point in buying a 50dB door to hang in a timber frame and plasterboard wall with only 30dB of isolation — yet this is done all too often! Every aspect of the studio must be taken into account. Any weakness can spoil an otherwise good design.

FIG. 3 BASIC STUDIO DESIGN
DESIGN VALUES OF REVERBERATION TIME

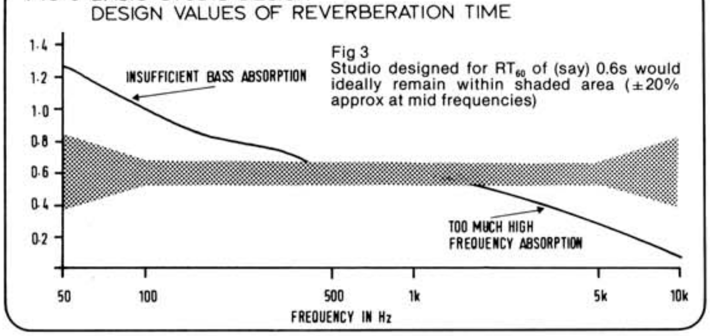


Fig 3
Studio designed for RT_{60} of (say) 0.6s would ideally remain within shaded area (±20% approx at mid frequencies)

(b) Ventilation

The result of good isolation is that you tend to have an airtight box and ventilation or air conditioning is necessary (see **fig 4**). An adequate ventilation system will take into account the amount of heat generated in the studio from equipment, lighting and people. The noise from air conditioning or ventilation must be kept low and to achieve this the air flow must be at low velocity from large ducts and blowers or compressors properly isolated. The ducts themselves must be acoustically baffled to prevent sound travelling through them from one area to another. Noise due to ventilation systems must not worsen the studio noise level by more than 5dB.

Attentuation of low frequencies in large ducts is very low so that long runs are an advantage. Separate ducts for different rooms and areas must be used, only meeting back at the plant to prevent loss of isolation acoustically to avoid picking up airborne noise outside the studio.

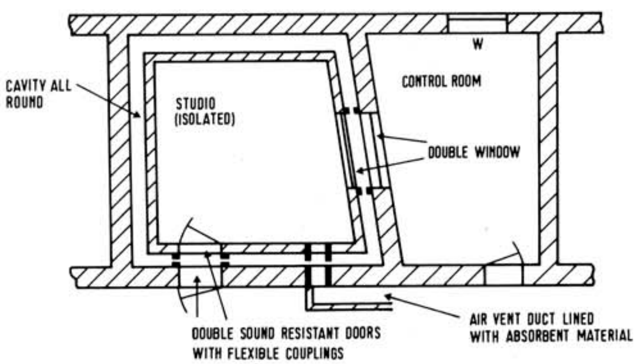
TABLE 1

INSULATION OF TYPICAL WALL STRUCTURES

(Note that the mass approximately doubles for each 5dB increase in insulation. Values are approximate and assume walls are fully sealed.)

Isolation dB	Weight lb/sq ft	Weight kilos/m²	Construction
25	2	10	2in stud frame clad both sides with ¼ in plywood
30	4	20	As above but clad with ½ in plaster
35	10	50	2in compressed straw slab skimmed plaster both sides or 2in hollow clay block with ½ in plaster both sides
40	25	120	3in clinker block with ½ in plaster both sides or double 2in wood wool slab with 2in cavity and ½ in plaster both sides
45	50	250	4½ in solid brick with ½ in plaster both sides
50	100	450	9in solid brick with ½ in plaster both sides or double 4½ in brick with 2in cavity and ½ in plaster one side
55	200	1000	18in solid brick with ½ in plaster both sides or 15in dense concrete with ½ in plaster both sides or double 9in brick, 2in cavity and ½ in plaster both sides

FIG. 4 BASIC STUDIO DESIGN
PRINCIPLES OF A MECHANICALLY AND ACOUSTICALLY ISOLATED STUDIO



(c) Lighting

Studios need the right kind of lighting which must give both flexibility and repeatability. A studio can look and feel quite different under alternative lighting effects. Simple systems are available which enable lighting to be controlled from a desk mounted panel. More complex systems include memories which allow effects to be recalled either manually or in sequence. Drama productions benefit greatly from such possibilities and production time can be reduced considerably in video work by using the right kind of system.

