The Role of Acoustics in Curtain Wall Design:

Strategies to Achieve Desired Performance Criteria

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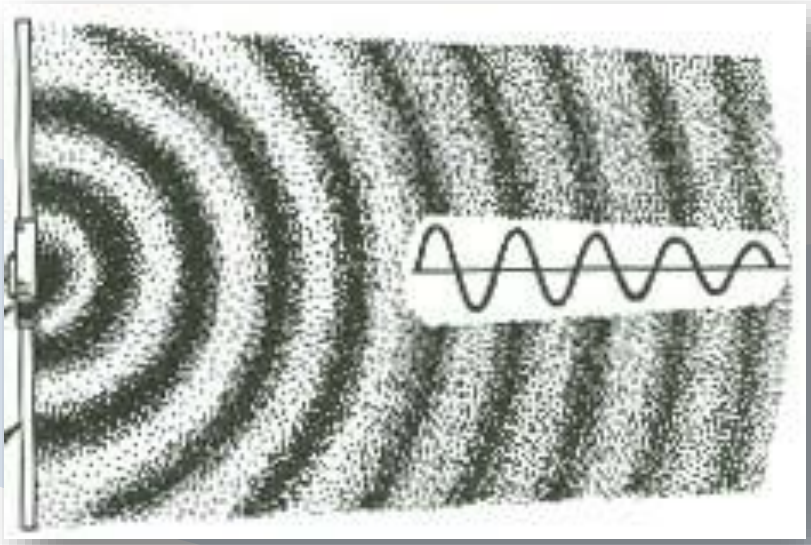
Goals

- Basics of Acoustics
- Ratings in Architectural Acoustics
  - Single Number Metrics
  - Code Requirements
- Acoustical Performance of Curtainwall
  - Elements that affect noise level
  - Effect of glazing parameters
- Noise from Curtainwall Systems
- Sound Isolation at Vertical Condition
- Sound Isolation at Horizontal Condition

Acoustics Basics

What is Sound?

- Sound is short-term pressure fluctuations that propagate through a medium
- In air, it is a pressure wave of fluctuations above and below atmospheric pressure



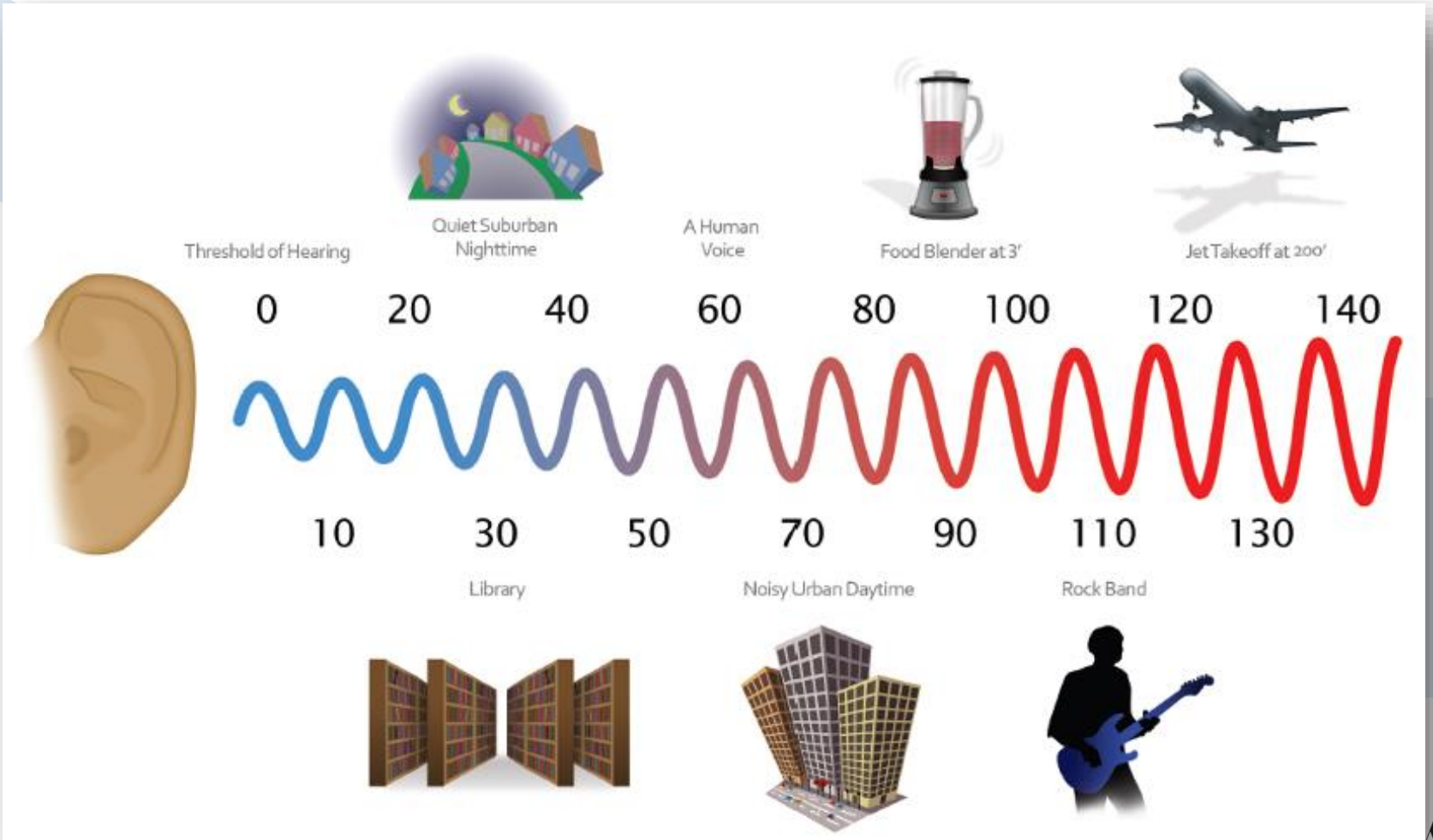
Sound Level: Decibels

- The decibel (dB) is used to measure sound level and is a LOGARITHMIC unit that describes a ratio.
- Sound levels add logarithmically:

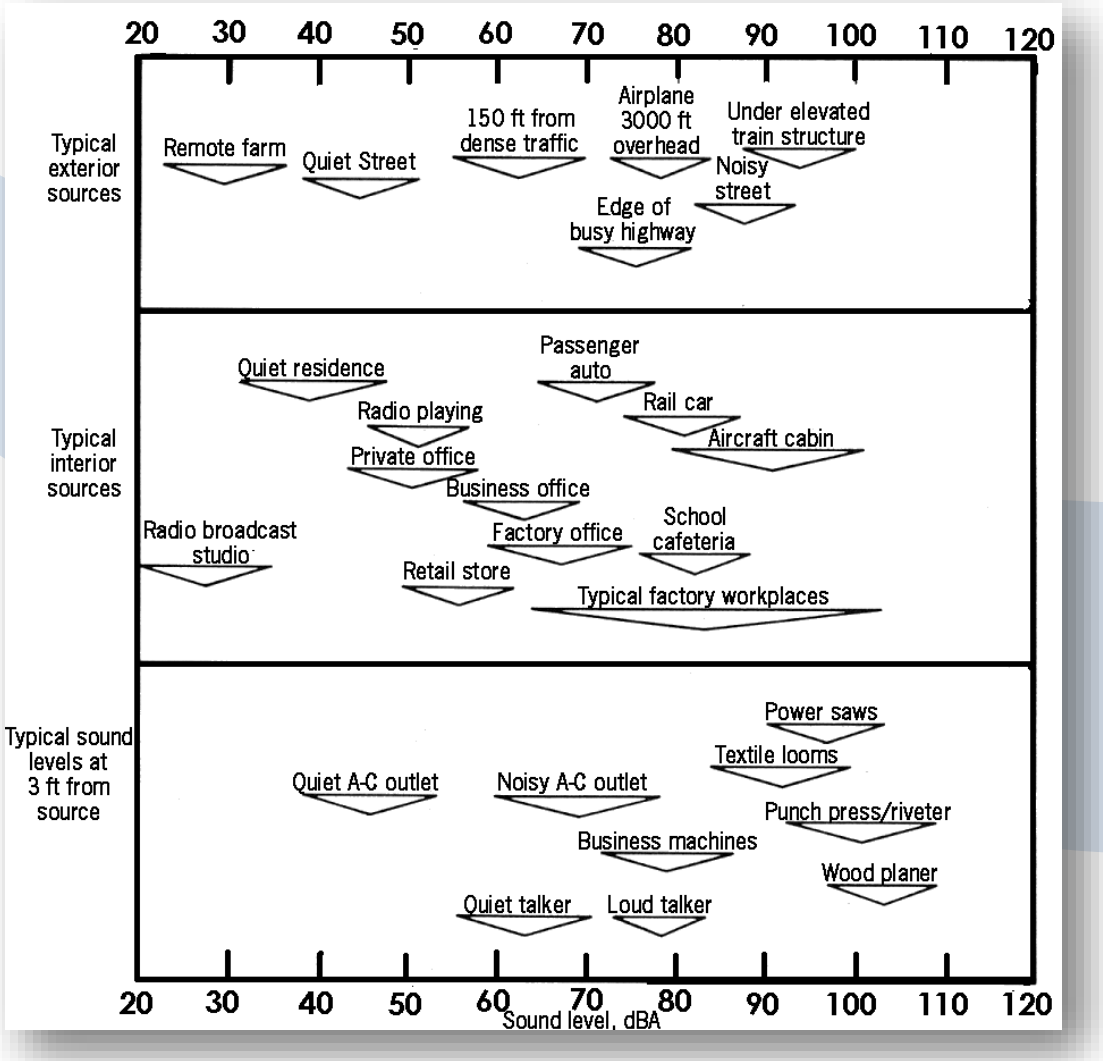
  93 dB + 93 dB = 96 dB

  80 dB + 90 dB = 90 dB
- Subjective reactions vary in the population. These are the rules of thumb regarding change.
  - A change of around 3 decibels is just noticeable
  - A change of around 6 decibels is obvious
  - An increase of about 10 decibels is perceived as twice as loud.

Sound Levels of Various Sources

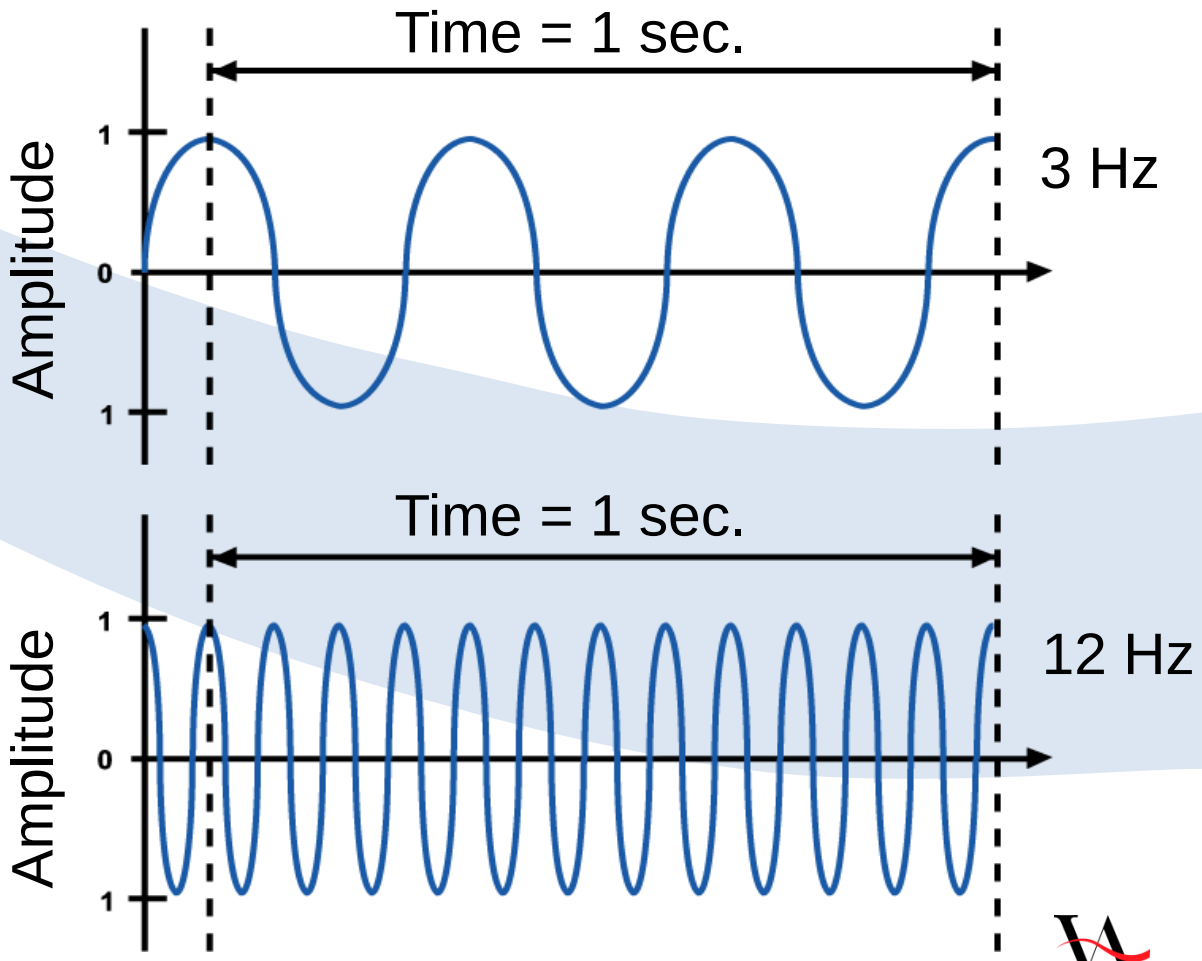


Sound Levels of Various Sources

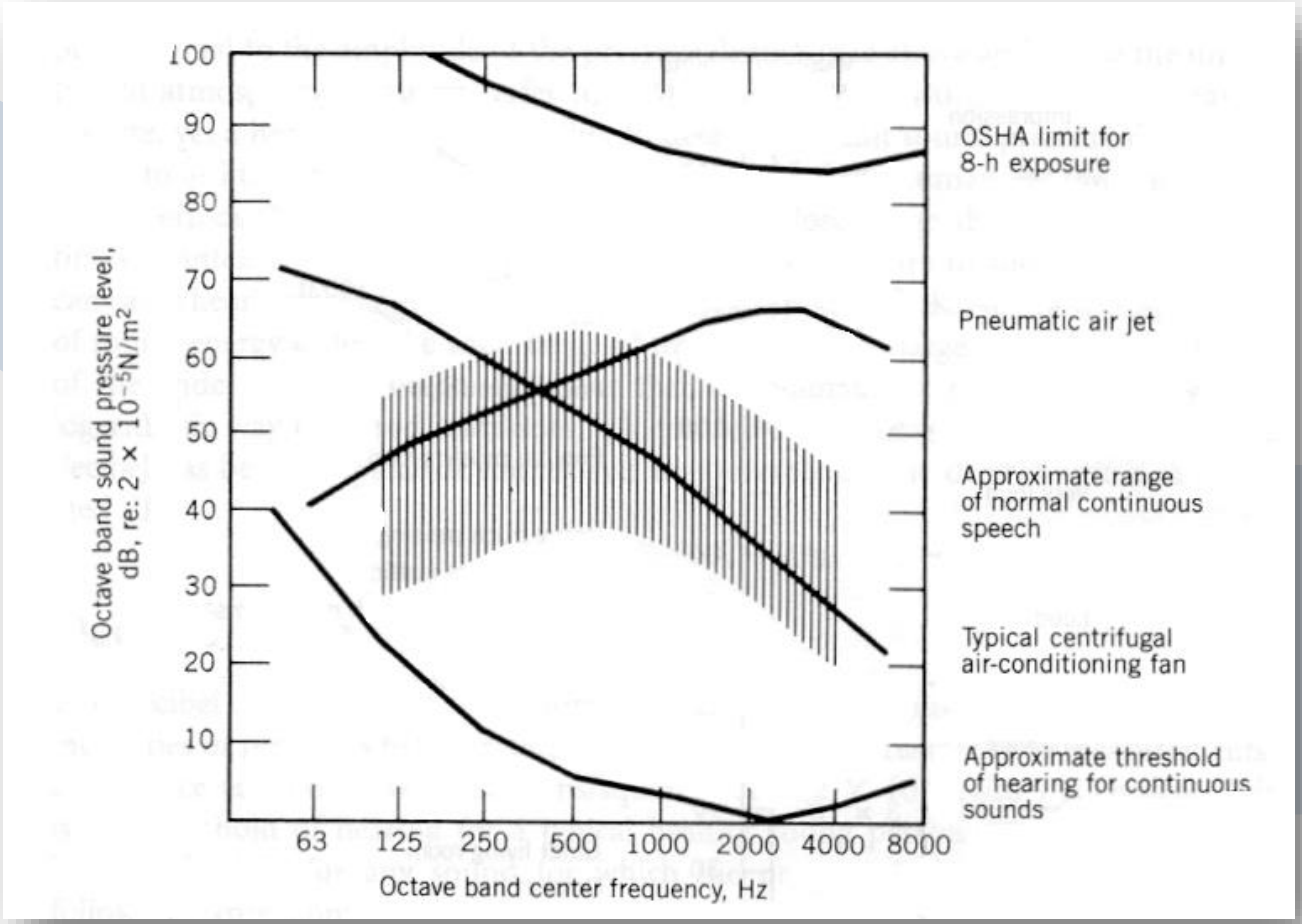


Sound Frequency

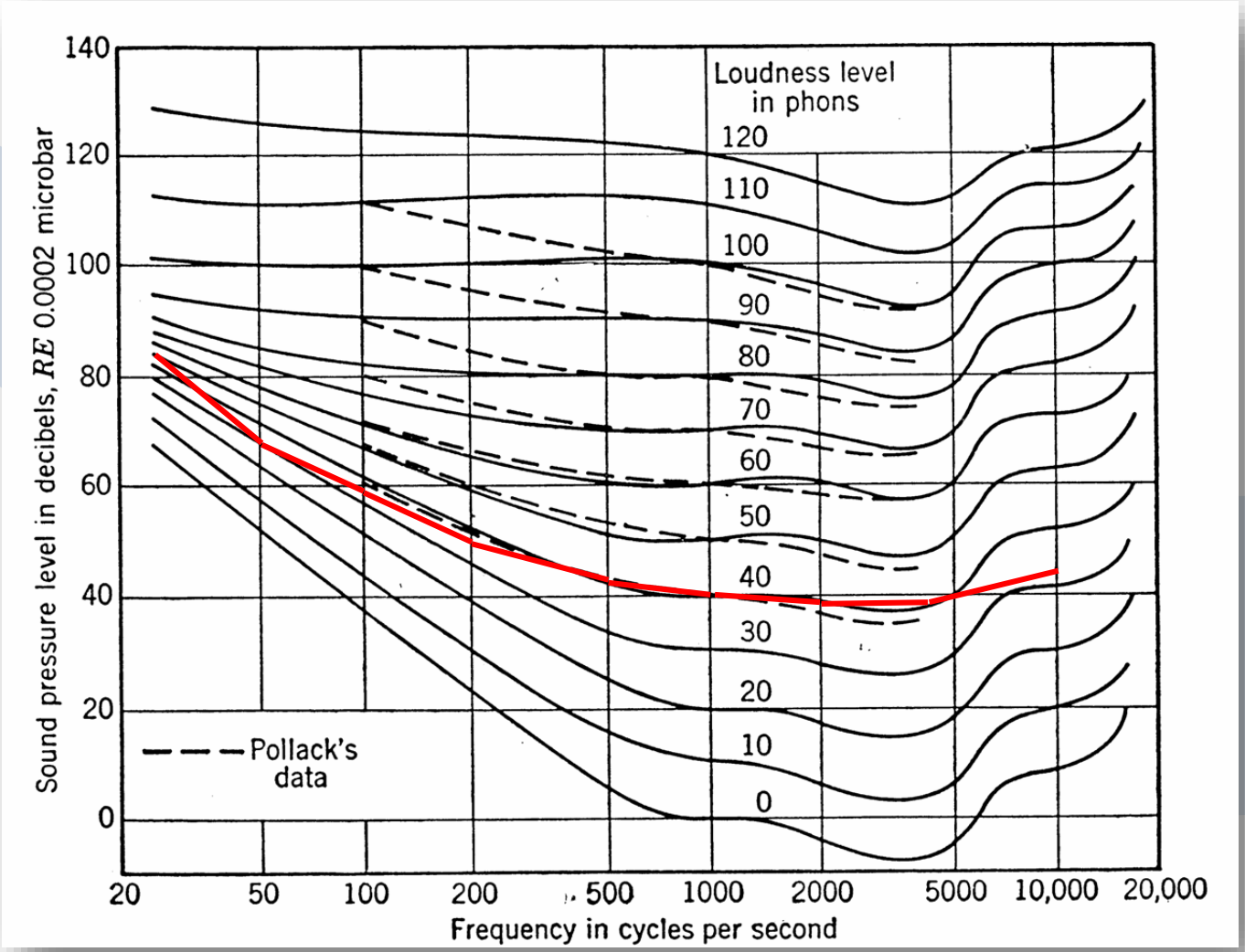
- Frequency is how quickly the wave oscillates.
- Frequency is related to the pitch of a sound.
- Measured in Hertz (Hz) = cycles per second.



Sound as a Function of Frequency



Equal Loudness Contours



Acoustical Ratings: Single-Number Metrics

Important Ratings in Architectural Acoustics

L_{eq} — **Equivalent Level**
The average noise level over a specified time period (often 1 hour)

CNEL — **Community Noise Equivalent Level**
L_{dn}, DNL — **Day-Night Noise Level**
Both are a noise description of the 24 hour average noise level, taking into account humans' increased sensitivity to noise in the evening and nighttime.

