The Fast Path of the Molecules: from the Engine Cylinder to Mass Spec and what this has to do with Lube Oil Consumption

Sven Krause, Lars Schomann, Andreas Behn, Matthias Feindt,
Ann-Christin Preuss, Gerhard Matz

The 10th Harsh-Environment Mass Spectrometry Workshop
September 16 2015, Baltimore, MD

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Oil Emission Measurement Technology

IAM
INSTITUT FÜR ANALYTISCHE MESSTECHNIK HAMBURG E.V.

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Oil Emission Measurement Technology

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- Spin-off from Institute of Measurement Technology at Hamburg University of Technology (TUHH)
- Office in Hamburg on the campus of TUHH
- Close cooperation with research faculty TUHH
- Member from FVV, Hamburg

FVV

Der Wirtschaftsverein
für den Hamburger Süden

HK Hamburg Chamber of Commerce

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Shell

PAE Laboratory
Dr. Warnecke

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Institute of measure-
ment technology
Prof. Dr. Matz

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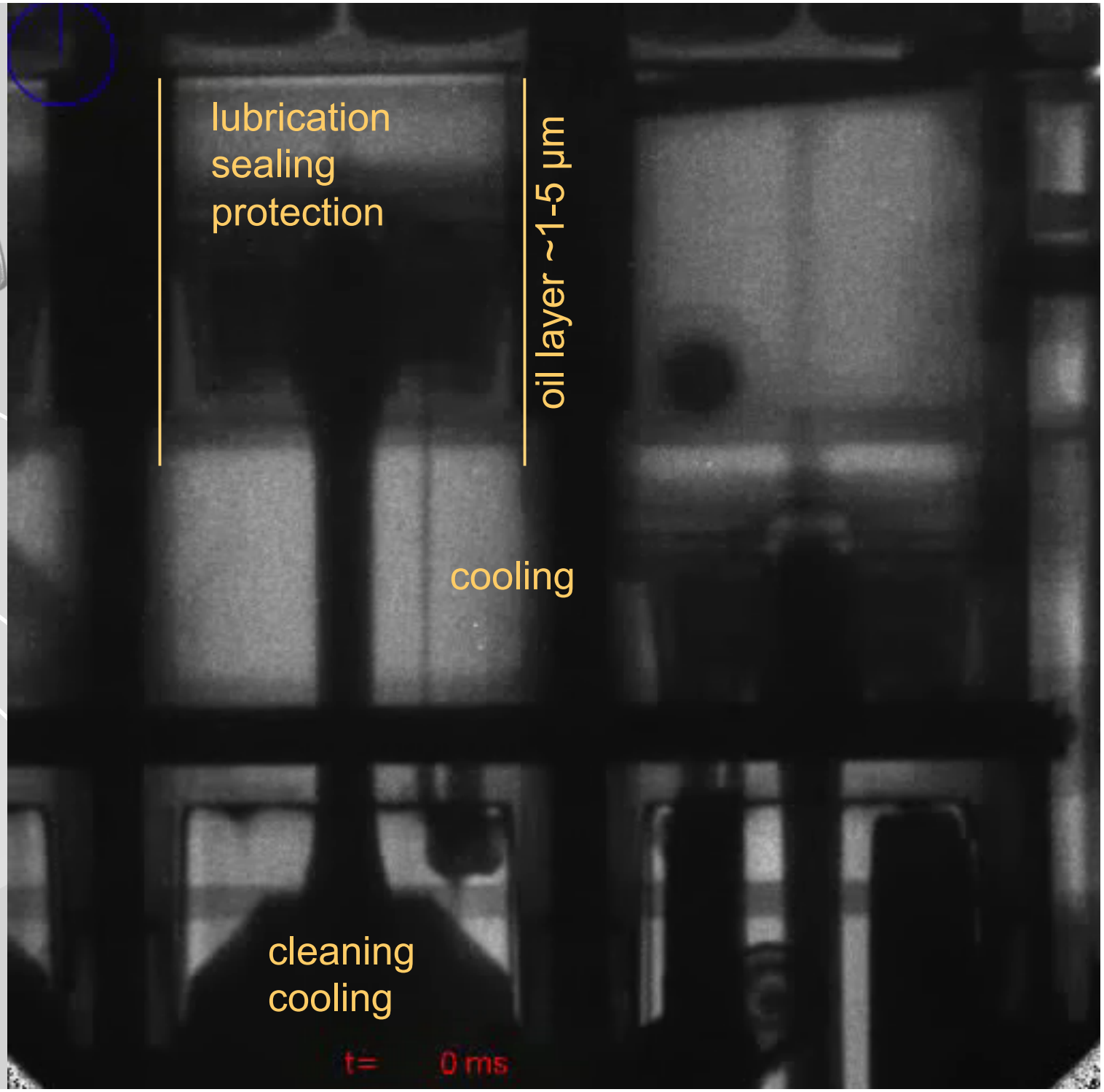
4-Stroke S.I. Engine

Cylinder 3 und 4

Tasks of the oil

Neutron Radiographie TU München FRM II
by courtesy of Dr. B. Schillinger



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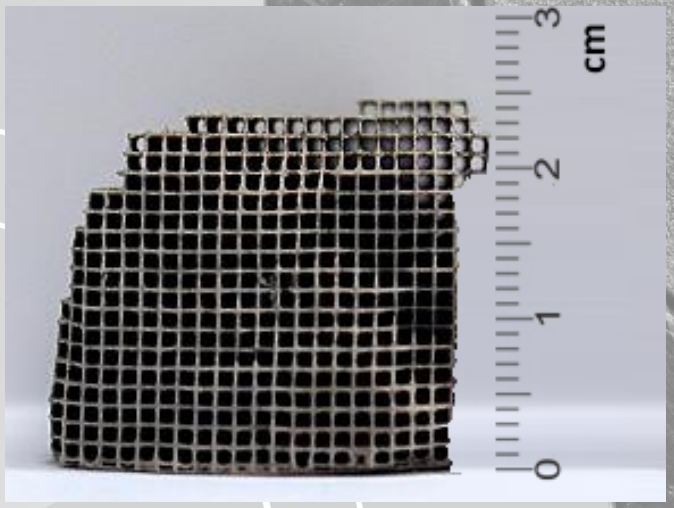
Why?

Customer requirements

Emission regulations



Catalyst poisoning

Real driving emissions

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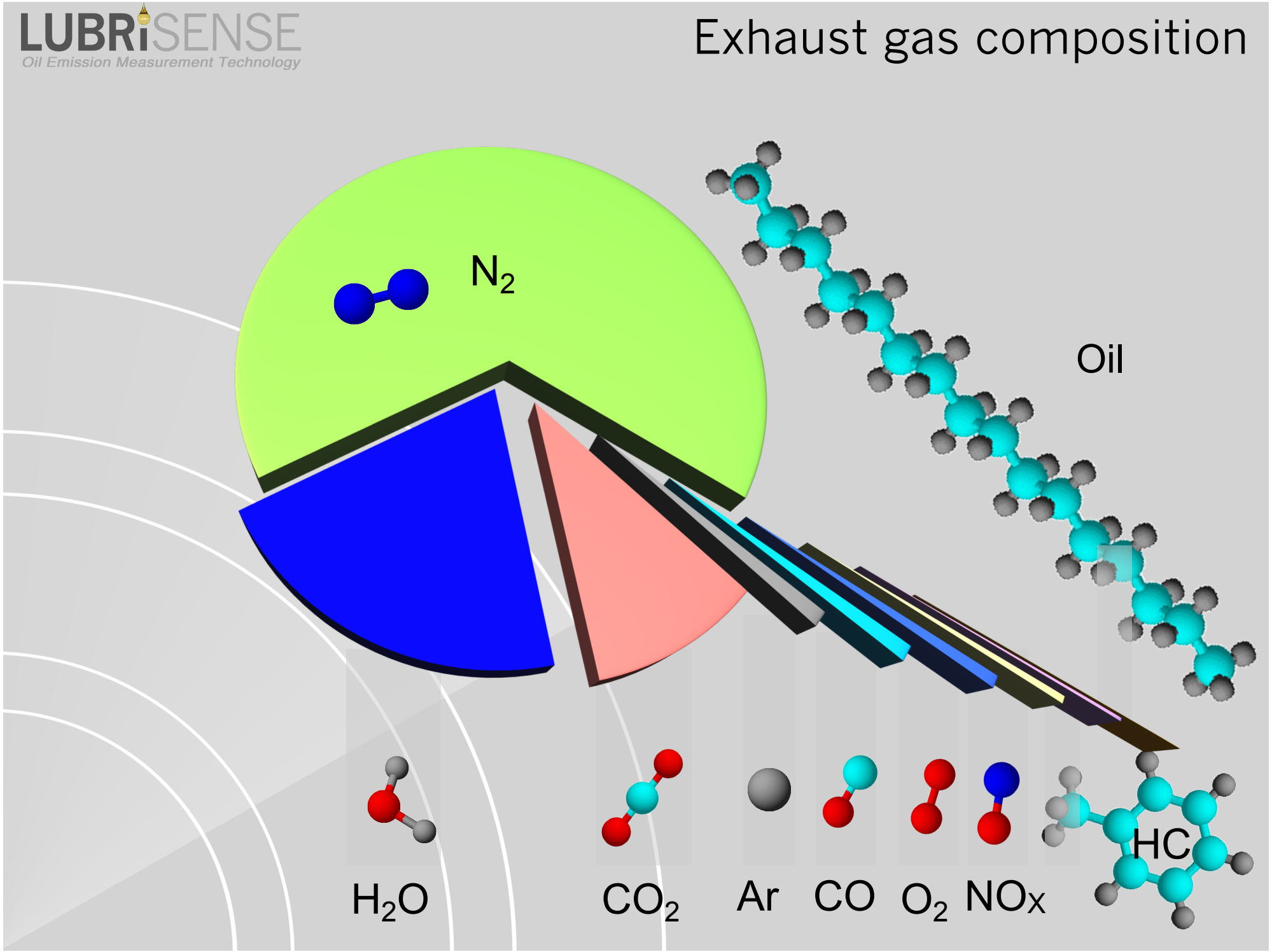
Exhaust gas composition



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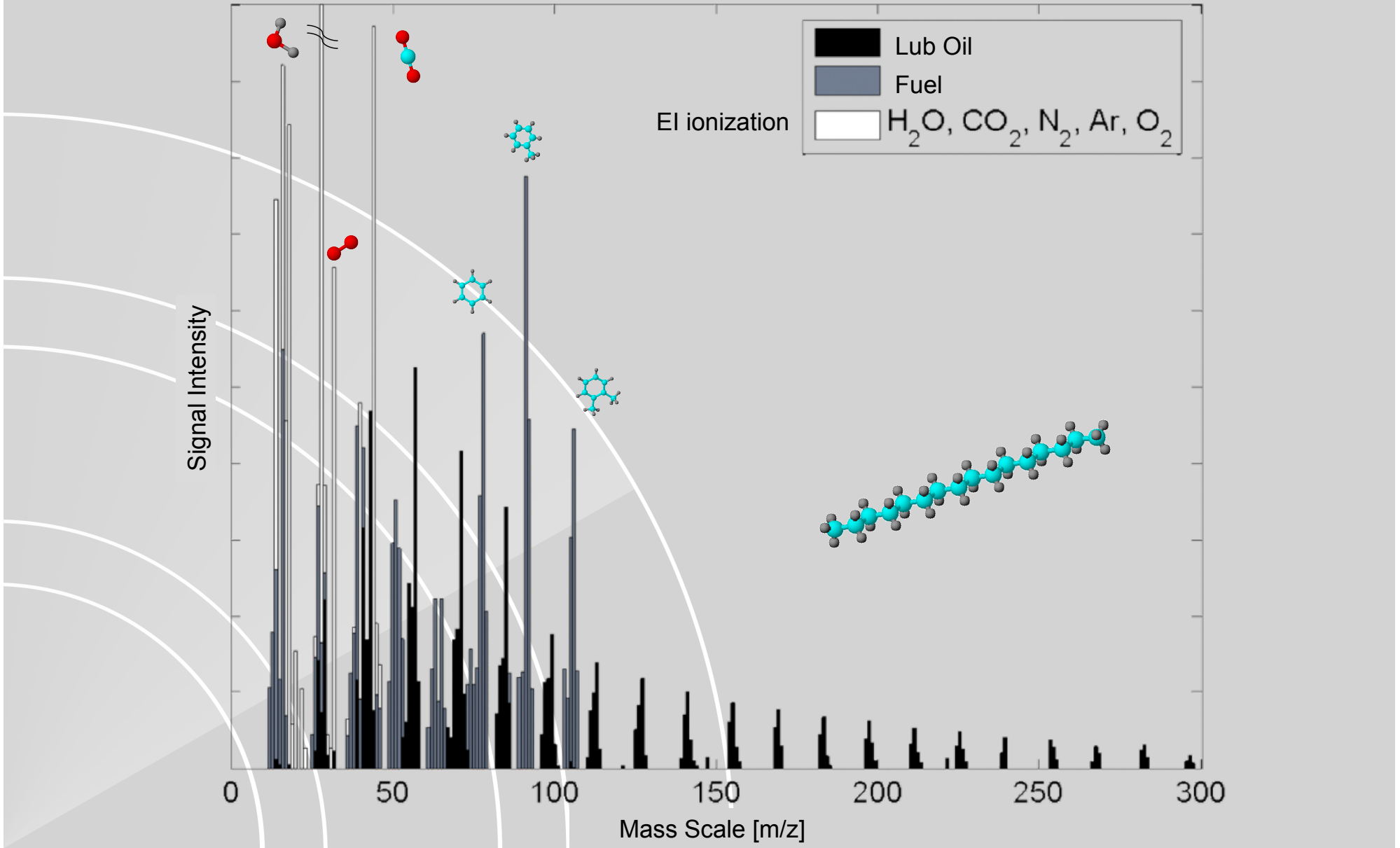
Exhaust gas composition



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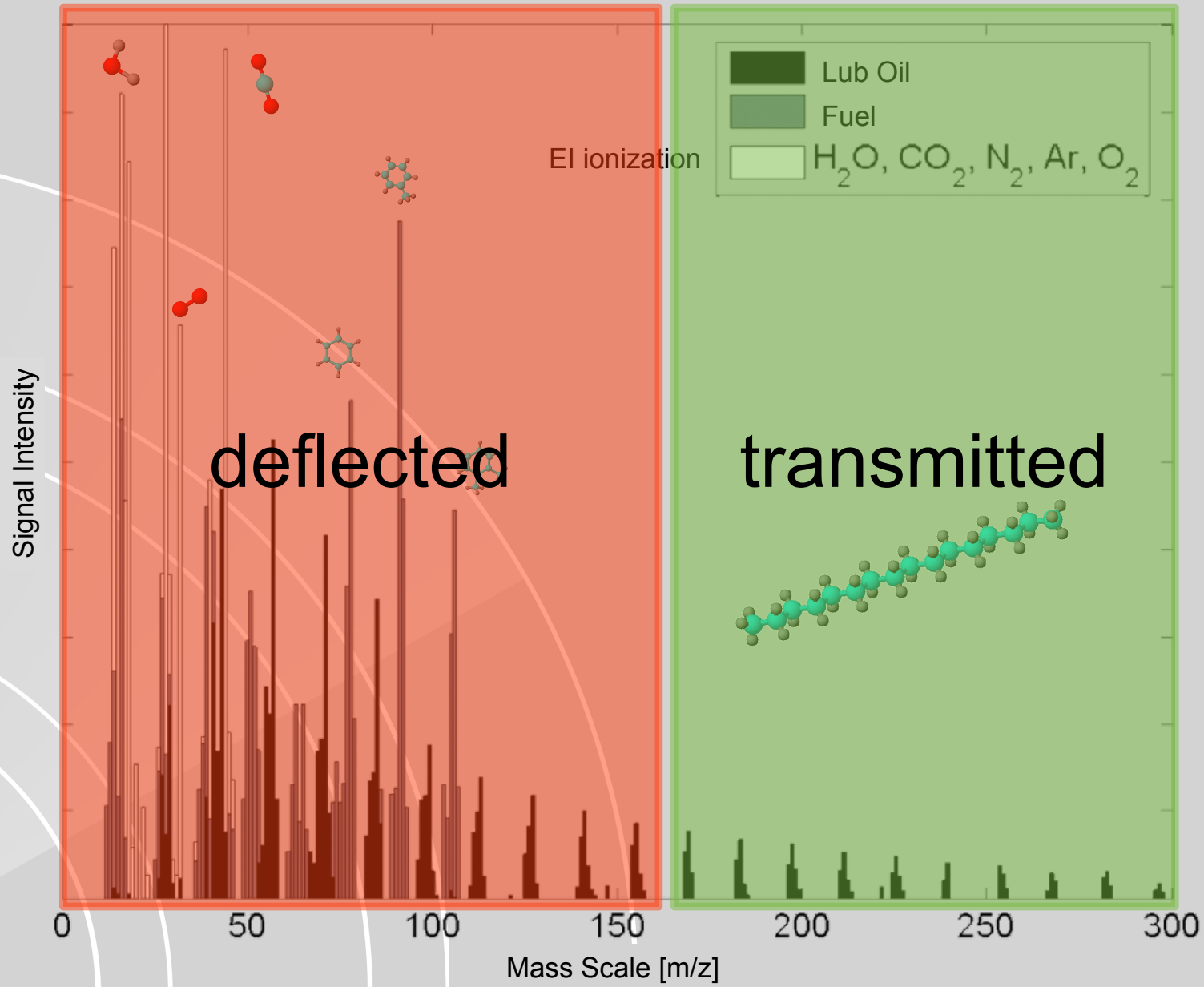
High Pass Mass Filter



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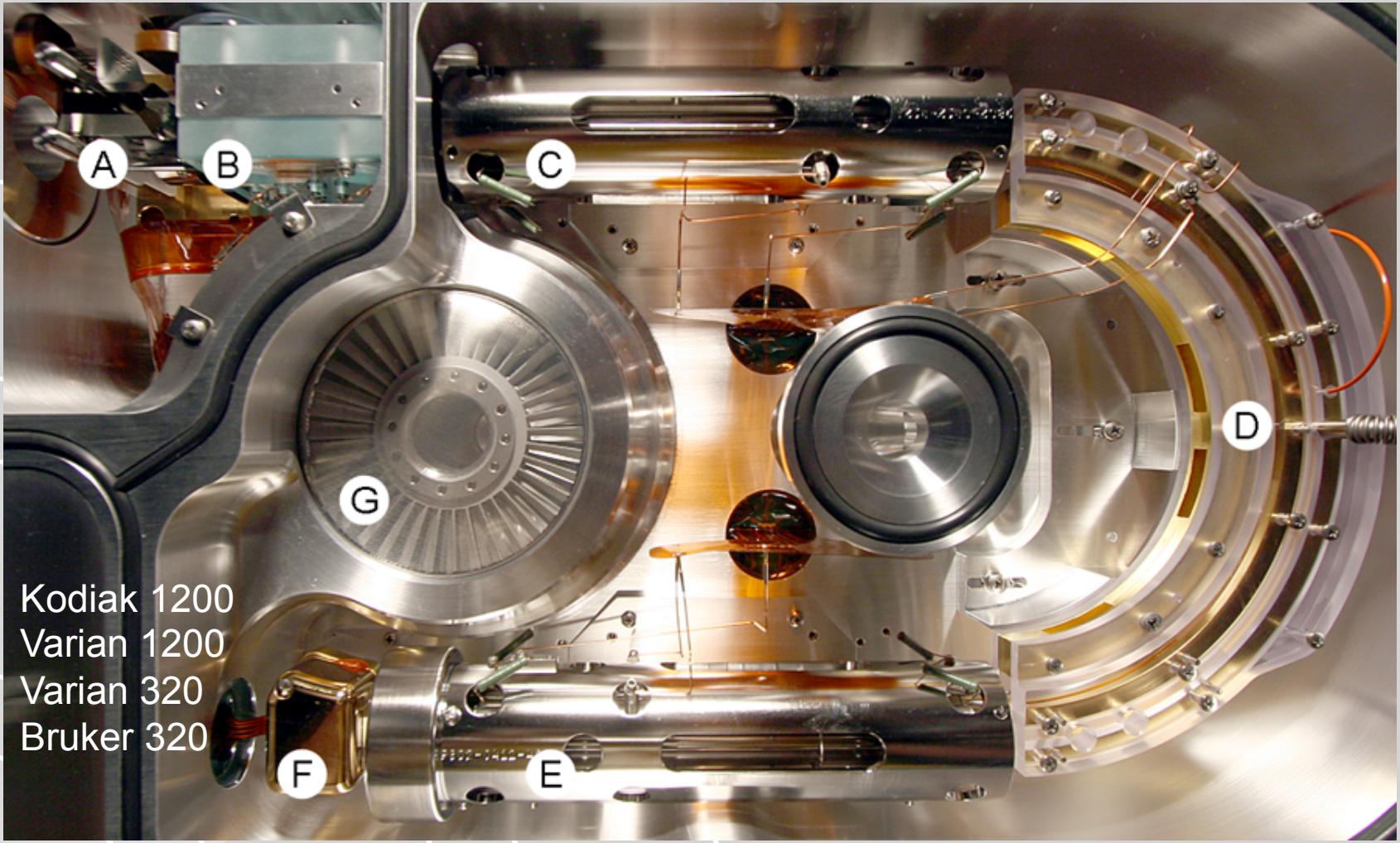
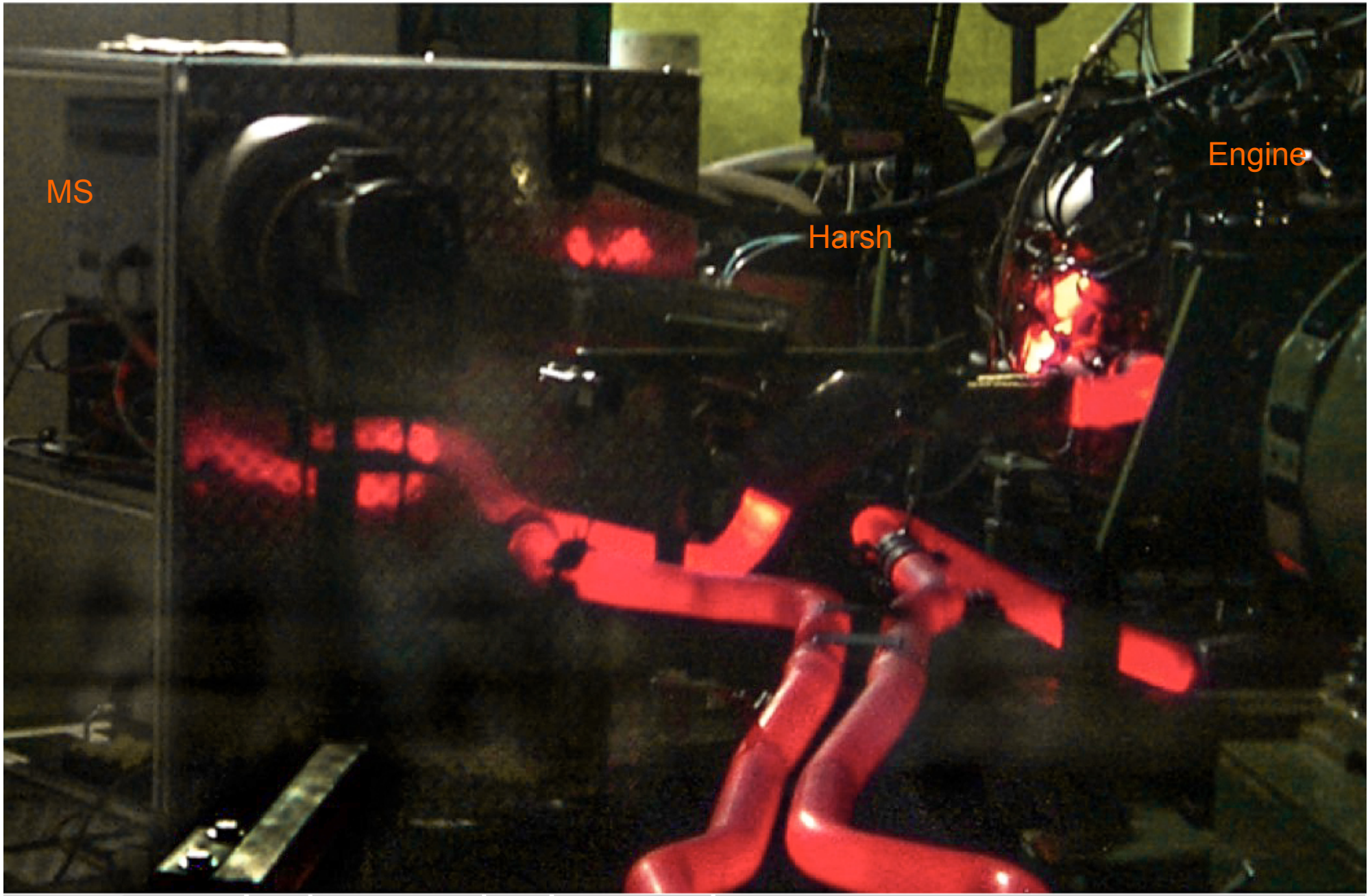
The 1st Generation Lubrisense 1200



A Ionen source, **B** Hexapole, **C, D, E** Quadrupole
F Detector, **G** Turbo pump


