

AVL List GmbH (Headquarters)



# Monitoring & Diagnosis Expertensystem AVL EPOS™ für Haupt- und Hilfsmotoren

MCN Workshop Seevetal, 25.04.18

**H. Mohr, V. Lamaris,  
R. Teichmann**

# Introduction



We all know:

Engines operate fine in the field ...

... until wear & tear happens.

Therefore – and to avoid incidents as shown left - AVL developed an expert system allowing

- permanent engine monitoring and early fault detection
- direct root cause information
- detailed knowledge on engine reliability and performance
- optimized engine balancing
- data-stock for condition-based maintenance
- NO<sub>x</sub>, SO<sub>x</sub> and CO<sub>2</sub> emission tracking

Let's see ...



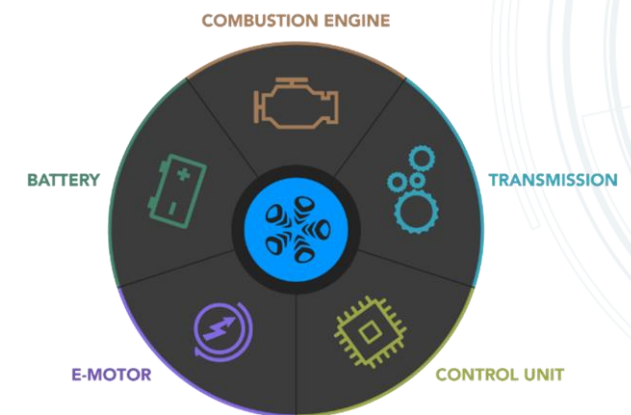


- Introduction
  - AVL as company
  - AVL EPOS™ Expert Condition Monitoring
- Field Experiences
  - 2-Stroke Engines
  - 4-Stroke Engines
  - Multi-Engine Application
- Outlook
- Conclusion

# Our Experience for your Success



- AVL achieves unique results in regards to the development and improvement of all types of powertrains as well as in the field of measurement and test technology.
- AVL – over 65 years' experience
- Involved in more than 1,500 engine development projects
- More than 4,000 engine testbed installations