STC — **Sound Transmission Class**
A single number rating for assessing speech transmission through a structure

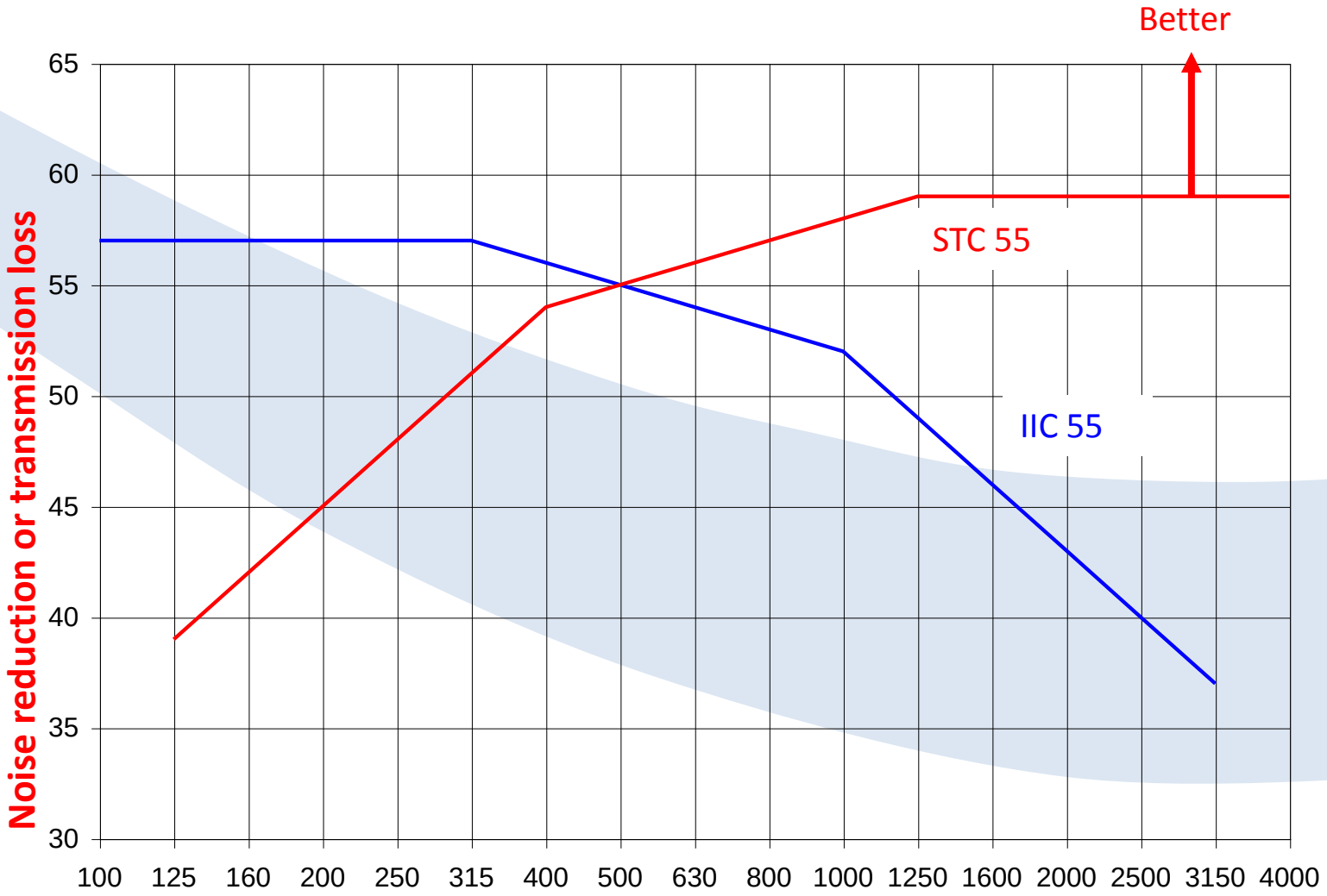
OITC — **Outdoor-Indoor Transmission Class**
A single number rating for assessing traffic noise transmission through a structure

Sound Transmission Class

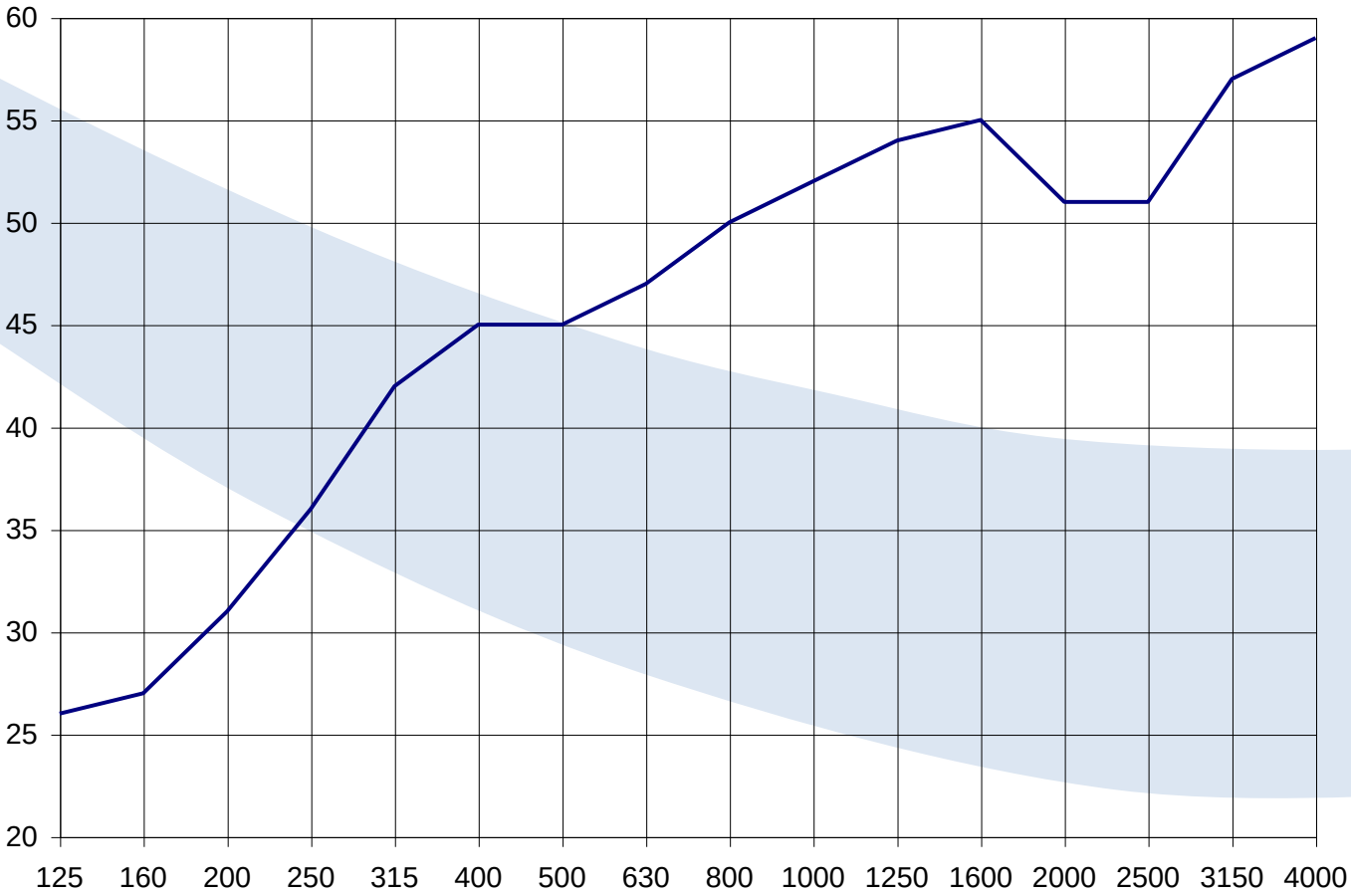
- Test procedure defined in ASTM E90 (laboratory) and E336 (field)
- Noise is generated in source room
- Measure noise levels in receiving room in third-octave bands from 125–4000 Hz

WESTERN ELECTRO-ACOUSTIC LABORATORY (WEAL)

Reference Contours



STC Example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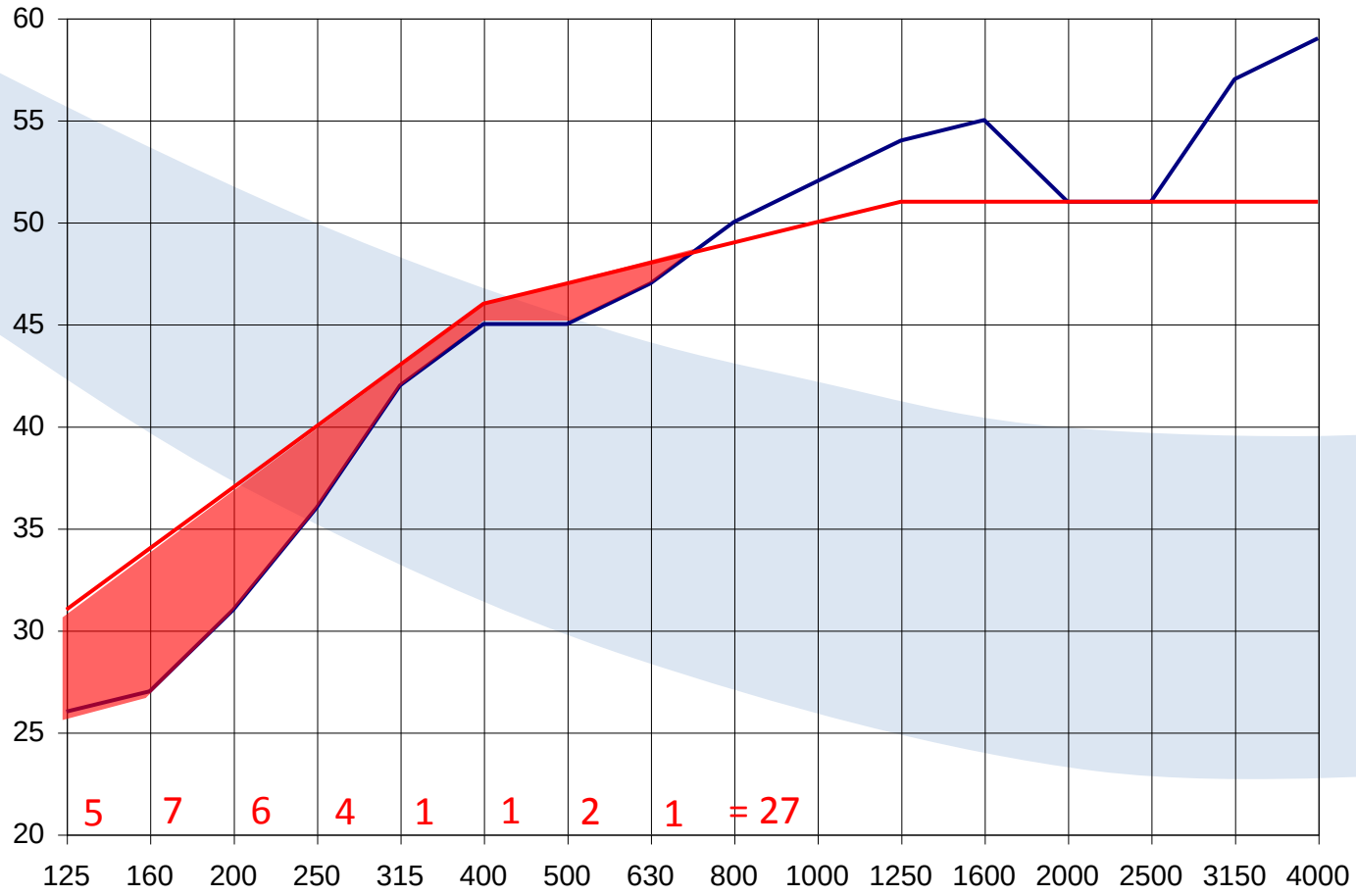
STC Example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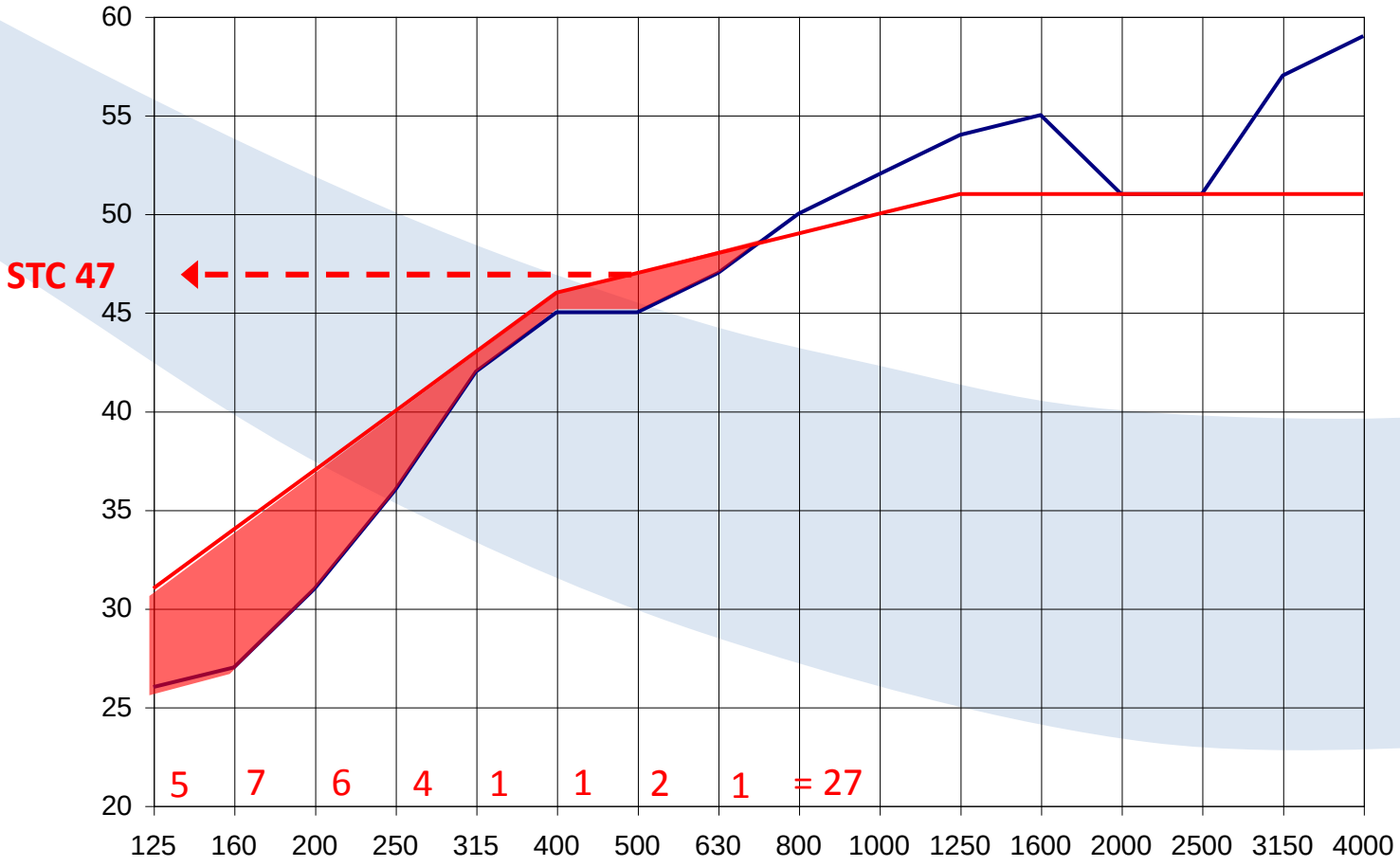
STC Example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400
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1600
2000
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3150
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Single Number Ratings – STC

Intent: a single number rating to compare isolation of different assemblies.

These single-number ratings correlate in a general way with subjective impressions of sound transmission for speech, radio, television, and similar sources of noise in offices and buildings.

Limitations:

- Only appropriate for noise sources with a sound spectrum similar to the reference contour.
- Does not deal with low frequency noise (<100 Hz)

Single Number Ratings – OITC

Intent: a single number rating to assess the isolation provided of different assemblies specifically for traffic and aircraft noise.

These ratings provide an evaluation and rank ordering of the performance of test specimens based on their effectiveness at controlling the sound of a specific outdoor sound spectrum

Limitations:

- Intended for traffic and therefore assumes a particular traffic spectrum that does not hold for all locations.
- Uses 80 and 100 Hz octave bands which have higher uncertainties in laboratory measurement.
- Limited evidence to show improvement over STC
- A good approximation is STC – 6.

Exterior Façade Design

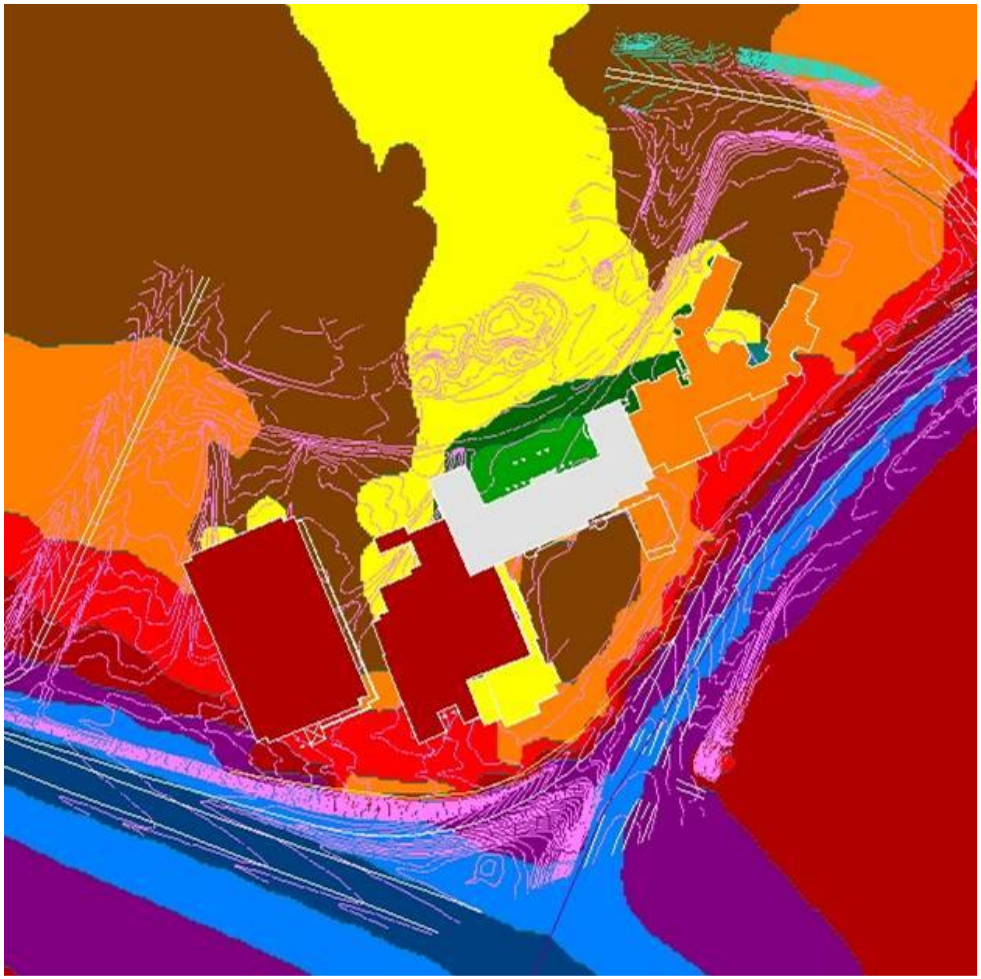
Exterior Façade Design

1. Define Exterior Noise Environment
    a. Measure
    b. Model
2. Calculate Interior Noise Level
    a. Transmission Loss (STC)
    b. Radiating Area
    c. Room Absorption
3. Which window?
    a. Glazing types
    b. Characteristics
    c. Breakpoints

Measurements

Noise Model

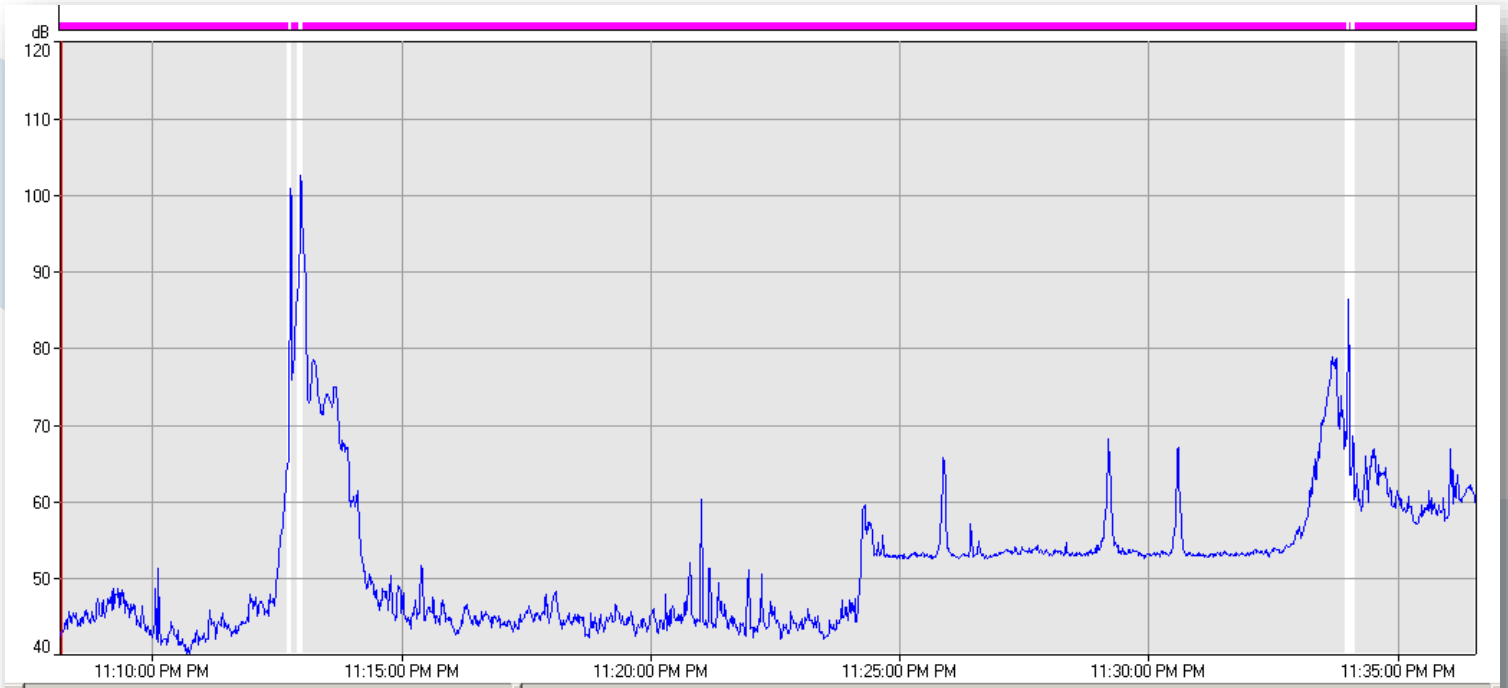
- Quick and accurate model generation based on project drawings with 3D terrain data.
- Predict exterior noise levels with changing terrain and barriers.
- Predict exterior noise levels with height up the building façade, above where it is practical to measure.



