

Handled by, department

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## Measurement of sound absorption in a reverberation room according to ISO 354, EN 20354 and EN ISO 11654

(2 appendices)

This is a translation of the Swedish report P702033 dated April 11, 2007.

### Test object

Stiff felt draperies composed of smaller elements according to the enclosed photographs.

### Arrival of test objects

March 2007.

### Date of test

April 4, 2007

### Results

The sound absorption coefficient ( $\alpha_s$ ) and the practical sound absorption coefficient ( $\alpha_p$ ) are given in enclosure 1-2. The weighted sound absorption coefficient ( $\alpha_w$ ) and the sound absorption classes have been calculated according to EN ISO 11654 and these results are given in table 1.

The results are valid for the tested objects only and for the actual mounting conditions, including mounting depth.

Table 1

Test object	SS-EN ISO 11654		Enclosure
	Absorption class	$\alpha_w$	
Stiff felt drapery composed of smaller elements according to figure 1. Thickness of elements: 5 mm. Mounting depth: 100 mm	E	0,2(H)	1
Stiff felt drapery composed of smaller elements according to figure 2. Thickness of elements: 5 mm. Mounting depth: 100 mm	D	0,4(MH)	2

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## Measurement method

The measurements have been carried out according to ISO 354:2003, which is equivalent to EN ISO 354 and SS-EN ISO 354. The evaluation has been carried out according to ISO 11654, which is equivalent to EN ISO 11654 and SS-EN ISO 11654. 4 loudspeaker positions and 6 microphone positions have been used giving 24 different combinations for the reverberation time measurements. For empty room 3 decays have been used for averaging the time and for test objects 5 decays have been used, for each combination of loudspeaker and microphone.

The absorption coefficient  $\alpha_s$  has been evaluated from:

$$\alpha_s = \frac{55.3 V}{c \cdot S} \left( \frac{1}{T_2} - \frac{1}{T_1} \right)$$

where

- V = Volume of the reverberation room (m<sup>3</sup>)
- S = Area of the test object (m<sup>2</sup>)
- c = Speed of sound in air (m/s)
- c = 331 + 0.6t
- t = Temperature in the air (°C)
- T<sub>1</sub> = Reverberation time of the room without test object (s)
- T<sub>2</sub> = Reverberation time of the room with test object (s)

## Measurement uncertainty

From a world wide Round Robin<sup>1)</sup>, in which SP took part, with 23 participating laboratories from 11 countries, the following measurement uncertainty has been calculated

Frequencies (Hz)	Uncertainty
100-630	± 0,15
800-1250	± 0,10
1600-2500	± 0,15
3150-5000	± 0,20

<sup>1)</sup> The figures are calculated from twice the standard deviations, rounded to the nearest 0,05. The data from the Round Robin is documented in a letter from the ASTM to the participating laboratories.

## Test room

A reverberation room with the dimensions 7,64 m x 6,16 m x 4,25 m giving the volume 200 m<sup>3</sup> and the total surface area 211 m<sup>2</sup> was used.

## Mounting

The sound absorbing material was mounted according to figure 1 and 2 respectively on the floor in a frame with the dimensions 3,00 m\* 3,60 m. The frame was sealed to the floor with tape. The mounting depth is the distance between the floor and the upper surface of the test object as given in table 1 and the enclosures 1-2.



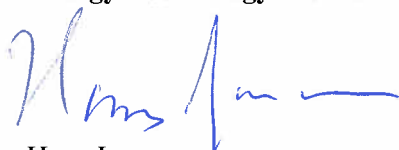
**Figure 1.**



**Figure 2**

**Instrumentation**

Instrument	Manufacturer	Type	Serial no.
Microphone	Brüel & Kjær	4943	503967
Microphone	Brüel & Kjær	4943	503326
Microphone	Brüel & Kjær	4943	503325
Microphone	Brüel & Kjær	4943	503324
Microphone	Brüel & Kjær	4943	503323
Microphone	Brüel & Kjær	4943	503322
Microphone Preamplifier	Brüel & Kjær	2619	970996
Microphone Preamplifier	Brüel & Kjær	2619	970948
Microphone Preamplifier	Brüel & Kjær	2619	469905
Microphone Preamplifier	Brüel & Kjær	2619	726792
Microphone Preamplifier	Brüel & Kjær	2619	726825
Microphone Preamplifier	Brüel & Kjær	2619	970968
Microphone Multiplexer	Norsonic	834	10050
Real-Time Analyzer	Norsonic	830	11533
Sound Level Calibrator	Brüel & Kjær	4230	1410947
Programme	SP	Absorp	960627
Power amplifier	PA1		
Noise generator	NG1 ( white noise )		
Loudspeakers	SP	HGT2, HGT7, HGT4, HGTtak	
Hygrometer	Vaisala	HM 132	42154
Temperature meter	Vaisala	HM 132	42154

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Energy Technology - Acoustics**


