Film-Tech

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Dolby Laboratories, Inc.

Technical Guidelines for Dolby Stereo Theatres

Updating for the Playback of Dolby SR Films

SPECTRAL RECORDING
DOLBY STEREO SR

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TECHNICAL GUIDELINES FOR DOLBY STEREO THEATRES — UPDATING FOR THE PLAYBACK OF DOLBY SR FILMS

For over a decade, Dolby Stereo 35mm release prints have been used to distribute high-quality audio to cinemas. This low-cost optical release format has promoted better attention to auditorium acoustics in the building of new theatres, and selection of superior audio equipment for existing and new theatres. These improvements have not been applied universally, however, and in many theatres the limitation to audio quality on a film is not the sound-track mix or the sound-track format, but is still the playback environment in the theatre.

The situation has become more acute with the introduction of Dolby Stereo release prints using the new Dolby spectral recording process, Dolby SR, which provides the sound-track with the potential of significantly greater dynamic range, especially at extreme low- and high-frequencies. This improved sound-track performance will only be apparent if the entire playback chain is of comparable quality to the sound-track itself — in fact, an SR film may well highlight any deficiencies or shortcomings in the theatre playback environment.

For example, the extended dynamic range of an SR film can cause significant problems with playback in a theatre with poor acoustics or inadequate equipment — low-level components of the sound-track can be lost, and high-level signals can cause system overload and audible distortion.

Dolby Laboratories does not enforce mandatory specifications to qualify a theatre for purchase of SR decoding equipment. However, to realize the full potential of Dolby SR, the theatre should comply with the minimum specifications listed in this document. Theatres not meeting these specifications will not benefit fully from the Dolby SR format.

Dolby Laboratories publishes a list of Dolby Stereo equipped theatres. This list is frequently used by film distributors in matching sound-track release formats to particular theatres. Future editions of this list will include separate listings of those ***premium*** theatres that are capable of faithfully reproducing the Dolby SR format. To be included in this separate listing, theatres must have installed suitable Dolby SR decoding equipment, but ***must also confirm that the theatre has an overall playback performance equal or superior to the minimum specifications listed below.***

While occasional film titles may be released in single inventory — i.e., all prints are recorded in Dolby SR — many titles will be issued with separate SR prints. In this case, theatres on the ***premium*** Dolby SR theatre list will usually be given first access to Dolby SR encoded prints. However, theatres not on the ***premium*** list should have no difficulty in obtaining conventional A-type Dolby Stereo prints.

This distinction between ***premium*** theatres (those with Dolby SR decoding equipment ***who also*** meet the technical specifications) and conventional Dolby Stereo theatres re-inforces the importance of a theatre's achieving the required playback specifications ***along with*** purchase of Dolby SR equipment.

This booklet does not cover information on installation of Dolby SR decoding equipment, which can be found in the relevant equipment manuals.

Each specification in this document is defined in bold-face type, and has supporting notes alongside. While few of the specifications should be considered definitive on a "pass-or-fail" basis, all describe contemporary good practice. The material below is broken down as follows:

A-chain characteristics

1. A-chain frequency response
2. Exciter lamp supplies
3. Slit illumination uniformity
4. Projector wow and flutter

B-chain characteristics

5. Screen B-chain characteristics
6. Surround B-chain characteristics
7. Power amplifier requirements
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Acoustic characteristics

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MINIMUM THEATRE SPECIFICATIONS

1. 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 k5 band, and no more than 3 dB down in the 16 kHz band.

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 0.00050" performs much 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.

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 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.

2. 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. 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

The only existing 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.

4. 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. 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 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.

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.

5. 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 beyond 10kHz to 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. See Figure 1.

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 may well require use of bi-amplification and an active cross-over. The required uniformity of response will normally require use of constant directivity high-frequency horns.

