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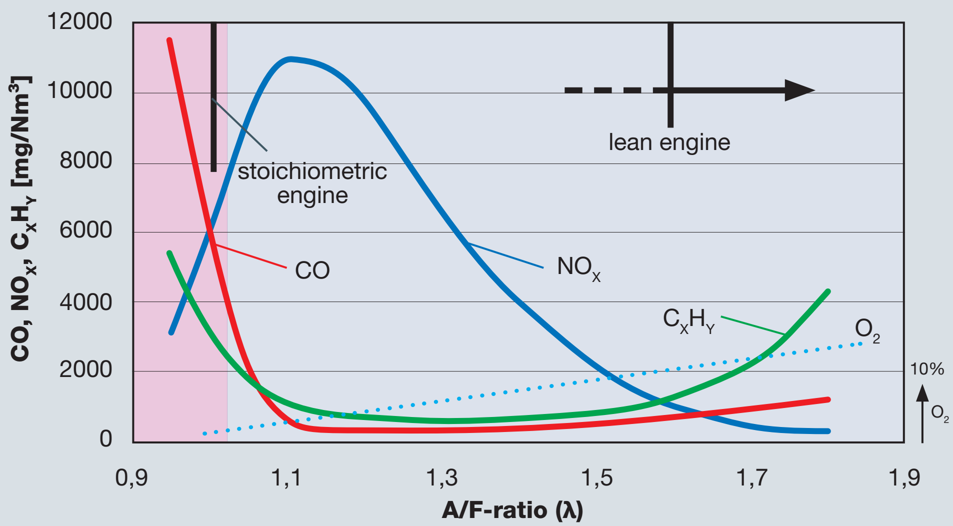
Application description

Engine Emissions: Gas Compression, Power Generation, and CHP

Theoretical background 1

Development of emissions based on Lambda (λ) values



In general:

The curve on the combustion chart shifts, depending on the relation between air and fuel ratio

NO_x:

$NO_x = NO + NO_2$ –> measure NO_x separately

- NO_2 components can fluctuate widely
- Consisting of fuel NO_x and thermal NO_x
- Highest NOx value = highest mechanical efficiency

CxHy:

$C_xH_Y + O_2$ –> $CO_2 + H_2O$ (combustion equation)

Rich burn engines (λ ≤ 1)

Characteristics:

- Engines with air deficiency (Lambda = 1): Fuel is therefore not used efficiently
- Typical applications: Compressor stations (comparable to gasoline engine in cars)
- Typical working range: λ~0.85 to 0.95

Advantage and disadvantage for rich engine:

+ High performance density
+ Initial cost is lower than lean burn engine
+ Secure operation
+ Low emissions with controls
– High fuel consumption
– High emissions (if not controlled)
– Not suitable for use with bio-gas

NO_x (nitrogen oxides):

$NO_x \leq NO_x$ max.: low NO_x component due to incompletely burned or unburned fuel (HC)
–> no max. temperature development (so less thermal NO_x is generated)

C_xH_Y or HC (hydrocarbon, e.g. methane):

Due to the lack of oxygen, not all fuel (HC) is combusted
–> high C_xH_Y value

CO (carbon monoxide):

Oxygen deficiency in the combustion process leads to the inability of all CO molecules to be converted into CO_2. As a result, fuel leaves the engine incompletely burned or unburned.
–> leads to high fuel consumption (HC slip)

Lean burn engines (λ > 1)

Characteristics:

- Engines with excess air (lean engines)
  –> Fuel is used efficiently
- Typical applications: Gas compression, power supply for hospitals, government buildings, server buildings, sewage plants, mining
- Typical working range: λ~1.05 to 1.3

Advantage and disadvantage for lean engine:

+ Suitable for use with bio-gas
+ High fuel efficiency
+ Low in emissions
– May require oxidation catalyst
– Higher initial cost

NO_x (nitrogen oxides):

$NO_x > NO_x$ max.: An elevated O_2 level leads to a lowering of the combustion chamber temperature, therefore low NO_x percentage (lower levels of thermal NO_x)

CxHy or HC (hydrocarbon, e.g. methane):

If excess oxygen levels are too high, the combustion temperature is lowered such that the flame temperature is no longer sufficient to burn up all of the fuel (HC)
–> Increased C_xH_Y value

CO (carbon monoxide):

Excess oxygen in the combustion process leads to the ability of the CO molecules to combine with O_2 to CO_2
–> Oxygen is left over

