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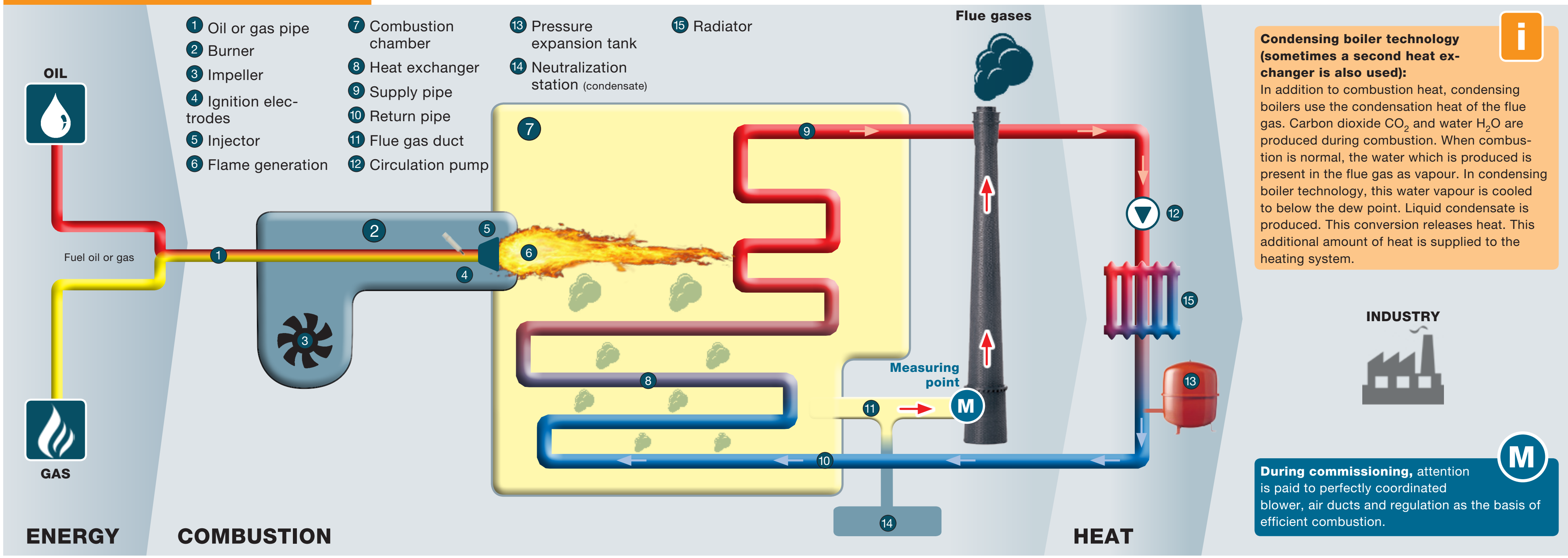
Application description burner / boiler

Layout & function



Typical combustion processes of a boiler system

I. **Fuel supply and preparation**
A: Oil The fuel is conveyed from the oil tank to the burner using a pump; this is triggered through heating adjustment (depending on the thermal energy requirement). The fuel is warmed by preheating. The solenoid valve opens, the fuel is atomized in the injector and sprayed into the combustion chamber.
B: Gas The fuel is conveyed to the burner by the pressure in the gas network; this is triggered through heating adjustment (depending on the thermal energy requirement). The solenoid valve opens, the fuel is atomized in the injector and sprayed into the combustion chamber.

II. **Combustion air input**
The combustion air is fed to the burner flame using a blower. Sufficient combustion air supply ensures a wide adjustment range, stable combustion and optimum emission values.

III. **Ignition of the burner**
Ignition sparks (ignition electrodes) ensure that the fuel-air mixture ignites and continues to burn autonomously. Flame monitoring through:
Gas: ionization flame detector (ionization electrodes)
Oil: photoelectric flame detector or infrared detector

IV. **Combustion**
The fuel gases flow through the heat exchanger surfaces of the boiler and in the process release the thermal energy to the heating water via the inner surfaces. The heating water is conveyed via the supply pipe to the radiators by the circulation pump and there releases the heat into the environment. The cooled water flows back via the return pipe so that it can be heated again. A hot water storage tank can be installed to keep a certain supply of hot water. Good insulation and adherence to the specified temperature (e.g. 60°C) must be guaranteed.

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Measurement

Measuring point (M) testo 340 / testo 350

Where does measurement take place?
- In the flue gas duct

Why are measurements taken?
- Flue gas measurement for troubleshooting/diagnosis
- Flue gas measurement for regular inspections and services
- Compliance with emissions limit values
- Optimization of burner efficiency
- Setting for different load points

What is being measured?
- O_2
- CO_2 (is calculated with the testo 340)
- CO
- NO
- NO_2
- SO_2
- Flue gas loss
- Draught/pressure
- Differential pressure
- Temperature
- Differential temperature

Typical readings at the measuring point:

Measurement parameter	Oil-flue gas composition	Gas-flue gas composition
O_2	2 to 5%	2 to 3 %
CO	5 to 80 ppm	0 to 50 ppm
CO_2	10 to 15.4%	6 to 12 %
NO	20 to 100 ppm	10 to 100 ppm
NO_2	2 to 25 ppm	2 to 25 ppm
SO_2	5 to 40 ppm (depending on the sulphur content of the fuel)	5 to 40 ppm (depending on the sulphur content of the fuel)

Oil:
- Flue gas temperature: +40°C to +200°C (+40°C with condensing systems)
- Pressure in the flue gas duct: -0.5 to +0.5 mbar/hPa

Gas:
- Flue gas temperature: +250°C to +500°C (+40°C with condensing systems)
- Pressure in the flue gas duct: -0.5 to +0.5 mbar/hPa

Advantages of the Testo emissions instruments

testo 340: Setting and service measurement

Advantages:
- Always ready to use thanks to robust, low-maintenance technology
- Self-cleaning effect in the special hose (PTFE): condensate and dirt particles do not adhere
- Easy setting: the hose extension (up to 7.8 m) means you can see the boiler display even in measuring locations which are a long way away
- No downtimes due to pre-calibrated and exchangeable gas sensors
- Measuring range extension (factor 5): unrestricted measurement of high concentrations (CO up to 50,000 ppm)
- Suitable for use with biogas and the measurement of SO_2 and H_2S

testo 350: Official emissions measurement (country-dependent)

The testo 350 is recommended for official emissions measurements (gas cooler available, dilution of high CO values).

Advantages:
- Integrated gas preparation for precise (dry) results even in the case of unsupervised long-term measurements
- Bluetooth connection allows comfortable work even in the case of long distances (up to 100 m with no obstructions) between the Control Unit and measuring location
- Suitable for official emissions measurements (country-dependent)
- Measuring range extension (factor 2, 5, 10, 20 or 40 times): unrestricted measurement of high concentrations (CO up to 400,000 ppm with factor 40)
- Suitable for use with biogas and the measurement of SO_2 and H_2S

Typical measurement aperture

Practical tips

Drop/low flue gas temperature:
- There is a condensate droplet on the thermocouple —> fix the probe horizontally or downwards, so that condensate is extracted or can drip off
- A lot of condensate comes out, which means the readings are falsified or the measuring instrument is destroyed —> use of gas preparation instead of condensate trap

Unusually high flue gas losses:
- Incorrect calibration of the measuring instrument
- Wrong fuel setting
- External combustion air temp. probe is directly measured on the system

Low values for pressure measurement:
- Pressure sensor not correctly zeroed
- The draught path in the measuring instrument is leaking

High values for pressure measurement:
- Pressure sensor not correctly zeroed
- Too strong a flue draught —> installation of a flue draught regulator, open cleaning port and measure

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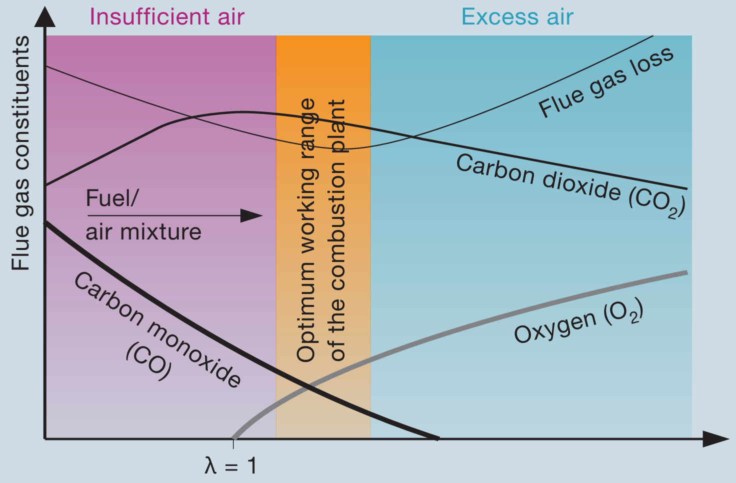
Theoretical knowledge 1

Determination of the emissions using the combustion chart

—> optimum ratio of fuel quantity to combustion air quantity (fuel-air ratio λ)



Combustion air and humidity influence the flue gas volume:

- Flue gas volume is diluted, that is the relative concentration of the gas components falls
- Use of reference values is required to compare results with specifications or with the results of other measurements
- Example: relative SO_2 concentration falls between 0.14 and 0.20% depending on the humidity and excess air (see table):

	N_2	CO_2	SO_2	H_2O	O_2
stoichiometric / dry	82.6	16	0.20	0	0
stoichiometric / moist	74.7	14.4	0.18	10.7	
25% EA / dry	82.8	12.7	0.16	0	4.4
25% EA / moist	75.6	11.6	0.14	8.7	4

Fig. 1 Reference values

Average excess air:

Gas: λ = 1.05 to 1.15

Oil: λ = 1.1 to 1.2
(1.21 with strong flue draught)

Stoichiometric = allocation of air quantity to fuel quantity (for combustion, exactly the amount of oxygen is supplied which is needed arithmetically for complete combustion)
EA = Excess air

Excess air (optimum working range)

Disadvantages:

- Low fuel utilization
  (unburned residues in the flue gas)
- Increase in the NO_X values (nitrogen oxides)
- Energy losses due to dilution with cool air
- Low efficiency (a lot of heat is lost)

Advantages:

+ Reliable operation
+ Fuel is fully burned
  (hardly any soot)

CO (carbon monoxide):
O_2 increases with excess air, because the oxygen supplied is no longer consumed through oxidation due to a lack of CO. The increasing quantity (dilution effect) means the flue gas loss becomes greater.
Particle size of the fuel: the smaller the fuel's particle size is, the more intensive the contact with oxygen is and the less excess air is required.

