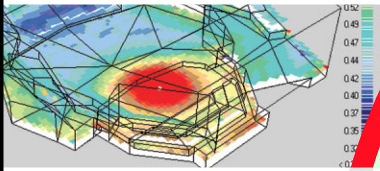
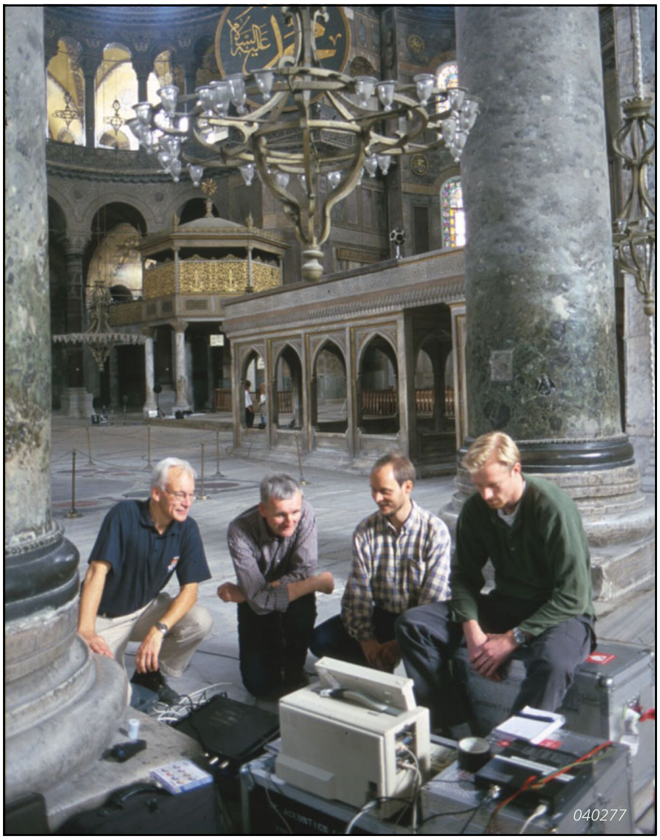


PRODUCT DATA

ODEON Room Acoustics Modelling Software — Types 7835, 7836 and 7837

Brüel & Kjær is the sole worldwide distributor of ODEON, a reliable, easy-to-use, modelling software tool for indoor acoustics, developed at the Technical University of Denmark.

ODEON is PC software for simulating the interior acoustics of buildings where, from the geometry and properties of surfaces, acoustics can be calculated, illustrated and listened to. ODEON's prediction algorithms (image-source method combined with ray tracing) allow reliable predictions in modest calculation times. ODEON is ideal for the prediction of acoustics in large rooms such as concert halls, opera halls, auditoria, foyers, underground stations, airport terminals, and industrial workrooms. For noise prediction of large machinery in industrial environments, a special ray-tracing algorithm has been developed allowing the modelling of surface and line sources. ODEON is a proven tool for predicting the acoustics of new buildings, as well as for evaluating and recommending improvements in existing ones.



USES AND FEATURES

USES

- Prediction and optimisation of the room acoustics of planned buildings
- Prediction of effect of building changes on room acoustical properties
- Improvement of room acoustics of existing buildings

FEATURES

- Fast modelling using the included tools: parametric room editor, graphic editor or import from CAD systems
- Numerous tools for model verification
- Flexible choice of sources, receivers and materials
- Modest calculation time
- Visual results – reflectograms, 3D reflection paths, 3D maps and a wealth of other graphs
- High-quality auralisation, binaural as well as surround
- Effective project management
- Easy copy and export of results for project reports or presentations
- Tool for comparison between measurements and simulations

Brüel & Kjær

About ODEON

The Origin of ODEON

Fig. 1
Odeon of Herodes Atticus, Athens

The classic, greek odeon evolved from the development of the large, open-air theatre into a more intimate, roofed-over venue for music performance (a place to sing 'odes') and, as such, was the first known instance of the construction of concert halls. The first (1991) version of ODEON was aimed at the prediction of auditorium acoustics. Since then, ODEON has been continually developed and refined, and is now available in three state-of-the-art editions: **Industrial**, **Auditorium**, and **Combined**[1]. All editions run on Microsoft® Windows® 98/NT®/ 2000/XP.

Calculation Method – Algorithms and Applications

ODEON is based on prediction algorithms (image-source method and ray-tracing) allowing reliable predictions in modest calculation times. Scattering due to surface roughness and diffraction is taken into account using a novel method that accounts for frequency dependent scattering: the Reflection Based Scattering Coefficient. It is ideal for the prediction of large-room acoustics such as in concert halls, opera houses, foyers, underground stations, airport terminals, industrial workrooms and various auditoria. For noise prediction of large machinery in industrial environments, a special ray-tracing algorithm has been developed allowing the modelling of surface and line sources.

Constructing Your Model

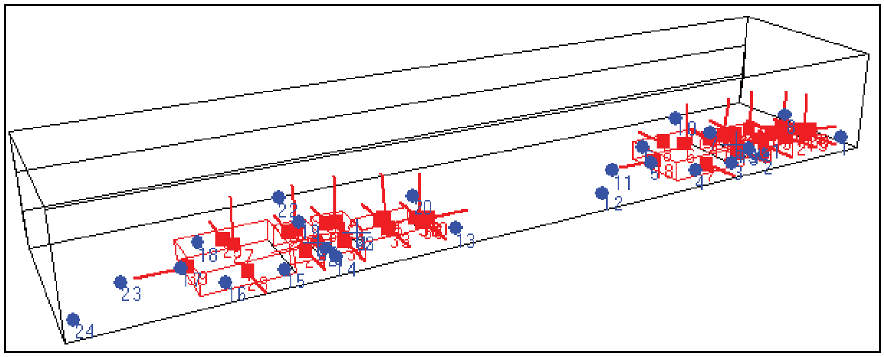
Fig. 2
From image to model – the surface geometry and properties of the real or proposed building are input to your model

Modelling the Room

3D room geometries can be modelled using the ODEON parametric modelling language, or using the ODEON extrusion modeller, an intuitive graphical tool. They can also be conveniently imported from third party CAD programs in the DXF format. Finally the modelling methods may be combined, allowing you to select the tools best suited for your purpose.