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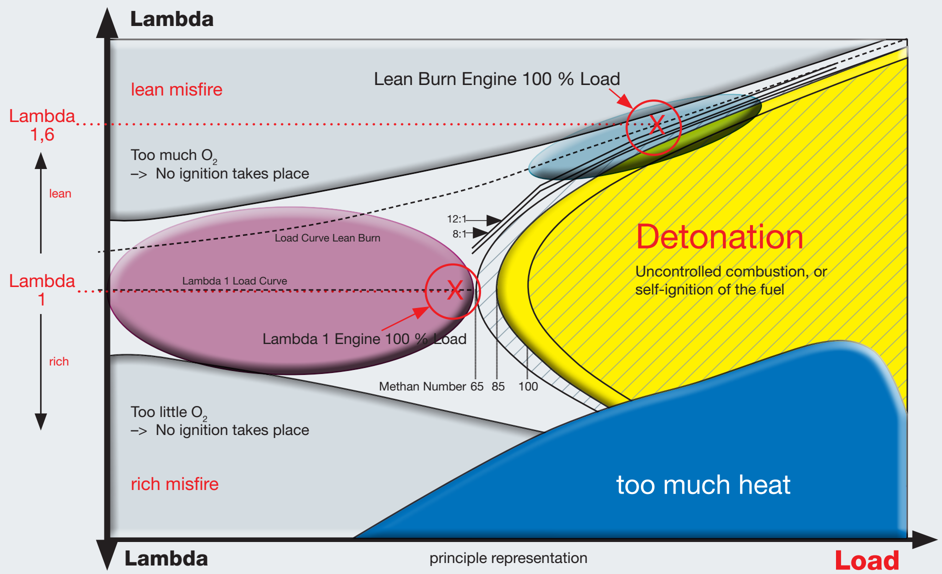
Theoretical background 2

Correctly configuring the engine to prevent “knocking” and “spark failures” of the engine.



Rich engine

Secure engine operation
- Large engine adjustment corridor

"Lean misfire" or "rich misfire"
- In rich combustion engines, this is unusual
- Exact adjustment of the engine using measuring instrument (testo 350) necessary to optimize catalyst life

Lean engine

Efficient operation
- Exact adjustment of the engine using measuring instrument (testo 350) necessary
- Small engine adjustment corridor

If engine incorrectly adjusted:
- "Lean misfire" or "knocking risk"

* Counts in general for all engine applications

Setting options for rich engines

Incorrect configuration of the fuel/air mixture:
Depending on the load point and on the specifications provided by the engine manufacturers or the national emission regulations

High HC and/or NO_x values after TWC (3-way catalytic converter):
–> Measurement before/after TWC, see high NO_x values before TWC

High NOx levels before TWC:
–> High temperatures in the combustion chamber: Set ignition in “earlier” direction and check Lambda probe

High NOx or HC values before TWC:
–> Cylinder error caused by misfire: burnable gas composition, ambient temperature and humidity, temperature and pressure of the burnable gas, inlet air temperature after the turbocharger etc.

Setting options for lean engines

High NOx levels before Selecitve Catalytic Reduction (SCR):
–> Measurement before/after SCR, see high NO_x values before SCR

High NO_x levels before SCR:
–> Ignition point too early
–> Shift ignition point towards late

Too low methane count (often fluctuation with bio-gas):
–> low ignition temperature
–> premature ignition

Setting options for knocking:
–> incandescent burnup (combustion and oil residue) on burner walls
–> premature ignition
–> new engines have knocking sensors
–> Stone impact, rattling chains etc. can lead to error signals from the knocking sensor (=acoustic)

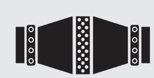
!

CAUTION:
"Ignition point too early" leads to knocking, "ignition point too late" leads to spark failures –> precise adjustment only possible with measuring instrumentation. "Guideline values" can also have an effect on other parameters (e.g. lubricants, temperatures etc.), which can lead to increased wear.

Why a catalytic converter?

General

Principle:



Catalytic converters increase the speed of a chem. reaction by lowering the activation energy. Catalytic converters are not used up themselves.

Rich engine

3-way catalytic converter (TWC):
- Controlled catalytic converter: is controlled by a λ probe (sensor which analyses the air/fuel ratio in the flue gas of a combustion process)
- Reduces pollutants by up to 90%: CO and NOx and HC
- Optimum working range: λ~0.98 to 0.998

Lean engine

Oxidising catalytic converter:
Reduces CO and HC emissions; NO_x emissions, however, are not reduced.

SCR (Selective Catalytic Reduction) = DeNOx:
NOx reduction in exhaust gases

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Emissions Measurements

Measurement point 1 efficiency test measurement

Measurement point before the catalytic converter
(after the turbocharger)

Why are measurements taken?

- Checking and inspecting engine efficiency
- Error detection/analysis of the engine's operating conditions, including engine control system
- Optimum adjustment of the engine in order to save fuel —> better efficiency
- Correct adjustment of the relations between ignition timing, excess air etc. of the engine

Typical exhaust gas properties:

- **Temperature:** approx. +1,200 °F
- **Overpressure:** up to approx. 100 mbar (dependent on turbocharger and catalytic converter)

Typical measurement values with testo 350:**

Meas. parameter	Natural gas	Landfill gas	Oil
O_2	8 %	5 to 6 %	8 to 10 %
NO	100 - 300 ppm	100 - 500 ppm	800 - 1000 ppm
NO_2	30 - 60 ppm	90 - 110 ppm	10 - 20 ppm
CO	20 - 40 ppm	350 - 450 ppm	450 - 550 ppm
CO_2	10 %	13 %	7 to 8 %
SO_2		30 ppm	30 to 50 ppm

** lean burn engine

Practical information:
Excess air, fuel pressure, the timing of the engine or the ambient temperature or humidity can have significant impact on the emission. Must consider all when tuning or adjusting engines.

