

# Noise Control Absorption and Transmission

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## Noise Control Terminology

- Noise reduction (NR):

$$NR = L_{p1} - L_{p2}$$

- Insertion loss (IL)

$$IL = L_p - L_{p'} = (\text{After} - \text{Before})$$

At same location

- Attenuation: reduction of noise at greater distances
- Sound absorption
  - Sound absorption coefficient ( $\alpha$ ) = fraction of sound absorbed
  - Varies with frequency
- Sound transmission loss (TL) =  $10 \log(W_{\text{incident}}/W_{\text{thru}})$ 
  - Governed by physical properties of material & type of construction

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### **Sound level and “hardness of room”**

- **Free-field: totally without reflecting objects**
  - sound pressure level in any given direction from the noise source may be measured without the presence of interfering reflection.
  - e.g., measurements made outdoors at the top of a flagpole
  - e.g., anechoic chamber. In an anechoic chamber the ceiling, floor and all the walls are covered by a highly absorptive material which eliminates reflections.
- **Reverberation chamber**
  - all surfaces are made as hard and reflective as possible and where no parallel surfaces exist
  - creates a so-called diffuse field in which the sound energy is uniformly distributed throughout the room
  - Can measure noise anywhere, but is average of reflections
- **Majority of rooms are somewhere in-between**

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### **Fields**

- **Free field**
  - No interruptions
- **Reverberant field**
  - Reflections add significantly to sound level
  - Sound drops < 6 dB with doubling of distance
  - Boundary between free field and reverberant changes according to reflectivity of room surfaces
- **Near field**
  - Very near sources
  - Waves radiation from contributing sources not combined into uniform sound field
  - Wide variations in noise from location to location
  - With increasing distance becomes more uniform until like point source

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## More Fields

- Far field
  - Waves combine into a regular pattern of propagation
  - More uniform
  - -6 dBA with doubling of distance if no reflections
  - Reality somewhat different
    - Ground; uneven ground
    - Wind
- Direct field

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## Math of Sound Field (again)

$$L_p = L_w + 10 \log \left[ \frac{Q}{4\pi r^2} + \frac{4}{R} \right] + k, dB$$

- $L_w$  independent of environment for vast majority of sources
- Q term determined by directionality and placement of the source
- $4/R$  is room absorption effect
- Equation applicable anywhere in the room
- Allows separation of direct and reverberant contributions

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# Sound Absorption

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## Sound Absorption

$\alpha$  = sound absorption coefficient  
= (energy absorbed/energy incident)

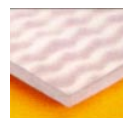
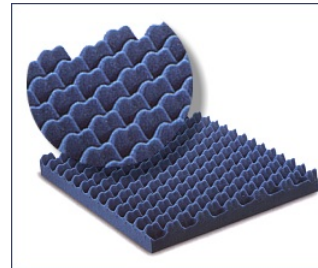
Theoretically varies from 0 to 1

Actually, can reach 1.05)

Good values: soft, thick, porous, fuzzy

Low values: rigid, hard, smooth

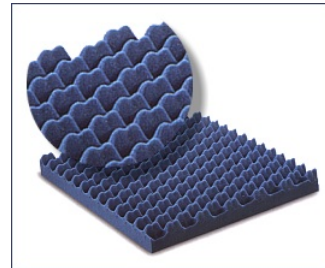
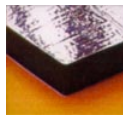
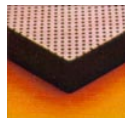
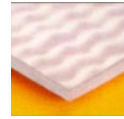
Low-freq. absorption increases with thickness for porous materials (diminishing returns)



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## Sound Absorbing Material

- Low frequencies difficult to absorb
- Polyurethane and polyester foams must be open-cell (absorb water)
- Fiberglass often used
- Surface sometimes must be protected – reduces sound absorption