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Technical Manager



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**Appendices**

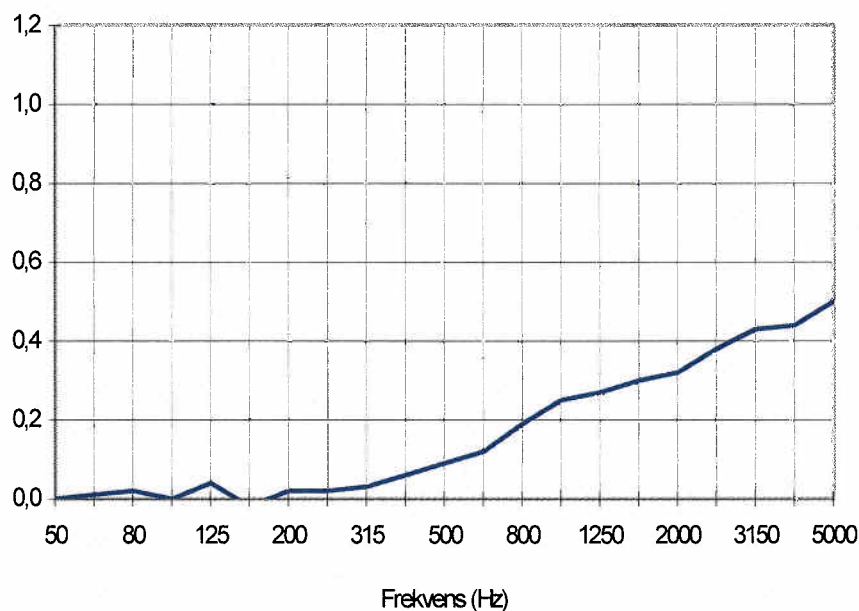


## Appendix 1

## Measurement of sound absorption

Test	Measurement of sound absorption coefficient in a reverberation room according to EN ISO 354 and evaluation according to EN ISO 11654
Client	Abstracta Anders Karlsson
Object	Stiff felt drapery composed of smaller elements according to figure 1. Thickness of elements: 5 mm.
Date of test	April 5, 2007
Conditions	Mounting depth: 100 mm. Surface area: 10,8 m <sup>2</sup> . Room volume: 200 m <sup>3</sup> . Temperature during measurements on object/in empty room: 20/20 °C. Relative humidity during measurements on object/in empty room: 85/85 %.
Results	Sound absorption class: <b>E</b> . Weighted sound absorption coefficient $\alpha_w = \mathbf{0,2(H)}$ .

### Sound absorption coefficient



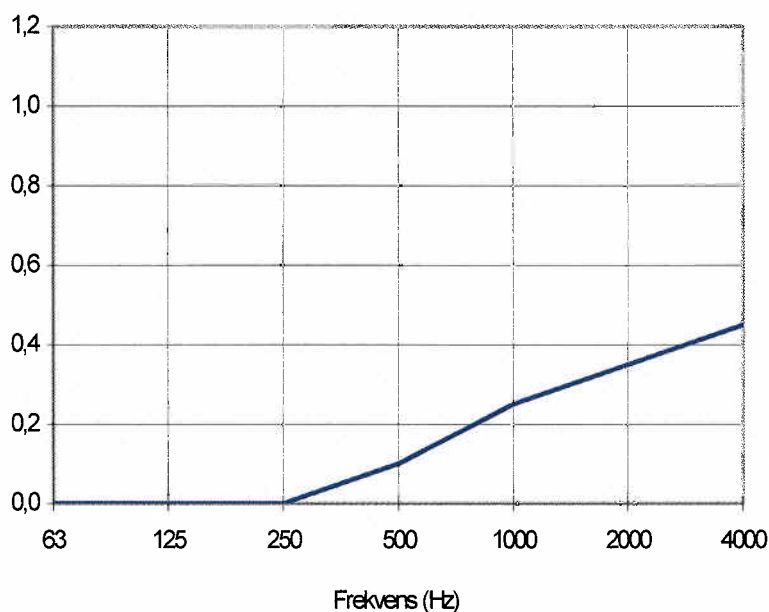
Frekvens (Hz)	$\alpha_s$
50	0,00
63	0,01
80	0,02
100	0,00
125	0,04
160	-0,02
200	0,02
250	0,02
315	0,03
400	0,06
500	0,09
630	0,12
800	0,19
1000	0,25
1250	0,27
1600	0,30
2000	0,32
2500	0,38
3150	0,43
4000	0,44
5000	0,50

## Appendix 1

## Measurement of sound absorption

Test	Measurement of sound absorption coefficient in a reverberation room according to EN ISO 354 and evaluation according to EN ISO 11654
Client	Abstracta Anders Karlsson
Object	Stiff felt drapery composed of smaller elements according to figure 1. Thickness of elements: 5 mm.
Date of test	April 5, 2007
Conditions	Mounting depth: 100 mm. Surface area: 10,8 m <sup>2</sup> . Room volume: 200 m <sup>3</sup> . Temperature during measurements on object/in empty room: 20/20 °C. Relative humidity during measurements on object/in empty room: 85/85 %.
Results	Sound absorption class: <b>E</b> . Weighted sound absorption coefficient $\alpha_w = \mathbf{0,2(H)}$ .

### Practical sound absorption coefficient



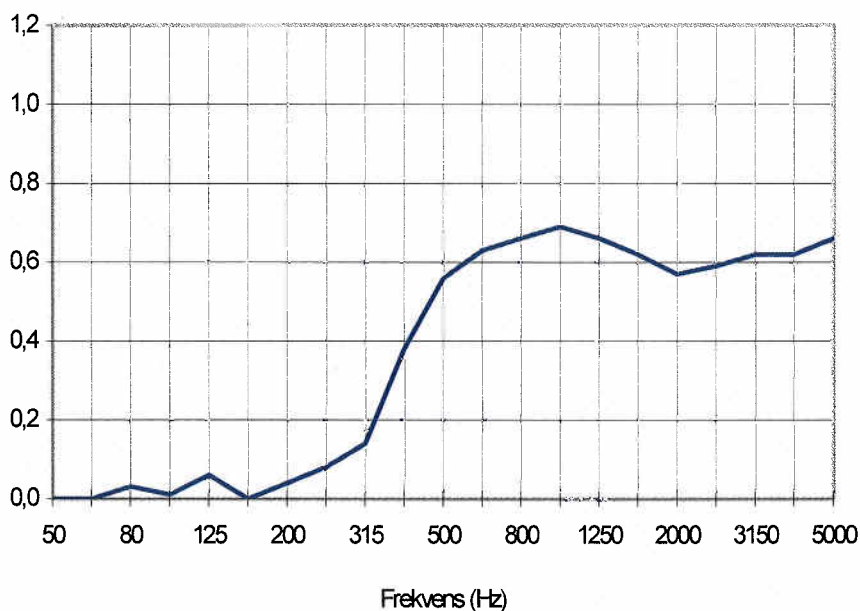
Frekvens (Hz)	$\alpha_p$
63	0,00
125	0,00
250	0,00
500	0,10
1000	0,25
2000	0,35
4000	0,45

