ACOUSTIC DESIGN

ERIK IPSEN
Head of Research & Design

DANOLINE

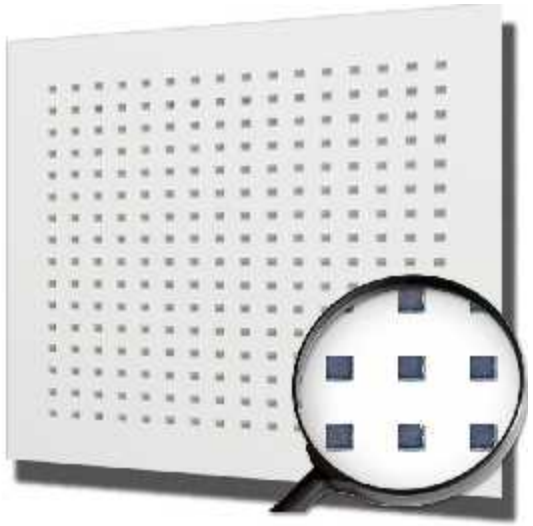
BACKGROUND

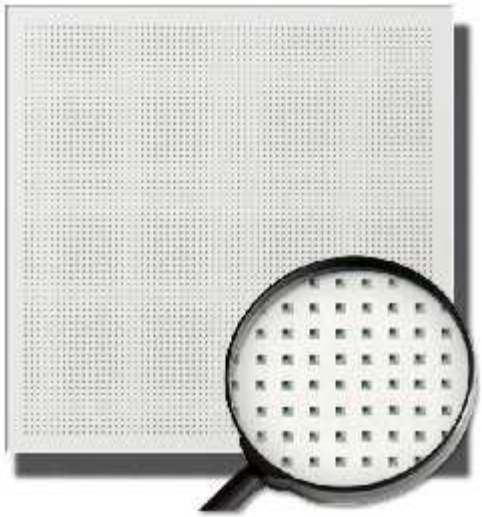
- Architect, M.A.A. (Member of the Danish Architect Association)
- Member of the Danish Acoustic Standardization Board
- Member of the Swedish Acoustic Standardization Board
- Member of the European Acoustic Standardization Board

- 20 years of experience with acoustical development
- Own testing facilities:
  - Sound absorption
  - Sound reduction
  - Sound diffusion

KNAUF DANOLINE

PERFORATED BOARDS





CLADDINGS

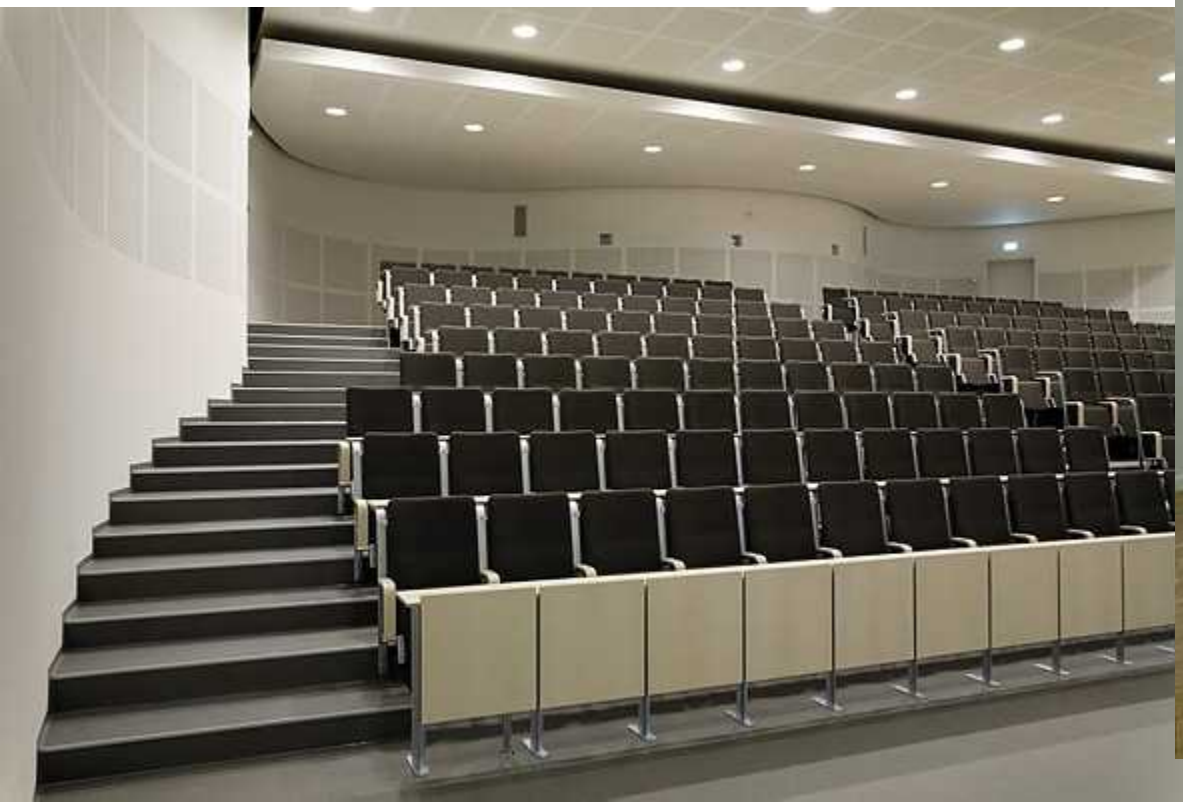
SUSPENDED CEILINGS



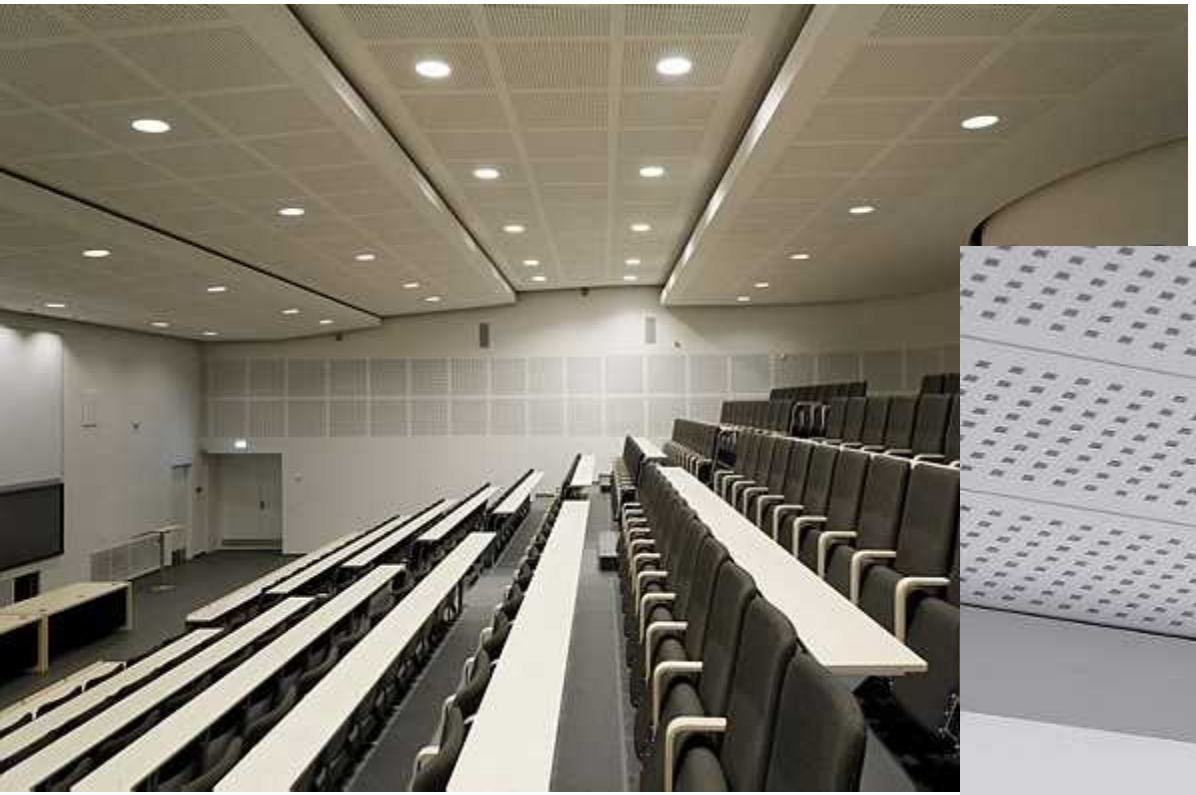



SELF SUPPORTING CEILINGS

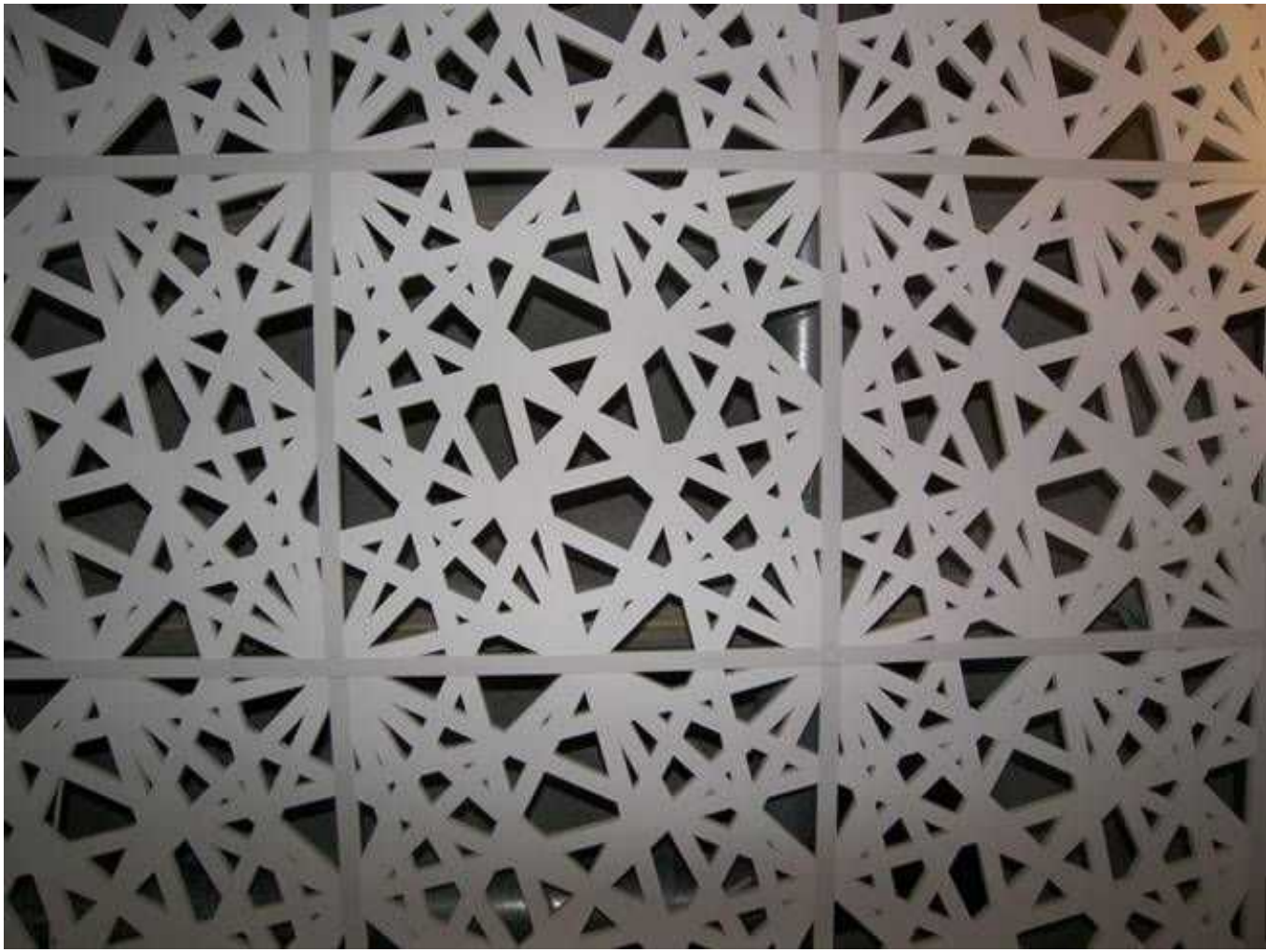
CURVES



MITRED BOARDS



STRUCTURES



GOAL

SOUND CONTROL THOUGH
ARCHITECTURE AND INTORIOR DESIGN

AGENDA

- SOUND
- REVERBERATION TIME
- SOUND CONTROLLING TOOLS
- SOLUTIONS SCHOOLS

SOUND

THE FIRST | THE LAST

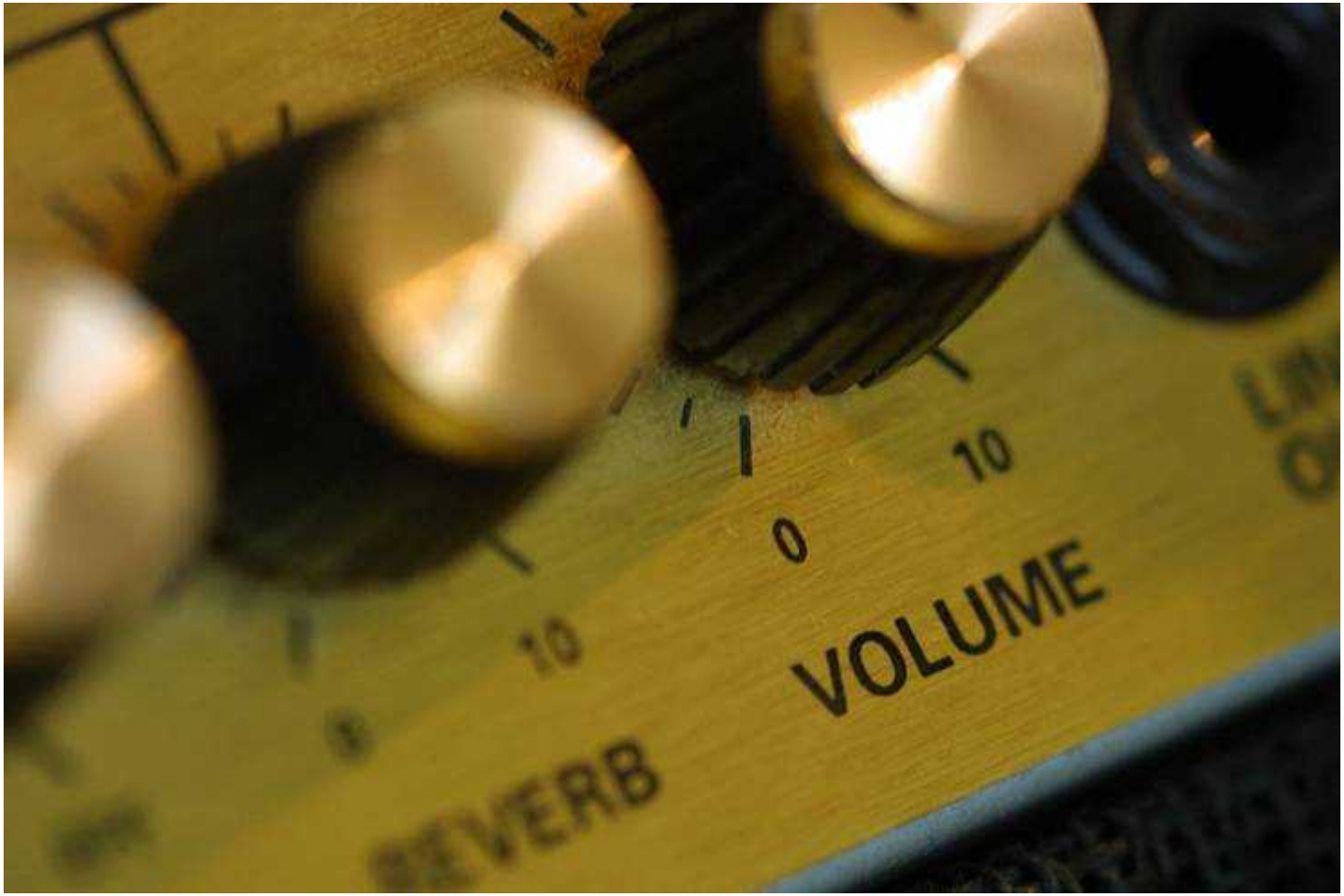
MOVEMENT OF SOUND

SOUND or NOISE

PERCEPTION OF SOUND

PERCEPTION OF SOUND

SOUND LEVEL



PURPOSE OF THE ACOUSTICS

REVEBERATION TIME

ROOMS FOR WORK

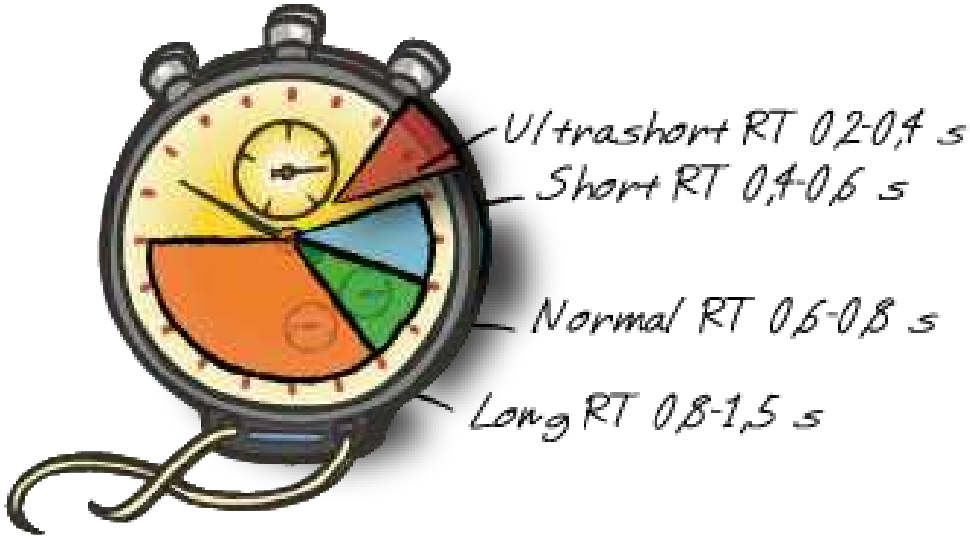
ROOMS FOR SPEECH

REV. TIME: CLASSROOMS

Efterklangstid, T [2]	
Klasserum	≤ 0,6 s
Undervisningsrum til sløjd	≤ 0,6 s
Undervisningsrum til sang og musik mindre end 250 m³ (korsang og akustisk musik) [4] [5]	≤ 1,1 s
Undervisningsrum til sang og musik mindre end 250 m³ (elektrisk forstærket) [4]	≤ 0,6 s
Gymnastiksale mindre end 3500 m³	≤ 1,6 s
Gymnastiksale større end 3500 m³	≤ 1,8 s
Svømmehaller mindre end 1500 m³	< 2,0 s
Svømmehaller større end 1500 m³	≤ 2,3 s
Fællesrum samt fællesgange, der benyttes til gruppearbejde og lignende	< 0,4 s
Fællesgange, der ikke benyttes til gruppearbejde og lignende.	< 0,9 s
Trapperum	< 1,3 s

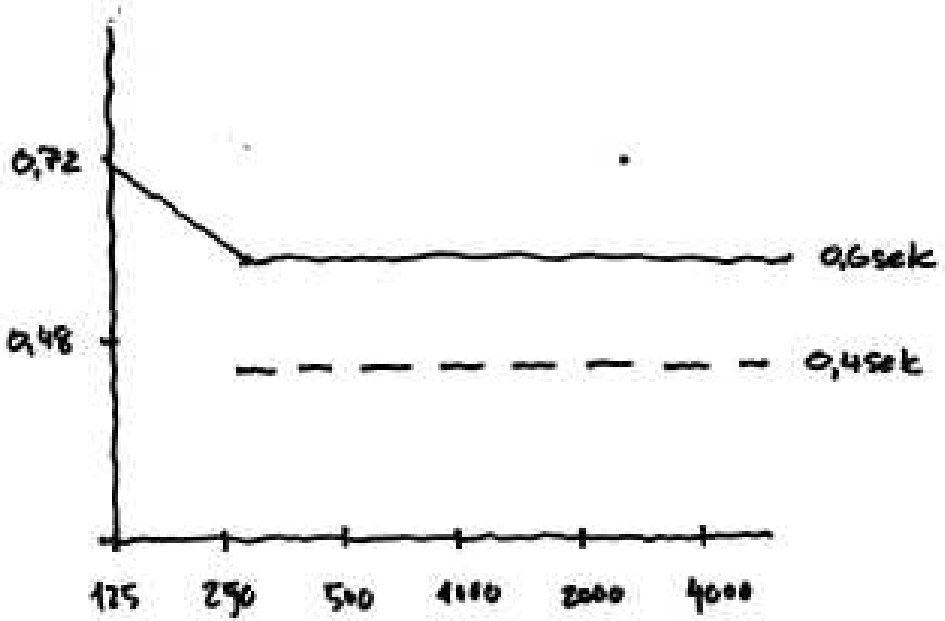
Absorptionsareal, A [5]	
Åbne undervisningsområder [2] [7]	≥ 1,3 × gulvareal
Fællesrum med oftshøjde større end 4 m og rumvolumen større end 300 m³	> 1,2 × gulvareal

REVERBERATION TIME

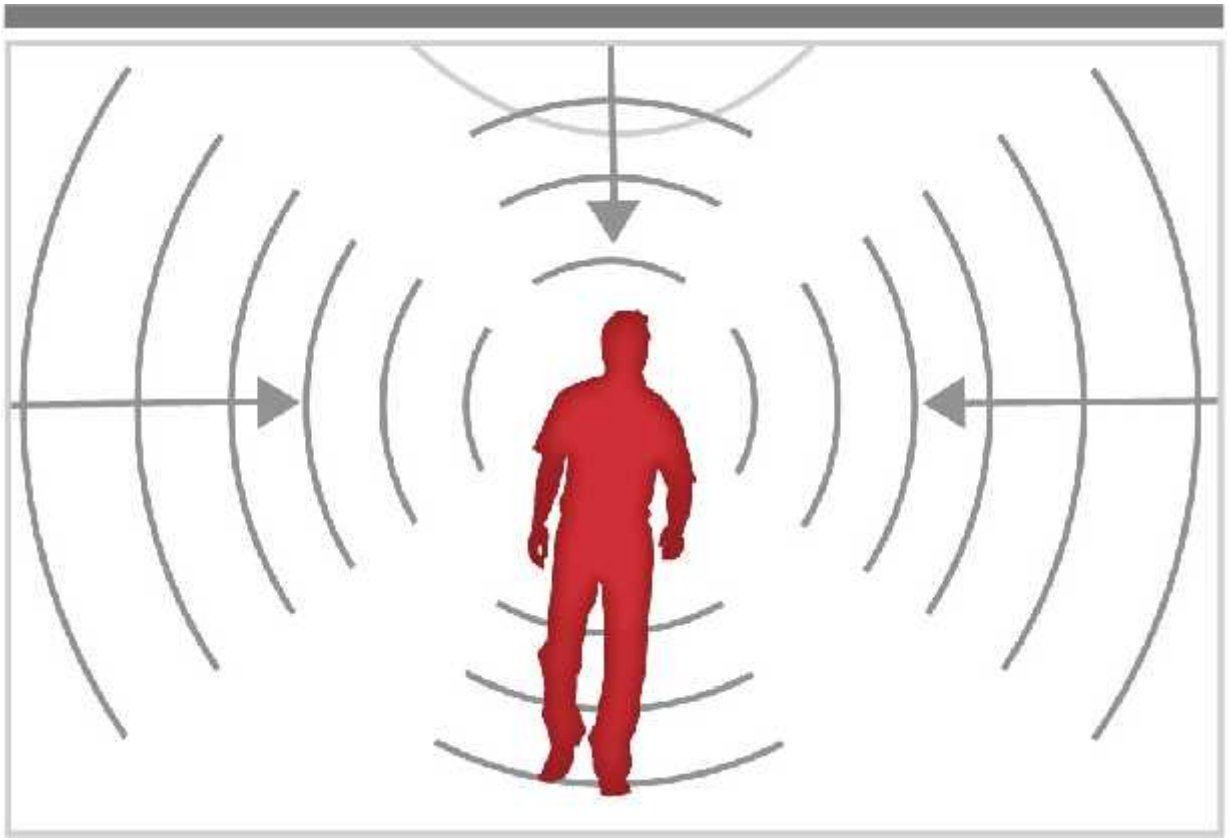


EDUCATION ROOM

CLASSROOM 0.6 sec. (min. 0.4 sec.)



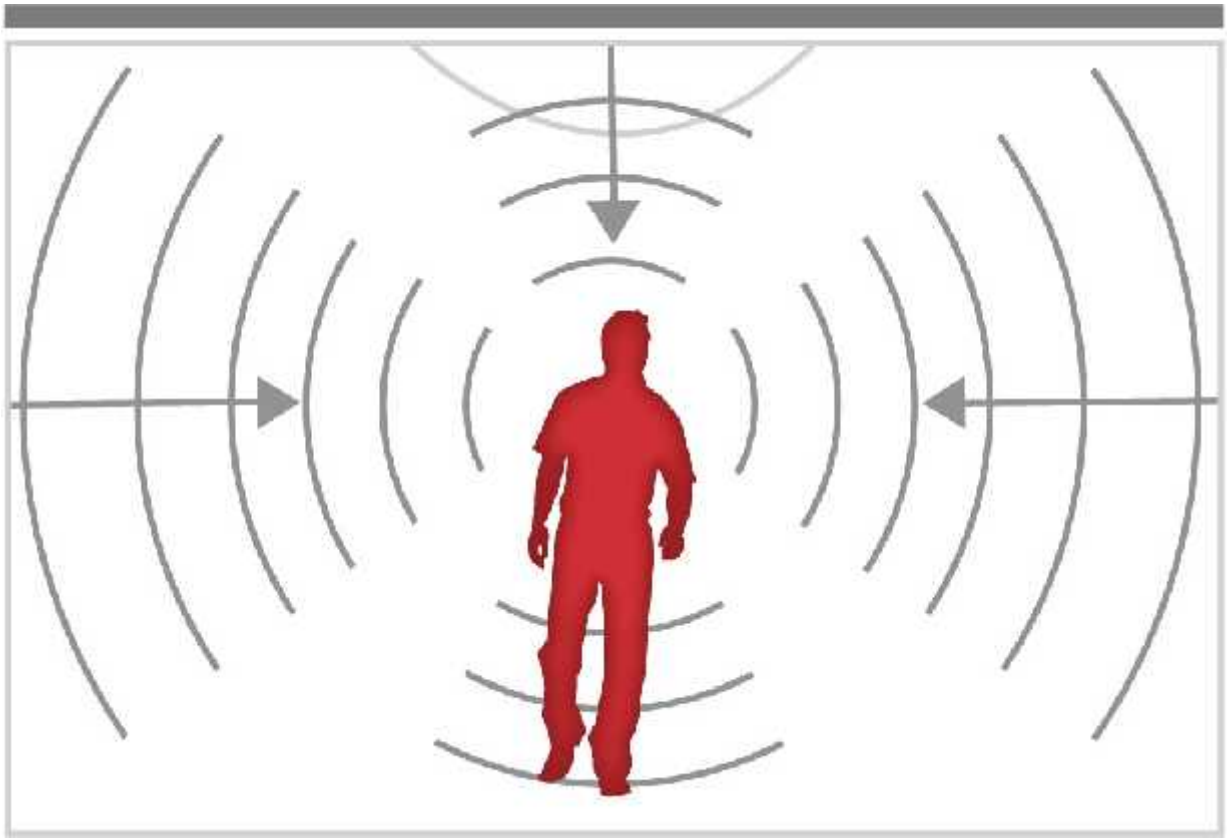
HIGHER ABSORPTION IN CEILING



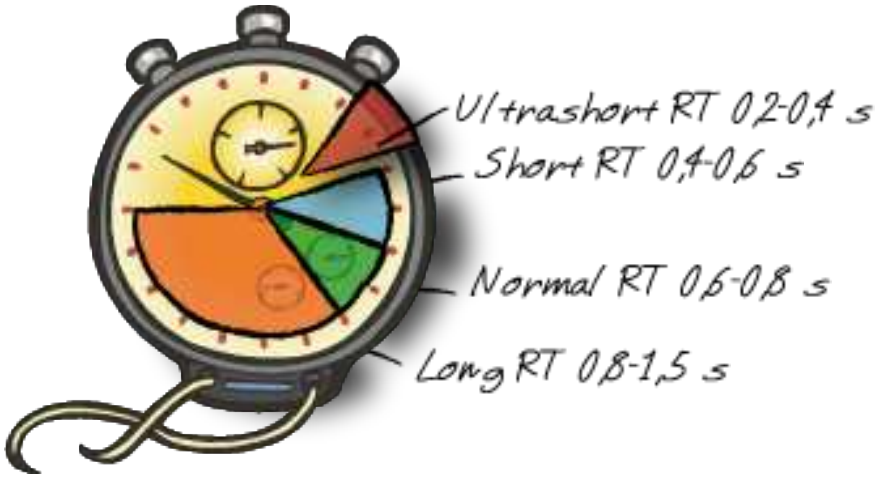
CAUTION !!!

