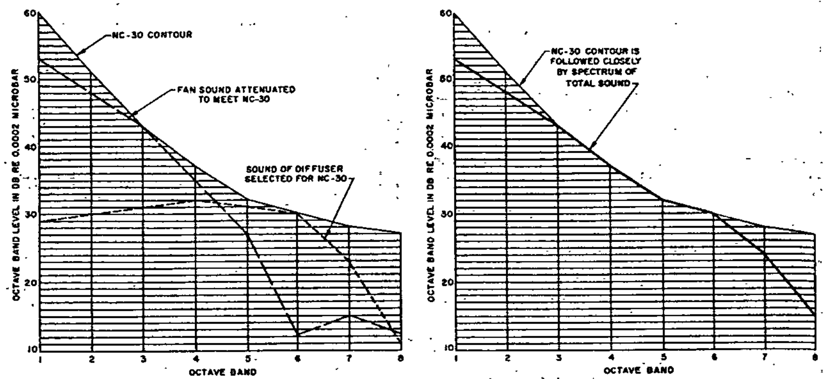

Fig. 3 .... Illustration of Well Balanced Sound Spectrum Resulting from Proper Selection of Air Outlets and Duct Attenuation.

flow velocity over the vanes. Doubling the velocity will increase the sound level by approximately 16 db. Although some generalized data have been published on the sound generated by a few styles of diffusers[22] and grilles,[23] selections should be based on ratings for the particular make. When comparing different manufacturers' ratings, corrections may have to be applied for any differences in the acoustical environment on which the ratings are based.[3,24]

The maximum air flow velocity, and hence the sound level, depend not only on the air quantity, size, and design of the air outlet, but also upon the air approach configuration.

When a volume control damper is installed close to an air outlet, the air flow velocity in some parts of the outlet will increase when the damper is throttled to build up resistance. Table 6 can be used to estimate the increase in sound level from the increase in resistance of the outlet-damper combination, since both are a function of the degree of damper opening.

To avoid the increase in noise level shown in Table 6, volume control dampers should be located several duct widths upstream from the air outlet, so that air streams from the damper will not impinge on the vanes or cones of the outlet.

Direct Ratings

Since there is no path attenuation involved, it may be possible to save time by selecting air outlets from ratings expressed directly in terms of the noise level (loudness level, A-sound level, or NC level) which they produce in a *typical* room at a typical listener's position (see Fig. 4). This shortcut method is accurate within ± 2 db, provided that the amount of room absorption on which the ratings are based is within ± 40 percent of the amount of room absorption available per outlet in the proposed installations.

Table 6 .... Effect of Damper Throttling on Noise Generated by an Air Outlet

(At a Given Air Quantity)

Effective Damper Opening (Reference Only)	*Resistance of Outlet-Damper Combination*	*Increase in Noise Level*[a]
100%	100%	0 db
82%	150%	4½ db
70%	200%	8 db
50%	400%	16 db

[a] For dampers located close to outlet.

Sound Power Ratings

Whenever there are several different sources of sound, it is more convenient to use ratings in terms of the sound power generated in each octave band, or at least in each of the most important bands. Sound power ratings have the advantage of being absolute, i.e., independent of room absorption. For duct-connected central station equipment, octave band sound power ratings are the only practical way to express acoustic performance. Unless design specifications are also expressed in terms of power level, it is necessary to convert them to that form before equipment power level ratings can be applied.