## Appendix 2

### Measurement of sound absorption

Test	Measurement of sound absorption coefficient in a reverberation room according to EN ISO 354 and evaluation according to EN ISO 11654
Client	Abstracta Anders Karlsson
Object	Stiff felt drapery composed of smaller elements according to figure 2. Thickness of elements: 5 mm.
Date of test	April 5, 2007
Conditions	Mounting depth: 100 mm. Surface area: 10,8 m <sup>2</sup> . Room volume: 200 m <sup>3</sup> . Temperature during measurements on object/in empty room: 20/20 °C. Relative humidity during measurements on object/in empty room: 85/85 %.
Results	Sound absorption class: <b>D</b> . Weighted sound absorption coefficient $\alpha_w = 0,4(\text{MH})$ .

#### Sound absorption coefficient



Frekvens (Hz)	$\alpha_s$
50	0,00
63	0,00
80	0,03
100	0,01
125	0,06
160	0,00
200	0,04
250	0,08
315	0,14
400	0,38
500	0,56
630	0,63
800	0,66
1000	0,69
1250	0,66
1600	0,62
2000	0,57
2500	0,59
3150	0,62
4000	0,62
5000	0,66

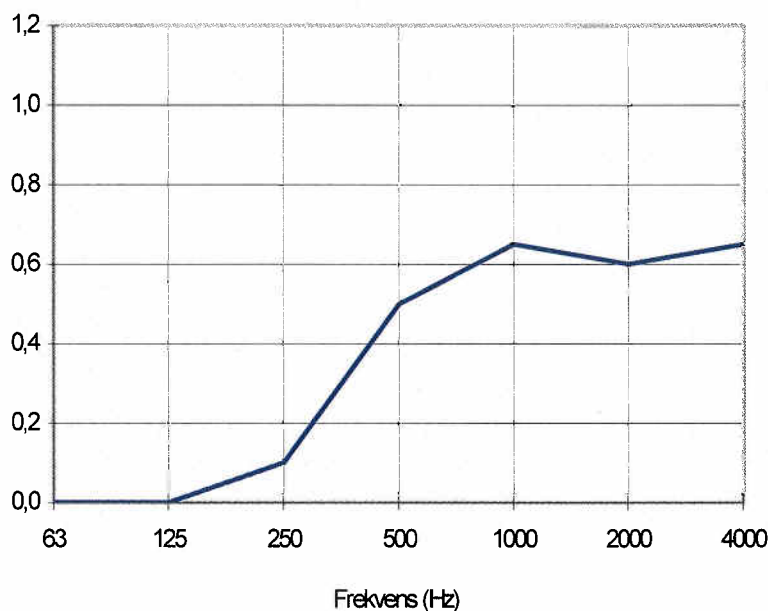
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## Appendix 2

## Measurement of sound absorption

Test	Measurement of sound absorption coefficient in a reverberation room according to EN ISO 354 and evaluation according to EN ISO 11654
Client	Abstracta Anders Karlsson
Object	Stiff felt drapery composed of smaller elements according to figure 2. Thickness of elements: 5 mm.
Date of test	April 5, 2007
Conditions	Mounting depth: 100 mm. Surface area: 10,8 m <sup>2</sup> . Room volume: 200 m <sup>3</sup> . Temperature during measurements on object/in empty room: 20/20 °C. Relative humidity during measurements on object/in empty room: 85/85 %.
Results	Sound absorption class: <b>D</b> . Weighted sound absorption coefficient $\alpha_w = 0,4(\text{MH})$ .

### Practical sound absorption coefficient



Frekvens (Hz)	$\alpha_p$
63	0,00
125	0,00
250	0,10
500	0,50
1000	0,65
2000	0,60
4000	0,65

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## Determination of sound absorption coefficients of an office screen in a reverberation room according to ISO 354 and NT ACOU 085 (2 appendices)

### Client

Abstracta AB

### Test objects

Two office screens designated: DoReMi + Alumi screen

The dimensions of the screen elements was: height: 1,50 m, width: 1,40 m.  
The screen had a 0,14 m gap between the floor and the underside of the screen.

The office screen was absorptive on both sides. Two screens were tested.

### Arrival of test objects

November 9, 2005

### Date of test

November 15, 2005

### Results

The sound absorption coefficient ( $\alpha_s$ ) are given in enclosure 1. The weighted sound absorption coefficient ( $\alpha_w$ ) and the sound absorption classes have been calculated according to NT ACOU 085 and can be seen in table 1. The sound absorption coefficient has been calculated from the two-sided area of the test objects. The result is valid for the tested objects only.



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Table 1 - Summary of results

Office screen:	NT ACOU 085		Enclosure
	Absorption class	$\alpha_w$	
DoReMi	B	0,80	1

### Measurement method + Alumi screen

The measurements have been carried out according to ISO 354:1985 and SS 02 52 61. The evaluation is based on NT ACOU 085. 4 loudspeakers and 6 microphones have been used giving 24 different combinations. For empty room 3 decays have been used for averaging the time and for test objects 5 decays have been used, for each combination of loudspeaker and microphone.