What Do We Measure?

Metric	Description	Purpose
LDN or CNEL	Average Daily Exposure	General acceptance. Code/General Plan compliance.
Lmax	Typical Short-Duration Noise Event	Sleep disturbance. Intrusiveness.
Spectrum	Relative balance of low and high frequencies	Very important for designing glazing

Average vs. Maximum Levels



Cursor: 07/27/2002 11:08:09 PM PM - 11:08:10 PM PM LAeq=42.3 dB

LAeq

	Name	Start time	Elapsed time	LAeq [dB]
1	Total	07/24/2002 02:43:43 PM PM	219:39:31	63.4
2	Exclude	07/25/2002 11:21:57 AM AM	39:25:21	22.0
3	Unmarked	07/24/2002 02:43:43 PM PM	218:36:14	63.4
4				
5	(All) Exclude	07/25/2002 11:21:57 AM AM	39:25:21	22.0
6	(All) Horn	07/25/2002 02:03:14 PM PM	0:00:11	78.9
7	(All) Train no horn	07/25/2002 02:02:29 PM PM	0:03:21	75.9
8	(All) Specific 3	07/27/2002 11:00:00 PM PM	0:59:45	64.0
9	(All) Time Block	07/24/2002 03:00:00 PM PM	258:00:00	63.0

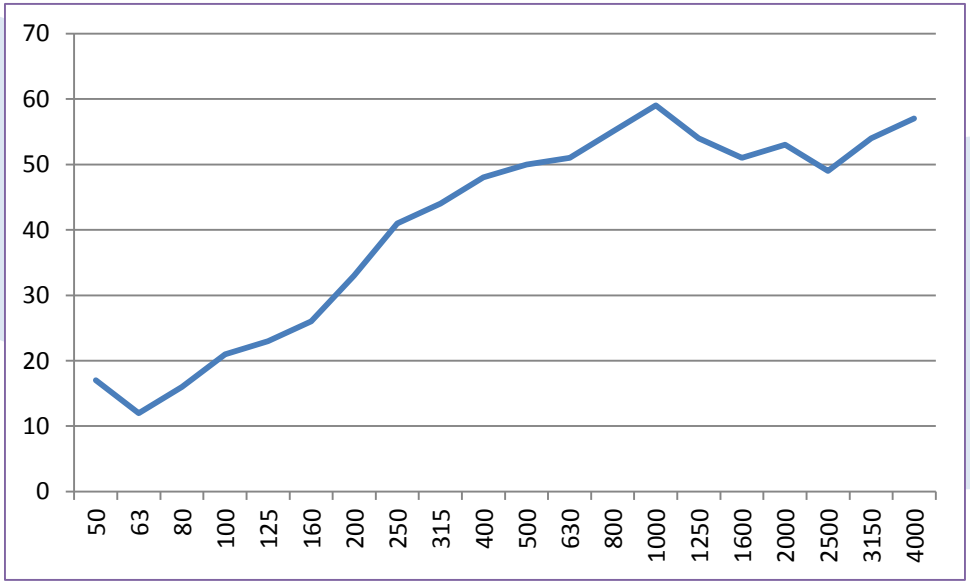
One Equation To Rule Them All

$$SPL_{inside} = SPL_{outside} - TL + 10\log S - 10\log A + C$$

One Equation To Rule Them All

$$SPL_{inside} = SPL_{outside} - TL + 10\log S - 10\log A + C$$

Transmission Loss



One Equation To Rule Them All

$$SPL_{inside} = SPL_{outside} - TL + 10\log S - 10\log A + C$$

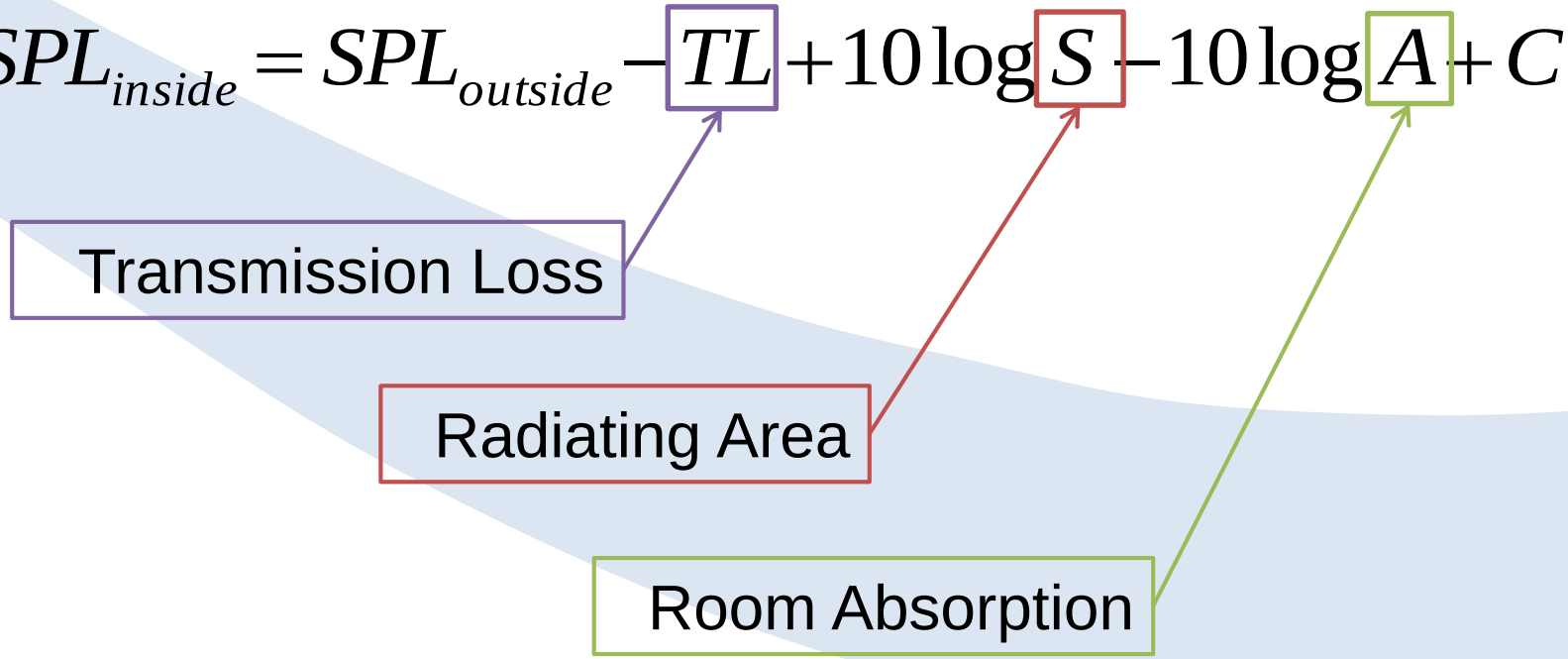
Transmission Loss

Radiating Area

Doubling window
area = 3 dB increase

One Equation To Rule Them All

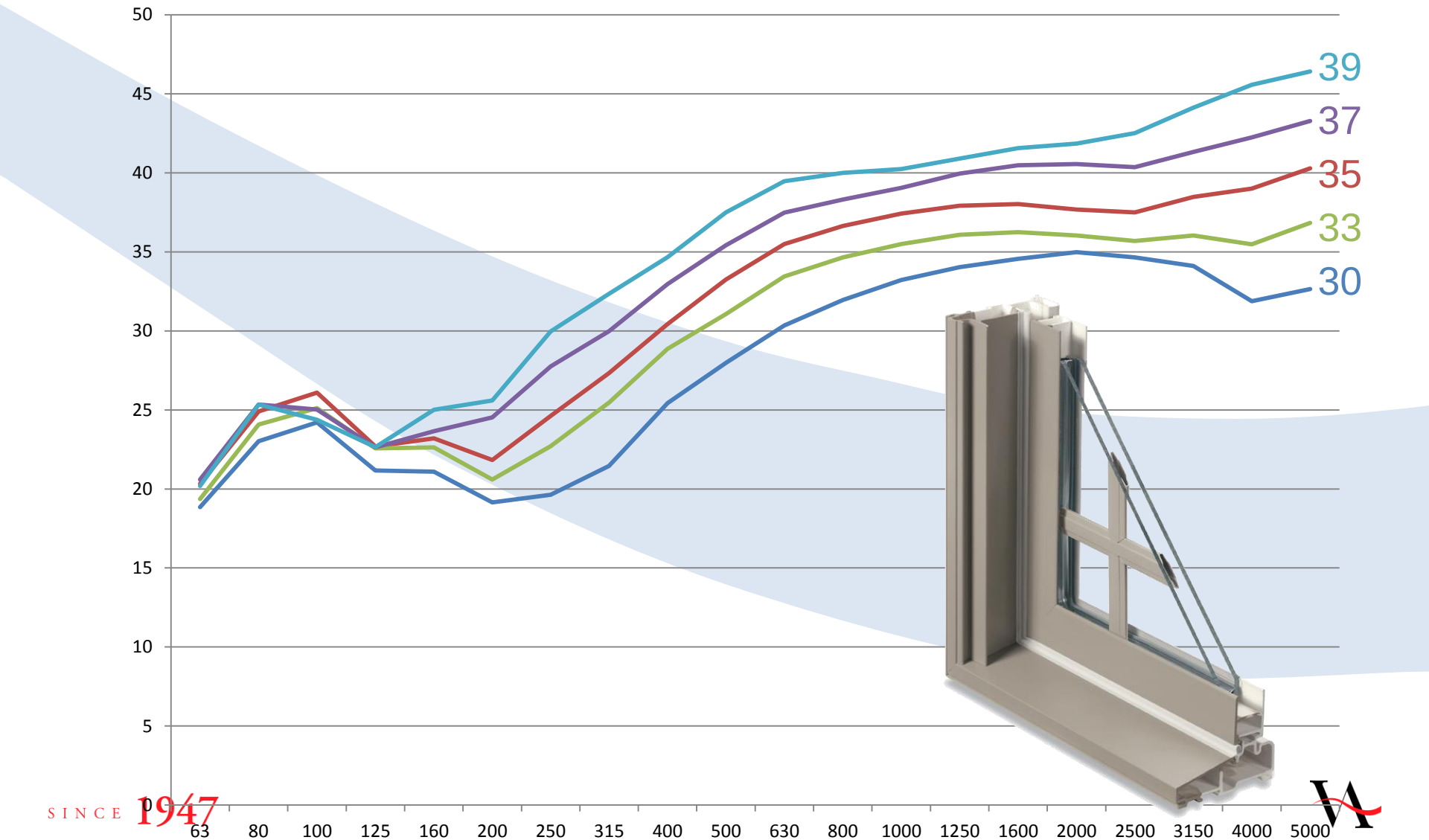
$$SPL_{inside} = SPL_{outside} - TL + 10\log S - 10\log A + C$$



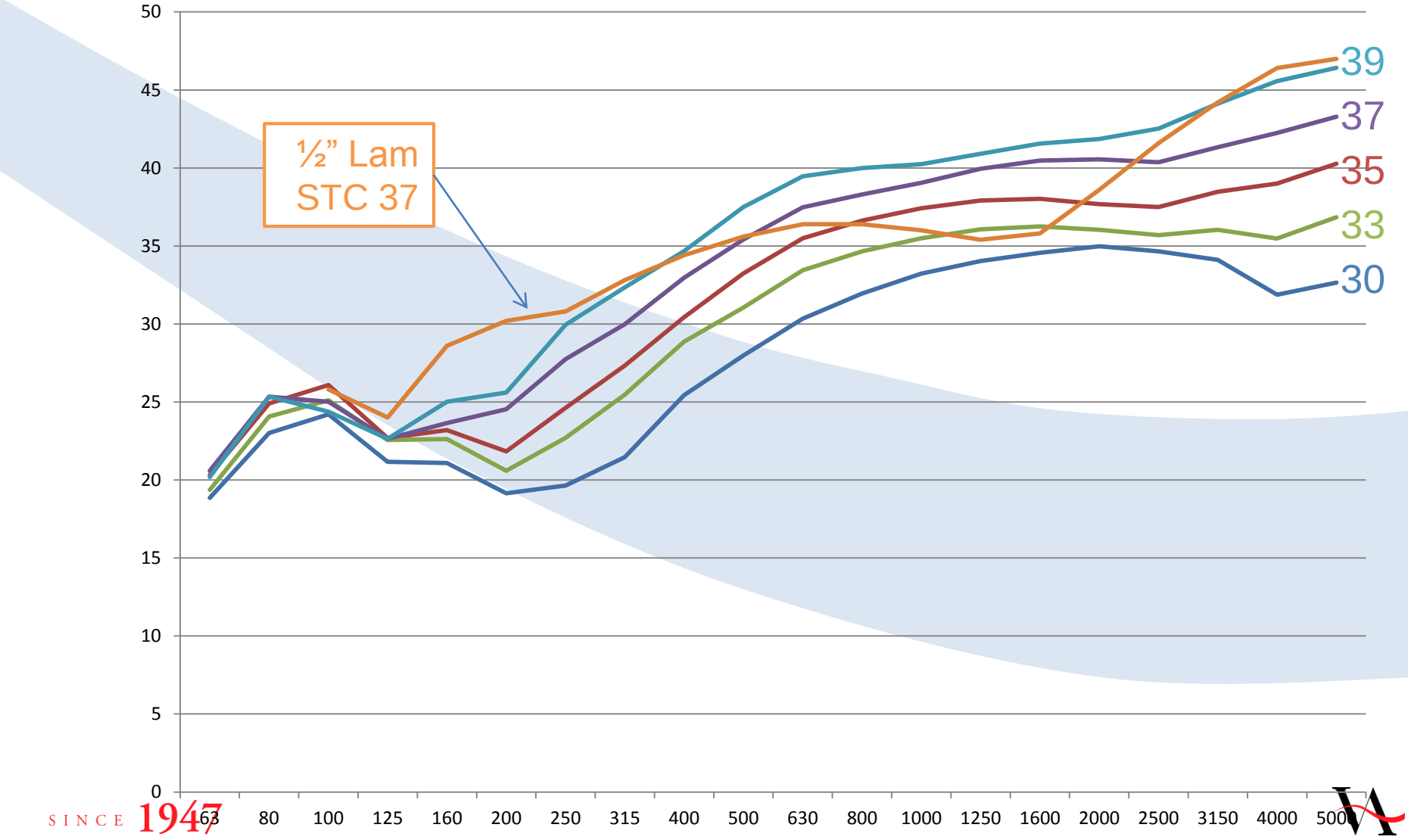
Glazing Types

Glass type	Typical STC Range	Comments
Single plate	24-29	Not used.
Dual plate	26–35	Standard residential.
Dual, lam over plate	33-38	Typical acoustical product.
Dual, lam over lam	33-38	Increased LF performance.
Single lam	33-42	Not typical because of Title 24.
Triple	40-50	When high isolation required.

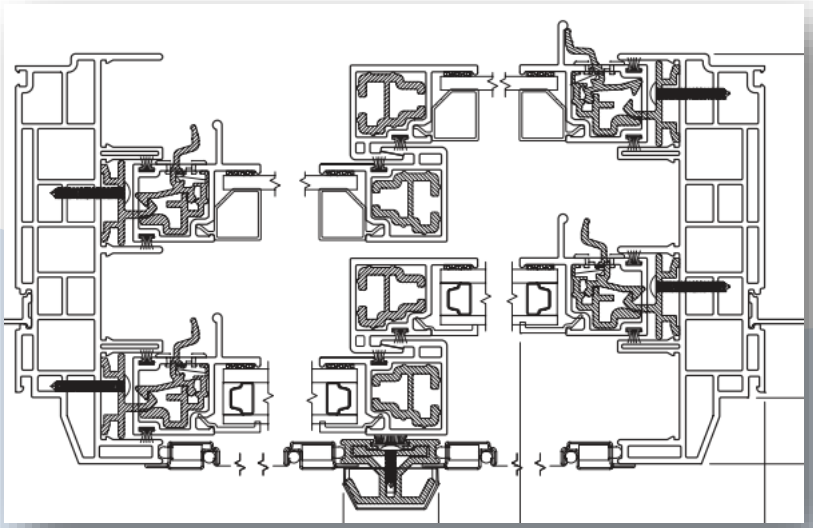
The Problem with Dual-Glazing



Dual vs. Single Laminated

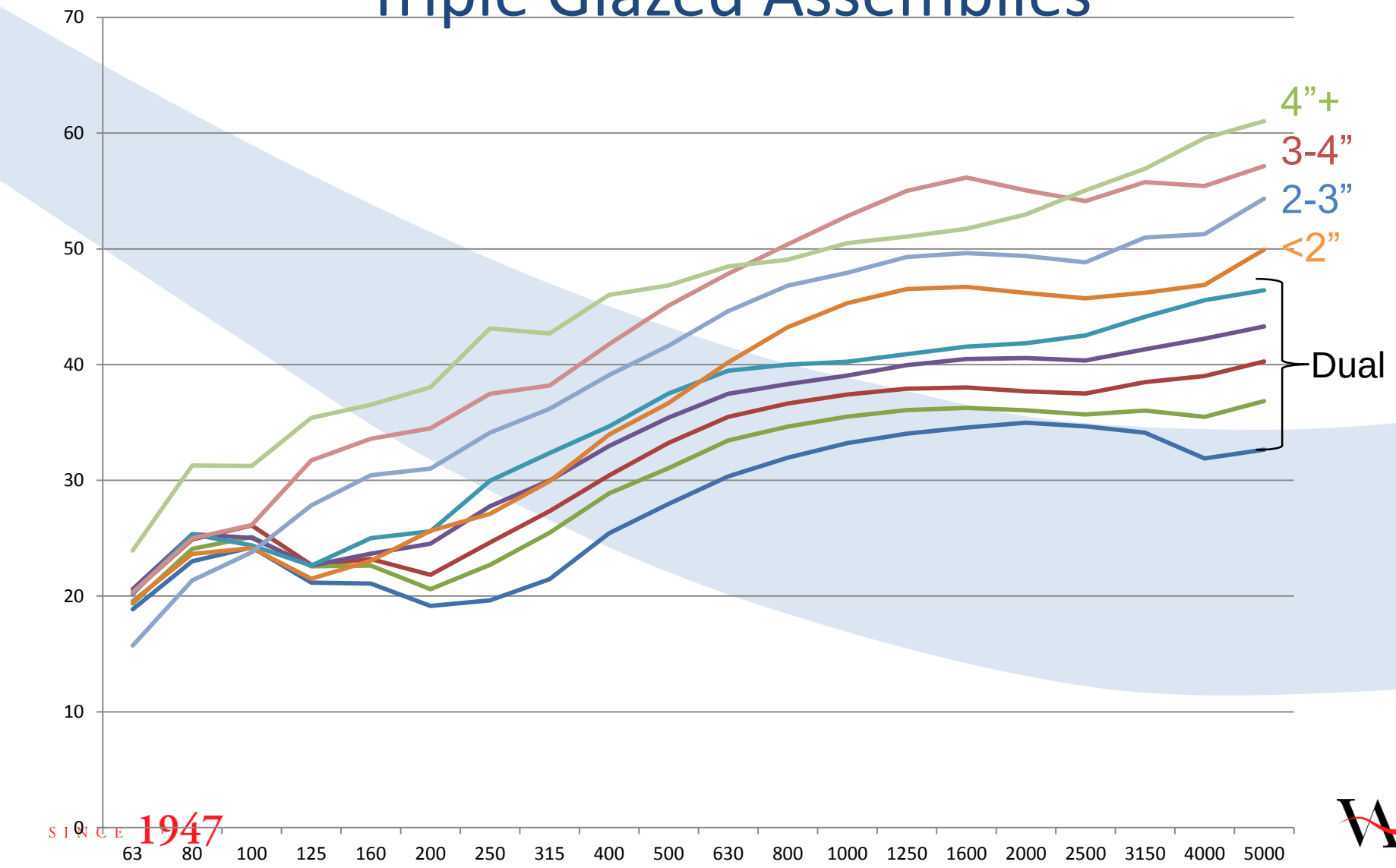


Triple Glazed or Storm Window



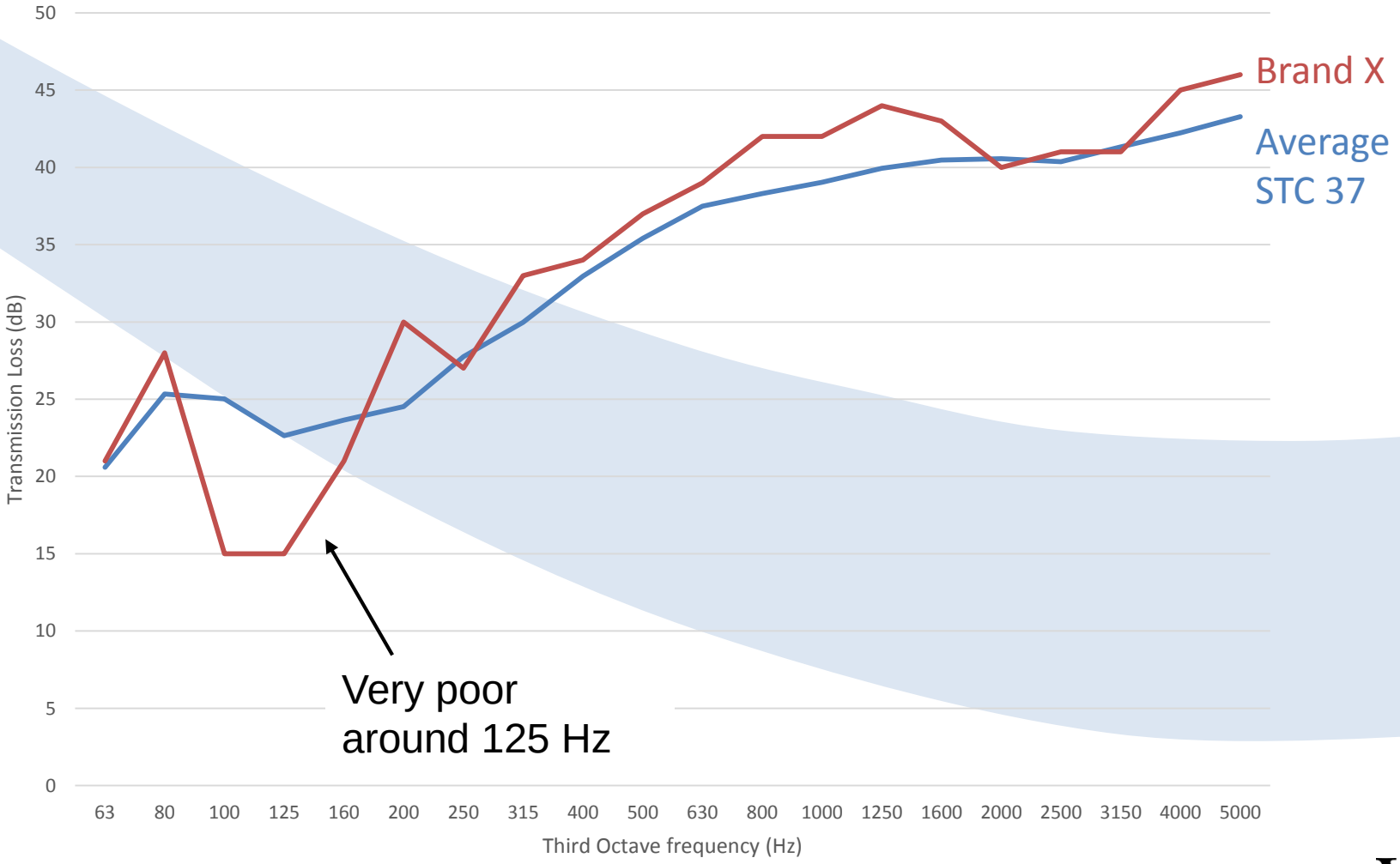
The Importance of Airspace

Triple Glazed Assemblies



SINCE 1947

Not Just About the STC!