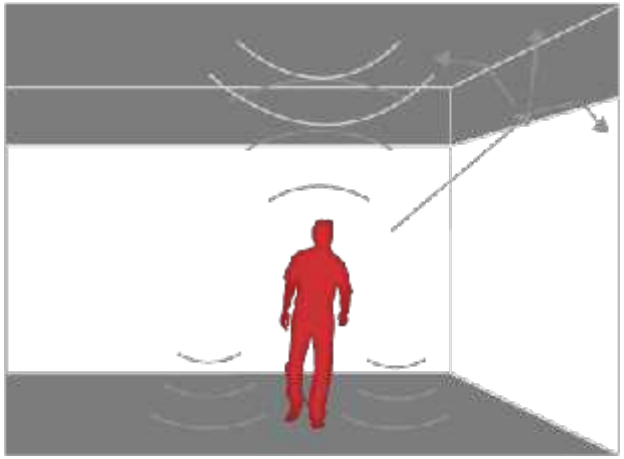
- DRY ACOUSTICS
- LARGE, PLAIN WALL SURFACES (USE OF WALL ABSORBERS)
- RISK OF GEOMETRIC REFLECTIONS
- LACK OF SOUND ABSORBING MATERIALS
- IRREGULAR ABSORPTION PROFILE
- LARGE CEILING HEIGHTS
- INCLINED CEILING AREAS WITHOUT ABSORBERS
- DOUBLE STOREY ROOMS WITH BALCONIES (MEZZANINE DECK)
- CURVED SURFACES
- PARALLEL HARD SURFACES
- CIRCULAR ROOM DESIGNS
- LACK OF DIFFUSION
- ROOM DIMENSIONS 2:1
- LARGE GLASS SURFACES
- FLOOR COVERINGS WITH DRUMMING SOUND

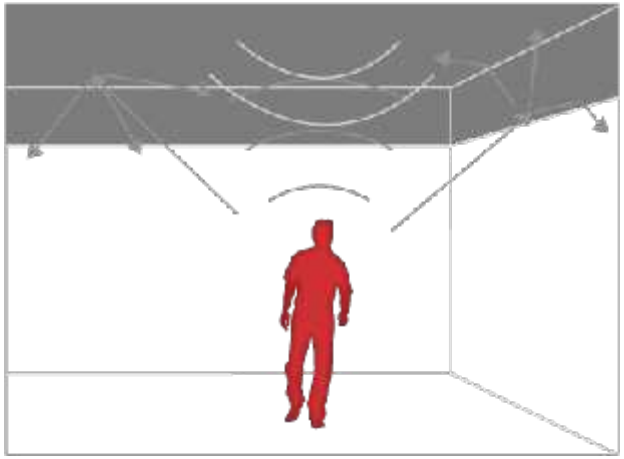
CLOSED ROOM

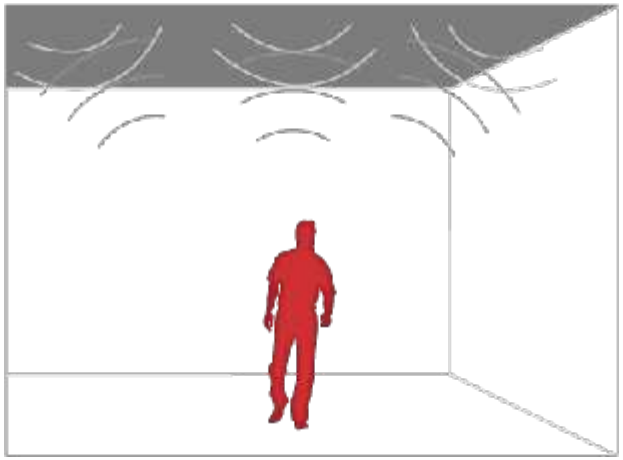


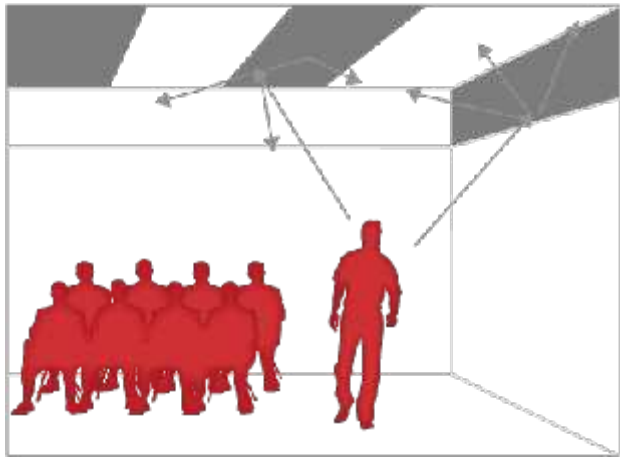
REVERBERATION TIME



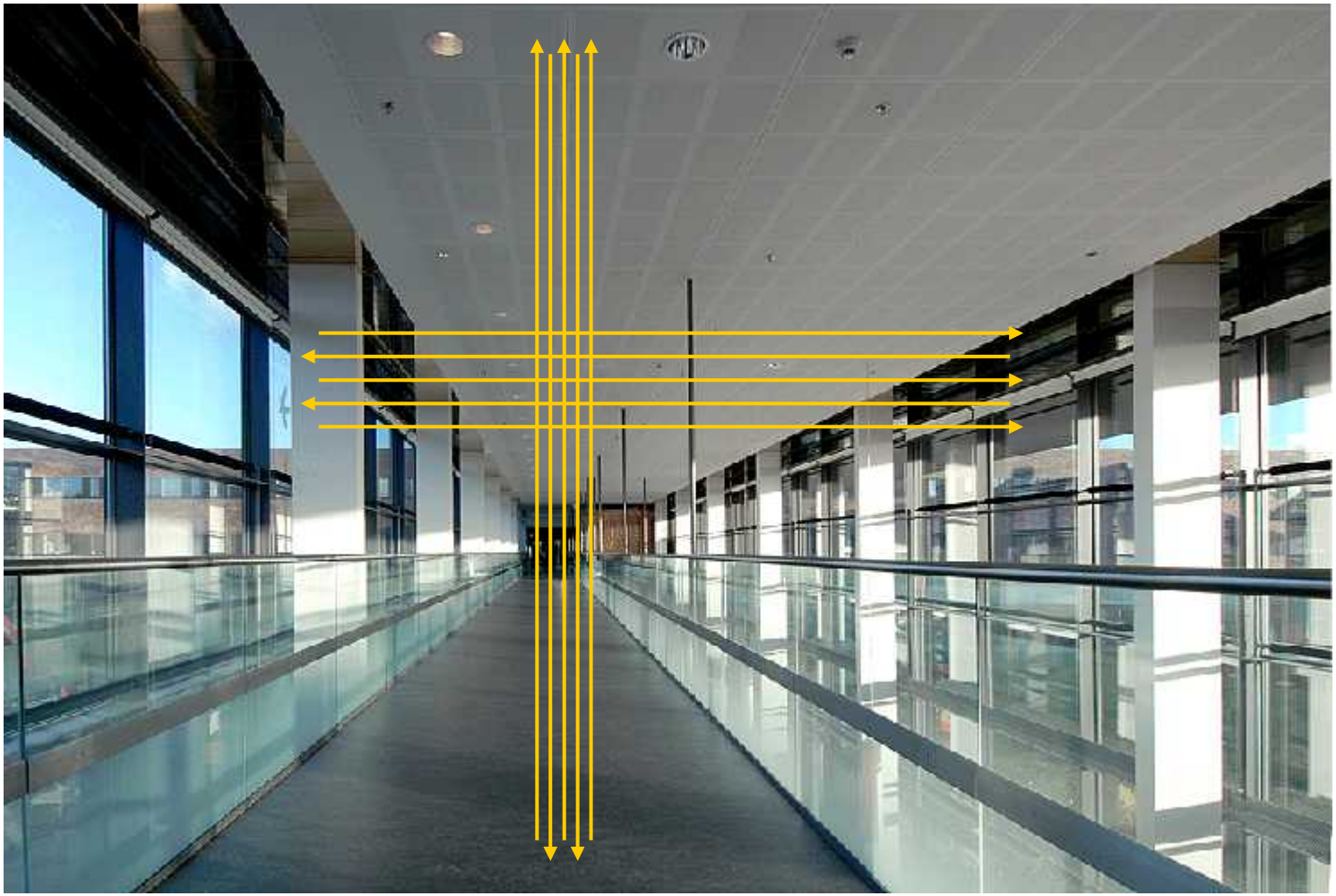




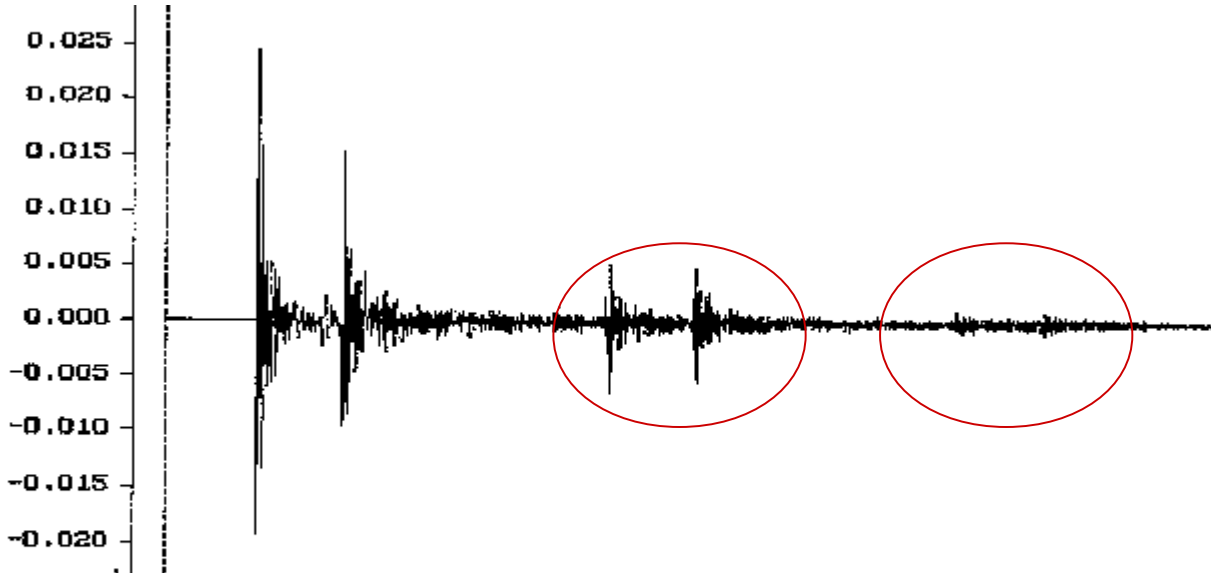




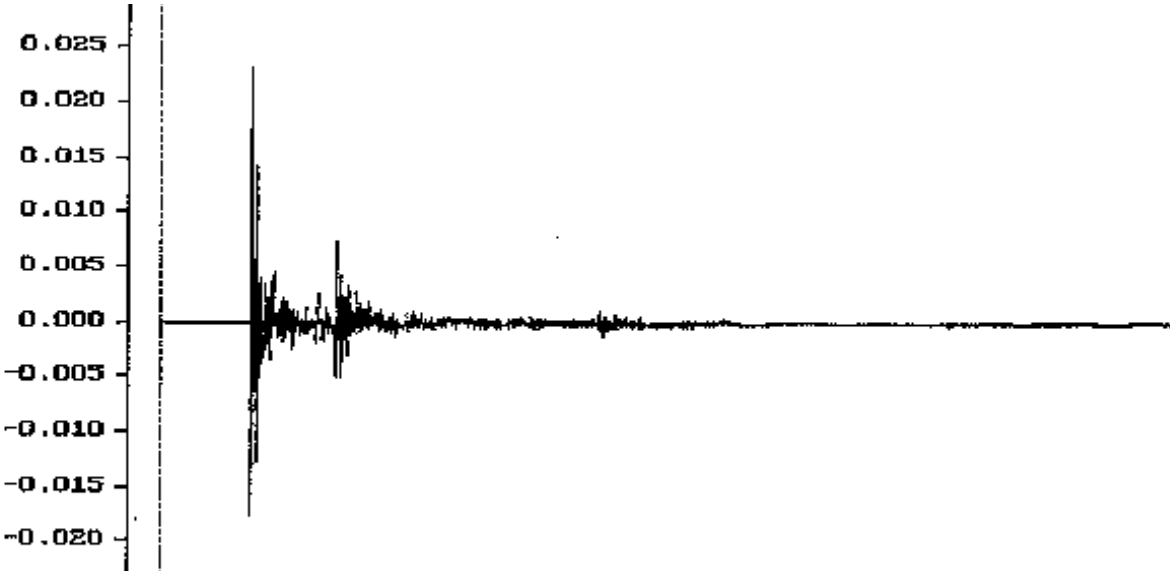
REVERBERATION TIME



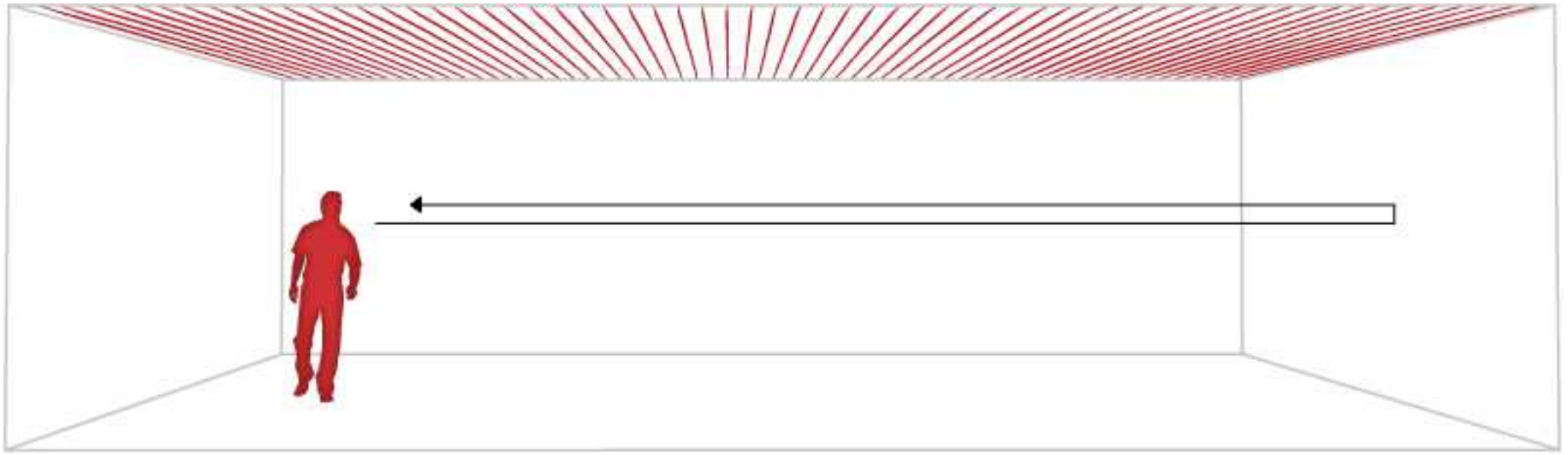
PLAIN TILES



KINOPANEL



ECHO



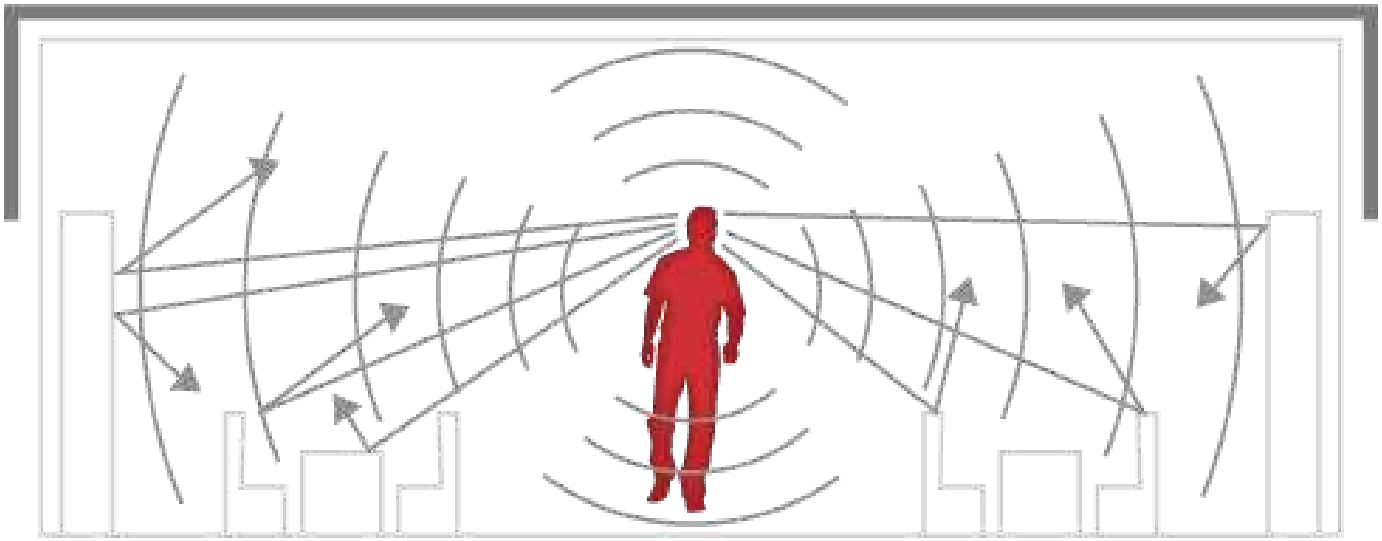
8.5 m

50 ms = 17 m / 2 = 8.5

REV. TIME – BEFORE AND AFTER

	125	250	500	1000	2000	4000
ABSORBERS IN A EMPTY ROOM	**1,12**	**1,25**	**2,02**	**1,84**	**1,71**	**1,52**
ABSORBERS AND DIFFUSERS	**0,72**	**0,65**	**0,70**	**0,72**	**0,69**	**0,70**
ABSORBERS,DIFFUSERS & FURNITURE	**0,69**	**0,59**	**0,61**	**0,58**	**0,57**	**0,59**

DIFFUSION / ABSORPTION



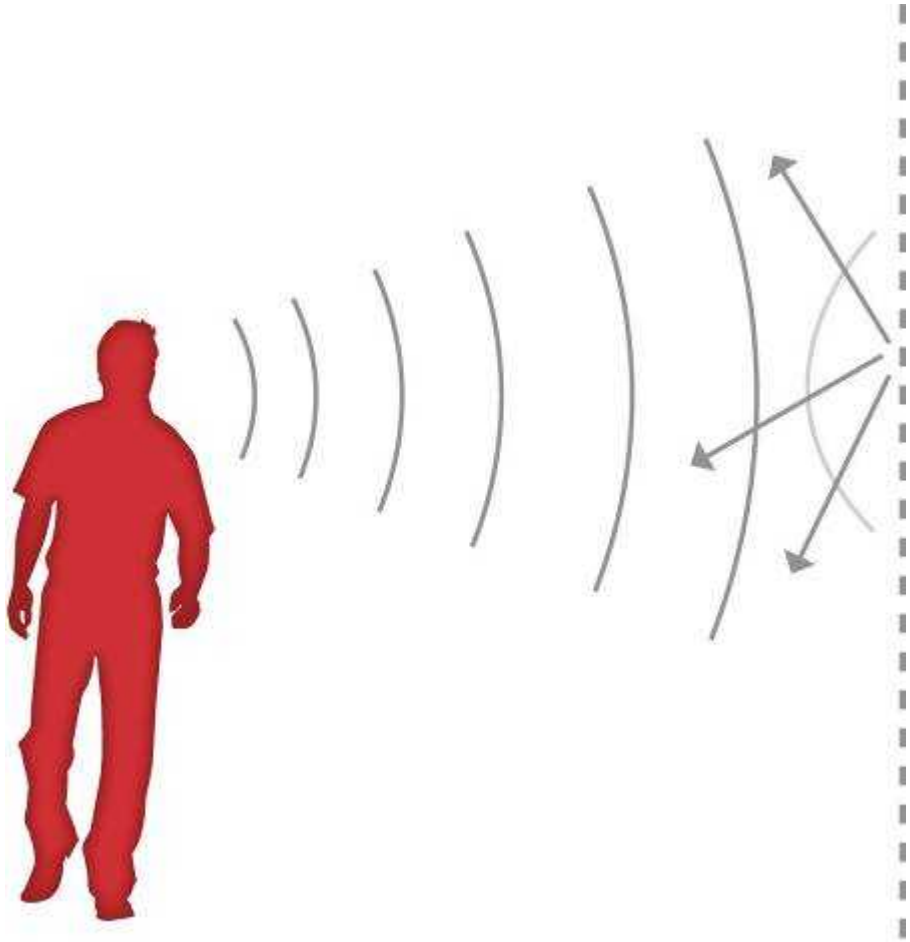
SUM UP

- EFFICIENT ABSORBERS IN CEILING GIVES RISK OF ECHOS.

- LACK OF DIFFUSION GIVES VERY LOW EFFECT OF ABSORBERS

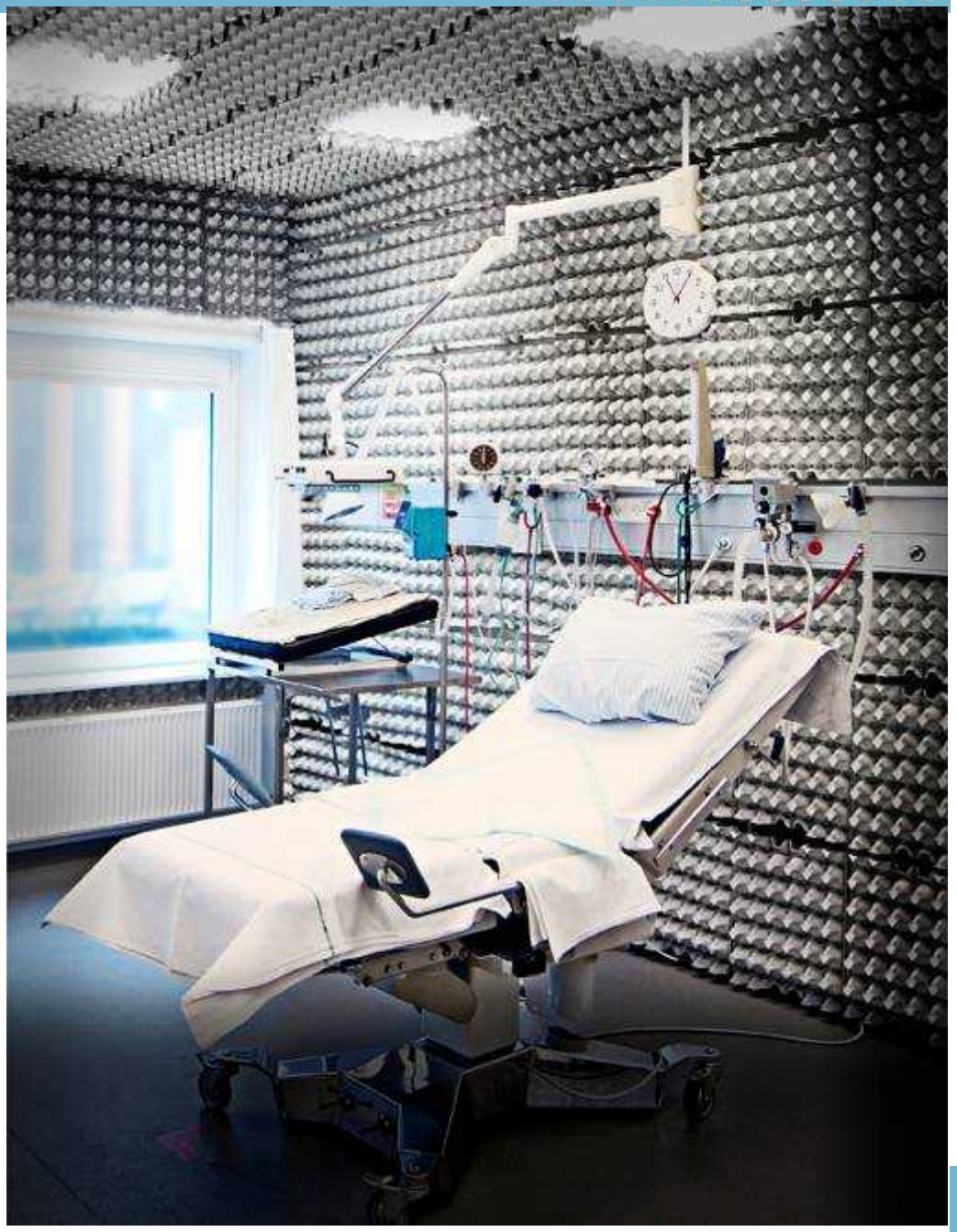
SOUND CONTROLLING TOOLS
MATERIALS

ABSORBERS

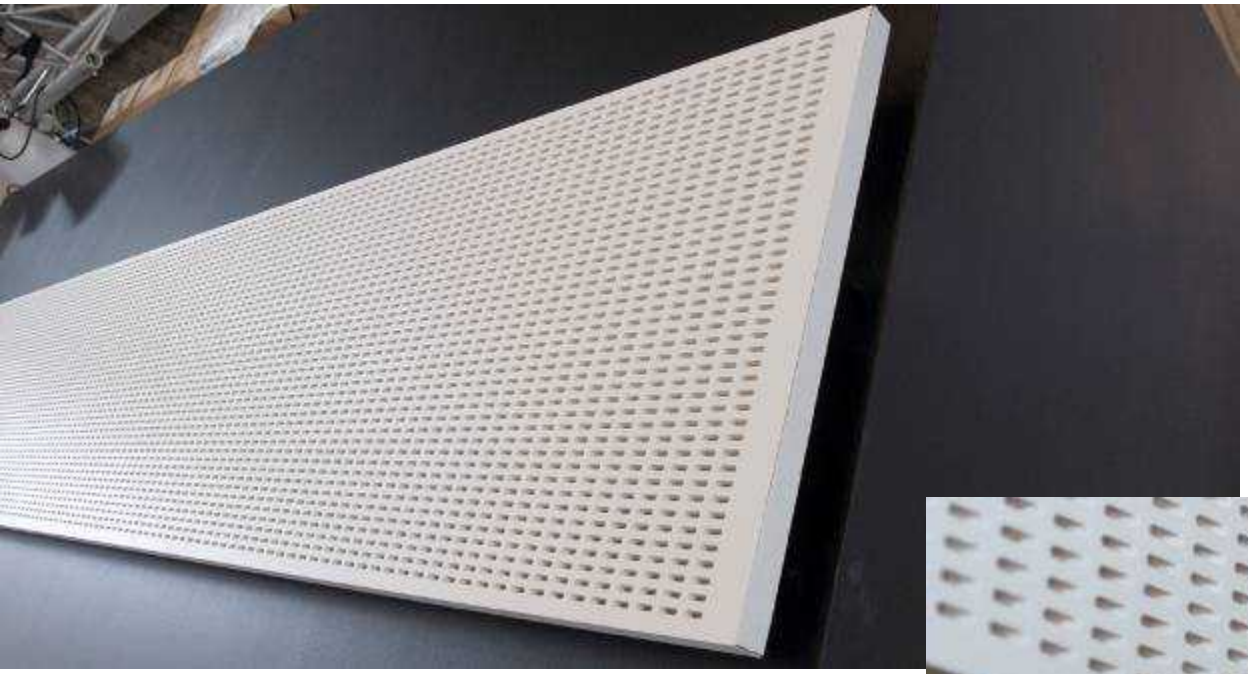


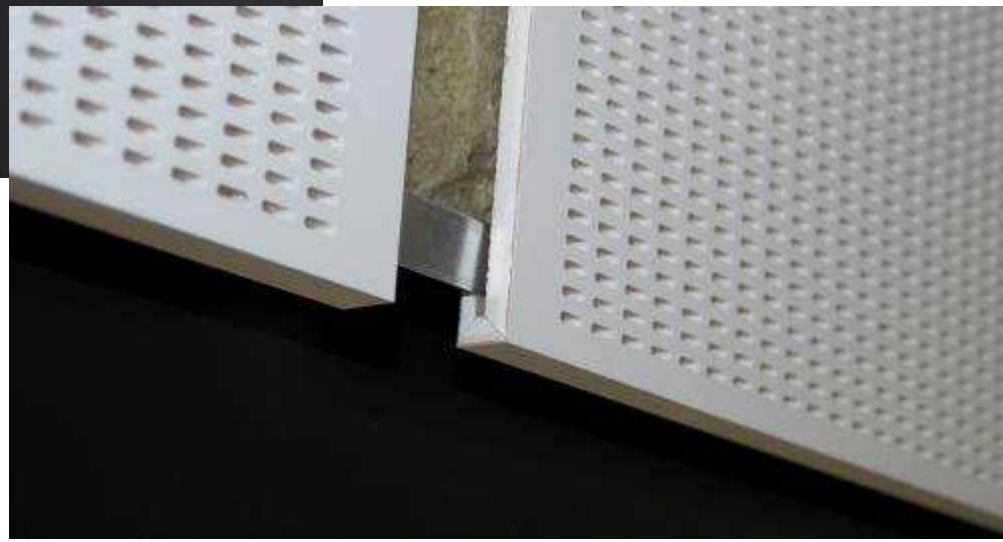
ABSORBERS

- Visual skin
- Design
- Absorbs sound
- Diffuse sounds
- Reflect sounds
- Part of the indoor climate
- Reflects light
- Stability
- Breathes
- Fire security

