National Metrology Centre
A*STAR

CREATING GROWTH, ENHANCING LIVES

Laboratory Update Acoustics & Vibration Lab National Metrology Centre Singapore

Cui Shan
Mechanical Metrology 1

Sep 2019

Passion Made Possible

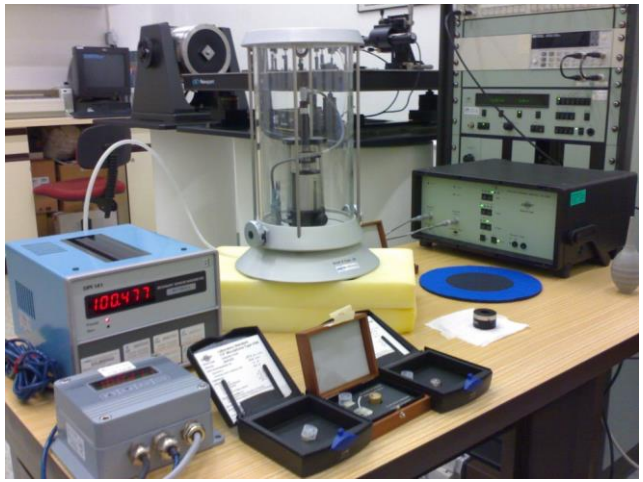
Content

Lab Overview

Technical Areas in Acoustics & Vibration Laboratory

Acoustics & Vibration Laboratory

Air-Borne Acoustics

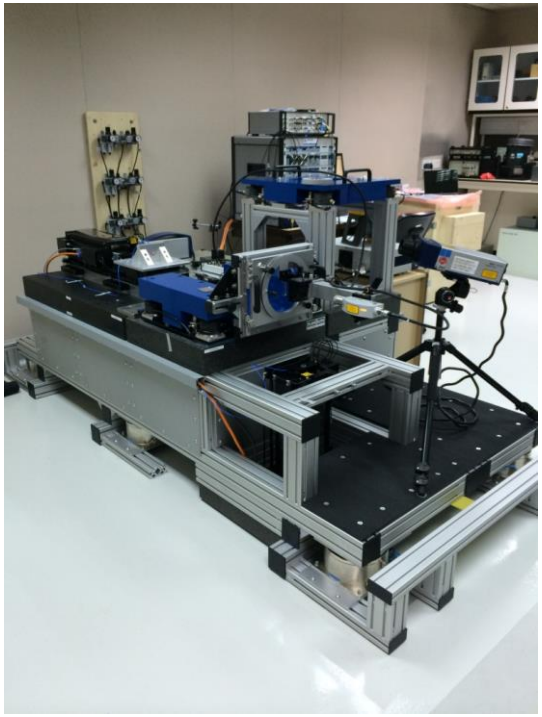


Caltest, Constr, Aerosp, EnvCon, Govt, Semicon

Underwater Acoustics & Ultrasound

R&D, OilGas

Linear Vibration

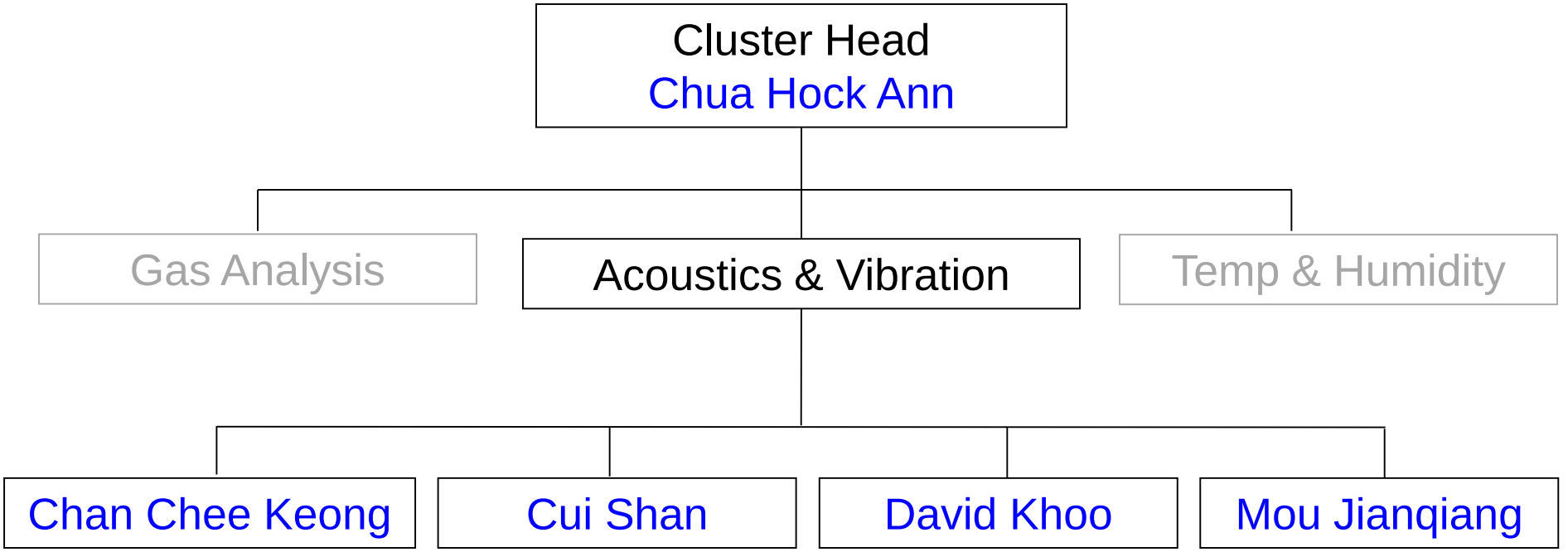


Caltest, Electr, Constr, Semicon, PreEng, OffMar, PackMat, ProcAuto, EnvCon

National Metrology Centre
A*STAR

Passion Made Possible

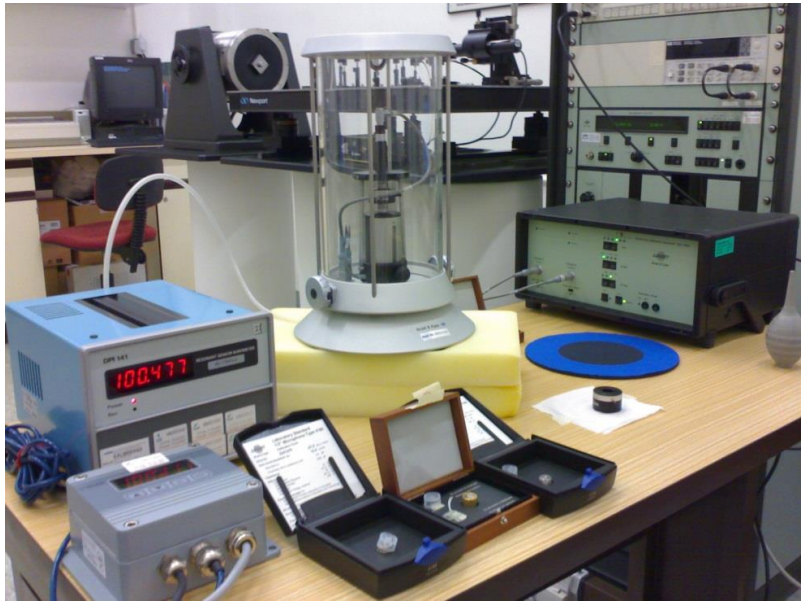
Staff

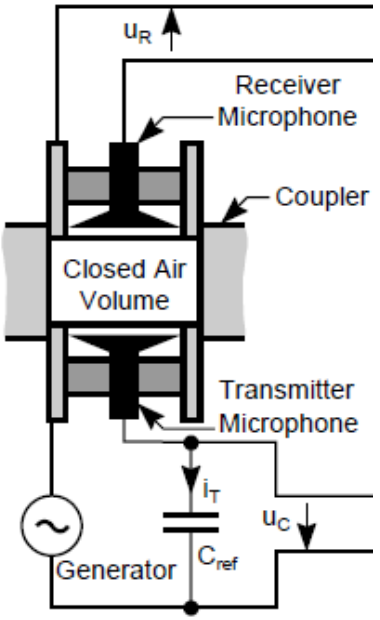

Cluster Head
Chua Hock Ann
Gas Analysis
Acoustics & Vibration
Temp & Humidity
Chan Chee Keong
Cui Shan
David Khoo
Mou Jianqiang

Airborne Acoustics

Primary Acoustic Standard

- **Primary Microphone Calibration System according to IEC 61094-2: 2009**
