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INTER-NOISE 2009
Report

ACTIVE 09
Report

FEATURE
The design of low-noise vehicles for air, road, and rail transportation

MEMBER SOCIETY PROFILE
The Portuguese Acoustical Society

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Features

Departments

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Portland, Oregon, venue for NOISE-CON 11, with Mount Hood in the background. Photo courtesy of Travel Portland/Brent Bradley.

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NOISE/NEWS INTERNATIONAL

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I-INCE

The International Institute of Noise Control Engineering (I-INCE) is a worldwide consortium of societies concerned with noise control and acoustics. I-INCE, chartered in Zürich, Switzerland, is the sponsor of the INTER-NOISE Series of International Congresses on Noise Control Engineering, and, with the Institute of Noise Control Engineering of the USA, publishes this quarterly magazine and its Internet supplement. I-INCE has an active program of technical initiatives, which are described in the Internet supplement to NNI. I-INCE currently has 46 Member Societies in 39 countries.

INCE/USA

The Institute of Noise Control Engineering of the USA (INCE/USA) is a non-profit professional organization incorporated in Washington, D.C., USA. The primary purpose of the Institute is to promote engineering solutions to environmental noise problems. INCE/USA publishes the technical journal, *Noise Control Engineering Journal*, and, with I-INCE publishes this quarterly magazine and its Internet supplement. INCE/USA sponsors the NOISE-CON series of national conferences on noise control engineering and the INTER-NOISE Congress when it is held in North America. INCE/USA Members are professionals in the field of noise control engineering, and many offer consulting services in noise control. Any persons interested in noise control may become an Associate of INCE/USA and receive both this magazine and *Noise Control Engineering Journal*.

NNI and its Internet Supplement

www.noisenewsinternational.net

The primary change in this PDF-only volume of *NNI* is the ability to have "hot links" to references, articles, abstracts, advertisers, and other sources of additional information. In some cases, the full URL will be given in the text. In other cases, a light blue highlight of the text will indicate the presence of a link. At the end of each feature or department, a light blue back to toc will take the reader back to the table of contents of the issue.

- The Internet supplement contains additional information that will be of interest to readers of *NNI*. This includes:
- The current issue of *NNI* available for free download
- *NNI* archives in PDF format beginning in 2003
- A searchable PDF of annual index pages
- A PDF of the current *NNI* conference calendar and a link to conference calendars for worldwide meetings
- Links to I-INCE technical activities and I-INCE Technical Reports

GUEST EDITORIAL

A Global Technology Assessment

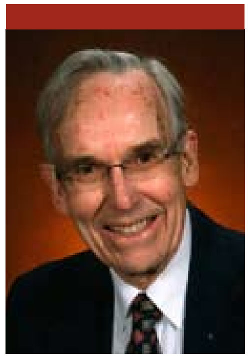
In an informal partnership with leading academies of engineering in the world, International INCE is collaborating in a global assessment of noise control technology. Twenty-six countries have their engineering academies represented in the International Council of Academies of Engineering and Technical Sciences (CAETS). One of CAETS' objectives is to advise governments and international organizations on technical and policy issues related to the areas of expertise within the academies.

In 2007, the CAETS Council, which is the governing body of the organization, approved a proposal by the Royal Swedish Academy of Engineering Sciences (IVA) to form a CAETS Noise Study Committee with the task to make an assessment of the technology currently available and needed in the future to control the major sources of noise emissions in the world's communities, workplaces, and homes. Members of five engineering academies have been active on the committee since its formation. In 2008 June, together with the Royal Academy of Engineering (RAEng) and the National Academy of Engineering of the U.S.A. (NAE), IVA organized a forum at the Institute of Sound and Vibration Research in the U.K. to make an assessment of the European technology to quiet transportation vehicles—aircraft, road vehicles, and trains. In 2009. this was followed by a second CAETS forum held in conjunction with INTER-NOISE 2009 in Ottawa, Canada, on August 24-26. The Ottawa forum addressed non-vehicular sources that present worldwide noise problems in occupational, domestic, and community settings. Topics included low-noise machinery and equipment, building noise, and codes, practices and standards for low-noise equipment and buildings. A summary of the 2008 forum appears in this issue of NNI and a summary of the 2009 forum has been posted on the Internet at *http://www.noisenewsinternational.net/docs/caets-2009.pdf*

These two forums completed the assessment phase of the CAETS Noise Committee's work. The third and final forum of the series will be held in conjunction with INTER-NOISE 2010 in Lisbon, Portugal, on June 14-16. The objective of the third forum is to focus on bringing the CAETS technology assessment to the attention of the world's policymakers and the public. Through this they may become aware of what noise control technology can and cannot do to assist in quieting the world. The forum is intended to stimulate action to bring about change in the manner in which policymakers are approaching the noise issue. The CAETS assessment clearly demonstrates that controlling the noise emissions of the dominant noise sources in urban and suburban areas is the key to a quieter world.

I-INCE Technical Study Group 5 published its report "A Global Approach to Noise Control Policy" in 2006 September. This report, while comprehensive, received little attention from the world's policymakers. In response to a CAETS request for background information, I-INCE TSG 7 is now preparing a new report in which emphasis will be placed on the technology available and the technology needed in the future to control the dominant, inanimate noise sources in the societies of the world. Some of these sources are under direct human control (e.g. lawnmowers), while others are remotely controlled (e.g. wind turbines). Collectively the dominant noise sources have a major impact on quality of life and human health around the world. The TSG 7 report will provide background information on global issues related to the noise emissions of the dominant sources.

Cooperation with the CAETS academies represents a golden opportunity for International INCE, the world's foremost professional society focusing on noise control engineering, to work with those in government and industry on the implementation of noise control technology available today and on the development of noise control technology for the products of the future. back to toc



William W. Lang

I-INCE Vice President for Rules and Governance

Health Matters

Bernard Berry

European Editor
I-INCE VP for Europe and Africa

As we deal, during our busy professional lives, with all the complex "engineering" aspects of noise control, it is all too easy to lose sight of the fundamental reasons *why* we are so busy measuring what we measure, predicting what we predict, designing what we design, planning what we plan etc., etc.

At the very center of the many inter-related objectives which we all have is "human response" to the acoustical environment. In other words: "What is the impact of that environment on those exposed to it?" But our understanding of the subject of human response is evolving rapidly, as are the expectations and level of knowledge of the general public with whom we interact, and it is worth taking stock.

As many writers on such issues have previously noted, in the early days of noise control, the primary focus was on the reduction of the very high noise levels which were known to be capable of causing direct hearing damage. After significant progress was made with that task, the emphasis gradually shifted to concerns about more indirect aspects—such as *amenity, comfort,* and *environmental quality*. Here again, significant progress has been made over the years and we are now in a situation where most of the developed world have some form of environmental noise legislation which ensures that the numbers of people highly annoyed are minimized. See for example I-INCE publication no. 09-1, 2009, "Survey of Legislation, Regulations, and Guidelines for Control of Community Noise," by Hideki Tachibana and William W. Lang.

More recently, in the last 5 to 10 years, a number of developments have combined to mean that greater emphasis is now being put on the potential direct consequences for human health of exposure to environmental noise, at moderate levels. These developments include a number of in depth reviews of the scientific evidence as well as a number of initiatives by the World Health Organization such as the recently published Night Noise Guidelines.

In Europe, a number of major health-related research projects such as RANCH and HYENA have been completed and have provoked considerable interest. Also the development of noise maps across Europe, as a result of he European Noise Directive, and Action Plans associated with these maps, has highlighted the importance of having reliable and consistent evidence on how environmental noise exposure influences human health and wellbeing.

In recognition of the importance of these issues, the European Commission has recently begun the funding of a European Network on Noise and Health which includes 33 partners from 17 countries across Europe. It has been funded in order to establish a research network of European scientists working on environmental noise exposure and health. The initial objective will be to review the existing literature on environmental noise exposure and health focusing on consolidation of existing knowledge and the identification of gaps in the evidence and future research needs. A further objective is to ensure that the most up-to-date measures of noise exposure assessment are applied to health studies. The network will also assess complex analytical models of noise and health effects that take into account moderating factors such as the joint effects of air pollution and noise. Furthermore, the network will aim to improve the measurement of health outcomes relevant to noise research taking examples from other areas of biomedicine and extending analyses on existing large studies of noise and health. The network will also help to improve communication between researchers on noise and researchers on air quality. Ultimately, the aim is to develop new designs for research on noise and health and to provide the EU with a new strategy for the development of noise and health in the future. An important element of the network is the exchange program for junior researchers in noise and health designed to increase expertise among junior researchers in this important

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The Portuguese Acoustical Society (SPA)

The Portuguese Acoustical Society (SPA) is an independent, non-profit and non-governmental association. This society, founded in the year 1980, was conceived to be a specialized organization intended to gather Portuguese acousticians, and to promote and develop acoustics within the country, being simultaneously a forum to exchange information and scientific knowledge among its members. Providing a link between areas of different scientific fields that have acoustics as a common subject, SPA accomplishes an important role in joining forces for the development of noise control engineering. It also aims at promoting technical and scientific advances in acoustics throughout the country, and to facilitate the recognition, in Portugal and abroad, of activities developed by those basically working in acoustics, and by those who are simply interested in it.

The SPA was established in the 80s. At the time, some important initiatives were taken by the former group of SPA members with the purpose of encouraging technicians working in acoustics to join and work together to promote acoustics in Portugal. Additionally, some relations at an international level were established in order to support the birth of Portuguese Acoustical Society. Among all these, a special reference is due to SEA (Spanish Society of Acoustics) and to its president at the time, Prof. Andrés Lara-Saenz, who suggested the creation of a strong connection between the two societies in order to better co-operate within the administrative space of the Iberian Peninsula. This relationship has been established in various events jointly organized by the two societies throughout the years. In fact, the first joint international event promoted by SPA founders was held in Lisbon, in 1978, under the theme Environmental Acoustics: 1st Congresso Luso-Espanhol, launching then a continuous series of co-operating activities between the two societies. Others occasionally followed. However, since 1998, and once in a year, SPA and SEA jointly organize Iberian events; some held in Spanish territory some in Portuguese territory, gathering in average about 300-400 participants from Portugal and Spain. The INTERNOISE 2010, held this year (2010) in Lisbon, Portugal, is an example of this extremely fruitful cooperation.

Nationally, SPA organizes Workshops, Seminars and Lectures on acoustics, in a wide range of sub-topics. Under the scope of Portuguese Acoustical Society activities, monographs and thesis are sponsored, and scientific announcements mailed whenever necessary, and placed on its web page. As deliverables, SPA distributes to all its members this magazine, the Revista Española de Acústica, the CD Acta Acústica United with Acústica, and all other relevant information.

The Portuguese Acoustical Society is actually the national body responsible for the technical follow-up of standardization production/translation/implementation, both internationally and within the country. Initially, environmental and building acoustics were the major fields dealt with by the Society. Nevertheless, in recent years other areas of interest have emerged as a result of the society concerns and scientific and technical evolution. Nowadays, a wide variety of acoustical areas are covered, as well as the area of vibrations.

The funding of SPA derives mainly from membership fees, donations, and profits from seminars, congresses and encounters.

The Portuguese Acoustical Society is an affiliated society of European Acoustics Association (EAA), International Commission for Acoustics (ICA), International Institute of Acoustics and Vibration (IIAV), and of I-INCE. It is also a member of FIA (lbero-American Federation of Acoustics), holding the Presidency of this Federation (Professor Jorge Patrício), since 2006. FIA, to which SPA was a founding member, is an international organization formed by the Acoustical Society of Brazil, Argentina, Chile, Peru, México, Colômbia, Venezuela, Spain and Portugal.

The Portuguese Acoustical Society has approximately 300 members, including individuals, students, and associates. The SPA members come from all working areas: researching, academia, certification, labs, administrative and legal bodies, etc. Associate members are organizations that include consultants, manufacturers, engineering contractors, suppliers, designers, and other companies. Nowadays, the Portuguese Acoustical Society is considered an important partner and a consultant for legal authorities and private institutions when dealing with education, accreditation, normalization, legislation and investigation.

The first president of Portuguese Acoustical Society was Prof. Pedro Martins da Silva. Then followed Prof. José Luís Bento Coelho, and since 1999 Prof. Jorge Patrício.

It is clear that people are becoming increasingly aware of their surrounding environment. In this framework, the industry has recognized an increasing demand for quiet environments and

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INTER-NOISE 09 Report

inter•noise 2009
innovations in practical noise control

2009 August 23-26
Ottawa, Canada

Over 1000 international experts on acoustics and noise control engineering visited Ottawa, Canada in August, 2009 to participate in INTER-NOISE 2009, the 38th International Congress and Exposition on Noise Control Engineering. The congress immediately followed ACTIVE 09, the 2009 International Symposium on Active Control of Sound and Vibration—reported upon elsewhere in this issue. Sponsored by the International Institute of Noise Control Engineering, INTER-NOISE 09 was organized on behalf of the Canadian Acoustical Association (CAA) and the Institute of Noise Control Engineering of the United States (INCE/USA). The team of organizers comprised researchers and staff from the National Research Council Canada (NRC), in cooperation with executive and staff of INCE/USA. The congress theme, *Innovations in Practical Noise Control*, stressed the importance of innovative thinking to achieve practical, cost-effective results. The congress was held in the Westin Hotel in downtown Ottawa on August 23-26, 2009.

The congress was opened on Sunday, August 23 by congress Co-Presidents Trevor Nightingale (NRC) and Joseph Cuschieri (INCE/USA) who welcomed the delegates and introduced the distinguished guests, beginning with Dr. Richard Normandin, NRC Vice-President for Physical Sciences, who gave an overview of activities at the NRC. He was followed by Christian Giguère, President of the Canadian Acoustical Association and Patricia Davies, President of INCE/USA who gave warm greetings from their respective host organizations. Finally, Tor Kihlman, representing the Royal Engineering Society of Sweden gave a summary report of a workshop sponsored by the International Council of Engineering and Technical Societies (CAETS) and held in the United Kingdom at the Institute for Sound and Vibration Research (ISVR) in June, 2008. The complete report appears as a feature article in this issue.

The first Distinguished Lecture for INTER-NOISE 09 was titled *Noise Induced Sleep Disturbances and After-Effects on Performance, Well-Being and Health* by Barbara Griefahn (IfADo - Leibniz Research Centre for Working Environment and Human Factors at TU Dortmund, Germany) and Mathias Basner (German Aerospace Center (DLR), Institute of Aerospace Medicine, Germany). The lecture was presented by Professor Griefahn immediately following the opening ceremonies. Abstract

Trevor Nightingale (NRC)

Dr. Richard Normandin

Christian Giguère

Patricia Davies, President of INCE/USA

Tor Kihlman

Barbara Griefahn

Michel Bérengier

Following the lecture, there was a Welcome Reception for all of the delegates, in the Westin Hotel.

Unlike past INTER-NOISE congresses, Distinguished Lectures on Monday, August 24 and Tuesday, August 25 were presented not in one plenary session, but in two parallel morning sessions. Thus, the second Distinguished Lecture was presented on Monday morning, August 24 by Michel Bérengier (Laboratoire Central des Ponts et Chaussées, France). *The lecture was titled Emission, Propagation and Control of Road Traffic Noise: Some Solutions for the Future*. Abstract

In parallel with the above lecture, the third Distinguished Lecture titled *Building Impact Sound Sources and Ratings* was presented by Jin Yong Jeon (Hanyang University, Korea). Abstract.

Parallel sessions then began and continued throughout the day. At noon, the exposition opened. Over 50 companies and agencies took part in the exposition where they presented their measurement equipment and software, testing and consulting services, and products and facilities. The sponsoring national associations, CAA and INCE/USA, as well as the NRC Institute for Research in Construction also participated, distributing publications and technical information related to their respective activities. An excellent job of organizing the exposition was done by exposition manager Richard J. Peppin. A very well attended second reception for all delegates was then held in the exposition area after the close of the parallel sessions.

Monday's Distinguished Lecture structure was followed again on Tuesday, August 25. Noureddine Atalla presented the paper *Modeling the Sound Transmission Through Sandwich-Composite Structures with Attached Noise Control Materials* which was prepared by Noureddine Atalla (Université de Sherbrooke, Canada) and Sebastian Ghinet (National Research Council, Institute for Aerospace Research, Canada). Abstract

In parallel with Professor Atalla's lecture, a Distinguished Lecture titled *Perception and Environmental Impact of Wind Turbine Noise*, was presented by Kerstin Persson Waye (Occupational and Environmental Medicine, The Sahlgrenska Academy, University of Gothenburg, Sweden). Abstract

On Tuesday evening, the INTER-NOISE 09 banquet was held at the Canadian Museum of Civilization just across the Ottawa River in Gatineau, Quebec. The Museum was opened specially for the INTER-NOISE delegates, and an excellent dinner was followed by outstanding performances by First Nation dancers.

The format of the Distinguished Lectures was again different on Wednesday, August 26. In the morning, Rajendra Singh (Ohio State University, USA) presented a paper titled *Gear Noise: Anatomy, Prediction and Solutions*. Abstract

Prior to the closing ceremony on Wednesday afternoon, J. David Quirt (National Research Council, Canada) presented the final Distinguished Lecture titled *Controlling Air-Borne and Structure-Borne Sound in Buildings*. Abstract

Following the lecture, the closing ceremony was held. Co-Presidents Trevor Nightingale and Joseph Cuschieri thanked all of the individuals who worked so hard to make INTER-NOISE 09 a success; special recognition was given to Brad Gover and Stuart Bolton, who served as Co-chairs of the technical program. Then followed three announcements of meetings to be held in 2010. Marion Burgess invited INTER-NOISE attendees to attend the International Congress on Acoustics, ICA 2010, which will be held in Sydney, Australia in August, Courtney Burroughs and Jorge Patricio, respectively, did the same for NOISE-CON 2010 held in Baltimore, USA in April, and INTER-NOISE 2010 to be held in Lisbon, Portugal in June.

More than 625 invited and contributed technical papers were presented over three days. The single largest topic receiving attention was sound in buildings, including: sound transmission, speech privacy, classroom acoustics, noise sources and ratings, acoustics of green buildings, and acoustical characterization of building materials. One of the largest sessions dealt with lightweight constructions (such as wood-framed). This highlighted the need to define better and more satisfactory construction details, particularly for the control of low frequency noise from foot falls. The technical program also included significant contributions on transportation noise (including aircraft), community and environmental noise (including health effects of noise exposure), acoustical measurements and characterization of materials.

One notable event during INTER-NOISE 2009 was a meeting of the *Perfect Head Society*. This group recognizes that the only perfect heads that exist on earth are those that are not covered by hair. At the next meeting of the Society, your managing editor intends to give each member a comb on the condition that they never part with it.

The Perfect Head Society meets in Ottawa. Left to right: Paul Schomer (USA), Keith Attenborough (UK), Gilles Daigle (Canada).

Concurrent with INTER-NOISE 2009 was the Second Forum of the International Council of the Academies of Engineering and Technological Sciences (CAETS) on Worldwide Noise Sources. The forum focused on sources of noise, in particular the technologies available for the reduction of product noise. CAETS is planning on using the outcome of this forum for support in developing recommendations for low-noise products and their worldwide promotion. A summary of the CAETS forum is planned for the June issue of this magazine.

The papers presented at INTER-NOISE have been collected and put on a CD-ROM which is available at the INCE/USA page at the Atlas Bookstore. An announcement appears on the last page of this issue. The titles of the papers presented at the Congress have been indexed according to the INCE Classification of Subjects, and the list is available here. The author index is available here. back to toc

First Nation dancer

Noureddine Atalla

Kerstin Persson Waye

Rajendra Singh

J. David Quirt

Almost one-hundred registrants from seventeen countries participated in ACTIVE 09, the 2009 International Sympoisum on Active Control of Sound and Vibration.

The symposium was held immediately preceding INTER-NOISE 09 in Ottawa Canada on August 20-22, 2009. It was held in the Westin Ottawa hotel. Alain Berry served as the general chair of the meeting, and Patrice Masson served as the technical program chair. Both are from the Université de Sherbrooke in Canada. At the opening session, Alain Berry greeted the registrants and introduced Steven J. Elliott, who presented the first of five distinguished lectures given at the symposium. Elliott is from the the Institute of Sound and Vibration Research, University of Southampton, U.K. His presentation was titled Active control of vibration in aircraft and inside the ear. Abstract

Two parallel sessions followed. After lunch on August 20, Kenneth A. Cunefare of the Georgia Institute of Technology presented the second distinguished lecture titled Challenges in distributed active noise and vibration. Abstract

Two parallel sessions were then held for the rest of the day. On Friday morning, August 21, ACTIVE 09 opened with a distinguished lecture by Rudolf Maier of EADS Innovation Works. The title of his presentation was Challenges and applications for active and noise and vibration control in aerospace. Abstract

Two parallel sessions were held for the rest of the morning. The afternoon distinguished lecture was presented by Christopher R. Fuller with the title Active control of portable generator set noise: heuristic verses design. The authors, all from the Vibration and Acoustics Laboratories at Virginia Tech were Christopher R. Fuller, C. Papenfuss, and T.D. Saux. Abstract

Parallel sessions continued during the afternoon. In the evening, the symposium banquet was held on a boat during a tour of the Rideau Canal in Ottawa.

The fifth and final distinguished lecture was presented on Saturday morning by Emmanuel Friot. The title was Estimation and global control of noise reflections. The co-authors were Emmanuel Friot and Alexandre Gintz of the CNRS – Laboratoire de Mécanique et d'Acoustique. Abstract

Alain Berry, General Chair of ACTIVE 09

Steven J. Elliott

Kenneth A. Cunefare

The symposium ended with a single session of papers. In all 57 papers were presented at ACTIVE 09. The proceedings of the symposium was edited by Phillippe Micheau, Courtney Burroughs, and George Maling. The CD-ROM contains not only the papers presented in Ottawa, but the papers presented at all of the previous ACTIVE symposia, a collection of 747 papers on active control of sound and vibration. Previous symposia were:

ACTIVE 06 Adelaide, Australia
ACTIVE 04, Williamsburg, USA
ACTIVE 02, Southampton, UK
ACTIVE 99, Fort Lauderdale, USA
ACTIVE 97, Budapest, Hungary
ACTIVE 95, Newport Beach, USA

The CD-ROM is available at the INCE/USA page at the Atlas Bookstore. An announcement appears on the last page of this issue. back to toc

Rudolf Maier

Christopher R. Fuller

Emmanuel Friot

(**Health Matters**, *continued from page 4*)

area. Throughout the 24 months of the Network results will be disseminated to the EU, to national governments, to fellow researchers and users including ICBEN, research councils and the general public across Europe and worldwide.

With the next major conference of ICBEN—the International Commission on the Biological Effects of Noise—being scheduled for 2011 in London, it will be important for close liaison to be maintained between I-INCE and ICBEN to ensure that noise control professionals worldwide are made aware of the latest thinking on this vital topic. back to toc

— Bernard Berry
European Editor, NNI

See, for example, B. F. Berry, N. D. Porter, and I. H. Flindell, 1998. *Health effects-based noise assessment methods; a review and feasibility study*. NPL Report CMAM 16 July 1998, and C. Clark and S. Stansfeld. 2007. T*he Effect of Transportation Noise on Health and Cognitive Development: A Review of Recent Evidence*. International Journal of Comparative Psychology, 2007, 20, 145-158. http://www2.gsu.edu/~wwwscp/ijcp-vol20-2-3-2007/06.Clark_PDF.pdf

(**Member Society Profile**, *continued from page 6*)

reliable products to achieve such aims. Also, being the society working towards a sustainable environment, and in view of these challenges, acoustics will play a key role in the future, and SPA will certainly be fundamental for all of those who have acoustics as their main concern. This year SPA is commemorating its 30th anniversary. We are proud and honored to have the INTERNOISE2010 in Lisbon. It is the result of the international recognition to what Portuguese Acoustical Society have done for the progress and development of acoustics worldwide, and in Portugal.

Finally, for those interested, additional information about SPA structure and activities may be found at http://www.spacustica.pt. back to toc

This is the 68th in a series of articles on the Member Societies of International INCE.

Member Society Profile is a regular feature of *Noise News International*. If you would like to have your society featured, please contact George Maling at inceusa@aol.com.

The design of low-noise vehicles for air, road, and rail transportation

Janet Moss, Noise Control Foundation, Poughkeepsie, NY 12603

Introduction

A technological problem that is of serious concern in Europe is the emission of noise from transportation sources. There is strong evidence that technology available today for quieting many transportation vehicles is being underused. To assess the state of noise control technology for transportation noise sources, the International Council of Academies of Engineering and Technical Societies (CAETS) approved holding a workshop at the Institute of Sound and Vibration Research (ISVR), Southhampton, United Kingdom, on June 2-4, 2008. CAETS is an independent nonpolitical, non-governmental international organization of engineering and technological sciences academies. The Royal Swedish Academy of Engineering Sciences and the Royal Academy of Engineering (UK) sponsored the workshop. Tor Kihlman (Sweden) and Philip Nelson (UK) were the general co-chairs for the meeting. Paolo Gardonio was the chair of the local organizing committee, and Maureen Mew was the local coordinator. The Noise Control Foundation held the workshop secretariat, and prepared a "source book" on which this article is based.

The objectives of the workshop were to identify and prepare an inventory of the technology available today for the design of low-noise vehicles and to assess what technology needs to be developed in the future for the reduction of transportation noise. This technology assessment will provide CAETS with background information and recommendations on the state of noise control technology in order for CAETS to make a clear statement on the noise emissions issue.

The workshop assessed the state of noise control technology today and recommended emission goals for the future that will support sustainable development. For road and rail vehicles, emission limits should be set so that they drive the technology rather than as now where they slowly follow the technological developments. For aircraft, technology development is driven in the short term by requirements for noise certification in conjunction with local airport limits and in the longer term by visionary European goals. Experts in aircraft, road, and rail technology were asked to serve as panelists and to make a presentation on a specific topic followed by a few minutes of questions and answers. Each panelist's presentation was guided by specific questions focused on the topic that the panelist was asked to address. For example, what is today's technology? Is present knowledge fully implemented in current-production vehicles? What are the key barriers at the present time to the introduction of quieter vehicles?

Air Transportation Vehicles

The first day, June 2, was devoted to air transportation vehicles, and the morning session was chaired by Jeremy Astley of ISVR. The following topics were covered:

- Technologies for reducing engine noise
- Technologies for reducing airframe noise
- Noise reduction versus reductions of other emissions
- The role of air traffic management and airport planning
- Noise implications of novel engine and airframe concepts

The types of vehicles covered were:

- Long- and short-haul turbofan powered subsonic transports
- Commuter aircraft and business jets
- Open-rotor powered aircraft
- Supersonic jet transports
- Novel configurations

Background

Challenging goals for time-averaged sound levels in communities around airports have been adopted in Europe and in Asian countries including Japan, Singapore, Australia, and New Zealand. Even with an expected three-fold increase in air traffic by the year 2025, the European Union (EU) aims for a significant reduction in community noise around airports by 2025. Just to maintain the status quo in airport communities will require at least a 5 dB reduction in the average level of the sound from the existing fleet of jet transports. To comply with the challenging goals requires reducing the sound produced by newly-delivered airplanes as well as a reduction in the sound from airplanes now in service and likely to remain in service beyond 2025.

Goals for aircraft noise in communities around airports are consistent with ambitious industry targets set forth in the Advisory Council for Aeronautics

Research in Europe (ACARE) 2020 vision [1]. For that vision, European airframe and engine manufacturers, together with airplane operators, air-traffic controllers, and airport management, are committed to a 10-dB reduction in the day-evening-night averaged sound level below that experienced in communities around airports in the year 2000 from the sound of departure and arrival operations by fixed-wing airplanes. Achieving this challenging goal must be combined with a 50 percent reduction in specific fuel consumption relative to that achieved by engines that were newly introduced to service in the year 2000.

To reach the ACARE goals will require the full exploitation of current noise reduction technology, the development of new noise reduction technologies for newly-designed aircraft entering service during this period, and the imaginative use of new operational and air traffic management procedures. Meaningful reductions in the levels of sound in airport communities will also require application of additional noise reduction technologies to airplanes that now comprise the fleet of jet transports operating at airports in Europe.

Over the next twenty years, newly-designed aircraft are likely to be introduced at a rapid rate. These aircraft will likely be evolutions of current aircraft but designed to achieve significant reductions of noise and carbon emissions. In the longer term (beyond 2025) further reductions in noise and carbon emissions are likely to involve the development of entirely new aircraft and engine configurations. The enabling technologies that will be needed for both of these phases of development are now becoming apparent.

The following questions were sent to the panelists:

1. What is today's technology and how effective is its exploitation?
2. What technologies are in the pipeline for new airplanes that might be introduced in 2020? Will they achieve the ACARE goals?
3. What are the new technologies and air traffic management procedures that will provide long term solutions to aircraft noise in airport communities?
4. Will trade-offs be required between noise and carbon emissions in the design of future aircraft?
5. Are there fundamental technical or practical barriers to development of a 'silent' aircraft? ('silent' = average sound levels that do not exceed the sound levels caused by sources other than aircraft beyond airport boundaries during departure and arrival operations.)
6. If the noise-reduction goals were to be framed in terms of achieving "Quota Count" (QC) goals rather than in terms of lower limits on noise-certification levels, how might the technological developments be modified?

