

Current and New Approaches for Brake Noise Evaluation and Rating

By

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Introduction

- **Brake noise development costs and times by far are dominated by testing due to lack of predictive tools**
- **Efficiency of test evaluation is strongly lacking professional standardization ; existing standards only make poor usage of test results; technical level of inhouse/ proprietary standards often to be questioned**
- **European noise working groups – EKB- developed and propose a couple of new standards which will be brought to official standards or recommendations like VDA or ISO after successful implementation**

NVH related Test Standards under Development

- **EKB 3006 „Description of a Noisy Brake Application“**
- **EKB 3007 „Brake Noise Rating System“**
- **EKB 3008 „Universal Standard Test Data Exchange Format“**
- **Focus of presentation: EKB 3007 Brake Noise Rating System, based on EKB 3006 and 3008**

Note: EKB = Expertenkreis Bremsgeräusch; Brake Noise Expert Group

Test Standard: “Description of a noisy Brake Application” - EKB 3006

- **Current global practice:** one frequency at highest dB level – important information get lost
- **Additional:**
 - 3 frequencies at highest dB level per stop
 - Squeal duration of 3 frequencies per stop
 - Equally applicable for vehicle and dynamometer testing

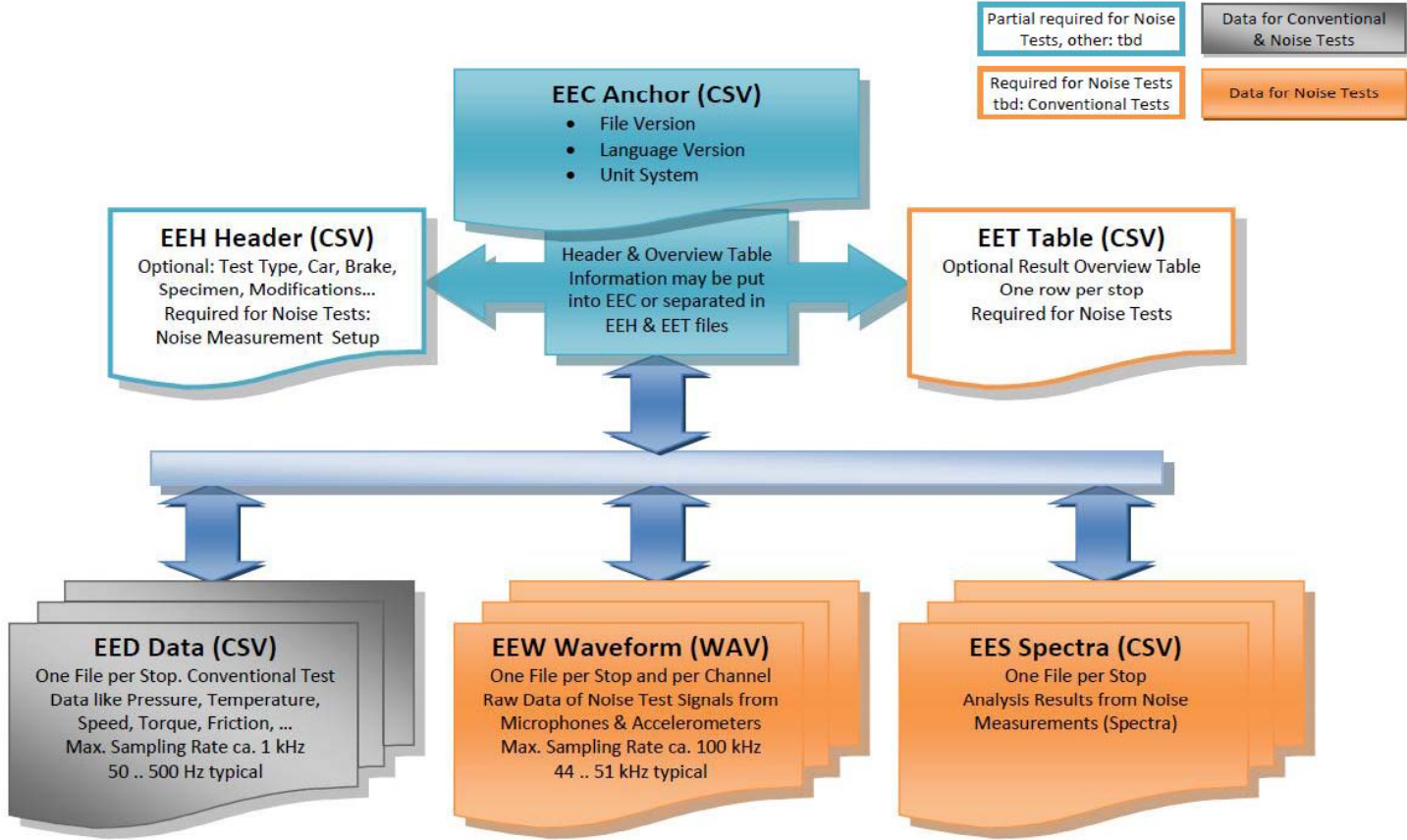
Test Standard: “Universal Test Data Exchange Format” - EKB 3008