  - **Phase calibration enabled**
  - **Less sensitive to environment changes based on steady state response**
  - **Improved correction factors on heat conductions**
  - **Chamber air pressure stabilisation enabled**
  - **Uncertainty: <0.06 dB from 32 Hz to 16 kHz, 0.09 dB for 20 kHz, 0.15 dB for 25 kHz**





Secondary Acoustic Standard

- Established since 1998 to support factory noise control and boundary noise regulations in Singapore

- Calibration services:
  - Sound level meters
  - Acoustic calibrators
  - Working standard microphones
    - 20 Hz to 20 kHz
    - Uncertainty < 0.8 dB
  - MEMS microphone characterization

National Metrology Centre
A*STAR

Passion Made Possible

New Development
Secondary Free-Field Acoustic Standard

- Established since Jun 2018 for free field calibration of microphones and sound level meters

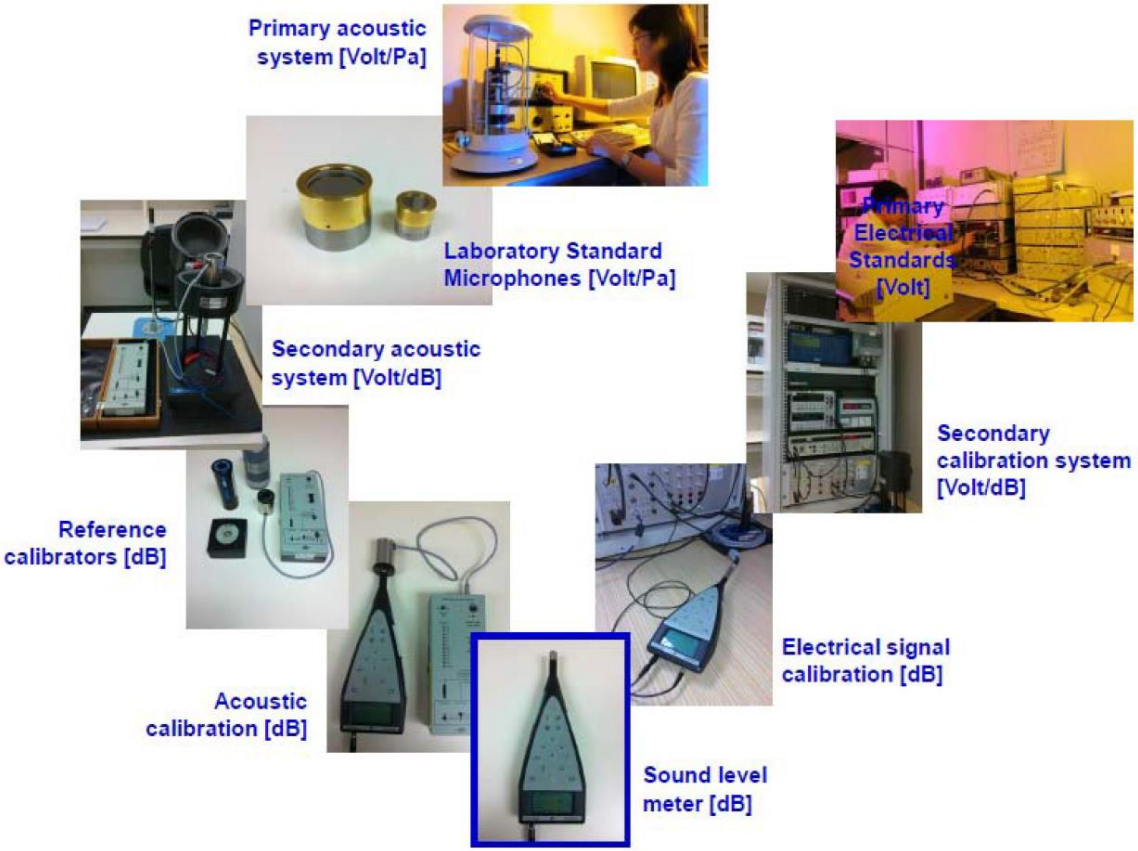
- New capabilities in free field:
  - Sound level meters
  - Working standard microphones
    - 125 Hz to 20 kHz
    - Uncertainty < 0.5 dB
- Aerosp, EnvCon, workplace safety and health, acoustic NDT