The afternoon was devoted to a discussion period chaired by Philip Nelson (ISVR). The discussion questions were:

1. What is a realistic estimate of the dates for the introduction of the noise-reduction technology that has been presented today for production versions of civil jet transports and how might the introduction dates vary with the thrust class of new designs for turbofan engines?
2. What is a realistic expectation for residents in communities in the vicinity of European airports for the reduction in the average level of the sound from aircraft that might be achieved by the year 2025, relative to the average sound level experienced by the communities in, for example, 2005? Background for question: The estimated reduction in average sound level should consider the increase in the annual number of operations by civil jet transports expected in 2025 relative to the annual number of operations in 2005 as well as the likely schedule for the introduction of large numbers of new designs for jet transports incorporating new noise-reduction technology.
3. What practical and economically reasonable program can be envisioned to reduce the sound from takeoff and landing operations of the aircraft that will comprise the entire fleet of civil jet transports and business jets operating at European airports in the period from 2010 to 2020? Background for question: If the ultimate objective of research on aircraft noise-reduction technologies is to reduce the average sound level (specifically the day-evening-night averaged sound level) in airport communities caused by takeoff and landing operations of civil jet transports and business jets, and if the expected increase in the average number of daily operations does materialize, and if the rate at which new aircraft noise-reduction technology can be introduced is such that only a few hundred of the new-design transports will, at best, be in the fleet operating at European airports by 2025, then it is clear that the average sound level in most airport communities will NOT be significantly reduced unless some practical way is found to reduce the sound produced by the Chapter 3 and Chapter 4-compliant airplanes that are in the fleet in 2008 as well as those to be produced and delivered for service over the next 5 to 10 years.
4. What efforts will be made in Europe to ensure a broad-based international approach to achieving the very worthy goals of the ACARE project? Background for question: The task of developing a civil jet transport is international in scope with risk-sharing partners in many non-European countries for the European airframe and engine manufacturers. Similarly, the prime airframe and engine manufacturers in non-European countries can be expected to have

risk-sharing partners in European countries. Because the market for civil jet transports is international, special requirements for reducing the noise of future jet transports cannot just apply to European manufacturers, but have to be developed and apply to all relevant manufacturers, including those in Russia, China, and Japan as well as those in the USA, Canada, and Brazil.

5. Is it reasonable to assume that supersonic business jets will be required to comply with the same noise-certification standards of ICAO Annex 16 as are required for subsonic civil jet transports at the same takeoff gross mass? Background for question: An effort is underway to develop a business jet with the capability to cruise at a supersonic speed over populated areas.
6. What limitations on applications of noise-reduction technology might be expected as a result of requirements for stringent limitations on engine emission of atmospheric pollutants? Background for question: New designs of turbofan engines for civil jet transports that have significantly lower emissions of oxides of nitrogen as well as carbon dioxide may not be compatible with technologies to reduce the sound produced during departure operations, which is the cause of the largest exposure to aircraft noise in most airport communities.

The Panel Presentations

The panelists for the first day's presentation were:

Jeremy Astley, ISVR, Air Transportation Session Chair
Introduction to the aircraft noise problem

Eugene Kors, Snecma
Engine noise reduction. SILENCE(R) and beyond

Pierre Lempereur, Airbus
Airframe noise reduction—current and future technologies

Andrew Kempton, Rolls Royce
Applying noise technology to aircraft designs

Callum Thomas, Manchester Metropolitan University
Controlling and mitigating impacts near airports

Ann Dowling, U. of Cambridge
Towards a silent aircraft

Introduction to the Aircraft Noise Problem

Jeremy Astley

The Environmental Impact of Air Transport

The environmental impact of aircraft noise is a local problem. It arises at takeoff and landing and affects populated areas close to airports. Noise is an important environmental impact of air transport, along with; NO_x emissions which impact on local air quality, and carbon emissions which have a global impact contributing to global warming and climate change. Carbon emissions currently pose the most significant long term threat to the continued expansion of the air transport. Noise, however, remains a critical constraint in planning new airports and in increasing or maintaining the volume of passenger movements through existing facilities.

Aviation accounts for 3 percent of current global carbon emissions, offset to some extent by an average year-on-year increase in the efficiency of commercial aircraft entering service of approximately 1.5 percent per annum. Noise levels of new aircraft entering service have also fallen, by between 0.3 and 0.5 EPNdB per annum on a weight adjusted basis. This represents a decrease of between 20 and 30 dB since the introduction of the turbofan engine almost five decades ago. In the current climate, however, further reductions in aircraft noise must be achieved in a way that does not compromise efficiency and reduced fuel burn.

Sources of Aircraft Noise

There are three dominant sources of aircraft noise: fan noise, jet mixing noise and airframe noise. Fan noise and jet mixing noise are the major contributors at takeoff. Fan noise and airframe noise dominate at approach.

Fan Noise. Tone and broadband sources both make an important contribution to fan noise. Fan tones are generated by rotating (rotor locked) pressure fields on the fan face, and also the periodic interaction of rotor wakes with the stationary vanes. A more subtle tone mechanism at high power settings are lower frequency 'buzz saw' tones which are generated at multiples of the shaft rotation frequency by non-linear effects associated with shocks which form ahead of the rotor blades. Fan broadband noise is associated with unsteady random flow in the turbulent boundary layers which form on the fan and on the stationary vanes, on turbulence in the rotor wakes, and in the boundary layer on the fan case. These all generate noise which radiates from the engine. All of these mechanisms are important and they must be reduced simultaneously to bring about an overall reduction in noise.

Methods to mitigate fan noise at source include:

- The design of advanced low-noise fan blades, driven by 3D CFD and validated by rig and engine tests.
- Improved parametric studies using semi-analytic models to reduce broadband noise.
- Flow control (wake filling, trailing edge blade treatments, etc.) to reduce fan noise at source.

The radiation of fan noise can also be reduced very significantly by the use of acoustic liners in the intake and bypass ducts. Optimized liner configurations, driven by advanced CAA tools and validated by rig and engine tests, offer the potential for significant further improvement.

Jet Noise. Jet noise is more difficult to control at source. It is generated in the jet mixing layers which extend up to ten diameters downstream from the exhaust nozzle. Radiated acoustic power varies as U^8 or U^6 and the most effective way to reduce jet noise is to reduce U, the jet velocity. This has been achieved in the turbofan engine by increasing the proportion of the flow which passes through the bypass duct rather than through the engine core (the "bypass ratio"). This becomes counterproductive however in terms of overall aircraft efficiency as bypass ratio increases into double figures.

Reducing jet noise is hindered by difficulties encountered in its accurate prediction for specific engine and nozzle configurations. Large noise databases are extensively used for this purpose. RANS and LES computations are also beginning to yield useful design data. Many current attempts to reduce jet noise focus on the idea of modifying the turbulent structure within the shear layers in a noise reducing way. Current or proposed technologies include:

- Forced mixers for long cowl engines with buried nozzles
- Chevrons for short and 3/4 cowl engines
- Deployable tabs on the exhaust nozzle using shape metal alloys
- Offset and scarfed nozzles
- Flow control devices such as microjets and plasma actuators

Airframe Noise. The landing gears and high-lift devices deployed at approach (slats and flaps) are the main sources of airframe noise. The radiated sound power varies as U^6 and noise benefits can be achieved from improved low-speed aerodynamic performance. Measured data and semi-empirical "engineering" models are currently central to industry predictions. RANS, LES and DES are also applied but are computationally intensive and not yet suitable as prediction tools. Proposed technologies to reduce airframe noise include improved low-speed aerodynamic performance, landing gear fairings, liners for leading edge slots, brushes and porous edge treatments for flaps, and flow control.

Characterizing Noise for New Aircraft Certification

Two equivalent international frameworks for characterizing the noise attributes of new aircraft came into effect in the late 1960s and have been revised from time to time by their originators the Federal Aviation Administration (FAA) and the International Civil Aviation Organization (ICAO). They use "Effective Perceived Noise Level" (EPNL) measured in dB as a metric for aircraft noise, giving airframers and engine manufacturers a single parameter to target for certification. The EPNL measures the duration, level and tone content of noise radiated by an aircraft at three conditions: sideline (lateral), cutback, approach. The permitted EPNL is related to aircraft take-off weight. Local airport regulations are also important in determining the acceptability of new aircraft from a noise perspective. The London airports quota count (QC), which also uses EPNL as a metric but does not adjust for take-off weight, is particularly significant.

Characterizing Noise for Airport Operation and Planning

Environmental time-averaged noise metrics are commonly used for noise monitoring and planning near airports (e.g. the 92 day LAeq, is common in the UK). These are used to define levels of nuisance experienced by communities affected by aircraft noise and to set noise penalties for airlines. The relationship between public attitudes to aircraft noise and noise metrics such as LAeq is ambiguous, however, as is the relationship between these measures and EPNL.

Noise Targets and Potential Obstacles to Quieter Aircraft

A 10 dB reduction on EPNL between 2000 and 2020 has been targeted by the Advisory Council for Aerospace Research in Europe (ACARE) as a goal for European aircraft and engine manufacturers. While this is on track to be satisfied by traditional tube-and-wing, turbofan designs, trade-offs and inter-dependencies with other environmental targets, such as carbon emissions, may drive the design of future aircraft in directions which give greater fuel efficiency rather than optimal noise reduction. In the longer term, radical new designs such as the blended wing, may deliver efficiency and noise benefits, provided that the necessary enabling technologies can be developed.

Technologies for Engine Noise Reduction—SILENCE(R) and Beyond

Eugene Kors

The purpose of this presentation is to describe the SILENCE(R) Engine Technology Project and the new technologies that are in the pipeline to reduce noise in new aircraft entering service before 2020.

The SILENCE(R) Project started in April, 2001, and took six years to complete at a cost of 112 M €. The European Commission provided 50 percent of the funding. The project was coordinated by Snecma and was supported by 51 partners. The goal was to reduce engine noise by 5-6 dB, validate individual technologies, identify the applicability of these technologies over a range of products, and produce a cost/benefit analysis. The SILENCE(R) Technology Platform dealt with turbo-machinery noise reduction technology, exhaust noise reduction technology, and airframe noise reduction techniques.

The engine noise reduction technologies that were studied included integrated fan designs, the UHBR (ultra high bypass ratio) fan, the LP compressor, high-speed LP turbines, the negatively scarfed intake, novel liners, intake lip liners, anti-icing adaptive liners, exhaust splitters, and low-noise fan nozzles. Active wall-mounted stators were also studied.

The low-noise compressor for UHBR engines is a high-speed compressor with computational fluid dynamics simulations to identify potentials of noise reduction in a high-speed LPC of an aero engine. It has a computational-fluid-dynamics-based design and is subjected to back-to-back testing on a compressor rig using modal analysis techniques. There has been a blade-passage-frequency tone reduction by 8 dB with no performance penalties. Large-scale testing was carried out in Germany on a fan rig at AneCom Aerotest.

The objective was to minimize low-pressure turbine noise. Data reduction involving circumferential and radial mode detection demonstrated that highly-loaded turbines can be acoustically designed to maintain noise levels with weight and cost reductions.

A zero-splice liner was developed for the nacelle with several prototypes being developed in various facilities. Follow-on industry research and testing demonstrated a clear benefit. The zero-splice technology applied to an Airbus A380/Trent 900 showed up to a 4-7 dB reduction on takeoff and a 2 dB reduction on approach.

The hot-stream liner-test facility handled flows up to mach 0.4, temperatures to 550˚C, and sound pressure levels up to 140 dB over the frequency range between 0.5 and 5 kHz. Twenty-three liner configurations were tested.

The exhaust plugs had multiple, light-weight designs, manufactured for full-scale validation. A down-selection process was used for best performance. The exhaust nozzle treatment is a computational-fluid-dynamics design with model tests for down-selection and flight and static test for full-scale validation. A turbine noise liner is integrated into the exhaust nozzle which is tested in-flight and during static tests (A320/CFM56-5B).

Hybrid functioning involving active control at low frequencies and passive absorption at high frequencies with a cut-over frequency of 1400 Hz produced high attenuation levels over a wide frequency range.

The Vital Project is a four-year program costing 92 M€ that started in 2006 dealing with advanced configurations for engine architectures. Objectives of this program are CO_2 reduction, NO_x reduction, and noise reduction with a strong focus on fuel-burn reduction through increased bypass ratio achieved either with conventional engine architecture, a geared turbofan, or a counter-rotating turbofan.

The objectives of the JTI Clean Sky program are similar—CO_2 reduction, NO_x reduction, and noise reduction. This seven-year research program was scheduled to start in mid-2008 at a cost of 1600 M€ of which 421 M€ will be devoted to engines. The conventional engine architecture, the counter-rotating fan, and the open-rotor engine will be evaluated for improvements in fuel burn and noise reduction.

For both the Vital Project and the JTI Clean Sky program, targets vary over the product range but all comply with the ACARE 2020 objective.

Airframe Noise Reduction—Current and Future Technologies

Pierre Lempereur

The A380 aircraft is an example of the implementation of current technology. During the concept phase of the design of the aircraft, market requirements became more demanding. The increasing importance of local airport requirements such as the London airports quota count (QC) system which, unlike certification requirements, are independent of aircraft weight and therefore more challenging for larger aircraft, has meant that aircraft noise levels of QC4 at departure and QC2 at approach—which had been tolerated in previous aircraft—were not acceptable in the market for new aircraft, irrespective of weight and size. A 3 dB reduction in certified sideline and flyover noise levels relative to the previous baseline was needed. Although departure noise was the driver, approach noise benefited from the improvements.

Airbus and its engine suppliers ensured that the external noise requirements were met by the identification of all factors contributing to the external noise performance and their mechanisms, by the development and application of more accurate noise prediction tools, by the implementation of new technologies for lower noise, and by a rigorous monitoring of all acoustic risks throughout the development.

During the acoustic design of the A380, significant noise reductions were planned by attacking all noise sources, by optimization of low-speed performance, by the specification and facilitation of low-noise operational procedures, by reducing airframe noise, by improved optimization of Nacelle acoustic treatment and by reductions in engine noise at the source.

The International Civil Aviation Organization (ICAO) Committee on Aviation Environmental Protection approved two procedures for “close-in” and “distant” departures. Non-optimal handling of departure trajectories is one reason for frequent noise limit infringements. To optimize departure procedures, the A380 has a new automatic flight function to reliably and continuously handle departures with optimum noise trajectories, taking into account ambient conditions, airport constraints and adjacent areas to be protected, and aircraft parameters

The research and technology objectives of ACARE embodied in its Vision 2020 “Strategic Research Agenda” (SRA) are to reduce perceived noise to one half (10 EPN dB) at takeoff and approach, and to eliminate noise nuisance outside airport boundaries. To achieve these objectives, aircraft noise must be reduced at the source, acoustic treatments must be optimized, low-speed aircraft performance improvements must be exploited for reduced noise, and noise-reducing operational procedures must be facilitated at approach and takeoff in conjunction with improved land planning near airports.

For take-off operation, engine noise is the major contributor to the overall aircraft signature. However as individual engine sources are reduced other sources, including airframe, play a more important role. For approach operation, airframe noise is a major contributor to the overall aircraft noise signature, equalling or in some instances exceeding fan noise. The main airframe noise sources are the high-lift devices and landing gear. In future aircraft it is likely that low-noise, high-lift systems will be incorporated with slat-track fairing, leading-edge sealing, flap-edge treatment, gap acoustic liner, and a slat cusp design. Low-noise landing gears will probably be achieved by further attention to their fairing, shape, and flow control.

Low-noise exhaust systems have already been achieved in aircraft such as the A380 by the use of a very high-bypass ratio engine with reduced jet exhaust velocities and increased mass flow to achieve thrust. The use of spliceless liners in the intake is a novel feature of the A380 which have made a significant contribution to reducing fan noise in the forward arc. In the future it is likely also that nozzle lip treatments will reduce exhaust noise by promoting faster mixing of the jet exhaust and minimizing turbulence creation in the mixing process.

The negatively-scarfed inlet which redirects sound away from the ground is a promising noise reduction technology which has not been implemented to date, as is the concept of extending an acoustic liner up to the lip of the intake. Splitters in the bypass duct offer potential noise reductions in the bypass duct, in conjunction with more comprehensive optimization of aft duct acoustic treatments.

Noise abatement is possible during aircraft approach with a continuous descent approach which includes the following:

- Increased ILS glide interception altitude
- Increased ILS glide slope
- Optimized sequencing of aerodynamic configuration settings and speeds
- Optimized descent energy sharing (slope vs. deceleration)
- All descent at idle power, throttle variations avoided
- Additional aerodynamic noise avoided

Such abatement would need to take into consideration air traffic management, airport capacity, new flight-management and air traffic control systems, and discrepancies of the impact among airplane classes.

For the future, shielding of major engine noise sources may be accomplished by mounting the engines above the fuselage. In the far future an advanced airframe of the flying-wing type with integrated engines to achieve optimum reduction of airframe and engine noise has been demonstrated to be feasible.

In conclusion, recent and currently in-development aircraft are achieving a step change in noise reduction with reference to previous generations. They incorporate some new noise reduction technologies and noise is a strong driver for their overall optimization. A number of noise technologies are still under development and a major research and technology effort is to be undertaken to achieve targeted noise reductions and to solve issues of their integration into next generation products.

Controlling and Mitigating Impacts Near Airports

Callum Thomas

As early as the 1920s, it was recognized that aircraft noise could generate opposition to aviation and accordingly in order to protect its growth, governments enacted legislation to remove the right of citizens to sue for nuisance from aircraft in flight. Later, following the introduction into service of commercial jet aircraft in the 1950s there was a sudden realization that noise disturbance could seriously threaten the growth of airports and that further action and investment in quieter technologies would be necessary.

In the past, the phase-out of noisy aircraft and significant investment in much quieter jets has occurred at such a rate that, despite significant traffic growth, the area of noise contours and the number of people exposed to noise has declined at many airports. Failure to prevent urban encroachment upon airports has, however, negated the benefits of improved technology with the result that millions of people living near airports continue to be exposed on a daily basis to high levels of noise.

Accordingly, the disturbance caused by aircraft noise remains the most significant environmental impact arising from the operation of airports and this is now threatening their future growth. A recent survey of European airports[1] has indicated that up to two thirds already have their operations constrained by noise related issues and that this figure could increase to 80 percent in the next 5-10 years. This is significant at a time when many airports are reaching the limit of their infrastructure capacity and planning approvals for further growth are becoming more difficult to achieve.

Noise disturbance is the single most important issue raised by opponents of airport expansion. An emerging planning constraint imposed upon airports seeking infrastructure development is the establishment of a limit upon the amount of noise generated over a given period of time by their operations. As a result a number of major airports have noise limits which could, in theory, restrict operations to less than the capacity of the infrastructure they have provided.

At many airports, therefore, the ability to grow in response to demand can be directly related to their efforts to control aircraft noise and there is a very clear business case that links airport capacity with investment in noise management. Some airports invest many millions of Euros every year in noise control programmes, the construction of specific infrastructure (noise bunds, engine test facilities) and the mitigation of noise impacts through the provision of sound insulation, the payment of compensation to local residents and house purchase schemes. A description of the variety of methods used to manage aircraft noise can be found in Thomas et al. (2003)[2]

As noise capacity limits are reached, airports will increasingly need to balance the noise levels generated by each individual movement against the potential for future traffic growth. Although all airports differ in terms of their infrastructure, local geography and proximity to residential areas, it is paradoxical that many of the airports that are most popular with airlines, are those that are closest to major urban conurbations (where the customers are) and, therefore, those which in many respects are the most noise sensitive. It is also noteworthy that many of these major airports are likely to approach their ultimate capacity over the coming 10-20 years. Failure to make full use of available capacity and consequential failure to meet demand will have direct economic implications for airports and airlines alike as well as the regions they serve.

It is understandable, therefore, that while airlines may be reluctant to dispose of perfectly airworthy aircraft simply because they are too noisy, they also recognize that without such action, they will fail to gain access to some key airports, they would be restricted in the times that they could operate at others, or could incur increased operational charges or noise penalties. This is a particular problem for airlines from some developing nations which wish to access major airports in industrialized countries.

Further it is evident that despite the significant achievements of the past half century, the challenge posed by aircraft noise will continue to have a significant and increasing effect on airport and airline development and economics in the future. Forecasts suggest that the anticipated rate of traffic growth will outstrip the benefits of fleet replacement with the result that noise contours around many airports are likely to grow again, increasing the number of people exposed to disturbance in the future.

In addition to increasing numbers of people being exposed to noise, disturbance in communities will further be exacerbated because the perception of what is an “acceptable” level of annoyance or nuisance will decline as people become more affluent and develop higher expectations of quality of life. This is important because it will drive increasing community opposition to airport (and therefore aviation) growth.

While there are guidelines and limits laid down by the World Health Organisation relating to noise as it directly affects health, at progressively lower levels of exposure there is less clarity as to what is ‘acceptable’ or ‘reasonable’ in terms of nuisance or disturbance. It is becoming increasingly clear that communities and individuals respond very differently and exhibit differing degrees of tolerance to noise depending upon a wide variety of social, economic, and cultural factors. Equally, the nature of the way in which noise impacts upon communities will vary according to a variety of issues (such as weather conditions) that affect lifestyle.

There is considerable potential for further research into the development of indicators of impact, nuisance and tolerance, improved operational and noise mitigation programmes, but most importantly into airframe and engine technologies.

Towards a Silent Aircraft

Ann Dowling

Introduction

The vision of quieter and more environmentally friendly flying is a step closer as researchers from Cambridge University and the Massachusetts Institute of Technology (MIT) unveiled a revolutionary concept with the Silent Aircraft Initiative (SAI). Originally conceived as making a major reduction in the noise experienced by people in the vicinity of airports, this highly-efficient design also offers improvements of around 25 percent in the fuel consumed in a typical flight compared to current aircraft.

The SAI worked toward this goal by researching airframe configurations and techniques for controlling airflow, drag and descent. In addition, design specifications emphasized low fuel consumption.

The SAI design is intended for the generation after next. The next generation of aircraft will enter into service in 2030. The SAI generation aircraft is intended for introduction in latter half of this century. This design will improve the airframe and the engines, as much of the noise from a landing plane comes from the airframe. Some of the key design features employed are:

- the overall shape of the aircraft which is a single flying wing – this allows the body to provide lift as well as the wings allowing a slower approach which reduces noise and the shape improves fuel efficiency in cruise
- flaps and slats have been eliminated; these are a major source of airframe noise when a plane is landing
- the undercarriage has been simplified and its aerodynamics improved
- the engines are mounted on the top of the aircraft
- novel, ultra-high bypass engines, which have variable size jet nozzles to allow slower jet propulsion during takeoff and climb for low noise, and are optimized for maximum efficiency during cruise which requires higher jet speeds.

The goal is to design a plane that even people living under the departure and approach routes to major airports would hardly notice. Many of the design innovations that make the SAI aircraft quieter than conventional aircraft also make it more fuel efficient, meaning fewer "greenhouse gas" emissions.

Design Features

To implement the key design features, the following major design innovations will be incorporated into the SAI aircraft:

Blended-wing design. The SAI aircraft will be an "all-lift" aircraft. The entire body of the plane, including the wing and fuselage, will generate lift. In conventional commercial aircraft, only the wings generate lift. The all-lift design will allow for quieter operation because the shape of the plane will provide lift at lower speeds than usual. This means the plane will be able to land using slower engine speeds — the higher the engine speed, the greater the noise.

This body design also means there will be no wing flaps, which make noise at landing, because the wing will generate lift without them. Overall, the blended-wing design will be more fuel efficient because the plane will generate lift at a wider range of speeds.

Engine placement. The SAI aircraft's three smaller engines, of the GRANTA 3401 class, will be mounted in the back of the plane and on top of the wing. In this position, the fuselage will shield much of the engine noise from the ground, deflecting it upward. In the standard aircraft design, the engines are mounted underneath the wings and that means engine noise is reflected downward.

Engine integration. In the SAI aircraft, the engines will be integrated into the fuselage, situated in long ducts made possible by the shape of the fuselage. The engines will be placed inside the ducts, which will be equipped with extensive noise dampening layers. By the time the engine noise escapes the ducts, it will have already been significantly absorbed.

Redesigned undercarriage. The undercarriage of the SAI aircraft will be more aerodynamic than that of a traditional commercial jet, meaning a quieter take-off and landing and greater overall efficiency in flight.

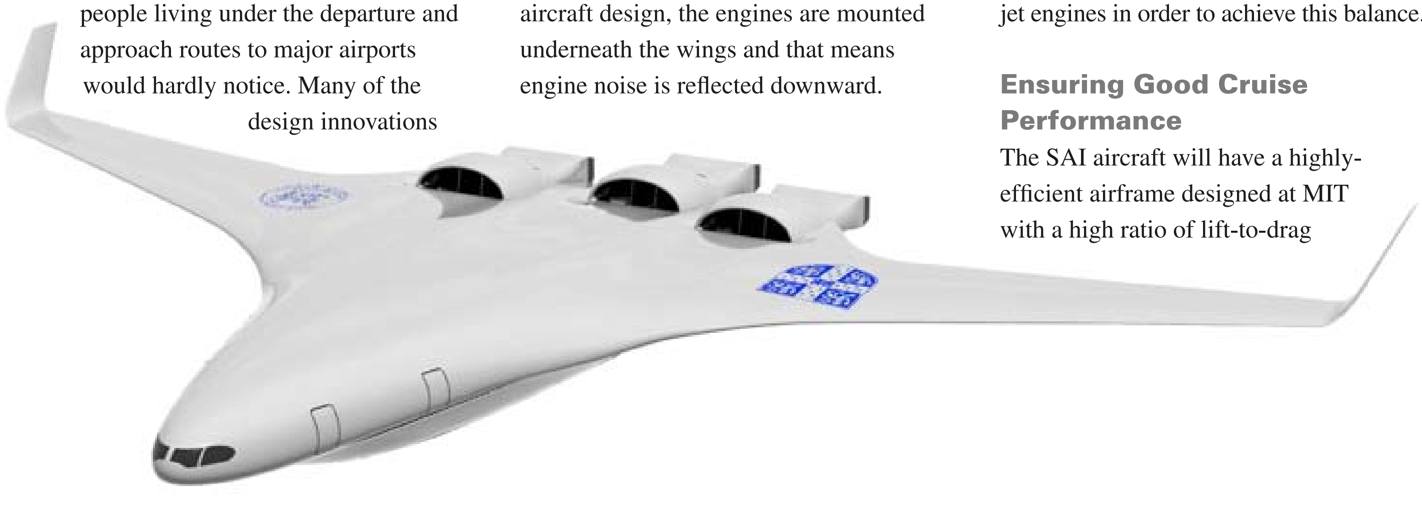
The SAI paid careful attention to the reduction of noise at take-off and landing while ensuring good cruising performance. An enhanced form of Continuous Descent Approach will significantly reduce the noise generated by the aircraft on landing.

Reducing Noise at Take-off

The engines are the major sources of noise from aircraft at take-off; and therefore, to meet the SAI noise target, a novel engine design was required. A team of researchers from the University of Cambridge worked closely with engineers at Rolls-Royce to produce a completely new engine design. This balanced the reduced jet speed required for noise reduction against the level of thrust required for take-off. The team found that the total exhaust area must be about twice that of today's conventional jet engines in order to achieve this balance.

Ensuring Good Cruise Performance

The SAI aircraft will have a highly-efficient airframe designed at MIT with a high ratio of lift-to-drag



forces. This will reduce the cruise fuel burn. Larger engines would increase the drag experienced during cruise, which would counteract the benefits on fuel consumption of the efficient airframe. The SAI design reduced the amount of drag contributed by the engines by changing the way they will be mounted on the airframe. Instead of hanging below the wing, they will be embedded within the aircraft. By locating the engine intakes on the upper surface it will be possible to partially shield people on the ground from the engine noise.

Reducing Noise at Landing

The airframe of a landing aircraft is as noisy as its engines. The noise generated by the airframe drops very quickly as the aircraft speed is reduced. The efficient airframe of the SAI aircraft will enable a low-speed approach. The low-noise SAI aircraft will have no flaps, a drooped leading edge, and a simplified and streamlined undercarriage.

The Silent Aircraft Initiative has brought industry, academia, and other stakeholders together around a "grand challenge" that has captured the enthusiasm and imagination of all partners; there has been effective collaboration, knowledge exchange, and development of a real team approach. The Initiative has confirmed that the solution for an extremely low-noise aircraft must be a highly-integrated combination of engine and aircraft design and operation.

Discussion — Day 1

Question:

Are today's technologies to reduce aircraft noise being fully exploited? Do we have things that we know will benefit but are not being put into play?

Responses:

1. We are under pressure within the SNECMA noise group as well as at Rolls Royce to come up with designs that are quieter. The airframe manufacturers are always pushing for quieter engines in the same way they are pushing for more fuel-efficient power plants. So any technology needs to buy its way onto the aircraft and is a compromise between the different environmental parameters—costs, risks. I'm not aware of technologies that are not included in that compromise but should be.
2. It's a tradeoff. With the current designs there's the option to have more noise reduction but this results in more drag and thus in more fuel consumption. So when you talk to customers, the airframers or the airlines, there are always tradeoffs which influence the designs that you see today. Of course aircraft can be made quieter if people are willing to pay a higher price in fuel consumption.
3. If a noise reduction technology was not implemented in an aircraft, the only reason would be that, if it were included, the craft would not fulfill its objectives in terms of what the market expects from it. But although technology might be ready for implementation, can take a minimum of five years before it is seen in an operational aircraft—the time that is taken from planning to implementation.
4. Where a gap exists is in the down-level aircraft still flying which are not using the new technology. Today's latest technology is not being fully exploited because aircraft have a very long life span. Many of the active aircraft are not using these technologies. It is a question of economics. Few people want to pay more for their tickets because some aircraft are put prematurely into obsolescence.
5. The best way to reduce noise is to reduce it in the initial design. It is harder to subsequently retrofit aircraft. If an ultra-high-bypass-ratio engine under the wing is going to hit the ground on taxiing, the aircraft can't be retrofitted with that engine. Another issue is that Chapter 2 aircraft (aircraft that meet the Stage 2, Chapter 2 limit but don't meet Chapter 3) have been phased out in a number of countries and are no longer flying in Europe, the U.S., or parts of the Far East or Australia. These aircraft are moved on to developing countries. So there is a large part of the aircraft fleet which some countries are eager to receive even though they are noisier. To insist that those aircraft be phased out to reduce noise would have a detrimental economic impact on some countries.
6. There are tangible benefits to be had by improving operational procedures as well as retrofitting existing aircraft fleets.

