Theater Engineering Conference

Acoustics

Quieting and Noise Isolation*

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Summary—**The purpose of this paper is to describe some of the objectionable noises, their causes, some of their remedies, and to point out that it is much easier to avoid these troubles in building a new theater than to rectify them in an old one.**

Noise is any undesirable sound, but all sounds do not have the same effect on a person, and low tones, of course, are not nearly so objectionable as higher tones. Howard Hardy recently said in *The Frontier:* "A sound source of many component fragments will sound much louder than one of the same intensity which has a pure tone." Considerable confusion exists among inexperienced observers about the particular psychological factors with reference to noise. It has been shown that noise of a frequency below 500 cycles is not nearly so objectionable as noise consisting of high-frequency tones and harmonics.

The object in noise reduction in design is to shift the objectionable sound from high to lower frequency, as well as to lower its intensity. Loudness alone is not an indication of the annoying effect. People do not object to noisy machinery as much as to erratic and unexpected sources of sound. Such things as high-frequency screeches are definitely more disturbing than the low frequency of thuds or all the lower tones.

There is no doubt that high noise levels in theaters require the operation of the sound system at a higher level, and even though the audience does not realize that the sound level is higher than otherwise would be the case, it does put them under a nervous tension, and if the noise is extremely high, the sound level has to be so much higher to overcome the noise that it really becomes annoying.

There are several misconceptions that should be explained. Many

* Presented October 24, 1947, at the SMPE Convention in New York.

people do not differentiate between sound isolation and acoustical conditioning. Sound isolation fundamentally consists of two things—soundproofing of solid-borne noises such as shocks and machinery, and the sound insulation of air-borne noises such as is provided by thick walls and special construction, which prevent the sound from being transmitted from one point to another.

On the other hand, acoustical conditioning consists of three factors, the control of the reverberation time, controlled by the amount of sound-absorbing material used; the control of reverberation characteristics determined by the type of materials, and how they are used; and by the elimination of sound focal points and standing waves, which is done by the elimination of opposing parallel and concave surfaces.

As stated above, all of these faults are much more easily avoided in new construction than cured in old construction. Wherever a theater is to be built, a noise survey of the site is absolutely necessary to determine the noises in the surrounding area. Outdoor and traffic noises in some areas may reach 85 to 90 decibels above zero reference sound level of 10^{-16} watt per cubic centimeter.

The noise in the theater itself should be kept to a point where it is lower than the audience noise (a good value of audience noise is about 30 to 35 decibels), which means that the outside walls of the theater may be required to have an insulation value of 55 to 60 decibels, which if dependent upon mass alone, requires a brick wall two feet thick. Fortunately there are other ways of doing this by special construction which is much less costly than a two-foot brick wall.

There are some noises that are not under the control of the architect and engineer, such as street noises caused by automobiles, bus traffic, airplanes, railroad trains, streetcars, subway and elevated trains, and garbage and ash collectors.

Of course, there are audience noises about which nothing can be done, except hope for a quiet audience. There may also be noises from adjacent property—music, loudspeaker systems, juke boxes, hand trucks, factory operations, and about the noisiest source is a bowling alley.

Windows have no place in the theater, as they are always weak points in any wall which allow sound transmission. If there must be windows they should be fastened so they cannot be opened, to reduce sound transmission. In some cases, where there is noise on adjacent property such as floors above or below the theater, it may be necessary to construct isolated ceilings and floors, and even isolated suspended walls, as in broadcast-studio construction.

Of course, there must be fire-escape doors, which should be fitted tightly to provide as good sound isolation as possible. This also helps in the operation of the air-conditioning system.

A good example of noise isolation occurred at radio station WOR, with studios on the first floor, where there was a corridor at the rear which led from the street to the freight elevators. Many times during the day there were deliveries by hand trucks which were very noisy and interfering noises were heard in the studios. The solution was surprisingly simple. About an inch and a half of street-paving asphalt was laid on the floor of the corridor, which eliminated that noise in the studios.

There are a number of controllable noises in a theater. First there are the noises from the projection, the rewind, and generator rooms. The best insurance there of course is to specify and get quiet operating machines. As Mr. Hardy has reported in another paper, the acoustic problem is being thoroughly considered in the manufacture and design of projectors. The ceilings of these rooms should have noise-reducing treatment, such as fireproof acoustical tile, or some kind of fireproof treatment having as high a value of sound absorption as possible.

