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Dolby Stereo Technical Guidelines for Dolby Stereo Theatres

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DOLBY STEREO®

Technical Guidelines for Dolby Stereo Theatres

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Many people contribute to these guidelines. Particular thanks are due to David Schwind of Charles Salter Associates for much of the acoustic advice. Elizabeth Cohen of Cohen Acoustics, John Eargle of JBL and Tomlinson Holman of USC and Lucasfilm, provide significant contributions to this ongoing project. From within Dolby Laboratories there are numerous witting and un-witting contributors: in particular Tom Bruchs, Sam Chavez, Louis Fielder, John Iles, Lonny Jennings, Scott Robinson, Charles Seagrave and David Watts.

Some manufacturers' equipment is specifically cited in this material. Such citations are definitively non-exclusive – manufacturers are welcome to contact Dolby Laboratories with information about any equivalent or superior performance equipment that they believe should be included in future editions of these guidelines. Omission of specific equipment does not imply lack of fitness.

Ioan Allen
September 20th 1993

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1.0 Introduction

Modern film sound-tracks are proving increasingly demanding to exhibitors; not only is the theatre owner being asked to buy new front-end decoding equipment for a variety of sound-track formats, but these new formats are placing increasing demands on many aspects of theatre sound.

Dolby Laboratories has published a series of documents over the years, discussing the requirements of each progressively improved sound-track format the company has introduced. This booklet provides guidelines for theatres trying to take full advantage of the most common existing sound-track formats at the time of writing, and anticipates what increasing demands the digital sound-track on Dolby SR•D prints may present.

New Sound-track Formats

We should begin by re-iterating what seems fairly obvious to the engineers involved in film sound-track technology, what is frequently missed by some people involved in exhibition, and is certainly misunderstood by much of the movie-going public -- the sound-track format, mono, Dolby Stereo, Dolby Stereo SR, and now the digital sound-track of Dolby SR•D, does not itself define how loud or quiet a sound-track will be, or how extended the frequency response. The film-maker determines the artistic extents of the sound-track, not the format designer. The film-maker decides during the post-production process how loud the loudest bits of his films should be, how quiet the quietest -- how extended the frequency range should be, how wide the stereo, and how loud the surround effects. The role of the inventor, scientist and engineer involved in the technology of film sound is to make it possible for the full artistic range of the director to be carried on the film sound-track. And the role of the film exhibitor is to ensure that this full sound-track capability can be reproduced in the theatre.

The two Dolby Stereo formats most challenging for theatre playback are Dolby SR and the digital sound-track of Dolby SR•D release prints. The analog SR format is in some respects less demanding of theatre criteria, but in some areas, especially the A-chain, requires as careful attention as the new digital sound-tracks. These guidelines discuss these issues, and explain the minimum acceptable playback parameters for both of these new high-fidelity sound-track formats.

2.0 B-Chain

2.1 Dynamic Range Requirements

The most obvious feature of the new high-fidelity sound-tracks, analog SR and digital SR•D, is a significant increase in dynamic range. The potential for louder sounds requires attention to loudspeakers, power amplifiers and sound isolation between screens. Reproduction of quieter sounds requires attention to sound isolation (again), and background noise.

2.1.1 Power Amplifier Size

1. Each channel of the sound system should have a power handling capability easily capable of playing back an SR film recorded at 100% modulation level at all frequencies throughout the audio bandwidth. This should be the very minimum capability for Dolby digital playback, and a crest factor (safety margin) may require a significant increase in power amplifier size.

The dialog level on both the analog and digital SR•D sound-tracks will be at the same acoustic level as that of the dialog of a conventional Dolby Stereo film. Occasional sound effect "stings" and music, though, can have a level far greater than found on conventional films, and this increased peak level capability is one of the great advantages of both analog SR, and the digital sound-track on a Dolby Stereo SR•D print. Depending on the signal content, the peak levels on an analog SR sound-track can be 3dB higher, rising to 9 dB higher at frequency extremes, as shown in Figure 2.1. The digital sound-track can provide a peak level 12dB above conventional A-type Dolby Stereo films; it is also important to note that this peak level capability (around 103 dBC for each stage/screen channel) is constant with frequency.

As a very rough guide, analog SR sound-tracks in small and medium sized theatres, peak levels will require power amplifiers for the screen channels with total power output ratings of at least 250 watts. The mono surround channel for SR playback will probably need at least 400 watts.

Large theatres will require even more power -- however, the incremental cost increase of a 500 watt power amplifier when compared with a 250 watt unit is trivial. If in doubt, a theatre should always install amplifiers with a power safety margin.

It is unlikely that any film mix will take full use of the SR•D digital capability for more than an occasional "sting". But examination of analog SR tracks shows regular clipping at 100%. So, for a very minimum, power amplifiers should be able to reproduce the typical levels of analog SR. More power is required if a safe margin is to be provided for SR analog, and for playback of the digital Dolby Stereo sound-track.

Total insurance of enough power for a Dolby SR•D digital sound-track can be derived from Fig. 2.2. Unlike some optimistic nomograms for power requirements, this model takes no account of room volume and reverberation time. Transient sounds (of short duration) are not augmented by reverberation, and the required power for a given sound-pressure-level at a specific seat is directly controlled by the direct sound field -- an inverse-square law characteristic based on how far the listener is from the loudspeaker.[1]

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[1] One of the difficulties in calculating sound pressure levels comes from the increased reverberation times in large rooms. This increased reverberation will only be applied to steady-state, or quasi-steady-state, signals. Dialog is mainly made up of short staccato sounds (like t's, k's, p's). Consequently a mix balance created in a small room, with a short reverberation time, will sound different in a big room, with those music components with sustained sounds being augmented by reverberation. The dialog may sound relatively *quieter* with respect to the music. Sound pressure levels for the playback of Dolby Stereo are set up using pink noise, a quasi-steady state signal source. Theoretically, this means that in a big auditorium (say 1000 seats or more), the music will play at the same level as in a small room, but the staccato elements of dialog will play lower. It can be argued on a theoretical basis that in a really big theatre, for dialog to have the same level as in a small theatre, the reference SPL should be increased from 85dBC to (say) 86 or 87dBC. The result

The power requirement derived from Fig. 2.2 is the total power needed for a screen channel. If the system is bi-amped (virtually essential) the power for each HF and LF section should be approximately two-thirds of that shown.

For an analog SR sound-track, power amplifier headroom capability can be tested by installing a Cat. No. 85C Dolby pink noise generator into the Dolby processor, and assuming Fader 7 is the normal operating level, turning the fader up by 3 points, i.e. up to Fader 10. Examine the power amplifier output signal on the oscilloscope, and confirm that the signal is not clipped, which will be evidenced by squaring of the signal peaks. Do not run this test for extended periods of time, as loudspeakers could be damaged. The test should be repeated for each stage loudspeaker channel.

To verify power amplifier capability for a fully modulated SR•D digital sound-track, the following test can be used...

A tone burst generator is used to insert a signal into the theatre sound system. The output level of the generator is set such that it would generate a playback level in the theatre of 103 dB. Ideally, there should be some means of bringing the level up from no sound to the maximum 103 dB level at a reference seat two-thirds of the way back in the house with a fader. The easiest way is to run the signal into the cinema processor and then use the house fader to control the level. The tone generator should be able to output tones at the following frequencies: (for Left, Center, Right, and each Surround Channel) 63Hz, 200Hz, 1kHz, 4kHz, and (for subwoofer) 50 Hz. The different frequencies will give a better idea of the capabilities of the system if it has speakers that have a deficient response and therefore need excessive eq (which limits headroom). The tone should be gated with a synchronous (zero crossing) switch that has an "on" time of 750 msec (3/4 sec) and an "off" time of 2 sec. In regards to damaging speakers from this high-level signal, the short "on" time with a relatively long

would be a consistent dialog playback level, but an increase in level of steady-state signals, sustained music or effects.

"off" time should allow for a realistic test of the sound system headroom without damaging the speakers (or, less likely, the amps) in the process. A storage scope is connected to the output of the power amp for the channel to be tested. The tone-bursts are switched on for that channel and the fader turned up while observing the scope trace. As the fader is raised to the 103 dB level look on the oscilloscope for signs of the amplifier clipping. If the maximum level can be reached with no sign of clipping and with no audible sign of stress from the loudspeaker, the channel will probably be satisfactory for the demands of a digital soundtrack.

2.1.2 New Jiffy test film

An updated version of the well-known Jiffy test film is now available from Dolby Laboratories. The new Jiffy test film contains both an SR soundtrack and a digital soundtrack. There are six minutes of subjective audio tests, in some cases different for the analog and digital soundtracks, which include high-level tone bursts for checking power amplifier and loudspeaker capability. The test film also contains some quick visual tests, to verify framing and checking for ghosting and shutter problems.

2.2 Screen Loudspeakers

2.2.1 Location

The Left and Right screen loudspeakers should be mounted at the left and right extremes of the screen width when the masking is fully opened for projection of a 2.35:1 (Cinemascope) aspect ratio anamorphic picture. If screen masking covers these loudspeakers when a 1.85:1 picture is being projected, high-frequency attenuation due to the screen masking should not exceed 2 dB at 8 kHz.

The obvious intention of many elements in a stereo sound-track is that a sound should seem to emanate from the same location as the related picture image. When an actor closes a door at the left of the picture, the sound of the closing door should come from the same location; when we see a trumpet player close to the right edge of the screen, the sound should come from the same side of the screen. The objective of stereo sound is to place the apparent sound source sufficiently close to the image of the trumpet, in a way such that sound and picture together seem "real".

Listening to music in the home places no specific demands that stereo width be accurately defined -- there is no picture to which the sound should match. Typically, though, the two loudspeakers will subtend a total included angle of around 60 degrees to the listener. In the home the distances from the loudspeakers are short, and the room surfaces (furnishings) are absorbent -- as a result the listener will hear dominantly the direct signal from the loudspeakers.

In a commercial theatre, however -- no matter how small, and no matter how absorbent the materials on the walls and ceiling -- the path lengths are so much greater that what most of the audience hears with non-transient material is dominantly reverberant information coming from many directions, reflected from many room surfaces. This is why with a typical theatre layout, measurements show that at best only in the first row or two of seats does the near-field direct signal dominate.

As a result, from a prime seat where the screen subtends an ideal projection angle of 45 degrees, the listener may hear an acoustic width of only 25 or 30 degrees from loudspeakers typically 40 degrees apart, mounted at the screen ends. Further back, dominance of the reverberant field increases, and acoustic width therefore narrows still more. Indeed, in the back rows of most theatres, so much directional information is lost and the sound becomes so diffuse that few, if any, spot effects can be directly associated with the action on the screen.

This progressive attenuation of stereo width towards the rear of the house explains the requirement for maximum possible width in loudspeaker placement. As films are mixed to match picture in the dubbing theatre, it is difficult to conceive of situations where the screen is so large, and the reverberation so short, that the sound image is too wide for any of the audience not sitting in the front one-or-two rows.

This requirement for maximum stereo width holds equally true with the narrower screen image of a 1.85:1 movie, and to the maximum width of a 2.35:1 anamorphic print. Even though the masking has moved in to sharp-matte the 20% narrower picture image, the widest possible audio image should be retained -- in this way, the sound/picture match will "work" for the largest possible percentage of the audience.

Some years ago, narrowing the masking and covering the left and right loudspeakers when projecting a 1.85:1 picture caused major audio problems. (Not surprisingly, when considering the high-frequency attenuation resulting from black felt!) Happily, new techniques and materials have been developed to answer the problem. Black muslin, or acoustically-transparent, loudspeaker grille cloth (as used for high-fidelity loudspeakers) stretched over an "open" frame can be used for an insert covering the small area of the masking obscuring the high-frequency horns. For new theatres, masking cloth (Harkness 2000M) has been developed which appears matte black, is acoustically virtually transparent and is only slightly more expensive than the black felt it makes obsolete.[1]

But even if acoustically transparent masking cloth is used, care should be taken that the hard mounting edge (typically plywood) which supports the cloth does not cover any part of the horn mouth. Care should also be taken that cloth folded back on itself at the mounting edge does not attenuate the high-frequencies, and that "bunching"

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[1] Harkness Screens, The Gate Studios, Station Road, Boreham Wood, Herts WD6 1DQ, England, Tel: 081 953 3611, Fax: 081 207 3657.

masking cloth in front of a loudspeaker can cause severe high-frequency attenuation.

2.2.2 Loudspeaker Type

Figure 2.2 can also be used for guidance as to suitable loudspeaker types. Manufacturers' literature should be consulted as to the maximum power handling capability of a given loudspeaker. While there are several manufacturers offering a wide variety of loudspeaker types, most quality theatres today are installing bi-amplified systems, with a constant directivity high-frequency horn and a direct radiator cone diaphragm-vented box low-frequency unit.

2.2.3 Loudspeaker Walls

Since the earliest days of loudspeaker design, it has been recognised that low-frequency response can be assisted by mounting the transducer in a plane baffle. An infinite sized baffle puts the transducer in what is termed a 2 pi space. This better bass efficiency is why the classic cinema loudspeaker for many years, the Altec A4, was provided with "wings", plane wooden sheets mounted on either side of the LF unit. This concept was extended in the late seventies, when three or five A4 units would be connected with a wooden frame with a solid plane baffle connecting each unit. A similar idea was used by Tomlinson Holman with the THX loudspeaker system[1], where the loudspeaker system is mounted in a wall, covered with sound absorbent material. This baffle gets close to the theoretically perfect 2 pi baffle, but if the wall extends from floor to ceiling it can also effectively cancel transmission of rear screen echoes, as discussed later.

2.2.4 Cross-overs

A bi-amplified system, with active cross-overs, is an essential requirement of any high-quality contemporary theatre sound system.

[1]THX is a registered trademark of Lucasfilm Ltd.

The most important reason for bi-amping is the capability of power handling of bass and treble simultaneously. In addition, an active cross-over enables a smooth characteristic over the cross-over region, with minimum phase discontinuity. Active cross-overs also make possible a signal delay to the low-frequency unit, improving coherency of arrivals of HF and LF signals in the seating area, and further improving signal phase continuity around the cross-over region.

2.2.5 Stage Loudspeaker Characteristic Curve

The B-chain frequency response of the Left, Center and Right screen channels should conform to the wide-range characteristic defined in ISO2969. The response should extend smoothly from 40 or 50Hz at low frequencies to significantly beyond 10kHz, and ideally as far as 16kHz. The level difference between any two locations in the normal seating area, measured in 1/3 octaves from 150Hz to 10kHz, should not exceed 3dB[1]. See Figure 2.3.

The quality of a theatre's B-chain can be assessed in two areas: first, how closely the curve matches the required frequency response; and second, how uniformly the same response is maintained throughout the seating area. Matching the required response almost certainly requires use of bi-amplification and an active cross-over. The required uniformity of response will normally make use of constant directivity high-frequency horns mandatory.

A complete discussion of B-chain equalization techniques can be found in each Dolby cinema processor manual.

[1] In most theatres, the reverberant field dominates in most of the normal seating area. In small rooms, however, with a seating capacity of less than, say, 150 seats, that sector of the audience seated closer to the screen receive a signal dominated by the direct field. In such cases, inverse square law losses can cause a noticeable fall-off in energy over the first few rows of the theatre, and may make it impossible to sustain the quoted 3dB figure. In these small theatres, the installer should verify a smooth fall-off with distance from the screen, and an even distribution laterally across the seating area.

Note: the USA national equivalent standard to ISO2969 is ANSI PH22.202M, and the British Standard is BS5550:7.4.1.

2.2.6 Measurement

There is a discussion of B-chain measurement techniques in each Dolby cinema processor manual. Until the last few years, it was normal practice to use a single calibrated microphone, placed in a "normal" seat location, asymmetrically located with respect to the theatre's centrelines, and set approximately two-thirds of the way back in the theatre. See Figure 2.4. A conscientious installer would then move the microphone to an alternative location, and "average" the equalisation for the best overall results.

In recent years, microphone mutltiplexers have come into increasing prominence, typically with four calibrated microphones. Measurement of four locations in the theatre results in a much more even equalisation throughout the seating area. Practical experience suggests that best results are achieved with the microphones placed substantially in the reverberant field, in a layout such as that shown in Figure 2.5. Again, care should be taken not to place microphones on each central axis of the theatre, where standing waves can cause aberrant conditions.

In mixdown, dubbing theatres, and small review rooms used for print quality control, where the listening/viewing area is small with respect to the size of the room, the microphone locations should be located within the area of interest.

The microphones should normally be mounted at listener's head height. However, if the seats have high backs, the microphones should be raised up so that they are at least 9 inches above the top of the seat, thus avoiding any grazing effects.

2.3 Surround Loudspeakers

2.3.1 Number and Location

The first step in determining the number, type and location of surround loudspeakers, is to consider the likely power handling requirements. Dolby SR, for example, can require a peak level in the middle of the auditorium of a minimum of 92 dBC with normal program, and as much as 6dB more if the sound-track were used to its full low-frequency limits. For an SR•D digital sound-track, the equivalent level is 103dBC for a mono surround playback, or 100dBC for individual left and right surround strings of a stereo surround installation. Assuming no assistance from reverberation (ie the maximum peak level is that required to deliver a transient sound, see section 2.1.1 above), the dimensions of the theatre can be used to calculate the total loudspeaker power required.

The first thing to do is to calculate the total electrical power required. In some cases the proximity of the surround speakers to a wall may contribute to their efficiency. However, this factor has been omitted from the present calculation since it is only valid for low and middle frequencies and only if the speakers are against a wall and not spaced away from the actual hard surface.

The desired maximum rms sound pressure level at the listeners' ears is 100 dB per surround channel for a stereo surround configuration. The total electrical power required from each side's power amplifier is given by

$$Watts = 10^{\left(\frac{Lp - S + 20\log r}{10}\right)}$$

where

Lp = desired SPL (100 dB in this case)

S = speaker sensitivity , dB SPL at 1 meter distance for 1 watt input

r = distance from wall to centerline of theater in metres

See Figure 2.11

Having determined the total electrical power required per side, we must now find out how many speakers are required to handle this amount of power. The number of speakers N is calculated from

N= electrical power (calculated above) *divided by* the power rating per speaker

This is the minimum number of speakers per surround side required to handle the necessary power. A greater number of speakers may be required to secure good uniformity of coverage of the audience area. In practice, the number of speakers required is the *larger* of the two numbers derived from coverage requirements and power handling ability.

The speakers should be connected in series/parallel so that they all receive equal power and the impedance presented to the power amplifier is around 4 ohms. Most well-designed modern amplifiers will drive 4 ohm loads with a somewhat higher power output than they will a 8 ohm load, but as this ability is a function of the details of each amplifier, the manufacturer's data should always be consulted. Some amplifiers will drive impedances lower than 4 ohms; again, consult the manual or manufacturer.

It may be desirable in some installations to arrange the series/parallel connection so that the rear-most speakers receive slightly less power than the front ones. This is done to match the lower sound level heard from the screen speakers in the rear of the auditorium. In general, this practice is most appropriate in long rooms with short reverberation times.

Next, consider that this power has to be shared by a given number of loudspeakers, which should be spread about the back wall, and the two rear side walls of the theatre. Optimum sound balance between channels dictates that surround loudspeakers should be evenly spread from half-way back from the left side-wall, through the auditorium back wall, to a point half-way up the right wall. This configuration takes account of the ratio of screen to surround sound pressure levels, and also seems subjectively optimum when the visual dominance of screen activity is taken into account. (See Figure 2.6). Avoid placing any surround speakers further forward than 50% or 60% of the way from the rear to the front of the house. Placing speakers too close to the screen results in surround sound blending into screen sound for audience in the middle part of the house (especially when the "draw" of visual screen action is taken into account -- see Figure 2.7).

2.3.2 Loudspeaker Type

Manufacturers' literature should be consulted for the power handling of a given surround loudspeaker, and this determines the number of speakers required.

Selection of a suitable *type* of loudspeaker, though, demands assessment of more than just power handling capability. Diffusion is also a major requirement of surround channels, meaning that surround signals should never appear to come from a point source. This means that a large number of loudspeakers are always preferable to a few, regardless of power handling.

Avoiding localization to a local speaker will also be assisted by selecting a speaker without too wide a dispersion, as an excessively wide dispersion will cause a domination of high-frequencies at the seat closest, or directly under, a given loudspeaker. For this reason, three-way bookshelf-type units should be avoided, as wide dispersion is one of the *intended* design parameters of these units, primarily designed for the home for music listening.

2.3.3 Mounting Angles

Some types of loudspeakers intended for surround use are mounted in a box with a built-in down angle. Care should be taken not to accept this fixed angle as correct for any given auditorium. Depending on the mounting height, the angle should be set to achieve the most uniform response across a lateral row of seats. In cases where a low ceiling results in the surround speakers being mounted lower than would be desirable, any downward cant would make a bad situation worse, enhancing localisation to the nearest loudspeaker for those seats closest to the walls. In such a situation the loudspeaker drivers should be aimed horizontally, getting a percentage of the dominant direct signal above the heads of listeners in the closest seats.

2.3.4 Characteristic Curve

The Surround B-chain frequency response should conform to ISO2969 from 125 Hz to 8 kHz, after correction for near-field response. The level difference between any two locations in the normal seating area, measured in 1/3 octaves from 150 Hz to 8 kHz, should not exceed 3dB. Below 150Hz it may not be possible to achieve this 3dB tolerance, depending on the equalizer in use. Care should be taken, though, to achieve the smoothest possible response at these lower frequencies.

Matching the surround characteristic to the target curve will invariably require equalization, either with an optional module available from Dolby Laboratories, or in the case of the CP50, use of an outboard free-standing equaliser. Achieving satisfactory uniformity requires a moderately large number of surround loudspeakers. Ceiling-mounted loudspeakers are unacceptable, as all films are mixed assuming a horizontal surround field; in addition, a very large number of ceiling speakers would be needed to achieve uniform seat-to-seat response.

The bandwidth of the surround channel on a stereo optical film is intentionally band-limited to around 7 kHz, to avoid the risk of operational problems such as bad sound-head azimuth, and excessive impulse noise with worn prints. SR•D digital sound-tracks, though, and occasional 70mm magnetic prints have full bandwidth discrete effects on the surround track, and this will require analysis of surround loudspeaker response beyond 8 kHz. Surround equalization is more or less essential for quality theatre sound, as otherwise panned sounds cannot move smoothly around the theatre, or from front-to-back. For information on updating older Dolby cinema processors, see Section 5.0 below.

Several psycho-acoustic mechanisms combine to cause the perceived response from surround speakers to differ from that of the screen loudspeakers.