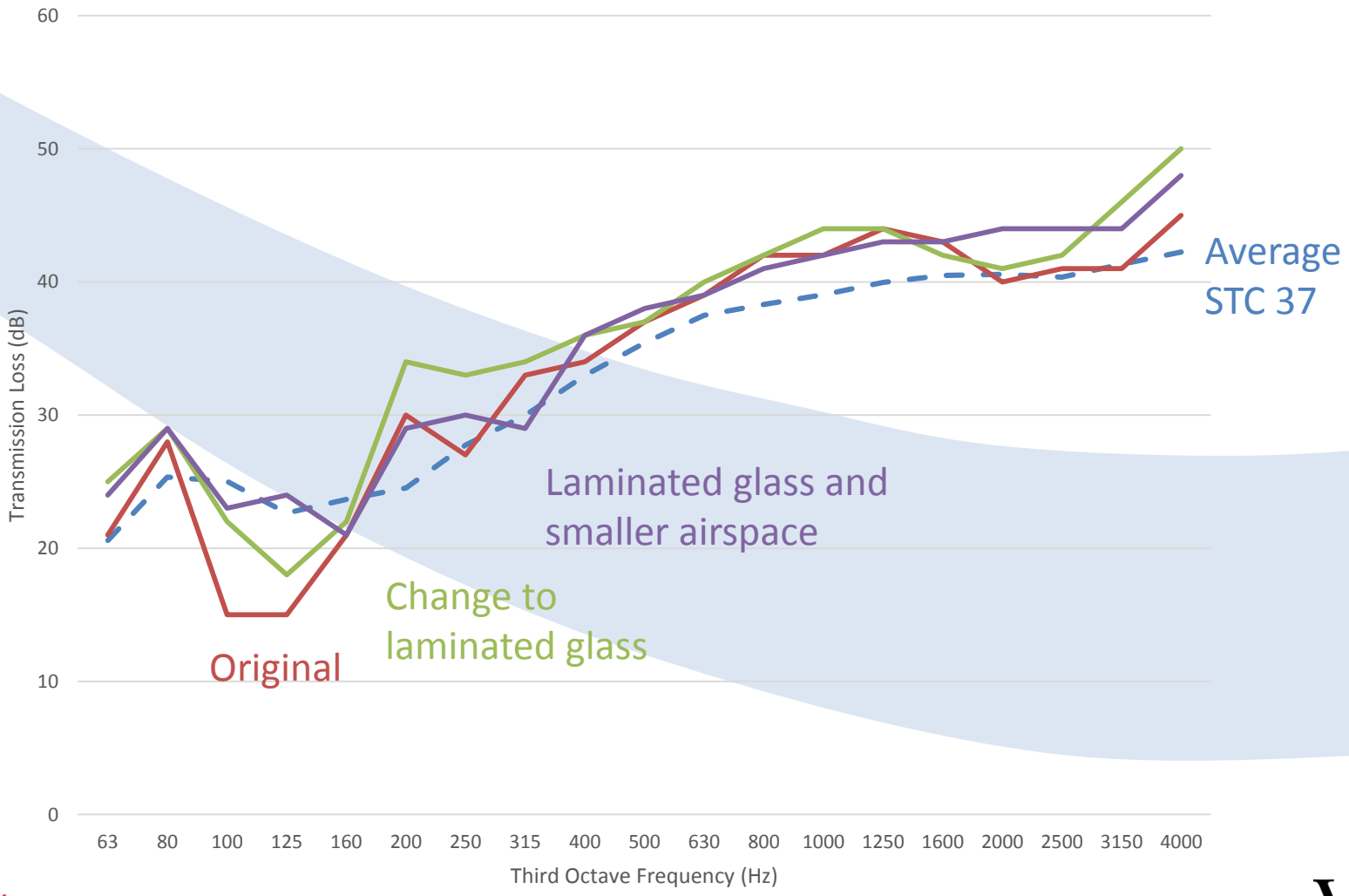


SINCE 1947

Not Just About the STC!

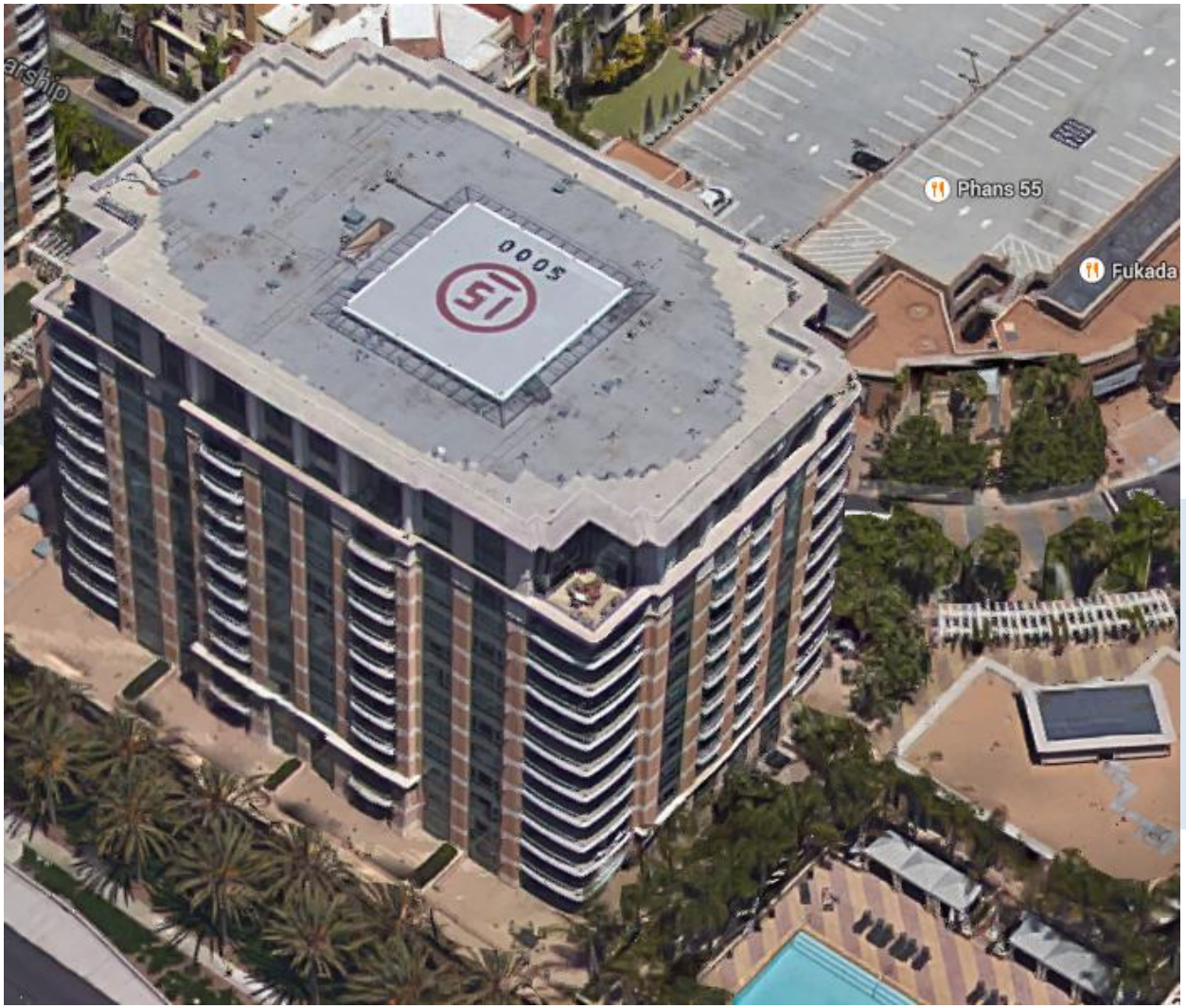
Glazing	STC Rating	Resultant Interior Noise Level (CNEL)
Average STC 37	37	45
No lam, 1” airspace	37	49
Lam, 1” airspace	40	46
Lam, 5/8” airspace	40	45

Effects of Glazing Parameters



SINCE 1947

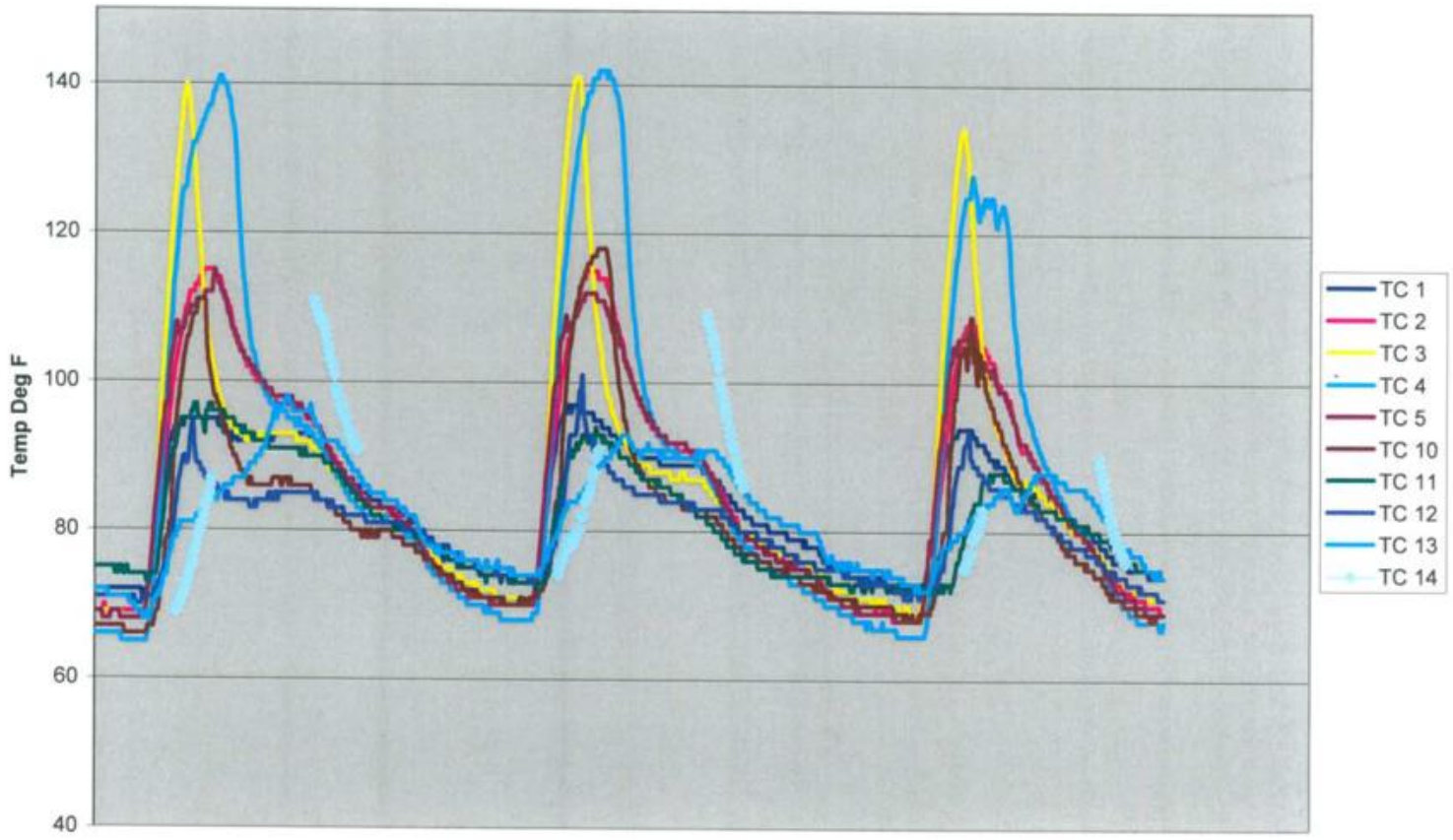
Noise of Curtainwall



Popping

- Occupant complained for popping or pinging noises from the curtainwall.
- Sound level as high as 50–55 dBA. Vibration can be felt in mullions.
- Top floor, two-story space, very large curtainwall relative to floor area.
- Only occurs during daytime; temperature change suspected.

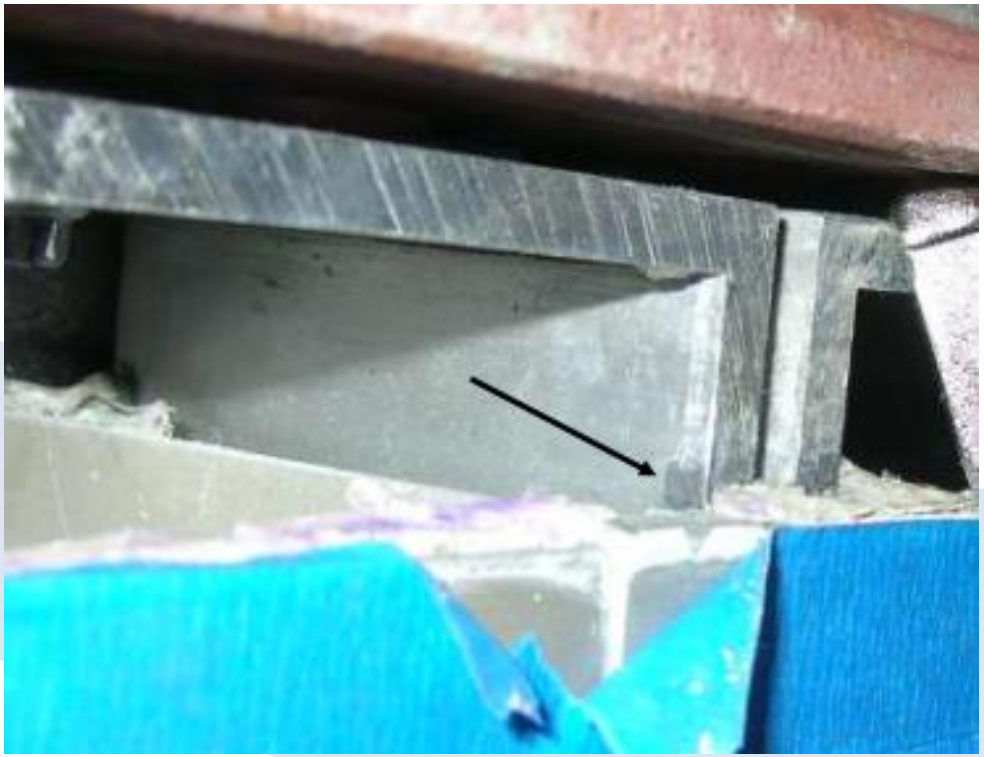
Temperature Measurements



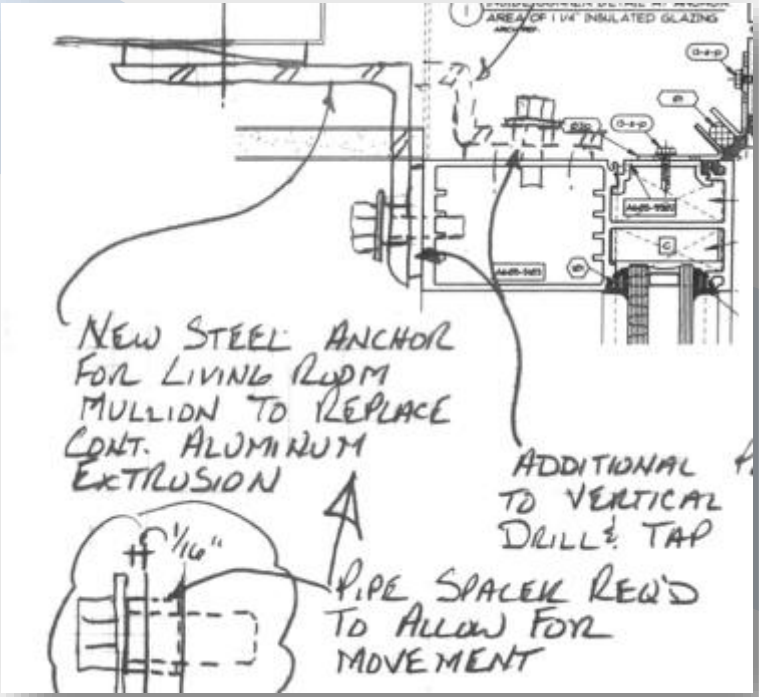
High air temperature was 91 deg F.

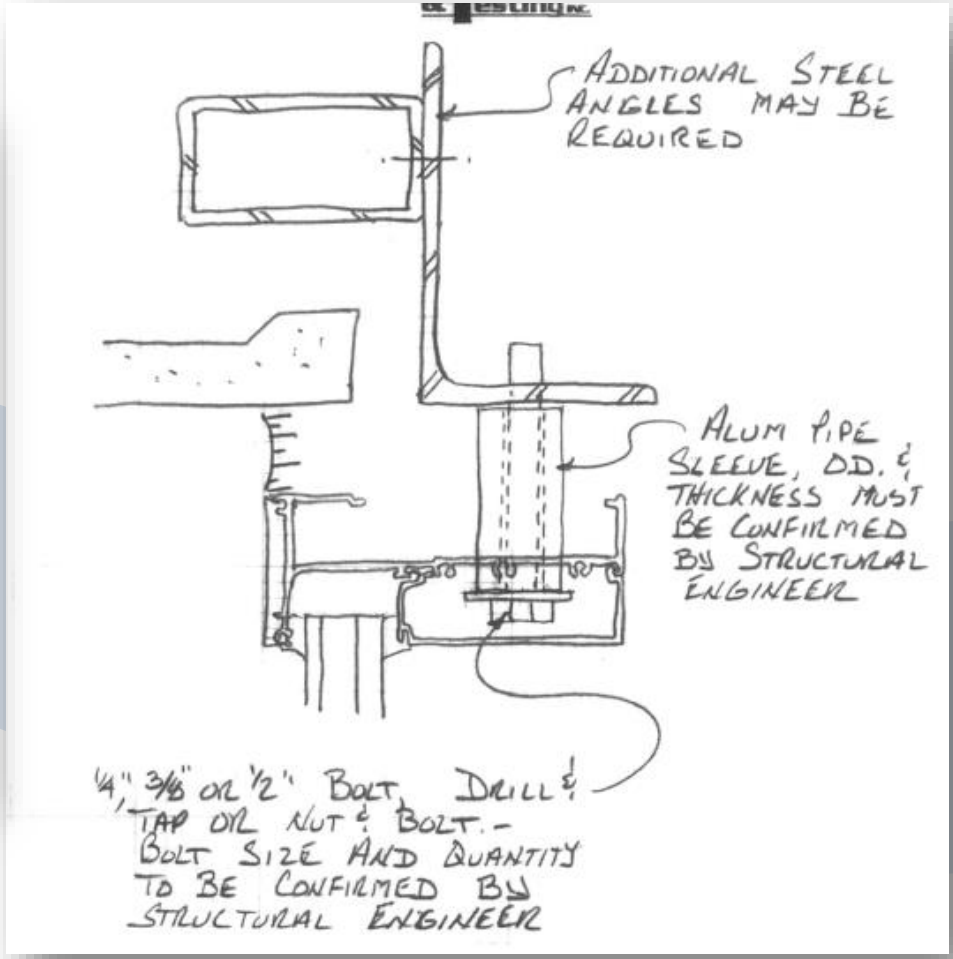
Deflection

- Vertical movement of mullion of 0.140” (3.55 mm).
- Horizontal movement of mullion of 0.090” (2.29 mm).
- Aluminum framing shows marks of rubbing during movement.