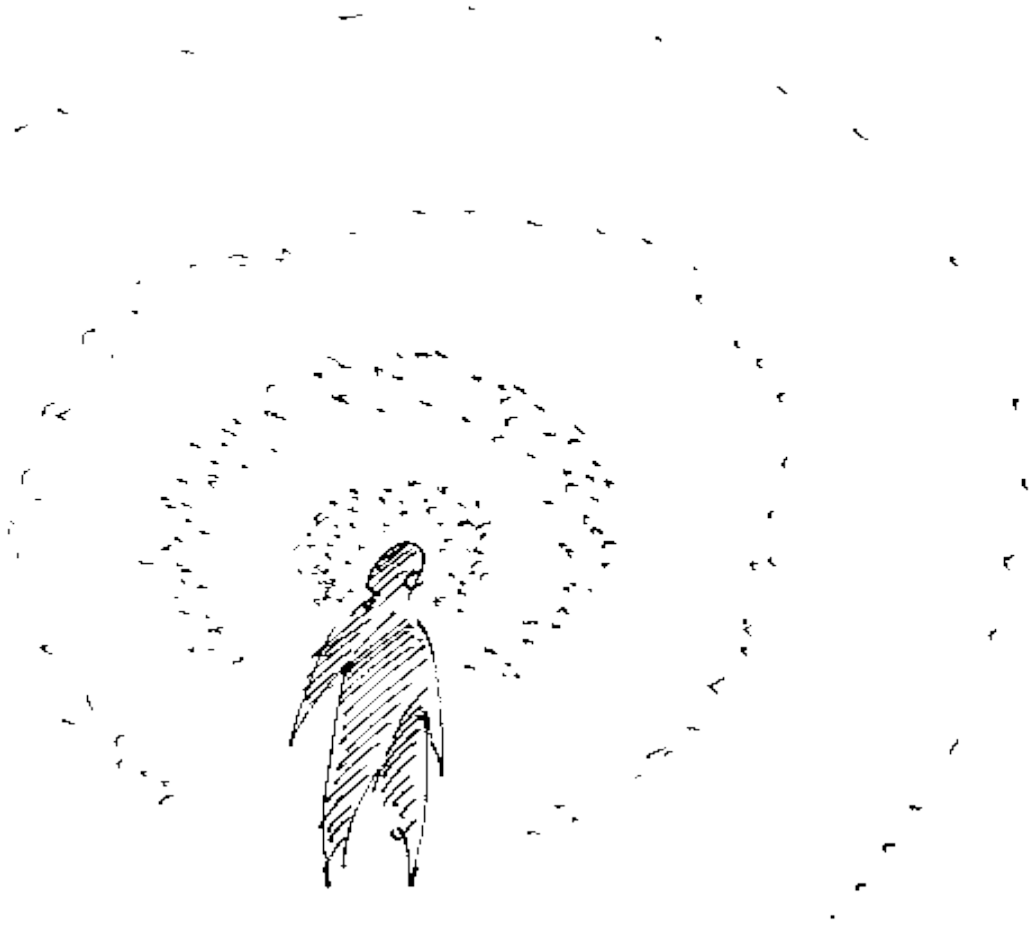


ADIT – WALL LINING

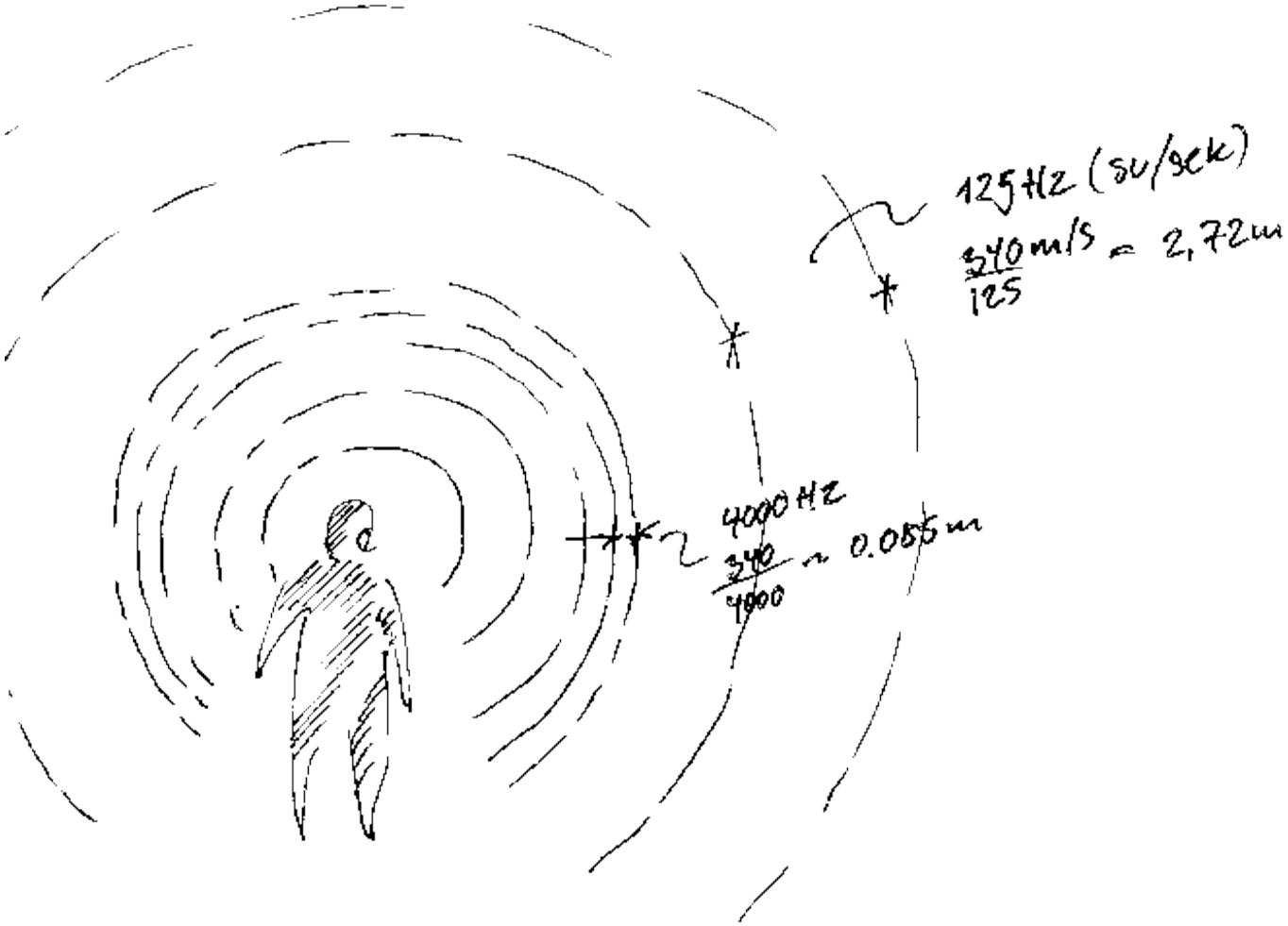




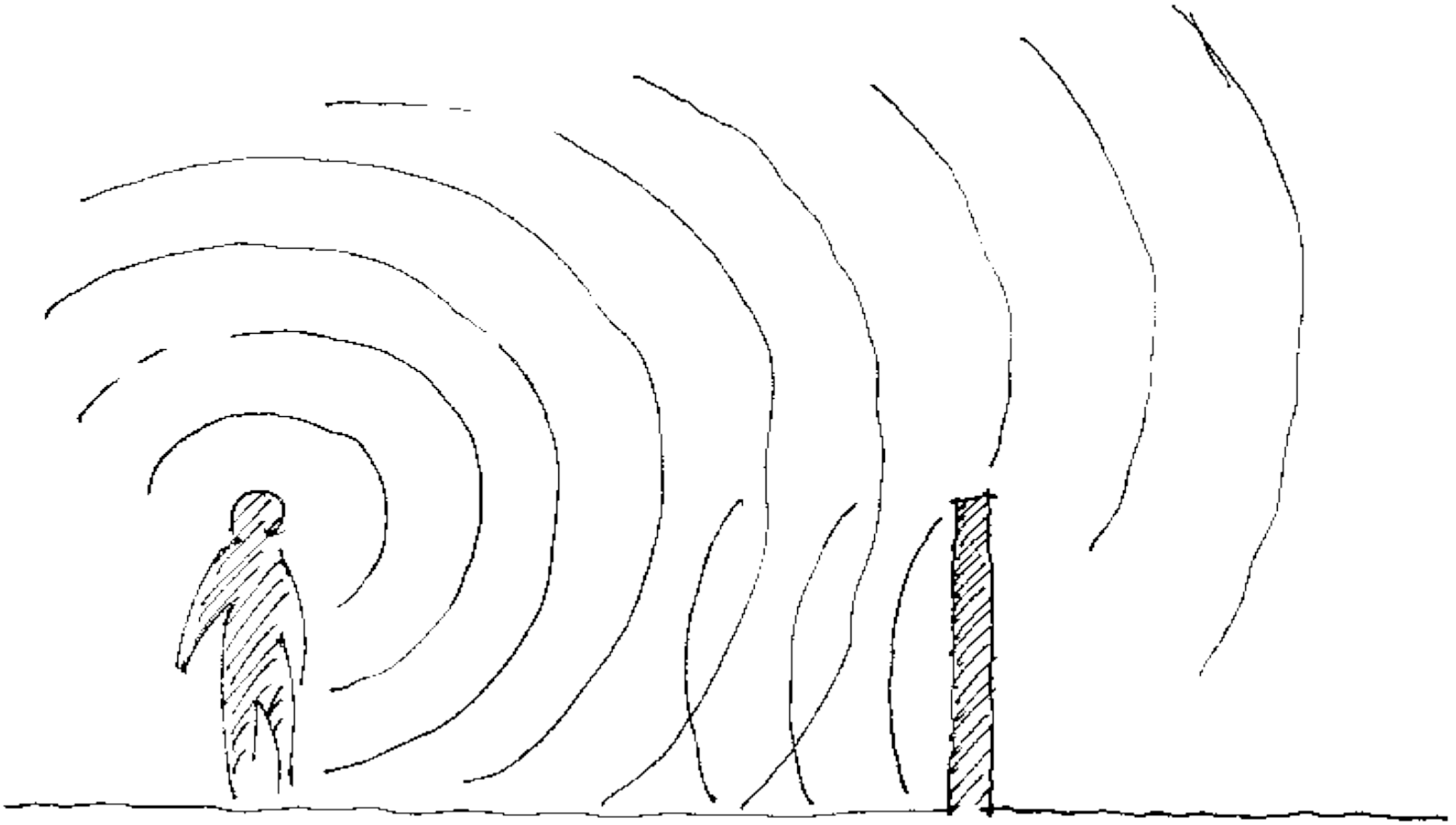
SPREADING OF SOUND



SOUND WAVE LENGTH



REFLECTION



ACOUSTIC MATERIALS

- FIBROUS ABSORBERS
- PERFORATED ABSORBERS
- PERFORATED ABSORBERS WITH ACOUSTIC BACKING
- DIFFUSERS
- MEMBRANES
- SLIT ABSORBERS

REFLECTION

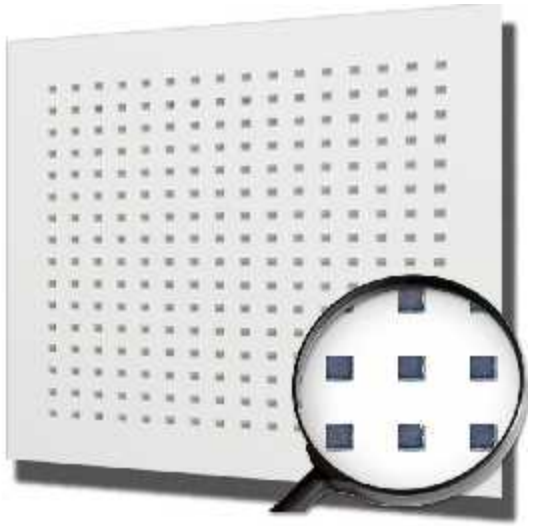
MEMBRANE ABSORPTION

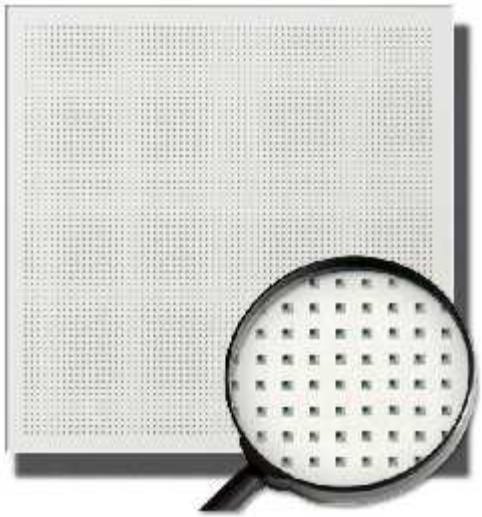
RESONANCE ABSORPTION

RESONANCE ABSORPTION

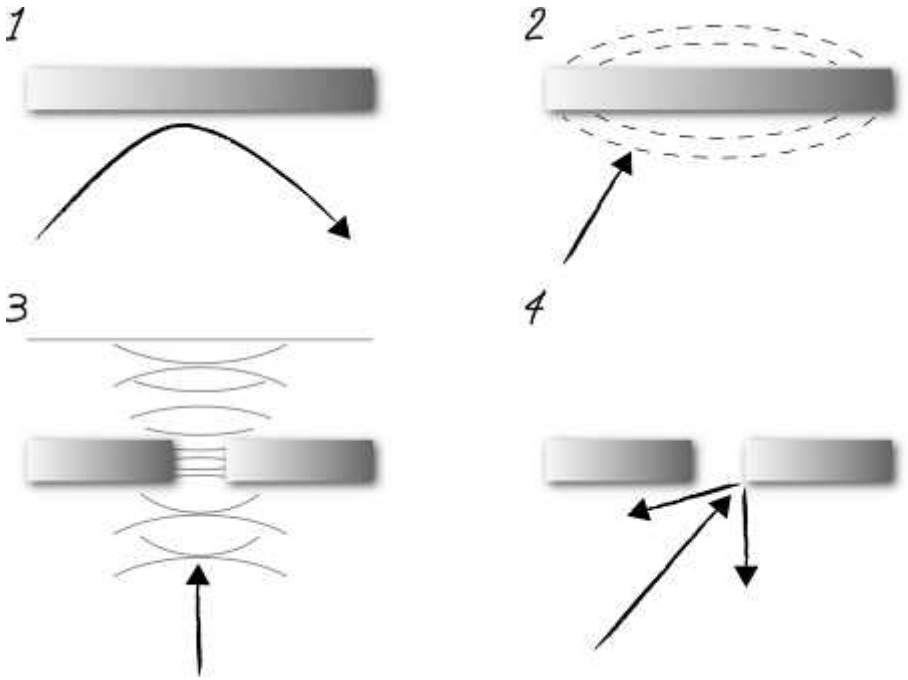
DIFFUSION

PERFORATED BOARDS

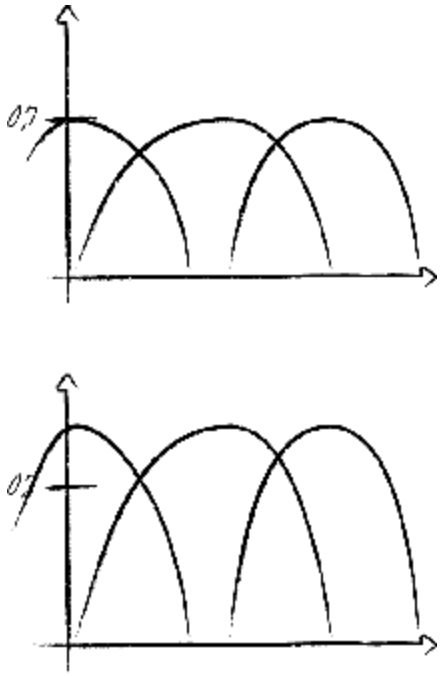




EFFECTS OF PERFORATED TILES



SOUND REGULATING EFFECT



ACOUSTIC BALANCE

ABSORPTION PROFILE

DANAK

AV 107/004
DANAK 100/922
Page 7 of 8
Graph Sheet 2

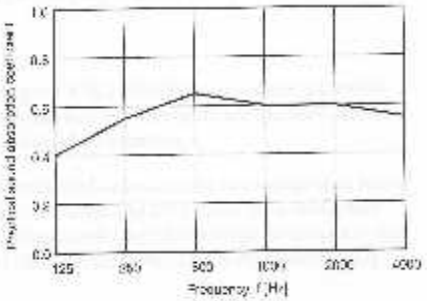
Laboratory Measurement of Sound Absorption Coefficient according to EN ISO 354:2003

Client: Danogips A/S, Klavermarksvej, 9500 Hobro
Date of test: 2004-01-19

Test specimen: Danoline Plain 600 MI
Thickness: 10 mm
Module size: 600 mm × 600 mm
Mounting depth: 200 mm (Type E-200 mounting)

Test area: 10.8 m²
Room volume: 210 m³
Room surface: 305 m²

Frequency f [Hz]	α_s
125	0.40
250	0.55
500	0.65
1000	0.60
2000	0.60
4000	0.55



Practical sound absorption coefficient, weighted sound absorption coefficient, and absorption class according to EN ISO 11654:1997:

$\alpha_w = 0.65$ Absorption class: C

SPEECH CONTROL

DANAK

AV 123/07
DANAK 100/1090
Page 7 of 8
Graph Sheet 2

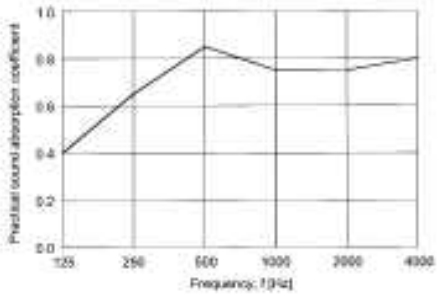
Laboratory Measurement of Sound Absorption Coefficient according to EN ISO 354:2003

Client: Danoline A/S, Klavermarksvej 4, 9500 Hobro
Date of test: 10 January 2007

Test specimen: Danoline Contur 600 Tangent T1. Perforation 21.5%
Thickness: 13 mm
Module size: 480 mm × 600 mm
Mounting depth: 200 mm (Type E-200 mounting)

Test area: 10.8 m²
Room volume: 215 m³
Room surface: 305 m²

Frequency f [Hz]	α_s
125	0.40
250	0.65
500	0.85
1000	0.75
2000	0.75
4000	0.80



Practical sound absorption coefficient, weighted sound absorption coefficient, and absorption class according to EN ISO 11654:1997:

$\alpha_w = 0.80$ Absorption class: B

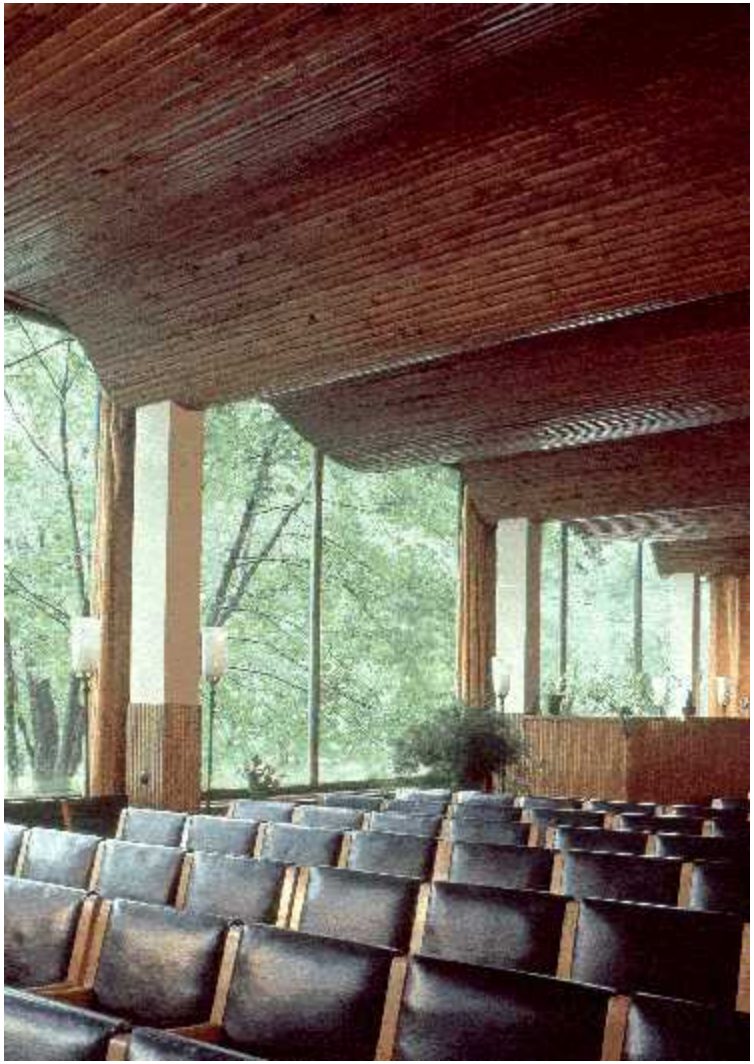
NOISE CONTROL

SUM UP

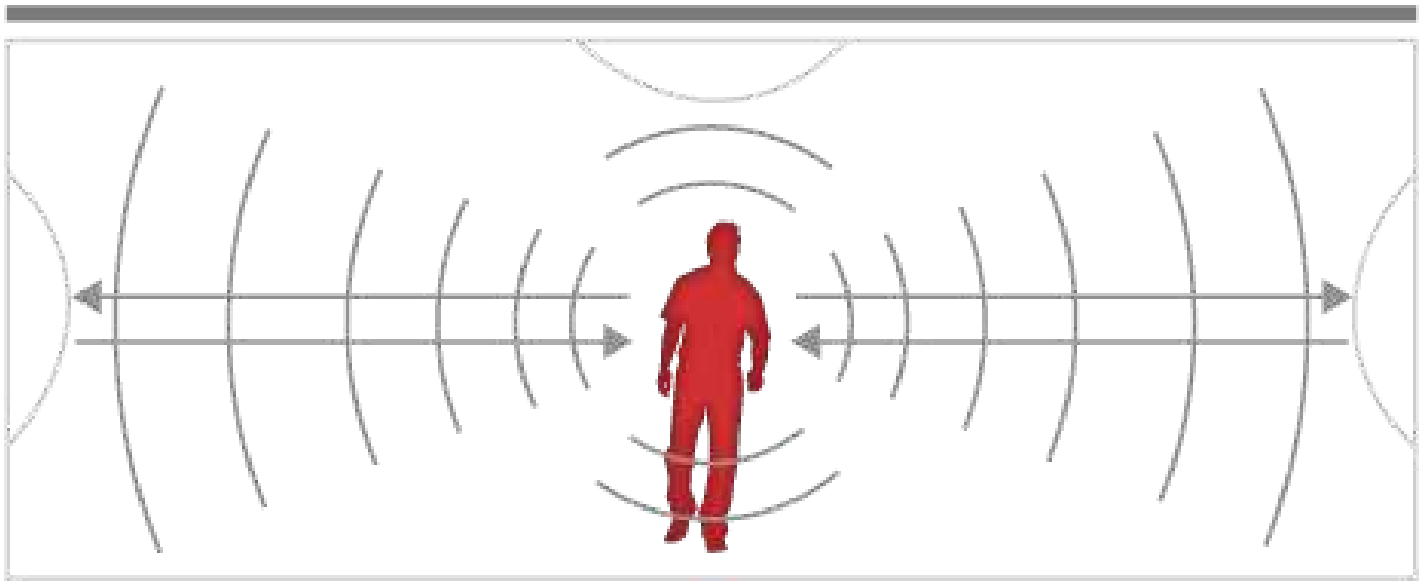
- PRODUCT ABSORPTION PROFILE CAN BE DESIGNED.
- ABSORPTION VALUES FOR SPEECH CONTROL UNDER 0,70 aw
- ABSORPTION PROFILE FOR NOISE REDUCTION OVER 0,70 aw