1 Specific features for each of the three ODEON editions are listed in the Ordering Information.

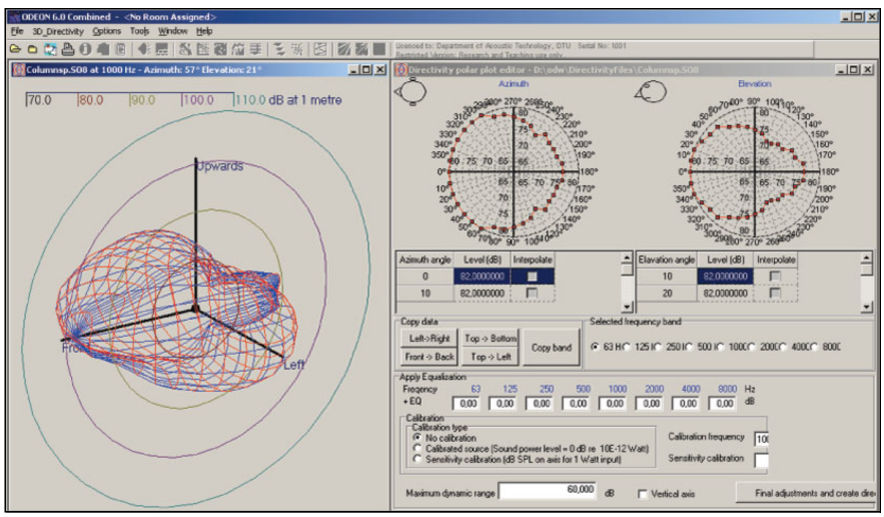
Fig. 3
The ODEON model requires only details that are essential for acoustics calculation. Appropriate sound sources and receivers are assigned and located in the model



Defining Sources

Point sources can be defined by directivity pattern, gain, equalisation and delay, allowing the definition of natural sound sources as well as loudspeaker systems. ODEON has a list of common sources to choose from and also supports the Common Loudspeaker Format (CLF) used by several manufacturers. The Industrial and Combined editions also allow the definition of line and surface sources that are particularly useful for calculations in industrial environments. Positions, orientations, etc., are automatically reflected in 3D displays.

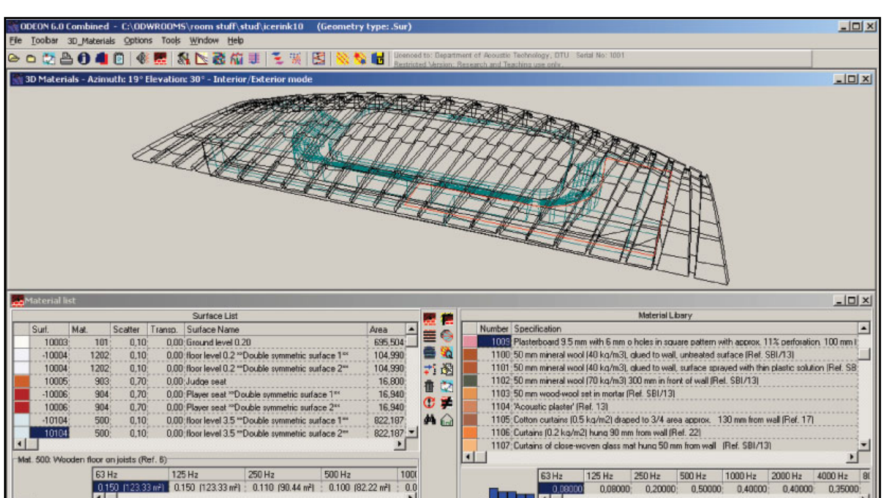
Fig. 4
Example of a point source definition with a special directivity pattern – a loudspeaker column that improves the speech intelligibility in a church



Materials

Materials are defined by the absorption coefficients from 63 to 8000 Hz and a scattering coefficient. A transparency coefficient can also be used. Materials are selected from an extendable library of materials. The surface list is linked to a display showing the selected surface in 3D.

Fig. 5
*Surfaces are listed in the left-hand column. Selecting a surface in the list will highlight it in the 3D display. To assign a material to a surface, click on the material (right-hand column) and on the **Assign** button. Support for Layers makes it easy to assign one material to a selected group of surfaces*



Checking your Model

To ensure that calculation results are reliable, it is essential that geometries are consistent. ODEON includes a number of tools for geometry verification, e.g., the '3D Geometry Debugger' with a check for duplicate, overlapping or warped surfaces, see Fig. 6. The ray-tracing display can also be used in the verification of room geometry, as can the '3D Billiards' display shown in Fig. 7.

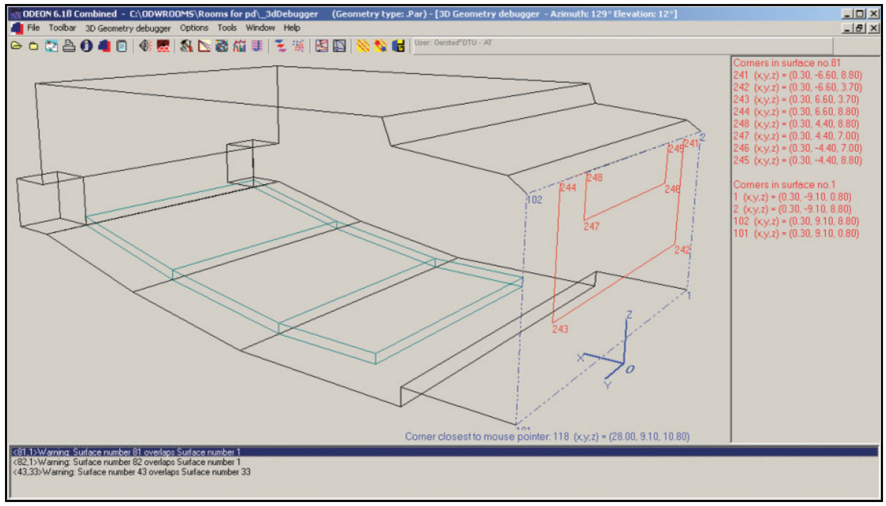


Fig. 6
The '3D Geometry Debugger' points out errors in the model such as overlapping, duplicate or warped surfaces. This makes it safe and easy to locate and correct possible errors in the model description

