ACOUSTICS OF RECORDING STUDIOS

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Process and environment

The recording of music, either voice or instrumental, is a core industry supporting the entertainment arts. The process begins with the production of music in a studio. Here the audio generated by a musical instrument is captured by a transducer, either a microphone or an electronic pickup built into the instrument itself. The electronic signal from the microphone is transmitted to a control room where it is routed through various electronic devices and stored for future use. The signals may be in analog or digital format and may be transmitted via electrical or fiber optic cables or by means of a wireless transmitter. The signal can subsequently be played back and remixed, stored, or combined with other recorded signals until the final product has been produced. It is then packaged as part of a storage device for later presentation in commercial or home theaters, or distributed electronically to a playback or other receiver system. This issue of *Acoustics Today* will deal with aspects of the interaction between these processes and the acoustical spaces in which they occur.

"Foley stages... are often indistinguishable from junkyards, due to the general clutter."

Studios

A studio, in the most general sense of the word, is a space where music is played, recorded, and edited. In a narrower sense it is where music is played and captured by a microphone. A control room is a separate room where one or more mixers work and music is played back, edited, and stored.

Studios can range in size, from a closet to scoring stages accommodating a full symphony orchestra. Figure 1 shows sketches of several different types. In small home studios the mix board and other electronic equipment is located in the same space as the musicians. In larger facilities these functions are separated into different rooms, which may in turn be subdivided. All studios have common requirements irrespective of size. There may, in addition, be specialized requirements which are size dependent or function dependent. A summary of the common requirements is listed in Table 1 below. Some of these are acoustical in nature while others are purely functional.

Home studios

Home studios, sometimes known as project studios, are increasingly common as high quality recording equipment becomes smaller and more affordable. The sophistication of this electronic gear has had a direct influence on the proliferation of small studios since excellent recordings can now be made in a low-cost environment. The initial reaction from commercial studios was an effort to limit home studios through land-use regulations. A decade or two ago, under pressure from the commercial studio owners, Los Angeles prohibited people from using their homes to make commercial recordings. This led the City of Los Angeles, with the worst smog in the country, to require that people get into their cars and drive to a commercial studio to do their work, while raising the cost of the process. Under the cost pressures, rather than environmental enlightenment, the amount of time given to prepare the audio for a 45 minute television program has decreased from a week to about two days. Mixers now spend one day doing the bulk of the work in a home studio and a second day presenting it to the "suits" and transferring the results into the studio memory banks. The home studios can be equipped with the same equipment as the commercial studio, so after getting the executive input, changes can be made at the commercial site with no loss in quality.

The second problem confronting a home studio user is that regulations in residential neighborhoods restrict noise levels at neighboring properties. These property-line ordinances typically limit nighttime noise levels to 45 dBA or 5 dB

Table 1 – Common Studio Requirements

Acoustical	Functional
Quiet – below NC 20	Adequate ventilation and thermal control
Isolation from the surroundings	Access to bathrooms
Adequate reverberation	Visual contact with the control room
Freedom from acoustical defects	Storage areas
Reasonable diffusion	Equipment maintenance facilities
Isolation for different instruments	Break rooms and private phone areas
Control of bass reverberation	Communication areas (internet access)
Variable absorption	Offices and conference rooms
Moveable gobos (reflecting or absorbing acoustic panels)	Handicapped access
	Access to cabling

over the existing ambient, whichever is higher, within residential properties. Property line ordinances can limit the level at which a musician can play or require substantial construction to meet the local codes. Neighbors can also be sensitive to musicians arriving on Harleys in the middle of the night.

Picking a location that provides natural sound isolation is a good start. If a basement is available, it is probably the best choice; or a separate structure can be used. Probably the most common choice, and one of the most difficult, is a garage. A two-car garage is about 24 feet square, enough for a one-room studio. However garages are lightly constructed and must be heavily reinforced to achieve adequate sound isolation. Exterior surfaces of plaster, brick, or cement board, having a surface mass density of 10 lbs/sq ft (49 kg/sq m) or greater, can be used on the exterior with double drywall interior surfaces supported on a separate framing system or resilient isolators. The garage door must be removed, although it can be retained as an applied decorative element over an exterior wall.