National Metrology Centre
A*STAR

Passion Made Possible

Peer Review in Airborne Acoustics

- 1st Round: 19-21 Aug 2014
  - Pee reviewer: Dr Ryuzo Horiuchi of NMIJ
  - 11 CMCs under inter-RMO review
- 2nd Round: Jan 2020 with 31 CMCs more



National Metrology Centre
A*STAR

Comparisons Participated in Airborne Acoustics

Laboratory standard microphone calibration using reciprocity method

- APMP.AUV.A-K3
  - Frequency range: 31.5 Hz to 25 kHz
  - CMCs supported: 11

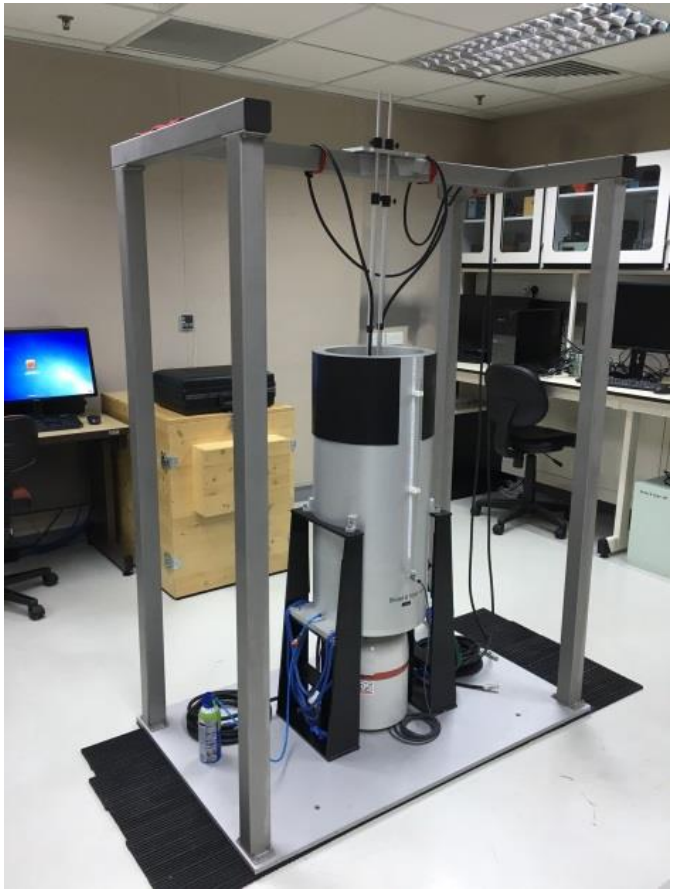
Underwater Acoustics & Ultrasound

Underwater Acoustics Metrology

- Verify and validate MEMS hydrophone performance
  - For Marine geographics, seismic surveys, subsurface imaging
  - Fit for purpose, low cost & better scalability

MEMS:
sensing below 100 Hz

Traditional:
sensing up to 120 kHz



National Metrology Centre
A*STAR

Passion Made Possible

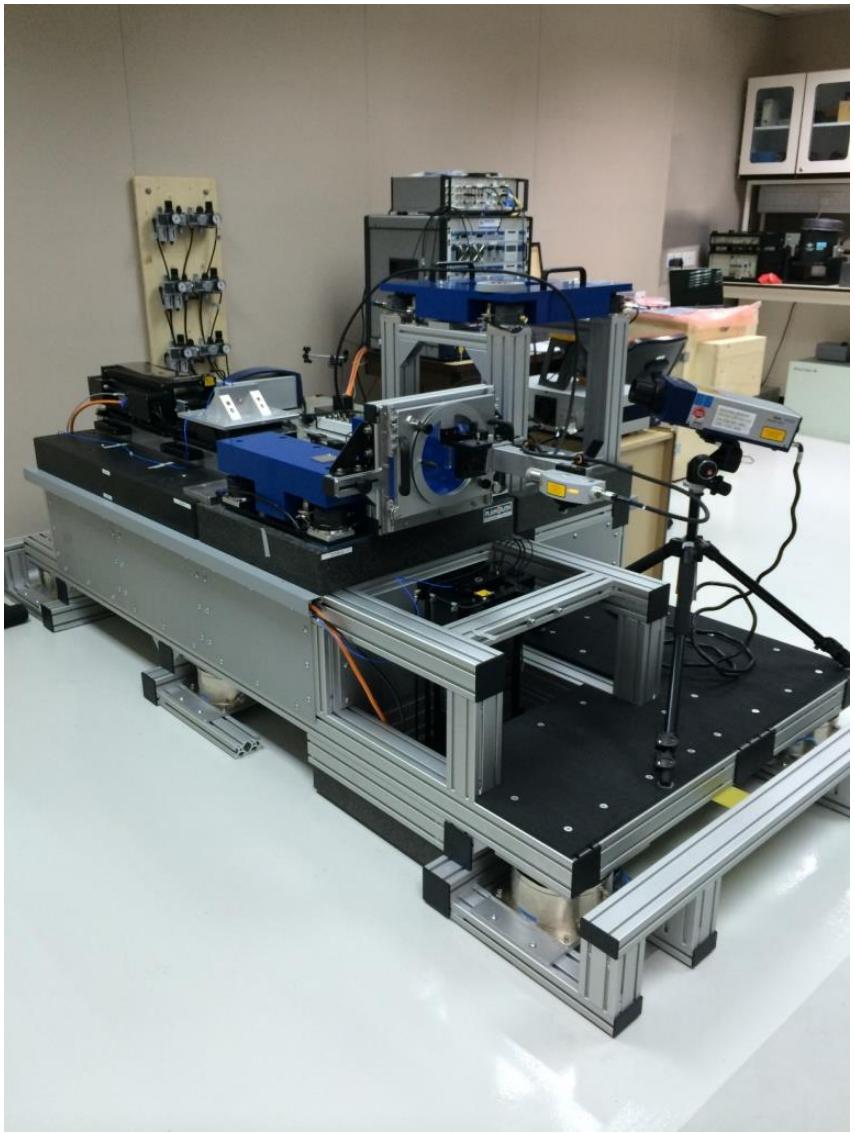
Ultrasonic NDT Equipment Calibration

- **Ultrasonic NDT Equipment Calibration**
  - **Using 5-step ultrasonic block in accordance with ASTM E797**
  - **Thickness and linearity calibration**