MS
Harsh
Engine

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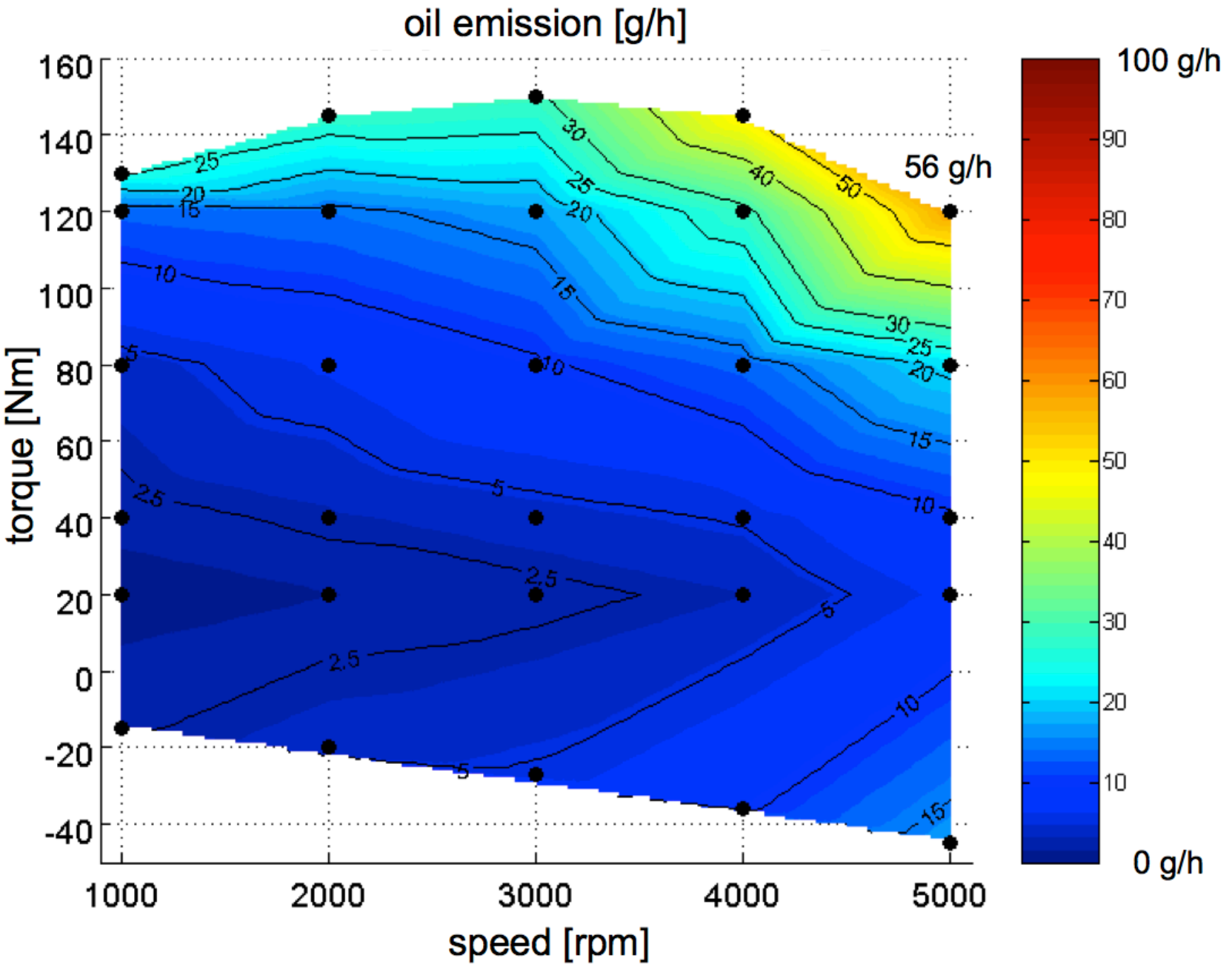
results

operation map of oil consumption



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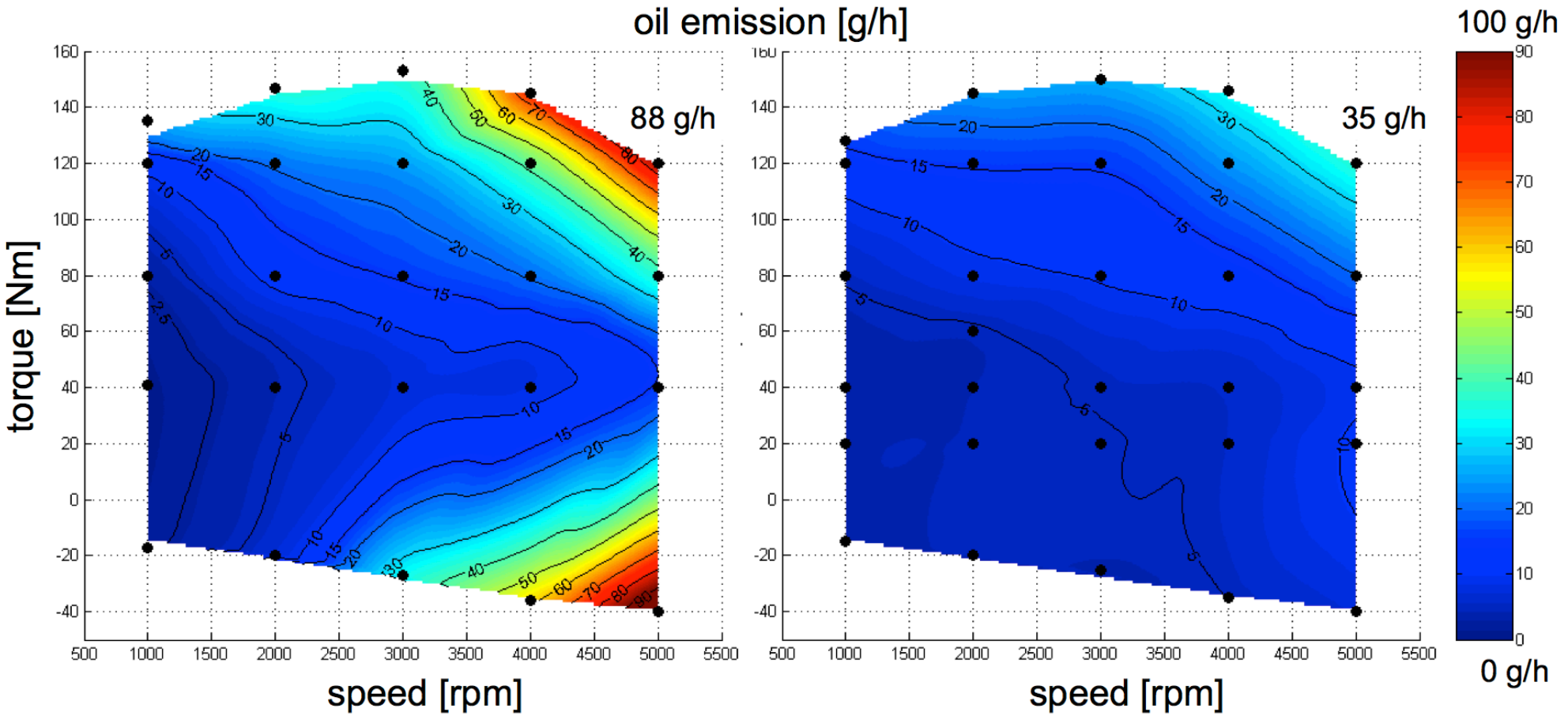
results
piston ring design



variant A

variant B

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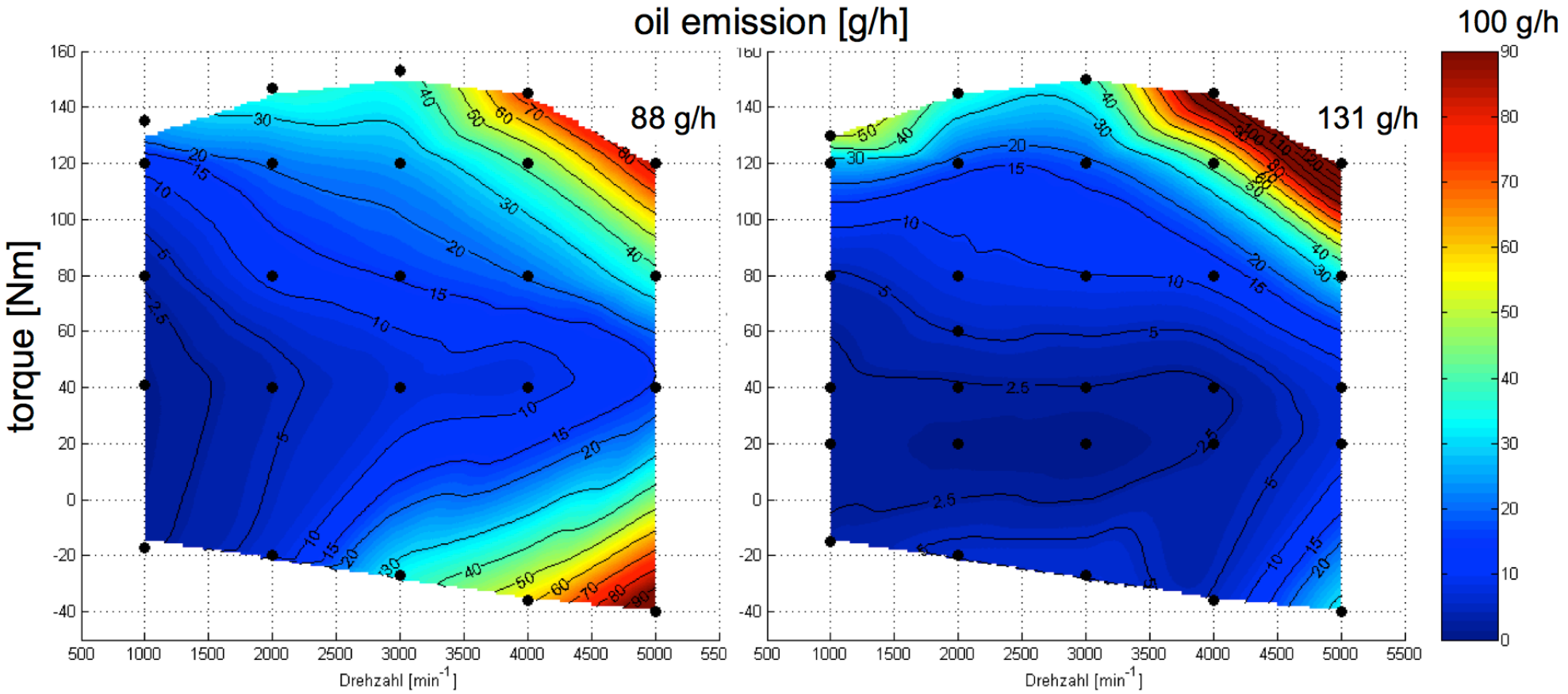
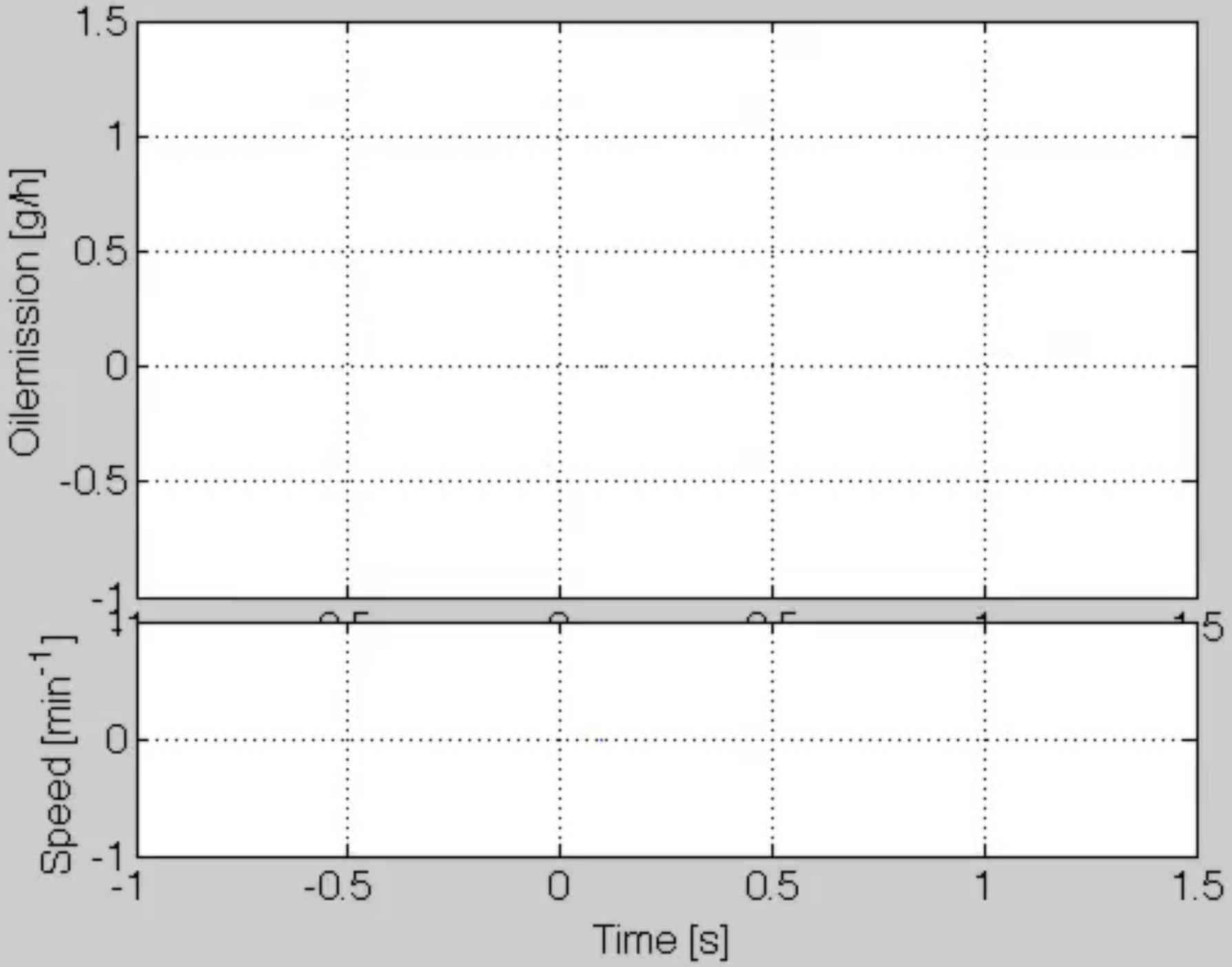
results
oil formulation



high viscosity

low viscosity

Measurement



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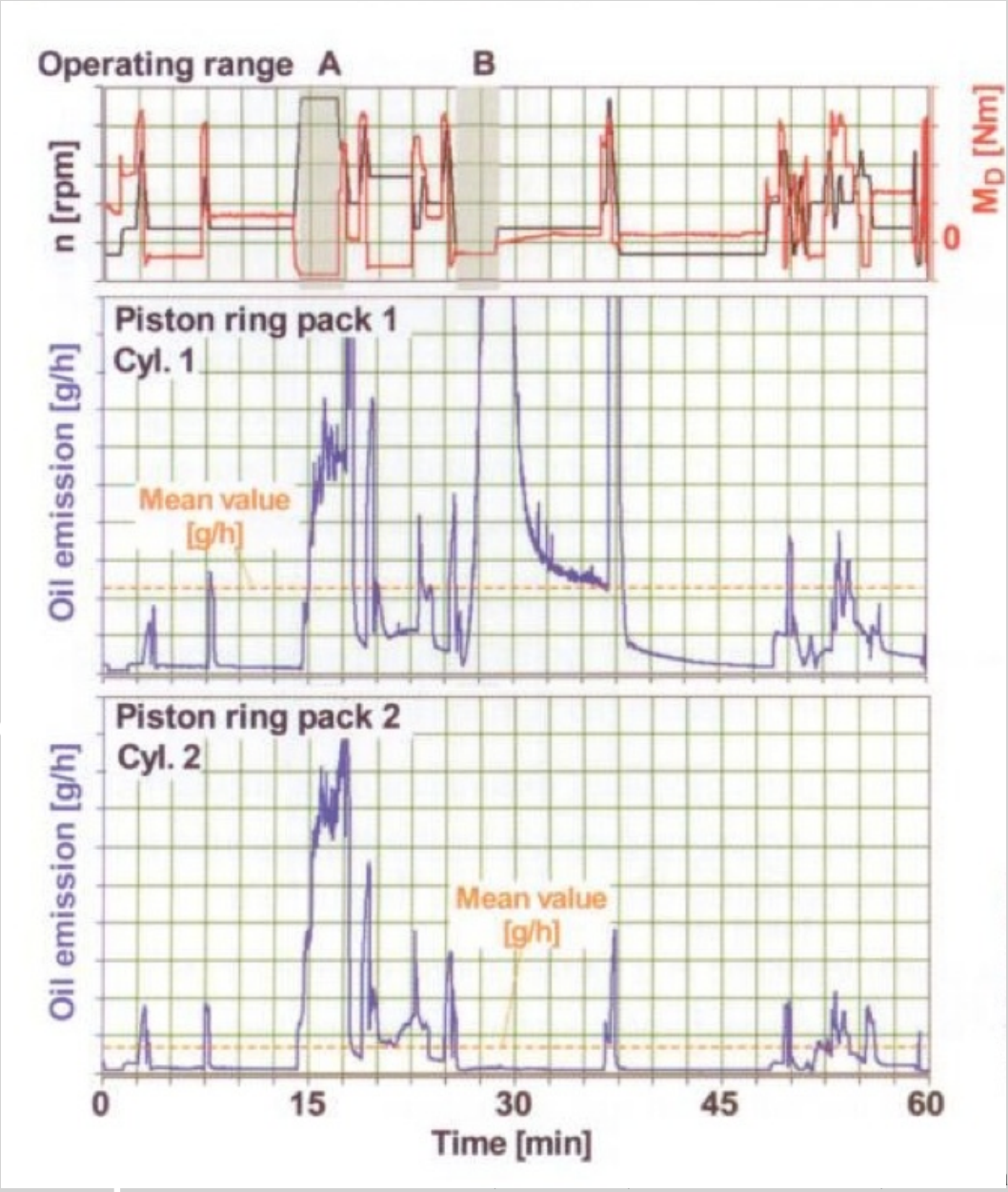
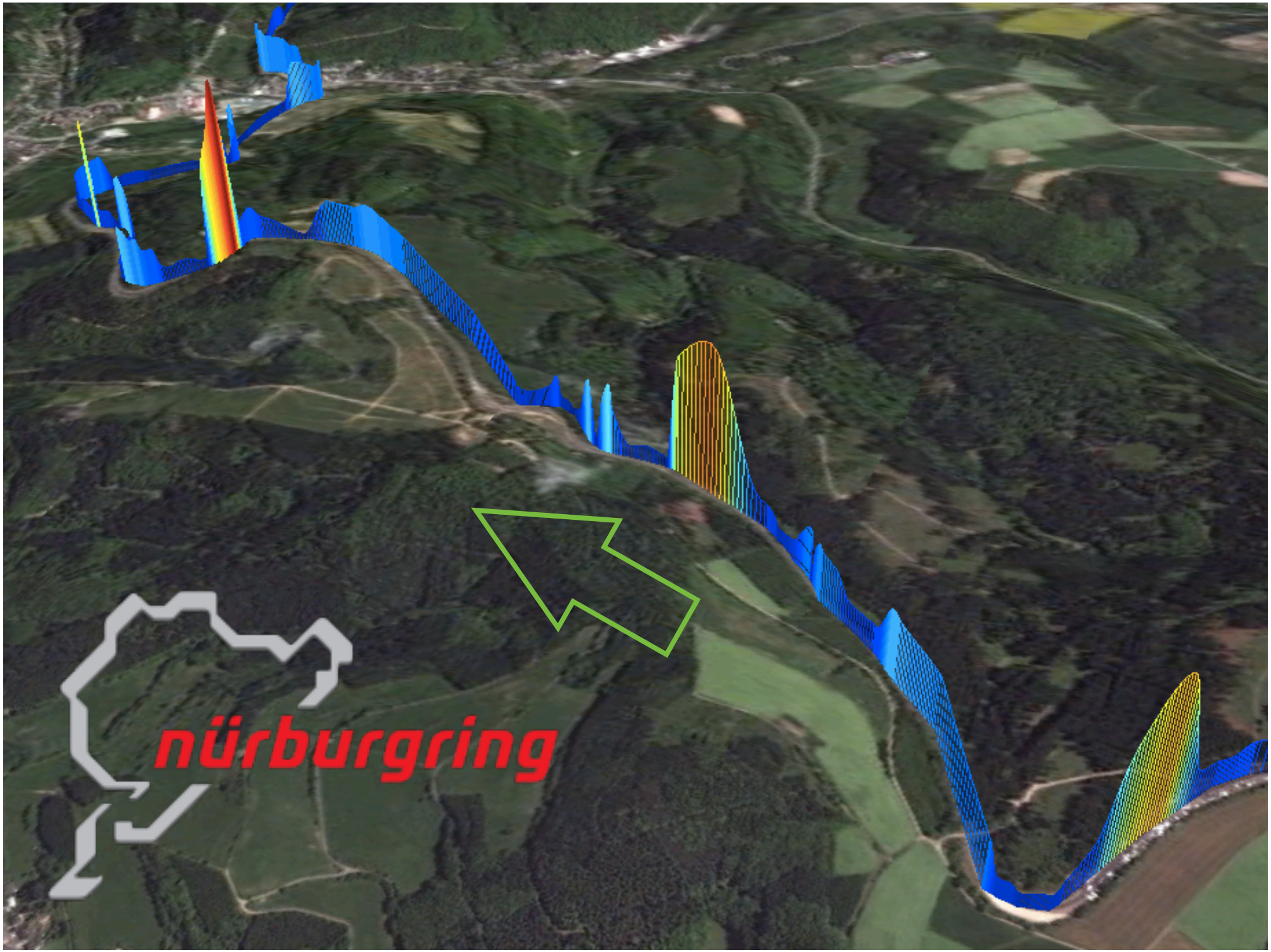
Measurement
dynamic driving cycles



High oil emissions can occur in dynamic driving cycles. Even if the operation map measurement shows low oil emission.

Recommended publication:

Freier, R., Künzel, R.: Online-Messung des Ölverbrauchs – Ein effektives Werkzeug für die Motorenentwicklung, ATZ Automotive Engineering Partners Ausgabe Nr.: 2010-05


nürburgring

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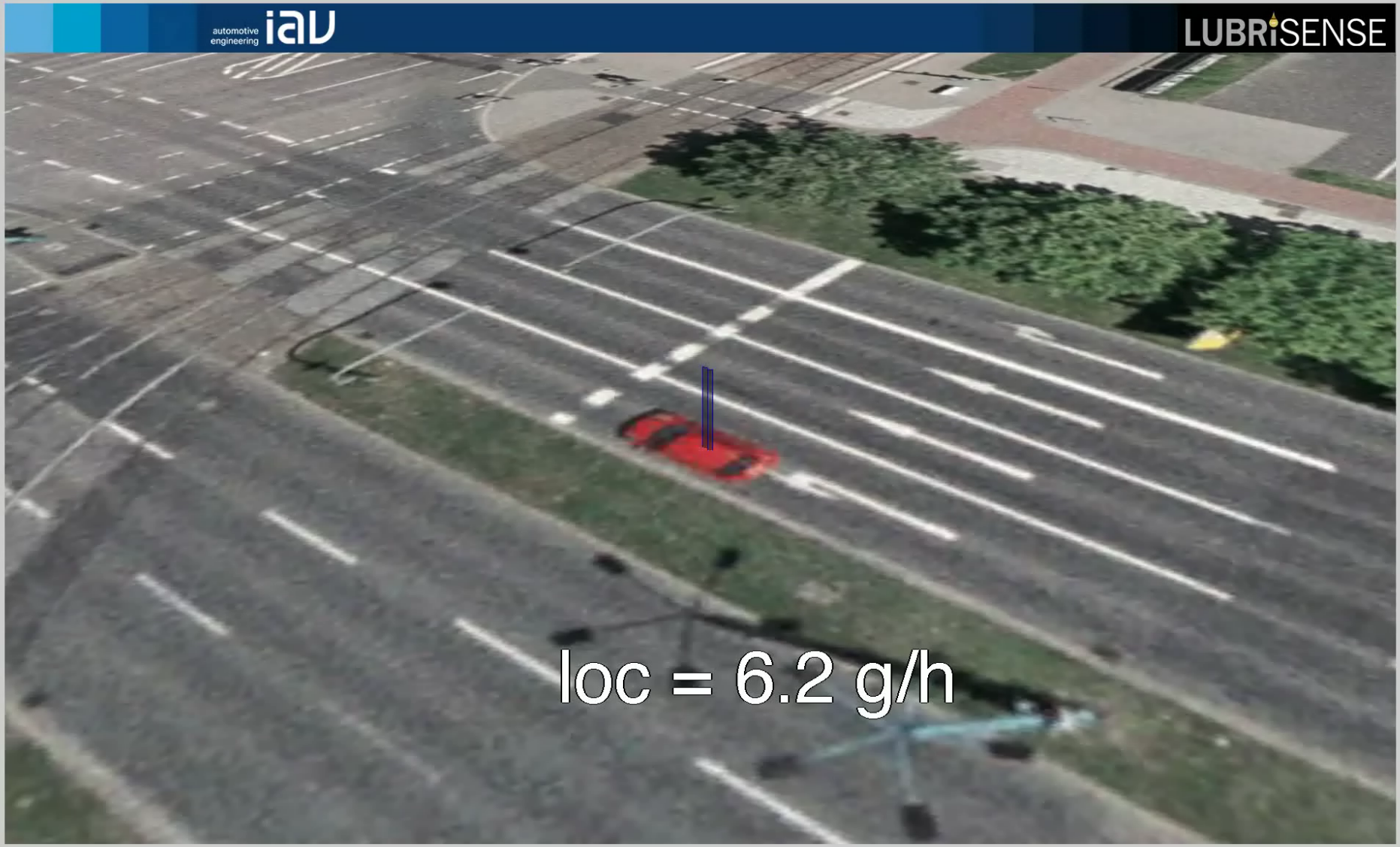
Measurement

city driving cycle



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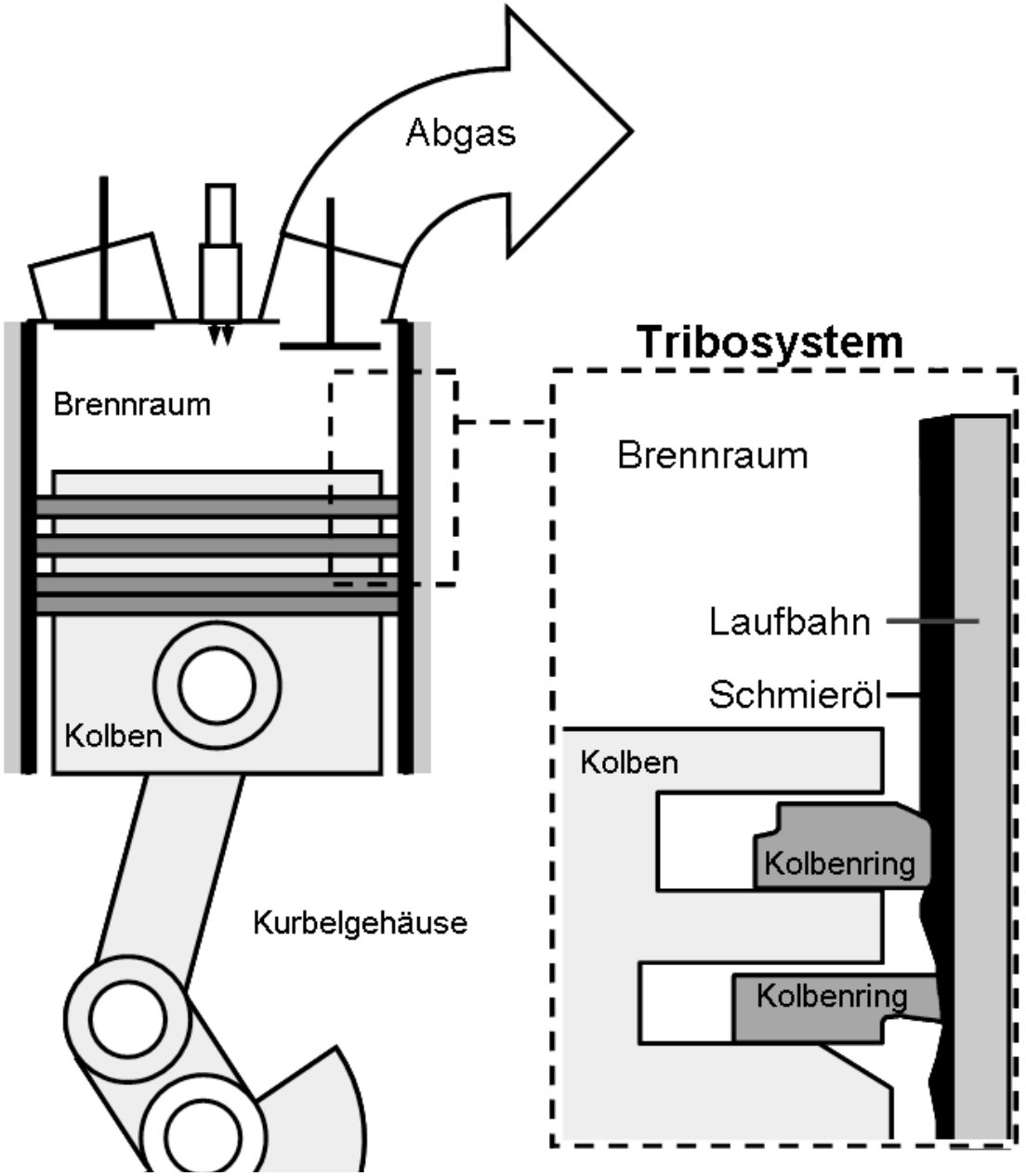
Research project
In-cylinder Measurement