CO_2 (carbon dioxide):
CO_2 decreases again with λ=1, however not through a chemical reaction, but as a dilution effect due to the increasing amount of combustion air which itself brings in virtually no CO_2.

Insufficient air

Disadvantages:

- Fuel is not fully burned
- Occurrence of troublesome/poisonous substances (e.g. soot and CO)
- Reduction of energy utilization
- Unreliable operation which may lead to switch-off

CO (carbon monoxide):
CO is present —> there is not enough oxygen for complete oxidation of CO to CO_2

O_2 (oxygen):
There is only a little oxygen present in this range or it is not measurable, as any oxygen supplied is immediately used to oxidize the CO.

CO_2 (carbon dioxide):
When the O_2 concentration rises, CO reduces to CO_2 through oxidation. CO_2 increases to the same extent. This process is completed at or a little over λ=1, CO approaches zero and CO_2 reaches its maximum.

Soot emissions in the flue gas (fuel oil)

Soot (carbon) is produced when not all the fuel oil components are fully burned. Causes:

- Lack of air during combustion due to blocked, closed supply air
- Oversized boiler or burner, boiler with very low water content (frequent switching on and off)
- Excess fuel, burner fuel throughput too high for the boiler size
- Poor atomization characteristics/incorrect nozzle spray angle (especially on older burners without oil preheating)
- Longer burner running times, rise in the flue gas temperature
- Misfires due to blocked oil filters, water droplets in the oil, defects in oil preheating, air in the oil supply or in the filter, more viscous components in the oil (ageing), fluctuating fuel oil properties

—> Higher efficiency: Flue gas temperature as low as possible (1 mm soot layer increases the flue gas temperature by approx. 50 degrees —> increased energy requirement of approx. 2.5 to 3%).

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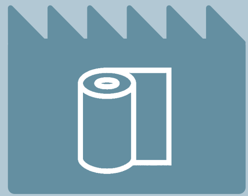
Theoretical knowledge 2

Use of burner/boiler systems in practice

Heating systems in public buildings

Where: Hospitals, universities, museums, schools, football stadiums, etc.
Uses: Heating, ventilation, hot water
Output range: Approx. 10 - 1,600 KW

Hot steam – paper mills

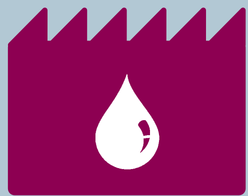


Where: Paper mills
Uses: Steam and hot water production
Output range: Approx. 150 - 6,000 KW

Greenhouse heating system

Where: Greenhouse
Uses: Back-up system for a cogeneration plant, heat and CO_2 supply
Output range: Approx. 300 - 1,000 KW

Hot steam – oil extraction plants



Where: Oil extraction
Uses: Steam and hot water production
Output range: Approx. 500 - 7,500 KW

Differences between heated and unheated measurement gas hose and probe

Heated measurement gas hose and probe

	Advantages	Disadvantages
Flue gas probe	+ Less contamination and deposition of dust particles + Reduction of temperature gradients and condensation of flue gas where there are large differences between flue gas and ambient temperature + No sooting effects in the probe shaft due to condensate, because the heating temperature is above the flue gas dew point + Low corrosion effects + More suitable for long-term measurements in the >1 day to months range + Higher measuring accuracy for long-term measurements of NO_2 and SO_2	- Electricity supply needed - Probe size and weight make handling at the measuring point and transport more difficult - Measurement of the flue gas temperature is influenced by heated probe
Measurement gas hose	+ Less contamination and deposition of dust particles + More suitable for long-term measurements	- Electricity supply needed - Greater weight makes handling at the measuring point and transport more difficult

Unheated measurement gas hose and probe

	Advantages	Disadvantages
Flue gas probe	+ Fast and convenient short-term measurements + No electricity supply needed + Accurate measurement of the flue gas temperature, no falsification due to heat from the heated probe + Easy handling at the measuring point and during transport	- Greater contamination with long-term measurements and frequent use - Greater condensation effects, because condensate forms in the area of the probe outside the measurement aperture - Greater absorption effects on SO_2 and NO_2 with long-term measurements, if the probe is not cleaned regularly
Measurement gas hose	+ Short-term measurements can be carried out quickly and conveniently + No electricity supply needed + Easy handling during measurement and transport + Easy extension of the hose + Fast response time of the gas measurement parameters through very low dead volume	- Greater depositions in the measurement gas hose, especially with long-term measurements and frequent use - Greater absorption effects on SO_2 and NO_2, if the measurement gas hose is contaminated after long-term operation