Linear Vibration

Broad Frequency Range Primary Vibration Standard

- Sine-approximation method
- **0.1 Hz to 350 kHz**: one of the widest frequency range
- **Phase measurement** enabled
- **Laser vibrometer** calibration up to 350 kHz and nm scale for semiconductor and HDD industry
- **Seismic accelerometer** calibration from 0.1 Hz to 160 Hz
- **Accelerometer** calibration and **MEMS** characterization from 0.1 Hz to 20 kHz



NMC's primary vibration standard

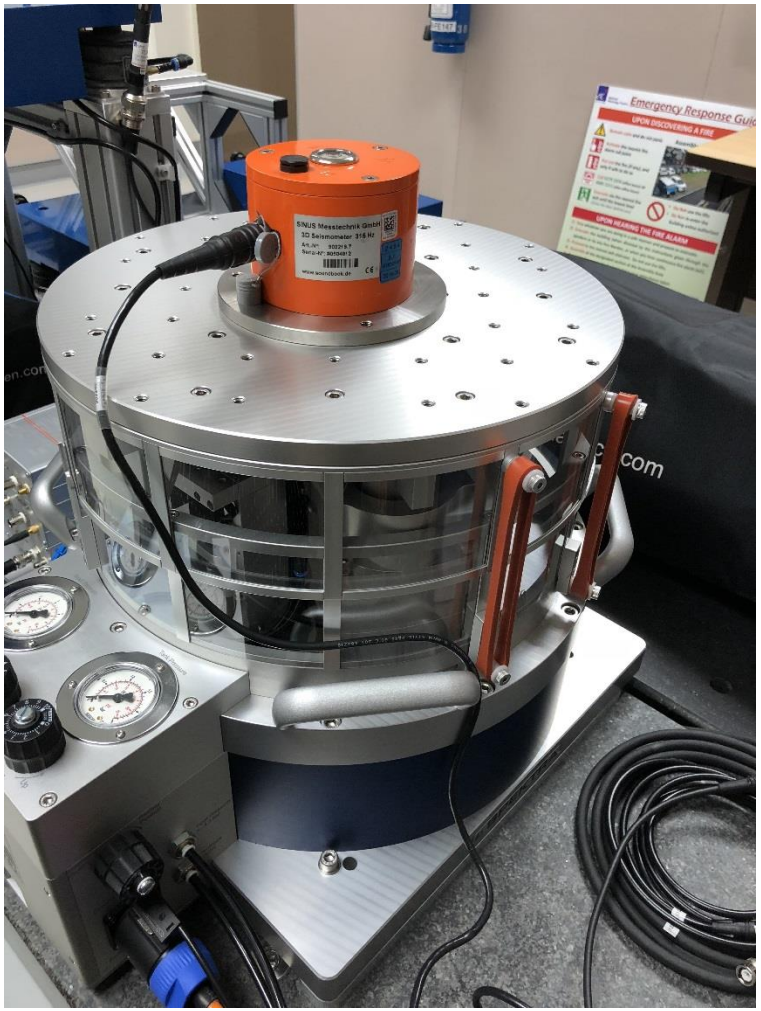
National Metrology Centre
A*STAR

Passion Made Possible

New Development
Geophone Calibration

- **Since Jun 2018, as an upgrade to the existing system**

- **Calibration services:**
- **heavy payload geophone and seismic sensor calibration**
  - **Payload up to 50 kg**
  - **0.1 Hz to 400 Hz**
- **Constr, EnvCon, CalTest**



National Metrology Centre
A*STAR

Passion Made Possible

Linear Vibration Peer Review

- **Conducted on 26-28 Sep 2016**
  - **Pee reviewer: Dr Hideaki NOZATO**
  - **NMC's 1st peer review in linear vibration area**
  - **52 CMCs under intra-RMO review**

National Metrology Centre
A*STAR

Comparisons Participated in Linear Vibration

Complex sensitivity of accelerometers:

- CCAUV.V-K3
  - Frequency range: 0.1 to 40 Hz
  - CMCs supported: 23
- CCAUV.V-K5
  - Frequency range: 10 Hz to 20 kHz
  - CMCs supported: 29

Activities in Measurement Assurance Programme (MAP) of NMC

Measurement Assurance Programme (MAP) 2018 - 2019

- **Training**
  - Airborne acoustic measurement and calibration (09 Sep 2019)
- **Consultancy**
  - 2 projects to help local labs to establish seismic vibration calibration capabilities
- **Proficiency Test**
  - 3 on vibration calibration
  - 1 on sound level meter calibration
- **Technical Assessment**
  - 4, in 2019
  - 3, in 2018

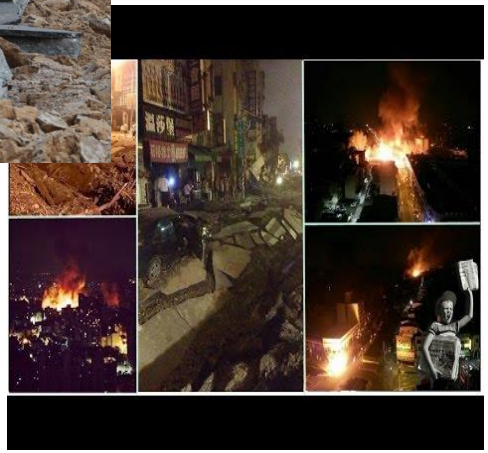
Applications

Leakage Detection for Natural Gas Transmission Pipeline

Acoustic method to localise leakage + mass balance method to reduce false alarm & measure leakage rate