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## Sound Absorption

Material	125	250	500	1k	2k	4k	NRC
Brick, unpainted	.02	.02	.03	.04	.05	.05	.04
Brick, unglazed	.03	.03	.03	.04	.05	.07	.04
Brick, unglazed, painted	.01	.01	.02	.02	.02	.03	.02
Carpets, heavy and on concrete	.02	.06	.14	.37	.60	.65	.29
on 40 oz hairfelt or latex rubber	.08	.27	.39	.34	.48	.63	.37
Concrete block, coarse	.36	.44	.31	.29	.39	.25	.36
Concrete block, painted	.10	.05	.06	.07	.09	.08	.07
Floors							
concrete or terrazzo	.01	.01	.02	.02	.02	.02	.02
linoleum or asphalt on concrete	.02	.03	.03	.03	.03	.02	.03
wood	.15	.11	.10	.07	.06	.07	.09
wood parquet in asphalt or concrete	.04	.04	.07	.06	.06	.07	.06

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### More absorption

Material	125	250	500	1k	2k	4k	NR C
<b>Foams:</b>							
1", 2 lb/cuft polyester	.23	.54	.60	.98	.93	.99	.76
2", 2 lb/cuft polyester	.17	.38	.94	.96	.99	.91	.82
<b>Glass</b>							
large panes of heavy plate	.18	.06	.04	.03	.02	.02	.04
ordinary window glass	.35	.25	.18	.12	.07	.04	.16
<b>Glass fiber</b>							
1", 3 lb/cuft	.23	.50	.73	.88	.91	.97	.76
1", 6 lb/cuft	.26	.49	.63	.95	.87	.82	.74
Gypsum board, .5" on 2"x4", 16" o.c.	.29	.10	.05	.04	.07	.09	.07
<b>Sprayed on acoustical material</b>							
1" cellulose appl. To metal lathe	.47	.90	1.10	1.03	1.05	1.03	1.02
Plywood paneling	.28	.22	.17	.09	.10	.11	.15

### Sound absorption on walls, ceilings



$$\bar{\alpha} = \frac{\sum_{i=1}^N S_i \alpha_i}{\sum_{i=1}^N S_i}$$



Alpha value for EACH frequency range

Works best if evenly distributed

### Example Absorption Coefficient Problem

- Find absorption coefficient at 1,000 Hz for a 40'x70' room with 12' ceiling, given:
  - Floor:  $\alpha = 0.1$
  - Ceiling:  $\alpha = 0.7$
  - Walls:  $\alpha = 0.2$
- Step 1: Determine areas
  - $S_{\text{floor}} = 2800 \text{ ft}^2$ ;  $S_{\text{ceiling}} = 2800 \text{ ft}^2$ ;  $S_{\text{wall}} = 2640 \text{ ft}^2$
- Step 2: Solve average absorption coeff.

$$\bar{\alpha} = \frac{\sum_1^N S_i \alpha_i}{\sum_1^N S_i} = \frac{2800(0.1) + 2800(0.7) + 2640(0.2)}{2800 + 2800 + 2640} = 0.34$$

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### Room Constant

$$L_p = L_w + 10 \log \left[ \frac{Q}{4\pi r^2} + \frac{4}{R} \right] + k \quad , dB$$

$$R = \frac{S \bar{\alpha}}{1 - \bar{\alpha}}$$

- Reverberant field component
- Absorption,  $a = S \bar{\alpha}$ 
  - Units of area
  - Call Sabins to prevent confusion with actual room areas
- Actual absorption often greater than computed value
  - Process equipment and other surfaces not counted
  - Add 25% to R

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### Example Problem, Room Constant

- Determine R at 1k Hz for case where many production machines are in the area:
  - $\alpha = 0.34$
  - $S_{\text{room}} = 8240 \text{ ft}^2$
  -
$$R = \frac{S\bar{\alpha}}{1-\alpha} = \frac{(8240)(0.34)}{1-0.34} = 4245 \text{ ft}^2$$
- Note that “blows up” at  $\alpha \geq 1.0$ 
  - R applies best to equations when room relatively square and  $\alpha < 0.15$ .
  - Otherwise, use with less confidence

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### Room Constant, More Complicated