Oil consumption mechanism

Evaporation

Reverse Blow-By

Throw off

Scrape off

Blow-By

Oil-Fuel-Interaction

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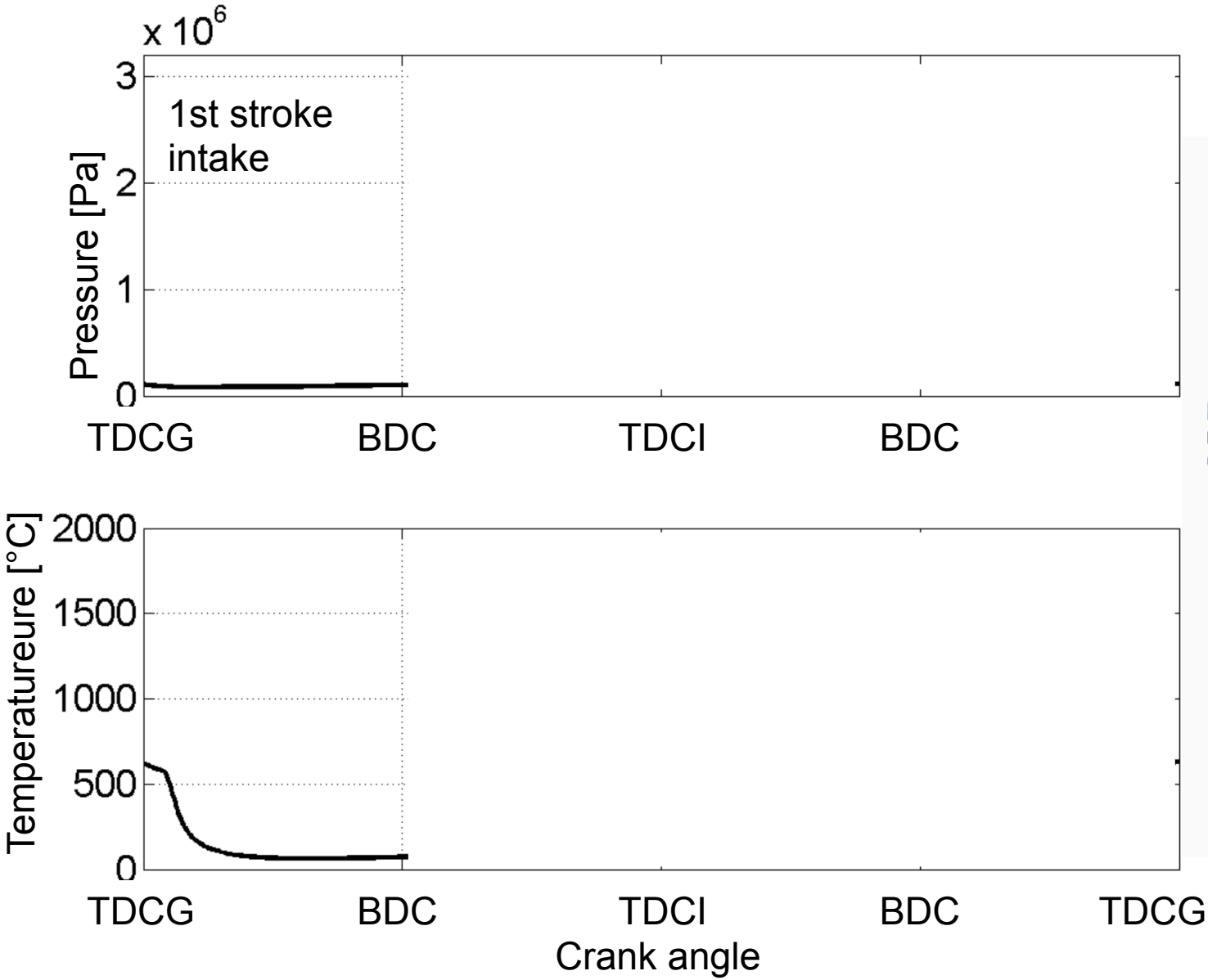
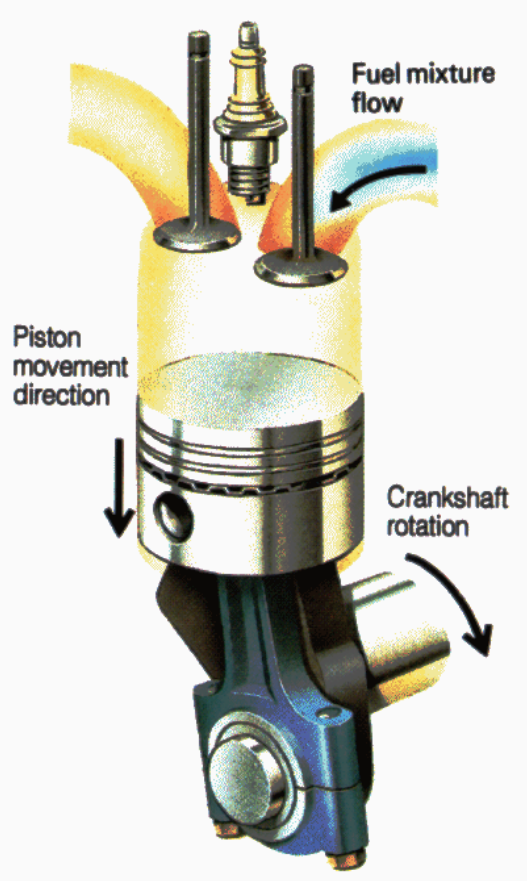
Research project
In-cylinder Measurement



1st stroke
intake



Source: www.mechanics-tips.com

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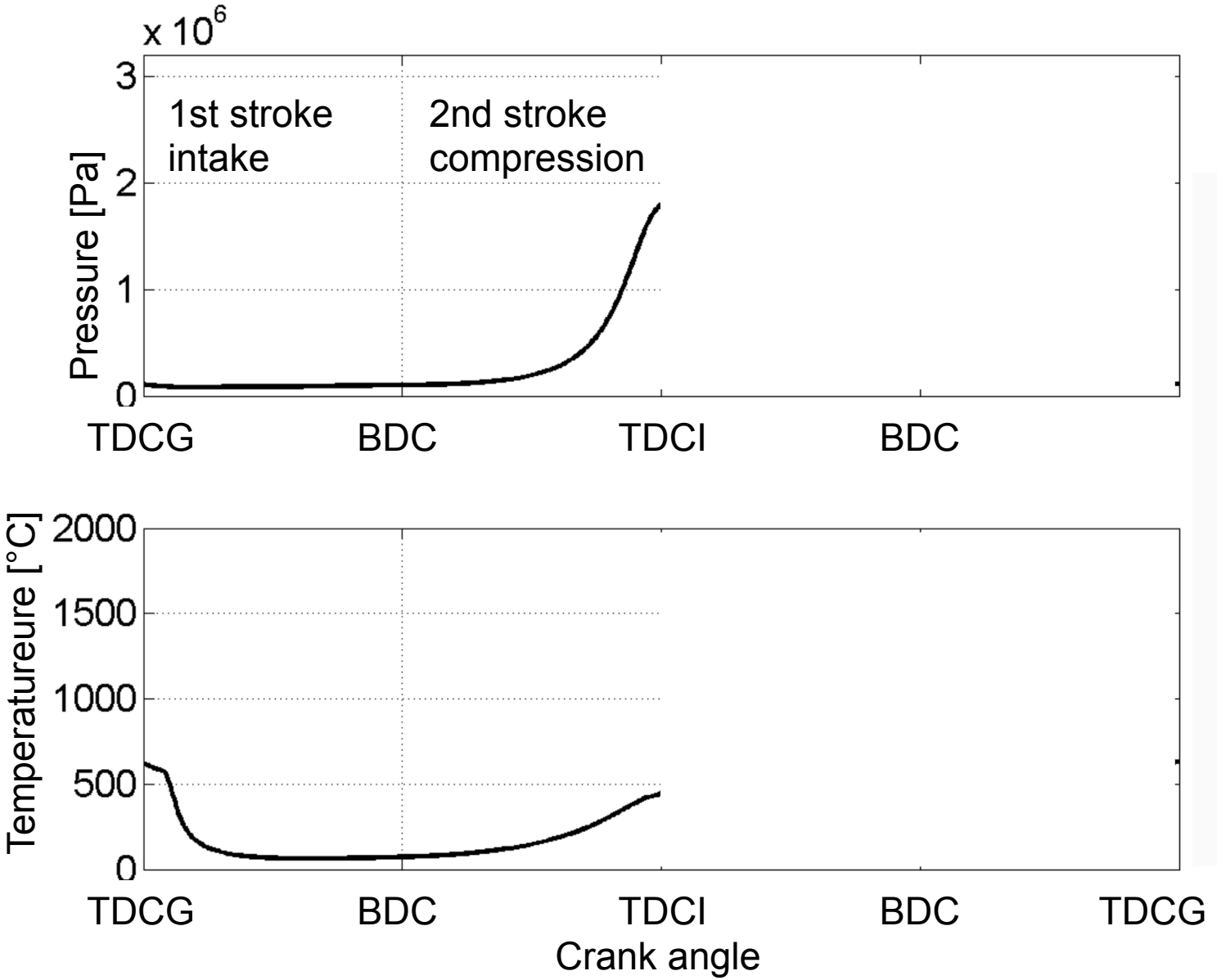
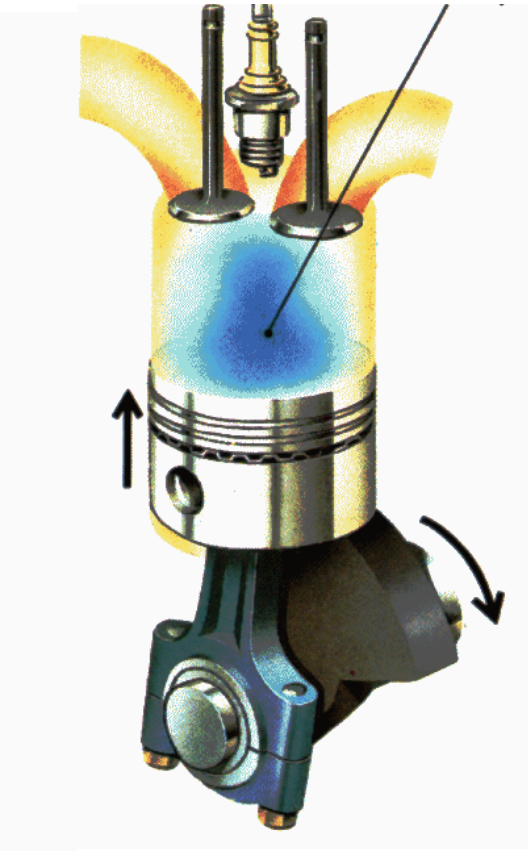
Research project
In-cylinder Measurement



2nd stroke
compression



Source: www.mechanics-tips.com

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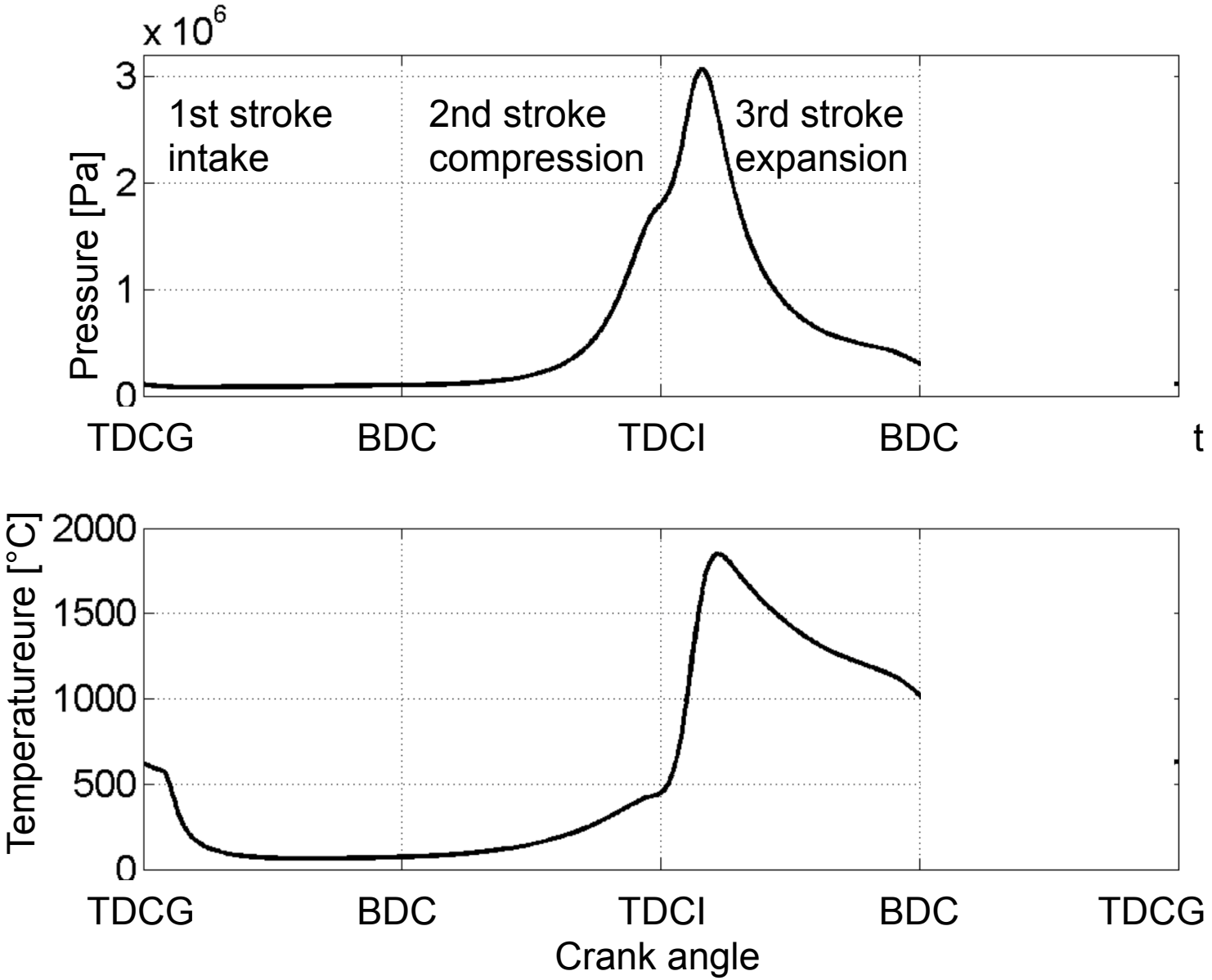
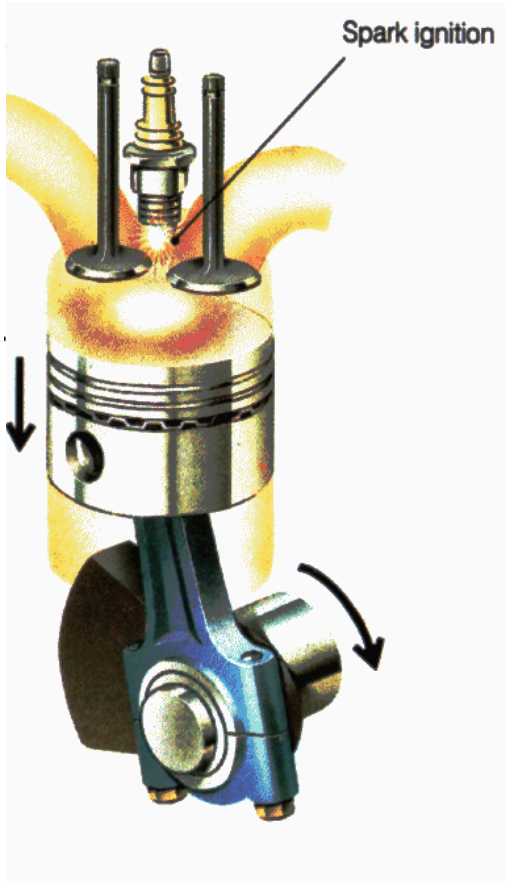
Research project
In-cylinder Measurement



3rd stroke
expansion



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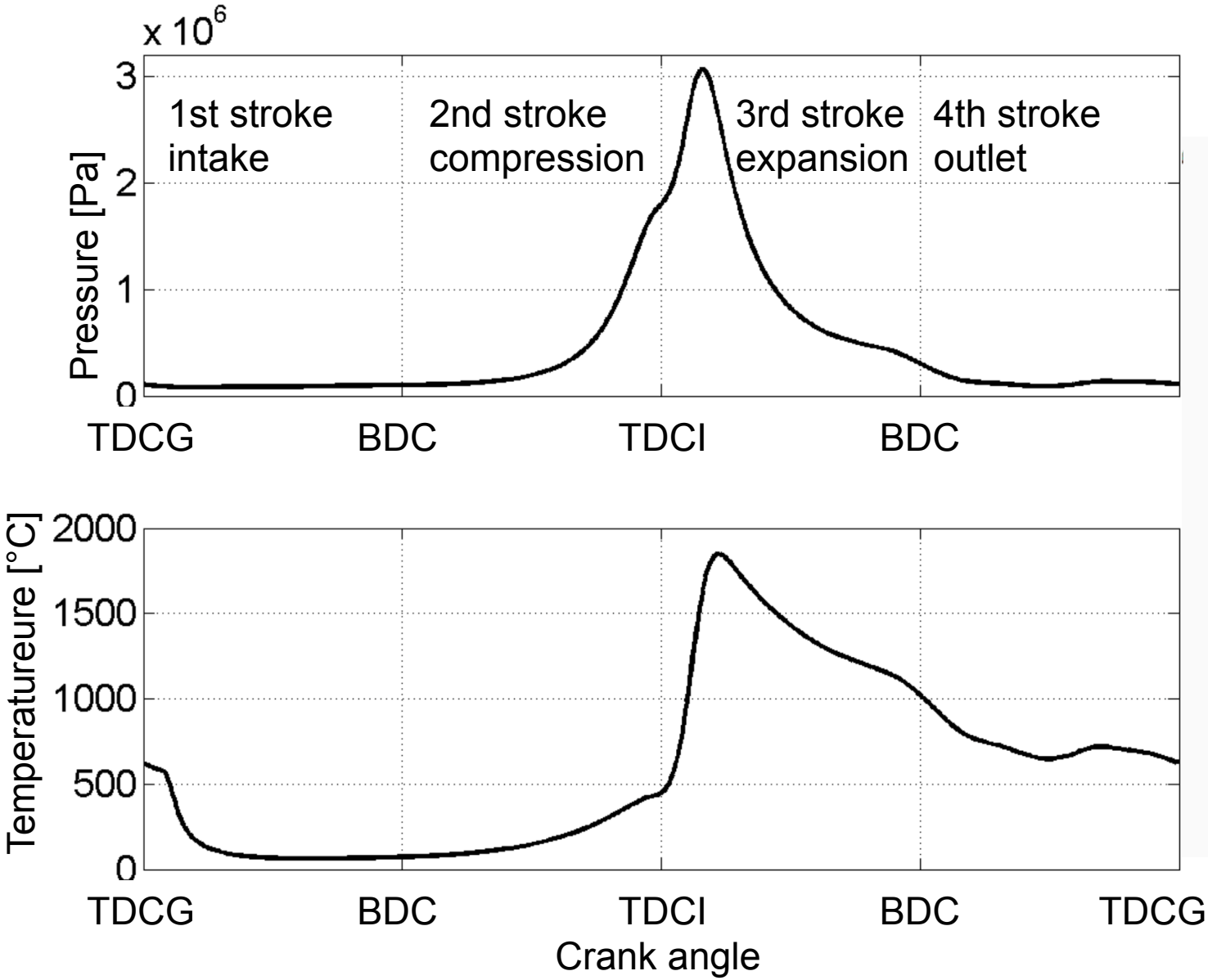
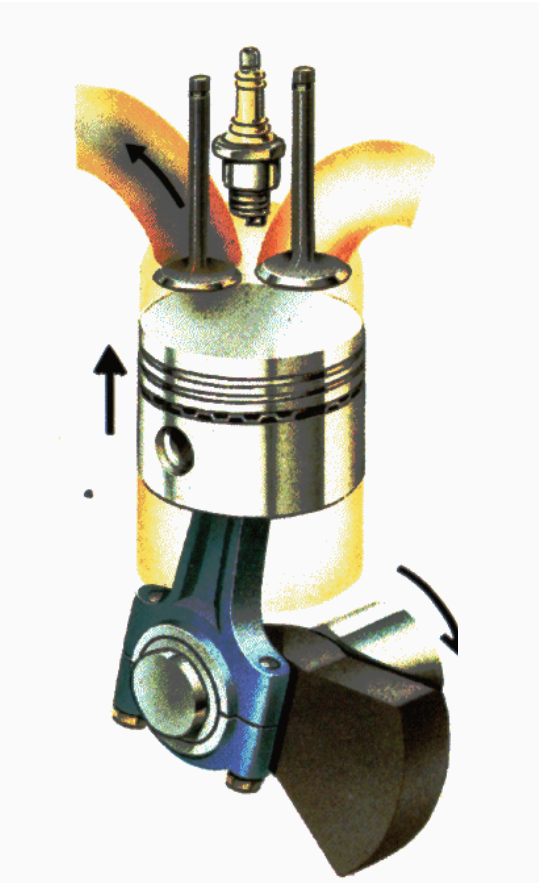
Research project
In-cylinder Measurement