A garage ceiling is too low and raising it requires added structural framing and review by a structural engineer. For sound control it should have a solid plywood roof and, at a minimum, a separately supported double-drywall interior. The fan coil unit can be located above the ceiling with an access panel for service or a package unit outside the building can be employed. Careful calculations are necessary to ensure isolation of the fan coil supply and return from the studio. Silencers or snaked flexible duct surrounded by batt insulation can help provide the necessary attenuation.

Figure 2 gives an example of a design for a personal studio, built into a freestanding garage. It illustrates some of the difficulties in making a successful conversion. The layout of a successful project studio is quite personal and reflects the working habits of the user. In this example, the operator can mix and compose on a keyboard, which doubles as a Musical Instrument Digital Interface (midi) controller linked to a computer. A small number of musicians can be accommodated for a recording session. Movable wall panels, hung on angled supports, provide absorption and can be replaced with diffusive elements or simply removed. Storage closets also double as bass traps. The floors are hardwood with throw rugs for variable absorption.

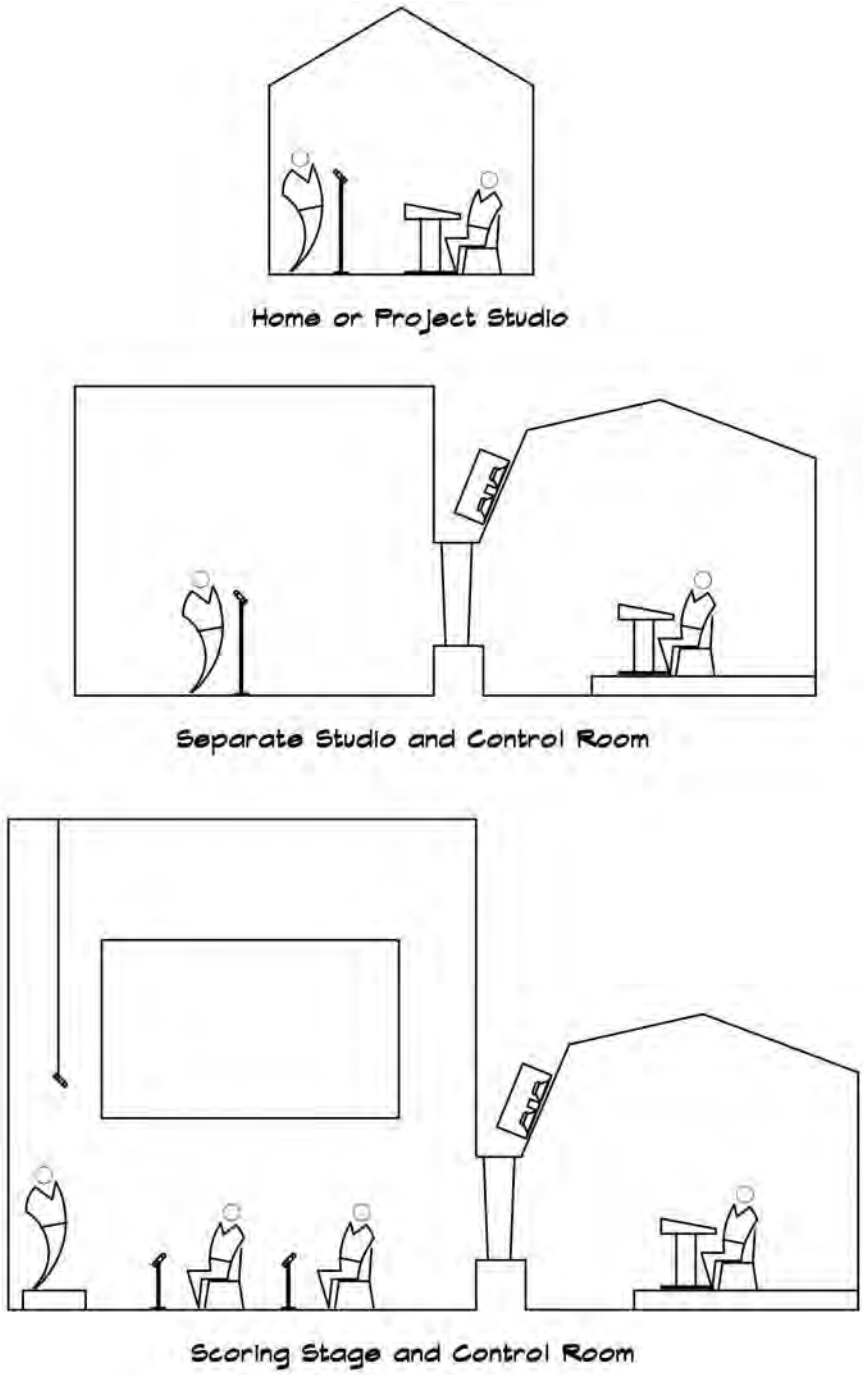

Fig. 1 Types of sound studios

Recording studios

Formal recording studios consist of one or more rooms, where music is played and recorded. The musicians may all be present at the same time or they may never see one another. With the ability to send recorded music from place to place electronically, musicians may perform in rooms a continent away and days or weeks apart. When musicians are playing simultaneously, separate rooms are desirable to isolate the instruments so that they do not bleed into other microphones. Isolation booths or simple baffles (gobos) also can be helpful in separating the studio into different acoustic environments.

Studios can be generic or highly personal, based on the working preferences of an individual user. A good example of the latter is Hum Studio in Santa Monica, CA, designed for Jeff Koz, a well-known composer. Figure 3 shows the floor