- **Relates to performance and noise data coming from different kind of brake dynamometers or vehicle data acquisition systems**
- **Standardized description of:**
 - **test material**
 - **test setup**
 - **relevant test parameters**
 - **test data extracts**
 - **continuous time recordings**

Universal Test Data Exchange Format EKB 3008

- **Option for standardized evaluation software packages for different source test equipment**
- **Data converting by macro to use standard in house evaluations**

EKB 3008 Exchange File Format Block Diagram



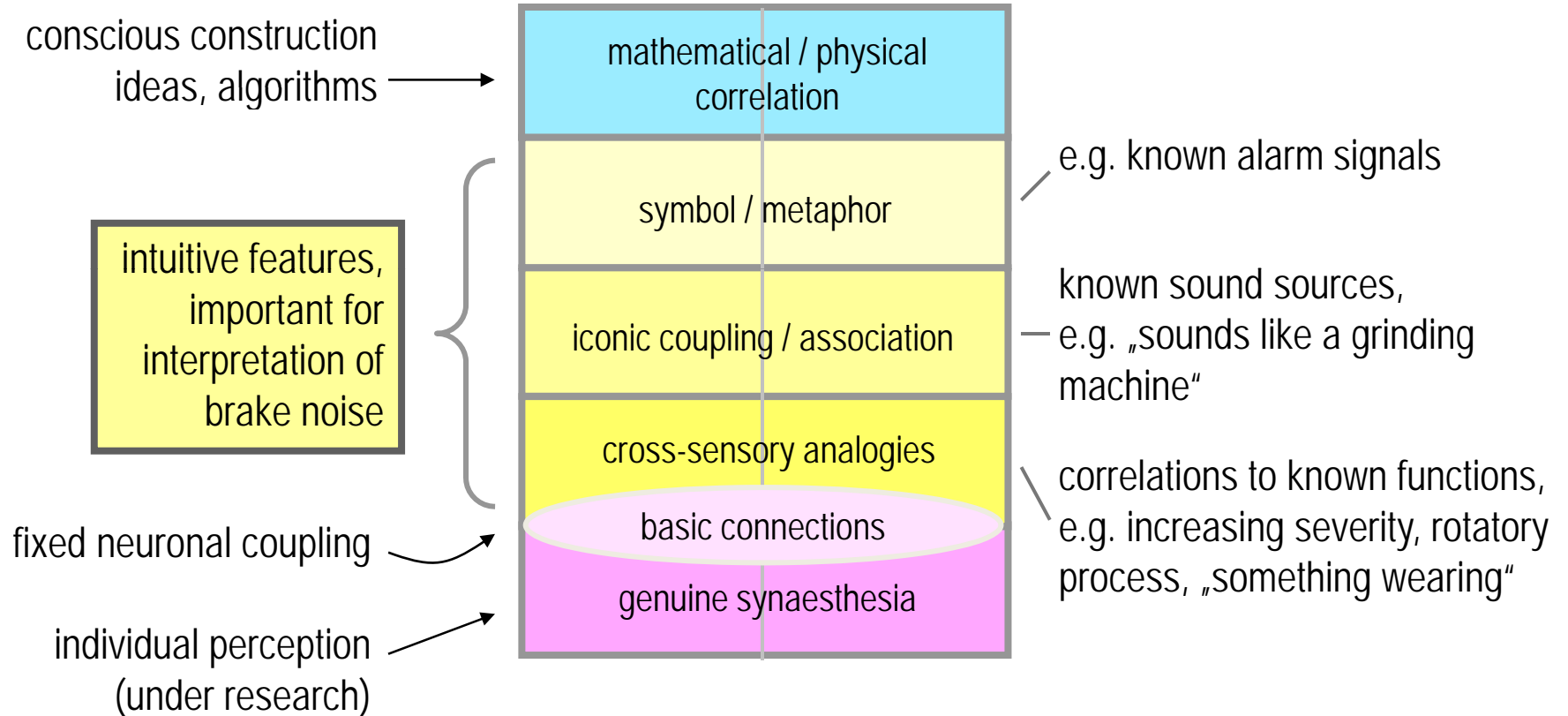
Development of a Brake Noise Rating System – EKB 3007