First, the surround information comes from a multiple array of loudspeakers, as opposed to a single source. Second, part of the signal comes from behind the listener, and the ear/brain combination reacts differently to sources behind the head. Finally, and probably of greatest significance, the average movie-goer selects a seat two-thirds of the way back in the theatre, and in a conventionally shaped theatre is thus normally much closer to the surround loudspeakers than to the speakers behind the screen. As a result, near-field response will be a far greater percentage of the surround signal than the screen signal, where far-field components normally dominate.

This large number of variables means that the ideal correction characteristic will be unique for each theatre. Figure 2.8 shows how the X-curve of ISO2969 should be modified for surround use in a typical theatre, where most of the audience is closer to surround loudspeakers than to the screen.

2.3.5 Measurement

Measurement microphones should be left in the same location as when used to measure the screen channels. In addition, they should normally be left at the same orientation. A stereo surround set-up should be measured and equalized independently for the left and right channels.

Reference level (generated with a Cat. No. 85 Pink Noise Generator) is 85 dBC for each stage loudspeaker. A monaural surround channel should also be set to 85 dBC, a procedure described in each Dolby cinema processor manual. With a stereo surround installation, for Dolby SR•D or Dolby Stereo 70mm, the left and right surround chains should each be set to 82 dBC at the reference pink noise level.

2.4 Sub-woofers

The installation must include sub-woofer(s), driven by dedicated power amplifiers--analog SR signals have to be derived from a bass extension module in the cinema processor.

Both Dolby Stereo 70mm magnetic and Dolby SR•D digital have dedicated low-frequency channels, requiring sub-woofers -- and one of the main benefits of Dolby SR with optical sound-tracks is the improvement in signal handling at frequency extremes. Figure 2.1 shows the relative peak level capabilities of an SR sound-track compared with those of mono and conventional Dolby Stereo. The significant increase in potential low-frequency signal energy requires the use of dedicated sub-woofers. Existing theatre bass bins (such as A4 units) are not acceptable.

With a Dolby digital sub-woofer track, the potential levels are even higher. Monitor levels are set for 10 dB of "in-band gain", as shown in Figure 2.9. This level setting procedure requires use of a real-time analyzer. Attempting to use a sound-level meter for sub-woofer level setting is extremely unreliable, for several reasons:

a) Different sub-woofers have different effective low-pass filters, either caused by cabinet/speaker design, or by an actual low-pass filter. Even though the frequency range of interest is only up to 120 Hz with an SR•D track, the varying out-of-band components above 120 Hz can lead to variations of 3 or 4 dB when read on a sound level meter.

b) There can be a substantial variation between meters at low frequencies, where C-weighting is not necessarily accurately followed.

c) Room nodes can affect the loudness perceived by a sound level meter, whereas the eye can easily see the effect of nodes when viewing the analyzer.

As real-time analyzers are always needed to adjust notch-filtering of room nodes, as described in Section 2.4.4, use of an analyzer instead of a sound-level meter does not affect installation time.

Many theatres which have been equipped with sub-woofers over the last few years have adequate relative low-frequency loudness when compared with stage channels at mid and low-levels. Some contain limiters such that if overloaded go smoothly into saturation without any clipping distortion—in such a case the signal may not sound distorted, but the peak levels are not correctly replayed. Badly designed sub-woofers, though, show significant distortion components at all levels[1] , and non-linear frequency response. The bandwidth of the digital sub-woofer channel on a Dolby digital sound-track extends from 5 Hz to 120 Hz. A linear sub-woofer acoustic response is desirable from, say, 25 Hz to 120 Hz. The 120 Hz sound-track cut-off is extremely steep, so a suitable sub-woofer need have little response above this frequency.

2.4.1 Location

While sub-woofer location is not critical, a single unit should not be mounted on the centre-line of the theatre. If two sub-woofer cabinets are used, they should be mounted asymmetrically; ie they should *not* be mounted equally spaced either side of the centre-line as for channels 2(Le) and 4(Re) of a 70mm system. This asymmetric mounting reduces stimulation of standing waves derived from room dimensions.

To achieve maximum power, two sub-woofers should be mounted as close together as possible, thus achieving cross-coupling. Standing two sub-woofers to one side of the centre channel loudspeaker is probably a reasonable solution. On the other hand, if the target is to reduce the level of spot resonances, the two units should be separately mounted

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[1]For background information see Engebretson, Low-Frequency Sound Reproduction, JAES May 1984, and Fielder and Benjamin, Subwoofer Performance for Accurate Reproduction of Music, JAES, June 1988.

at, say, one-third of the way from the left wall, and one-fifth of the way from the right wall, though this, of course, will require more power.

2.4.2 Need for Bass Extension with Dolby SR

Modern main-channel loudspeaker systems have better low-frequency performance than systems designed a few years ago. However, extreme low frequency signal information requires special processing when derived from an optical sound-track, in order to suppress "streaking" noise and other processing artifacts. This circuitry, and a parametric equalizer to smooth out the primary room node, is contained on the optical bass extension module -- Cat. No. 160 or Cat. No. 560 in CP50 and CP200 units, Cat. No. 241 in CP55 units, and Cat. No. 441 in CP65 units. Also, see Section 5.0 below for information on retrofit modules for Dolby SR•D digital playback.

2.4.3 Tuning

All cinema processor sub-woofer driver modules contain a simple parametric equalizer. This should always be used, as every room will have at least one dominant resonant frequency, which if not damped will lead to a characteristic low-frequency "ringing" every time the sound-track contains extreme low frequency information. Instructions for adjusting the parametric equalizer can be found in each Dolby cinema processor manual.

2.4.4 Power Requirements

For the playback of an analog optical soundtrack the subwoofer channel power requirements are not substantially different than a stage channel, i.e. an amplifier of the same power rating as one used for the front stage channel should be adequate.

For playback of an SR•D soundtrack however, the power requirements for the subwoofer become more demanding. Two factors work together to raise the required amplifier size. One factor is the headroom available in the subwoofer channel. Like the boom channels on a Dolby Stereo 70mm mag print, the subwoofer channel is recorded 10 dB lower than the other channels on a digital soundtrack. The cinema processor is then adjusted to playback 10 dB higher, this providing 10 dB more headroom to produce effects like explosions and stings at more realistic levels. This level requirement implies an amplifier power requirement 10 dB or 10 times more than any other channel.

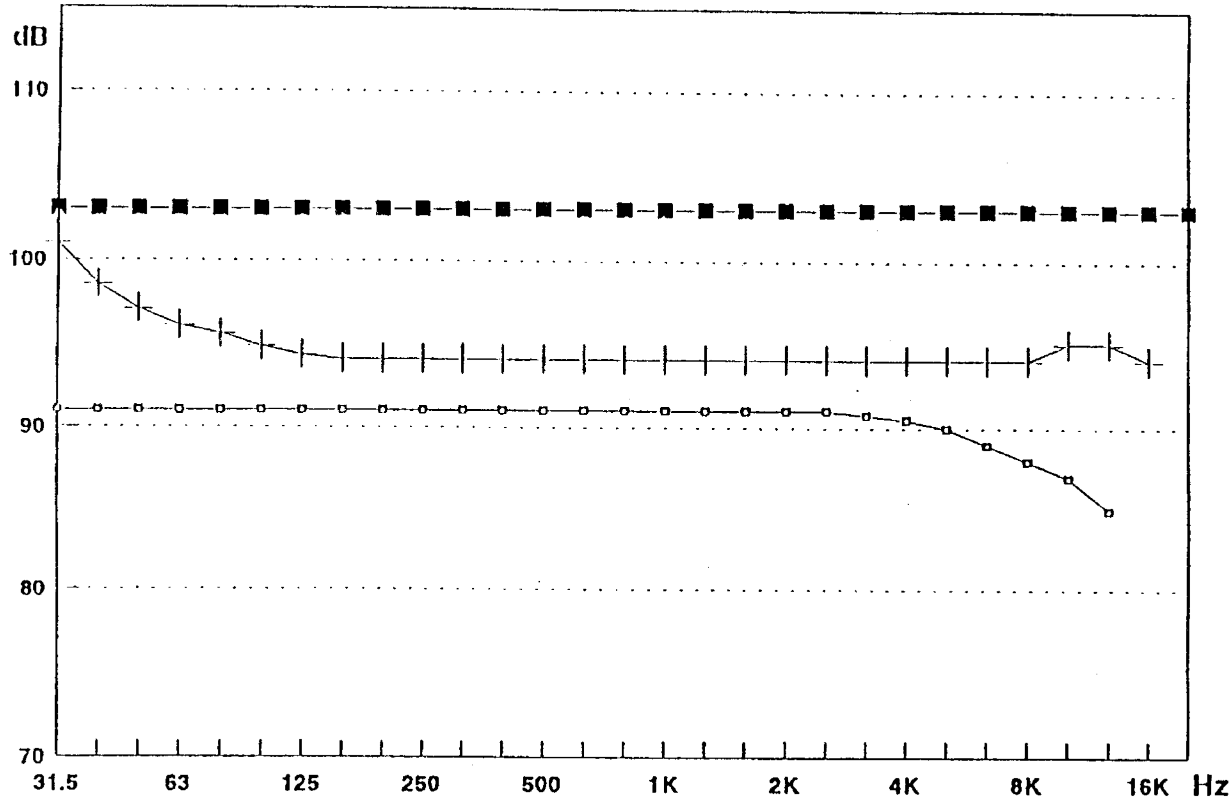
In addition, though, the subwoofers normally used for cinemas are less efficient than the stage speakers. Most of the models used are at least 3-5 dB less efficient than contemporary direct radiator stage speakers. This means at least an additional 3 dB or two times more power because of the lower efficiency of these speakers. Combined, the requirements become difficult - 13 dB or 20 *times* the power rating of one of the screen channel amps. Figure 2.10 is an outline of the power requirments of the subwoofer channel depending on the size of the auditorium and can be used to determine the amps needed. As can be seen from the chart, it makes sense to use a model of subwoofer that has good efficiency since this will keep the power requirements smaller. However, be aware of claims of unusually high efficiency for subwoofers.

In loudspeaker design the laws of physics limit the maximum amount of efficiency improvement that can be achieved without a tradeoff in either low frequency response or enclosure size. In other words, for a given size of speaker enclosure the efficiency of a system can be increased but only at a loss to the low frequency performance of that system. This is why bass bins for stage speakers that are about the same size as subwoofers are more efficient but they cannot reproduce the deep bass that can be produced by a true subwoofer design.

Fortunately, there are ways to make the amplifier demands more reasonable. Sometimes it can be relatively easy to get increased headroom from the existing system. For example; if the system presently has two subwoofers each rated at 8 ohms and one stereo amp with each half driving one sub, it may be possible to wire the two subs in parallel and connect them across the amp running in a bridged mono mode. If the amplifier is of good professional quality with the capability of driving the equivalent of a 2 ohm load on each channel, it is possible to get as much as 4-5 dB more headroom by simply rewiring the subwoofers in this fashion.

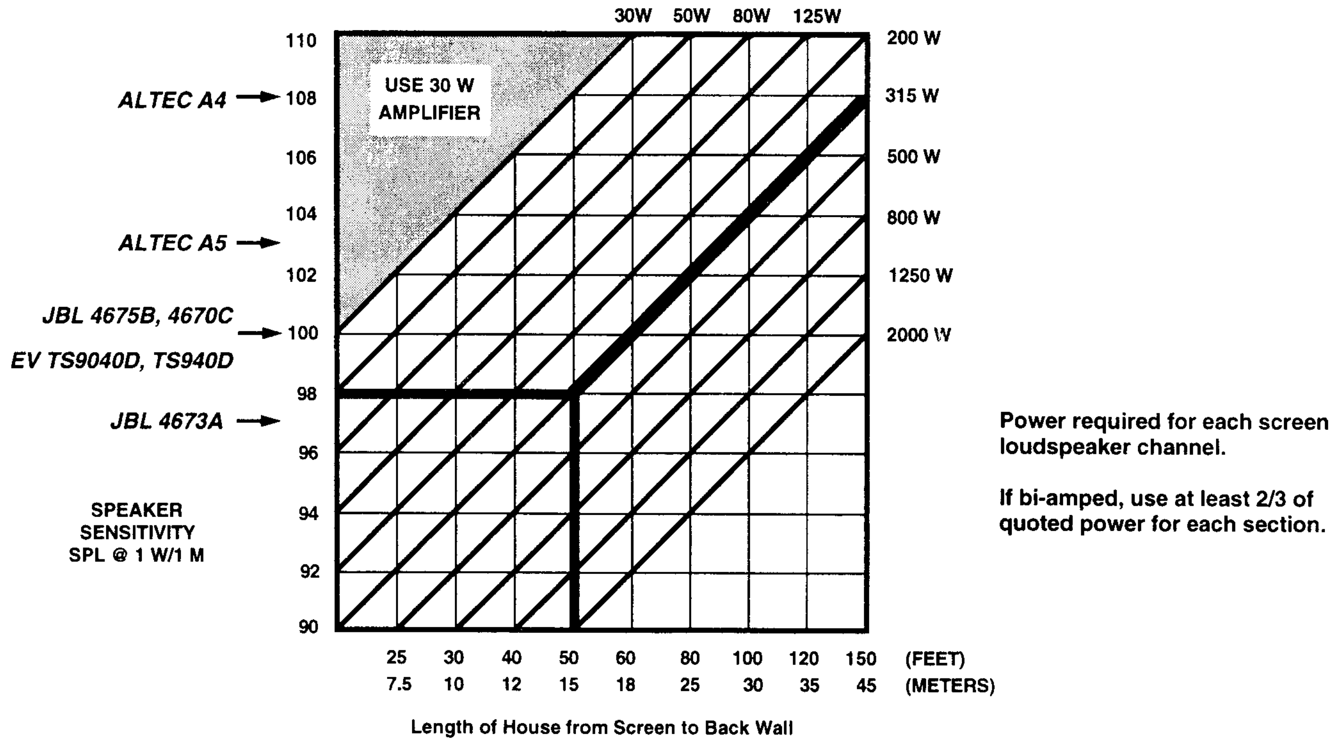
As mentioned earlier, multiple subwoofer units can be grouped to take advantage of mutual coupling. If the units are placed together ideally, doubling the number of subwoofers gives an extra 3 dB of output level due to efficiency gained by mutual coupling. Figure 2.10 shows the reduction in the amplifier power needed if more than one subwoofer is used, assuming that they are mutually coupled. As an example, if the system is as above with each half of a stereo amp driving a single 8 ohm subwoofer, two more subwoofers can be installed (mounted close to the other two for coupling) each wired in parallel with each of the other two, it can provide as much as 6 dB more headroom than before. Half of the gain is due to the efficiency increase of doubling the number of units and the other 3 dB comes from the greater power output of the amplifier when driving a 4 ohm load on each channel instead of 8 ohms. Of course, one can always just buy more and/or bigger amps. This however, quickly becomes unwieldy if the system is something like 10 dB deficient, and it is usually more practical to increase the efficiency of the system as well.

The placement of the subwoofer can also be critical if increasing the efficiency of the system is needed to keep the amplifier requirements practical. Generally speaking the units should be mounted as close as possible to as many boundary surfaces (read walls and floor) as possible. This means that the subwoofers should be installed (coupled together) at least on the floor and if possible next to the back wall and/or the side wall behind the screen. Unless the back wall behind the screen is appreciably greater than 10 feet behind the screen it is more desirable to have the subs back up against the wall on the floor instead of up next to the masking. The increase in efficiency is preferable to the small delay in the bass signal because of the subwoofer being slightly behind the stage speakers. Corner mounting of sub-woofers in this way, however, may lead to a more pronounced primary room resonance. A further increase in efficiency would result from having the unit on the floor, and mounted in a baffle wall that extends to the dimensions of the screen, this of course would help the bass response of the stage channels in their proper locations as well.