Question:

If the only constraints on the industry from ICAO certification requirements were suddenly made much more severe in response to increasing public pressure, would the industry be able to respond with existing technology or would we have to wait 20 years? How quickly could the industry respond and would that greatly increase costs? Could improvements come about using both operations and existing technology?

Responses:

1. If there is a new, more stringent requirement, then one way or another I think the industry will comply with it. In the example of the inlets which are two or three times as long as what you see today, assuming that the engine can bear the additional weight, there are all kinds of not so efficient things you can do. Tradeoffs can be difficult with high costs to the operators.
2. It seems that the consensus within ICAO involves industry, but one can't help thinking that this is only part of the story. To what extent should local legislation and politics, if you

like, drive noise reduction if that the research process doesn't continue to deliver feasible reductions?

3. Because up to 80 percent of airports are noise-constrained below their operational capacity, some airports are planning additional capacity for growth. It's usual that planning approval is turned down, and often on noise grounds. So noise is still the number one capacity constraint in the air transport system. The airports that are most popular with the flying public are close to the largest centers of population, and they are the most noise-sensitive airports. The market to a degree is driving it. But growth is outstripping the rate of technological development.
4. So what you're saying is that the mechanisms are in place to regulate, that there is a market drive to ensure that noise gets reduced.
5. There is a market drive to ensure that noise gets reduced, but airport operators would argue that technology is not moving rapidly enough. Otherwise airports wouldn't have to invest millions of pounds a year. Certification needs to be more stringent. It's just part of the process.
6. It was suggested that there is a wide margin between the current certified levels and the limit. But in fact for today's aircraft, industry builds a whole family of airplanes with different fuselage lengths and passenger numbers. Often there are airplanes we need to make that are more affordable, which come very close to or even at the limit. Although only a few products are involved, it is still important to get a product family accepted by the market. The airlines want to have a wide choice. They say if they grow, they want to grow into a larger aircraft of the same family and need to have the guarantee today that an airplane family will be able to meet all requirements. So in our design process, although an airplane may be well below the limit, if you expand that family of airplanes in the future, you may get very close to the limit. That is the reason why today some new aircraft may seem to have a large margin below the noise limit. The majority of the fleet is below, but there are always aircraft that are over or very close to the limit. So the certification limit of ICAO is, in that way, still a driver.
7. You said that ICAO is the driver. The Airports Council International likes to say that we should impose more stringent noise limits in the future. We wanted to phase out the marginally Chapter 3 aircraft, and ICAO said no. Some political drive is needed.
8. ICAO's mandate is to look at all rules that are environmentally beneficial, technically feasible, and economically reasonable. So they are always trying to achieve that balance. For a number of reasons, there's also the need to have a margin between the noise you think an aircraft is going to make and the certification limit you must achieve. Because there will be variables in the design process as it goes along, the aircraft might end up noisier than you originally thought it was going to be. A margin is needed between nominal levels and what you are prepared to guarantee. That's another reason why you often find the aircraft noise significantly lower than the actual certification limits. The certification process really is a license to operate. And then you have certain airports that impose more stringent requirements. Airports would like to have the noise reduced because that concerns them most. But you are also considering fuel burn and the impact on climate change—ICAO needs to balance all these different issues.
9. I can understand the issue of technical feasibility. But with policy, everything has to be technically feasible otherwise it becomes an aspiration. The term is economic reasonableness. One of the problems we have is putting a financial value on noise capacity at airports. One can put a financial value on the operating costs of an airline, on having to pay for new aircraft, or on the need for pay back. But when you talk about providing noise capacity at airports, it is very difficult to put a figure on it. If an airport has to build a new runway which cost 3-4 hundred million euros because it's run out of capacity due to aircraft noise, then suddenly you can see how expensive noise has become. Schipol is a good example. We need to be able to get the sustainable balance between airline economics and airport capacity constraints.
10. It is a question of economic balance. Because this isn't really measured very well on the opposite sides of the equation, it becomes open to different political positions and becomes a debate. Whether or not we'd like to have more stringent noise limits in the future depends to some extent on how loudly the environmental lobby starts to shout. I don't know to what extent industry is prepared for the environmental lobby becoming stronger or having a more focused voice in terms of driving ICAO downwards before 2013. This remains important. There is pressure to reduce noise levels through certification procedures.
11. While we appreciate the balanced approach ICAO takes, discussions are continuing in that framework.
12. I believe the CAEP (ICAO Committee on Environmental Protection) has a meeting every three years with activity in between leading up to the CAEP meeting. The next CAEP meeting is in 2010.
13. With 5 percent growth per year the industry will be 25 percent bigger in 2013 than it is now. So if you are trying to offset the effects of growth by improving technology, then when we discuss noise again, the challenge will be even greater than it is now.

That's just a reality ICAO will have to deal with. One of the problems is that because of the long lead-in times, it is far more difficult to catch up with where we should be.

Question:

There were some fairly obvious, helpful minor adjustments to conventional design from this morning's discussion that come out of European research—that look like they are practical. The ACARE goals look as if they are achievable with some of these things implemented plus some changes to airport operations. And for 2020, getting a 10 dB reduction over that period, do we still think that's achievable?

Responses:

1. That's a goal that was agreed to by the chairman of Rolls Royce. We want progress to control the fuel burn, the emissions, and the noise. It's going to get progressively harder and it might be that the view will be to let the world decide if the targets should change. So perhaps there should be more fuel burn reduction and less noise reduction. That is the flavor you get from the press these days.
2. It looks like we are on target. It's getting tougher, but the ACARE target looks possible—ambitious but potentially achievable. The realization of the target may depend on the balance given to other objectives.
3. Changing attitudes and growth may mean that the targets are not ambitious enough.
4. I'm unsure about new technology based on flow control. I suspect that this is a bit further down the line.
5. Active noise control techniques are not yet ready. Industry is working on many things, but we still think active noise control has a future. However, it is not one of the things we would put on the list as being ready to put into production.

Question:

Are there known validated technologies and operational procedures that provide longer-term solutions to the aircraft noise problem?

Responses:

1. Just ensure that existing procedures are implemented and customized to individual aircraft movements rather than being generic.
2. Is there an existing technology which is not used at the moment because the operators don't want to use it?
3. There is, for example, continuous descent approaches when there are capacity constraints on runway usage. So it's a matter of developing a system to ensure that the appropriate operational procedures are implemented and that they are customized to the conditions that exist at the time.
4. Air traffic control in the U.K. is prioritized on capacity and safety, and environmental considerations come last. If the environmental considerations were given a high priority in air traffic control, we could see more continuous descent approaches and less stacking for example— issues like that, which are of concern to the public.
5. In Sweden they recently put the environmental factor ahead of capacity. Safety is number one, environment is two, and capacity is three. But we don't have the U.K. traffic situations.
6. Going to an ultra-high bypass ratio would be a possible way to reduce noise. But it's not attractive because of its impact on fuel burn. However, variable area nozzles and geared fans are a way of offsetting some of the fuel burn disadvantages.

Question:

Will tradeoffs be required between noise and carbon emissions in the design of future aircraft?

Responses:

1. That's a very big issue which we need to discuss in some detail because there are obvious pressures greater than there have ever been before towards energy efficiency in aircraft travel. We've seen a number of graphs this morning where noise actually goes in the wrong direction when you increase your specific fuel consumption. So an aircraft that might save the planet may not be a terribly quiet one. Obviously the bypass ratio is one thing as we saw this morning is that you could get better fuel burn but would increase the noise as a consequence. Another example is the open rotor where you have potentially greater reductions in specific fuel consumption (SFC), but that's always going to be a noisy beast to deal with. That would change the landscape considerably.
2. It's clear that fuel consumption is getting a very high priority. Many airlines make it clear that they're looking for a more fuel-efficient aircraft.
3. Do you believe they would be willing to compromise on noise for that benefit?
4. It's a question of whether they want to be out of business or want to be restricted in operations because of noise. They definitely don't want to go out of business because the fuel bill is too high. So I think it's a priority for them to first make sure their business stays healthy, and therefore they must have an acceptable fuel bill.
5. I take issue with your phrase that open rotors will be noisy beasts, because that's a bit emotional. Undoubtedly there are tradeoffs, and the tradeoffs can be noise emission compromises. If you aren't concerned about fuel burn, you can design a quieter aircraft.
6. There is recognition from industry that the drive for SFC is an important one. With rising fuel costs, staying in business is clearly going to take priority. It's inevitable. Not just to stay

in business, but in order to address climate changes as well.

7. I think it's very important that noise doesn't get pushed aside in all this. One thing we might effectively get across here is that there is a danger that noise may get dropped from the issues.
8. The air transport industry has no option but to deal with climate issues. That's the position from which we start. Unless we deal with that we don't have an industry. The air transport industry can never be the only special case that's allowed to increase while everybody else tries to deal with climate change. The primary objective must be to address the climate change challenge and the shortage of aviation fuel. Another point is that all groups (NGOs) opposed to the air transport industry whether for climate change or for noise in local communities are now working as one. So they appear together, they speak, they coordinate their activities. The pressure is going to continue on two fronts. As a responsible industry we have to give priority to climate change. Then it's up to the public to decide whether they're willing to put up with the annoyance at home.
9. I've been polling attitudes among many local authorities, a few airline people, and a lot of airport people on noise disturbance at Heathrow. They were asked if they were more concerned about climate and fuel burn or noise. The overwhelming response was that the public is still mainly concerned about noise. The air quality issue is only for the professional people who understand the issue of climate change.
10. We shouldn't forget a common method to reduce carbon dioxide emissions and noise—stopping or limiting the growth of air transport. This is an option we should discuss with the air transport sector.
11. Limitations to growth are big issues. I'm interested in the panel's views on the cruising speed requirement because Ann's silent aircraft was specified to run at Mach .8. I'm wondering to what extent a considerably slower cruising speed would do to help both fuel efficiency and noise issues if that were acceptable to the airlines.
12. Airplanes that are currently flying at Mach .5 are considered very quiet. They are also efficient with fuel.
13. Perhaps we need reductions in both noise and emissions. Inevitably emissions in the current climate will take priority; but we should be looking for all opportunities where we can win on both and then look at the implications of winning on both. And if you can have both, would you go slower? That's up to the airlines and the customers to consider, because that may be the only way we survive as an industry.

Question:

Are there fundamental technical practical barriers for developing a silent aircraft?

Responses:

1. Well the aircraft I was describing was based on the center-body, so that's a pretty big barrier. An awful lot of money will be required to develop the center-body airframe.
2. Ann's study shows that silent aircraft might be possible but with considerable risk and uncertainty and considerable investment in technology. Is there anything about Ann's study that would lead one to believe it's just a complete impossibility?
3. We have to acknowledge it's a very significant investment. One of the very important messages I got from Ann's talk, especially the mountain graph, showed there was a compatibility between SFC reduction and noise reduction in that design. We ought to try to capture that; it is important. We need to send a message to encourage aircraft manufacturers to think radically.
4. Are you saying that bringing aircraft up to a suitable technology readiness requires a significant investment, which imposes a significant barrier?
5. From what I understand, if the ACARE goals were set to take account of the anticipated growth rate, they would be weak—not sufficiently strong.
6. I don't think the ACARE targets were designed to assume a certain growth rate in order to keep noise exposure constant or reduced. It's a very hard question to answer if you don't have the necessary models to predict it. Within the aircraft development community these calculations are being done—making assumptions about growth and replacement of existing fleet, and what the noise levels of such aircraft would be and what the expected growth is in different regions. I think it would be difficult to expect to come up with an answer to that question.
7. Such scenarios are made with climate change. Assumptions are made about the globe and about the development of the emissions. And so we can calculate the impact in 2025. I don't see any problem.
8. I have one possible vision of the future. Given that the rate of technological advance and operational improvement is slower than the greater growth of the industry, then sooner or later at certain airports around Europe the noise contours are going to expand. That means an increasing number of people will likely be exposed to noise in 2025. The other issue is that because of affluence, attitude, and change, those same people are going to be more sensitive to aircraft noise than they are now. All things being equal, there will be more people reacting more strongly to noise. Their expectations will be higher even if we deliver the technological improvements to take care of growth. They will not be satisfied because of their expectations. However you add it up, the challenge

that we need to address is to achieve as much noise improvement as possible given whatever the restrictions are. My answer to the question is that we cannot take the pressure off noise.

9. In terms of statistics if you take the example of Heathrow which some of you have visited recently, the current limit on air traffic movements is 480,000 per year. The expansion now being considered is an application for building a third runway to increase the number of movements to 650,000 per year. That is perceived by a majority of the residents as a significant increase in noise. The extent to which the increasing noise caused by the number of movements can be compensated by reductions in sound levels by the aircraft industry is presently unknown. There are different opinions on what will happen, what the result will be. But for many of the population it is already perceived as a significant increase, an unavoidable increase.
10. The situation for many residents around the airports is unacceptable right now. If we have an increase in movements and a noise reduction which doesn't compensate for the increase, this will worsen the situation and will make air transport even more unacceptable to the public.
11. We can certainly report our concerns that the projected growth will not be compensated for by the noise reduction technology.
12. If a third runway is built at Heathrow, you put 30,000 people into a noise contour that they have not been in before. If you build a new runway at Gatwick, you have another 7,000 people who never have been exposed to airport noise before; and they are going to be hypersensitive.
13. Priority has to be given to both noise and emissions because the industry's ability to grow will be constrained by those two issues. We need to do what is economically feasible.
14. The important points are that there is a growth problem here in the aeronautical business and that, although the technologies are set and they seem to be achievable, what we do not account for is the increase in growth. That is perceived as being a real problem. But although we have not been able to evaluate the extent of that problem, it's being worked on by the ICAO Committee on Environmental Protection.
15. There has been an assumption for a long time now in the environmental noise industry that a doubling in the numbers is equivalent to a 3 dB change in sound level. That makes sense in engineering terms, but there is increasing evidence that it doesn't make sense in attitude terms, in terms of public acceptance. Certainly the results of our latest 2005 national study in England show that a doubling in numbers is more equivalent to something like a 6-10 dB increase in sound levels. That may not have been considered at the time the ACARE goals were devised; it makes the problem worse I'm afraid. But that's what the data is telling us.
16. What we're saying is that the ACARE goal of reducing noise by 10 dB does not mean that noise around airports will go down by 10 dB. There are issues of growth and there are issues of replacing the existing fleet. There are also issues of what actually annoys people. It is difficult to make these assessments.

Question:

If the noise-reduction goals were to be framed in terms of achieving "Quota Count" (QC) goals rather than in terms of lower limits on noise-certification levels, how might the technological developments be modified?

Responses:

1. It's not certain that the future technology development will be modified because the goal is to reduce noise however it is measured.
2. More work is probably required to ensure that the proper rating scales are developed to better capture public perception, particularly when going into radical designs.

Question:

Will trade-offs be required between noise and carbon emissions in the design of future aircraft?

Responses:

1. This depends very much on the definition of noise nuisance. If you have levels for the threshold of noise nuisance as defined by the World Health Organization, then we will have a lot of external costs around the airports. If you have to internalize this, it might change the attitudes of the air transport sector because they have to pay more.
2. Development might change if ambitious noise nuisance thresholds were to be used around airports. It might be possible for technology development to be modified if very stringent noise nuisance thresholds are used.
3. What we might then be doing is to trade noise for increased fuel burn.
4. The debate is already taking place at some airports as to whether flight paths should be optimized to minimize noise disturbance or to minimize CO_2 emissions. So as climate-change pressure builds, this becomes a live debate that Brisbane and other airports have been through.

Question:

What efforts will be made in Europe to ensure a broad-based international approach to achieving the very worthy goals of the ACARE project?

Responses:

1. In the U.S. the FAA, NASA, and others have goals which are, broadly speaking, similar to the ACARE goals. Rolls Royce as a company collaborates

both with Airbus and Boeing in noise research programs. The whole aviation business is international. It's not a just-for-Europe issue.
2. That certainly is my impression. The international collaborations are quite good and there seems to be a free exchange of scientific data as well if you take the AIAA conferences into account which have been running for many years. They alternate between Europe and the U.S., so they are an international endeavor. Whether or not these conferences have been officially broadened is another issue.

Road Transportation Vehicles

The second day, June 3, was devoted to road transportation vehicles, and the morning session was chaired by Wolfgng Kropp of Chalmers University of Technology (Sweden). The following topics were covered:

- Driveline
- Tyres4
- Road surfaces
- Aerodynamics
- The types of vehicles covered were:
- Double-axle trucks
- Delivery vans (single axle)
- Private automobiles
- Hybrid-electric vehicles

Background

Many Europeans are exposed to noise levels at home from road traffic that is far above levels for a good environment and the problems are increasing. There is a gap of at least 10 dB between the emissions from vehicles in ordinary traffic and possibilities to assure reasonable levels in the built environment through noise control measures on the immission side. Noise mapping is now underway as required by the EU's Environmental Noise Directive [2] to provide substantiating data. The noise emission produced by a road vehicle depends on the design of the driveline, the tyre, and the road surface; and varies with speed and type of vehicle. Working Party 29 of the United Nations Economic Commission for Europe (UNECE) sets emission limits for vehicles and tyres. Except for heavy duty vehicles at low speeds, the noise emissions from individual road vehicles in ordinary traffic are almost the same today as 30 years ago. The standardized test method used in the type approval (certification) of vehicles has been ineffective.

A recent Royal Swedish Academy of Engineering Sciences (IVA) report [3] concludes that a 5 dB emission reduction can be achieved with existing technology. It is necessary to reduce both the rolling noise and the driveline noise. The necessary reductions are case specific. For cars, new platforms may need to be designed. The situation is somewhat different for heavy vehicles. There, encapsulation and screening have been used extensively to adapt to tightened limits and modified test procedures. Technology solutions are available, but they demand that exterior noise properties be taken into account in the very early design phase. Heavy vehicles are built in modular systems and stricter noise limits may necessitate basic changes in the components; engines, transmission gears, etc. The required emission reductions of 10 dB to achieve reasonable immission levels remain a technological challenge.

The following questions were sent to the panelists:

1. To produce an immediate 5 dB noise emission reduction (as reported in the IVA pilot study [3]) what changes in tyre/road interaction, driveline, and mufflers are required?
2. What is today's technology concerning noise reduction from vehicles and tyre/road interaction?
3. What are the key obstacles to quieter vehicles, tyres, and roads?
4. Are there vehicle types, tyres, or roads that should no longer be produced due to their sound?
5. If actions on the climate-change issue include demands for cars with less powerful engines and slower top speeds, would such changes give a potential for less noise from driveline and tyres?
6. What noise emissions can be expected as a result of future developments (e.g. hybrid cars or alternative fuel)?

The afternoon was devoted to a discussion period chaired by Tor Kihlman (Chalmers). The discussion questions were:

1. At what stage in the design of a new road vehicle would a manufacturer have to consider noise emission requirements that are lower than the current requirements to achieve lower levels of community noise and at what cost to the manufacturer? Background for question—For many products that must be designed to comply with noise-emission requirements , the overall cost of incorporating noise-control design features is lowest when the features are incorporated starting in the preliminary design stage. Substantial increases in manufacturing costs may be incurred if noise-control design features are incorporated after serial production has started.
2. For heavy-duty vehicles (HDV), what improvements in engines, gearboxes, and driveline components are anticipated that could significantly reduce the vehicle's noise emissions? Background for question—Techniques for reducing the noise emitted from those components may differ from those applicable to passenger cars, vans, and light-duty vehicles.
3. What complications and/or simplifications in future vehicle design can be anticipated to meet any new noise emission requirements due to the climate change and fuel issues (e.g. harder rubber to reduce rolling

resistance, lower pressure drop in mufflers, lower vehicle weight)? For cars and for HDVs? Background for question—It is often assumed that actions taken as a result of any new requirements on road vehicles to mitigate the effects of vehicles on climate change will result in lower noise emissions from the vehicles.
4. In designing low-noise vehicles, should a strong emphasis be placed on reduction of the low-frequency content of the vehicle's noise? Background for question—Low-frequency sound propagates with little attenuation through the ground, the air, and building facades and often causes vibration of the structural elements of roadside buildings.
5. Will the new ISO 362 test method together with significantly lower limits on noise emission in UNECE Regulation 51 be effective in reducing day-evening-night average sound levels from ordinary traffic? Should the Terms of Reference of UNECE Working Party 29 be reformulated to require significant reductions in the day-evening-night average sound levels from road traffic? Background for question—The old ISO 362 test method for vehicle exterior noise measurement provided data on noise-emission levels that did not correlate well with the day-evening-night average sound level used in the EU for rating and monitoring transportation noise. Reduction of the limits on noise-emission levels by up to 10 dB had no corresponding reduction in immission levels. An I-INCE Technical Report on noise emission from road vehicles documented the failure of noise-emission regulations in the EU to reduce community noise levels.
6. Primary consideration during the workshop has been given to road vehicles with four or more wheels. What is being done to control the noise emissions from vehicles with fewer than four wheels? Background for question—Motorcycles, mopeds, and other two- and three-wheel motorized vehicles constitute a significant and increasing fraction of the road traffic in the EU, particularly in urban areas, because of their advantages in parking, traffic jams, fuel economy, and the cost of purchase and operation. Control of the noise emissions of two-wheeled vehicles should not be overlooked.
7. In EU documents such as European Commission C(2007)5765 of 29 November 2007, the goal for 2020 is a reduction by 10 dB or more of external noise of surface transportation. What steps have been taken to reach this goal? Background for question—Due to the long life spans of road transportation vehicles, steps would have to be currently in progress to reach this goal by 2020.
8. Should noise-emission requirements be established in the EU for vehicles already on the road and manufactured prior to the date when newly-manufactured vehicles have to comply with new EU requirements for low levels of noise emission? Background for question—Passenger cars stay in operation for ten years or more. The automotive aftermarket provides parts, equipment, tyres, and accessories to keep light and heavy vehicles on the road for many years. Heavy-duty vehicles often use re-treaded tyres for which the tread design produces higher levels or tyre-pavement interaction noise than the original tread design. Research to develop lower-noise vehicles is certainly needed, but the likely schedule for their introduction delays any significant reduction of traffic noise levels for decades. The noise emissions from millions of vehicles now on the road can be controlled by requiring that all replacement items not cause an increase in the noise emission levels above those produced when the vehicle design was first type approved. These noise emission requirements might be enforced as part of mandatory annual vehicle safety inspections.
9. Ten to fifteen years ago most car industries developed lightweight vehicles often manufactured from composite materials. Why were these types of car never produced? Background for question—Much of the advanced technology to produce lower noise vehicles may be archived by the vehicle manufacturers.
10. How can the popular programs within the EU to erect roadside noise barriers be augmented to introduce quieter designs for pavements and tyres as well to mandate that newly-manufactured road vehicles sold within the EU comply with significantly lower noise-emission requirements? Background for question—Constructed with public funding, roadside noise barriers provide noise reduction for those in dwellings close to the barrier. Barriers do nothing to reduce traffic noise for residents living near a roadway in high-rise buildings or distant from the barrier. Moreover, barriers do nothing to control the sources of noise emission that are the responsibility of the manufacturers of road vehicles. The design for the tread of the tyres and the surface of the road are important considerations in reducing tyre-pavement interaction noise. (The CANTOR project could provide leadership in the research needed to facilitate the design of low-noise vehicles.)

The Panel Presentations

The panelists for the second day's presentations were:

Wolfgang Kropp, Chalmers, Road Transportation Session Chair
Reduction potential of road traffic noise

Ernst-Ulrich Saemann, Continental
The design of tyres for low-noise emission

Thomas Beckenbauer, Müller BBM
Design and construction of low-noise road surfaces—state of the art, challenges, and constraints

Ulf Sandberg, VTI
The tyre/road interaction and noise generation

Juha Plunt, Müller-BBM
The design and production of low-noise road vehicles, SUVs, and motorbikes

Kaj Bodlund, Volvo Trucks
The design and production of low-noise road vehicles, especially heavy-duty vehicles and busses

Introduction to the Road Noise Problem

Wolfgang Kropp

One third of the European population is exposed to noise levels that are considered annoying. Ten percent of the population is subjected to levels that carry serious health risks. A conservative estimate is that the social costs of traffic noise are €40 billion per year, of which 90 percent come from cars and trucks. That is a loss of 0.4 percent of the total EU GDP. By comparison, noise costs to society are about 30 percent of the cost of road accidents. The conclusion is that there is an unbalance of 10 dB(A) between the emissions from ordinary traffic and possibilities to achieve reasonable immission situations even with optimal use of measures on the immission side. The problem is still more severe in existing situations.

In order to investigate the potential for noise reduction, the complex interaction between tyre, road, and vehicle designs with respect to traffic noise emission and especially immission at people's homes has to be taken into account. In this context one has to consider that

- The technical potential for road traffic noise reductions has to be discussed case-specifically where driving cycle and traffic composition are defined.
- Reductions of different sources are not additive.
- The relative importance of different sources depends on traffic situation and speed.
- Road traffic noise reduction needs a thoroughly-planned, holistic approach.
- A study made by IVA[3] concluded that a 5 dB(A) emission reduction can be achieved by utilizing technology available today while 10 dB(A) will need further research and development.

An important finding of the study is that in order to obtain a reduction of the total noise by 5 dB(A) it is necessary to reduce both rolling noise and propulsion noise. Based on the NORD2000 traffic noise calculation scheme one comes to the conclusion that with a typical mixture of light and heavy traffic and with a reduction of tyre/road noise by 6 dB(A) the needed reduction of propulsion noise is then around 4 dB(A) for a driving speed of 30 km/h and around 2 dB(A) for a driving speed of 110 km/h.

The conclusion from the report is that the potential for reducing propulsion noise is sufficient to obtain these 2-4 dB(A) reductions. However, the necessary lead time may be different for car manufacturers and heavy vehicle manufacturers. It is unlikely that manufacturers of passenger cars ever were forced to explore the potential for exterior noise reduction. New platforms may need to be designed. The situation is somewhat different for heavy vehicles. There, encapsulation and screening have been used extensively to adapt to tightened limits and the modified test procedure. Technology solutions are available, but may demand that exterior noise properties be taken into account in the very early design phase. Heavy vehicles are built as modular systems; and stricter noise limits may necessitate basic changes in the components, engines, transmission gears, etc. Substantially stricter noise limits must therefore be enacted over a very long time period.

The potential for reducing tyre/road noise is distributed between tyre and road. For the tyre the following can be concluded:

- Exploiting the spread of noise emission from tyres on the market one might identify a potential for reduction of tyre noise by 2-3 dB(A).
- Although there is a potential, it might be difficult to utilise this, having in mind all the different properties required from tyre performance.
- Tightening the tyre noise limits according to the FEHRL proposal, will give a rather moderate reduction in Sweden [1-2 dB(A)]; however, the action is definitely necessary to accelerate technology development towards quieter tyres and to increase the priority of noise performance when designing tyres.
- Top speed limits and less focus on high performance with respect to handling as well as on fashion criteria will definitely encourage the development of quieter tyres.
- Attention and resources should be focused on the development of quiet and safe tyres with low rolling resistance.

This means that 2-3 dB(A) reductions should be potentially possible for the tyres, so 3-4 dB(A) will be required from the road surface. Already the optimization of the road texture can yield up to 2 dB(A) for an SMA 0/11 surface. Semi-dense surfaces can yield reductions between 2 and 4 dB(A). With increasing absorptivity of the surface the reduction can increase up to more than 6 dB(A). However the use of such highly-absorbing surfaces (open porous asphalt) demands regular cleaning. In addition one has to cope with a loss of efficiency of about 1 dB(A) per year, at least at the very beginning when the surface is newly laid.

An aspect which is often neglected is the quality control of the road surface manufacturing process. For the same type of road pavement, carefully monitoring the properties of the road surface, which are related to its acoustical behavior, can yield several decibels of rolling-noise reduction. Acoustical measurements of the finished road surface are essential.

Although there is potential for a reduction by 5 dB(A), one has to take into account that there are no simple solutions, and unfortunately the complexity of the problem is often ignored.

The lack of noise limits for road surfaces is surprising. In order to make progress there have to be "coordinated" noise limits for roads, tyres, and vehicles.

The design of tyres for low-noise emission

Ernst-Ulrich Saemann

Tyres are an important part of vehicle safety. Their basic functions are to carry the load, to transmit forces from contact area to vehicle, and the damping of irregularities of the road. The small contact patch (footprint) is the only direct link between the vehicle and the road. This link must handle large forces under all conditions, and this is possible because the tyre is a high-tech product, engineered using the most modern tools.

The tyre characteristics must ensure the following requirements:

- Safety (braking on dry, wet, snowy, and icy roads as well as good aquaplaning behavior)
- Handling (tyre characteristics at high speed)
- Economy (mileage performance, fuel consumption [rolling resistance] and resources [weight])
- Environment (rolling noise, emissions, fuel consumption [rolling resistance])
- NVH (mechanical and acoustical comfort)

The tyre engineer can design to meet these requirements; but, unfortunately, there exists strong interactions between tread pattern and tread compound as well as between contour, construction and fabrics, and body compounds. Pattern and tread compound influence the tyres appearance, dry grip, wet grip, snow/ice grip, and aquaplaning. The contour, construction and fabrics, and body compounds influence the high-speed capability, durability, and bead seating. All four areas have an influence on the features of handling, rolling noise, NVH, rolling resistance, and wear behaviour.

The most important task of a tyre is to carry the vehicle's maximum load. The tyre load capacity is determined mainly by the air volume inside a tyre, and with increasing vehicle weight the tyre size has increased over the years. For example, with a modern mid-class vehicle (LI>96) it is not possible to use a tyre with high-aspect ratio like one from the 80´ series with 185 mm width. But in a good-looking, smaller-aspect ratio like 55´, a tyre width of at least 225 mm is necessary to carry the load. Such wider tyres do not necessarily produce more noise, but measurements at Continental show for a given tyre size and category a spread in tyre/road noise of up to 3 dB(A). The main influencing factors on rolling noise are shown by comparing two completely different tyres before and after grinding. While the maximum sound level between the two tyres before grinding may differ by many dB(A)s, the two tyres produce nearly the same sound level after grinding. A tyre with no tread band acts like a membrane and the sound level is then determined only by the inflation pressure of the tyre. Unfortunately, a tyre without a tread band has no useful features.