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

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

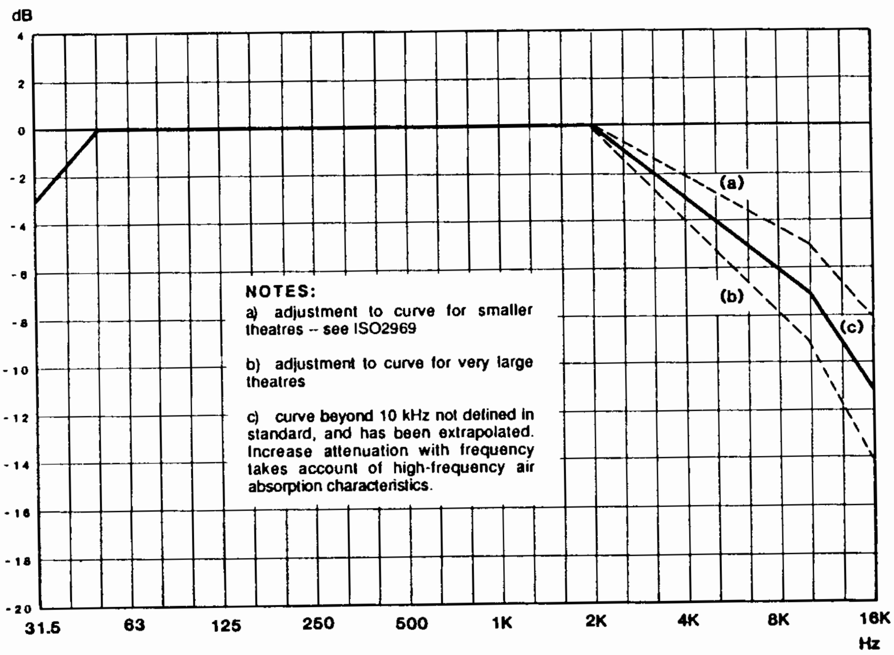

Figure 1: Target B-Chain Screen Loudspeaker frequency response

6. 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 3 dB.

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 will normally prove 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, thus avoiding the risk of various operational problems, including bad sound-head azimuth, and excessive impulse noise with worn prints. Occasional 70mm magnetic prints have full bandwidth discrete effects on the surround track, and this may require analysis of surround loudspeaker response beyond 8 kHz.

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 will normally dominate.

This large number of variables means that the ideal correction characteristic will be unique for each theatre. Figure 2 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.

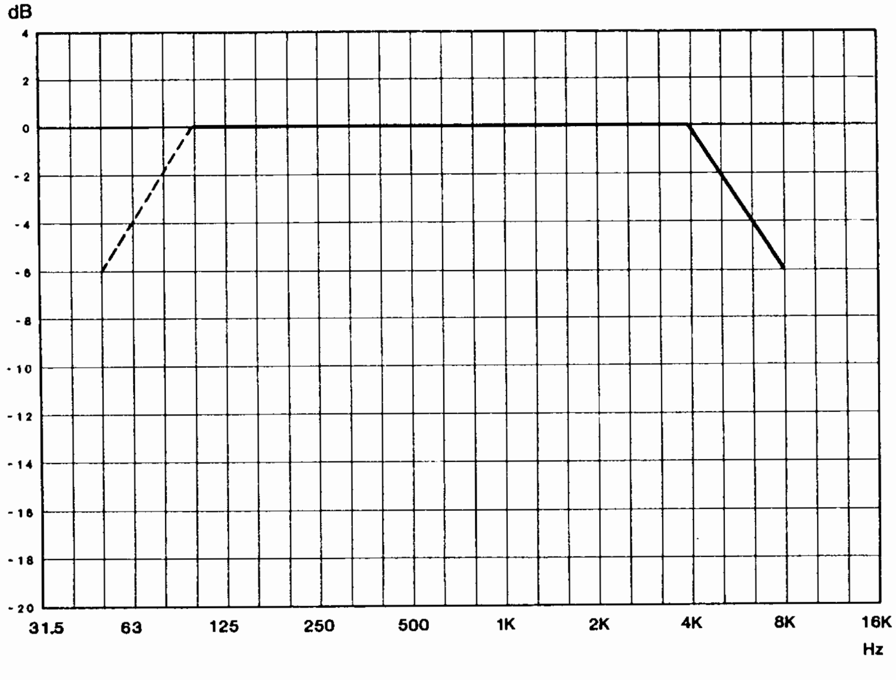

Figure 2: Typical Surround B-chain frequency response

7. Each channel of the sound system should have a power handling comfortably adequate to play back an SR film recorded at 100% modulation level at all frequencies throughout the audio bandwidth.

