



HOCHSCHULE FÜR UNIVERSITY OF
TECHNIK STUTTGART APPLIED SCIENCES

Joseph-von-Egle Institute
for Applied Research

Project No.: 122 007 04P-101

**Determining the sound absorption of free-standing luminaires with
reflection and acoustics screen in a reverberation chamber according to DIN
EN ISO 354**

Analyses conducted on behalf of
Herbert Waldmann GmbH & Co. KG
Peter-Henlein-Strasse 5
D-78056 Villingen-Schwenningen

Report No. 122 007 04P-101

University of Applied Sciences of Stuttgart
Joseph-von-Egle Institute for Applied Research
Schellingstraße 24, 70174 Stuttgart

1. Location and date of measurements

The measurements were conducted on 3/20/2008 in the reverberation chamber of the sound technology laboratory of the University of Applied Sciences (HFT) of Stuttgart, Center for Building Physics, Pfaffenwaldring 10a, 70569 Stuttgart-Vaihingen.

2. Sampling

The test objects were delivered and set up on 3/20/2008 by employees of the manufacturer.

3. Test objects

- 1) TYCOON free-standing luminaire, STRAIGHT, EOS STRUCTURELAB RX 1 reflection and acoustics screen system.

Free-standing luminaire with STRUCTURELAB reflection and acoustics screen RX1 – Z – 125O (125 cm x 125 cm), reflectance value 65%. Covering made of coated fiberglass cloth, opaque, weight approx. 410 g/m². Distance of screen to upper luminaire edge approx. 30 cm, total height approx. 2.85 m. Figure 1 in Attachment 1 shows a sketch of the luminaire with screen, Figure 2 is a picture of the manufacturer, and Figure 3 a photograph of the luminaire in front of the reverberation chamber of HFT Stuttgart.

Measurements were conducted with two, three, and four luminaires in the reverberation chamber.

- 2) TYCOON free-standing luminaire, STRAIGHT, EOS STRUCTURELAB RX 1 reflection and acoustics screen system.

Free-standing luminaire with STRUCTURELAB reflection and acoustics screen RX1 – Z – 125T (125 cm x 125 cm), reflectance value 35%. Covering made of PVDF fabric, translucent, weight approx. 240 g/m². Distance of screen to upper luminaire edge approx. 30 cm, total height approx. 2.85 m. Figure 4 in Attachment 1 shows a photograph of the luminaire in the reverberation chamber of HFT Stuttgart.

One measurement was carried out with one luminaire in the reverberation chamber.

4. Testing methods

The measurements were carried out in a reverberation chamber based on DIN EN ISO 354, Version 12/2003, while taking Appendices A, B, and ZA into consideration. In the method applied, the noise was cut out. The luminaires with screens were regarded as individual objects in accordance with section 6.2.2 and arranged irregularly in the reverberation chamber. The determinations included the equivalent sound absorption surface AT for two, three, and four luminaires in the reverberation chamber. The distance of the luminaires was > 2 m for two and three luminaires in the reverberation chamber, and > 1.50 m for four luminaires in the reverberation chamber.

The change in the equivalent sound absorption surface A of between 1 m² and 12 m² required according to the standard was not achieved, even with four luminaires in the reverberation chamber. The absorption of the individual objects is too low.

The equivalent sound absorption surface $A_{Obj.}$ for an individual object was determined based on the following relation:

The equivalent sound absorption surface $A_{Obj.}$ for an individual object was determined based on the following relation:

$$A_{Obj.} = A_T/n$$

with:

$$A_T = A_2 - A_1 = 55.3 V (1/c_2 T_2 - 1/c_1 T_1) - 4 V (m_2 - m_1)$$

with the following meanings:

- $A_{Obj.}$ = equivalent sound absorption surface for an individual object (in this case, a partition) in m²;
- A_T = equivalent sound absorption surface of the test object in m²;
- n = number of individual objects;
- A_1 = equivalent sound absorption surface of the empty reverberation chamber in m²;
- A_2 = equivalent sound absorption surface of the reverberation chamber with test object in m²;
- S = surface of the test object in m²;
- V = volume of the empty reverberation chamber in m³;
- c_1 = speed of sound in the air in m/s at the temperature T_1 ;
- c_2 = speed of sound in the air in m/s at the temperature T_2 ;
- T_1 = reverberation time of the empty reverberation chamber in s;
- T_2 = reverberation time of the reverberation chamber after introducing the test object in s;
- $m_{1/2}$ = atmospheric absorption coefficient in 1/m, calculated for the climatic conditions present during the respective measurement.

Climatic conditions:

Empty reverberation chamber

Temperature: 18.4°C, relative humidity: 30%, atmospheric pressure: 957 hPa

Reverberation chamber with test object 1:

Temperature: 19.3°C, relative humidity: 30%, atmospheric pressure: 957 hPa,

Reverberation chamber with test object 2:

Temperature: 19.5°C, relative humidity: 30%, atmospheric pressure: 956 hPa

Test sound was pink noise.

In the empty state, the reverberation chamber has the following dimensions:

(L x W x H): 7.89m x 5.54m x 4.65m; V=203m³

The following measuring devices were used:

Analyzer:	Manufacturer: Norsonic	Type: 840	SN: 17816
Amplifier:	Manufacturer: Norsonic	Type: 215	SN: 708
Speaker:	Manufacturer: Norsonic	Type: 229	SN: 15013
2x Pre-amplifiers:	Manufacturer: Norsonic	Type: 1201	SN: 25346 SN: 26009
2x Microphones:	Manufacturer: Norsonic	Type: 1220	SN: 24604 SN: 25533
Climate measurement:	Manufacturer: Testo	Type: 445	SN: 727451

The analyzer was calibrated by the Dortmund Board of Weights and Measurements on 12/12/2006.

5. Measurement results

Tables 1 to 4 list the mean values of the reverberation times T_1 in the empty reverberation chamber, T_2 in the reverberation chamber with the test objects and the equivalent sound absorption surface for an individual object A_{Obj} , as a function of the frequency. Attachment 2 shows a graph of the equivalent sound absorption surface A_T for two, three, and four luminaires in the reverberation chamber. Attachment 3 shows the equivalent sound absorption surface of the individual object A_{Obj} , for test body 1. The determination was made by arithmetic averaging of the results from the measurements with two, three, and four luminaires. Table 3 additionally lists the averaged equivalent sound absorption surface of the individual object for octave band steps. Attachment 4 shows the equivalent sound absorption surface of the individual object A_{Obj} , for test body 2.


The report comprises: 4 pages of text
4 tables
4 attachments

Publication of the report in excerpts requires the prior approval of the University of Applied Sciences of Stuttgart. The measurement results listed relate only to the tested object with the setup as outlined. The material information was provided by the client.

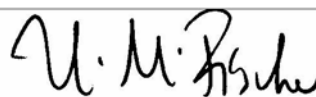
Stuttgart, March 28, 2008

Administrator:

Head of Lab:



Dipl.-Ing.(FH) A. Drechsler



Prof. Dr.-Ing. H.M. Fischer

Frequency [Hz]	T ₁ [s]	T ₂ [s]	A _{Obj.} [m ²]	A _{Obj.} [m ²]
100	13.82	12.56	0.12	-
125	11.81	9.81	0.28	0.25
160	11.92	9.55	0.34	-
200	12.39	9.24	0.45	-
250	11.17	7.70	0.66	0.60
315	10.85	7.49	0.68	-
400	9.26	6.31	0.83	-
500	7.56	5.14	1.02	0.99
630	6.78	4.65	1.11	-
800	6.95	4.73	1.11	-
1000	6.65	4.61	1.11	1.17
1250	6.01	4.10	1.30	-
1600	5.38	3.75	1.36	-
2000	4.73	3.42	1.39	1.37
2500	3.89	3.00	1.36	-
3150	3.08	2.51	1.41	-
4000	2.37	1.99	1.57	1.57
5000	1.80	1.57	1.72	-

