CINEMA SOUND SYSTEM MANUAL

I. INTRODUCTION:

The decade of the 1980's has seen many improvements in the quality of motion picture sound. Dolby Laboratories began the cinema sound revolution during the middle 1970's, with noise reduction and equalization of cinema loudspeaker systems. In 1981, JBL demonstrated the first flat power response loudspeaker systems at the Academy of Motion Picture Arts and Sciences. In 1983, Lucasfilm, Ltd. introduced the THX® system, along with their program of cinema certification. As the 1980's have progressed, Dolby stereo optical sound tracks have gained in favor, increasing the number of stereo houses significantly. The application of Dolby Spectral Recording™ to motion picture release prints represents another step forward in sound quality.

As new cinema complexes are being planned and constructed, acoustical engineers are now regularly engaged to deal with problems of architectural acoustics and sound isolation between adjacent exhibit spaces. More attention is being paid to the specification of sound equipment and its careful integration into the cinema.

JBL's commitment to the motion picture market is very strong. The company has become the acknowledged leader in the field, and JBL's products are routinely specified for major studios and post-production facilities throughout the world.

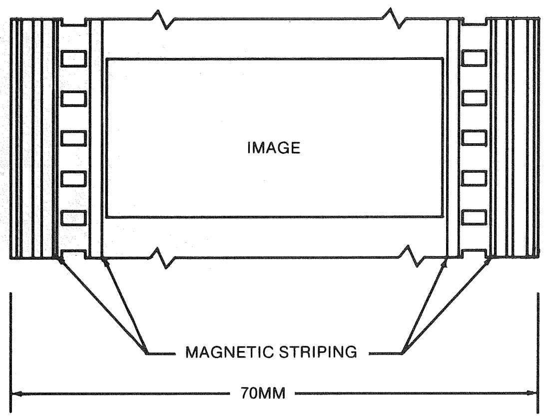
This manual has several goals. First, it will provide a background in basic system concepts, and then move on to acoustical considerations in the cinema. The subject of electroacoustical specification will be discussed, as will the problems of mounting and aiming of the components. Electrical interface and system checkout will be covered in detail. JBL believes that the more dealers and installers know about the basics of sound in the cinema, the better will be the results of their work in all areas.

II. BASIC SYSTEM CONCEPTS:

A. Film Formats:

There are basically two film gauges, 35 mm and 70 mm. The projection ratios for 35 mm can be either 1.85:1 ("flat") or 2.35:1 ("scope"). Seventy mm prints are normally projected at a ratio of 2.2:1. The advantages of the 70 mm format are the availability of six magnetic tracks and, of course, larger image area. The cost of a 70 mm release print is quite high, and these prints are made primarily for exhibition in premier houses in large metropolitan locations. Today, the general practice with 70 mm is to use three channels behind the screen (left, center, and right) and a single surround channel feeding multiple loudspeakers. Options are to use the remaining two magnetic tracks for subwoofer signals and/or split (two channel) surrounds. The 35 mm format was modified during the 1950's to handle four magnetic tracks: three screen channels and a single surround channel. At the same time, the standard monophonic variable area optical track was maintained. Figures 1A and B show the channel layout for both 70 mm and 35 mm magnetic standards. At present, 35 mm magnetic sound is no longer in general use.

A. 70 mm



B. 35 mm

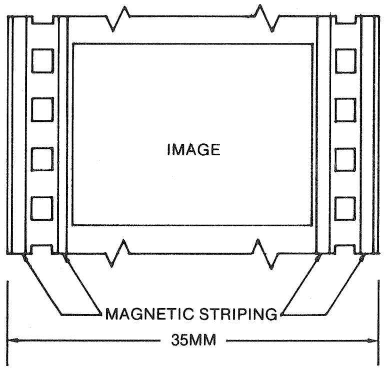


Figure 1. 70 mm six track magnetic format (A); 35 mm four track magnetic format (B)

Today, the Dolby Stereo Optical system is virtually a standard format on 35 mm film. In this process, the dual bilateral variable area optical sound tracks, which were formerly modulated with a single monophonic signal, are now modulated in stereo, as shown in Figure 2. Recording on the two soundtracks is accomplished through a matrix, which accepts input for the three screen channels and the single surround channel. The signals intended primarily for the left and right screen loudspeakers are fed to the left and right channels. Program material intended for the center screen loudspeaker, including most on-screen dialog, is fed to both stereo channels in phase. The in-phase relationship between the stereo channels triggers the playback matrix to steer that information primarily to the center screen loudspeaker, through a combination of gain control and altering of coefficients within the matrix circuits. In a similar manner, information intended for the surround channels is fed to both stereo channels so that there is a 180° phase relationship between them. This phase relationship triggers the playback matrix to steer that information primarily to the array of surround loudspeakers.

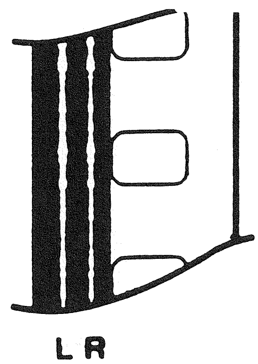


Figure 2. 35 mm Dolby Stereo Optical format

The surround channel is delayed relative to the other channels so that, by the precedence effect, the surround channel will not dominate the perceived sound field in the middle and back of the house. The reason for this is that the matrix output contains certain "leakage" signals which will be disturbing to a listener if such signals were to be heard from the surround loudspeakers. In practice, the surround channel is delayed with respect to the screen channels so that the most distant listener will hear that channel delayed by a minimum of 20 milliseconds. Since the ear will "lock in" on earlier arrival sounds, localization will be maintained in the direction of the screen for all patrons, while effects intended only for the surround channel will be clearly heard from the surrounds. This problem is further addressed by rolling off the response of the surround channel above about 7 kHz.

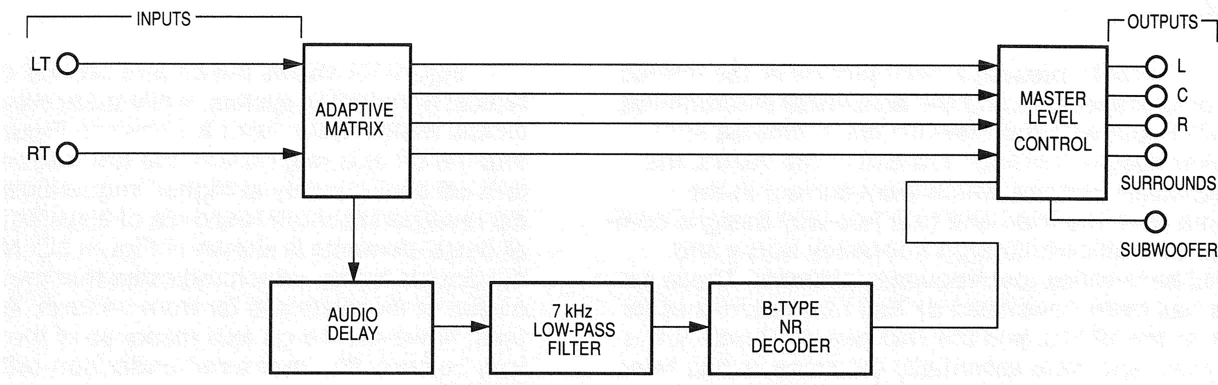
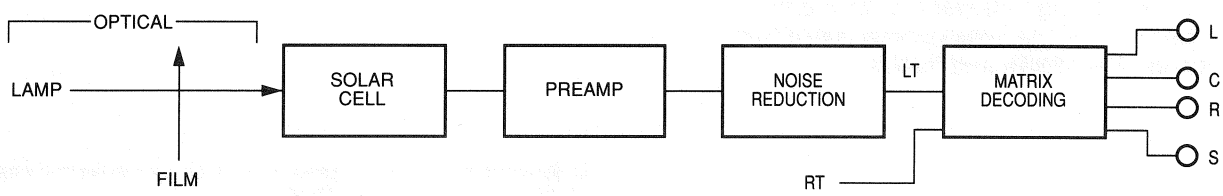


Figure 3. Block diagram of the Dolby Stereo Optical playback matrix

A. A-Chain



B. B-CHAIN

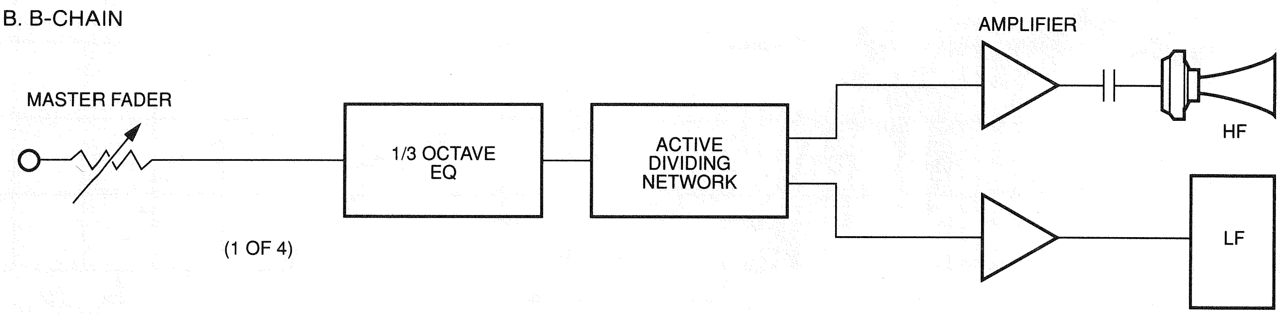


Figure 4. Block diagrams of the A- and B-chains in a motion picture sound installation

B. A-and B-chains:

For convenience in defining responsibilities for system specification and alignment, the playback chain is customarily broken down into the A-chain and the B-chain, as shown in Figure 4. The A-chain is comprised of the preamplifiers (optical or magnetic), light source (optical), magnetic heads, solar cells (optical), associated equalization (signal de-emphasis), noise reduction and directional decoding required for flat electrical output at the end of that chain, and overall gain control for the system.

The B-chain is comprised of one-third octave equalization, dividing networks (low or high level), power amplification, and loudspeakers. JBL, UREI, and their associated companies are involved with components used in the B-chain of the system.

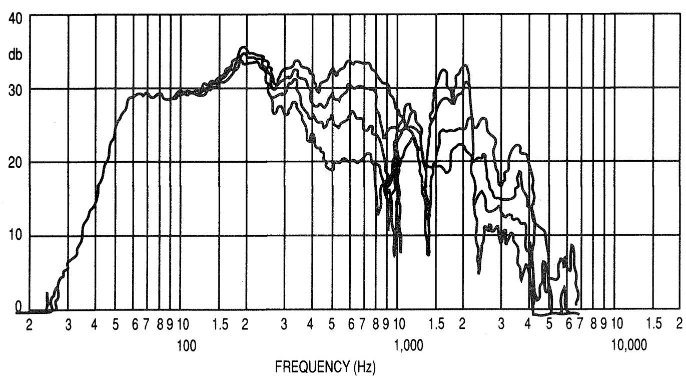
C. Integration of Loudspeakers into the Acoustical Environment:

In order to present a clear picture of the interaction of loudspeakers and the acoustical environment, we will begin with the previous era in cinema loudspeaker design. Through the end of the 1970's, the loudspeaker systems which were current in the cinema were the tried and true two-way designs composed of multicellular high frequency horns and hybrid horn/reflex low frequency systems. These systems had been developed by Bell Laboratories as far back as the 1930's, and the versions used until just a few years ago were essentially the same as had been developed and refined by Lansing and Hilliard (1). These systems were well engineered in terms of efficiency, ruggedness, and low distortion, given the acoustical performance demands of the day. Their designers had also successfully coped with the problems of frequency division and arrival time differences between high and low frequency sections. The chief weakness of these systems was their lack of uniform coverage. System design stressed output conversion efficiency, because of the small power amplifiers available during the 1930's and 1940's.

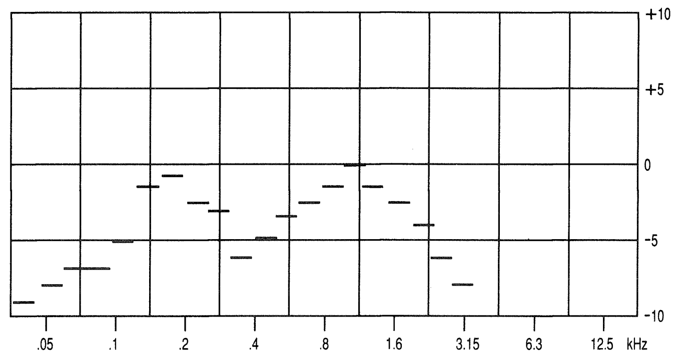
Figure 5A shows the on and off axis curves of a typical horn/reflex system, while polar response of a typical multicellular horn is shown in Figure 5B. Note that the off axis response of the low frequency system falls off considerably at higher frequencies. The typical reverberant room response of a system composed of these elements is shown in Figure 5C. Note here the double hump, which indicates that the total power output of the system is far from uniform. At the same time, however, the on axis response of the system may be fairly flat, measured under non-reflective conditions.

If any attempt is made to equalize the response of this system in the cinema, then the response along the major axis of the system will be anything but flat. This is precisely the problem which Dolby Laboratories encountered when they introduced equalization into cinemas during the 1970's.