# Solutions for all Customer Segments



Passenger Cars



2-Wheelers



Racing



Construction



Agriculture



Commercial Vehicle



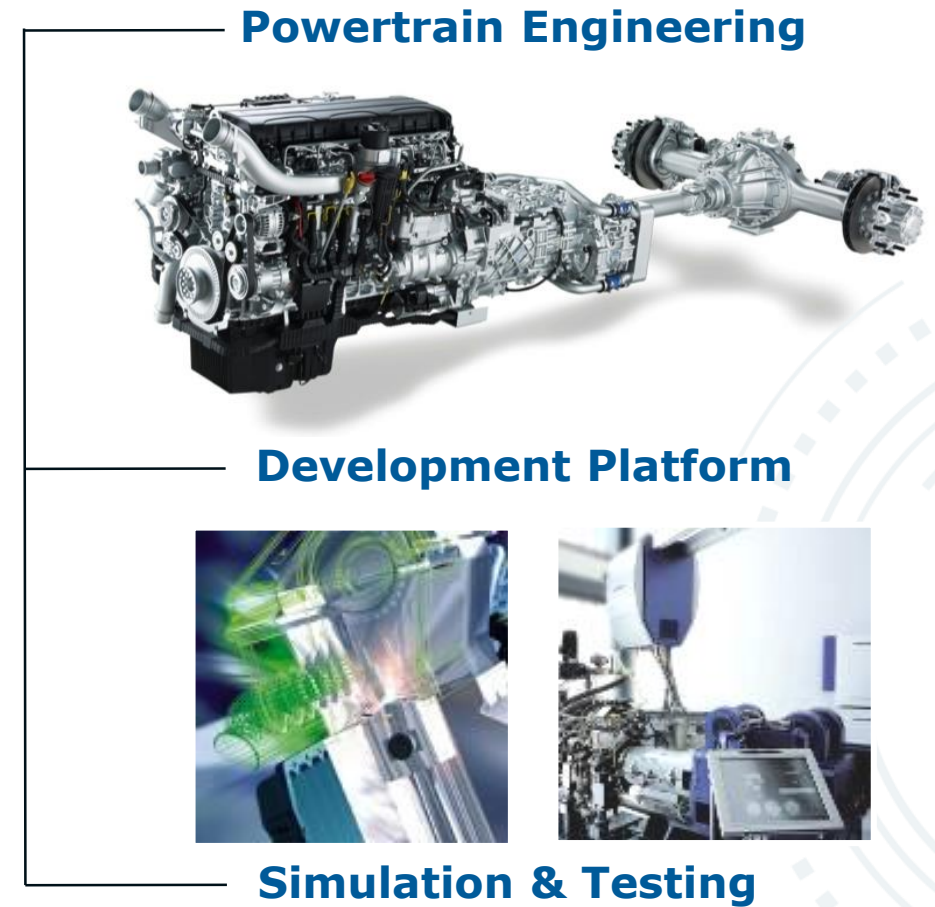
Locomotive



Marine



Power Plants



# Enterprise Development

**RESEARCH 10%**  
of turnover in-house R&D

**INNOVATION 1500**  
granted patents

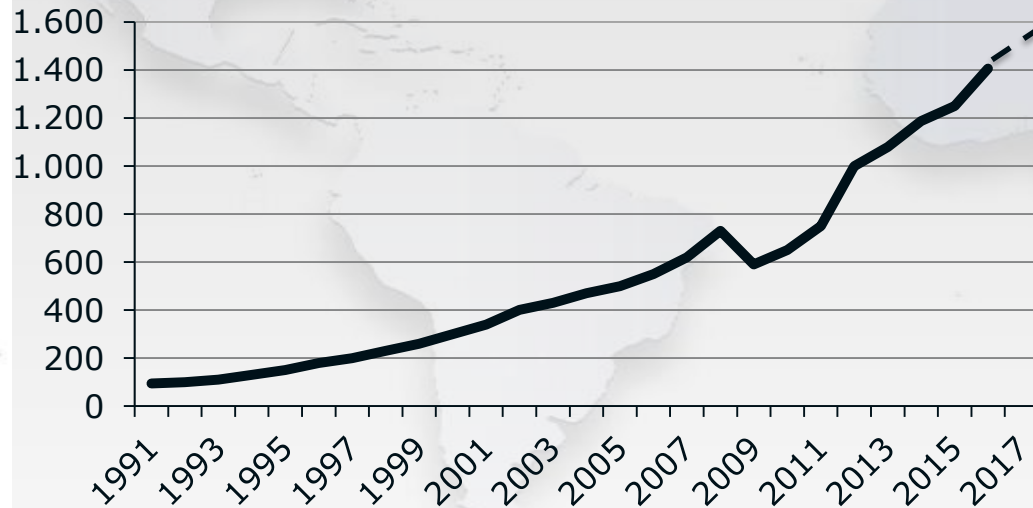
**STAFF**  
**9.500** employees

**65%** engineers and  
scientists

**GLOBAL FOOTPRINT**

- 30** engineering locations
- >220** testbeds
- Global customer support network

## GROWTH



## SALES

1995:  
0.15 billion €

2017:  
1.55 billion €

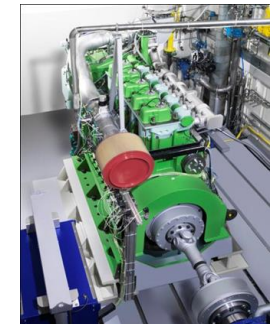
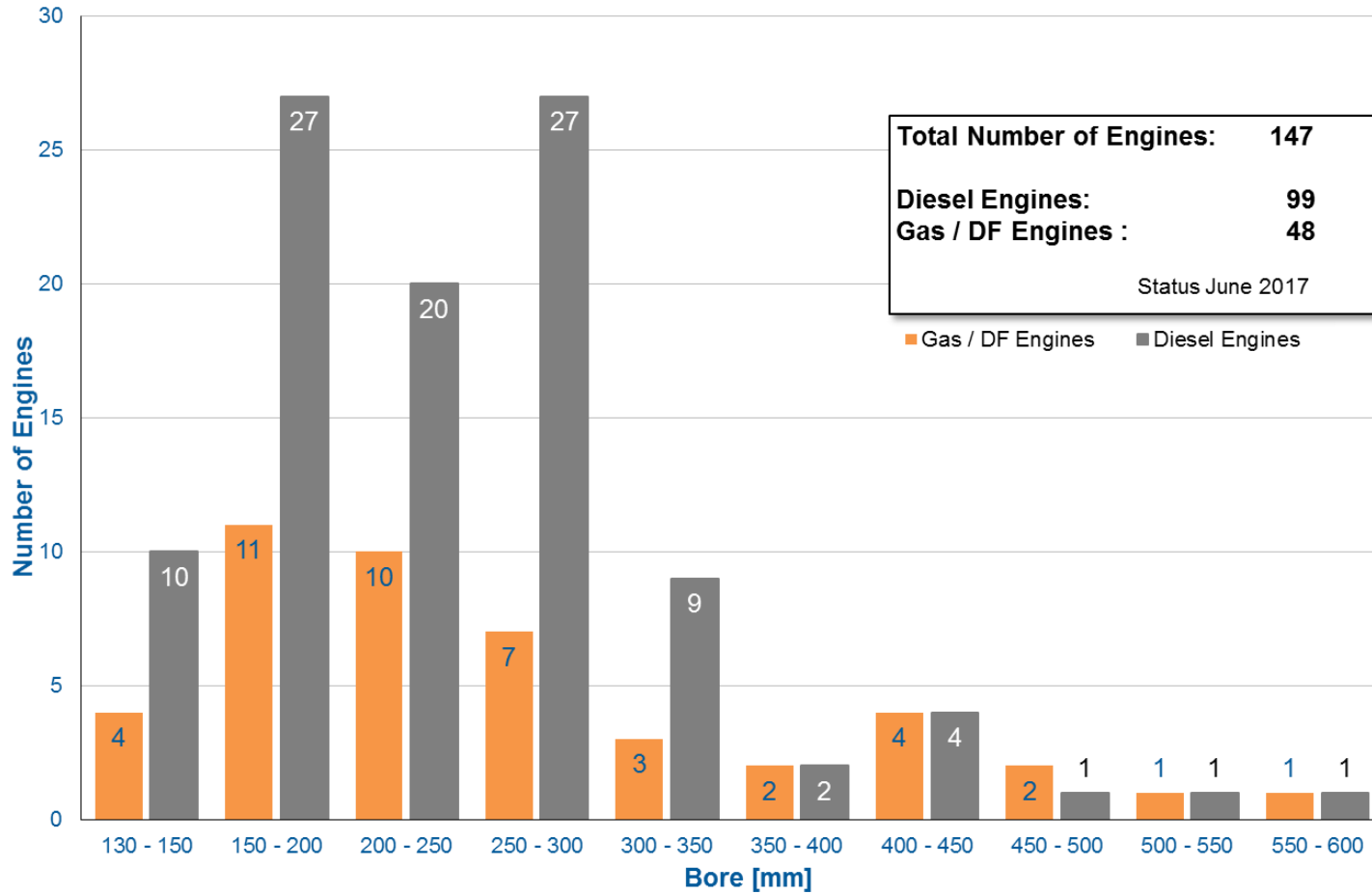
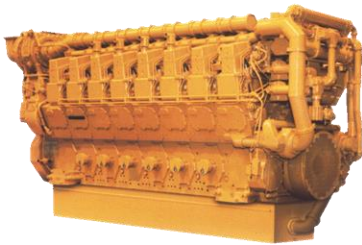
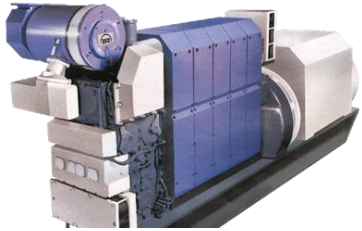
Plan 2018:  
1.71 billion €

**EXPERIENCE**  
**70** years !

**5** powertrain  
elements

**ONE  
PARTNER**

# Large Engines Designed by AVL





# User Reference: Fred. Olsen Express DF-Conversion



## CAT 3618 DF-Conversion for High-Speed Craft Application for

- reducing fuel consumption costs
- improving 'green' image

### Project Tasks:

- DF-conversion concept incl. BOOST engine modelling
- detail and layout design
- CRUISE M modelling for early demonstration of operational behavior for customer and class
- preparation, supervision and evaluation of prototype engine testing at 3<sup>rd</sup> party test bed provider
- participation in engine commissioning on board





# Field Application Services

## Examples

- Excessive Liner Wear Survey
- Root-Cause Investigation for Piston Crown Rupture
- FIE Quality Improvement Potential Evaluation
- Bearing Seizure Analysis
- TC Retrofit Layout Check
- Liner Cracking at High Load – Specification & Production Evaluation



## Tasks

- Inspection on Board/at Site by dedicated & OEM independent Experts
- Data & Information Collection
- Internal Root-Cause Investigations
- Use of Simulation Tools
- Elaboration of Improvement Tasks
- Report Generation, Presentation & Discussion @ Customer
- Follow-up & Evaluation of Improvement

# Expert Condition Monitoring System



**AVL EPOS™**  
PREDICTABLY POWERFUL





# AVL EPOS™ in a Nutshell



## Expert Condition Monitoring System

- for all Large-Bore Engines (2-/4-strokes)
- for all Fuels (HFO, MDO, Gas, ...)
- for all Applications
- for Newbuilts and Retrofits

**Permanent evaluation** of engine behavior with regard to reliability, performance and emissions

**Operators benefit** from early fault detection, avoidance of severy engine damages & fuel savings (up to 3 %)

## More than 125 installations on

- Car Carriers
- Container Vessels
- Crude Oil Carriers
- RoPAX Ferries
- Cruise Liners
- Locomotive
- Power Plants

