EUROPEAN
TURBINE
NETWORK

AIR FILTRATION WORKSHOP

20th February 2014 (Brussels)

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AAF

EUROPEAN TURBINE NETWORK

Workshop Agenda

Talks / Lectures

1) Introduction on air filtration principles, *Marc Van den Eynde, Camfil*

2) Standards EN779:2012, *Richard Ringström, Camfil*

3) Highlighting shortcomings of EN779:2012 standard and its' consequences on real life performance, *Richard Ringström, Camfil*

4) Standard EN1822:2009 – advantages and assurances for real life performance, *Richard Ringström, Camfil*

5) Impact of air quality on GT application (Capex versus Opex), *James Ross, AAF*

6) Current ongoing program regarding ISO-29461 standards, *Wim van Gelder, Donaldson*

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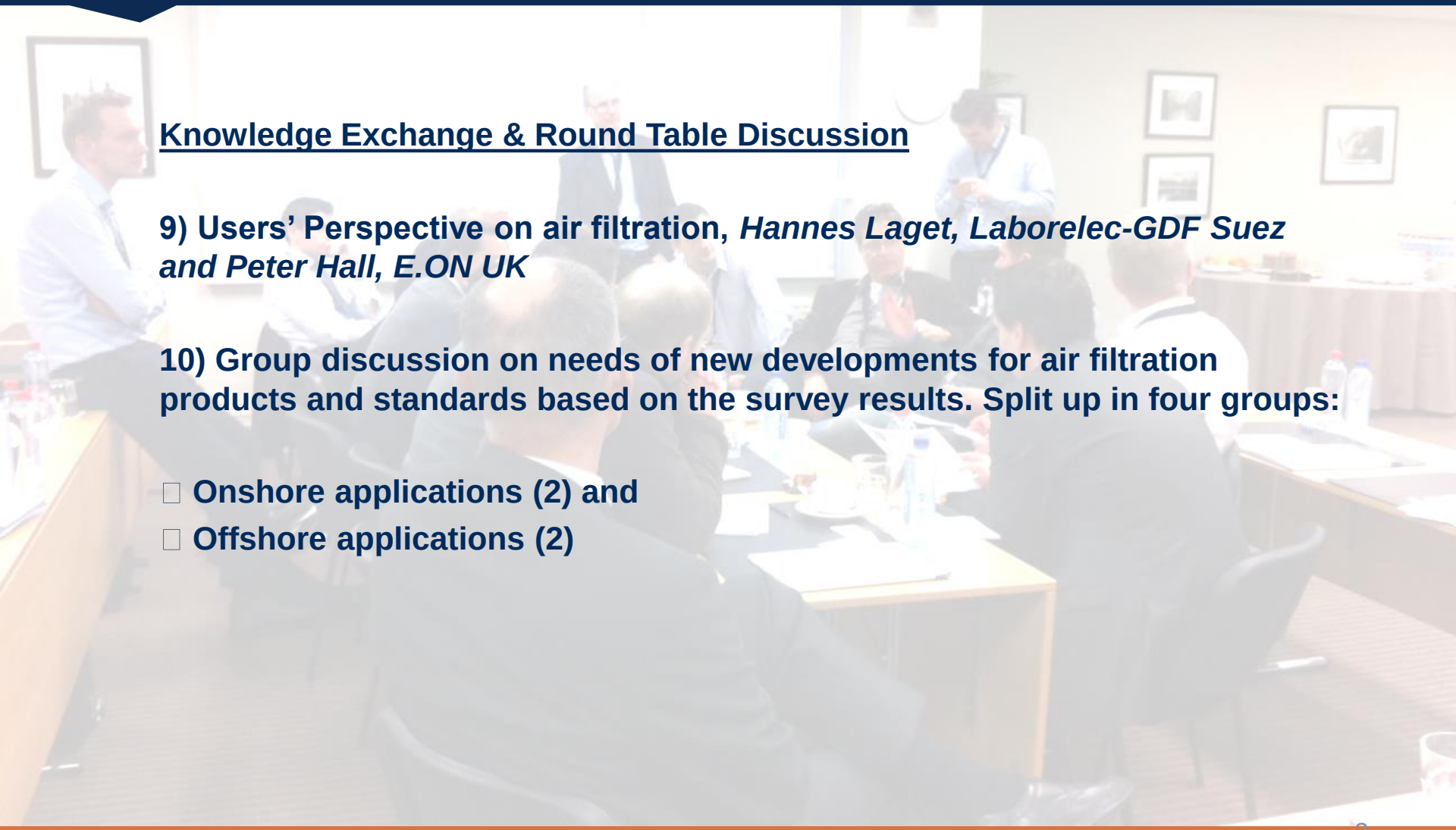
Workshop Agenda