Lighting should be suspended on a grid system which enables lighting units to be secured where they are wanted and readily moved, replaced or maintained. There are several proprietary systems ranging from very modest scaffold poles to the fully professional remote controlled TV and film studio systems.

Regardless of the complexity or simplicity of the system, light fittings and mountings must not introduce acoustic noise through ringing vibration or humming of chokes and control devices. Electrically there must be no interference. These factors are taken care of by proper attention at the planning stage and by good installation. An experienced

48 ▶

engineer will design with these factors in mind and will know how to deal with any problems which may arise.

(d) Noise levels
Before attempting to specify the isolation and noise levels it is a good thing to be aware of some of the magnitudes involved and how they relate. **Table 2** gives a rough idea of levels of some familiar sounds.

Noise performance of a studio is usually defined by a noise rating or NR curve which takes account of the subjective effect of human hearing. Low frequencies can never be attenuated as effectively as mid and high frequencies but fortunately they don't need to be. See **fig 5**.

(e) Reverberation
Reverberation is controlled by using boxes or panels designed to absorb particular bands of frequencies. At the low frequencies special resonators may be required. The number of boxes and the extent of such treatment depends upon the desired reverberation time. Having the correct reverberation time makes the difference between success and failure of a studio. Treatment to secure the right results is expensive but far less expensive than adopting a compromise (which may look attractive) and then spending further money and loss of working time trying to correct deficiencies. Although this seems to be an obvious statement, a great many studio owners fall into the trap of false economy and many commissions of acoustic consultants are, in fact, rescue operations.

It was stated earlier that reverberation time should be reasonably constant over the frequency range of interest. Absorbing high frequencies is comparatively easy and is often accomplished by curtains, furnishings and book-lined walls. In fact it is often necesary to avoid too much absorption at higher frequencies. Furnishings are not very effective at low frequencies and there is no substitute for correctly designed acoustic absorber panels.

TABLE 2

SOUND PRESSURE LEVEL

Pascals	Microbars (Dynes/sq cm)	dB above the threshold	Description
20.0	200	120	Pain. Close to aircraft engine or steam hammer
6.0	60	110	Monitor level in Pop studio
2.0	20	100	
1.0	10	94	Loud machinery in factory
0.6	6.0	90	Loud orchestra/choir
0.2	2.0	80	Average orchestra or chamber music
0.1	1.0	74	
0.06	0.6	70	Average speech
0.02	0.2	60	Ambient in quiet office
0.006	0.06	50	Quiet Church ambient
0.002	0.02	40	Countryside on a quiet night
			Good, well isolated studio
0.0006	0.006	30	
0.0002	0.002	20	
0.00006	0.0006	10	Virtually no audible sound
			Pin drop on soft carpet 10ft away
0.00002	0.0002	0	Threshold level

A short RT_{60} means that a greater surface area in the studio has to be acoustically treated which obviously means higher cost.

The technique of multitrack music recording requires very short RT_{60} to improve separation between instruments, vocalists and tracks. Straight stereo or mono recording of small music groups and choirs requires a *natural* balance and this is aided by a somewhat longer RT_{60} which the musicians themselves usually appreciate.

The final choice of reverberation time should be arrived at with the help of an acoustics consultant who will also specify the type and extent of the acoustic treatment.

It should be remembered that there are so many variables in the design and construction of a studio that it would be unusual if everything were to come right first time. It may be necessary to vary the number or type of absorbers.

Proof of performance

However modest your studio, it is advisable to carry out some tests to ensure that design and construction have achieved the desired result.

Your acoustic consultant will normally carry out this service and the measurements he makes should reasonably agree with the design specification.