Dolby Stereo A-type —+— Dolby Stereo SR -■- Dolby Stereo Digital

Figure 2.1 Peak power levels - A-type, SR, SR•D



SINGLE SCREEN CHANNEL POWER REQUIREMENTS FOR 103 dB SPL @ 2/3 BACK FROM SCREEN

Figure 2.2 Power Needed versus Room Size

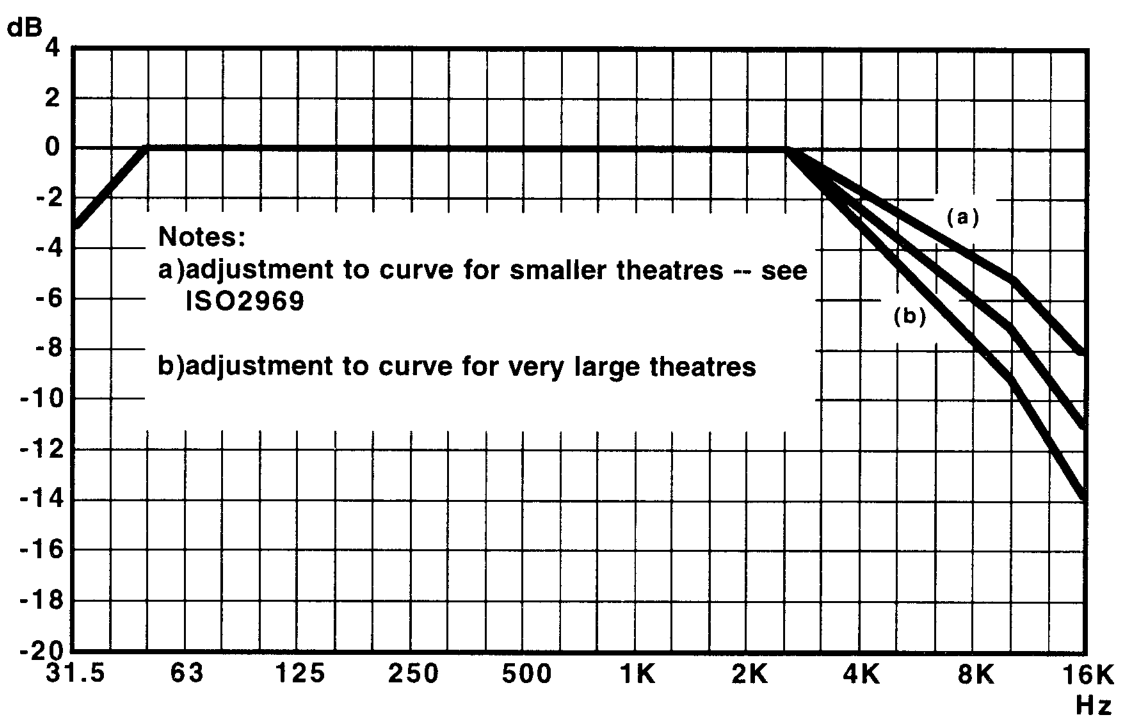


Figure 2.3 Stage Loudspeaker Characteristic Curve

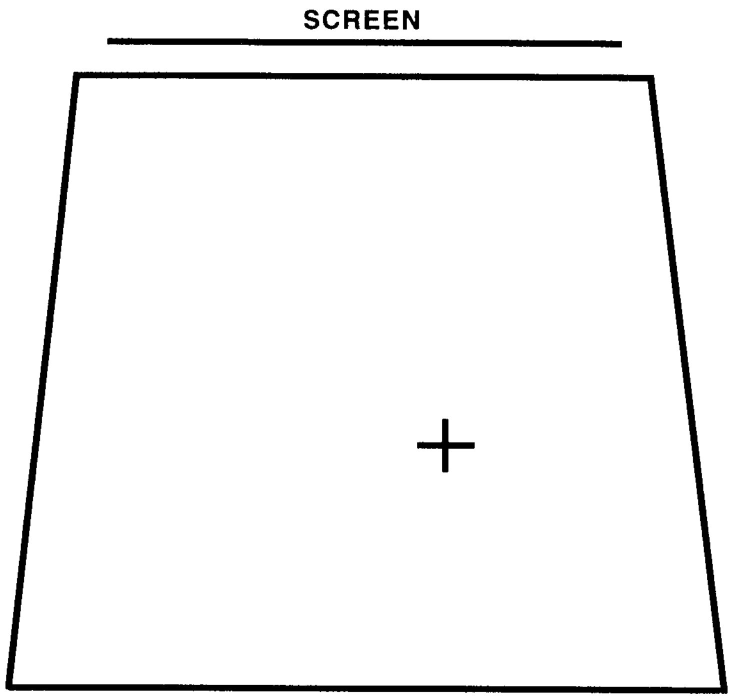


Figure 2.4 Single Microphone Equalization Location

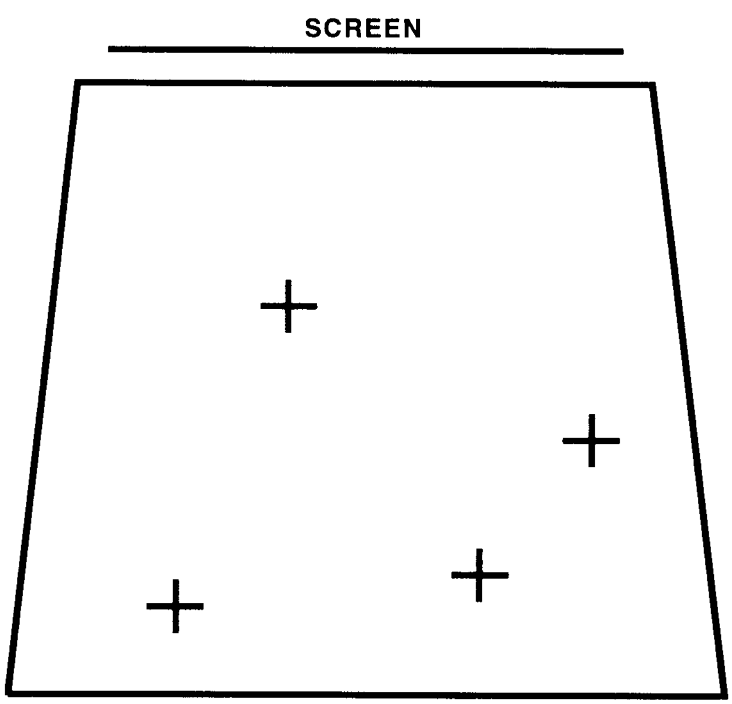


Figure 2.5 Multiplexed Microphones Equalization Location

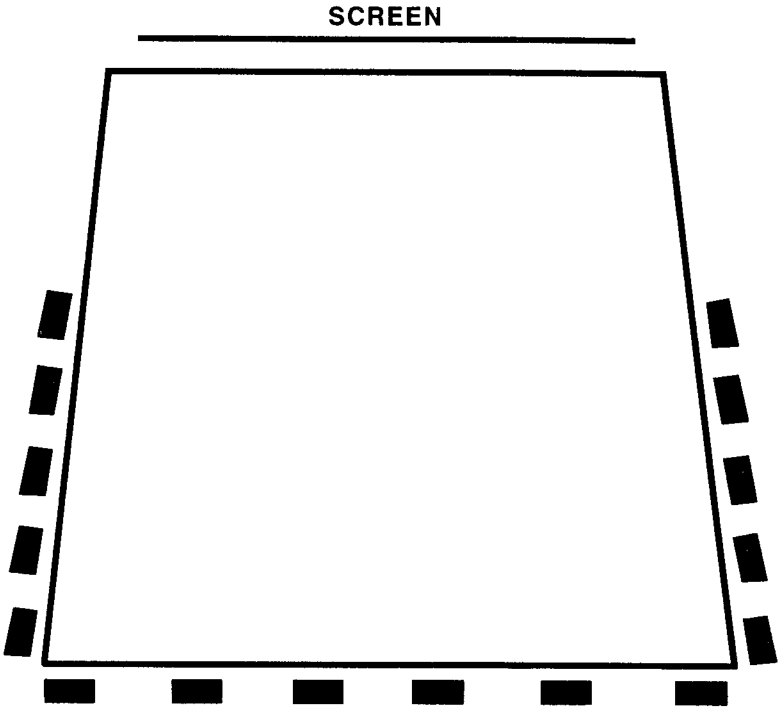


Figure 2.6 Good Surround Location

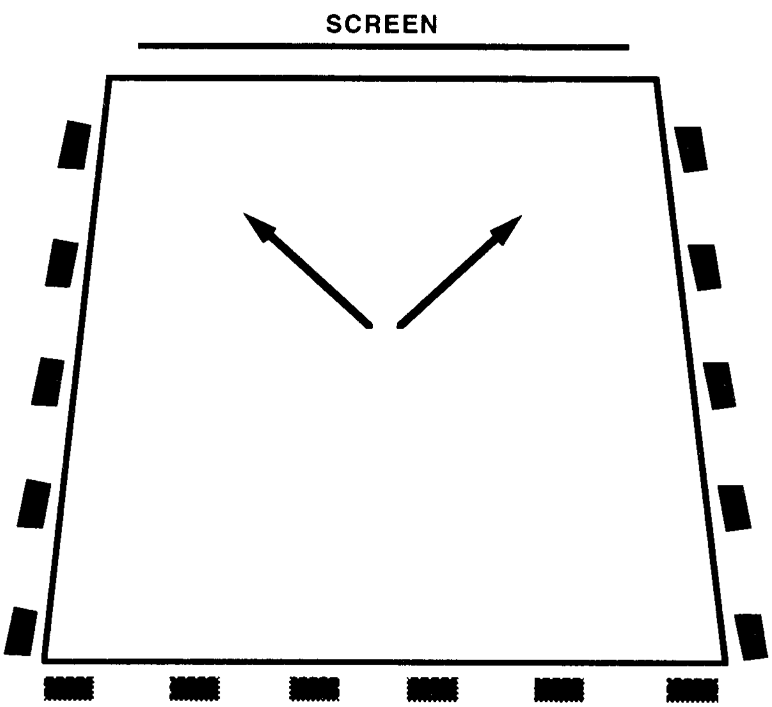


Figure 2.7 Surrounds Too Far Forward

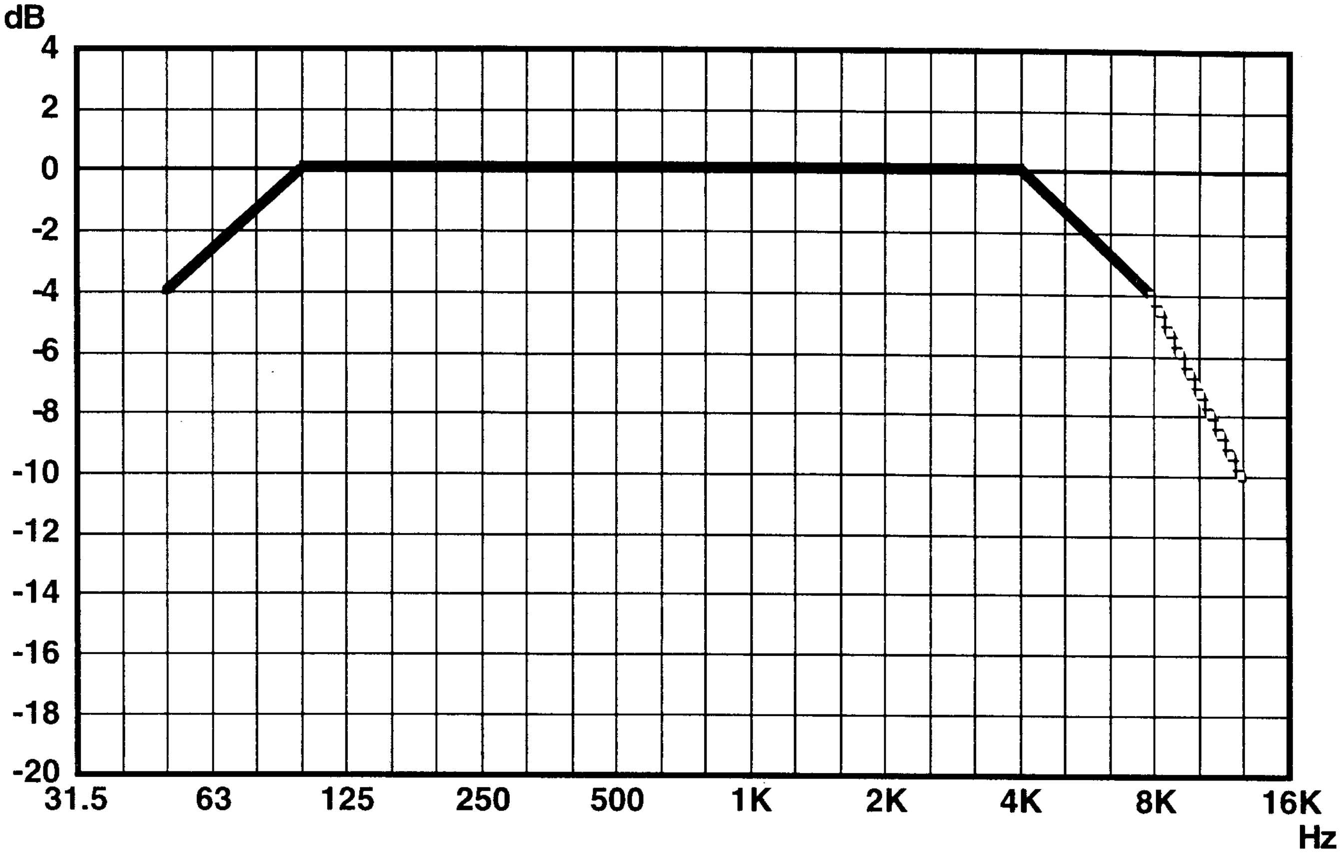


Figure 2.8 Typical Surround Characteristic Curve

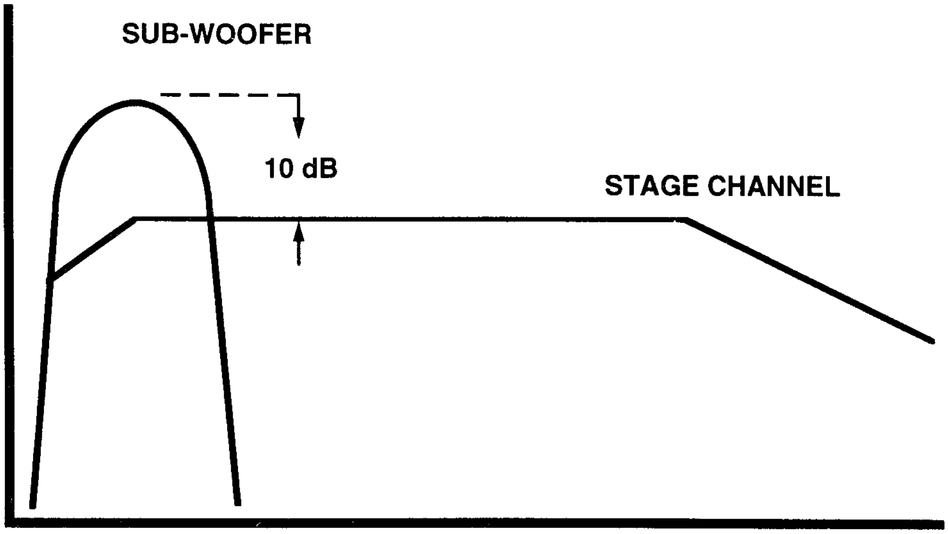
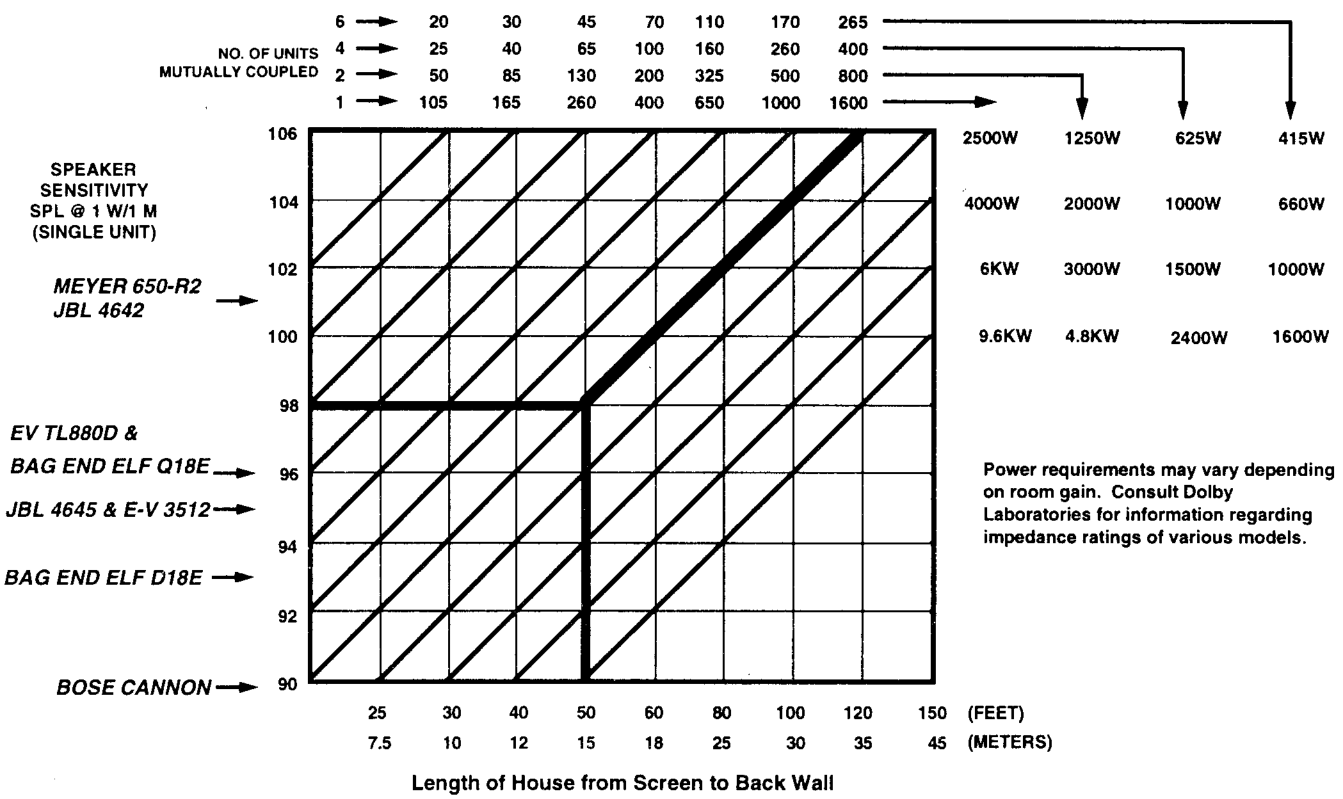
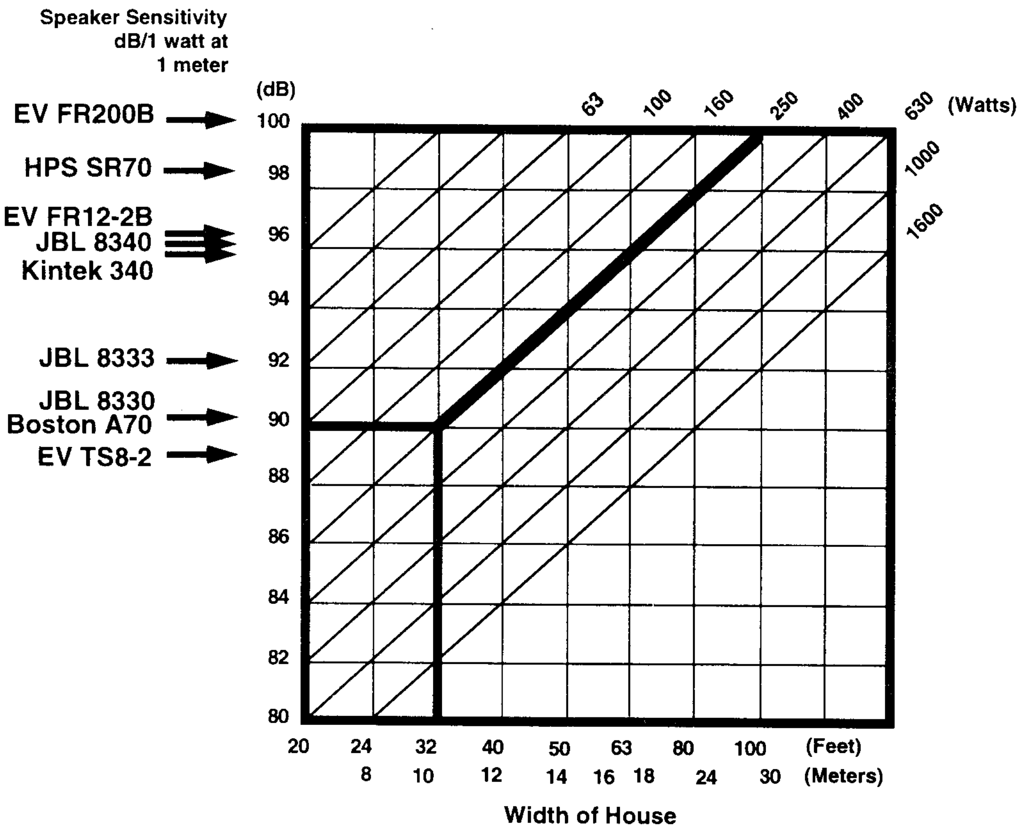


Figure 2.9 Sub-Woofer Level Setting



POWER REQUIREMENTS FOR SUBWOOFERS FOR 113 dB SPL @ 2/3 BACK FROM SCREEN

Figure 2.10 Subwoofer Power Requirement



Example:
Step 1: Surround loudspeaker sensitivity 90 dB. Move horizontally to house width (in this example, 32 feet), and then move up diagonally to find minimum power needed, 250 watts.

Step 2: See text on how to find number of loudspeakers needed.

Figure 2.11 Power needed for a single surround channel (left or right) for 100 dB SPL at center of house. (See text, Section 2.3.1)

3.0 A-Chain

3.1 Analog

3.1.1 Frequency Response

The equalized A-chain frequency response, measured at the Lt and Rt pre-amplifier outputs, should be flat to within ±1 dB from 30 Hz to 14 kHz. When a pink noise test film is used, and the pre-amplifier response measured in third-octaves, the output should be flat up to and including the 12.5 kHz band, and no more than 3dB down in the 16 kHz band.

Later versions of optical pre-amplifier boards installed in Dolby theatre equipment exhibit improved stability, and better linearity and phase response at high-frequencies. CP50 and CP200 units should ideally be updated with CN108 pre-amplifier cards of Revision C. All CP55 and CP65 unit pre-amplifiers have adequate performance. See Section 13B below.

A complete discussion of A-chain alignment can be found in each Dolby cinema processor manual.

3.1.2 Slit

This bandwidth specification ideally requires a projector sound-head slit height of around 0.00075". A slit height of 0.00100" is unacceptable as impossibly large amounts of hf boost are needed to achieve a flat response above 10 kHz. A slit height of less than 0.00050" performs better at high frequencies, but the need for increased pre-amplifier gain may make the system more prone to spurious interference resulting from stray light landing on the solar cell.[1]

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[1] Most projector manufacturers offer retro-fit slit lens assembleies with a slit height of 0.00050 or 0.00075". In addition, slit-lens assemblies for a variety of projectors are manufactured by Sankor Ltd., distributed by Marble Company Incorporated, P.O. Box 160080, 421 Hart Lane, Nashville, TN 37216, Tel: 615-227-7772, 800-729-5905, Fax: 615-228-1301.

The pink noise on current Cat. No. 69 optical test film has a frequency response nearly flat up to 16 kHz, as shown in the calibration chart in Figure 3.1. The old black and white Cat. No. 69 test film has been replaced by two new test films. Cat. No. 69T (Dolby Tone) and Cat. No. 69P (pink noise) are both now printed on color stock, which represents release print behavior more accurately. The color stock fades, however, so the test films should be replaced after about six months of use.

3.1.3 Exciter Lamp/Supply

The exciter lamp supply should have a regulated output.

An unregulated exciter lamp supply results in gain variations, bad decode tracking, and can cause audible hum.

A well-designed regulated supply will have a ripple level of less than 3%.

3.1.4 Illumination Uniformity

The projector sound-head optical assembly should provide uniform illumination across the slit. When measured with a snake-track test film, output variations should not exceed ± 2dB from the average level.

Uneven illumination along the slit is frequently the cause of bad-quality optical sound playback. Level-dependent distortion and bad stereo imaging are the two most obvious results.

The most likely causes of uneven illumination are:

- Dirty optics or slit
- Misaligned optics
- Dirty or carbonized exciter lamp
- Insufficient voltage for exciter lamp

and less likely:

Uneven slit width resulting from bad machining

One method of checking illumination uniformity is to run a scanning beam uniformity test film (snake-track) loop (SMPTE Test Film No. P35-SB or equivalent), and to evaluate the summed Lt and Rt pre-amplifier outputs (or the center channel processor output with the unit set to mono, Format 01) with an AC milli-voltmeter, or preferably an oscilloscope.

A new test film is also available from Dolby Laboratories to check illumination uniformity quickly and simply. The Cat. No. 566 test film provides an instant visual display of any illumination problems and only requires the use of a real-time analyzer.

3.1.5 Wow and Flutter

The projector should exhibit no audible wow or flutter.

Most contemporary first-class projectors have sound-heads designed and manufactured to a quality such that wow and flutter will not prove a problem. Badly maintained older projectors and some inferior contemporary designs, though, can have severe sound-head transport speed problems -- detectable speed variation is one of the few failings that can render a well-aligned A-chain playing an SR optical film audibly inferior to a 16-bit digital system.

It is generally accepted that flutter should be less than 0.15% DIN weighted to be inaudible. Measurement methods[1] are described in IEC 386, and a suitable test film is available from the SMPTE (No. P35-FL). A subjective test for wow and flutter is contained in the Jiffy test film from Dolby Laboratories, Cat. No. 251.

[1] A suitable meter for measuring wow and flutter is available from Leader Instruments, Japan--Model Number LFM-39A

If cleaning and lubrication of the sound-head is carried out according to the manufacturer's recommendations, and the measured flutter is still unacceptable, a skilled mechanic should be consulted. In some cases, machining and balancing the flywheel and sound-drum, or the rebuilding of bearings, can reduce the problems to an acceptable level.

3.2 Digital

It is important to note that factors such as mechanical alignment, illumination uniformity, and print cleanliness which affect sound quality of analog playback in a more-or-less linear way, may have no immediate audible effect in digital playback, but serve to reduce the margin for error when defects such as scratches or dirt are encountered.

Figure 3.2 shows, in symbolic form, the effects of misalignment, uniformity of illumination, wear, and cleanliness on the reproduction of analog and digital prints.

3.2.1 Alignment

Digital soundheads manufactured by Dolby Laboratories are factory aligned, and no on-site adjustments to the soundhead should be required. Verification of correct alignment is described in the DA10 digital film sound processor installer's manual. Mechanical alignment of the Soundhead with respect to the projector film path may be verified by threading a length of film through the Soundhead and observing equal tension on each edge.

3.2.2 Wow and Flutter

The elimination of flutter components at frequencies greater than 96 Hz which are not present in the master recording is inherent in the reproduction of sound by the digital processor. This is because the output sample rate is held constant for the duration of a perforation.

Lower frequency flutter and wow from mechanical inperfections are attenuated by digital filtering of the sample rate generator control function. Steps in sample rate are limited to approximately 0.005%, a factor of around 30 below the audible minimum. A much higher "slew rate" of about 6.4% / second (about 1 semitone / second) is permitted during projector ramp-up to speed in order to avoid getting out of synchronization with the picture.

Although digital processors from Dolby Laboratories are designed to track projector speed variations with a range from -7% at 24 fps to +7% at 25 fps, best performance will be obtained by maintaining projector speed as closely as possible to the intended speed as recorded.

3.2.3 Illumination Uniformity

The illumination source for Dolby Digital Soundheads is a tungsten-halogen projector bulb. Uniformity of illumination may be verified by observing the video signal at the DA10 on a 25MHz oscilliscope, triggered by any Dolby digital signal; the process is fully described in the DA10 and DA20 Installion manuals. Illumination should be uniform over the width of the perforation area to within $\pm$0.5 Volt.

3.2.4 Exciter Lamp / Supply

The digital soundhead exciter lamp supply should be a DC regulated power supply set for 11 Vdc, supplying approx. 6 Amps for each lamp and fan. Polarity must be observed, not for the lamp, but to ensure that fan rotation is correct. In an emergency, any DC supply with adequate capacity and regulation of 3% or better will serve.

3.2.5 Soundhead and Surround Delay

Proper adjustment of Soundhead Delay and Surround Delay are critical to setup of the Digital Processor. Complete procedures for delay adjustments are contained in the DA10 and DA20 Installer's Manuals. It should be noted that the optimum surround delay setting for a digital processor is different from that for surround playback of an analog surround track. The requirement for playback of a digital surround channel is to achieve coherent arrivals of screen and surround sounds over the optimum seating area. For an analog sound-track, slightly greater delay is required, so as to achieve masking[1] of any crosstalk from front channels to the surrounds.

Figure 3.3 provides a table of approximate delays for digital surround delays. Aproximately 15mSec should be added to these numbers for analog surround delay settings. In a small theatre, the height of the surround speakers should be taken into account, bearing in mind that the table is based on the difference in path lengths at the optimum seating area to the screen channels and the closest surround loudspeakers.