Table 1: Mean values of the reverberation times T₁ in the empty reverberation chamber, T₂ in the reverberation chamber with test object 1 and equivalent sound absorption surface for an element A_{Obj.} as a function of the frequency (one-third octave values and octave values). The test object 1 in this example were two TYCOON free-standing luminaires, STRAIGHT, EOS, with STRUCTURELAB reflection and acoustics screen RX1 – Z – 125O (125 cm x 125 cm), reflectance value 65%, covering made of coated fiberglass cloth, opaque, weight approx. 410 g/m².

Frequency [Hz]	T ₁ [s]	T ₂ [s]	A _{Obj.} [m ²]	A _{Obj.} [m ²]
100	13.82	11.45	0.16	-
125	11.81	9.00	0.29	0.28
160	11.92	8.40	0.38	-
200	12.39	8.16	0.46	-
250	11.17	6.73	0.65	0.59
315	10.85	6.56	0.66	-
400	9.26	5.38	0.85	-
500	7.56	4.61	0.92	0.95
630	6.78	4.06	1.08	-
800	6.95	4.08	1.11	-
1000	6.65	3.84	1.21	1.22
1250	6.01	3.48	1.34	-
1600	5.38	3.26	1.35	-
2000	4.73	3.00	1.38	1.37
2500	3.89	2.66	1.38	-
3150	3.08	2.29	1.36	-
4000	2.37	1.88	1.39	1.46
5000	1.80	1.47	1.63	-

Table 2: Mean values of the reverberation times T₁ in the empty reverberation chamber, T₂ in the reverberation chamber with test object 1 and equivalent sound absorption surface for an element A_{Obj.} as a function of the frequency (one-third octave values and octave values). The test object 1 in this example were three TYCOON free-standing luminaires, STRAIGHT, EOS, with STRUCTURELAB reflection and acoustics screen RX1 – Z – 125O (125 cm x 125 cm), reflectance value 65%, covering made of coated fiberglass cloth, opaque, weight approx. 410 g/m².

Frequency [Hz]	T ₁ [s]	T ₂ [s]	A _{Obj.} [m ²]	A _{Obj.} [m ²]	Mean value A _{Obj.} 2, 3, 4 luminaires
100	13.82	11.42	0.12	-	-
125	11.81	8.07	0.32	0.29	0.27
160	11.92	7.33	0.43	-	-
200	12.39	7.45	0.44	-	-
250	11.17	5.78	0.68	0.60	0.59
315	10.85	5.75	0.67	-	-
400	9.26	4.64	0.88	-	-
500	7.56	4.05	0.94	0.97	0.97
630	6.78	3.58	1.08	-	-
800	6.95	3.58	1.12	-	-
1000	6.65	3.44	1.16	1.18	1.19
1250	6.01	3.14	1.26	-	-
1600	5.38	2.92	1.32	-	-
2000	4.73	2.70	1.35	1.36	1.37
2500	3.89	2.39	1.40	-	-
3150	3.08	2.09	1.39	-	-
4000	2.37	1.71	1.51	1.51	1.51
5000	1.80	1.38	1.64	-	-

Table 3: Mean values of the reverberation times T₁ in the empty reverberation chamber, T₂ in the reverberation chamber with test object 1 and equivalent sound absorption surface for an element A_{Obj.} as a function of the frequency (one-third octave values and octave values). The test object 1 in this example were four TYCOON free-standing luminaires, STRAIGHT, EOS, with STRUCTURELAB reflection and acoustics screen RX1 – Z – 125O (125 cm x 125 cm), reflectance value 65%, covering made of coated fiberglass cloth, opaque, weight approx. 410 g/m². Also listed is the mean value for A_{Obj.} in octaves from the measurements with two, three, and four luminaires.