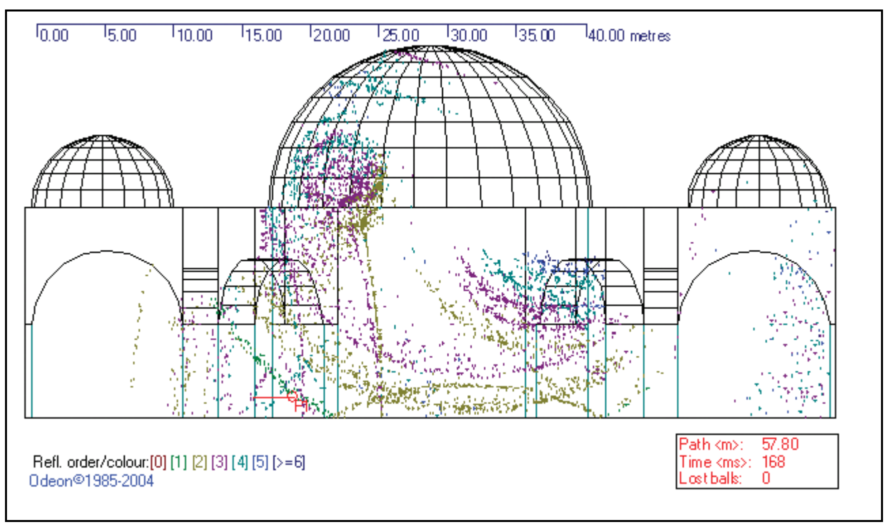
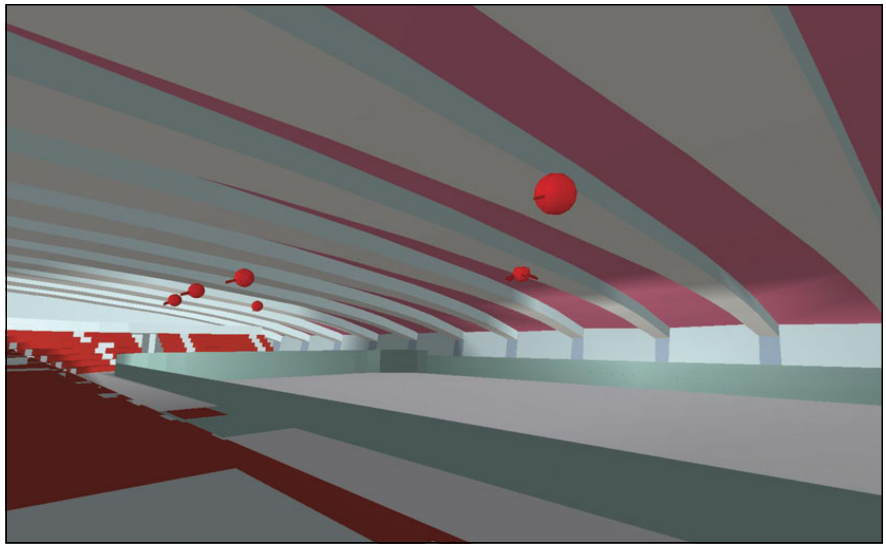


Fig. 7
The '3D Billiards' display is a tool that can be used for investigating or demonstrating effects such as scattering, flutter echoes, focusing or coupling effects. A burst of 'billiard balls' are emitted from the source and bounce off the surfaces in the room

3D OpenGL Display

The '3D OpenGL' display shows geometry, materials and source positions. This display is useful when checking the validity of room geometries or source and receiver locations. The surface colours are mapped on to the acoustic reflectance of the surface materials – particularly useful when checking that materials are assigned correctly in complicated models and also useful for presentation purposes.

Fig. 8
The 3D OpenGL display is useful for checking the validity of the model. It can be viewed from all aspects, both inside and outside, using rotation, move and zoom features



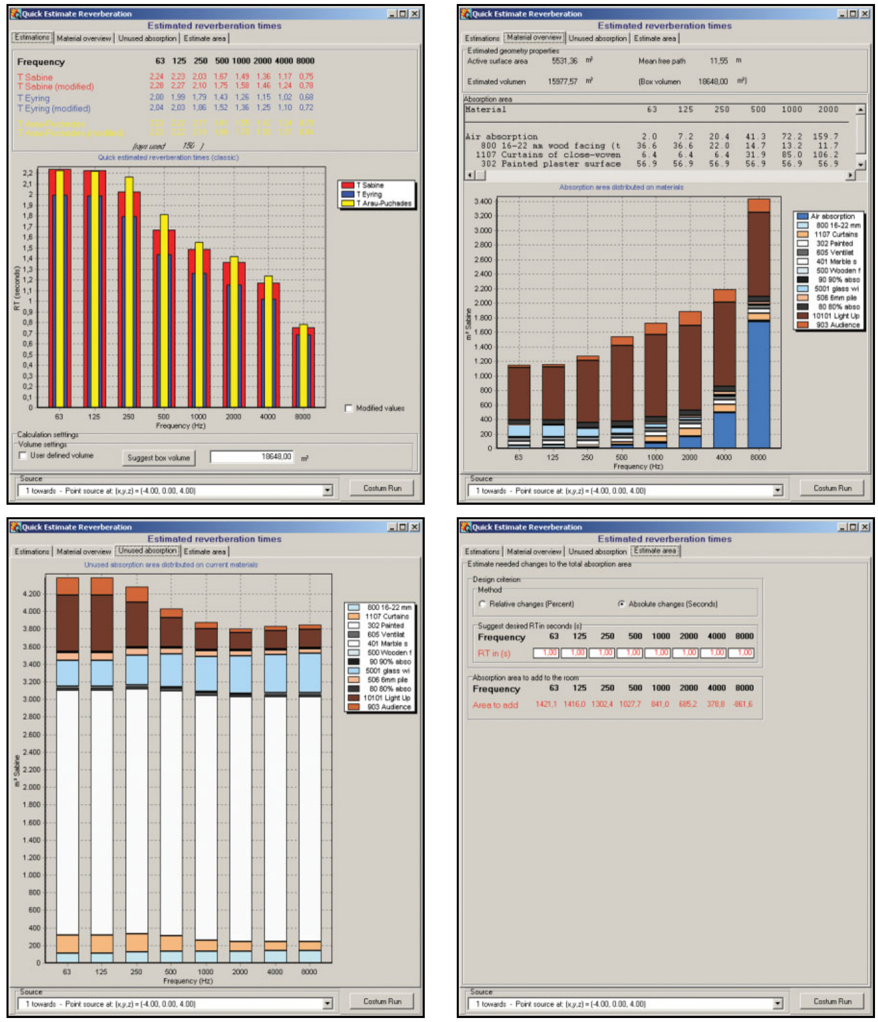
Project Management
Thorough project management is an important ODEON feature. ODEON always ensures that results stored with a project are consistent with the specified geometry, materials, sources, etc. A project stored in the program archive contains all the information needed for full documentation. A project, and all its associated data, can be saved into a compressed file for easy backup or e-mail transfer.