Knowledge Exchange & Round Table Discussion

9) Users' Perspective on air filtration, *Hannes Laget, Laborelec-GDF Suez and Peter Hall, E.ON UK*

10) Group discussion on needs of new developments for air filtration products and standards based on the survey results. Split up in four groups:

- **Onshore applications (2) and**
- **Offshore applications (2)**

Lecture Highlights

Strong focus of filtration science and first principles

Understanding the challenge; mass of dust versus concentration of very small sub-micon particles; water, salt and RH

Significant scale of engine performance limiting particle ingestion (billions of sub-micron particles)

Zooming in on today's EN standards, test dusts, measurement techniques, comparing filter against filter

Update of EN-779 and its mandatory minimum efficiency rating (discharge effect)

How to interpret test data correctly

Initial Efficiency versus Average Efficiency (779 versus 1822); how this relates to engine performance

Lecture Highlights

ISO Standardisation

Ongoing projects within WG9

The actual ISO 29461 set of standards consists of:

- Part 1: Static filter elements
- Part 2: Cleanable (Pulse jet) filter systems
- Part 3: Mechanical integrity of filter elements
- Part 4: In-situ testing
- Part 5: Marine and Offshore environment filter systems
- Part 6: Cartridge testing method

Conclusions

A new set of ISO standards ISO 29461 (part 1 to 6) are dedicated to filters for rotary machinery where part 1 is ready.

Wider scope for air filtration for rotary machinery in different environments using different applications

A standard provides a solid base of performance comparison - real life will always be different.

Sharing experiences and feedback will be key.

Lecture Highlights

ISO Standardisation

ISO 29461-1:2013

"Static filter elements"

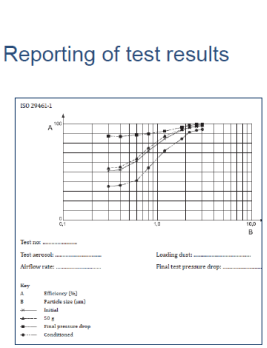
Base platform: EN779, ASHRAE 52.2, earlier ISO work

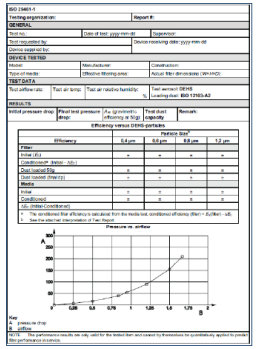
Cover filters from coarse to E11/E12 class
New treatment for electrostatically enhanced filters
No classification system yet included

→ released in 2013

ISO 29461-1:2013

Reporting of test results





ISO 29461-1:2013

New electrostatic discharge method
- IPA vapor treatment

Figure A.3 — Principle of the isopropanol container (vessel and lid)

Lecture Highlights

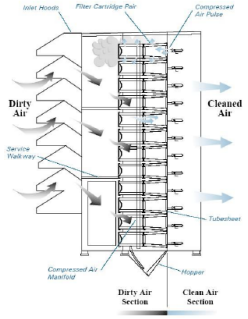
ISO Part 2 – 6 Definition and Scope

ISO 29461-2

Project work:

- Definition of scope
- Definition of test system
- Definition of test procedure
- Definition of test dust

- New approach for procedure



ISO 29461-5

"Marine and Offshore environment filter systems"

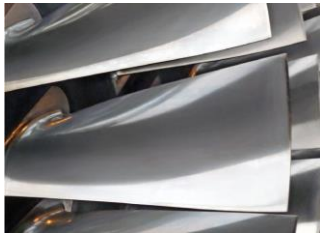
Salt challenge

- Dry, wet/deliquescent
- New vs. loaded filters

Running project

Lecture Highlights

CAPEX Vs OPEX



	Phase 1 & 2 CAPEX Plant Build Budget		**Phase 3 – 10 year period** Operating Expenditure due to performance losses
No HEPA	1 billion Euros		Power Gen (Lost Revenue) = 30k MwHrs = Euro 1.2m/annum Additional Fuel Burn (Costs) = 278k GJ = Euro 834k TEN YEARS & 3 ENGINES = 61m Euro's
Add HEPA	+ 650k Euro 1%	Negligible Installation Increase Ancillary Engineering costs	E12 Additional Filter Costs 506 elements per GT @ Euro 200 at 3yr increment = 1m Euro's opex increase for 3 GTs

Note typical inlet fiter and duct system for 260MW = nominal 1m Euro
Assumes 8000 hours baseload
MwHr at 40 Euro ~ GJ of Fuel 3 Euro per
Ignores Offline Forced Waterwash and Associated costs / lost revenue
Excludes any savings related to engine parts
10m Euro Typical large retrofit

Gas turbine air filtration – a user's perspective

Conclusions

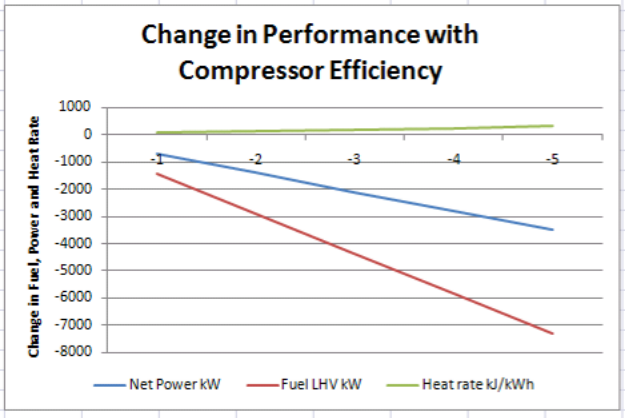
Higher final filter efficiencies turn generally in substantial benefits for the GT O&M

Water removal is a key factor in proper filter performance

A total cost of ownership approach enables the comparison of offers from different filter suppliers

Solutions – can we justify the cost?

compressor efficiency %	-1	-2	-3	-4	-5
Net Power kW	-702.2	-1404.4	-2106.6	-2808.8	-3511
Fuel LHV kW	-1460	-2920	-4380	-5840	-7300
Heat rate kJ/kWh	59.695	119.39	179.085	238.78	298.475



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Air Filtration Survey Explained

Structured questionaire with 38 questions issued in advance of workshop with rating system

Designed to capture the most important issues relative to Turbine filtration and engine operation

Extract questions

		Delta	Offshore (OG)	Onshore (PG)
Filter characteristics	11) Performance under variable relative humidity?	11	9.57	8.08
	12) Shaker test importance?	12	3.00	3.00
	13) Dry burst test? (continuous pressure drop)	13	6.20	5.22
	14) Wet burst test? (continuous pressure drop)	14	7.80	5.56
	15) Salt retention?	15	9.57	8.50
	16) Water repellency?	16	9.29	8.62
	17) Oil repellency?	17	8.71	6.25