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[1]For a discussion of how acoustic masking is used to suppress crosstalk in 4:2:4 matrix systems, see "Multi-Channel Audio and Surround Sound in the Movie Theatre and in the Home," Dolby Pub. No. S88/8292

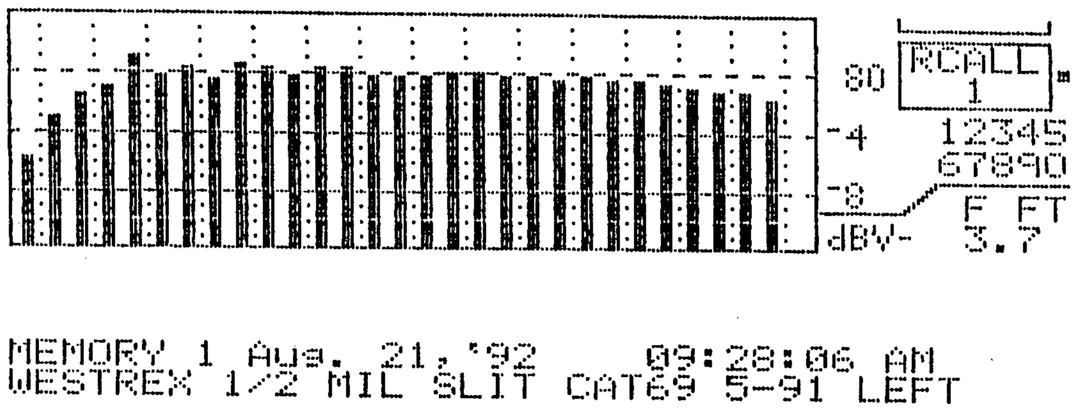

Figure 3.1 Cat. No 69 Pink Noise Frequency Response

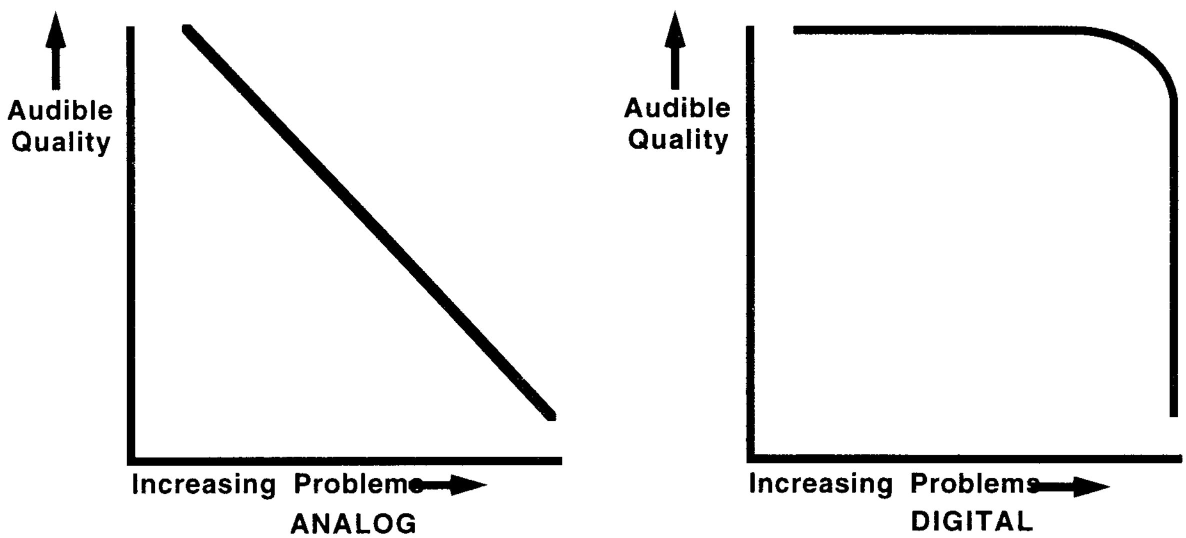

Figure 3.2 Analog versus Digital Problem Audibility

Width (in feet)

Length (in feet)

	20	30	40	50	60	70	80	90	100	110	120	130	140
20	10	10	10	10	10	10	10	10	10	10	10	10	10
30	10	10	10	10	10	10	10	10	10	10	10	10	10
40	20	20	20	20	20	20	20	20	20	20	20	20	20
50	30	20	20	20	20	20	20	20	20	20	20	20	20
60	30	30	30	30	30	30	30	30	30	30	30	30	30
70	40	30	30	30	30	30	30	30	30	30	30	30	30
80	50	40	40	40	40	40	40	40	40	40	40	40	40
90	50	50	40	40	40	40	40	40	40	40	40	40	40
100	60	50	50	50	50	50	50	50	50	50	50	50	50
110	70	60	60	50	50	50	50	50	50	50	50	50	50
120	70	70	60	60	50	50	50	50	50	50	50	50	50
130	80	80	70	70	60	60	60	60	60	60	60	60	60
140	90	80	80	70	70	60	60	60	60	60	60	60	60
150	90	90	80	80	80	70	70	70	70	70	70	70	70
160	100	100	90	90	80	80	70	70	70	70	70	70	70
170	110	100	100	90	90	80	80	80	80	80	80	80	80
180	110	110	100	100	100	90	90	80	80	80	80	80	80
190	120	120	110	110	100	100	90	90	90	90	90	90	90
200	130	120	120	110	110	100	100	100	90	90	90	90	90

Width (in metres)

Length (in metres)

	10	15	20	25	30	35	40	45	50
10	20	20	20	20	20	20	20	20	20
15	20	20	20	20	20	20	20	20	20
20	30	30	30	30	30	30	30	30	30
25	40	40	40	40	40	40	40	40	40
30	50	50	50	50	50	50	50	50	50
35	60	60	50	50	50	50	50	50	50
40	80	70	60	60	60	60	60	60	60
45	90	80	70	70	70	70	70	70	70
50	100	90	80	80	80	80	80	80	80
55	110	100	90	90	80	80	80	80	80
60	120	110	110	100	90	90	90	90	90
65	130	120	120	110	100	100	100	100	100
70	140	140	130	120	110	110	110	110	110
75	150	150	140	130	120	120	110	110	110

Figure 3.3 Digital Surround Delay Setting

4.0 Acoustics

4.1 Criteria

4.1.1 Noise Floor

The steady-state theatre noise floor should preferably be below NC25, with NC30 the worst case acceptable. Intermittent increased noise floors should not exceed NC35.

Dolby SR and SR•D sound-tracks can contain very quiet sounds, as well as louder peaks than conventional film sound-tracks. Playback of these subtle components requires extra attention to background noise levels in the theatre.

Background noises can be broken into two types: steady-state noise, caused by HVAC equipment, refrigerators, projector noise and distant traffic rumble; and intermittent noise, caused by adjacent traffic noise, aircraft noise, footfall and adjacent screen breakthrough.

Figure 4.1 details the frequency characteristics of a family of NC curves in the range of interest. It should be noted that these curves show the NC figures for noise measurements made in whole octave bands, as conventionally used for background noise measurements. Figure 4.2 shows a family of curves for use in third-octave bands.

Normal techniques for background noise measurements are intended to quantify steady-state noises, and may not adequately define the annoyance of "chatter" noise, such as running projectors. Such noises should be subjectively inaudible in the seating area.

Reference: SMPTE RP141 -- Background Acoustic Noise Levels

4.1.2 Reverberation Time

The reverberation characteristic for a theatre should be within the ranges shown in Figures 4.3 and 4.4.

Certain acoustic parameters differ depending whether a space is intended for music performance (a concert hall), or film sound-track reproduction (a cinema). The most obvious of these is reverberation, which in the cinema should be effectively as low as possible, and in the concert hall may consciously be extended in the design, to improve the subjective loudness of the music, and to make a more *pleasant* sound. In the cinema, the prime requirement is a more *accurate* sound; reverberation needed to make the sound more *pleasant* is added during the mix during sound-track production. As most dubbing theatres are now moderately small, with short reverberation times, the mix will add adequate reverberation for all replay theatres.

Within reason, the reverberation characteristic of a theatre should be as short as possible. Excessive reverberation results in coloring of the sound and reduced intelligibility of the dialog. Assuming a theatre is built with sound absorbent material on all surfaces, the resultant reverberation characteristic will increase with room size, in consequence of greater reflection time delays caused by increased path lengths. Figure 4.3 shows the recommended reverberation time at 500 Hz for varying room volumes.

In normal rooms, absorbency is lowest at low frequencies and greatest at high frequencies, especially as attenuation in air increases with frequency. As a result, reverberation time will normally increase at low frequencies, and become increasingly shorter at high frequencies. This changing characteristic should be smooth, and above 150 Hz, if measured in third-octaves, there should be no reversals; i.e. no higher band should show a higher reverb-time.

Figure 4.4 shows the acceptable range of reverberation time change with frequency. This is a scaling curve, and the value at a given frequency should be multiplied by the optimum reverberation time at 500 Hz found from Figure 4.3.[1]

4.1.3 Reflections

Optimization of reverberation time, though, is not enough to ensure good acoustics. A good theatre design will also avoid resonances and reflections. Good practice dictates that the front of the loudspeaker wall should be heavily damped with sound absorbing material, and even more important, that the rear wall of the auditorium should be heavily damped. Any theatres still using A4 type loudspeakers with wings should apply sound absorbing material to the front surface. Acoustically absorbent material can be added to an existing theatre, but new theatre designs should also consider issues such as minimum port glass size (see below), as too large a glass area in the projection room wall can cause both picture and sound-reflection problems. Other sound reflection problems can come from converted old theatres with proscenium arches which face the screen, and ceiling beams and vertical column faces reflecting sound from the screen.

4.1.4 Early Lateral Reflections

Another difference in acoustic requirements between cinema and concert halls relates to the desirability of early lateral reflections (sounds that reflect off the side walls at the front of the auditorium). In a concert hall, with a music performance, these reflections can be attractive, adding to stereo width, and giving the music more "body". But the same effect with dialog in a cinema can be disastrous to speech intelligibility, as the central speech image becomes diffuse, and there are multiple delayed reflections. For this reason, the side walls at the front of a cinema should be as absorbent as possible, and the loudspeakers should have a spatial response tailored to minimise the amount of signal which can hit the side walls (especially at frequencies above, say, 500Hz). The controlled directivity from use of horns is the

[1] Reverberation time measurement techniques are discussed in ISO3382.

only practical way this can be achieved. Direct radiator cone loudspeakers are not suitable for stage loudspeaker use, as not only will energy be reflected off the side-walls, but signals will also be reflected off the ceiling, further muddying dialog clarity.

4.1.5 Rear Screen Damping

No behind-screen acoustic reflections should be audible in the seating area.

Behind screen echoes have historically been responsible for many of the intelligibility problems with cinema sound. The most effective method of achieving screen front/back isolation is to mount the loudspeakers as integral elements within a well-damped wall; this will block all but the lowest frequency back-screen audio. The front surface should be covered with acoustic absorbent material, damping any front/back reflections in the auditorium.

A wall also creates a perfect plane baffle, as described in classic loudspeaker design literature, thus significantly improving extreme low-frequency response and linearity. This is one of the reasons that a loudspeaker wall is one of the major elements of the THX loudspeaker system.

Without an isolation wall, attenuation of behind-screen reflections becomes much more difficult. The first and most obvious requirement is that the high-frequency horns should be mounted as close as possible to the rear of the projection screen, minimizing acoustic reflections off the screen surface itself. (The front of the horn should never be more than an inch or two from the screen.) Next, each loudspeaker assembly should be draped with substantial acoustically absorbent material, wrapping the entire assembly up against the screen. Finally, as much of the cavity surface area behind the screen as possible -- rear wall, side-walls and ceiling -- should be covered in absorbent material.

One further consideration relating to systems without a loudspeaker wall is that the front surface of any large area bass bins, (and even more important, if fitted, the speaker wings), should have absorbent material mounted on front surfaces with cut-outs for the woofers. Without such material, significant reflective "ping-pong" echoes can build up between the screen and the parallel rear wall of the theatre.

4.2 New Theatre Design

Interior acoustics are of most importance for dialog intelligibility. Excess reflected sound can result in flutter echoes or reverberation which diminishes dialogue intelligibility.

It is not necessary to provide specific sound-reflecting surfaces in motion picture theatres. Most of the surfaces can be sound-absorbing. Some might argue that it would become difficult to sustain adequate loudness; suitable modern power amplifiers and loudspeakers, however, can easily be selected which provide enough power. Experience indicates that sound-absorbing rooms promote excellent speech intelligibility provided they are reasonably quiet.

Sound-absorbing material can be used to reduce reverberation and control echoes. Standing waves can result in low-frequency room resonances which accentuate a "boomy" quality. Standing waves can be controlled using sound-absorbing material with an air space behind, such as a lay-in ceiling.

4.2.1 New Theatre Location

Select a quiet location to reduce the costs of construction to prevent noise intrusions. Areas and adjacencies to avoid:

a) Next to window glazing.

b) Building service areas such as toilets, mechanical rooms, electrical rooms and elevator equipment rooms.

c) Other noise generating adjacencies.

Remember to review the use of spaces above and below the theatre for potential noise generation. Avoid locations beneath equipment rooms, and dance and exercise studios, or above parking garages or subway train lines. Airport flight paths, truck loading areas, and busy traffic intersections should also be considered during site selection, as the increased cost of adequate sound isolation may be significant.

Never locate a theatre below a curb-mounted air handler with direct bottom inlet and discharge, unless the ductwork is fully enclosed in special sound attenuation construction.

4.2.2 Ceilings

In order to avoid excessive bass, specify a lay-in ceiling with sound-absorbing tiles having an NRC rating of 0.90 or greater. The tiles are typically comprised of 1.5" thick fiberglass with a painted glass cloth facing.

4.2.3 Floors

Unless absolutely impossible, aisles and floors should always be carpeted.

4.2.4 Walls

Sound Transmission Design Criteria

Walls, doors and floor/ceiling constructions are rated for their sound transmission properties according to ASTM Standards E90, E336, and C413 which result in a single figure of merit rating system known as Sound Transmission Class, or STC.

The selection of appropriate STC ratings needs to be made on the basis of the background noise criteria selected in the theatre and the level of noise anticipated in the adjoining spaces. Continuous background noise can play an important role in perceived sound isolation by masking transmitted sound. The sum of the STC rating plus NC rating should always equal or exceed 95 at common walls between theatres. Other sources of intrusive noise should be evaluated.

All sound-rated partitions must incorporate full height slab-to-structure framing containing fibrous insulation and gypsum board sealed airtight at the head and sill with a bead of acoustic sealant. All penetrations must be sealed airtight and recessed boxes fully enclosed. Four-gang and smaller junction boxes can be sealed using sheet caulking on the back and sides, as shown in Figure 4.5. Larger boxes can be effectively sealed using one-hour fire-rated gypsum board construction. Comply with the standards outlined in ASTM Standard E497, "Installation of Fixed Partitions of Light Frame Type for the Purpose of Conserving Their Sound Insulation Efficiency."

Figure 4.6 shows minimal and typical multiplex demising wall designs necessary to achieve acceptable auditorium isolation.

Table 2 below presents suitable STC ratings. Note that higher numerical STC ratings transmit less sound, and higher NC ratings permit louder background sound due to the ventilation system.

Table 2: STC Ratings for Common Walls Between Theatres

Minimum in-situ STC Rating	Noise Criteria	Description
STC 60	NC 35	Minimum Standard
STC 65	NC 30	Typical
STC 70	NC 25	Desirable

In order to avoid sound "flanking" the walls, continuous metal roof decks are discouraged without gypsum board ceilings, and independent floor slabs with an elastic joint are required at STC 65 and greater walls.

Figure 4.7 shows a more sophisticated wall design, used to ensure isolation between projection rooms and auditorium -- a construction of this type can be a major element in isolating projector and machinery room noise.

Sound-Absorbing Wall Treatments

The wall behind the audience should be covered in sound-absorbing material entirely.

Typical sound-absorbing panels are comprised of 1.5" thick glass-fiber-core wrapped in porous fabric having inherent flame-resistant properties. Panels are available with fabric edge wrapped conditions and with resin hardened edges, metal, or wood frames. Complete pre-fabricated sound-absorbing panels are available.

If the side walls are not angled, avoid hard flat parallel gypsum board surfaces facing one another across the room, particularly in the audience area at ear height, in order to avoid flutter echoes.

4.2.5 Seats

Choice of seat design can have a significant effect on acoustic quality, especially in the small theatre. This becomes obvious when standing at the screen and looking at what the loudspeaker "sees" -- a major part of the sound field will be seats, or optimistically, audience.

First, a seat should be chosen which will be sufficiently damped as to offer no reflections to the screen. If the seats have fold-up bases (squabs), the undersurface should be damped. Never use seats with a plastic or metal reflective undersurface.

Next, an ideal seat has acoustic properties that do not change when a person sits in it; ie the absorption with respect to frequency does not change. In this way, regardless of what percentage of the house is filled with audience, the frequency response will be the same. Better quality seat manufacturers will provide information on this subject; contact Dolby Laboratories for information on testing procedures if you wish to carry out your own evaluation.

The most sophisticated seat selection will also consider high-frequency grazing at the top of the seat, and low-frequency aberrations caused by the potentially resonant chamber under a row of seats.

4.3 Background Noise

4.3.1 HVAC Design

General Layout

Mechanical equipment having rotating parts should not have any direct physical contact with the walls or ceilings of theatres.

Do not locate air-moving devices in the ceiling plenum directly above the theatre. This includes heat pumps, fan-powered boxes, variable air volume boxes (VAV), fan coil units (FCU), exhaust fans, and air handlers (AHU).

VAV boxes may be located above theatres only if the ceiling is comprised of at least one layer of 5/8-inch thick gypsum board. Other equipment should be reviewed for its radiated sound level if it must be located above the space. Avoid using fan-powered VAV boxes due to high levels of radiated noise.

Locate air-moving devices above storage rooms, corridors or the projection room. If for some reason they *must* be located over the auditorium, placement at a corner where they are supported by two load-bearing walls or a structural column will be of great benefit.

Consideration could also be given to the use of stanchion supports on the roof. Noise from the air-handler is transmitted in two ways: direct transmission of rumble through the building structure, and airborne noise through the ducted air. If air-handlers have to be mounted on the roof at auditorium corners as described, extend the ducting as far as possible before a downturn to reduce airborne noise.

All air handlers and projector exhaust fans must be vibration isolated.

Again, never locate air-handling devices on the roof directly over the theatre.

Air Handling and Distribution

Review supply air diffuser selections and specify an NC rating five points less than required.

Lay out supply air ductwork and registers to have equivalent duct lengths between diffusers and the fan.

Only those ducts, pipes and conduits essential to serve a specific auditorium space should be allowed to penetrate its walls.

Supply Air Ductwork

Provide an exclusive duct branch and zone system to serve each auditorium/screen so as to avoid crosstalk.

Size ductwork mains over the theatre to have one-inch thick internal duct liner.

The discharge sound level of the supply fan being used should be reviewed in order to specify the appropriate duct length and/or sound attenuator.

Excess turbulence generated noise may be avoided by using 90^{o} duct turns; provide long radius elbows. If unavoidable, specify air-foil turning vanes.

Dampers

Dampers should never be located directly behind the face of the air distribution device.

Plumbing and Piping Systems

Avoid locating plumbing and rainwater leaders in the walls or ceiling spaces of the theatre.

Any piping located in the walls or ceiling of the theatre space should be attached with resilient mountings.

Provide a clearance between pipes and gypsum board or other finish surfaces. Do not allow pipes to make rigid metal-to-metal contact between ceiling hanger wires, supports, framing, or other structure to which finishes are attached.

Penetrations

Ducts penetrating the sound-rated wall or floor/ceiling construction should be in an insulated sleeve packed with one-inch thick mineral wool fire safing and sealed on both sides using backer rod and acoustical sealant.

Piping penetrations less than three inches in diameter should be sealed using acoustic sealant filling a 1/4-inch clearance. Larger pipes should be treated similar to ducts.

Avoid any back-to-back penetrations, such as electrical panel boards, junction boxes or fire extinguisher cabinets. Offset penetrations two stud cavities.

4.3.2 HVAC Maintenance

Regular HVAC maintenance is essential to ensure the minimum noise level the system is capable of. Bearings should be lubricated, and belt tension and condition verified, at manufacturers' recommended intervals; most important, filters should be cleaned on a scheduled basis. Dirty filters have been found responsible for a theatre noise floor 10dB above the measured figure at the time of system installation.

4.4 Sound Isolation

4.4.1 Ceilings and Floors

A suspended gypsum board ceiling must be specified if:

a) Air-handling equipment is located above the room (a concrete floating floor may be necessary in the equipment room).

b) The floor above the theatre is uncarpeted.

c) The floor slab above is not at least six inches of regular weight concrete.

d) The Sound Transmission Class of the floor/ceiling construction will be inadequate using a lay-in tile (i.e., lightweight wood frame construction).

Provide mineral wool or fiberglass insulation above all gypsum board ceilings.

The above analysis should also be conducted on the floor/ceiling assembly below the theatre. Gypsum board ceilings are generally necessary in lightweight wood frame construction where concrete is not used.

4.4.3 Doors

Doors are among the most likely paths of noise intrusions. Vestibules are the most reliable means to obtain adequate noise reduction without extensive care in specification and quality assurance procedures during construction, including performance verification of the actual installation. The vestibule should be carpeted, have a sound-absorbing lay-in ceiling, and have full-height walls which are insulated and faced with wall carpet.

A very simple test for obvious sound leakage is to switch off auditorium lights and look for any visible light leakage around the doors.

Table 3: Typical STC Ratings for Sound-Rated Doors

STC 35	1-3/4 inch thick solid-core wood door with double gasketing at the head and jambs and fixed threshold with door bottom.	Use only at vestibule or guarded entry conditions.
STC 42	2-1/4 inch thick sound-rated wood door and adjustable neoprene head and jamb gasketing with flat threshold and automatic door bottom.	Use only at carpeted corridors which are designated as quiet zones.
STC 49	2-1/4 inch thick insulated steel door having tandem offset magnetic gaskets at the head and jambs with cam-lift hinges and flat threshold.	Require manufacturer's authorized representative to supervise installation and prepare punch list.

