Acoustics: Room Criteria

THE ARC.

Room criteria measures have been developed to evaluate existing background noise levels in rooms as well as specify required background levels for rooms to be constructed.

Criteria are also often used for diagnostics of faulty equipment

THE ARC.

ILLINOIS INSTITUTE OF TECHNOLOGY

A Weighted Sound Level:

Devloped in early 30's for the measurement of noise

Noise Criteria (NC):

Originally developed in late 50’s in response to growing HVAC noise problems in offices

Room Criteria (RC):

Developed in mid 80’s in response to failings of NC method

RC Mark II:

Developed in mid 90’s in response to failings of NC/RC

New NC:

Developed in 2000’s in response to failings of NC/RC

THE ARC.

ILLINOIS INSTITUTE OF TECHNOLOGY

Design vs Diagnostics

- Some criteria are more useful as a design criteria and some are more useful for diagnosing HVAC problems
- ASHRAE's latest recommendations (to appear in a future handbook) are
  - Use dBA and NC for design criteria (i.e. what you put in your design documents and the levels you would design to meet)
  - Use RC Mark II (and possibly RNC) for diagnostics use when responding a noise complaint

THE ARC.

ILLINOIS INSTITUTE OF TECHNOLOGY

A Weighted Level (dBA)

- The simplest noise criteria is measuring or specifying a maximum A weighted level (dBA)
  - This is highly limited as a diagnostic because all spectral information is eliminated during measurement and is not included in specification
  - The difference between the A and C weighted levels (i.e. LC – LA) is related to the low frequency content. ANSI S12.2 states the spectrum is considered imbalanced if LC – LA>13 dB
- A weighted sound level is probably the most popular design criteria
  - S12.2 gives recommended A weighted levels in Table C.1

THE Academic Resource Center

ILLINOIS INSTITUTE OF TECHNOLOGY

Table C.1 A-Weighted Criteria

Occupancy	Max dBA
Small auditoriums (≤500 seats)	35-39
Large auditoriums, theaters, and churches (>500 seats)	30-35
TV and broadcast studios (close microphone pickup only)	16-35
Private Residences:	
Bedrooms	35-39
Apartments	39-48
Family/Living Rooms	39-48
Schools:	
Lecture Halls and Classrooms (V<20000 ft3)	35
Lecture Halls and Classrooms (V>20000 ft3)	40
Open-plan Classrooms	35

THE Academic Resource Center

ILLINOIS INSTITUTE OF TECHNOLOGY

Occupancy	Max dBA
Hotels/Motels	
Individual Rooms	39-44
Meeting/Banquet Rooms	35-44
Offices	
Executive	35-44
Small, Private	44-48
Large, with conference Tables and Small Conference Rooms	39-44
Large Conference Rooms	35-39
Open-plan Office Areas	35-39
Copier/Computer Rooms	48-53
Circulation Paths	48-52

THE Academic Resource Center

ILLINOIS INSTITUTE OF TECHNOLOGY

Occupancy	Max dBA
Hospitals and Clinics	
Private Rooms	35-39
Wards	39-44
Operating Rooms	35-44
Laboratories	44-53
Corridors	44-53
Movie Theaters	39-48
Small Churches	39-44
Courtrooms	39-44
Restaurants	48-52
Shops and Garages	57-67

THE Academic Resource Center

ILLINOIS INSTITUTE OF TECHNOLOGY

A-Weighted Sound Level

Calculating A weighted sound level for a given spectrum of sound levels

f (Hz)	16	31.5	63	125	250	500	1000	2000	4000	8000
LEQ (dB)	79.3	71.2	56.4	48.2	40.1	36.1	31.1	27	24	21.1

First adjust the given sound level by the A weighted adjustments given in Chp 3, Table 3.1 of LAA

f (Hz)	16	31.5	63	125	250	500	1000	2000	4000	8000
Adjust (A weighting)	-56.7	-39.4	-26.2	-16.1	-8.6	-3.2	0	1.2	1	-1.1