If the ceiling is high, acoustical absorbing materials should be used on the walls also; to four or six feet from the floor. The projection ports should be fitted with optical glass. However, as that represents another maintenance problem, another way that the noise can be retarded from getting into the auditorium is by lining the top and sides of the ports with acoustical tiles. The viewing ports should be fitted with plate glass which reduces the amount of transmission through these openings.

Another source of noise is noisy electrical equipment. The only precaution required is to buy good equipment, making sure that it is operated in the most efficient manner by engaging the services of an organization thoroughly competent in maintenance of sound equipment for the theater, to maintain the equipment. There are reliable organizations which provide that service.

Other noises originate in the lobby, the promenade, the ladies' and men's lounges, and the rest rooms. The ceilings of all these spaces should be treated with noise-reduction materials with carpets on all spaces except the rest rooms.

The ventilating systems are sources of noise such as motor or fan noises, which can be both air-borne and solid-borne. One airborne noise is the noise of the air itself in rushing through the ducts and grills, and the solid-borne noises can be caused by the vibrations being transmitted through the ducts.

The best insurance against these noises is to operate an air-conditioning system so that the air in the ducts flows at low velocity. At the registers, both supply and return, the air velocity should not exceed 250 or 300 feet per minute. Metal registers, where the metal is placed edgewise, are also a source of noise. At the higher air velocity the fins may begin to vibrate. It is best to use a flat punched register, with at least 50 or 60 per cent opening so the air is not constricted, and will not appreciably increase in velocity in the openings.

In one theater which had air noise in the ducts, the trouble was corrected by putting in sound baffle boxes, sound traps, in the branch ducts just before they went to the inlet registers. In this manner it was still possible to get a sufficient amount of air with the existing motor and fan.

In a new system, install low-speed, quiet operating fans because high-speed fans are prone to greater and higher frequency noises.

Another cause of noise is the water-supply system, such as knocking in the pipes when a faucet is turned on, and there may be vibration in the pipes, especially with copper and brass pipe. The proper way to prevent the knocking is to have the proper air cushions installed in the pipes and to make sure the valves seat properly.

Water lines can be fastened in shock-absorbing mounts so that vibration will not be transmitted to the theater structure. The troubles encountered in a hot-air system are very much the same as in ventilating. A hot-water heating system is like any other water system, but with steam heat, hissing valves should be replaced with quiet operating vent valves on the radiators. A big source of noise is steam systems is in the pressure-reducing valves. In one installation the noise was as high as 90 decibels within a foot or two of the valve. The valve and steam-pipe line causing the noise and vibration were isolated from the rest of the building to prevent transmission of structural-borne noises and covered with alternate layers of various materials to reduce the noise in the rooms where the pipes and valves were located. The pipes on both sides of the valve should be hung in shock-absorbing mounts for sufficient distance, so the vibration will not be transmitted to the rest of the structure.

The rest rooms should be separated from the auditorium by at least two walls, not necessarily two walls built together, but at least two walls separating the rest rooms from the audience.

Other sources of trouble are noisy reactors and transformers for fluorescent and cold-cathode lighting. Wherever these are noted, they should be corrected. Noisy electric switches cause clicks at times, which can be eliminated by replacement with mercury switches. Oftentimes vibrations are set up by different kinds of machinery, motors, pumps, forced-draft fans, oil burners; they should all be located on antivibration mounts to prevent the vibration from being transmitted to the building structure. Quite often this vibration will set up very serious noises in some other part of the building.

If there are any elevators in the same building, all the machinery, the hoist drums, the controllers, the contactors, the motors, should all be hung on vibration-isolation mounts, and the guide rails for the elevators should be mounted on antivibration mounts.

A certain amount of trouble is caused by concavity of rear walls in theaters. Oftentimes domes and other concave surfaces catch sounds and retransmit them to other points, sometimes louder than they were in the original location. The answer is to eliminate the use of concave surfaces if possible. If it is necessary to use concave surfaces, make sure that the distance from the focal point to the concave surface is either at least twice or less than one half the distance to the populated area of the theater.

In one theater the author collaborated with Mr. Schlanger in revising the acoustical treatment. In this theater having this trouble the dome was eliminated and replaced with a flat ceiling.

In conclusion two points should be emphasized for either new construction or for alteration; one, engage the services of a registered architect who has had experience in theater construction as there are points that the average architect will never encounter; two, always see that he engages the services of a competent acoustical engineer.