0	Not Important
5	Moderately Important
10	Critical Importance

For user satisfaction as follows:-

0	Totally Unsatisfied
5	Barely Acceptable
10	Totally Satisfied

Air Filtration Survey Explained

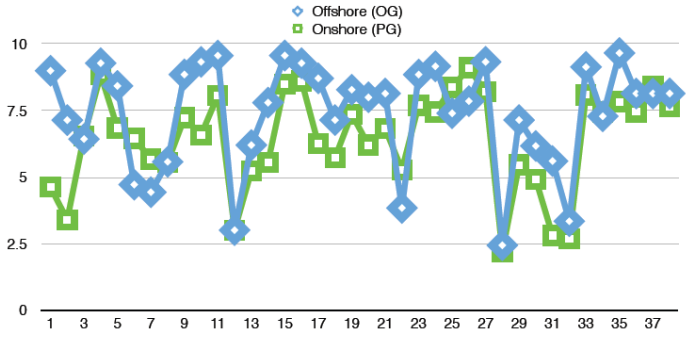
22 responses were recieved and compiled into a statistical model.

Contrast areas of importance and the gap in market satisfaction

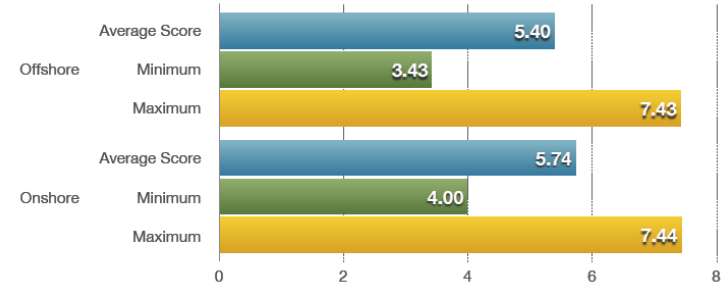
Divide the sectors O&G (Offshore) and Power Generation (Onshore)

Correlation of results between sectors

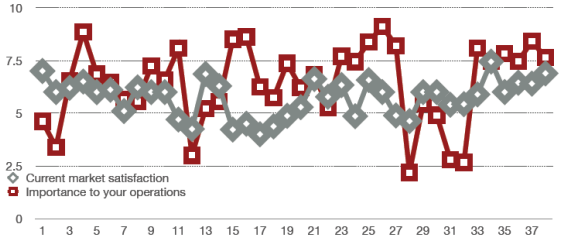
Graph 1: Operation Importance



Graph 4: Trend Comparison Satisfaction



CURRENT MARKET SATISFACTION ALONGSIDE IMPORTANCE TO YOUR OPERATION (ON-SHORE)



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DATA SUMMARY
IMPORTANCE RATING
38 Questions Rated Important Over 8

OFFSHORE
Questions Rated above 8 = 20

ONSHORE
Questions Rated above 8 = 9

TOP 3 BY HIGHEST RATING

1# Clean Compressor

2# Salt Retention

3# Performance under variable humidity

1# Final Filter service life

2# Filter System Performance

3# Water Repellence

GAPS BETWEEN IMPORTANCE & SATISFACTION

1# Salt retention

2# Water repellence

3# Filter test dust

1# Salt retention

2# Water repellence

3# Performance under variable humidity

ONLY 7 CATEGORIES

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Roundtable discussions

After dividing into three groups (x1 Off, x2 On)

Do we agree with our own results of the survey summary?

Importance Rating

Satisfaction – importance Gap

Try to explain how you interpreted the topics we will focus on now?

Conclusions and Follow-up Actions

Reduce the initial survey data and working group outcomes into a published report

ISO Standards – Joining Up the data with the standards

Make ALL Data Live through ETN

- All presentations available to ETN members
- ETN members to fill out the Survey in order to get a bigger reference database on importance and gaps.
- ETN & Filtration Companies → Suggest further steps for interactive cooperation between operators, OEM's and Filtration companies.

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End of Presentation

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