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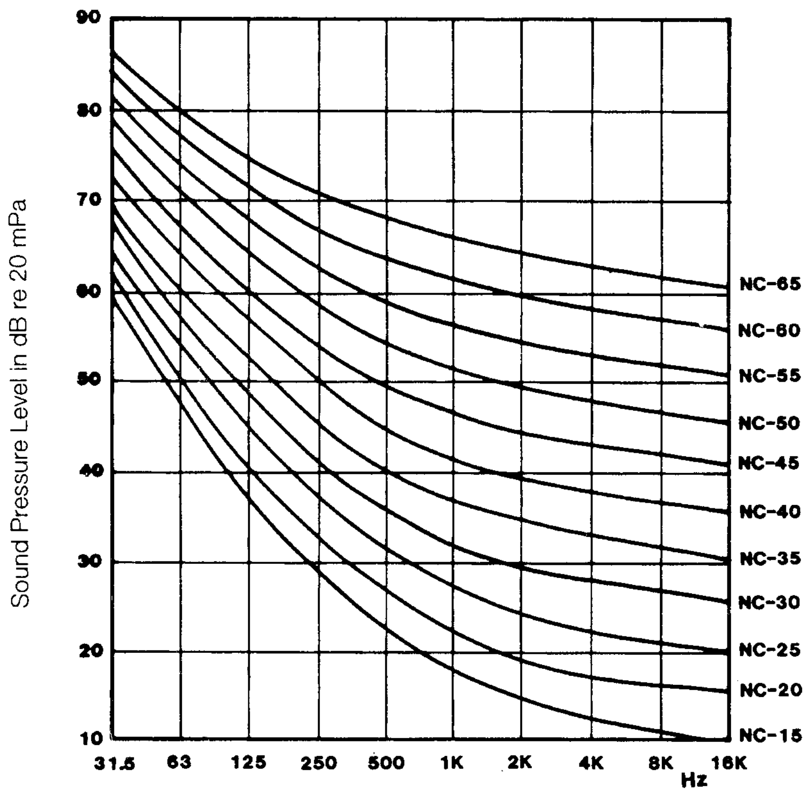


Figure 4.1 Noise Floor in Whole Octaves

NOTE: Historically, noise floors have been measured with a sound level meter with adjustable tilters switched in whole octaves. This one-third octave figure is intended for use with 1/3 octave real-time analysers. Care should be taken that electrical noise floors do not limit accuracy of measurements, especially at high frequencies where microphone preamplifier noise may exceed acoustic noise levels.

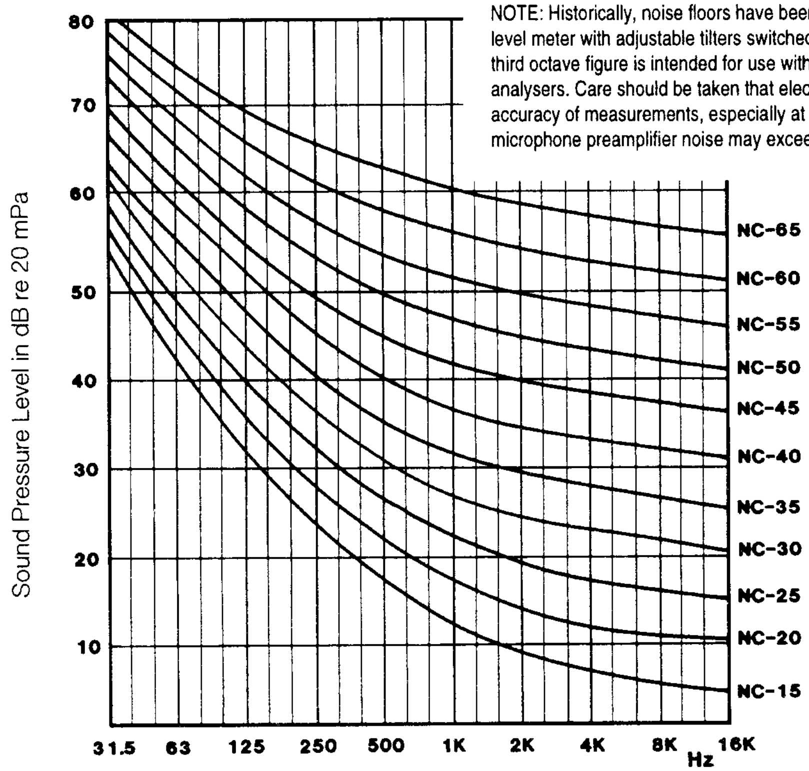


Figure 4.2 Noise Floor in Third Octaves

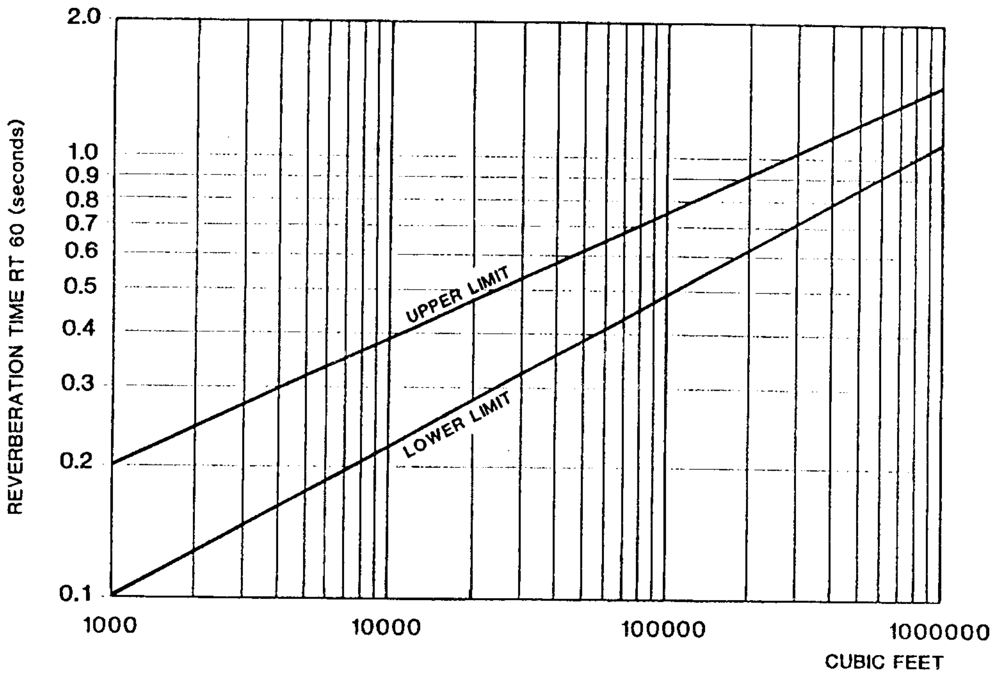


Figure 4.3 Acceptable Reverberation versus Room Volume at 500 Hz

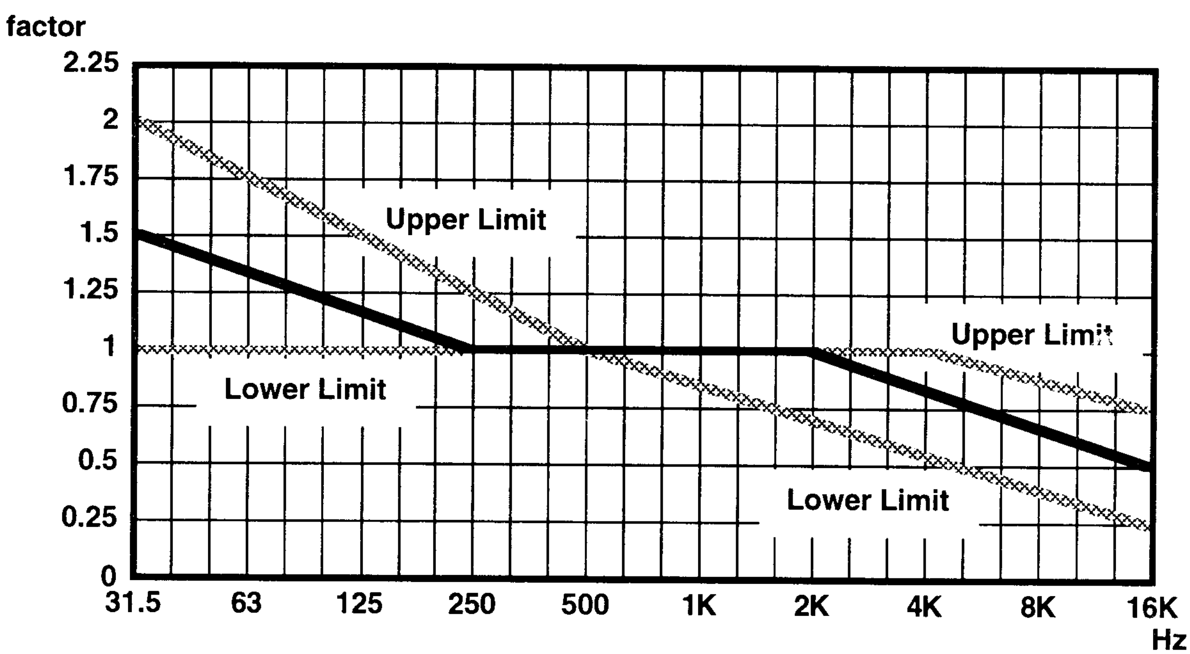


Figure 4.4 Reverberation Scaling Curve for Audio Bandwidth

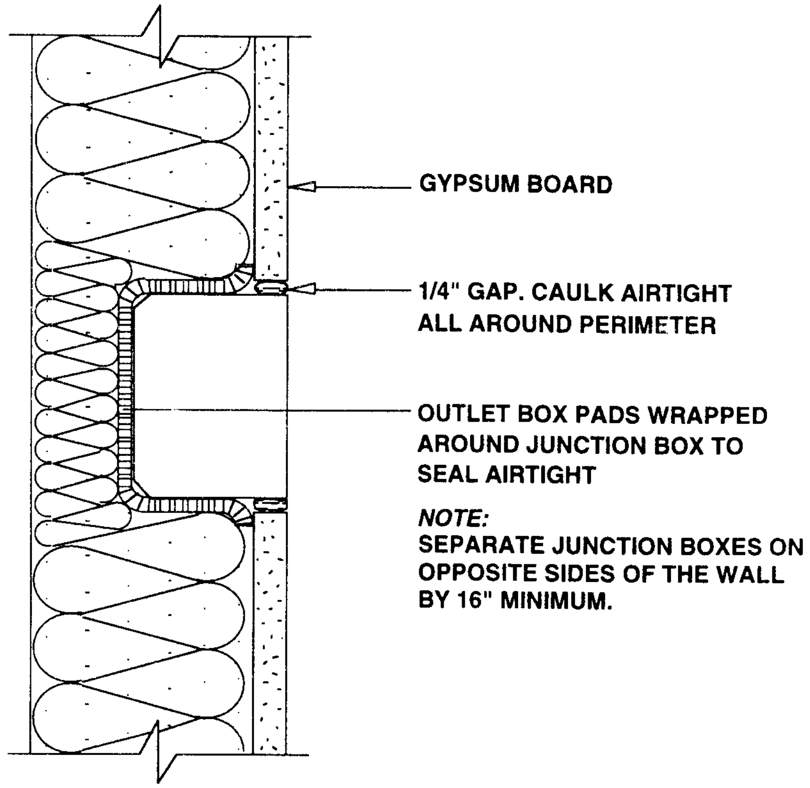


Figure 4.5 Junction Box Treatment

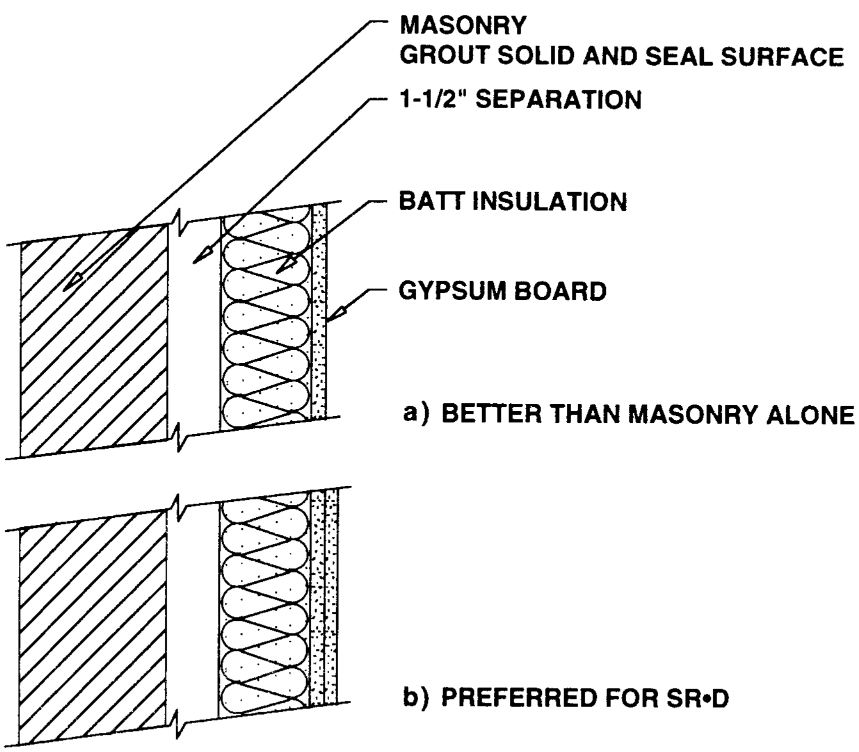


Figure 4.6 Recommended Demising Wall Design

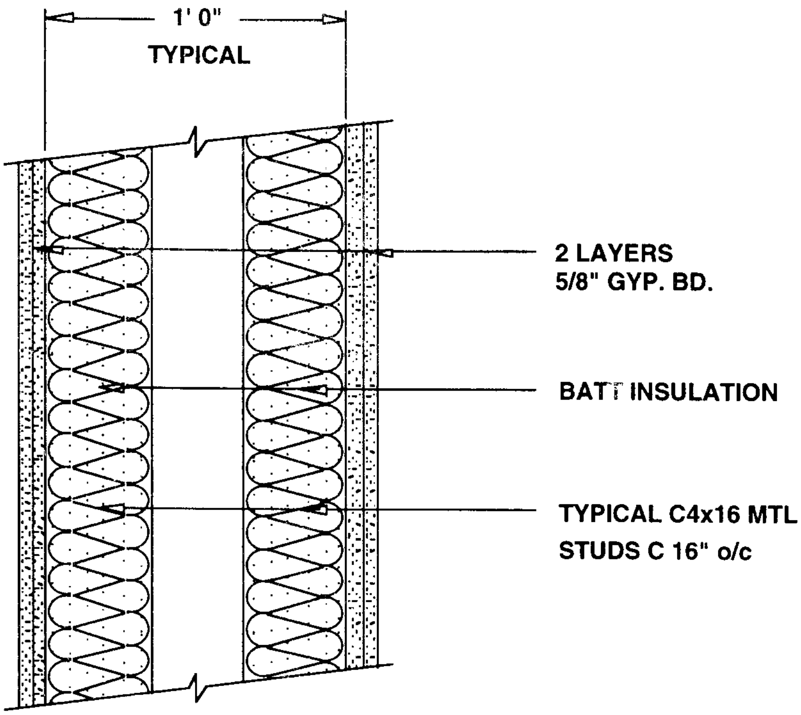
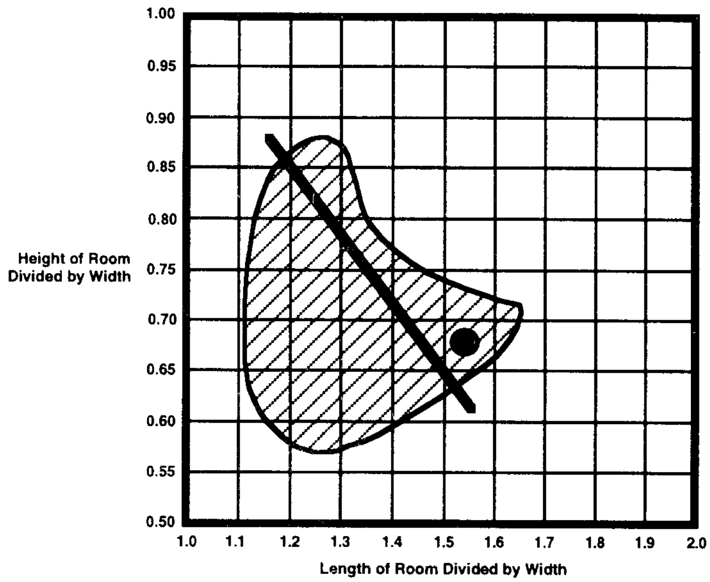


Figure 4.7 Screening Room/Projection Room Minimum Wall Design



Note: Enter drawing with ratio of length to width of room. Proceed up to black line, and then move horizontally to find ratio of height to width. Example length to width is 1.5:1. Move from 1.5 up to black line, then horizontally to 0.65. Height should be 0.65 of width.

Black dot represents good cinema practice. Bad acoustics may well result from any design outside the hatched area.

Figure 4.8 Optimum Theatre Shape

5.0 Cinema Processor Updates

5.1 CP50

While theoretically the CP50 could be updated for the playback of the Dolby SR•D sound-track, the cost of labour and material necessary approach the cost of a new Dolby CP65, and so such an update approach is strongly discouraged.

5.2 CP55 and CP200

Many boards in cinema processors manufactured by Dolby Laboratories have been replaced from time-to-time with new versions with superior performance. Taking full advantage of the specifications of a Dolby SR and SR•D film will require updating selected boards.

Matrix decoders. Significant improvements have been made by Dolby engineers over the years in the technology used to decode the four channels (L,C,R and S) from the two tracks on the film. Current modules provide stable inter-channel separation adequate to be indistinguishable from discrete sound-tracks with much program material. As "discreteness" is frequently quoted to be superior with 70mm magnetic when compared with simple matrix decoders used with 35mm stereo optical, updating to the latest technology is well worthwhile for SR playback.

Current (since 1992) production versions of the Cat. No. 150 decoder module are Revision E. Currently acceptable modules date back to Revision D, which was introduced at Serial Number 12000. In addition to superior decoding performance, the current modules have increased headroom for all channels, and a low-noise surround delay circuit -- both of benefit with the wider dynamic range of Dolby SR films. Cat. No. 150 modules of revisions A, B, and C should be replaced; old Cat. No. 116 decoders are certainly unacceptable for SR playback.

Optical pre-amplifiers. Later versions of optical pre-amplifier boards installed in Dolby theatre equipment exhibit significantly improved high-frequency response, improved stability and better linearity and phase response at high frequencies. CP50 and CP200 units should be updated with CN108 pre-amplifier cards of Revision C, which was introduced with Serial Number 11570. All CP55 and CP65 unit pre-amplifiers have adequate performance.

Dynamic range. Dolby SR and Dolby SR•D playback may also justify updating other modules in older CP50 and CP200 cinema processors. Some early boards have performance specifications more than adequate to play back conventional mono and Dolby Stereo films, but exhibit headroom and noise floor characteristics which could be improved for the new sound-tracks. Cat. No. 64 equalizer modules of Revision B, for example, have a significantly lower noise level than earlier variants.

Cat. No. 441. This surround/sub-woofer card provides two channels of surround equalization and the required capabilities for stereo surrounds and a sub-woofer channel for the playback of an SR•D sound-track. This module is for use in a CP55, where it replaces the Cat. No. 241 module.

Cat. No. 560. Provides the same functions as the Cat. No. 441 above, for use in a CP200, where it replaces the Cat. No. 160.

Cat. No. 517. Replaces the Cat. No. 117 in a CP200. Essential to handle the greater dynamic range of modern sound-tracks. Provides greater dynamic range, lower distortion and additional features for playback of Dolby SR and SR•D.

Cat. No. 137L. Link card required for use with Cat. No. 517 output card -- replaces Cat. No. 137 in a CP200.

6.0 Picture Issues

Picture projection quality should conform to existing published standards.

Needless to say, installation of a Dolby SR decoder to achieve improved sound quality in a theatre will not affect the quality of the picture image. But as a large-screen high-definition picture presentation can be damaged by inadequate sound, the full fidelity of Dolby SR sound can only be achieved with the complement of a well-projected picture. The movie-going experience can only be fully realised when picture quality and sound quality are matched.

Selection of state-of-the-art lenses, non-reflective angled port glass, and the installation of three-bladed shutters can provide radical improvements in perceived picture quality.

6.1 Screen Size

There are obvious trade-offs with selection of too small or too large a screen. As the picture gets larger, the audience becomes more involved in the story, begins to feel they are participating and not just witnessing. But as the picture gets larger, the visibility of picture flaws -- grain, jump and weave, become more apparent. Back in 1953, Twentieth Century Fox did some fundamental research into screen size, during the development of Cinemascope (with its 2.35:1 aspect ratio). While granularity has been improved since the fifties with modern film stocks, jump and weave of the picture image remain essentially unchanged, even with modern projectors. The conclusion then was that the ideal picture size should be that which *subtends a horizontal angle of 45 degrees* at the prime seat. Given an empty theatre, a movie-goer by-and-large selects a seat two-thirds of the way back, on the centre-line of the house, and as result the ideal geometry is set as shown in Figure 6.1. Obviously, discussion of screen size in terms of feet or metres becomes a secondary dimensional issue, depending on the size of the theatre. The key dimension is the angle subtended at a prime seat.

This is one area where selection of a picture parameter in a new theatre design directly affects the sound. Assuming the loudspeakers are mounted at the left and right extremes of a Cinemascope screen image, this 45 degree angle makes possible a fairly smooth sound field, with reasonable stereo imaging throughout the theatre (assuming a sensibly short reverberation time, as discussed in Section 4.1.2 above). Screens much wider than this aspect ratio will not only exhibit excessive picture flaws at seats in the front of the theatre, but will exhibit subjectively excessive stereo "ping-pong". Screens with an aspect ratio narrower than this ideal 45 degree figure will lead to a sound essentially mono in the back of the house, especially if there is excessive reverberation. This effect can easily be detected in old theatres badly twinned a few years ago, with a dividing wall built straight down the middle of the house.

No layout of surround speakers, mono or stereo, can compensate for an incorrect stereo balance, left to right, across the screen.

If the ideal Cinemascope screen subtends an angle of 45 degrees at the prime seat, and granularity, jump and weave are the controlling parameters, the ideal screen ratios for other formats can be derived. In the USA, 1.85:1[1] is the most popular shooting format, but it is apparent that this ratio is very inefficient in terms of use of the film frame. Blown up too large, a 1.85:1 film will reveal excessive granularity. For this reason, a best compromise with 'scope and 1.85 screen sizes is to set the picture height the same, and only to adjust the horizontal masking, as shown in Figure 6.2. Maintaining the same width and adjusting vertical masking, will degrade the quality of the 1.85 image, showing up every picture flaw and excessive granularity.

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[1]The ANSI standard for picture dimensions is PH22.195.

In Europe, 1.66:1 is a popular shooting format. This is clearly a much more efficient use of the film frame, and here the screen height can be increased without excessive picture problems. Figure 6.3 shows how a theatre would equip for an ideal presentation of 'scope, 1.85:1 and 1.66:1 aspect ratios. Obviously this requires both vertical and horizontal adjustable masking.