Discussion

MR. W. E. MACKEE: Seat men think the most important thing is a seat. The carpet man thinks carpet is most important. The man who sells lighting tells you how to light your theaters. The acoustical people say the most important thing is acoustics. I think you have forgotten the real purpose of a motion picture theater.

First you must understand that there is a different type of audience in the small motion picture theater today. Sixty per cent of these have less than 500 seats, and 74 per cent have less than 750 seats. What is a motion picture theater? Before the war the average audience was supposed to be 19 years of age and pictures were made for them. Then the war started, and exhibitors thought they would go out of business for our younger people were all going to war. As a matter of fact, we did more business. We got an entirely new audience; older people are going to the movies, discovering the movies. The average is 32 or 33 years of age. They go more often and they pay more, that is our audience today. Why do they go to see motion pictures?

They go primarily for two reasons, rest and recreation. They can stay home and listen to the radio; incidentally radio audiences have dropped, and motion picture audiences have increased. They are not staying home and listening to the radio. We draw these facts from the radio industry. The motion picture audience of today is composed of older people. They demand a different type of picture than we had before the war.

What comes out of the radio? Charlie McCarthy. Charlie McCarthy is not successful in motion pictures. One picture that brought all the people in is one you probably do not remember—"Mrs. Miniver." It was not designed for the 19-year-old audience. It was designed for older people. Just about that time, the audience aged. More people are coming in and they are staying in.

In the motion picture industry we have to bring them out of their homes. You have a nice living room, and you have your radio and your family, but you go a mile or five miles to a motion picture theater. Why do you do that, and pay real money for it? You do that because the modern theater today is just as good as your living room. The seats are very comfortable, and the most important thing in the theater is not sound. The most important thing is the picture image, going back to the fundamental purpose of the motion picture. Sound is secondary. In the pictures that come to us, too often sound predominates, but the audiences go for rest and recreation and a series of pictures flashed on the screen. Sound is just explanatory. Anything you can do to remove your noises is desirable, but do not forget that the motion picture basically is a series of photographic images flashed on the screen.

DR. RICHARD COOK: Recently in Washington the picture was flashed on the screen, but for some reason the sound did not come on. There were catcalls from the audience, "Where is the sound?" They wanted sound right away.

DR. E. W. KELLOG: All we try to do in the way of better sound is to improve the value of the theater for seeing the pictures.

MR. MACKEE: We do not want newsreels in the small theaters. The football pictures are full of sound and noise. We can do without a newsreel. We keep sound down as low as we can. Air conditioning, yes; and quiet, yes; and a nice comfortable theater. We do not say you should eliminate sound, but we definitely are finding out what these older people want, and that is the most important thing as far as dollars and cents in the box office are concerned.

MR. JOHN K. HILLIARD: Why is it, especially in a dramatic sort of picture, when the sound is low, the audience is sitting there listlessly, and if the sound is brought to the proper intensity, not necessarily loud, the audience immediately reacts and applauds a scene, where if the sound were below what it should have been, there is absolutely no reaction from the audience.

MR. MACKEE: If it is so low they cannot hear, they start to clap. If they can hear, we do not hear any comment. Some theaters have earphones. We could not understand why people would put on earphones when they are not deaf. We asked one or two, and they said it was because they can control the sound.

MR. LEONARD SATZ: Sound is so much a part of motion picture presentation that I do not see how you could improve one without improving the other. Maybe some prefer to call it intangible, but when a patron comes into the theater and sits down, it is primarily to enjoy himself. If the sound is not good, he will leave the theater. He does not want to strain to hear the words. We consider sound in the smaller theaters just as important as in the larger theaters.

MR. GONZALEZ: During the war, we operated 1200 theaters. We had upwards of 12 to 14 theaters in some installations. We put in proper acoustic material, with the proper absorption, and someone painted the material with oil paint. Where there was reverberation, the sound was distorted. We found that at these places where the sound was improper, the soldiers would walk a half mile or a mile to go to a theater that had good sound, and attendance at the improperly wired theater fell off, which proves that we needed good sound.

Mr. Content said that the recirculating velocity should be limited to 250 feet per minute, and that the duct be limited to 500 feet. That is rather expensive in design. We found that we could safely go as high as 1200-foot velocity without interfering with the sound system in the theater. So long as the duct was properly designed so that there were no abrupt changes of air to cause sound or air noises in the supply grills, we went as high as 600 feet velocity without any perceptible increase in the noises.