The dialog level of an SR film when played back will be at the same 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 is one of the great advantages of the Dolby SR format. Depending on the signal content, the **peak** levels on an SR film, especially at frequency extremes, can be up to 9 dB higher, as shown in Figure 3.

This will typically require power amplifiers for the screen channels with total power output ratings of at least 250 watts. Surround channels will probably need at least 400 watts.

Large theatres will require even more power — luckily, 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 equip with amplifiers with a power safety margin.

It is very difficult to determine audibly the onset of clipping when pink noise is used as a test signal — consequently this test is more conveniently carried out with an oscilloscope connected to the power amplifier output terminals.

Power amplifier headroom capability can be verified 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.

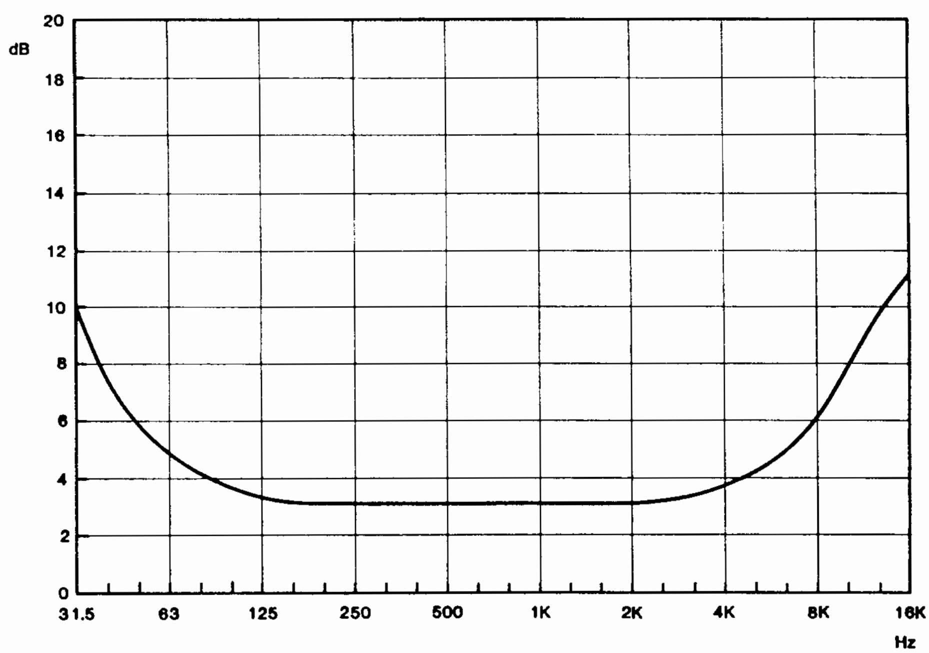

Figure 3: Potential increase in peak levels with Dolby SR over Dolby A-type

8. The installation should ideally include sub-woofer(s), driven by an optical bass extension module and a dedicated power amplifier.

One of the main benefits of Dolby SR with optical sound-tracks is the improvement in signal handling at frequency extremes. Figure 3 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.

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 in CP50 and CP200 units, and Cat. No. 241 in CP55 units.

9. 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 films 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 or adjacent screen breakthrough.

Figure 4a 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 4b shows a family of curves for use in ***third-octave*** bands.