- **The new brake noise rating system – EKB 3007 - should allow brand specific criteria and the free choice of sophistication level**
- **Applicability for all kind of noise tests**
- **Important deficiency of most existing noise rating systems – lack of squeal duration**
- **Proprietary aspects currently block development of standardized noise rating systems**

Brake Noise Rating and Psychoacoustics

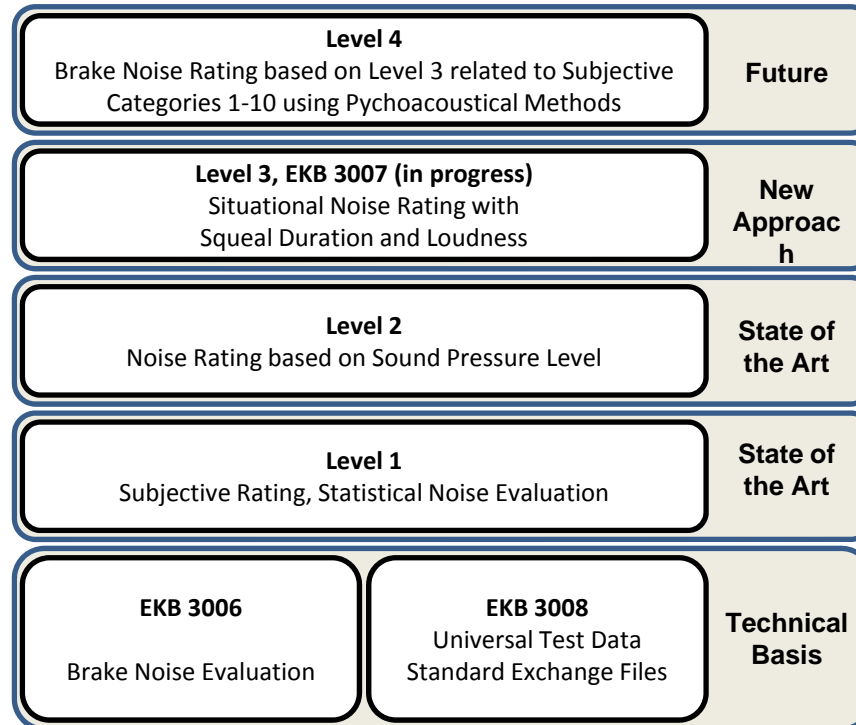
- Computerized brake noise rating must get aligned with the driver's subjective perception
- The bridge between physical measurements to driver's perception is psychoacoustics **and need to be applied to measured noise data**
- The cross-sensory implications, e.g. associative content of noise have to be taken into account
- BONI (Brake Objective Noise Index) – is an early application of psycho acoustics for noise rating developed by Bosch GmbH