THE Academic Resource Center

ILLINOIS INSTITUTE OF TECHNOLOGY

A-Weighted Sound Level

Add the A weighting adjustment to the given sound levels. Then use the following formula to calculate the overall sound level.

$$Lp\ (dBA) = 10\log\left(\sum_{16\ Hz}^{8000\ Hz} 10^{0.1*Lp}\right)$$

Reference the overall A weighted sound level to the given tables to see if the sound level is satisfactory

The Academic Resource Center

ILLINOIS INSTITUTE OF TECHNOLOGY

Is dBA sufficient?

- Recent research (Ryherd, 2008) has shown that simple A weighted levels correlate with worker perception and performance as well as any other room criteria
- For this reason, A-weighted levels should probably always be considered as a possible criteria for offices

THE Academic Resource Center

ILLINOIS INSTITUTE OF TECHNOLOGY

NC Method

- The NC method was originally developed by Leo Beranek in the late 1950s and became very popular with architects and consultants
  - A description of the original NC method is found in LAA and most architectural acoustics texts
  - It is basically a comparison of spectra to a set of curves similar to equal loudness contours

THE Academic Resource Center

NC Limitations

- NC method was limited in that the curves used for evaluation/design did not extend down to low frequencies
  - Energy efficient HVAC systems that started being developed in the 1980s had significant low frequency sound levels that were not well measured by NC
- No check for unbalanced spectrum
  - A room with a low noise level but a rumbly or hissy spectra can be just as bad as a noisy room.

New NC Method

In 2008 an update to the NC method was published in ANSI S12.2-2008. The new standard:

- Updates NC curves down to 16 Hz
- Relates NC level directly to SIL level
- Includes checks for spectral imbalance and identification of rumbly spectra that could possibly or likely be highly dissatisfying