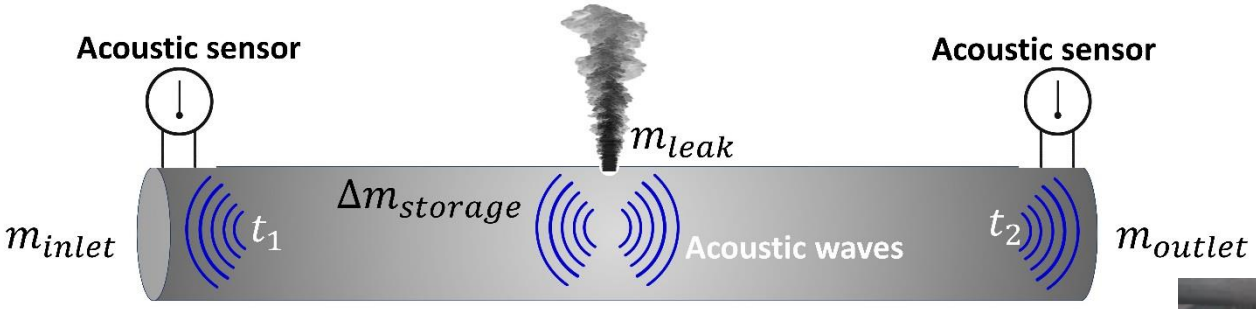
SAFETY!

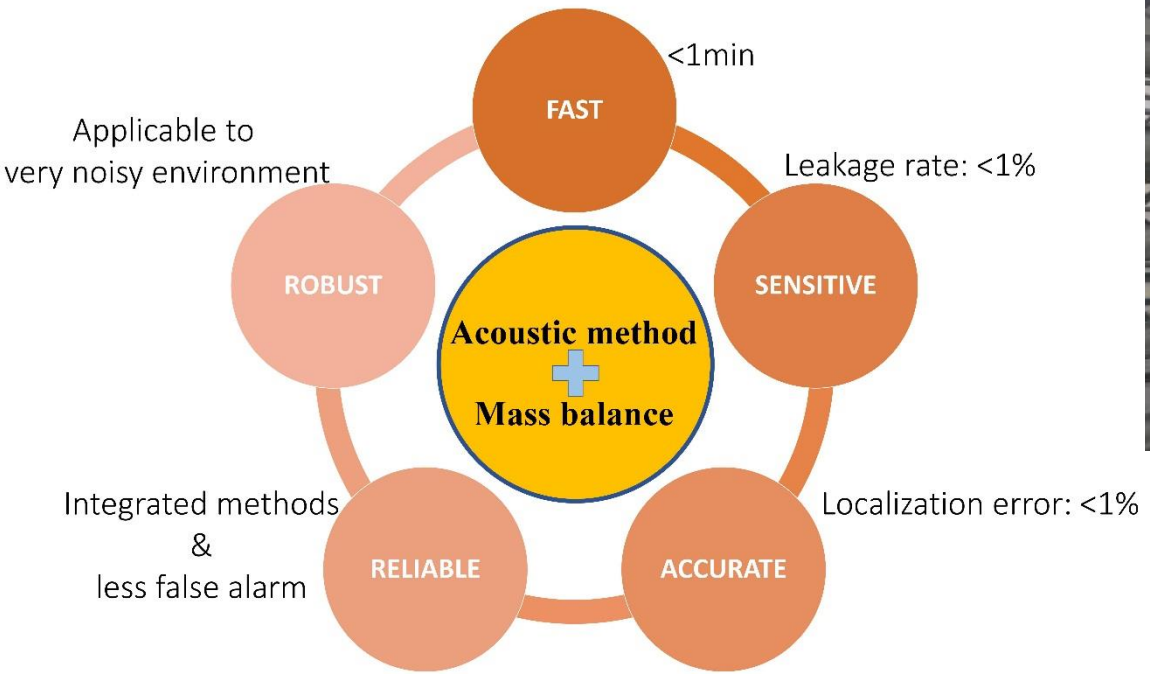
- Funded by Energy Market Authority of Singapore
- To enable real-time monitoring of leak(s) along the gas transmission pipeline (high pressure)
- To enable timely response to leak events



Metrology Centre
A*STAR

Outcome & achievements





- Maximum operating pressure: 35 bar
- Length: > 600m
- Main pipe diameter: 50.8 mm
- Leak locations: 8
- Leak sizes: 0.8 mm, 1.6mm, 3.2mm, and 9.5 mm
- Bypass points: 3

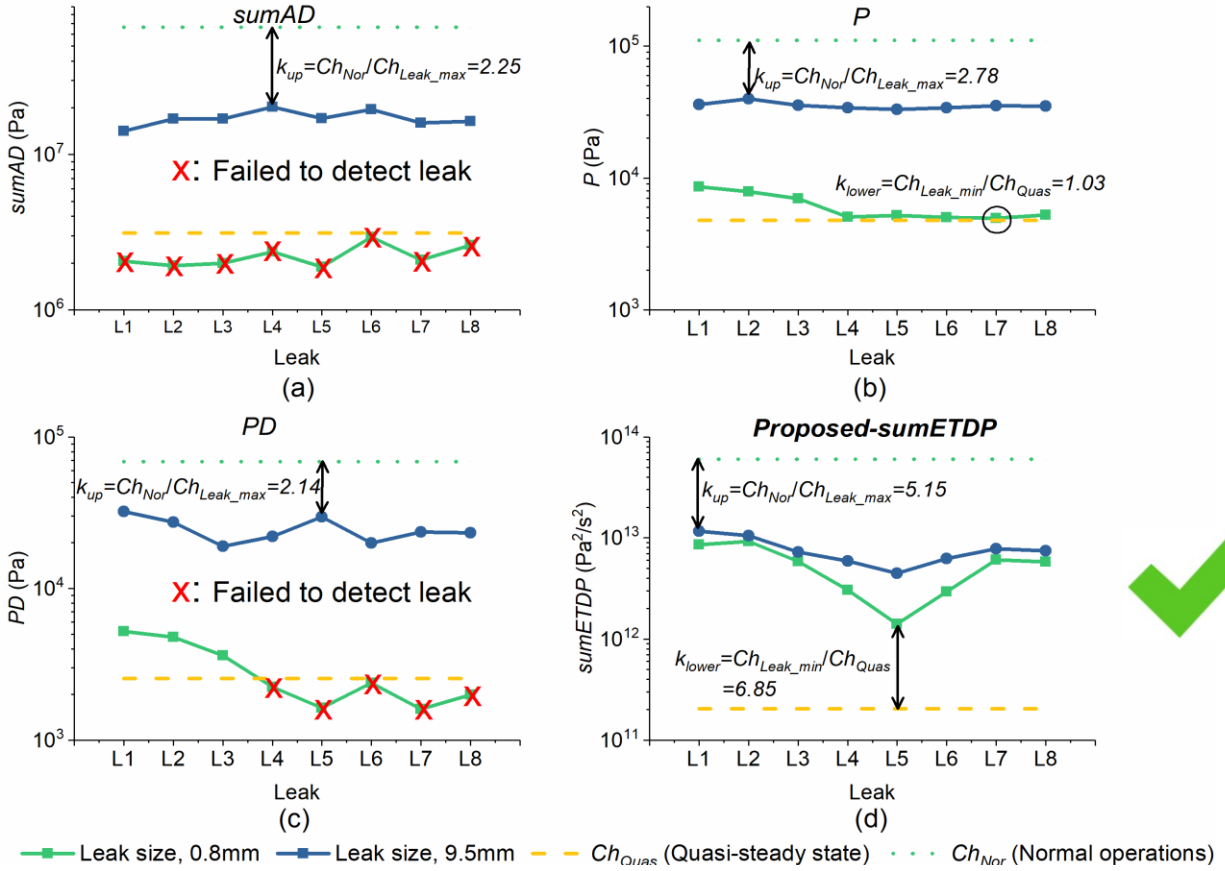
- Invention Disclosures: 3
- Conference presentations: 6
- Journal publications: 1 published, 2 submitted & 2 under review.