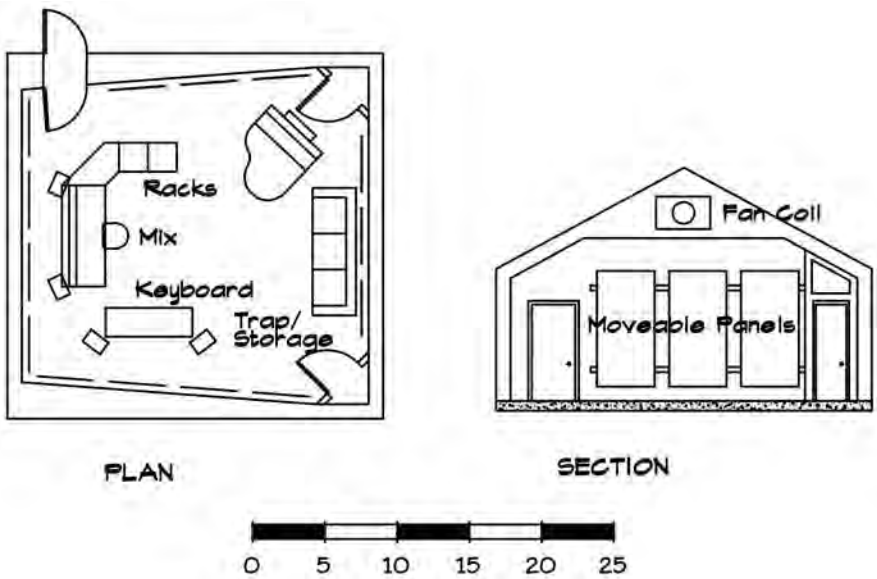

Fig. 2 An example of a garage studio

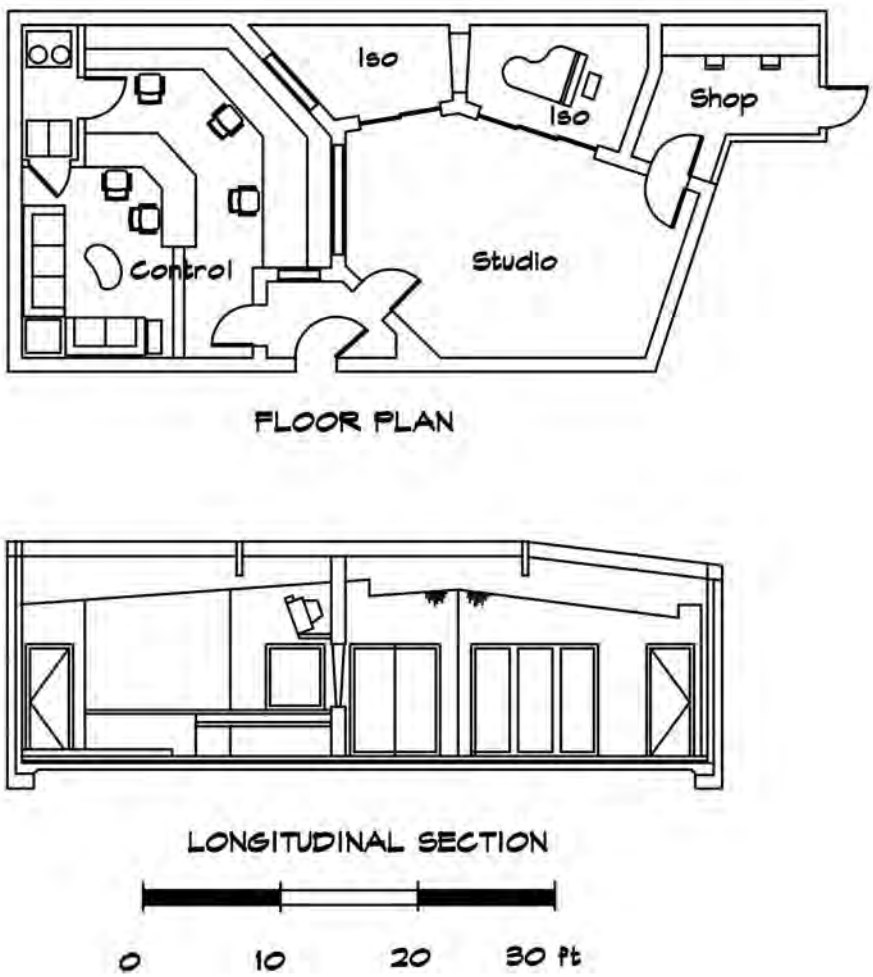

Fig. 3 Hum Studio A, Santa Monica, California, USA (Acoustician: Marshall Long Acoustics, Architect: Walter Meyer Associates)

plan for the main studio and control booth. Since most of the composition work is done at a keyboard with small digital mix boards, the traditional control room layout was not used. Instead, three work stations, each with a keyboard, a mix board and a computer, were arrayed along the front and side walls of the control room. Each could be used simultaneously during recording and mixing sessions. The main composing station was designed around the users' equipment. Since listening is done via small near-field loudspeakers, there was no need for large stereo monitors and no need for a large loudspeaker bridge above the main window. This arrangement freed up the center of the room for a client couch and social area instead of being dominated by a massive mixing console.

Hum studio consists of several rooms accessed from a small foyer separating the studio from the control room. Foyers can sometimes be used as isolation rooms particularly if there is a need for feedback such as with an electric guitar. Two isolation booths, with sliding glass doors, are available for individual instruments such as a piano or vocals. The walls and ceiling are constructed of multiple layers of drywall with a wood panel finish on the ceiling. Square quilted absorbers are hung from hooks on the walls and can be removed or folded to reduce their area. The mid-frequency reverberation time is about 1.2 sec and flat with frequency. Figure 4 shows the range of reverberation times appropriate for a sound studio.

Bass trapping is done using the return-air plenum built above the ceiling as illustrated in Fig. 5. Flexible ducts in this area make the space into a bass absorbing plenum. The area is filled with fiberglass insulation. Low frequency energy can enter via the diffusers and break out of the ducts into the treated volume. The segmented ceiling requires surface-applied wood diffusers to control flutter echo. The control room is designed to be much deader than the studio, about 0.5 sec at mid-frequencies. The walls are faced with 2" (52 mm) cloth-wrapped fiberglass panels. The ceiling is hard—two

layers of 5/8" drywall hung from springs to provide noise isolation through the ceiling- roof. Bass traps are built into the space above the equipment closet and into the video monitor enclosure. Windows are arranged so that there is visual contact between the control room and any point in the studio, including the isolation booths.

