# *E-NEWSLETTER*

*June 2018 issue*

# *THE SOCIETY OF ACOUSTICS SINGAPORE*

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**Registration No: 0331/1989**
**Year of Registration: 1989**

**President: Dr Gan Woon Siong**
**Secretary: Prof Y F Zhou**
**Treasurer: Dr Venu**

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## I.CONFERENCE NEWS

**The 25th International Congress on Sound and Vibration(ICSV25 ) will be held in Hiroshima , Japan from 8 to 12 July 2017.**

**Woon Siong Gan will be organising three structured sessions on:**

1. **Nonlinear acoustics and vibration**
2. **Acoustic metamaterials & phononic crystals: fundamentals and applications**
3. **Sound propagation in curvilinear spacetime**

**Please visit www.icsv25.org for more informations.**

**The 13 th Western Pacific Acoustics Conference will be held from 11-15 November ,2018 in New Delhi, India.**

**The abstracts deadline has been extended to 15 July 2018…Sofar the number of abstracts submitted is 404.**

**Woon Siong Gan will be organising two structured sessions at this conference on:**

**1.Nonlinear acoustics & vibration**

**2.Acoustic metamaterials & phononic crystals: fundamentals and applications.**

**Please visit the website: www.wespac2018.org.in for more informations.**

## II.ANNONCEMENTS

**The Society of Acoustics will be sending out invoices to members with outstanding membership subscriptions. Members are encouraged to make payment in support of the Society.**

**The E-Newsletters will be made available to industrial contacts in an effort to promote the activities of the Society.**

**The Society is also exploring the possibility of organising talks and other professional events in collaboration with acoustic societies of other countries.**

**Membership Certificates will soon be made available to all members who had made full payments of membership dues**

**The Society aims to increase membership by inviting all persons, including those from the institution of higher learning and other related societies such as the Institute of Architects, Singapore and the members of the mechanical engineering division of the Institution of Engineers, Singapore who are qualified in the various field of Acoustics to join our Society.**

**We are especially keen to invite students to join our society and we are establishing the Youth Chapter soon.**

## III.INTERNATIONAL ACOUSTICS NEWS

**Woon Siong Gan was recently elected as a Director of the International Institute of Acoustics and Vibration(IIAV) for the period 2018 to 2022.**

## IV.MEMBERSHIP SUBSCRIPTION

| | |
|---|---|
| Fellow | S$70 |
| Member | S$50 |
| Associate | S$30 |
| Student | S$15 |
| Corporate | S$200 |

**FEE BASED ON ANNUAL RATE**

**FOR MORE INFORMATION PLEASE CONTACT: Dr. Woon Siong Gan at email: wsgan5@gmail.com**

**Membership application forms can be downloaded from the society website: www.acousticssingapore.com. Please complete and email to wsgan5@gmail.com**

## V.ARTICLE

### My paper" Application of Holography to Noise Source Identification " revisited[1]

**Woon Siong Gan**

**The paper Application of Holography to Noise Identification was published in the Proceedings of InterNoise 74. It is the first paper on the application of acoustic holography to noise source identification(NSI). Today NSI is a very common and important tool in noise control engineering. For instance there is the product manufactured by B and K.**

**The subsequent papers on the application of acoustic holography to NSI after my 1974 paper are:**

**1.E G Williams and J D Maynard, Holographic imaging without the wavelength resolution limit, Phy Rev Lett.,45,554-557,1980.**

**2.E.G.Williams, J.D.Maynard & E. Skudrzky, Sound reconstruction using a microphone array, J.Acoust.Soc.Am.,68,340-344,1980.**

**3.J.D.Maynard,E.G.Williams & Y.Lee, Nearfield acoustic holography,I.Theory of generalized holography & the development of NAH, J.Acoust.Soc.Am., 78,1395-1413,1985.**

**B & K patented algorithms SONAH and ESM allow accurate measurements with relatively small array without encouraging edge effects. A basic PULSE acoustic holography system comprises measurement & post-processing software , a planar sliced wheel array of 18 microphones & LAN-X1 data acquisition hardware including the frame module & front panels. The system is ideal for mapping noise from engine, vehicle components, appliances, power tools etc.**

**Sofar the acoustic holography systems for NSI ,including that from B and K are based on nearfield acoustic holography in which the hologram is taken near the sound source. The reason is all the detailed informations on the object are contained in the nearfield sound field or in the evanescent waves.**

**Although the technique used in my 1974 paper the correlation filtering technique is not commonly used, it marked the beginning of digital holography. My paper is an extension of optical holographic correlation filtering technique to acoustics .**

**The phased hologram is used. That is, only the phase is recored and the amplitude is not recorded.**

**The noise source to be identified is analogous to the desired filtered image. One first records the phase-only acoustic hologram, the holographic spatial filter function using the object wave and a reference wave. The desired noise source is in this case, f ⊙ h where f = the text being filtered and h = the Fourier transform of the holographic filter function.**