Outcome & achievements

1. Able to detect small leaks less than 1% of the operating gas flow rate.

- Acoustic-based method with the proposed characterization ***sumETDP*** **(detectable leak flow rate at 0.62 % for air and 0.89% for natural gas pipes)**

Existing Methods*
sumAD
P
PD
Proposed New Method
sumETDP



The invented method is being applied for intellectual property protection.

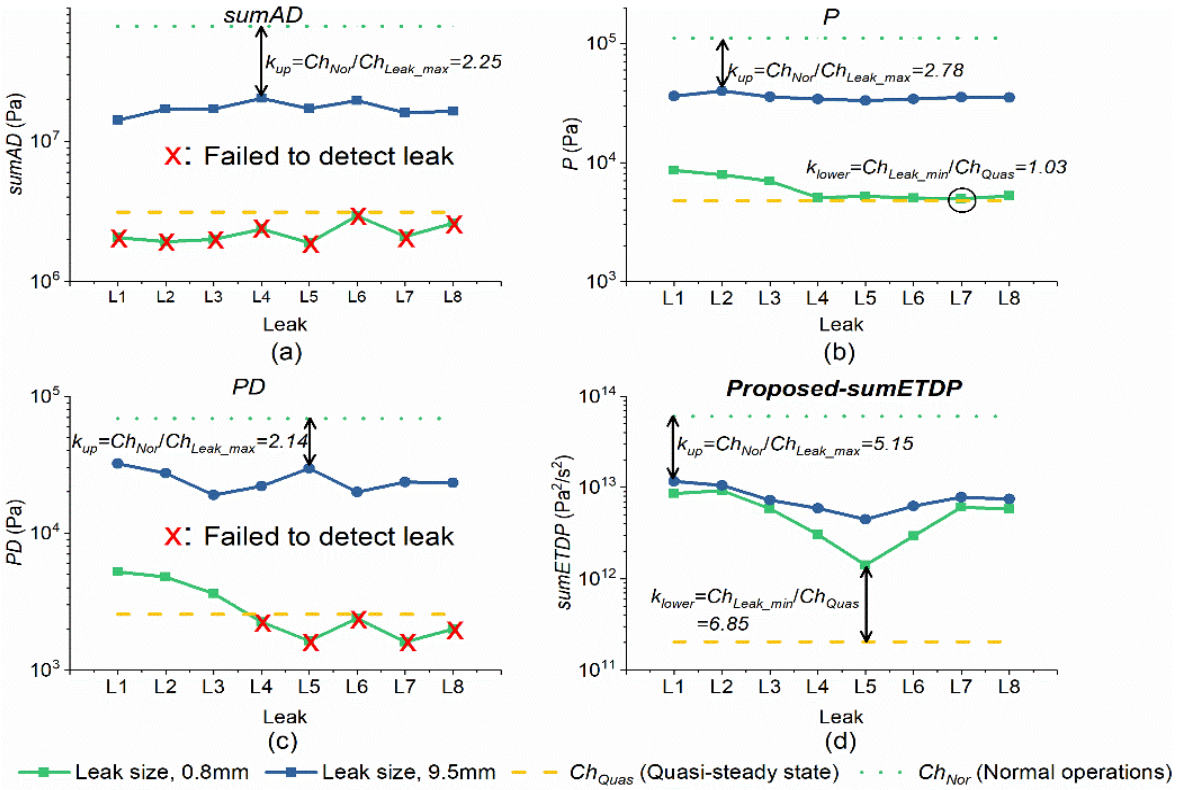
*Meng, Lingya, et al. "Experimental study on leak detection and location for gas pipeline based on acoustic method." *Journal of Loss Prevention in the Process Industries* 25.1 (2012): 90-102.

Outcome & achievements

2. False alarm rate less than 5% with lab experimental verification.

- Acoustic-based method with the proposed characterization ***sumETDP***

Characterization	Detection Success rate
Existing	
sumAD	46.875 %
P	96.875 %
PD	56.250 %
Proposed	
sumETDP	**100.000 %**



The false and missing alarm rates are both **0 %** using the proposed method.