SOUND CONTROLLING TOOLS
POSITIONING OF ABSORBERS

ACOUSTIC DESIGN & ARCHITECTURE

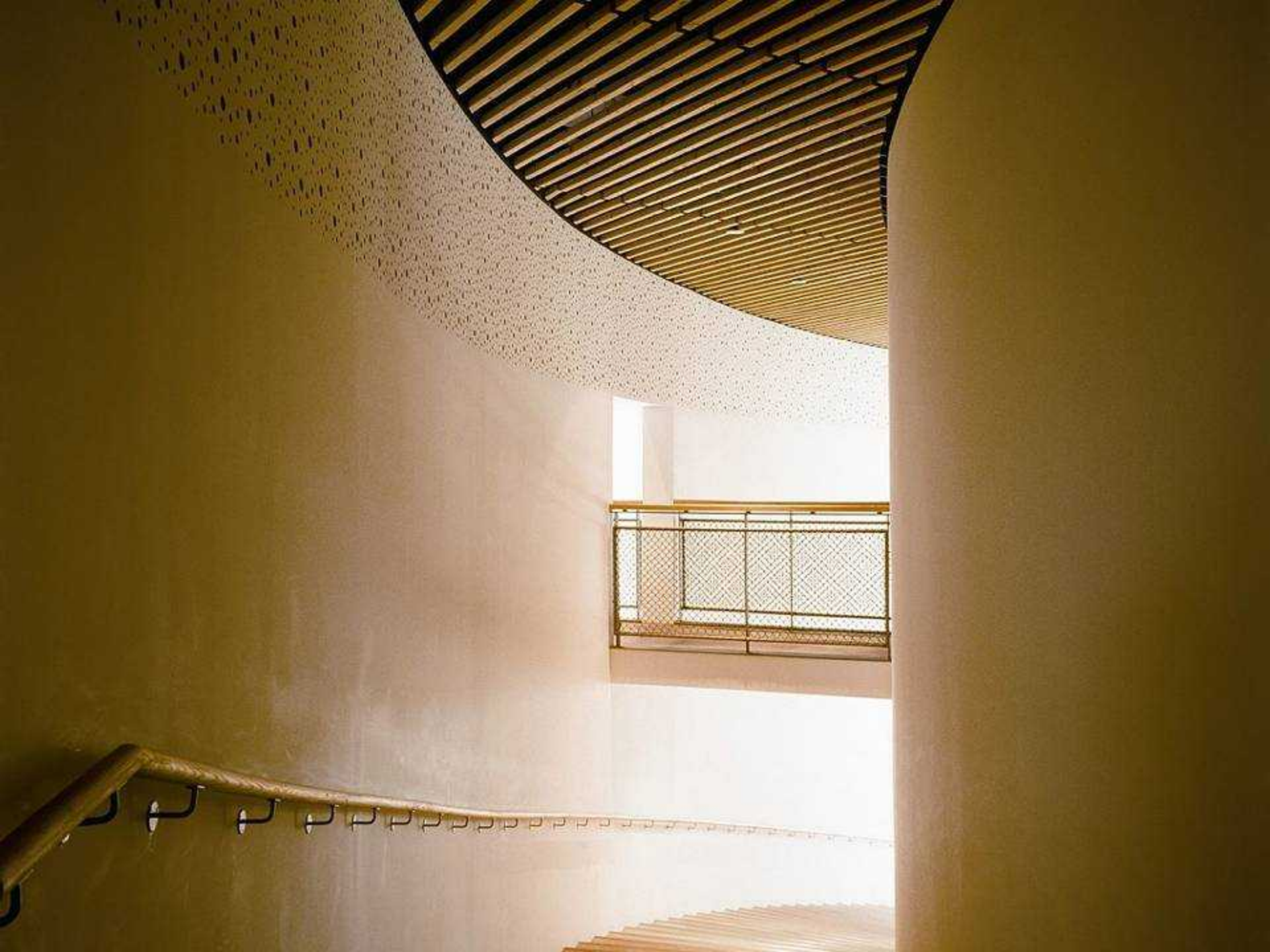


NORMAL CEILING HEIGHT

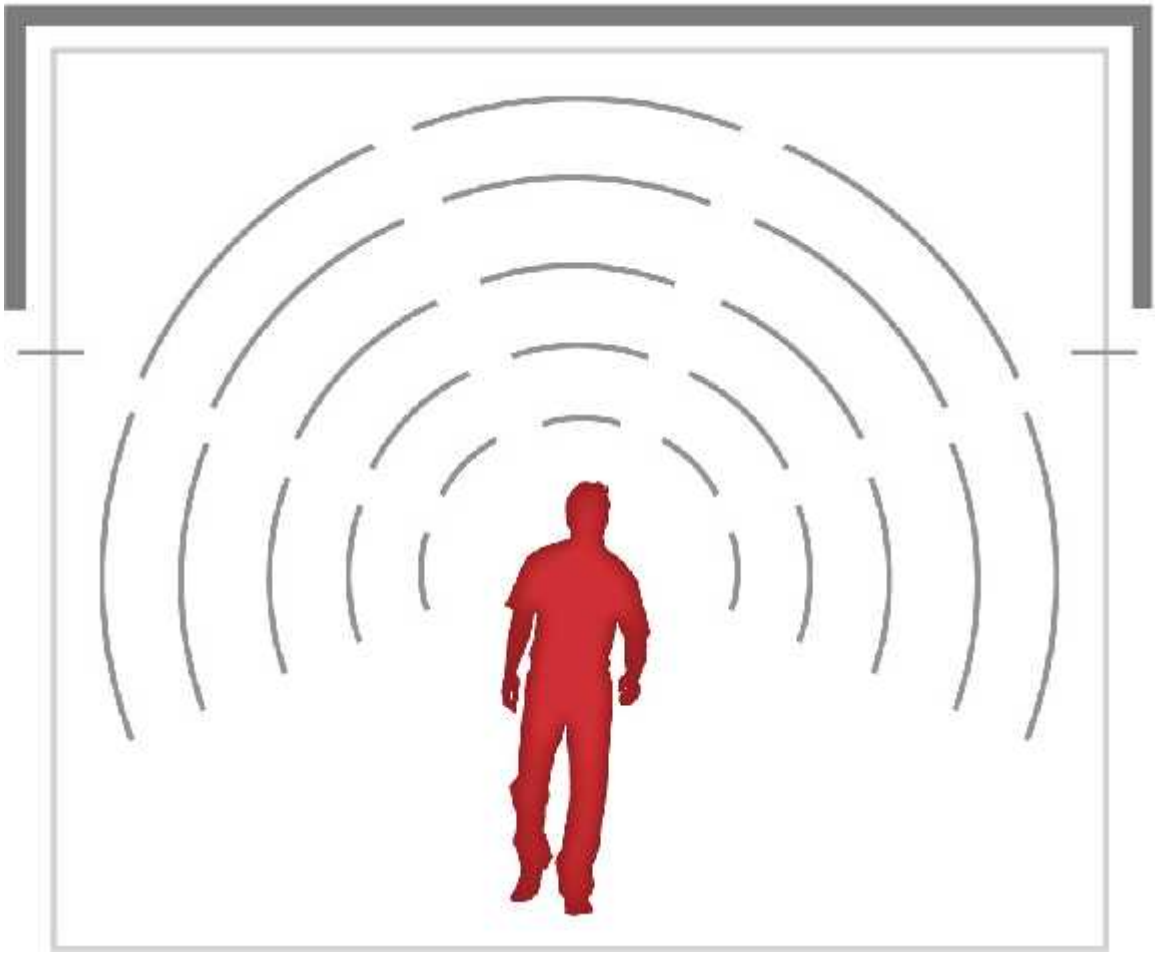



EPISERVERDAGEN

NARROW ROOM



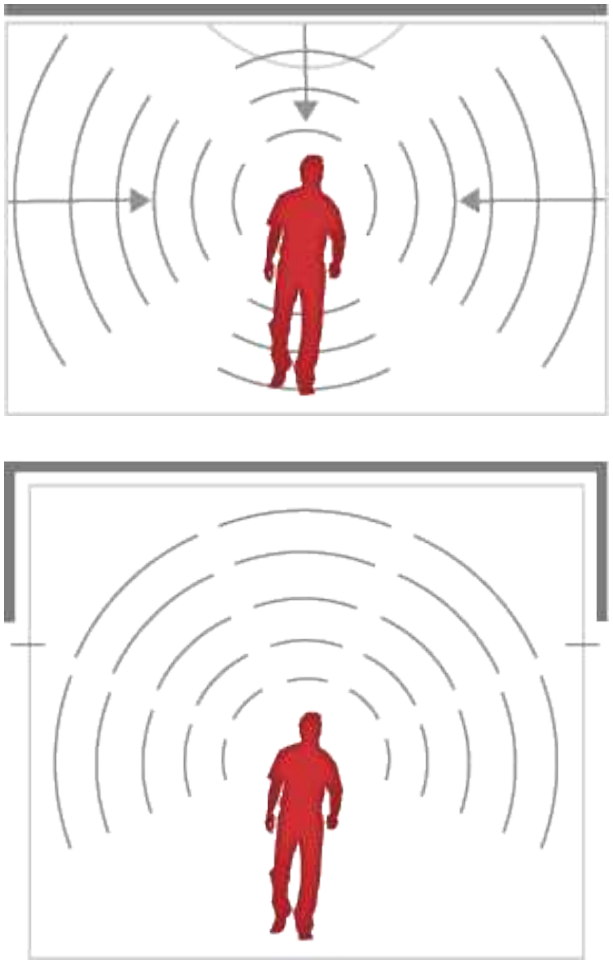
LARGE CEILING HEIGHT



AMOUNT OF ABSORBERS

% of floor area

2.5 – 2.8 m	100% absorption materials on ceilings
2.8 – 3.2 m	115% absorption materials = (100% on ceiling +15% on walls)
3.2 – 3.8 m	120% absorption materials
3.8 – 4.0 m	125% absorption materials
above 4.0 m	No recommendation



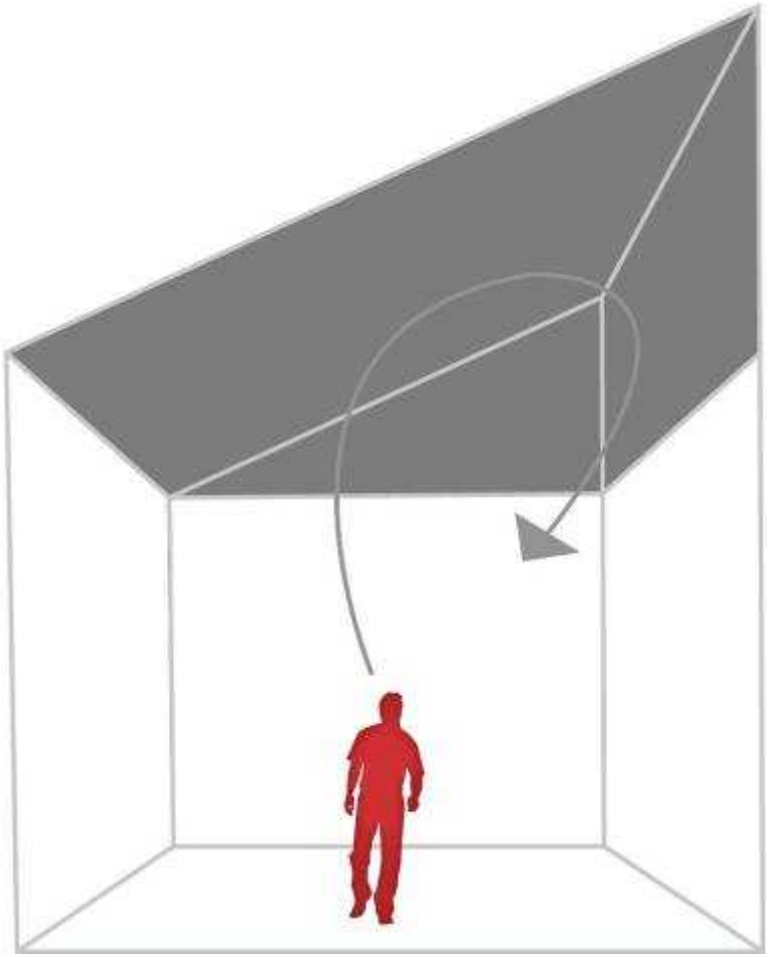
SUM UP

- CEILING HIGH OVER 2,6 m SHOULD BE ADDED WITH WALL ABSORBERS.

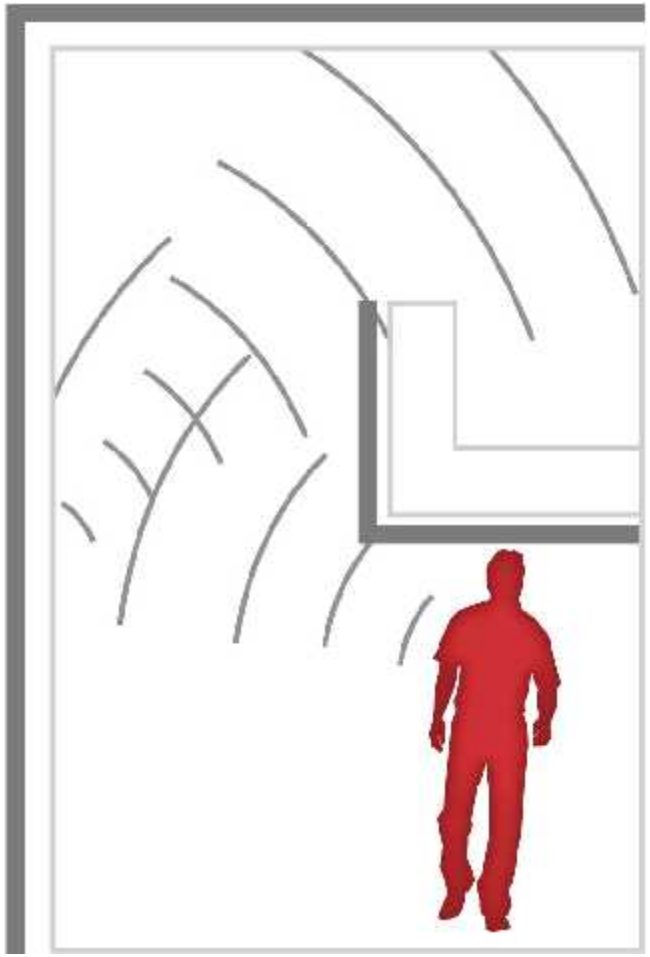
- WORKPLACES WITH A CEILING HIGH OVER 4m IS NOT RECOMMANDED.

SOUND CONTROLLING TOOLS
GEOMETRIC SOUND REGULATION

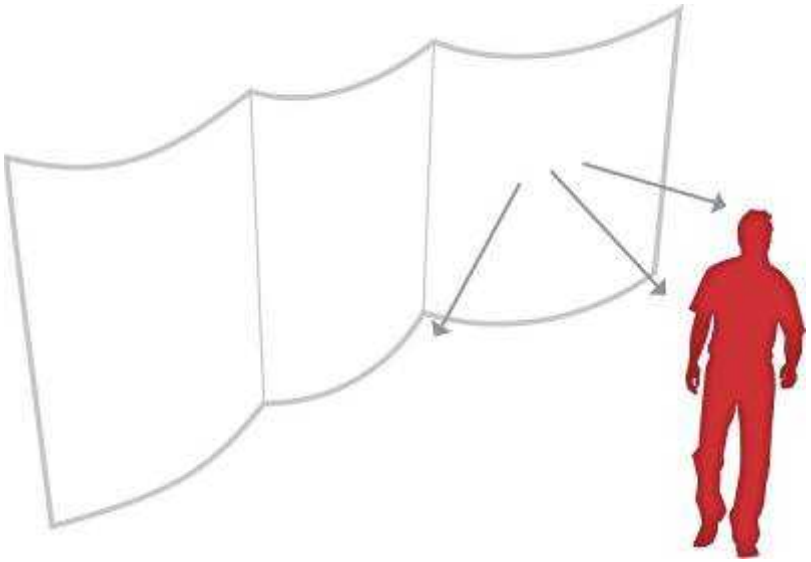
INCLINED CEILINGS

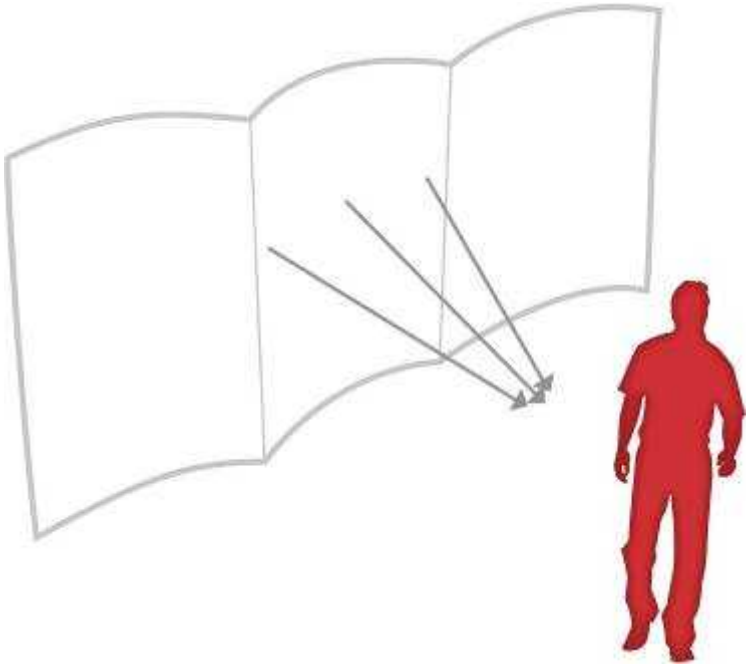


MEZZANINE

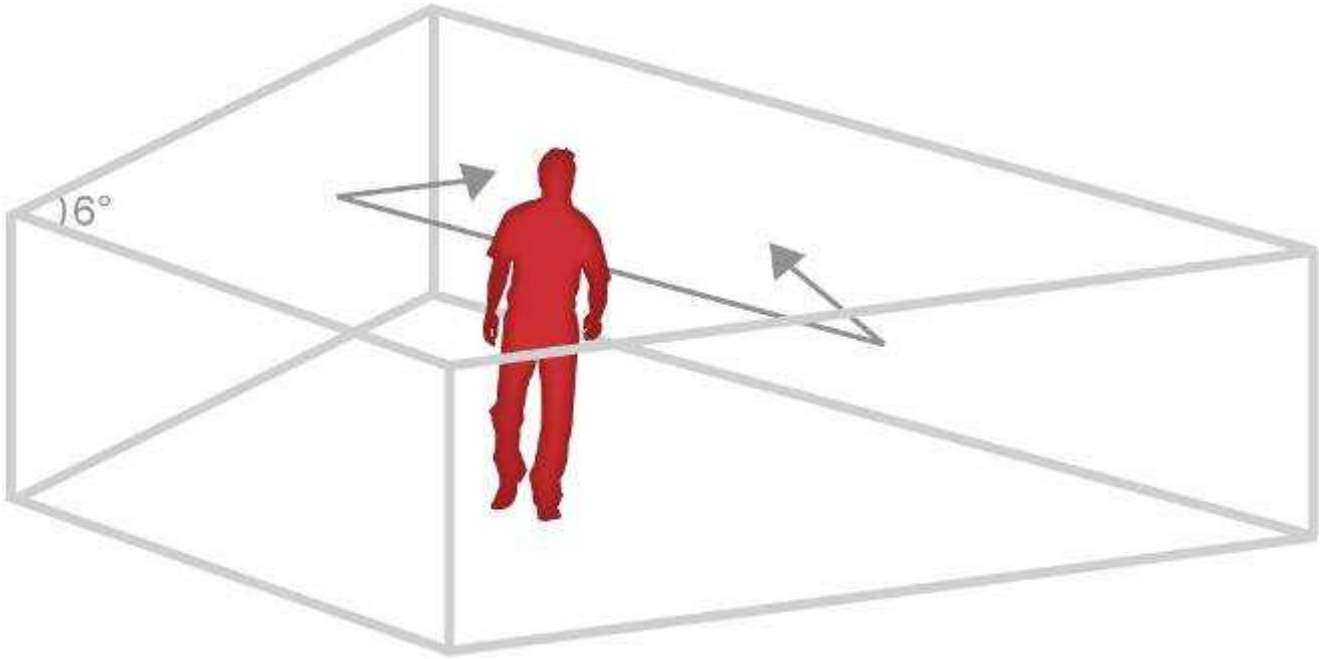


CURVED SURFACES

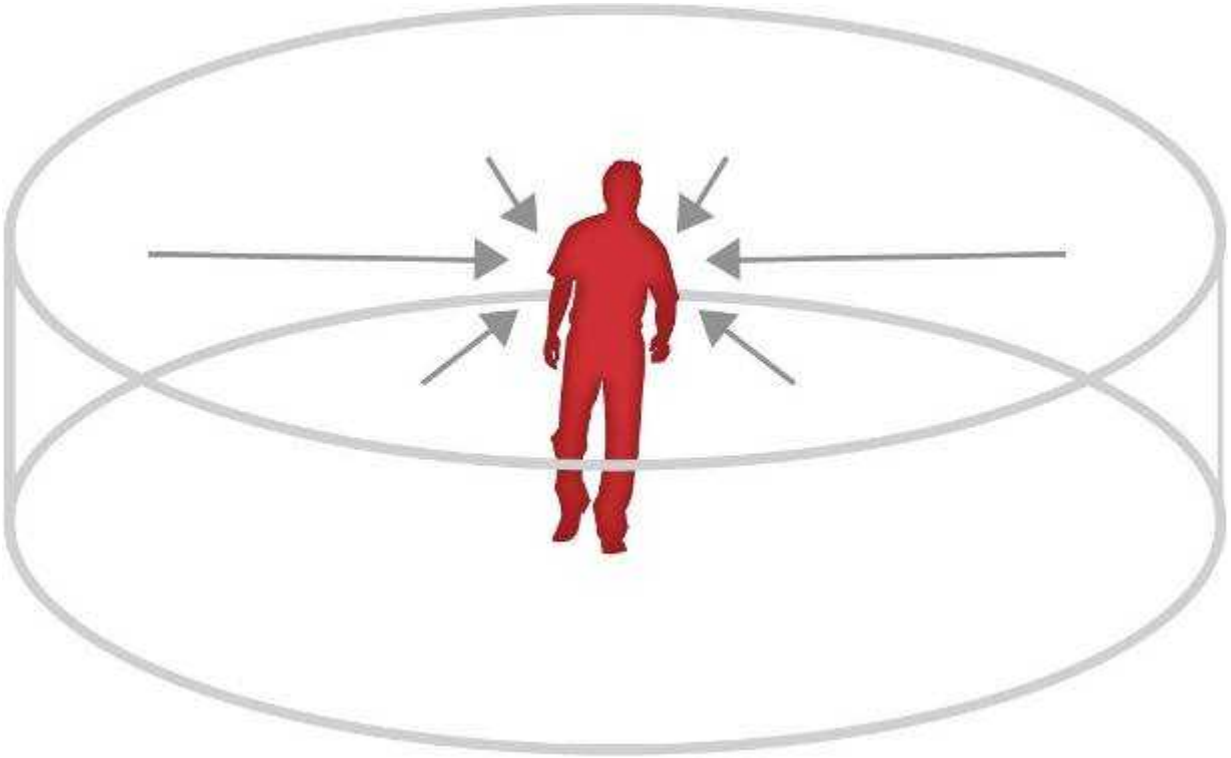


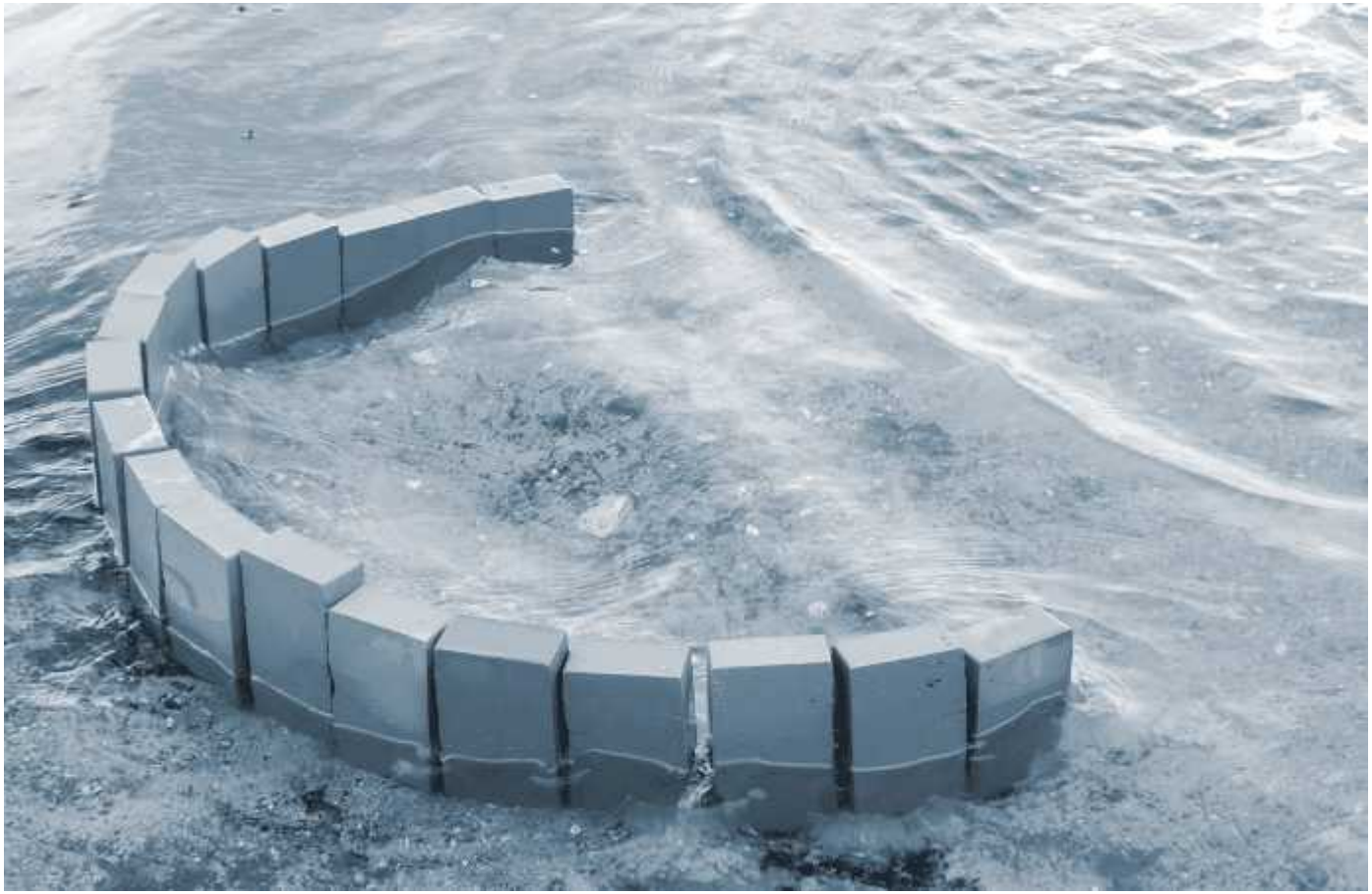


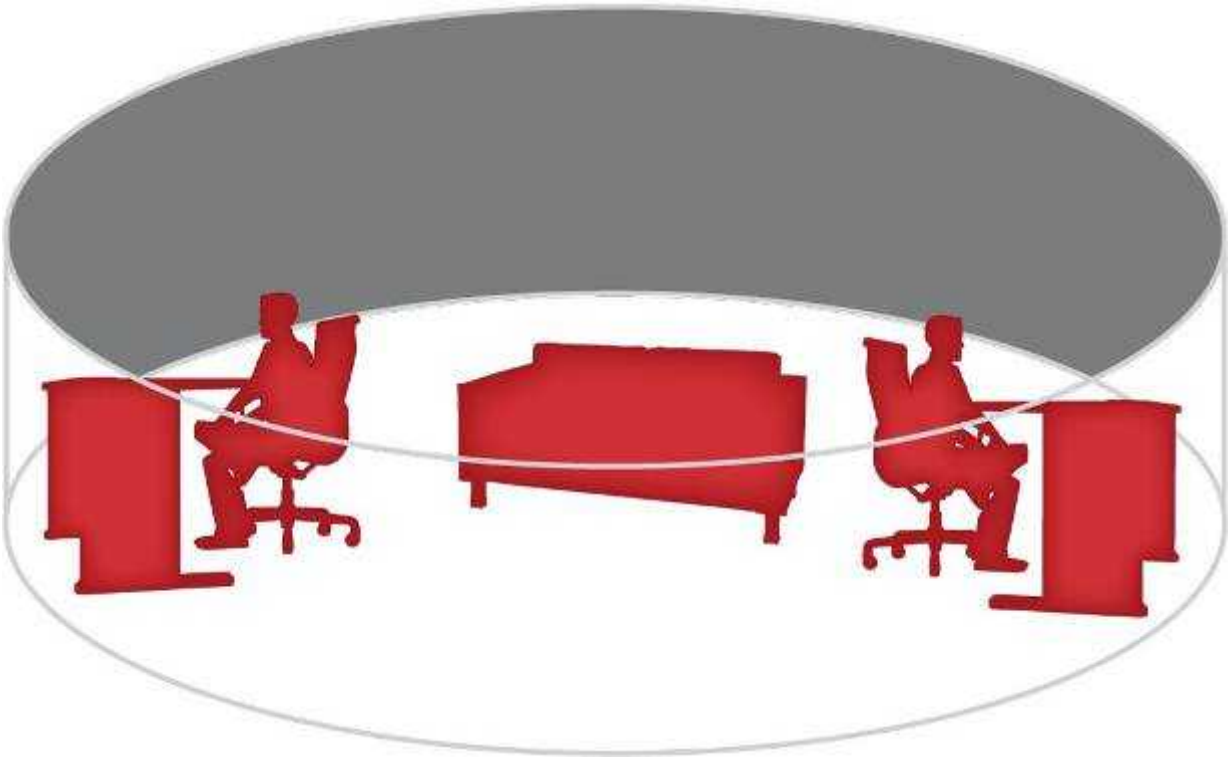
INCLINED WALLS



ROUND ROOMS



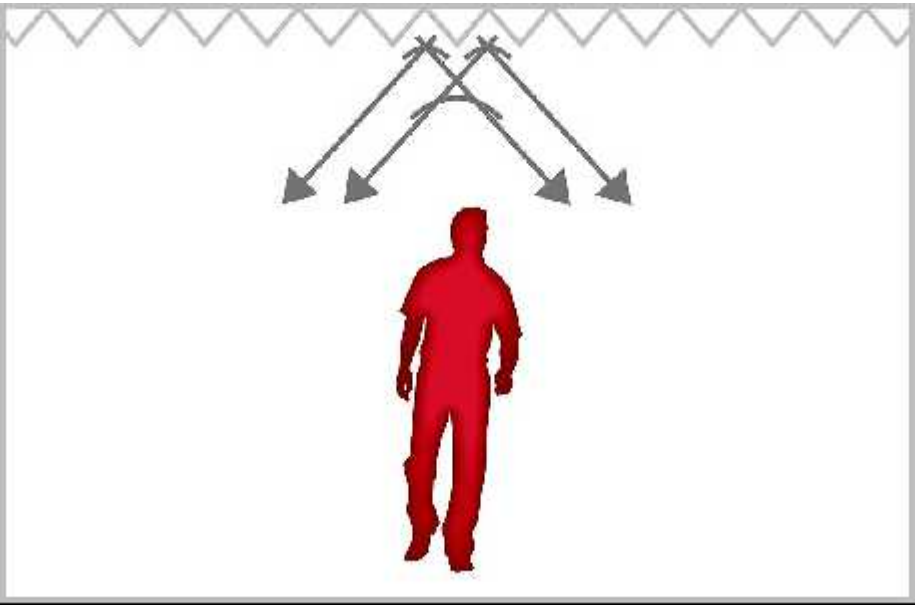


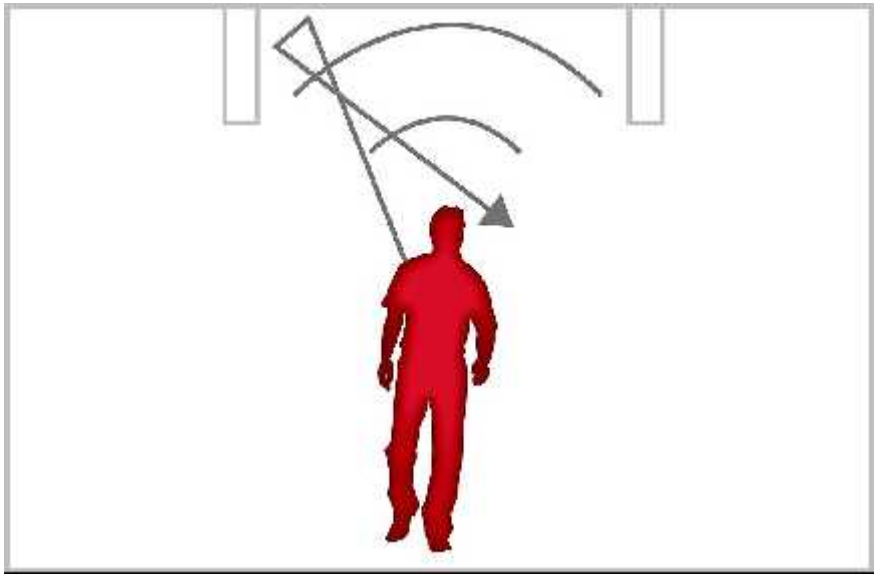



FACKSAL 4
TILL FACKSAL 3


42
41
40
39
23
22
21
20
19

STRUCTURED CEILINGS





SUM UP

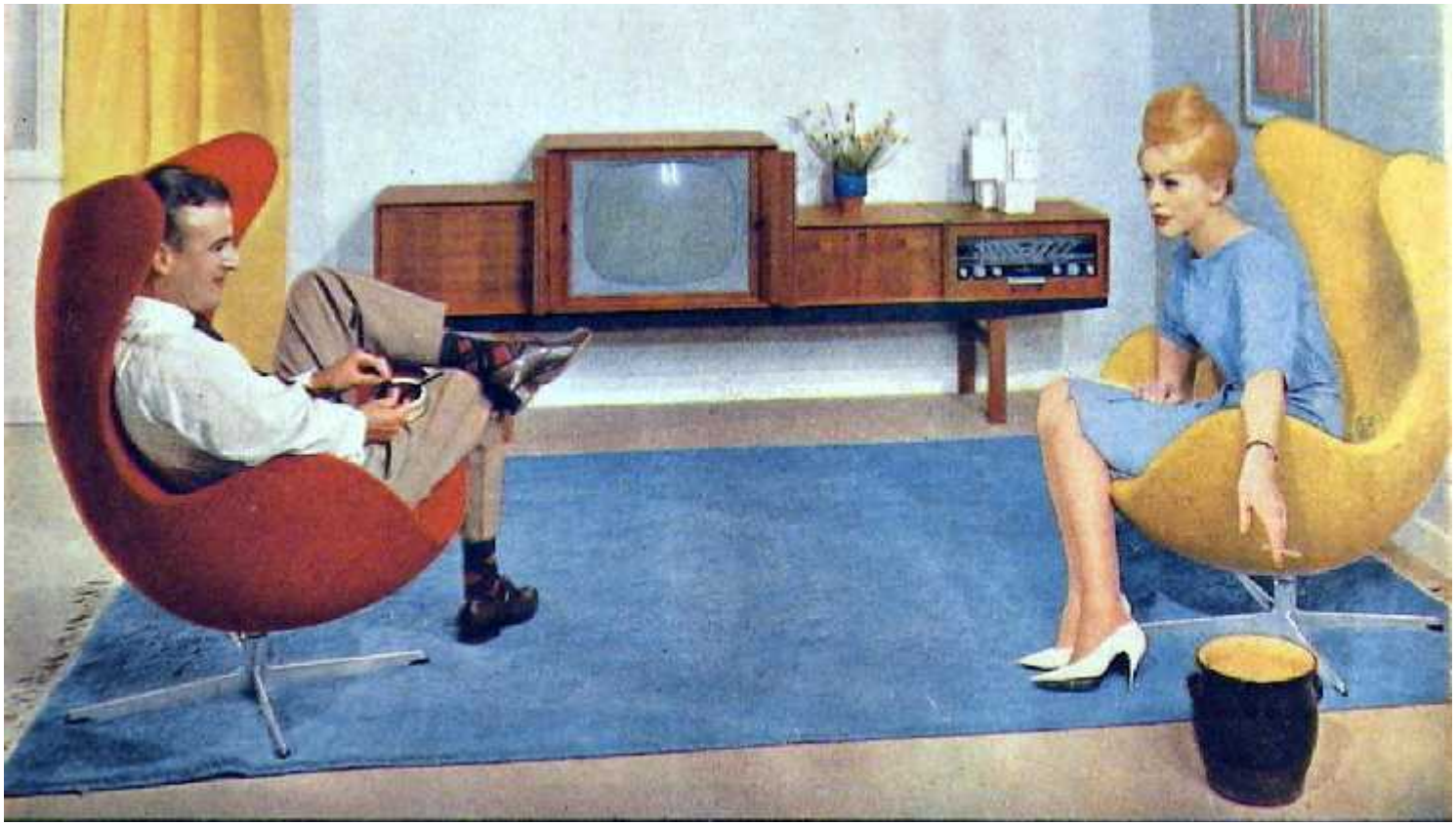
- SOUND REGULATING MATERIALS SHOULD BE PLACED WHERE THE SOUNDWAVES HIT FIRST.