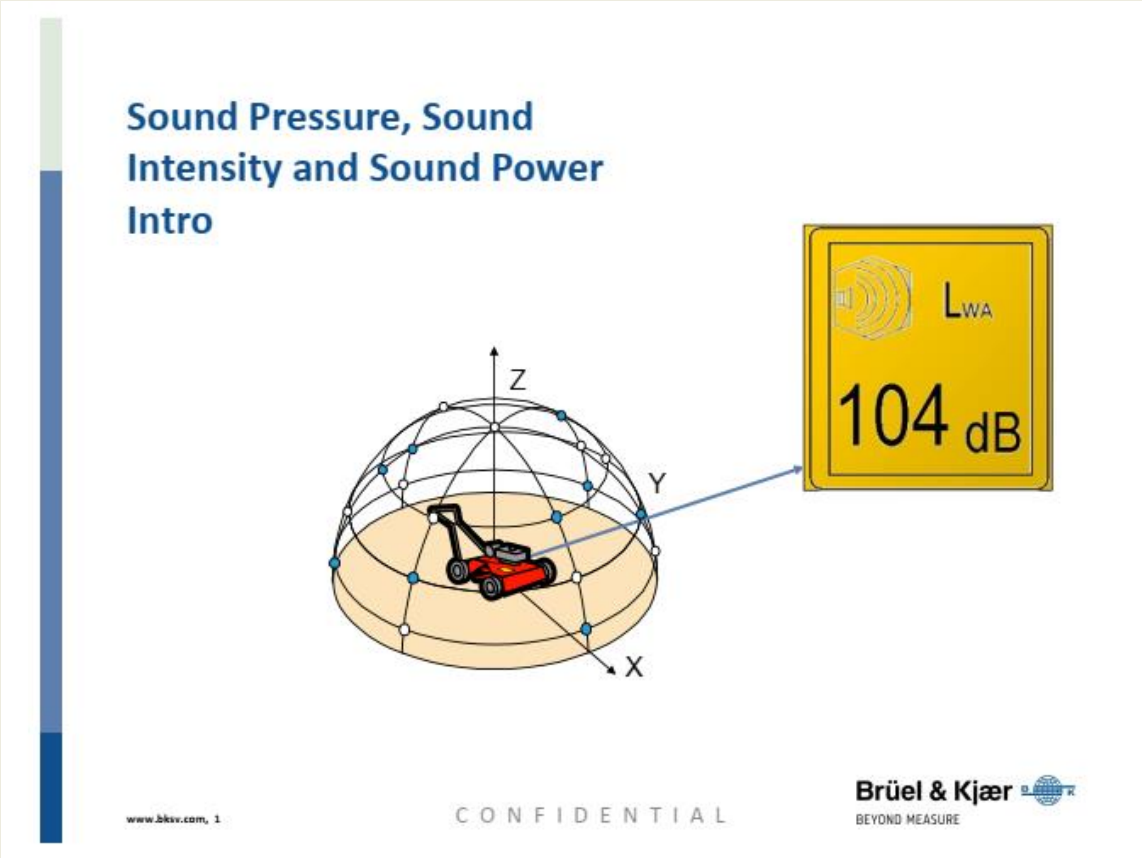
**Application of digital computing to this work**

**Correlation filtering technique sets the environment suitable for digital computing work. The noise signal will have to be digitised and the equation for correlation filtering will have to be in discrete form for digital Fourier transform operations.**

**Reference**

1. **W.S.Gan, Application of holography to noise source identification, Proceedings of InterNoise 74,Washington,D.C.,30 September-2 October 1974.**

**Powerpoint Presentation of Wilfred Lim of B and K at the International Noise Awareness Day (INAD) Seminar,April 2018**


Sound Pressure, Sound Intensity and Sound Power Intro
Z
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X
LWA
104 dB
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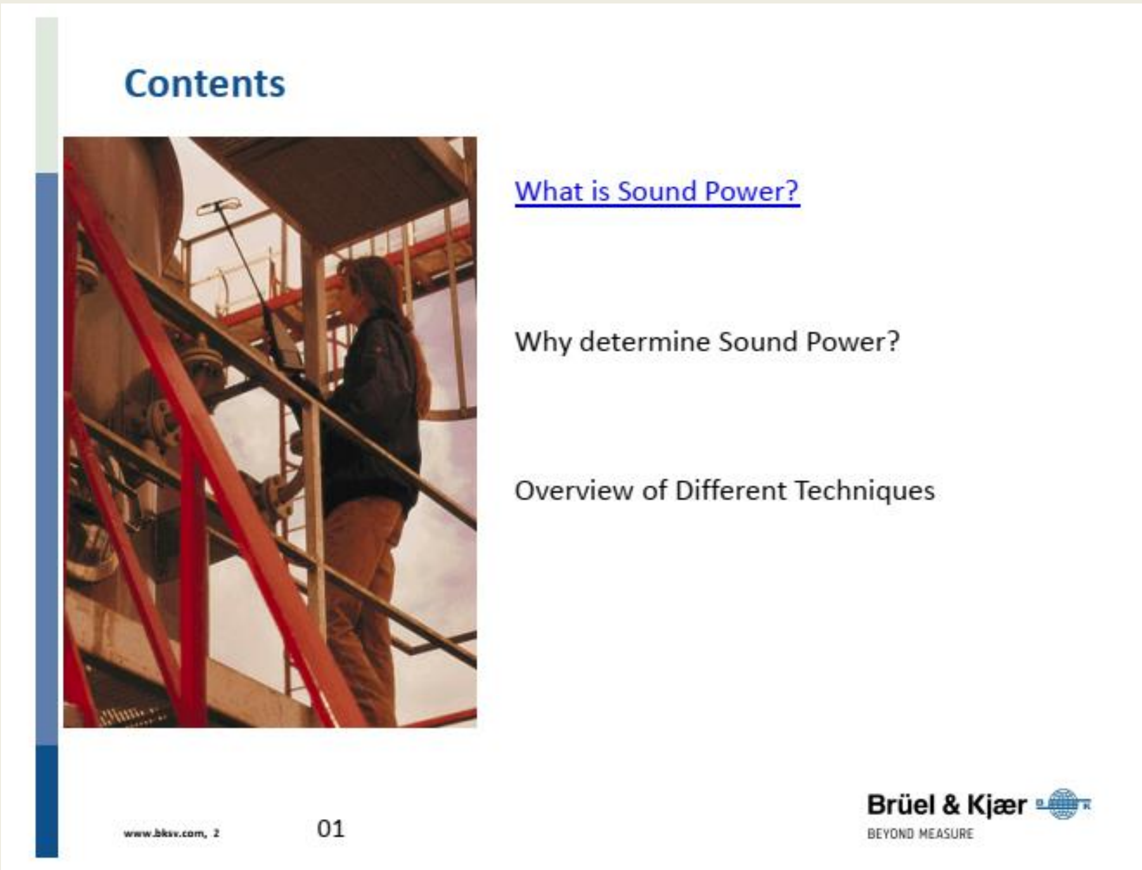
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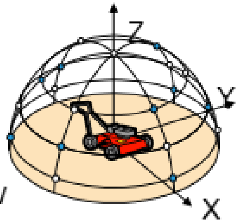
## What is Sound Power?