Disregarding the normal tyre features and only looking for the noise reduction potential, measurements on different slick tyres were performed. In addition to a very small motorbike tyre, some wide slick tyres with different tread compounds were measured according to UNECE R117. Small slick tyres are not necessary less noisy than wide slick tyres. The sound level depends on the tread compound. The average sound level of a modern slick tyre is 68 dB(A) at 80 km/h. To go one step further in the evaluation of the noise sources slick tyres with a frictionless Xylan surface were measured during rolling on a dyno drum. The influence of a frictionless tyre on sound was not as big as expected. The overall level is not much reduced and Xylan only has an effect on the higher frequencies above 1 kHz. Therefore at the moment the slick tyre at 68 dB(A) has to be stated as the physical limit of possible noise reduction on tyres, and the author has no idea how to lower the radiated sound of a blank tyre.

Tyre manufactures have searched for years for a construction which fulfils the targets of the automotive industry and generates less noise. It is important when developing low-noise tyres to avoid the first block harmonic in the frequency range around 1 kHz as this is the range with maximal sound level during coast-by. One way to lower the rolling noise is to use a softer tread compound. By changing the tread hardness it is possible to gain 3 dB, but skew stiffness is reduced. By changing the void volume it is possible to gain 6 dB, but good aquaplaning behaviour is drastically reduced. In addition to a tread compound with high damping, the void volume of a tyre is the main parameter to adjust the aqua-planing level required by the vehicle manufacturer. There is no real target conflict between rolling noise level and wet braking on high μ surfaces or on low μ surfaces. The spread in the measurements made by Continental are quite large, but there is a tendency for tyres which are optimized for shorter, wet braking distance on low μ surfaces to radiate more sound during coast-by. A discussion of the target conflicts has shown that there are ways to lower the radiated sound of passenger car tyres. A further reduction of tyre excitation by tread pattern optimization cannot be expected. Because the tread pattern is needed to achieve the required safety level, further noise reduction has to be addressed mainly by optimized tyre constructions. The possibility to construct quieter tyres will improve substantially if an agreement on reasonable maximum speed limits could be reached.

If the main focus of the tyre design is on low noise, it is currently possible to build tyres which are nearly on the sound level of blank tyres as realized by the author in the EC project SILENCE. This was reached mainly by tuning the tread pattern and by choosing proper compounds. But the basic tyre performance was not on the same level as modern passenger car tyres. It is not acceptable for the customers to gain noise reduction but loose safety. Of course the results show the potential to work further on the concept and modify this tyre stepwise to bring the basic performance to an acceptable level without increasing the sound level. A further reduction of tyre excitation by tread pattern optimization cannot be expected. Because the tread pattern is needed to achieve the required safety level, further noise reduction has to be addressed in the future mainly by optimized tyre construction. But this leads to the described target conflicts because the requirements for noise, safety, and rolling resistance on the tyre construction are contradictory. For the future the author sees a reduction potential of 2 to 3 dB(A) overall for rolling noise depending on the other tyre features.

In developing tyres for the future, tyre manufactures are obliged to follow the automotive mega trends: Environment, Safety, Affordable cars, and Information. The information trend has no direct influence on tyre development. For affordable cars low-cost tyre technologies will be developed (with less mass and more radiated sound) and for safety the wet grip, dry grip, and winter performance will be enhanced. Currently the most popular trend is to reduce CO_2 emissions which puts pressure on the tyre manufactures to build tyres with less rolling resistance and that can influence the possible noise reduction.

Design and construction of low-noise road surfaces – state of the art, challenges, and constraints

Thomas Beckenbauer

To produce durable road pavements, mixes of mineral aggregate and powerful binders are used. Depending on the gradation curve of the mineral aggregate, the pavement shows a particular void content. Based on the void content road pavements can be classified by two main groups: dense and porous pavements. Both dense and porous road surfaces can be produced with cement and bituminous binders. The stone size distribution of the mineral aggregate and the percentage and kind of binder affect the acoustical behaviour of the road surface. Shape and kind of the minerals play a minor role for dense road surfaces. Porous road surfaces affect the void structure and the achievable void content of the pavement which is acoustically meaningful. For safety reasons the road pavement must also show good skid resistance which results from choosing appropriate materials and surface treatment, including surface dressings and different dense cement concrete pavements.

Independent of the type of road pavement and its civil engineering properties there are three characteristics which are suitable to describe the acoustical behaviour of the road surface—surface roughness, porosity, and elasticity. All three can be defined by a set of parameters which influence the acoustical behavior of a road surface independently of each other. These parameters—roughness depth, texture wavelength distribution, and shape—describe the road surface texture and affect the acoustical behaviour of a pavement. These parameters are exemplified by means of two different road surfaces with the same maximum aggregate size—a surface dressing 0/8 and a stone mastic asphalt 0/8.

The shape of a texture can be quantified by determining the shape factor g. For convex textures (positives), g takes values between 40 and 60; for concave textures (negatives), the value is 60 up to 90. The shape factor g improves the discrimination between different road pavements and road surface textures. It is derived from the Abbot curve of a profile for both convex and concave shaped textures. The curve indicates the percentage contact length PCL within the characteristic profile length of 100 mm depending on the penetration depth. The shape factor g corresponds to the PCL value at 50 percent penetration. Extensive statistical evaluations based on more than 30 different road surfaces have shown that the shape factor g adds new information to the description of road surface textures because it is statistically independent from the other two parameters described above. An alternative for using the shape factor would be to keep the phase information of the texture spectrum rather than looking only at the magnitude of the roughness depending on wavelength. Texture spectra of real road surfaces show distinctive spectral maxima. Therefore, for each texture spectrum two characteristic parameters can be determined: λ_{max} and R_{max}.

The texture spectra and coast-by noise for an average passenger car tyre at 80 kmh were compared. The acoustical level difference at 1 kHz is not more than 5 dB in both cases whereas the maximum roughness differs by 15 dB on a logarithmic scale for the surface dressings and by 9 dB for the hot rolled surfaces. This means that only a small part of the pavement roughness is acoustically effective. Based on measurements on a great variety of dense road surfaces a lot of different combinations of λ_{max}, R_{max} and g values could be used to search for parameter sets which lead to low coast-by levels. In order to be able to plot the results three dimensionally, the data sets consisting of R_{max}, λ_{max}, g and L_{pAF}

(coast-by level) had to be reduced by one dimension. Therefore, a new quantity, the characteristic shape length—g' = g / 1% λ_{max} · —has been introduced. As a matter of fact, there is a local minimum. The coast-by levels get very low if the R_{max} values range from 60 to 200 microns and the g' values range from 400 to 700 mm. Coast-by levels of such pavements are about 7 dB lower in comparison with the "loudest" pavements under investigation which contained a maximum aggregate size of 11 mm.

Nowadays single- and double-layer porous asphalts are laid using layer thicknesses between 4.0 and 8.0 cm. The void content typically amounts to more than 20 percent. Tortuosity values are greater than 1 which means that the acoustically effective length of the open voids is bigger than the layer thickness. The voids are tight-tortuous. The specific air flow resistance amounts to r = 2000 Pa s/m^2 for specimens which are produced in the laboratory and to r = 10.000 Pa s/m^2 for ready-laid pavements.

For typical frequency responses of the absorption coefficient of porous road surfaces, the trend of the curve cannot be influenced by the mix of the materials or the way of laying. This means that pronounced maxima of the sound absorption alternates with pronounced minima. A bigger layer thickness helps to shift the absorption maxima towards lower frequencies and to broaden the absorptive effect within the important frequency range from 200 Hz to 4 kHz. The void content has to be greater than 24 percent in order to gain a maximum absorption coefficient of > 0.9. The effect of porous, sound absorbing pavements is threefold:

1. a reduction of the sound power of the noise which is generated in the tyre contact patch,
2. a reduction of the horn effect, thus reducing the sound radiation of the tyre road contact, and
3. a reduction of the air pumping effect

The important noise sources of road vehicles fall into two groups: tyre/road noise and drive-line noise. In contrast to the tyre/road contact drive-line noise sources are located at different heights above road surface. The sound absorption of porous road surfaces affects sound radiation and sound propagation of both groups of noise sources; therefore, sound-absorbing, porous road surfaces reduce the noise of passenger cars and trucks as well. Porous road surfaces act on the noise damping of different noise sources depending on the thickness of the porous layer. A bigger layer thickness is necessary to shift the absorption maxima towards lower frequencies. This is important for the damping of low frequency tyre road noise which is related to low-speed traffic conditions and/or the percentage heavy vehicles of the total traffic volume.

For making target-oriented mixes and attaining good final absorption coefficients, it is necessary to choose suitable materials, to run multiple acceptance tests in the laboratory, and to carefully control the laying, especially the temperatures of the asphalt mix and compaction during the laying. A wrong gradation curve of the mineral aggregate causes poor absorptive behaviour of the specimen with absorption coefficients of not more than 0.52 at maximum. In contrast, a target-oriented gradation curve yields a maximum absorption coefficient which is close to the optimum of 1.0. The type of base course and the way of laying also affects the acoustical result. Bitumen may rise into the porous-wearing course thus reducing the acoustically-effective layer thickness.

Decreasing void content yields lower absorption maxima. In practice void content and air-flow resistance are not independent of each other as lower void contents are related to higher air-flow resistances. Higher air-flow resistance means higher water-flow resistance. Thus porous pavements with lower void contents not only cause worse acoustical performance but also increase the risk of clogging.

The wrong gradation curve of the mineral aggregate causes a poor absorptive behaviour of the specimen with absorption coefficients not more than 0.52 at maximum. In contrast, a target oriented gradation curve yields a maximum absorption coefficient which is close to the optimum of 1.0. This result is typical for the laboratory situation where specimens are taken out of small asphalt plates that are compacted by means of a roller device. The ready-made porous asphalt on a real road typically shows not more than 0.8 for the maximum absorption coefficient.

State-of-the-art surfaces and the latest developments in laying high-efficient, noise-reducing road surfaces were measured in pass-by tests on different road surfaces with different noise reduction capabilities for cars and heavy trucks (more than 3 axles). The results for a texture-optimised surface with exposed aggregate and for a single-layered porous road surface 4/8 with a thickness of 4 cm (standard drainage asphalt) were compared. Twinlay-M is a development of the two-layered porous asphalt 4/8-11/16, which has an optimized texture due to a stone size distribution of 2-4 mm in the upper layer. However, in practice this concept has not yet shown convincing results concerning the acoustical life-cycle.

Some of the most promising new surface concepts are thin layers with a moderate void content and optimised textures in hot application. These surfaces are characterised by small particle size distributions (typically 4-6 mm), a fine texture, and some sound absorption due to the void content. The French products Novachip and Microville are examples of this concept as well as the Dutch product ZSA-SD. The advantage of this technology is its low raw material consumption and the fast laying process which may yield a very effective construction method. Unfortunately, up to now little data on the practical operation and durability has been gathered. Concerning the noise reduction, this technology works especially for car tyres. The reduction of truck tyre induced noise, however, works much better with two-layered porous asphalt than with thin layer asphalt, particularly on rural roads. At the moment there is reasonable hope to reduce tyre/road noise further by using one more road surface property which has not been taken into account so far. That is elasticity. In various small scale experiments it was shown that road pavements with reduced stiffness are able to reduce tyre/road noise by some 3 dB.

Missing contractual needs and missing acoustical quality management in road pavement construction represent key obstacles for the laying of road pavements with reproducible acoustical properties. Another obstacle to further improvements and further development of noise reducing pavements is that road constructors stick to traditional materials and road paving methods. There are computational models available now which predict the tyre/road noise based on road surface properties. These could help to "play" with different materials, machinery, and laying concepts in lab scale experiments. The properties of the road surfaces realized in these experiments could be measured and put in a model in order to assess acoustical results.

The key problem with acoustically high-efficient porous road surfaces is clogging. Although production and the acoustical performance of porous pavements saw a substantial improvement process in recent years, particularly in connection with the two-layer concept, clogging cannot be avoided. This means that porous pavements loose their noise reduction potential over time. There is hope that clogging can be avoided or at least diminished in the near future by means of new chemical matter coatings or mixture additives which prevent dirt particles from sticking to the bituminous surface of the voids or being embedded into the bituminous mortar film. A change from production to product-oriented action in producing road pavements would help to overcome the key obstacles.

A model-driven design for a noise reducing road surface was an outcome of the EU 6th framework project ITARI. The high efficient noise reducing texture has been developed by means of a computational model (SPERoN) for tyre/road noise. The design could be realized by applying industrial processes on a trafficable location.

High costs are often used to argue against advanced concepts for noise reducing pavements. Costs actually depend on the degree of noise reduction, and the values are true for the situation in Central Europe. At the moment the ultimate level difference for passenger cars with respect to a common stone mastic asphalt 0/8 is seen at –15 dB using a perfect texture, high-sound absorption and elasticity. The more the new concepts get accepted, the lower the costs could be.

The tyre/road surface interaction and noise generation

Ulf Sandberg

The rolling process is a tyre/road interaction, with the following implications which are important for the performance and the construction of the tyres and the road surfaces:

- There must be a good contact between tyre and road surface.
- Longitudinal forces for powering the rolling, side forces for keeping the tyre on track and forces for braking must be transferred in the tyre/road interface.
- To prevent water from separating the tyre from the road, the tyre tread and the road surface must both have a drainage capacity; i.e. the tyre must have a suitable tread pattern and the road surface must have a certain texture.
- Air and water in the contact area must be transported away from it at extremely high speeds.
- For the best molecular contact, the tyre tread must be able to envelop a reasonable part of the road surface texture.
- Durability requirements give restrictions on material, tread pattern and road surface texture.

The above items are important since they put severe constraints on the freedom of road surface and tyre construction. Together they determine the tyre and road construction and thus the noise generation mechanisms. For example, had not the water drainage problem existed, such as when driving in wet weather, we could run on tyres which have no tread pattern on road surfaces which are smooth (this is the ideal as long as racing competitions are performed in dry weather). In this way we could get a quiet tyre/road interaction.

Generation mechanisms for tyre/road noise are extremely complex. A number of different mechanisms are working simultaneously and sometimes in a uniform way; sometimes in a conflicting way. It becomes even more complicated when it is considered that the mechanisms have their highest impact in different frequency ranges. Furthermore, it is arguable whether some of the mechanisms are generation or just amplifying mechanisms.

There are two families of mechanisms: vibration-related mechanisms and air displacement and radiation mechanisms. The author described the major mechanisms within each family, referring to analogies in generation of music by various instruments, such as for the vibration-related mechanisms radial vibrations by impact between road surface asperities and tread blocks, tangential vibrations affected by the stick-slip process ("scrubbing"), and stick-snap adhesion effect. For the air displacement and radiation mechanisms there is air pumping, and air resonant radiation. Other amplifying effects related to aerodynamics included tyre torus cavity resonances, pipe resonances in the tread pattern, and the horn effect (similar to the horn of a loudspeaker). Effect on sound propagation by sound absorbing surfaces is a special noise-reducing effect.

Typical road traffic noise spectra were presented for car and truck tyres on dense and on porous road surfaces. Truck tyre noise generally has a peak in the spectrum at a little lower frequency than car tyres. Typical differences between dense and porous surfaces include a valley for porous surfaces in the frequency range 500-1250 Hz, while dense surfaces show a peak at around 800-1000-1250 Hz, and higher levels at the higher frequencies. Many of the typical frequency ranges of various mechanisms covered the medium frequencies 800-1250 Hz, which were either at the lower or the higher end of the frequency range. This overlap at the medium frequencies was the cause of the so-called "Multi-Coincidence Peak" (due to many mechanisms coinciding here) which was very prominent around 1000 Hz in tyre/road noise spectra for almost all car tyres when running on dense and not too rough surfaces. A major challenge for tyre developers is to reduce the noise emission at this multi-coincidence peak since only this could reduce overall noise levels.

Where are the sound sources located? In general they are very close to the tyre/road interface, within a few centimetres, but at lower frequencies they may continue up along the tread circumference a few decimetres.

What are the key obstacles to quieter vehicles, tyres, and roads? The answers follow:

1. Marketing of vehicles for high power and high speeds is very common
2. Motor journalists focus on high performance and "driving pleasure"
3. Poor acceptance among some authorities that noise reduction may be associated with a (sometimes) quite substantial cost
4. Lack of technology-forcing noise emission limits (legislation too weak and too slow)
5. Acoustic and technical durability of low-noise road surfaces is far from ideal
6. Fear among some people that noise reduction may compromise safety (this fear is often without substance)
7. Reluctance in the industry to give vehicle exterior noise the same weight as interior noise and sound quality (since only the latter is a good selling argument)
8. Free speeds on some German motorways gives serious constraints on tyre optimisation; it would be better if tyres were optimised for the max legal speeds in all other countries rather than for what he called "the absurd top speeds" of 250 km/h or higher.

Can environment only be improved while power is also improved? Bearing in mind the present popular development in the vehicle industry where increasing engine power appears "impossible" to be compromised.

Are there vehicle types, tyres, or roads that should no longer be produced due to their sound? The answers offered are:

1. Vehicles possible to drive over 180 km/h
2. The Hummer and SUVs do not seem to comply with basic transportation needs (with a few exceptions) and are mostly used as luxury vehicles with excess fuel consumption and higher exterior noise
3. Tyres wider than justified purely for technical performance (today's trend is that wider tyres are considered to look "sportier" and are thus used for that purpose)
4. Tyres of speed category higher than "T" (190 km/h); referring to the discussion earlier about the extreme top speeds
5. HRA surfaces (hot-rolled asphalt), which give very high tyre/road noise; a special U.K. problem where these used to be very popular
6. Transversely tined cement concrete surfaces, which give very high and subjectively objectionable tyre/road noise; a special U.S. problem where these are still very popular; Europe abandoned these some decades ago
7. Surfaces with aggregates (chippings) larger than 11 mm. This is a special problem in countries (such as Sweden, Norway and Finland) where large aggregates in road surfaces are used in order to resist the severe wear of studded tyres.

How will climate change countermeasures affect future tyres and road surfaces, and vice versa? The following answers were offered:

1. Much lower rolling resistance will be required
2. The Hummer and SUVs are likely to be subject to environmental penalties (by difficulties in complying with limits)
3. Ever wider tyres, which are not needed for technical reasons, are likely to be subject to environmental penalties (probably by difficulties to meet limiting values)
4. Rough (megatexture) and uneven road surfaces must be avoided (better maintenance and better production needed)
5. Surfaces with fine textures will become much more frequently used than today (for example, so-called thin asphalt layers and surfaces being similar to the quiet ISO 10844 surfaces)

The design and production of low-noise automobiles, SUVs, and motorbikes

Juha Plunt

What changes are needed to produce a 5 dB(A) immediate noise emission reduction?

To comply with ISO 362-1, a reduction in tire/road interaction noise of ~ 6 dB(A) is needed. This may be be accomplished by reducing tire width and specifying softer tires, but would limit top speed performance, which has to be introduced in engine control software to be "immediate" (2-3 years from now). New vehicles could be equipped with low-noise tires and greater sound absorption in wheel houses. A reduction of ~ 5 dB(A) in the powertrain is needed and can be accomplished with better encapsulation of diesel engines and increased intake and exhaust muffler volumes. This also means longer than "immediate" noise reduction of the vehicle (at least 3-5 years).

Immediate reductions can be accomplished as soon as the vehicle owners take responsibility for the maintenance and operation of their vehicles. Abiding speed limits could produce an average 10 percent reduction (≈ 2 dB(A)). Not altering vehicles to be sportier (louder) concerns a small number of vehicles but has a large impact on peak noise levels. Eco-driving (more economical planet-friendly) will also produce substantial reductions. This involves using the lowest gears possible, lowering speeds on highways, moderate acceleration, and avoiding unnecessary stops.

In planning traffic, low-speed roads (30-40 kph), especially those with speed bumps, should be avoided since they lead to use of lower gears and higher rpm. Planning for continuous traffic flows with a minimum of stops and jams also reduces noise (not so immediate results).

What is today's noise reduction technology?

Engine radiation (especially diesels) in light vehicles could be improved mainly as follows:

- Engine development to restrict noise radiation (interior comfort driven)
- Increase of torque at low rpm, and higher shift ratios (interior comfort driven)
- Engine compartment absorption (interior comfort driven) and encapsulation
- Wheelhouse absorption
- Absorption under floor panels (interior comfort driven?)

For passenger cars, most of these efforts are already driven by competition to provide the best interior noise comfort to the car owner. Very little, except further engine compartment encapsulation, can be added in order to reduce exterior noise without serious impact on product cost or other attributes.

Although noise from tire/road interaction can be achieved by using tires with lower noise emission, this has lower priority than the primary tire attributes of safety, dynamics, and rolling resistance. The above also applies to most SUVs and pick-up trucks, although they are generally not as comfort driven as passenger cars. Here legislation is important.

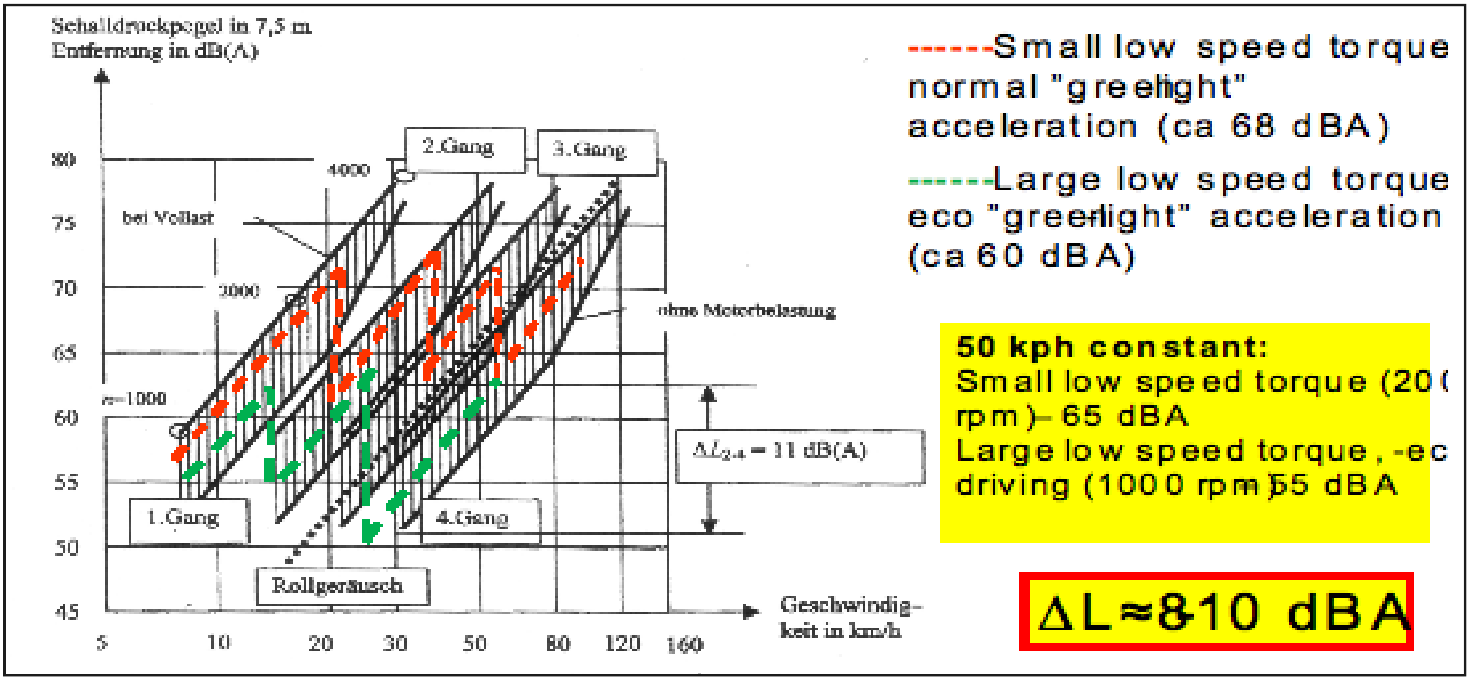


Figure 1. Illustration of the noise reduction potential, using gear shifts at lower rpms (ecodriving)

What causes the large variations in measured propulsion noise increase from acceleration?

Car specification and design: Cars with more torque at low engine speeds can be accelerated from the same speed using lower rpm (diesel engines, turbocharged engines, hybrid cars, electric cars), while cars with relatively small engines need more downshifting (higher rpm) for efficient acceleration.

Driver influence: Again, the driver has significant control over the amount of noise produced by his vehicle by using eco-driving practices. Eco-driving is easier with a car that has good torque at low engine speeds.

What are the main obstacles to quieter vehicles?

Propulsion: Cost of extra NVH components. Legal requirements will help since they are "neutral" with respect to competition between automakers.

Examples:

- Engine compartment encapsulation (adds cost, increases engine compartment size, complicated cooling solutions
- Wheelhouse absorption (limited effect, cost addition)
- Absorption under floor panels (limited effect, cost addition, increased floor height)

Tire/road interaction: The tire specification is mainly based on

- Vehicle weight
- Vehicle performance
- Vehicle dynamics (active safety, braking, friction etc)

Difficult to harmonize noise generation properties with the other main attributes

Are there vehicles or tires that should no longer be produced?

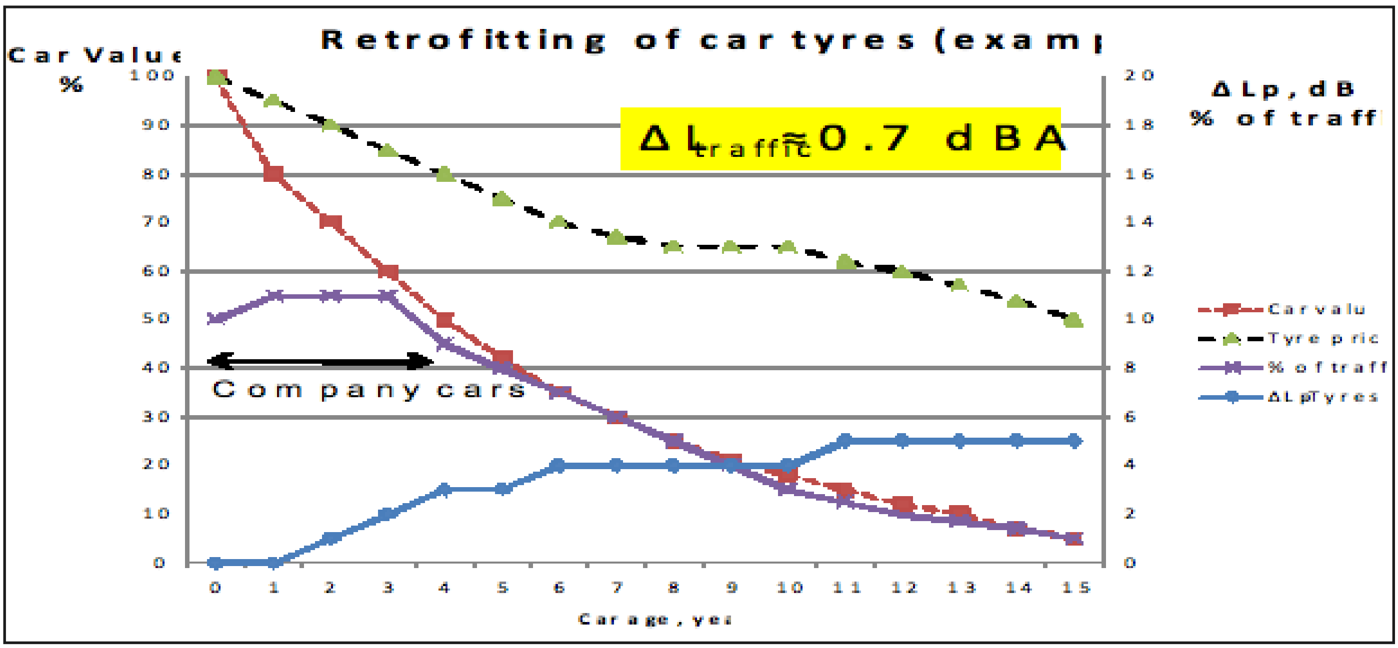
Modified vehicles and exhaust components that increase the noise level should be banned. There may also be more rigorous restrictions for studded tires in Nordic countries, and the use of special SUV tires shall be limited to special needs (e. g. military, search and rescue).

What is the effect of climate-change-driven trends and actions?

Lower weight vehicles with less powerful engines are being produced. In these the engine development should be toward more low-rev torque and a lower top speed.

Hybrid- and electric vehicles are becoming more popular. These have good low rpm torque due to the electric drives and allow for quiet propulsion for city driving. The selected combustion engine type can be critical (avoid small diesels running at high speeds).

Include also a limited top speed in addition to fuel type and specified CO_2 in the classification of cars as environmentally friendly with economic incentives.



Traffic planning should be for smooth, uninterrupted traffic flows which will reduce CO_2/km as well as optimizing speed limits to allow for high-gear, low rpm driving (restrict 30-40 kph stretches).

What noise emissions can be expected due to future developments?

Environmentally-friendlier vehicles and driving will produce less noise. Plug-in hybrids can provide very quiet and sustained low speed (urban) driving, and tire/road noise will dominate entirely down to almost 0 kph for those. They are also economically attractive to commuters and taxis, especially with rising fuel prices.

By downsizing petrol engines, noise will increase due to higher average rpm and acceleration at lower gears and much higher rpm. Diesel engines may provide some noise reduction due to their good low rpm torque, provided that the driver applies eco-driving.