Sound stages

Sound stages are large open rooms used for indoor movie production. Acoustically they are designed to be dead with all surfaces except the floors covered with 4 to 6 inch (100 to 150 mm) deep blankets of absorptive material. In the early 1950s many were built using recycled army mattresses hung on the walls. The floors are smooth and flat so that cameras can be dollied. The exposed wall surfaces can be faced with commercial quilted blankets covered with hardware cloth below an elevation of about 10 ft (3 m). The best rooms are built with isolated construction, floated floors, double-studded walls, and separately suspended drywall ceilings. Access is provided via sound rated doors, which can be quite large. Some facilities have control rooms adjacent to the stage for mixing and recording. Not infrequently, audio recording is done using directional microphones that transmit signals to wireless receivers located in racks in the same room but often 75-100 ft (23-30 m) away.

The most difficult aspect of sound stage design is noise control. Isolation from exterior noise is a challenge because many stages are built in converted warehouses with lightweight roofs and little thought to the isolation of traffic and aircraft noise. Large air conditioning units are required to cool the stage lighting fixtures and this equipment is often located on the roof, where it is difficult to control. It is preferable to separately support air handlers on grade or on an elevated steel platform dedicated to that purpose. Ductwork should be isolated from the structural framework either by resilient suspension or by a separate support system. Silencers located at a roof or wall penetration provide exterior as well as equipment noise control.

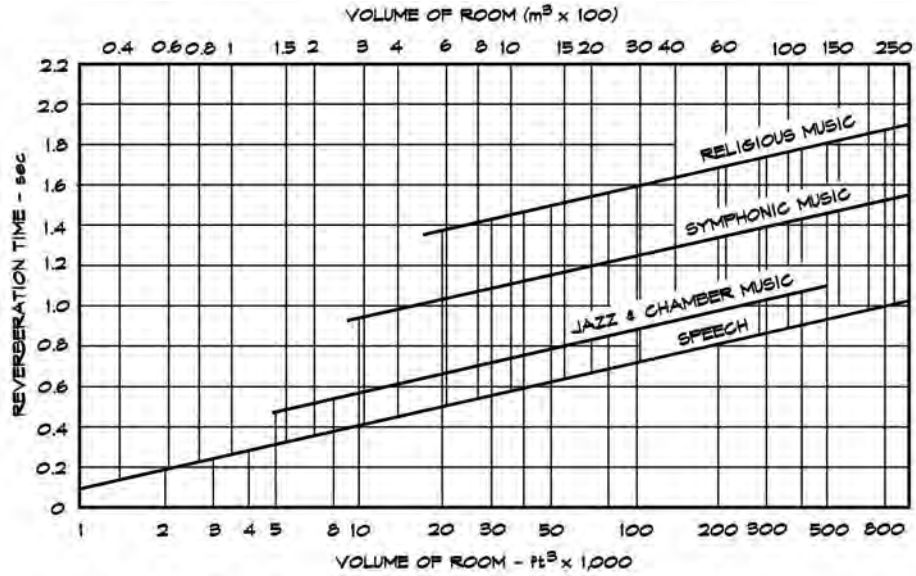

Fig. 4 Reverberation times for studos in the 500–1000 Hz. range (Doelle, 1972)