4th stroke outlet



Source: www.mechanics-tips.com

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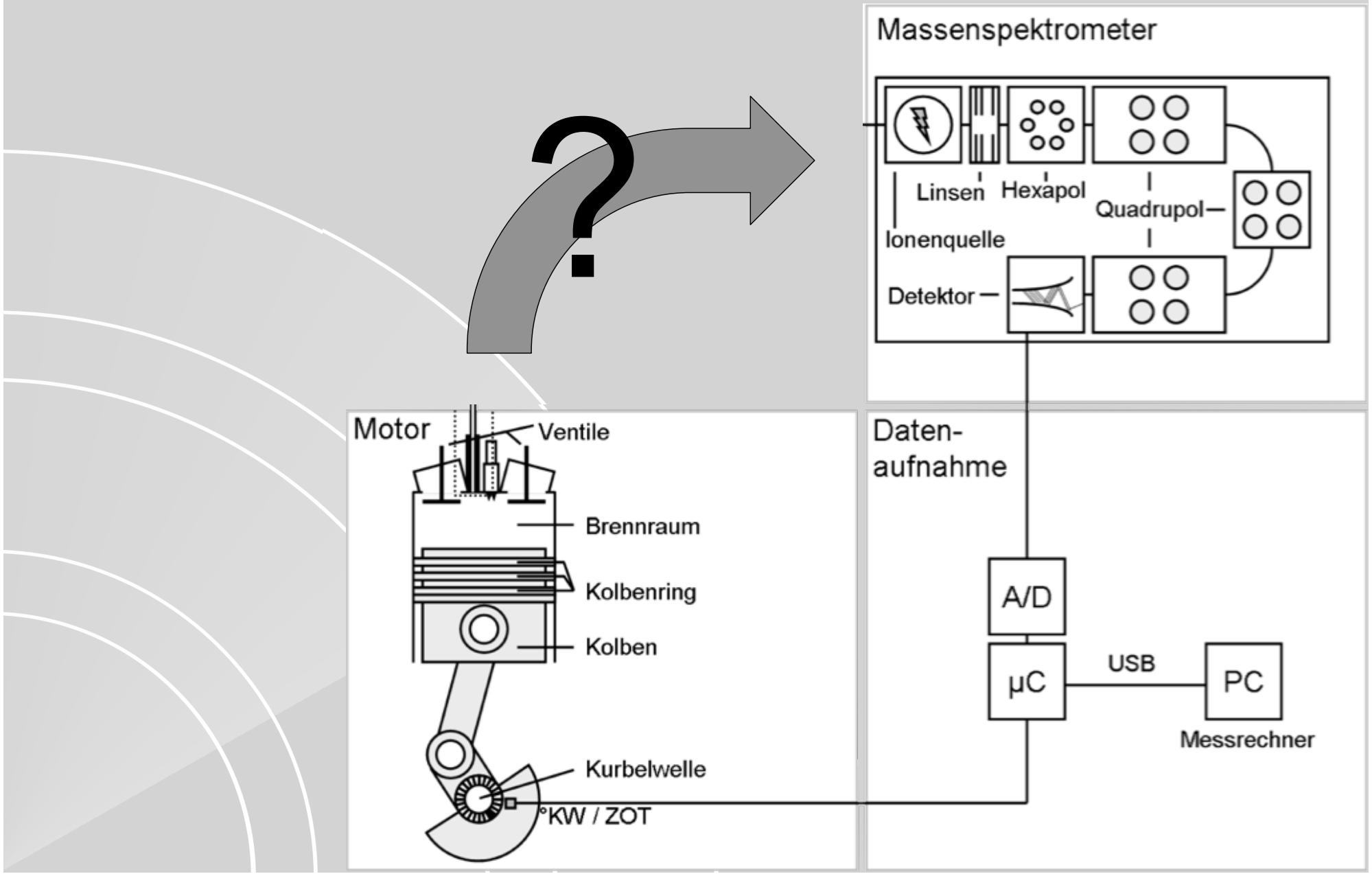
Measurement System



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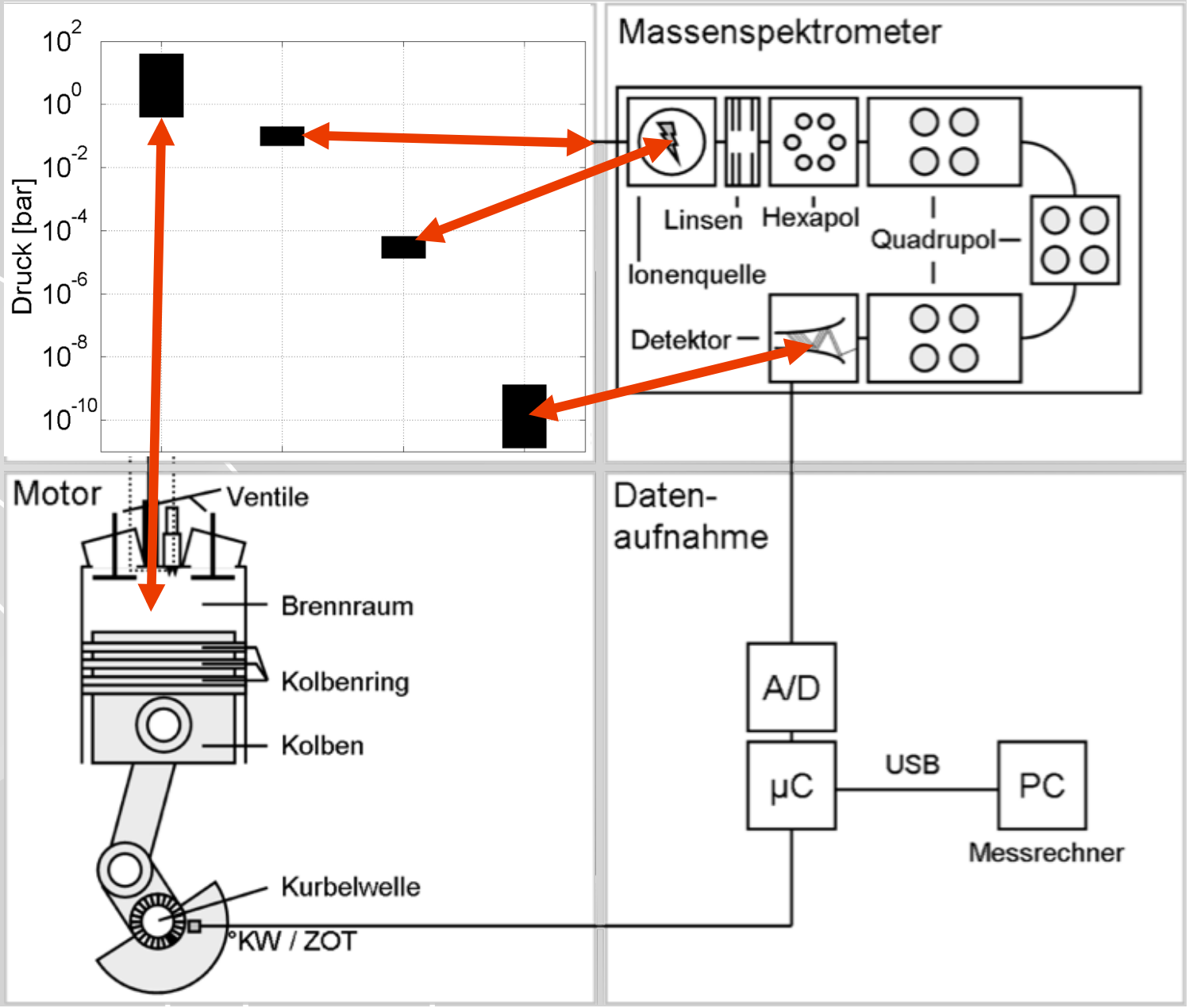
Measurement System



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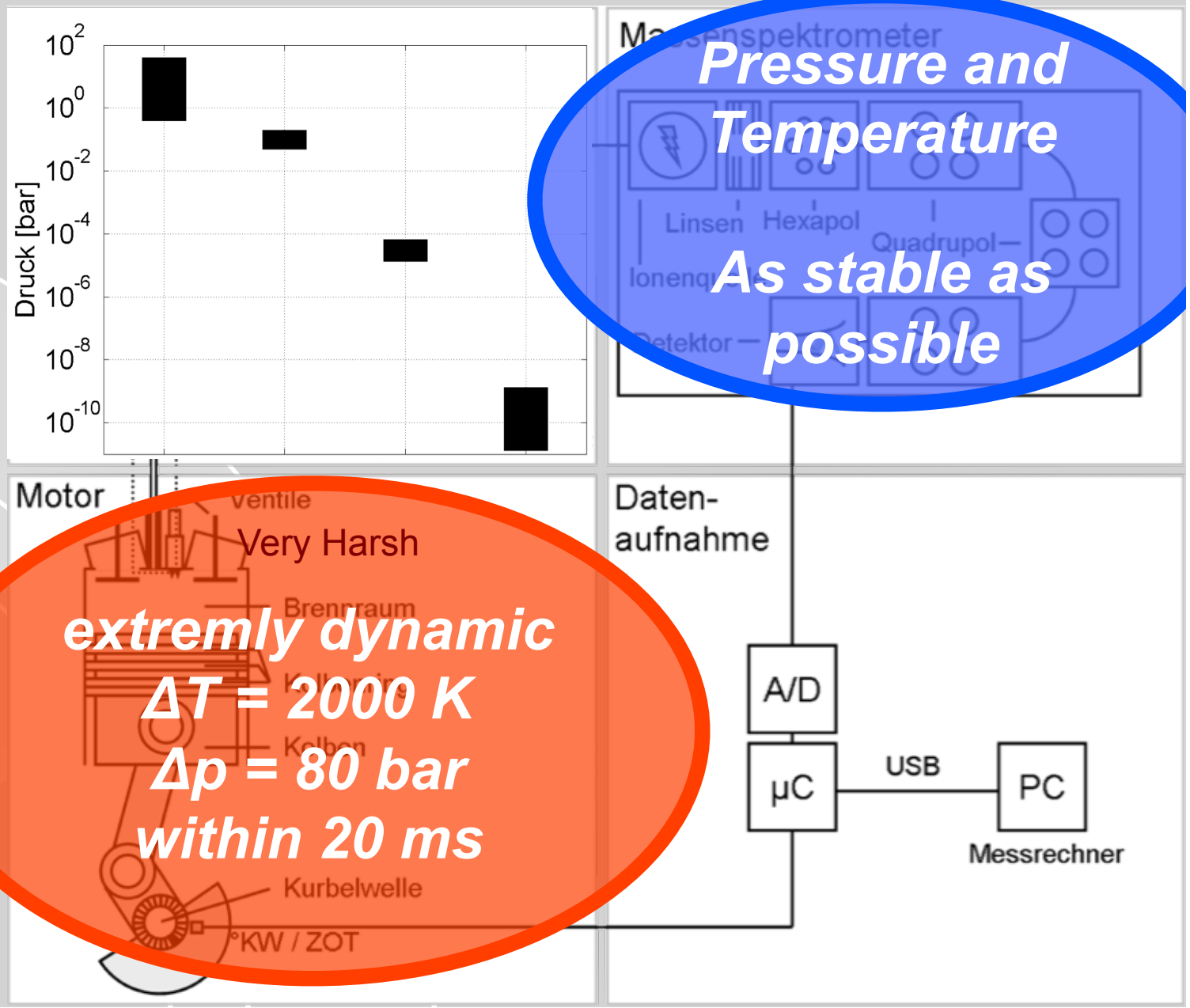
Measurement System



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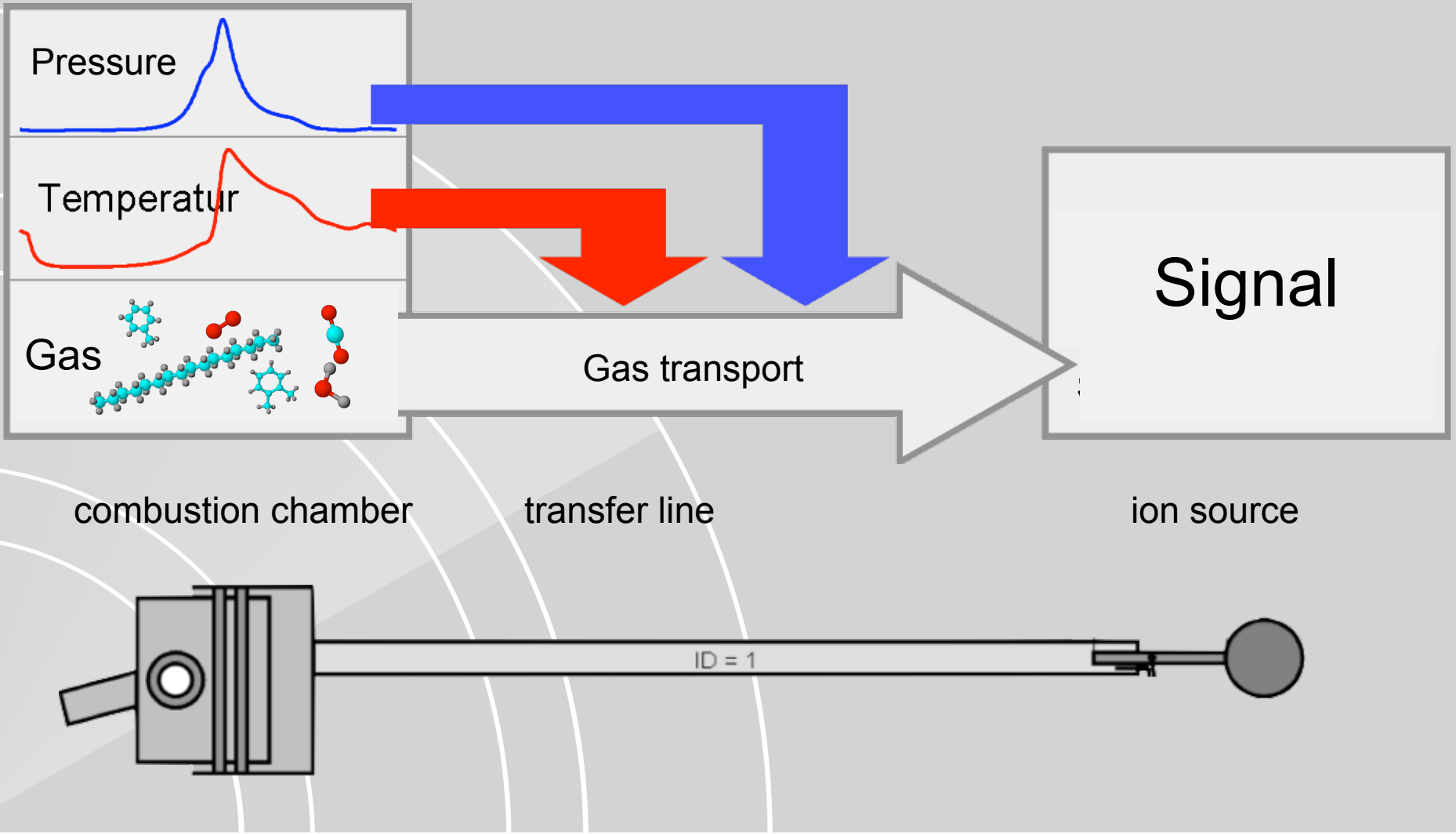
Gas transport



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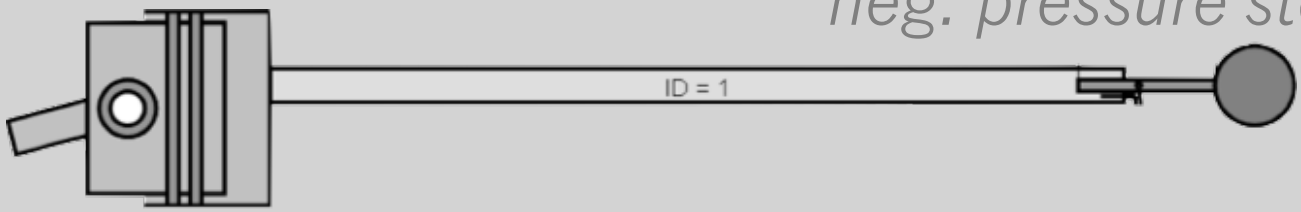
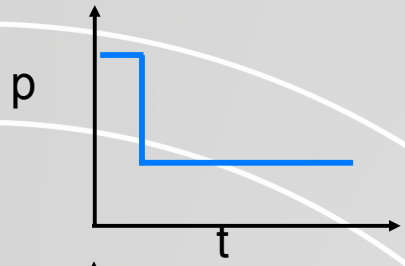
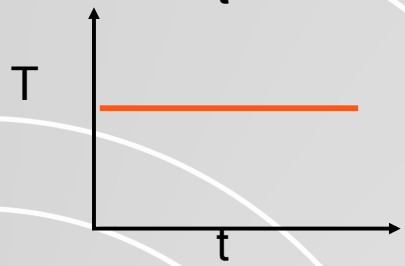
Gas transport

neg. pressure step

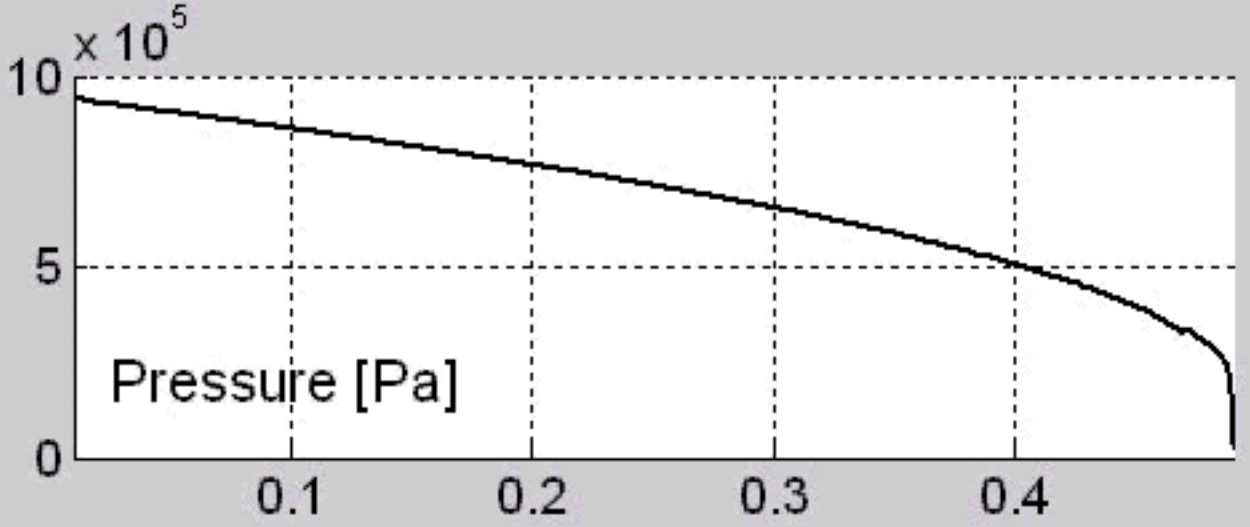


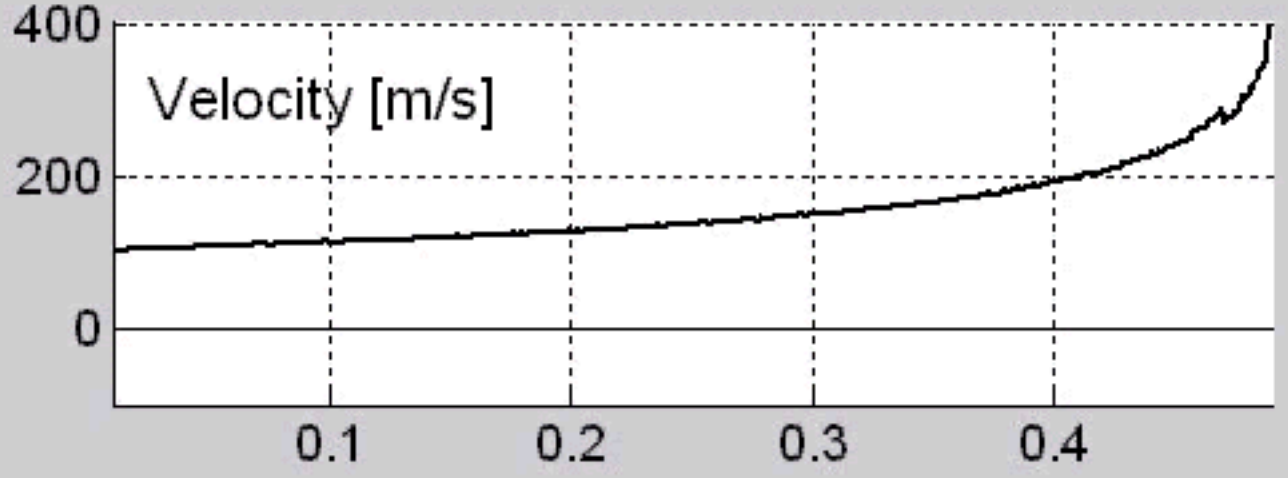
Backwash





Combustion chamber





Forevacum MS

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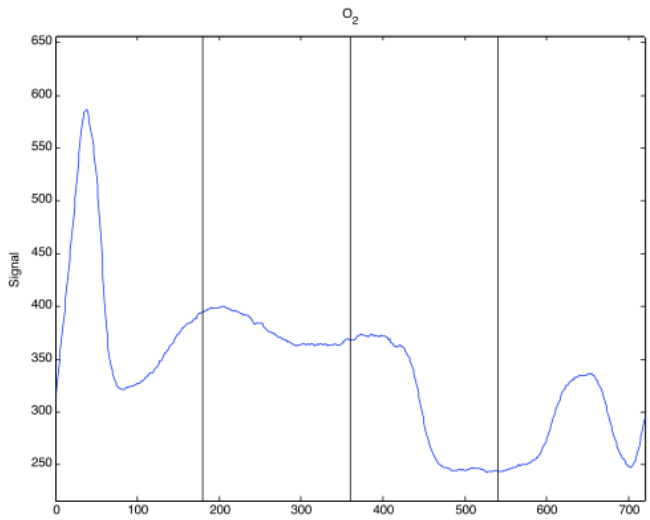
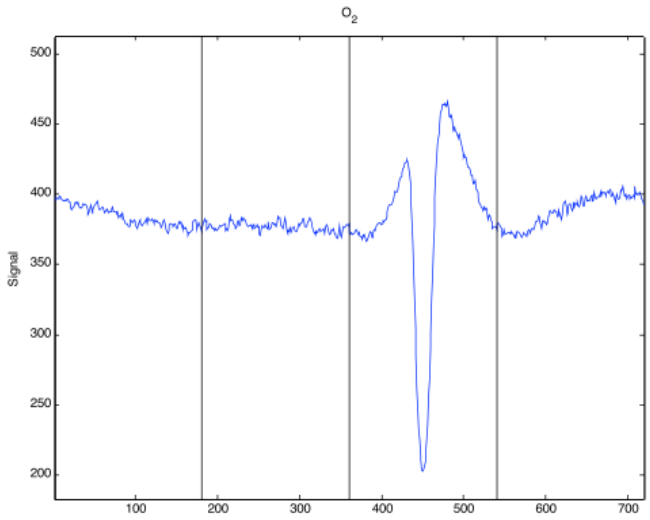
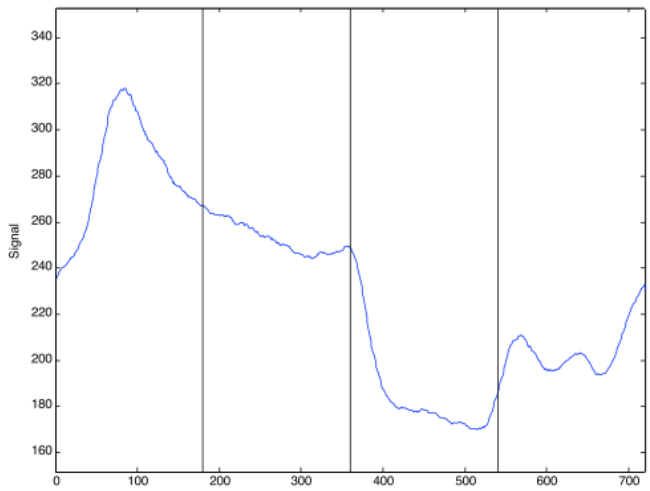
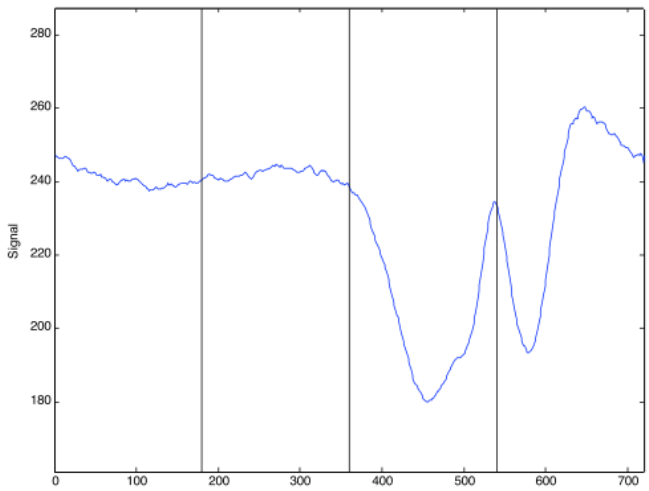
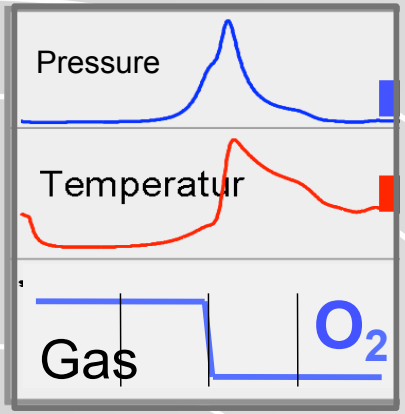
O_2-Measurement