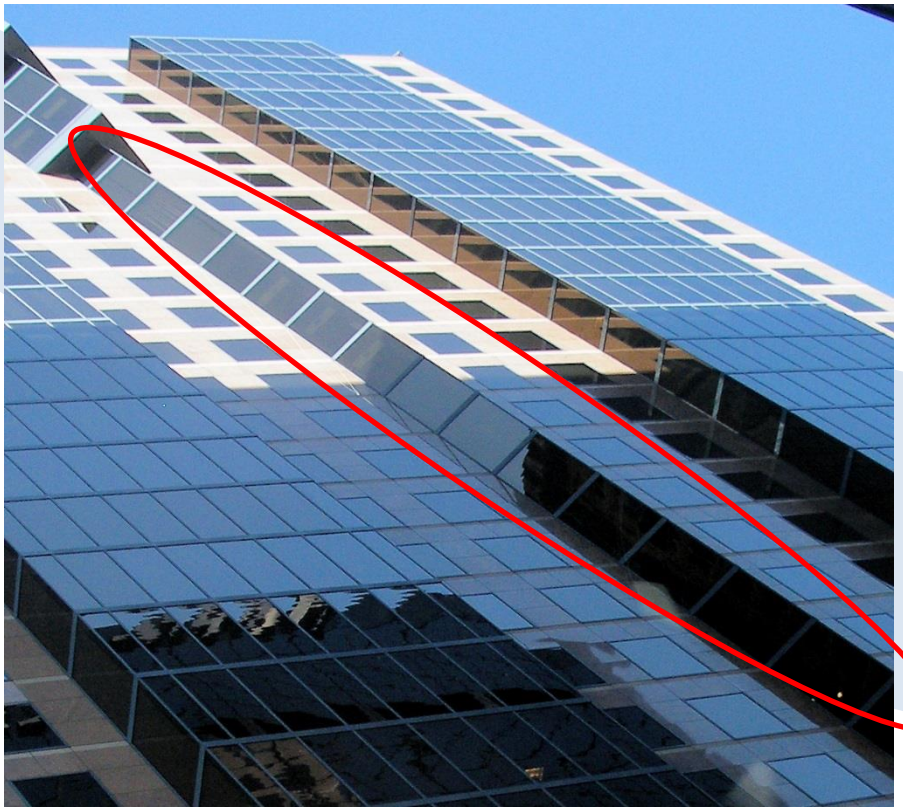


Mitigation


NEW STEEL ANCHOR FOR LIVING ROOM MULLION TO REPLACE CONT. ALUMINUM EXTRUSION
ADDITIONAL TO VERTICAL DRILL & TAP
PIPE SPACER REQ'D TO ALLOW FOR MOVEMENT

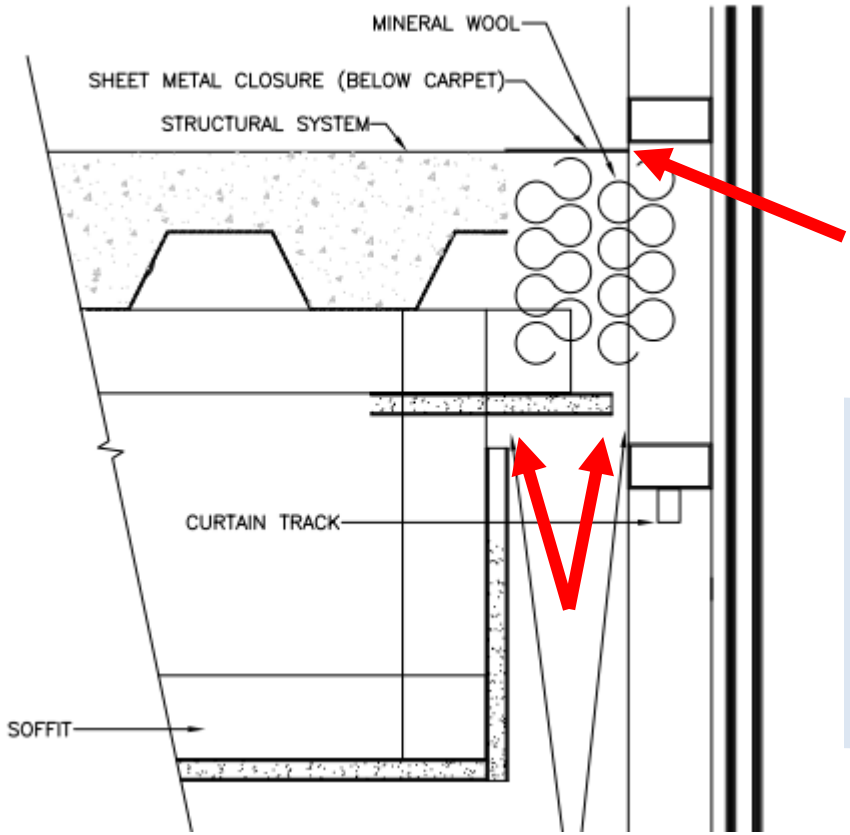

ADDITIONAL STEEL ANGLES MAY BE REQUIRED
ALUM PIPE SLEEVE, OD. & THICKNESS MUST BE CONFIRMED BY STRUCTURAL ENGINEER
1/4", 3/8" OR 1/2" BOLT, DRILL & TAP OR NUT & BOLT. - BOLT SIZE AND QUANTITY TO BE CONFIRMED BY STRUCTURAL ENGINEER

Vertical Noise Isolation at Mullions

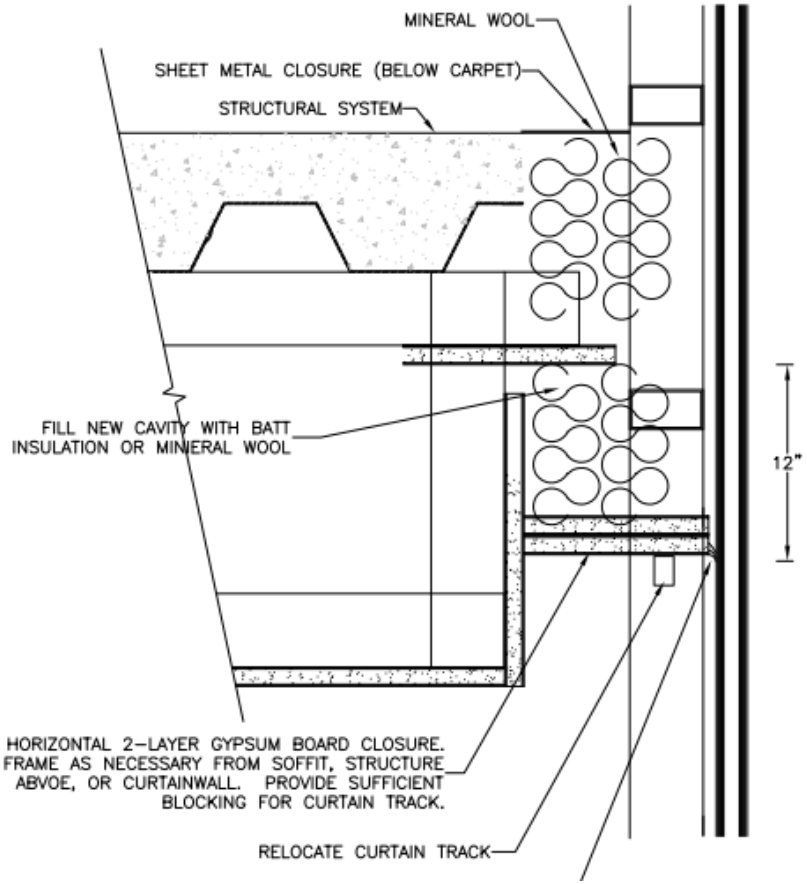


Vertical noise transmission between offices at corner mullion condition

Gaps at Edge-of-slab Condition

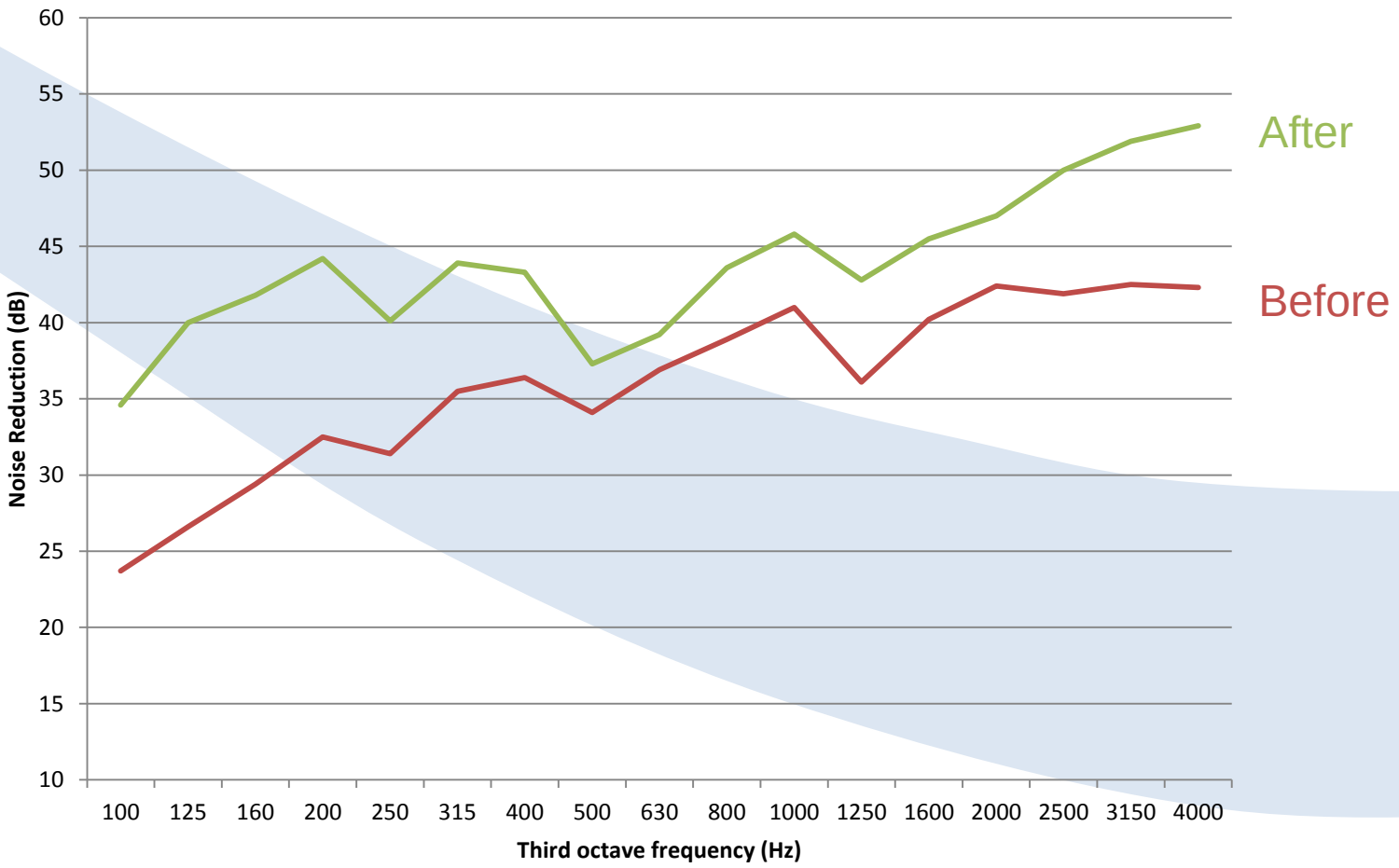


Mitigation

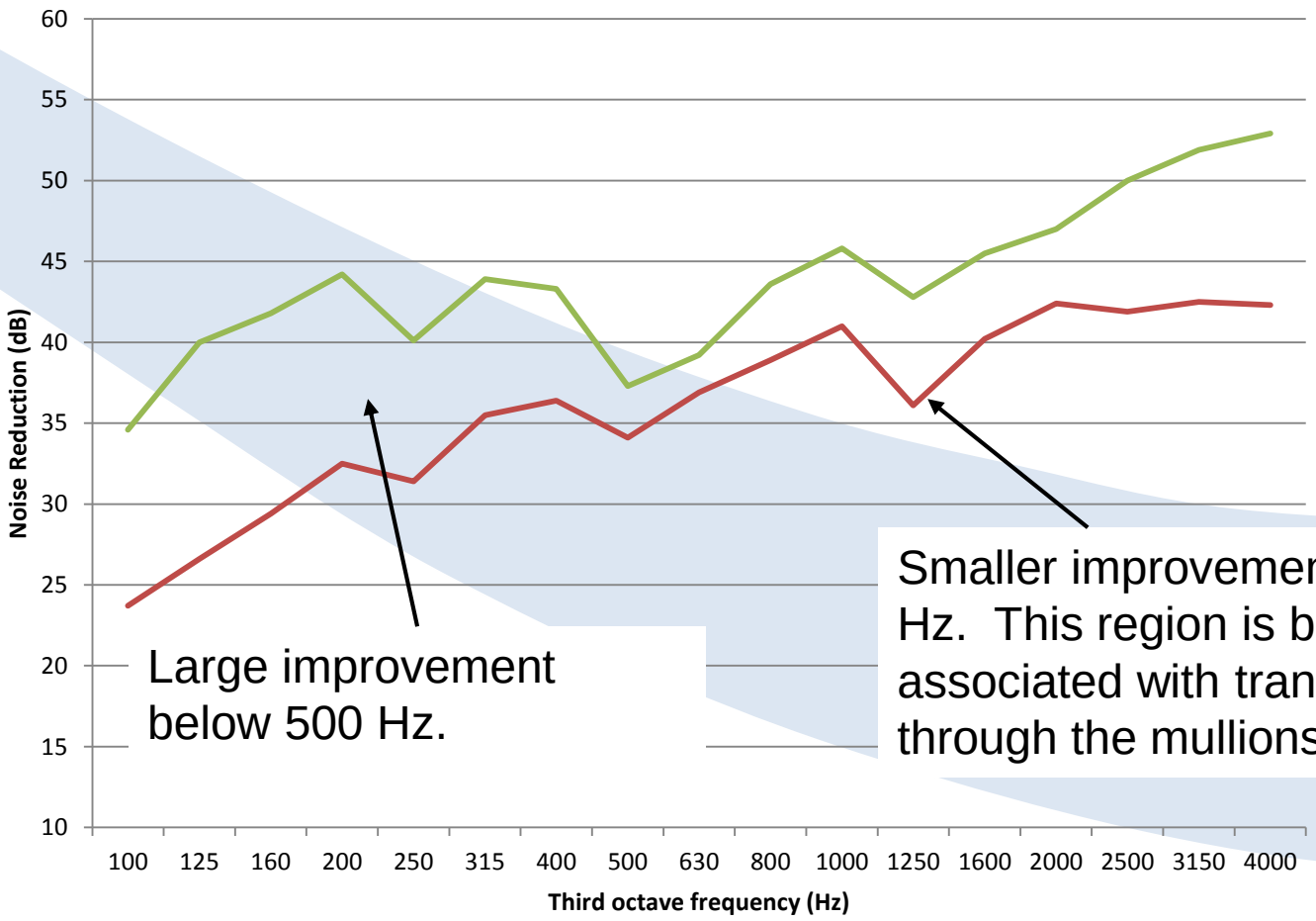


- Frame horizontal gypsum board closure about 12” below existing.
- Caulk to ceiling and glass.
- Fill cavity with insulation

Mitigation Results

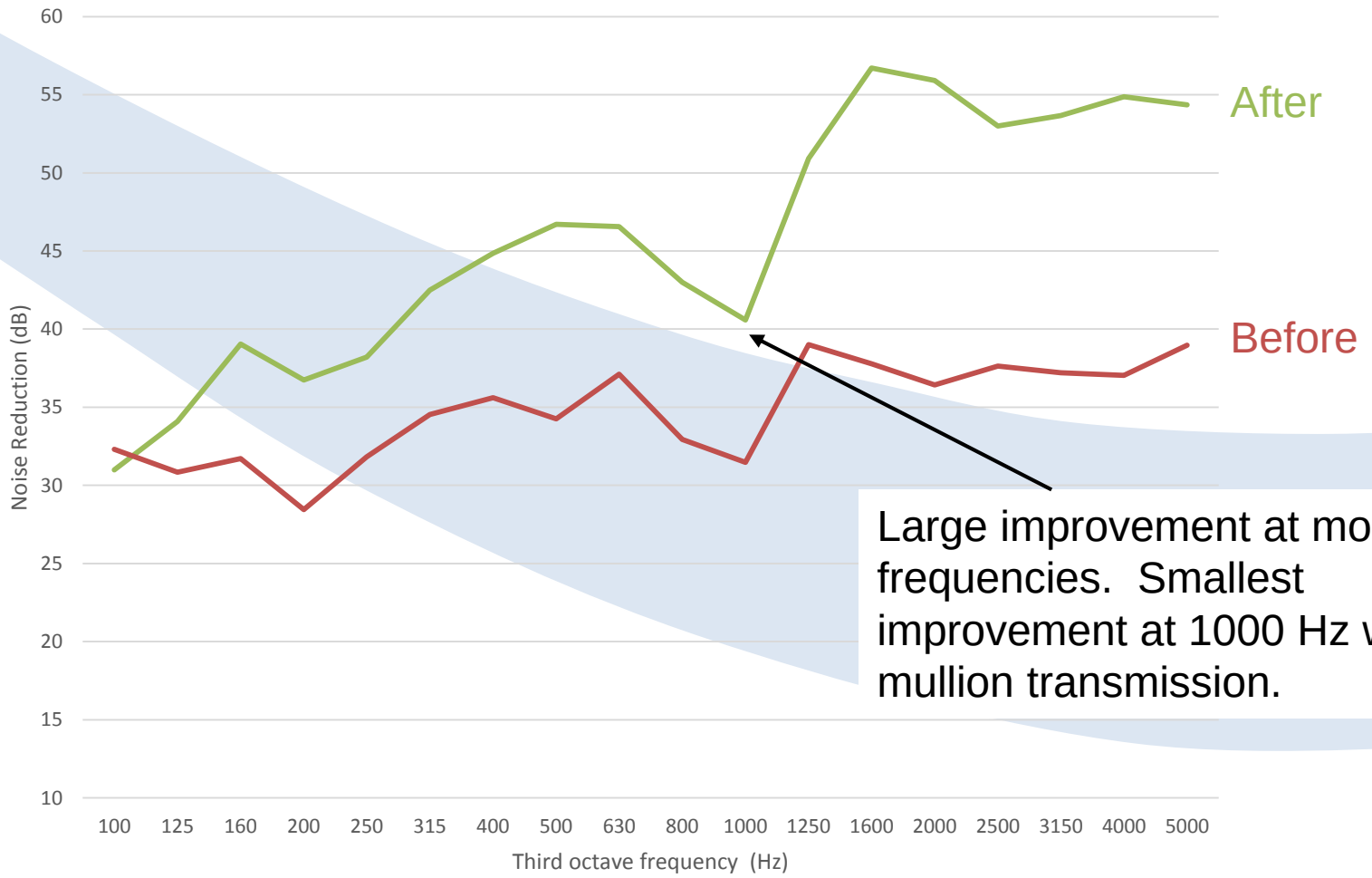


Mitigation Results



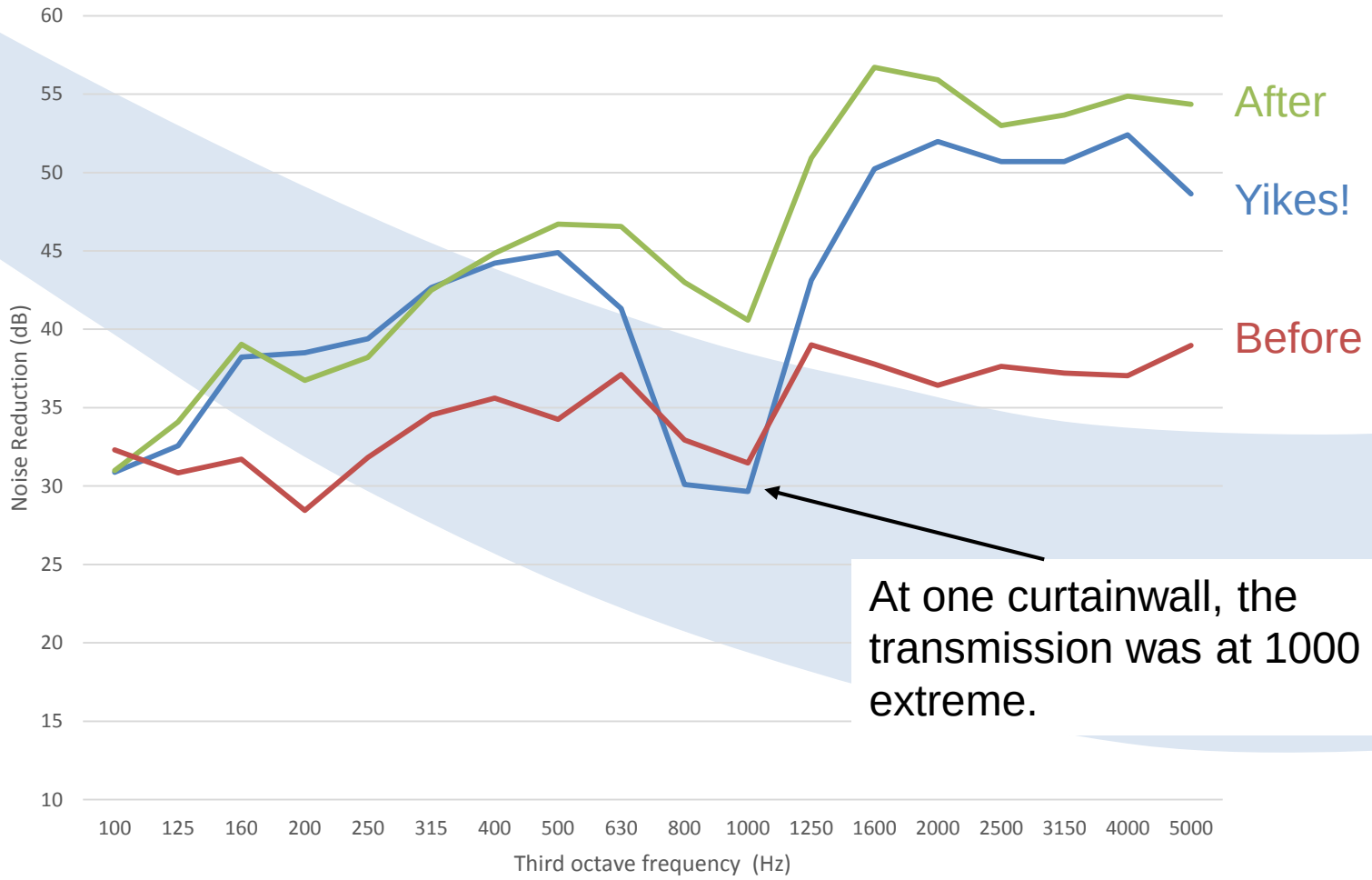
Another Edge-of-Slab (Wood joist building)

Mitigation



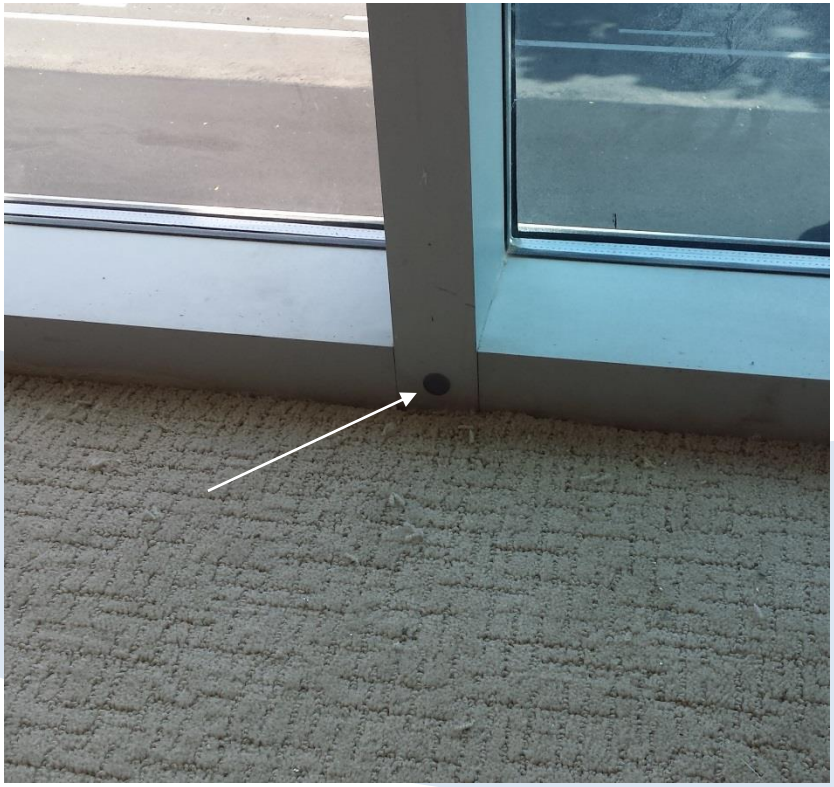
Large improvement at most frequencies. Smallest improvement at 1000 Hz which is mullion transmission.