Cross-Sensory Implications of Sound Sensation



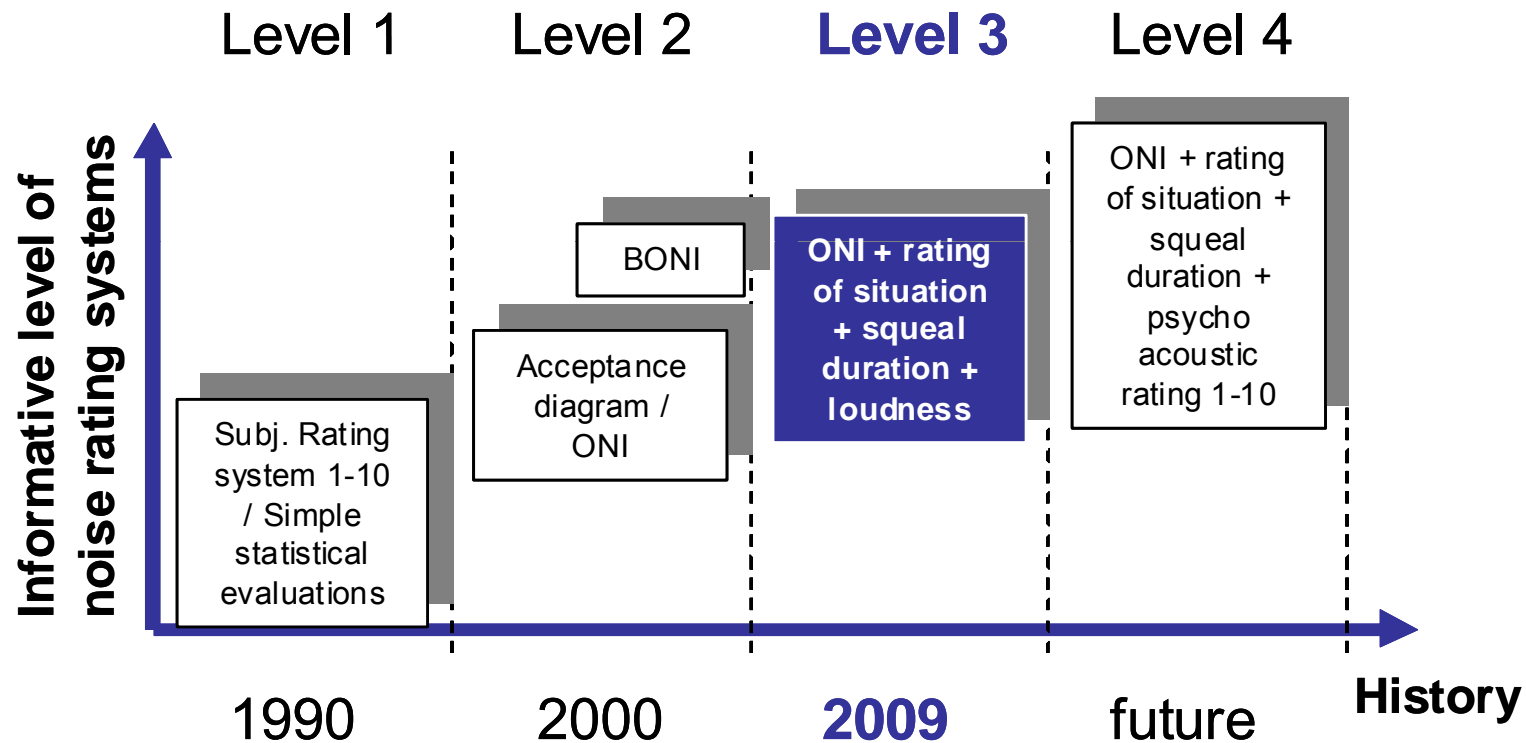
Main perceptual strategies of cross-sensory coupling