- Note that simple definition “blows up” at  $\alpha \geq 1.0$
- R applies best to equations when room relatively square and  $\alpha < 0.15$ .
- For cases where 2 parallel walls are relatively hard and others are lined, use:

$$R = \frac{S}{\left(\frac{1}{S}\right)\left[\frac{S_x}{\alpha_x} + \frac{S_y}{\alpha_y} + \frac{S_z}{\alpha_z}\right] - 1}$$

Where: x, y, z are sets of parallel walls

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## R Computed from Reverberation Time

- Time required for steady-state SPL to decrease by 60 dB after source stopped

$$R = \frac{S}{\frac{T(S)}{0.049(Vol)} - 1}, \text{ sec}$$

S, total room surface area, ft<sup>2</sup>

T, time in seconds

V, room Volume in ft<sup>3</sup>

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## Important Note about Absorption

May provide negligible reductions for workers in near field

Room absorption affects only workers at some distance from source

Useful for distant workers if room relatively hard:  $\bar{\alpha} < 0.4$

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### Example 9.8

- Small machine relocated
  - Originally (room 1) was 90 dBA at 3 ft when located in the center of the room and room 1 empty
  - Room: 20' x 20' x 8'
    - Concrete floor;
    - lay in acoustical panels;
    - 3/8" plywood walls
  - $S_{\text{ceiling}_1} = S_{\text{floor}_1} = 400 \text{ ft}^2$ ;  $S_{\text{wall}_1} =$
- What is sound at 3 ft in Room 2?
  - Room 2 empty and centered in middle, also
  - 30' x 30' x 10'
    - concrete floor
    - 1" thick gypsum ceiling
    - unpainted brick walls

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### Solution 9.8

$$L_p = L_w + 10 \log \left[ \frac{Q}{4\pi r^2} + \frac{4}{R} \right] + k, \text{ dB}$$

	Material	Freq	125	250	500	1000	2000	4000
Room1	concrete floor	$\alpha$	0.01	0.01	0.02	0.02	0.02	0.02
	ceiling panels	$\alpha$	0.08	0.25	0.74	0.95	0.97	0.99
	3/8" plywood	$\alpha$	0.28	0.22	0.17	0.09	0.10	0.11
	Eq. 9.24	$\alpha_{\text{mean}}$	0.15	0.17	0.29	0.31	0.32	0.33
	Eq. 9.25	R	254	295	588	647	678	709
	Octave band	SPL	89	89	86	84	83	81
	Eq. 9.23	PWL	93	94	92	90	89	87
Room1	concrete floor	$\alpha$	0.01	0.01	0.02	0.02	0.02	0.02
	gypsum ceiling	$\alpha$	0.29	0.10	0.05	0.04	0.07	0.09
	unpainted brick	$\alpha$	0.02	0.02	0.03	0.03	0.05	0.05
	Eq. 9.24	$\alpha_{\text{mean}}$	0.10	0.04	0.03	0.03	0.05	0.05
	Eq. 9.25	R	333	125	93	93	158	158
	Eq.9.23	SPL	88	92	90	88	86	84
	A-weighting	SPL	-16	-9	-3	0	1	1
	Corrected dB	SPL	72	83	87	88	87	85
						87.1 dBA		

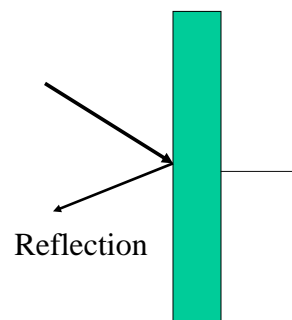
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## Transmission Losses

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### Sound travels through walls

- Absorbing material alone:
  - A lot of sound goes through the wall
- Solid partition:
  - Much sound is reflected back into the room
- Combination walls:
  - Some goes through, some gets reflected



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## Transmission Loss Computations

- TL is defined as the sound pressure reduction due to a partition
- $TL = L_P \text{ (source side of wall)} - L_P \text{ (other side of wall)}$
- Transmission coefficient,  $\tau$

$$\tau = \left( \frac{\text{Energy Transmitted}}{\text{Energy Incident}} \right)$$