**Sound Power**, *W* (Watts): The rate per unit time at which airborne sound energy is radiated by a source

**Sound Intensity**, *I* (W/m$^2$): The rate of acoustic energy flow per unit area

$$W=\int_S I_n \; dS$$




**Sound Power Level** $L_W$: $P_0$ = 1pW

i.e. in dB (decibel)

$$L_W = 10\log\frac{P}{P_0}$$

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## Some Sound Power Numbers

| Situation and sound source | sound power $P_{ac}$ watts | sound power level $L_W$ dB re $10^{-12}$ W |
|---|---|---|
| Rocket engine | 1,000,000 W | 180 dB |
| Turbojet engine | 10,000 W | 160 dB |
| Siren | 1,000 W | 150 dB |
| Heavy truck engine or loudspeaker rock concert | 100 W | 140 dB |
| Machine gun | 10 W | 130 dB |
| Jackhammer | 1 W | 120 dB |
| Excavator, trumpet | 0.3 W | 115 dB |
| Chain saw | 0.1 W | 110 dB |
| Helicopter | 0.01 W | 100 dB |
| Loud speech, vivid children | 0.001 W | 90 dB |
| Usual talking, Typewriter | $10^{-5}$ W | 70 dB |
| Refrigerator | $10^{-7}$ W | 50 dB |

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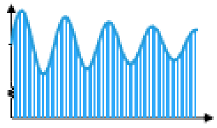
## Basic Parameters of Sound

**Sound Pressure**, [Pa]: *p*

A fluctuating pressure superimposed on the static pressure by the presence of sound.

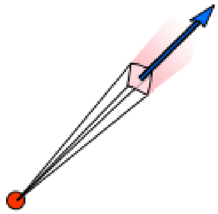
Receiver



**Sound Intensity**, [W/m²]: $\vec{I}$

The rate of acoustic energy flow per unit area.

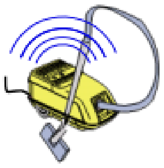
Path



**Sound Power**, [Watts]: *W*

The rate per unit time at which airborne sound energy is radiated by a source.

Source



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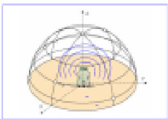
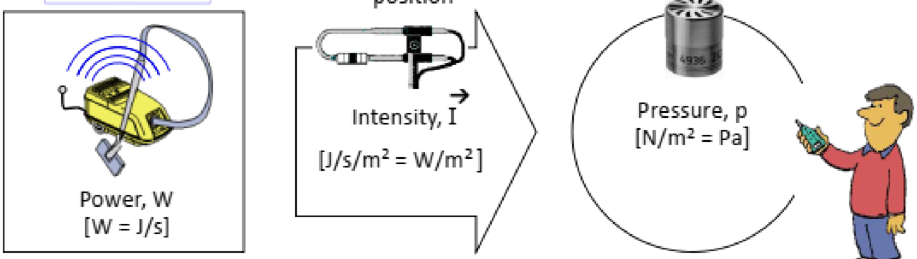
## The Three Basic Parameters of Sound

| Sound Power | Sound Intensity | Sound Pressure |
|---|---|---|
| | A vector, describing the *amount* and the *direction* of flow of acoustic energy at a given position | A scalar, describing the pressure fluctuations at a given position |






| | *Source* | *Path* | *Receiver* |
|---|---|---|---|
| Estimation: | Calculated | Measured | Measured |
| Usage: | Noise rating of machines | Location and rating of noise sources | Evaluation of the harmfulness and annoyance of noise sources |

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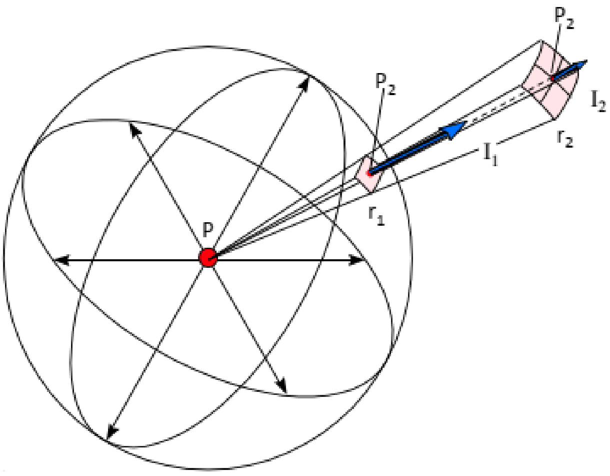
## Basic Parameters of Sound

Under free-field conditions:




**Sound Pressure Level** – **Receiver**

$$L_p = 10\log_{10}\frac{p^2}{p_o^2}$$

$$p_o = 2\times10^{-5}\,N/m^2 = 20\mu Pa$$

**Sound Intensity Level** – **Path**

$$L_i = 10\log_{10}\frac{I}{I_o}$$

$$I_o = 1\,pW/m^2$$

**Sound Power Level** – **Source**

$$L_w = 10\log_{10}\frac{W}{W_o}$$

$$W_o = 1\,pW$$

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Why determine Sound Power?

Overview of Different Techniques

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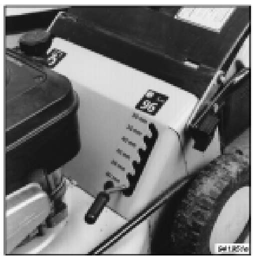
## Why determine Sound Power?