Frequency [Hz]	T ₁ [s]	T ₂ [s]	A _{Obj.} [m ²]	A _{Obj.} [m ²]
100	13.82	13.29	0.09	-
125	11.81	10.37	0.38	0.34
160	11.92	9.95	0.54	-
200	12.39	10.72	0.41	-
250	11.17	9.20	0.63	0.58
315	10.85	8.83	0.69	-
400	9.26	7.50	0.83	-
500	7.56	6.12	1.02	0.98
630	6.78	5.53	1.10	-
800	6.95	5.66	1.09	-
1000	6.65	5.41	1.15	1.20
1250	6.01	4.83	1.36	-
1600	5.38	4.44	1.33	-
2000	4.73	3.93	1.49	1.47
2500	3.89	3.32	1.59	-
3150	3.08	2.74	1.56	-
4000	2.37	2.16	1.67	1.76
5000	1.80	1.65	2.07	-

Table 4: Mean values of the reverberation times T₁ in the empty reverberation chamber, T₂ in the reverberation chamber with test object 2 and equivalent sound absorption surface for an element A_{Obj.} as a function of the frequency (one-third octave values and octave values). The test object 2 was one TYCOON free-standing luminaires, STRAIGHT, EOS, with STRUCTURELAB reflection and acoustics screen RX1 – Z – 125T (125 cm x 125 cm), reflectance value 35%, covering made of PVDF fabric, translucent, weight approx. 240 g/m².

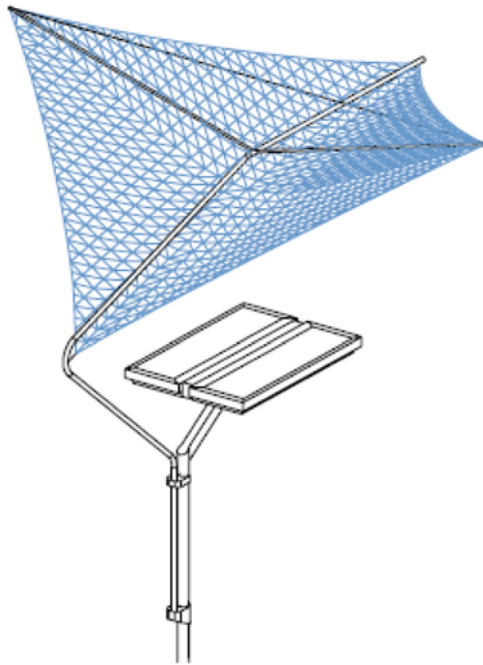


Figure 1: Sketch of test object 1



Figure 2: Photograph of the manufacturer of test object 1



Figure 3: Photograph of HFT Stuttgart of test object 1



Figure 4: Test object 2 in the reverberation chamber

Äquivalente Schallabsorptionsfläche A nach DIN EN ISO 354

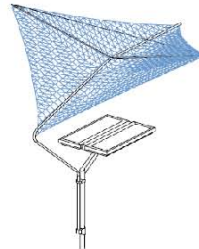
Messung der Schallabsorption in Hallräumen

Anlage 2

122 007 04P-101

Auftraggeber: Herbert Waldmann GmbH & Co. KG, D-78056 Villingen Schwenningen
 Herstellung & Vertrieb: Herbert Waldmann GmbH & Co. KG, D-78056 Villingen Schwenningen
 Idee, Design & Entwicklung: STRUCTURELAB Architekten
 Segel: STRUCTURELAB Architekten
 Prüfobjekt: Stehleuchten TYCOON, STRAIGHT, EOS

