Table 3 .... Summary of Sound Sources, Sound Paths, and Usual Noise Reduction Methods

Sound Source	Path Nos.*	Sound Paths		Noise Reduction Methods
		No.	Description	
Diffusers, Grilles, Registers Circulating Fans Unitary Equipment (located entirely within room)	1	1	Sound reflected by walls, ceiling and floor Direct sound radiation from Source to Ear	Room absorption and location of sound source have a great effect on received level, but are usually fixed by room layout. Only practical way to reduce noise is to select sufficiently quiet equipment.
Induction Coil Units and High Velocity Mixing Units (These are not only noise sources, but also attenuators for fan noise)	1, 2	2	SOLID BORNE SOUND TRANSMISSION *Noise radiated from casings and through walls of ducts and plenums is transmitted through walls and ceilings into air conditioned rooms*	Locate high velocity ducts and terminals, as well as noisy parts of low velocity ducts, in non-critical areas. Design ducts and fittings for low turbulence.
Unitary Equipment (located outside of room served) Remotely Located Air Handling Equipment: Fans and Blowers Dampers and Fittings Air Washers	2, 3, 4, 5, 6	3	Through supply *and* return ducts to terminals in air conditioned rooms (and hence to listener as in Path 1)	Select fans for minimum noise generation. Provide sound attenuation devices in supply and *return ducts.*
Compressors Pumps	4, 5, 6	4	SOLID BORNE SOUND TRANSMISSION *Noise is transmitted through equipment room walls and floor*	Locate equipment room away from critical areas.
		5	*Building structure transmits vibrations which turn into noise*	Provide sound absorption in equipment room and sound-isolating wall and floor construction.
Cooling Towers Air-Cooled Condensers	4, 5, 6, 7	6	*Transmission along pipe and duct walls*	Design equipment room floor for dynamic loads. Balance fans both statically and dynamically. Mount all machines on proper vibration isolators. Install flexible connectors in ducts and pipes.
Exhausters Window Air Conditioners	7, 8	7	Noise radiated to outside enters receiver's room through windows	Locate sound sources away from critical areas. Reduce sound radiation with shields and covers. Select equipment for low enough source level.
		8	Noise radiated to inside follows Path 1	Select sufficiently quiet equipment.
Cross Transmission between Rooms	9, 10	9	Through air outlet of one room into ductwork and out through next air outlet	Design and install duct attenuators to match transmission loss of partition (Path 10)
		10	SOLID BORNE SOUND TRANSMISSION *Through room partitions or over and around them*	Partitions should be extended to ceiling slab and be sealed tightly all around. Also seal around all duct and pipe openings.

* Sound from a particular source may take any of the paths listed in this column. It should be noted that Paths 2, 4, 5, 6, and 10 in italic type involve solid borne sound transmission (see text).

the sound output of equipment containing electric motors, fans and compressors. To indicate the generally undesirable character of noise containing pure tones, one approach which has been suggested is to rate the source level up to 10 db higher than the measured value in any octave band which contains a noticeable pure tone.[21,22]

Various specifications based on octave band levels are used to express the needs of differing situations:

1. For spaces in which ease of speech communication is most important, a maximum limit is sometimes specified for the speech interference level. This is defined as the arithmetic average of the sound pressure levels in the three octave bands of the speech frequency range (600–4800 cps).

2. For spaces in which speech privacy must be assured, such as private offices, hotel rooms, etc., minimum sound levels may also be specified in the speech frequency bands. These limits must be selected in accordance with the sound isolating value of the room construction.[23,24]

3. For general comfort specifications, limits are often set by reference to the *noise criterion* (NC) curves[25] shown in Fig. 2. It is often required, for example, that a sound not project above a specified NC contour in any frequency band.