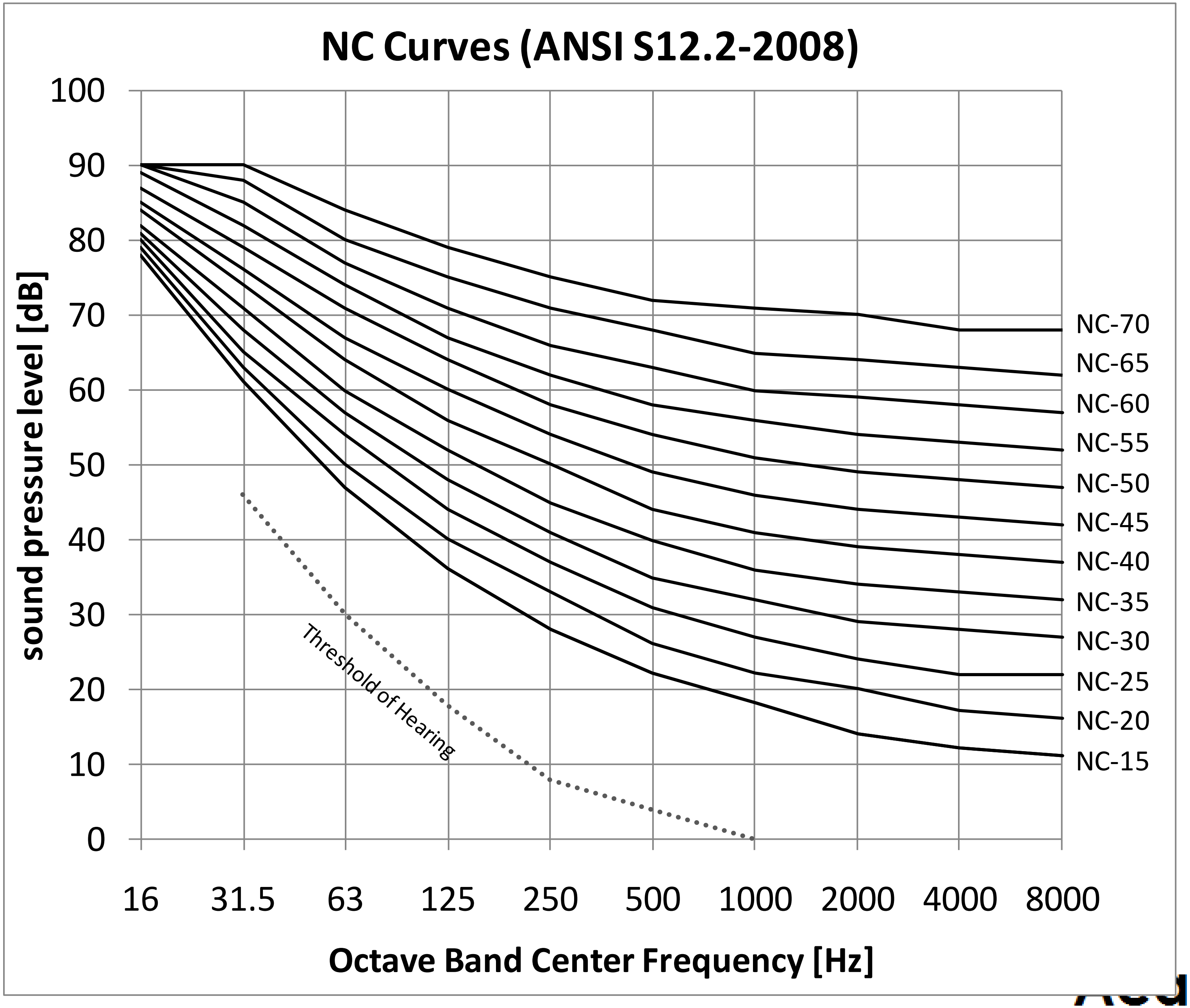
ILLINOIS INSTITUTE OF TECHNOLOGY

New NC Curves

	16	31.5	63	125	250	500	1000	8000	4000	8000
NC-70	90	90	84	79	75	72	71	70	68	68
NC-65	90	88	80	75	71	68	65	64	63	62
NC-60	90	85	77	71	66	63	60	59	58	57
NC-55	89	82	74	67	62	58	56	54	53	52
NC-50	87	79	71	64	58	54	51	49	48	47
NC-45	87	76	67	60	54	49	46	44	43	42
NC-40	84	74	64	56	50	44	41	39	38	37
NC-35	82	71	60	52	45	40	36	34	33	32
NC-30	81	68	57	48	41	35	32	29	28	27
NC-25	80	65	54	44	37	31	27	24	22	22
NC-20	79	63	50	40	33	26	22	20	17	16
NC-15	78	61	47	36	28	22	18	14	12	11
Hearing		46	30	18	8	4	0	-2	-4	-4

THE Academic Resource Center

ILLINOIS INSTITUTE OF TECHNOLOGY



Academic Resource Center

ILLINOIS INSTITUTE OF TECHNOLOGY

New NC Procedure

- Get octave band sound levels
- Compute the SIL (average of 250-2000 Hz octave band levels)
- Plot spectra and see if it exceeds the NC-SIL curve anywhere. If not, the spectra gets an NC-(SIL) rating e.g. NC-(42) rating
- If the spectra exceeds the NC-(SIL) curve anywhere, the tangency method is used to find NC value
  - Select the NC-(XYZ) curve tangent to the spectrum
- Check for spectral imbalance