Results

Calculation
Most calculation parameters are set automatically but, for special cases, the user may want to change some parameters, e.g., temperature and relative humidity.

Decay Curves
Two global-decay methods are available – the **Quick Estimate** based on statistical formulae, and the more precise **Global Estimate** based on ray-tracing, thus taking room shape, source position, and the position of absorbing materials into account. The global-decay methods can be used for checking the overall decay time and absorption in the model. The Global Estimate corresponds to the reverberation decay averaged over an infinite number of points in the model and thus represents an ideal in traditional reverberation time measurements.

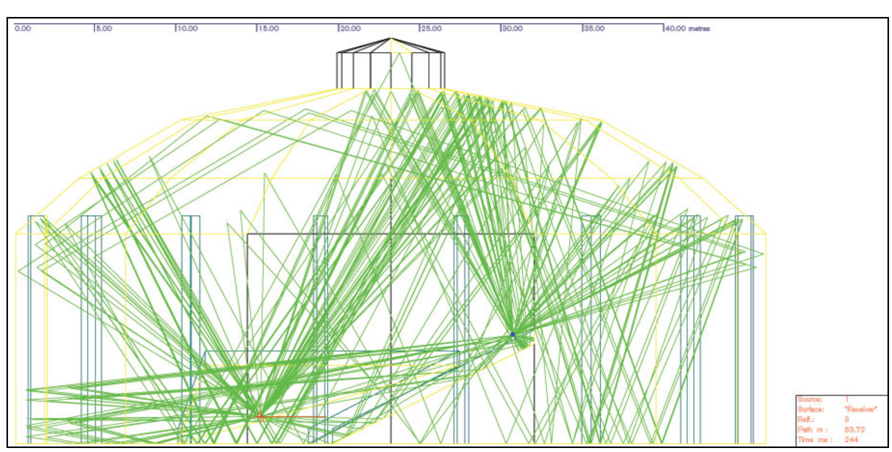
Fig. 9
Quick Estimate gives an overview of the model's reverberation time and absorption, and suggests the changes in absorption needed to obtain a certain reverberation time



Ray-tracing

Two ray-tracing displays are provided. The first shows single-point ray tracing, i.e., rays radiated from the source during calculation of point responses, which is useful for the verification of room geometry and source positions. The other shows two-point ray tracing, (see Fig. 10), for example the early reflection paths from a point source to a receiver, and is linked to the reflectogram (see Fig. 11) to locate the path of particular reflections.

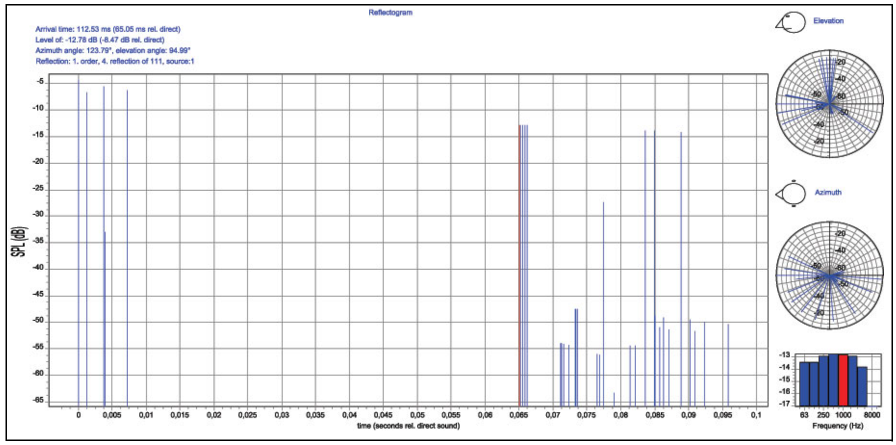
Fig. 10
Ray-tracing on the '3D Reflection Paths' display shows the path of each ray and is useful for checking room geometry. The tracing shows the focusing effect of the dome



Reflectogram

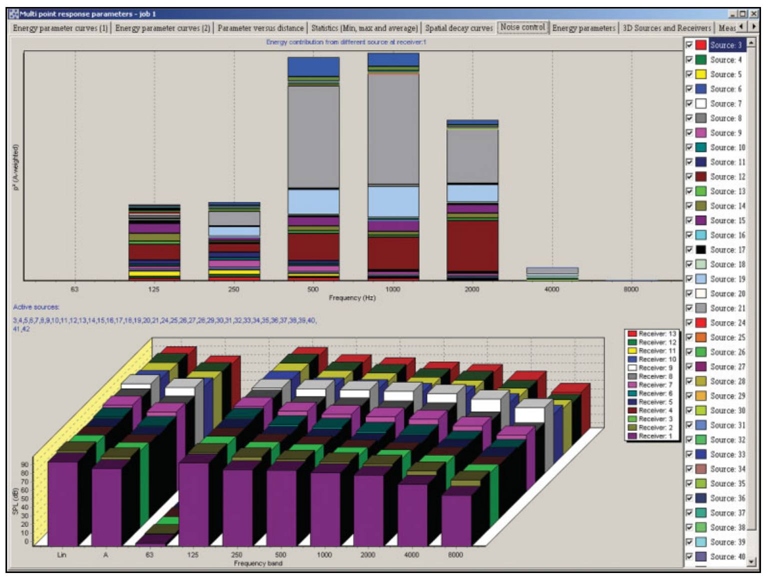
The reflectogram shows the arrival time and level of all reflections, referred to the direct sound. It helps identify useful, as well as unwanted, reflections. Selected reflections can be investigated further in the '3D Reflection Paths' display (Fig. 10).