- Given the knowledge of a sound source and the acoustic environment, one can predict the sound pressure level due to the source at a given distance in that environment

$$L_W = L_p + 10\log_{10}\left(\frac{A_S}{A_0}\right)\ \mathrm{dB}.$$


- To compare the noise emissions of sound sources of the same and different types
- To determine whether a sound source complies with noise specifications (legislation, standards)



- In **engineering work**, to assist in developing quiet machinery and equipment
- To be able to sell noise making machinery and equipment in EU member states (Directives)

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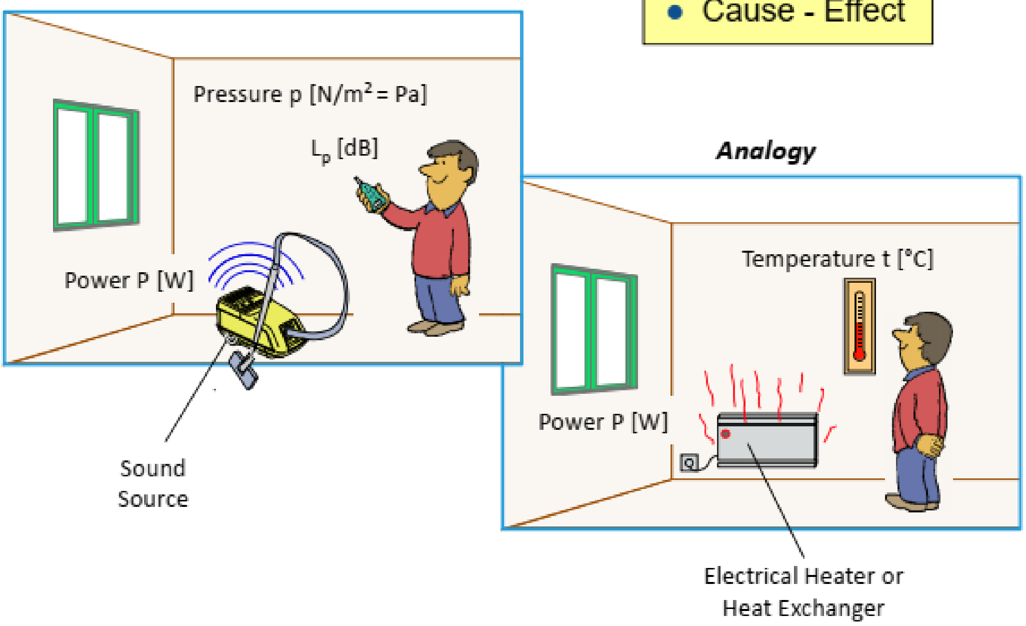
## Pressure vs. Power

- Cause - Effect

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COP: Coefficient of Performance

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## Overview of different techniques, Sound Power

- Overview – Pressure & Intensity
- Standards
- Advantages & disadvantages of the different Methods

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## A Little History……

- **Development of the Methods**
  - ISO 3740 series of standards for pressure-based measurements introduced in the 1970s
    - Require a known acoustic environment, that is a free sound field or a reverberant sound field
    - Most standards have now been updated (ver. 2 & 3)
  - Intensity-based methods began to be developed in the late 1980s
    - Can be used in almost any acoustic environment
    - Standardized in ISO 9614 (1993 & 1996 & 2002/2009)

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## Why Have Standards?

- Acoustic measurements are highly standardized
  - To make sure people use the same methods
  - To simplify comparison of results
- Standards for sound power determination
  - Three grades of sound power determination
    - Precision Grade 1 (most accurate)
    - Engineering Grade 2 (medium accuracy)
    - Survey Grade 3 (least accurate)