THE Academic Resource Center

ILLINOIS INSTITUTE OF TECHNOLOGY

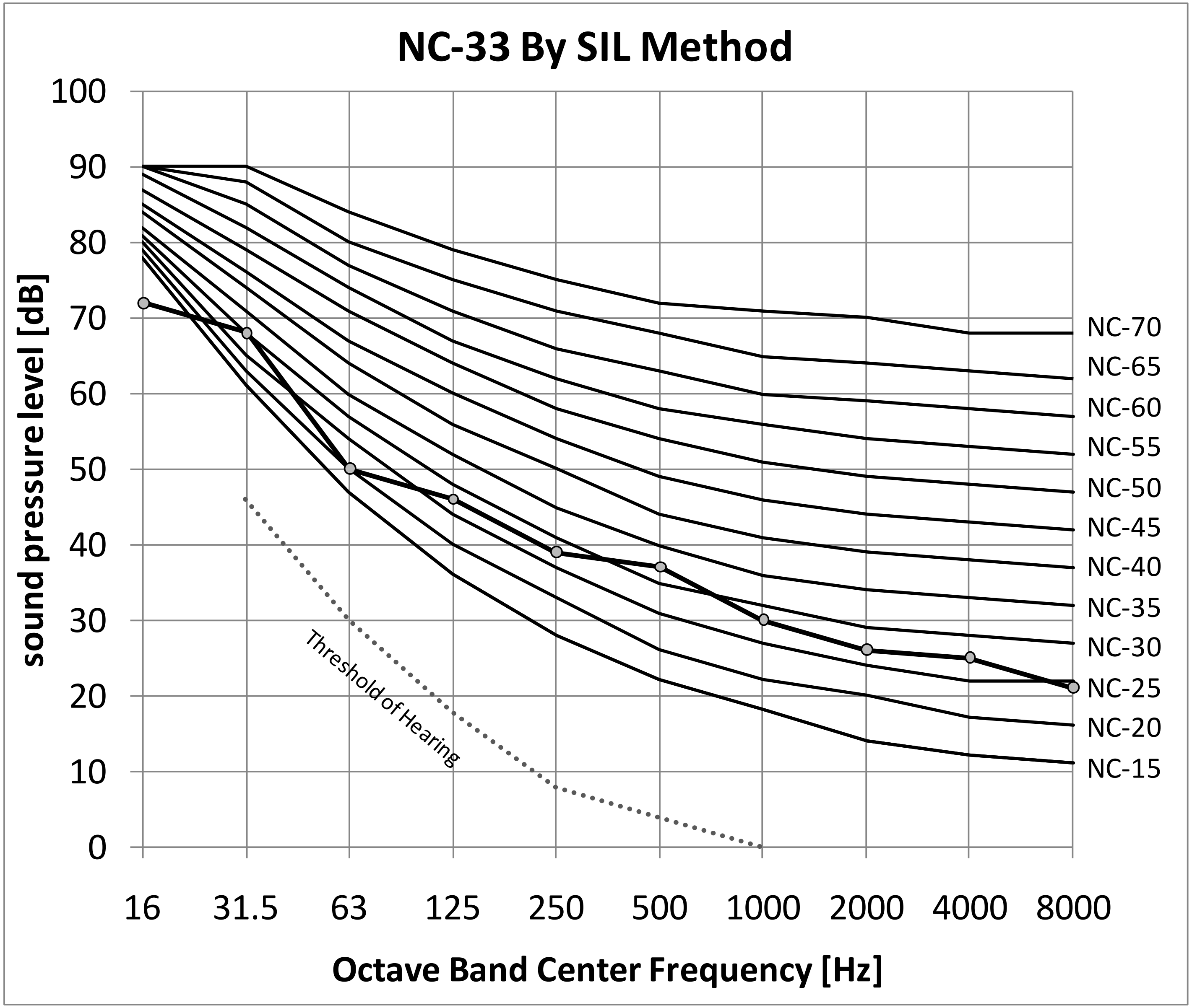
Finding the NC Rating

	16	31.5	63	125	250	500	1000	2000	4000	8000
Lp	72	68	50	46	39	37	30	26	25	21

- SIL=(39+37+30+26)/4=33 dB
- Spectra is below NC-33 curve at all frequencies so rate by the SIL
- Spectra does not exceed NC-33 curve at low frequencies so there is little chance of serious dissatisfaction