**Very flexible system concept** allow integration of other components and integration into other systems.





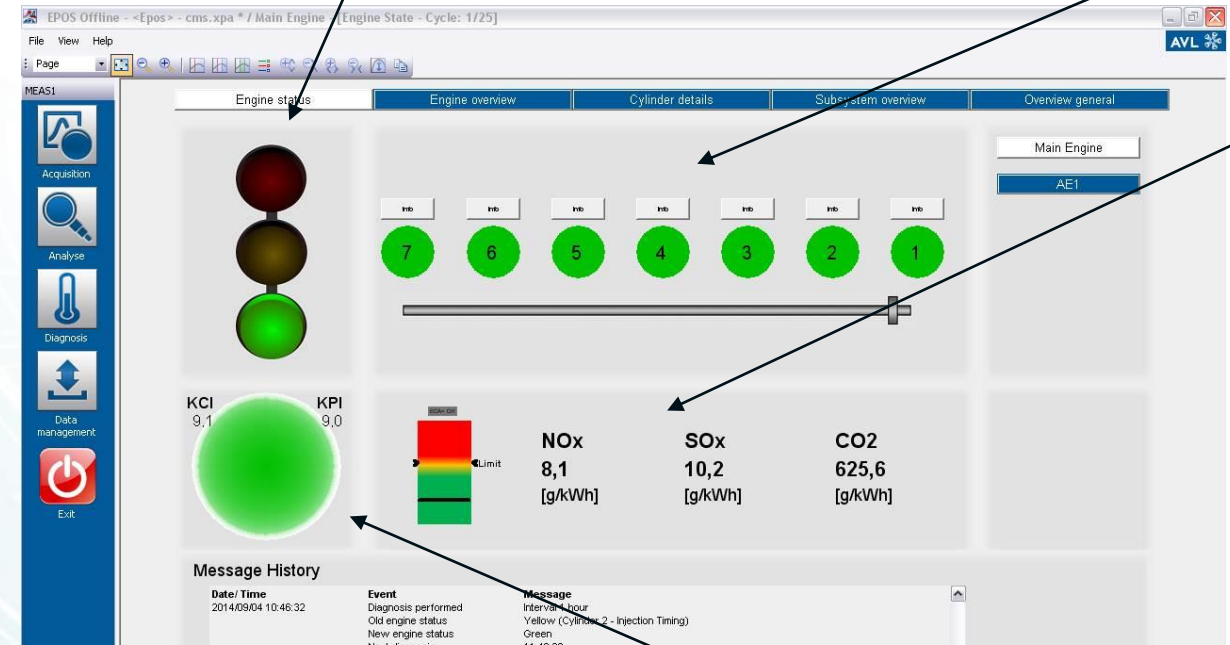
# AVL EPOS™ Work Environment

ENGINE STATUS via simple TRAFFIC LIGHT indicator

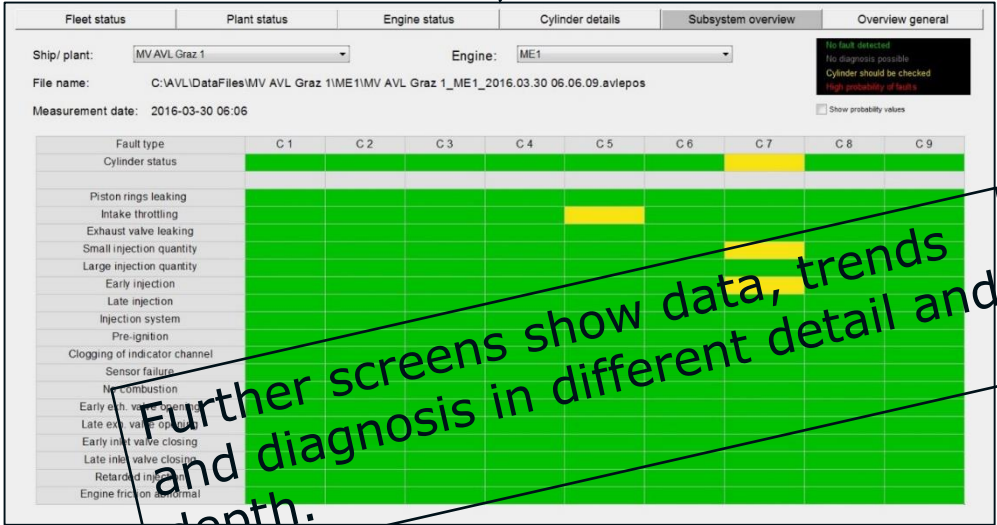
CYLINDER STATUS via TRAFFIC LIGHT colours

EMISSION MONITOR (optional)

FAILURE MATRIX – evaluation of measurement data regarding predefined engine faults



**KEY CONDITION INDEX (KCI)** – tracking engine condition via one parameter – how 'healthy' is the engine?  
**KEY PERFORMANCE INDEX (KPI)** – tracking engine performance via one parameter – how 'efficient' is the engine?

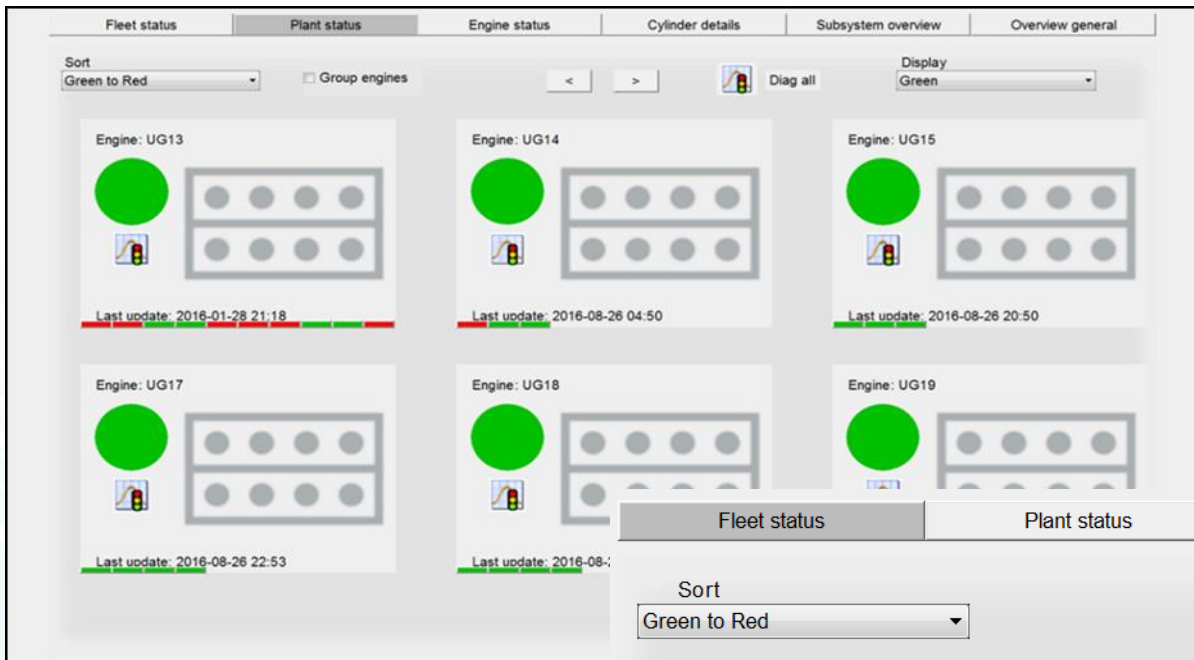


Fault type	C 1	C 2	C 3	C 4	C 5	C 6	C 7	C 8	C 9
Cylinder status	Green	Green	Green	Green	Green	Green	Green	Green	Green
Piston rings leaking	Green	Green	Green	Green	Green	Green	Green	Green	Green
Intake throttling	Green	Green	Green	Green	Green	Green	Green	Green	Green
Exhaust valve leaking	Green	Green	Green	Green	Green	Green	Green	Green	Green
Small injection quantity	Green	Green	Green	Green	Green	Green	Green	Green	Green
Large injection quantity	Green	Green	Green	Green	Green	Green	Green	Green	Green
Early injection	Green	Green	Green	Green	Green	Green	Green	Green	Green
Late injection	Green	Green	Green	Green	Green	Green	Green	Green	Green
Injection system	Green	Green	Green	Green	Green	Green	Green	Green	Green
Pre-ignition	Green	Green	Green	Green	Green	Green	Green	Green	Green
Clogging of indicator channel	Green	Green	Green	Green	Green	Green	Green	Green	Green
Sensor failure	Green	Green	Green	Green	Green	Green	Green	Green	Green
No combustion	Green	Green	Green	Green	Green	Green	Green	Green	Green
Early exhaust valve opening	Green	Green	Green	Green	Green	Green	Green	Green	Green
Late exhaust valve opening	Green	Green	Green	Green	Green	Green	Green	Green	Green
Early intake valve closing	Green	Green	Green	Green	Green	Green	Green	Green	Green
Late intake valve closing	Green	Green	Green	Green	Green	Green	Green	Green	Green
Retarded injection	Green	Green	Green	Green	Green	Green	Green	Green	Green
Engine friction abnormal	Green	Green	Green	Green	Green	Green	Green	Green	Green

Further screens show data, trends and diagnosis in different detail and depth.