Adding more effective over-drive gears that allow highway driving with very low rpm improves fuel consumption, but not noise emission since tire/road noise dominates. Also, to become classified as a "green car," a car should have limited top speed of e.g. 150 kph.

After-market issues, retrofitting tires:

It may seem to be a serious issue that cars usually are fitted with cheaper and cheaper tires when they get older, assuming that cheap tires may be substantially noisier. A simple calculus according to the chart below shows however that this probably leads to an increase of traffic noise level of less than 1 dB(A), if the following assumptions are made:

The relative traffic work (nbr cars x average mileage) is largest for young cars (0-3 years old) and drops successively, since both the average mileage drops (taxis and company cars are relatively young) as also the number of cars when they get very old.

During the first years, when the car has substantial value, very good tires are normally retrofitted (small risk for increased noise). Successively, when the cars get older, noisier tires are fitted, however the relative traffic work becomes more and more limited.

After-market issues, retro-fitting exhausts is similar to retrofitting tires.

- Cars <3 years old, probably no need or original muffler
- Cars 3-6 years, some original, some "low cost" replacements
- Cars > 6 years mostly "low cost" replacements

Low-cost replacement mufflers are often from the same manufacturer but no trade mark, usually not too bad (3-5 dB(A) louder).

However, a "pirate" manufacturer may sell at a very low cost but may be >5dBA louder.

Beware! The customization of exhausts for motorbikes and cars can greatly increase noise. For example, one rebuilt HD Softtail bike can increase exhaust noise by 40 dB(A) (=10,000 legal bikes). This is clearly illegal, but legal action to control and punish this is rare, although illegal exhausts are used on most custom and sports bikes. The number of extremely customized cars is relatively small in comparison.

How can an exhaust certification or control system be applied?

There can be a manufacturer declaration for noise at different "driving" conditions, combined with a fine if the aftermarket system is found to be louder in an independent laboratory test.

Certification as part of regular vehicle safety approval tests is not effective since exhausts are easily replaced for the approval test. Roadside checks may be more effective if penalties are high.

The design and production of low-noise road vehicles, especially heavy-duty trucks and busses

Kaj Bodlund

The development of engines and mufflers is mainly driven by the exhaust gas emission legislation. Euro 1, 2, 3, 4 and 5 have passed and soon Euro 6 will be passed including several incentive programs and we also have a rather different exhaust emission legislation in the US and Japan. This has required frequent noise certifications during the last years but only to keep up with the design changes defined by the exhaust gas emission issues.

There is also a clear power trend of about +10 hp / year. Higher injection pressures and a quicker injection have produced more engine noise, but SCR (selective catalytic reduction) engines have at the same time given us much better exhaust mufflers (less outlet noise). This is, however, not the case for EGR (exhaust gas recirculation) engines, which is also a common engine type. The main focus in product development has thus been on the exhaust gas issue. The resources for power train noise reduction work have at the same time been relatively small and the noise issues are often neglected until late in the development process.

In summary, the noise reduction work has been concentrated for many years on issues related to the exhaust emission changes, and not to lessen the noise but to stay at the same level as 1993.

Noise legislation is furthermore not very effective. The only real challenge is the drive-by test. Only Austria and Japan have a few added test conditions, e.g. engine braking and pass-by. There is actually no international standard if one considers how the national regulations are applied. Different test conditions, limit values, definition of max values, number of test runs, selection of test vehicles, COP rules (conformity of production), test responsibilities and certification processes are used in different countries. This should be harmonized.

Volvo companies deliver truck and bus chassis that are completed by a bodybuilder. Only tractors are completed at the factory, but all the vehicles are noise certified by Volvo. The bodybuilder has thus a freedom to change the vehicle without considering the noise aspect.

The European outdoor noise directive 2000/14/EC includes some completed truck types such as refuse collection vehicles, suction vehicles, tower cranes, and concrete mixer trucks but; there are no noise limit values only reporting and marking demands. These trucks are provided with special noise sources and special noise tests are thus required.

Some truck drivers provide their trucks with open pipe exhaust systems that increase the low frequency noise by >25 dB. This is done to save fuel and to get a more masculine V8 like sound from the truck. Furthermore, what about the maintenance of the vehicles? It is e.g. not uncommon that some of the noise shields are removed from the vehicle. The noise levels must thus be controlled in real life situations, on the road, and not only during certification tests for new trucks.

An interesting and more realistic test code is suggested by the PIEK organization.6 This test code is presenting several realistic and valuable test alternatives as a complement to the ISO 362 standard for certification purposes.

Noise encapsulation can be used to some extent but cooling performance demands require an open front and back so that the air can enter and escape from the encapsulation. A soft nose that is useful in front crash situations, would be an alternative but is presently stopped by the vehicle maximum length rules. A soft nose could be used to integrate more noise traps in the front of the vehicle.

Trucks are built in many different specifications, e.g. different cab sizes, axle arrangements (4*2, 6*2, 4*4, 6*4, 8*4, AWD etc.), engine sizes and power levels, emission levels, gearbox alternatives, wheel bases, and exhaust line installations and with or without auxiliary equipment such as retarders and PTO (power take off) installations. However, modularization and commonality of the components are very important for the business and also for the noise shields. This severely reduces the possibility to use extensive noise encapsulations. Good sound absorbers that are strong, can withstand high temperatures, oil and water, and that can be manufactured in a simple way are needed. Traditional porous fiber materials do unfortunately not meet all the necessary demands. New materials are required.

Discussion — Day 2

Question:

Let's start off with the tradeoffs between climate change issues and noise issues. There is a question concerning top speeds and the possibilities to make quieter tires. If for reasons which may be driven by climate change, the top speed in a passenger car is set at 150 km/h per hour, would it be easier to produce a tire that was some dB quieter?

Responses:

1. At the moment we have to build tires for the maximum speed of the vehicle, e.g. for Porsches up to 330 km/h. But if future vehicles have a maximum speed of 150 km/h, tires can be made of softer materials, the sidewall construction can be changed, and then we will have lower-noise tires. At the moment we have to ensure that the driver is safe at 250 km/h in his vehicle, so we have to use very hard tire compounds with very stiff tire construction and features which are only made for this high-speed range. The only problem at the moment is that the minimum speed symbol is "Q" that means 160, so only tires with a minimum of 160 are on the market. Legislation must be changed if we are to market tires in the future for lower speeds.
2. In most other countries but Germany there are speed limits. In Japan, for example, I think that the maximum is 110. In the U.S. also there are limits. I have imported tires from Japan which are not possible to buy here because of the speed concerns, but they are regular tires in Japan. The same is true in Australia. These tires are quieter than corresponding tires here in Europe. It's just a matter of deciding to have a maximum speed limit in all of Europe so you don't have to construct tires for 230/250 km/h. But that is a political issue. It is not a political issue that is just internal in Germany; it affects all of Europe.
3. You are not completely right. For the U.S. we have to ensure that the Porsche has the same tires on it. That means for the U.S. market we have to make tires for the Porsche only if it has a speed limit of 90 mph. So we have to build the tires for the maximum speed of the vehicles for all the countries. There are some vehicles in Japan and the U.S. with lower maximum speed, and these vehicles can be supplied with softer tires.

Question:

How durable are the graded porous asphalt road surfaces? Are there differences between the single-layer configuration and the double-layer configuration? Are there problems in respect to maintaining the cleanliness and functionality of the double layer compared to the single layer?

Responses:

1. Unfortunately the situation is not better with the double-layer porous asphalt compared to the single-layer porous asphalt. Both deteriorate with age, but deterioration depends on the situation in which the porous asphalt is used—the motorway situation with higher speeds or the urban area situation which is worse for porous asphalt and where about 1 dB noise reduction per year is lost if there is no cleaning applied to the surface. If cleaning is done, about ½ dB per year could be gained. But the problem is not yet solved.
2. What we've experienced in Australia, particularly in the Sydney Harbour Tunnel which has been open for some years now, is that the quality of the laying, the workmanship, the product manufacturer, and the techniques for laying such surfaces are in many cases suspect. What is the experience in Europe and in Germany in particular with respect to these control measures?
3. The situation is the same. We also have differences between road constructors—differences concerning the initial noise reduction values for these types of surfaces. But if the civil engineering laboratories and the road constructors are controlled or supported by some acoustical and civil engineering investigation work or measurements, the results are better than if there is no help from the acoustical side.
4. What you are suggesting are quality control measures. What sort of quality control measures are in place and what sort of quality control measures can be applied?
5. At the moment when quality control is applied, the mixture is tested in the civil engineering laboratory. Then small plates which were laid with the mixture tested in the civil engineering laboratory are sent to the acoustical laboratory. The absorption coefficient and the air flow resistance are tested to see if they are good enough. If not, the civil engineering laboratory gets feedback describing what's wrong with the mixture. Then the mixture is changed to try to improve it, it is tested again, and a specimen again sent to the acoustical laboratory.
6. The key word you used was "try." How effective has that trial process proven to be?
7. We now know exactly what we can recommend concerning, for instance, the grading curve for the mineral aggregate. It's pretty clear now what the technical laboratory has to do. There is some incompatibility concerning the binder compound; that's what they are working on. The civil engineers want to increase the binder content in order to improve the durability. The acousticians want to decrease the binder content. A tradeoff has to be found.

Question:

Why are there no requirements on road surfaces? There must be methods developed to make specifications on road surfaces and to control them afterwards. At what stage in the design of a new road vehicle would a manufacturer have to consider noise emission requirements that are lower than the current requirements to achieve lower levels of community noise and at what cost to the manufacturer?

Responses:

1. As early as possible. It also depends on how much this requirement will be lowered. If it's a couple of dB, every manufacturer should be prepared for such a decrease in the sound levels; and they are probably not too surprised that they need to do some corrections to the product. If it's 5 dB as we are discussing here, most manufacturers would probably need time to change some major platform details to get sufficient space for any additional mufflers or sufficient space for encapsulations or additions to the car. They will try to find solutions that do not add new details to the vehicle because they are eager not to create too much cost per unit. Development costs are generally rather cheap compared to costs per unit. So maybe they should have at least 3 to 5 years notice in advance about a 5 dB reduction in requirements. Of course the tire part has to be considered too; car manufacturers are not producing tires.
2. At the moment the measurement procedure for the vehicle pass-by test is fixed, and for the next two years the vehicle manufacturers have to take measurements by the old method and the new method to compare, and they will see where the limit value will be. I think there will be a reduction by 3 to 4 dB. But this is only for new vehicles. So as you mentioned, after sometime it's only for a fraction of all vehicles on the market. For a major strengthening, make it in steps so that they have 2 or 3 years after the first step to second step. So we have to expect in 5 or 6 years that it's made for all vehicles. The tires are part of the vehicle and they are included in this measurement procedure. That's why vehicle manufacturers ask us to meet the new limit values for the tires. So it is necessary now to produce tires that can meet the new limit values, which are not completely fixed but are 3 to 5 dB lower than the current ones.

Question:

Will the new ISO 362 test method together with significantly lower limits on noise emission in UNECE Regulation 51 be effective in reducing day-evening-night average sound levels from ordinary traffic?

Responses:

1. No. We have the old ISO 362 which was a procedure to make a measurement of the complete vehicle; to give a value of the noise behavior of the complete vehicle. In this procedure you come to the measurement area; and, at the noisiest gear, you accelerate at full open throttle. That means in a second gear for a normal passenger car you have to go with full open throttle through the testing. This was a procedure which was not so good for the high-powered engines from the German automotive industry, and that's why they asked for a change of ISO 362 and made a new proposal. In the new proposal you come to the measurement area and must accelerate in such a way that, at the end of 20 m, you have a maximum acceleration of 2 m/s^2. That means if you make it at full open throttle, you have to use the fourth, fifth, or sixth gear of your Porsche to get only 2m/s^2. So this is not a measurement of the engine power; it is a measurement of the rolling vehicle which is mainly tire noise. They also propose that you have to make a coast by with engine on with 55 km/h through the test track and have to take the average of this slow acceleration with the coast by. This is a new type approval value for the vehicle, and this way all high-powered vehicles will pass the new legislation values. That's why I say no, because now we have vehicles on the market which are type approved, and they can make any sound that they want if they use the second gear at full open throttle. That's why we'll have no noise reduction with a new 362; we will have more noise on the roads.
2. The reason to develop the new test method was to get a better and more relevant method for road traffic, but you indicate that we're going the wrong way.
3. I would like to modify that. I think that it has some sense—whether it's very well designed or not—but as I mentioned, it is possible to make much less noise with a good, low-revolution torque car. The testing problem was not only with the German car manufacturers—Porsche was perhaps a bit extreme—but also with the Swedish car manufacturers. Both vehicles are in the same class, which have reasonably good engine power; but what do you usually do in traffic? You want some acceleration which may be, e.g. 2 m/s^2. You are not thinking of putting the car in second gear and making a burn-out. There are people who like to make a burn-out at red lights, but they are a subject for the police rather than traffic noise regulations.
4. There is another problem. We now know that road/tire noise is more important in the new type-approval procedure. And if the legislation does not prescribe that the tires at the stage of type approval will be used during the lifetime of the vehicle, aftermarket use of tires with higher emissions will increase the noise levels. So we need a requirement that vehicle tires used for the type approval must be used for the whole lifetime of the vehicle. Otherwise we get an increase in noise.
5. I have a question for Truls Gjestland or Juha Plunt. Does the new method require that the vehicle be tested with the tires that the vehicle is sold with, or are the tested tires intended to be fitted during the test but not necessarily on the vehicle that is sold? That is very important.
6. As far as I am aware the wording in Regulation 5103, which will be the new one, requires that vehicles be measured with the tires that are available on the market for the vehicle. It is not allowed to use any other tyres like special designed for the type approval test.
7. I think that is not completely true. It is mentioned that they must be typical for that vehicle, so the vehicle manufacturer can choose which kind of tires he will use.

Question:

Should the Terms of Reference of UNECE Working Party .29 be reformulated to require significant reductions in the day-evening-night average sound levels from road traffic? Are the terms of reference well formulated?

Responses:

1. The R5103 is made for new vehicles for type approval. So this does not have direct influence for the DEN average level. It's only made for the new vehicles; and as Tor Kihlman mentioned, if all these new vehicles are on the market, we have to wait many years because vehicles normally have a lifetime of 15 years or so.
2. I'd like to follow up that question about whether the terms of reference should be reformulated by asking whether it's not the terms of reference that's holding them back but the way that the Working Party on Noise (GRB) works. Does the panel will have any suggestions about how to approve the productivity and effectiveness of regulations coming from WP.29?
3. I take part in the GRB. In the WP.29 there are official delegates from public road administrations. They are not acousticians; all the scientific questions they send back to the working group. I think we have to raise that to a little more political level than technical level.
4. I would like to comment on the effectiveness of a speed limit of 30 km/h. If we look at the German regulation for the calculation of noise reception levels, we get a reduction of up to 3 dB(A) if you reduce the speed from 50 to 30 km/h. This is based on measurements of real traffic situations on roads with a speed limit of 50 compared to a road with 30. So I think your statement is a bit pessimistic about the reduction potential.
5. It's more a psychological problem for the driver because he's learned to go

into lower gears instead of keeping up in higher gears. Also, people try avoid slowing to 30, at least when you look at practical situations, especially with speed bumps. If you stand beside a speed bump and observe the traffic, a lot of people brake just before the speed bump and then accelerate again. They are going over the speed bump at 25-30, but what speed do they have on the average?

6. We as engineers are focused on two things—either we solve problems with technology or we ask legislators to solve the problems. We are not good at changing people's attitudes because the public has the opinion that engineers are pretty dull and nerdy. We need help, some good public relations. Look at Al Gore. He's made people more aware of saving the planet. We don't have to be moralists about it, but we can just jump on the same train. We will get some noise abatement if we can move away from a macho attitude towards driving—driving your Porsche like an idiot or putting a 40 dB higher exhaust on your Harley-Davidson. It's not sufficient for your macho attitude to have a Harley-Davidson; you must scare the people at the roadside too. So a large problem besides technology and legislation is how to change people's attitudes to promote more reasonable, confident behavior. Some who are not self-confident feel they have to show off.

Question:

Earlier in the workshop we heard about aircraft noise and the idea is to change the design of an aircraft completely. Why don't the vehicle industries try to do the same?

Responses:

1. It's very popular to buy green cars in Sweden. They are selling more new green cars now in Sweden than ordinary cars. Why not simply change the rules for when you will get the benefits of buying a green car? The car industry will follow immediately; the car industry has no interest in getting speedy cars up to 300 km/h. The problem is that there are people buying them. That's the only problem. It's not the tire industry, it's not the car industry, it's the people who are buying those cars. Where are they using them? They are not using them only in Germany; they're using them everywhere. Why? Because they make a power statement. Perhaps behavior scientists and good marketers should join the team of noise control.
2. In your comments on the type of vehicles we have now, there was some reference to hybrid vehicles. Is there something we could do to get a radical change to the type of engine that's used?
3. There is no conflict between an engine that can produce very good, low-rev torque without having much of a top speed. I have a cruising bike—two cylinder, a Harley copy—it has enormous torque at low revs. I can drive like that if I want for as long as I want. But it only has something like 60 HP. It's a big 1500cc bike. So it's a matter of what you want. You don't have to have a 300 top speed. Take the hybrid Toyota, for example. It has enormous low-speed torque. It has a top speed that most owners will not bring it up to. It's 150 or so.

Question:

In EU documents such as European Commission C(2007)5765 of 29 November 2007, the goal for 2020 is a reduction by 10 dB or more of external noise of surface transportation. What steps have been taken to reach this goal?

Responses:

1. A noise directive is one of the steps, but it is not specifically looking at the emissions but rather a complex approach with measures in the transmission path also.
2. Do you know what steps have been taken to reach this goal of a 10 dB reduction in 2020? Have you any knowledge of this?
3. We have the environmental noise directive which says that for hot spots there must be an action plan, and I think this is one of the instruments the EU is using. For the END the EU doesn't set limits, so it's the task of the agglomerations of the national states to set limits to get these reductions. There is no complete action plan looking at all the measures and making an integrated strategy to reach this goal.
4. So the answer to what steps have been taken to reach this goal is that very few steps have been taken to reach the goal.
5. Maybe I can answer that just on source measures. We now have a proposal from the commission for tire rolling noise reduction, and there will be a communication from the commission in early July which is on railway noise reduction. But other than that there is very little which is going in any concrete way towards this target I'm afraid.
6. About the tire noise limits, the target dates are between 2012 and 2016 so they are close to 2020. The nominal reduction in the limits is from 4 to 5 dB. That does not mean that the average L_{eq} level in traffic will be reduced by that amount. It's more likely to be around 2 dB. So it's very far away from the goal.
7. We have at the moment proposed limit values of 71 dB for tire size up to 245. As I have shown we have 68 for the slick tires, so we have only 3 dB left. It is not possible to lower the limit values by 8 or 10 or 12 dB.
8. That's true if you're looking at the same size and dimensions; but if you can design vehicles differently, you can also play with the dimensions. So it is up to the authorities to make up the rules for that.

Question:

Ten to fifteen years ago most car industries developed lightweight vehicles often manufactured from composite materials. Why were these types of cars never produced? Are we going in the direction of heavier vehicles probably for customer reasons?

Responses:

1. I think the industry now builds lightweight vehicles to save some weight for other purposes. Fifteen years ago we had a few small motors in a vehicle. Now we have a motor for each seat, we have a motor for the windows; we have many motors and many new components. The parking brake in the vehicle that was operated by hand is now an electronic parking brake operated by motor. We have many new features in the vehicle, and that makes the vehicles heavier. The pure vehicle construction is lightweight, but all the extras we have in the vehicle now make it heavier.
2. Can we expect any new developments towards more lightweight vehicles driven by the climate challenges?
3. Yes this is one of the major trends. The automotive industry is now looking at affordable cars which means cheap, so they cannot have all the comforts which are now built into small vehicles. These vehicles will be lighter weight vehicles.
4. I think the demands for improved safety for the passengers determines the development. All manufacturers are looking for five stars. I don't think you can sell a car again that gets only two stars testing safety tests. Even the small cars are very safe now for crash testing. Ten to fifteen years ago you died when you crashed a car at 50 km/h, and now you can walk out. You have to take that into account for some of the weight increase.

Question:

Should noise-emission requirements be established in the EU for vehicles already on the road and manufactured prior to the date when newly-manufactured vehicles have to comply with new EU requirements for low levels of noise emission?

Responses:

1. If there could be some economic encouragement for fitting an existing vehicle with a quieter tire than it had when purchased, then I think this would make a difference in two ways. It would immediately mean that the vehicle would be a couple of dB quieter. But also it would put pressure on the market to supply quieter tires—a multiple effect. That could be done if we had the instruments for encouraging the fitting of quieter tires before they are actually required.
2. On what road would vehicles be tested? We have many different road surfaces. What should the legal limits be for this? Should we have legal limits for all kinds of roads? So I think from the practical point of view it is not practical to place requirements on existing vehicles. We can only look at the new vehicles.
3. You have to mark the measured sound levels–or label–somewhere on the tire so that we can make that direct comparison and act accordingly. Secondly, I think there would be big enforcement headaches to try to get some on-road compliance. I think, as Ulf Sandberg said, bringing in some incentive scheme that people can recognize which equipment could be environmentally responsible or socially responsible. Which is the lowest noise equipment? As mentioned this morning, if you brought noise standards into the Euro standards then that could be brought into all kinds of existing or planned incentive schemes. And also look to road charges which I think in the next 10-15 years will probably be more widespread throughout Europe. There could be environmental differentiation by air quality emissions, by CO_2 emissions, and by noise possibly as part of the same holistic scheme.
4. I have a comment for Nina Renshaw. The new limit value for the normal size of the 245 is 71. I've shown the slick tire has 68 dB, so then we have 3 dB left. From my point of view it makes no sense to introduce a noise labeling possibility where we need to have 1 dB per class. Then we have two classes because we can't have this blank tire.
5. What we're thinking of now is not necessarily a grade because the current market doesn't allow for that. But a low noise mark could be awarded to models that are maybe 2 or 3 dB below depending on what the market currently allows. So at least the consumers could be thinking about noise possibly when they make the decision. I think at the moment people have no idea of the noise emissions from tyres.
6. We have two or three other goals. Government enforced very strict limitation for a NO_x. Heavy trucks without the possibility to reduce the NO_x emissions cannot enter the Tokyo metropolitan area. Is it possible to have this kind of strict regulation for the noise of tires and mufflers?
7. In principle, yes. For example, we have in Germany so-called noise protection zones where only low-noise vehicles can enter during a specific time. But for that we need a definition of what is normal emission and what is low noise. It's a problem that we don't have a definition for low-noise cars and low-noise tires.
8. Are there new ideas about how to improve the acoustic emissions of the cars already on the market?
9. During the last few meetings in Geneva there has consistently been a proposal from Russia concerning vehicles in use. They propose a test after 100,000

kms—a new type-approval test to show that the vehicle fulfills the original levels after 100,000 kms. So our proposal may be a little bit more in line with what you are thinking about here than the stationary test where you only check the exhaust level. I don't know if this is realistic, but the Russians think about that. They want to check how the vehicle performed over a lifetime, at least the first 100,000 kms.

Question:

In designing low-noise vehicles, should a strong emphasis be placed on reduction of the low-frequency content of the vehicle's noise? The idea is that mitigation measures that we take on the immission side—barriers, windows—work as low-pass filters. Today we only look at the noise without such low-pass filters. Should we place a stronger emphasis on the low-frequency content of the vehicle noise? If so, what consequences would that have in terms of the way cars, tires, and roads are designed?

Responses:

1. I'd like to comment on the spectral content in general. A lot of the data that Ulf Sandberg showed and the data that's been shown in the U.S. shows a strong peak in the tire noise in the 1,000-1,250 range. That reminds me of the old days when the first jets were coming in. It was clear in those days that A-weighting was the wrong weighting for the jet aircraft. It didn't compare well with the annoyance of propeller planes. That's when the effective perceived noise level was developed which eventually became the EPNDB for aircraft noise. Perhaps, in the case of tire noise and tire noise reductions, we may be using the wrong metric.
2. Also if we are using the linear weighting, then we have the maximum noise level at 1 kHz for the tire noise. But you are right. If we are using the A-weighting for low-frequency noise, then it's not so important to lower the low-frequency noise component because in the overall limit they are going down. But for tire noise, the maximum is also linear at 1 kHz.
3. I met some Austrians at a recent conference who said there is a movement against using noise barriers because the protected side has very low-frequency bias spectrum. So if you could reduce the low-frequency content of the traffic noise, it would argue against that and allow them to continue screening those areas without ending up with such a skewed spectrum in a protected area. The problem with that, of course, is in the areas where you are not using barriers; you end up with a very different spectrum.
4. Also we have observed in some studies, that behind barriers we can get rather strange and unpleasant low-frequency sound effects.
5. The perceived noise level calculation gives more emphasis to the 1000 Hz than A-weighting, and therefore you might get a different reaction. For example, there have been places in the U.S. where relatively modest decreases in the A-weighted level from tire noise have been shown to satisfy people. You have to wonder sometimes—they get a reduction of 2-3 dB on the A-scale, a lot of people would say that's not significant; but in terms of human reaction, that kind of a level does seem to reduce complaints.
6. The truck manufacturer and the car manufacturer have now left the room, but maybe there are ideas and knowledge in the rest of the group here to comment on the question of low-frequency noise vehicles.
7. It is quite important with the metrics when it comes to a special combination of a truck tire or say special road surfaces like those porous surfaces that have a high sound absorption that eliminates most of the peak around 1000 Hz, and that sets the peak down to 500 Hz. If they achieve 5 dB of noise reduction, one can predict how much people would respond to such a change in noise level; but when there are surveys made of what people think in terms of annoyance, one usually finds that the response to the annoyance questions is much higher than would be predicted from just the noise level difference. So it seems like we underestimate the subjective effect of such surfaces by the normal A-weighting that we are using. Or there may be issues other than noise that people weigh into their judgment. This is something that has been studied by some people.
8. Suppose that we have very effective road surfaces which would especially absorb at 1000 Hz. What do you say then?
9. We now know exactly what we can recommend concerning, for instance, the grading curve for the mineral aggregate. It's pretty clear now what the technical laboratory has to do. There is some incompatibility concerning the binder compound. That's what they are playing around with. The civil engineers try to increase the binder content in order to improve the durability. The acousticians want to decrease the binder content. A tradeoff must be found.
10. In Japan we have an indoor environmental guideline. Recently people complained of audible low-frequency noise, so we had to reduce low-frequency to below 500 Hz, because low-frequency sound is uneasy; and transmission loss is not good at low frequency.

Question:

Primary consideration during the workshop has been given to road vehicles with four or more wheels. What is being done to control the noise emissions from vehicles with fewer than four wheels? This is the motorcycle

problem which has several aspects. One is a question of illegal mufflers. That is not a technical problem. Can we put the original muffler on the bikes in such a way that it can't be removed? With a growing number of two-wheelers for commuting, especially in so many parts of Europe, what will this lead to? Are the noise emission requirements for these two-wheelers reasonable? We know that we can drive a two-wheeler very quietly. Let us discuss the noise emission situation and the risks and the limit values?

Responses:

1. Some years ago the noise emissions limits for motorcycles were such that the heavy motorcycles were allowed to meet as high noise levels as the heavy trucks. That may sound strange to us considering the type of transportation work they do. I'm not exactly sure of what happened in the last 5 or 6 years, maybe the limits are the same. One might want to consider reducing those limits. Against this, one will hear an argument that if we reduce the limits, we will only make people more interested in buying and replacing the exhaust systems so they get more noise. So if they would get quieter when they are new, people would be more tempted to put illegal exhaust systems on their motorcycles. So it would not benefit society to do that. Personally I think that's quite a relevant argument. The most important thing is to have much more stringent regulations with regard to the use of illegal exhaust systems and strictly enforce them. Juha Plunt and I had a discussion about this during the walk to the restaurant today, and he had some very interesting suggestions about how to manage that in reality. As you heard he is a biker himself, but he is using a legal exhaust system, so he is very much concerned about this.
2. It would be relevant to lower the limits because if we lower the legal limits, then the illegal would be easier to distinguish.
3. Holistically the issue is more complex than motorcycles being equal to trucks. It may be valid on a major road which is wide enough for both a motorcycle and a truck. It certainly is not valid for narrow streets and lanes in Europe, Italy, Greece, and other countries where such motorcycles are used in prodigious numbers and where the impact of such motorcycles coming down the streets in the middle of the night is enough to waken half the residents of such streets. I argue very strongly that it is not a valid basis to compare or continue to compare motorcycles with trucks on the basis that they may have been harder to silence in the past, but they are certainly much easier to silence now. From a regulatory standpoint, in Australia if you are caught with a motorcycle without a proper silencer, you can be fined or have your motorcycle confiscated. Such rules would obviously work quite well in Europe if the regulatory authorities are prepared to impose conditions and regulations and penalties.
4. As long as they are getting away with whatever they are doing with the motorcycle—because they are not called in for an annual inspection, and if they are, they change back to the original equipment—there is no danger for them. I think that there are two ways to handle this. One is the regulatory way that you actually enforce in use control. In the SILENCE project there is a proposal for a new simplified pass-by test that the police can do if they are not just doing the stationary control because it's not that correlated to the pass-by. So there's a proposal for a simplified pass-by test that can be used on the road by the police and controlled by a figure that was made by the manufacturer when it was type approved. So there's a proposal that can make this much stronger. It is agreed that there should be some sort of enforcement, a heavy fine the first or second time you are caught; and the third time your motorcycle is taken away. That is the regulatory thing. The other is related to raising the awareness of the owners to be ashamed of the need to display their machismo or masculinity by going around late at night waking people up. They would not think about doing that; they should have a considerate attitude. Now you can do that because of your ego. That should appeal to people that you are not allowed to do so much harm to people.
5. I think it's essential as well to tackle the supply side and make retrofitted systems much harder to come by. The example we saw before was from a European website apparently in the Netherlands. How are these examples so easy to find, and why is there no enforcement? These retrofitted systems are available easily through the Internet or at garages. It's essential to tackle the supply as well as the demand, and I would imagine it's easier to tackle it that way.
6. Can the muffler to a motorcycle engine be integrated into the engine? The trend in the truck and car business is 'yes' to this idea because the exhaust emission legislation puts a very high demand on the exhaust after treatment i.e., mufflers with very expensive materials and made in stainless steel and with rare metals and active layers.
7. Motorcycle mufflers, like all mufflers, have a limited life. You cannot integrate a muffler on a permanent basis into the design of a motorcycle engine to provide a maintainable, reliable vehicle.
8. The replacement silencers have to fulfill the same type approval level as the new ones. So at least the legal side of replacement silencers should be at the same level as the new. There is no reason for having an illegal industry.
9. In the year 350 the Romans banned

chariots throughout the empire at night because it woke people up, and here we are 1600 years later worrying about motor bikes. And I imagine in 1600 years we'll still be worrying about something else waking people up. We're certainly not going to solve it by 2020, unfortunately.