4 operation points

O_2	2000 min^{-1}	4000 min^{-1}
120 Nm		
20 Nm		



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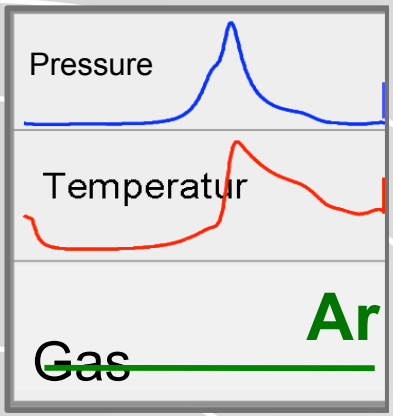
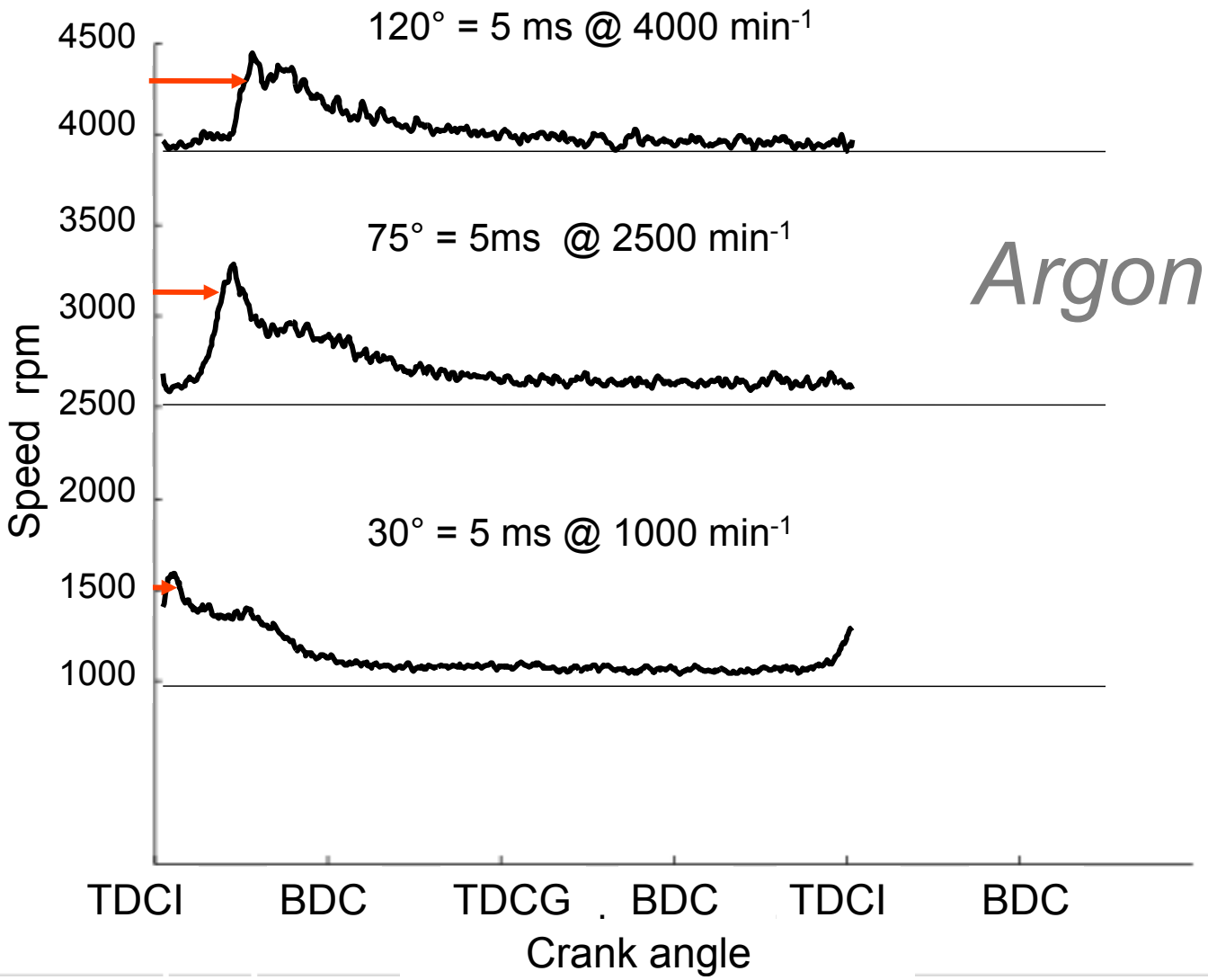
Argon-Measurement

Speed ramp

Conditions in Combustion chamber





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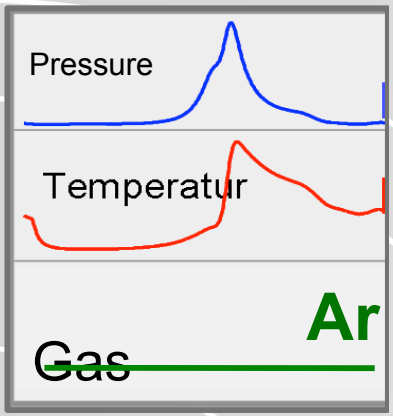
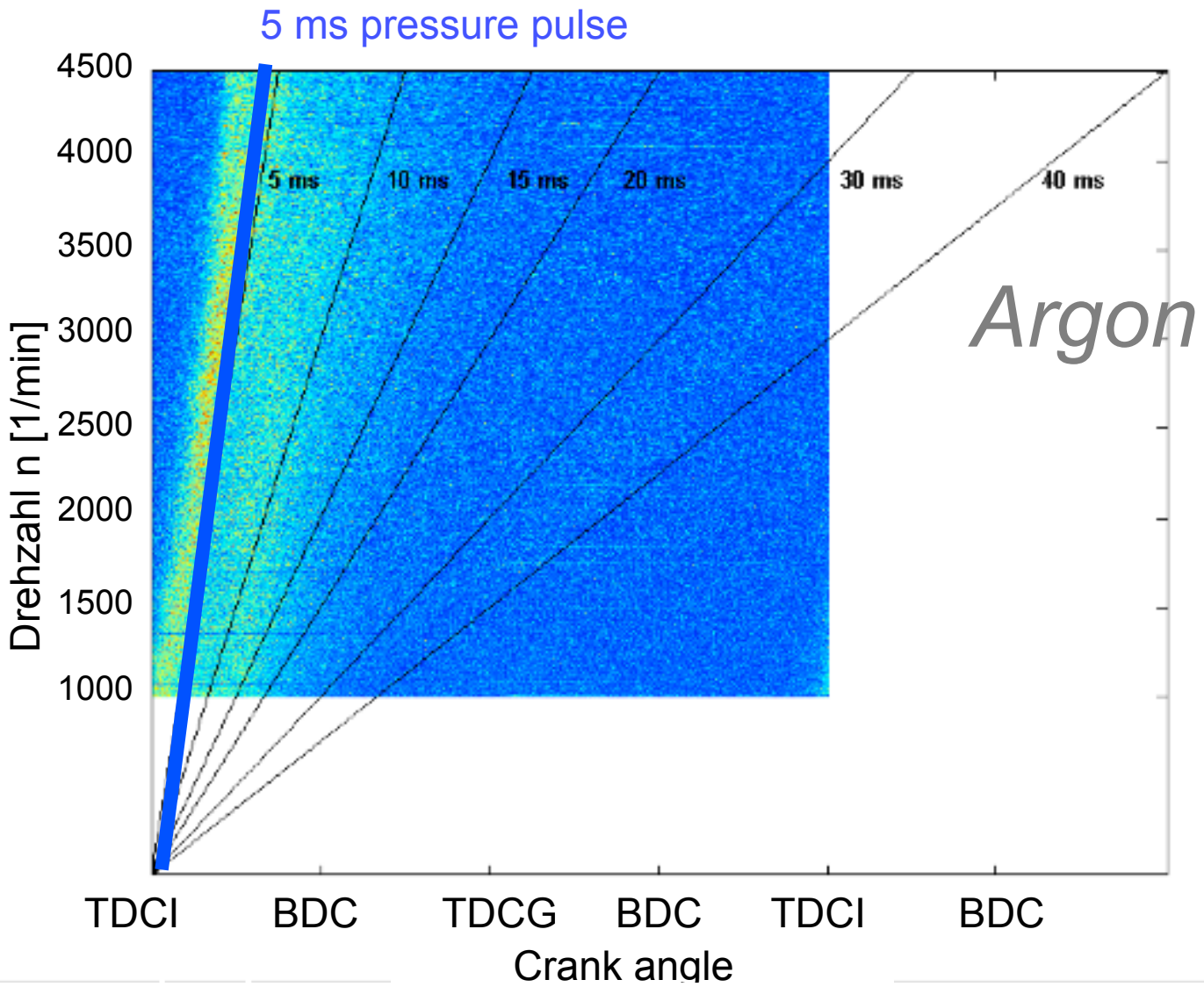
Argon-Measurement

Speed ramp

Conditions in Combustion chamber





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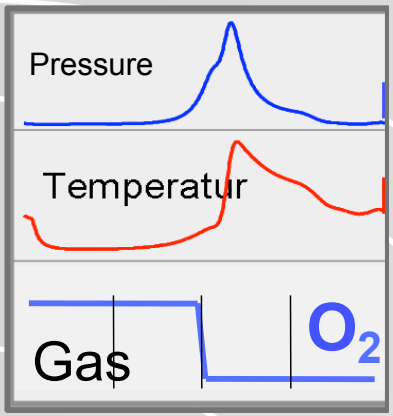
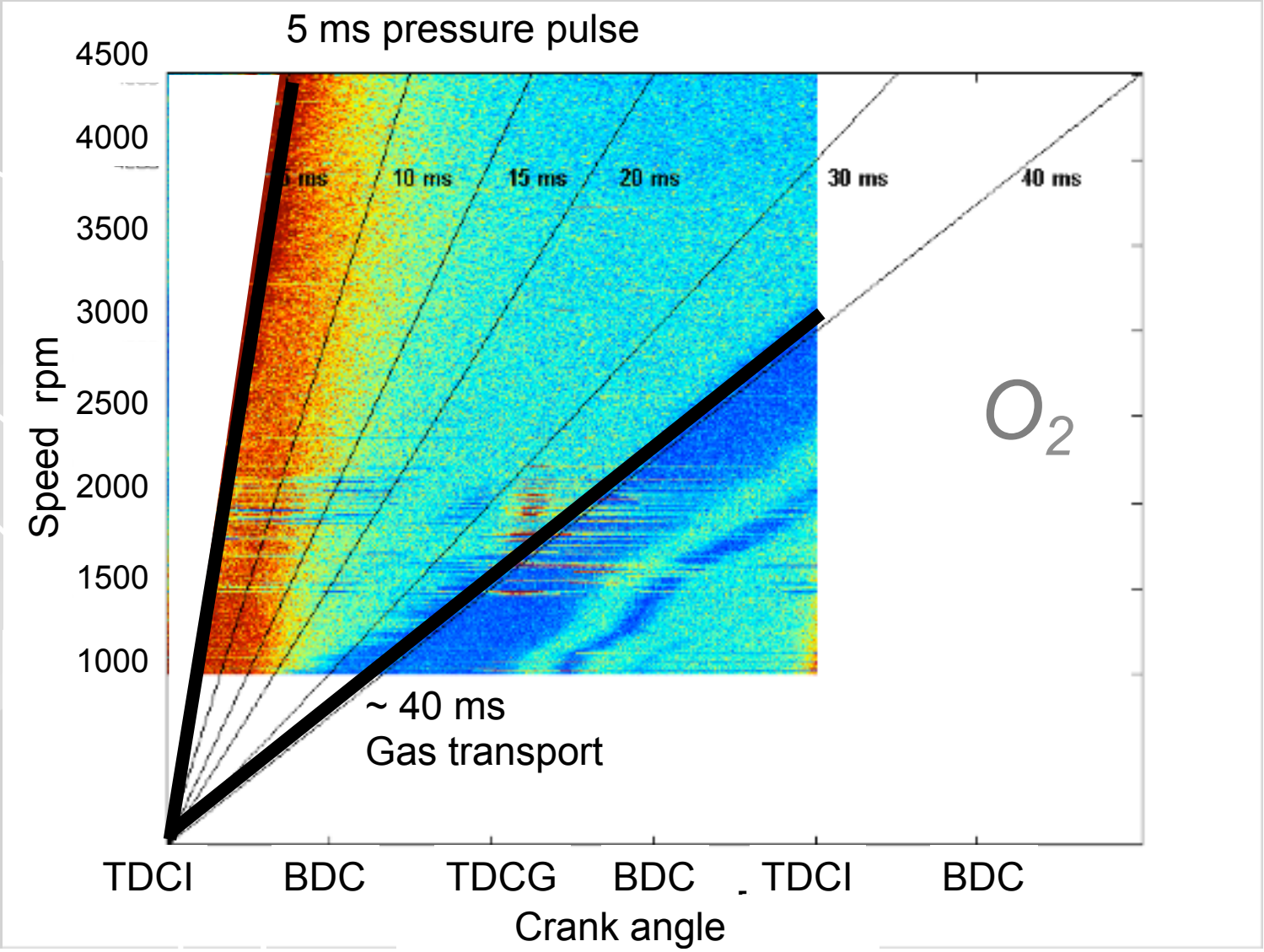
O_2-Measurement

Speed ramp

Conditions in Combustion chamber





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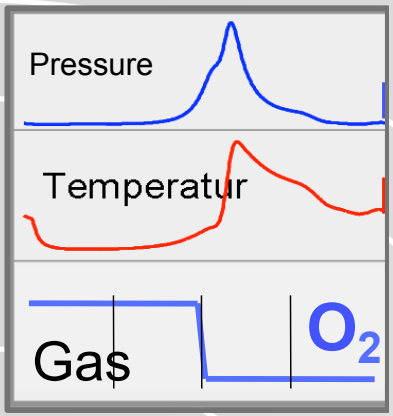
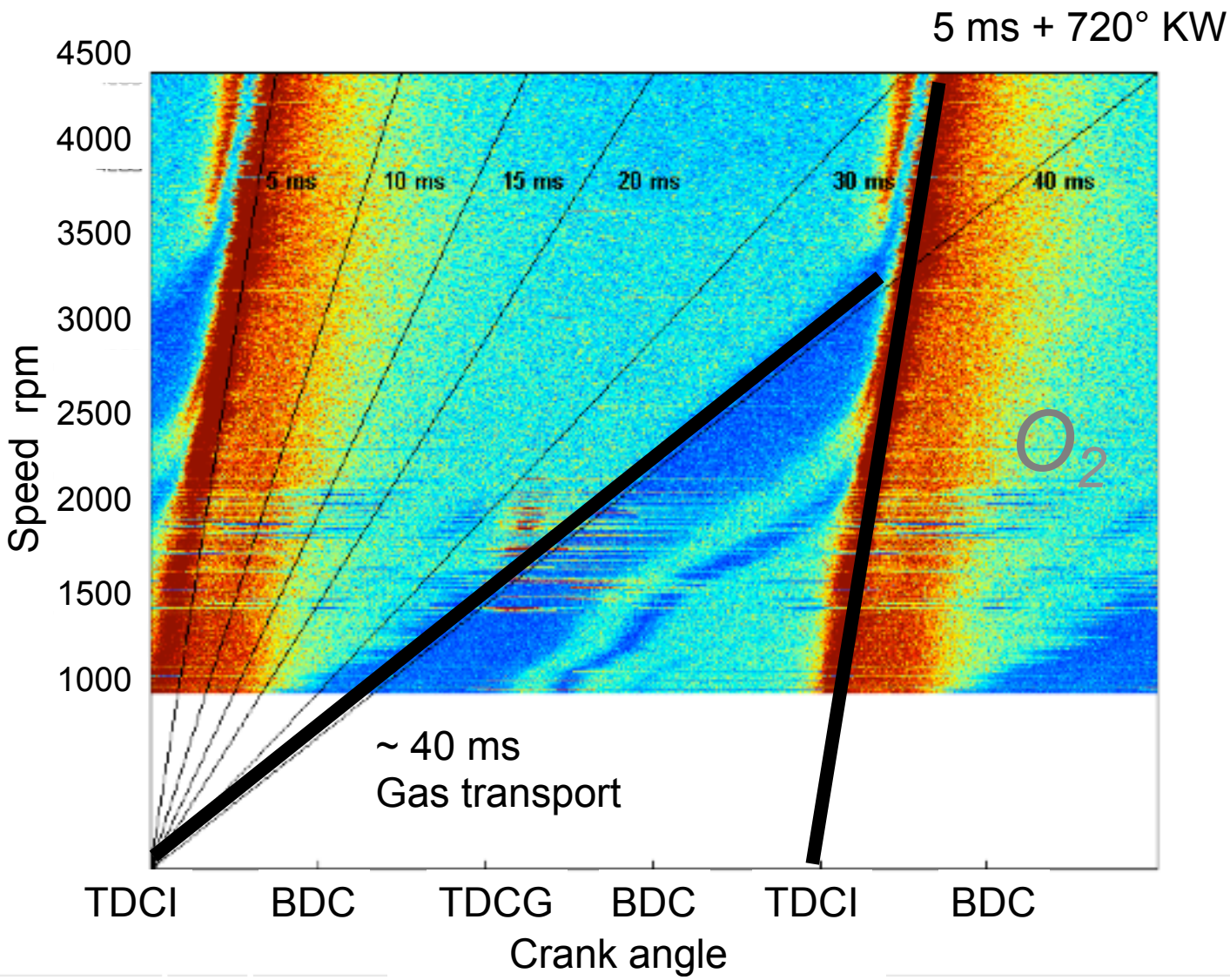
O_2-Measurement

Speed ramp

Conditions in Combustion chamber





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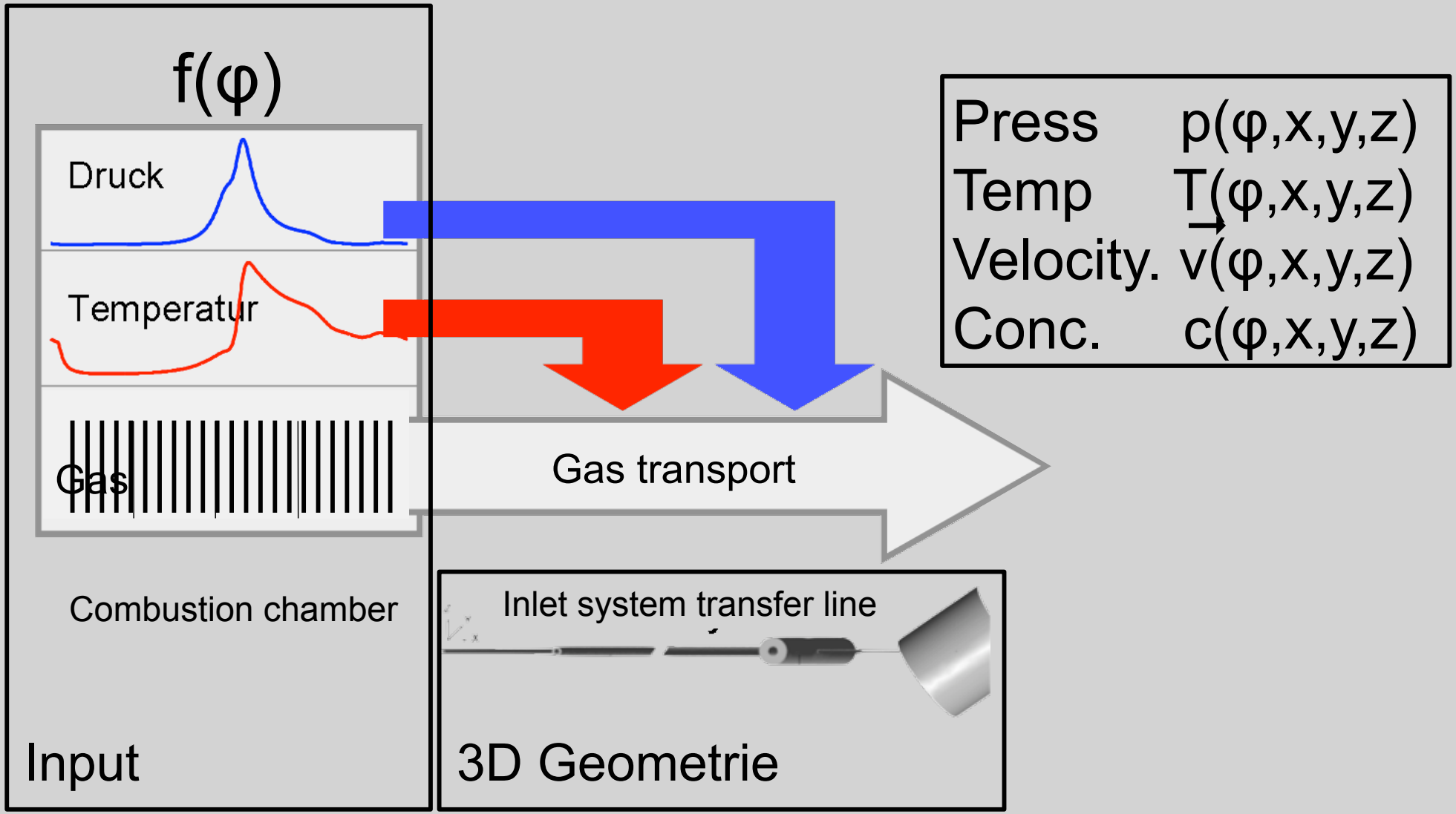
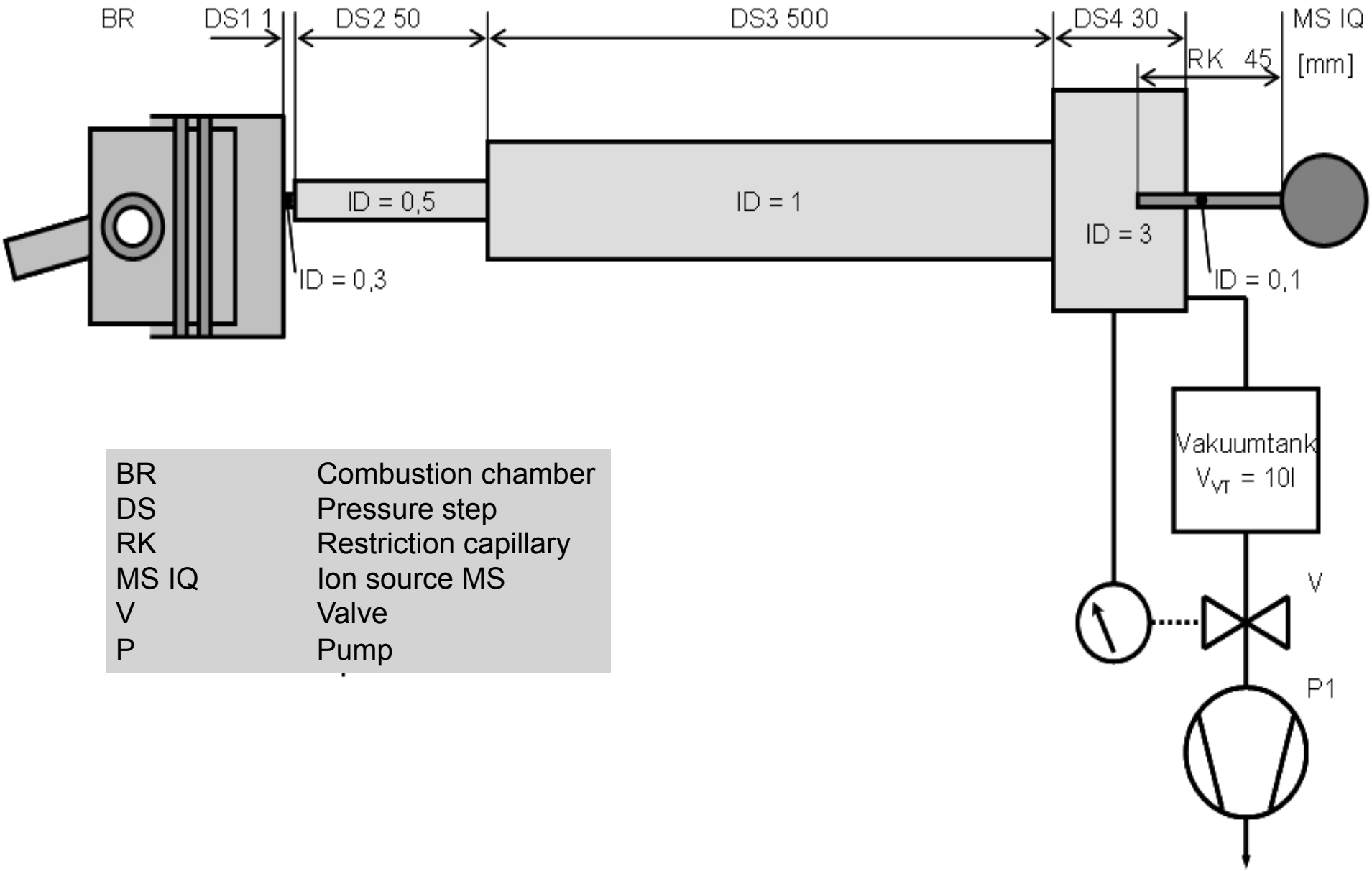
Computational Fluid Dynamics, CFD

Simulation of transient gas transportes





BR	Combustion chamber
DS	Pressure step
RK	Restriction capillary
MS IQ	Ion source MS
V	Valve
P	Pump

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Pressure reduction

Br DS1 DS2 DS3 DS4 MS IQ

Pressure [Pa]

10^6 10^5 10^4 10^3 10^2 10^1 10^0

Full power

low power

Combustion chamber

4 Step capillary

Pressure control

RK

Ion source

allowed range

Length x

Unterkritisch
Überkritisch

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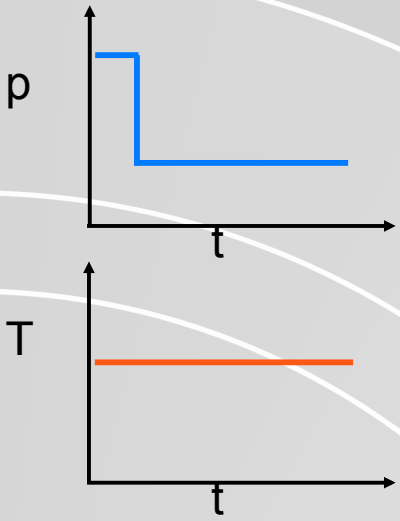
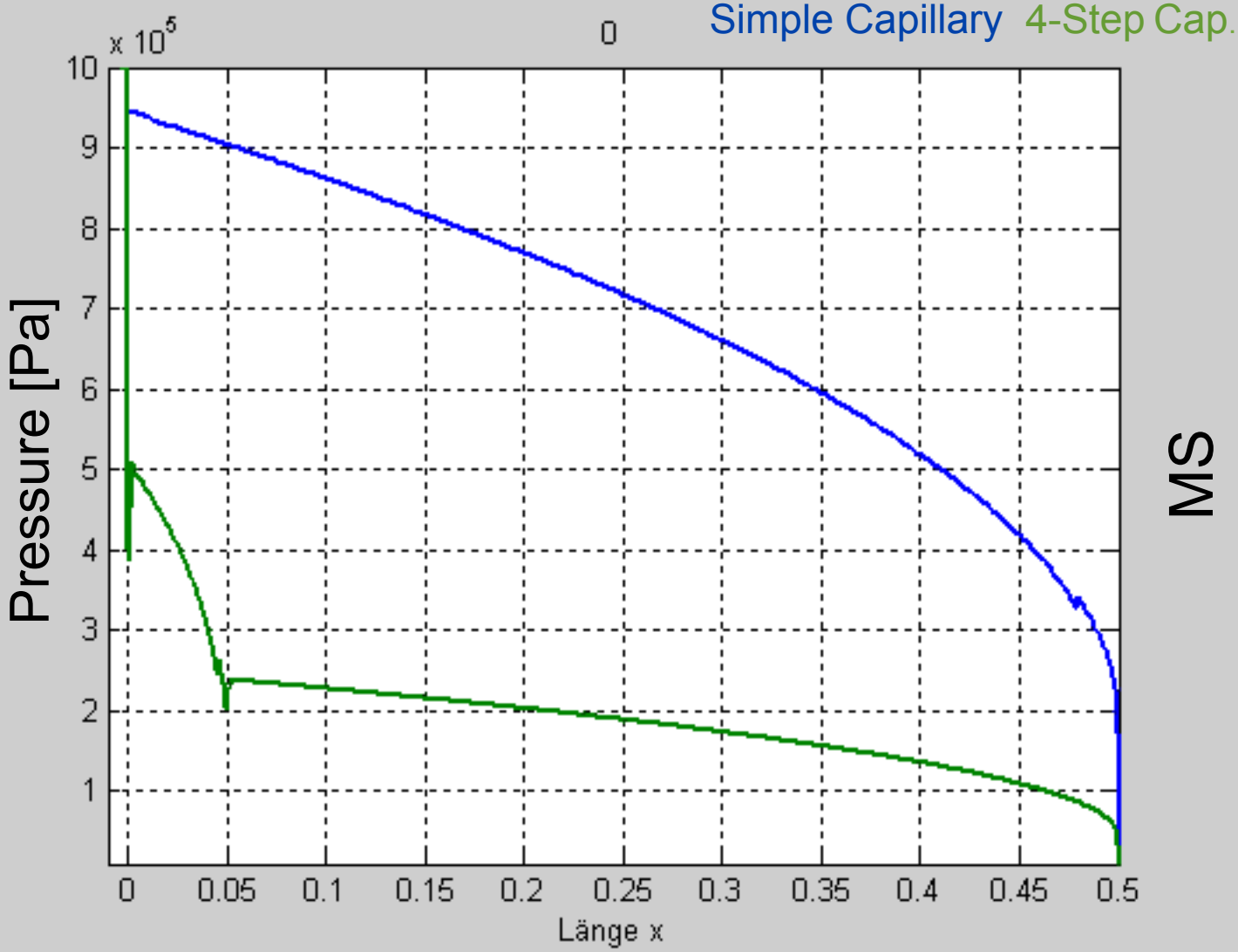
Pressure

Transient results



Simple Capillary 4-Step Cap.