Fig. 11
Reflections within the dome of the same theatre (see Fig. 10). The clustering of reflections points to an echo problem. Ray-tracing helps identify echo-causing room surfaces



Noise Control

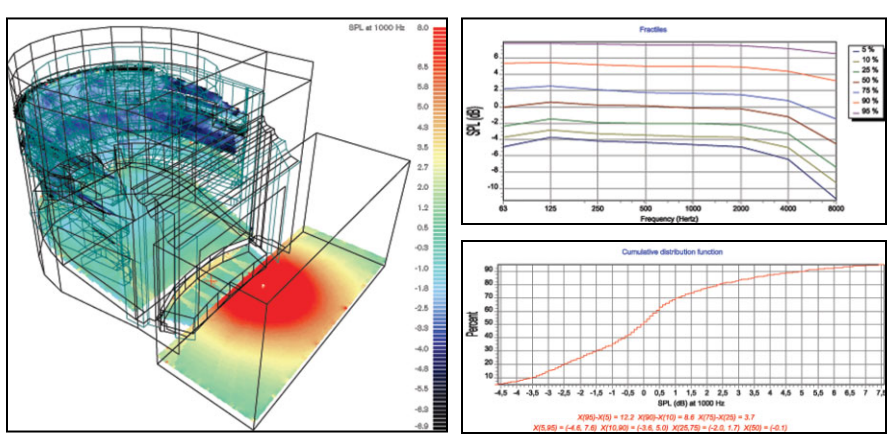
Fig. 12
The noise control display allows identification of the dominant noise sources at different receiver positions in a room. You can interactively turn sources on and off while viewing the impact noise levels at the different receiver positions



Maps

Maps of calculated parameters can be calculated for any number of selected receiver surfaces. Such parameters include, e.g., sound-pressure level, energy parameters or intelligibility (Speech Transmission Index). The resolution of the map (grid resolution) is selected to give sufficient detail within an acceptable length of calculation time.

Fig. 13
Calculated SPL mapping. The graphs on the right show the corresponding 'cumulative distribution graph' and 'fractiles' for the SPL grid. Opera House project for Ankara Congress and Cultural Centre (Architect: Özgür Ecevit, Acoustics: Jordan Akustik, Denmark)



Reflector Coverage

Reflectors are often used to direct reflections into areas that need sound reinforcement. The reflector coverage display allows fast evaluation of the receiver area covered by a number of reflectors for a selected source position.

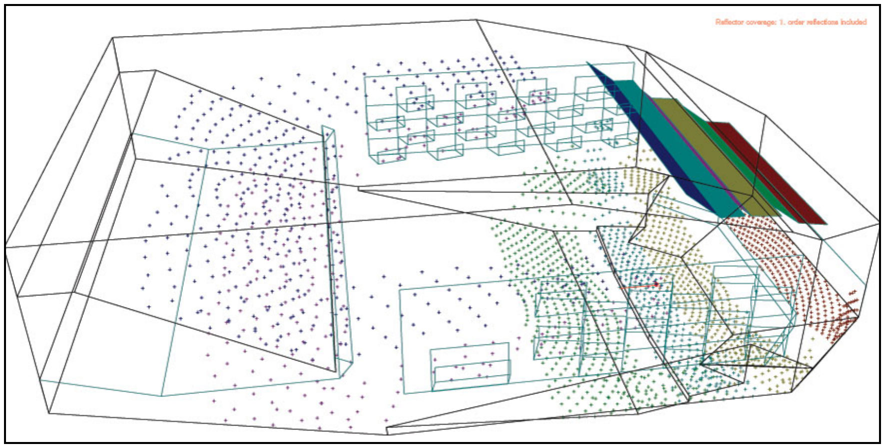


Fig. 14
The Royal Festival Hall in London – for each reflector, the reflection pattern shows how well it directs sound to the intended audience area

Auralisation

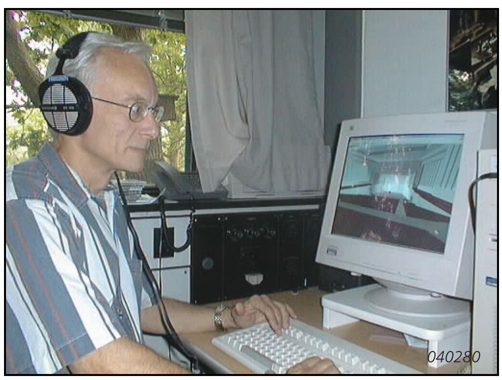


Fig. 15
In auralisation, you can 'replay' sound in the model and hear how the design affects music, speech or other acoustic signals. Since the ultimate goal is to improve perceived sound quality, this is a very powerful tool for the designer as well as for presentation to clients

The input signal for auralisation is a digital recording (.wav file) or any signal played on the recording input of the sound card. In ODEON, this recording can be processed for headphone playback using a calculated Binaural Room Impulse Response (BRIR) or for surround playback, using a multichannel impulse response calculated using Ambisonics technology. In either case, all calculations including ray-tracing, calculation of reflections received at a receiver point, binaural filtering or Ambisonics decoding, octave band filtering and convolution is carried out in a one-step process which does not require pre- or post-processing. The BRIRs for headphone auralisation include *full filtering* of each reflection in nine octave bands (the 16 kHz band being extrapolated) and applying a set of HRTFs (Head Related Transfer Functions) for each reflection. A BRIR for auralisation is typically based on more than 100000 reflections. The resulting sound is saved as another standar1wav file or played in real-time over the sound card if the sound card supports this.