10. The Japanese government is now preparing a noise abatement system for mufflers to reduce illegal mufflers.

Question:

Are there common interests on the relation of the climate change issue and the noise issue for road vehicles? For air vehicles the tradeoffs were clear. What tradeoffs do we have between climate change and noise? Are there topics—developments, health, and climate change issues—where the demands are counteracting the way people drive their vehicles. Lowering top speeds is, of course, good for the climate change issue and for traffic safety. Are there other obvious areas where there are conflicts between the climate change issue and the noise issue? A few years ago we had an appointment with our environment commissioner in EU, Margot Wallström, in Brussels to discuss noise. In our preparation for this visit, we emphasized the relation between actions to reduce climate change and actions to reduce noise. And we wanted to present it that way. Then we got a very strong warning—do not mention climate change in Brussels; that issue is dead in Brussels. Right now climate change is not dead in Brussels, but noise is rather dead.

Responses:

1. I think there are some tradeoffs between noise and climate change. That is when you use secondary measures and when you increase the weight. I think this is of minor importance and where the synergy between noise reduction and climate change stop. As you already mentioned, a lower speed limit and things like that are more important. But there is another aspect and this refers to the mileage of the vehicles. If you drive less, you will reduce CO_2 emissions and you will reduce the noise. It is important to look at all ways to avoid traffic. We haven't discussed this in this workshop up to now.
2. The so called synergy between noise and climate change is not a very realistic one. It's really a political issue, if you are going to make it such. The politics are trying to argue that people should drive slower, not drive at all, or provide the link between vehicle noise and CO_2 emissions. It is a tortuous one which will, in the end, be determined by the individual's positions and not by government regulation, not by any pressure that we can bring to bear, and would be in my opinion a grave mistake to link CO_2 and its reduction to noise.
3. It would seem to me that there would be more of a connection, from the U.S. point of view, between the cost of gasoline and its consequence on the reduction in weight of vehicles, speed, less emphasis on horsepower, and your ability to make some progress in the noise side. I would say gasoline consumption is a better argument than climate change
4. We heard yesterday that there are bad things that can happen between noise and CO_2 emissions and climate change. There don't seem to be any negative things here. So you could say that you don't see any bad things that are going to happen if climate change gets initiated more, and there could be some good things. For example, better gas mileage, that sort of thing.
5. I agree with some of the points that have come before that there is some danger in making the link too close with climate change. At the moment climate change is anything but dead on the agenda at Brussels and in most of the capitals in Europe. But these things tend to have cyclical nature. Eventually politicians will get sick of hearing about this, especially if the pressure falls on the fuel prices. So strategically there could be some danger in that. I think there could be more value in trying to raise the profile of noise in its own right by raising public awareness of the health effect that it has and the cost effectiveness of taking measures at the source. And in terms of technical measures at the source for road vehicles there don't seem to be any tradeoffs that I'm aware of. We can always point out that it's a win-win situation with safety, air pollution, climate, and definitely fuel prices. Pressure exists on fuel efficiency and certainly towards lighter vehicles and stimulating the market more for hybrid and electric vehicles. That's certainly a move in the right direction and should be an opportunity for those who are developing low-noise technologies as well to maybe even making some strides on the back of that. But speaking from a personal perspective I would warn against trying to take a free ride on the back of climate change and the attention it has now because noise is an issue which will probably run along for 10-20 years before we see real progress whereas climate and fuel prices are probably more immediate and more on top of where we are in the media right now.
6. When we look at private cars, there are no obvious conflicts except, perhaps, lighter engines with higher rpms. But when we come to heavy vehicles, Kaj Bodlund pointed out the conflict between lower emissions, lower diesel fuel consumption, and noise. They do demand a higher injection pressure and thus more noise.
7. In the Netherlands they just made a positive link between air quality and noise reduction from roads by running the competition for noise barriers that incorporate methods to reduce the flow of pollutant from the road to the

protected side of the barrier. They had a competition and built about 8-10 of the best solutions. Now if it proves to be viable that you can reduce the pollutants going from the road to the protected side, it could be used as an argument for increasing the use of barriers or building taller barriers. But it will be a completely different family of barriers that will be used.
8. A proposal and its outcome in respect to major highways and roads that have already sufficient width and demarcation lines and areas to the side in which the barriers could be effective is unquestionably of value. Now part of the problem in the cities and villages in England, Germany, and other countries is that these are roads that run through the middle of town and villages where such barriers are not possible or not necessarily practical.

Question:

Ernst-Ulrich Saemann mentioned that there is a 3 dB difference between the slick tyre and the proposed limit for tires. I wonder what we need for tires, or what we need for surfaces or what we need for vehicles. If there were unlimited resources in an ideal world—money, people, etc.—what would you need to go further than that 3 dB?

Responses:

1. At the moment we have no idea how to lower the noise very much. We can make a change of the tread pattern a little bit, and then I show you the limit of 68 for the slick tyre. So we have to work to do. The tyre industry spends a lot of money, and the laboratories are working on this; but at the moment I have no one in the world who can tell me what I can do to lower the noise from a real tyre by more than 3-4 dB.
2. I would like to point out that the slick tire is not the quietest tire in all situations. It may be on the ISO surface, but on other rough surfaces, it is actually the noisiest tire.
3. I think we have to distinguish between the legal limits which are to be tested on the ISO surface and the vehicles on a normal urban road.
4. What we aim at is quieter traffic, quieter immission levels in urban areas.
5. We have to fulfill the limit values on the ISO reference surface, and it is a lot of work for us to do this but afterwards on a normal road it's not so good. Legal limits are made on either surface. What is right, of course, is that on the normal rough surface the tire vibrations are more excited and the tread pattern is not so important. If I make then a heavy construction and do not have to look for the CO_2, then I can have low noise values, of course.

Rail Transportation

The third day, June 4, was devoted to rail transportation, and the morning session was chaired by David Thompson of ISVR. The following topics were covered:

- Rolling noise generated by wheel/rail contact
- Aerodynamic noise (speeds above 300 km/h)
- Traction noise
- High speed passenger trains
- Local passenger trains
- Freight trains
- Light rail

Background

Noise emission limits for new rail vehicles became effective in the European Union in 2002 with the introduction of the Technical Specifications for Interoperability (TSI), replacing the previous interoperability regulations managed by the railways. However, these limits only apply to new rolling stock. With a typical vehicle life of 30 years, and no regulations on existing rail vehicles, it will be many years before the TSI make a significant impact. Cast-iron brake blocks have long been identified as a source of high wheel roughness and therefore noisy vehicles. Significant advances have been made in reducing the noise emissions of passenger trains over the last 25 years by the widespread use of disc brakes, which give a reduction of about 10 dB, although this has been partly offset by higher speeds. Until recently, the interoperability regulations for freight vehicles specifically required the continued use of cast-iron brake blocks. Alternative composite blocks producing smooth wheels are now available; but the K blocks require substantial modification to existing vehicles, and there have been problems with the development of LL blocks intended for direct retrofitting. The new TSIs effectively require the elimination of cast-iron brake blocks, but there is evidence that many new wagons are gaining exemptions from the limits. Other technology such as wheel and rail damping requires the coordinated effort of both vehicle manufacturers and track maintainers which is difficult to manage.

The following questions were sent to the panelists:

1. What progress has been made with fitting composite brake blocks to freight wagons in Europe? How can this process be speeded up? What is the cost of replacing cast-iron brake blocks on the whole European fleet?
2. What other techniques are available today for noise reduction at the source (e.g. wheel dampers, wheel design, rail dampers, acoustic grinding)? What noise reductions are possible using these techniques?
3. What is preventing the implementation of these techniques on a wider scale?
4. To what extent are the current TSIs leading to quieter passenger vehicles in service? Is it feasible to introduce stricter limits?
5. In view of future increases in train speed (and the possible introduction of maglev), what needs to be done to reduce aerodynamic noise?
6. What are the particular problems that need to be solved for light rail?

The afternoon discussion session was chaired by Phil Nelson and Tor Kihlman.

The Panel Presentations

The panelists for the third day's presentations were:

David Thompson, ISVR, Rail Transportation Session Chair
Introduction to the rail noise problem

Pierre-Etienne Gautier, SNCF
Railway noise: state of the art and perspectives for reduction

Janne Färm, Bombardier
The role of vehicle manufacturers in reducing noise and the impact of the TSIs

Paul de Vos, DHV
Progress with fitting composite brake blocks and economic methods of stimulating this

Michael Jäcker-Cüppers, UBA
The role of government agencies in promoting railway noise reduction

Introduction to the railway noise problem

David Thompson

Railway Noise in Context

After a long period of declining market share, especially in freight, railways are expanding across Europe. High speed trains can compete effectively with air on routes up to 3 hours and commuter networks are often overcrowded. UK passenger-km figures in 2007 are the highest since 1946. Railway noise is more localised in its effect on the community than road traffic noise.

Nevertheless it is seen as important to encourage modal shift to rail and for this noise emissions must be reduced. Noise source limits for rail vehicles have only been introduced since 2002, within the scope of Technical Specifications for Interoperability (TSIs). However, these only apply to new vehicles and are strongly focused on the vehicle contribution to the noise.

Sources of Railway Noise

The main source of railway noise is rolling noise. Aerodynamic noise becomes dominant at speeds over 300 km/h, while traction and fan noise are important only at low speed. Other sources include curve squeal, impact noise and the noise from bridges but these are more localised in their effect.

Rolling noise increases at a rate of 30 $\log_{10}V$, where V is the speed. It is excited by the combined surface roughness of the wheel and rail. Both wheel and track contribute to the radiated sound, often their contributions being of similar magnitude. Noise reduction technology, therefore, needs to deal with both sources.

Technology for Reducing Railway Noise

Reduced roughness. Cast-iron block brakes applied on the wheel tread lead to corrugation of the wheels. Their elimination, for example by using disc brakes, can reduce rolling noise by 10 dB. This has been known for over 25 years, yet freight vehicles in Europe have continued to use cast-iron brake blocks until recently, as these were required for interoperability. Under the TSIs, the noise levels set effectively rule out cast-iron blocks. Composite blocks (K-blocks) can be used on new wagons to achieve the required levels, which are similar to those for disc braked stock. However, retrofitting on existing vehicles is problematic. LL blocks intended for simple retrofitting have been more difficult to develop but are being tested.

Rail grinding is also effective in reducing noise where rail roughness becomes excessive. The "specially monitored track" concept is used in Germany whereby the noise level is monitored regularly and grinding is applied when a threshold level is reached.

Reducing wheel noise. The wheel component of noise can be reduced by various changes to the wheel design. Very small wheels can reduce the wheel component dramatically (by up to 20 dB) although they increase the rail component slightly. Optimised wheel cross-section shapes can be effective for disc braked wheels (up to 5 dB reduction in wheel component), but there are constraints on the shape for tread-braked wheels which limit any such benefit. A variety of forms of wheel damping are available and widely used and can also reduce the wheel component by several dB. A wheel-mounted shield has also been demonstrated to be successful.

Reducing track noise. Stiff rail pads are known to reduce track noise by increasing the decay rate of waves in the rail. However, they cannot be used in practice due to the need to protect sleepers and ballast from high-impact loads. Rail dampers are an effective way of increasing the track decay rates while maintaining the isolation of the sleepers. These can reduce the track component of noise by 2-8 dB depending on the rail pad stiffness of the initial situation. Several designs are available and have been approved for use in France, Germany and the Netherlands.

Local shielding. A combination of vehicle-mounted skirts and low trackside barriers can be used to give significant noise reductions (up to 10 dB), but there are other practical problems associated with implementation. To be effective there has to be no gap between skirts and barrier, but this is problematic for international operation. An integral barrier can be constructed on a slab track that is closer to the source than for ballasted track. Although slab track is initially noisier than ballasted track, the resulting design with integral barriers can be several dB quieter than ballasted track.

Cost-benefit analysis. Various cost-benefit analyses have shown that reduction of noise at source is often more cost-effective than high trackside barriers especially when considered on a route or network basis.

Barriers to Introducing Technology

The railway is a safety-critical environment operating in a harsh economic situation and is resistant to change. Large projects for new lines will often not adopt new technology unless it has been proven (Hong Kong is an exception). There is, therefore, a need for demonstration projects such as the IPG project in the Netherlands to gain experience with new technology including insight into lifecycle costs.

Conclusions

The replacement of cast-iron brake blocks on freight wagons in Europe is underway and will eventually reduce the noise from the noisiest rolling stock by 10 dB. Achieving further reductions for freight and passenger stock will be more complex involving a number of measures applied together. Nevertheless, measures applied at the source are often more cost-effective than widespread use of high noise barriers.

It is important to understand the breakdown of source contributions in a particular situation so that measures can be chosen and designed appropriately. As ownership and operation of the infrastructure is segregated by European law from that of the vehicles, a key question is how to divert budgets that might be allocated to noise barriers into reduction at source.

Perspectives for techniques to reduce rolling and aerodynamic noise

Pierre-Etienne Gautier

Railway noise originates from different sources on the train. The understanding of the mechanisms of noise generation differs for the various sources. The principal sources are rolling noise, aerodynamic noise, traction and auxiliaries, brake screech, and metal bridges.

Rolling noise is the major source at current commercial speeds. It is created by microscopic defects on wheels and tracks with amplitudes of a few microns. The noise depends on the quality of the rolling surfaces that is controlled by wheel roughness and rail roughness. The track is the major contributor at lower frequencies and the wheel at higher frequencies. The “TWINS” rolling noise model was the basis for the design and testing of optimized wheels and track. Noise at the source is reduced by rail grinding which, in itself, is a noisy operation. It reduces the radiated noise by 3 to 5 dB(A), but its effectiveness is limited in time (less than one year) and such track maintenance requires a major effort. Track dynamic absorbers reduce the rolling noise by damping the waves in the tracks. They produce a 2 to 3 dB(A) reduction in total noise that has been confirmed after one year. Other research on rolling noise reduction has involved prototype wheels with lower emissions both for the TGV as well as freight wagons resulting in 4 to 10 dB(A) reductions. Important progress in TGV noise reduction is attributed to control of the rolling noise whereby the noise energy has been reduced by a factor of 10. Composite brake blocks installed on freight wagons have produced noise reductions of 10 dB(A).

Aerodynamic noise becomes dominant at speeds above 300 km/h. A number of experimental investigations have been undertaken to characterize aerodynamic noise at 250 km/h and 350 km/h. Aerodynamic noise is due both to the body and to the pantograph. The principle for reducing this noise is known: shrouds and low-noise pantographs. Different shroud types have been investigated in cooperation with the automotive industry and universities (MIMOSA project) with testing of small-scale, model trains.

In the EU project SILENCE, several other noise sources have been under investigation using the results of pass-by measurements with 72 microphones located 6 m from the train and with beamforming and dedopplerisation techniques and spatial integration around the source location. The sources investigated were traction gear, fans, diesel motors, brake screech, curve squeal, and metal bridge noise.

Brake screech was measured with a TGV stopping from a speed of 300 km/h in a distance of 3.35 km. Brake and disk modelling were undertaken looking for instabilities and small vibration around steady, sliding motion. With non-linear modelling, the transient solution on unstable modes was projected with the conclusion that the response is in an unstable mode and as a forced response in its harmonic frequencies. A simplified, three-dimensional brake model with viscous damping uncouples the modes that were coupled by friction. The same model was used to analyze the transient solution of several unstable modes.

Modeling also enabled the design of solutions for metal bridges using FEM models for lower frequencies and SEA at higher frequencies. A prototype bridge incorporated a modification of rail fasteners (-10 dB(A)), an absorptive barrier (-8 to -10 dB(A)), and rail vibration absorbers (-3 to -4 dB(A)). Combining solutions from the prototype with optimized fasteners and dynamic absorbers for rails produced a measured reduction of 10 to 11 dB(A).

From this development work on components, can the global pass-by noise be effectively reduced? Is it worth working on all sources? How much do we finally get from measures on components? Can the noise reduction be perceived?

To answer these questions, sound synthesis undertaken as part of the SILENCE project involved time-signal computation that divided the source spectrum into broadband noise and pure tones. Specific loudness was used to select the principal pure tones. For software the project used VAMPPASS and a decoder to listen to the B-format time signal with the available hardware.

The principal objective of the SILENCE project was to predict the best combination of solutions to reduce the pass-by noise of an AGC train under normal operating conditions at 30 km/h and 80 km/h. Inputs to the model were the noise source characteristics of the existing train from measurements, a recording of the pass-by noise of the existing train, and the noise reduction provided by each solution that was achieved in the laboratory. For the existing train, the noise sources were defined in VAMPPASS. The signature and one-third octave band spectra were compared with pass-by measurements at 30 and 80 km/h in both the diesel and electric modes. Pass-by noise measurements using an array of microphones have shown that the contributions of the HVAC unit, the cooling of the electrical converter, and the cooling of the traction motor are negligible. These sources have not been modified.

The conclusions of this work are that progress (-10 dB(A)) has already been realized on the TGV, on passenger trains, and soon on freight trains; there is need for commercialization of the prototype solutions; and there is further need for research on brake screech, curve squeal, and aerodynamic and traction noise.

The role of vehicle manufacturers in reducing noise and the impact of the TSIs

Janne Färm

There are approximately 30 specialists in acoustics and vibration within Bombardier; Mainline and Metros, the biggest division, has 17 specialists. We work with the following:

Norms and standards e.g. TSI and ISO

- Development of quieter products
- Prediction models, BRAINS
- Predictions and break-down of customer requirements to requirements on component level
- Type testing of complete vehicles
- Trouble shooting

Our different roles in reducing noise are necessary as the economy demands lower cost, the environment demands reduced noise, and survival requires development.

There are three things driving Bombardier to reduce noise. The first, internal pressure since trains offer an environmental-friendly mode of transportation. However, they are noisy. If we are to remain a popular means of transportation, we need to lessen the noise and improve the acoustic comfort onboard. We are also driven by customer pressure for faster trains without increasing noise and more specified requirements. And through legal pressure, TSI requirements are a minimum requirement and secures the use of state-of-the-art technology.

We are active in research and development projects on European, national, and company levels to reduce noise. InMAR and Silence are two ongoing EU-funded projects, LZarG and the Green Train are two national projects, and ATD Bogie and Traction Noise is a BT group-funded project. In addition, each division runs P-development projects e.g., PM-motors.

The actual areas of development include rolling noise, aerodynamic noise, and traction noise. For rolling noise, the cheek-mounted disc brakes act as wheel dampers without additional cost. The friction between wheel and disc adds damping but this can probably be improved. This phenomenon is not yet fully understood. Also in rolling noise development is the need for a reduction of the squeal noise for light rail and metros as well as bogie skirts which are needed for future high speed trains to reduce both aerodynamic noise and rolling noise

The reduction of aerodynamic noise requires an improved shape on the train front, high-speed pantographs with improved shape, inter-car covers, and bogie skirts, especially for the front bogie. Traction noise includes electro-magnetic noise from motors and transformers which can be reduced by randomly switching frequencies to reduce tonal noise and the improved design of transformers can also reduce the EM-noise. Fan noise is also a part of traction noise which can be reduced as follows:

- Shape optimized fans with uneven blade spacing reduces tonal fan noise
- Forced ventilated or water cooled motors instead of self-ventilated motors
- Noise mufflers for self-ventilated motors
- Controlled cooling with reduced fan speed at stations

Bombardier participates in revisions of standards and TSIs. Our goal is to have cost-effective and efficient procedures to measure the noise. One important aspect is to have standards that increase the repeatability of test results e.g. with a good description of the test track as we have in the TSI. With our experience from type testing we can constructively contribute in this kind of work, and with future stricter limits for the TSIs we can contribute with the technical and economical consequences this implies.

A key element for success is good prediction tools which reduce the uncertainty and lead to lower contractual values. With these tools we reduce the economic risk and can focus more on development than on trouble shooting, and with reliable predictions we can more easily discuss different requirements with our customers.

TSIs have led to a strict description of the test track for more predictable and repeatable results. Acoustic measures on a train are measurable on the test track. The TSI limits promote sound trains with good noise design, although the existing limits can not be lowered further without major changes, e.g. covered bogies will be needed for high speed trains.

Many customers' requirements are tougher than TSI, but this is a positive situation. The customers will indirectly pay for the improved acoustic performance which can lead, in long term, to stricter legal limits that will then be in balance with technical development.

In conclusion, it is in Bombardier's interest to reduce the noise from rail vehicles; and we are active in many areas to achieve this. We have to keep a balance between environment, development and economy.

Progress with fitting composite brake blocks and economic methods of stimulating this

Paul de Vos

Rail freight transport noise is a major concern in mainland Europe as most freight wagons are equipped with cast iron brake blocks, freight trains run mainly at night, and freight traffic is booming. The obvious technical solution is to change from cast iron brakes to composition or sinter metal brake blocks, with an expected reduction of the noise production of around 8 dB(A) on good quality track. Newly purchased wagons are currently equipped with K-blocks, in order to comply with the requirements of the TSI Noise, which has been in place since 2003. However, the speed of this fleet renewal is too low to cope with the growing adverse reactions to increased freight traffic. The sub-optimal solution to install trackside noise barriers is costly and has decreasing acceptance. Retrofitting the fleet is a cost-effective measure from a macro-economic point of view; but vehicle owners, however, are reluctant to engage in this process as long as there is no clear incentive. Some member states are prepared to follow the Swiss example and reimburse the cost for retrofitting, but state aid rules based on the Treaty of the European Communities prevent such direct subvention. Authorization of such funding is only conceivable under very strict conditions. Indirect incentives probably require the involvement of the infrastructure manager but show distinct advantages such as the opportunity to focus on certain lines and certain components of the fleet. Irrespective of the methods for incentives, the range of feasible technical solutions needs to be expanded to establish a healthy market situation. Promising national initiatives need to be expanded and coordinated.

Continental Rail Freight Traffic

The expansion of the European Community towards the East and the emerging economies in the Far East have caused a boom in freight transport, with annual growth figures of more than 10 percent in rail freight transport. In addition, certain lines with shared passenger-freight traffic have seen an even higher growth once the passenger traffic was shifted to newly-built, high-speed lines. This applies particularly to the Rhine Corridor in Germany, one of the most heavily used lines in Europe. This growth leads to strong adverse reactions from residents. Existing noise reduction programs, which usually provide packages of noise barriers and window insulation, show low cost efficiency, require long planning periods and suffer from low acceptance. It has been known and acknowledged for more than a decade, that noise reduction at the source would be the preferred option (e.g. Stairrs project, Position Paper of the EU working group on railway noise). The Swiss Noise Reduction Program, implemented into a legislative framework in 2001, was the first example of an integrated approach, building on cost-effective solutions at the source. The UIC noise action program, based on a 1997 common decision, builds on the experience from Switzerland. Retrofitting the entire existing fleet, with full federal funding, is the key element of the Swiss program, and it has been the intention of many initiatives to copy this example.

Retrofitting: The Technology

Wheel tread defects such as high levels of roughness, often developing into "polygonisation," are caused by high wheel tread and brake block temperatures, resulting in periodic wear. These phenomena are typical of cast iron brake blocks. Such phenomena are not found, or are at much lower levels, with composite material brake blocks. In addition, composite materials show higher friction coefficients. In spite of the purchase price being higher than that of cast iron brake blocks, composite blocks have been used in the UK and Portugal (and in various networks outside Europe) for many years. For mainland Europe, the large variety of requirements for brake blocks has lead to only two compliant products after many years of testing and trying. These requirements include not only braking performance, but also low temperature and ice behavior, friction coefficient as a function of speed, electric resistance of the wheel rail contact, self destruction in case of the brake being stuck, and also wear and durability. Noise performance has only been an issue since the TSI-Noise has come into force (2006), and since then composite brake blocks, indicated as K-blocks, have been the standard for wagons admitted newly on the market.

For existing wagons, however, K-blocks are not the obvious solution. Because of the higher friction coefficient, the brake requires lower braking force, which means a drastic modification of brake cylinders, rigging and valves. In some cases (in Switzerland, it was found that this applies to 11 percent of the wagons, but in older fleets this figure would be higher), even the wheel sets have to be modified. Therefore, the search has been for a brake block material with friction coefficient comparable to that of cast iron, but with noise performance comparable to K-blocks. This factotum is indicated as LL-block ("LL" for very low friction coefficient). Both K-blocks and LL-blocks achieve reductions of the noise production of roughly 8 dB(A) on very good quality track and 5 dB(A) on average track, compared to the reference wagon with cast iron blocks.

Retrofitting: The Cost

There are more than 600,000 freight wagons, homologated for international traffic, in Europe (EU 27). The fleet has been drastically rationalized over the last decades, following a general over-capacity, but lately there is a growing demand for freight vehicles with which the supply market is unable to cope. Today, less than 10,000 of these are equipped with K-blocks, most of them thanks to the Swiss retrofitting program. In practice, because of the complicated modification, the retrofitting could only be done in combination with a large overhaul of the wagon, which takes place every 7 years (11 years for tank wagons). The actual cost for retrofitting is composed of different elements: engineering, workshop, and material cost. These range from roughly € 5,000 for a 2-axle wagon to Ð 13,000 for a 4-axle wagon requiring wheel set exchange. Usually, when the first wagon in a new series of a certain wagon type is retrofitted, the retrofitted wagon type has to be approved, requiring a series of field tests that cost up to € 300,000 per wagon type. The German Railway DB has put a lot of effort in developing a prediction tool for the life cycle cost of retrofitter wagons. K-blocks are substantially more expensive than cast iron blocks because of the market situation with only two products approved, but the price difference is balanced out by a much longer lifetime. In turn, this longer lifetime of the block is compensated by a somewhat higher wear of the wheel tread, but there are definite indications that the overall lifetime of the wheel could be maintained if the re-profiling regime is modified. A 2004 study estimated that the overall difference in life cycle cost between the existing fleet and the retrofitted fleet would amount up to 3.5 billion Euro for EU 25.

The search for a suitable LL-block has been going on for more than 10 years now. Projects like Eurosabot and Euro Rolling Silently have tried to come up with the ultimate solution. Operational tests have been carried out in the Dutch Noise Innovation Program, which is currently monitoring the majority of a total of approximately 300 wagons with LL-blocks. So far, only one product received preliminary approval (for testing only). LL-blocks are available as sintered metal or composite material blocks. The actual exchange of cast iron blocks for LL-blocks requires no further modification of the wagon (only the brake block clamp needs to be modified) and can be done virtually at any place and moment where the wagons stands for about 30 minutes. The sinter blocks are even more expensive than K-blocks, but again that is more or less balanced out by a longer life time. Therefore, the assumption is that the life-cycle cost of LL-blocks is more or less neutral. Whether or not a wagon retrofitted with LL-blocks still requires a wagon type approval test (with significant cost) is a matter of dispute.

Funding

According to a 2005 study carried out by UIC, the Member States plan a total of 10 billion Euro worth of noise barriers and insulation windows in order to clean up the existing noise situation and cope with the expected traffic growth. Almost 4 billion of that could be saved if the fleet were to be retrofitted. The rail operators and wagon owners, however, are not prepared to assume the cost for the retrofitting; and as long as the TSI-Noise refers to new vehicles only, there is no legal way to force them to do so. With the expected savings for the national economies, there is a clear scope to publicly fund the retrofitting, and this option has been suggested on many occasions, again following the Swiss example. European state aid rules prevent direct subsidies, unless some very strict conditions are fulfilled. This includes a maximum share of 30 percent of the eligible investment cost7, which would leave a large proportion to be funded by the market. The most promising option would be to declare the EU-wide retrofitting an "initiative of general European interest" for which the Commission could be prepared to allow a larger coverage (and contribute to the funding). Such direct funding may also work as an incentive to run new quiet vehicles on particular networks. In Switzerland, the Federal State supplies a refund of € 0.0062 per wagon kilometer to the operator (including foreign operators) of any quiet wagon in Switzerland. Such a system would be considered state aid and cannot be implemented within the European Community.

An alternative route of funding, suggested by the author since 2000, is through the Infrastructure Manager (IM). According to Directive 91/400, the IM is entitled to collect charges from the users of the infrastructure. In most European countries, the IM is required, by national law, to balance his income and expenses; but the national government may supply balancing funds if required. This opens the door to a system of boni and/or mali added to the charges, representing an incentive for operators to run retrofitted wagons simply because they earn money for them. Various initiatives have recently emerged, exploring the legal options. In the Netherlands, a system of boni was introduced in July 2008, based on article 11 of 2001/14/EC, the performance regime. It will work on retrofitted wagons only and will equal € 0.04 per wagon kilometer. It leaves open the option to introduce a malus for non-retrofitted wagons after a period of 3 years. In Germany, there are ideas to introduce a bonus, supplied by the Federal State to the IM, on the order of € 0.01 per wagon kilometer. This would serve as a 5-year balance for retrofitting with LL-blocks, but the earn-back period would be far too long for K-blocks. The system will be further developed in the next 3 years. Similar thoughts are emerging in Austria. The attraction of the system of boni is that it mainly affects the wagons with a large mileage and that it could be focused, if so desired, on certain corridors. If such systems would be operational in The Netherlands, Germany, Austria and Switzerland, it would represent a strong statement and incentive to the operators in transalpine transport.