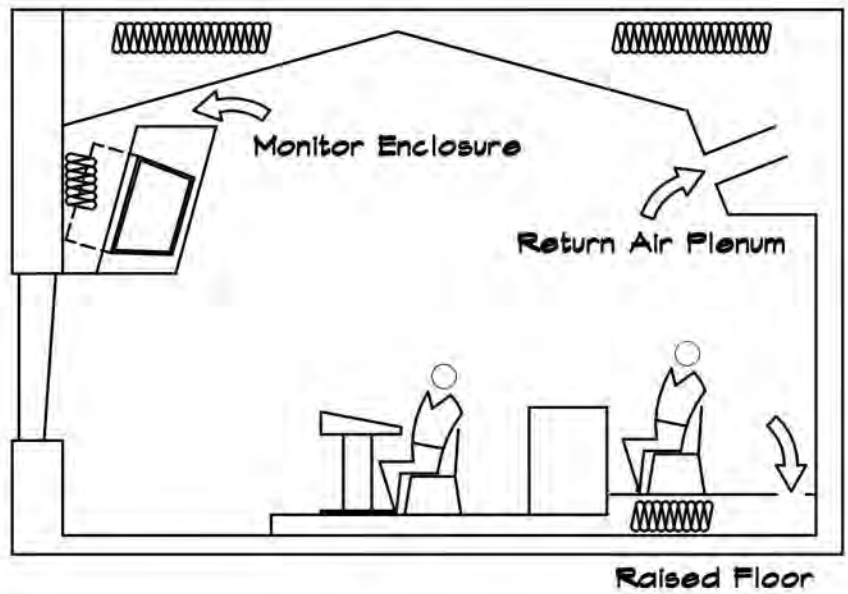

Fig. 5 Found space bass traps

Scoring stages

Scoring stages are rooms in which the music for a film is recorded. The orchestra conductor, who is often the composer, faces both the musicians and a large screen on which the film is projected. As he conducts, he may listen through a single headphone to a click track, which aids in synchronization of the film and the score. Visual cues are also projected onto the screen in the form of streamers that progress from left to right across the screen to mark the beginning of a transition or effect when they reach the right-hand side.

A scoring stage is large, almost the size of a concert hall. Like concert halls, the best ones are shoebox-shaped with high ceilings and irregularly shaped diffusers on the walls and ceiling. A very good one, Studio 1 at Abbey Road Studios in London, is shown in Fig. 6. Its dimensions are 92.6 ft × 59.7 ft × 39.4 ft high (28.2 m × 16.1 m × 12.2 m) and its total volume of 218,000 cu ft (6172 cu m) is about one-third that of Boston Symphony Hall. At one end there is a large (44 ft or 13.4 m wide) projection screen with the control room in an opposite corner.