***"We do not have standards to measure correctly, rather to ensure everyone measures the same way."***

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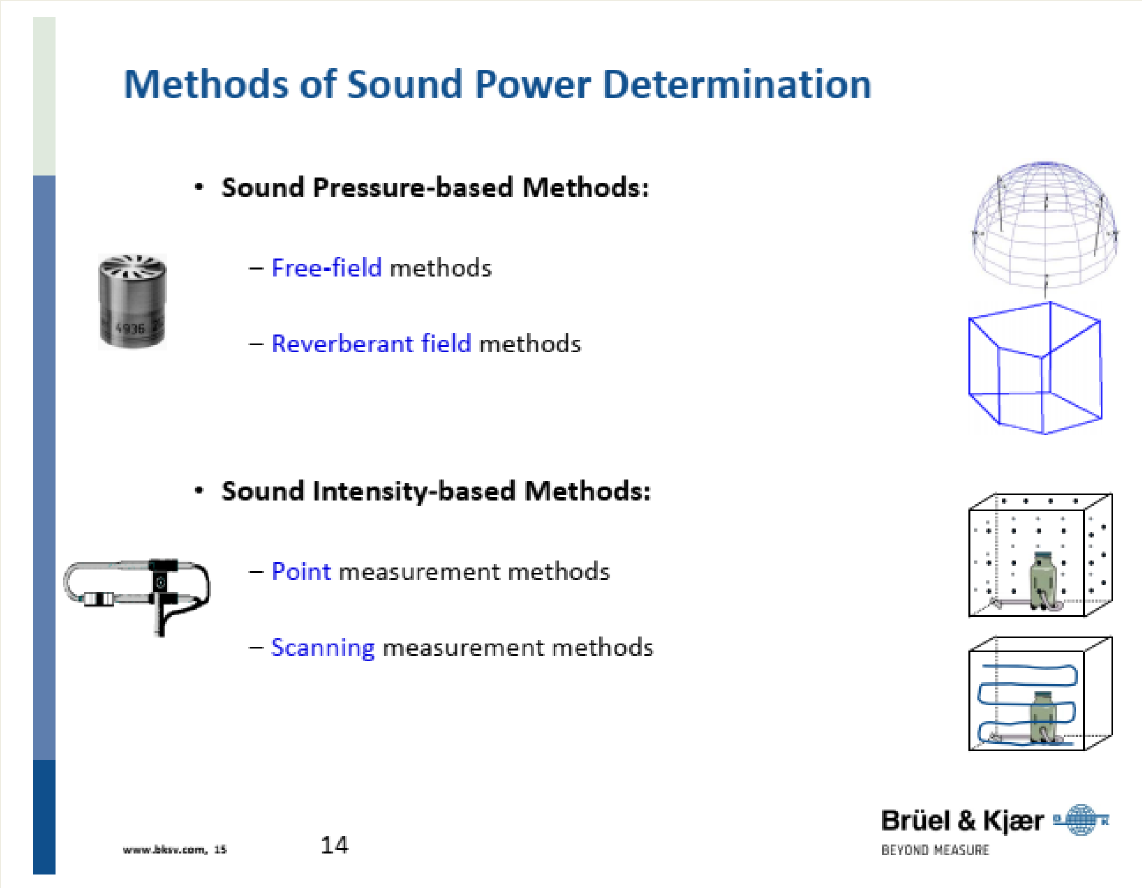
Methods of Sound Power Determination
• Sound Pressure-based Methods:
– Free-field methods
– Reverberant field methods
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• Sound Intensity-based Methods:
– Point measurement methods
– Scanning measurement methods
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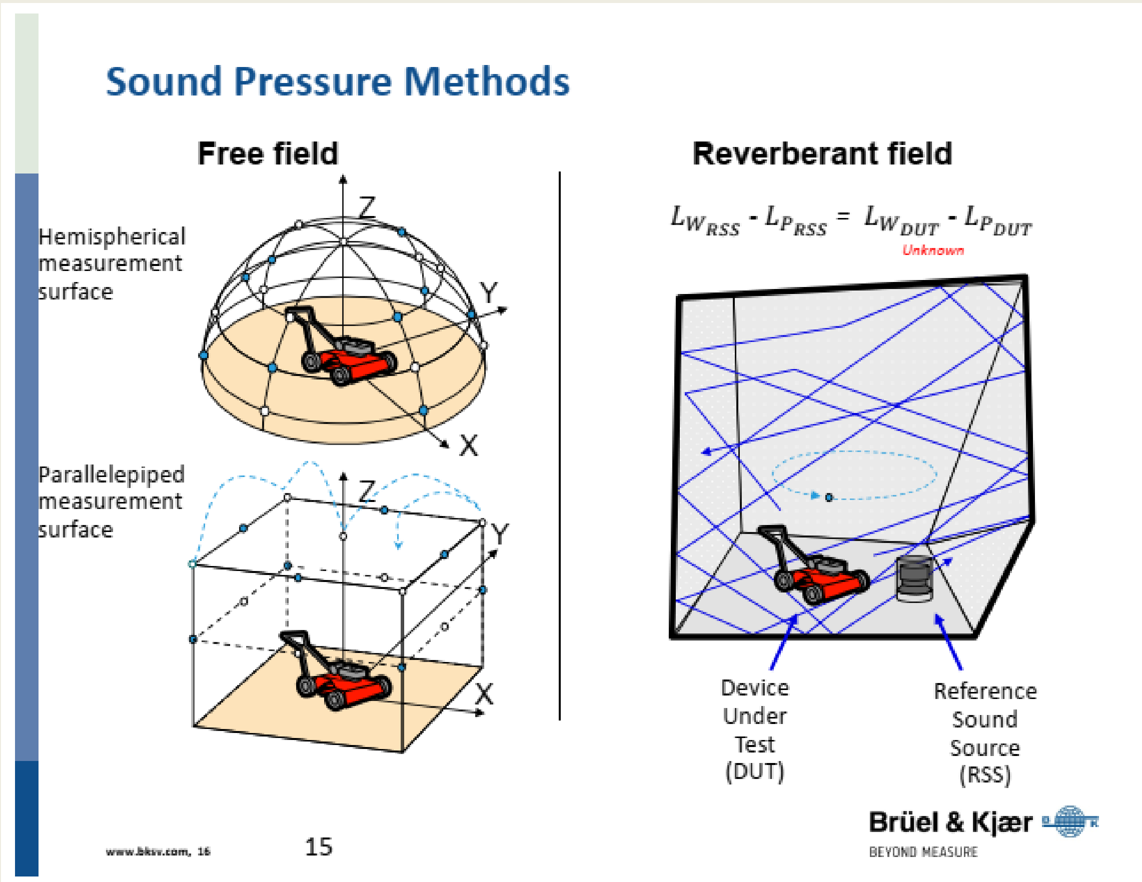
Sound Pressure Methods
Free field
Reverberant field
Hemispherical measurement surface
Parallelepiped measurement surface
Z
Y
X