Sometimes the Mullion Transmission Is a Problem…

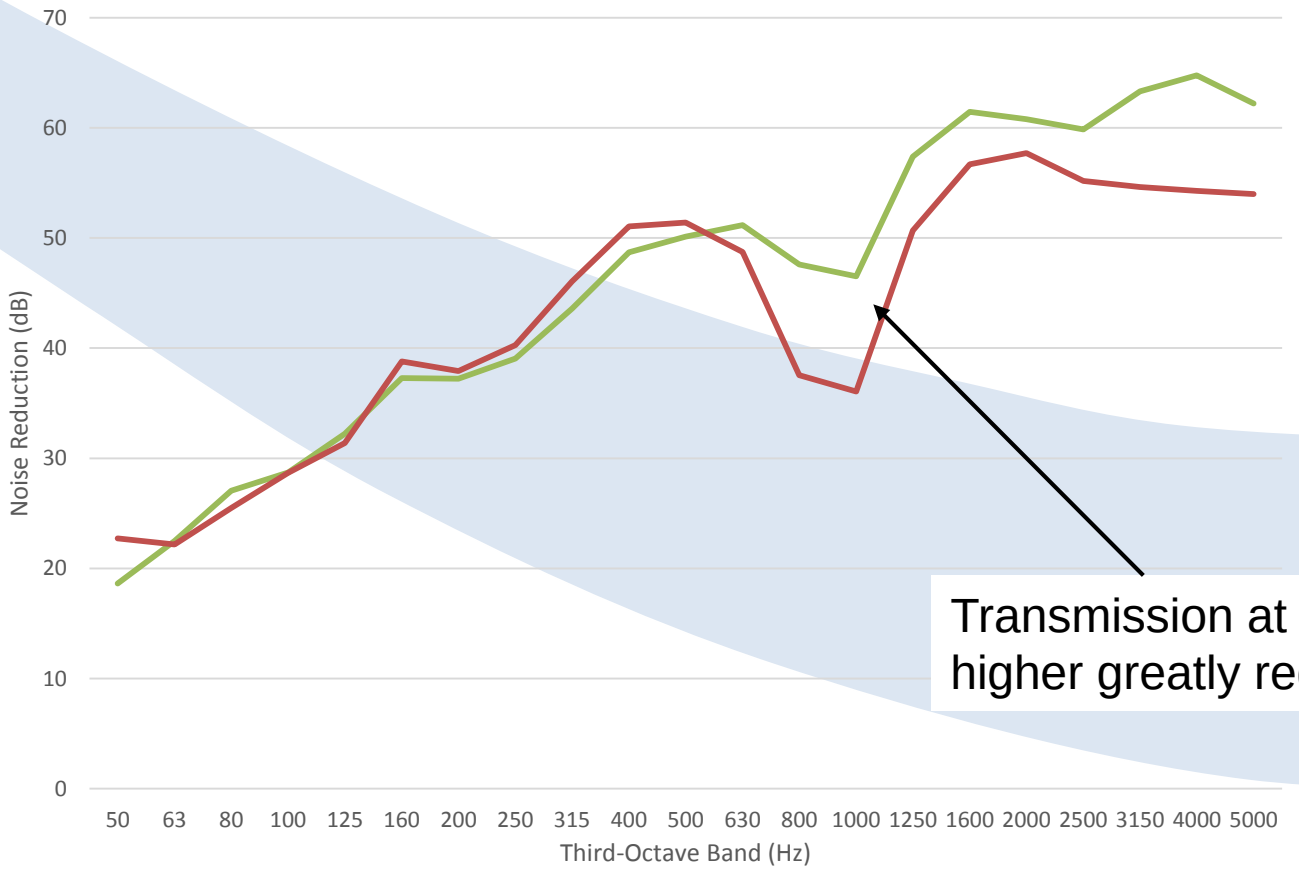


Mitigation

- Holes drilled in mullion at floor above.
- Acoustical caulk pumped into mullion to fill the mullion for the height of the spandrel.
- About 14–18 inches high.



Mullion Mitigation



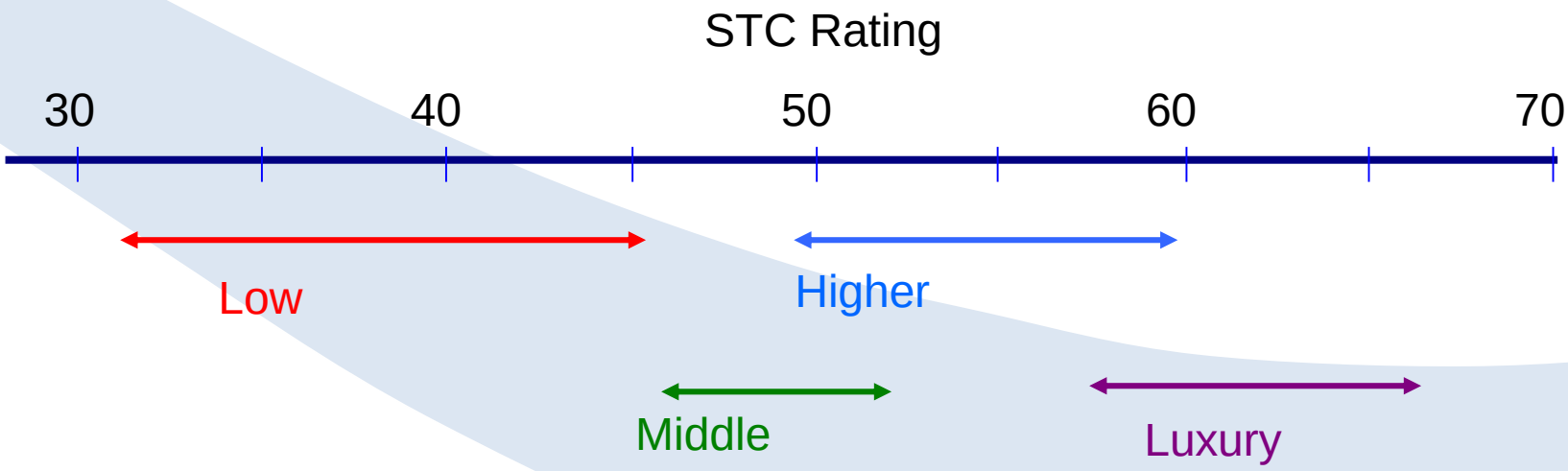
After
NIC 51

Before
NIC 41

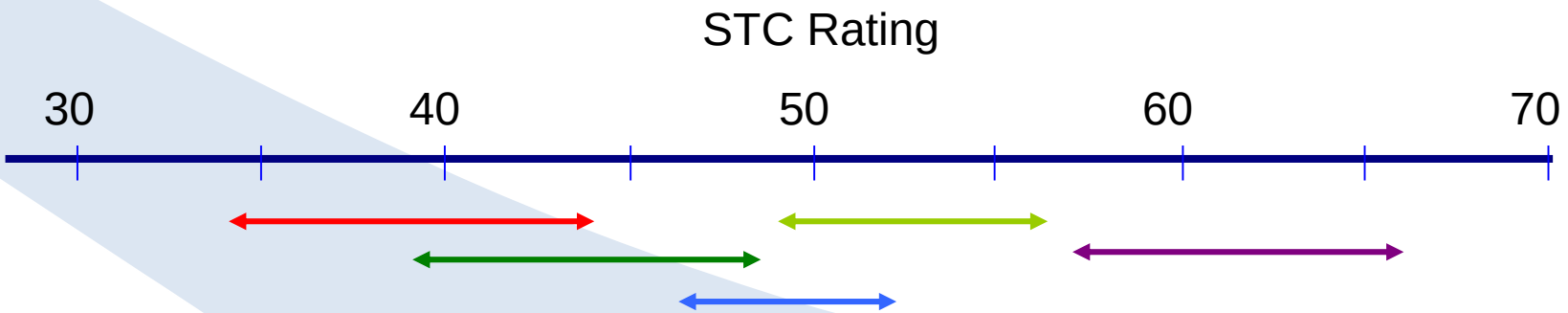
Transmission at 1000 Hz and higher greatly reduced.

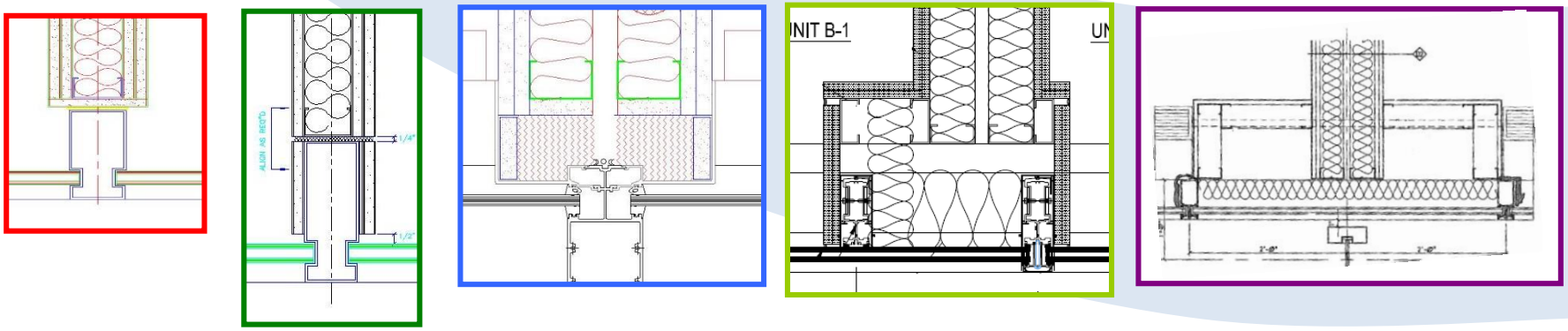
Horizontal Noise Isolation at Mullions

How Much Isolation You Need…



…Defines What Type of Mullion Detailing You Need

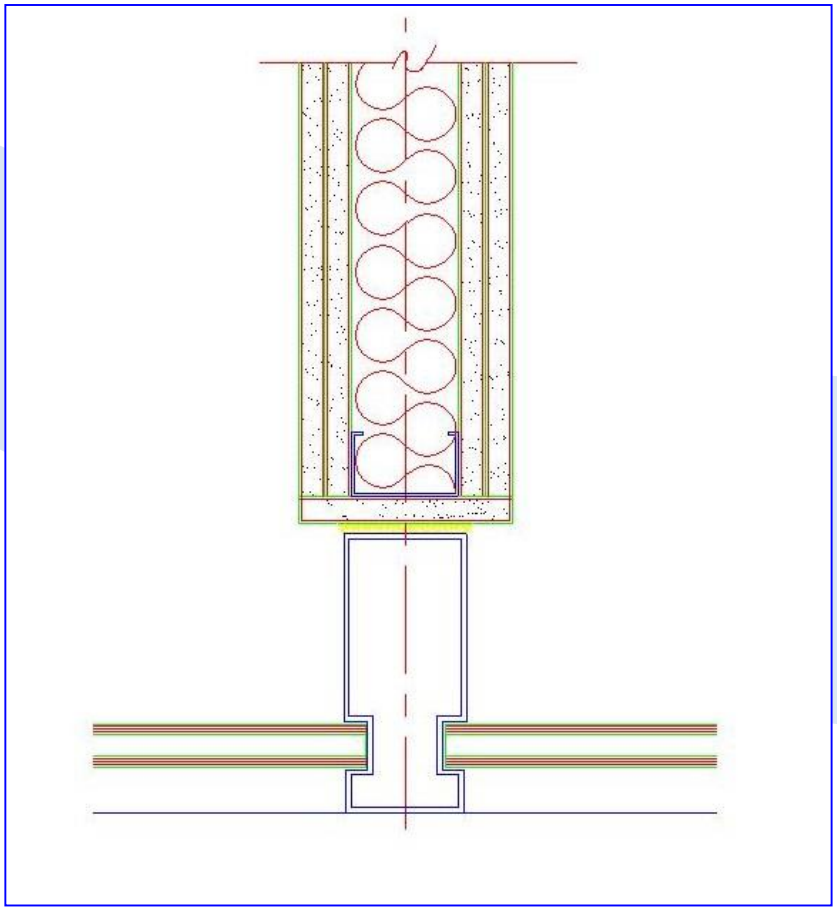




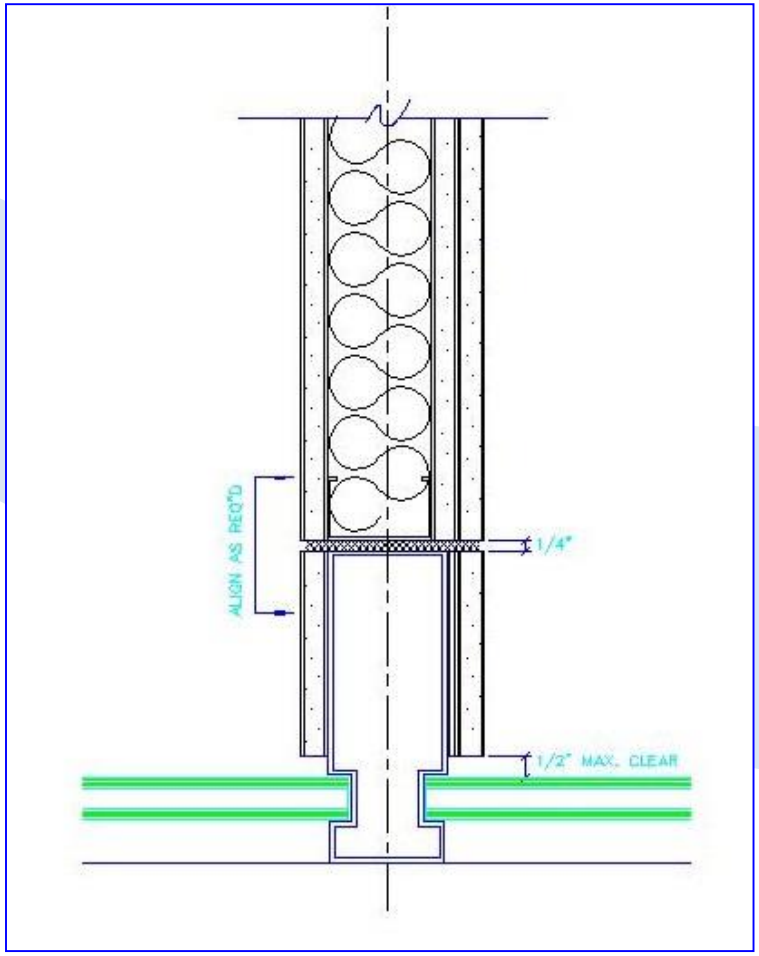
…with thought to FLANKING CONSIDERATIONS

- This condition occurs in primarily concrete structure
- Mullions/windows
- Curtain wall connections to slab
- Floor conditions
- Ceiling (slab) conditions
- Interior intersection details
- Penetrations
- *Curtain wall intersection at wall*