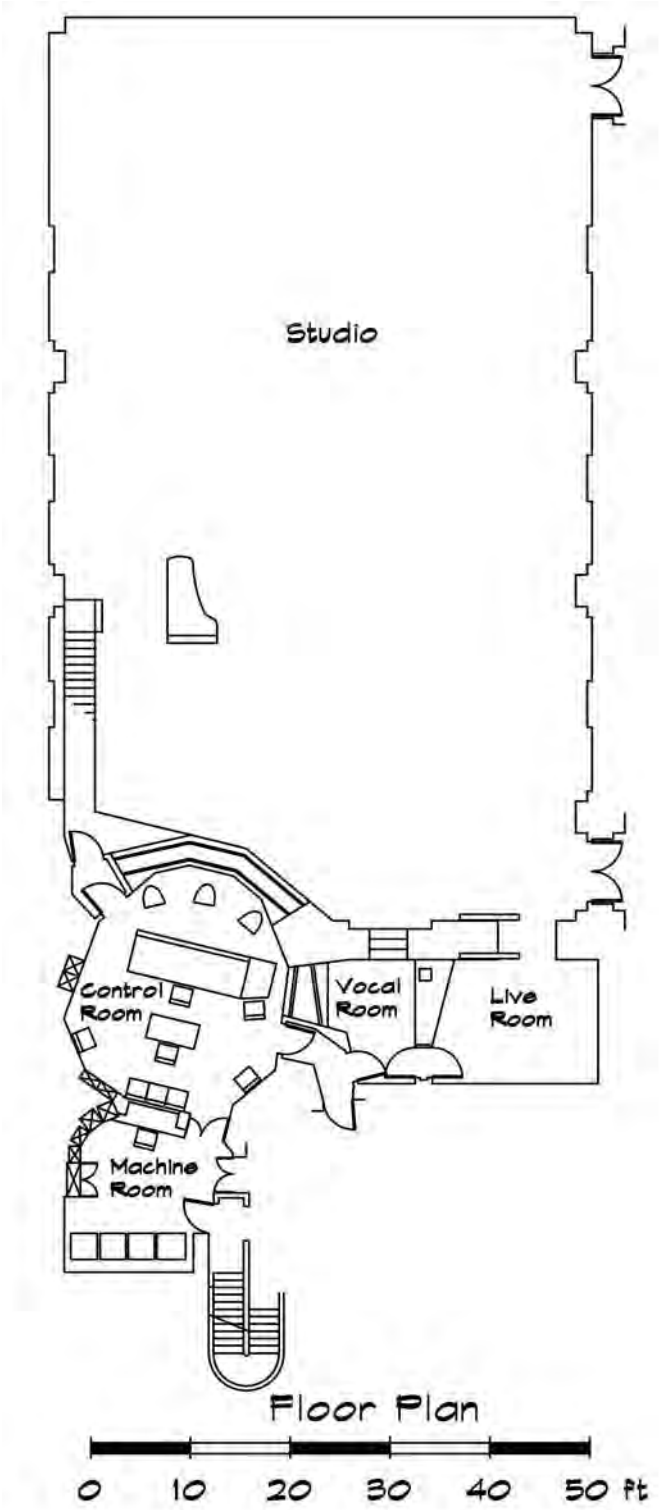

Fig. 6 Abbey Road Studio 1, London England (Abbey Road Studios, 2001)

Scoring stages are designed much like concert halls but without the requirements for an audience. The floors are flat and the walls and ceiling surfaces feature irregular shapes for diffusion. Reverberation times can be changed using moveable curtains or panels. For film, from 5 to 8 mics are used for the right-center-left and surround signals, and another 30 to 35 mics for individual instrument groups. The high ceilings sometimes make it difficult for the musicians to hear each other so 12 to 18 foldback channels are provided from the mix board to individual players through headphones. The orchestra can be seated on risers for visual cohesion and arranged to achieve a balanced sound.

Since sound stages are smaller than concert halls the orchestra cannot play quite as loudly as they would under performance conditions. When they do, the reverberation in the room, particularly the bass, can overwhelm the direct sound and yield a muddy recording. If the balance is correct and the control room is set up properly, the recording engineer can do a live mix including surrounds if necessary; however, the recorded tracks can be remixed at a later time, or used for sweetening.

The reverberation characteristics of a scoring stage are much the same as a concert hall. Abbey Road, in London, has a mid frequency reverberation time of about 2.2 seconds, rising slightly at the lower frequencies and remaining fairly constant at high frequencies. The lack of audience and seat absorption limits the falloff of the high frequencies to that due to curtains, musicians, and air absorption, so these rooms can be somewhat brighter than a performance hall. These stages have multiple hanging curtains, suspended on line sets from the ceiling, which can be lowered to reduce the reverberation time.