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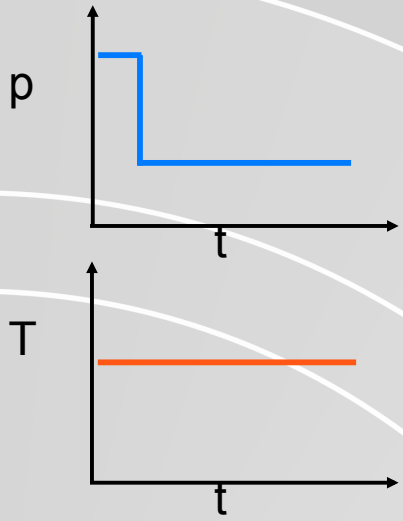
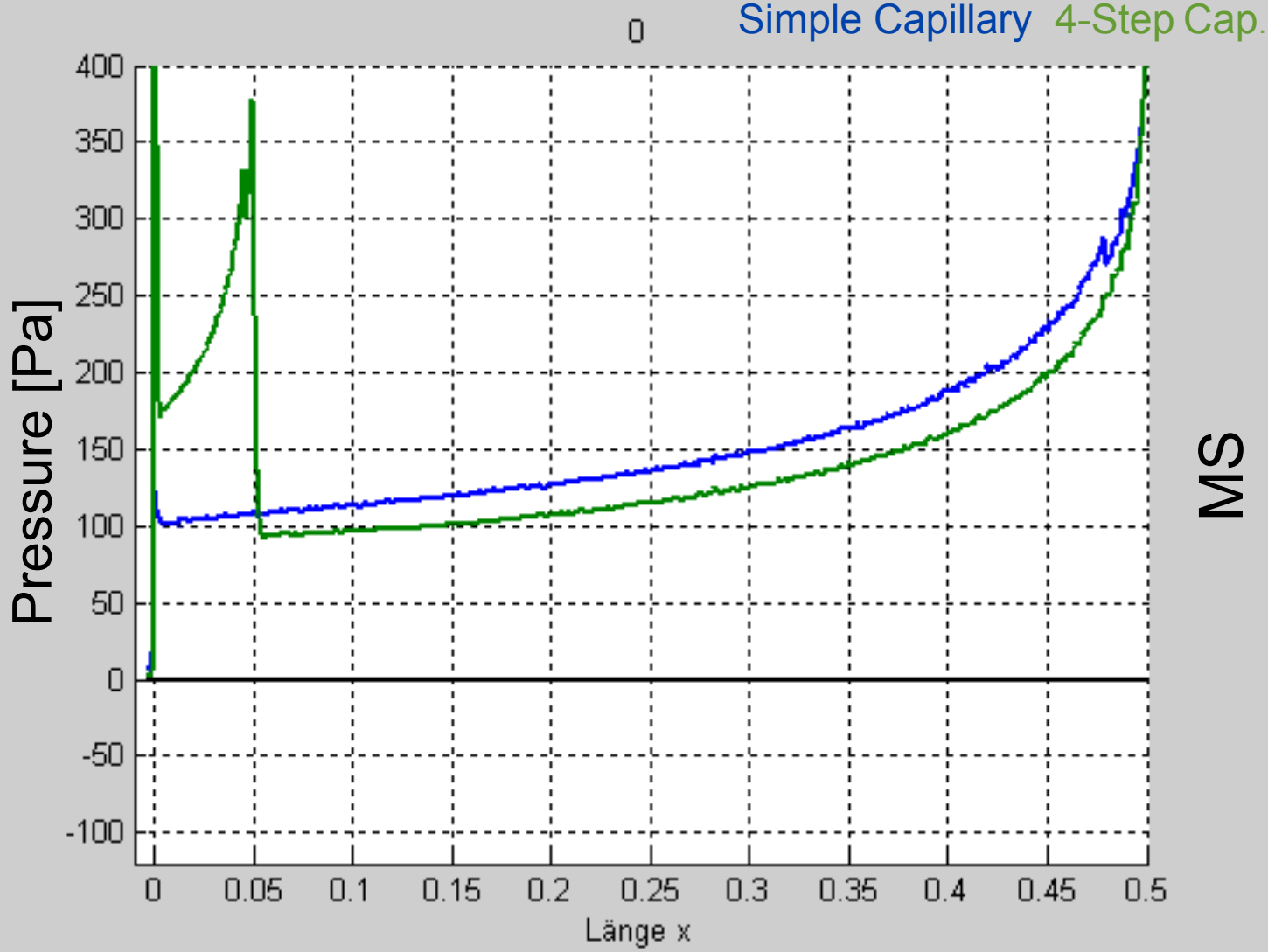
Velocity

Transient results

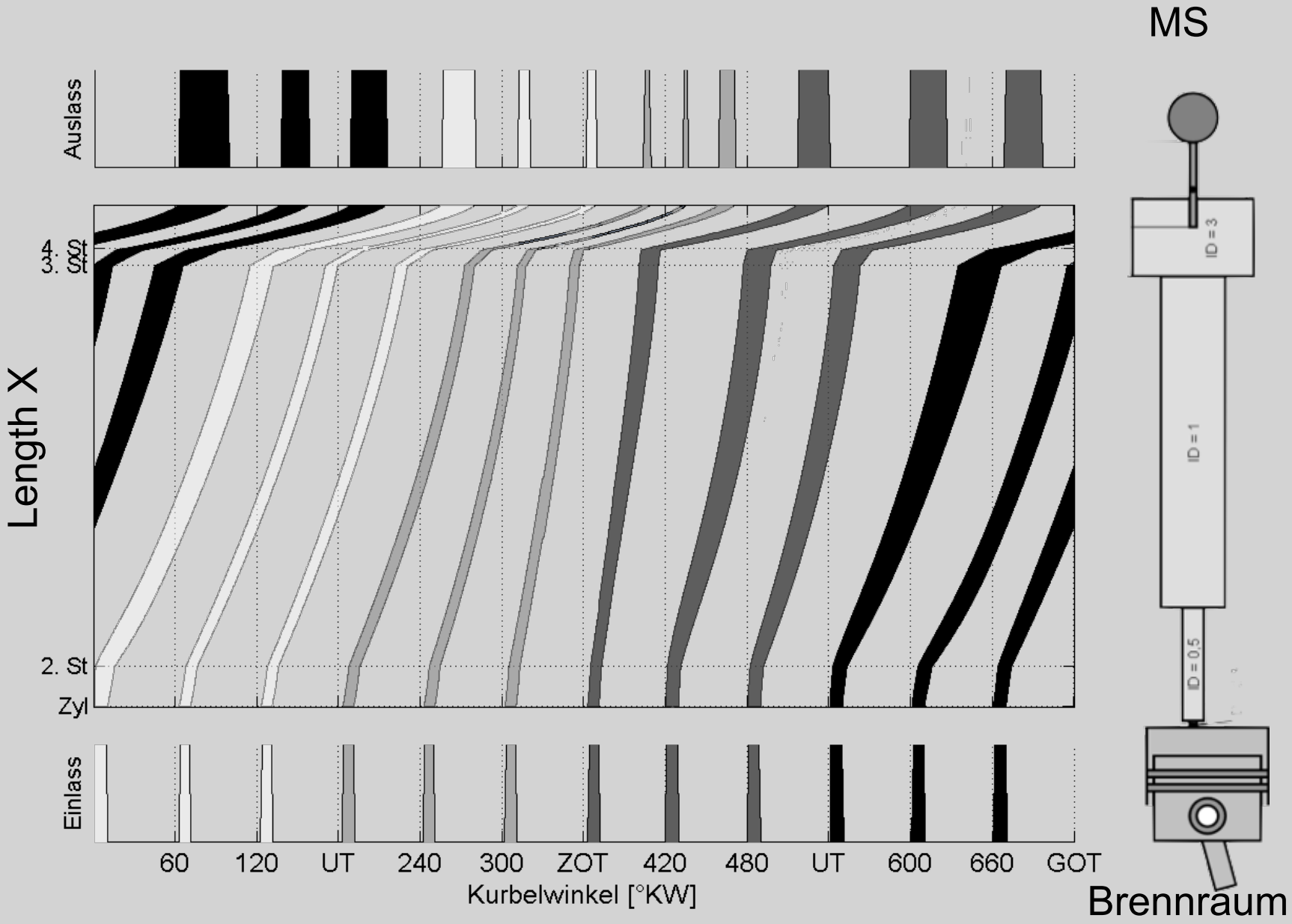




LUBRiSENSE
Oil Emission Measurement Technology

Gas transport

Test concentration pulses



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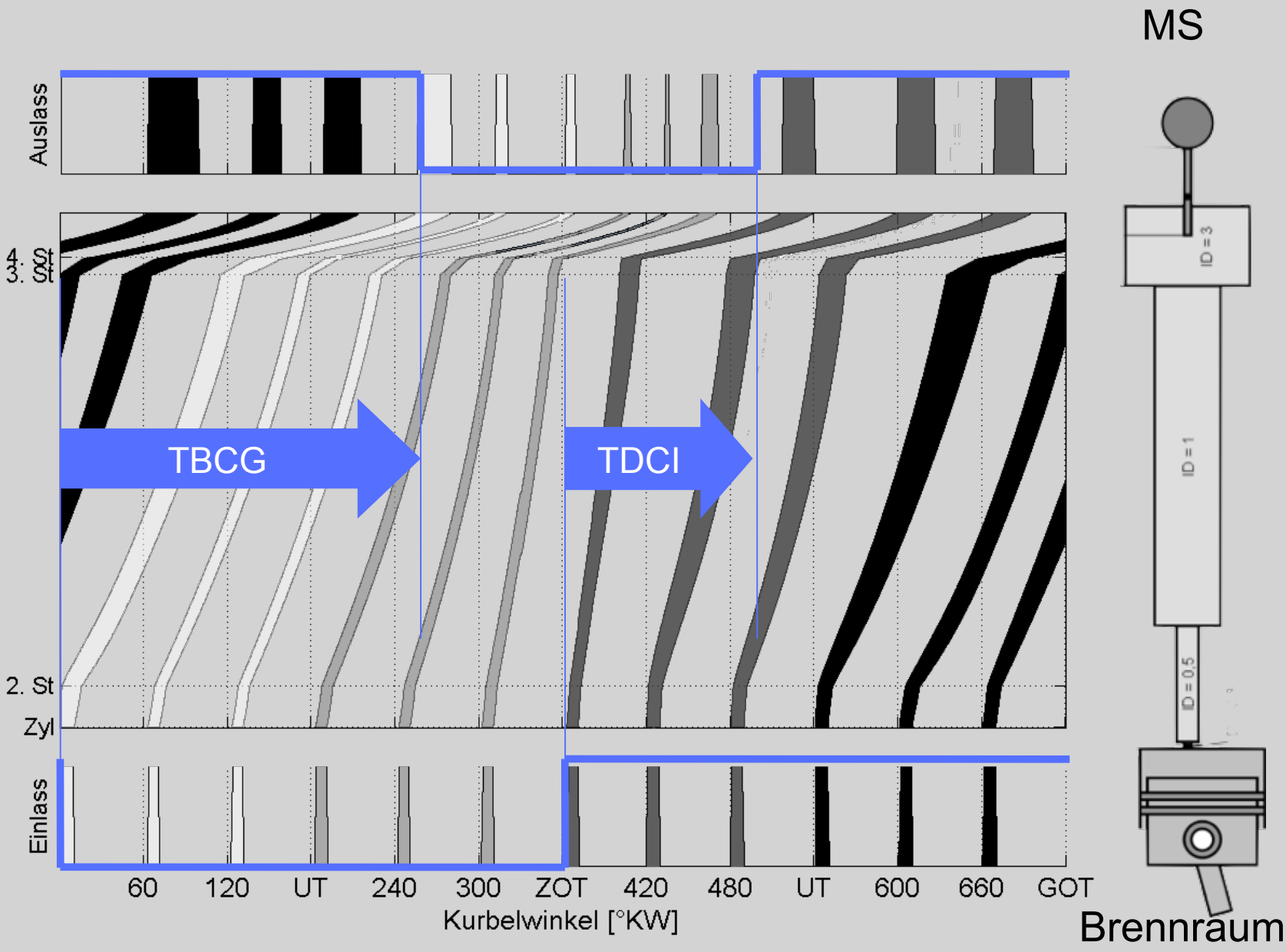
Gas transport

Test concentration pulses



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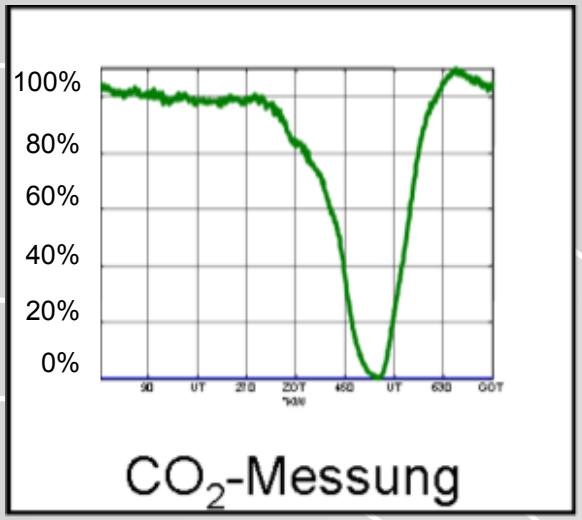
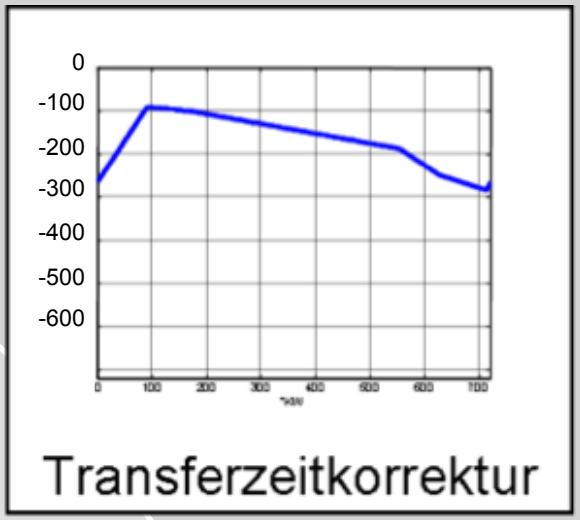
Transfer time determination

Geneticr Algorithm

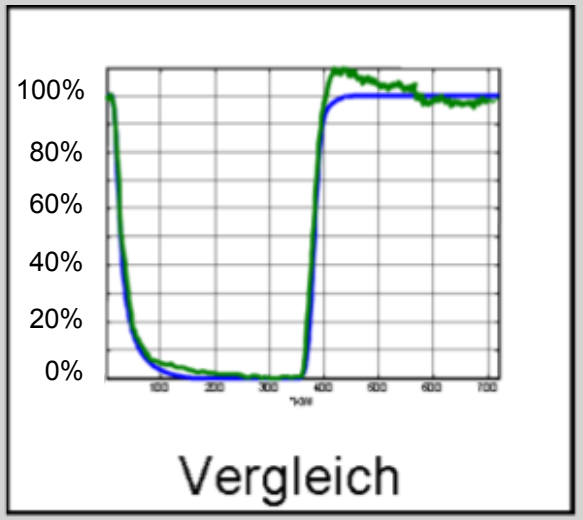
CO_2-Measurement



Transfer time correction function



Signal comparioson



Fitnessfunktion:

$$\min = \| CO_{2\,Sim} - CO_{2\,Mess,\,Korr} \|$$

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Oil Emission Measurement Technology

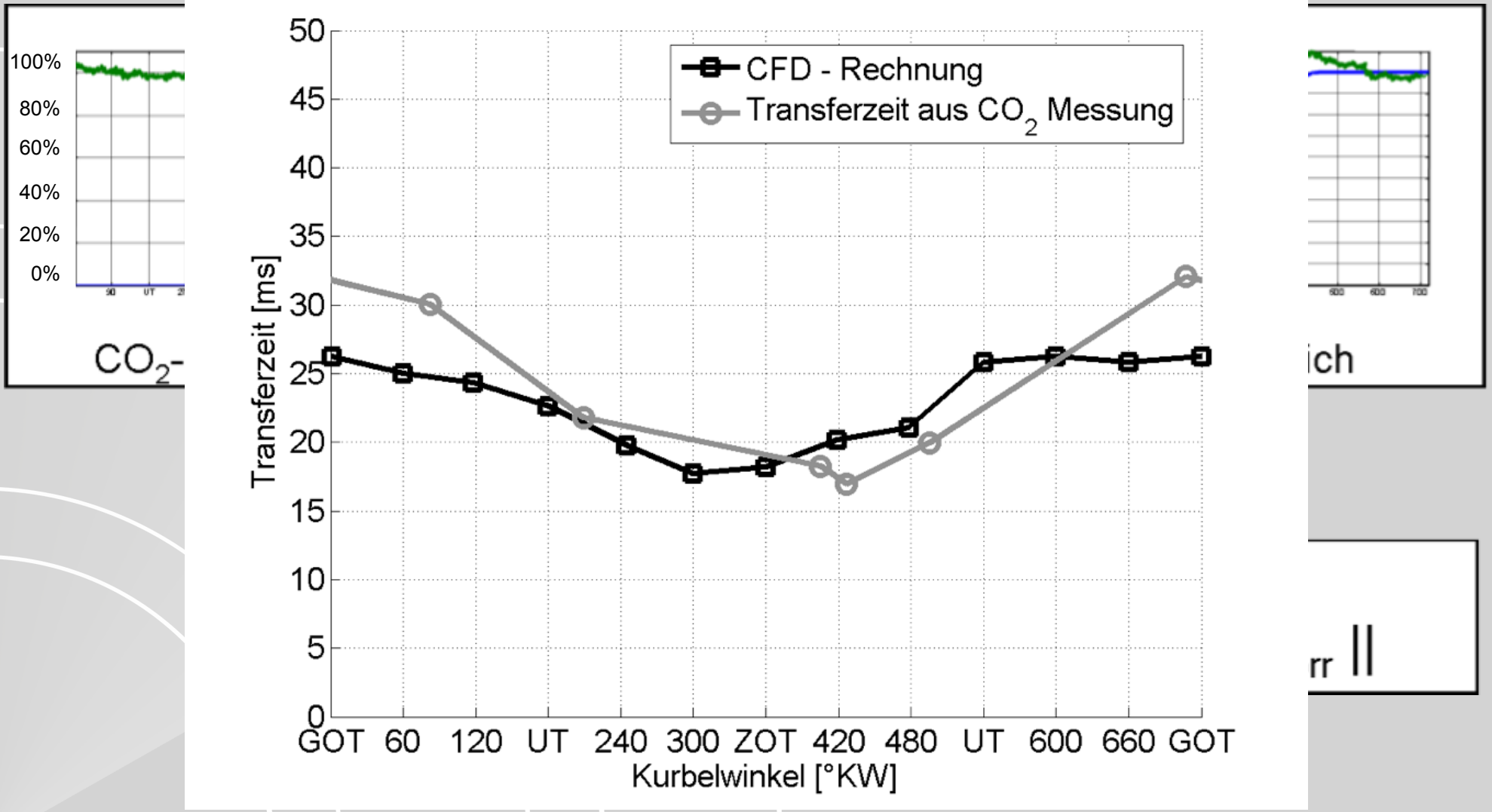
Transfer time determination

Geneticr Algorithm

CO_2-Measurement

Transfer time

Signal comparioson



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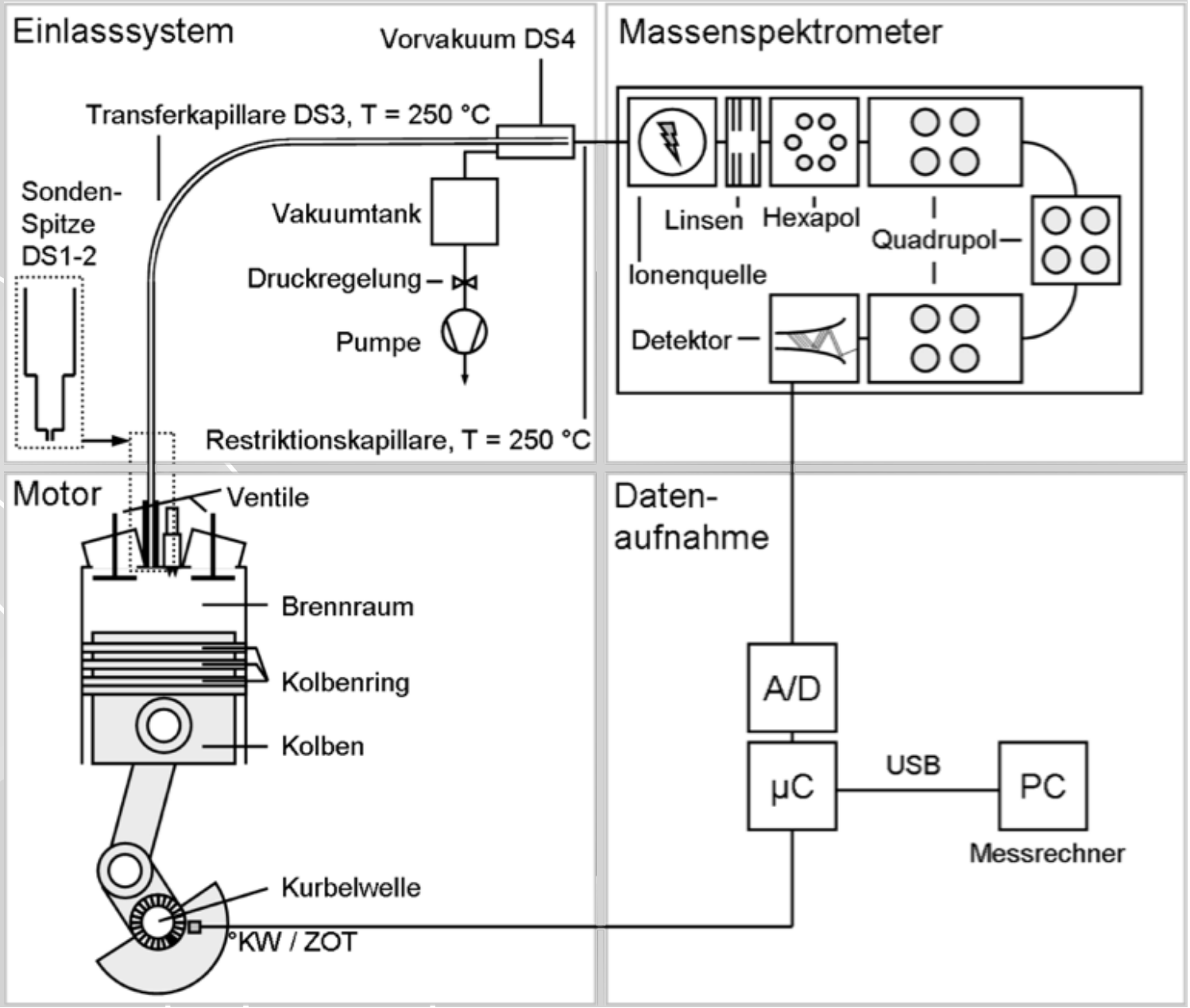
Measurement System