One disadvantage of these initiatives is that they are ahead of European Commission initiatives which may introduce a more integral and coordinated approach. One important condition is that at least one LL-block be available with unlimited approval for international traffic. Therefore, the German Transport Ministry intends to launch not only a pilot project (Quiet Rhine) to retrofit 5,000 German wagons (50 percent with K-blocks, 50 percent with LL-blocks), but also a Research and Innovation Program, intended to substantially shorten the time to market new brake block products, to facilitate all necessary testing, and to support manufacturers who are willing to engage into the further development of these products. It is matter of great concern, that in spite of major efforts, the LL-block is still not available today. However, it is a comforting thought that in due time, when the existing fleet will have reached the end of its economical life time, the problem will solve itself. But are the millions of residents along the main freight corridors in Europe prepared to wait another 40 years?

The role of government agencies in promoting railway noise reduction

Michael Jäcker-Cüppers

The EU member states play an important role in the mitigation of railway noise. The state has to set the abatement targets via legislation in order to protect the population and – as there is in general no market for quietness – has to set the framework for the internalisation of external costs due to railway noise. State aid for research and financial support for railway noise abatement is another important state instrument. The general quality target for noise abatement is to avoid harmful noise effects in all railway operational conditions. Combined effects (various sources) have to be taken into account in a receptor-related policy. Railway operation must be in permanent compliance with the targets. Quantified targets for mainly equivalent levels L_{eq} in dB(A) can be found in legislation, mitigation programmes and various other papers. The CALM Noise Research Strategy Paper of Sept. 2007 "Research for a quieter Europe in 2020" proposes the following targets in Table 1.

The noise levels L_{night} along freight lines are up to 75 dB(A), this requires reductions between 20 to 35 dB(A) which is possible only with a combination of measures and instruments. This also means that all stakeholders must contribute to these reduction targets (infrastructure managers, railway undertakings, wagon owners implementing the measures, member states, European Union enforcing the instruments etc).

The setting of noise reception limits is the most straightforward state instrument. In general the compliance with these limits is the responsibility of the infrastructure managers. The following mix of measures and instruments is applicable:

- operation related measures and instruments (differentiation for daytime/nighttime)
  - speed limits
  - volume restrictions (i.e. ban for noisy vehicles)
  - noise emission related track access charges (eTAC)
- track related measures (local measures at the source):
  - low noise track design
  - rail grinding (maintenance)
  - rail absorbers (retrofitting)

Table 1: Mitigation targets for noise

Target class	Lden dB(A)	Lnight dB(A)	source	effects
minimum	65	55	UBA	health risks
medium	55	45	WHO	high annoyance
optimum	50	40	VROM, UBA	annoyance

- transmission related measures:
  - barriers etc
  - increase of distance
- measures at the receiver:
  - sound insulation windows
  - orientation of sensitive rooms

Noise reception limits will, in general, be different for new and existing situations.

- for planning situations : according to precautionary principles optimum (Table 1) targets should be aimed at for:
  - new (+substantially altered) railway infrastructure
  - new houses near existing infrastructure (recommendations for new purely residential areas in Germany correspond with the optimum targets [DIN 18005: "Noise Protection in Urban Planning"])
- for existing situations:
  - the short term target should be equal to the minimum target (Table 1)
  - a multistage approach is recommended to reach the medium targets at least
  - state aid for remedial programmes (old environmental burden) might be important for economically viable solutions
- permanent compliance with the limits can be safeguarded by the instrument "emission ceiling":
  - resulting in maintenance of vehicles and rails
  - increased volumes, speeds must be compensated by measures at the source
  - vice versa: measures at the sources allow higher volumes, etc.

Operators and wagon owners can contribute to the targets by the use of well-maintained low-noise vehicles. This can be and is prescribed by another important state instrument, the noise emission limits (EU competence). They should be based on the best available technology (global measures at the source) and must be economically viable (cost-benefit analysis).

The current EU practice is to set limits only for new vehicles (TSI) thus additional instruments for in-service vehicles are required:

- the above-mentioned noise related track access charges to promote the use of quiet vehicles.
- state aid for the retrofitting of cast-iron block braked vehicles
  - either as direct subsidy for the wagon owners
  - or as state compensation for the reduction of track access charges (bonus model)

Thus an optimized railway noise abatement strategy consists of:

- the introduction of noise reception limits
  - with ambitious targets for planning situations
  - with a multistage approach for existing situations
- supplemented by the best available technology of vehicles
  - enforced by noise emission limits
  - and incentivised by eTAC (further innovation)
- retrofitting of the existing freight fleet via eTAC and state aid
- optimization of the mix of measures and instruments with cost-benefit analysis (low benefit threshold and valuation of health risks)
- safeguarding of the noise reduction via maintenance regulations and emission ceiling
- state aid for research

The assessment of the current railway noise abatement policy shows that

- reception limits for new railway infrastructure are introduced in most European member states (but with limits above optimum targets)
- emission limits are set for new interoperable vehicles (TSI):
  - limits for conventional railbound vehicles do not always use best available technology
    - diesel traction (among others there are exceptions for UK)
    - coaches: no rail dampers required
  - the revision proposals in Chapter 7.2 and 7.3 of the TSI Noise should soon be implemented
    - inclusion of infrastructure (roughness or noise emission limits for tracks)
    - inclusion of wheel monitoring
    - reduction of limits by 2 to 5 dB(A) for pass-by noise
- retrofitting of the freight fleet:
  - instruments: EU Commission tends to a combination of differentiated track access charges (eTAC) and emission ceiling
  - financing: no European funds available
  - German government decision in 2007:
    - eTAC best instrument for stimulating retrofitting
    - probably combined with state aid (compensation of bonuses to the infrastructure)
    - at the end of the retrofitting process: regulation of the emissions (ceiling, operational restrictions etc.)
    - currently preparation of a pilot project to create the technical, administrative and legal basis for eTAC
      - installation of wagon tracing devices in the Rhine valley
    - supplemented by an innovation program for K- and LL-blocks (aim: unlimited homologation)

Discussion – Day 3

Question:

What progress has been made with fitting composite brake blocks to freight wagons in Europe and how can this process be speeded up and what is the cost of replacing cast iron brake blocks on the whole European fleet? Is the K-block standard for new wagons?

Responses:

1. Indirectly true. The noise limits are set so the railways need to fit K blocks in order to meet them.
2. Disk brakes may be used as well. In some cases it's economically more advantageous to do this. There are wagons that operate a high mileage on steep gradients, for example.

Question:

What is a homologated block? Why is it important and what relevance does it have on the fundamental issues?

Responses:

1. Homologation is a type of approval of the block, so it's necessary otherwise you can't operate with those blocks.
2. Because there are 600,000 to 700,000 wagons, it would take more than eleven years to retrofit the whole fleet.
3. The number of vehicles to be retrofitted is decreasing every year as we proceed with the process.
4. The lengthy and difficult product approval process and the cost for retrofitting the whole fleet in the EU is 3 billion euros.
5. That might be a bit high. With the K-blocks it should be between 2-3 billion euros.
6. Currently there are approximately 9,000 wagons with K-blocks and only 300 wagons with LL-blocks.
7. As far as economic incentives are concerned, direct state aid should be avoided as it is against EC law.
8. It could be solved by identifying a program of common importance for the European railways. Then direct state aid could be given, but this would take some time and the outcome is not certain. So the better way would be to use indirect methods for providing aid, such as economic incentives or noise-related track access charges.
9. Who is to impose the legislated track access charges?
10. The rail networks—infrastructure operators. These charges would affect wagon owners economically because they are extra charges, and must be balanced with respect to the return on investment of the owners.
11. Would track access charges be different depending on the routes in Europe? If they imposed some noise-related track access charges along the beautiful Rhine, then perhaps some of the shippers would want to send their product by another route to avoid the excess charge.
12. Yes, that would be the idea. The side effects would be that operators, instead of putting freight on rail, could put freight on river or road transport, if available, to avoid track access charges.
13. But it depends very much on how you do it. If you have just a bonus-malus system, then the noisy vehicles have to pay for the low-noise vehicles. But if you have a strict bonus system, there is no change for the normal vehicle and you get a deduction for the low-noise vehicles. This is compensated for by the state, so the state is indirectly financing the retrofitting.
14. I think it's a bonus system because they increase the charge and then they lower it for the low-noise vehicles.
15. There is a pilot project in Germany to fund the retrofit of 5,000 wagons.
16. Are legal incentives such as a night ban, a freight ban, speed limits, or capacity limits less desirable? Economic incentives are preferred, but there are other legal incentives.

Question:

What other techniques are available today for noise reduction at the source (e.g. wheel dampers, wheel design, rail dampers, acoustic grinding)? What noise reductions are possible using these techniques?

Responses:

1. You could consider the starting point to be a train of freight wagons with K-blocks, which is similar to a train with disc-braked passenger vehicles. In effect, the first 8-10 dB noise reduction has been achieved, and we're looking for the next 10 dB.
2. It is always dangerous to put noise reduction numbers if the reference is not specified. The reference must be stated one way or another.
3. So it is a problem to maintain the acoustical quality of reduction throughout the industrial development.
4. It depends on the train speed and the relative contribution of the sources.
5. I would suggest we take from 4-5 to 6-8 dB which implies still more research is needed.
6. Bogie shrouds with no barriers offer a 2-3 dB improvement. Bogie shrouds and low barriers together could provide up to 10 dB.
7. A10 dB reduction may be optimistic. Perhaps 5 dB is more realistic; it depends on the way the barrier is constructed and the overlap between barrier and shroud. It is difficult to get optimum reduction.
8. That can be reached if you combine bogie shrouds with low-barriers. A low barrier means one close to the track and below the window. It is the same height as the platforms—30 to 50 cms.
9. The group hasn't considered high barriers, typically with the height of 1 meter to 1.2 meters, optimally lined and appropriately positioned adjacent to the side of the rail which can achieve very effective sound reduction for the track-side noise.
10. This is what is now used, so this is the current state of the art.
11. For acoustic grinding you can have even greater noise reductions if you shorten the interval between the grinding.

12. Is the grinding monitored?
13. Yes, currently we have an increase of 6 dB(A), but this increase can be lowered after optimum grinding by 2 or 3 dB(A). The intervals between grinding can be shortened to get reductions of up to 4 or 5 dB(A) if you optimize it. It is a question of money.
14. Is the acoustic performance determined by the acoustic grinding?
15. It's also the technique of grinding the rail. With normal grinding we get grinding-induced roughness, but that is removed with the second step in the grinding process. The process is different when you do acoustic grinding. After acoustic grinding you have a much smoother track than after normal grinding.
16. One further problem is that the grinding up to now is a bit complicated because you have to ban traffic for the grinding during the nighttime. What we would like to have is an in-service grinding. That means a grinding wagon operating during normal traffic hours. It would be economically more viable to have this type of grinding. There has been a project in Germany—high-speed grinding—but I haven't seen any results of this project.
17. What progress has been made in developing more effective rail grinding procedures?
18. We have a special grinding for very small surfaces, and we have now the instruments to measure the roughness of the grinding process. I do not believe the level can be lowered but the scheme can be improved—shortening the intervals.
19. There is a limit to how much you can do with rail grinding unless you also grind the wheels.
20. Are the wheels ground regularly as well? Is there anything to be gained?
21. There are roughness level differences between freshly ground wheels and in-use ground wheels—10 dB at the roughest levels. There is some potential to have better maintenance procedures.
22. I remember a system that was used in the 1970s in the Toronto subway system where wheels that were not performing acoustically well were identified when the trains passed a measuring station. Is this the system that we're going to use? Where they do not have such a measuring system, how is the wheel taken care of? Is that something that should be taken up in the discussion here?
23. We should have better maintenance procedures for the wheels. For example, in a tram it is normally the driver who determines if the wheels are okay. He can hear the front wheels but not the rear wheels of the tram, so it's a subjective estimation of the quality. We need objective measurements to improve maintenance procedures.
24. We have a number for the reduction that we can get when we improve the grinding of the rail. What range do we have for the wheels?
25. About 2 dB. We should assess the potential. It is a subject that should be investigated, and the state of the wheels of urban trams can be very variable.
26. You mention the proper procedure for trams, but what is it for subway systems? Is it the same as for trains?
27. It is similar to the procedure for trams. It might be even worse because we think there is no exposed population around.
28. The potential to develop flat spots on the wheels was very marked in the older generation trams with inferior braking systems. In the newer trams it is not quite as bad because the braking systems are more modern in their design and more effective. But trams have a liability that suburban trains and long-distance trains don't have and that is they stop more frequently and, therefore, the brake usage is greater. As a consequence, the irregularities of the wheels are more marked.

Question:

To what extent are the current TSIs leading to quieter passenger vehicles in service; is it feasible to introduce stricter limits? TSI requirements are seen as minimum for new vehicle specifications. Customer requirements are often tougher and lead to quieter trains, but benefits are not necessarily seen on standard track. This has little effect on freight due to long vehicle life. Stricter limits are not possible without major changes in design such as skirts for high speed trains. A reduction of 2-5 dB in TSI limits is proposed.

Responses:

1. For interoperable vehicles we see that these limits influence customers purchasing vehicles that don't have to be interoperable. These limits have become a standard. We have expiration limits; that were not so common before the TSIs. The test procedure was in an appendix, and now it has been moved into the TSI and also into the standard. It has been taken into account in newer contracts, but it only covers surface vehicles.
2. This means that for freight wagons you have to do something else, such as using wheel dampers or shielding or another method.
3. To make a stricter limit less than 2 dB will not be perceived as an improvement, and more than 5 dB is seen as a very big step. So the range is probably correct.
4. For existing vehicles, the aim is 2-5 dB(A) for 2016. For new trains and for new wagons, 2018.
5. Stricter limits are not possible without major changes. Would they be for high-speed trains or for conventional railways?
6. Inboard bearings don't sound like a major change, but the problem is that they don't fit in the profile right now. A major change would be to have inboard bearings, but that's not

an easy change to implement on all trains, especially on the high-speed trains. This is only in development, and Pierre-Etienne warned us about upcoming, tougher requirements that probably will call for skirts by 2016. Perhaps we will be forced to reduce the level above this range.

7. Is it feasible to have a working wheel damper for freight that stands the temperature of tread braking? If we had at least two or three industrial products available in the market, how much would be the practical impacts on the wheel? The current designs use metal which should not be too expensive to manufacture. The question is how much the manufacturing industry manufacturing would charge as an extra added value for these kinds of wheel sets. Many manufacturers don't want to invest in such designs unless they are forced.

Question:

Has the use of K-blocks resulted in any identifiable improvement in the long-term circularity or trueness of freight wagons wheels?

Responses:

1. The dominant problem right now with the K-blocks is the additional wear on the wheels.
2. I haven't seen any data for this problem, but there are a number of K-block vehicles in use.
3. It's likely that the K-blocks result in smoother wheels and short wave lengths. But that still only brings us to the point where freight wagons are at the same level as passenger wagons.

Question:

In view of future increases in train speed (and the possible introduction of maglev), what needs to be done to reduce aerodynamic noise?

Responses:

1. Improved shape at front shrouds around bogies, improved low-noise pantographs, improved inter-car covers, improved calculation methods, noting that high-speed trains run at low speed where rolling noise is important.
2. Are maglev trains of any interest for discussion for the rest of the century?
3. I think not in Europe. In Europe they seem to be completely stalled. But otherwise they would have the same or similar aerodynamic problems. The same problems but it is easier because they don't have the same problem with the low-noise pantograph and there is not the same close contact to the rail or the track.
4. Yes, but the bottom of the maglev is rather complicated, and that's a major problem for the aerodynamic noise.
5. It was proposed in an INTER-NOISE keynote lecture several years ago maglev trains at low speed as a solution to the noise problems from transportation vehicles. That does not seem to be a very realistic solution.

Question:

What are the particular problems that need to be solved for light rail?

Responses:

1. Squeal noise is a particular problem for light rail as is brake screech.
2. The quality of the rail is a problem with track networks especially when we have combined traffic. So we would need special maintenance procedures for the track network.
3. Traction noise is a big problem, as is the auxiliary equipment which is often mounted on the roof which could be quite noisy for the outside.
4. During the daytime, light rail may be quiet with respect to existing traffic whereas at night time people are awakened by this noise early in the morning.
5. Are there noise problems in France or Sweden?
6. We have improved the trams, but inside the houses the noise is still a problem.
7. We haven't touched on the subway systems as a noise problem. Are they covered by the approaches we have taken here?
8. Most of the problems are the same. One typical problem for the subways or metro systems is that they very often have problems with fan noise which is not such a big problem for other transport systems.
9. Has ground-borne noise been a problem in many cases?
10. That's typical for trams and subways because they run really close to buildings compared with high-speed lines or standard lines.
11. One of the problems with underground railways and tramways is the low-frequency noise even when using Cologne eggs and other advanced vibration isolators. What steps, if any, have been made to address the low-frequency noise effect problem, ground vibration effect problem that will manifest itself as noise in houses overlying or adjacent to such tunnels?
12. Up to now there have been a number of EU-sponsored initiatives going on in the EU. There have been research projects carried out in the last EU framework, mainly for acoustic modeling and ground-borne vibration. From the economic side, the International Union of Railways has been assessing existing measures. For underground railways and trams some problems still exist.
13. So these problems have not been covered in this discussion?
14. The problem of ground-borne vibration, at least at the research stage, has been given a lot of attention for the past ten years. What is missing is attention to the practical situations taking into account the complexity of various situations that can be

encountered such as the variations of the soil properties and variations in the design of buildings. Where there has been significant progress, as you mentioned for insulation. There have been many modeling initiatives. It may be that some other approaches should be taken. There are many models for ground-borne vibration throughout Europe and elsewhere.

15. We have some measures to reduce the ground-borne vibration at track side.
16. The rail track and supporting structure introduce a new low-frequency resonance problem associated with those isolators which gives you a relatively high Q and significant transmissibility of the low-frequency ground-borne vibration to adjacent buildings and structures.
17. With underground railways, virtually every metro system has plenty of examples of soft-base plates or floating slabs which reduce noise. I'm not sure about maintenance costs in all cases. An interesting aspect of the problem is that ground-borne noise is now becoming a problem of surface railways where they have efficient noise barriers and insulation. The removal of direct air-borne noise is very quickly replaced in people's annoyance by ground-borne noise. In Switzerland recently the Swiss Federal Railways (SBB) did a survey where they found that 170 track-km, about 5 percent of their national system, was affected by ground vibration. Only about half of that—this is for the surface railway—was found to be the low-frequency sensory vibration problem. The other half was due to ground-borne noise, and only 5 km of that was in tunnels, far less than the amount of vibration isolated track that the SBB has already implemented in tunnels. Ground-borne is becoming the next problem after direct air-borne noise. People will perhaps never be satisfied. Take one source of noise away and they will just move their annoyance to the next.

Question:

How feasible are the European Rail Research Advisory Council (ERRAC) recommended targets for 2020? What needs to be done to achieve 5-8 dB reductions by 2020? What other sources need to be tackled? What pressures are there to reduce noise?

Responses:

1. One problem that I have observed is associated with the entry to and departure of high-speed trains from tunnel portals. Can this problem be addressed by appropriate design of both the front of the train and the portal entrance and exit? To what extent have these measures been effectively introduced into systems like TGV, ICE, and other systems that are truly high-speed trains with tunnel portals or sections of enclosed railway?
2. The problem occurs mainly in tunnels that now accommodate wide trains. The problem that exists, for example, in Japan is having some kind of sonic boom. It is necessary to take some measures at the end of the tunnel to prevent this. Recently the same problem occurred in some long tunnels in Germany. These problems are more or less solved, but there is still some fundamental knowledge of the actual mechanisms needed to improve the treatment measures. Research is still being done on this subject.
3. Does this answer the question of how feasible are the ERRAC targets?
4. Probably not. It depends on what the target is for. If the target is for what the noise-reduction goal should be, we're talking about bringing it down about 3-5 dB in 2016. It cannot be reduced by another 5 dB by 2020.
5. Are these targets of 5-8 dB below what is currently achievable with the measures that were mentioned this morning? Were these measures designed to reach these targets? The targets are not achievable with the current state of the art. They are research targets for the next 10 or 15 years and not regulatory targets.
6. An example is that we have the capability to put disc brakes and wheel dampers on any freight car, and then it will be very quiet. But in practice to put it on all freight cars, that's a completely different story. The technical means are available; it's a question of the cost.
7. We had a demonstration train in Germany, a freight train, with a noise reduction of 20 dB(A). This was achieved with a combination of rail grinding, disc brakes or composite block brakes, shielding, and bogie shrouds. It was achievable, but at a high cost and increased operational maintenance.

Discussion Questions Answered

1.What progress has been made with fitting composite brake blocks to freight wagons in Europe? How can this process be speeded up? What is the cost of replacing cast-iron brake blocks on the whole European fleet?

- Switzerland is in the process of retrofitting 100 percent of its freight wagons.
- The UIC Action Program gave system approval for installation of K blocks in 2003.
- More manufacturers are needed; only two are producing homologated K-blocks.
- The K-block and disc brakes are de facto standards for new freight wagons
- More than 11 years will be required to retrofit the entire fleet of 600,000 wagons.
- Three manufacturers are producing LL blocks with limited homologation.
- The homologation product approval process is lengthy and difficult.
- The cost for retrofitting the entire EU fleet with K blocks will be €2-3 billion.
- There will probably be higher lifecycle costs with the new blocks.

- There are currently ~9000 wagons with K-blocks and ~300 wagons with LL-blocks.
- Economic incentives would avoid direct (illegal) 'state aid' such as
  - noise-related track access charges from infrastructure companies,
  - 'bonus-malus' was introduced in The Netherlands (bonus initial 3 yrs) and Switzerland, and
  - in Germany pilot funding for 5000 wagons to be retrofitted.
- Legal incentives would less desirable (night ban, freight ban, speed limit, capacity limits)

2. What other techniques are available today for noise reduction at the source (e.g. wheel dampers, wheel design, rail dampers, acoustic grinding)? What noise reductions are possible using these techniques?

- Acoustic grinding yields 3 dB (greater with more frequent grinding)
- Rail dampers yield 2 to 4 dB (2 to 8 dB in track component)
- Slab tracks are initially noisier but barriers can be incorporated
- Wheel dampers: 2 to 4 dB (4 to 10 dB in wheel component)
- An optimized wheel shape and wheel screens can also reduce noise
- Cheek-mounted brake discs yield 2 dB
- The above could yield from 4 up to 6 to 8 dB
- Bogie shrouds yield 2 to 3 dB
- Low trackside barriers and bogie shrouds combined yield up to 5 to 10 dB (limited in practice, especially for international operation)

3. What is preventing the implementation of these techniques on a wider scale?

- Technology demonstration projects to improve 'Technology Readiness'
- The need for industrialisation of prototype solutions (wheel dampers, rail absorbers, etc.)
- High cost
- Gauging issues for bogie shrouds
- No incentives via TSI, especially for track improvements

4. To what extent are the current TSIs leading to quieter passenger vehicles in service? Is it feasible to introduce stricter limits?

- TSI requirements are seen as the minimum for new vehicle specifications—customer requirements are often tougher
- TSIs lead to quieter trains but benefits are not necessarily seen on standard track
- There is little effect on freight due to long vehicle life and low renewal rate
- Although they cover only interoperable vehicles they also influence other vehicles
- Influence of rail roughness: K-blocks 5 to 8 dB in practice
- Need to include limits on infrastructure and wheel monitoring
- A reduction of 2 to 5 dB in TSI limits is proposed for 2016 (new wagons) and 2018 (wagons in service)
- Stricter limits are not possible without major changes in design, e.g., skirts for high speed require inboard bearings
- Freight wheel dampers have potential but need to survive high temperatures; cost unknown

5. In view of future increases in train speed (and the possible introduction of maglev), what needs to be done to reduce aerodynamic noise?

- Improve shape at front
- Install shrouds around bogies (esp. leading bogie) limited space to install
- Improve low-noise pantographs
- Install inter-car covers or alter the design
- Improve calculation methods
- High-speed trains also run at low speed so rolling noise is important
- Maglev is unlikely in Europe – aerodynamic noise issues are similar, no pantograph or closer inter-car gaps, and 'rough' bottom

6. What are the particular problems that need to be solved for light rail?

- Squeal noise
- Brake screech
- Quality of rail surface, especially for on-street running which needs special maintenance procedures
- Traction noise (especially inside the vehicle) and roof-mounted auxiliaries (outside the vehicle)
- Rolling noise is not an issue and may be too quiet; signal-to-noise ratio

7.What are the particular problems that need to be solved for subways?

- Fan noise
- Ground-borne noise: research over last 10-20 years; lot of track isolation systems
- Ground-borne noise is also becoming an issue for surface railways (e.g., with noise barriers)

8.How feasible are the European Rail Research Advisory Council recommended targets for 2020? What needs to be done now to achieve them?

- Targets are 5 to 8 dB below what is currently achievable
- Targets are intended to motivate research
- Targets could possibly be achieved but at a very high cost

9.What other railway sources need to be tackled?

- Traction noise
- Fans (optimized fans, forced ventilation, mufflers for ventilation, controlled cooling)
- Brake screech
- Curve squeal
- Bridge noise (including noise from rails)

10.What pressures are there to reduce railway noise?

- Environmental Noise Directive (END) action plans (but no limits)
- Targets for improved reception limits
- Reduce noise to stimulate modal shift
- Maintaining the same noise levels with higher speeds and more traffic

11.In what areas is further research and work needed?

- More reliable prediction tools are needed
- Cheek-mounted brake discs need to be optimized

12.What progress has been made in developing new and more cost-effective grinding procedures?

- 'Acoustic' grinding – planing and milling after initial passes
- Need better understanding of the grinding process
- High-speed grinding tests are underway
- Grinding has a limited effect unless wheels also smooth
- Need better maintenance procedures for wheels (especially trams)

13.Has the use of K blocks resulted in any identifiable improvement in long term circularity or trueness of freight wheels?

- Clear reductions in 'acoustic' roughness and hence noise
- Main problem is increased wear of wheels

14.What is being done about 'sonic booms' from high-speed trains at tunnel portals?

- Occurs mainly in long narrow tunnels with slab track, e.g. Japan
- Hoods effective in Japan
- Recent example in Germany

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Pan-American News

Paul Donovan, Pan-American Editor

USA

New Documents Related to the Acoustics of Health Care Facilities are Available

Two new documents related to acoustics and health care facilities are available.

Sound & Vibration for Health Care Facilities January 1, 2010 Version 2.0, Including New Guidelines for NICUs

This completely revised 80-page document was commissioned in 2006 to serve as the comprehensive "reference standard" for the *2010 FGI-ASHE* Guidelines (see below) and is cross-referenced to it. Version 2.0 supersedes previous editions 1.0 & 1.1. It is completely revised, updated and re-designed in a user-friendly format to provide completely detailed information, constructive advice for designers and engineers, reference tables, case study photos, charts and graphs. *Sound & Vibration* is intended to be used alongside the 2010 Guidelines. *Sound & Vibration* has already been adopted as the sole Reference Standard for two LEED "Environmental Quality" credits in the *Green Guide for Health Care* (www.gghc.org) and *LEED for Healthcare* (in draft).
To order: www.healthcareacoustics.org (downloadable pdf)

2010 FGI-ASHE Guidelines for Design and Construction of Health Care Facilities Accepted as building code by over 42 states, 7 U.S. federal agencies and several foreign countries, this is the first edition in the 60-year history of the Guidelines to include comprehensive acoustical criteria* (see above) for all aspects of noise, sound systems, speech privacy and building vibration. *The Guidelines* is the only general document you need if you are involved in the planning, design, construction, operation and renovation of any type of licensed healthcare facility. *The Guidelines*—a new edition of which appears every four years--have been in continuous existence since first authorized by the Hill Burton Act of 1947 and published by the Public Health Service, but they have never before included comprehensive acoustical criteria.

Training sessions related to these documents are available. Eighteen HSW-accredited training sessions are currently available during the first half of 2010 via webinar and in person in various U.S. cities. If you would like to arrange a special session for a design or engineering firm, for a chapter meeting, or for an association, contact the committee co-chairs at: dsykes@healthcareacoustics.org.

A New American National Standard is Available

A new standard, American National Standard, ANSI/ASA S12.42-2010, *Methods for the Measurement of Insertion Loss of Hearing Protection Devices in Continuous or Impulsive Noise Using Microphone-in-Real-Ear or Acoustic Test Fixture Procedures*, is available from the Acoustical Society of America.

This standard specifies microphone-in-real-ear (MIRE) methods for the measurement of the insertion loss of active and passive circumaural earmuffs, helmets, and communications headsets, and specifies acoustic test fixture (ATF) methods for the measurement of the insertion loss of active and passive earplugs, earmuffs, helmets, and communications headsets. The MIRE methods are appropriate for use with continuous noise whereas the ATF methods may be used with both continuous noise and high-level impulsive noise test signals. The standard contains information on instrumentation, calibration, and electroacoustic requirements, procedures for determining sound pressure levels in the ear with and without the hearing protection devices in place, and procedures for calculating the corresponding insertion loss values. The standard also describes how to combine the active contribution of insertion loss for active devices measured using the MIRE method with the passive real-ear attenuation measured in accordance with ANSI/ASA S12.6 to obtain an attenuation value for use in estimating sound pressure levels for active protectors in accordance with ANSI/ASA S12.68. Requirements for reporting of the data are also described.

To purchase an electronic copy of this ANSI Standard or other National or International Standards on Acoustics, Mechanical Vibration and Shock, Bioacoustics, or Noise, please visit the Acoustical Society of America's Home Page at http://asa.aip.org and click the "ASA Store" button. The price is 130 USD per copy.