The recording of symphonic music can also be done in an empty concert hall. In these cases the room is often extensively modified to accommodate this use. For example, when Royce Hall at UCLA is used for recording, a wooden platform for the musicians is constructed over a portion of the seating area and the opera chairs in the orchestra section are covered with 3/4" (19 mm) plywood over visqueen sheets to decrease high-frequency absorption (Murphy, 2001).

Foley

Foley stages, where sound effects are generated by physical manipulation of devices, are often indistinguishable from landfills, due to the general clutter. They were named for Jack Foley, an early sound effects pioneer. A typical Foley stage consists of a dead room with walls and ceiling covered in broadband absorption and a hard-surface floor having multiple pits each 3 to 4 feet square, in which there are different walking surface materials. The Foley artists watch the film, projected on a screen against one wall, while making the sound effects with their hands and feet and an assortment of mechanical gadgets. For example, if the film requires the sound of running along a sidewalk, the artist runs in place on a concrete slab in time with the film actor's steps, with a microphone suspended nearby. Gravel, wood, or sand may each have a separate pit. Water effects are created in a basin or large trough.

Since space is expensive, Foley pits sometimes are built into a traditional studio. This is less desirable than a dedicated space since recording studios are more reverberant than Foley stages and water is seldom available. Foley is messy and dirty and requires space around the pits for microphones and props. One approach is to build prop storage areas on the walls with absorptive panels mounted as

Fig. 7 Abbey Road Studio 1, London, England (Photo credit Shawn Murphy)

doors. The airspace behind the panels improves bass absorption and the props are close by. Figure 7 gives an example of a Foley stage design based on this concept. There are large libraries of sound recordings available along with those maintained by the studios. These are available for scratch tracks and for the less critical applications. Foley stages must be quieter than recording rooms since effects are mixed hotter than music. Thus the background noise is more apparent to the mixer.