MR. WETHERELL: When I design a motion picture house one of my main interests is in the appearance of the finished product and its effect on the viewer. I wonder if there is not one point that has not been touched on concerning sound. Someone mentioned that sound is secondary. It seems to me it might be, to this extent. The aim of the acoustics and sound engineer should be to produce sound that is so natural it becomes the background of the picture. You come to the theater, you see the picture, the sound is woven around the action. It should be so natural and so keyed that you do not realize you are listening to artificial sound. It is not the aim to have sound so natural that perhaps it is secondary, but it is quite an art to produce sound that is natural and accurately follows in tone and volume the action.

MR. BEN SCHLANGER: I want to defend what the paper said about air noises. There are certain dramatic sequences where the words are spoken softly and during those periods air noises are very disturbing. Maybe in the louder sequences—I do not mean noise but higher levels and less dramatic—air noise may not be disturbing, but you have to design for the more particularized mood in the picture once in a while.

MR. E. J. CONTENT: There are parts in the picture where sound levels will reach as high as 80 or 90 decibels, and certain parts which will be of low intensity as low as 30 or 35 decibels. If you have noises masking the sounds, they are not producing the desired effect upon the viewer. The only way you can keep background noises to 30 or 35 decibels is to operate the air-conditioning system at low velocity as mentioned.

MR. D. G. BELL: We have the main trunk lines approximately 700 feet per minute in the lines to the outlets. The principal noise from the duct system usually originates in the fan, in the blower, and it has been necessary in many other cases to add an acoustic absorbent in the duct for ten or twelve feet after the blower in the duct, immediately after the blower; and using those velocities which are recommended by the American Society of Heating and Ventilating Engineers, we have kept the noise in the theater down to 30 and 35 decibels.

MR. SHEPARD: I believe the point that Mr. Gonzalez brought out may not have been followed perfectly. He wanted to show that by proper designing, you can have fairly high velocity without the introduction of noise which can be generated by any vibrating element in the system. It can be reduced by the proper construction, the proper handling of beams, and possible use of acoustical materials. In many of the installations in the theaters that I have visited where that was done, I do not know what the actual velocities were but they were fairly high, and the noises were not excessive; just where you would have to obtain the maximum velocity, I do not known.

MR. SCHLANGER: It is ridiculous to try to save a few dollars by using a higher velocity than you should when you have already invested so many thousands of dollars in a theater.

MR. SATZ: Do you have any special preference for slab cork for vibration eliminators, cement pit with cork, for heavy fans; would you say that one is more efficient than the other?

MR. CONTENT: That all depends on the weight of the machine, the frequency of the vibration, and other factors, such as the weight of the noise-making parts. The isolating material must be loaded to a point where the transmission of the vibration through the material is very low. It is possible to use vibration mounts where there will be more vibration transmitted than if there were no isolation at all. Each individual problem must be analyzed carefully.

MR. SATZ: Do you find that glass fabrics are any less suitable than cotton?

MR. CONTENT: I see no reason to condemn one as against the other. Sound will transmit through the glass fabrics, through the pores as well as through the cotton or other materials. Sound as we hear it is a movement of air, and it will get through the pores of the glass cloth just as well as the cotton.

MR. A. D. PARK: What is the recommended treatment for the rear wall of a motion picture theater?

MR. CONTENT: The best treatment for a rear wall is not to make it concave. Break it up. If you do that, you may not need sound-absorbing material. All you want to do is to prevent echoes which are reflected from the rear wall from reaching the audience. If that wall disperses sound sufficiently so it will not produce echoes, if it is a concave surface, you must use an absorptive material with a high coefficient, so that very little sound will be reflected back to cause trouble in the audience.

MR. JOHN VOLKMANN: It depends considerably on how far the rear wall is from the seating area, that is, the front of the room. In certain seating regions, it is possible where, in addition to shaping the walls, you have to put a lot of absorptive material on it too. I know of cases where we have had a lot of absorbing material on it, and we had to angle the rear wall down, as well as treat it, purely because the surfaces which, as I say, were treated with rock wool, perforated and paneled and cloth-covered on top of that—they were so disposed that they were on a curved surface, and because they were so disposed, they tended to concentrate the sound into localized regions and not until we angled them forward did we get rid of the concentration effect.