The absorption coefficient  $\alpha_s$  has been evaluated from:

$$\alpha_s = \frac{55,3V}{c \cdot S} \left( \frac{1}{T_2} - \frac{1}{T_1} \right)$$

where

- $V$  = Volume of the reverberation room (m<sup>3</sup>)
- $S$  = Area of the test object (m<sup>2</sup>)
- $c$  = Speed of sound in air (m/s)
- $c$  =  $331 + 0.6t$
- $t$  = Temperature in the air (°C)
- $T_1$  = Reverberation time of the room without test object (s)
- $T_2$  = Reverberation time of the room with test object (s)

### Measurement uncertainty

From a world wide Round Robin<sup>1)</sup>, in which SP took part, with 23 participating laboratories from 11 countries, the following measurement uncertainty has been calculated.

Frequencies	
(Hz)	Uncertainty
100-630	± 0,15
800-1250	± 0,10
1600-2500	± 0,15
3150-5000	± 0,20

<sup>1)</sup> The figures are calculated from twice the standard deviations, rounded to the nearest 0,05. The data from the Round Robin is documented in a letter from the ASTM to the participating laboratories.

### Test room

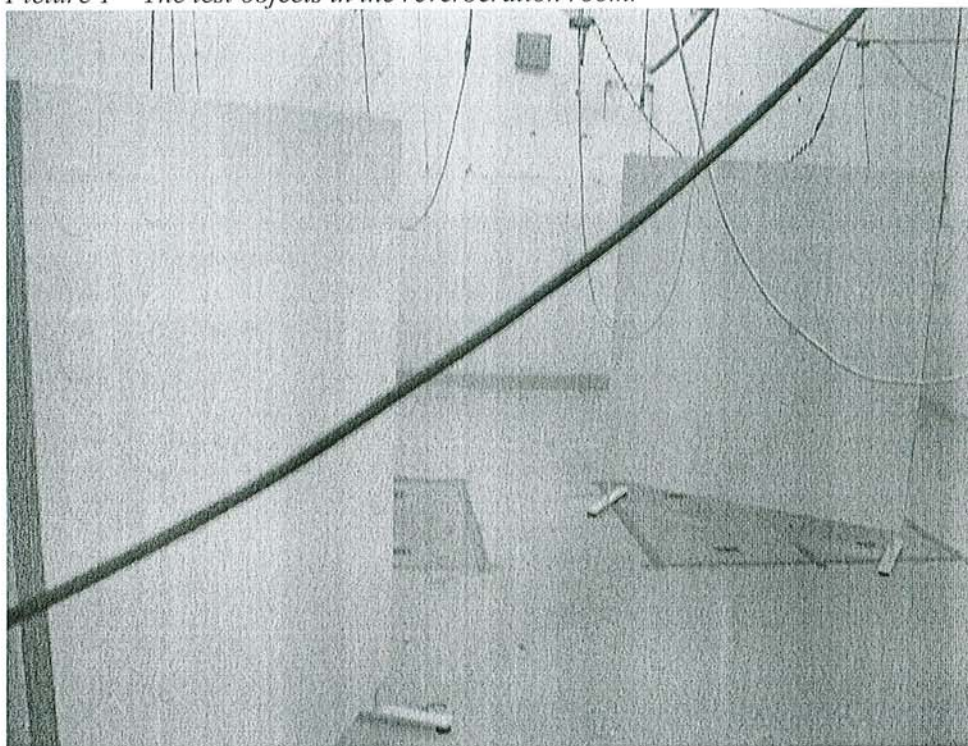
A reverberation room with the dimensions 7,64 m x 6,16 m x 4,25 m giving the volume 200 m<sup>3</sup> and the total surface area 211 m<sup>2</sup> was used. The suspended diffusers have been arranged according to the Nordtest method NT ACOU 012 and SS-ISO 354.