Brake Noise Rating System EKB 3007



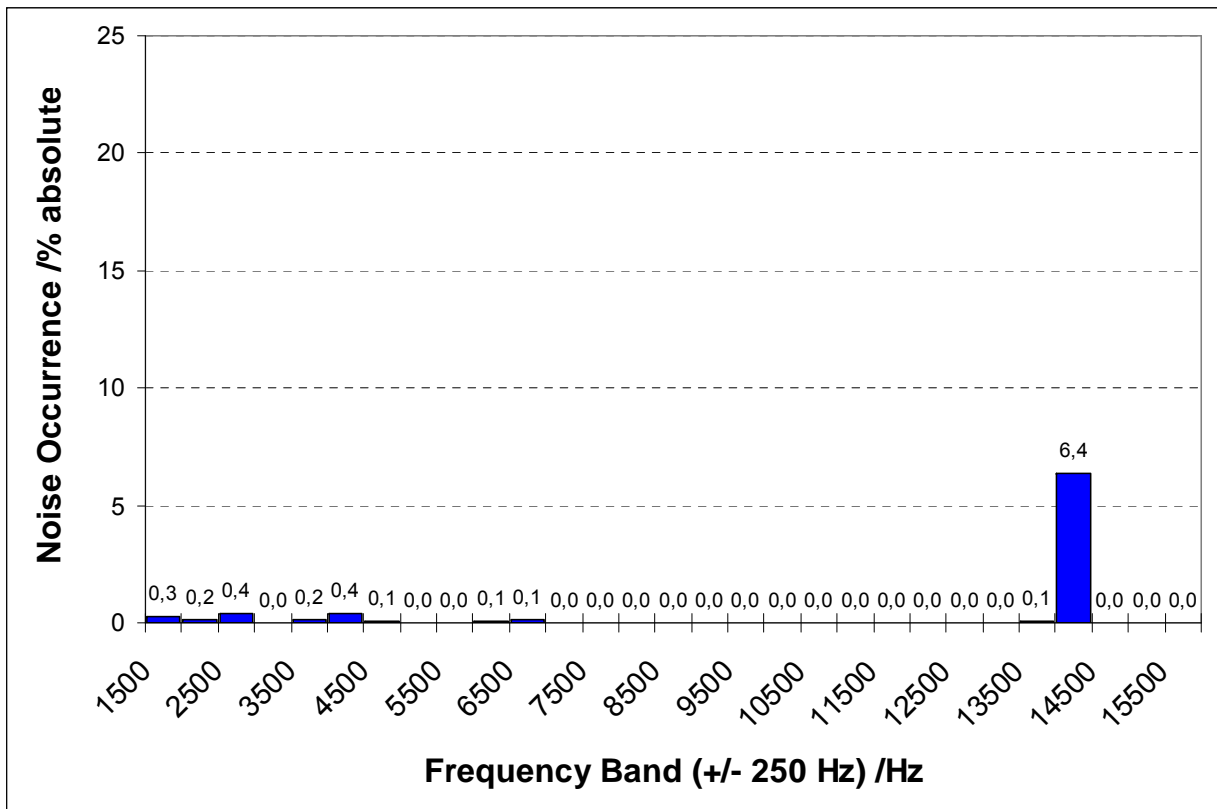
Brake Noise Rating System EKB 3007

Historical Development of Brake Noise Rating Systems



History of noise rating system development

Level 1 – Statistical Noise Evaluation



Average SPL
78,3 dB(A)

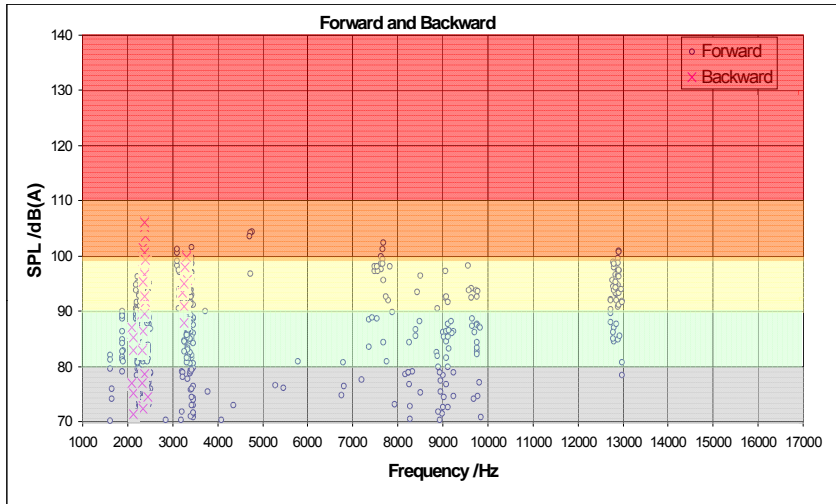
Global occ.
2,6 %

Max SPL
98,8 dB(A)