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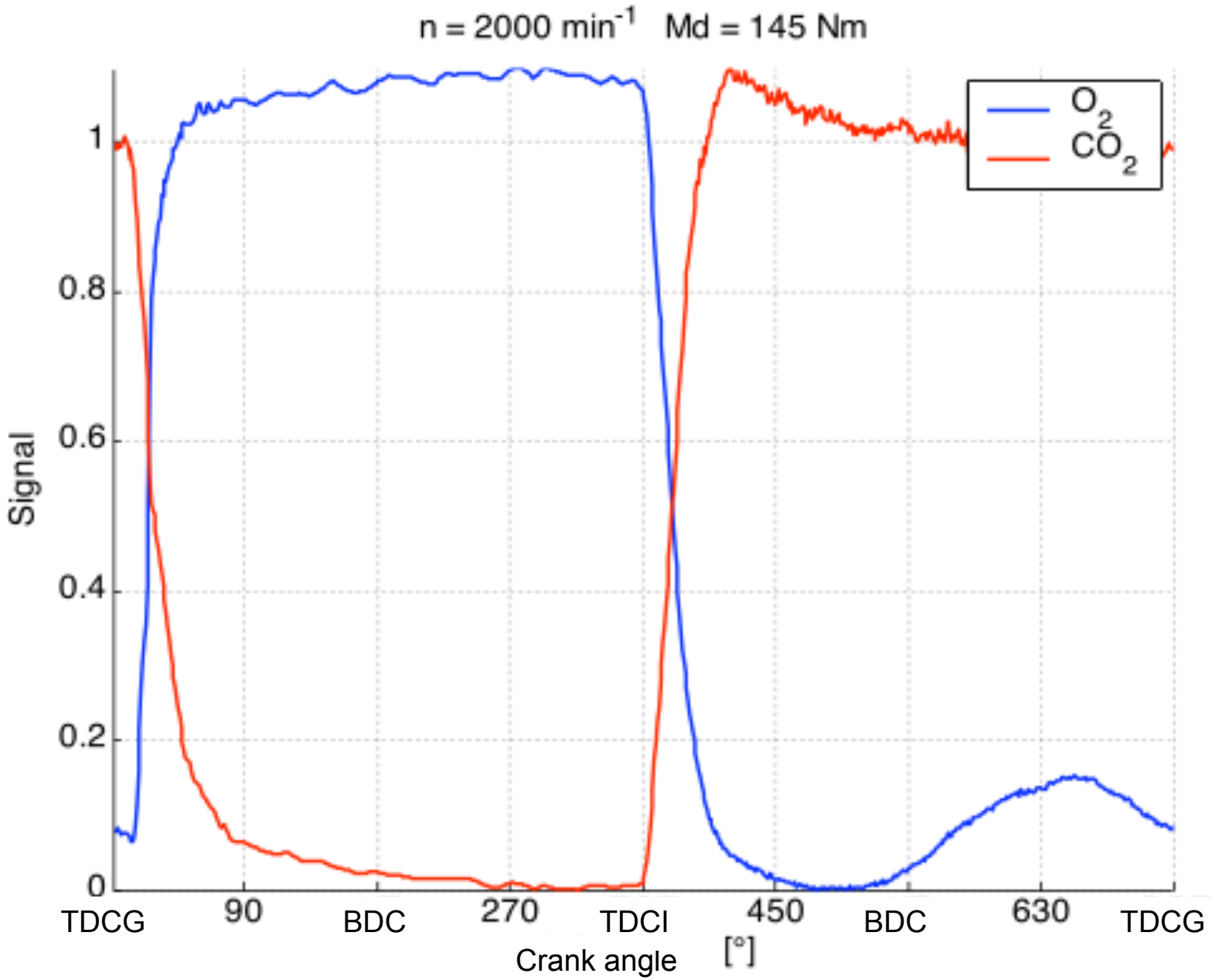
Measurement

O_2 / CO_2 – Signal Transfer time corrected



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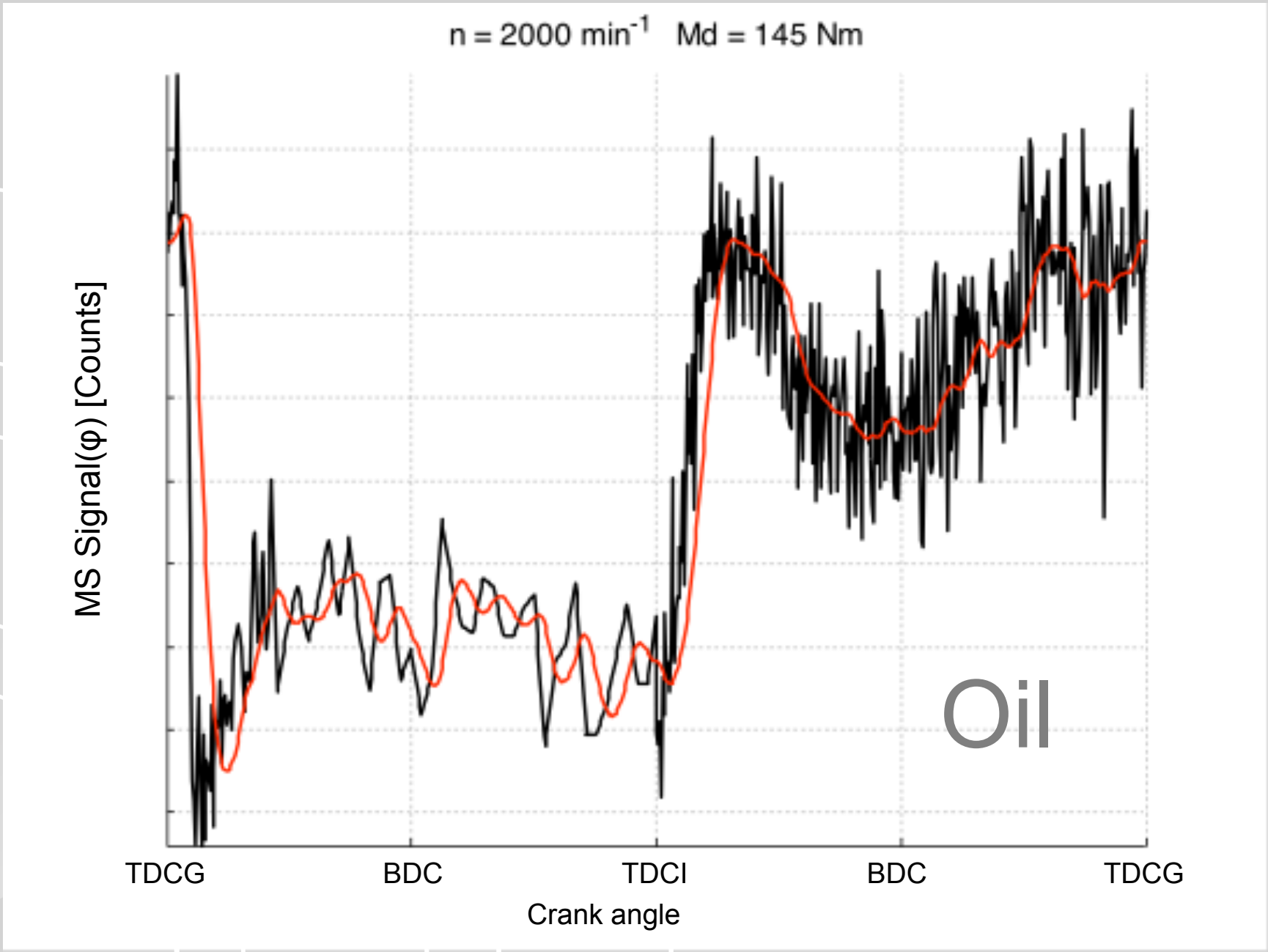
Measurement

Oil – Signal Transfer time corrected



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Oil Emission Measurement Technology

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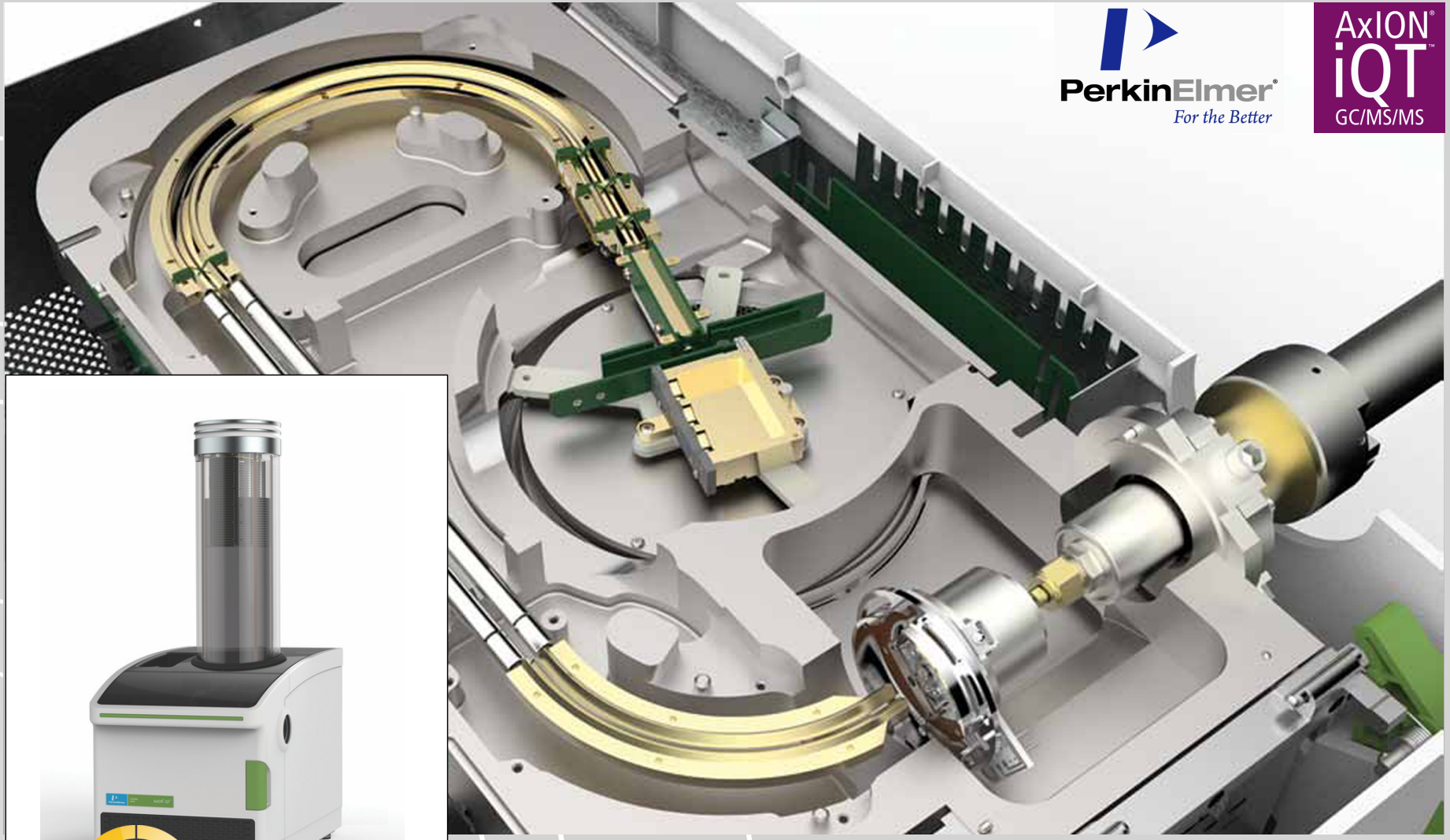
PiKal$_2$

LUB360 the new Lubrisense

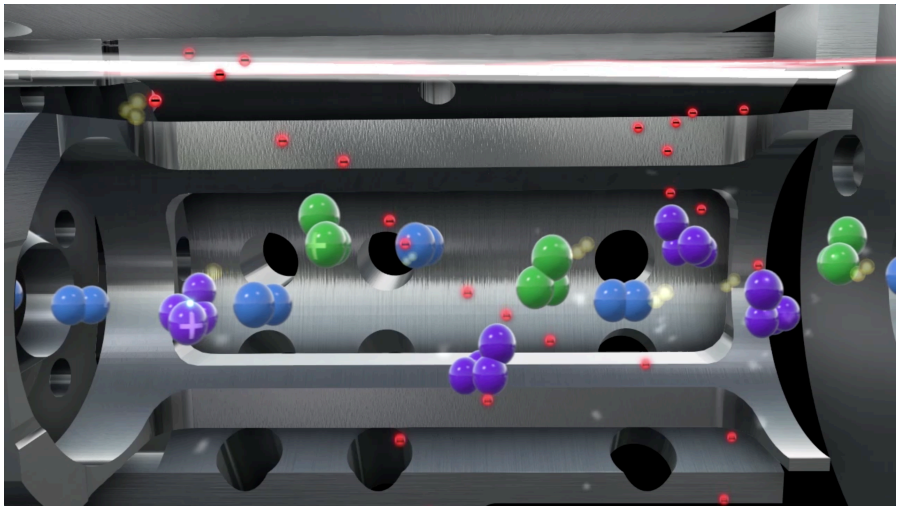


LUB360

Mass Spectrometer

Ion source

Standard EI and Cold EI



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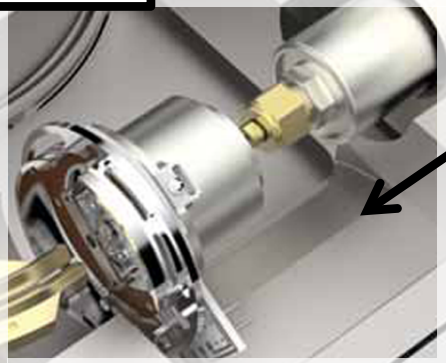
AxION® iQT™ GC/MS/MS



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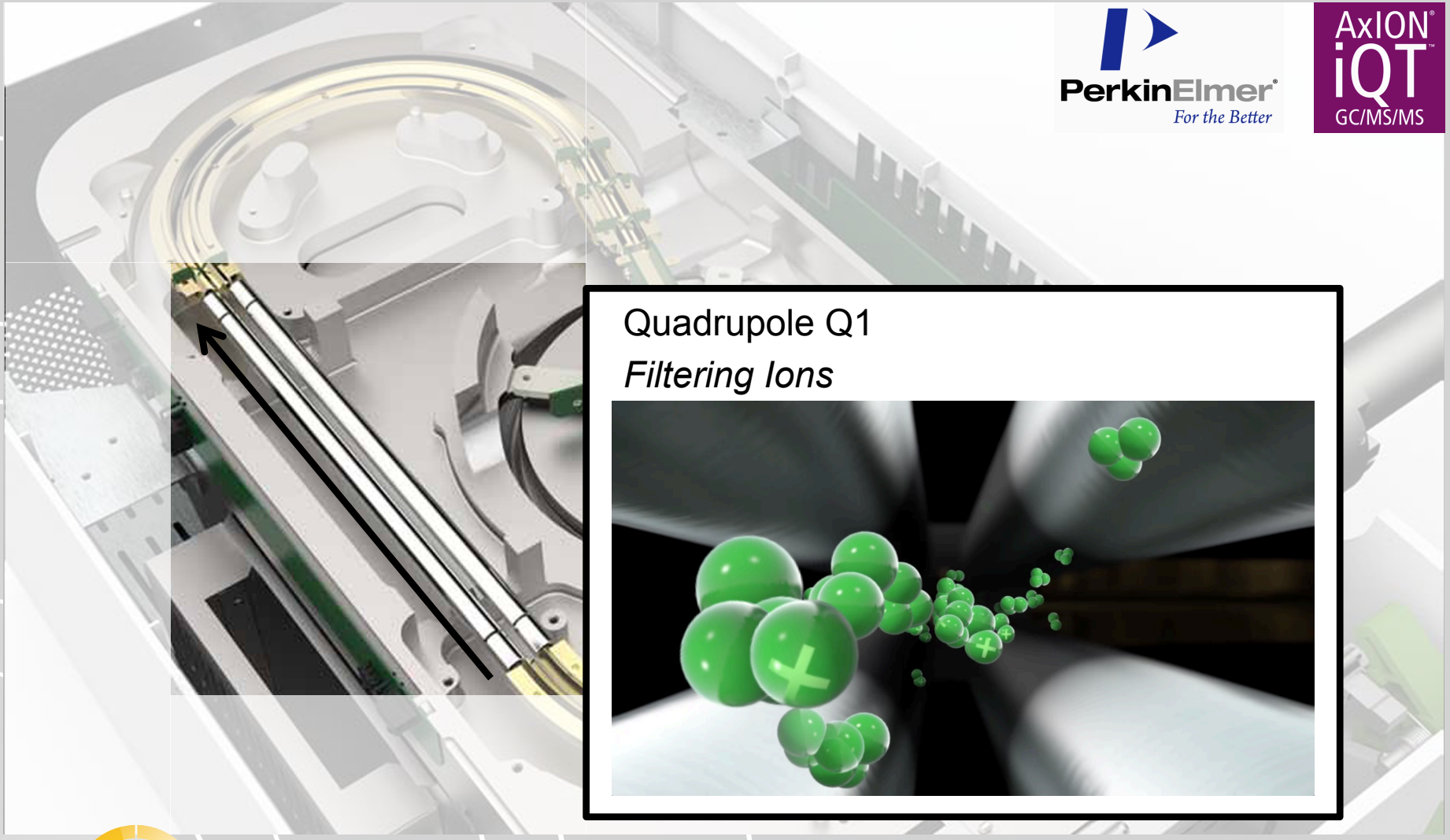
Mass Spectrometer



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Mass Spectrometer

PerkinElmer
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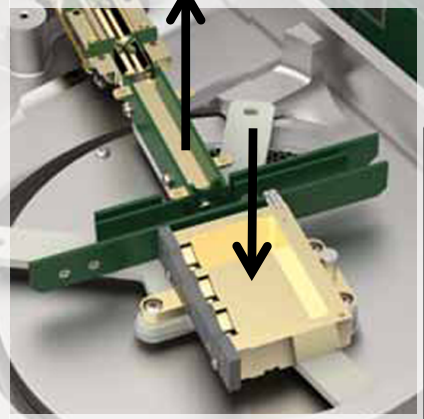
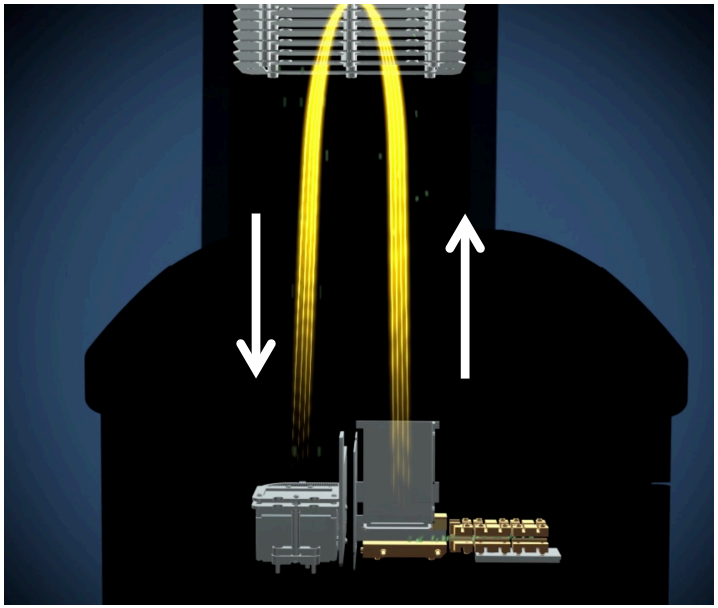
AxION iQT GC/MS/MS



Ion Pulser / TOF / Detector

Separation of Ions



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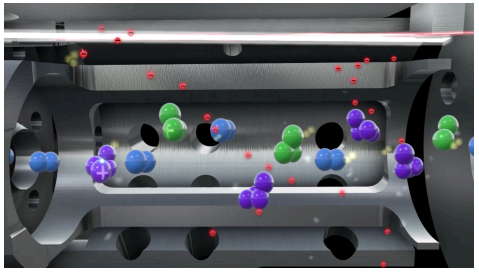
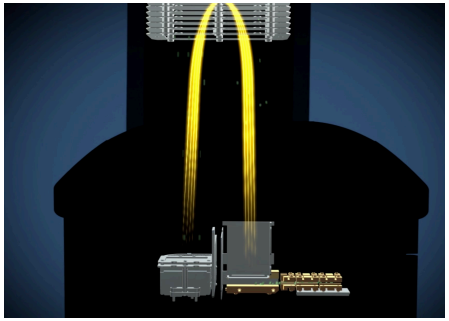
Combination of ColdEI – TOF