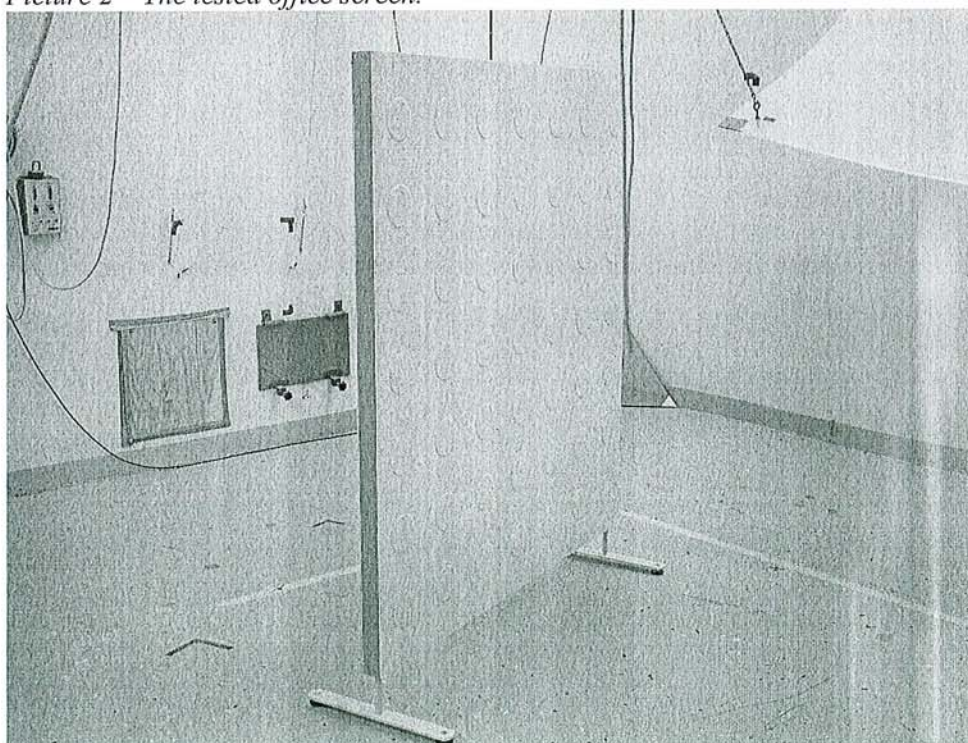
## Mounting

The office screen elements were placed in a reverberation room. They had a distance of at least 1 m to the nearest wall.

*Picture 1 – The test objects in the reverberation room.*



*Picture 2 – The tested office screen.*



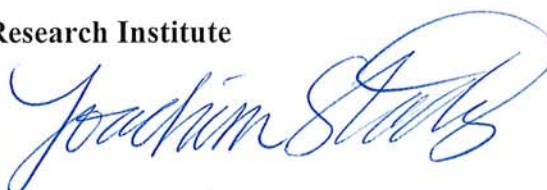
## List of instruments

Instrument	Manufacturer	Type	SP no / Serial no
Microphone	Brüel & Kjaer	4943	503327
Microphone	Brüel & Kjaer	4943	503326
Microphone	Brüel & Kjaer	4943	503325
Microphone	Brüel & Kjaer	4943	503324
Microphone	Brüel & Kjaer	4943	503323
Microphone	Brüel & Kjaer	4166	500736
Microphone Preamplifier	Brüel & Kjaer	2619	970996
Microphone Preamplifier	Brüel & Kjaer	2619	970948
Microphone Preamplifier	Brüel & Kjaer	2619	469905
Microphone Preamplifier	Brüel & Kjaer	2619	726792
Microphone Preamplifier	Brüel & Kjaer	2619	726825
Microphone Preamplifier	Brüel & Kjaer	2619	970968
Microphone Multiplexer	Norsonic	834	10050
Real-Time Analyzer	Norsonic	830	11533
Sound Level Calibrator	Brüel & Kjaer	4230	1410947
Programme	SP	Absorp	960627
Power amplifier	PA1		
Noise generator	NG1 ( white noise )		
Loudspeakers	SP	HGT2, HGT7, HGT4, HGTak	
Hygrometer	Vaisala	HM 132	42154
Temperature meter	Vaisala	HM 132	42154

**SP Swedish National Testing and Research Institute**  
**Energy Technology - Acoustics**



Håkan Andersson  
 Technical Manager



Joachim Stadig  
 Technical Officer

## Appendices



## Appendix 1

**Measurement of sound absorption coefficient**

Test Measurement of sound absorption coefficient in a reverberation room according to SS-EN 20354 (ISO 354).

Client Abstracta AB

Object Office screens designated: DoReMi. **+ Alumi screen**  
Height: 1,50 m. width: 1,40 m. The screens had a 0,14 m gap between the floor and the underside of the screen.

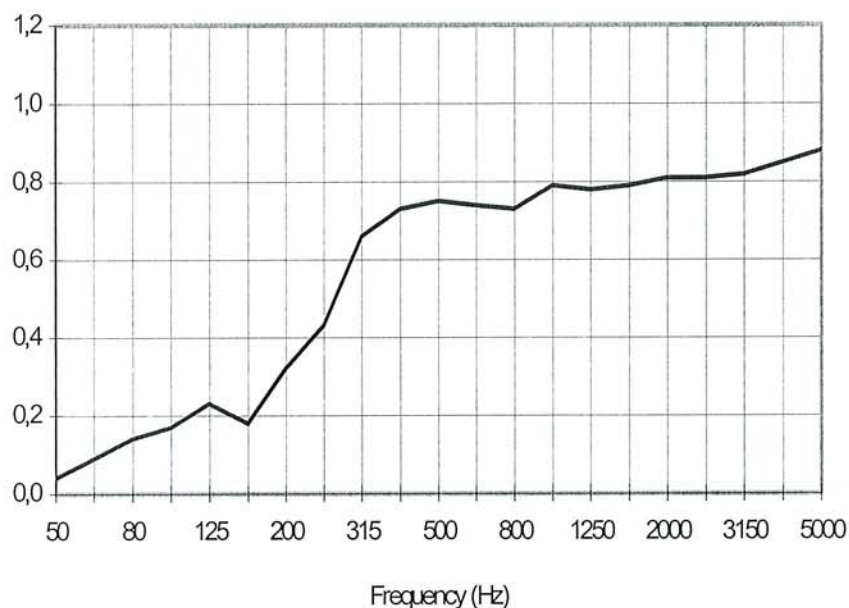
Date of test November 15, 2005

Conditions Two-sided surface area: 8,40 m<sup>2</sup> (2 office screens).  
Room volume: 200 m<sup>3</sup>.  
Temperature at measurement on object/in empty room: 20/ 20 °C.  
Relative humidity at measurement on object/in empty room: 82/ 82 %.

Result *Sound absorption class according to NT ACOU 085: **B***  
*Weighted sound absorption coefficient  $\alpha_w$ , according to NT ACOU 085: **0,80***

Sound absorption class C according to EN ISO 11654.  
Weighted sound absorption coefficient  $\alpha_w = 0,75$  according to EN ISO 11654.