ADR

ADR or automatic (sometimes automated) dialog replacement is a technique using voice over, or the recording of dialog after the film has been shot. Whenever possible, film makers like to use the original sound recorded during filming but background noise or technical problems can make this impossible. In ADR the actors rerecord their parts in sync with the film. ADR stages are small, sometimes no bigger than a bathroom, and relatively dead. Low-frequency reverberation is a concern. Most have at least 2" (52 mm) thick panels on the walls. Since dialog replacement includes singing, ADR artists prefer rooms that are not completely dead (Farmer, 2001) and have a bit of volume, on the order of 8' × 12' × 9' (2.4 m × 3.7 m × 2.7

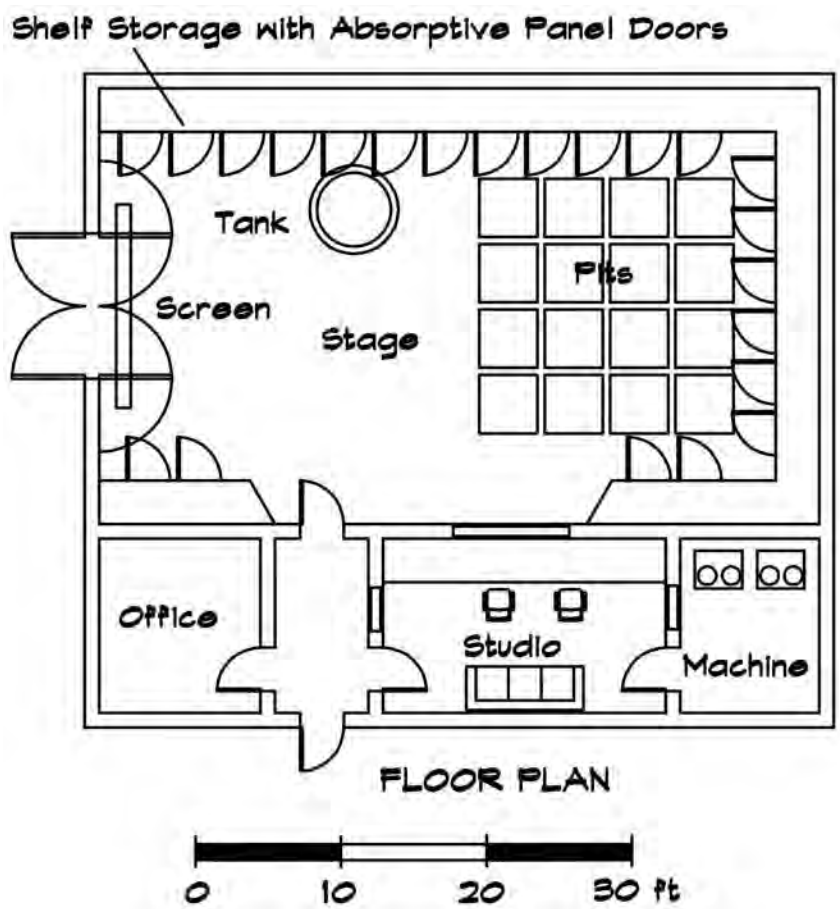

Fig. 8 Foley Stage

m). Larger stages can be used for recording voice over by adding absorptive panels around the actors. Flutter echo is particularly important to control so at least two nonparallel wall surfaces require treatment. ADR rooms should have a flat reverberation time versus frequency characteristic. Diffusion can be helpful and throw rugs are used to vary the room characteristics.

With animated films the dialog is often recorded first and the animation created later to fit the sound. With film or video, the actors must watch the picture and synchronize their voices to it. Video monitors are built into voice-over booths for this purpose. A communication system including a window between the booth and the studio and an intercom is a necessary part of the design.

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