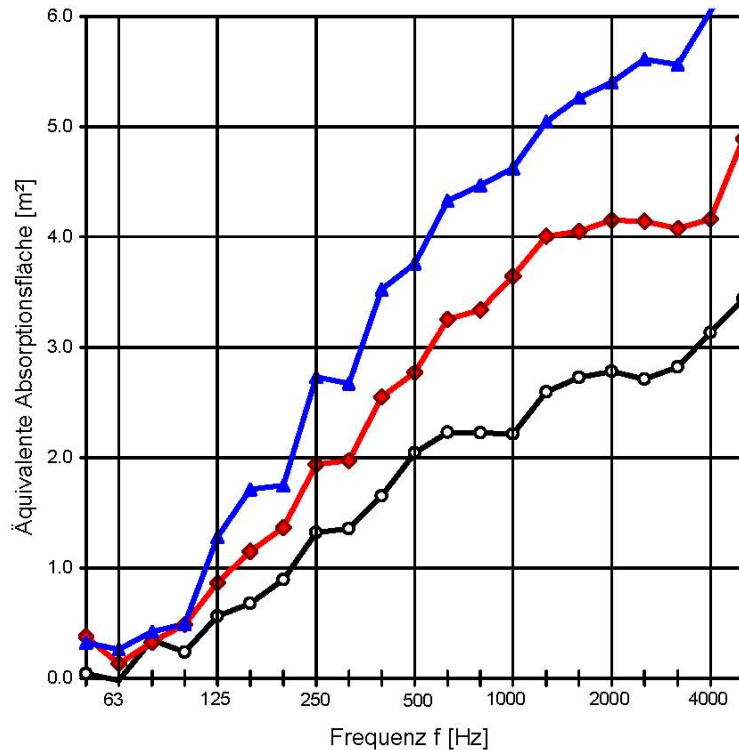
mit Reflektions- und Akustiksegel STRUCTURELAB RX1-Z-1250 (125 cm x 125 cm), Reflektionsgrad 65%.
 Bespannung beschichtetes Glasfasergewebe, opak, Gewicht ca. 410 g/m².
 Abstand Segel zur Leuchtenoberkante ca. 30 cm, Gesamthöhe ca. 2.85 m.
 Die Messungen erfolgten in Anlehnung an die Norm.



Volumen Hallraum: $V_S = 203.0 \text{ m}^3$
 Prüffläche (Segel): 1.56 m^2

- 1 — 2 Leuchten mit Segel
- 2 — 3 Leuchten mit Segel
- 3 — 4 Leuchten mit Segel

Frequenz [Hz]	A ₁ [m ²]	A ₂ [m ²]	A ₃ [m ²]
50	0.04	0.38	0.32
63	-0.02	0.13	0.26
80	0.34	0.32	0.42
100	0.23	0.49	0.49
125	0.56	0.86	1.28
160	0.68	1.15	1.71
200	0.90	1.37	1.75
250	1.32	1.94	2.73
315	1.36	1.97	2.67
400	1.65	2.55	3.52
500	2.04	2.77	3.76
630	2.23	3.25	4.33
800	2.22	3.34	4.47
1000	2.22	3.64	4.63
1250	2.60	4.01	5.04
1600	2.73	4.05	5.26
2000	2.78	4.15	5.40
2500	2.71	4.14	5.61
3150	2.82	4.08	5.57
4000	3.13	4.16	6.04
5000	3.44	4.89	6.55



Prüfschall: Rosa Rauschen
 Empfangsfilter: Terzfilter

Die Ermittlung basiert auf Prüfstandsmessungen, die in Terzbändern gewonnen wurden.