National Metrology Centre A*STAR

Possible

26

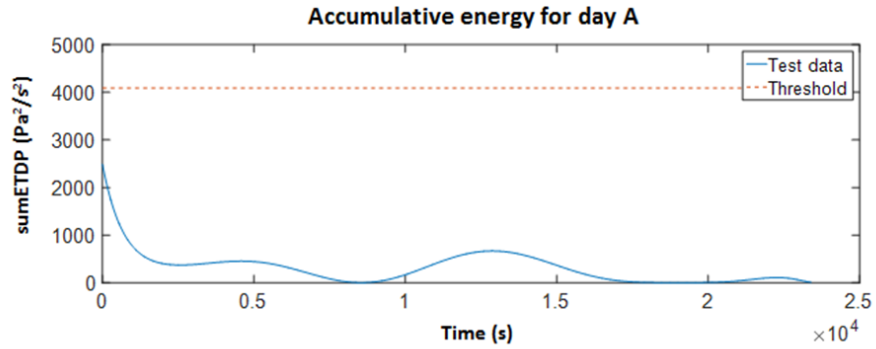
Outcome & achievements

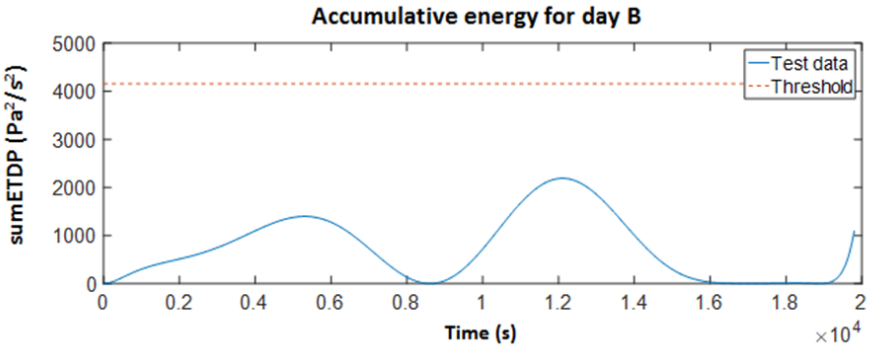
2. False alarm rate less than 5% with lab experimental verification.

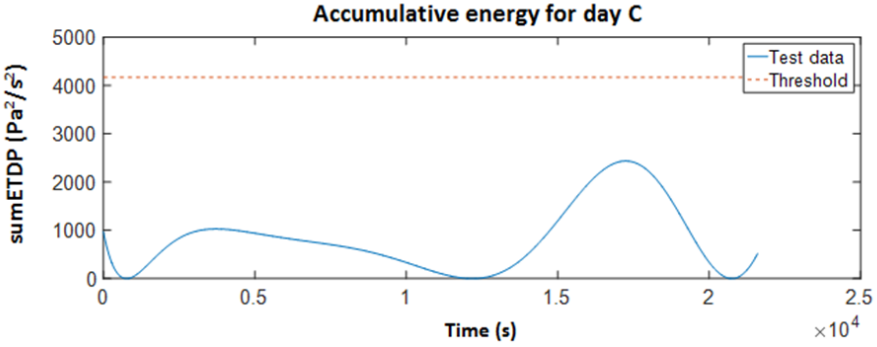
- Validation using actual field operation data (without leakage) from gas transmission pipelines

The false alarm rate is **0 %** using the proposed method.

  - As all test data is below the leak detection threshold







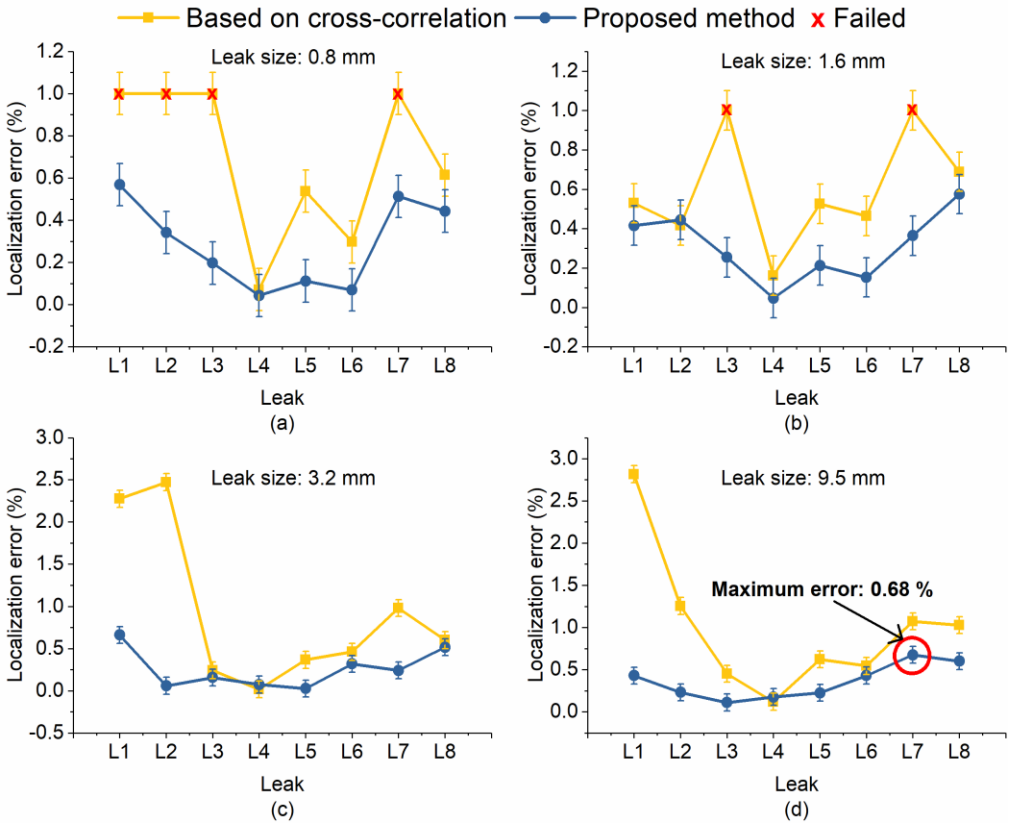
National Metrology Centre
A*STAR

Passion Made Possible

RESULTS AND FINDINGS

3. An accurate leak localization with error less than 1 % of the pipeline length.

- A proposed new technique for gas leak localization in pipelines



Operating pressure (bar)	Maximum error
35	**0.68 %**
28	**0.83 %**

Note: 64 cases, including 4 different leak sizes, 8 different locations and 2 pressure levels, were tested.