Abs. occ.
49

Absolute Noise - Occurrence in Frequency Blocks

Level 2 – ONI (Objective Noise Index)



Level	Sound Pressure Level dB(A)	Weighting
A	≤ 70 - 80	1
B	≥ 80 - < 90	3
C	≥ 90 - < 100	10
D	≥ 100 - < 110	30
E	≥ 110	100

$$NoiseIndex = \frac{1 \times N_G(LeveA) + 3 \times N_G(LeveB) + 10 \times N_G(LeveC) + 30 \times N_G(LeveD) + 100 \times N_G(LeveE)}{N_{total}}$$

Table with sound pressure levels and their related factors

New: Level 3

- **Brake Noise Rating based on:**
- **Situational ONI**
 - Braking Parameters:**
 - Disc temperature
 - speed
 - brake pressure
 - forward / reverse direction
- **Squeal duration**
- **Loudness**

Under final Definition: Level 4

- **Brake Noise Rating based on Level 3**
- **Related to subjective categories 1 – 10 using psychoacoustical methods**
- **Under discussion:**
integration in the overall vehicle noise surrounding

The Challenge of Subjective Rating

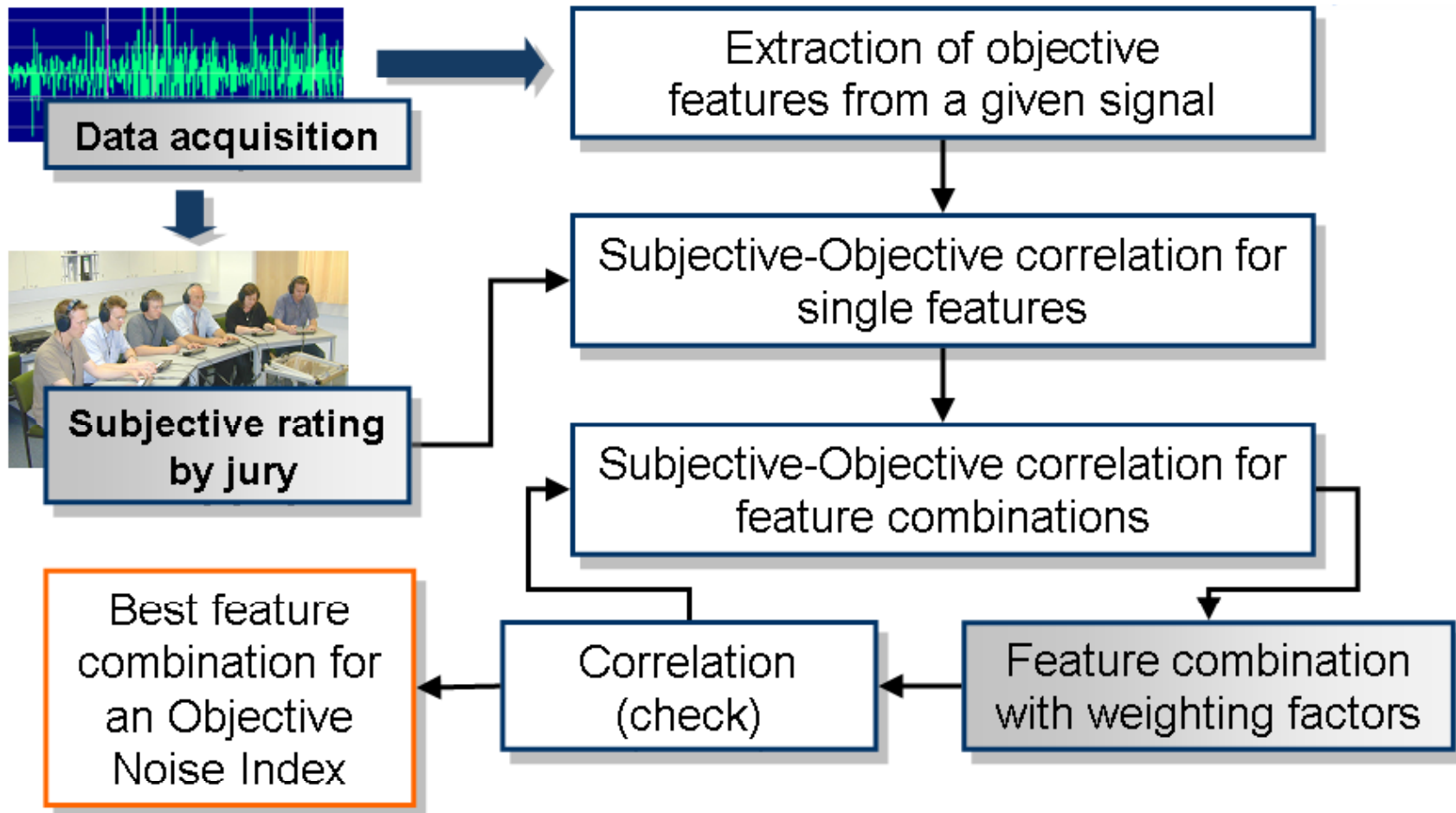
1	2	3	4	5	6	7	8	9	10
unbearable squeal		heavy squeal		moderate squeal		little squeal		traces of squeal	no