In the US, where normally only 2.35:1 'scope and 1.85:1 films are presented, only adjustable horizontal masking is needed to ensure optimum picture quality. The speaker location should be set at the extremes of the 'scope screen, so care should be taken that neither the masking nor the masking edge-mounting damage the high-frequency response when a 1.85:1 movie is presented.

Over the last few years, a few theatres in the USA have installed screens with a fixed 2:1 aspect ratio, chopping off the sides of a 'scope picture, and the top and bottom of a 1.85:1 picture. This bad practice should be strongly discouraged, as with a 1.85:1 picture, in particular, significant picture action is likely to be clipped.

6.2 Screen Type

Many of the decisions taken in theatre design are based on cost -- not surprisingly when considering the building and operation expense of a modern multiple-screen complex. But when one considers that the purpose behind movie-going is to see a picture, compromises in the quality of the image on the screen seem inappropriate. The cost of a larger lamphouse may seem significant during theatre building, but will soon seem trivial on an ongoing basis, especially with improved patron recognition of superior presentation.

Gain screens provide improved illumination, but *only on a reflected axis* from the projector lens. Someone sitting on the centre-line of the theatre will see a brighter image on the centre of the screen, but the illumination will fall off towards the edges. Viewers seated to one side of the theatre will see a brighter image towards the side of the screen on which they are seated, but the illumination will fall off significantly on the opposite side of the screen.

Only matt-white, non-gain screens can achieve uniform illumination across the entire screen width, *regardless of the viewer's location*. Gain screens only make sense for special applications where the viewer is seated on axis (such as slide or video one-on-one AV presentations). Depending on theatre shape, matt-white screens may place an additional requirement that the wall surfaces by the screen are dark, and do not allow excessive reflection. See scetion 6.5 below.

Next, modern good quality lenses have been developed over many years to achieve an in-focus image over a flat screen. Curved screens in a single dimension (ie a horizontal wrap) would require virtually impossible lens geometry to achieve optimum focus throughout the screen area. And while lenses could be developed to achieve approximate focus throughout the area of a two-dimensionally curved screen, such a shape may well have several sound and picture problems; first, the illumination will not be uniform throughout the seating area, and, more pertinent for this document, such a screen has to be solid (without perforations) requiring separation of high and low-frequency loudspeaker units, with consequent dispersion and damage to the sound image.

6.3 Light on Screen

For many years, the nominal screen luminance figure in the USA has been defined as 16 foot-lamberts. Many theatres fall short of this figure, by design or accident -- with inadequate lamp-house capability, worn-out lamps, or mis-aligned equipment. A few films have been released "timed" assuming theatres projecting at 12 foot lamberts. A very simplistic analysis of this trend shows a most obvious flaw -- 16 leads to 12, then 8, 6 etc, and sooner or later no light on the screen at all! But more seriously, 16 foot-lamberts was not a random selection. The nature of current film stocks is such that a projection luminance of 16 fL ideally balances between black and white saturation conditions.

For example, films *timed* for 10 fL and projected at 10 fL will look correct at mid-density, but the film is so light that all bright shots will loose graduation, and will tend towards clear film.

Not only should the centre-screen luminance be 16 fL, but the luminance across the screen should be uniform, as described in the relevant standards. A fall-off of 20% at the screen edges is the maximum acceptable.[1]

6.4 Color Temperature

The optimum screen color temperature is 5400^{O}K, with a good theatre tolerance of $\pm$200^{O}K. See SMPTE 196M, attached.

6.5 Reflected and Ambient Light

Reflected light should not exceed 0.25%.

6.6 Porthole Design

Porthole design affects both picture and sound. First, good design practice makes the size of the porthole and viewport the very minimum necessary. Large port apertures act as acoustic reflectors bouncing sound back towards the screen, and can also result in a large amount of ambient light leakage from the booth worklights.

Good acoustic practice requires a double-stud isolation wall between auditorium and projection booth. With such a wall design, there must be no hard coupling between the two walls, as typified in the design shown in Figure 4.7. Both projection and viewing ports should be double-glazed to achieve sound isolation. Regardless of the wall structure, projector noise will escape through any single sheet of projection glass.

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[1] See ANSI PH22.196:Screen Luminance, included in Appendix.

Port glasses should be angled to reduce lateral reflections; as a worst case example, internal reflections from a single port glass set at 90^{o} to the line from lens to screen will result in numerous reflections leading to a soft screen image apparently out-of-focus. A good result will be a front glass set at perhaps 7^{o} forward from the lens angle, and a rear (auditorium side) glass set at 15^{o} backwards.

Care should be taken over the quality of glass used, and optimum projection requires coating to further avoid internal reflections.[1]

Figure 6.4 shows a front-and-back pair of port glasses optimised to avoid internal reflection problems.

6.7 Shutters

Three-bladed shutters raise the flicker frequency such that white skies on the screen will seem essentially flicker-free. While pan flicker will still occur, the stability of white areas is significant in terms of reduction of "picture fatigue". While the cost pof purchase of three-bladed shutters is relatively low, increased illumination is required to compensate for the shorter "on" time. This could become really significant if the existing lamp-house is running near its maximum rating, and a larger lamphouse is required.

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[1] In the US, a suitable material is "Water White Glass," available from Schott Glass, 400 York Avenue, Duryea, Penn. Both sides of the glass should be coated with "Photopic HEA--Multilayer Anti-reflection Coating #6035001" by Optical Coating Laboratory, Santa Rosa, CA, or by approved equivalents.

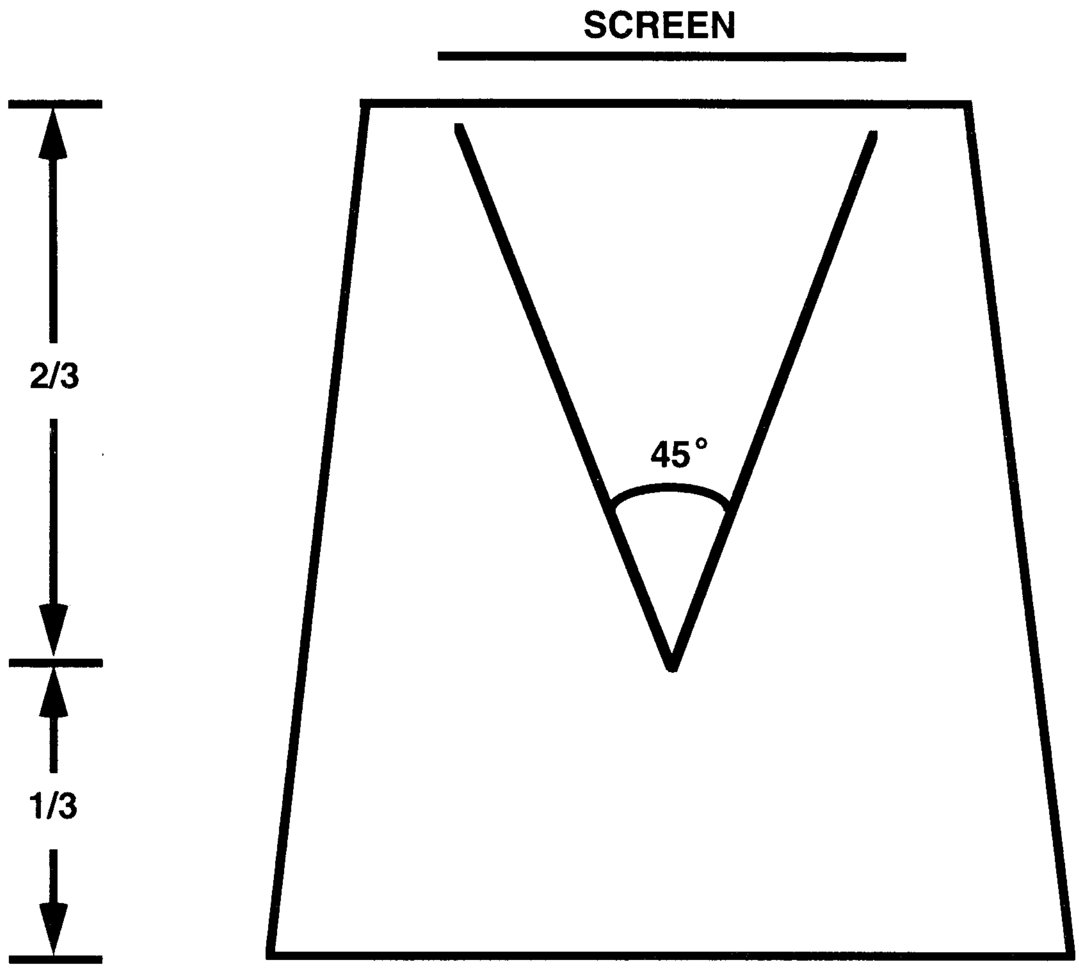

Figure 6.1 Optimum Subtended Screen Angle

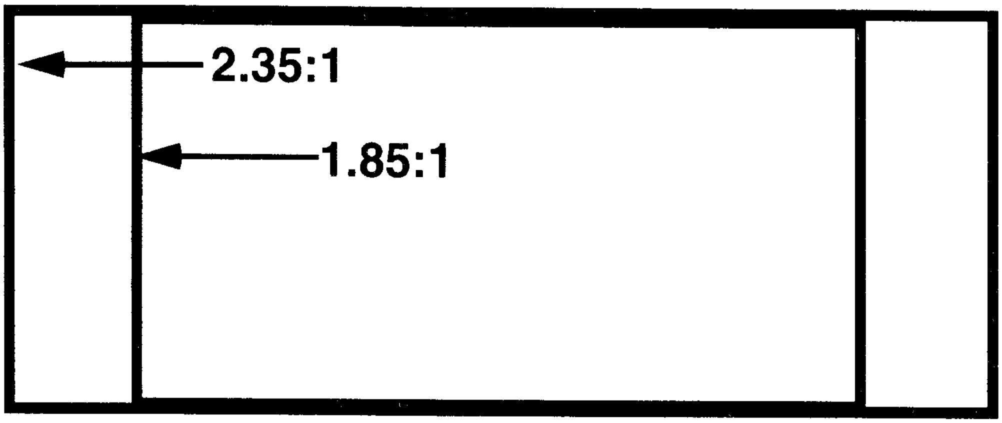

Figure 6.2 Adjustable Masking 2.35:1 and 1.85:1

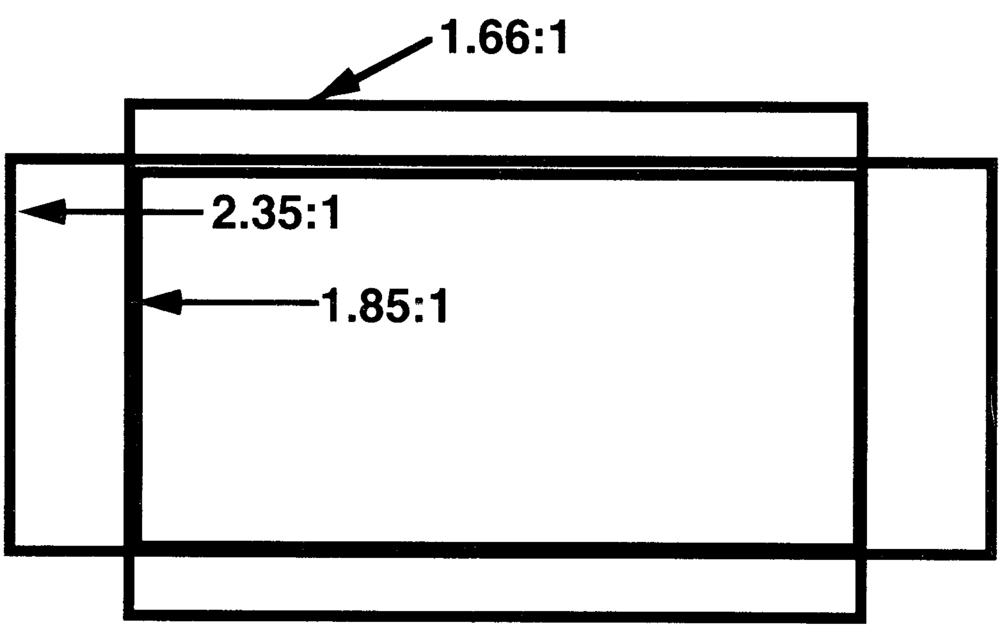

Figure 6.3 Adjustable Masking 2.35:1, 1.85:1, and 1.66:1

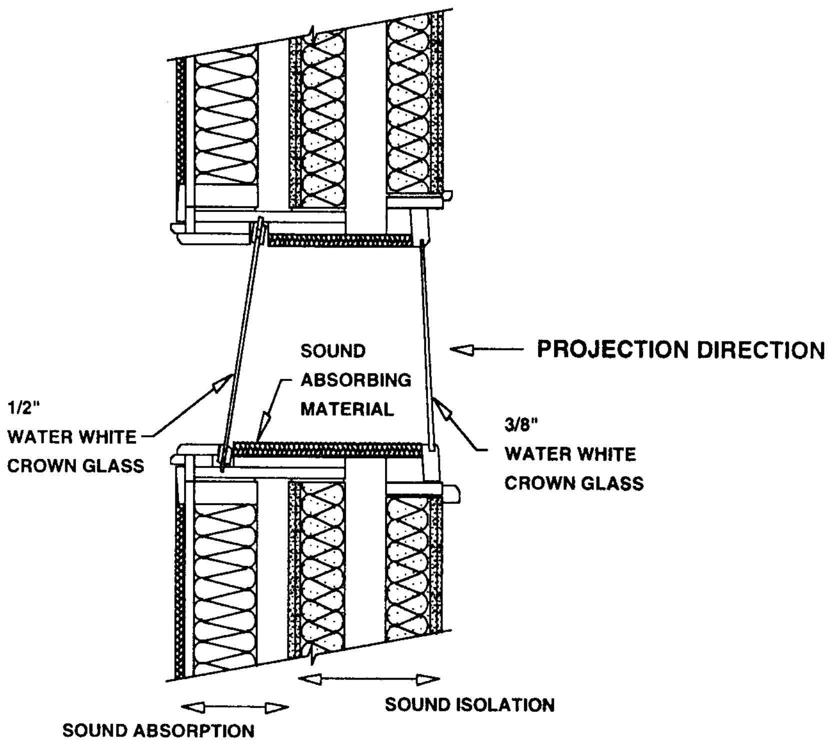

Figure 6.4 Superior Partition - Minimum Internally Reflective, Sound Isolation Port Design

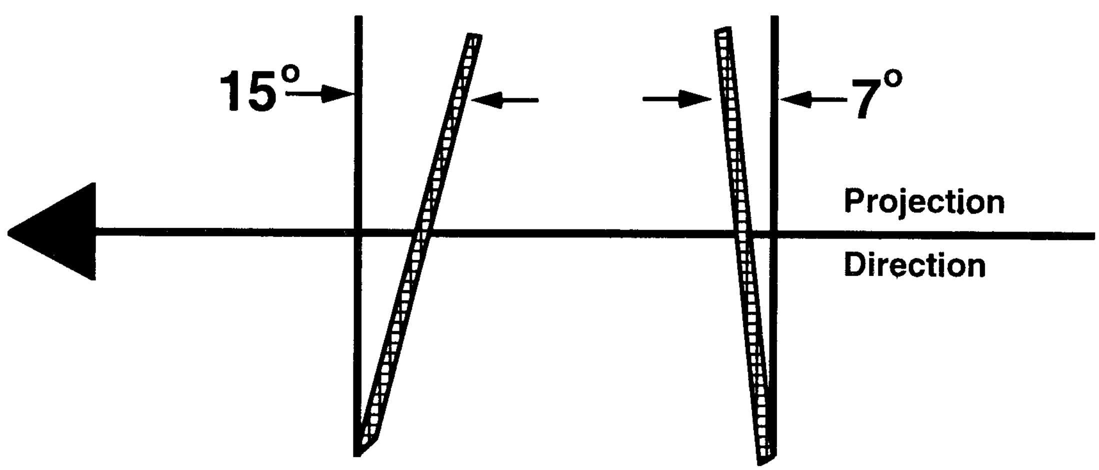

Figure 6.5 Optimum Port Glass Projection Angles

7.0 Test Films

7.1 Sound

7.1.1 Analog

Cat 69P

Pink Noise on color stock

Cat 69T

Dolby Tone on color stock

Cat 97

Left/right test film for solar cell alignment

Cat 151 and Cat 151B

The Cat. No. 151B is an optional alternative to the existing Cat. No. 151. Unlike the 151, the 151B utilizes band limited frequency pink noise on front and surround channels, making it easier to achieve timbre matching. Engineers may find this film easier to use in practice than the Cat. No. 151, though both films will be available for the time-being.

Cat 566

Lack of illumination uniformity along the slit is a major cause of distortion and inadequate high-level high-frequency response with analog soundtracks. Until now the only method of measuring uniformity was with a snake track, a difficult and cumbersome procedure. This new test film only requires use of a real-time analyzer, and provides an instant visual display of any illumination problems.

7.1.2 Digital

Cat 1010: Synchronization test film

Enables setting of sound delay to match picture sync with digital sound reader varying projector mounting locations. Contains digital "pip", analog "pip", picture sync mark, and frame/sprocket markers for visual verification.

Cat 1011: Channel Identification test film

Contains verbal identification for each main channel (Left, Centre, Right, Left Rear and Right Rear), and a low frequency tone for sub-woofer.

7.2 Picture

7.2.1 RP40

35mm picture test film, manufactured by the SMPTE. Used for checking focus, lens resolution and aspect ratios.

[SMPTE RP105: Picture Jump and Weave]

7.3 General Purpose

7.3.1 *Jiffy*

This is an updated version of the well-known *Jiffy* test film, now containing both an SR sound-track, and a digital sound-track. There are six minutes of subjective audio tests in some cases different for the analog and digital sound-tracks. The test film also contains some quick visual tests, to verify framing and check for ghosting and shutter problems.

7.4 Trailers

7.4.1 Cat. No. 451 *Mancini* trailer. Dolby Stereo SR, 1.85:1 aspect ratio. A one minute helicopter journey across the Columbia Gorge with a stirring orchestral score written by Henry Manicini.

7.4.2 Cat. No. 3185/3235 *Train* Trailer. Dolby Stereo SR•D for use in Digital equipped theatres. A 60-second sound effect fanfare to introduce a Dolby Stereo digital feature.

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8.0 Other Information

8.1 Equipment Manuals

The following manuals are equipment manuals are available from Dolby Laboratories:

8.1.1 CP55

8.1.2 CP65

8.1.3 CP200

8.1.4 SRA5

8.1.5 DA10

8.1.6 DA20

8.2 Standards

8.2.1 ANSI202M (ISO2969)

8.2.2 Light on Screen and Reflected/Ambient Light. SMPTE 196M-1993

8.2.3 Measurement of screen luminance SMPTE RP98

8.2.4 Projected Image Quality of 70-, 35- and 16-mm Motion-Picture Projection Systems
SMPTE EG 5-1994

SMPTE and ANSI documents can be ordered from:

SMPTE: 595 West Hartsdale Ave.
White Plains, NY 10607

(In the USA, the SMPTE can also provide ISO and IEC documents)

ISO documents can be ordered from:

ISO: Central Secretariat, Case Postale 56
CH-1211 Geneve
Switzerland

IEC documents can be ordered from:

IEC: 3 Rue de Varembe, Case Postale 131
CH-1211 Geneve
Switzerland

8.3 Other Information Sources

8.3.1 Technical Journals and Magazines

Technical information on motion picture sound, and theatre sound systems and installation can be found in a wide variety of journals and magazines. The best known are:

SMPTE Journal:
Society of Motion Picture and Television Engineers (SMPTE)
595 West Hartsdale Ave.
White Plains, NY 10607

Film Journal:
244 West 49th Street, Suite 305,
New York, NY 10019

Box-Office Magazine:

6640 Sunset Blvd., Suite 100
Hollywood, CA 90028

Image Technology (incorporating Cinema Technology):
British Kinematograph, Sound and Television Society (BKSTS),

547-549 Victoria House, Vernon Place
London WC1B 4DJ
England

Journal of the Audio Engineering Society:

AES
60 East 42nd Street, Room 2520
New York, NY 10165-2520

8.3.2 Inter-Society Committee

This committee meets irregularly, and has a membership from all aspects of the motion picture industry, producers, theatres, and equipment manufacturers. Discussions are of technical issues of current interest -- for example, the committee has been heavily involved in discussions relating to the adoption of 6000 feet shipping reels for motion picture distribution in the USA.

Contact: John Mason
Eastman Kodak Company
6700 Santa Monica Boulevard
Hollywood, CA 90038
Tel.: 213-464-6131

8.3.3 TEA

The Theatre Equipment Association provides a forum for the interchange of information between equipment manufacturers and equipment dealers. The membership is largely from the USA, with increasing representation from overseas. The TEA also hosts an annual seminar series covering motion picture industry issues ranging from theatre sight lines to crowd control at the concession stands. Communication is by mail, and at an annual convention held each summer at a different location in the USA.

Contact: The Theatre Equipment Association
244 West 49th Street, Suite 305
New York, NY 10019

8.3.4 THX

THX is a division of LucasArts Ltd which publishes a set of criteria for theatre performance. They provide regular training courses for the measurement of theatre performance, and for the installation of THX loudspeaker systems.

Contact: THX Division
LucasArts Ltd.
PO Box 2009
San Rafael, CA 94914

8.4 Dolby Technical Help

8.4.1 Training Courses

Dolby Laboratories provides regular training courses for theatre equipment installers, theatre operations staff, and studio personnel. Course material contains specific information about theatre equipment installation, and much of the material discussed in these guidelines. The courses are held several times a year, in different locations in the USA, and in London.