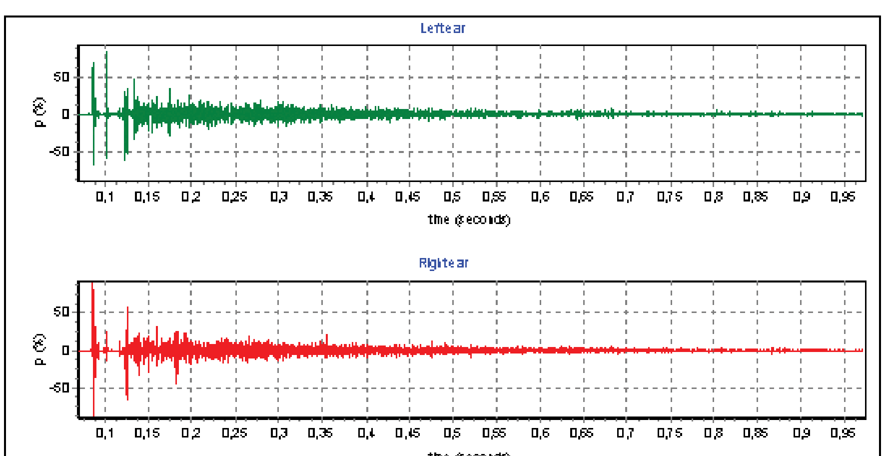
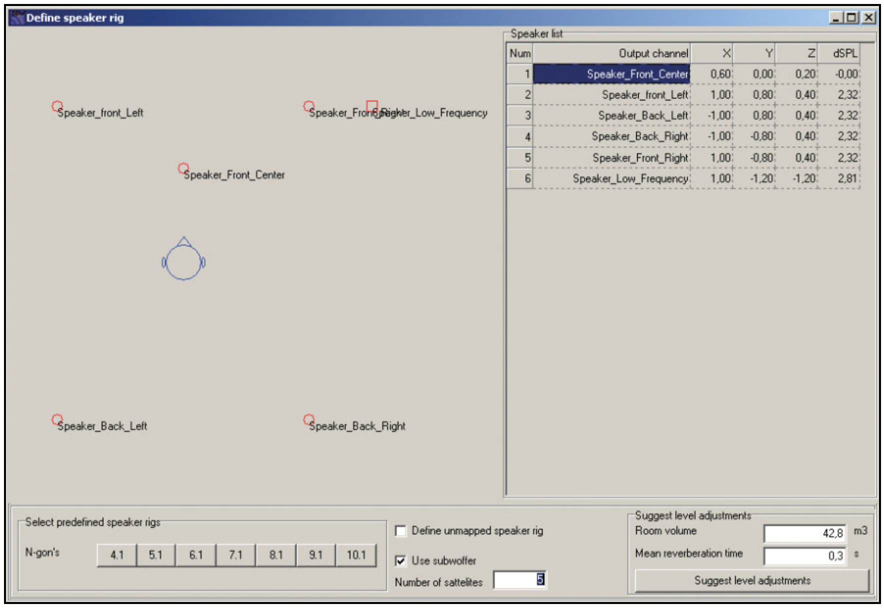


Fig. 16
BRIR (Binaural Room Impulse Response) calculated at a receiver position

Fig. 17
For a larger audience, ODEON can present auralisation via multi-channel loudspeaker systems. The setup for a standard type 5.1 (6-channel) system is illustrated, with four corner speakers, one front centre speaker and one subwoofer



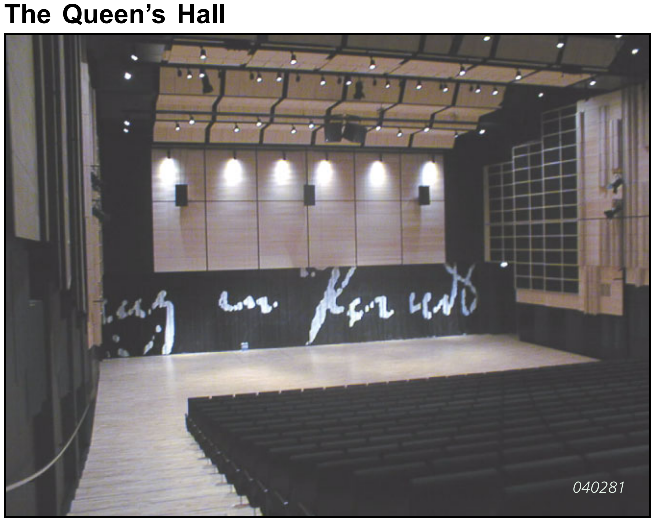
Printing and Export

Results, graphic displays and calculation properties can be printed in high quality from within ODEON. Graphics can be exchanged via the Windows® clipboard or via files in multiple formats. Calculated results can be exported to a text file.

Case: Multi-purpose Hall

The Queen's Hall

Fig. 18
The Queen's Hall, Copenhagen, acoustically designed with the aid of ODEON



ODEON was used for the design of the Queen's Hall in the recent expansion of the Royal Library in Copenhagen. Known locally as the 'Black Diamond' and inaugurated in 1999, the hall is mainly designed for chamber music but will also be used for rhythmic music, meetings and lectures.

The Queen's Hall holds up to 600 people and its reverberation time can be adjusted from 1.1 s up to 1.8 s, while side-wall mounted acoustic diffusers prevent flutter echo. Simulations during the design phase, using ODEON, had shown that this would be necessary – see the calculated decay curves (Fig. 20 and Fig. 21).

Fig. 19
ODEON model of the Queen's Hall shows flutter echo reflection paths

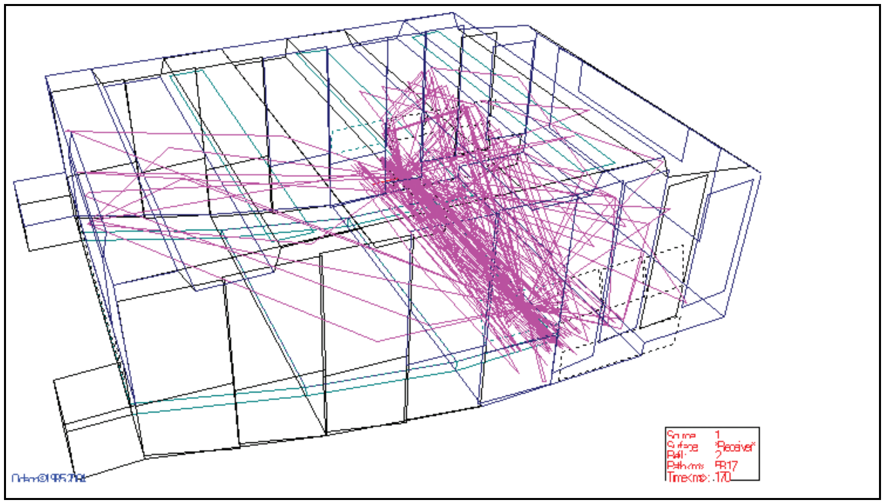


Fig. 20
Flutter echo in Queen's Hall as seen in the decay curve simulated by Odeon. Upper curve is the normal decay curve whereas the lower curve is the intensity curve displaying the directional fraction of the energy. When clicking at a point in the intensity curve ODEON will show the orientation of that time slice in a 3D display