# AVL EPOS™ Work Environment

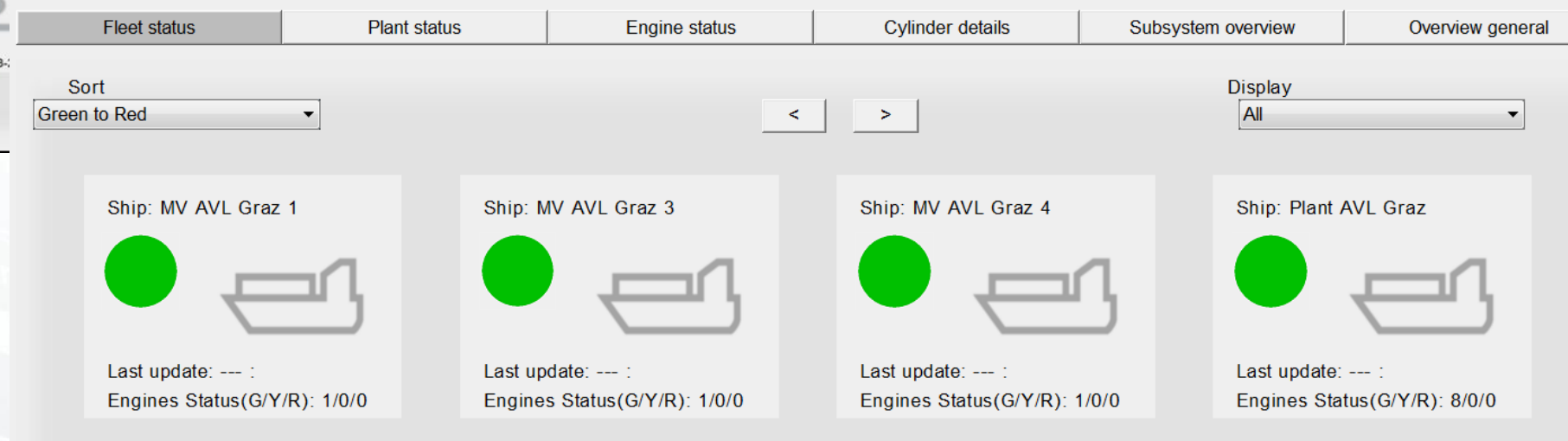
## Plant / Fleet Graphical User Interface



Fleet status | **Plant status** | Engine status | Cylinder details | Subsystem overview | Overview general

Sort: Green to Red |  Group engines | < > | Diag all | Display: Green

Engine ID	Last update
Engine: UG13	2016-01-28 21:18
Engine: UG14	2016-08-26 04:50
Engine: UG15	2016-08-26 20:50
Engine: UG17	2016-08-26 22:53
Engine: UG18	2016-08-26 22:53
Engine: UG19	2016-08-26 22:53



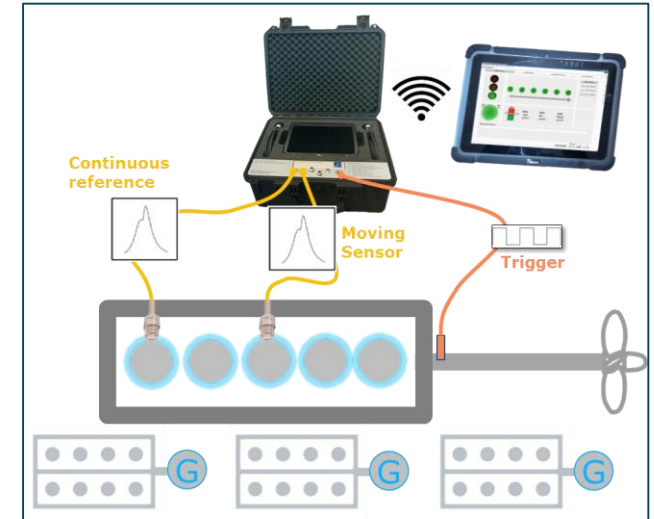
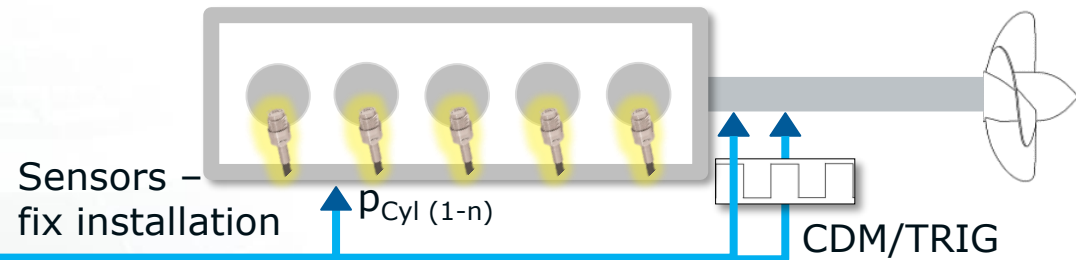
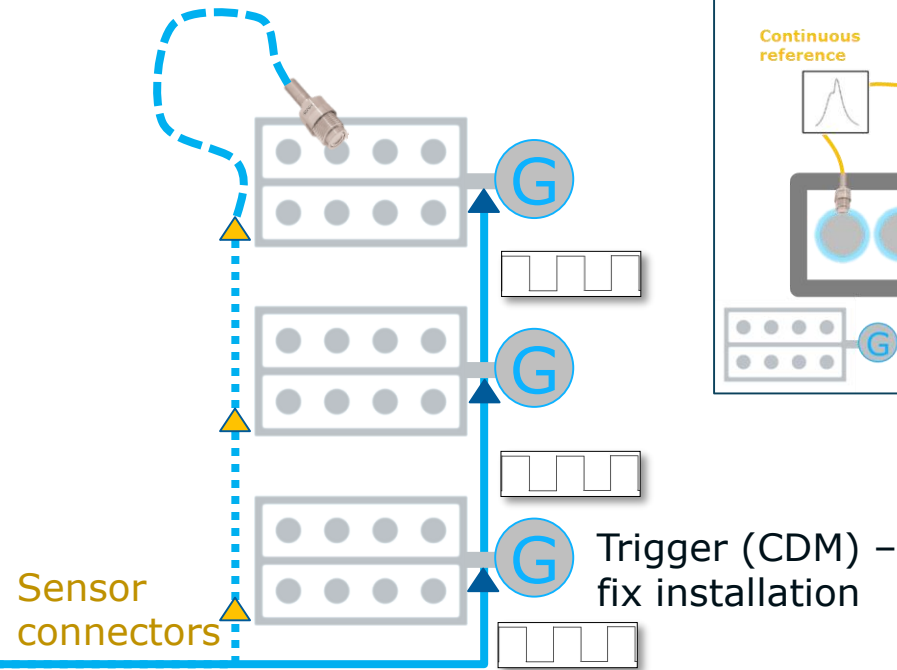
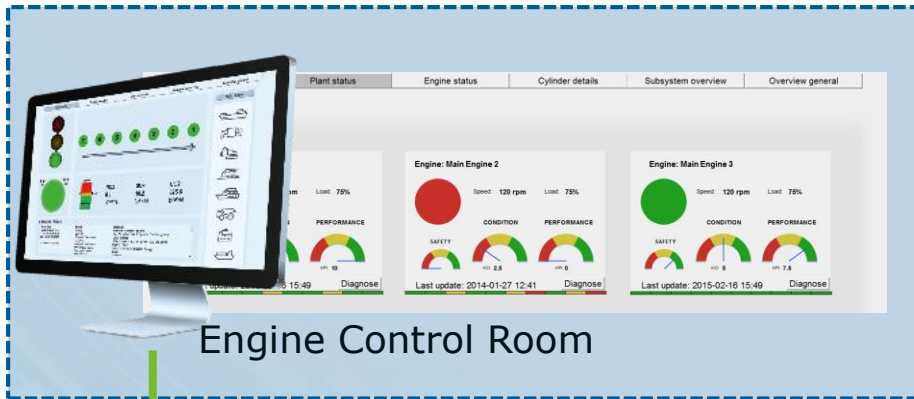
Fleet status | **Plant status** | Engine status | Cylinder details | Subsystem overview | Overview general