Measurement point 2 emission test measurement

Measurement point after the catalytic converter
(at the end of the exhaust pipe)

Why are measurements taken?

- Testing catalytic converter efficiency
- Checking emission limits (dependent on national emission standards)

Typical exhaust gas properties:

- **Temperature:** approx. 490 °F
- **Overpressure:** no high overpressure in the flue gas
- **NO_x value:** Values range according to local regulations from 10-20 ppm to many 100s ppm

Typical measurement values with testo 350:

Meas. parameter	Type of engine	Limit values*
CO	Natural gas	50-1,500 ppm
NO + NO_2	Compression ignition (Diesel)	50-750 ppm
NO + NO2	Other 4-stroke (gas engines)	50-750 ppm
NO + NO_2	Other 2-stroke (gas engines)	50-750 ppm
O_2	Reference value	15%

*dependant upon local regulations

Measurement ports

- Drilled hole or short, welded-on piece with external thread
- Bore hole with internal thread, directly integrated into the exhaust pipe
- Various flange solutions

Alternative: Drop line from higher elevation to ground. Line can be heated or non-heated.

Caution: Blow out line prior to sampling to remove moisture build up.

Information:
Many measurement locations can often only be reached using a ladder, platform or similar.

* Counts in general for all engine applications

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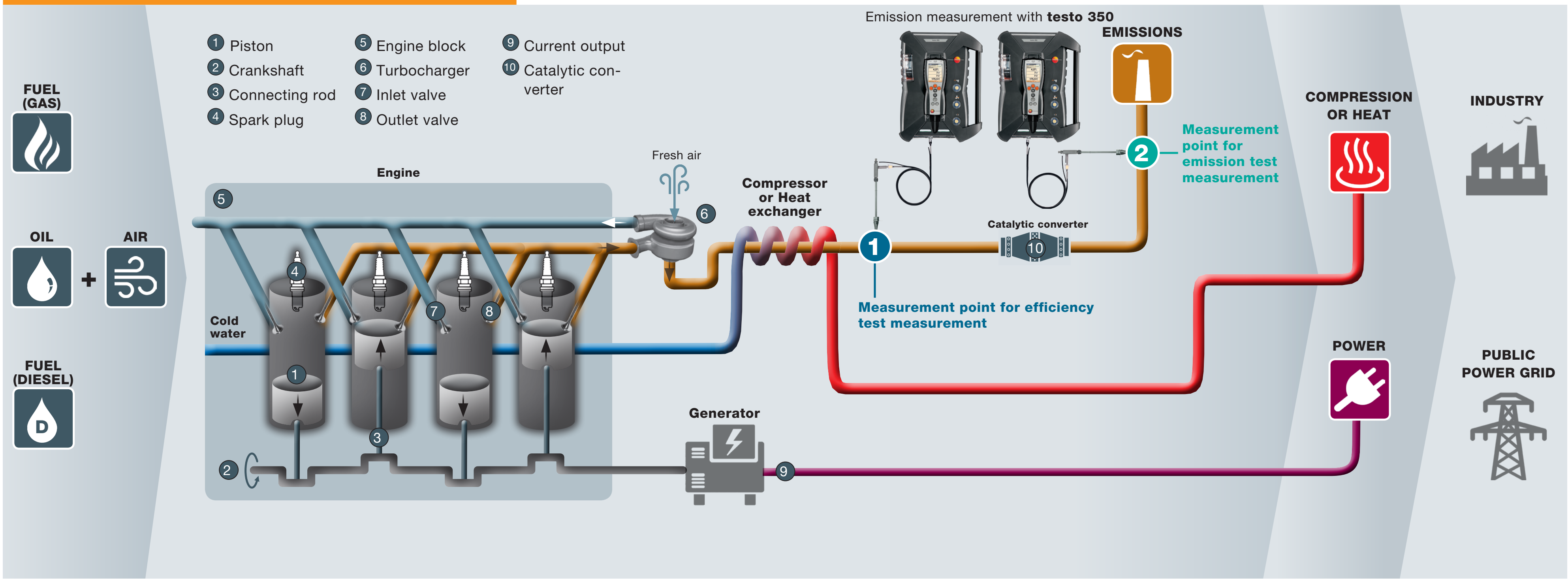
Schematic of Engine Application



Typical combustion process in a CHP engine

I. The fuel/air mixture is **drawn** in by way of the inlet valve.

II. The mixture is **compressed** and heated.

III. **Ignition of** the fuel-air mixture (by a spark plug in richburn engines, by compression via self-ignition in diesel engines).

IV. This causes a **rotary motion** of the crankshaft. The rotary motion is converted into electricity by the generator.

V. Burnt up exhaust gas is **ejected** through the open outlet valve.

VI. The **turbocharger**, driven by the exhaust gas, compresses the combustion air that is supplied to the engine. As a result, engine output is increased while fuel consumption is reduced and emission levels are improved.

VII. The **compressor or heat exchanger** utilizes the pressure or heat stored in the exhaust gas to operate the system.

* Counts in general for all engine applications