Isolation is measured by producing high sound levels outside the isolated area and measuring the sound level inside. This may be carried out wideband or at selected frequencies. Weighting curves may be used.

Noise level is measured in the studio to establish the residual noise from ventilation, lighting and other plant. In a good studio noise level will be much too low to give a reading on a sound level meter. Expensive low noise microphones are needed, preferably with a ⅓-octave analyser.

Reverberation time can be measured with band limited pink noise on discrete tones at a sufficient number of frequencies to establish the performance. The test signal is switched off and the decay plotted against time on a chart recorder.

Results may be supplied as figures or graphs. Sophisticated designs usually call for graphs showing variation or performance with frequency. Acoustic measurements are time consuming and sometimes require the use of very expensive equipment. Some consultants use specially prepared tapes and make recordings which are later analysed by a computer or in the laboratory.

The whole question of sound and noise is made complicated by the incredible design and range of the human hearing system. The ear responds to changes in air pressure at frequencies roughly between 20 and 20,000 times a second. It responds to frequencies in the middle of the range better than to those at the extremes, but the sensitivity to high and low frequencies alters as the sound level rises becoming more linear as the sound level increases. This is one of the reasons why hi-fi equipment is often played loudly. Loud sounds appear to have more bass and treble.

A healthy human ear can hear sound pressure levels as low as 0.00002 Pascals (Pa) and can tolerate without pain, sound pressures as high as 20Pa which is a linear range of one million times. However the sensation of loudness works on a logarithmic scale and the decibel (dB) is used as a unit which gives manageable numbers and reasonable correlation with subjective hearing. The dB is 20 times the common logarithm of the ratio of the sound pressures. It is a ratio and not an absolute. However, if 0dB is made equal to 0.00002Pa (threshold of hearing) then any other sound pressure can be expressed as a ratio to it.

Weighted curves (**fig 6**) are used to graph subjective sensation and are used to arrive at the actual isolation required for a studio. The noise level in a studio affects the signal to noise ratio of the resulting programme in a similar way to noise in the electronic part of the system. There is always some noise and it is necessary to ensure that the S/N ratio is good enough for your purpose.

The signal is the sound arriving at the microphone — say around 70dB sound pressure level. For an S/N ratio of 50dB the studio noise must not be higher than 20dB (70-50 for the mathematically minded). This would be satisfied subjectively by meeting the NR20 noise rating curve.

Fortunately low frequency noise is subjectively less important or studios would become even more expensive.

Remember that silence is expensive — don't over-specify. To keep costs within reasonable limits your studio must be designed so that it is appropriate to its intended use. ■

FIG. 5 BASIC STUDIO DESIGN
TYPICAL NOISE RATING CURVES FOR STUDIOS

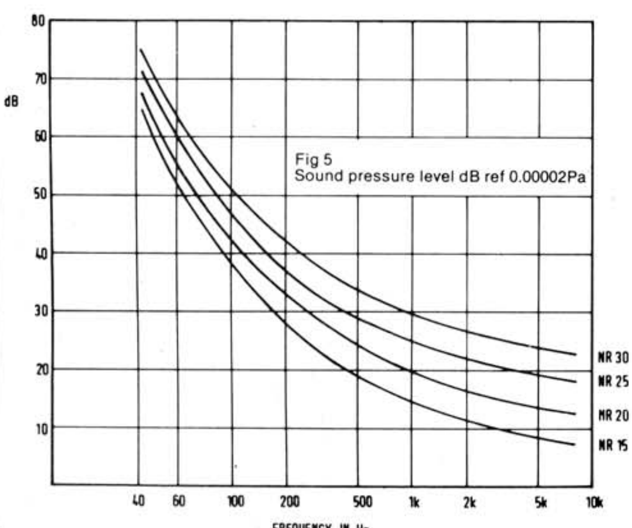


FIG. 6 BASIC STUDIO DESIGN
'A' WEIGHTING CURVE