Sort: Green to Red | < > | Display: All

Ship Name	Last update	Engines Status(G/Y/R)
Ship: MV AVL Graz 1	---	1/0/0
Ship: MV AVL Graz 3	---	1/0/0
Ship: MV AVL Graz 4	---	1/0/0
Ship: Plant AVL Graz	---	8/0/0

# AVL EPOS™ System Configurations

## Full Diagnosis Functionality





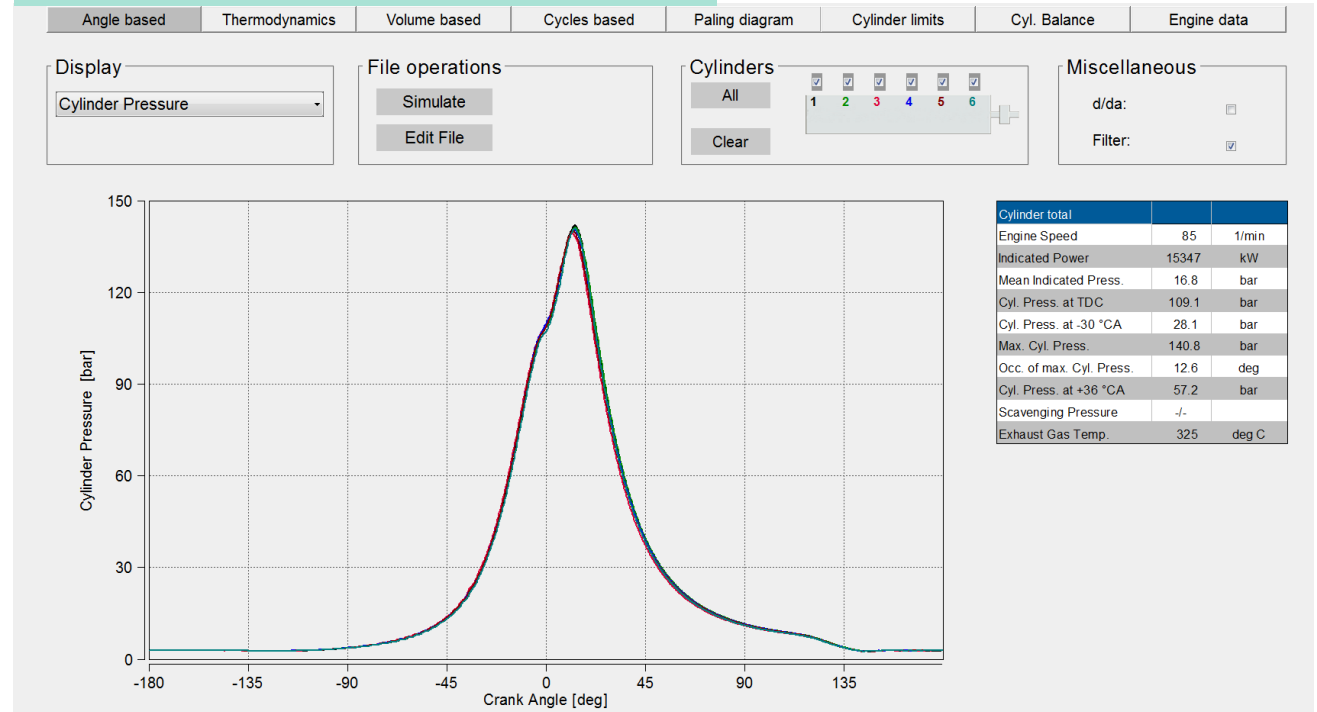
# Field Experience 2-Stroke Engine

## Engine Performance Analysis & Evaluation

### M/T Vessel



### Measured Cylinder Pressure Traces

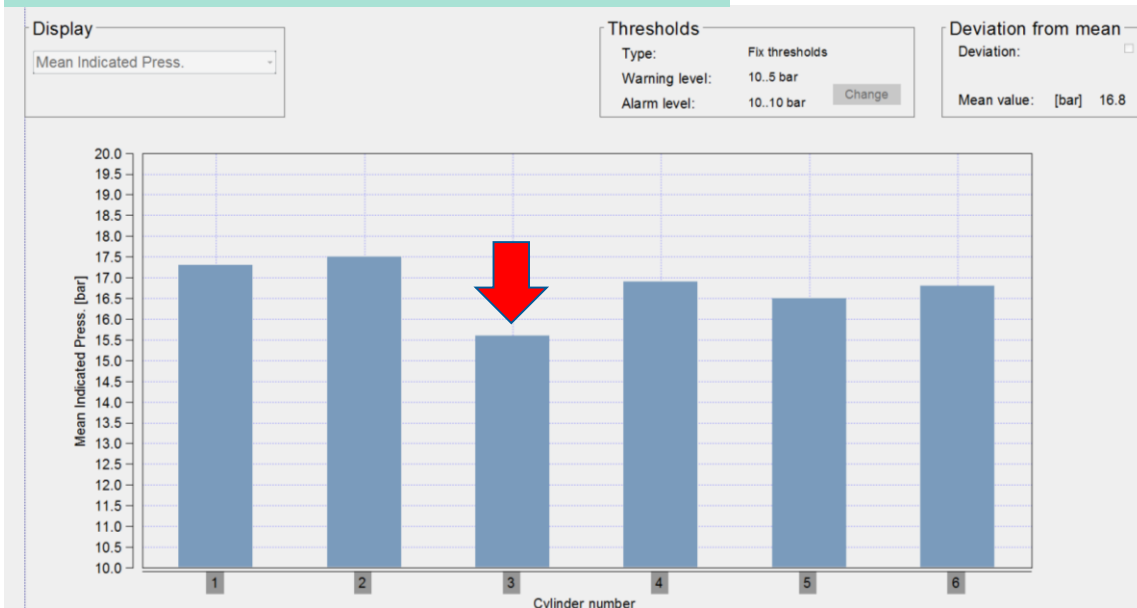


Cylinder Pressure Traces → No significant deviations between cylinders are detected