$L_{W_{RSS}} - L_{P_{RSS}} = L_{W_{DUT}} - L_{P_{DUT}}$
Unknown
Device Under Test (DUT)
Reference Sound Source (RSS)
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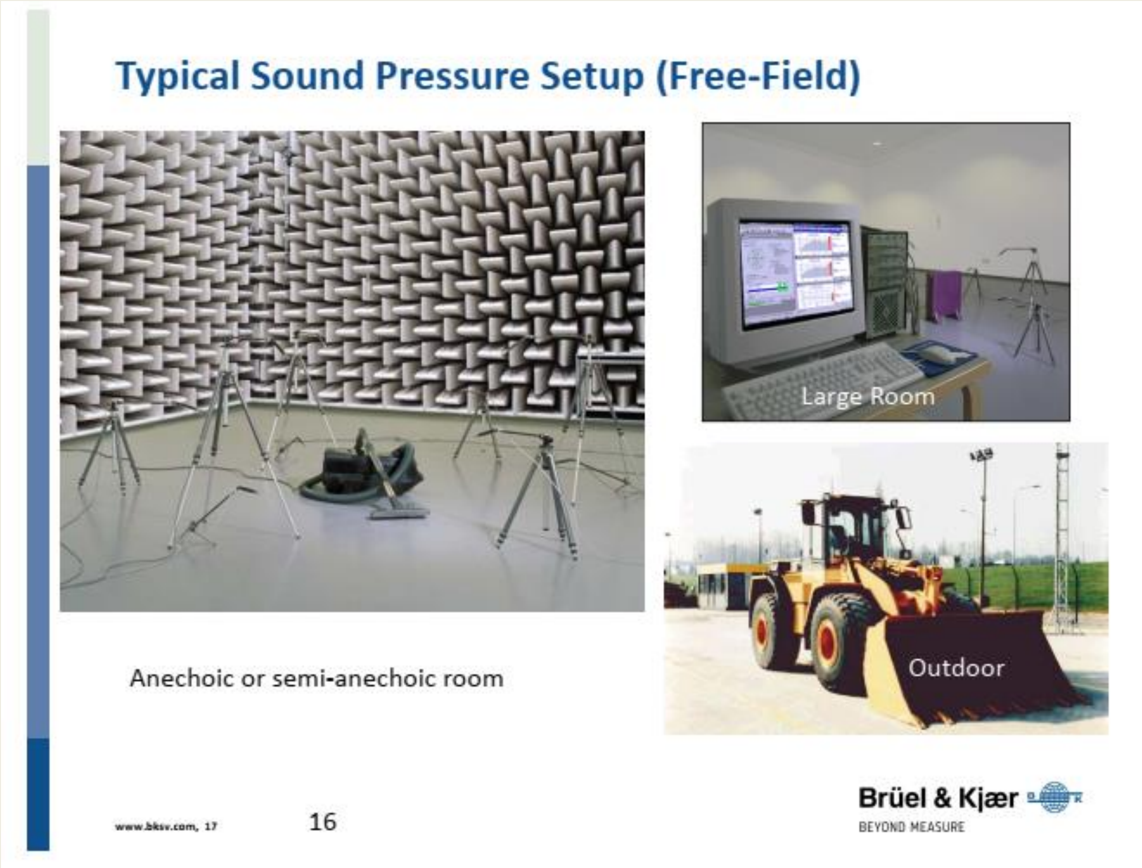
Typical Sound Pressure Setup (Free-Field)
Large Room
Outdoor
Anechoic or semi-anechoic room
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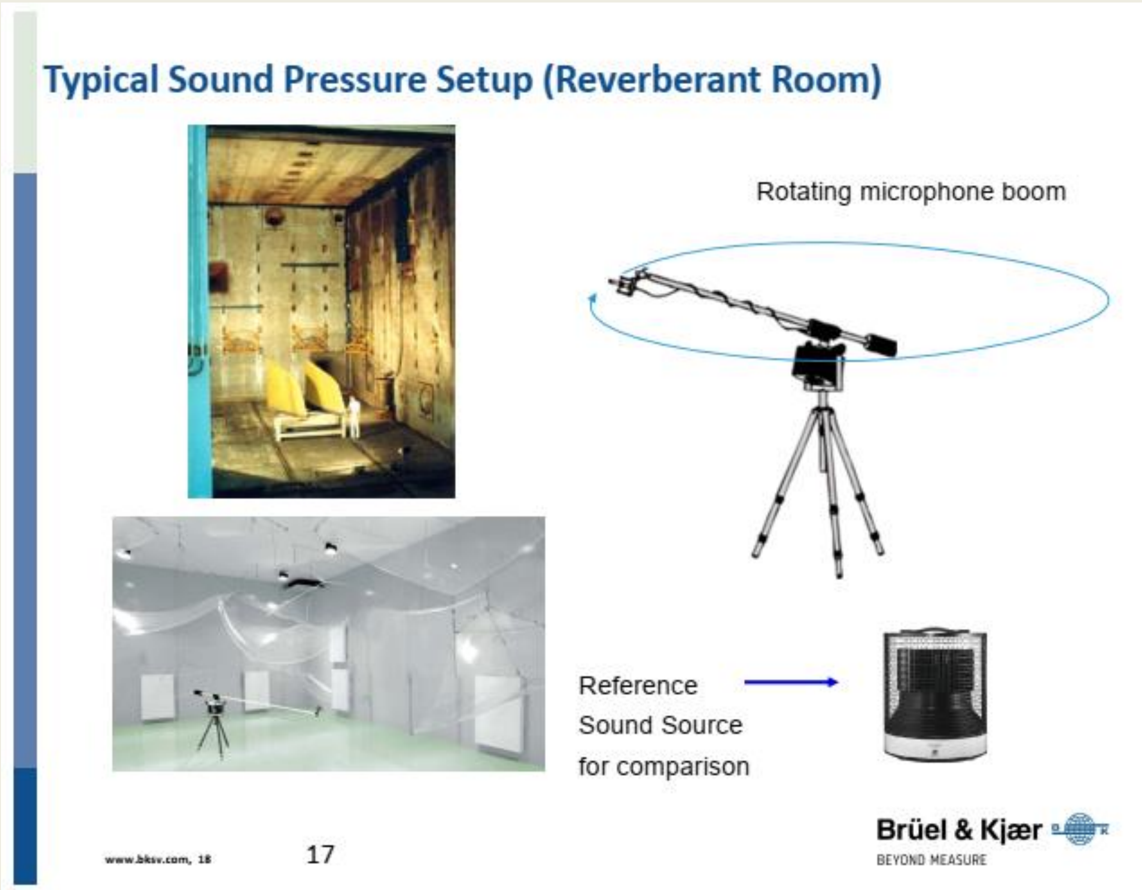
Typical Sound Pressure Setup (Reverberant Room)
Rotating microphone boom
Reference
Sound Source
for comparison
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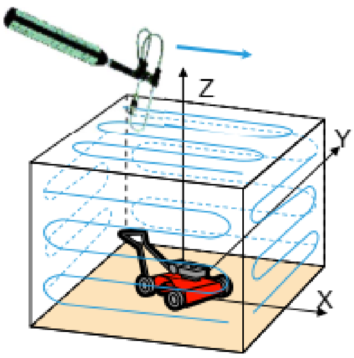
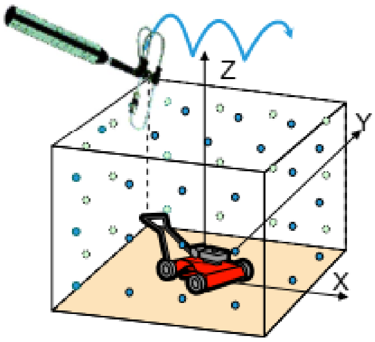
## Sound Intensity Method *(no special test facility)*