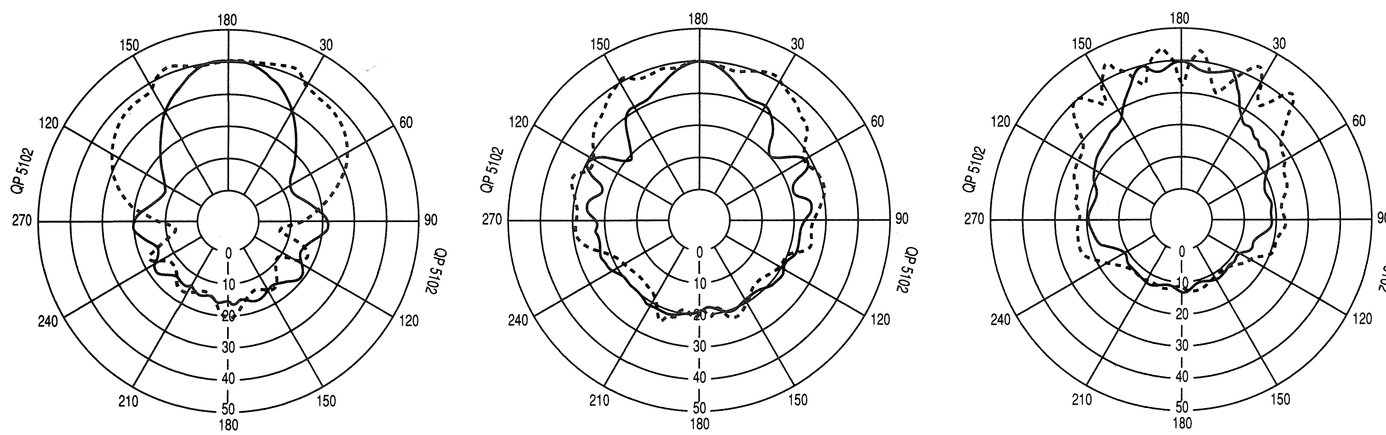
A. Off-axis response of ported horn system.



C. Reverberant (power) response of a cinema system composed of elements similar to those shown at A and B.



B. Polar characteristics of a 2 x 5 multicelluar horn



Multicellular horn (2 x 5, 1000 Hz vertical (solid); horizontal (dashed).

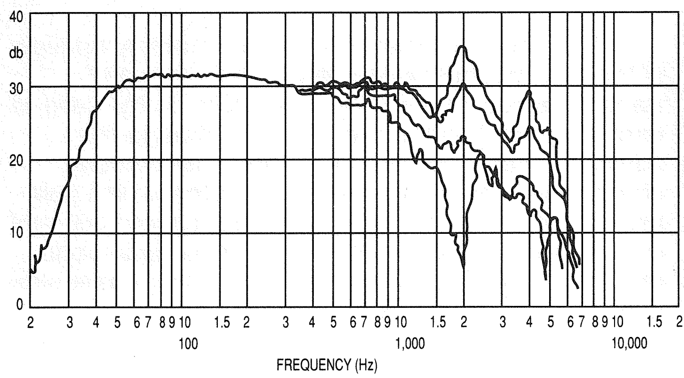
Multicellular horn (2 x 5, 2000 Hz vertical (solid); horizontal (dashed).

Multicellular horn (2 x 5, 10 kHz vertical (solid); horizontal (dashed).

Figure 5. Theater equalization of old style cinema system

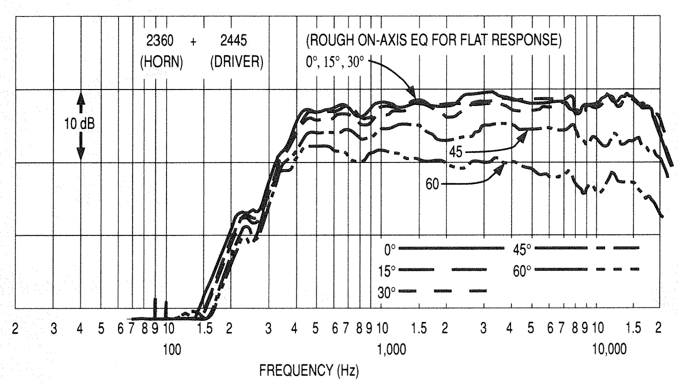
D. Power Response and Power-Flat Systems:

The discrepancy between on axis and reverberant room response in the older systems was solved with the introduction of a new family of systems based on uniform coverage high frequency horns and simple ported low frequency enclosures. Figure 6A shows the horizontal off axis response of a dual 380 mm (15 in) low frequency system. Observe that the response below 500 Hz is uniform over a wide angle.



A. Off-axis response of dual 380 mm (15") LF transducers in a ported enclosure

Figure 6B shows the off axis response curves for the JBL 2360A Bi-Radial™ horn, coupled to a JBL 2445J high frequency driver which has been equalized for flat power response. Note that the off axis curves are essentially parallel, indicating that the horn produces a solid radiation angle which is uniform with respect to frequency. The need for equalization of the compression driver comes as a result of the natural high frequency roll-off which occurs in these drivers above about 3.5 kHz. This frequency is known as the "mass break point" and is a function of diaphragm mass and various electric and magnetic constants in the design of the driver.

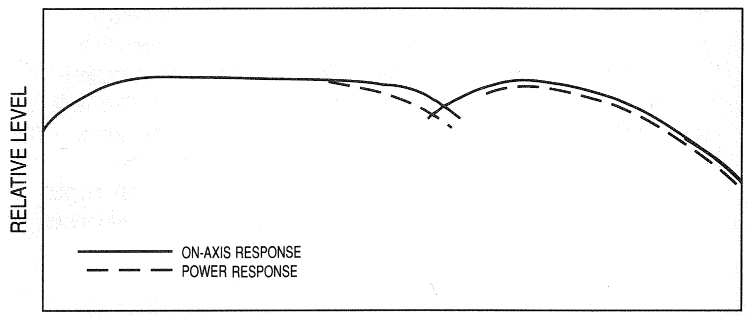


B. Off-axis response of a JBL 2360 horn equalized for flat power response

Figure 6. Off axis characteristics of ported low frequency systems and Bi-Radial horns

When the 4648A low frequency system and the 2360/2445 combination are integrated into a full range system for cinema use, the -6 dB beamwidth above 500 Hz is smoothly maintained at 90° in the horizontal plane and 40° in the vertical plane out to 12.5 kHz. At lower frequencies, the system's coverage broadens, eventually becoming omnidirectional in the range below 100 Hz.

When the system described above is equalized in a typical cinema environment, both direct sound and reverberant sound can be maintained quite smoothly, as shown in Figure 7. The system's reverberant response is proportional to its power output, or to its power response, and the matching of the system's on axis and power response indicate that the reflected sound field in the cinema will have the same spectral characteristics as the direct sound from the loudspeaker. When this condition exists, sound reproduction, especially dialog, will sound extremely natural.



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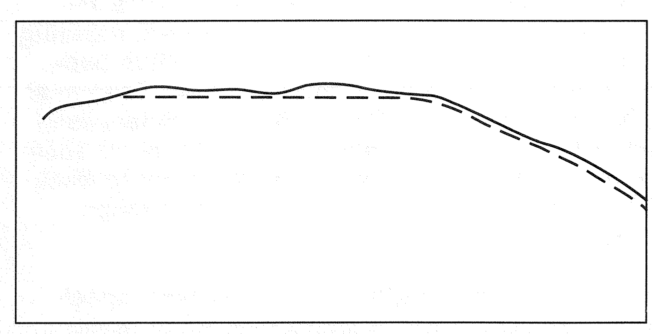


EQUALIZED

Figure 7. Cinema equalization of power-flat systems

JBL pioneered this concept for the cinema (2,3). It has become the guiding principle in much of JBL's product design, and it has been adopted by the industry at large.

E. Coverage Requirements for Proper Stereo Reproduction:

In the cinema, it is expected that all patrons will be able to appreciate convincing stereo reproduction. In contrast, standard two channel stereo in the home environment often imposes strict limitations on where the listener must sit in order to perceive stereo imaging. The factor which makes the big difference in the cinema is the presence of the center channel. Not only does the center loudspeaker lock dialog into the center of the screen, it further reduces the amount of common mode information the left and right channels must carry, thus making it possible for listeners far from the axis of symmetry to hear the three channels with no ambiguity, or tendency for the signal to "collapse" toward the nearer loudspeaker. In the Dolby stereo matrix, the same convincing effect is largely maintained through gain and coefficient manipulation during playback.

Ideally, each patron in the house should be within the nominal horizontal and vertical coverage angles of all the high frequency horns. This requirement can usually be met by using horns with a nominal 90° horizontal dispersion and by toeing in the left and right screen loudspeakers. In very wide houses, the spreading of high frequencies above approximately 5 kHz, as they pass through the screen at high off axis angles, actually helps in providing the desired coverage.

Another goal is to maintain levels as uniformly as possible throughout the house. In most houses, it is recommended that the high frequency horns be aimed at a point two-thirds back in the audience area at ear level along the center line of the house. Where the back wall of the house is highly absorptive, the horns can, in fact, be aimed at the back wall, resulting in further reduced level variation from front to back. Such was the case in the Samuel Goldwyn Theater at the Academy of Motion Picture Arts and Sciences in Beverly Hills, California, and our measurements show that, over most of the frequency range, front-to-back levels in the house are maintained within a range of 5 dB.

The surround loudspeakers, if properly specified, can easily produce a sound field which is uniform throughout the back two-thirds of the house, and level variations can often be held within a range of 2 to 3 dB. Details of surround system specification will be covered in a later section.

When all of the above points are properly addressed, the sound in a cinema can approach that which we take for granted in a post-production screening facility. It is only when such details as these have been carefully worked out that the effects intended by the sound mixer can be appreciated by the viewing audience.

III. ACOUSTICAL CONSIDERATIONS:

A. Noise Criterion (NC) Requirements:

The usual sources of noise in a cinema, outside of the patrons themselves, are air handling and transmission of noise from the outside. In the case of multiplex installations, there can be leakage from adjacent cinemas as well. Not much can be done about a noisy audience, but it is true that at the post-production stage, mixing engineers take into account certain masking noise levels which may be encountered in the field and even do the final mix under simulated noisy conditions (4).

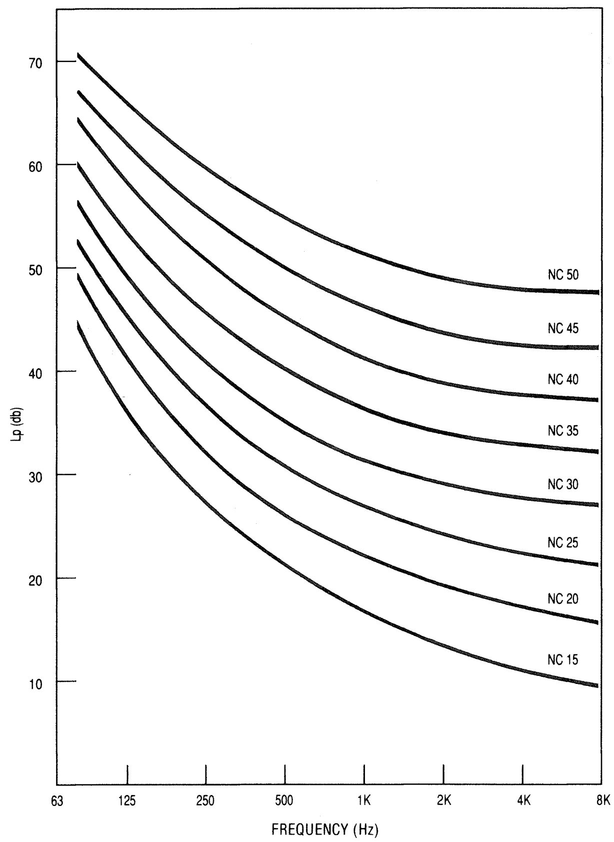


Figure 8. Noise Criterion (NC) curves

Acoustical engineers make use of what are called Noise Criterion (NC) curves in attempting to set a noise performance goal for cinemas. These curves are shown in Figure 8. In implementing this data, the acoustical designer settles on a given criterion and then determines the cost and other factors which may be involved in realizing it. Low noise air handling requires large ductwork and is expensive. Even more likely to be a problem is through-the-wall isolation from adjacent cinemas. The general recommendation made by Lucasfilm (5) is that interference from adjacent cinemas should be audible no more than 1% of the time. Considering that NC-30 may represent a typical air conditioning noise level for a theater, the desired degree of isolation between adjacent spaces does not represent a hardship in terms of wall construction.

As an example of what may be required, let us assume that the normal maximum levels in a multiplex cinema are 95 dB-SPL, with levels exceeding this value only about 1% of the time. It is clear that the isolation from an adjacent cinema must be on the order of 65 dB if the NC-30 criterion is to be met, and this will call for a wall structure which will satisfy a Sound Transmission Class (STC) of 65 dB. There are a number of double wall, or single concrete block wall, constructions which will satisfy this requirement, and economic considerations usually take over at this point. Acoustical engineers and consultants are usually on firm ground here. Standard STC curves are shown in Figure 9.