9. (continued)

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

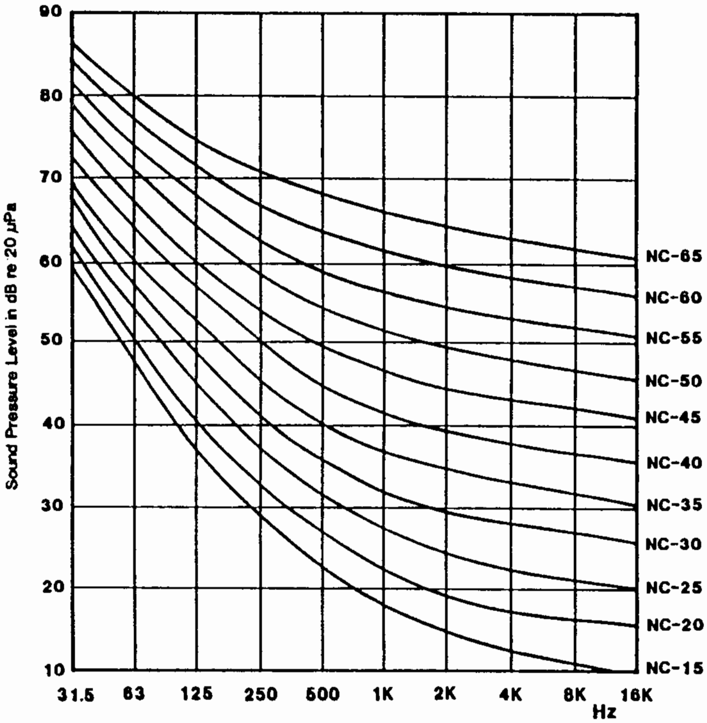

Figure 4a: Family of NC-Curves, whole octave

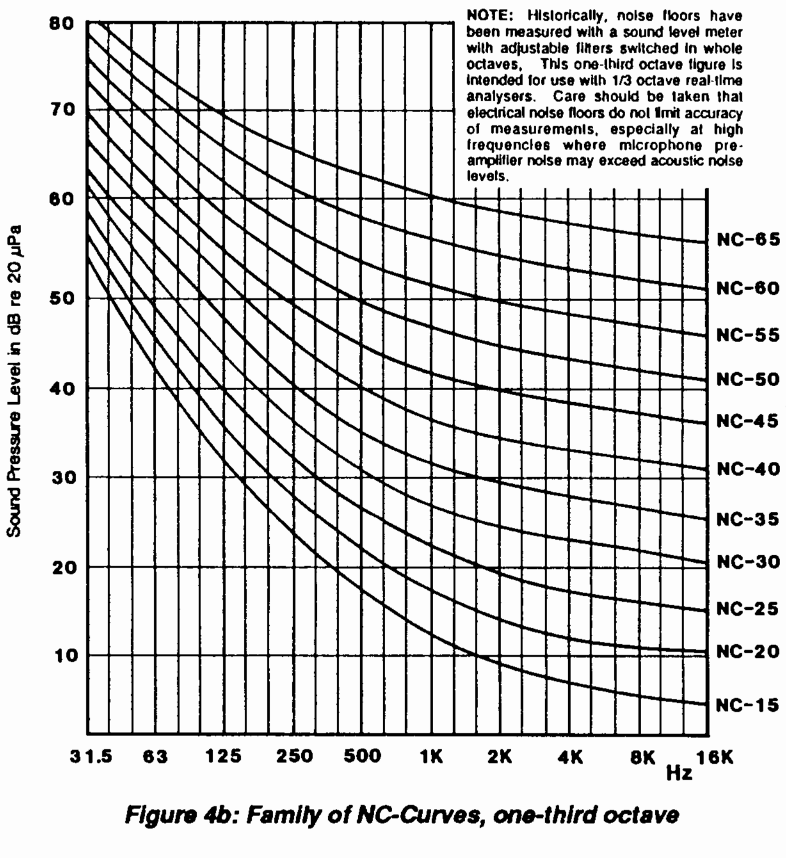

Figure 4b: Family of NC-Curves, one-third octave

10. The reverberation characteristic for a theatre should be within the ranges shown in Figures 5a and 5b.

Within reason, the reverberation characteristic of a theatre should be as short as possible. Excessive reverberation results in colorization of the sound and reduced intelligibility of the dialog. Assuming a theatre is built with optimum 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 5a shows the optimum 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 5b 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 5a.