Squeal Annoyance Rating Scale

3

- **Nowadays brake noise rating systems are following simple mathematical equations based on the measured physical data only**
- **There is no general physical description of subjective brake noise rating in place**
- **To accomplish correlation, Bosch was using hearing tests and a set of acoustical attributes including the time duration of single sound samples to interpolate above rating scale.**

Development of BONI



The Challenge of Subjective Rating contd

- **BONI was verified with a specific set of brake frequencies embedded in a specific vehicle noise surrounding and can be used as a startingpoint to level 4**
- **The new rating system however wants to be applicable to any kind of noise surrounding, starting from noise dyno, low cost or luxury car, truck or just for the pedestrians**
- **A major challenge for project engineers: weighting of various brake noise situations from free driving to noise search and opened windows**

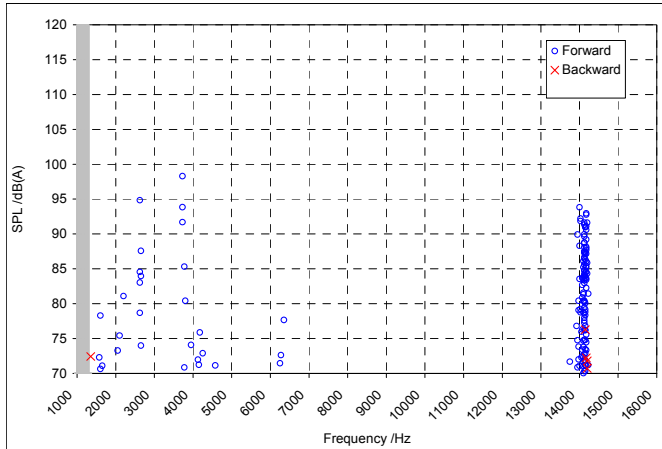
Comparison Brake Noise Rating Systems

Capabilities, different character and limitations of various noise rating systems are demonstrated by 2 examples from SAE 2521 noise tests

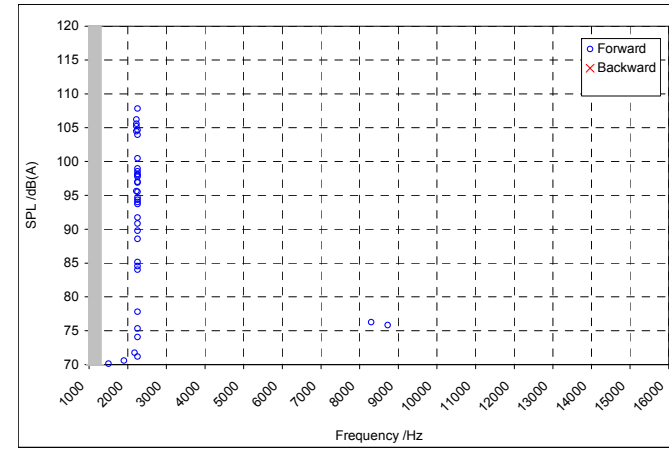
Test	Average SPL	Max. SPL	Global Occur.	Absolute Occur.
A	80.5 dB(A)	98.3 dB(A)	7.60%	153
B	91.9 dB(A)	107.8 dB(A)	1.90%	37