- STRUCTURES MIRRORS THE SOUNDWAVES / THINK ABOUT THE FORM OF THE STRUCTURE AND HOW IT REFLECTS SOUNDS.

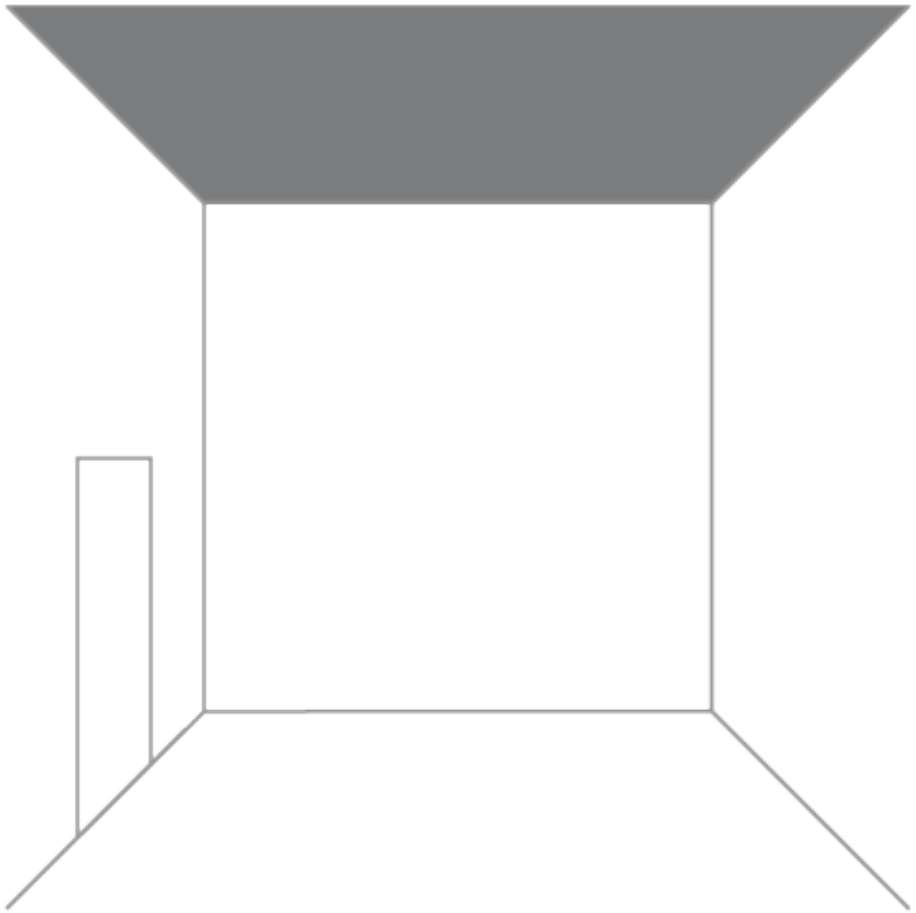
danoline®
[creating expressive ceilings]

SOUND CONTROLLING TOOLS
FURNITURE

FURNITURE

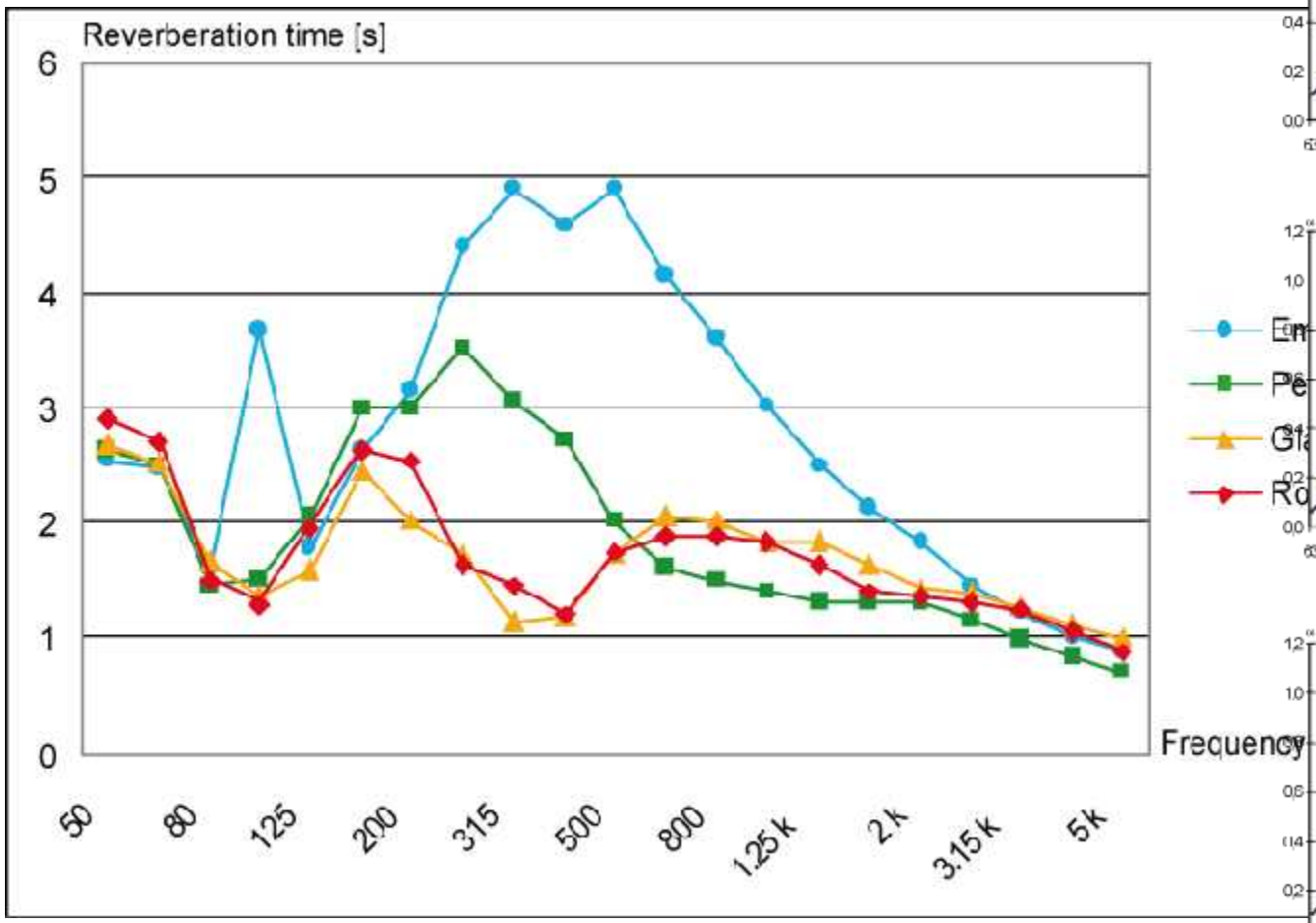


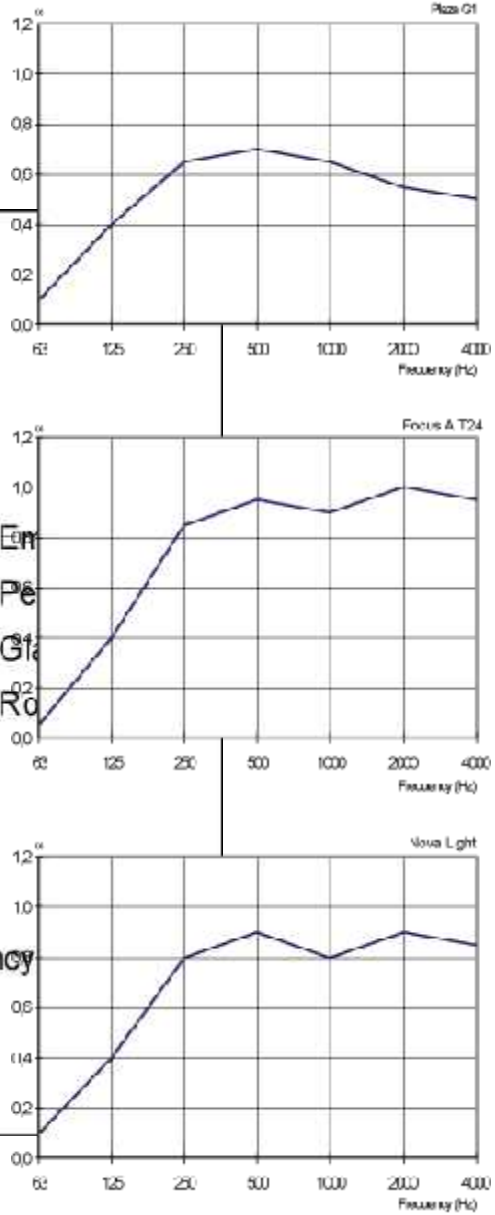
CEILING TYPES



| DIFFFERENT CEILING TYPES
| NO WALL ABSORBERS
| NO FURNITURE

CEILING TYPES



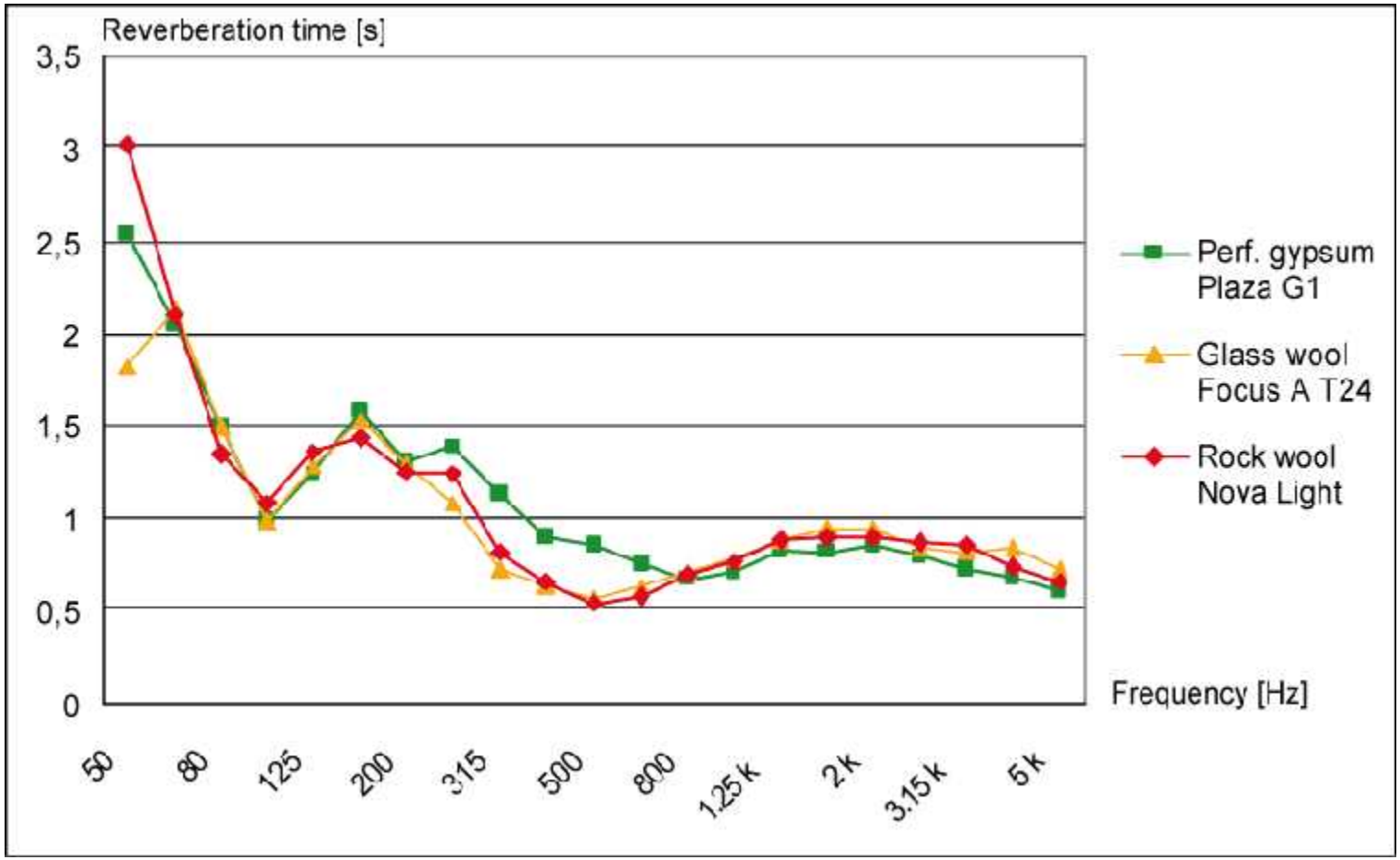


| DIFFERENT CEILING TYPES | NO WALL LININGS | NO FURNITURE

FURNITURE

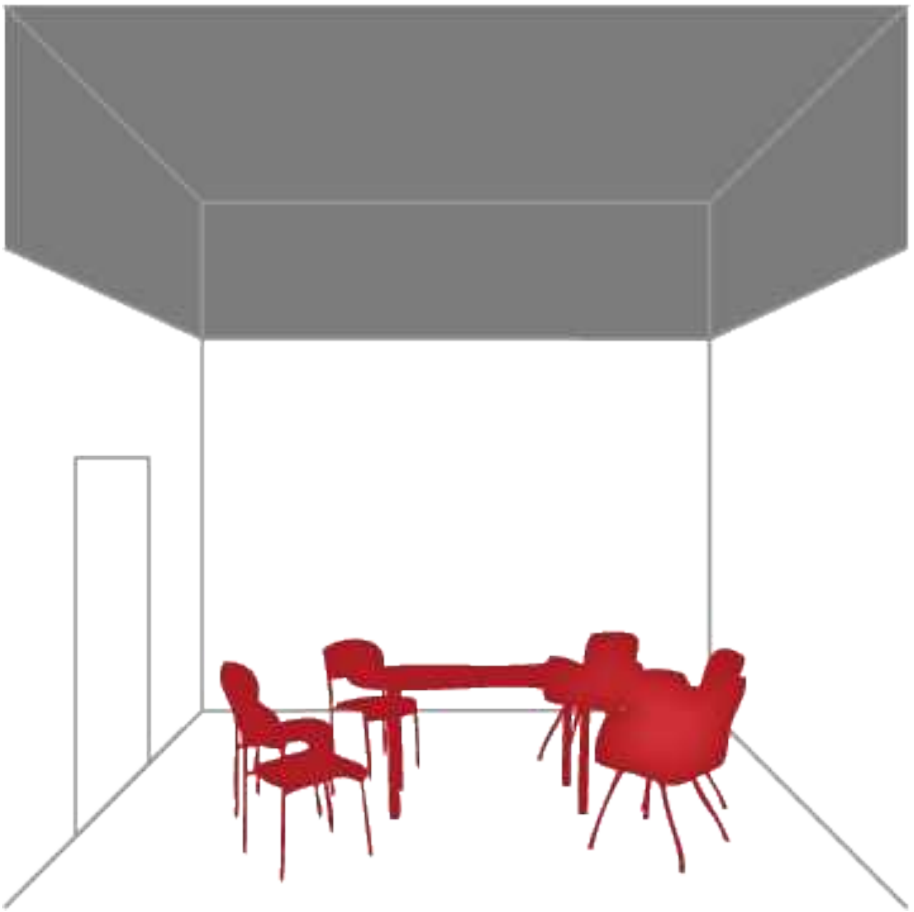
- DIFFERENT CEILING TYPES
- NO WALL LININGS
- MODERATE FURNISHING

FURNITURE



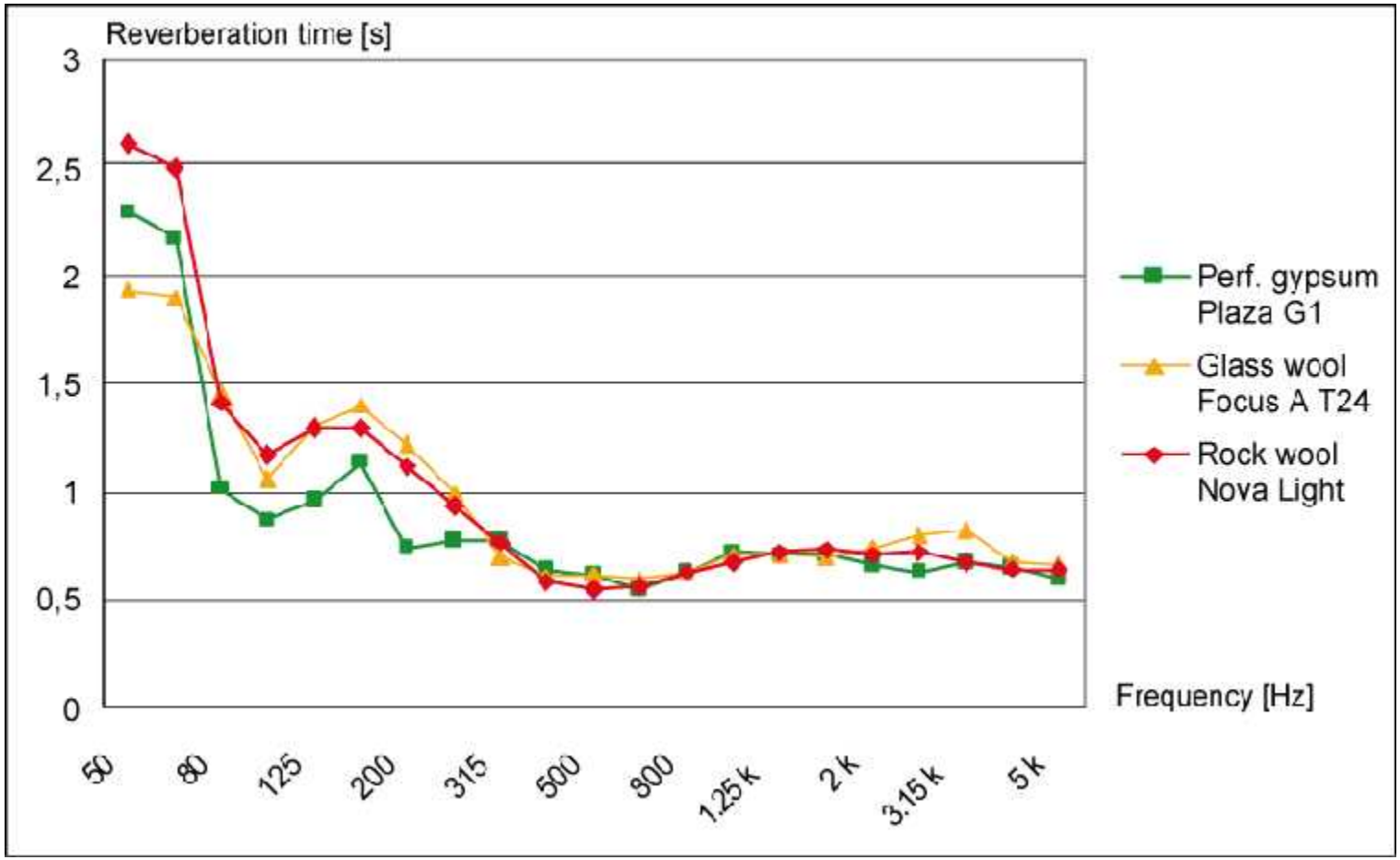
| DIFFERENT CEILING TYPES | NO WALL LININGS | MODERATE FURNISHING

FURNITURE AND WALL LININGS



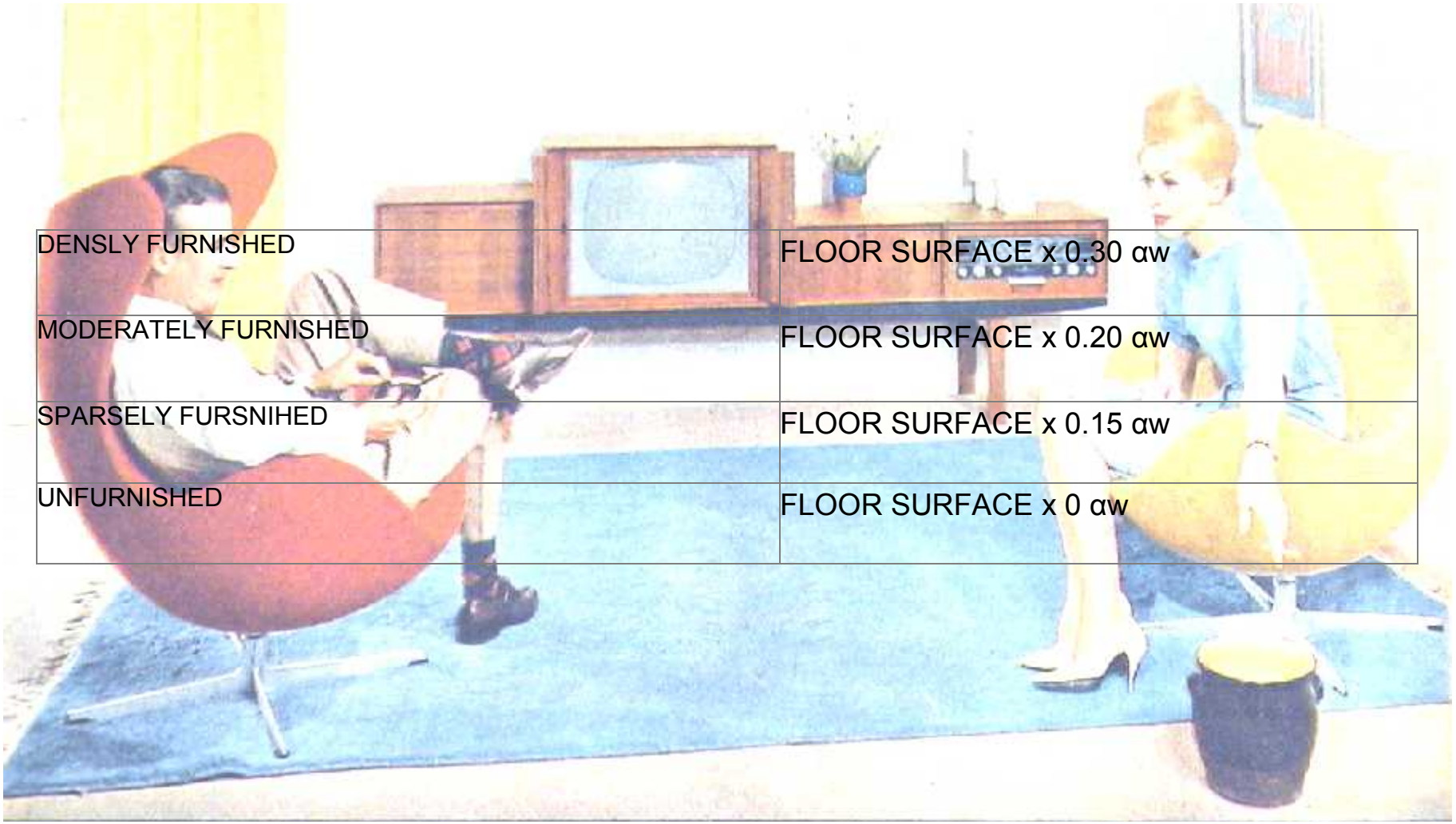
- DIFFERENT CEILING TYPES
- WALL LININGS
- MODERATE FURNISHING

FURNITURE AND WALL LININGS



| DIFFERENT CEILING TYPES | WALL LININGS | MODERATE FURNISHING

FURNITURE DIFFUSION FACTOR



DENSLY FURNISHED	FLOOR SURFACE x 0.30 αw
MODERATELY FURNISHED	FLOOR SURFACE x 0.20 αw
SPARSELY FURSNIHED	FLOOR SURFACE x 0.15 αw
UNFURNISHED	FLOOR SURFACE x 0 αw

FURNITURE

SUM UP

- FURNITURE HAS A MAJOR INFLUENCE OF SOUND DIFFUSION / AND THE EFFECT OF HOW EFFICIENT A ABSORBER IS PERFORMING.

- THE EFFECT IS VERY IMPORTANT IN LARGE ROOM OFFICES.