Sound absorption coefficient



Frequency (Hz)	$\alpha_s$
50	0,04
63	0,09
80	0,14
100	0,17
125	0,23
160	0,18
200	0,32
250	0,43
315	0,66
400	0,73
500	0,75
630	0,74
800	0,73
1000	0,79
1250	0,78
1600	0,79
2000	0,81
2500	0,81
3150	0,82
4000	0,85
5000	0,88

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## Measurement of sound absorption coefficient

Test Measurement of sound absorption coefficient in a reverberation room according to SS-EN 20354 (ISO 354).

Client Abstracta AB

Object Office screens designated: DoReMi. **+ Alumi screen**  
Height: 1,50 m. width: 1,40 m. The screens had a 0,14 m gap between the floor and the underside of the screen.

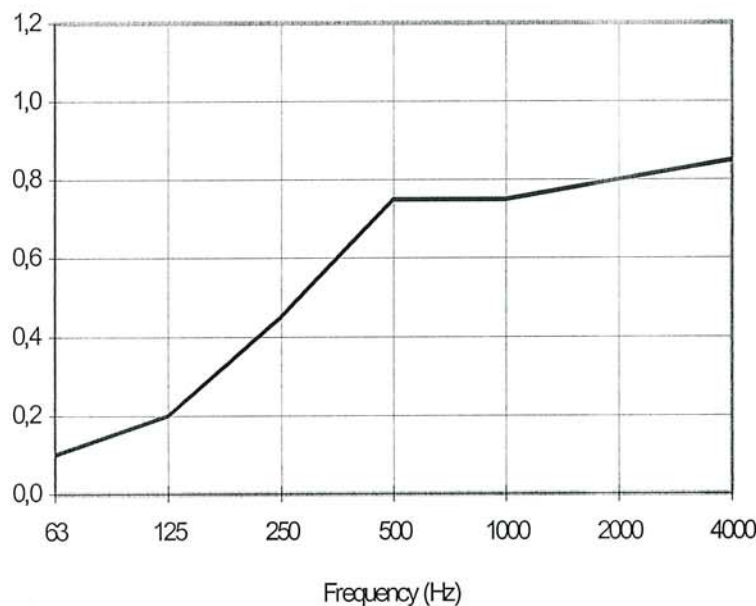
Date of test November 15, 2005

Conditions Two-sided surface area: 8,40 m<sup>2</sup> (2 office screens).  
Room volume: 200 m<sup>3</sup>.  
Temperature at measurement on object/in empty room: 20/ 20 °C.  
Relative humidity at measurement on object/in empty room: 82/ 82 %.

Result *Sound absorption class according to NT ACOU 085: **B***  
*Weighted sound absorption coefficient  $\alpha_w$ , according to NT ACOU 085: **0,80***

Sound absorption class C according to EN ISO 11654.  
Weighted sound absorption coefficient  $\alpha_w = 0,75$  according to EN ISO 11654.

Practical sound absorption coefficient



Frequency (Hz)	$\alpha_p$
63	0,10
125	0,20
250	0,45
500	0,75
1000	0,75
2000	0,80
4000	0,85

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## **Determination of sound absorption coefficients of an office screen in a reverberation room according to ISO 354 and NT ACOU 085 (2 appendices)**

### **Client**

Abstracta AB

### **Test objects**

Three office screens designated: SOFTLINE

The dimensions of the screen elements were: height: 1,70 m, width: 1,00 m.  
The screen had a 0,10 m gap between the floor and the underside of the screen.

The office screen was absorptive on both sides. Three screens were tested.

### **Arrival of test objects**

November 9, 2005

### **Date of test**

November 15, 2005

### **Results**

The sound absorption coefficient ( $\alpha_s$ ) are given in enclosure 1. The weighted sound absorption coefficient ( $\alpha_w$ ) and the sound absorption classes have been calculated according to NT ACOU 085 and can be seen in table 1. The result is valid for the tested objects only.



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Table 1 - Summary of results

Office screen:	NT ACOU 085		Enclosure
	Absorption class	$\alpha_w$	
SOFTLINE	A	0,90	1

### Measurement method

The measurements have been carried out according to ISO 354:1985 and SS 02 52 61. The evaluation is based on NT ACOU 085. 4 loudspeakers and 6 microphones have been used giving 24 different combinations. For empty room 3 decays have been used for averaging the time and for test objects 5 decays have been used, for each combination of loudspeaker and microphone.

The absorption coefficient  $\alpha_s$  has been evaluated from:

$$\alpha_s = \frac{55,3V}{c \cdot S} \left( \frac{1}{T_2} - \frac{1}{T_1} \right)$$

where

- $V$  = Volume of the reverberation room (m<sup>3</sup>)
- $S$  = Area of the test object (m<sup>2</sup>)
- $c$  = Speed of sound in air (m/s)
- $c$  =  $331 + 0.6t$
- $t$  = Temperature in the air (°C)
- $T_1$  = Reverberation time of the room without test object (s)
- $T_2$  = Reverberation time of the room with test object (s)

### Measurement uncertainty

From a world wide Round Robin<sup>1)</sup>, in which SP took part, with 23 participating laboratories from 11 countries, the following measurement uncertainty has been calculated

Frequencies	
(Hz)	Uncertainty
100-630	± 0,15
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### Test room