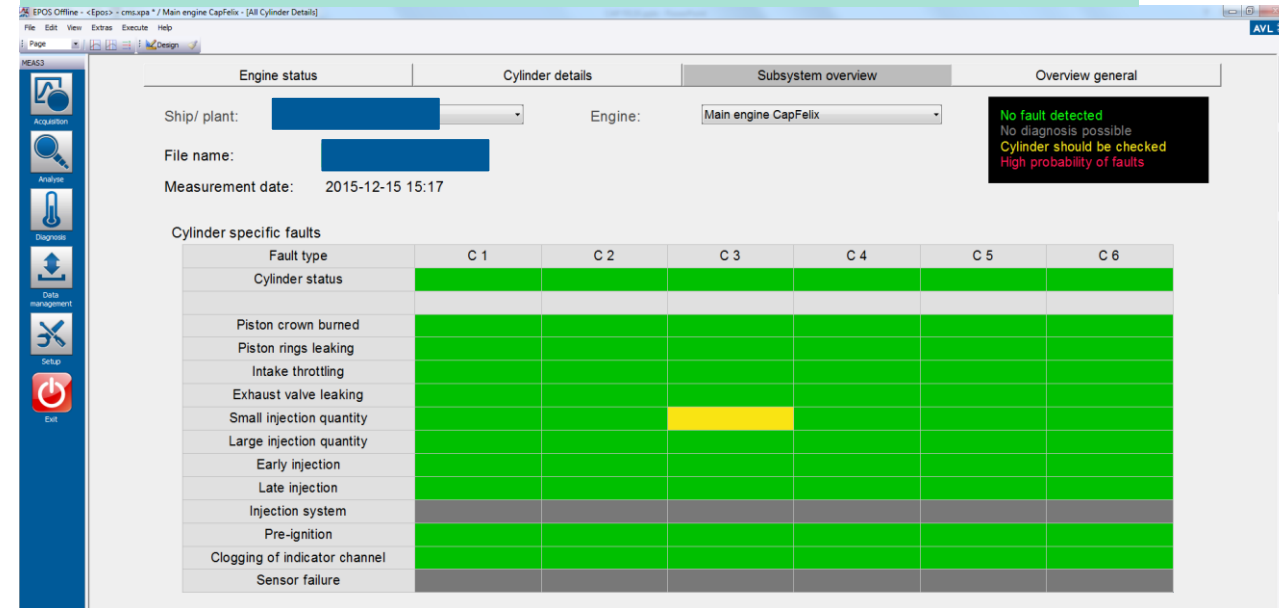
# Field Experience 2-Stroke Engine

## Engine Performance Analysis & Evaluation

### Cylinder Mean Indicated Pressures



### AVL EPOS™ Diagnosis Results – Subsystems Overview

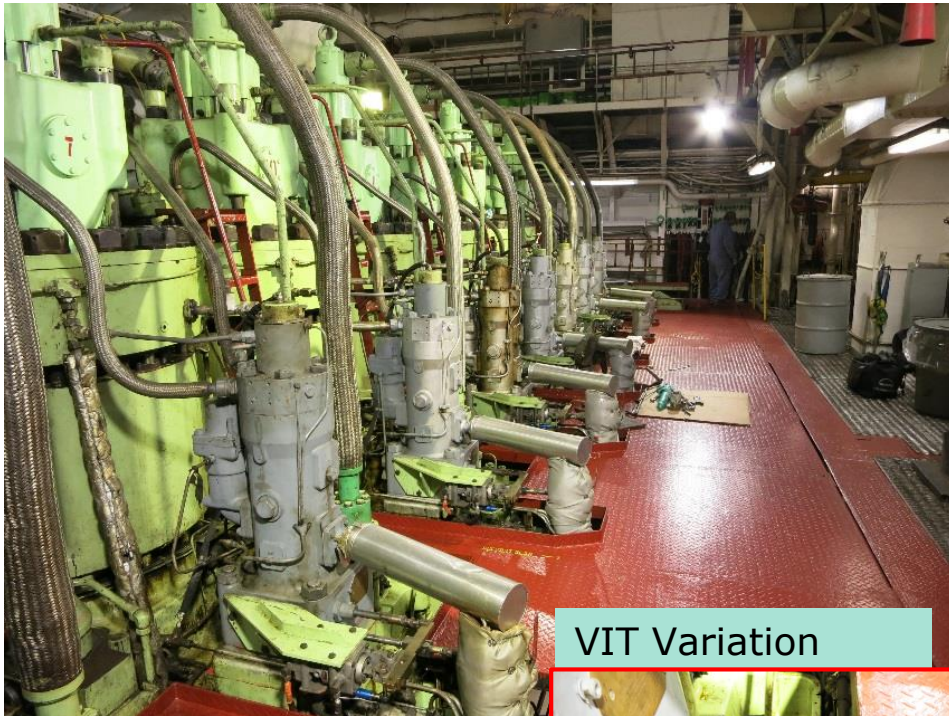


- AVL EPOS™ indicated that cylinder no. 3 has lower fuel quantity which causes the lower mean indicated pressure ( ~10 % lower compared to mean value of all cylinders)
- Fuel pump & fuel rack has been checked → excessive wear of fuel pump detected!!!

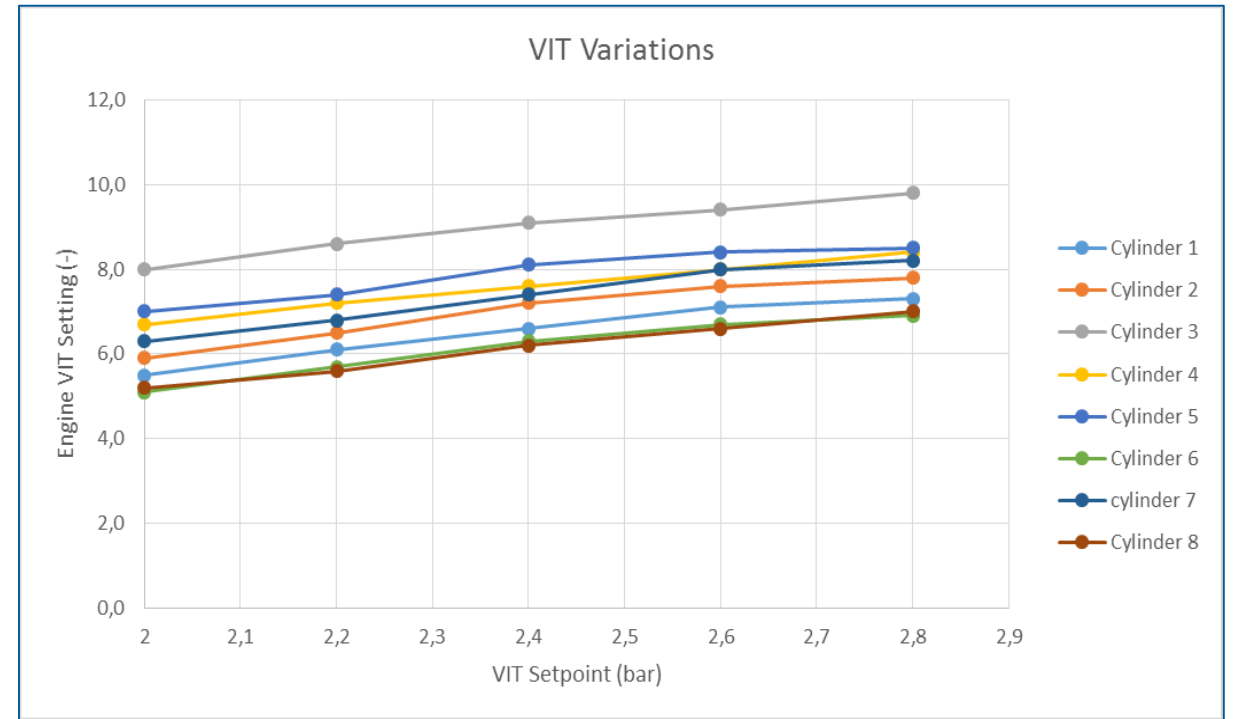
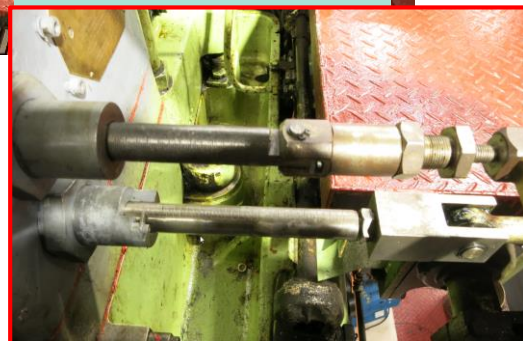
# Field Experience 2-Stroke Engine