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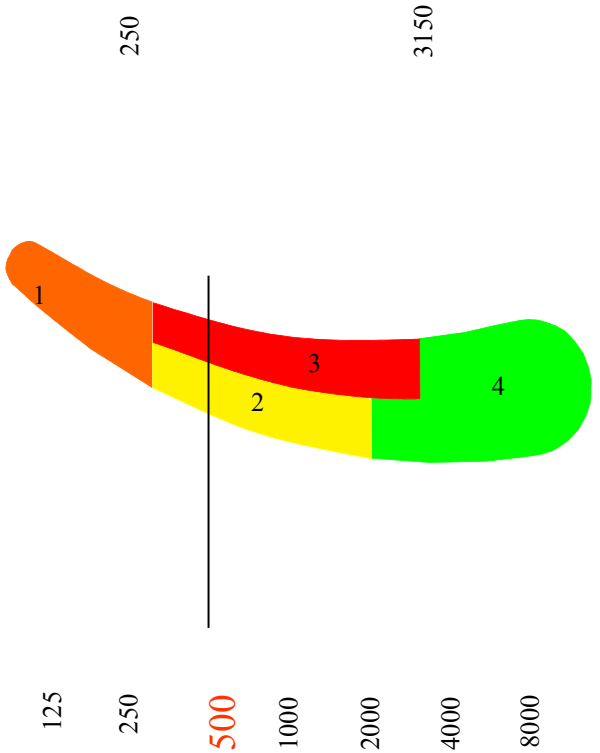
[creating expressive ceilings]

SOLUTIONS

SCHOOLES

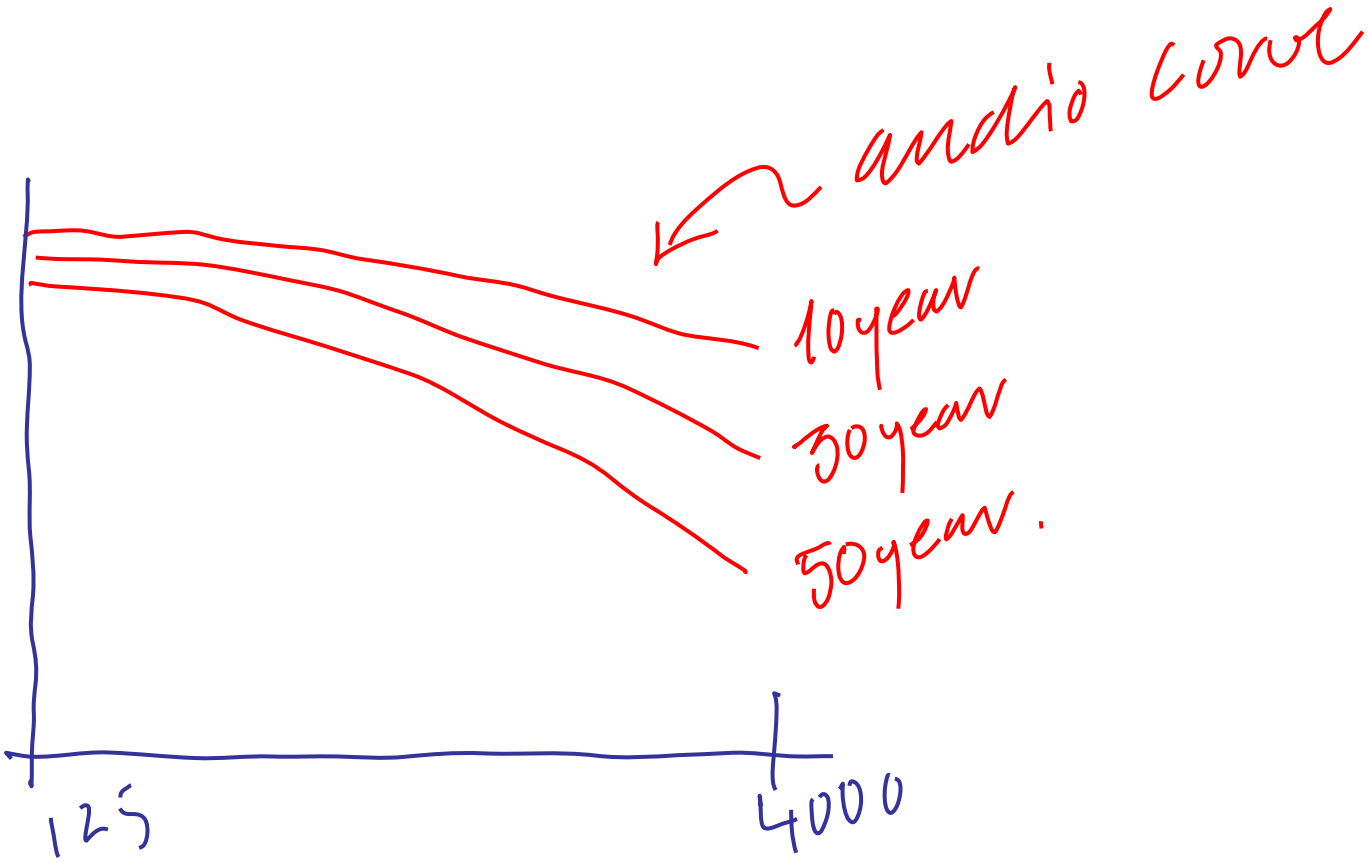
IMPORTANT FREQUENCIES

- CONSONANTS
- 250 - 3150 Hz
- The most important frequency - 500 Hz

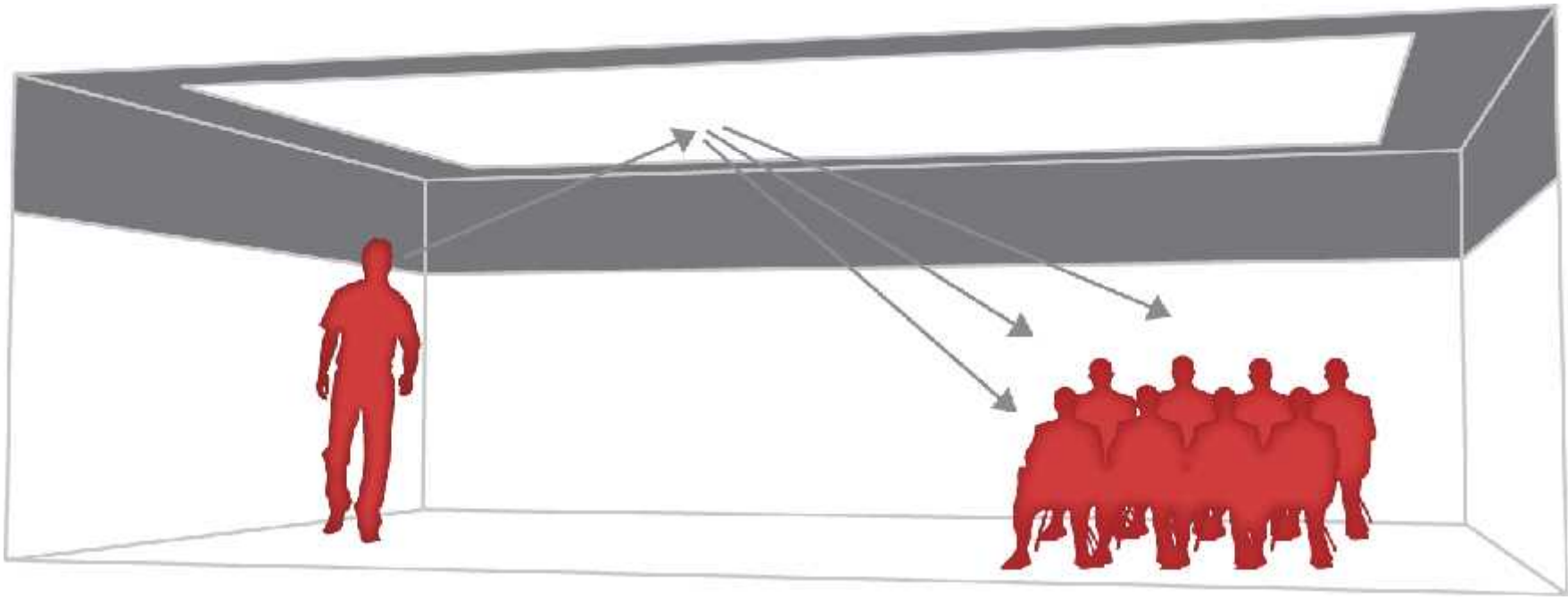


FREQUENCIES

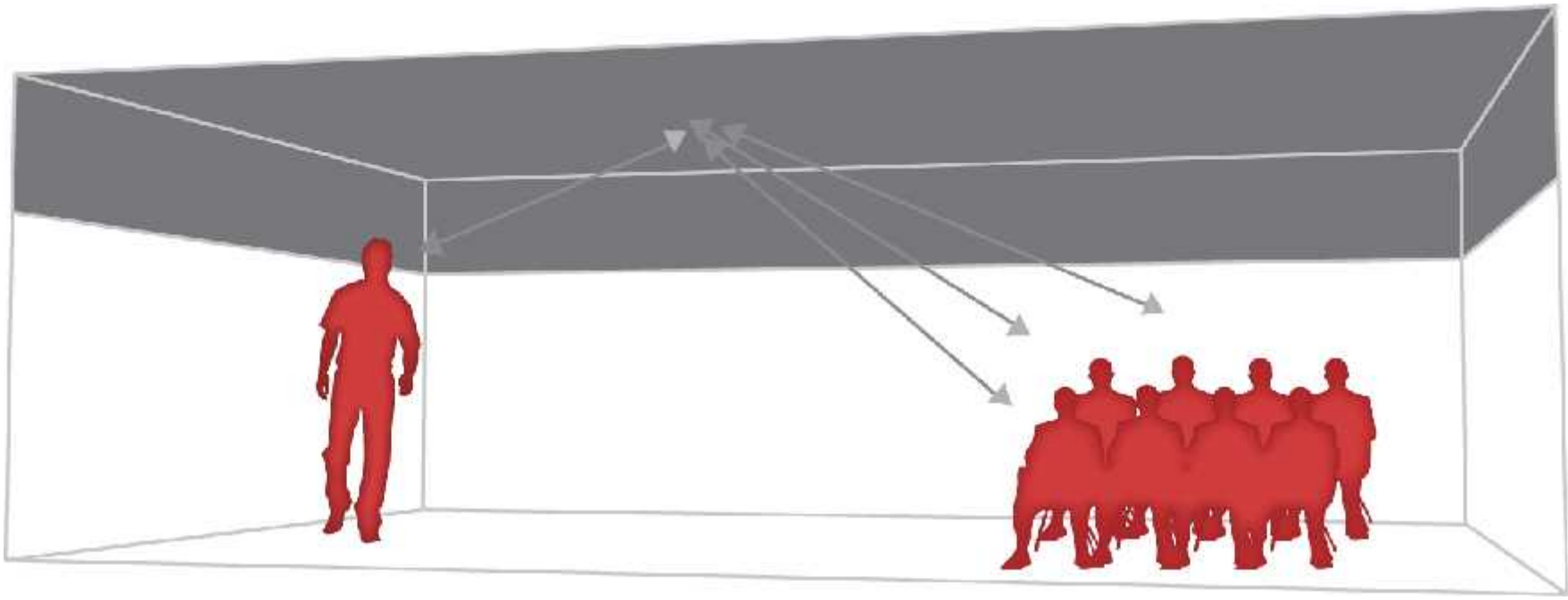
20 -20.000 Hz



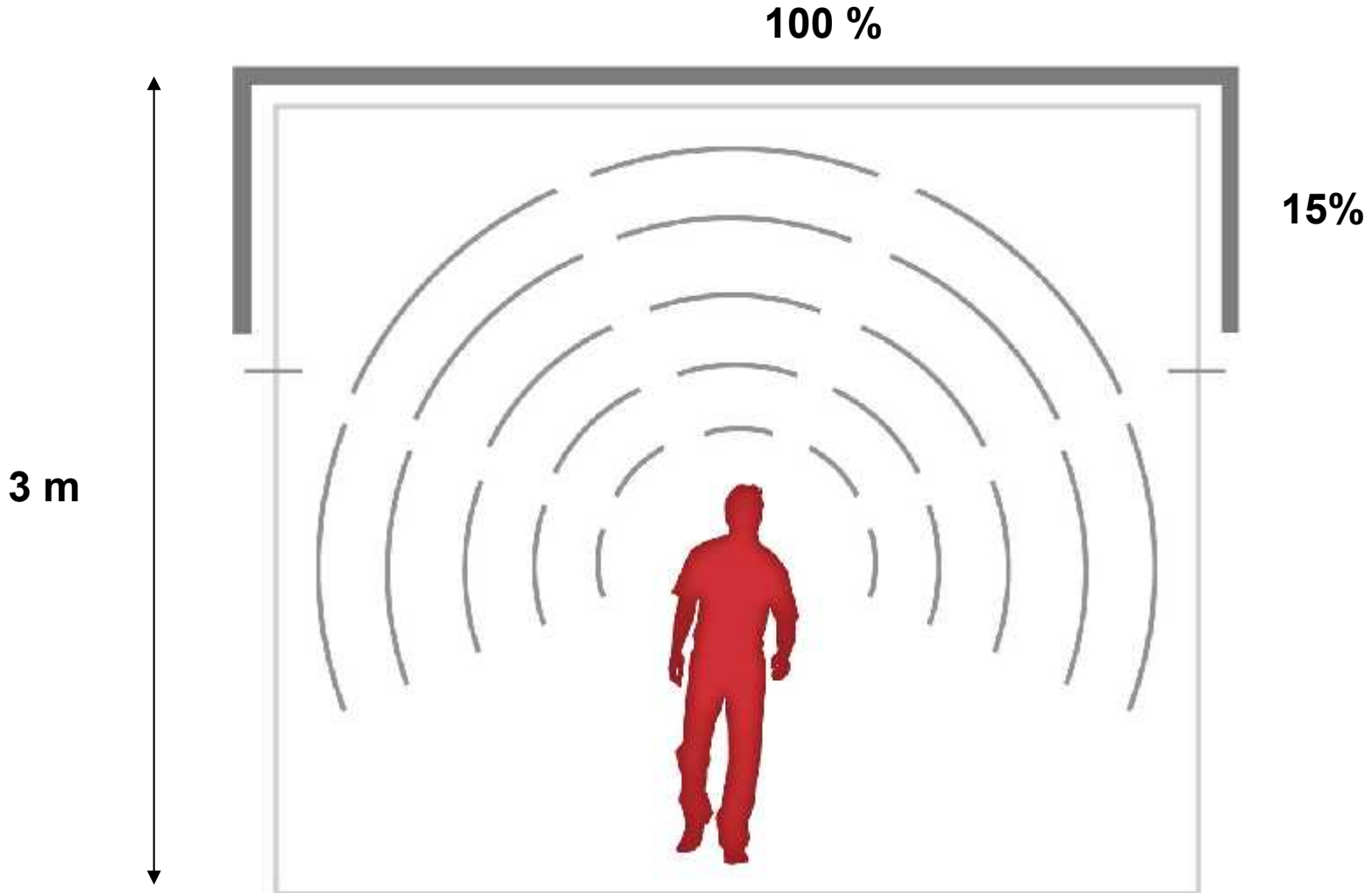
ROOMS FOR SPEECH



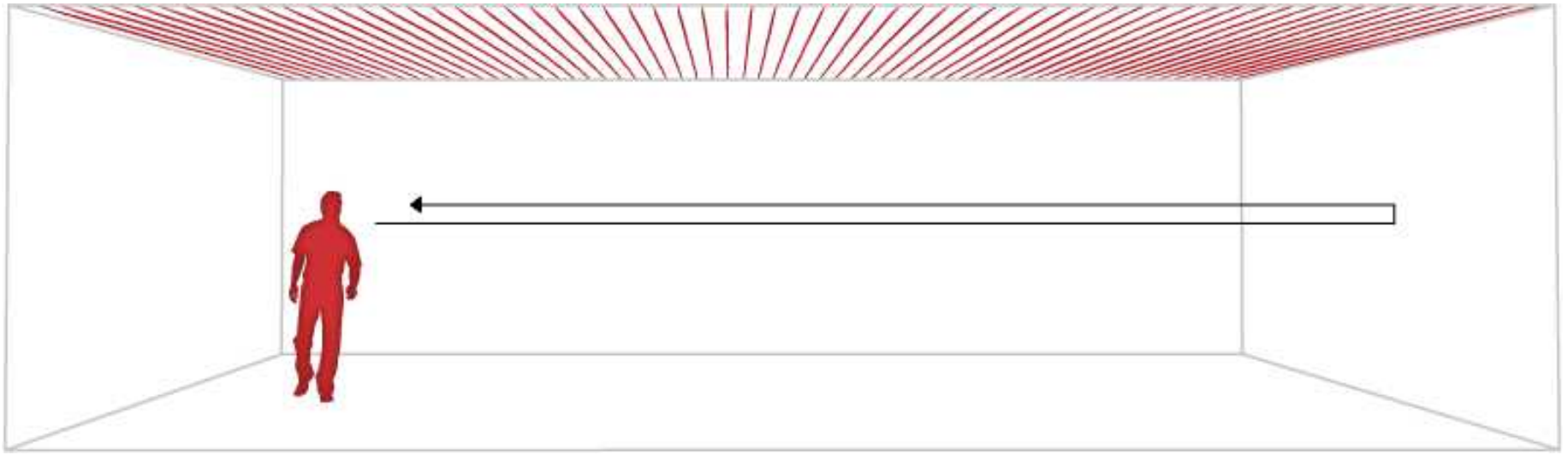
ROOMS FOR SPEECH



CEILING HEIGH



ECHO

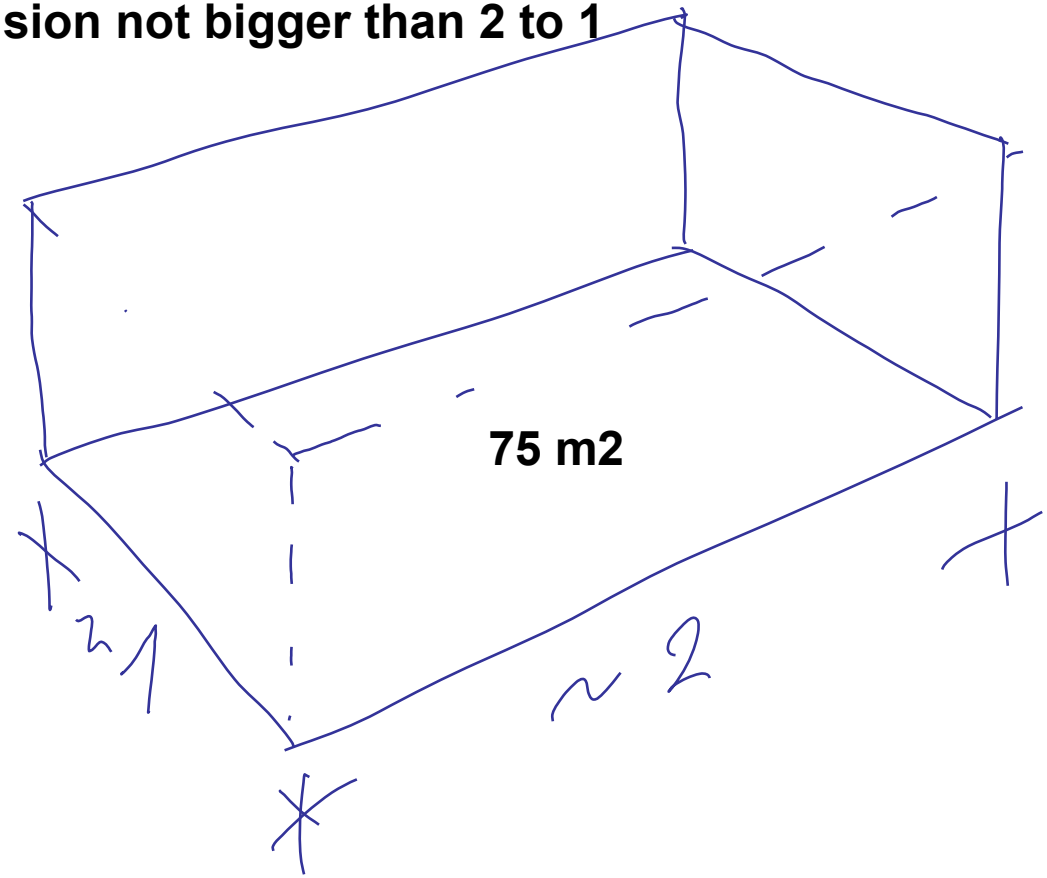


8.5 m

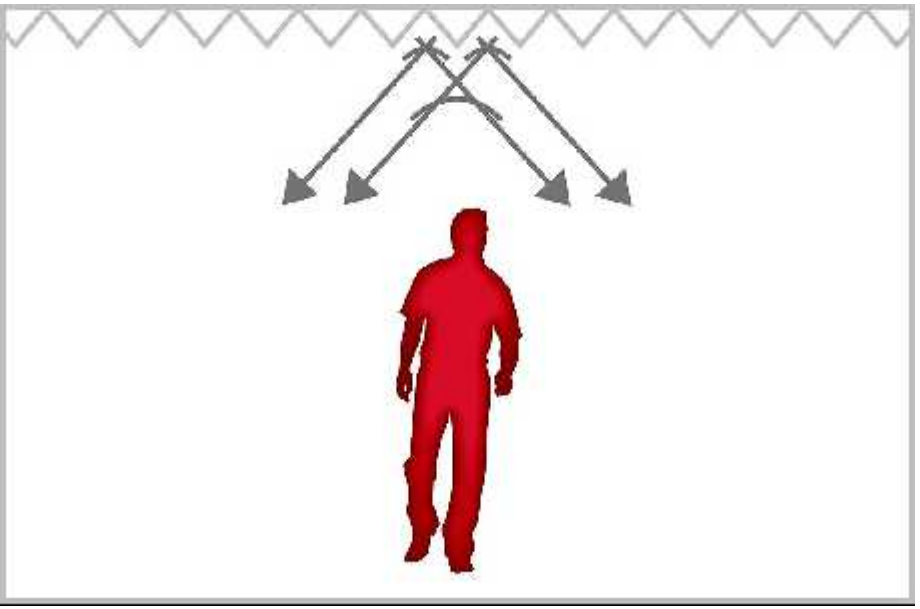
50 ms = 17 m / 2 = 8.5

DIMENSION

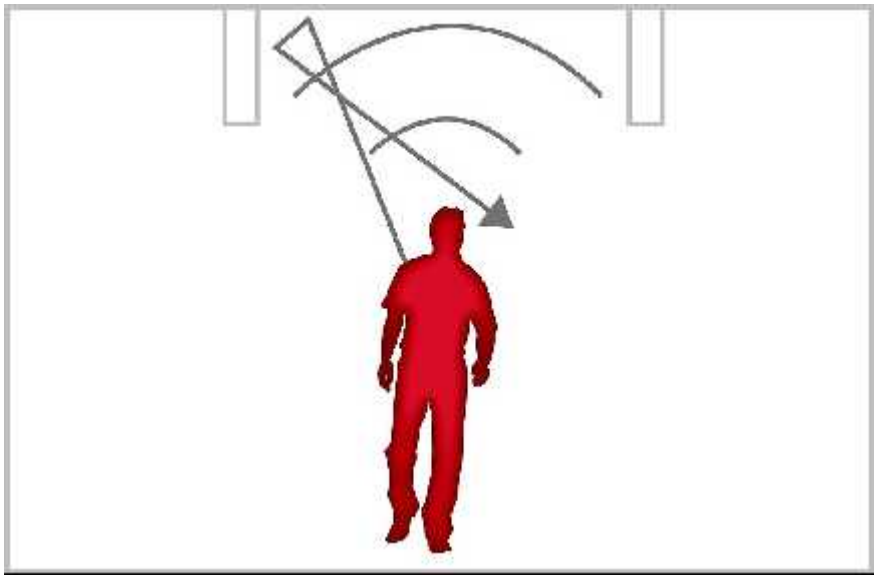
Dìmension not bigger than 2 to 1



BULK HEADS - DELAYED ECHOS

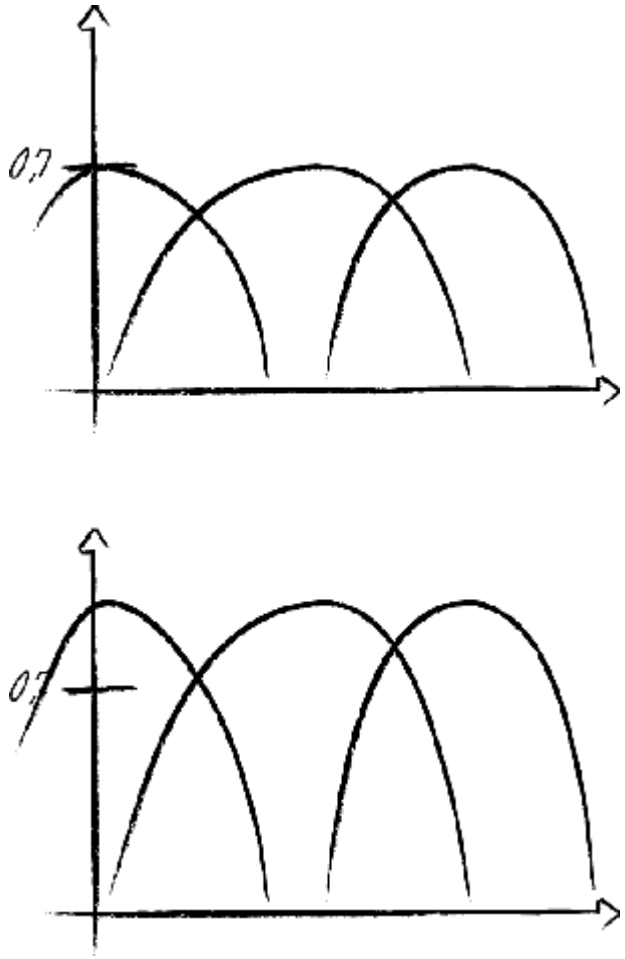


GOOD DIFFUSION



RISK OF DELAYED ECHO

ABSORPTION PROFILE under 0,70 aw



DANAK

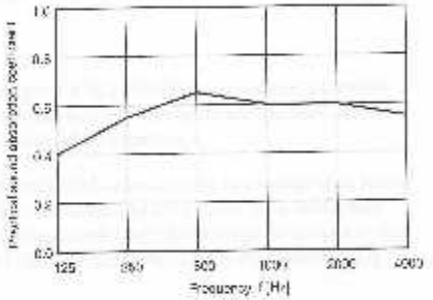
Laboratory Measurement of Sound Absorption Coefficient
according to EN ISO 354:2003

Client: Danogips A/S, Klavenæsvej, 9500 Hobro
Date of test: 2004-01-19

Test specimen: Danoline Plexo 600 MI
Thickness: 10 mm
Module size: 600 mm × 600 mm
Mounting depth: 200 mm (Type E-200 mounting)

Test area: 10.8 m²
Room volume: 210 m³
Room surface: 305 m²

Frequency / Hz	α_s
125	0.40
250	0.55
500	0.65
1000	0.60
2000	0.60
4000	0.55

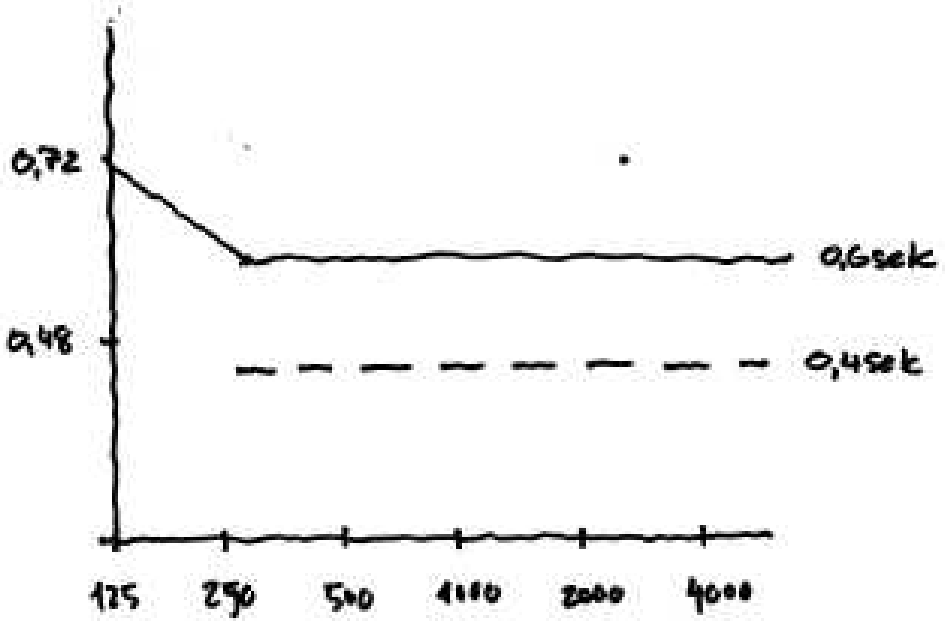


Practical sound absorption coefficient, weighted sound absorption coefficient and sound absorption measured according to EN ISO 11654:1997

$\alpha_w = 0.65$ Absorption class: C

LEVELED REVERBERATION TIME

CLASSROOM 0.6 sec. (min. 0.4 sec.)