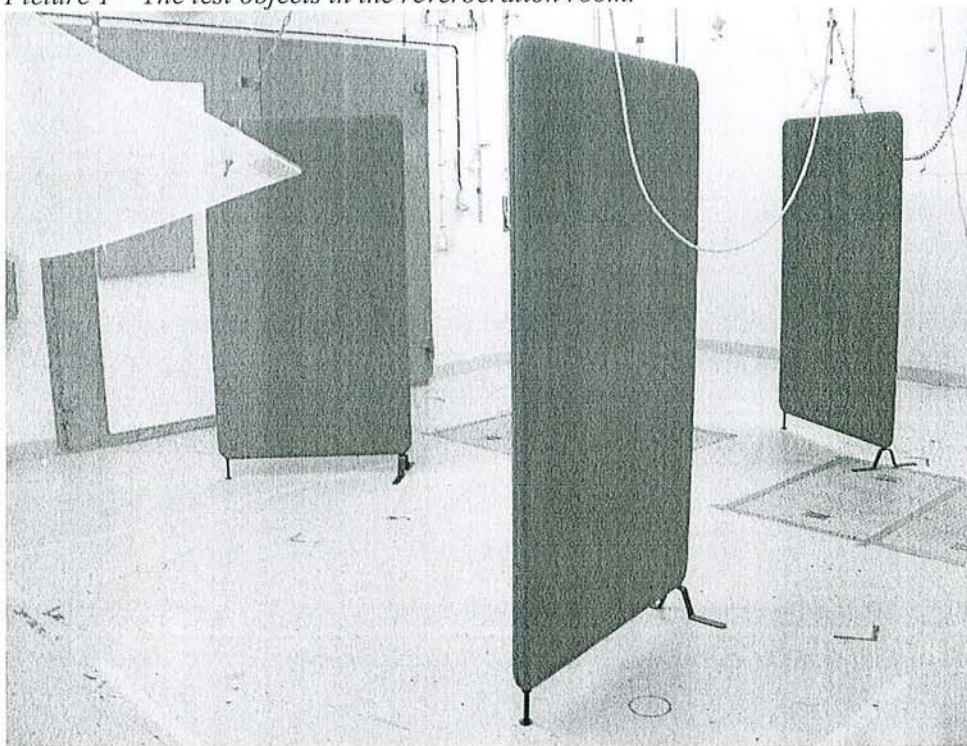
A reverberation room with the dimensions 7,64 m x 6,16 m x 4,25 m giving the volume 200 m<sup>3</sup> and the total surface area 211 m<sup>2</sup> was used. The suspended diffusers have been arranged according to the Nordtest method NT ACOU 012 and SS-ISO 354.



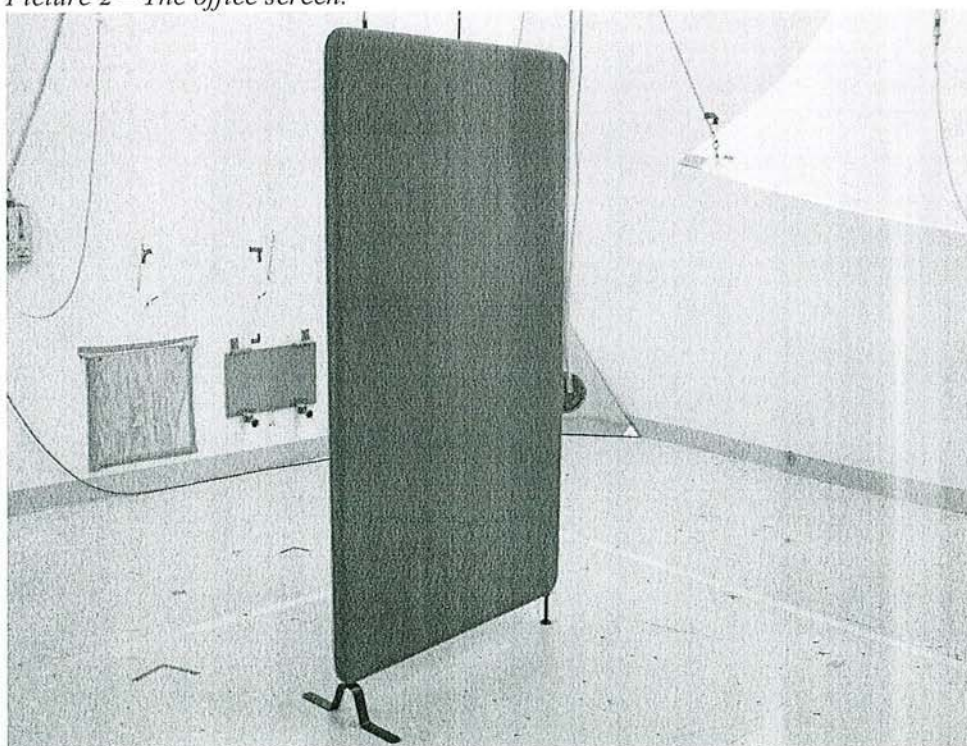
## Mounting

The office screen elements were placed in a reverberation room. They had a distance of at least 1 m to the nearest wall.

*Picture 1 – The test objects in the reverberation room.*



*Picture 2 – The office screen.*



## List of instruments

Instrument	Manufacturer	Type	SP no / Serial no
Microphone	Brüel & Kjaer	4943	503327
Microphone	Brüel & Kjaer	4943	503326
Microphone	Brüel & Kjaer	4943	503325
Microphone	Brüel & Kjaer	4943	503324
Microphone	Brüel & Kjaer	4943	503323
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Microphone Preamplifier	Brüel & Kjaer	2619	970996
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Microphone Multiplexer	Norsonic	834	10050
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Hygrometer	Vaisala	HM 132	42154
Temperature meter	Vaisala	HM 132	42154

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Technical Officer

## Appendices



## Measurement of sound absorption coefficient

Test Measurement of sound absorption coefficient in a reverberation room according to SS-EN 20354 (ISO 354).

