A good concert hall should at least meet the NC-20 curve, and preferably the NC-15 curve. For lecture halls and classrooms, the noise levels should be at (or below) the NC-30 curve, or better yet, the NC-25 curve. T_{60} reverberation times should also be < 0.5 seconds in lecture halls and/or classrooms, in order to avoid speech interference problems, particularly in the speech intelligibility range of 500 – 4000 *Hz*. A teacher using a normal voice will produce a sound pressure level of ~ 46 *dB* at the ears of a student 30 *ft* away; the NC-30 curve corresponds to an average background noise level of ~ 36 *dB* in this frequency range, thus a 10 *dB* difference in speech *vs*. noise level, as required for speech intelligibility.

Today, audio/acoustic engineers can harness the power of the computer and use sophisticated computer programs to create accurate 3-D simulations of the acoustical environment/acoustical properties of an arbitrarily-shaped room – be it a concert hall, a theatrical stage, a church, *etc*. Ray-tracing techniques are used to simulate 3-D sound propagation from accurately-modeled sound sources, or even actual recorded sounds, reflecting off of the 3-D surfaces of the room, including frequency-dependent absorption and diffusivity coefficients of these surfaces.

The most common measure of the reverberation time for these programs is T_{30}, (the time for the sound intensity to decay to 1/1000th of its steady-state value – noting that $T_{60} = 2\ T_{30}$) which is calculated from the slope of the curve fit through the simulated ray-tracing generated reverberation time data for the sound intensity level *vs*. time as the sound intensity level decays from −5 *dB* to −35 *dB*. The T_{30} reverberation time obtained in this manner is a more sensitive indicator of the true reverberation properties of a room than that obtained from the Sabine equation, because it takes into account both the absorption <u>and</u> the <u>*diffusivity*</u> of the room surfaces, as well as the detailed specifics of the geometry of the room (limited only by the accuracy input to the 3-D model of the room). In such acoustics ray-tracing programs, one can also investigate T_{30} *e.g*. in different octave bands (*i.e*. as a function of frequency) much more easily than T_{60}, which requires significantly more computation time.

Ray-tracing acoustical simulation software programs can also obtain accurate estimates of the sound pressure levels everywhere in the simulated room (and as a function of frequency) to enable the {as uniform as possible}sound pressure levels independent of the location of a person in the room, thus eliminating and/or minimizing dead spots or hot spots in the room.

Please see/read the P406 Lecture Note hand-out on “EASE Examples” for more details.

Speech intelligibility is another important acoustical attribute of a listening room, particularly for lecture halls, theater- and church-goers – *i.e*. any room or acoustical environment where public speeches are important. One statistic for speech intelligibility is Definition D_{50} , defined as the ratio of the integral of the square of the overpressure within the first 50 *msec* of the initiation of sound associated with *e.g*. a very short sound impulse (< 50 *msec* duration) to that integrated over all time for that same sound, expressed as a percentage:

$$\boxed{D_{50} \equiv 100 \times \left[\frac{\int_{t=0}^{t=50ms} p^2(t)dt}{\int_{t=0}^{t=\infty} p^2(t)dt} \right] \ (\%)}$$