CALCULATION OF REVERBERATION TIME

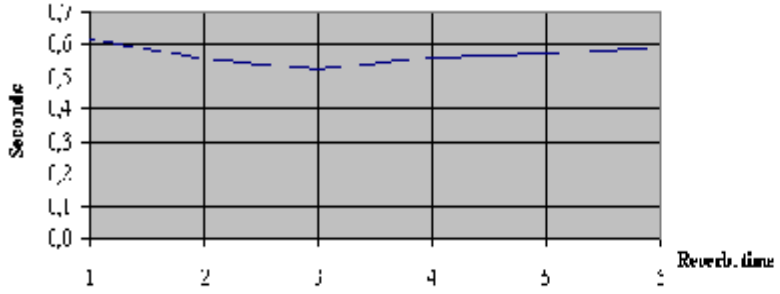
Volume: 210 m³

Calculation:

Placing of Absorbtion	Face: [type]	Area: [m²]	Description:	125 Hz	Am²	250 Hz	Am²	500 Hz	Am²	1000 Hz	Am²	2000 Hz	Am²	4000 Hz	Am²
20	24.0	Bedded double glazed window	0.10	2,40	0,07	1,68	0,05	1,20	0,05	1,20	0,02	0,48	0,02	0,48
22	30	Light door	0,25	0,75	0,20	0,60	0,15	0,45	0,10	0,30	0,00	0,21	0,07	0,21
32	70.0	Linoleum on concrete	0.02	1,40	0,02	1,40	0,03	2,10	0,04	2,80	0,04	2,80	0,05	3,50
18	75.0	2-12.5mm gypsum wall w 5cm min wool	0.15	11,25	0,10	7,50	0,06	4,50	0,04	3,00	0,04	3,00	0,05	3,75
44	70.0	plafond/mineral	0.15	10,50	0,15	10,50	0,15	10,50	0,15	10,50	0,15	10,50	0,15	10,50
121	70.0	Contour 600 M1 suspended 200 mm	0.43	30,00	0,55	38,50	0,65	45,50	0,60	42,00	0,60	42,00	0,65	45,50
		Reverb. Time		0,62		0,56		0,52		0,50		0,57		0,59	

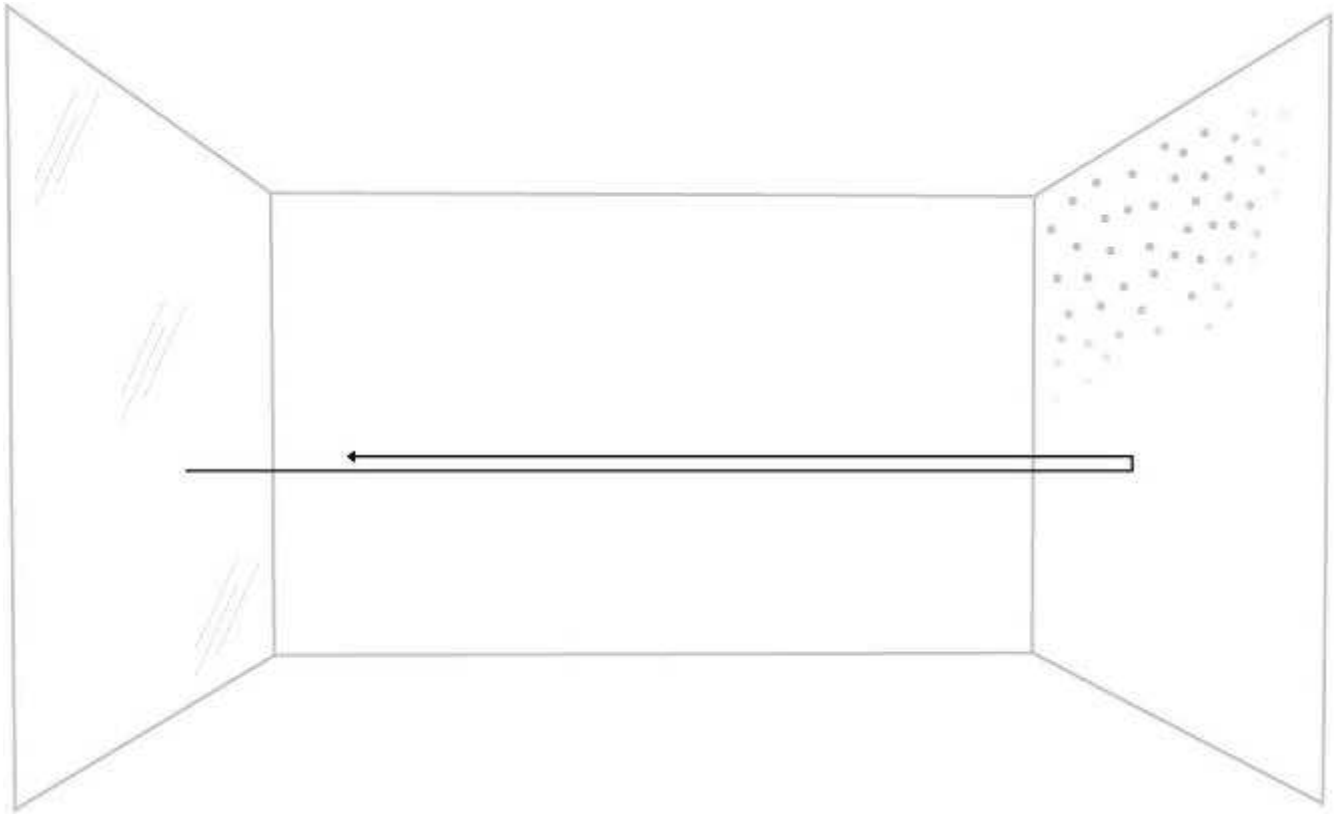
Wished reverb. time

Existing conditions

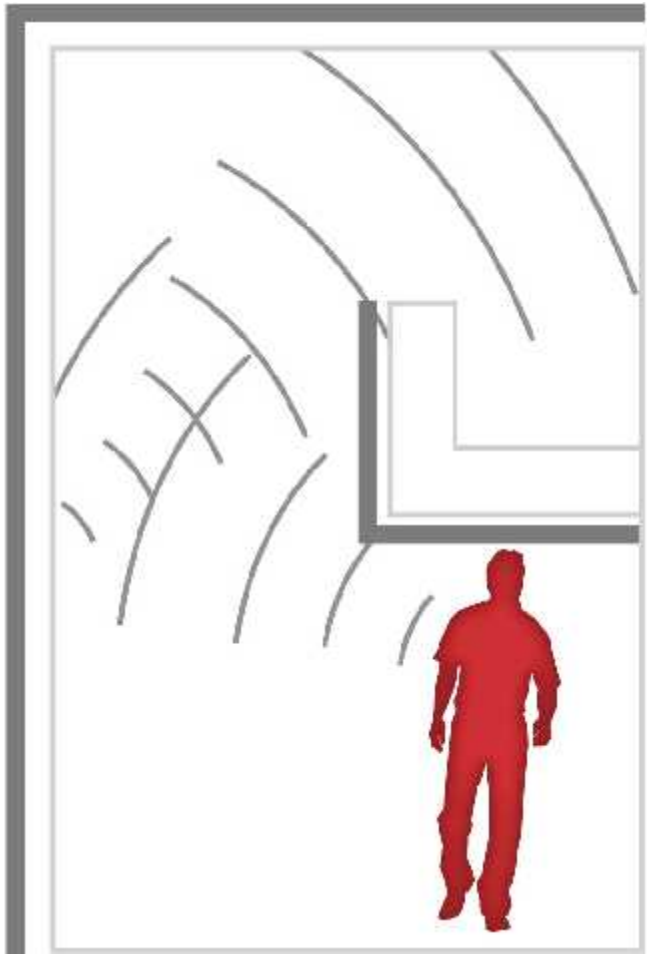


GLASS FACADES

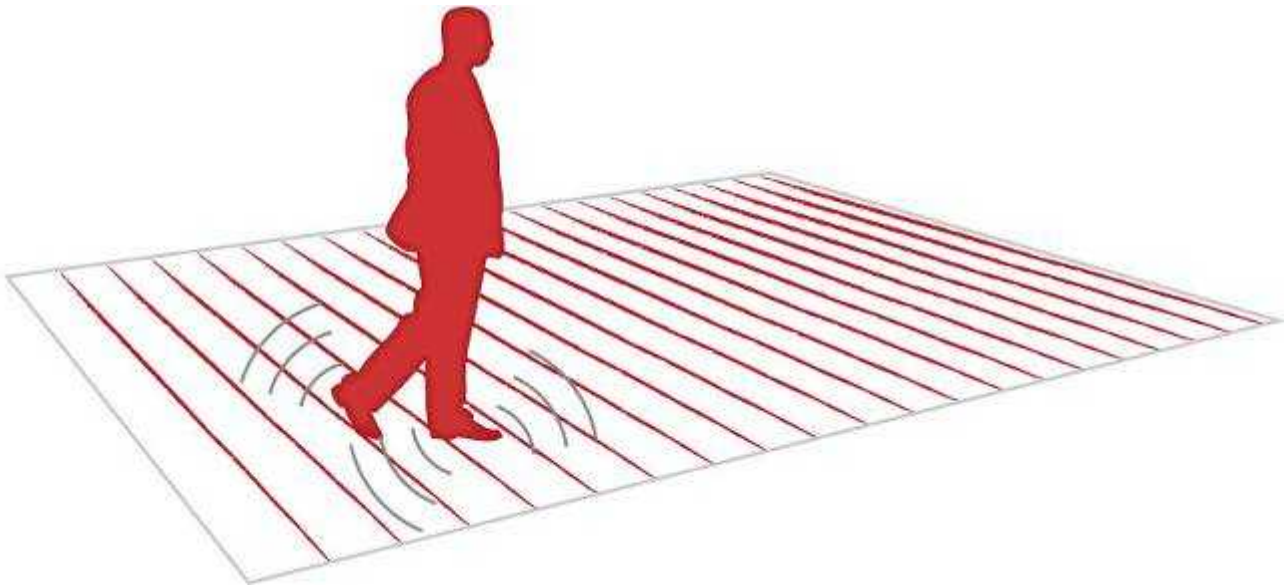
GLASS FACADES



MEZZANINE



DRUM SOUND



SUM UP

- EFFICIENT ABSORBERS IN CEILING GIVES RISK OF ECHOS.

- LACK OF DIFFUSION GIVES VERY LOW EFFECT OF ABSORBERS

SUM UP

- PRODUCT ABSORPTION PROFILE CAN BE DESIGNED.
- ABSORPTION VALUES FOR SPEECH CONTROL UNDER 0,70 aw
- ABSORPTION PROFILE FOR NOISE REDUCTION OVER 0,70 aw

SUM UP

- CEILING HIGH OVER 2,6 m SHOULD BE ADDED WITH WALL ABSORBERS.

- WORKPLACES WITH A CEILING HIGH OVER 4m IS NOT RECOMMANDED.

SUM UP

- SOUND REGULATING MATERIALS SHOULD BE PLACED WHERE THE SOUNDWAVES HIT FIRST.

- STRUCTURES MIRRORS THE SOUNDWAVES / THINK ABOUT THE FORM OF THE STRUCTURE AND HOW IT REFLECTS SOUNDS.

SUM UP

- FURNITURE HAS A MAJOR INFLUENCE OF SOUND DIFFUSION / AND THE EFFECT OF HOW EFFICIENT A ABSORBER IS PERFORMING.

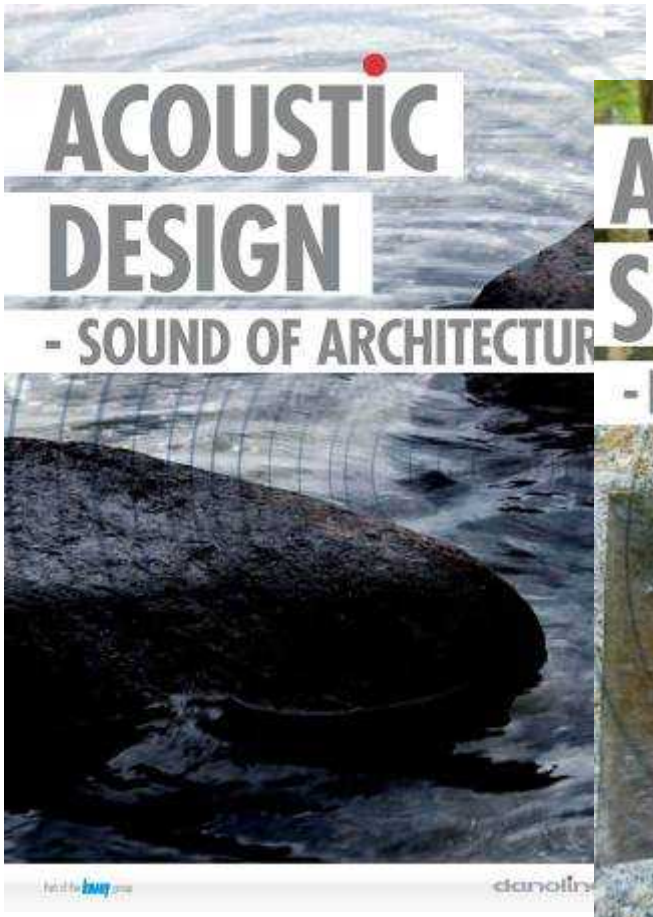
- THE EFFECT IS VERY IMPORTANT IN LARGE ROOM OFFICES.

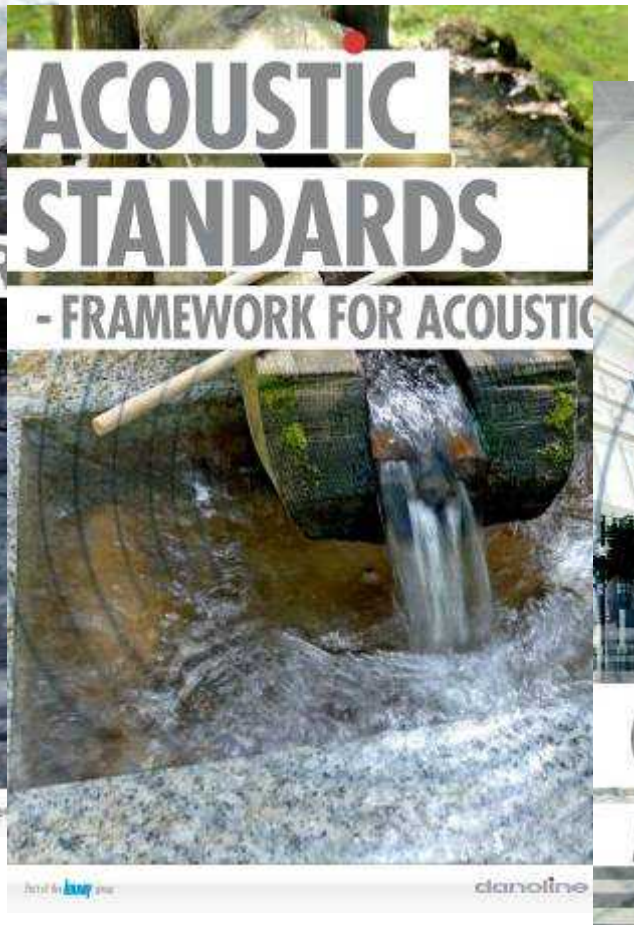

EPISERVER

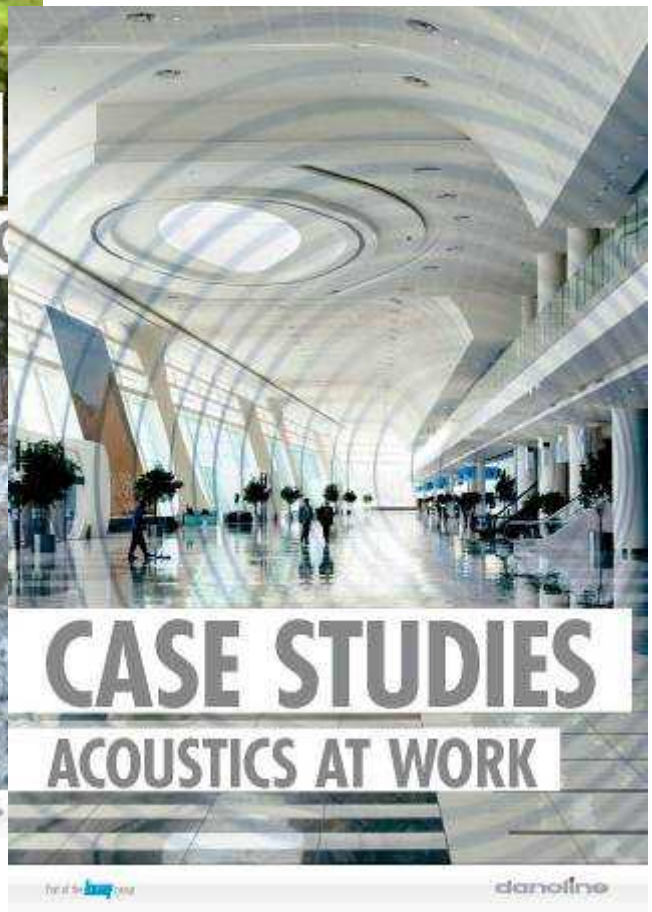
GOAL

SOUND CONTROL THOUGH
ARCHITECTURE AND INTORIOR DESIGN

ACOUSTIC DESIGN BOOKS

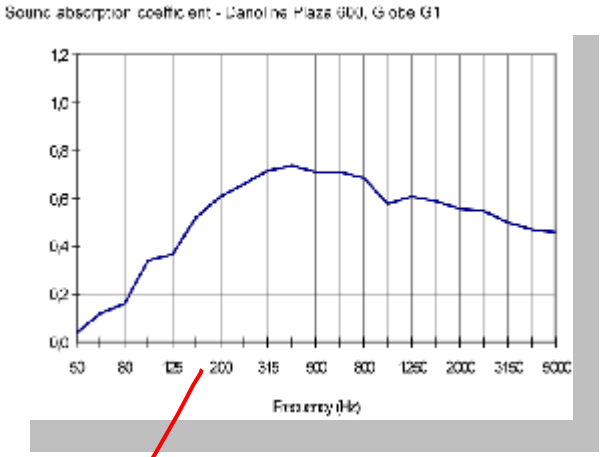


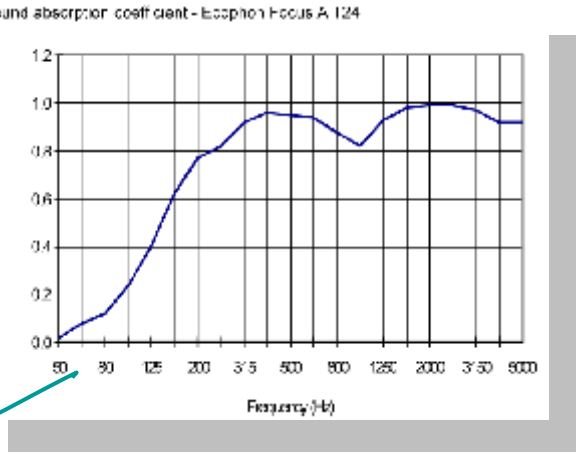




Measurements on site

perforated gypsum or mineral wool





Room	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz	Average / Highest *)
Room A (C absorber)	0.6	0.6	0.5	0.5	0.5	0.5	0.5 / 0.6
Room B (A absorber)	0.6	0.6	0.5	0.4	0.5	0.5	0.5 / 0.6

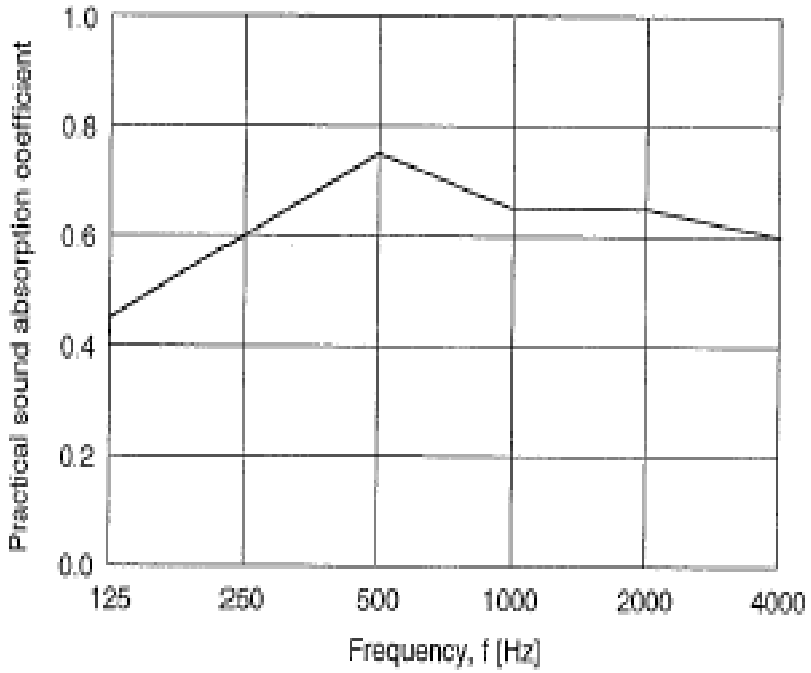
ASTM

- NRC (NOISE REDUCTION COEFFICIENT)
- AVERAGE 250 – 2000 Hz
- 400mm SUSPENSION
- EN STANDARDS: 200mm SUSPENSION

ASTM - NRC

Test area: 10.8 m²
Room volume: 210 m³
Room surface: 305 m²

Frequency f [Hz]	α_p
125	0.45
250	0.60
500	0.75
1000	0.65
2000	0.65
4000	0.60



250 – 2000 Hz

Test area:	10.8 m²
Room volume:	210 m³
Room surface:	305 m²

Frequency f [Hz]	α_p
125	0.45
250	0.60
500	0.75
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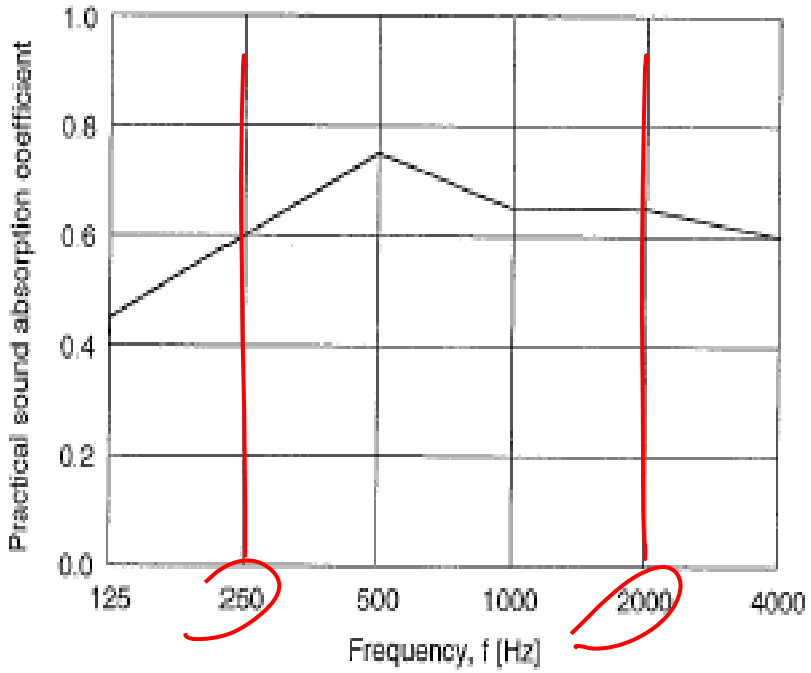
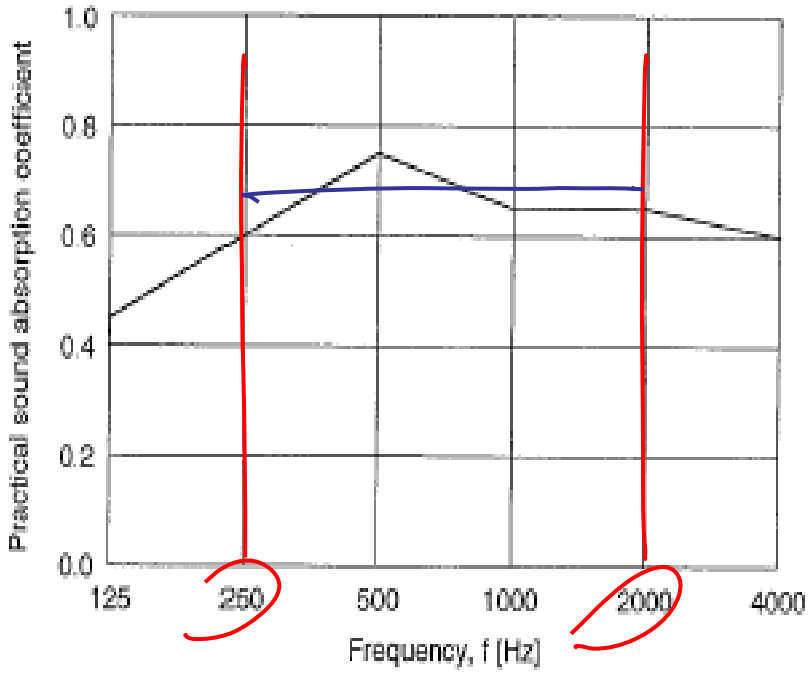


AVERAGE

Test area:	10.8 m²
Room volume:	210 m³
Room surface:	305 m²

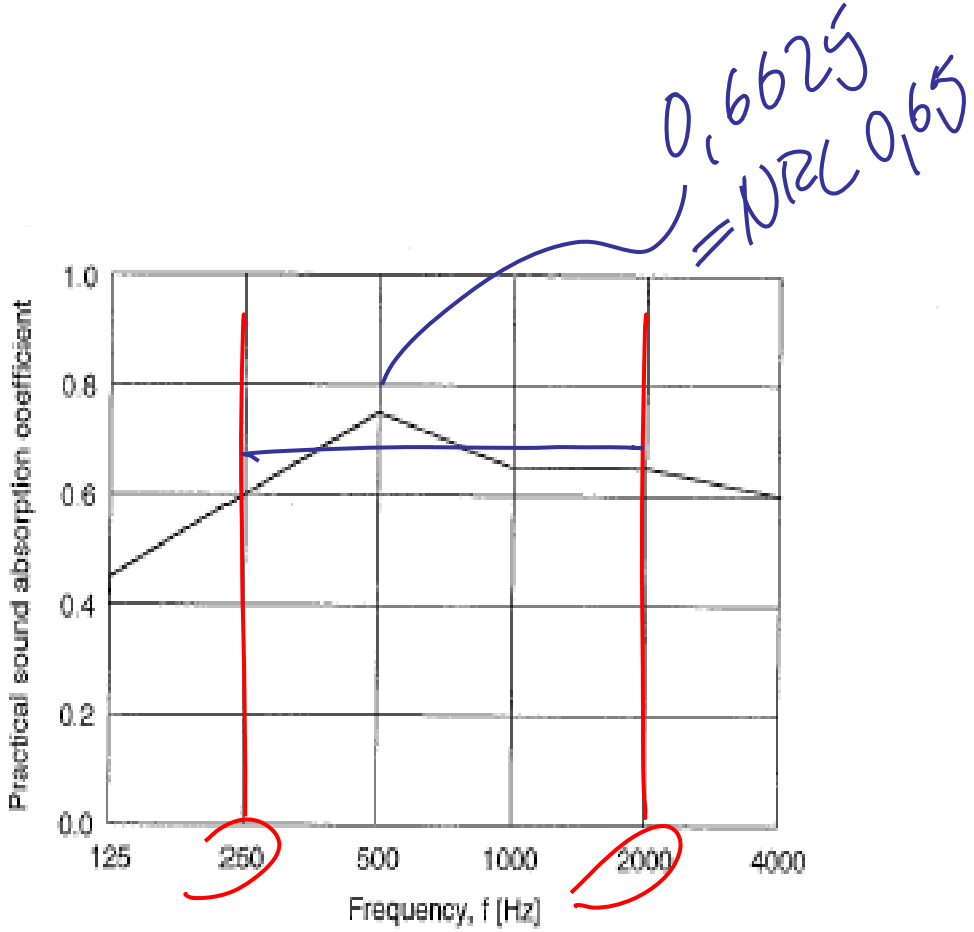
Frequency f [Hz]	α_p
125	0.45
250	0.60
500	0.75
1000	0.65
2000	0.65
4000	0.60



NRC VALUE

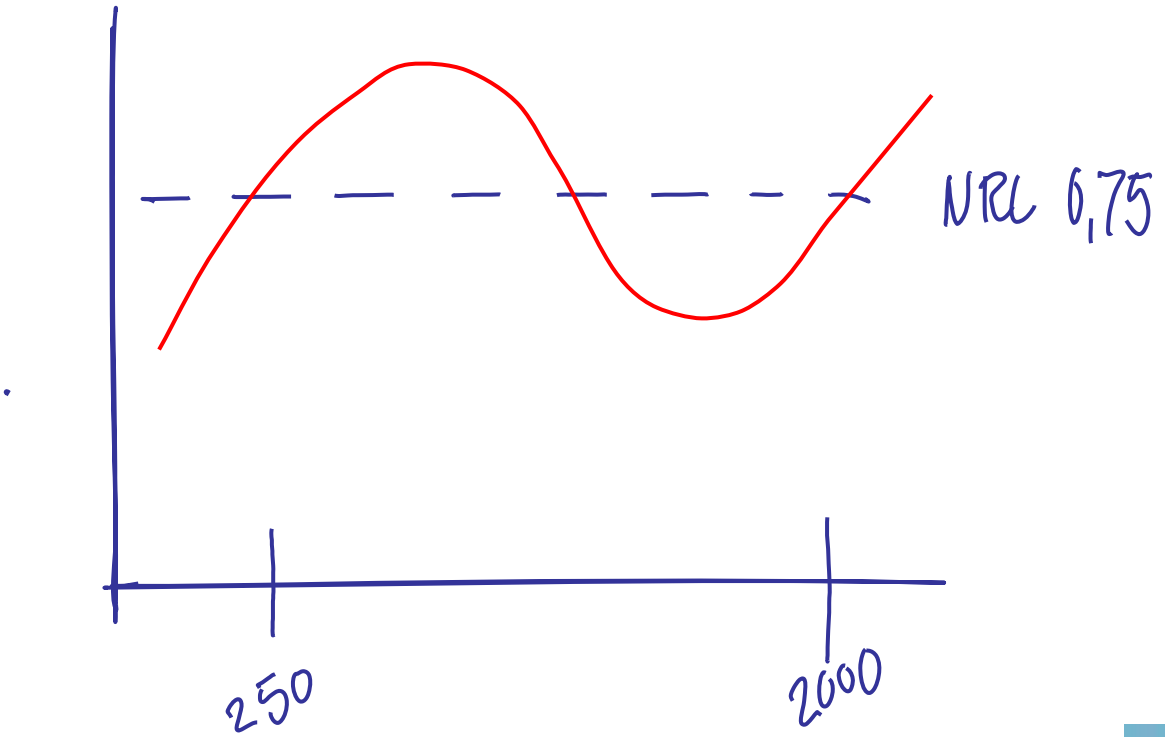
Test area: 10.8 m²
Room volume: 210 m³
Room surface: 305 m²