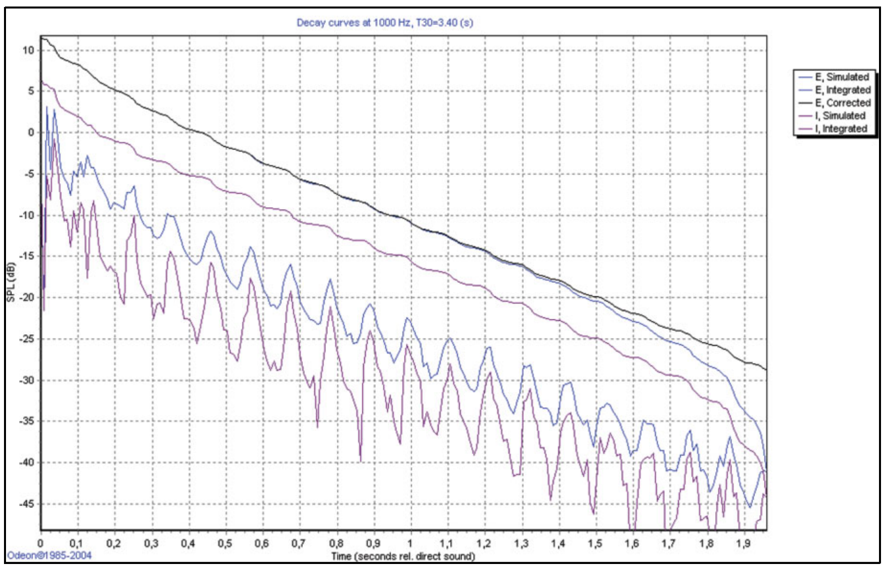
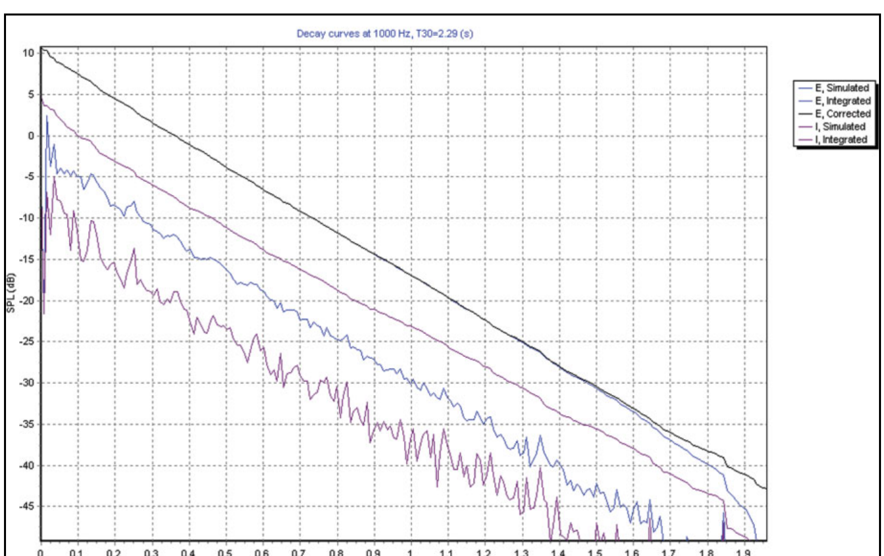


Fig. 21
ODEON decay curve documenting the effect of diffusors in Queen's Hall



For each receiver point in the model, the squared impulse response is calculated and shown as a decay curve and an integrated decay curve. These results can be directly compared to those measured at the same points in the real room.

Prediction of Noise in Industrial Environments

Elsamproject, the Danish Power Project Agency, has verified ODEON's prediction accuracy. In a turbine hall at a power plant (also illustrated in Fig. 2 and Fig. 3), the A-weighted sound-pressure level was measured at twelve receiving points and compared to the levels estimated by ODEON. The room and its machinery were modelled by 54 surfaces. The sound sources were modelled by 30 surface sources (the surfaces of the two turbines) and four point sources (ball bearings). Relevant data for radiated sound power were measured with the intensity method. Test results show very high correlation between measured and estimated results, the average deviation being less than 1 dB.

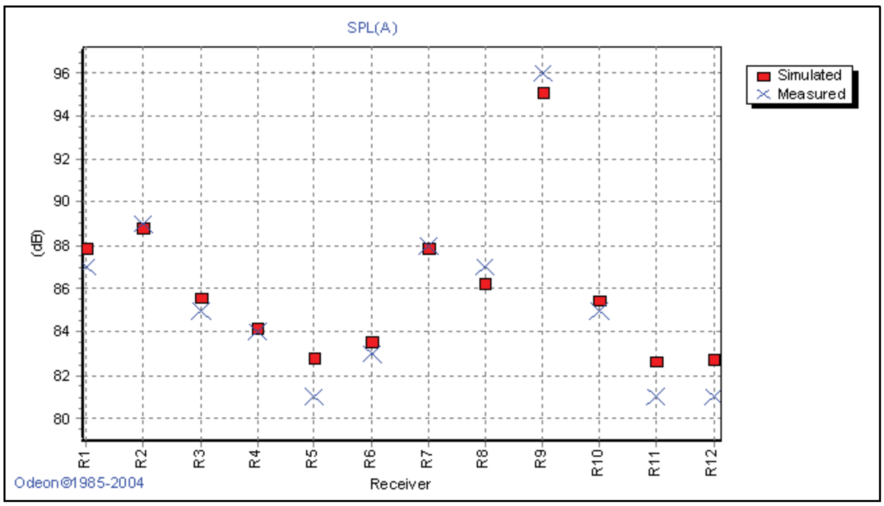


Fig. 22
Comparison of measured and simulated sound-pressure levels (please refer to Fig. 2 and Fig. 3), showing very high correlation. This figure demonstrates a graph facility included in ODEON that allows easy comparison of measured and simulated parameters. Measured data can be imported from a text file or pasted directly from the measurement made with the DIRAC Room Acoustics Software Type 7841

Specifications – ODEON Room Acoustics Modelling Software Types 7835, 7836 and 7837

OPERATION
The software is a true 32-bit Windows® program, operated using buttons and/or menus and shortcut keys

HELP
Context-sensitive help is available throughout the program

CALCULATION METHOD
Hybrid: combining ray-tracing with image-source modelling
Early Reflections: Image-source model and ray-tracing
Late Reflections: Ray-tracing method simulating diffuse reflections
Scattering: Frequency dependent, using *Reflection Based Scattering Coefficient* method that accounts for surface roughness and diffraction