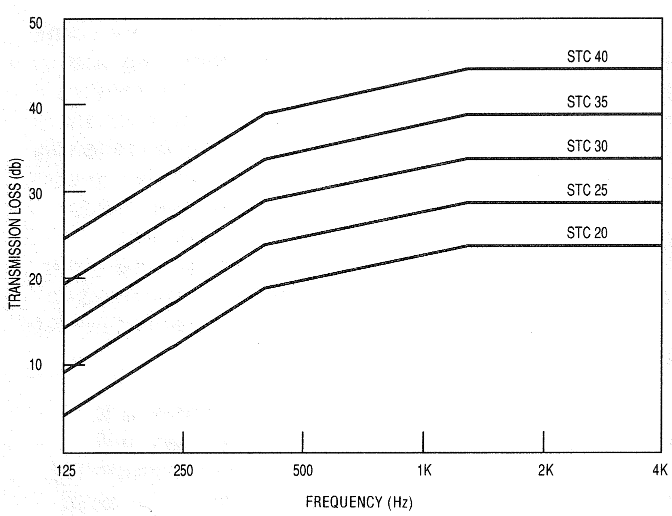


Figure 9. Sound Transmission Curves

The isolation task is certainly easier with new construction, since buffer areas can be designed between adjacent exhibition spaces. The most difficult problems occur when older spaces are to be subdivided to make multiplex cinemas, inasmuch as the chances of coupling through walls or through common air handling are compounded.

It is obvious that the architect must work closely with an acoustical engineer if the job of isolating adjacent spaces is to be done correctly. There is nothing here that does not yield to straightforward analysis, although the job is often a tedious one.

B. Control of Reverberation and Discrete Reflections:

After the problems of sound isolation have been addressed, the acoustical engineer then turns to those problems which are generated entirely *within* the cinema itself, reverberation and echoes. The acoustical "signature" of a cinema should be neutral. Reverberation *per se* is not generally apparent in most houses, and any perceived sense of reverberation or ambience during film exhibition normally comes as a result of the surround channel.

This is not to say that the cinema environment should be absolutely reflection free. Strong initial reflections from the sides of the house may be beneficial, in that they convey a sense of natural acoustical space; however, they should not be followed by a clearly audible reverberant decay.

Traditionally, reverberation time in auditoriums increases at low frequencies and decreases at high frequencies. This is a natural consequence of the fact that many surfaces which are absorptive at middle and high frequencies are not very effective sound absorbers at low frequencies. At higher frequencies, there is additional absorption due to the air itself, and this excess attenuation of high frequencies tends to lower the reverberation time. Figure 10 shows the normal range of reverberation time, as a function of the value at 500 Hz, while Figure 11 shows the acceptable range of reverberation at 500 Hz as a function of room volume.

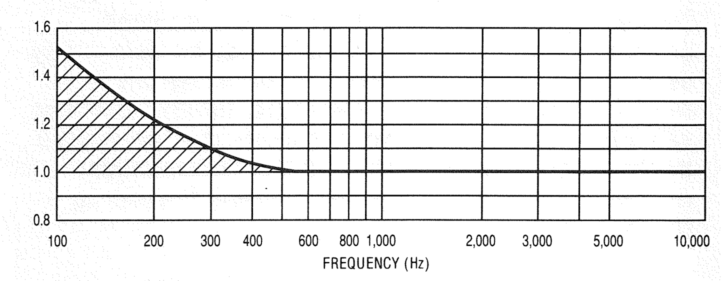


Figure 10. Variation of reverberation time with frequency (relative to the value at 500 Hz)

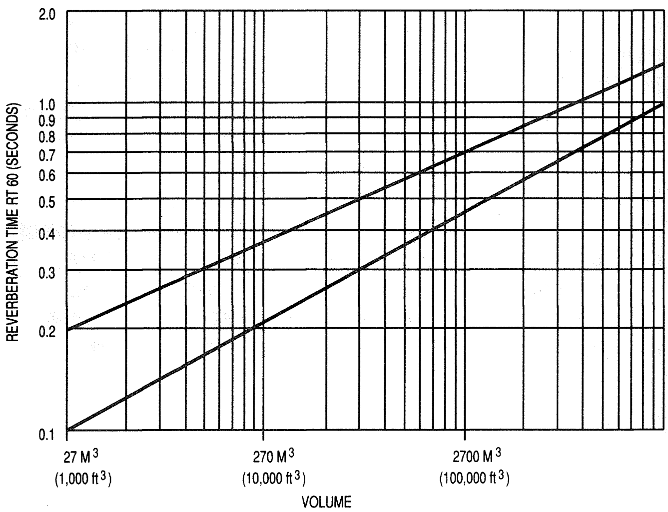


Figure 11. Suggested range of reverberation time at 500 Hz as a function of room volume

As an example, let us consider the Samuel Goldwyn Theater at the Academy of Motion Picture Arts and Sciences. Its volume is 5660 cubic meters, and the recommended range of reverberation time at 500 Hz is between 0.6 and 0.9 seconds. At low frequencies, the reverberation time could range from 1.2 seconds to 1.8, while at high frequencies it could range from 0.3 to 0.5 seconds. Most houses are, of course, much smaller than this, and their reverberation times may be shorter.

The requirements for specifying the proper finishing materials, along with any special needs for added low frequency absorption, fall squarely in the hands of the acoustical designer. In the smaller houses, there is often little choice but to make the room acoustically "dead"; however, some degree of reflectivity, even though it may not be perceived as such, will be beneficial.

Discrete reflections are likely to be a problem only if they are displaced from the direct sound which gives rise to them in both time and spatial orientation. Side wall reflections are usually perceived by the listener well within a time interval which does not allow them to be heard as such. However, a reflection off the back wall can rebound from the screen itself, creating a "round trip" echo which may be delayed by as much as 100 milliseconds. The effect here is to render dialog difficult to understand. In older cinemas with balconies, such reflections were often generated by the balcony fascia itself. Substantial acoustical damping had to be placed on the fascia in order to diminish the problem.

In most cinemas constructed today, echo problems can generally be dealt with by ensuring that the back wall is quite absorptive and that substantial damping is installed behind the screen.

C. The Role of the Acoustical Consultant:

An acoustical consultant should be chosen on the basis of previous jobs well done. There is much which is learned simply by having encountered—and solved—many problems. Stating it another way, an experienced consultant has probably seen most of the common mistakes and knows how to spot them before they become problems. While much of what a consultant does may seem obvious, and even simple, it is the breadth of experience which qualifies a good consultant to take on a difficult task and succeed at it.

In addition to the points discussed so far in this section, the consultant will look for potential difficulties in the following areas:

1. Flanking leakage paths: When acoustical isolation has been addressed in wall construction, flanking paths through, or around, the wall may become significant. For example, sound often leaks through electrical or air conditioning conduit, even though the wall itself may act as a good barrier to sound transmission. Such paths can crop up in many places and need to be identified early in the construction phase of the project.

2. Integrity in construction: Many building contractors routinely take shortcuts, and somebody needs to watch them carefully. The acoustical isolation of double wall construction can be nullified by the presence of material left between them which bridges the air barrier between the two sections.

3. Impact and structure-borne noise: These are some of the most difficult problems to fix, since they are literally "built in." Plumbing noises, elevator motors, and air handling machinery located on the roof are just a few of the offenders here. Once the installation has been made, the problem is very expensive to correct, and a good consultant will have an eye out for such things at the design stages of the project. Related problems, such as projector noise and other noises associated with concession activities need to be identified early in the project and corrected before construction begins.

As standards for film exhibition continue to improve, such points as we have raised here will become more important. In a recent monograph (5), Ioan Allen of Dolby Laboratories stressed the need for noise ratings in the cinema lower than NC-25, with NC-30 representing the worst acceptable case.

IV. SPECIFYING THE CORRECT LOUDSPEAKERS AND AMPLIFIERS:

A. Hardware Class vs. Room Volume:

In all but the smallest cinemas, dual low frequency systems, such as the JBL 4670C and the 4675B, should be specified. Normally, there will be three of the systems behind the screen in left, center, and right positions. The 4670C has the Flat-Front Bi-Radial® 2380A Horn, while the 4675B has the large 2360A Bi-Radial® Horn. The differences in performance are basically high frequency vertical pattern control in the range from 500 to 1000 Hz. Because of its small vertical aperture, the 2380A Horn loses pattern control below 1000 Hz, tending to produce a slight dip in power response when the system is equalized for flat on axis response. Whenever possible, the 4675B systems should be specified, but there are situations where space behind the screen is limited, and the smaller horn must be used.

Both systems are capable of the same acoustical output, inasmuch as they are both limited by the power handling capabilities of their identical low frequency sections. The following table indicates the sustained maximum sound pressure level in the reverberant field which these systems can produce, based on room volume. Levels for a single unit, as well as for the three units, are given. Median reverberation times as given in Figure 11 are assumed in these calculations, as are system directivity index and estimated room surface area.

Table 1: Maximum reverberant levels for JBL 4670C and 4675B systems in theaters of various sizes:

Volume required:	Level, single unit:	Level, three units:	Typical seating:	Power single unit:
270 m^3 (10,000 ft^3)	116 dB	121 dB	75-100	800 W
540 m^3 (20,000 ft^3)	113 dB	118 dB	150	800 W
1350 m^3 (50,000 ft^3)	111 dB	116 dB	300	800 W
2700 m^3 (100,000 ft^3)	109 dB	114 dB	500	800 W
5400 m^3 (200,000 ft^3)	107 dB	112 dB	1000	800 W

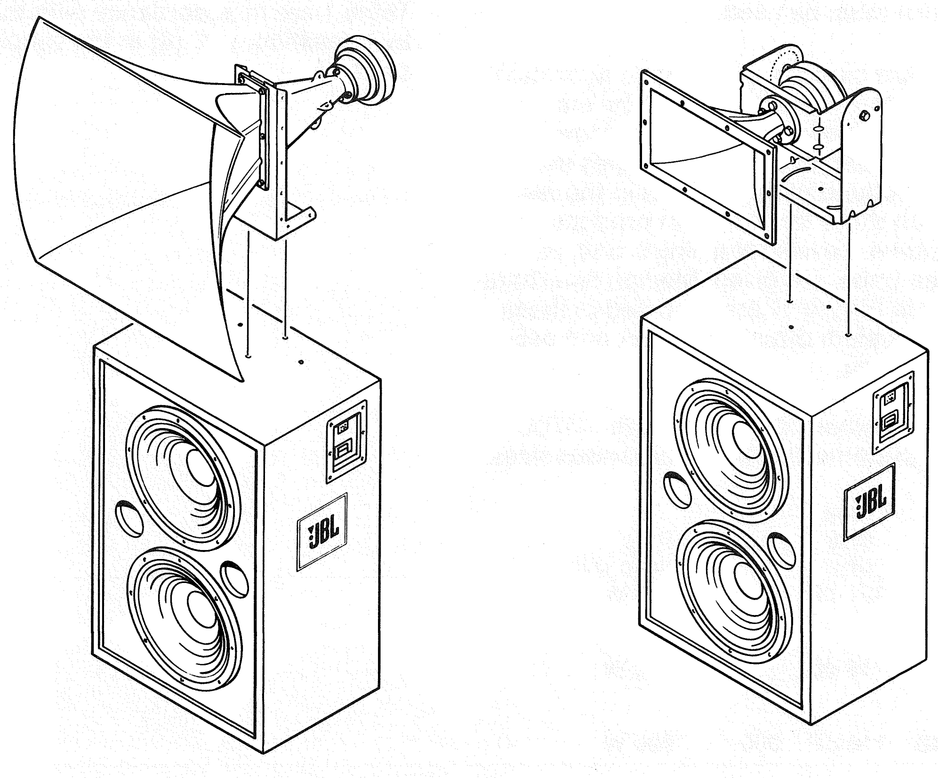
For spaces in excess of 2700 m^3, JBL recommends that the 4675B-2 be specified. This system has two low frequency enclosures, making a total of four low frequency transducers. This will raise the total output level capability by just slightly over 3 dB.

The actual level requirements in the filmmaker's dubbing theater are established by relating them directly with modulation level on the recorded medium. For magnetic media, this is established as 85 dB(C) in the house when the modulation on the film is so-called "zero level," or 185 nanowebers/meter. This last quantity has to do with recording technology, and we need not concern ourselves with it further, except to note that modulation peaks often exceed zero level by 8 to 10 dB. Thus, the peak output per loudspeaker may be only 95 dB. Good engineering practice allows additional headroom of 6 to 8 dB above this, so it is clear that the values we have listed in Table 1 are not excessive in the cases of the larger houses. In the smaller houses, we can certainly make do with smaller amplifiers than indicated in the table; but even then, the cost of the added power is very slight, and the benefit substantial. The powers recommended in Table 1 are in accordance with the suggestions made by Lucasfilm, Ltd. (6) in the specification of THX systems.

B. JBL Screen Loudspeaker Systems:

The main JBL loudspeakers recommended for behind-screen use are discussed in this section. Since all of these systems can be assembled and repaired in the field, we will show them in exploded views, along with a parts list and a wiring diagram for use with a high-level dividing network.

The models 4670C-HF, 4671A, 4673A, 4675B-HF, and 4648-TH are shown, respectively in Figures 12 through 16. Wiring instructions for biamplification will be discussed in a later section.



Complete system assembly diagram for 4670C and 4675B.

Figure 12.