Projektnummer: 122 007 04P-101
 Prüfdatum: 20.03.2008



Datum: 28.03.2008

Äquivalente Schallabsorptionsfläche A
nach DIN EN ISO 354
 Messung der Schallabsorption in Hallräumen

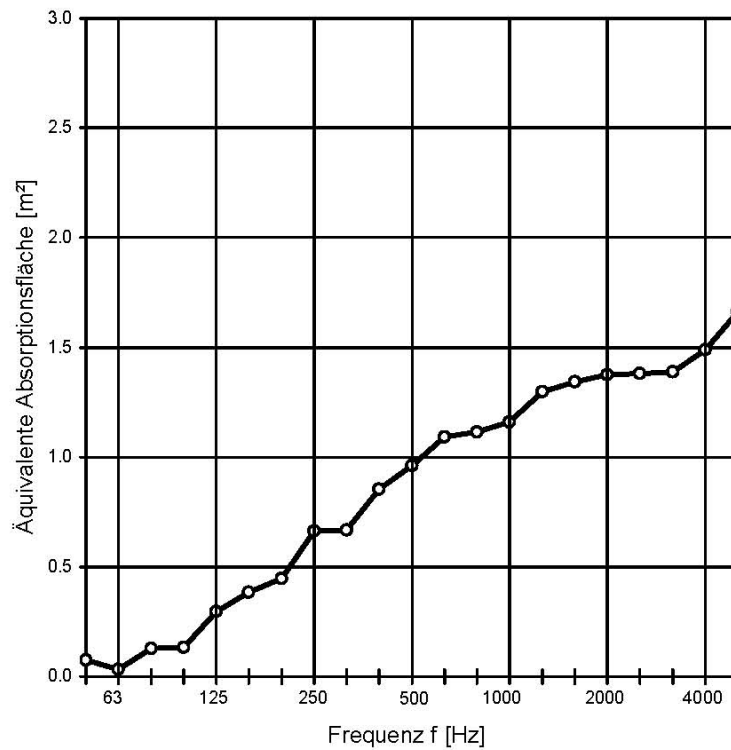
Anlage 3
 122 007 04P-101

Auftraggeber: Herbert Waldmann GmbH & Co. KG, D-78056 Villingen Schwenningen
 Herstellung & Vertrieb: Herbert Waldmann GmbH & Co. KG, D-78056 Villingen Schwenningen
 Idee, Design & Entwicklung
 Segel: STRUCTURELAB Architekten
 Prüfbjekt: Stehleuchten TYCOON, STRAIGHT, EOS
 mit Reflektions- und Akustiksegel STRUCTURELAB
 RX1-Z-125O (125 cm x 125 cm), Reflektionsgrad 65%.
 Bespannung beschichtetes Glasfasergewebe, opak,
 Gewicht ca. 410 g/m².
 Abstand Segel zur Leuchtenoberkante ca. 30 cm,
 Gesamthöhe ca. 2.85 m.
 Die Messungen erfolgten in Anlehnung an die Norm.
**Gemittelte äquivalente Absorptionsfläche für
 eine Leuchte, berechnet aus drei Messreihen
 mit zwei, drei und vier Leuchten.**



Volumen Hallraum: $V_S = 203.0 \text{ m}^3$
 Prüffläche (Segel): 1.56 m^2

Frequenz [Hz]	A_{Obj} [m ²]
50	0.08
63	0.03
80	0.13
100	0.13
125	0.30
160	0.38
200	0.45
250	0.66
315	0.67
400	0.85
500	0.96
630	1.09
800	1.11
1000	1.16
1250	1.30
1600	1.34
2000	1.38
2500	1.38
3150	1.39
4000	1.49
5000	1.66



Prüferschall: Rosa Rauschen
 Empfangsfilter: Terzfilter

Die Ermittlung basiert auf Prüfstandsmessungen, die in Terzbändern gewonnen wurden.

Projektnummer: 122 007 04P-101

Prüfdatum: 20.03.2008



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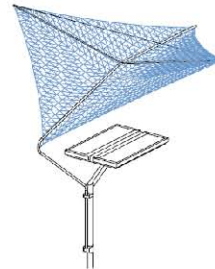
Datum: 28.03.2008

Äquivalente Schallabsorptionsfläche A
nach DIN EN ISO 354
 Messung der Schallabsorption in Hallräumen