## Engine Performance Optimization – BSFC Improvement

### Slow-speed Diesel Engine



VIT Variation

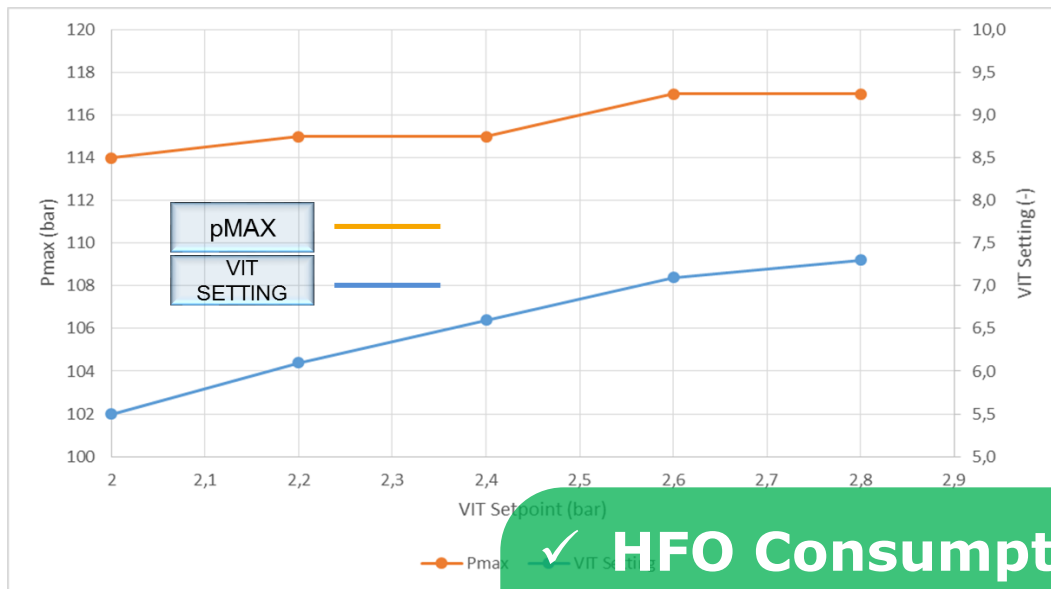




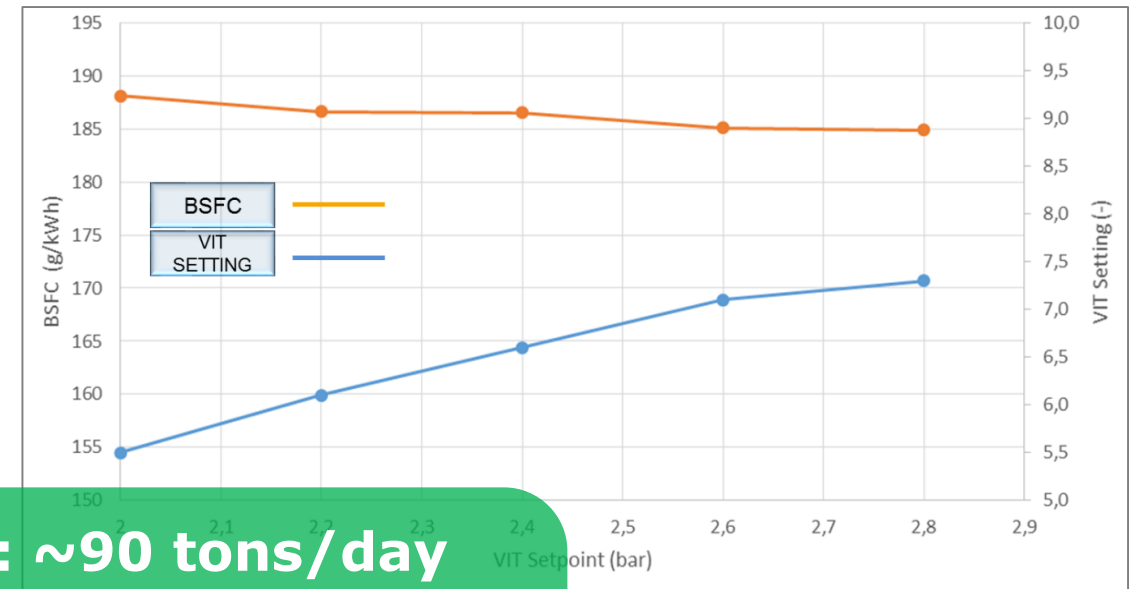
# Field Experience 2-Stroke Engine

## Engine Performance Optimization – BSFC Improvement

### $p_{max}$ -Variation vs. VIT



### BSFC-Variation vs. VIT



✓ **HFO Consumption: ~90 tons/day**

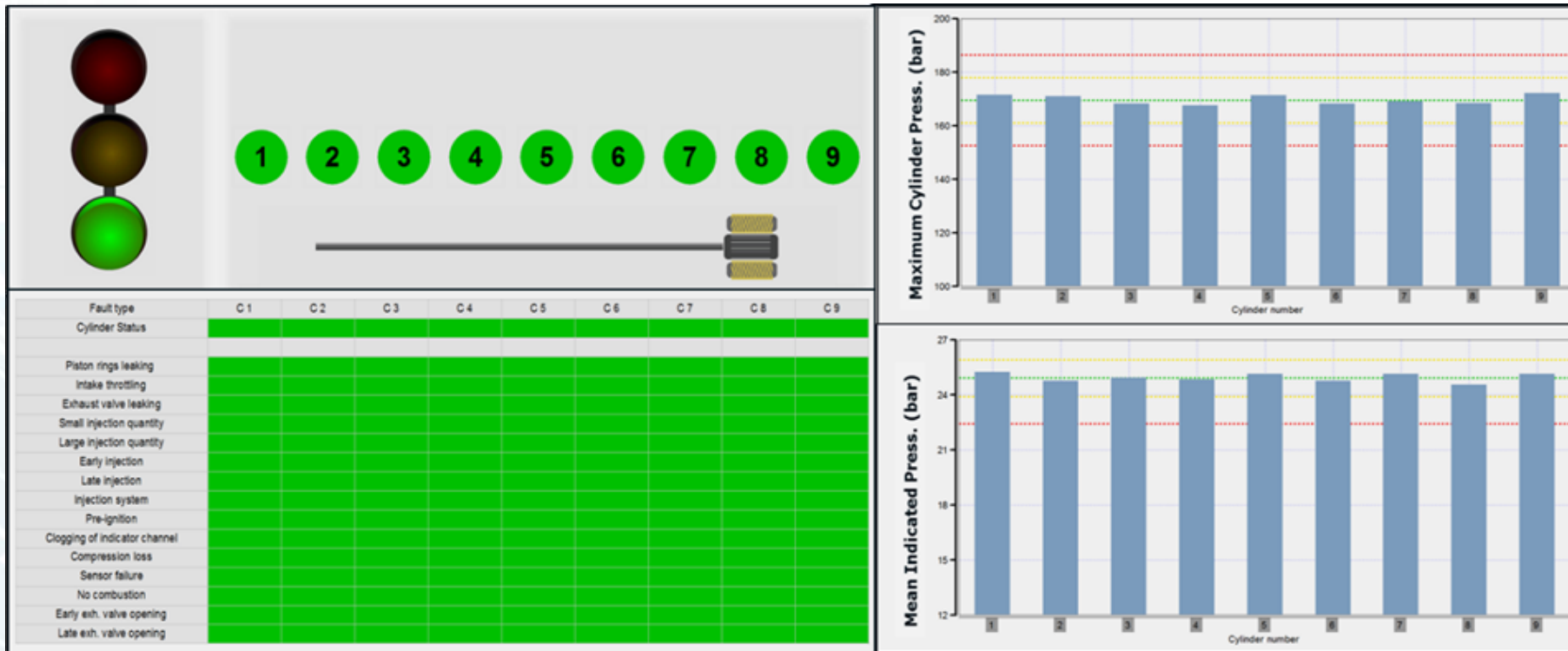
✓ **BSFC improvement → ~2-3 g/kWh**

✓ **Fuel Savings → ~60 tons/month !!!**

# Field Experience 4-stroke Marine Engine

## Engine Performance Optimization – Cylinder Balancing

Optimized Engine tuning based on AVL EPOS™ Indications & Analysis



- ✓ **Optimized cylinder balancing**
- ✓ **~1.5 % improved fuel efficiency**
- ✓ **Lower mechanical stress on crankshaft**

# Field Experience Multi Engine Application



- Linhares Geracao Power Plant in Brazil (207 MW<sub>el</sub>)
  - 24 medium-speed 20V gas engines, all equipped with AVL EPOS™
  - Cylinder pressure sensors achieved more than 16,000 h meanwhile
  - 16,500 measurements with corresponding expert engine diagnosis available
  - 107 events detected (cylinder misfire & balancing, gas admission valve malfunction, inlet/exhaust valve leakages, knocking behavior, ...)
- ⇒ Operator **saved approx. 1.5 Mio €** in first year of operation due to **optimized operation, early fault detection** and **avoidance of unplanned stops**



# Outlook

Cloud Services



Data Transfer



AVL EPOS™ Fleet  
ashore  
@ Owner/Operator  
or  
@ AVL Service

Ship: AVL 3

Ship: AVL 2

Ship: AVL 1

Last update: 2015-04-14 08:23  
Engines Status (G/Y/R): 3/0/0

AVL EPOS™ on Ships  
Local fast diagnosis  
Goal: full engine room  
expert monitoring



... as precondition for  
further use of **BIG** data  
to support ...

Fleet  
Operation  
Centers



# Potentials NO<sub>x</sub>-Monitoring & Optimization

Monitoring of **NO<sub>x</sub>, SO<sub>x</sub> and CO<sub>2</sub>** emissions of your fleet based on thermodynamic calculation (no analyzer required)

**Direct link** of engine emission to engine condition (cylinder specific emission values available)

Input to **fleet wide emission** tracking and **reporting** (MRV)

**Certified** compliance of system for NO<sub>x</sub> monitoring method



Exemplary calculation...