Sweep measurement method




Point measurement method




Sweep Method

Point Method

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## Typical Sound Intensity Setup

Measurement on a tumble drier

Measurement on a lawn mover

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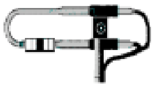
## Determination of Sound Power

- **Sound pressure based:**
  - \+ Fast, reliable results
  - \+ Easier-to-use
  - \+ Higher frequency and dynamic range
  - – More expensive test rooms


- **Sound intensity based:**
  - \+ Fewer demands to test room and background noise
  - \+ Includes location and ranking of noise sources
  - – Higher demands to operator's skills
  – Slower



Both techniques will yield the same result – **sound power**.
Which technique used depends on many factors:
(environment, ease of use, access to equipment, speed of test, etc.)

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## Overview of different techniques, Sound Power

- Overview – Pressure & Intensity
- Standards
- Advantages & disadvantages of the different Methods

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## Standards for Sound Power Measurements

International

International Organization for Standardization

http://www.iso.ch

*ISO*. The source of ISO 9000, ISO 14000 and more than 14 000 International Standards for business, government and society.
*ISO*. A network of national standards institutes from 148 countries working in partnership with international organizations, governments, industry, business and consumer representatives. A bridge between public and private sectors.

National

DIN Deutsches Institut für Normung e.V.

http://www2.din.de/

DIN, the German Institute for Standardization, is a registered association, founded in 1917. Its head office is in Berlin. Since 1975 it has been recognized by the German government as the national standards body and represents German interests at international and European level.

Industry

ecma INTERNATIONAL

http://www.ecma-international.org

Ecma International - Association for standardizing information and communication systems.
Before 1994 it was known as ECMA - European Computer Manufacturers Association.

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## ISO 374x Standards (Overview)

General view of the ISO 374x series of standards

| Standard | Accuracy | Test environment | Volume of source | Character of noise | Sound power levels | Optional information |
|---|---|---|---|---|---|---|
| ISO 3741 | Precision (Grade 1) | Reverberation room meeting specified requirements | Preferably less than 1% of test room volume | Steady, broad-band | In one or third octave bands. | A-weighted |
| ISO 3742 | | | | Steady discrete frequency or narrow-band | | |
| ISO 3743-1 | Engineering (Grade 2) | Hard-walled test room | | Steady, broad-band, narrow-band or discrete-frequency | A-weighted and in octave bands | Other weighted sound power levels |
| ISO 3743-2 | | Special reverberation test room | | | | |
| ISO 3744 | | Outdoors or in large room | No restrictions. Limited only by available test environment | Any | A-weighted and in one or third octave bands | Directivity information and sound pressure levels as a function of time; other weighted sound power levels |
| ISO 3745 | Precision (Grade 1) | Anechoic or semi-anechoic room | Preferably less than 0.5% of test room volume | | | |
| ISO 3746 | Survey (Grade 3) | Outdoors or indoors (i.e. no special test environment) | No restrictions. Limited only by available test environment | | A-weighted | Sound pressure levels as a function of time; other weighted sound power levels |
| ISO 3747 | | No special test environment; source under test not moveable | No restrictions | Steady, broad-band, narrow-band or discrete-frequency | | Sound power levels in octave bands |

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## Overview of different techniques, Sound Power

- Overview – Pressure & Intensity
- Standards
- Concept of Intensity based Sound Power Determination
- Advantages & disadvantages of the different Methods

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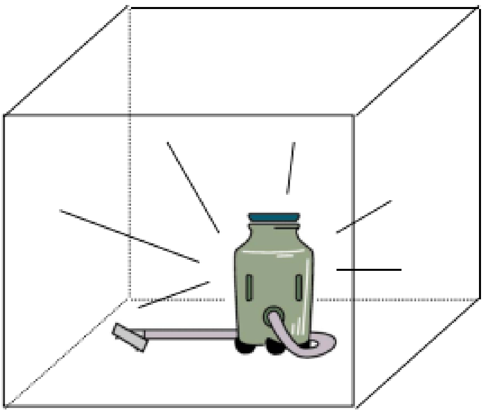
## Sound Power Level Calculation



$$W = \bar{I} \cdot S$$

$$L_W = L_I + 10 \cdot \log S/S_0$$

S = Surface Area
$S_0 = 1m^2$

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## Measurement Surfaces

- Any surface can be used
  - The most commonly use are…

Conformal Surface Hemisphere Box

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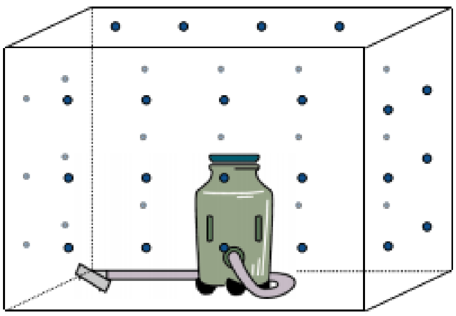
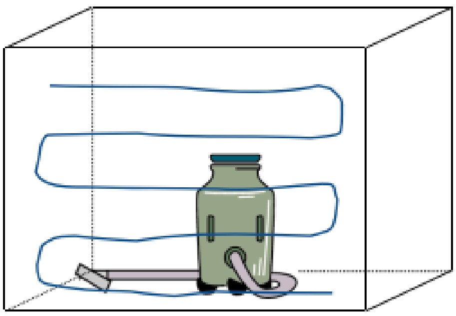
## The Sound Power Standards *(Intensity Based)*

**Point Measurements** **Sweeps**



**ISO 9614 Part 1**



**ISO 9614 Part 2 & 3**

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## Sound Power Determination based on Intensity

Advantages

- No anechoic or reverberation test chamber needed
- Near-field and far-field measurement acceptable
- No restriction on shape of control surface
- Steady background noise is excluded