Contact: Dolby Laboratories Marketing Department:

US Address: 100 Potrero Avenue
San Francisco, CA 94103
Phone (415)558-0200
Fax (415)863-1373

UK Address: Wootton Bassett
Wiltshire SN4 8QJ England
Phone 01793-842100
Fax 01793-842101

8.4.2 Dolby Technical Help Hot-Line

In the USA, technical help is available:

Monday-Friday 8.00am - 5.30pm (Pacific Time) (415)558-0200
(Outside of business hours for theatre emergencies call: (415)554-8537*)*

Reference test films for measurement of illumination uniformity, scanning beam location and picture test films are available from several sources, including:

SMPTE:
595 West Hartsdale Ave.
White Plains, NY 10607

DEFA: OPTRONIK GMBH
August-Bebel-Strasse 26-53
D 14482 Potsdam

Tel: 49-331-9652472
Fax: 49-331-9652471

Theatre Check List

	Measured OK	Checked OK
B-Chain		
Stage Power	☐	
Stage Loudspeaker Location		☐
Stage Characteristic Curve	☐	
Surround Speaker Number/Location		☐
Surround Power	☐	
Surround Characteristic Curve	☐	
Sub-woofer Power/Linearity	☐	
Sub-woofer Location		☐
A-Chain		
Analog Frequency Response	☐	
Analog Wow-and-Flutter	☐	
Analog Illumination Uniformity	☐	
Digital Illumination Uniformity	☐	
Digital Exciter Lamp Voltage	☐	
Digital Projector Delay Set	☐	
Digital Surround Delay Set	☐	
Acoustics		
Noise Floor	☐	
Reverberation Time	☐	
Reflections/Damping		☐
Masking Cloth		☐

	Measured OK	Checked OK
Processor Updates		
Cat. No. 108C		❐
Cat. No. 64B		❐
Cat. No. 150E		❐
Cat. No. 441		❐
Cat. No. 560		❐
Cat. No. 517		❐

Dolby Laboratories acknowledges with thanks permission from the SMPTE to reprint the documents in the appendix to this manual.

SMPTE STANDARD

ANSI/SMPTE 202M-1991
Revision and Redesignation of
ANSI PH22.202M-1984

for Motion-Pictures — B-Chain Electroacoustic Response — Dubbing Theaters, Review Rooms, and Indoor Theaters

1 Scope

This standard specifies the measurement methods and characteristic electroacoustic frequency response of the B-chain of motion-picture dubbing theaters, review rooms, and indoor theaters whose room volume exceeds 150 m^3 (5297 ft^3). It is intended to assist in standardization of reproduction of motion-picture sound in such rooms. It does not apply where the recorded sound is intended for reproduction under domestic listening conditions, i.e., for radio broadcasting, television broadcasting, tape, or disc. This standard does not cover that part of the motion-picture sound system from the transducer to the input terminals of the main fader, nor does it cover the electroacoustic response characteristic of motion-picture theater subbass loudspeakers (subwoofers).

2 Normative reference

The following standard contains provisions which, through reference in this text, constitute provisions of this standard. At the time of publication, the edition indicated was valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent edition of the standard indicated below.

ANSI S1.13-1971 (R1986), Methods for the Measurement of Sound Pressure Levels

3 Definitions

3.1 complete sound reproduction system: Represented diagrammatically in figure 1 and used in indoor theaters and review rooms and in motion-picture sound post-production facilities such as dubbing theaters, mix rooms, and ADR studios. The complete system is generally considered to consist of an A-chain and a B-chain.

3.2 preemphasized audio track: An audio record, either magnetic or photographic, containing high-frequency boost equalization which is intended for playback over deemphasized theater playback systems to curve N of this standard. A deemphasized theater playback system makes use of a combination of projector slit-height losses, electrical filters, loudspeaker frequency response, screen losses, and auditorium acoustics to roll off high-frequency noise due to the magnetic or optical sound track.

3.3 wide-range audio track: An audio record, either magnetic or photographic, which is intended for playback over theater playback systems aligned to curve X of this standard. Such a track is typically recorded without fixed pre- and deemphasis. Frequently, companding noise reduction is employed, and is used with complementary decoding in playback, to reduce the effects of noise due to the magnetic or optical sound track.

3.4 A-chain (transducer system): That part of a motion-picture audio system, as shown in figure 1, extending from the transducer to the input terminals of the main fader.

3.5 B-chain (final chain): That part of a motion-picture sound reproduction system, as shown in figure 1, commencing at the input terminals of the main fader and terminating in the listening area defined in figures 3 and 4 at which sound pressure measurements are taken.

CAUTION NOTICE: This Standard may be revised or withdrawn at any time. The procedures of the Standard Developer require that action be taken to reaffirm, revise, or withdraw this standard no later than five years from the date of publication. Purchasers of standards may receive current information on all standards by calling or writing the Standard Developer. Printed in USA.

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595 W. Hartsdale Ave., White Plains, NY 10607
(914) 761-1100

American National Standard
ANSI7C1291/16

Approved
October 30, 1991

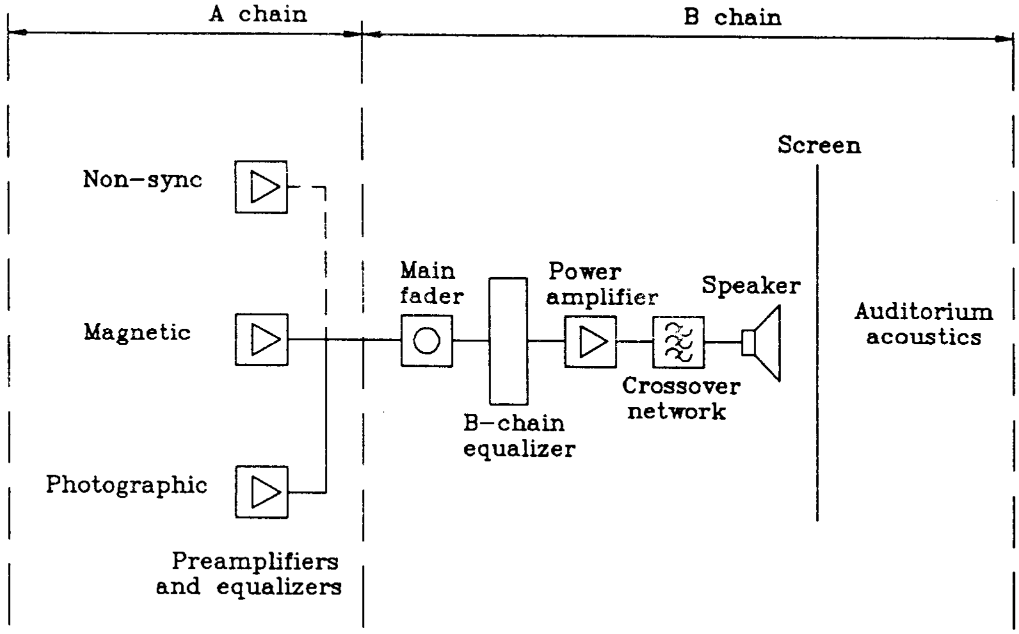


Figure 1 – Complete theatrical sound reproduction system

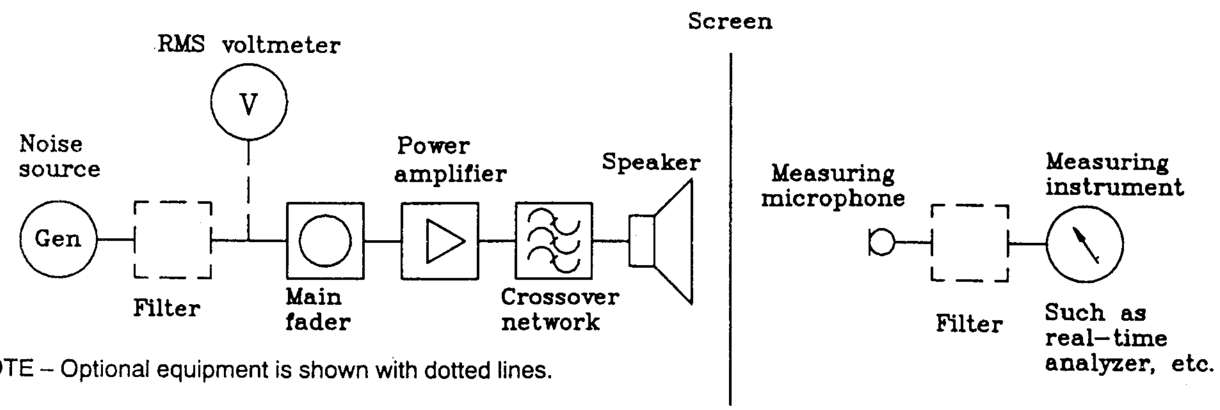
3.6 pink noise: A stochastic signal having a continuous spectrum with equal energy per equal logarithmic interval of frequency, and with a Gaussian probability distribution of instantaneous amplitude. (See 4.4.)

3.7 wide-band pink noise: Pink noise having a bandwidth exceeding the normal acoustic frequency range. A suitable test signal should have a frequency response flat to within ± 0.5 dB when measured in ⅓-octave bands with center frequencies from 25 Hz to 20 kHz with an integrating averaging technique.

3.8 electroacoustic response: The electroacoustic response of the B-chain is the spatially averaged sound pressure level measured in 1/3-octave bands expressed in decibels with respect to reference level when wide-band pink noise is applied to the input terminals of the main fader, preceding the power amplifier. (See figure 1.) The reference level is the average level of the electroacoustic response of the 1/3-octave bands over the frequency range from 400 Hz to 2 kHz. The electroacoustic response is computed as a spatial average over the listening area using one of the methods given in annex A.4.

4 Method of measurement

4.1 The electroacoustic response shall be measured with the equipment arranged in accordance with figures 2, 3, and 4. (See annex A.)



NOTE – Optional equipment is shown with dotted lines.

Figure 2 – Method of measurement of B-chain

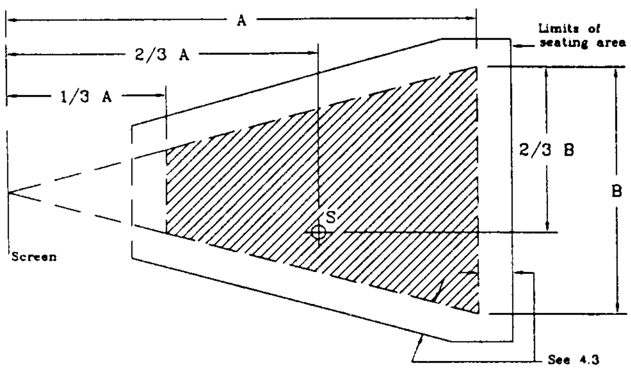


Figure 3 – Theater auditorium

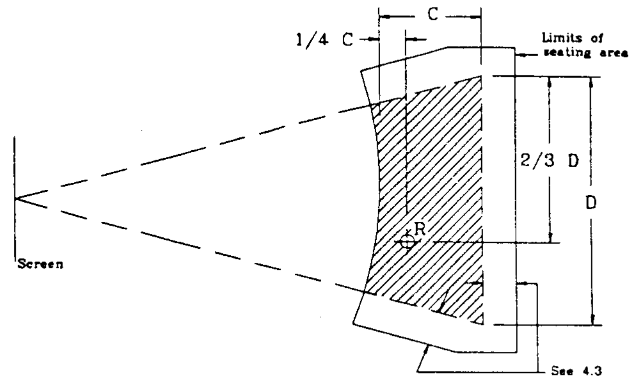


Figure 4 – Theater balcony

4.2 Sound pressure level (SPL) vs. frequency measurements (see annex A) shall be made as follows:

(a) In dubbing theaters or mix rooms, at each of the principal listening positions, such as at the position of each of the mixing personnel, and at the producer's location.

(b) In review rooms and review theaters, at a sufficient number of positions to cover the listening area and to reduce the standard deviation of measured position-to-position response to less than 3 dB, which will typically be achieved with four positions.

(c) In indoor theaters, at position S as shown in figure 3 and position R as shown in figure 4 should it exist, and at a sufficient number of other positions to reduce the standard deviation of measured position-to-position response to less than 3 dB, which will typically be achieved with four positions, but avoiding those aberrant locations described in A.4.

4.3 It is recommended that measurements be made at a normal seated ear height between 1.0 m and 1.2 m (3.3 ft and 4.0 ft), but not closer than 150 mm (6 in) from the top of a seat, and not closer than 1.5 m (4.9 ft) to any wall and 5.0 m (16.4 ft) from the loudspeaker(s).

4.4 A suitable single loudspeaker auditorium sound pressure level with wide-band pink noise is 85 dB SPL C-weighted and slow reading (See annex A.10). The measured level in any 1/3-octave band can be used directly if it exceeds the background noise in the band by at least 10 dB. If the background noise is between 4 dB and 10 dB below the test signal, the measurement may be corrected using the techniques described in ANSI S1.13-1971, table 4. (See annex A.4.)

4.5 A system for playing contemporary stereo films will generally employ four wide-range channels: screen left, center, and right loudspeaker systems, and a surround channel loudspeaker system generally employing a number of individual loudspeakers spaced around the room for uniform coverage. Each of these channels is to be measured and adjusted in turn.

5 Characteristic amplitude responses with respect to frequency

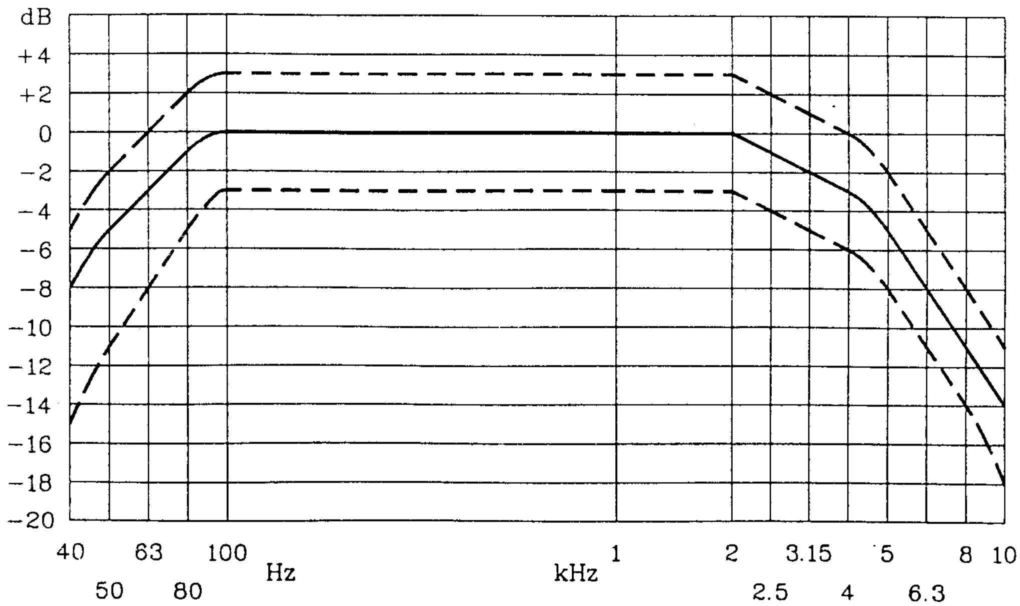
5.1 With the sound system set for playback of preemphasized audio tracks, the electroacoustic response of the B-chain shall be to curve N in table 1 and figure 5 within the tolerances given.

5.2 With the sound system set for playback of wide-range audio tracks, the electroacoustic response of the B-chain shall be to curve X in table 1 and figure 6 within the tolerances given.

5.3 It is recognized that many older sound systems currently present in theaters cannot meet the centerline of the standard over the fully extended frequency range. The response standard has been updated over the years to account for the changes in technology which permit a wider frequency range, but note the precaution on excessive equalization of these older systems in A.8.

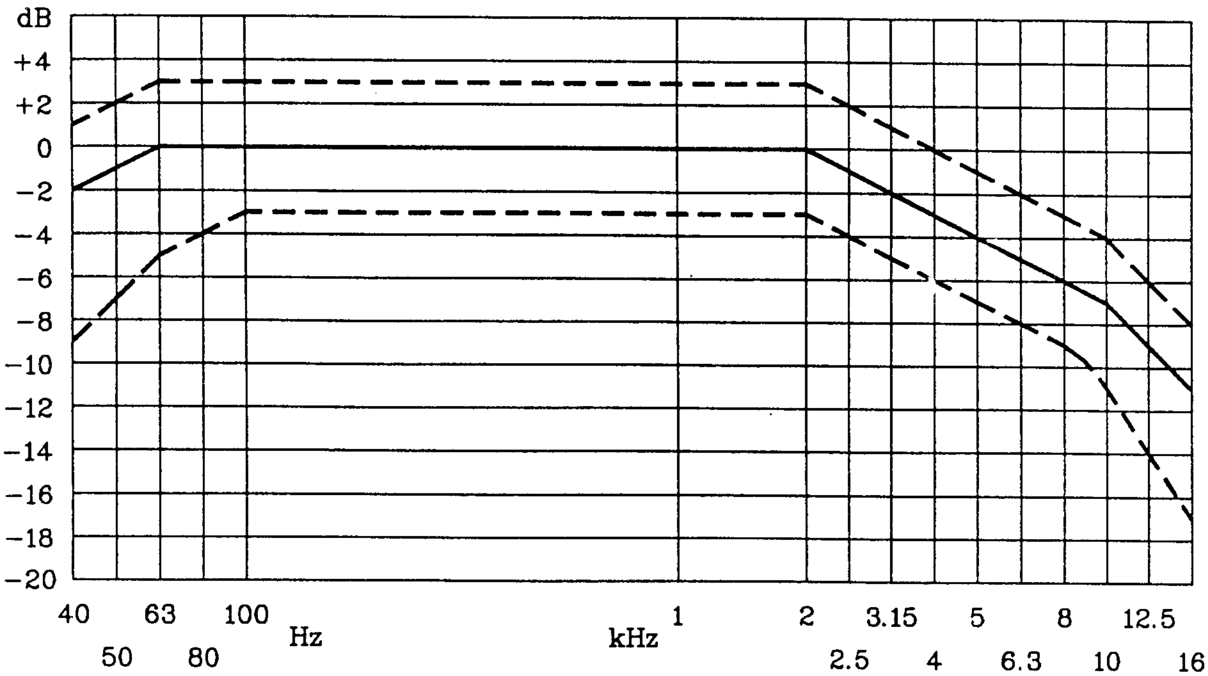
Table 1 – B-chain characteristics

Center frequencies of 1/3-octave bands Hz	Level Curve N dB	Level Curve X dB	Tolerances dB +	Tolerances dB –
40	–8	–2	3	7
50	–5	–1	3	6
63	–3	0	3	5
80	–1	0	3	4
100	0	0	3	3
125	0	0	3	3
160	0	0	3	3
200	0	0	3	3
250	0	0	3	3
315	0	0	3	3
400	0	0	3	3
500	0	0	3	3
630	0	0	3	3
800	0	0	3	3
1000	0	0	3	3
1250	0	0	3	3
1600	0	0	3	3
2000	0	0	3	3
2500	–1	–1	3	3
3150	–2	–2	3	3
4000	–3	–3	3	3
5000	–5	–4	3	3
6300	–8	–5	3	3
8000	–11	–6	3	3
10 000	–14	–7	3	4
12 500	—	–9	3	5
16 000	—	–11	3	6



NOTE – Tolerances are based upon 1/3-octave measurements. If 1/1-octave measurements are used, reduce the tolerance by 1 dB.

Figure 5 – Curve N of B-chain



NOTE – Tolerances are based upon 1/3-octave measurements. If 1/1-octave measurements are used, reduce the tolerance by 1 dB.

Figure 6 – Curve X of B-chain characteristic

Annex A (informative)
Additional data

A.1 Factors outside the scope of this standard

Compliance with this standard is a necessary but not sufficient condition for the achievement of high-quality sound reproduction in review rooms and theaters. Subjective judgments of sound quality are influenced not only by the frequency response of the B-chain which is the subject of this standard, but also by such factors as:

(a) A-chain performance, including frequency response, signal-to-noise, wow and flutter, and the like;

(b) electrical performance of the sound system, including headroom to clipping, hum and noise, and the like;

(c) room acoustics, including reverberation time vs. frequency, echoes and behind screen reflections, background noise, and intrusive noise;

(d) placement of loudspeaker sources vs. picture;

(e) loudspeaker distortion, and many others.

Therefore it is essential that the A-chain be correctly aligned within the tolerances of existing standards by the use of the appropriate photographic or magnetic test film and that relevant electrical deemphasis be applied (see annex B). For monitoring during recording, where magnetic masters are prepared with preemphasis for making photographic negatives, see ANSI/SMPTE 214M-1984. The other factors listed above should also be given due attention.

This standard was prepared in the belief that an extended and uniform frequency response is a fundamental component of good sound quality.

A.2 Preliminary checks

Preliminary checks for gross acoustic errors should be made prior to measuring the electroacoustic response as described in this standard. Typical checks include verification that the loudspeaker being measured is close enough to the screen to avoid any behind-screen echoes, and verification of speaker polarity. A wide-band pink noise test signal can be sent to combinations of loudspeakers (L and C, L and R, C and R) as a simple verification of consistent loudspeaker polarity. The correct polarity (in-phase) condition is the one producing the greatest bass response from the sum.

Evaluation of uniformity of loudspeaker distribution patterns can be crudely evaluated by ear using a wide-band pink noise test signal. A more exhaustive numerical analysis of uniformity can be derived by analyzing the point-to-point response as measured in A.5.

A.3 Theater changes from curve N to curve X

If a theater wishes to change from curve N to curve X, it is necessary to make suitable adjustments to the photographic A-chain in order to reproduce conventionally recorded audio records. A companding noise reduction system is normally used for recording and reproducing photographic tracks when used with curve X.

A.4 Qualifying the accuracy of measurements

A.4.1 Type of measurement

Measurements of sound fields from loudspeakers in rooms can take many forms. Tone burst, fast Fourier transform, time-delay spectroscopy, and maximum length sequence analysis may all prove useful, especially during the design phase of a loudspeaker system. Much of the analysis conducted with these methods has the object of reducing the effect of room acoustics on the measurements. Analysis of pink noise with a constant-percentage bandwidth real-time spectrum analyzer, such as a 1/3-octave real-time analyzer, on the other hand, includes the influence of room acoustics and has been found to be most useful in day-to-day alignment of sound systems. Traditional real-time analysis has been improved in reliability by the method outlined in this standard through the use of spatial and time averaging, which can yield typical differences as small as ± 1 dB from one setup of the equipment to another.

A.4.2 Background noise

See 4.4.

A.4.3 Maximum sound pressure level caution

The sound pressure level shall not be so great as to risk damage to loudspeakers.

A4.4 Microphone response, directivity, and mounting

The microphones used for theater measurements are subjected to three sound fields, all of which must be measured appropriately. They are the direct sound field from the loudspeaker, early reflections, and the reverberant sound field. Substantial errors can be introduced by using microphones which have large diaphragms, or which have cavities in front of the diaphragm, primarily because their response to direct sound fields and diffuse sound fields is different. Therefore, small diameter calibrated microphones are preferred for accuracy over large diameter types, but large diameter ones can be used for approximate conditions so long as their calibration is known, and the angle of incidence of the direct sound is equal to that of the calibration conditions. (But there may well be a difference in calibration for screen vs. surround loudspeaker systems due to the different nature of the sound fields from these sources.)