Extracts from 2 different SAE 2521 Noise Tests

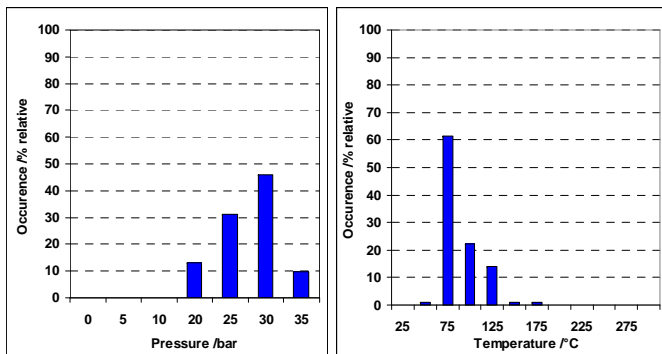
Comparison Brake Noise Rating Systems



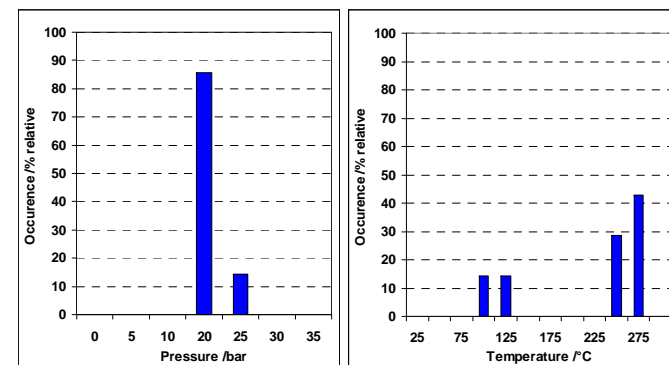
Frequency plot TEST A



Frequency plot TEST B



Situational parameters TEST A



Situational parameters TEST B

Noise Results coming from different Rating Systems

TEST	ONI	Acceptance Diagram	Honeywell	Level 3 Index	Average BONI	Global Occurrence
A	0.221	8.2	5.7	*	4.58	7.6%
B	0.216	7.8	6.9	*	5.51	1.9%

Noise results achieved by different rating systems (
*No Level 3 calculation possible, because of old noise description without duration)

Discussion Results from different Noise Rating Systems

- **Results are coming from established rating systems plus level 3**
- **Information level is rather different; results only can be compared within the same system**
- **Higher level systems come closer to the human perception of brake noise**
- **With respect to human perception lower level rating systems provide misleading results**
- **Since there are different goals of testing, qualifications like „good“ or „bad“ should be avoided**

Outlook

- **Levels 3 and 4 of the new brake noise rating system have a different character compared with existing systems**
- **They will be developed and tested by experts, being well familiar with all existing rating systems**
- **Level 3 will undergo a detailed test phase in 2009, supported by all members of the European Brake Noise Working Groups and hopefully also by other companies**
- **Level 3 contains already the most important parameters for brake noise rating**
- **Development of level 4 will start after successful validation and implementation of level 3**
- **To be discussed: do we need a general technical definition of subjective rating 1 – 10**

Summary

- **New standards are developed in order to close critical gaps for brake noise testing:**
 - **EKB 3006 „Description of a Noisy Brake Application“**
 - **EKB 3008 „Universal Test Data Exchange Format“**
 - **EKB 3007 „Brake Noise Rating System“ combines proven practice with innovative approaches. The paper summarizes and reveals knowledge, where at least parts today are handled proprietary.**

Thank You for Your Attention