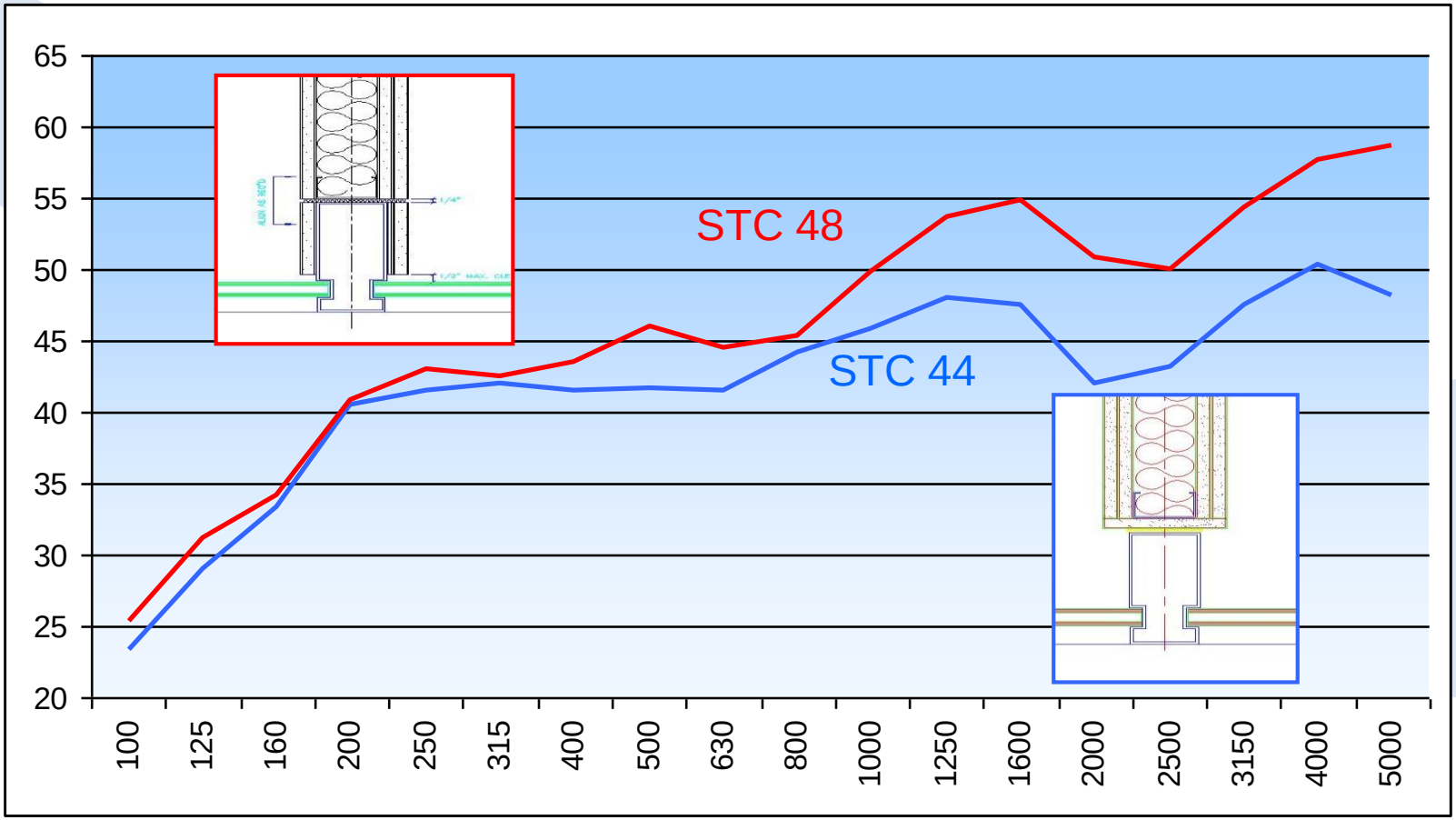
Bare Mullion



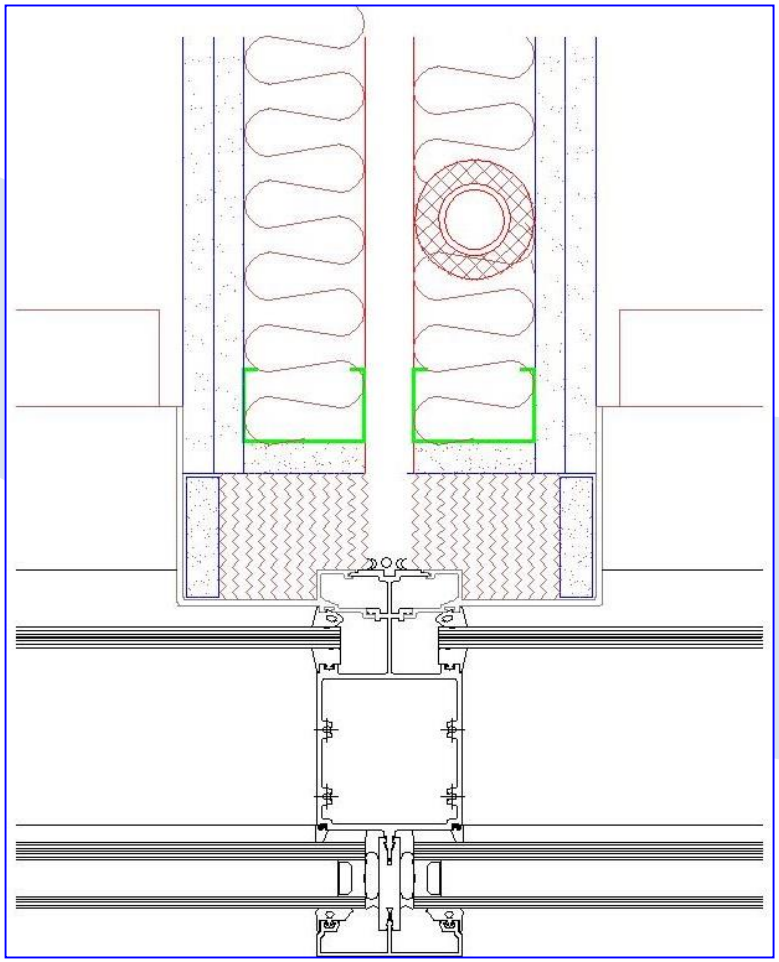
Wrapped mullion



Effect of wrapping mullion

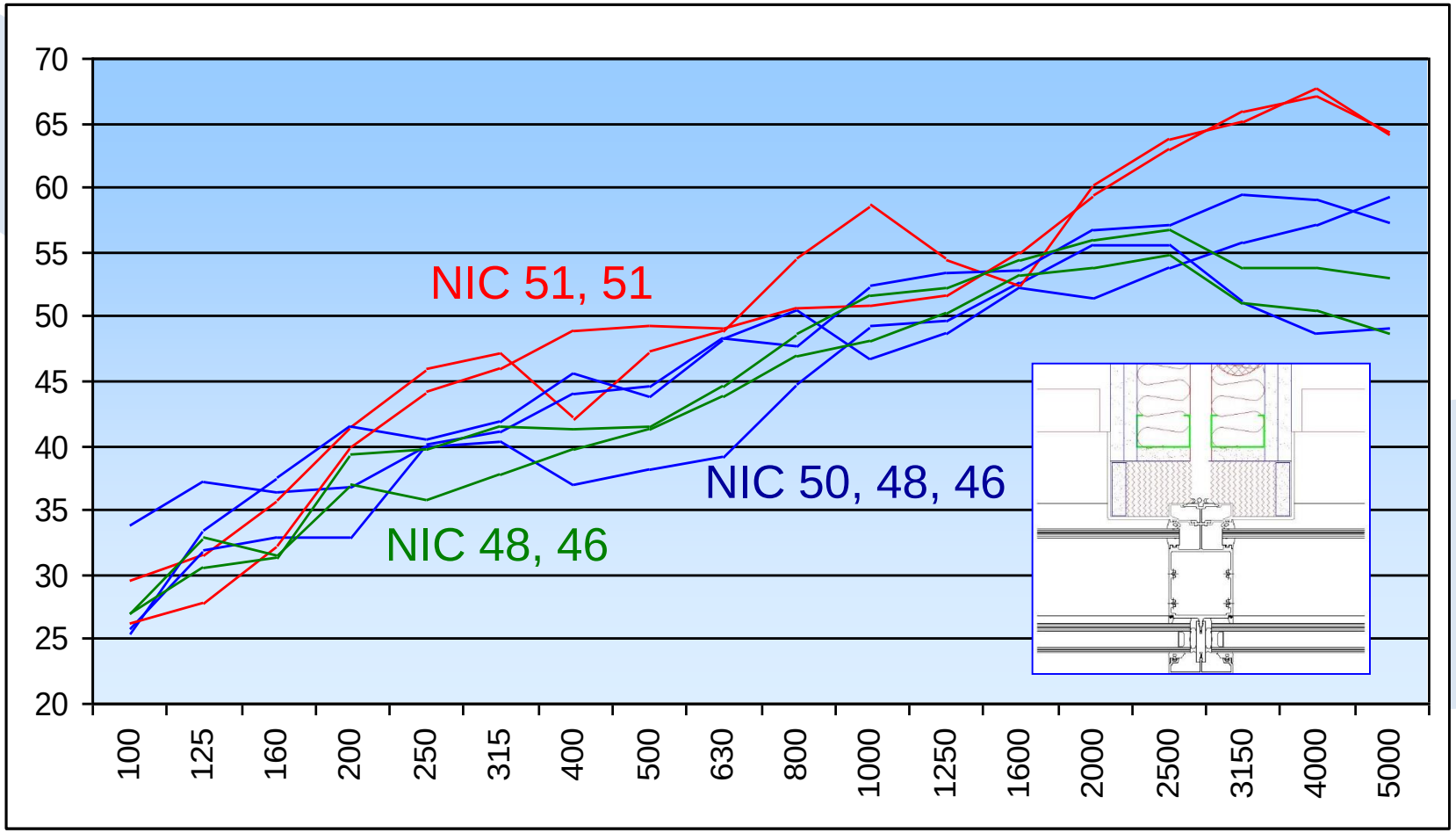


Trim piece

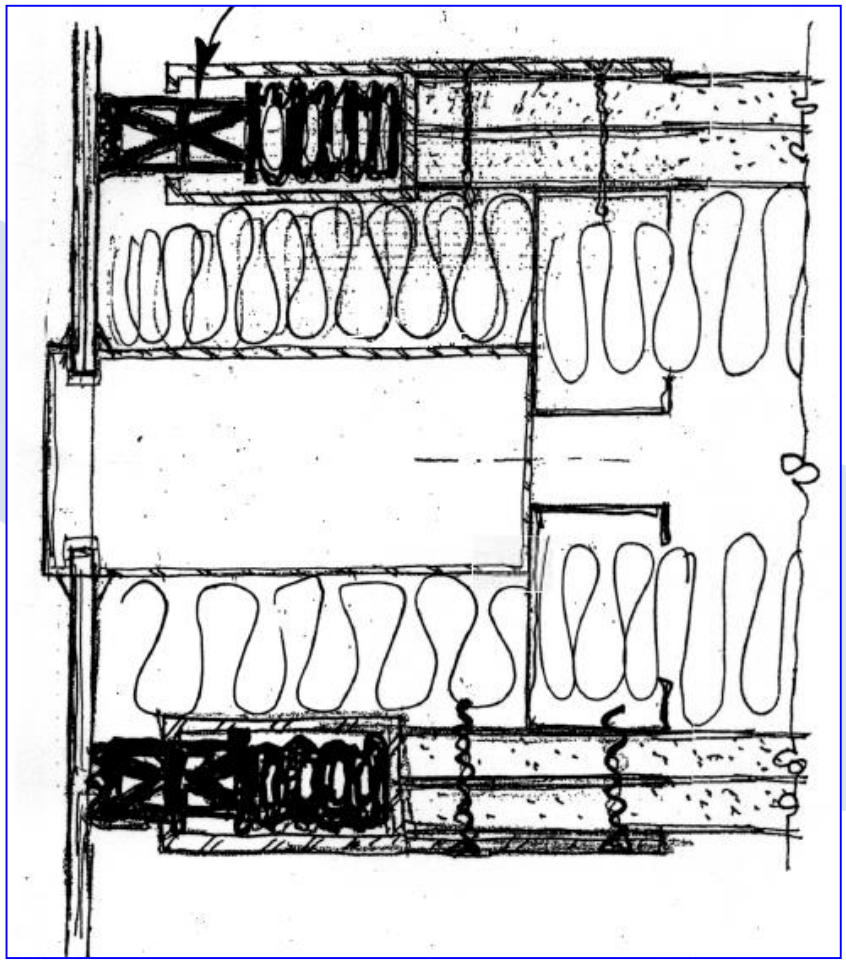


Trim Piece

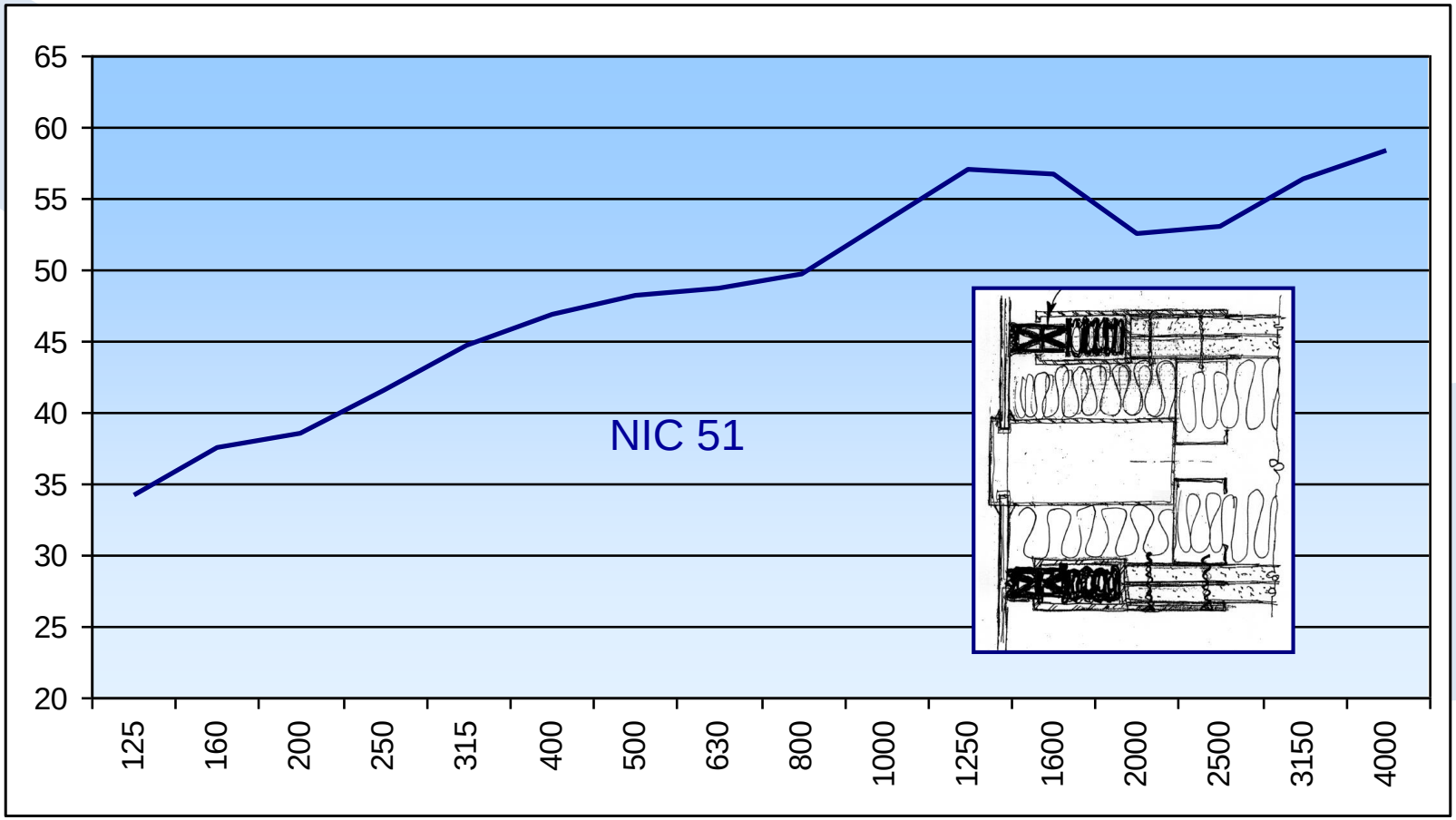
Effect of Trim Piece



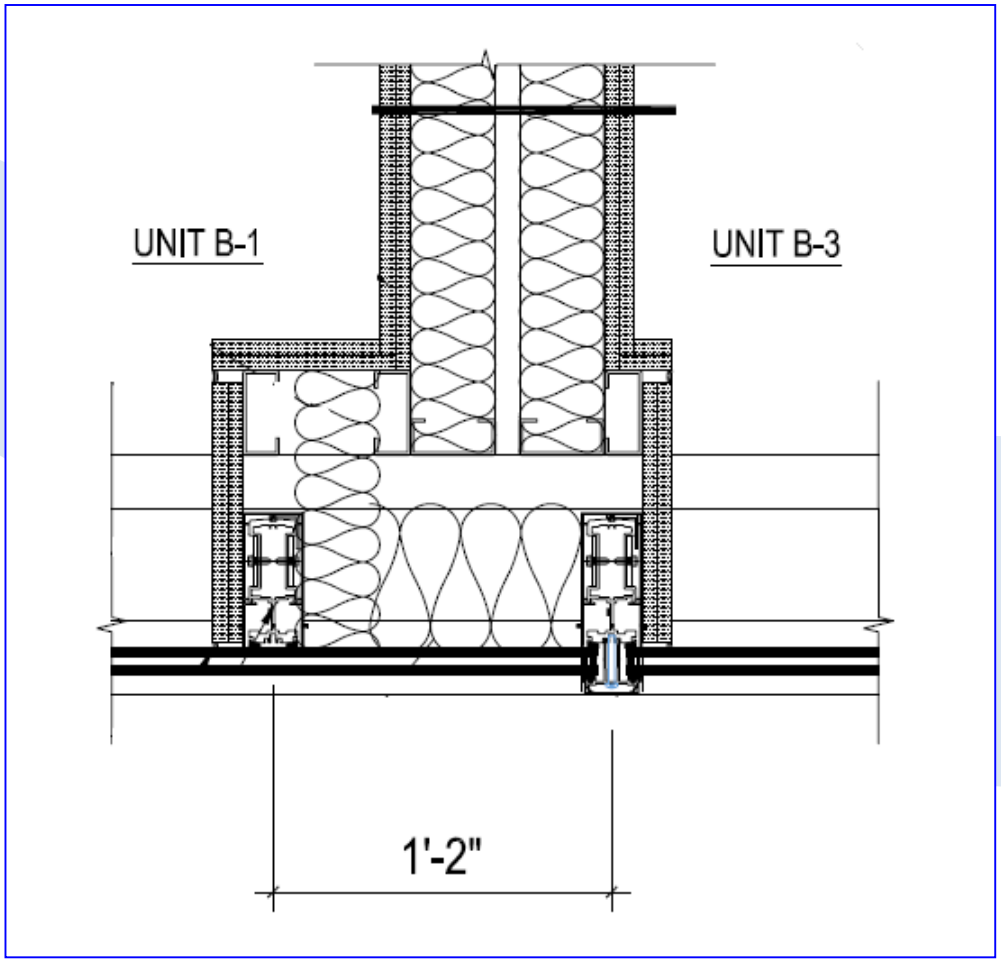
Trim piece with seals



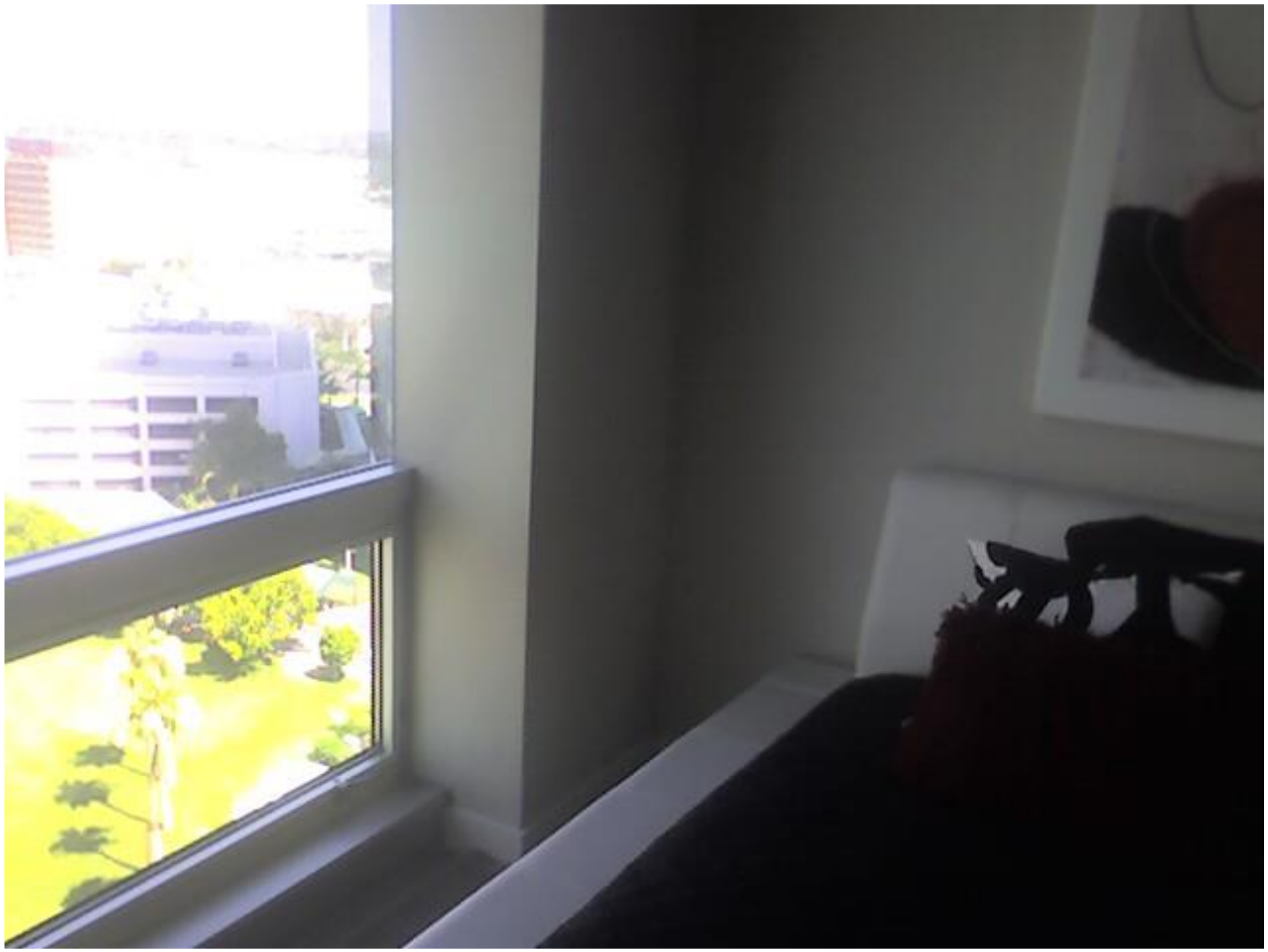
Trim piece with seals



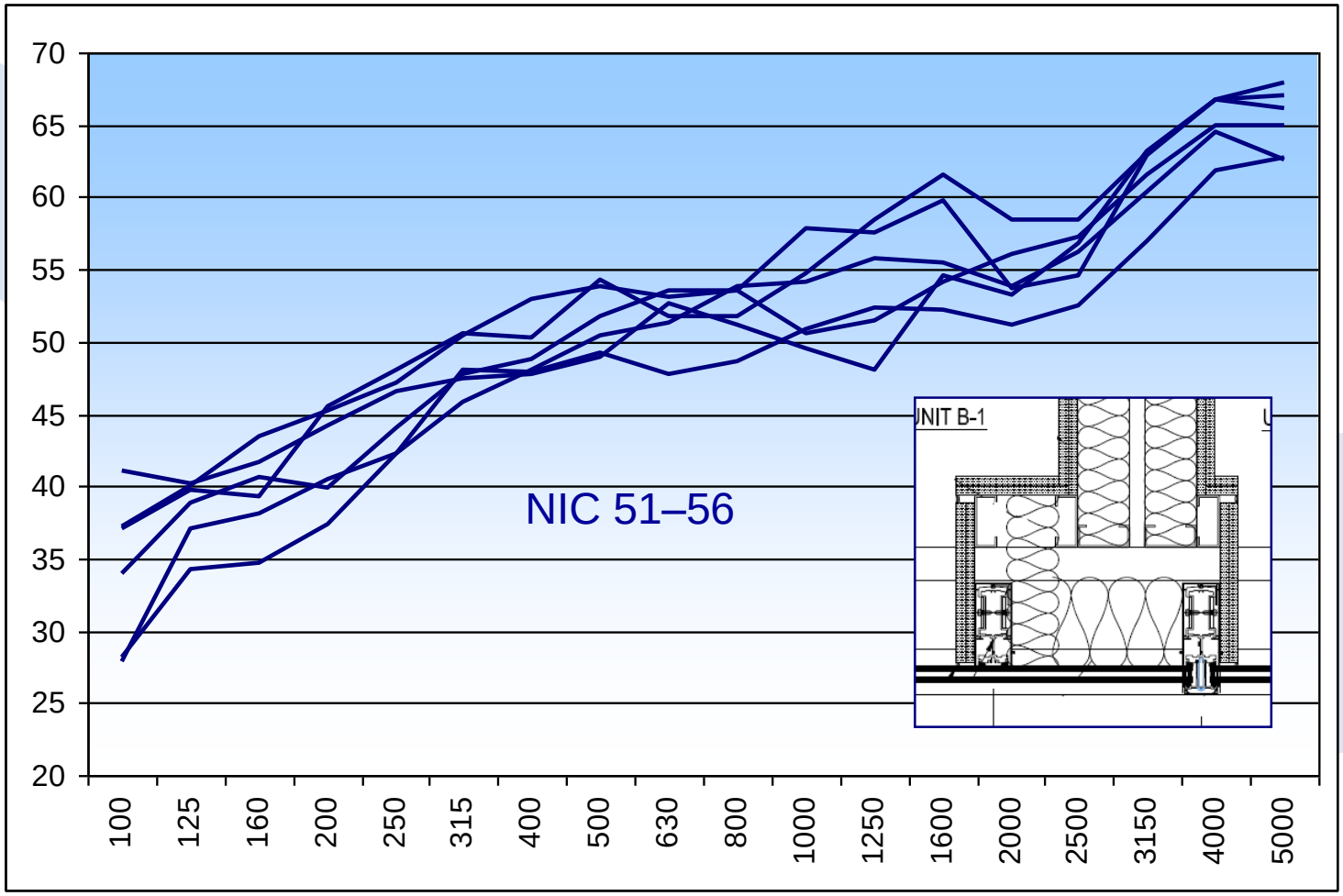
Wide or double mullions



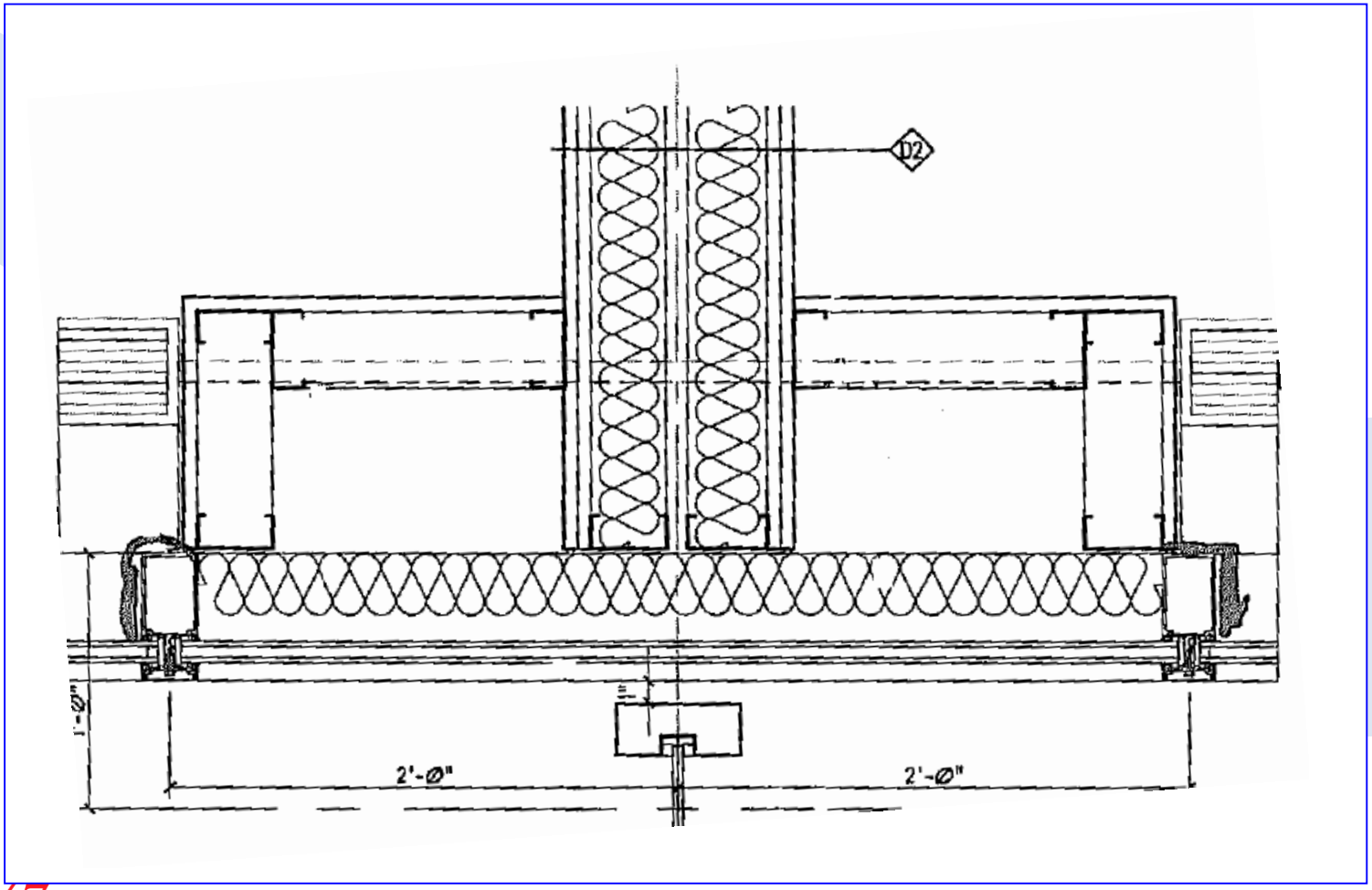
Wide or double mullions



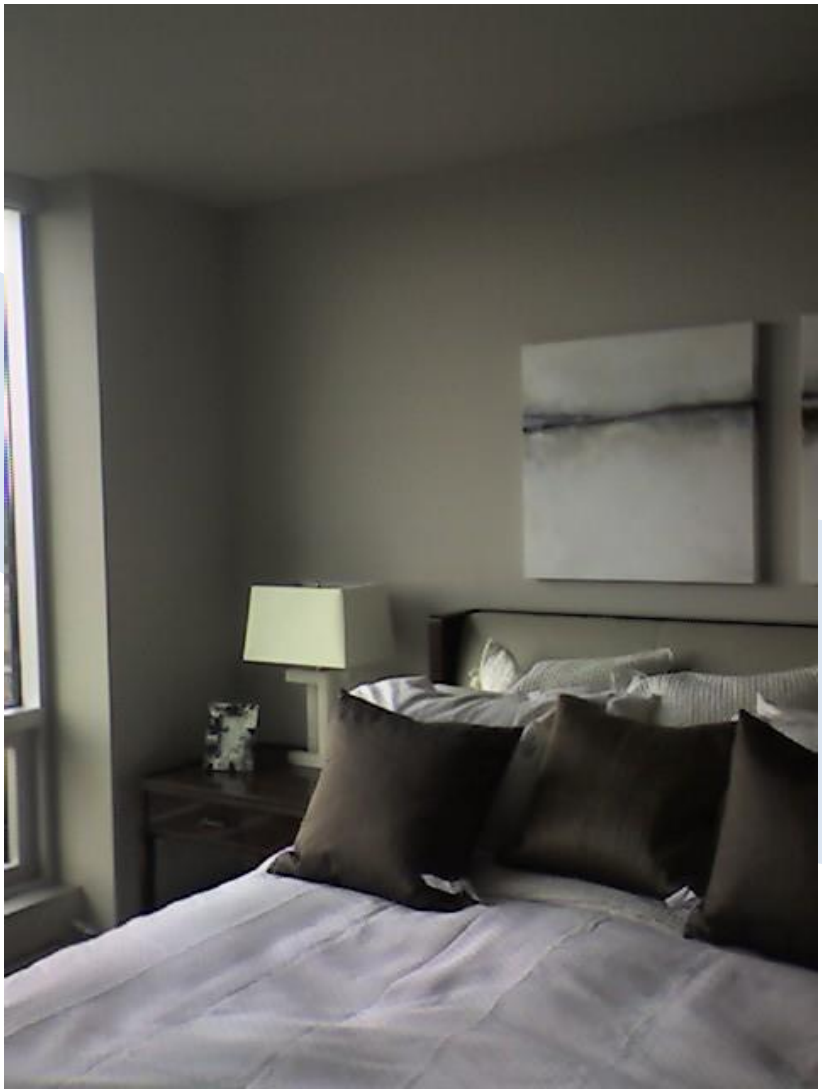
Wide or double mullions



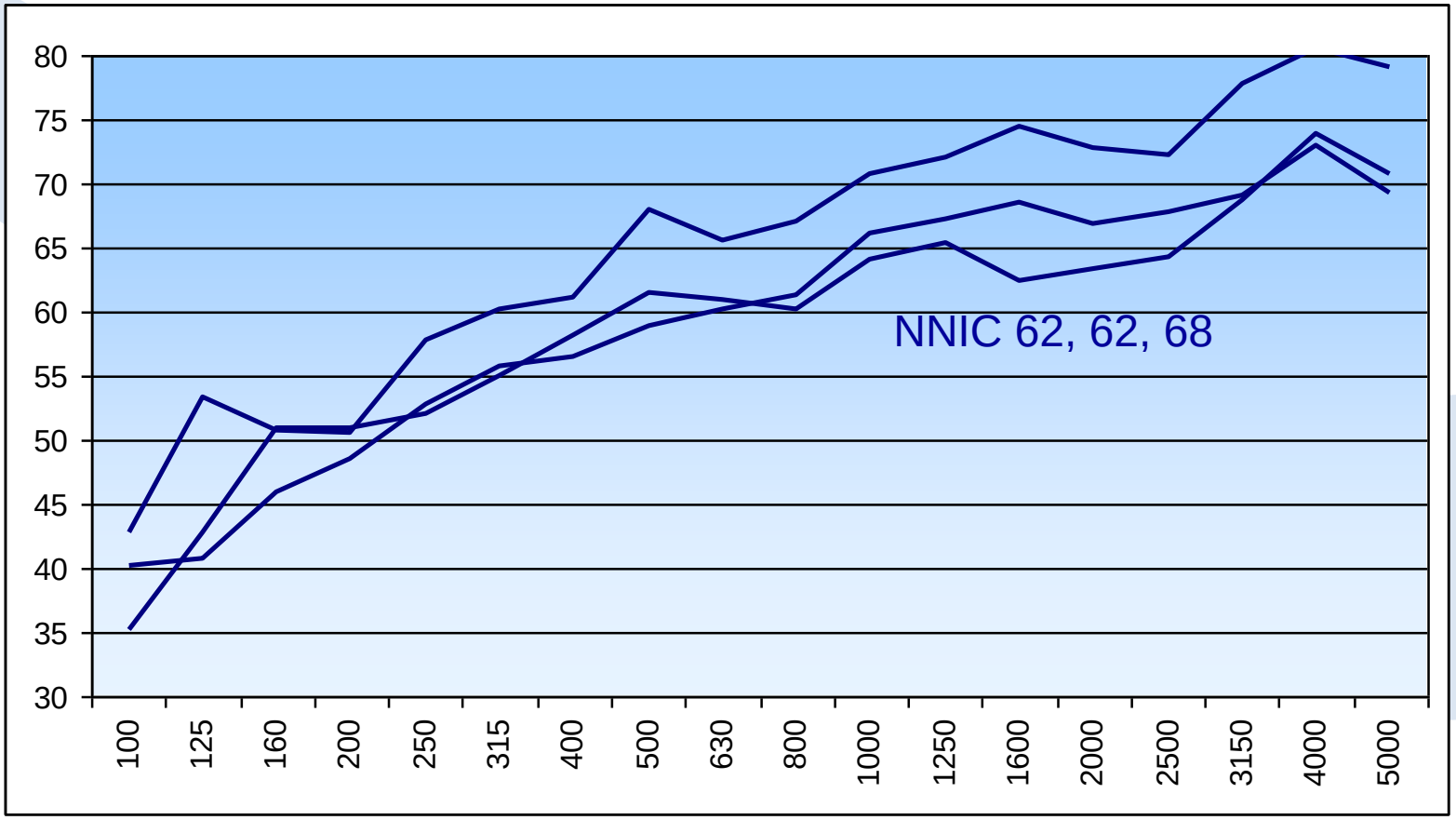
Double mullions with closure



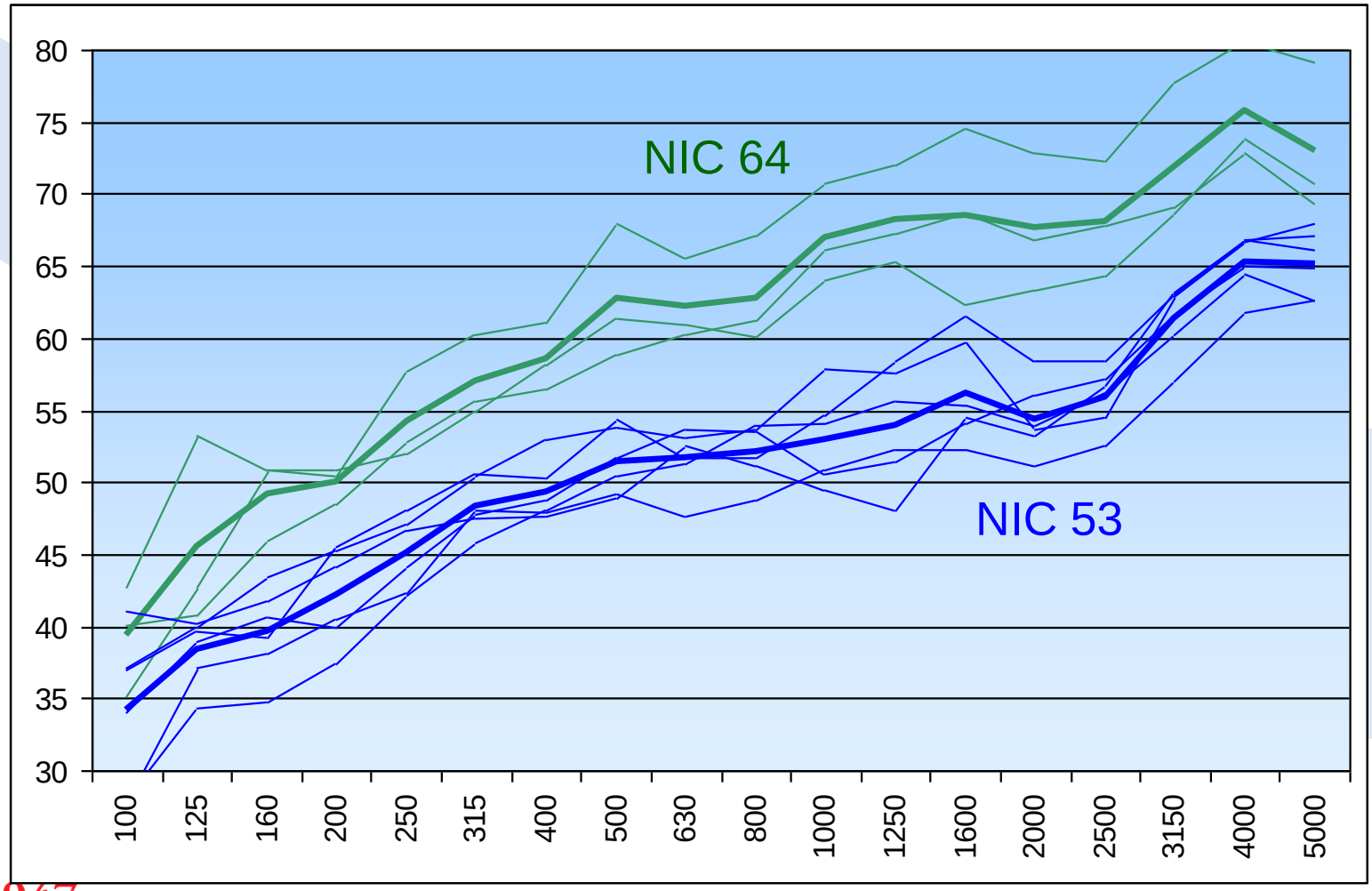
Double Mullion with Closure



Double mullions with closure



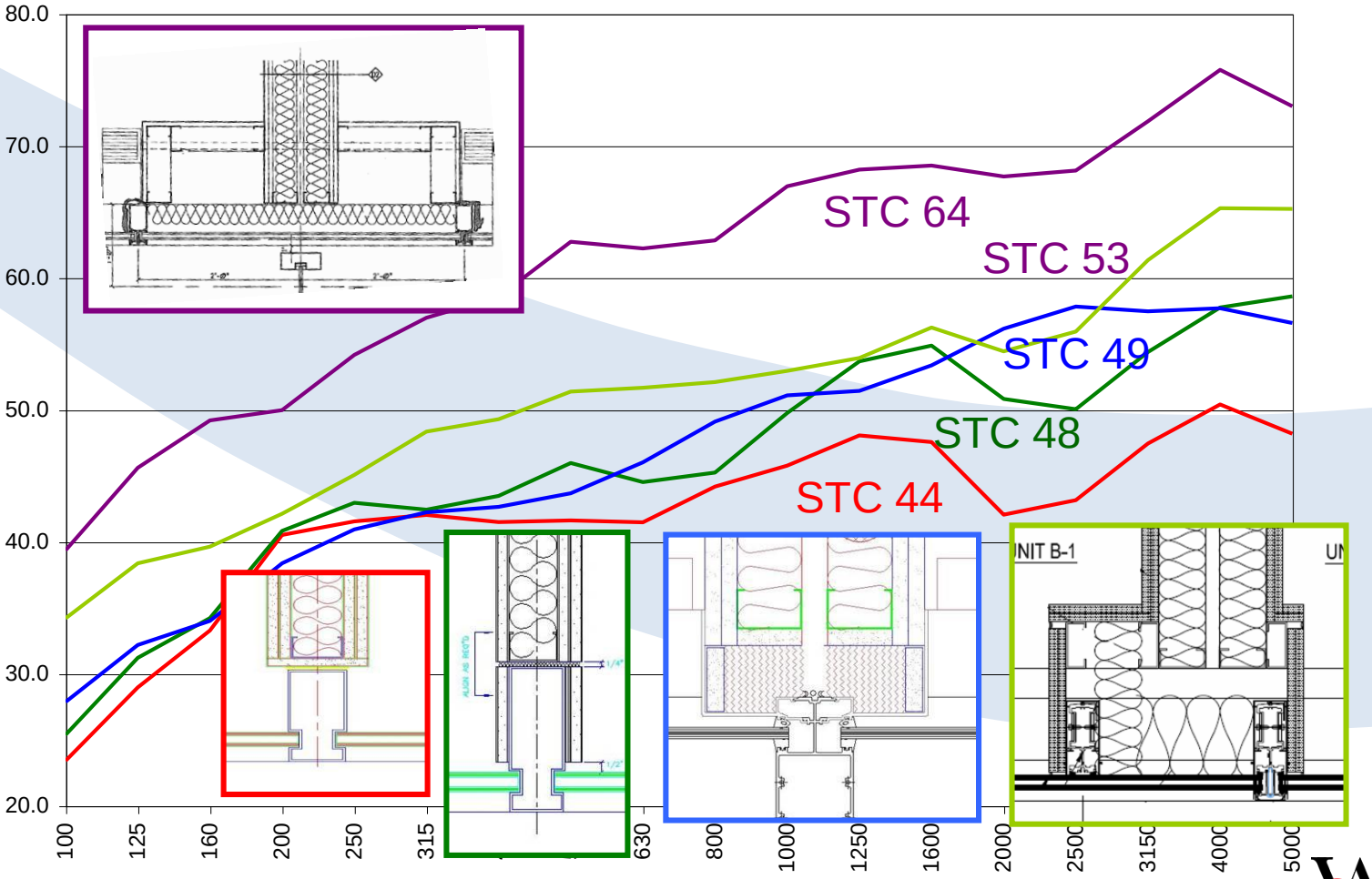
Effect of Ceiling Flanking



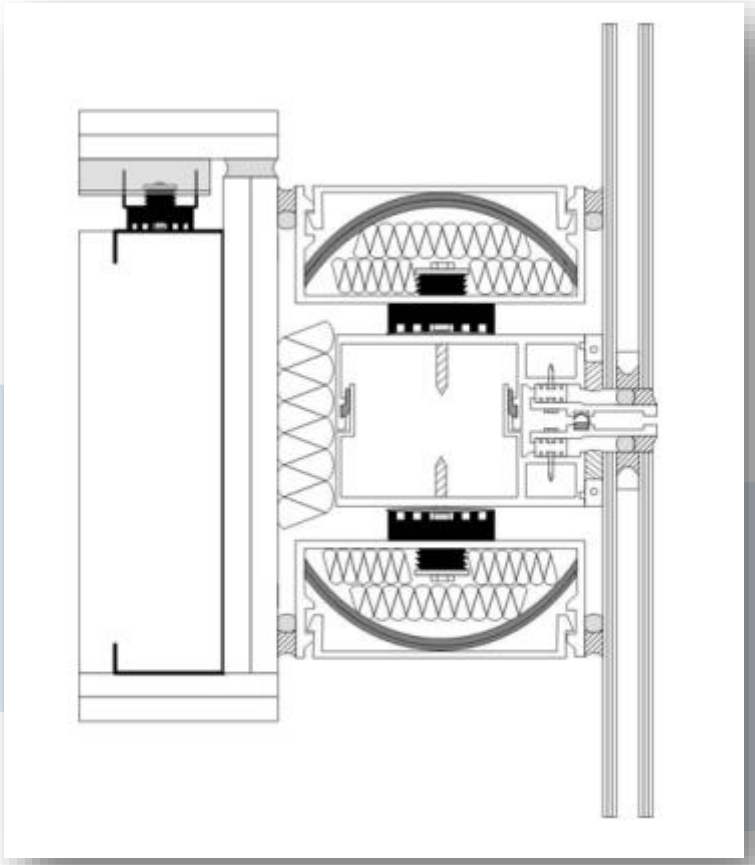
Summary Chart

Condition	Wall Min STC	Mullion	Result
Low (Office)	STC 40	Exposed	STC 35–40
Mid-level (Hotel)	STC 52	Wrapped or trim Trim	STC 46–53
Mid-High (Hotel, School, Condominium)	STC 58	Widened/double	STC 52–56
Luxury (Condominium)	STC 60+	Widened/double with closure	STC 60+

Effects of Mullion Flanking



Commercial Products



Summary

- Single Number Ratings
  - Noise levels typically measured as DNL or CNEL
  - Curtainwalls specified in terms of STC and OITC
  - Single numbers do not tell the whole story
- Acoustical Performance of Curtainwall
  - Exterior noise level, glazing area, acoustical room absorption will all affect the requirements for the glazing.
  - No single number can convey all of the effects – do not design to a rating.
  - Type of glass, thickness of glass and airspace have specific effects on the performance at various frequencies.
- Noise from Curtainwall Systems
  - Curtainwalls can generate noise due to friction or binding under thermal expansion.
- Sound Isolation at Vertical Condition
  - Edge of slab requires a solid acoustical block of some sort
  - Sound transmission through the curtainwall itself is sometimes a problem.
- Sound Isolation at Horizontal Condition
  - Sound transmission through mullions requires careful consideration.
  - The level of protection is determined by the required performance.

Thanks for your attention!