JBL4670C-HF

COMPONENT EXPLODED VIEW

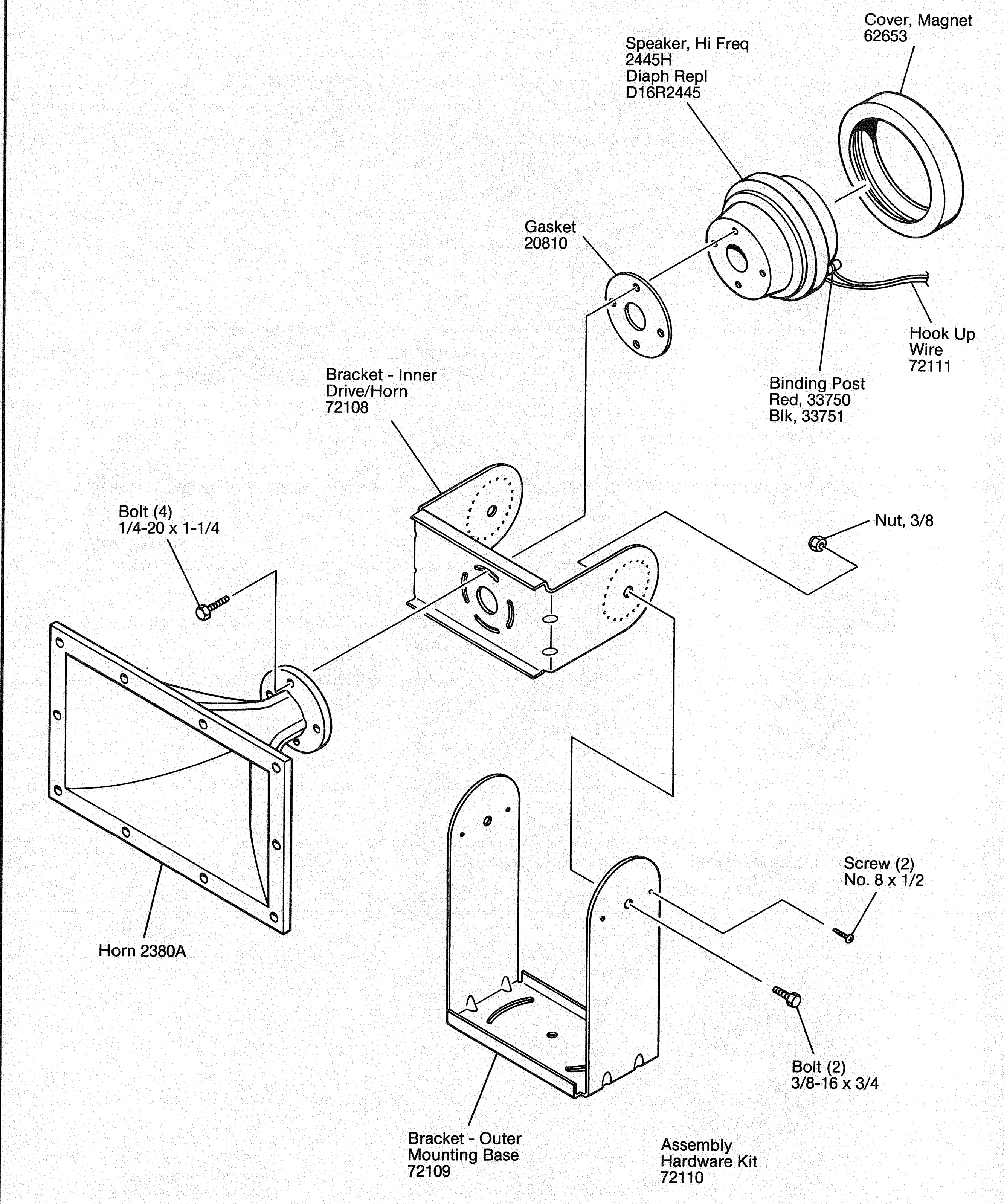
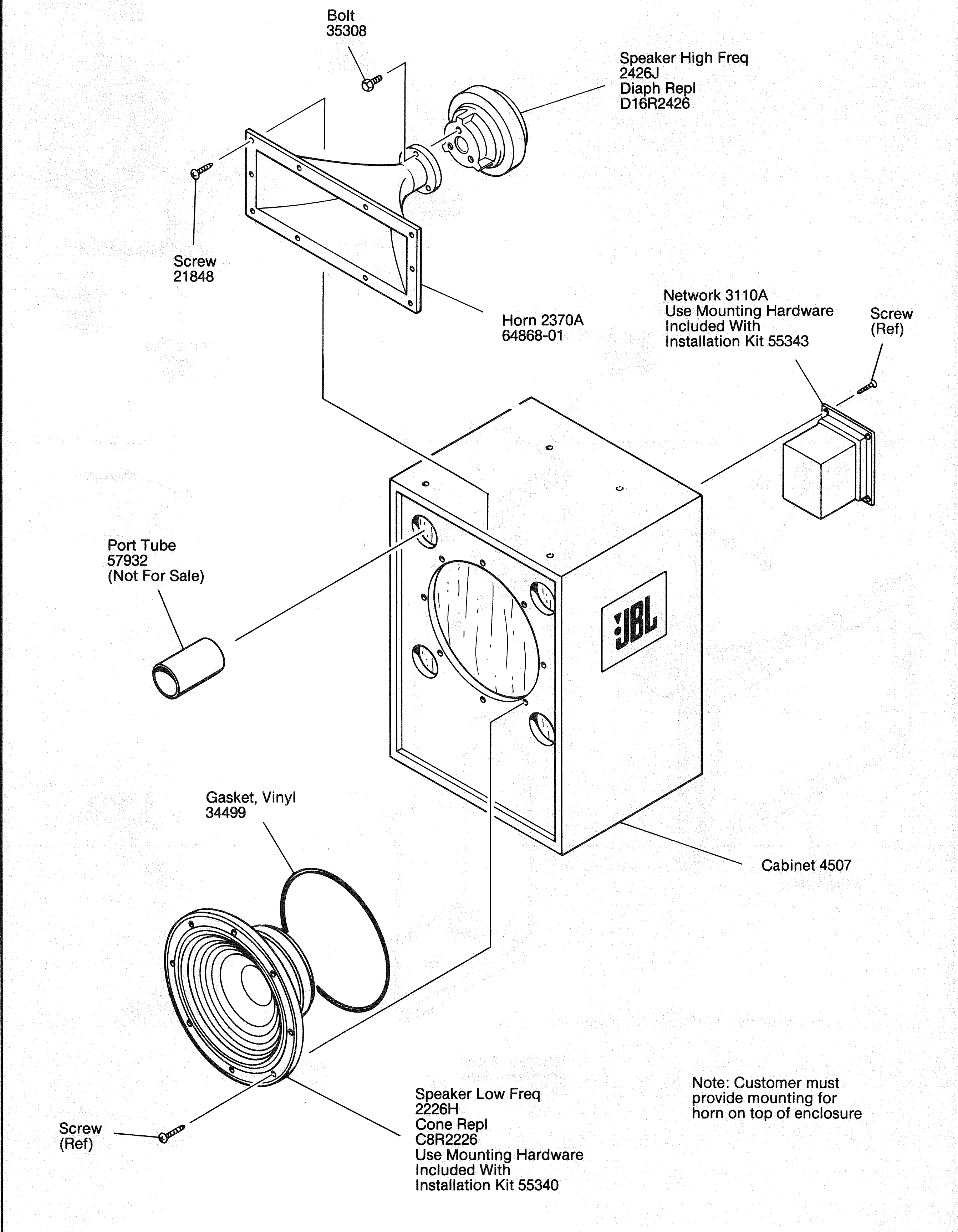


Figure 13.

JBL4671A

COMPONENT EXPLODED VIEW



JBL4673A

COMPONENT EXPLODED VIEW

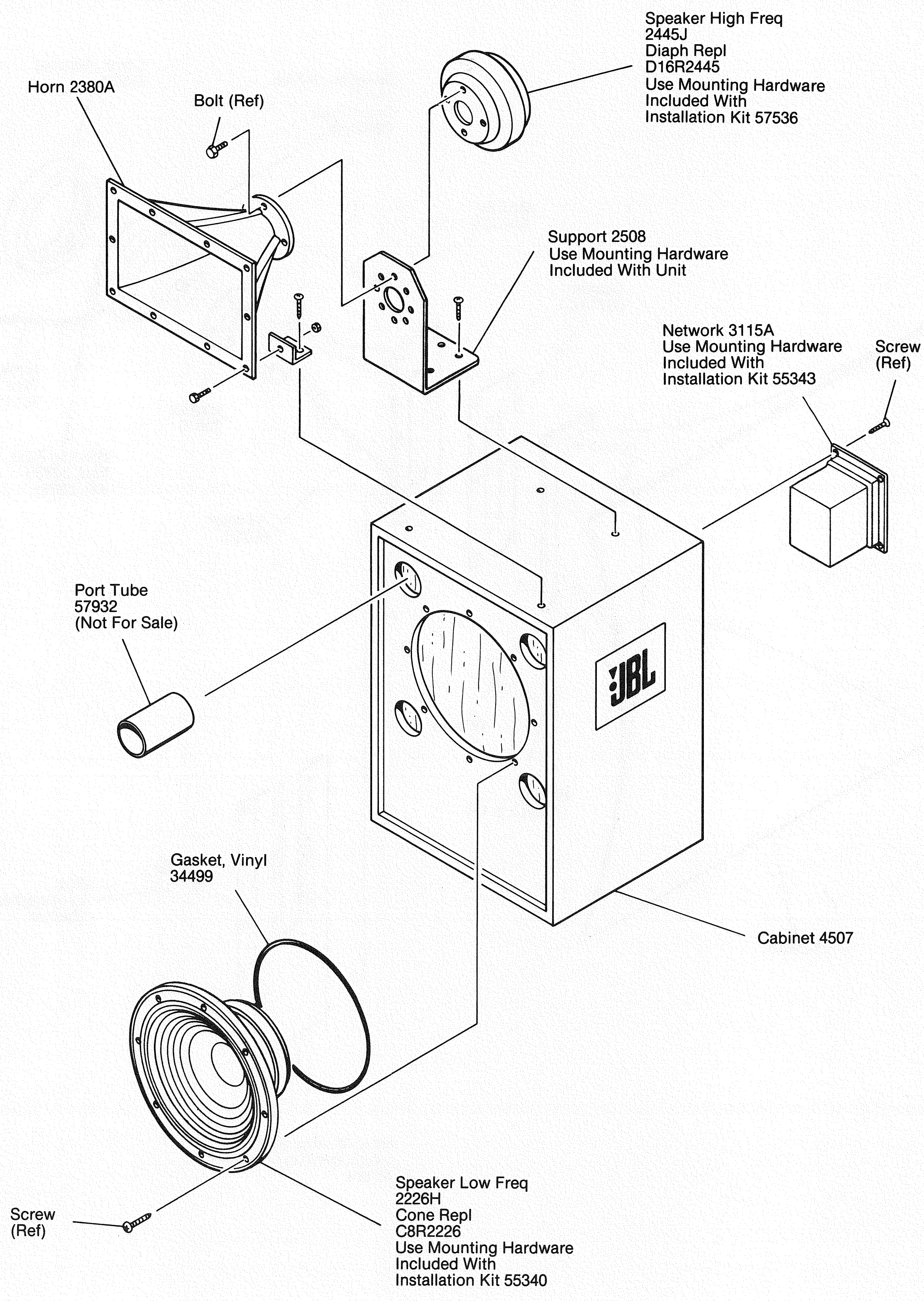


Figure 15.