Anlage 4

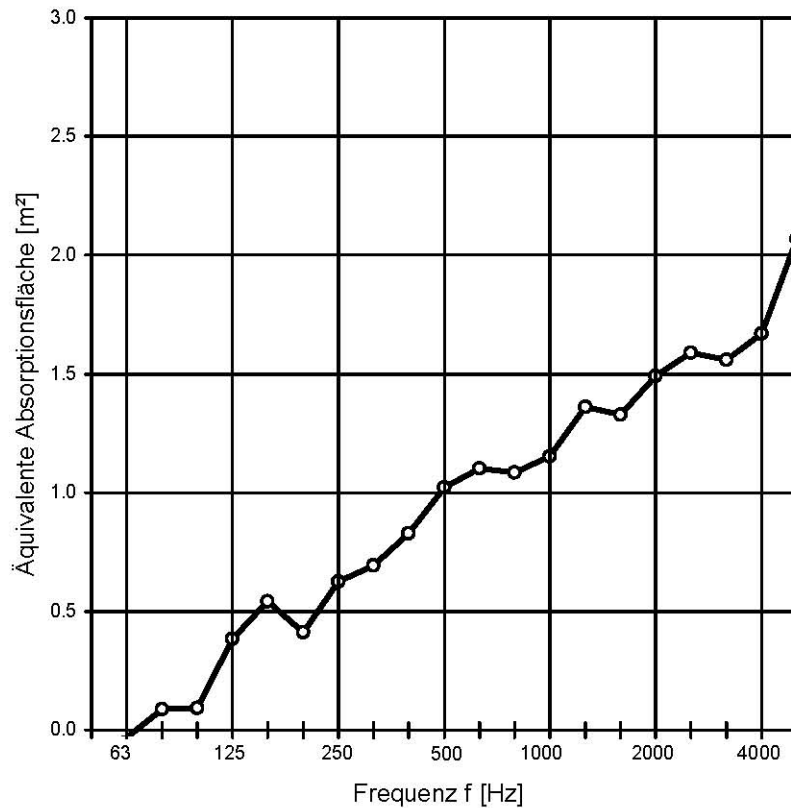
122 007 04P-101

Auftraggeber: Herbert Waldmann GmbH & Co. KG, D-78056 Villingen Schwenningen
 Herstellung & Vertrieb: Herbert Waldmann GmbH & Co. KG, D-78056 Villingen Schwenningen
 Idee, Design & Entwicklung
 Segel: STRUCTURELAB Architekten
 Prüfobjekt: Stehleuchte TYCOON, STRAIGHT, EOS
 mit Reflektions- und Akustiksegel STRUCTURELAB
 RX1-Z-125T (125 cm x 125 cm), Reflektionsgrad 35%.
 Bespannung Gewebe aus PVDF, transluzent,
 Gewicht ca. 240 g/m².
 Abstand Segel zur Leuchtenoberkante ca. 30 cm,
 Gesamthöhe ca. 2.85 m.
 Die Messungen erfolgten in Anlehnung an die Norm.



Volumen Hallraum: $V_S = 203.0 \text{ m}^3$ 1 — 1 Leuchte mit Segel PVDF
 Prüffläche (Segel): 1.56 m^2

Frequenz [Hz]	A_{Obj} [m ²]
50	-0.06
63	-0.03
80	0.09
100	0.09
125	0.38
160	0.54
200	0.41
250	0.63
315	0.69
400	0.83
500	1.02
630	1.10
800	1.09
1000	1.15
1250	1.36
1600	1.33
2000	1.49
2500	1.59
3150	1.56
4000	1.67
5000	2.07



Prüfschall: Rosa Rauschen
 Empfangsfilter: Terzfilter

Die Ermittlung basiert auf Prüfstandsmessungen, die in Terzbändern gewonnen wurden.

Projektnummer: 122 007 04P-101

Prüfdatum: 20.03.2008



**HOCHSCHULE FÜR UNIVERSITY OF
 TECHNIK STUTTGART APPLIED SCIENCES**

Datum: 28.03.2008