Client Abstracta AB

Object Office screens designated: SOFTLINE  
Height: 1,70 m, width: 1,00 m. The screens had a 0,10 m gap between the floor and the underside of the screen.

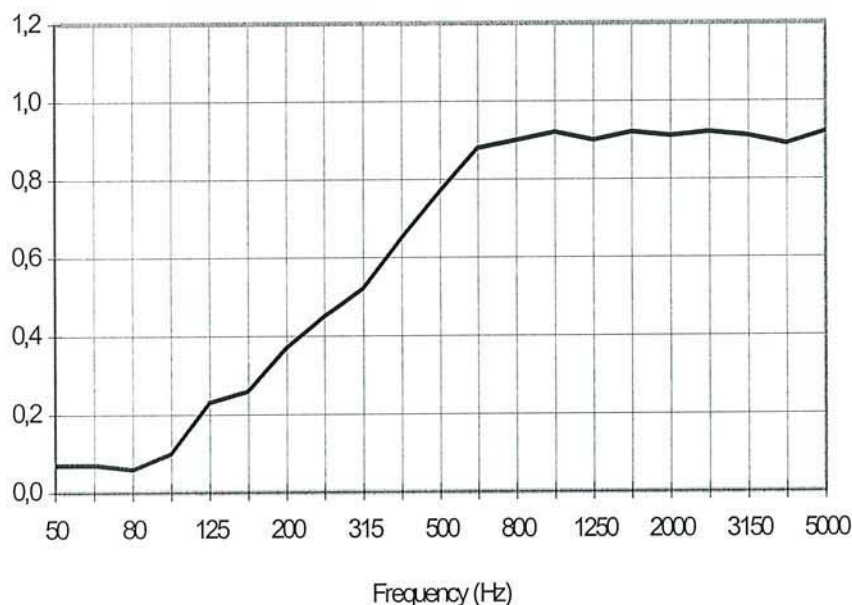
Date of test November 15, 2005

Conditions Two-sided surface area: 10,20 m<sup>2</sup> (3 office screens).  
Room volume: 200 m<sup>3</sup>.  
Temperature at measurement on object/in empty room: 20/ 20 °C.  
Relative humidity at measurement on object/in empty room: 82/ 82 %.

Result *Sound absorption class according to NT ACOU 085: A*  
*Weighted sound absorption coefficient  $\alpha_w$ , according to NT ACOU 085: 0,90*

Sound absorption class C according to EN ISO 11654.  
Weighted sound absorption coefficient  $\alpha_w = 0,75(H)$  according to EN ISO 11654

Sound absorption coefficient



Frequency (Hz)	$\alpha_s$
50	0,07
63	0,07
80	0,06
100	0,10
125	0,23
160	0,26
200	0,37
250	0,45
315	0,52
400	0,65
500	0,77
630	0,88
800	0,90
1000	0,92
1250	0,90
1600	0,92
2000	0,91
2500	0,92
3150	0,91
4000	0,89
5000	0,92

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## Appendix 1

**Measurement of sound absorption coefficient**

Test Measurement of sound absorption coefficient in a reverberation room according to SS-EN 20354 (ISO 354).

Client Abstracta AB

Object Office screens designated: SOFTLINE  
Height: 1,70 m, width: 1,00 m. The screens had a 0,10 m gap between the floor and the underside of the screen.

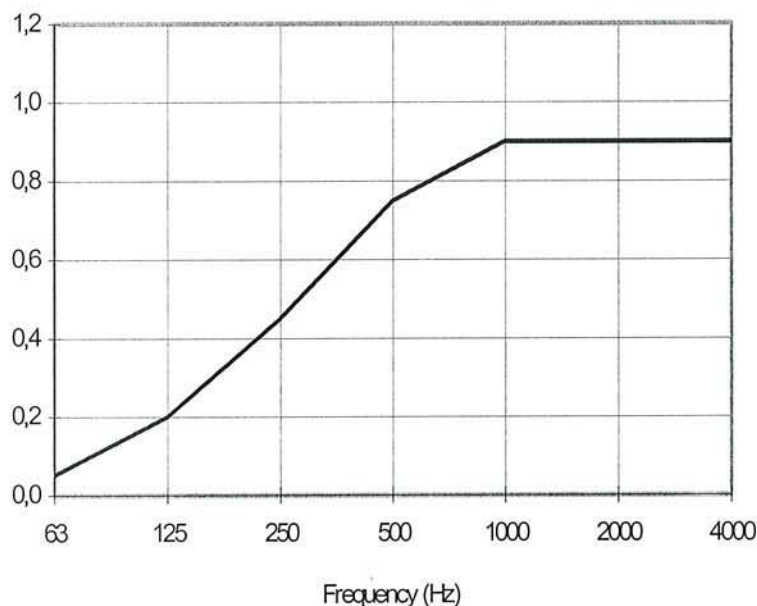
Date of test November 15, 2005

Conditions Two-sided surface area: 10,20 m<sup>2</sup> (3 office screens).  
Room volume: 200 m<sup>3</sup>.  
Temperature at measurement on object/in empty room: 20/ 20 °C.  
Relative humidity at measurement on object/in empty room: 82/ 82 %.

Result *Sound absorption class according to NT ACOU 085: A*  
*Weighted sound absorption coefficient  $\alpha_w$ , 0,90*  
*According to NT ACOU 085:*

Sound absorption class C according to EN ISO 11654.  
Weighted sound absorption coefficient  $\alpha_w = 0,75(H)$  according to EN ISO 11654

Practical sound absorption coefficient



Frequency (Hz)	$\alpha_p$
63	0,05
125	0,20
250	0,45
500	0,75
1000	0,90
2000	0,90
4000	0,90

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