JBL4675B-HF

COMPONENT EXPLODED VIEW

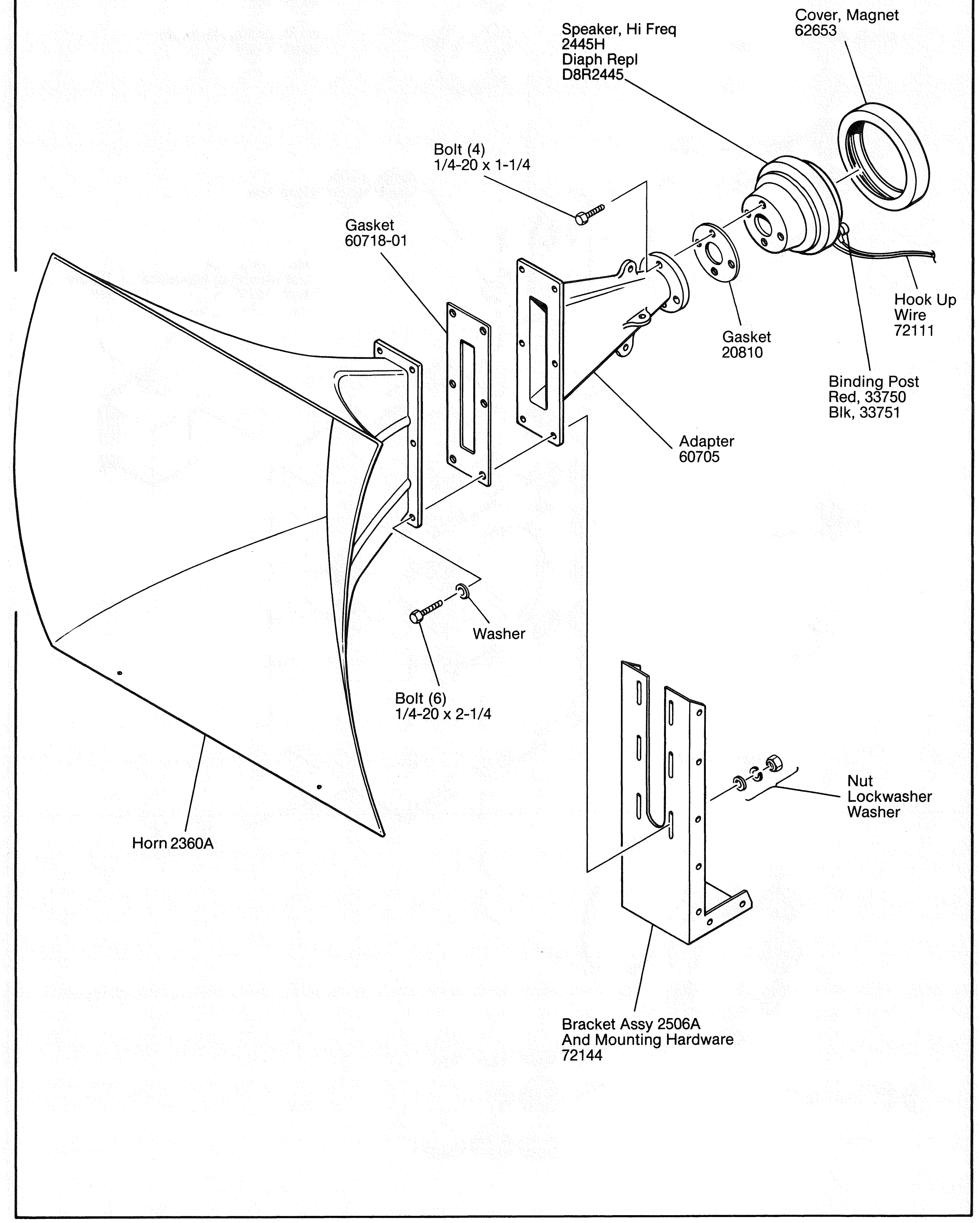
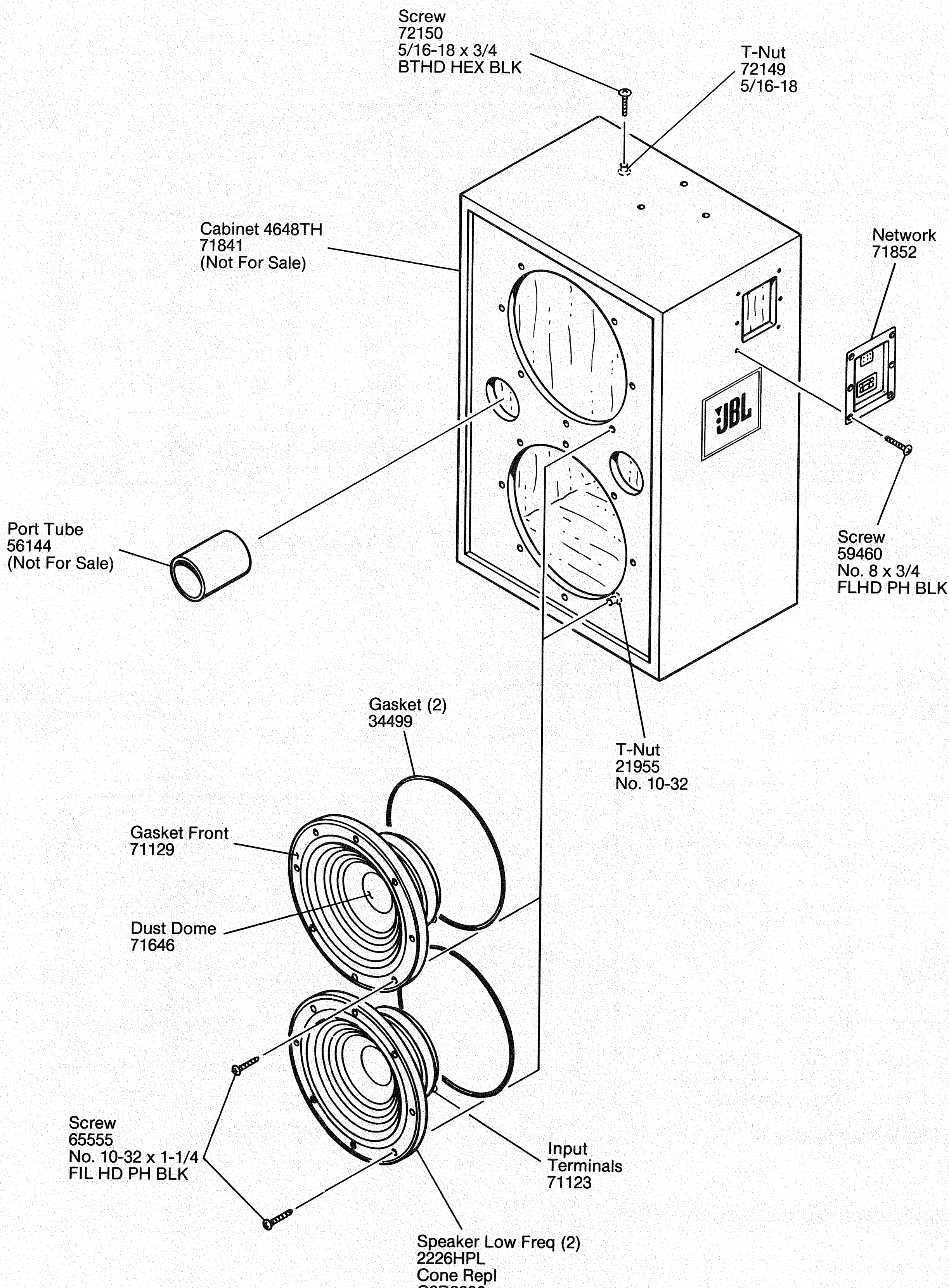
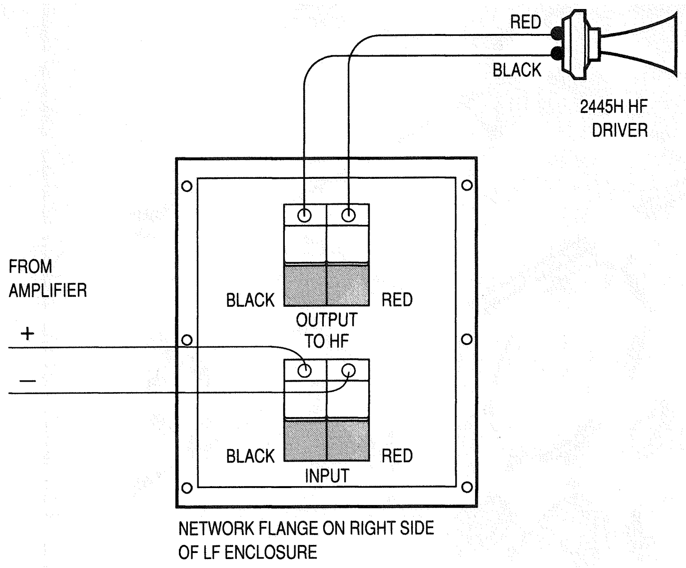


Figure 16.

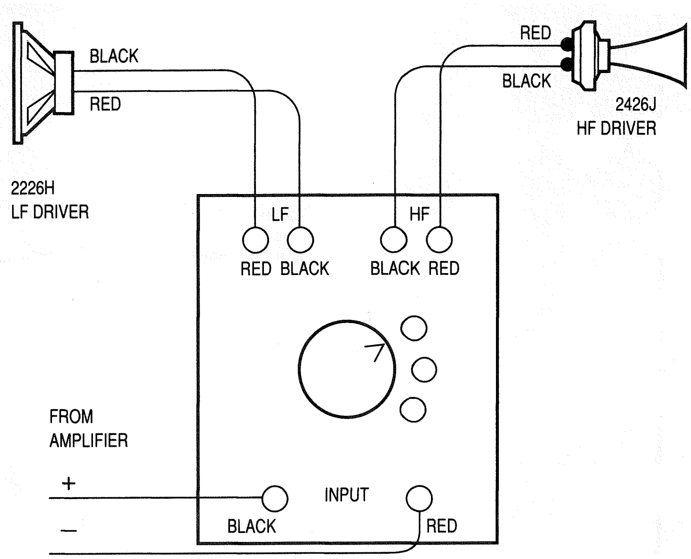
JBL4648TH

COMPONENT EXPLODED VIEW

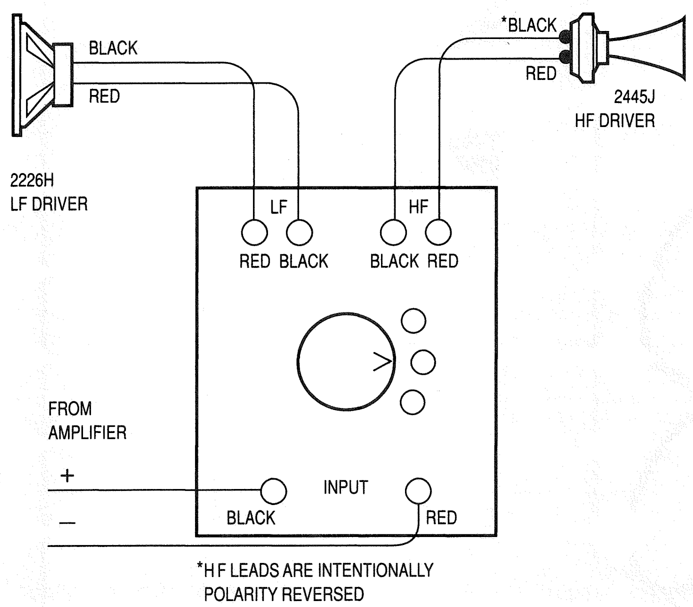




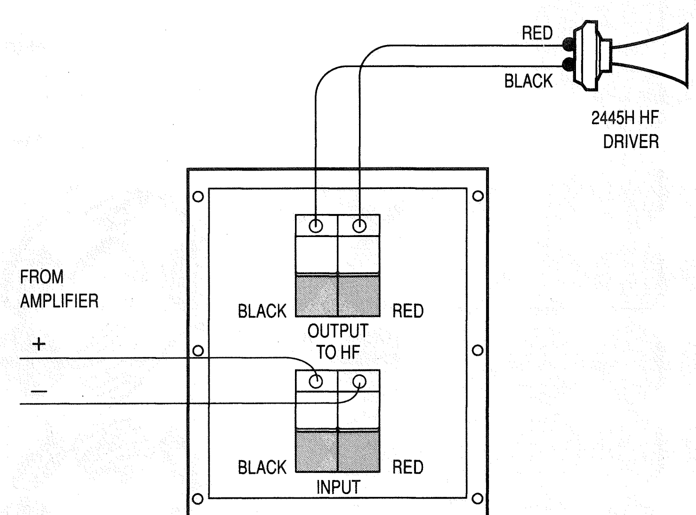
4670C wiring diagram.



4671A wiring diagram.



4673A wiring diagram.



4675B wiring diagram.

NOTE:
Input connections as shown here provide correct EIA polarity.

C. Subwoofers:

Subwoofers are an integral part of loudspeaker systems installed in mid and large size cinemas. In specifying them, the designer must take into account the reduced sensitivity of the ear to low frequency sounds. Figure 17 shows the Robinson-Dadson equal loudness contours. Note that, for a reference level of 85 dB, frequencies in the range of 30 to 40 Hz will have to be reproduced 15 to 20 dB louder in order to be perceived at the same subjective level.

Since low frequencies are essentially non-directional, we commonly specify subwoofer hardware by calculating the acoustical power requirements in the cinema for a given sound pressure level. Assuming that the reverberation times in modern theaters follow the data presented in Figures 10 and 11, we can present the data shown in the following table:

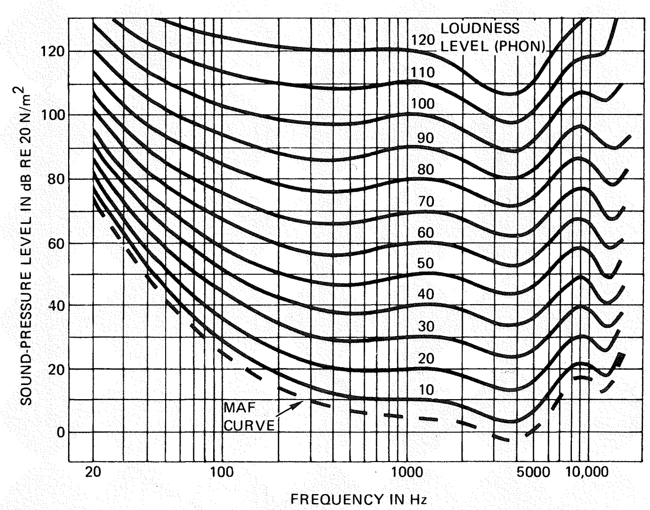


Figure 17. Robinson-Dadson equal loudness contours

Table 2: Acoustical power versus cinema size:

Theater volume (m^3):	Acoustical power required for 110 dB SPL:
270 (10,000 cu. ft.)	8 W
540 (20,000 cu. ft.)	12 W
1350 (50,000 cu. ft.)	16 W
2700 (100,000 cu. ft.)	32 W
5400 (200,000 cu. ft.)	80 W

When the proper room volume has been determined, the designer then can go to the following table and pick the required quantity of subwoofer modules that will ensure the needed acoustical power output:

Table 3: Efficiency and acoustical power output of multiple subwoofer modules:

Number of 2245 transducers:	Eff (%):	Power input (watts):	Acoustical power (watts):
1	2.1	200	4.2 W
2	4.2	400	16.8 W
4	8.4	800	67.2 W
8	16.8	1600	269 W