Frequency f [Hz]	α_p
125	0.45
250	0.60
500	0.75
1000	0.65
2000	0.65
4000	0.60

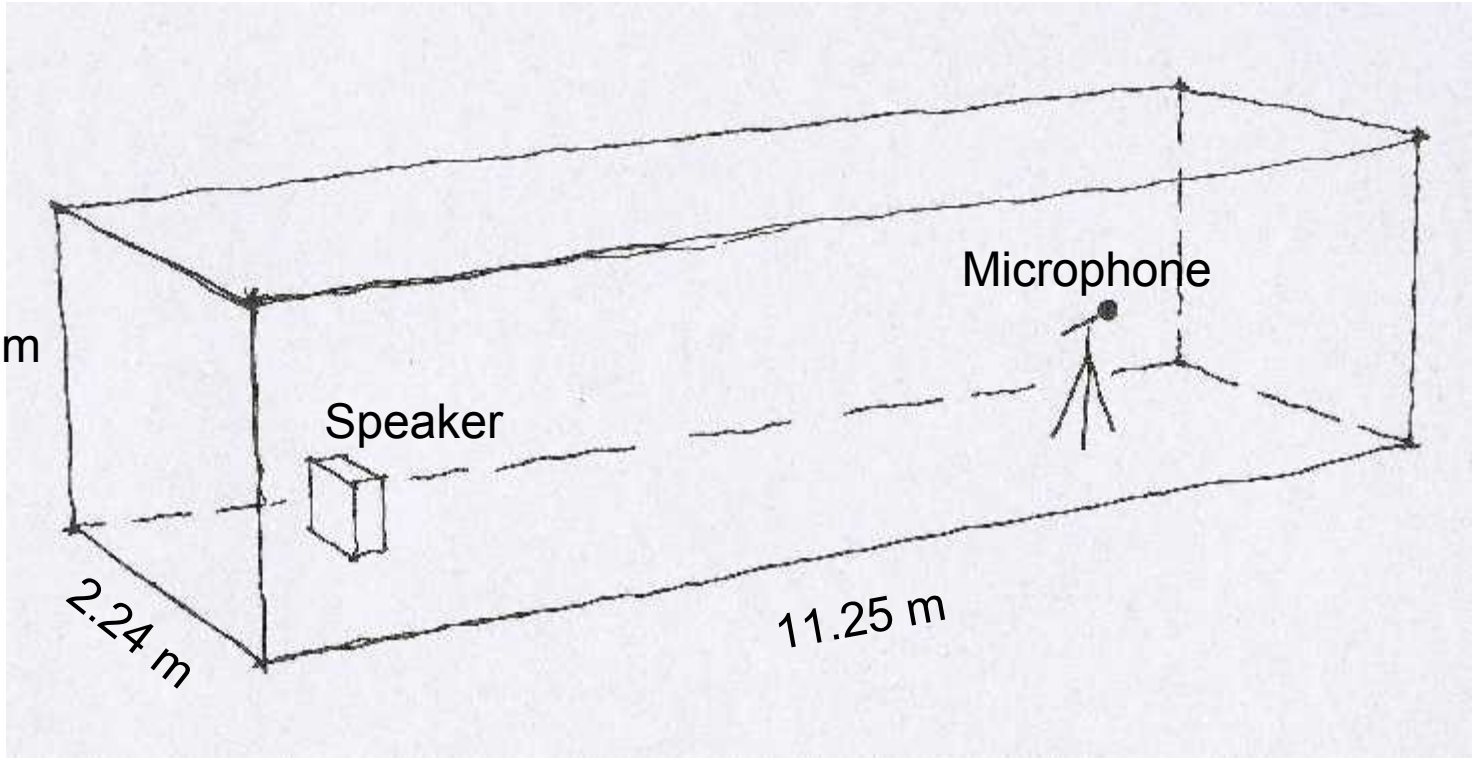


ASTM

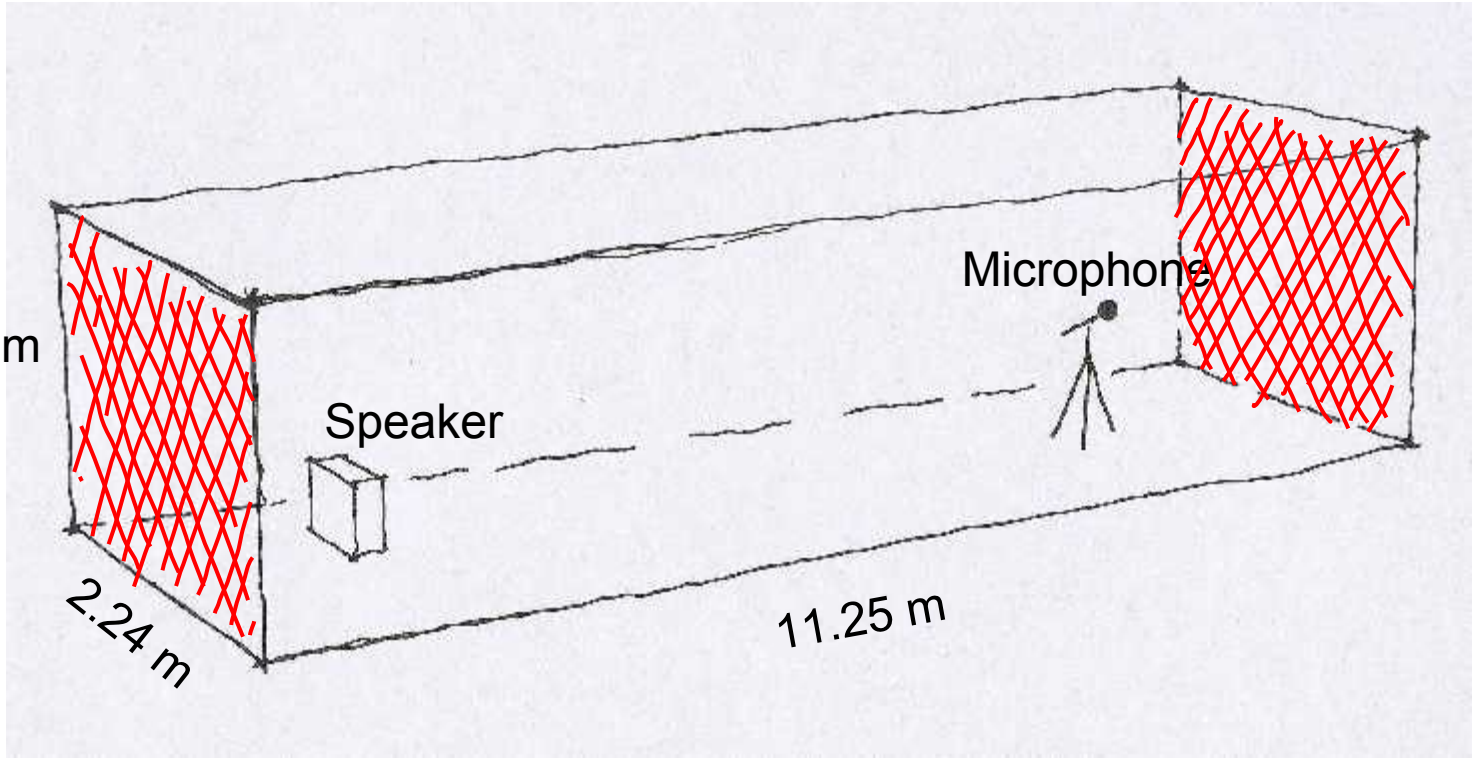
- NRC (NOISE REDUCTION COEFFICIENT)
  - AVERAGE 250 – 2000 Hz



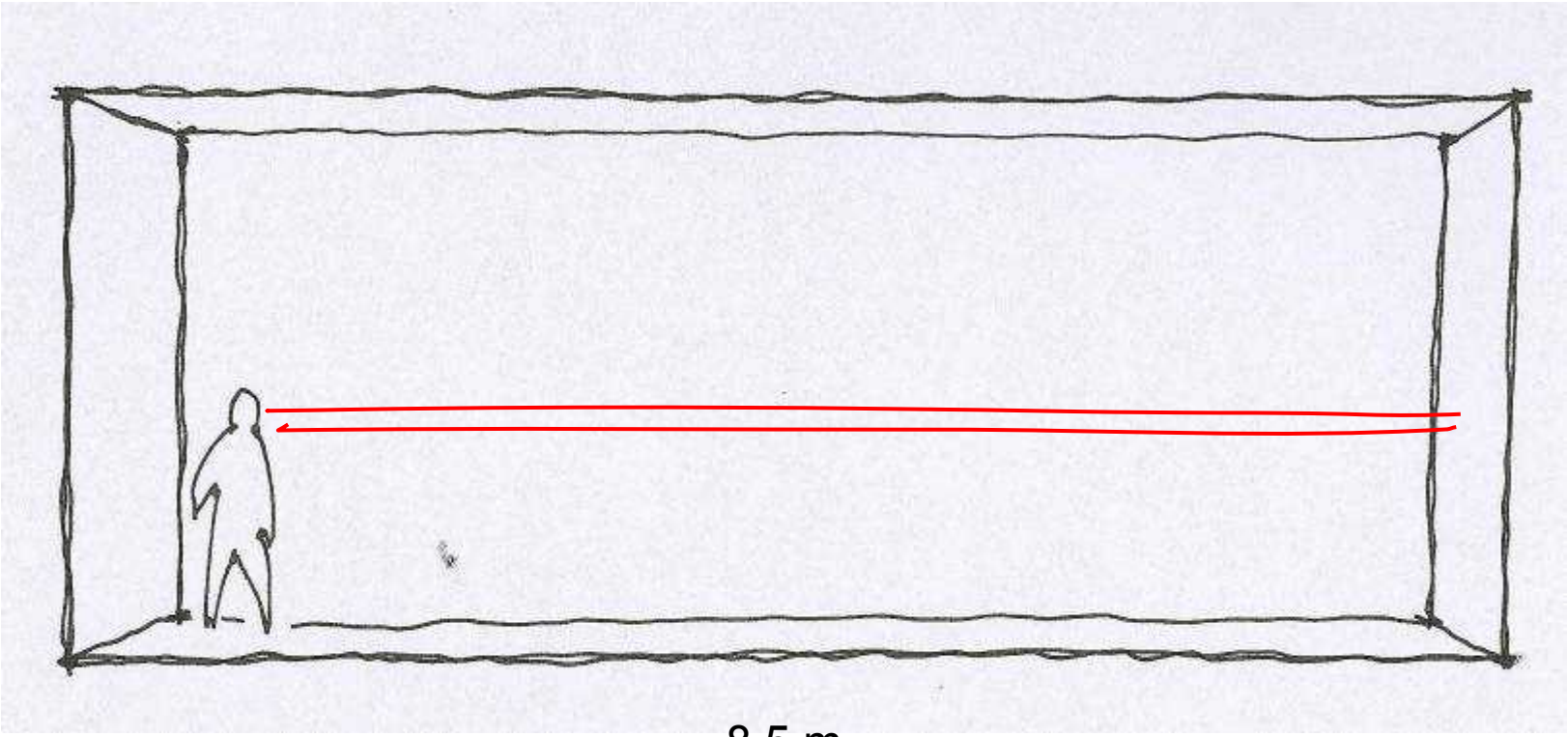
Sound Lab



Sound Lab



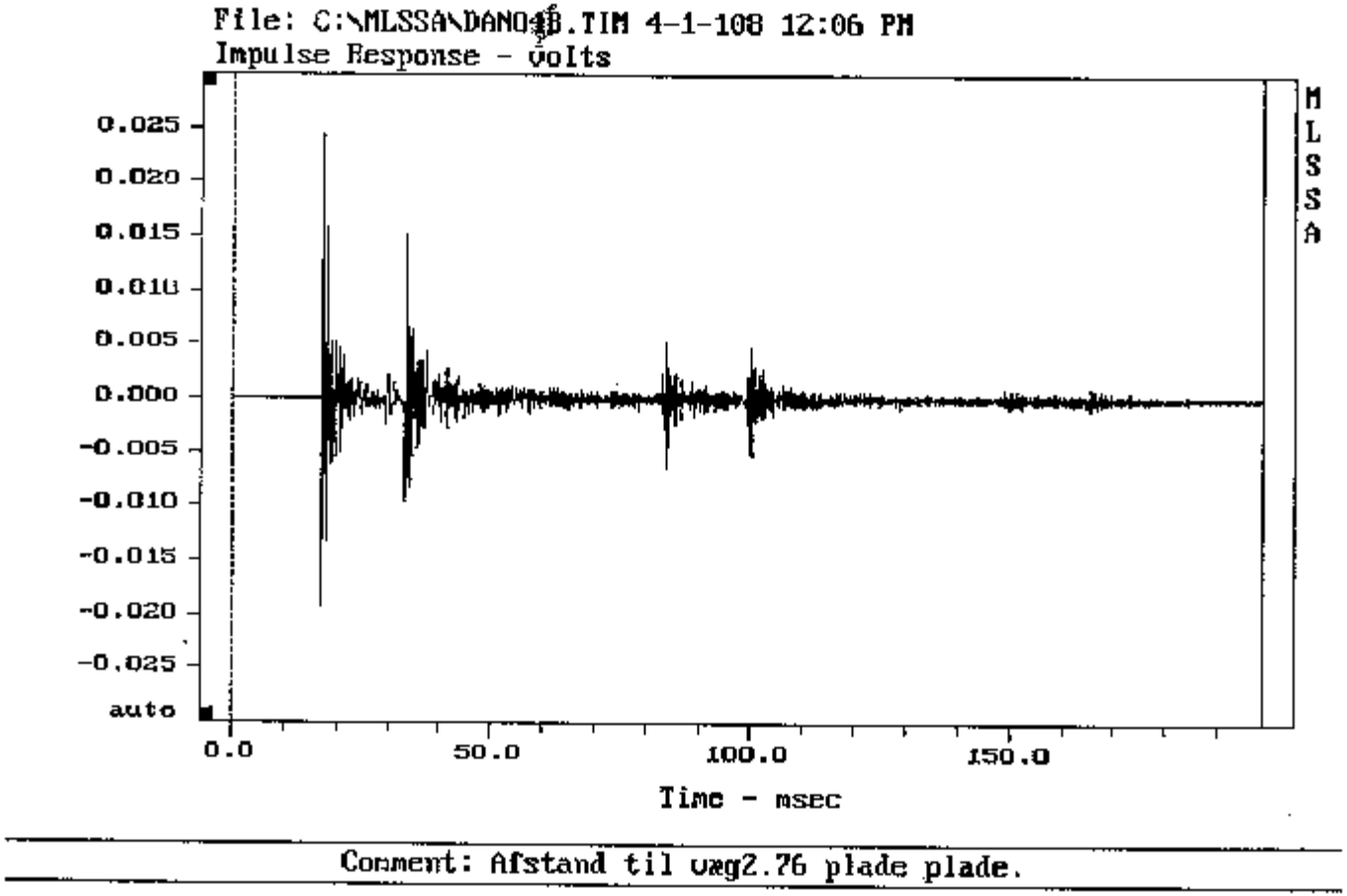
Short Reverberation time



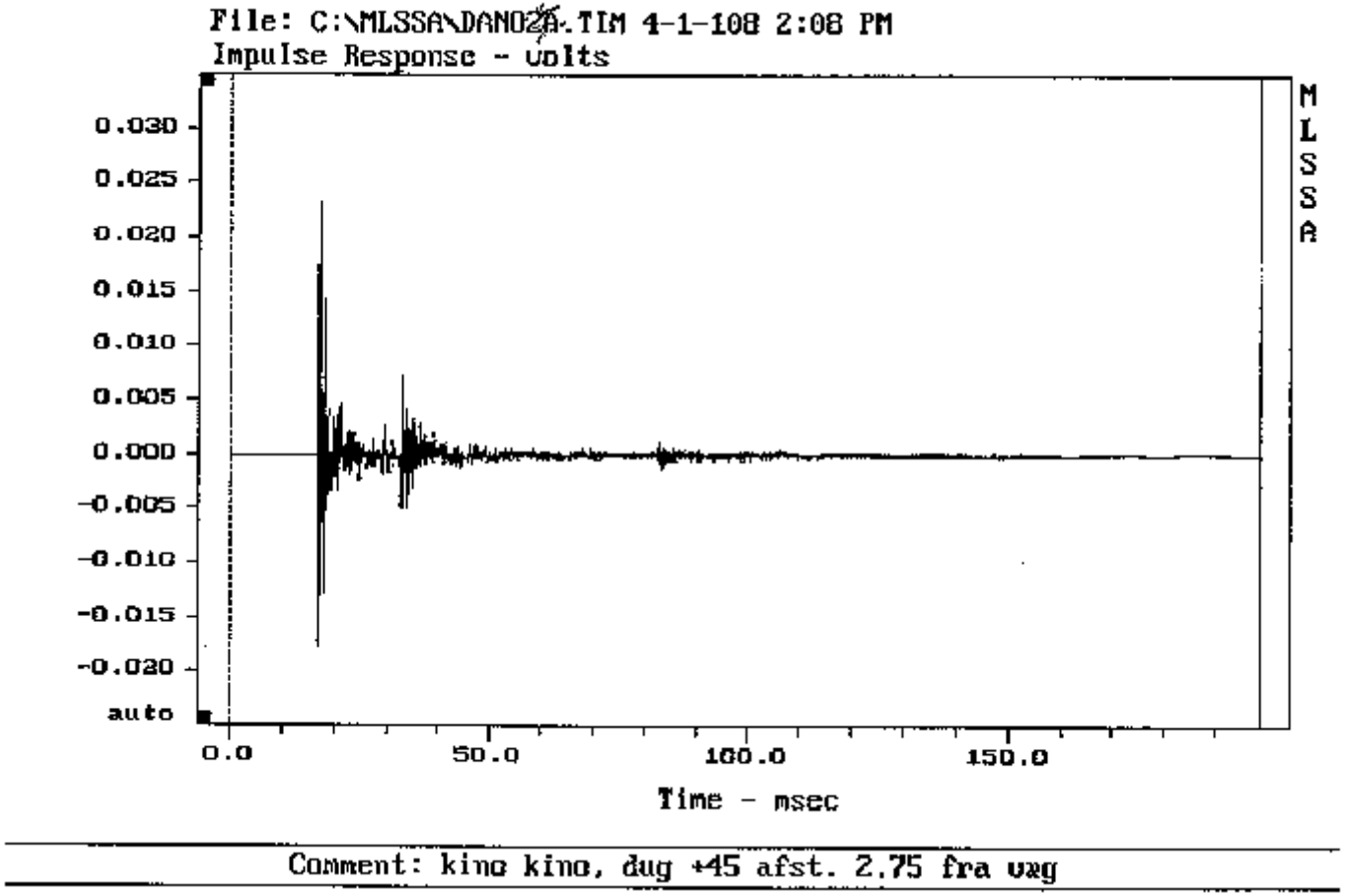
8.5 m

50 ms = 17 m / 2 = 8.5 + 8.5

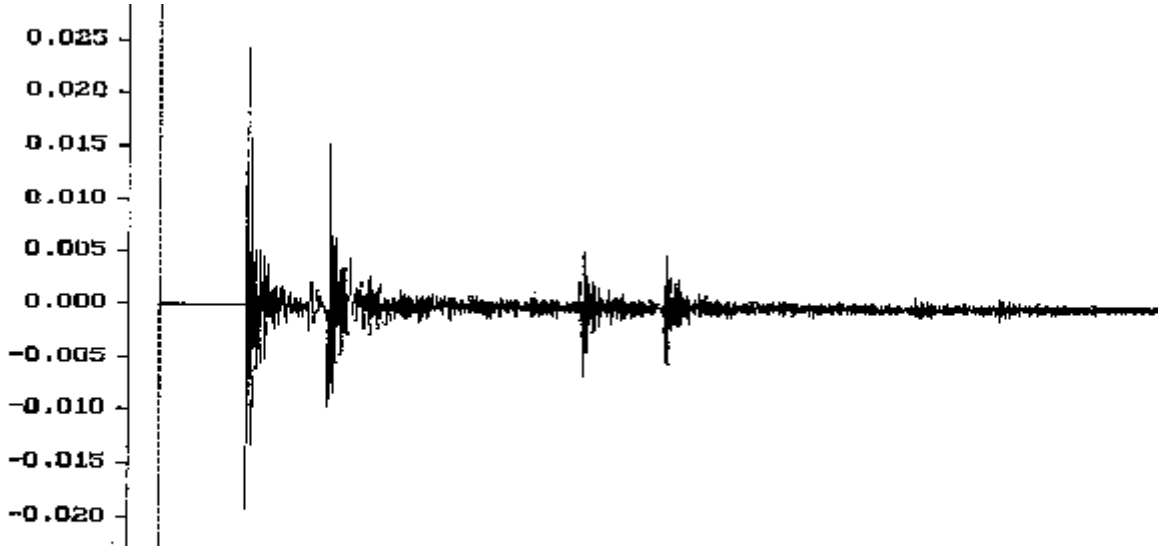
Flutter Plain Tiles



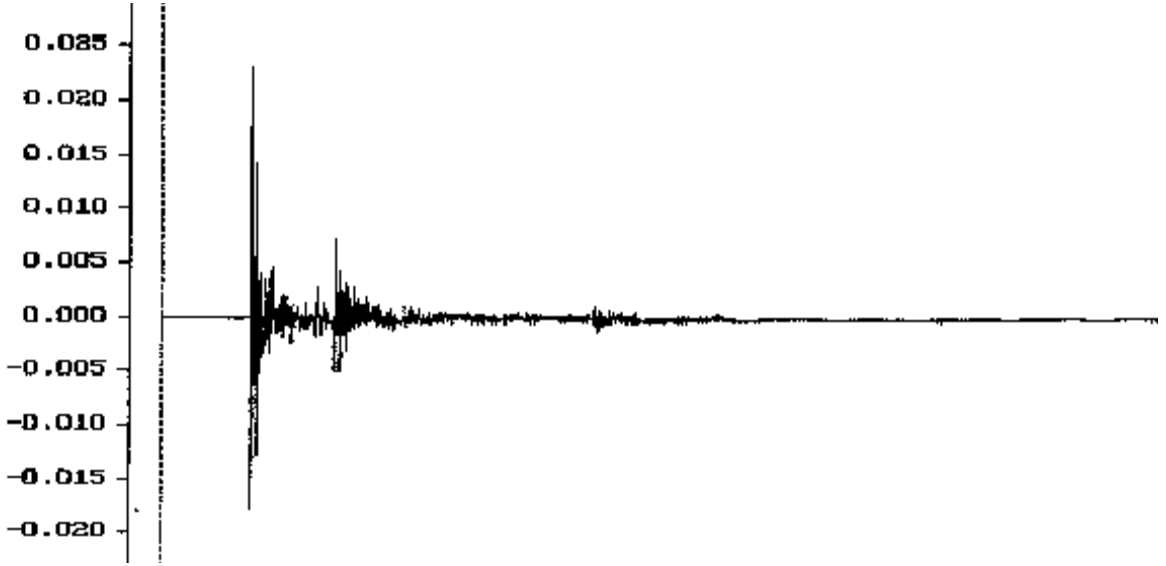
Flutter Kinopanel



Plain Tiles



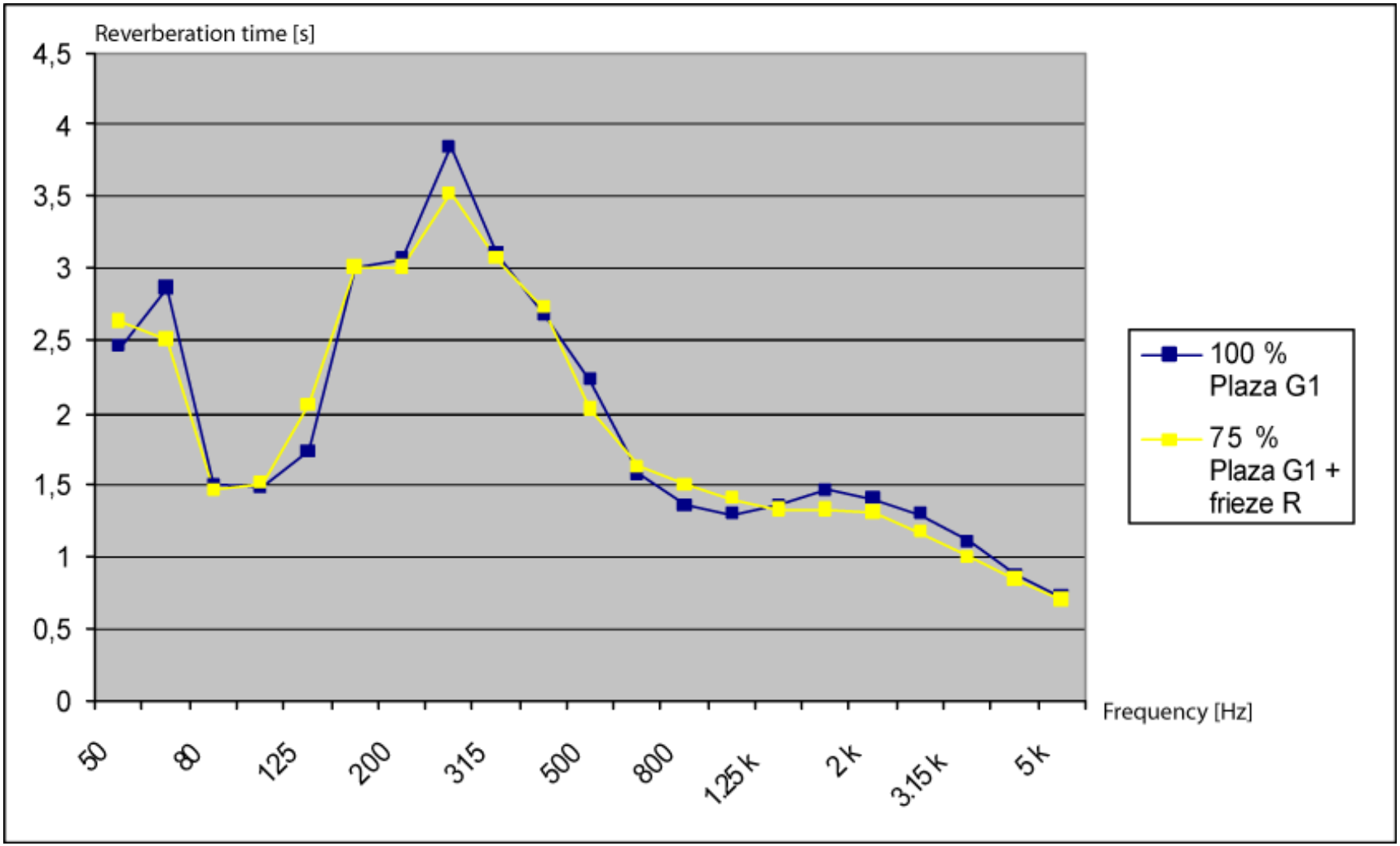
Kinopanel



dB Loss

	125	250	500	1 kH	2 kH	4kH
Plain	-11,5	-11,8	-1,8	4,9	15,8	10,7
	-12	-17	-2,7	4,5	7,5	10,4
	-20	-22,3	-19	-8,4	5,5	-2,2
	8,5	*10,5*	*17,2*	*13,3*	*10,3*	*12,9*
Kinopanel	-14,2	-13,8	-1,2	4,4	16,4	10
	-14	-15,3	7,6	0,3	7,5	5,1
	-35,3	-40,5	-36	-22,6	-6,9	-15,2
	21,1	*26,7*	*34,8*	*27*	*23,3*	*26,2*
	-13,6	-15,3	-2	4,2	17,4	10,2
	-15,2	-29,8	-7,9	3,5	6,2	1,75
	-45,5	-42,8	-35,7	-18,7	-7,5	-13,9
	31,9	*27,5*	*33,7*	*22,9*	***18,9***	***24,1***
Different Tiles	-11,6	-15,3	-2,65	1,7	9,1	7,2
	-13	-13	-8,4	0,8	1,7	[illegible]
	-33	-36,4	-35	-24	-9,7	-16,6
	21,4	*21,1*	*32,3*	*25,7*	***18,8***	***23,8***
	-13,1	-14,3	-1,4	4,4	11,2	9,8
	-12,6	-13,5	7,7	1,4	5,3	4,9
	-39,5	-39,2	-34,1	-17,7	-4,6	-9,1
	26,4	*24,9*	*33*	*22*	***15,8***	***18,9***
	-11,1	-14,6	-2,7	-0,2	10,1	7
	-20	-21	-4,9	-1,5	4,6	4,6
	-37	-39	-29	-20	-4,6	-11,1
	25,9	*24,4*	*26,3*	*19,8*	***14,7***	***18,1***

Influence of friezes



Unfurnished classroom with perforated gypsum ceiling; no wall absorbers