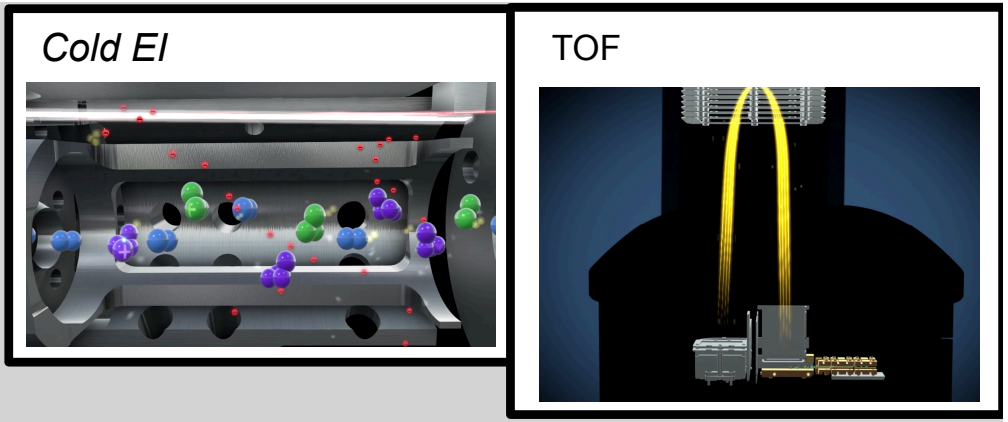
Cold EI



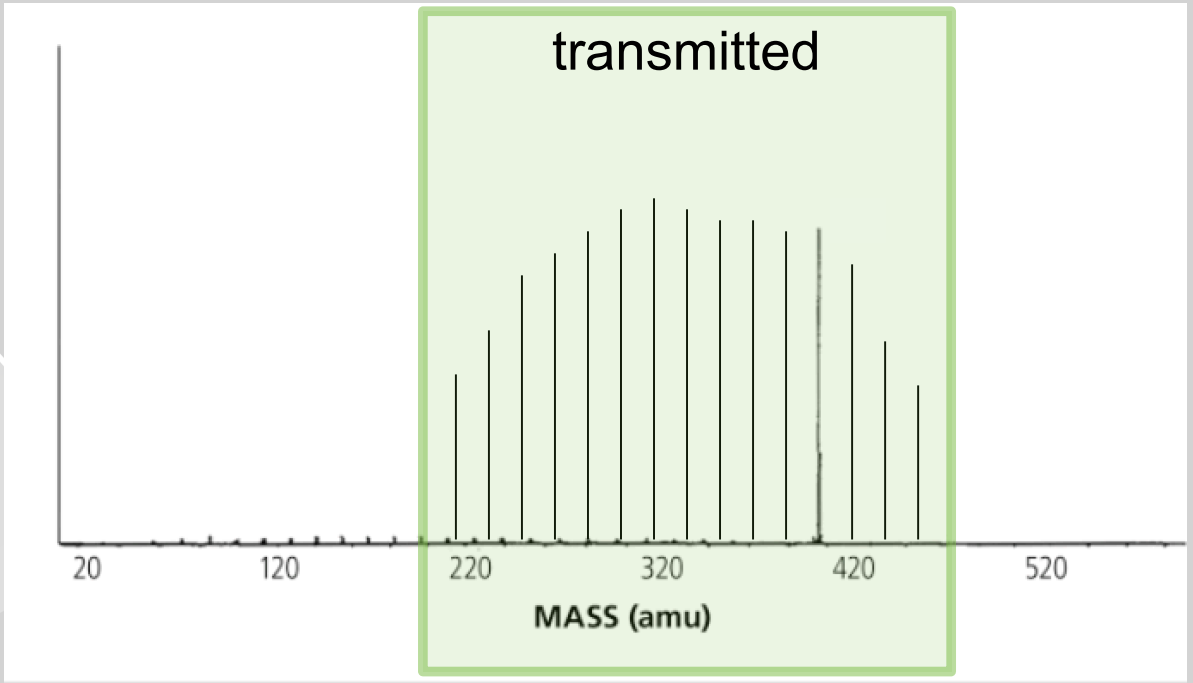
TOF



Combination of ColdEI – TOF



TOF: Instead of a single value
a complete spectra is measured



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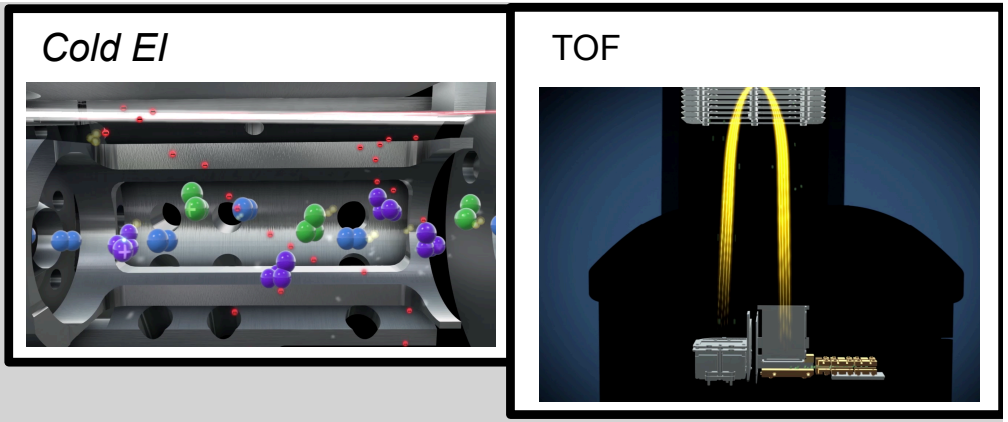
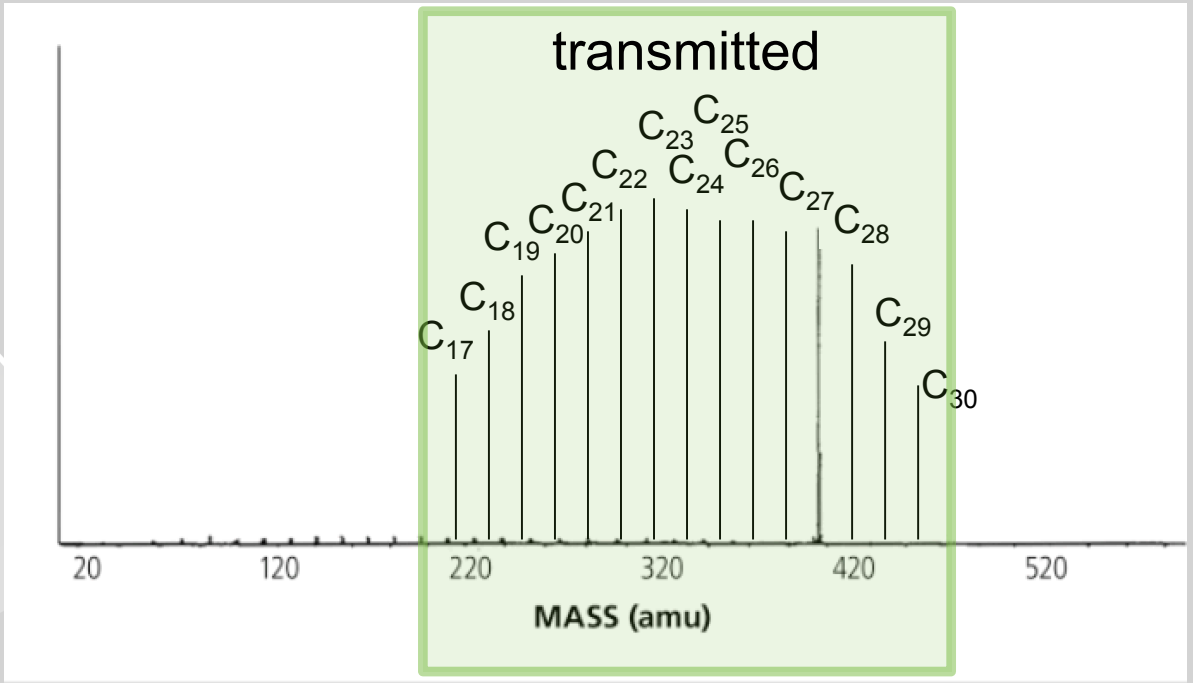
Combination of ColdEI – TOF

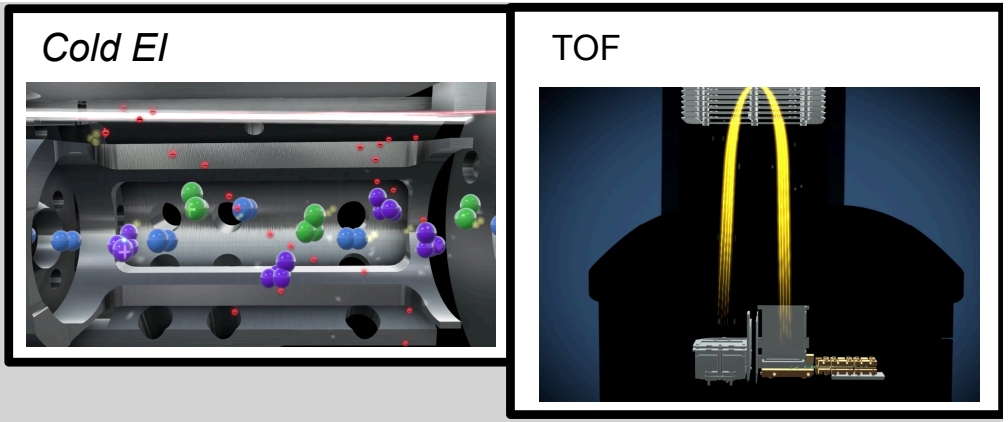


TOF: Instead of a single value a complete spectra is measured

ColdEI: mass of ions shows the molecular compostion of oil emitted



Combination of ColdEI – TOF



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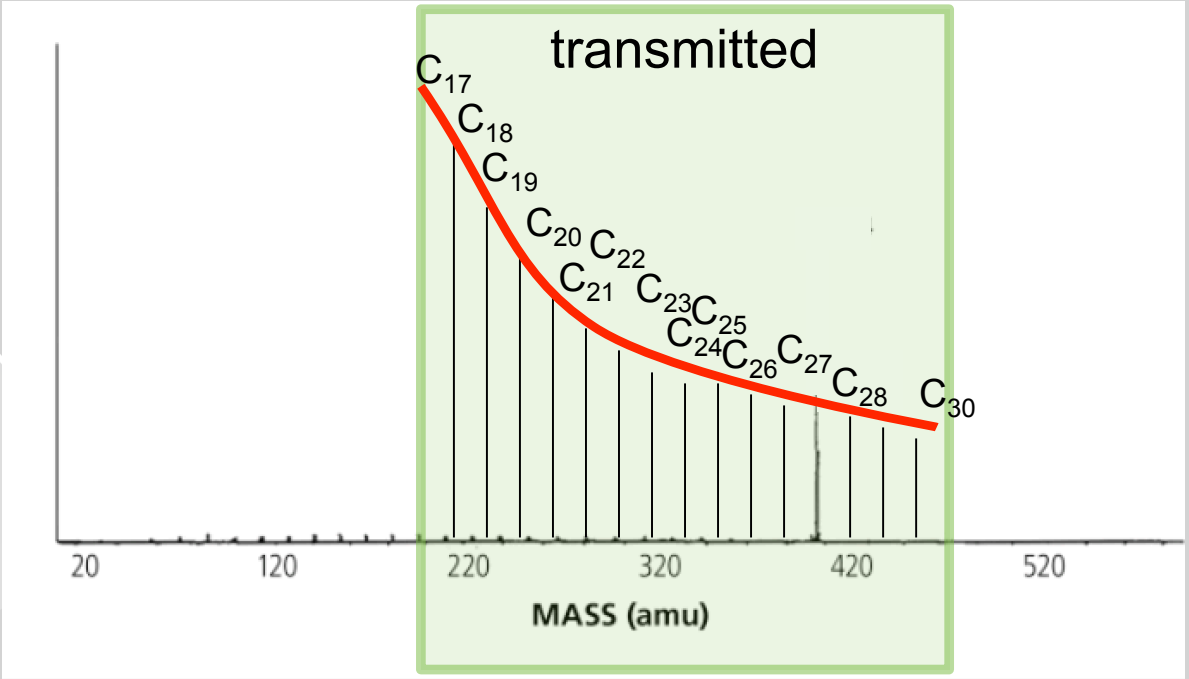

Gives information about the source of oil emission

more light molecules → evaporation → - cylinder liner
- tangetial pressure of piston rings

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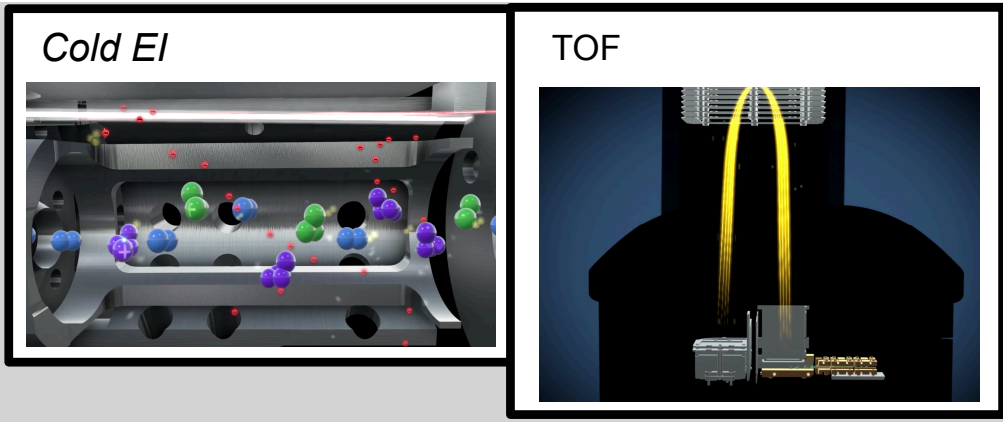
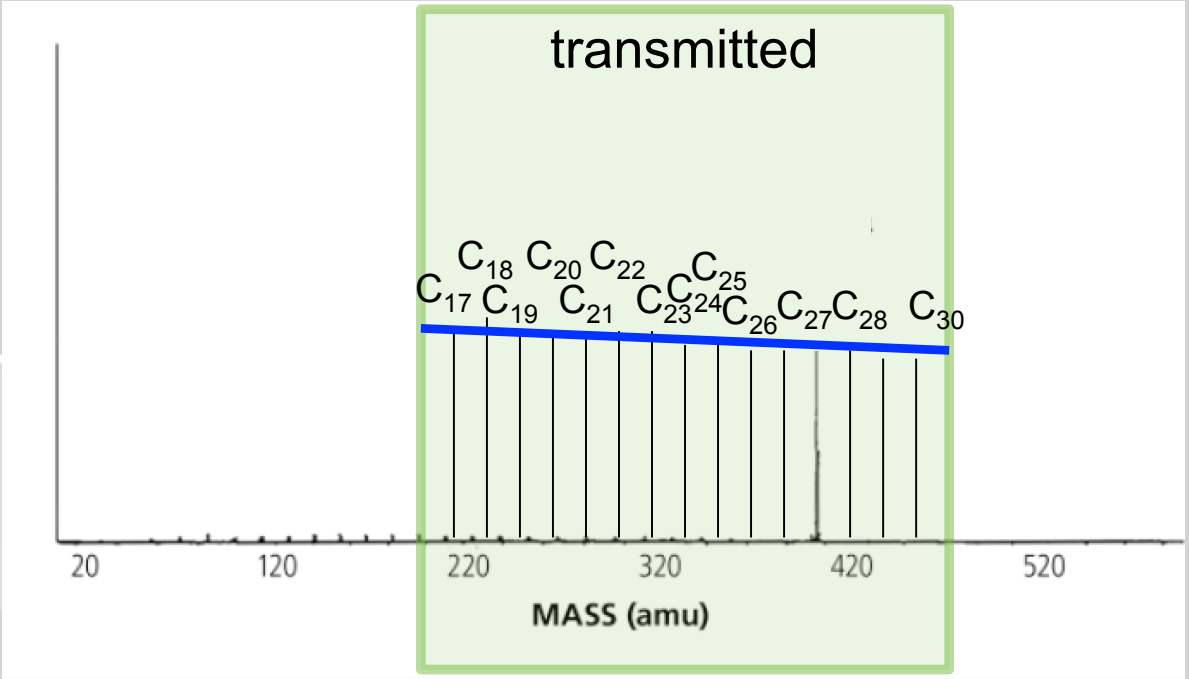
Combination of ColdEI – TOF



TOF: Instead of a single value a complete spectra is measured

ColdEI: mass of ions shows the molecular compostion of oil emitted



Gives information about the source of oil emission

more light molecules → evaporation → cylinder liner
→ tangential pressure of piston rings

more heavy molecules → droplets, mist → reverse blowby, throw off, scarp off
→ piston ring dynamics

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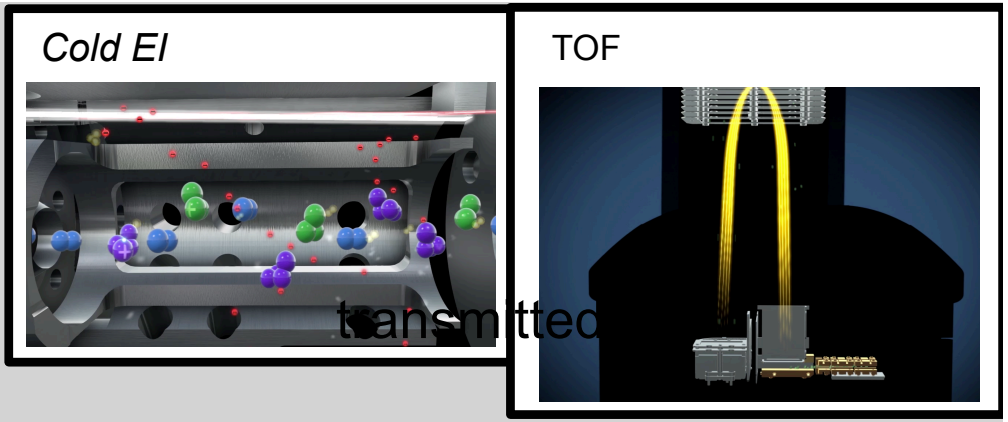
Combination of ColdEI – TOF

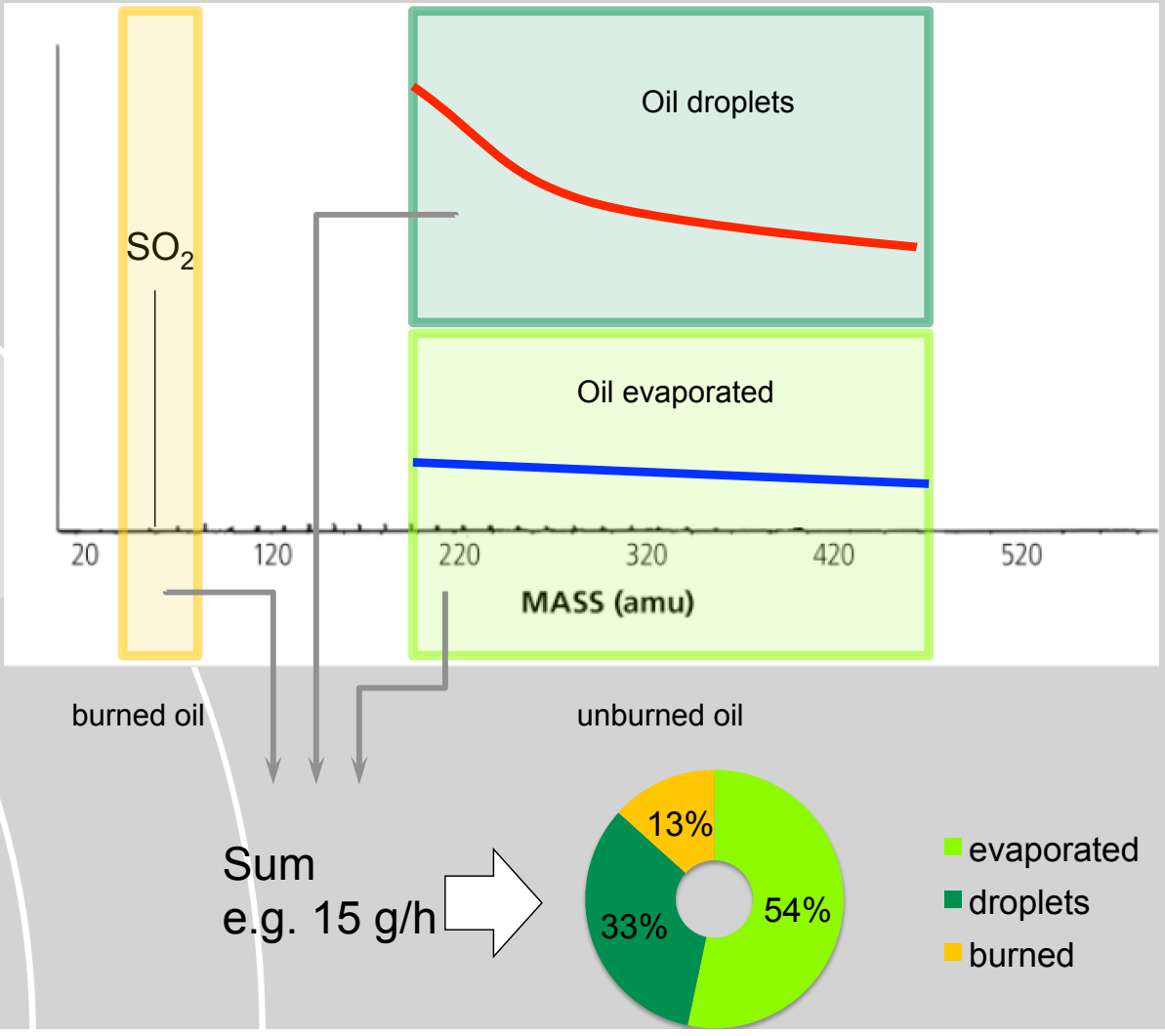
If high sulfur oil is used

SO_2 Trace (mass 64 m/z) is proportional to burned oil

TOF: Instead of a single value a complete spectra is measured

ColdEI: mass of ions shows the molecular compostion of oil Emitted





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SIMPLEXITY

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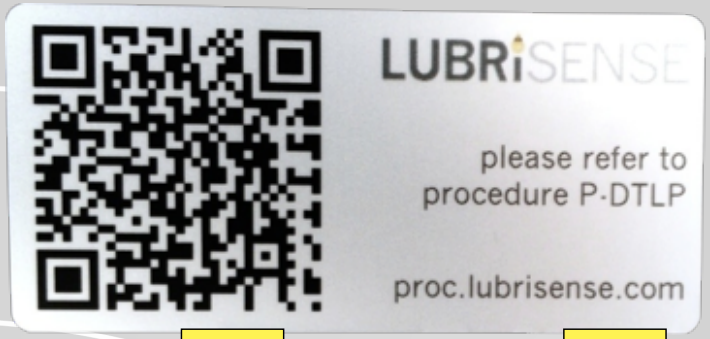

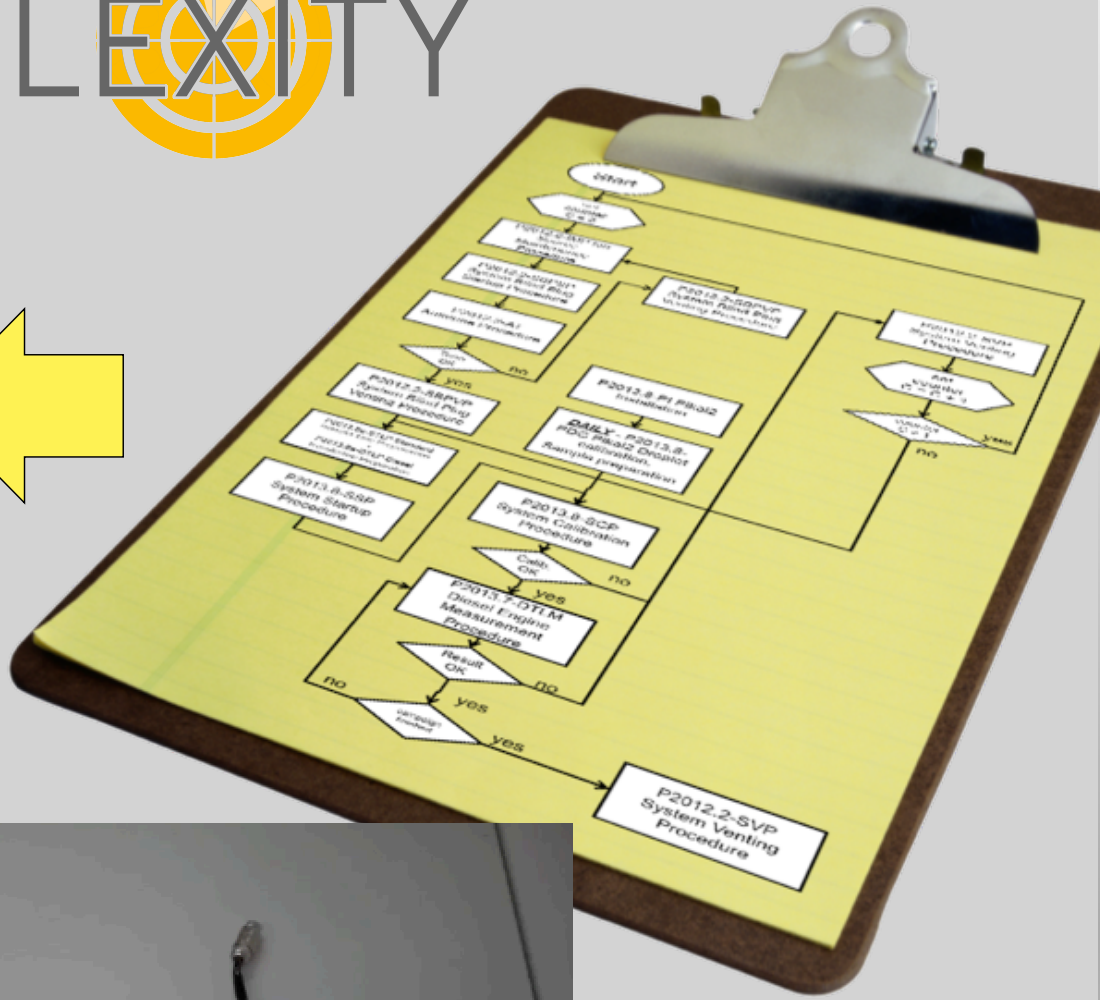

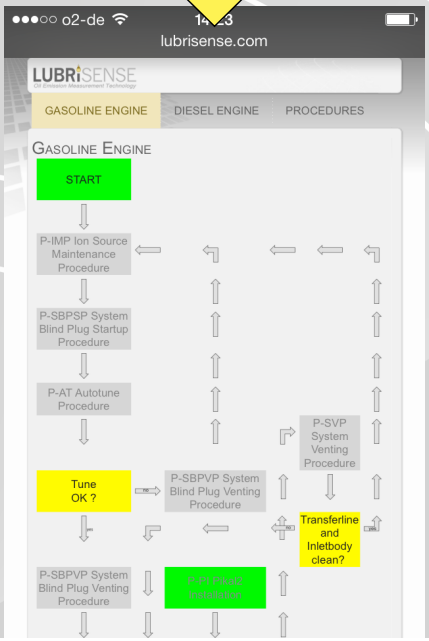

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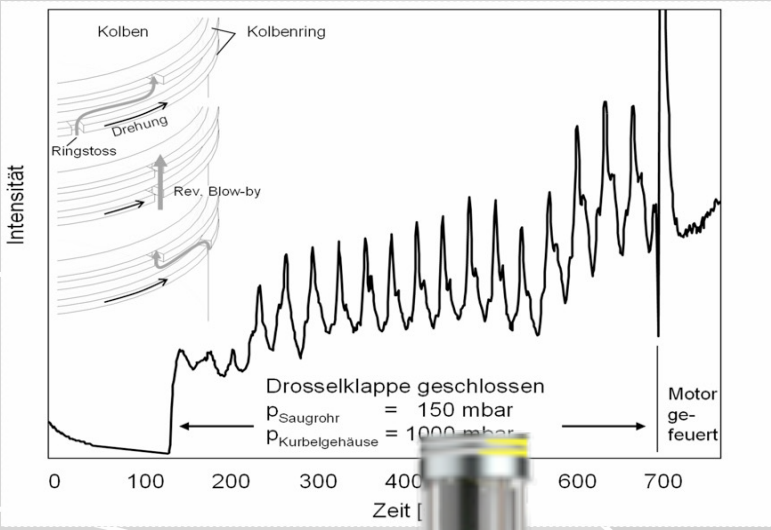

System Zur Messung Von Ölemissionen Im Dieselabgas

MTZ - Motortechnische Zeitschrift Ausgabe 05/2013 Seite 424-429

Autor(en): A. Behn, M. Feindt, S. Krause, G. Matz

Quelle: Springer Automotive Media Wiesbaden GmbH (2013)

Analyse des Ölverbrauches bei transientem Motorbetrieb

Motortechnische Zeitschrift, MTZ 01.2013

A. Frommer, A. Beeckmann, R. Freier, R. Künz

Ölemissionsreduzierung - Ein signifikanter

Zeitschriftenartikel: MTZ - Motortechnische Zeitschrift Ausgabe 11/2

Autor(en): Prof. Dr.-Ing. Jens Hadler
Quelle: Springer Automotive Media Wiesbaden GmbH (2013)

13. Internationales Stuttgarter Symposium | Automobil- und Motorentechnik

Armin Frommer, H. Ehnis, R. Freier, R. Künzel, MAHLE International GmbH

Ganzheitliches Konzept zur Optimierung der Ölemission

MTZ - Motortechnische Zeitschrift Ausgabe 01/2014 Seite 44-49

Autor(en): J. Hadler, C. Lensch-Franzen, M. Gohl, T. Mink

Quelle: Springer Automotive Media Wiesbaden GmbH (2014)