Note: Reverberation time measurement techniques are discussed in ISO 3382.

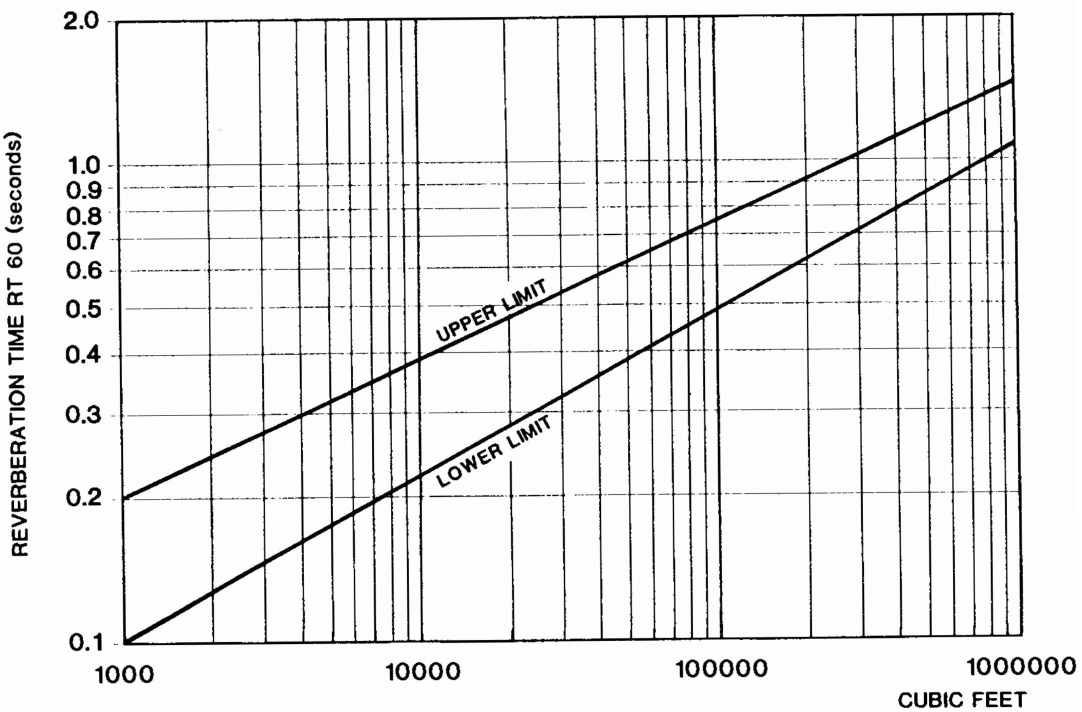

Figure 5a: Range of acceptable reverberation times at 500Hz v. room volume

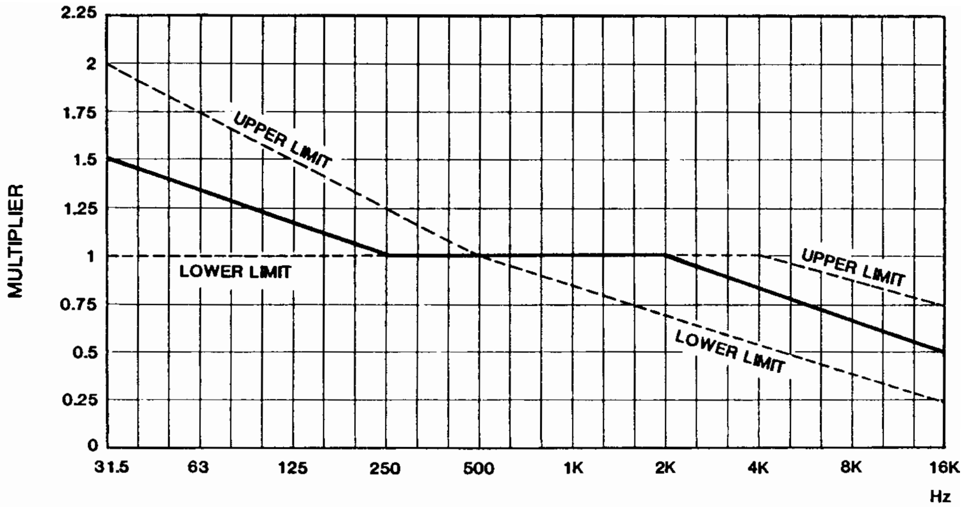

Figure 5b: Scaling curve showing variation of Rt v. frequency

11. 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 absorbant 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 acoustic 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 acoustic absorbent material.

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

**THX is a registered trademark of Lucasfilm Ltd*

12. 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 aspect ratio anamorphic picture. If screen masking covers these loudspeakers when a 1.85:1 picture is being projected, high-frequency attenuation 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. We see a trumpet player close to the right edge of the screen, and the objective of stereo sound is to place the apparent sound source sufficiently close to the image of the trumpet, 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 an angle of around 60 degrees. In the home the distance from the loudspeakers are short, and the room surfaces 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 is dominantly reverberant information coming from many directions, reflected from many room surfaces. Only in the first row or two at best 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 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, as 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 acoustically-transparent loudspeaker grille cloth (as used for high-fidelity loudspeakers) can be used for an insert covering the small area of the masking obscuring the high-frequency horns. For new theatres, masking cloth has been developed which appears matte black, is acoustically virtually transparent and is only slightly more expensive than the black felt it makes obsolete.

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.

13. 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 film may require updating selected boards in early CP50 and CP200 units.

13A. *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 most normal 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 production versions of the Cat. No. 150 decoder module are 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 and B should probably be replaced; old Cat. No. 116 decoders are certainly unacceptable for SR playback.