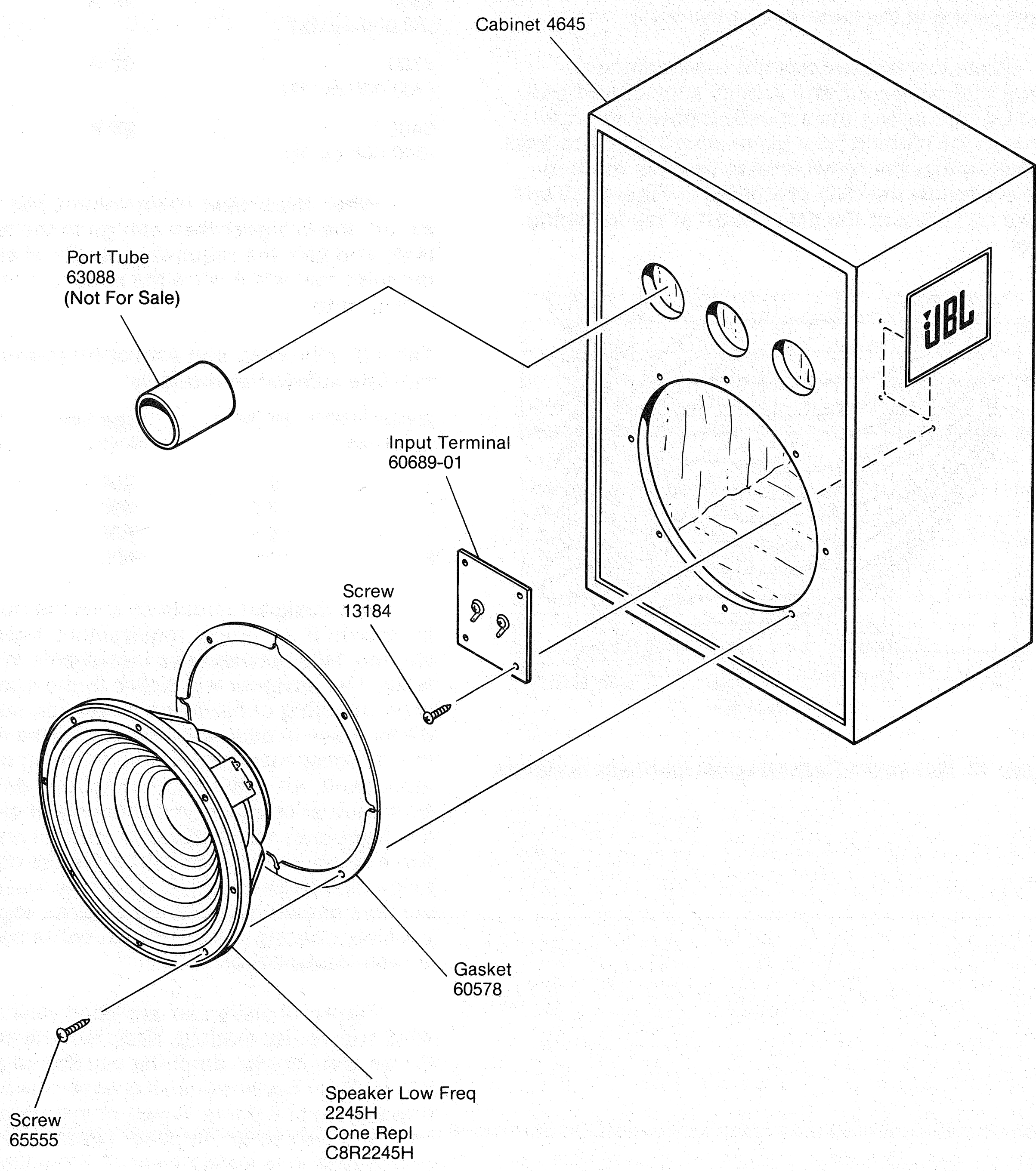
The designer should choose the next higher increment if the power requirement, based on room volume, falls between two increments in the above table. The designer will notice in the above table that each doubling of hardware resources results in a 6 dB increase in acoustical power. Three decibels of this increase results from the doubling of power input itself, while the additional three decibels results from mutual coupling, the property of closely placed low frequency transducers to interact and behave like a single transducer with twice the cone area and twice the efficiency (7). It is for this reason that subwoofers should be mounted as close together as possible directly below or adjacent to the center screen loudspeaker.

Figure 18 shows an exploded view of the JBL 4645 subwoofer module. Each module should be driven with its own amplifier capable of producing 200 watts of continuous sine wave power into a rated impedance of 8 ohms. A pair of subwoofer modules can be driven by an amplifier capable of producing continuous sine wave power of 400 watts into a 4 ohm load.

Figure 18.

JBL4645

COMPONENT EXPLODED VIEW



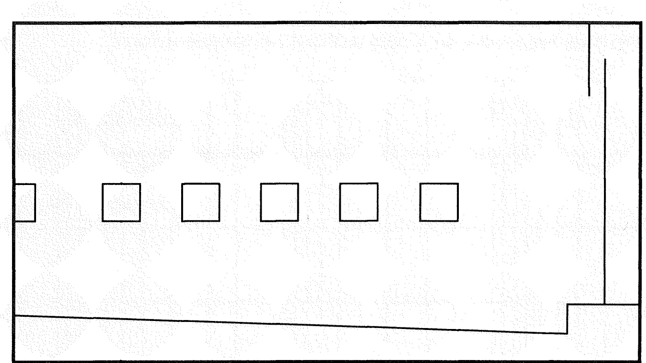
D. Surround requirements:

As a general rule, the total ensemble of surround loudspeakers should be capable of producing as much acoustical power as a single screen channel. Today, the JBL 8330 surround loudspeaker has become virtually an industry standard. It is capable of producing acoustical power output in the range of 2 watts. Since a typical dual woofer JBL screen loudspeaker is capable of producing continuous power output of 28 watts, it is clear that 14 of the 8330's will be required for power matching. In most houses, 12 units will suffice, but in larger houses more units will be required in order to maintain desired coverage and ensure adequate power output capability. JBL wishes to stress that as much attention be given to surround loudspeaker specification as is normally given to the screen loudspeaker specification.

The baffle of the 8330 has a downward slope of 15°, making it possible to mount the rear of the enclosure flush with the theater walls, while providing smooth coverage over the seating area. In smaller theaters, four of the units are placed on the back wall, with four each on the side walls. In larger theaters, more units will be placed on the side walls.

Good surround operation depends on "a significant quantity of insignificant sources." In other words, a patron in the theater should not be able to identify any one unit, but rather should sense the sound field created by all of them. Traditionally, the surround loudspeakers were mounted only in the back two-thirds of the house. Today, many systems specialists increase the "wrap-around" so that as much of the seating area as possible is covered uniformly by the surround loudspeakers. The height is often dictated by decor, but generally should be such that the tilted axis of the 8330 is pointed at the farthest patrons across the theater, and when this is done, the smoothness of surround response in the theater can be maintained within ± 2 dB. Details of surround location are shown in Figure 19.

Plan View



Side View

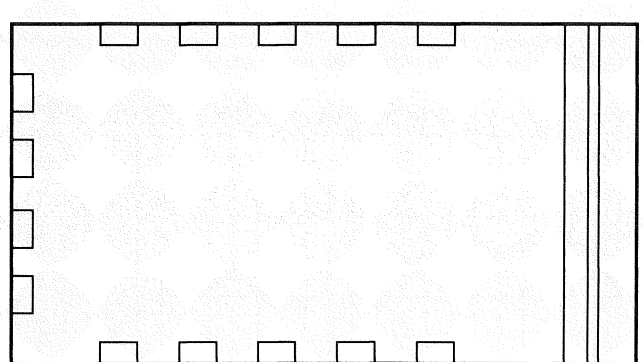


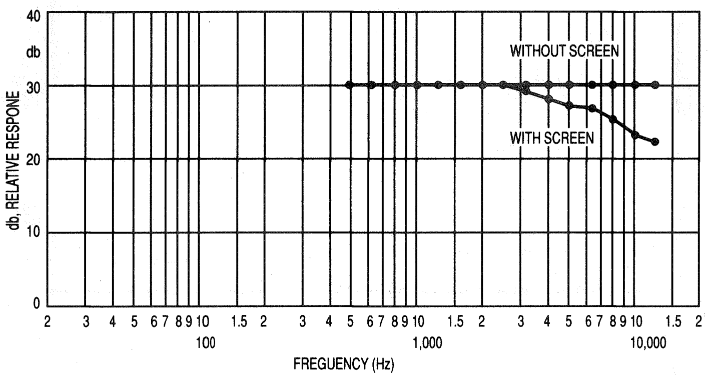
Figure 19. Plan and side elevation views of typical 8330 installation

E. Screen losses:

The mechanism of through-the-screen losses is not completely understood. The on axis loss appears to be a 6 dB/octave rolloff commencing at about 5 kHz. However, off axis response is quite different. At certain angles, high frequencies are transmitted through the screen with virtually no losses. The result of this is beneficial, in that patrons seated toward the sides are guaranteed good dialog articulation because of the added high frequencies which reach them. The basic loss, however, must be compensated for electrically.

With the newer high frequency hardware, this required equalization is that which results in flat power response. When this is provided, the diffuse field response measured in the house at a distance one-half to two-thirds back often fits the ISO 2969 X curve rather closely. Details of this are shown in Figure 20.

A. On-axis response, with and without perforated screen



B. House response (2/3 back): solid line, when system is adjusted for flat overall power output-ISO 2969 curve (dashed line).

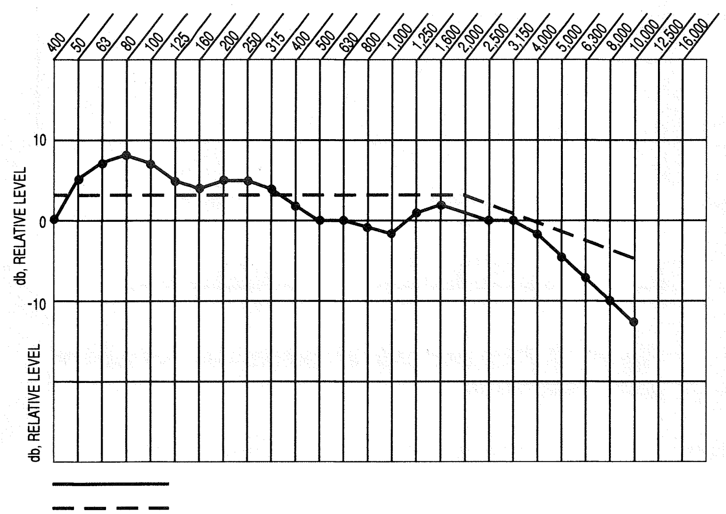


Figure 20. AMPAS data: axial screen loss data (A); overall flat power response in the house as compared with ISO 2969 (B)

From a design viewpoint, the engineer must ensure that there is adequate electrical headroom in the high frequency drivers to attain flat power response above 3 kHz. This usually requires that the signal be boosted 6 dB/octave above 3 kHz, and this means that the drive level at 12 kHz will be 12 dB greater than at mid frequencies. A driver must be specified which can handle this increased input — and at the same time be able to provide a good match with the low frequency system. All JBL cinema systems have been engineered with this requirement in mind.

F. Use of multiple high frequency elements:

In some very large old-style houses with balconies, a nominal high frequency coverage angle of 40° is not sufficient to provide vertical coverage. Some systems have been installed with multiple high frequency horns to take care of this problem, but the difficulty of interference, or "lobing," in the combining of the two horns remains, creating difficulties in system equalization. There are experiments under way to use stereo synthesizers as a method of alleviating gross effects of interference, but these experiments are only in the beginning stage (8). For the present, we do not recommend that horn stacking be applied in the cinema unless it is specified by a competent consultant who will assume responsibility for overall system performance.

V. MOUNTING REQUIREMENTS:

The following rules generally apply to screen loudspeakers:

1. They should be located vertically so that the horns are between one-half and two-thirds the height of the screen.

2. They should be placed so that the horn flanges are within a distance of 5 to 7 cm (2 to 3 in) of the screen.

3. All light reflective details, such as logos, mounting hardware and polished frames, should be painted matte black so that they will not show through the screen.

4. Platforms for loudspeaker mounting should be rigid and completely free from rattles; all exposed vertical surfaces should be finished with sound absorptive materials.

5. All other wall areas behind the screen should be finished with sound absorptive materials.

A. Platform and baffle construction:

If a THX system is specified, all details of the vertical baffle will have been provided in the THX construction specifications. Where there is no such specification, the installer will have to construct one large platform, or a number of smaller ones, depending on costs. Figure 21 shows a detail of a platform for behind-the-screen use. The loudspeakers should be mounted on sections of carpet, or some other such material, to inhibit rattles. Enclosures should be secured to the platform so that they have no tendency to move.

When possible, large wings should be mounted between systems, as shown in Figure 22. The surfaces should ideally be finished with sound absorptive material, as should any exposed wall areas behind the screen.