THE Academic Resource Center

ILLINOIS INSTITUTE OF TECHNOLOGY



Academic Resource Center

ILLINOIS INSTITUTE OF TECHNOLOGY

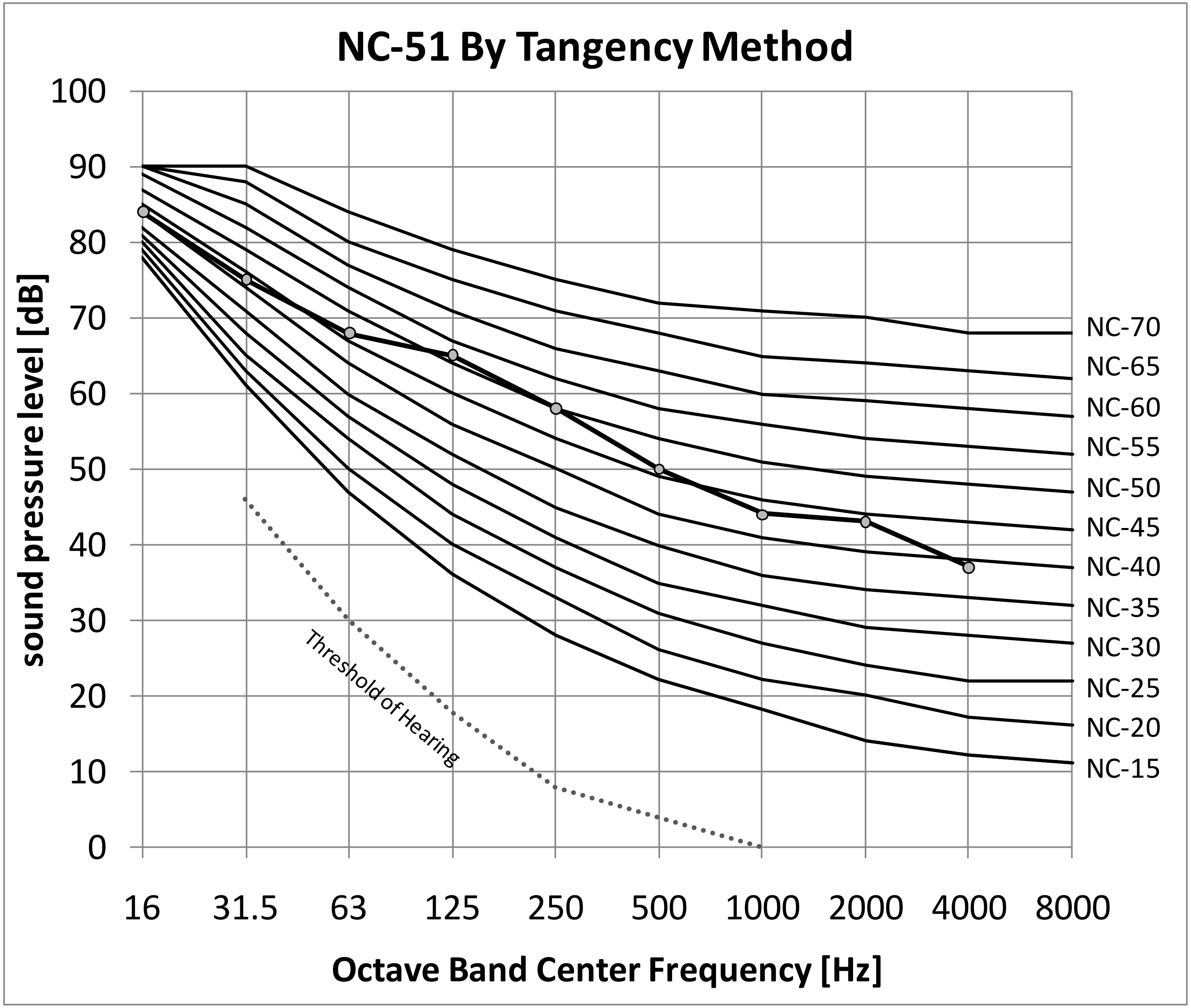
Finding the NC Rating

	16	31.5	63	125	250	500	1000	2000	4000
Lp	84	75	68	65	58	50	44	43	37

- SIL=(58+50+44+43)/4=49 dB
- Spectra is above NC-49 curve at 125 and 250 Hz so use tangency method
- 125 Hz band is tangent to NC 51, so NC rating is NC-51
- Spectra does exceed NC 49 curve at low frequencies but only by 2db so there is little chance of serious dissatisfaction.

THE Academic Resource Center

ILLINOIS INSTITUTE OF TECHNOLOGY



Academic Resource Center

ILLINOIS INSTITUTE OF TECHNOLOGY

RC Mark II the Updated RC

- The RC system was developed in late 70's and early 80's by Warren Blazier for ASHRAE as a response to LF and HF problems with NC
  - RC curves are considered spectrally balanced

THE Academic Resource Center

ILLINOIS INSTITUTE OF TECHNOLOGY

RC Mark II

- Curves are similar to RC
  - 5 dB/oct slope from 32-4000 Hz.
    - Goes through RC level at 1 kHz
  - Flat between 16 Hz and 32 Hz