- Transmission loss, TL

$$TL = 10 \log \left( \frac{1}{\tau} \right), \text{ dB}$$

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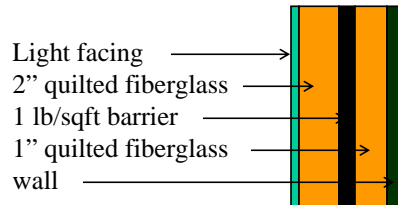
## TL Values -- continued

- TL varies moderately with frequency
- Greater values (generally) for more massive and dense
- Sound Transmission Class
  - Single number rating based on 125-4k Hz
  - Usually close to 1k Hz value
- Combinations in “sandwich” more effective

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## Combinations in “sandwich” more effective

- Two lightweight surfaces separated by layer of sound absorbing material
- Don't need dense or massive materials)
- More effective because of impedance mismatch (coupled)
- Mfg. Data generally for ideal environments; real world values lower
  - Subtract 5-10 dB
  - Noise flanks barrier



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## TL calculations

- Most walls are not made out of single material.
- Therefore, need to calculate combined TL

$$TL_{combined} = 10 \log \left[ \sum_1^n S_i \right] - 10 \log \left[ \sum_1^n S_i (10^{-TL_i/10}) \right]$$

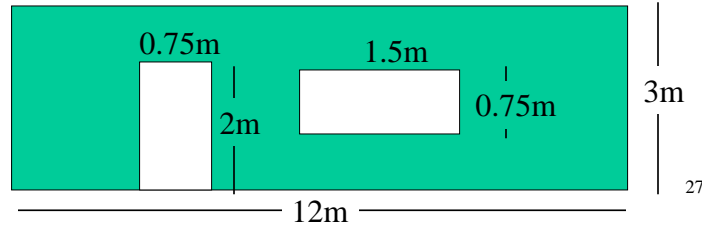
–Where: S = surface area of each material, l  
 TL<sub>i</sub> = transmission loss of surface, i

$$TL_{combined} = 10 \log \frac{\left[ \sum_1^n S_i \right]}{\sum_1^n S_i (10^{-TL_i/10})}, dB$$

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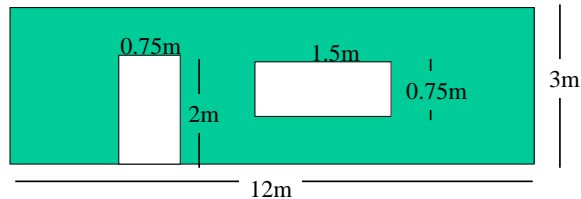
## Transmission Loss Problem

- What is the transmission loss for a 3m x 12m wall made of 4" hollow concrete block that has a 0.75m x 1.5m window of 0.75" plate glass and a 0.75m x 2m flush wood door (1.75" thick).
- Given:  $TL_{\text{Window}} = 43$ ,  $TL_{\text{Door}} = 35$ ,  $TL_{\text{Wall}} = 47$



## Answer to Transmission Loss Problem

$$\begin{aligned}
 S_{\text{Total}} &= 12 \times 3 = 36 \text{ m}^2 \\
 S_{\text{window}} &= 0.75 \times 1.5 = 1.125 \text{ m}^2 \\
 S_{\text{door}} &= 0.75 \times 2 = 1.5 \text{ m}^2 \\
 S_{\text{wall}} &= 36 - 1.125 - 1.5 = 33.375 \text{ m}^2 \\
 TL_{\text{Window}} &= 43, TL_{\text{Door}} = 35, TL_{\text{Wall}} = 47
 \end{aligned}$$



$$TL_{\text{combined}} = 10 \log \left[ \sum_1^n S_i \right] - 10 \log \left[ \sum_1^n S_i (10^{-TL_i/10}) \right]$$

$$TL_{\text{combined}} = 10 \log[36] - 10 \log[1.125(10^{-43/10}) + 1.5(10^{-35/10}) + 33.375(10^{-47/10})]$$

$$TL_{\text{combined}} = 45 \text{ dB}$$

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**The End**

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