by adding additional lining to the duct or providing package attenuation units. Noise is also produced at the grille and is expressed in dbe. All losses (attenuation) are expressed in decibels. The procedure follows:

Step 1. Determine the sound power level of the grille noise either from published data, or from actual measurements, or from approximate data given in the section on Noise Generated by Grilles.

Step 2. Determine the sound pressure levels in octave bands at a specified listener's position due to grille noise alone which is radiated from the end of the duct, using the acoustical properties of the room and the position of the listener (See the following section on Determination of Room Levels).

Step 3. Determine the allowable sound pressure level in octave bands (the criterion) at the listener's position either from published standard data (See the following section on Criteria for Noise Control) or from discussions with the architect or the ultimate user of the room under design.

Step 4. Subtract the criterion levels from the sound pressure levels at the listener's position (in decibels) to determine that the levels at least meet the criterion in each octave band. If the grille noise is higher than the criterion in any octave band, a larger grille size must be used.

Note: The total noise in the room is due to both the grille noise and the fan noise. If the grille noise levels just meet the criterion, then the fan noise emitted in the room must be at least 5 db below the criterion. Alternatively, the grille noise levels and the fan noise levels in the room could each be 3 db below the criterion, because when two noises of the same intensity are combined, the total level is 3 db higher than either. As a third alternative, the fan noise could just meet the criterion, and the grille noise be at least 5 db below the criterion.

Step 5. Obtain the sound power level in octave bands of the fan, either from published data, or from actual measurements, or from approximate formulas given in the following section on Noise Generated by Fans.

Step 6. Determine the existing attenuations in the path, for example, natural duct losses, losses at bends, and reflection losses at the outlet (See the following section on Sound Attenuation in Ducts).

Step 7. Determine the net source power levels by subtracting values from step 6 from step 5.

Step 8. Determine the sound pressure levels in octave bands at a specified listener's position using as basic data the net source power level from the duct, the acoustical properties of the room, and the position of the listener as done in Step 2 above.

Step 9. Subtract the criterion levels from the sound pressure levels at the listener's position (in decibels) as done in Step 4 to obtain the required amount of noise reduction NR in each of the eight octave bands (refer again to note following Step 4).

Step 10. Choose an economical means of providing the required NR. The noise reduction required usually must be obtained by treating the ducts between the source and the receiver either by adding an absorbing lining or by inserting a package unit (See Fig. 1) of known attenuation as a function of frequency. Because noise may be induced by vibration, a consideration of the fan mounting may be necessary. Also, if the fan room is adjacent to a quiet space, the construction of the fan room walls to provide adequate noise reduction should require attention. It is usually good policy to provide slightly more acoustical treatment than is necessary, thus obtaining a safety factor. A safety factor often used is 5 db greater noise reduction than would be indicated by the above procedure.

Frequently the controlling noise source in a building with a central station system is sound transmission through the walls of the apparatus room or from a duct plenum. Where such a room or plenum is near occupied rooms, the noise transmitted through the walls must be determined. The combined sound pressure levels resulting at a listener's position should be compared with the criteria as done in Step 4 for noise produced by grilles.

CRITERIA FOR NOISE CONTROL

Criteria for noise control in building spaces have evolved in the United States from several large scale studies and from the experiences of engineers who have recorded favorable and unfavorable reactions to known background noises in many types of rooms.[5]

The acoustical engineer should carefully question the user of the building to make certain of the kind of uses that he has in mind. For example, a coliseum used for sports only, need not be as quiet as a coliseum also used for concerts. As another example, a hall for band concerts need not be as quiet as one for chamber music. In fact, some rooms are better if they

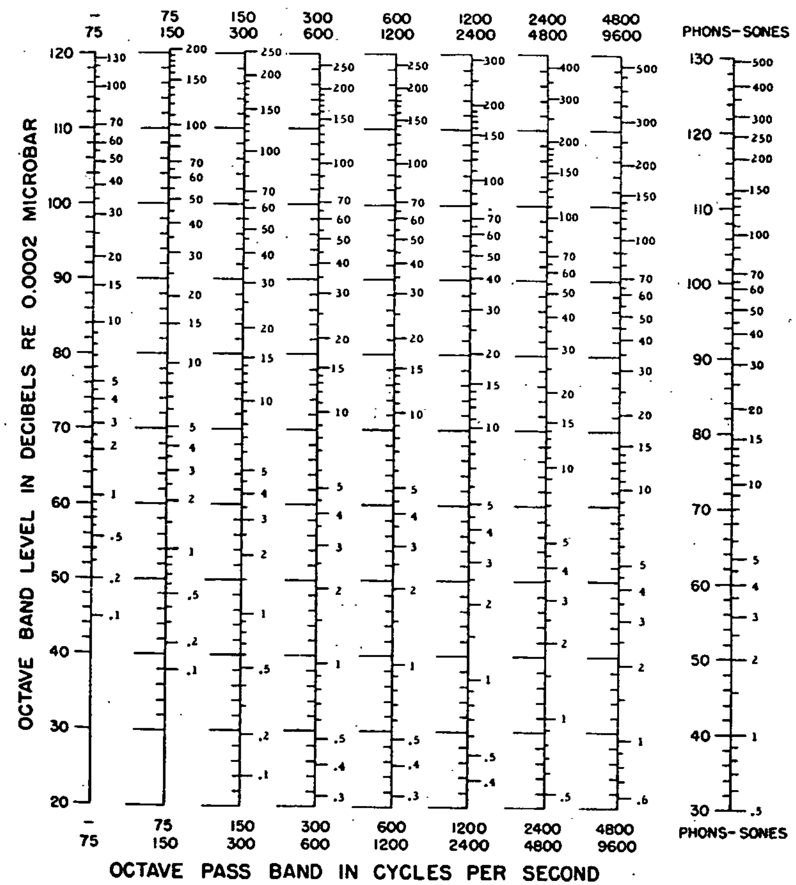

Fig. 2. Nomograms Relating L_p in Octave Bands to Loudness in Sones

The calculated total loudness in sones can be converted to loudness level in phons by means of the nomogram at the right.[3] (From Reference 3. Used by permission.)

are not too quiet. It has been found that libraries, drafting rooms, and study rooms that are too quiet are not so desirable as they would be with moderate noise levels. In very quiet rooms of these types, sounds such as whispering, turning of pages, creaking of the floor, coughing, closing of doors, etc., act to distract the occupants and to make them complain of *noise*. Introduction of a continuous spectrum noise properly distributed as a function of frequency produces a *quieter* condition even through the