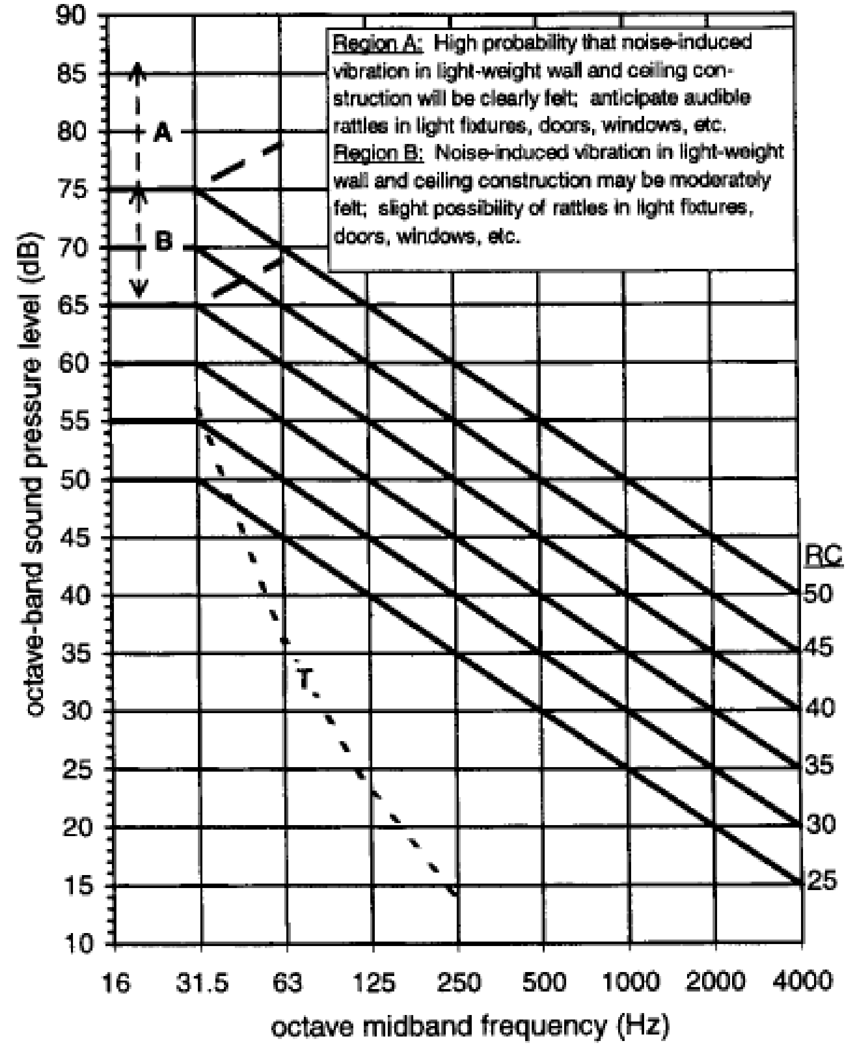


Fig. 1 – Family of room criterion (RC Mark II) reference curves.

THE Academic Resource Center

RC Mark II

- Compute PSIL (avg of 500, 1k and 2k bands) to get the RC reference curve for comparison and basic RC level
  - This is not SIL which is average from 250 to 2k
- Find average energy deviation between spectrum and RC reference curve in LF, MF and HF freq ranges

$$LF = 10\log\left[\left(10^{0.1\Delta L_{16}} + 10^{0.1\Delta L_{32}} + 10^{0.1\Delta L_{63}}\right)/3\right]$$

$$MF = 10\log\left[\left(10^{0.1\Delta L_{125}} + 10^{0.1\Delta L_{250}} + 10^{0.1\Delta L_{500}}\right)/3\right]$$

$$HF = 10\log\left[\left(10^{0.1\Delta L_{1000}} + 10^{0.1\Delta L_{2000}} + 10^{0.1\Delta L_{4000}}\right)/3\right]$$

ILLINOIS INSTITUTE OF TECHNOLOGY

RC Mark II

Quality Assurance Index (QAI) is a quantitative measure of spectral imbalance that is included in the RC Mark II