Note

- Beware of absorption material inside the control surface

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## General view of the ISO standards

| | Standard | Accuracy | Test environment | Volume of sound source | Character of noise | Sound power levels obtainable | Optional information available |
|---|---|---|---|---|---|---|---|
| Using sound pressure | ISO 3741 | Precision | Reverberation room | Preferably less than 2 % of test room volume | Steady, broad-band, narrow-band or discrete frequency | A-weighted and in one-third-octave or octave bands | Other frequency weighted sound power levels |
| | ISO 3743-1 | Engineering | Hard-walled room | Preferably less than 1 % of test room volume | Any, but no isolated bursts | A-weighted and in octave bands | |
| | ISO 3743-2 | Engineering | Special reverberation room | | | | |
| | ISO 3744 | Engineering | Essentially free-field over a reflecting plane | No restrictions; limited only by available test | Any | A-weighted and in one-third-octave or octave bands | Directivity information and sound pressure levels as a function of time; single-event sound pressure levels; other frequency weighted sound power levels |
| | ISO 3745 | Precision | Anechoic or hemianechoic room | Characteristic dimension less than half | | | |
| | ISO 3746 | Survey | No special test environment | No restrictions; limited only by available test environment | | A-weighted | Sound pressure levels as function of time |
| | ISO 3747 | Engineering or survey | Essentially reverberant field in situ, subject to stated qualification req. | | Steady, broad-band, narrow-band or discrete frequency | A-weighted from octave bands | |
| Using sound intensity | ISO 9614-1<br>ISO 9614-3 | Precision, engineering or survey | Any | No restrictions | Broadband, narrow-band or discrete frequency, if stationary in time | Band limited (one-third-octave 50 Hz-6 300 Hz) A-weighted and in 1/3-octave or octave bands. Grade of accuracy is determined from field indicators | Positive and/or negative partial sound power concentration |
| | ISO 9614-2 | Engineering or survey | | | | | |

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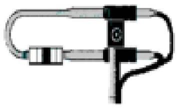
## Conclusions

- **Which Method to Use?**

**Each of the methods have their own advantages and disadvantages**

– Pressure methods maybe best-suited to production testing and audits

– Pressure methods best suited to use by non-qualified personnel

– Intensity methods maybe best-suited to R&D and engineering

– Intensity methods require more test skill

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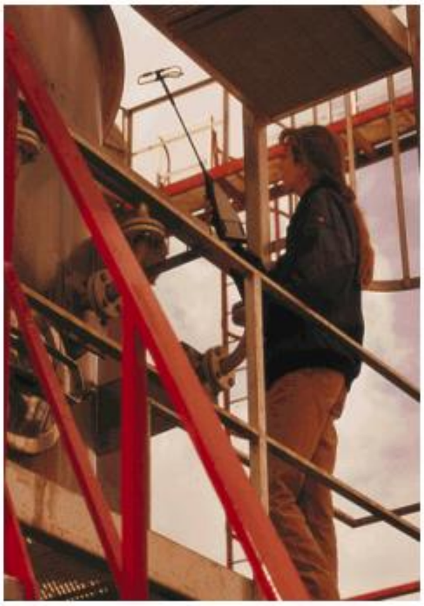

What is Sound Power?

Why determine Sound Power?

Overview of Different Techniques

Advanced Applications

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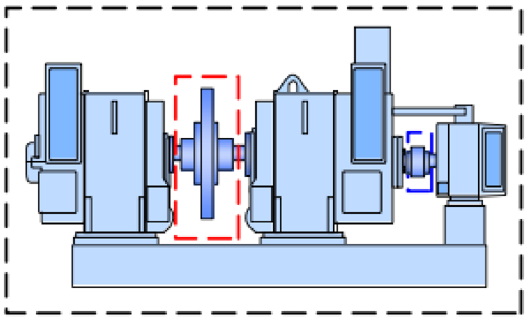
## Noise Source Ranking

- **Noise Source Ranking is:**

  The ability to 'segment' different components and calculate only the sound power per 'segment'. From these 'segmented' sound power numbers you can rank what part/piece is has the highest contribution to the overall sound power.



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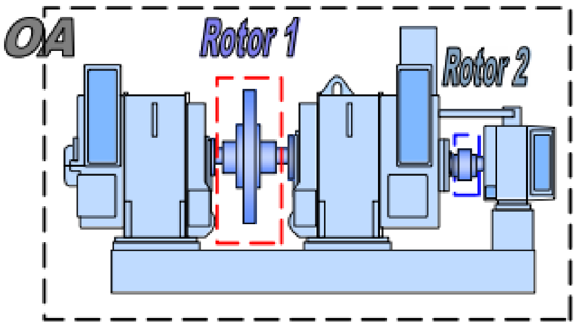
## When Would I Use Noise Source Ranking?

**Example:**

- You manufacture blower unit shown below
- Rotors in **blue** and **red** make too much noise when unit operates
- To design a quieter rotor you would like to know the 'sound power' of each rotor and their contribution to the overall sound power of the machine
- Noise source ranking allows you to measure sound power of each rotor during operation of machine




**Sound Power**

Overall Sound Power = 107.5 dB(A)
Rotor 1 = 105 dB(A)
Rotor 2 = 102 dB(A)

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## Literature for Further Reading

- Sound Intensity Primer
  *Brüel & Kjær*

- Sound Intensity, 2nd Edition by F.J. Fahy
  *E & FN Spon Publishing*

- **ISO Standards**
  - 9614-1, 1993: Sound Power Determination Using Sound Intensity (Point method)
  - 9614-2, 1996: Sound Power Determination Using Sound Intensity (Scan method)
  - 9614-3, 2003/09: Sound Power Determination Using Sound Intensity (Scan method)
  - 3741, 1999: Sound Power Determination Using Sound Pressure (Reverberant method)
  - 3744, 1994: Sound Power Determination Using Sound Pressure (Essentially free field method)

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# Any Questions?

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## VI.REPORT ON CONFERENCES

**The Regional Conference on Acoustics and Vibration (RECAV) organised by the Society of Acoustics(Singapore) and the Association of Acoustics and Vibration Indonesia(AAVI) was successfully held in Bali,Indonsia from 27 to 28 Nov 2017. There were 110 presentations from 14 countries with 60% of them from Indonesia. There were also some 18 exhibition booths. This reflected strong local participation and the international nature of the conference.**

## VII. BID FOR FUTURE INTERNATIONAL CONFERENCES

**Riding on the success of Wespac 2015, the society is bidding to host the International Congress on Acoustics(ICA) in Singapore in 2025 and to host the International Congress on Sound and Vibration(ICSV) in Singapore in 2021**

**Government Bodies**

www.mom.gov.sg

www.nea.gov.sg

www.lta.gov.sg

**Technical and Research Sites**

**Corporate Sites**

www.metaultrasound.com

www.noisecontrols.com

**(The Society welcomes interested parties to contribute relevant websites to the above e useful links. For more information, please contact us. Thank you.)**

## Disclaimers

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