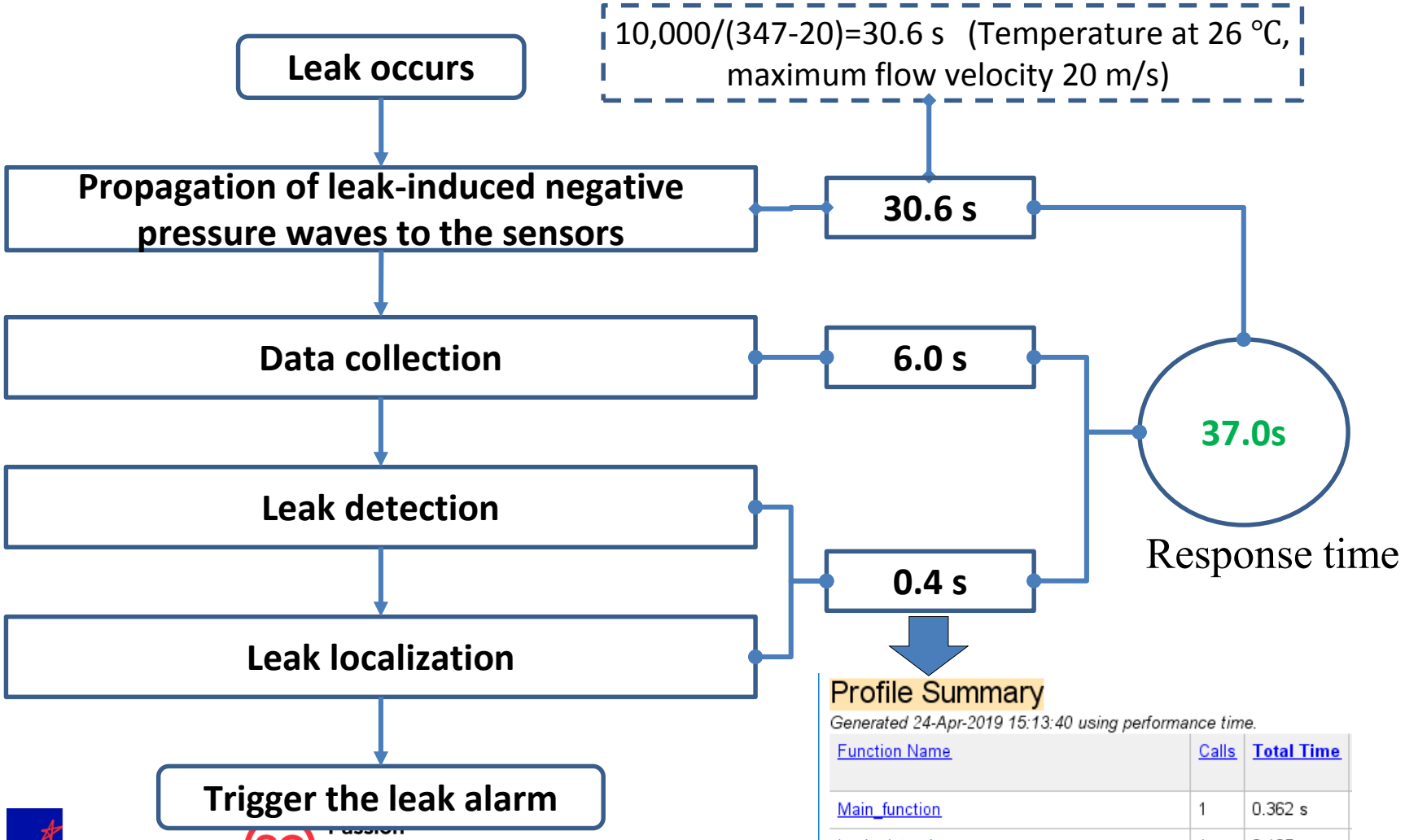
The invented method is being applied for intellectual property protection.

National Metrology Centre
A*STAR

Possible

RESULTS AND FINDINGS

4. A speedy leakage report system that is able to report a leak in 1 min



Profile Summary

Generated 24-Apr-2019 15:13:40 using performance time.

Function Name	Calls	Total Time
Main_function	1	0.362 s
Leak_detection	1	0.135 s
importdata	3	0.101 s
Leak_localization	1	0.077 s

National Metrology Centre

A*STAR

Made Possible

Publications

List of Publications

[1] S. Cui, and D. W. Y. Khoo, “Underwater calibration of hydrophones at very low frequencies from 30 Hz to 2 kHz”, The XXIInd IMEKO World Congress, 03-06 Sep 2018.

[2] Chen Runchang, Khoo Wee Yang David, Cui Shan, and Khoo Boo Cheong, “A Study of Plane Waves Propagating in a Pipe Filled with Real Gas”, ICSV25, 08-12 July 2018.

[3] David Wee Yang Khoo. A review on acoustical leak detection systems based on four criteria in api rp 1130. In 12th Pipeline Technology Conference, pages 81-91. May 2-4 2017. Berlin. Germany

[4] Sun Qiao, YANG Lifeng, Claire Bartoli, Ian Veldman, Gustavo P. Ripper, Thomas Bruns, Torben Rask Licht, Joanna Kolasa, Christian Hof, Guillermo Silva Pineda, Laurence Dickinson, Akihiro OTA, Yong Bong Lee, Alexander Yankovsky, and Cui Shan, “Final report of CCAUV.V-K3: key comparison in the field of acceleration on the complex charge sensitivity,” Metrologia, vol. 54, Tech. Suppl., 09001, 2017.

[5] Akihiro Ota , Hideaki Nozato , Tamio Ishigami, Wataru Kokuyama, Virat Plangsangmas, Pairoj Rattanangkul, Kuang Yih Tsuei, Yu-Chung Huang, Chan Chee Keong and Cui Shan, “Final report of the key comparison of APMP.AUV.V-K2,” Metrologia, vol. 54, Tech. Suppl., 09004, 2017.

[6] S. Cui, and Y. S. Meng, “Equivalent input noise measurement and its associated measurement uncertainties for MEMS microphones”, XXI IMEKO World Congress 31 Aug – 4 Sep 2015.

[7] S. Cui, H. A. Chua, and C. K. Chan, "Realization of medical ultrasound power measurement by radiation force balance method," MAPAN, vol. 27, pp. 251-255, Jan 2013.

National
Metrology Centre

A*STAR

CREATING GROWTH, ENHANCING LIVES

Thank you

Passion
Made
Possible