The QAI is the difference between the highest and lowest energy-average spectral deviations (do not remove any negative signs) .

If QAI < 5 dB and L16(Hz)<65,L32<65 spectrum is designated neutral (N) and acceptable

1. If QAI>5 dB, spectrum is designated LF, MF, or HF based on highest value of three
   - For 5 < QAI <10 dB spectrum is marginally acceptable
   - For QAI > 10 dB, spectrum is considered objectionable

If L16>65 or L32>65 spectrum is designated LFVb

If L16>75 or L32>75 spectrum is designated LFVa

THE Academic Resource Center

ILLINOIS INSTITUTE OF TECHNOLOGY

RC Mark II

- What is the RC Mark II level of this spectrum?

16	31.5	63	125	250	500	1k	2K	4K
61.8	46.0	43.2	32.2	35.9	30.9	24.9	20.9	17.0

THE Academic Resource Center

RC Mark II

RC Mark II					
f (Hz)	L_p (dB)	RC	Δ		
16	68.6	51	17.6	Δ_{LF}	13.7
32	61.8	51	10.8		
63	46	46	0		
125	43.2	41	2.2	Δ_{MF}	0.8
250	35.9	36	-0.1		
500	30.9	31	-0.1		
1000	24.9	26	-1.1	Δ_{HF}	0.0
2000	20.9	21	-0.1		
4000	17	16	1		
PSIL	**26**			QAI	13.7
				Max Δ	LF
RC Rating RC 26HVb					