Pressure calibrated measurement microphones are preferred to free-field types, since free-field microphones are generally used for measurements where sound from one direction predominates, such as in anechoic measurements. Pressure measurement microphones are typically adjusted for flat response for diffuse-field sound, and their response rises on axis. Since many measurements are made of typical systems at around the critical distance, where the sound pressure contribution of the direct and reverberant sound fields are equal, it is important to find that angle between the direct sound and the diaphragm for which the response is the flattest. This angle is 90° in typical 12.5 mm (0.49 in) pressure measurement microphones, so they would normally be used pointed at 90° relative to the direct sound. Using even smaller diameter microphones has the advantage of reducing the difference in response of on-axis sound and diffuse-field sound. Using typical recording microphones causes problems, since their calibration for mixed sound field conditions is usually unknown.

Some microphone mounting hardware and configurations in common use may cause errors up to ± 2 dB in measured frequency response of the direct sound, due to sound reflections from the mounting equipment entering the capsule. The best mounting hardware has small dimensions and is arranged so that first order reflections from it are reflected away from the microphone capsule.

The frequency response of the measurement microphone shall be known through calibration under conditions similar to its use. In particular, the measurement microphone shall be adequately omnidirectional and calibrated to be flat when measuring a mixture of direct and diffuse sound fields using the same mounting arrangement used in practice, and the angle of flattest direct field response shall be known from the calibration procedure and employed in making measurements.

A.4.5. Spatial averaging

A spatial average of different positions within the room, yet falling within the placements given in 4.2 and 4.3, greatly improves the reliability of equalizing the sound system, due to lessening the influence of specific room modes in the bass, and reducing the effect of lack of uniformity of high-frequency output of loudspeakers in the treble.

Care should be taken that none of the microphone placements used in calculating the spatial average are extraordinary. Positions should be avoided which are exactly on lateral or transverse theater centerlines, or are under the lip of a balcony. Microphone positions employed in a spatial average shall be distributed among a range of positions in lateral and transverse directions to minimize the influence of any particular room mode, but the points should lie within the requirements of 4.2 and 4.3. The minimum spacing of the microphones in an average shall be 1.0 m (3.3 ft).

The calculation of a spatial average shall be done by the sum of the squares of the sound pressure levels as follows:

$$L = 10 \log 10 [\frac{1}{N} \sum_{k=1}^{N} \text{antilog}10 \left(\frac{Lk}{10} \right)]$$

where N is the number of positions and L_k is the sound pressure level at each position. For four positions, the ⅓-octave by ⅓-octave average would be computed as follows:

$$SPL = 10 \log 10 [(\frac{1}{4}) (10^{\frac{L_1}{10}} + 10^{\frac{L_2}{10}} + 10^{\frac{L_3}{10}} + 10^{\frac{L_4}{10}})]$$

where L_1 equals the sound pressure level in a ⅓-octave band at position 1, L_2 equals the sound pressure level in the same ⅓-octave band at position 2, etc. If the range of sound pressure levels is within 4 dB, simple arithmetic averaging may be used. Large standard deviations may indicate significant acoustic or loudspeaker coverage problems.

A.4.6 Temporal averaging

Stochastic signals such as pink noise cause a fluctuating sound pressure level. The level fluctuations become more severe as the bandwidth of measurement is decreased and as the center frequency of the measurement is lowered. In order to obtain high accuracy with such a nonsteady-state test signal, it is useful to perform temporal averaging on the data obtained from a ⅓-octave band spectrum analyzer. At least two methods are widely used for temporal averaging, RC-type averaging in the detector circuit of the analyzer, and calculated averaging in an integrating real-time analyzer. With a calculated averaging method, accuracy can be very high if the measurement is adequately long. The minimum averaging time of a conventional real-time analyzer should be such that measurements even at low frequencies are readable with an accuracy better than the tolerances of the standard. It is recommended that measurements be time-averaged over a period of not less than 20 s in the lowest frequency bands for accuracy within ± 1 dB.

A.5 Methods of measurement

At least two methods of measurement are recognized as providing appropriate data for the evaluation of the electroacoustic response of the B-chain. For each of the methods, generate wide-band pink noise, and apply to each loudspeaker channel, left, center, right, and surround, in turn. The methods of measurement are:

(a) Measure the electroacoustic response with a set of four typically calibrated microphones connected to a microphone multiplexer switch (not a mixer), the output of which is connected to an audio-frequency ⅓-octave band spectrum analyzer. Position the set of calibrated microphones according to A.4.5. Temporally average the data for a sufficient amount of time to produce a standard deviation under 1 dB.

(b) Measure the electroacoustic response with a calibrated microphone and an audio-frequency ⅓-octave-band spectrum analyzer at each of a number of locations and compute the spatial average, as specified in A.4.5.

Other methods which conform to the accuracy of the given methods may be employed, such as use of a ⅓-octave band filter set and a voltmeter, measuring each ⅓-octave band level for each response position in turn and mathematically computing the averages. Measurement in whole-octave bands is now rarely employed, because of the ready availability of ⅓-octave analysis equipment.

Note that the pink noise source should be an electrical noise generator, not an optical or a magnetic pink noise test film, since the use of test films in aligning the B-chain will cause accumulating errors, and in many theaters, the active or passive A-chain deemphasis cannot easily be disabled.

A.6 Acoustical and psychoacoustical effects

The electroacoustic response resulting from a loudspeaker situated behind a motion-picture screen, or from an array of loudspeakers used for the surround sound channel in the auditorium, is affected by various factors before the sound is perceived by a listener. These include the following acoustical and psychoacoustical effects:

(a) Attenuation of high frequencies caused by the screen for the wide-band screen channels. With conventional theater loudspeakers and normally perforated screens, the attenuation on axis is 3 dB between 5 kHz and 8 kHz, with a 6 dB/octave characteristic rolloff at higher frequencies. This high-frequency attenuation is typically less off axis by a small amount. Old screens, where acoustic transmission is degraded by air-borne particulate matter clogging the perforations, can severely degrade high-frequency performance.

(b) A room gain reverberation component added to the direct signal. It should be noted that since reverberation in large rooms takes a finite time to build up, this component is only measurable with quasi-steady-state signals, such as pink noise. For accurate measurement, the sound field must have reached stasis for the reverberant component to add fully to the direct sound. This component has a frequency response proportional to the reverberation time vs. frequency characteristic, and will be most significant on sustained program material like held musical chords.

(c) High-frequency attenuation in the air, proportional to signal path length. This process applies to direct sound through only one path, and to the reverberant component through the average composite path length of sound. The result is that with all other factors held constant, for steady-state signals in more reverberant spaces, the sound will be duller, with rolled off high frequencies, since the average path length of the reverberation component is longer in the more reverberant room.

(d) Rows of seats have been shown to cause dips in the frequency response of sound fields at near grazing incidence. The dip is usually in the range of 80 Hz to 125 Hz, depending on the dimensions.

(e) All published experimenters have found that in a large room, a flat response near-field loudspeaker is subjectively best matched by a distant loudspeaker having a rolled-off high-frequency response in steady-state measurements. The source of the need for this measured rolloff appears to be the differing interaction of the sound field with the head, pinnae, and ear canal between a distantly originating sound field, and one originating close by, or by differences between transient and steady responses caused by the mechanism described in (b) above. Since the need for such an apparent rolloff with steady state signals is shown, this standard documents the response for best interchangeability of product across many auditoriums.

To account for (b) and (c) above, the measured characteristic to maintain subjectively identical response will differ slightly according mainly to auditorium size and reverberation time. The measured response by the method of this standard should have a slightly attenuated high-frequency characteristic in a large theater when compared with table 1 and figures 5 and 6, when comparing auditoria using the same absorption/frequency characteristics, due to the naturally longer reverberation time of the larger theater. In the same way, there should be a slightly elevated response in a small theater. Table A.1 gives approximately suitable correction factors which should be added numerically to the characteristic given in table 1 and figures 5 and 6.

Corrections for auditorium size are not normally required below 2 kHz, as a result of a flatter reverberation vs. frequency characteristic typical at mid-range frequencies, and the longer integration time of the ear at low frequencies. More accurate determination of the above correction factors for a particular auditorium can be deduced from measurement of the reverberation time vs. frequency characteristic.

Whenever possible, the electroacoustic response should be measured with the auditorium's typical operational humidity, since humidity variations are a significant component of day-to-day variation in properly operating modern sound systems.

Table A.1 – Approximate correction factors for auditorium size, dB

Frequency	Number of seats					
kHz	30	150	500	1000	1500	2000
2.0	0	0	0	0	0	0
4.0	1.0	0.5	0	−0.5	−1.0	−1.5
8.0	2.0	1.0	0	−1.0	−2.0	−3.0

A.7 Troubleshooting

With good acoustic design and modern loudspeakers with uniform coverage, not only should the overall spatially averaged electroacoustic response fall within the tolerances specified in clause 5, but the response for each position should also fall within those tolerances.

Provided that the B-chain meets the tolerances specified, the electroacoustic frequency response for sound reproduction should be satisfactory for all types of photographic and magnetic recordings, provided the additional items outlined in A.1 are given attention.

Care should be taken that deviations from the curve, although within the tolerance area, do not cause a tonal imbalance. Broad, low-Q effects have been shown to be of more perceptual significance than narrower, high-Q effects, which have even greater amplitude. For example, a situation where the overall bass response is at one extreme of the tolerance, and the treble response at the other, should be avoided.

If extreme amounts of electrical equalization are required to bring the response into conformity with the standard, or electrical equalization is required which is significantly atypical for the loudspeaker system in use, each element of the B-chain should be examined to determine the cause of the problem, which may be included in the following list:

(a) faulty power amplifier;

(b) incorrect or faulty loudspeaker performance;

(c) incorrect location, orientation, or directivity of the loudspeaker;

(d) room acoustical defects;

(e) incorrect adjustment of the loudspeaker crossover network (relative level of the bass and treble loudspeaker drivers), crossover wiring polarity reversal, relative time displacements between drivers due to different geometries;

(f) obscured perforations in the screen;

(g) dated loudspeaker design, unable to perform according to current specifications.

If the B-chain cannot be brought into conformance with the curve X characteristic described in this standard, but it is found possible to achieve conformance to the curve N characteristic, there still may be playback problems when playing material intended for a curve N environment. Sound records are preemphasized according to the intended playback environment — those intended for playback over curve N systems will have greater high-frequency preemphasis than those intended for curve X systems. This increased preemphasis may reveal power amplifier or loudspeaker deficiencies in a B-chain which are not evident when the system is being tested with a flat frequency response test signal such as pink noise.

Some high-frequency loudspeaker drivers exhibit more distortion than others; this may cause a subjective change in high-frequency response which will not be evident from the test procedures described in this standard.

Because the measurements deal only with the steady-state properties of the auditorium, acoustical defects such as backstage or auditorium echoes are not accounted for in the measurement procedure. Attempts to use these measurement results as a basis for major equipment redesign in a theater found defective have to be preceded by ascertaining that no grave acoustical faults are present. Possible problems are listed in A.1. Methods for finding or eliminating such faults are not covered in this standard.

A.8 Equalization

Adjustment of the electroacoustic response to curve X for record monitoring and playback of wide-range sound tracks will normally require some electrical equalization, typically ⅓-octave, which approximately corresponds to the critical bands of human hearing. The following points should be noted:

(a) A crossover network, if used, should be adjusted, if adjustable, to the smoothest response before equalization is attempted. If an electronic crossover is employed before the power amplifiers, its gain, and the gain of the following power amplifiers, should be set with a due consideration for the best headroom and signal-to-noise ratio.

(b) Equalization above 8 kHz should not normally be attempted with older loudspeaker designs which exhibit rapid rolloff beyond 8 kHz.

(c) Extreme equalization for low-frequency modes should be avoided, since the low frequency modes, particularly below 100 Hz, are often very narrow response anomalies which cannot normally be corrected with the relatively broader ⅓-octave-band equalizer without audible consequences at frequencies away from the modal one.

(d) A correction may be necessary to the basic curve promulgated by this standard when equalizing the surround channel due to the differences between screen and surround loudspeakers. Among these differences are the fact that surround channel loudspeakers are routinely placed closer to typical seating locations, increasing the ratio of direct-to-reverberant sound fields; the screen loudspeakers approximate a point source, whereas the surround channel uses an array of loudspeakers; and the radiation patterns of the loudspeakers are different between screen and surround loudspeakers. The correction necessary will tend toward an increase in the measured high-frequency response of surround loudspeakers compared to screen loudspeakers.

A.9 Uniformity of sound pressure level from different loudspeakers

Applying the same voltage of wide-band pink noise at the input of the B-chain for each loudspeaker system in turn should yield spatially averaged sound pressure levels which are equal within ± 1 dB (see A.4) as measured on a C-weighted and slow-reading sound level meter. In the event that the auditorium exhibits strong low-frequency room modes which could significantly affect wide-band noise level measurements, A-weighting should be used when matching loudspeaker levels.

A.10 Spectrum level

While 85 dBC is commonly used as a wide-band signal level reference (see 4.4), on some analyzers it may be convenient to use as a preferred sound pressure a decade level such as 70 dB SPL in each 1/3- octave band in the range 50 Hz to 2 kHz. In this case, with the overall response on curve X, the sum of all the 1/3-octave bands will add to approximately 83 dBC.

A.11 Future work

As first noted in A.6, it is recognized that more uniform perceived loudness and spectral balance from installation to installation would be promoted by accounting for the following factors:

(a) reverberation time vs. frequency;

(b) loudspeaker radiation pattern vs. frequency;

(c) the consequent direct-to-reverberant ratio at listening positions within the space due to (a) and (b);

(d) an accurate method to quantify the measured difference in frequency response between surround and screen channels as described in A.8.

The goal is to have constant perceived loudness and frequency response from installation to installation, and from position to position within an installation, using this standard and contemporary dubbing stage practice as a reference. This goal may be promoted by keeping constant within the ear canal the spectrum level and response throughout one and across many installations. As equipment becomes available capable of making reverberation time measurements, the results of such measurements, combined with information on the loudspeakers, may be used to add correction factors to the curves to promote greater uniformity.

Annex B (informative)
Bibliography

ANSI S1.11-1986, Specifications for Octave-Band and Fractional Octave-Band Analog and Digital Filters

ANSI PH22.208M-1984, Motion-Picture Film (35-mm) — Magnetic Audio Reproduction Characteristic

ANSI/SMPTE 214M-1984, Motion-Picture Film (35-mm) — Photographic Audio Reproduction Characteristic

ANSI/SMPTE 217-1985 (R1991), Motion-Picture Film (70-mm) — Magnetic Audio Reproduction Characteristic

SMPTE STANDARD

ANSI/SMPTE 196M-1993

Revision of SMPTE 196M-1986

for Motion-Picture Film — Indoor Theater and Review Room Projection — Screen Luminance and Viewing Conditions

1 Scope

This standard specifies the screen luminance level, luminance distribution, and spectral distribution (color temperature) of the projection light for theatrical, review-room, and nontheatrical presentation of 16-, 35-, and 70-mm motion-picture prints intended for projection at 24 frames per second. This standard also specifies review-room viewing conditions. It is the purpose of these specifications to achieve the tone scale, contrast, and pictorial quality of the projected print that will be of the quality intended during its production.

2 Normative reference

The following standard contains provisions which, through reference in this text, constitute provisions of this standard. At the time of publication, the edition indicated was valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent edition of the standard indicated below.

CIE S002-1986, Colorimetric Observers

3 Projector operating conditions

Measurement of screen luminance shall be made with the projector in normal operation (with shutter running), with its lens set at focus position, but with no film in the aperture. The measurement of spectral distribution (color temperature) of the projection light is best made with the shutter momentarily stopped and held open, and with no film in the aperture.

4 Photometer type

Screen luminance shall be measured with a spot photometer having the spectral luminance response of the standard observer (photopic vision), as defined in CIE S002 (see annex A.4). The acceptance angle of the photometer shall be 2° or less. The photometer response to the alternation of light and dark on the screen shall be to integrate over the range of 24 Hz to 72 Hz and display the arithmetic mean value.

5 Luminance level

5.1 Measurement location

To simulate audience viewing, screen luminance measurements shall be taken from the center of the seating area at a height of approximately 1 m (39 in) above the floor. To ensure reasonable luminance at other seating locations, measurements shall also be taken from the center and each end of the middle row, and shall be within the limits given in 5.3 or 5.4.

5.2 Theater nominal luminance

Theater screen luminance shall be nominally 55 cd/m^2 (16 fL) measured at the screen center. The luminance of the screen sides and corners shall be measured at a distance of 5% of the screen width from the screen edges. The readings shall be taken from each location specified in 5.1.

5.3 Theater luminance limits

Theater screen luminance at the screen center shall be between 41 cd/m^2 (12 fL) and 75 cd/m^2 (22 fL). Luminance at the screen sides shall be 75% to 90% of the screen center luminance.

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5.4 Review room luminance and limits

Review room screen luminance shall be 55 cd/m^2 ± 7 cd/m^2 (16 fL ± 2 fL) at the screen center. The luminance of the screen sides and corners, measured as described in 5.2, shall be at least 80% of the screen center reading.

6 Luminance distribution

The screen luminance shall be symmetrically distributed about the geometric center of the screen. The luminance of any point on the screen between the center and the edges, as measured from any seat in the middle row, shall not exceed the screen center reading (see annex A.2).

7 Spectral distribution

7.1 For 35- and 70-mm prints, the light reflected from the screen in review rooms and primary theaters shall have a spectral distribution approximating that of a blackbody at a color temperature of 5400 K ± 200 K, the use of short-arc or carbon-arc light sources being assumed. For general theaters, the color temperature shall be 5400 K ± 400 K.

7.2 16-mm prints are made for projection with either arc or tungsten illuminant. When the intended illuminant cannot be specified uniquely, 16-mm prints should be evaluated at 5400 K.

8 Multiple projector adjustment

8.1 Same format

The resultant luminance from all projectors intended for use in the continuous sequential viewing of material of the same format shall not vary by more than 7 cd/m^2 (2 fL).

8.2 Different formats

The resultant luminance from projectors intended for use in a sequential system of viewing material of different formats shall not vary by more than 14 cd/m^2 (4 fL) (see annex A.5).

8.3 Temperature

The apparent color temperature of the projection light from projectors intended for continuous sequential operation shall be consistent within a total range of 400 K. For 16-mm projection with light sources with a color temperature of less than 3500 K, the range shall be limited to 7% or 200 K.

9 Review room viewing conditions

All observers in a review room shall be located within a standard observing area which shall be:

– within the limits of a 15° angle on either side of a perpendicular to the center of the screen, in both the horizontal and vertical planes;

– at a distance of 3 picture heights ± 1 picture height from the screen.

10 Stray light

10.1 No stray light or illuminated area with luminance greater than 3.4 cd/m^2 (1.0 fL) shall be visible from the normal observing area of theaters or review rooms.

10.2 Screen luminance due to stray light, as described in annex A.6, shall be less than 0.25% of the screen center luminance for review rooms and primary theaters and less than 0.50% for other theatrical projection facilities.

Annex A (informative)
Additional data

A.1 Luminance level limits

Acceptable luminance levels are limited by a minimum value below which the visual process becomes less efficient and by a maximum value above which (assuming a shutter frequency of 48 flashes/s) flicker becomes objectionable. The permissible luminance range is limited by the criterion that a good release print must provide acceptable quality when projected at any luminance within the specified range. Users are reminded that screen luminance may decrease as a function of bulb age, dirt on optics, dirt on screen, etc. Projection equipment should be chosen to have more than sufficient light output to meet the specifications in this standard over a period of time. Usually, arc current is adjusted to compensate for changes in light output.

A.2 Light incident on the screen

Misadjustment of the projector light source optical system may cause luminance readings taken at various locations in the seating area and on various areas of the screen to exceed the screen center reading taken as described in clause 5 (hot spots). To avoid this possibility, it is desirable to measure directly the light from the projector falling on the screen. This may be done by measuring the incident light across the screen surface with a footcandle meter and adjusting the light source optics to ensure that no area on the screen receives incident light greater than the screen center.

A.3 Normal print

To provide interchangeability in motion-picture projection, it is desirable that print quality conforms to that of a normal print so that theaters can operate at known projection conditions and will, thereby, be able to exhibit projected pictures of good pictorial quality. It has not been possible to specify this normal print in terms of its optical density and other objective measurements because of the difficulties of specifying artistic quality in scientific terms. Accordingly, the normal print is defined as that print which conveys the desired artistic impression when projected under review room conditions as described by this standard.

A.4 Meter acceptance angle and response

A photometer with a photopic spectral response allows use of a well known standard response for all photometer manufacturers. A mesopic (partially dark adapted) response might be better but no standard has been set for the mesopic observer under typical screen viewing conditions. When entering a theater from daylight, we find it difficult to see others in the audience although they see us because they are partially dark adapted. The degree of adaption varies with the film subject matter. A typical film reduces the average screen luminance from 55 cd/m^2 to 5.5 cd/m^2 (16 fL to 1.6 fL). The rest of the theater is much darker. Because of increased blue sensitivity of the eyes (Purkinje effect) as one becomes somewhat dark adapted, a photometer with a photopic response may give readings on a xenon illuminated screen and a carbon-arc illuminated screen that are the same, although many observers see the xenon illuminated screen as the brighter. The xenon-arc spectrum has a peak in the blue region where, because of the Purkinje shift, there is increased sensitivity. A representative mesopic curve may be developed and adopted in the future.

A.5 Matching luminance of different formats

It may be necessary to adjust projector light output to compensate for the different aperture sizes and magnifications used when projecting different formats. The projector light source should be capable of achieving the specified screen luminance for the format with the least light efficiency (usually nonanamorphic wide screen). Adjustment may be made by changing arc current or by the use of attenuators in the light beam to reduce the screen luminance to the recommended value when projecting more light-efficient formats.

A.6 Stray light

Stray light is measured by comparing the center screen luminance described in clause 5 with the luminance of the image of an opaque test object placed in the center of the projector aperture. The test object preferably should have a diameter of 5% of frame width, and should not exceed 10%. The balance of the projected beam is attenuated by any suitable neutral density film that produces through the normal projection system an average screen luminance equal to 10% of the luminance of the screen as defined in 5.1. All sources of illumination in the auditorium, such as exit and aisle lights, should be used in their normal manner while stray light is being measured. Excessive stray light or flare should be corrected to ensure proper print contrast.

A.7 Other applications

Specifications for drive-in theater screen luminance are covered in SMPTE RP 12.

Annex B (informative)
Bibliography

SMPTE RP 12-1992, Screen Luminance for Drive-In Theaters

SMPTE RP 94-1989, Gain Determination of Front Projection Screens

SMPTE RP 95-1989, Installation of Gain Screens

SMPTE RP 98-1990, Measurement of Screen Luminance in Theaters