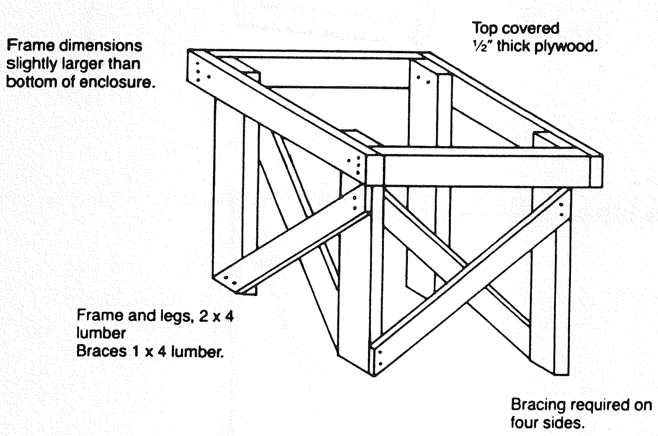


Figure 21. Isometric view of a platform

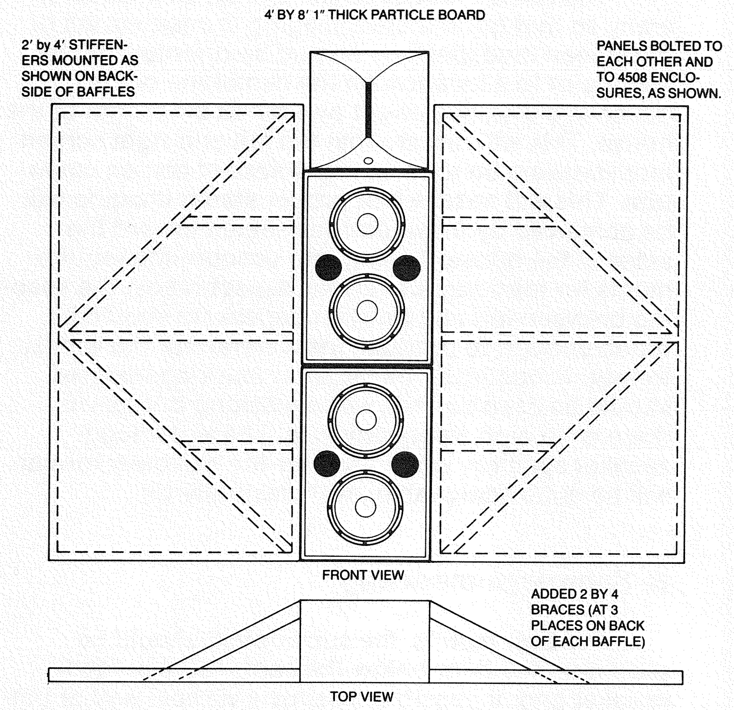


Figure 22. Application of wings between screen loudspeakers

The screen loudspeakers should be spaced laterally so that good stereo imaging is ensured. All of the screen loudspeakers should be oriented so that they point to a location on the centerline of the house at a distance about two-thirds the length of the house. This will require that the left and right screen loudspeakers be toed in, regardless of screen curvature. This will ensure that proper stereo imaging will be perceived by those patrons seated toward the sides of the house. Taking into account the requirements for masking for various aspect ratios, the spacing between left and right loudspeakers should be broad enough to produce ideal stereo for the widest format. Acoustically transparent masking material should be used so that, when masking is in place, there is no high frequency loss. The wider loudspeaker spacing, when used for the narrower format, will be quite acceptable, even desirable (5).

B. Subwoofer mounting:

For best results, the subwoofers should be placed on the floor below the center screen loudspeaker and, if possible, against a vertical wall or baffle. They should be clustered together, rest on rubber pads, and be free of rattles.

C. Surround mounting:

The model 8330 surround loudspeakers can be mounted several ways. Six integral T-nuts allow for an Omnimount® or other method of rigging, to be determined by architectural details and local building codes. Electrical connections are conveniently made at the top of the enclosure. In new construction, surround loudspeakers can be flush mounted behind grille materials and be invisible as such.

The electrical response switch on the 8330's should be placed in the ISO 2969 X curve position for theater application. Figure 23 shows details of surround mounting.

VI ELECTRICAL INTERFACE:

A. Wiring for a Non-biamplified Installation:

All wiring diagrams shown thus far in this manual are for non-biamplified, single amplifier application. Care should be taken that all connections are properly served with tinned wires or spade lugs, if required. The wire should be chosen on the basis of that gauge which will result in no more than 0.5 dB loss between the amplifier and the loudspeaker. Details of wire loss calculation are given in Section VI-D.

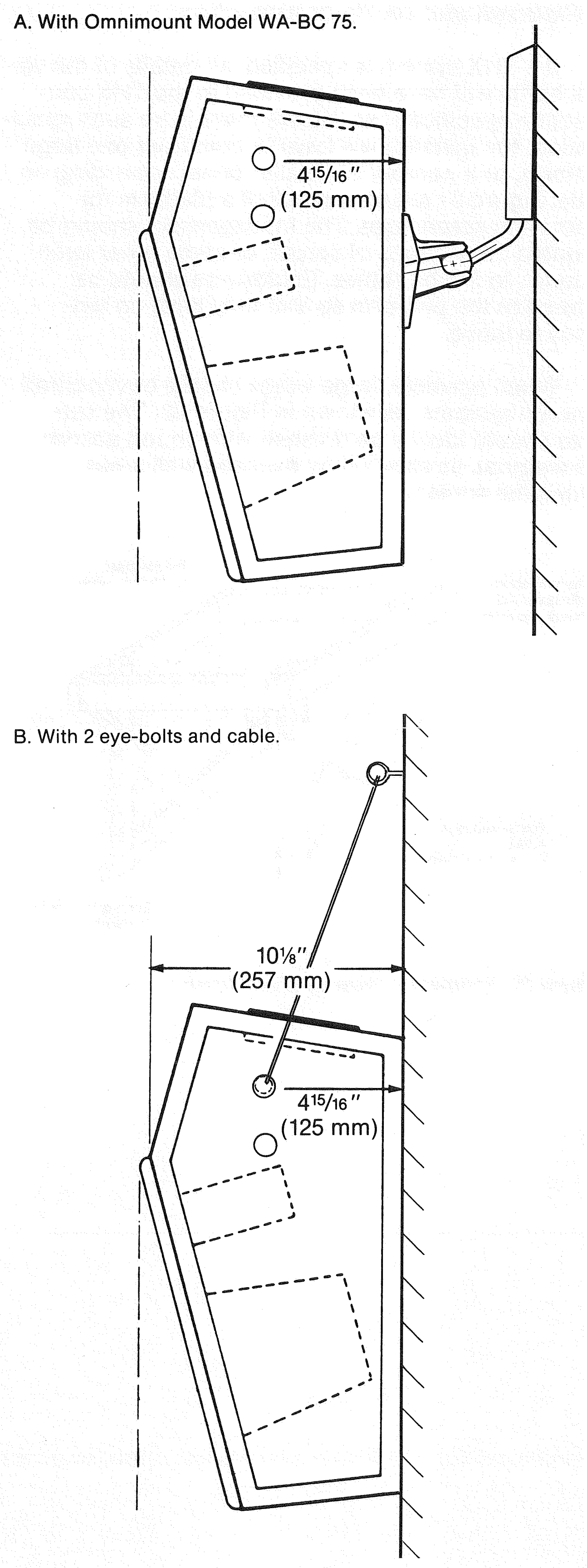
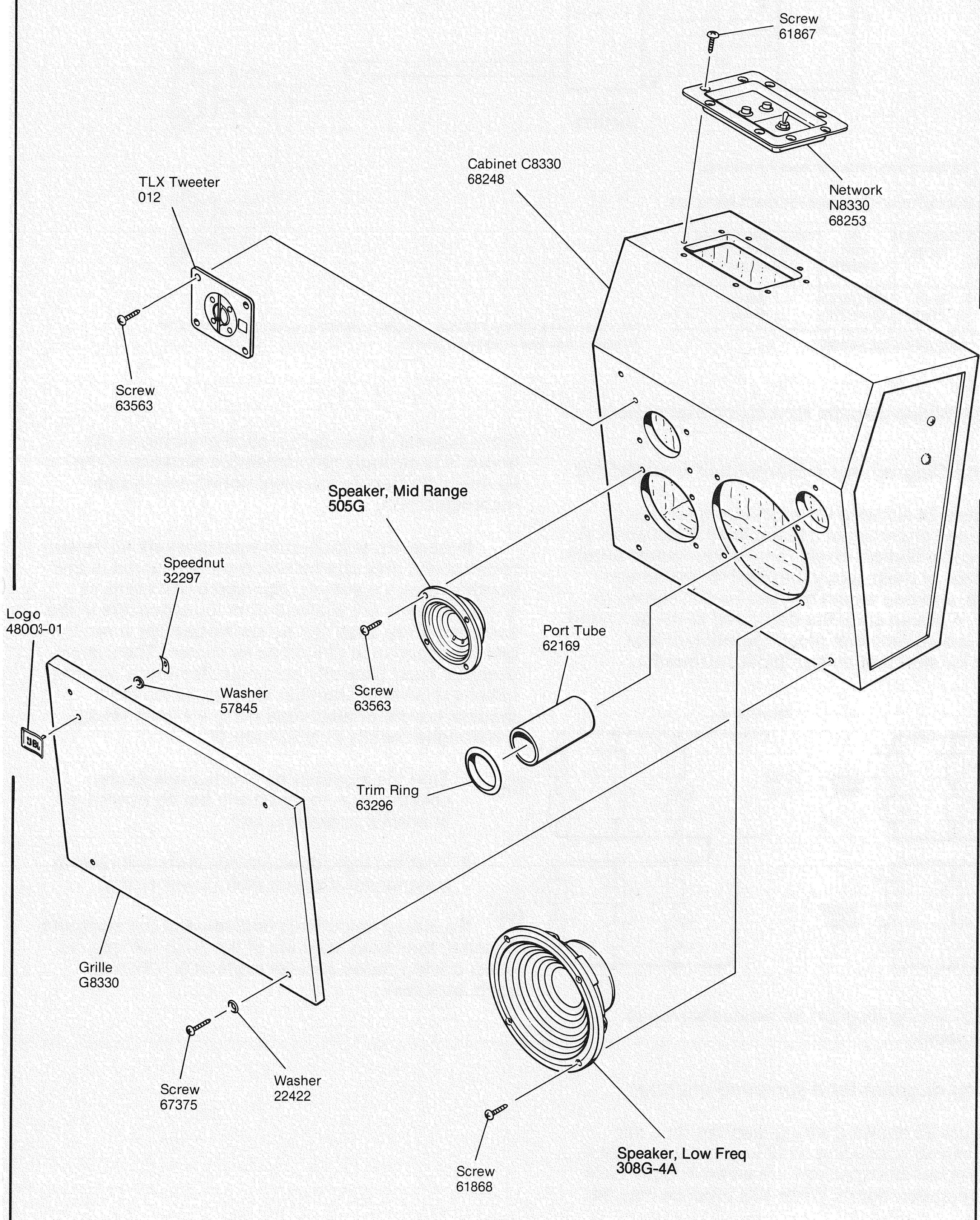
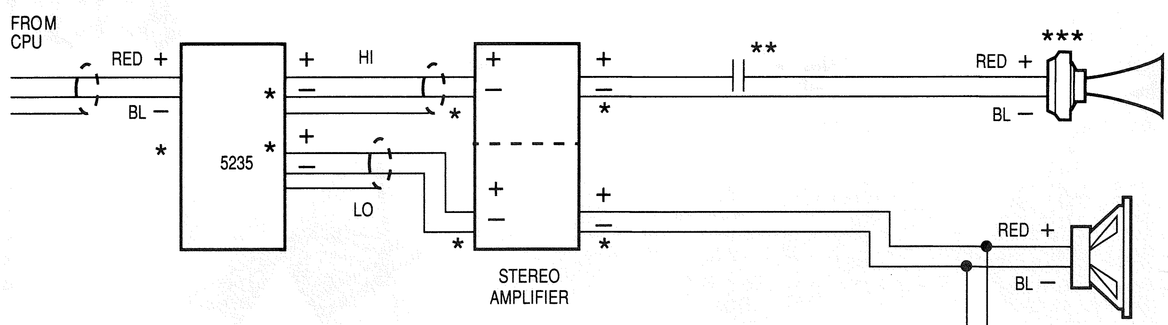


Figure 23. Details of surround loudspeaker mounting: Omnimount (A); use of aircraft cable (B)

JBL8330

COMPONENT EXPLODED VIEW





*-All wires to barrier strips to be served with spade lugs

**
BLOCKING CAPACITOR VALUES FOR DRIVER PROTECTION

CAPACITOR VALUE	JBL PART NUMBER	FOR OPTIMUM RESULTS AT THESE CROSSOVER FREQUENCIES*
36 μF	62772-0360	500 Hz
24 μF	62772-0240	800 Hz

*16 Ω OPERATION ASSUMED

***-Plug in card # 53-5333 for 5235 allows time offset adjustment to be made in LF path so that HF transducer can be wired in conventional polarity

Figure 24. Wiring diagram for a biamplified system

B. Wiring Diagram for a Biamplified Installation:

Figure 24 shows a wiring diagram for one of three screen channels of a biamplified installation. A complete installation would require four stereo amplifiers. Three of these would be used for the screen channels, and one would be used for the surround channel. A stereo amplifier dedicated to the surround channel would facilitate reconfiguration of that channel for stereo operation (split surrounds).

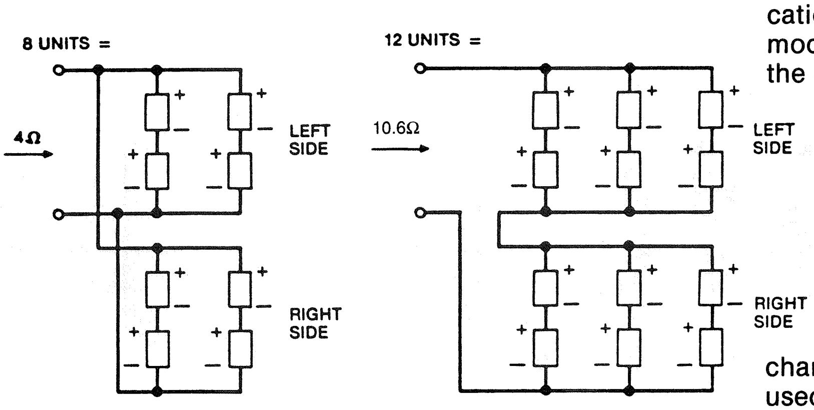


Figure 25. Wiring diagram for various surround configurations

C. Wiring diagram for a surround channel:

Figure 25 shows a wiring diagram for a surround channel consisting of 12 loudspeakers. Note that individual loudspeakers are wired directly back to the projection booth. While this practice may be more expensive than series-parallel wiring in the house, it is strongly recommended because of the flexibility it offers in troubleshooting and system reconfiguration.