13B. *Optical pre-amplifiers*. As discussed in Section 1 above, 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, which was introduced with Serial Number 11570. All CP55 unit pre-amplifiers have adequate performance.

13C. *Dynamic range*. Dolby SR 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 Dolby SR. Cat. No. 64 equalizer modules of Revision C, for example, have a significantly lower noise level than earlier variants.

If a particular cinema processor appears to have headroom or noise problems after installation of an SRA5 adaptor for SR decoding, the theatre engineer should call Dolby Laboratories. This will make it possible to determine whether performance at dynamic range extremes could be further improved by fine-tuning processor alignment, or whether module updates would be justifiable.

14. 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.

Many elements contributing to the quality of the projected image can be fully quantified by application of published standards, which cover virtually every consideration relating to the picture. The issues of most importance are discussed in the following documents:

ANSI PH22.196: Screen Luminance, Stray Light
SMPTE RP105: Picture Jump and Weave
ANSI PH22.195: Projected Area

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

15. Standards Documents

SMPTE and ANSI documents can be ordered from:

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

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

16. Equipment Manuals

Manuals are available from Dolby Laboratories for the following Cinema Processors:

CP50
CP200
CP55

A manual is available detailing installation instructions for the SR adaptor,

SRA5

17. Test Films

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: DEFA-AUSSENHANDEL, Milastrasse 2
DDR - Berlin 1058

Test films available from Dolby Laboratories include:

Cat. No. 69: Double-sided test film —
Dolby tone at 50% reference level
Pink noise
Cat. No. 97: Left/right test film for cell alignment
Cat. No. 151: Centre/surround shaped pink noise for surround loudspeaker level setting
Cat. No. 251: *"Jiffy"* test film — Dolby A-type material for subjective overall sound system evaluation
Cat. No. 351: *"Listen..."* demonstration film, Dolby A-type material, suitable for public exhibition

18. Other Information Sources

THX: Lucasfilm Ltd, P.O. Box 2009, San Rafael, CA 94912

19. Dolby Technical Help Phone Number

Monday - Friday 8:00 a.m. - 5:30 p.m. (Pacific Time) 415-558-0200
Outside of business hours for theatre emergencies call: 415-565-4436

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