Hard copies of standards can be purchased by contacting the Acoustical Society of America Standards Secretariat, 35 Pinelawn Road, Suite 114E, Melville, NY 11747-3177. Telephone: +1 631 390 0215 / Fax: +1 631 390 0217

FAA Seeks Comments Related to Data Collection

The FAA has invited public comments about their intention to request the Office of Management and Budget (OMB) to approve a new information collection. The data from this research are critically important for establishing the scientific basis for air tour management policy decisions in the National Parks as mandated by the National Parks Air Tour Management Act of 2000 (NPATMA). The research expands on previous aircraft noise dose- response work by using a wider variety of survey methods, by including different site types and visitor experiences from those previously measured, and by increasing site type replication. Comments are due on May 17, 2010. For further information contact Carla. Mauney@faa.gov.

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European News

Bernard Berry, European Editor

New ISO Standard for Reducing Noise in the Neighborhood of Airports

Living near an airport can be very noisy – with negative effects on health and the environment. The new standard **ISO 20906:2009, *Acoustics – Unattended monitoring of aircraft sound in the vicinity of airports***, will help regulators, professionals and researchers in their effort to reduce noise in the vicinity of airports.

This International Standard gives requirements for reliable measurement of aircraft sound. It describes a threshold system of sound event recognition in a complex sound environment with multiple aircraft and other sound sources. ISO 20906:2009 specifies:

- The typical application for a permanently installed sound-monitoring system around an airport
- Performance specifications for instruments and requirements for their unattended installation and operation, in order to determine continuously monitored sound pressure levels of aircraft sound at selected locations
- Requirements for monitoring the sound of aircraft operations at an airport
- Requirements for the quantities to be determined in order to describe the sound of aircraft operations
- Requirements for data to be reported and frequency of publication of reports
- A procedure for determining the expanded uncertainty of the reported data in accordance with ISO/IEC Guide 98-3, Uncertainty of measurement – Part 3: Guide to the expression of uncertainty in measurement (GUM: 1995).

Exposure to intense noise or noise over long periods can lead to hearing damage and other physiological impairments. Those impacts are recognized both for those working on the site of an airport and for those who live near the runways.

Mr. Berthold Vogelsang, Project leader and convenor of ISO Working group which prepared the standard, comments: "the environmental concerns of people living near airports is increasingly taken into account by governments, airport authorities and aviation companies. Manufacturers are developing quieter aircraft, governments are committing themselves to reduce noise around airports and plans to fight against noise pollution are being adopted. To achieve the objectives of such initiatives, regulators and aviation professionals need internationally agreed measuring tools and reference documents, ISO 20906 is a practical answer to this need."

ISO 20906:2009, *Acoustics – Unattended monitoring of aircraft sound in the vicinity of airports* was prepared by ISO technical committee ISO/TC 43, Acoustics, subcommittee SC 1, Noise, WG 52, Noise from aircraft at civil airports, and is available from ISO national member institutes (see the complete list with contact details at www.iso.org/iso/about/iso_members.htm). It may also be obtained directly from the ISO Central Secretariat, price 136 Swiss francs, through the ISO store (http://www.iso.org/iso/iso_catalogue/catalogue_tc/catalogue_detail.htm?csnumber=35580).

Denmark

New Reports on Noise Abatement

The Danish Road Institute has recently published two new reports on experiences and methods on practical noise abatement. The first report describes tools and guidelines for integration of noise in planning new roads as well as when maintaining the existing road network. The title is: "*Highway noise abatement - Planning tools and Danish examples*", see: www.vejdirektoratet.dk/pdf/rap173vi.pdf

The second report presents strategies for planning and designing noise barriers. The title is: "*Noise Barrier Design - Danish and some European Examples*", see: www.vejdirektoratet.dk/pdf/rap174vi.pdf

The reports have been produced as part of a research cooperation on noise between the Danish Road Directorate and California Department of Transportation (Caltrans) and University of California Pavement Research Centre (UCPRC) in Davis.

United Kingdom

Environmental Protection UK sponsored a workshop *Towards Integrated Noise Management* on March 10-11 in Kenilworth, Warwickshire. The workshop looked at practical means of transport noise mitigation. Issues around noise from entertainment remain pertinent as ever, and regimes existing and proposed for wind turbines large and small continue to confuse all. Our Spring Workshop enabled discussion on practical ways forward in integrating noise considerations into transport, planning and open spaces policy and communicating noise concerns beyond the specialists . We also updated what's going on with wind (and other machinery up for permitted development) and looked at the latest practice in managing entertainment noise.

On the program were the following topics:

Managing Environmental Noise

- Noise in context - WHO Guidelines for Night Time Noise
- Planning for reducing transport noise impacts
- Quiet urban areas
- Engaging politicians and the public in noise reduction

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Asia-Pacific News

Marion Burgess, Asia-Pacific Editor

Australia

Noise Campaigns in Australia

In West Australia, during *Noise Awareness Week*, August 2009, a special color supplement was featured in a major regional newspaper. Entitled "*Managing Noise in the 21st Century*" this supplement comprised 20 pages and spanned Noise and Hearing Loss, Hearing Aids and Hearing Protection, and Industry and Workplace Issues. Sixteen contributors provided engaging and informative articles in an appealing format, guaranteed to raise awareness. The liftout can be viewed at: http://www.commerce.wa.gov.au/WorkSafe/PDF/Misc/WANoiseSupplement.pdf

On the other side of Australia, in the capital city, Canberra, a media package was released to urge all Canberrans to consider the effect on others of their noise both at home and around town. The theme '*Your noise is not the neighbours' choice*' includes a dedicated website, cinema and radio advertising and a mail-out to ACT households over the summer. At the cinemas before the main movie starts there are a number of commercial advertisements. Those involved with the campaign consider this was a good opportunity to get the message across and developed the short video spherically for this purpose. For more information on the program and downloading the short video visit http://www.noise.act.gov.au/.

Rail and Road Noise Guidelines

Two states in Australia have recently released documents relating to control of noise from major infrastructure. In NSW the Department of Planning has released 'Development in Rail Corridors and Busy Roads – Interim Guideline' which provides guidance on building design, internal layout and architectural principles to achieve an acceptable internal acoustic environment. In Western Australia the Planning Commission has released "*State Planning Policy 5.4: Road and Rail Transport Noise and Freight Considerations in Land Use Planning*" and the guidelines apply to proposals for (a) new noise-sensitive developments near major transport routes, (b) new/upgraded railways or major roads, and (c) new freight handling facilities. These documents is available from www.planning.nsw.gov.au/rdaguidelines/documents/

Symposia Associated with the International Congress on Acoustics

The December issue of this magazine carried an article about ICA 2010, the 2010 International Congress on Acoustics. Following the main ICA Congress there are a number of associated symposia being held in the region.

ISRA 2010 International Symposium on Room Acoustics, 29 to 31 August 2010 in Melbourne, Victoria Australia. The International Symposium on Room Acoustics (ISRA 2010) provides a forum for an in-depth exchange of scientific and design research on room acoustics. It will be a single track conference with oral and poster presentations, as well as opportunities to visit acoustical spaces of interest in Melbourne. The keynote speakers for ISRA are Anders Christian Gade (Gade & Mortensen Akustik A/S), Toshiki Hanyu (Nihon University) and Mark Poletti (Industrial Research Limited). Leo L. Beranek will give the banquet speech. This symposium is organised to continue the series of specialised symposia on room acoustics:with the last one in Sevilla associated with ICA 2007 Madrid. Information from http://www.isra2010.org and Densil Cabrera, Densil@usyd.edu.au.

ISMA 2010 International Symposium on Music Acoustics, 25 to 26 and 30 to 31 August 2010 in Sydney and Katoomba, NSW Australia. International Symposium on Music Acoustics (ISMA 2010) brings together the world's researchers on music acoustics to discuss strings plucked and bowed, wind, brass and percussion, organs, keyboards, the voice, the nature of music, physical phenomena, techniques and modelling in music, perception and recognition of music. The program will overlap with and include special sessions of the main ICA 2010. This symposium is organised to continue the series of specialised symposia on music acoustics with the last one in Barcelona associated with ICA 2007 Madrid. Information from http://isma2010.phys.unsw.edu.au and Joe Wolfe J.Wolfe@unsw.edu.au

Acoustics and Sustainability, 30 to 31 August 2010 in Auckland New Zealand. Sustainability is not just a catch phrase, it has become an underpinning principle of living. Not only does sustainability relate to recycling of materials and reduction of emissions, it also includes the preservation of hearing. Therefore, the NZAS would like to include all areas of sustainability, including green star rating of buildings, innovative use of materials and building techniques to reduce emissions and protection of hearing from an early age. Information from http://icanz2010.acoustics.ac.nz

Non-Linear Acoustics and Vibration, 30 to 31 August 2010 in Singapore. This associated conference will cover the study of large amplitude sound waves and vibration. It will include theories and applications. Due to the exponential

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INCE Update

INCE/USA

Selen Okcu is awarded the 2009 Martin Hirschorn IAC Prize

In odd-numbered years, the 5000 USD Martin Hirschorn IAC Prize is given "*…as a contribution to the education of a graduate student studying noise control engineering in the United States of America who proposes a project related to an application of noise control engineering and/or acoustical conditioning of architectural spaces*." The 2009 award was given to Selen Okcu of the Georgia Institute of Technology for her proposed project: *Development of new acoustic metrics for complex hospital sound environments*.

Paul Donavan Receives the 2009 INCE/USA Award for Excellence in Noise Control Engineering.

Paul Donavan of Illingsworth Rodkin received the INCE/USA Award for Excellence in Noise Control Engineering at the awards ceremony on August 26, 2009. The ceremony took place during INTER-NOISE 09. The award is intended to provide, and disseminate widely, recognition for one or more individuals or institutions who have demonstrated one or more contemporary and outstanding products or processes in the applied art of noise control engineering. The award was given "*For Development of the Sound Intensity Method of Measuring Tire Noise Performance of in Situ Pavements*. In particular, the method developed was the onboard sound intensity (OBSI) method for measurement of tire noise.

INCE/USA Presents Three Distinguished Service Awards

For the first time in 2009, INCE/USA created a Distinguished Service Award. This INCE/USA Distinguished Service Award was first presented at the Awards Ceremony on August 26, 2009. Medal was presented to individuals who have shown exceptional dedication and service (above and beyond the call of duty) to INCE/USA. It is an award that acknowledges volunteers who provide significant and sustained help to INCE/USA and thus also the profession. The first awards went to Joseph Cuschieri, Courtney Burroughs, and Norah and George Maling.

Paul Donavan, left, receives the 2009 INCE/USA Award for Excellence in Noise Control Engineering from INCE/USA President Patricia Davies.

INCE/USA President Patricia Davies, right, joins the 2009 recepients of the INCE/USA Distinguished Service Award, Joseph Cuschieri, Courtney Burroughs, Norah Maling, and George Maling.

Five Students are Awarded prizes in the 2009 Student Paper Prize Competition

Five students were awarded 1000 USD prizes in the 2009 Student Paper Prize Competition. The prizes were awarded at the INTER-NOISE 2009 Congress in Ottawa, Canada on August 26, 2009. The awards were presented by Patricia Davies, INCE/USA president.

The photos of the two additional award winners are not available. They are: Jeremy Charbonneau, University of Windsor, Canada. *Comparison of loudness calculation procedure results to equal loudness contours*, and Csaba Huszty, The University of Tokyo, Japan, *An algorithm to adjust the clarity of room impulse responses for subjective tests*

More information on INCE/USA awards may be found on the awards page of the INCE/USA web site.

Yoon-Shik Shin, left. Purdue University, USA. Inflow Treatment for Small Scale Axial Fans under Unfavorable Inflow Conditions

Philip W. Robinson, left. Rensselaer Polytechnic Institute, USA. A Synthesized Aperture Goniometer for Diffusion Coefficient Measurements

Matthew Shaw, left. Brigham Young University, USA. Acoustical analysis of an indoor test facility for a 30-mm Gatling gun

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LMS Releases LMS Test.Lab Rev 10 with Increased Productivity and New Acoustics Applications

LMS International has released the latest version of LMS Test.Lab, its integrated solution for noise and vibration testing and engineering. LMS Test.Lab Rev 10A is said to not only offers significant improvements in productivity, efficiency and user-friendliness, it also introduces new applications, such as Time Domain Transfer Path Analysis (TPA) and MIMO FRF testing. Rev 10A integrates innovative solutions for acoustic testing – making LMS Test.Lab Rev 10A the most complete acoustic package on the market.

Bruno Massa, Vice-President Test Division at LMS International, "LMS Test.Lab is the solution that testing departments count on to increase test productivity while maintaining the utmost product quality. With Rev 10 of LMS Test.Lab, we continued to improve on efficiency and ease-of-use. With the integration of new acoustic testing capabilities and transfer path analysis techniques, test engineers can more efficiently trace where a sound is coming from and what the root cause is of particular noise and vibration issues. This significantly increases test productivity and delivers more reliable results."

LMS Test.Lab Rev 10A delivers a new extension to the renowned LMS Test. Lab Transfer Path Analysis capabilities: LMS Test.Lab Time Domain TPA. This new application complements frequency domain TPA and is the perfect solution for the analysis of transient phenomena. With this extension, LMS now offers a complete portfolio of TPA solutions for a broad spectrum of applications. The new LMS Test.Lab MIMO FRF Testing extends the modal testing techniques in LMS Test.Lab. With this new solution, users can specify their specific excitation signals, define a shaped amplitude spectrum and extend the application to multi-sine excitation.

LMS Test.Lab Rev 10A integrates new acoustic testing capabilities and scalable solutions for spot-on sound testing and analysis. The LMS Test.Lab Rev 10A Sound Quality solution has been extended with new psycho-acoustic metrics used in the automotive, aerospace, and white goods sectors. The LMS Test.Lab Sound Intensity's geometry module has been extended with a 3D acoustic mesh generator. The new intensity data sheet presents a clear overview of all measured and processed data, quality indicators and related components. User can easily analyze, browse and interpret data for sound power, source ranking and sound source localization.

The LMS Test.Lab Rev 10A High Definition Acoustic Camera supports both real-time far field and real-time near field sound source localization. The camera's array with wide angle lens provides sharp pictures even when taken close to the structure. For interior sound source localization with maximum accuracy, the new LMS Test. Lab 3D Acoustic Camera has a laser that automatically scans the geometry without operator intervention. During the scanning, pictures are taken to obtain a full 3D photorealistic image of the vehicle. With this solution, users can spot sources of interior noise problems with high precision and in record time.

Finally, LMS test.Lab Rev 10 takes optimal advantage of the new E-series signal conditioning input modules of the LMS SCADAS, which offer enhanced usability and increased efficiency. The E-modules provide a hardware-based solution to ensure faster test set-up and accurate measurements without data loss, even for demanding applications with high-channel count. For more information on LMS, visit http://www.lmsintl.com

Navcon Engineering Offers Analysis Tools

Navcon Engineering and Dynamic Design Solutions showed there FEMTools v 3.4 at the recent IMAC 2010 in Jacksonville, Florida, USA. FEMtools is a suite of software products for structural dynamics simulation, test planning, test-analysis correlation, FE model updating using static, modal and operational reference data, and design optimization. The application software is based on the solver- and platform-independent FEMtools Framework for unlimited customization and extension. New tools include FE mesh generation, mesh quality evaluation, mass properties identification from FRFs, and structural optimization using DOE/RSM. Applications include material identification and structural health evaluation.

Navcon Engineering is also running seminars in the fall on modal testing, FE models for structural analysis, environmental noise, acoustic intensity, and SoundPLAN user training. More details: http://www.navcon.com

RS Technologies Introduces LabMaster Portable

RS Technologies, a division of PCB Load & Torque, Inc., has introduced their LabMaster Portable Model 3210 for joint analysis torque-tension testing. Manufacturers who use threaded fasteners to assemble their products can benefit by using this system to verify the performance of their fasteners.
The LabMaster Portable is designed to test threaded fasteners and evaluate fastener coatings, lubrication, finish, and plating. The system will also analyze bolted joints and certify power tools. Combined with a torque-angle sensor and a thread torque-fastener tension research head the following measurements can be made: input torque, angle of fastener

rotation, clamp load, and thread torque. Specific calculations can then be performed, including: thread friction torque, underhead friction torque, torque tension coefficient (T = KDF), thread friction coefficient, and underhead friction coefficient. The LabMaster also calculates statistics for a series of tests such as Standard Deviation. ±3 Sigma, Cp, and Cpk.

The LabMaster Portable comes with LabMaster for Windows testing software, which uses a USB port to interface with a customer-provided laptop or desktop PC.

The system includes a durable hard shell case enclosure designed to survive a variety of manufacturing environments, a 4-channel data acquisition card that provides high-speed sampling, and a signal conditioning card compatible with most strain gage transducers and high-level devices.

Test setup is quick and easy employing full Windows• functionality with drop-down menus and point-and-click features. After set up, the LabMaster Portable module conducts data acquisition operations providing a real-time display to the operator. After the test is complete. the recorded data can be printed, plotted, and saved on the computer or archived on a network drive. Data can also be exported to Excel for further analysis. For more information about RS Technologies visit http://www.pcbloadtorque.com

PCB Load & Torque, Inc. Release Technical Papers

PCB Load & Torque, Inc., has recently released the following technical papers:

Torque Sensors – An Overview of their Design and Application reviews the basic technology of the strain gage torque sensors including structure designs, typical applications for reaction and rotary sensors and installation discussions. This paper includes an application questionnaire to help the reader determine the advantages of each type.

Load Cells – An Overview of their Design and Application reviews the basic technology of the strain gage load cell including design, model classifications, and performance specifications. This paper includes typical application examples and a questionnaire to help determine specific requirements. Specific topics discussed in both of these papers include:

- Principle of Operation
- Wiring standards
- Axis definition
- Design

To download these technical papers, visit http://www.pcbloadtorque.com TechnicalArticles.aspx. For more information about PCB Load & Torque, Inc. visit http://www.pcbloadtorque.com

The Modal Shop Introduces MiniSmartShaker™

This electrodynamic exciter is a small, portable permanent magnet shaker with a new generation of ultra compact precision power amplifier integrated in its base. The revolutionary SmartShakerTM design eliminates the need for a separate, cumbersome power amplifier - just plug the excitation signal from a dynamic signal analyzer or function generator directly into the BNC on the base of the shaker. The unit is supplied with a DC power supply but can be run directly from any 12-21 VDC supply.

The smart shaker features a suspension system using carbon fiber composite leaf armature flexures, avoiding the suspension damage common with some other small shakers. Isolated linear bearings provide low distortion and eliminate the need for reaction wrenches when mounting loads to the armature. A trunnion base with EasyTurnTM handle allows for convenient mounting and positioning. The exciter is delivered with a variety of 10-32 nylon stingers which provide electrical isolation from and flexible attachments to test articles. For more information, go to http://www.modalshop.com

European News

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Noise in Neighborhoods

- Managing event noise – festivals/sport
- Licensed premises

Planning and Noise

- Wind – Where are we now?
- Confusion remains around planning and noise assessment regimes for wind turbines large and small – update on current concerns
- National Policy Statements and noise

The full program is available on the Internet. back to toc

Asia News

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increase in computing power and the availability of advanced and sophisticated electronic measuring instrumentation, the field is gaining more attention during recent years. Applications are very broad and include non-linear non-destructive evaluation, harmonic medical ultrasound imaging, high intensity focused ultrasound for non-invasive surgery, cavitation, drug delivery and gene therapy. With the rise of biotechnology and nanotechnology, non-linear acoustics is becoming more important since it can be applied to these two large fields. Even in theoretical studies, non-linear acoustics finds relevance in the growing importance of chaos theory and turbulence. Information from wsgan@acousticaltechnologies.com

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Below is a list of international contacts for the advertisers in this issue. The telephone number is followed by the fax number where available. In cases where there are two or more telephone numbers per location, or several locations within a country, a bullet (•) separates the telephone number(s) from the respective fax number. Advertisers are asked to send updated information by E-mail to INCEUSA@aol.com.

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USA .... Graduate Program in Acoustics, The Pennsylvania State University, State College, Pennsylvania

Conference Calendar

Below is a list of congresses and conferences sponsored by International INCE and INCE/USA. A list of all known conferences related to noise can be found by going to the International INCE page on the Internet, www.i-ince.org.

2010 June 13-17
INTER-NOISE 10
Lisbon, Portugal
Contact: Portugese Acoustical Society
LNEC
Av. do Brasil 101
1700-066 Lisboa
Facsimile: +351 21 844 30-28
www.spacustica.pt/internoise2010/text/invitation.html

2011 July 25-27
NOISE-CON 11
Portland, Oregon
Contact:
Institute of Noise Control Engineering-USA
Amy Herron, Conference Coordinator
INCE/USA Business Office
9100 Purdue Road. Suite 200
Indianapolis, IN 46268-3165
Telephone: +1 317 735 4063
E-mail: ibo@inceusa.org
http://www.inceusa.org/nc11

2011 September 4-7
INTER-NOISE 11
Osaka, Japan
Contact: INCE/Japan
c/o Kobayasi Institute of Physical Research
3-20-41 Higashimotomachi, Kokubunji
Tokyo 185-0022
Facsimile: +81 42 327 3847
e-mail: office@ince-j.or.jp
home page: http://www.internoise2011.com

2012 August 12-15
INTER-NOISE 12
New York City, USA
Contact:
Institute of Noise Control Engineering-USA
Amy Herron, Conference Coordinator
INCE/USA Business Office
9100 Purdue Road. Suite 200
Indianapolis, IN 46268-3165
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Directory of Noise Control Services

Information on listings in the Directory of Noise Control Services is available from the INCE/USA Business Office, 9100 Purdue Road, Suite 200, Indianapolis, IN 46268-3165. Telephone: +1 317 735 4063: e-mail: ibo@inceusa.org. The price is USD 400 for 4 insertions.

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Mark your calendar and plan to participate!

NOISE-CON 2011

Portland, Oregon
July 25 – 27, 2011

The 27th annual conference of the Institute of Noise Control Engineering, NOISE-CON 2011, will run concurrently with the summer meeting of the Transportation Research Board, Committee on Transportation-Related Noise and Vibration (ADC40) on Monday through Wednesday (25-27 July, 2011). This conference is joining the overlapping transportation noise and vibration interest of the two organizations in Portland, Oregon to take advantage of the strong public interest and readily accessible public transportation project sites currently found in the Pacific Northwest. The technical program for the joint conference will provide an opportunity for public and private organizations to share technical information on noise and vibration topics associated with high speed rail, light rail systems, highway surface and tire noise and aircraft noise to name a few.

The INCE/USA Page at the Atlas Bookstore

www.atlasbooks.com/marktplc/00726.htm

INTER-NOISE 06 Proceedings

This searchable CD-ROM contains the 662 papers presented at INTER-NOISE 06, the 2006 Congress and Exposition on Noise Control Engineering. This, the 35th in a series of international congresses on noise control engineering was held held in Honolulu,Hawaii, USA on December 3-6, 2006. The theme of the congress was “Engineering a Quieter World.”

The technical topics covered at INTER-NOISE 06 included:

- Aircraft and Airport Noise Control
- Community Noise
- Fan noise and aeroacoustics
- Highway, automobile and heavy vehicle noise
- Machinery noise
- Noise policy
- Product noise emissions
- Sound quality.

The NOISE-CON 05 Proceedings Archive (1996-2005)

This searchable CD-ROM contains 198 papers presented at the joint NOISE-CON 05/ASA 150th meeting as well as 749 papers from the NOISE-CON conferences held in 1996, 1997, 1998, 2000, 2001, 2003, and 2004 as well as the papers from the Sound Quality Symposia held in 1998 and 2002. All papers are PDF files.

Several papers are taken from sessions organized by the Noise, Architectural Acoustics and Structural Acoustics Technical committees for this 150th ASA meeting. The three plenary lectures related to noise and its impact on the environment are included. Also included are papers in one or more organized sessions in the areas of aircraft noise, tire/pavement noise, and hospital noise.

Proceedings of Active 2009

ACTIVE 09, the 2009 International Symposium on Active Control of Sound and Vibration, was held in Ottawa, Canada on August 20-22, 2009. It was the seventh in a series of international symposia on this subject.

This searchable CD-ROM contains 690 full length papers on active control of noise and vibration. All papers are in PDF format. The latest in the ACTIVE series of international symposia on active control of sound and vibration was organized by the University of Sherbrook, Sherbrook, Canada and held immediately before INTER-NOISE 09. Fifty nine papers from ACTIVE 09 are on this CD-ROM.

The remaining papers are from:

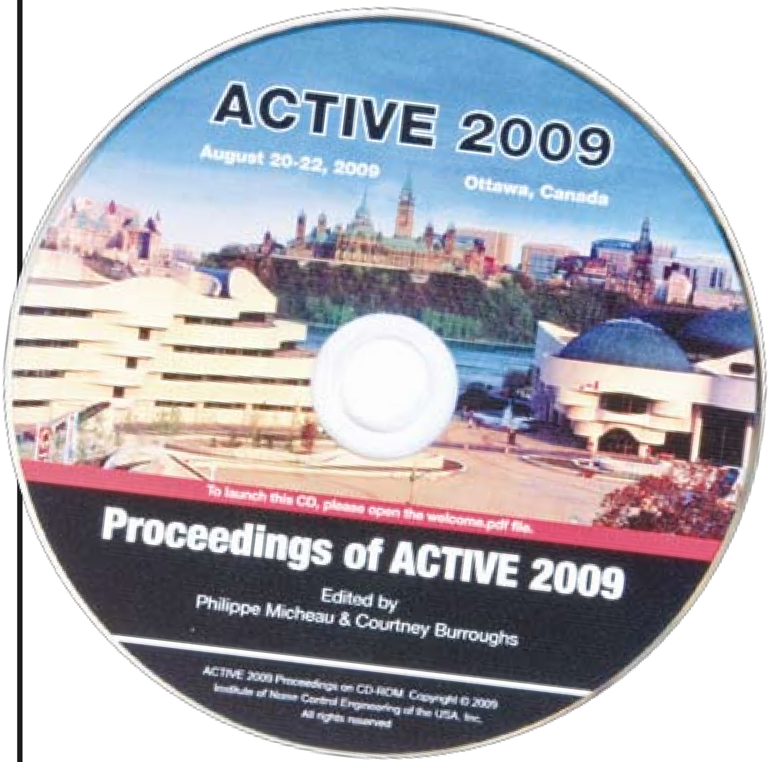
- ACTIVE 06 Adelaide, Australia
- ACTIVE 04, Williamsburg, USA
- ACTIVE 02, Southampton, UK
- ACTIVE 99, Fort Lauderdale, USA
- ACTIVE 97, Budapest, Hungary
- ACTIVE 95, Newport Beach, USA

These papers cover all areas of active control of sound and vibration.

Two indices of the papers presented at
ACTIVE 09 are available on the Internet:

Subject Index
http://www.atlasbooks.com/marktplc/00726active09index.pdf

Author Index
http://www.atlasbooks.com/marktplc/00726active09author.pdf



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INTER-NOISE 09 CD-ROM

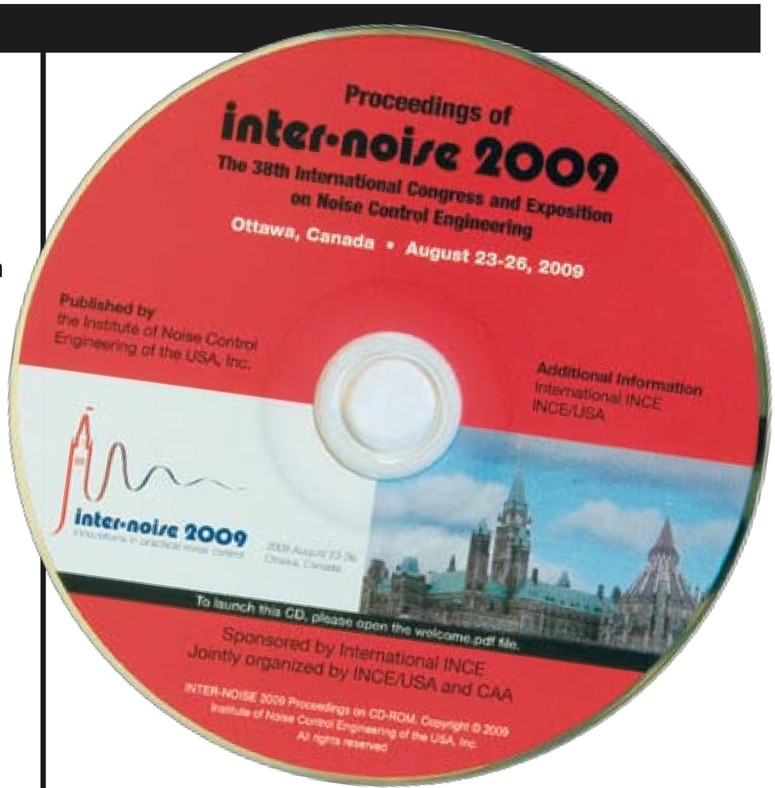
The Proceedings of INTER-NOISE 09, the 2009 International Congress and Exposition on Noise Control Engineering are now available on CD-ROM.

This searchable CD-ROM contains 627 papers This, the 38th in a series of international congresses on noise control engineering was held in Ottawa, Canada on August 23-26, 2009. The theme of the congress was "Innovations in Practical Noise Control."

The technical topics covered at INTER-NOISE 09 included:

- Aircraft and Airport Noise Control
- Active Noise and Vibration Control
- Building Acoustics
- Community Noise
- Barriers
- Fan noise and aeroacoustics
- Highway, automobile and heavy vehicle noise
- Machinery noise
- Noise policy
- Product noise emissions
- Railway noise
- Sound quality.

These papers are a valuable resource of information on noise control engineering that will be of interest to engineers in industry, acoustical consultants, researchers, government workers, and the academic community.



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