PSIL=(30.9+24.9+20.9)=26

□LF = 13.7 dB

□MF = 0.8 dB

□HF = 0 dB

QAI=(13.7-0)=13.7

QAI>10 so spectrum will be objectionable

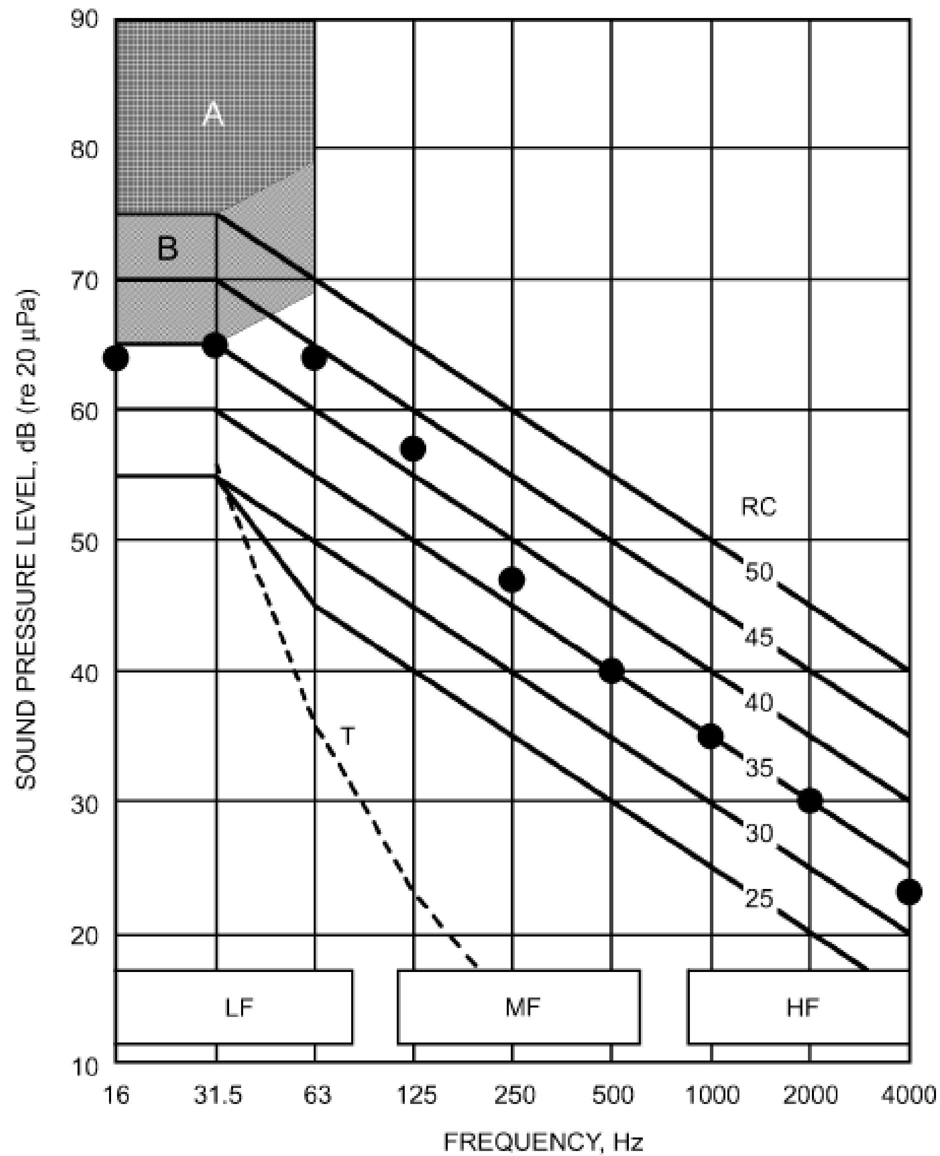
Note though that the LF region extends into the high vibration region so the spectrum gets an HVb rating and not just an LF rating

We give this a rating of

RC-26 HVb

ILLINOIS INSTITUTE OF TECHNOLOGY

RC Mark II



THE Academic Resource Center

ILLINOIS INSTITUTE OF TECHNOLOGY

References

- Archtiectural Acousitcs, Marshal Long, Chapter 3; (LAA)

- ANSI (**2008). *S12.2-2008: Criteria for Evaluating Room Noise (ANSI).***

- ASHRAE (**2007). *2007 ASHRAE Handbook: HVAC Applications (ASHRAE).***

- ANSI (2007). *S12.2-2008: Procedure for the Computation of Loudness of Steady Sounds* (ANSI).

- Prepared by Asfandyar Khan

THE ARC.