FREQUENCY RANGE
8 octave bands from 63 Hz to 8 kHz
Linear and A-weighted levels are calculated from octave levels

MODEL TOOLS
Editor: Text editor supporting parametric modelling
Import Facility: Import of DXF (Drawing Exchange Format) files from CAD software like AutoCAD®, 3ds max and IntelliCAD®
Verification: 3D display, 3D ray tracing, 3D view, automatic check for warped and overlapping surfaces
Patch Tool: Missing surfaces in imported geometries can be created using the integrated 3DView
Extrusion Modeller: Drawing tool for fast modelling of geometries such as industrial work rooms and offices

MODEL ITEMS *(properties in italics: industrial and combined editions only)*
Model Size: Maximum dimension 2000 × 2000 × 2000 m
Points: Max. 2500 per surface
Surfaces: Max. 50 000
Corners: Max. 100 000
Sources: Point, *Line* or *Surface* sources, up to a max. total of 250
Loudspeaker Format: Common Loudspeaker Format (CLF) supported, see www.clfgroup.org
Receiver Points: Virtually no limit to the number of points
Materials: Extendable materials library, specifying absorption, Scatter and Transparency coefficient. Built-in material editor

RESULTS *(properties in italics: auditorium and combined editions only)*
Ray-tracing: Dynamic display of ray-tracing
3D Billiard: Interactive display for visualisation of wavefronts
Quick Estimate: Fast estimation of reverberation time based on diffuse-field assumptions (Sabine, Eyring, and Arau-Puchades formulae)
Global Estimate: Estimate of reverberation time taking room shape, position of absorbing materials and source position into account
Single Point Response: *Detailed results and auralisation options for a selected receiver*
Multi-point Response: Acoustical parameters for a specified number of receivers
Grid Response: Map of room acoustical parameters as well as statistics for the grid receivers
Reflector Coverage: *3D display of early reflection hits for selected surfaces (1–5 order as desired)*

Specifications – ODEON Room Acoustics Modelling Software Types 7835, 7836 and 7837 (continued)

ROOM ACOUSTIC PARAMETERS ***(properties in italics: auditorium and combined editions only)***

- Sound Pressure Level, SPL
- A-weighted Sound Pressure Level, SPL(A)
- Rate of Spatial Decay, DL_2
- Reverberation Time, T_{30}
- Early Decay Time, EDT
- Speech Transmission Index, STI
- *Centre Time, Ts*
- Level rel. 10 m free-field, G
- *Clarity, C_{80}*
- *Deutlichkeit, D_{50}*
- *Early Lateral Energy Fraction, LF_{80}*
- *Early Support, ST_{early}*
- *Late Support, ST_{late}*
- *Total Support, ST_{total}*
- *A-weighted, Late Lateral Sound Pressure Level, LLSPL(A)*

AURALISATION

Input: Anechoic or semi-anechoic sound file in .wav format. Mono, stereo as well as multichannel recordings can be handled
Mixer: Multiple sources and multiple signals can be included in one simulation
Processing: Convolution of sound files with BRIRs (Binaural Room Impulse Responses), BFormat impulse responses and/or Surround impulse responses. All types of impulse responses are filtered using full filtering in nine-octave bands. For the binaural filtering a set of HRTFs (Head Related Transfer Functions) is applied for each reflection
Output: Binaural (2-channel) .wav file optimised for headphone playback – open-type headphones recommended
1st and 2nd order BFormat files (Ambisonics) output is an option for the advanced user
N-channel surround-sound for standard systems such as 4, 4.1, 5.1, 6.1 and 7.1 as defined by sound card/loudspeaker system and specified in the setup by user
Sound Card Minimum Requirements: Stereo, Duplex, 16 bits, 44100 Hz sampling. In order to support surround playback over loudspeakers the sound card must support surround sound, e.g., 5.1; see output section covered previously
For Loss-free Input from DAT Recorder: Digital input and output

PRINTOUT, GRAPHS AND EXPORT

Graphs and tables can be exported via clipboard or file in several formats (.wmf, .emf., .bmp., .gif., .jpg, .pcx, .png), or printed. Results, including parameters, reflection data, curves, etc., can be exported in ASCII (text) format for further processing in other programs. Exports animations in GIF format from any of the displays in the program, single-shot as well as sequence-shooting are available. An editing tool for animations is included

PROJECT MANAGEMENT

Job Control: Job List specifies source(s), receiver(s) and calculation type for each simulation
Max. Number of Jobs within a Project: 20
Changes: Consistency is maintained between results and setup of room and calculation parameters. Inconsistent results are deleted (after warning)
Saving Projects: Built-in utilities for copying, deleting and archiving projects including all associated data. Can save a project into a single compressed file for backup or e-mail

COMPUTER SYSTEM

Operating Systems: Windows® 98, NT®, 2000 and XP
RAM: Minimum 32 MB, recommended 128 MB
Free Disk Space: Minimum 100 MB, recommended 1 GB
CPU: Minimum 500 MHz Pentium® recommended
Auxiliary Hardware: CD-ROM drive, SVGA graphics display/adaptor and mouse or other pointing device

Ordering Information

Including the difference in features between the editions.

INDUSTRIAL EDITION TYPE 7835

Intended for environmental acoustics where SPL, SPL(A), T_{30} and STI are the important results. The Industrial edition allows modelling of point sources, line sources and surface sources, making it possible to model large and complex sound sources.
Single Point Response, Reflector Coverage and some auditoria parameters (see specifications) are not included.

AUDITORIUM EDITION TYPE 7836

Intended for calculation of large sets of room acoustical parameters. A number of graphical tools are built in including a reflectogram, a 3D reflection paths' display, and reverberation-curve displays. The Auditorium edition provides built-in auralisation features. Unlike the Industrial edition, the Auditorium edition is not capable of modelling line and surface sources.

COMBINED EDITION TYPE 7837

Combined features of Auditorium and Industrial Edition

SERVICES AVAILABLE

7835/6/7-MS1	1-year support and upgrade agreement
7835/6/7-X-100	Upgrade from Odeon versions 4.0 and later
7835/6/7-X-200	Upgrade from Odeon versions 3.x and earlier
7835/6/7-X-300	Extra Odeon license, MS1 contract included

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Local representatives and service organisations worldwide

Brüel & Kjær

BP 1950 – 15 2007-03 Rosendahls Bogtrykkeri