The contours of the NC curves were derived to express the background sound levels observed in loudness and speech interference studies in a large number of offices. These studies indicate that the background is least annoying if its spectrum, like these contours, is such that the loudness in phons is approximately equal to the speech interference level plus 22. If it is not feasible to provide enough attenuation to reach the desired NC level in the low-frequency range, a somewhat higher loudness level may sometimes be tolerated without compromising on the speech interference level. Experience has shown that the loudness level should not exceed the speech interference level plus 30. The NCA curves shown with broken lines in Fig. 2 are based on this limit.

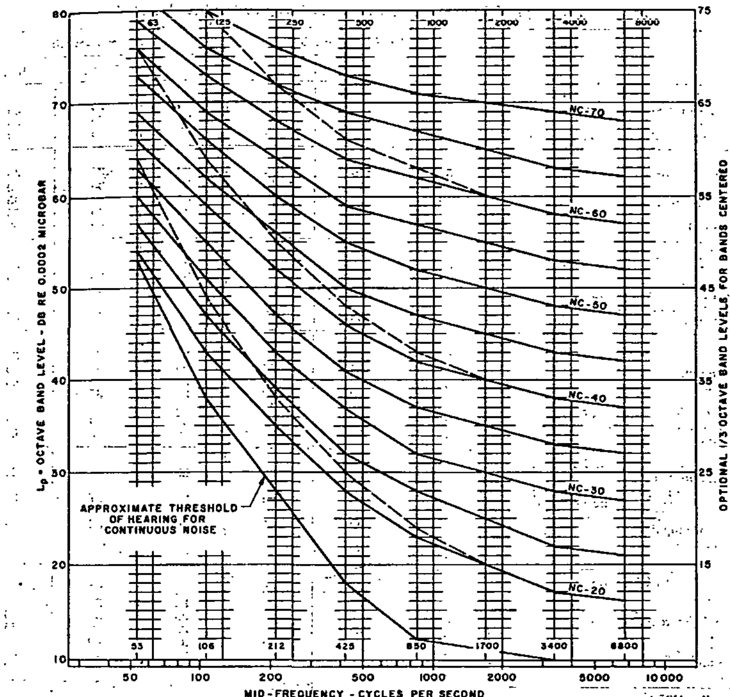

Fig. 2 .... Noise Criterion Curves for Specifying the Design Level in Terms of the Maximum Permissible Sound Pressure Level for Each Frequency Band[26]

Loudness or Loudness Level. Loudness of a sound, expressed in units of sones, is a single number rating based on statistical evidence of the response of humans to sound.[26,27,28] The loudness scale is a linear representation of the relative loudness of sounds to humans. Using equal loudness contours, each octave band level is assigned its loudness value. Total loudness is then calculated using Equation 7:

$$S = S_m + 0.3(\Sigma S - S_m) \quad (7)$$

where

S = total loudness.
S_m = loudness of the loudest octave band.
ΣS = sum of the loudnesses of all octave bands.

The logarithmic equivalent to loudness in sones is the loudness level in phons. One sone equals forty phons, and the loudness level increases ten phons for each doubling of loudness.

Any interpretation of loudness data should recognize that different authors have reported values based on differing loudness contours.

A-Scale Sound Level. This measuring method has the advantage of simplicity, since the A sound level is obtained from one reading on a single instrument. The A-scale of a standard sound level meter includes an electronic weighting network which de-emphasizes the low frequency portions of the noise spectrum, thus automatically compensating for the lower sensitivity of the human ear to low frequency sounds. The response curve of the A-scale weighting network is similar, over most of the frequency range, to an equal loudness contour.

The three systems of expressions described cannot be subject to conversion charts or expressions. Each describes a sound in a different frame of reference; sounds of differing spectra will therefore involve different comparisons between the systems. For a given spectrum shape, however, some approximate comparisons can be made. For sounds such as air flow noise, which have a broad spectrum and no strong pure tones, a rough estimate of either loudness level or NC level can be made from the A-scale sound level.[29]

$$\text{loudness level (phons)} = \text{A-scale level (db)} + 12 \pm 2 \quad (8)$$
$$\text{NC level} = \text{A-scale level (db)} - 6 \pm 2 \quad (9)$$