If there are eight 8-ohm loudspeakers in the surround array, they can be series-parallel wired in the booth to give a resulting impedance of 4 ohms as shown. If there are twelve 8-ohm loudspeakers in the surround array, they can be series-parallel wired to give an impedance of 6 ohms as shown. The system designer must carefully note manufacturers' specifications regarding amplifier loading. Since most modern transistor amplifiers carry a 4-ohm rating, the designer needs only to ensure:

1. That the amplifier be of adequate power specification so that it will not be overdriven in normal operation, and

2. That the individual loudspeakers will receive a signal input within their power rating.

If a stereo amplifier is dedicated to the surround channel, then both sections of the amplifier may be used, driving series-parallel loads of 5 1/3 ohms each, as shown.

D. Wire Gauges and Line Loss Calculations:

Good engineering practice requires that line losses result in no greater than a level loss of 0.5 dB at the load. In making the calculations to determine the smallest wire gauge that will ensure adherence to this, the engineer must keep in mind that the loss at the loudspeaker is due to actual power losses in the wiring as well as to losses due to impedance mismatching between the amplifier and load caused by the added resistance in the line. The following equation can be used to determine the loss in dB at the loudspeaker, taking both factors into account.

$$\text{Loss (dB)} = 20 \log \{R_1/(R_L + 2R_1)\},$$

where R_1 is the resistance in each of the two wire runs to the load and R_L is the nominal load impedance.

Details of the calculation method are shown in Figure 26. The simplest way to deal with wire losses is by an iterative design process of selecting a trial gauge of wire, solving for the loss, and then moving up or down in wire gauge as required to meet the design criterion. A calculation example is given in the figure.

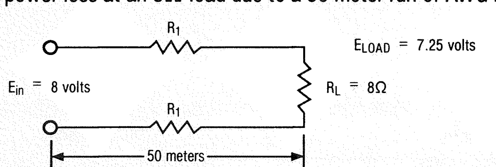
AMERICAN WIRE GAUGE (AWG)	RESISTANCE PER SINGLE RUN, 300 METERS (1000 FEET) OF COPPER (IN OHMS)
5	.3
6	.4
7	.5
8	.6
9	.8
10	1.0
11	1.2
12	1.6
13	2.0
14	2.5
15	3.2
16	4.0
17	5.0
18	6.3
19	8.0
20	10.0

NOTE:

Paralleling two identical gauges reduces effective gauge by 3.

EXAMPLE:

Find the power loss at an 8Ω load due to a 50 meter run of AWG #14 wire.



$$R = \left(\frac{50}{300}\right) \times 2.5 = 0.416\Omega$$

$$E_{LOAD} = \frac{8}{8 + (2 \times .416)} \times 8 = 7.25 \text{ volts}$$

$$\text{Power in load} = \frac{(7.25)^2}{8} = 6.56 \text{ watts}$$

$$\text{dB loss} = 10 \log \left(\frac{6.56}{8}\right) = .86\text{dB}$$

Figure 26. Wire Loss Calculations

E. Dividing Network Characteristics:

Stated simply, the purpose of a passive dividing network is to feed various parts of the frequency range into the intended transducers. In addition, practical networks provide for some degree of level adjustment (usually of the high frequency section) so that elements of various sensitivities can be used together. Recent network designs provide additional high frequency power response equalization, and a very few passive networks provide some degree of time offset (normally in the low frequency section) to enable specific high and low frequency elements to combine their response properly at the crossover frequency through alignment of their acoustical centers. Active networks accomplish their various operations electronically and are used in biamplification.

The cutoff slope of a network is defined by its *order.* For each degree of order, the cutoff rate is 6 dB/octave. Thus, a third order network will provide transitions in the crossover range of 18 dB/octave, and a fourth order network will provide transitions of 24 dB/octave.

The most common mistake made in field assembly of non-biamplified JBL cinema loudspeaker systems is miswiring and improper adjustment of the dividing network. The data presented in Figures 12 through 16 should be studied carefully, inasmuch as all network details are spelled out clearly.

The JBL model 5235 is an active dividing network whose characteristics are determined by using specific plug-in cards and by programming internal DIP switches. The general characteristics of the model are shown in Figure 27.

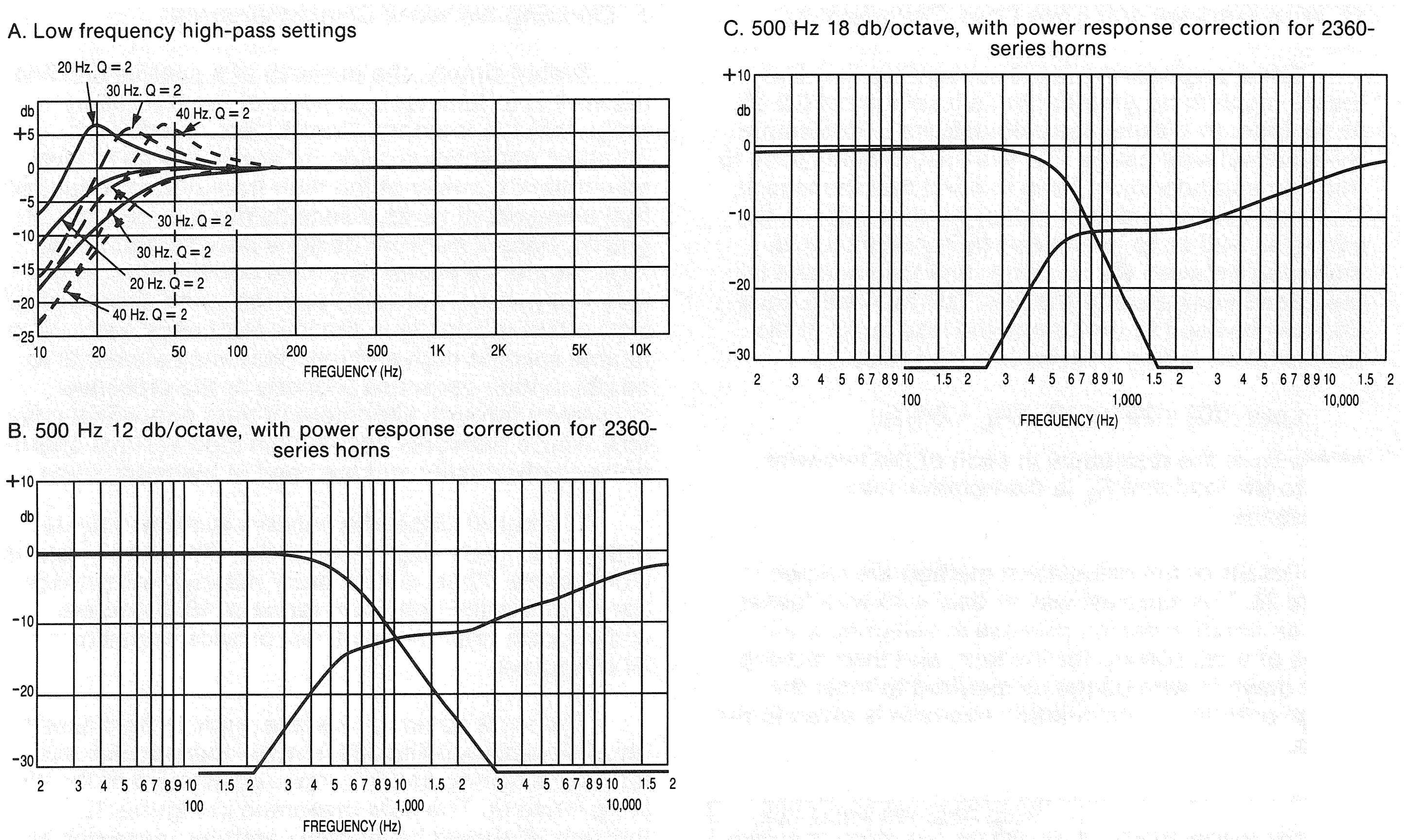


Figure 27. The JBL 5235 active dividing network (mechanical views and response curves)

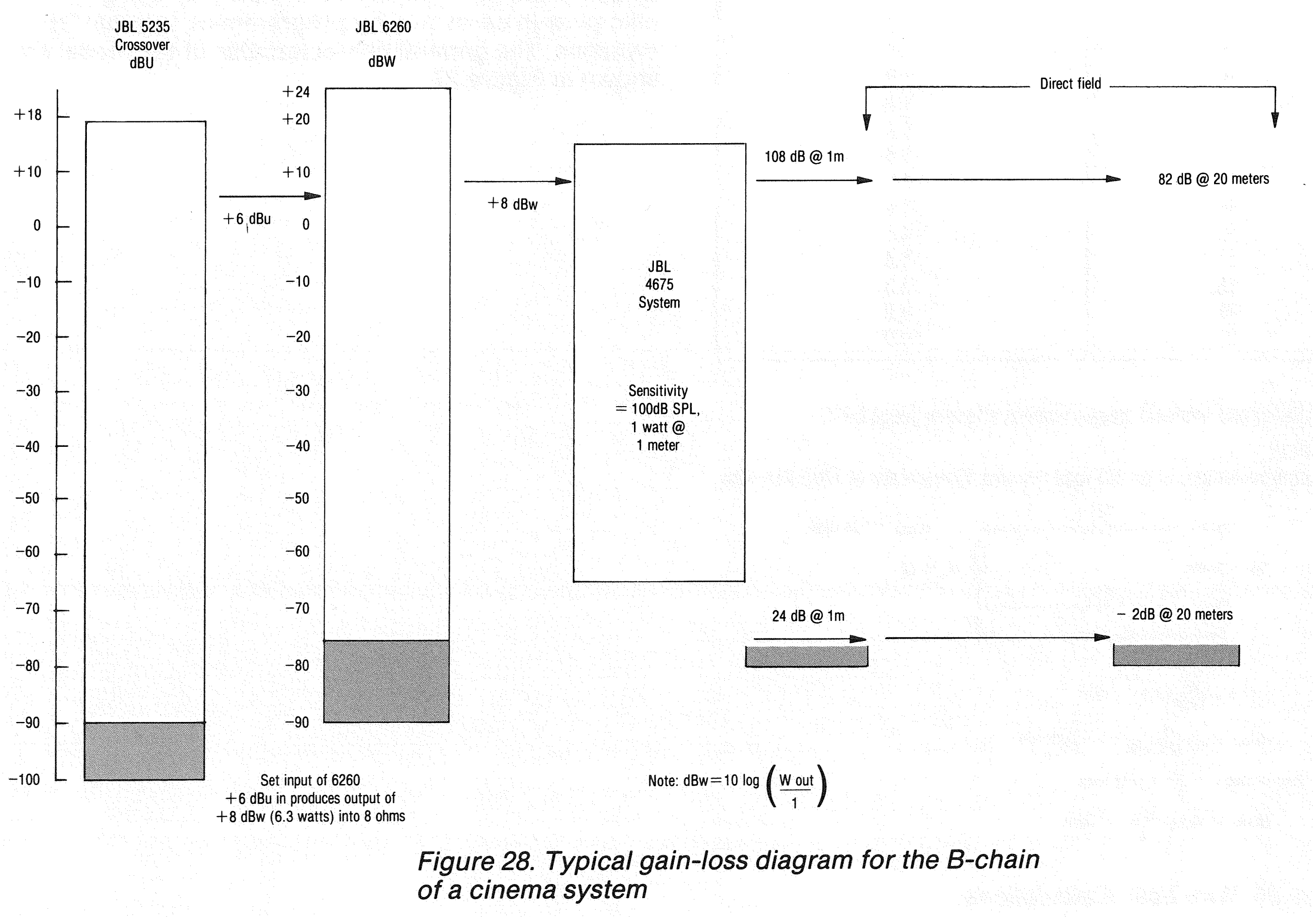


Figure 28. Typical gain-loss diagram for the B-chain of a cinema system

F. System Setup and Checkout:

The vast majority of system performance problems can be avoided through proper design procedures and proper assembly methods. If all has gone well, the system will work, and the field crew can proceed with final calibration and equalization of the system. Some points seem obvious:

1. When a loudspeaker has been assembled, either in the shop or in the field, it should be tested by sweeping with an oscillator-amplifier combination to ensure that there are no buzzes or rattles. Any defective components should be replaced. The procedure should be repeated when the loudspeakers are installed in the cinema.

2. As each pair of loudspeaker lines is laid, the ends at the loudspeaker should be shorted and a resistance check made at the booth. Any discrepancies should be corrected. After the loudspeaker is installed, an impedance check of the lines should be made from the amplifier end.

3. Set up a gain-loss diagram for the system prior to making any adjustments on the system. A sample is given in Figure 28, where we have shown the divisions of gains and losses in a screen channel for a non-biamplified system. Since most cinema systems have the same basic architecture, it is only necessary to establish the norms once.

Note that the gain-loss diagram for this system indicates clearly maximum output levels of each component in the system as well as the noise floor of each component. The goal in proper systems engineering is to ensure that the widest possible dynamic range is preserved throughout the chain. No electronic device ahead of the power amplifier should be driven into distortion before the power amplifier itself has reached its maximum output capability. Additionally, the noise floor of the system, once it has been established at the preamp, should not be compromised by allowing the signal level to fall too low at any subsequent point in the chain. The gain-loss diagram is a convenient means of ensuring all of these points.

All aspects of A-chain calibration should be performed according to the methods laid down in the various manuals supplied by the manufacturer's of cinema processing equipment.

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