**Main engine** **40 MW**  
 NO<sub>x</sub> Base (of limit) 85 %  
 NO<sub>x</sub> Tuned (of limit) 95 %

Fuel consumption 15.000 t/year  
 Fuel savings (1.5%) 225 t/year

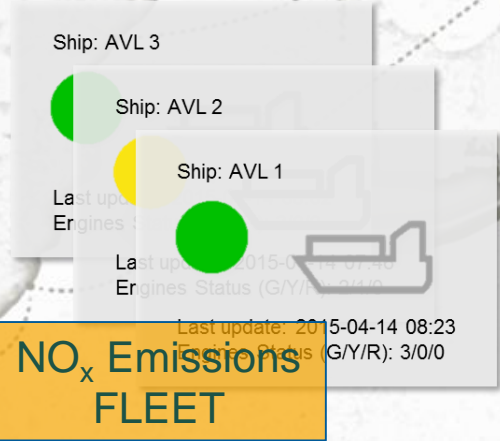
**Savings ~80.000 \$/year**



NO<sub>x</sub> Emissions Vessel 1



NO<sub>x</sub> Emissions Vessel 2





# Potentials NO<sub>x</sub>-Monitoring & Optimization

## Technical Approach

- Based on AVL's widely utilized combustion analysis software
- Two zone thermodynamical model based on cylinder pressure data
- Computation of combustion related properties from measured data
- Reaction-kinetic algorithm combines these cylinder individual parameters together with the corresponding engine and fuel data
- Accumulates NO<sub>x</sub>-emission results
- For complete emission report, CO<sub>2</sub> and SO<sub>x</sub> computed out of adjusted fuel mass balance

**No permanently installed emission analyzer necessary!**

## Required Input Data:

- Cyl. pressure curve
- Engine torque & speed
- Fuel consumption
- Bunker report
- Ambient conditions

Data accuracy is key for exact emission data, especially for cyl. pressure and fuel consumption

Gas Exchange and Combustion Analysis





- **Permanent monitoring** of main and auxiliary engines respectively the complete engine room enables **optimized operation with regard to fuel consumption and maintenance**
- Given reference examples show benefits clearly, in most cases **ROI** figures of **less than 2 years** are achieved
- Combination of **local intelligence for fast reaction/crew support and onshore fleet performance data evaluation** enable optimum ship management
- **Cloud services and big data technology** combined with ship/engine expertise & real-time ship simulation open **further improvement potential**
- **Additional detailed analysis technologies** require more and exact sensors, e. g. for fuel metering (AVL product in preparation)
- **Business models need to be flexible** – change from pure product offer to service agreement



# Thank You

**AVL** 

[www.avl.com](http://www.avl.com)

Contact:

Prof. Dr. Hinrich Mohr  
[hinrich.mohr@avl.com](mailto:hinrich.mohr@avl.com)

Dr. Vasilios Lamarinis  
[vasilios.lamarinis@avl.com](mailto:vasilios.lamarinis@avl.com)

Dr. Rüdiger Teichmann  
[ruediger.teichmann@avl.com](mailto:ruediger.teichmann@avl.com)