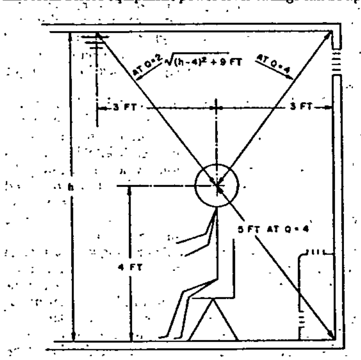

Fig. 4 .... Typical Distance from Sound Source to Listener, r

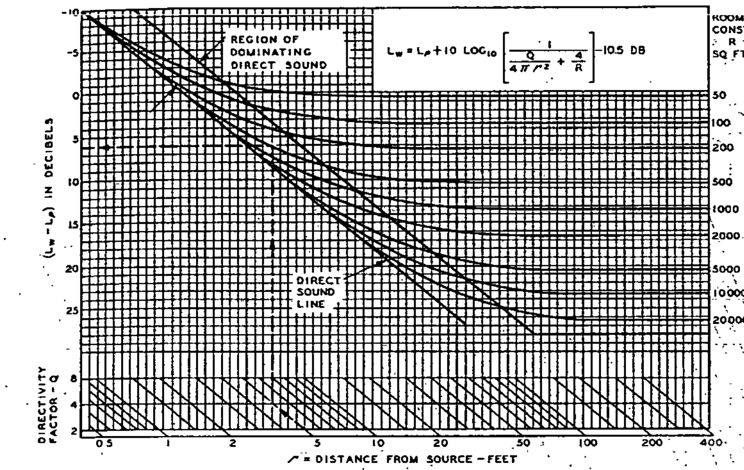

Fig. 5 .... Chart for Converting Sound Pressure Level L_p (in db re 0.0002 microbar) into Power Level L_W (in db re 10^{-12} watt)

Room Absorption Effect

The computation of the sound power level that corresponds to a specified room sound level is similar to a heat load calculation and involves the rate at which sound energy is dissipated by absorption at the walls, ceiling, and furnishings of the room, as well as the direct radiation of sound from the source to the listener:

$$L_W = L_p + 10\log_{10}\left[\frac{1}{\frac{Q}{4\pi n}\left(\frac{1}{r_1^2}+\frac{1}{r_2^2}+\cdots\right)+\frac{4}{R}}\right] - 10.5 \quad (10)$$

where

L_W = sound power level, db re 10^{-12} watt.
L_p = sound pressure level, db re 0.0002 microbar.
Q = directivity factor, dimensionless.
n = number of sound sources of equal sound power.
r_1, r_2, etc. = distance from sound sources, feet.
R = room constant, square feet.

Equation 10 is presented graphically in Fig. 5 for a single sound source. It should be noted that $(L_W - L_p)$ becomes a function of R only when the distance from the source is sufficiently great. The same is true if the number of sound sources, n, is sufficiently great.

The room constant R is therefore the most important variable in Equation 10. It can be calculated from Equation 11:

$$R = \frac{S\bar{a}}{1-\bar{a}} \quad (11)$$

where

S = total area of the ceiling, wall, and floor surfaces, square feet.
$\bar{a}$ = average sound absorption coefficient for the surfaces, S, dimensionless.

The room absorption $S\bar{a}$ needed for using Equation 11 can be determined in several ways:

1. For existing rooms, $S\bar{a}$ can be calculated from:
   a. The measured sound pressure level produced by a reference sound source[25] of known sound power output.
   b. The measured reverberation time, T, in seconds. This is the time it takes for the sound pressure level from an intermittent source (such as a shot) to drop 60 db.[26]

$$S\bar{a} = \frac{0.049V}{T} \quad (12)$$

where V = volume of the room, cubic feet.

Reverberation time is a good criterion of acoustical quality of a room and therefore is closely related to the type of activity for which the room is suitable. A short reverberation time means that sounds die out quickly. *Dead* rooms are good for conversation at close range and for studios for sound recording. *Live* rooms, on the other hand, have considerable echo and, therefore, are not suited for speech communication because words and syllables will blur into each other. However, live rooms are desirable for certain types of music, especially music composed for large churches.[27]

2. During the design stage, the room absorption can be computed as the sum of the absorption value for each surface and object in the room:

$$S\bar{a} = S_1\alpha_1 + S_2\alpha_2 + \cdots + A_1 + A_2 \cdots + 4mV \quad (13)$$

where

S_1, S_2, etc. = area of each type of room surface, square feet.
α_1, α_2, etc. = absorption coefficients[28] of each type of surface at a frequency typical for the band of sound being considered.
A_1, A_2, etc. = absorption units of occupants, furnishings, etc., sabines or square feet.
m = factor for absorption of sound in air.

This is the method which the architect or acoustical designer uses to determine the amount and kind of absorbing material needed to provide the proper acoustical quality for the particular space. For the mechanical engineer this computation is seldom