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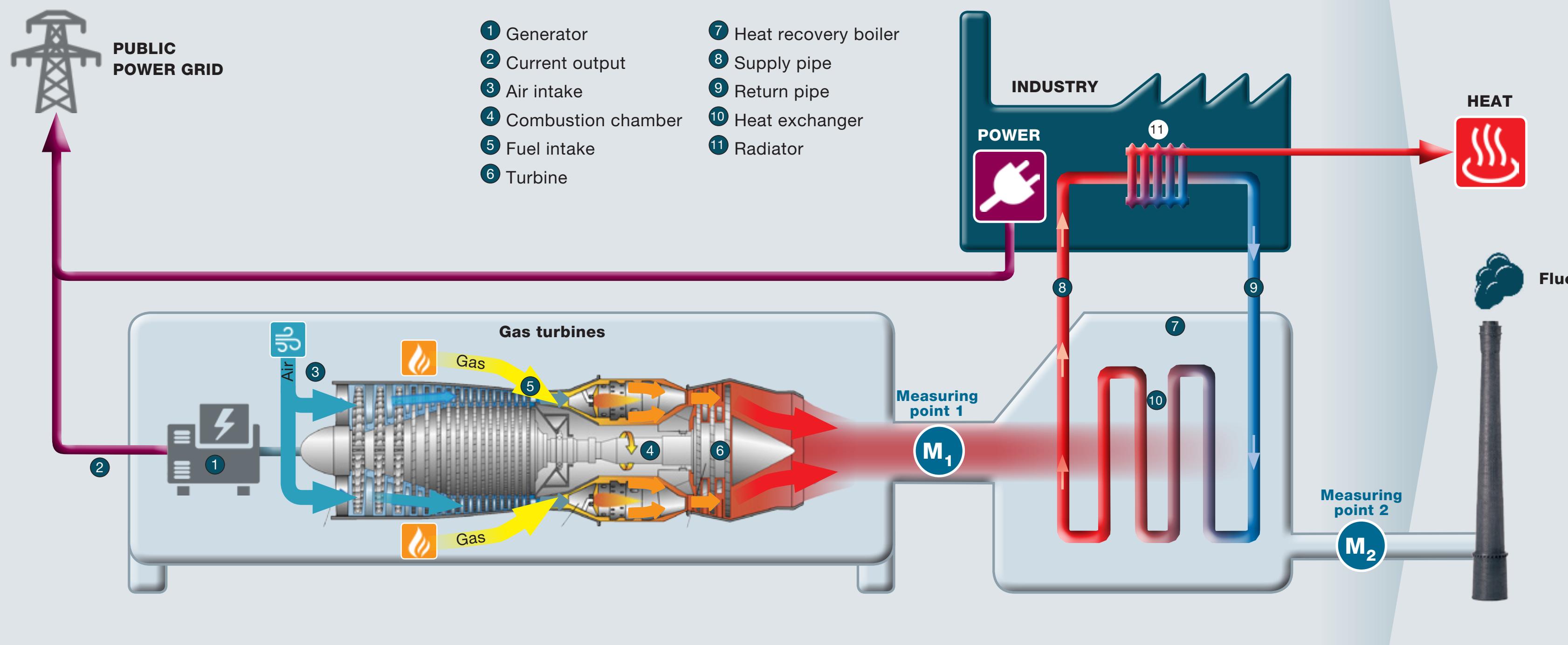
Application description gas turbine

Layout & function



Practical tip:
Generators for producing electricity can cause very high electromagnetic radiation in their surroundings, which interfere with wireless connections (e.g. between the control unit and the analyzer box).

Measuring point: Turbine outlet
A dynamic vacuum can be present at the turbine outlet. For this reason, it is recommended that the sampling point is carefully sealed. This prevents falsification of the measurement values by intake of air from the environment.

Typical combustion processes of a gas turbine:

I. Compressor
The compressor draws air in, and compresses it. In this process, the temperature of the air increases. Today the final compressor pressure values for gas turbines <10 MW is usually under 20 bar. The starter of the gas turbine provides drive for the compressor at the beginning of the start-up process. For the purpose of the regulation of the air quantity, the compressor has a blade setting system which allows the adjustment of the guide vanes, and thus the quantity of air drawn in, to be varied.

II. Combustion chamber
From the compressor, the air flows into the combustor. Here fuel is added which is then combusted under almost constant pressure. During this step, the exhaust gas heats up to temperatures over +1000 °C. The energy input in the combustor increases the velocity of the exhaust gas.

III. Turbine and generator
Subsequently, in the turbine, the energy-rich, hot exhaust gas expands almost to ambient pressure, losing its velocity. During the expansion process, the exhaust gas transfers power to the turbine. Approx. $^{2}/_{3}$ of this power are required to drive the compressor (air intake), the directly coupled generator transforms the mechanical energy into electrical. On the low-pressure side, roughly $^{1}/_{3}$ of the effective power is available for powering a second drive e.g for a generator, compressor or pump assembly, before the hot exhaust gas is drawn off into the heat recovery boiler.

IV. Heat recovery boiler
Since the exhaust gas still has a high temperature (+450 to +600 °C), it can be further used for producing steam in various cogeneration processes, for increasing the fuel utilization. After decompression to ambient pressure in the turbine, the exhaust gas is released to the environment.

V. Exhaust gas
The cooled exhaust gas then leaves the combined heat and power plant (CHP) through a chimney, at a temperature of now only approx. +70 °C.

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Measurement

M1 Measuring point 1: Monitoring the combustion process

Where does measurement take place?
- After the turbine

Why are measurements taken?
- Determination of turbine emissions
- Optimization of the turbine's degree of combustive effectiveness
- Setting for different load points
- Optimization to highest efficiency
- Reduction of fuel consumption

What is measured?
- O_2
- NO
- CO
- NO_2

Typical exhaust gas properties:
- Flue gas temperature: +450 to +600 °C
- Pressure in the exhaust gas duct: up to 25 mbar

Please note:
There is a dynamic negative pressure at this sampling point → it is crucial that this point is sealed, otherwise ambient air will be drawn in and measured.

M2 Measuring point 2: Monitoring for adherence to regional emission limit values

Where does measurement take place?
- After the heat recovery boiler

Why are measurements taken?
- Monitoring adherence to limit values in the exhaust gas
- Flue gas measurement for troubleshooting/diagnosis
- Flue gas measurement for regular inspections and services

What is being measured?
- O_2
- NO
- CO
- NO_2

Typical exhaust gas properties:
- Flue gas temperature: +70 to +90 °C
- Pressure in the flue gas duct: ± 2 mbar

Typical measurement values

Typical values and limit values of a gas turbine plant:

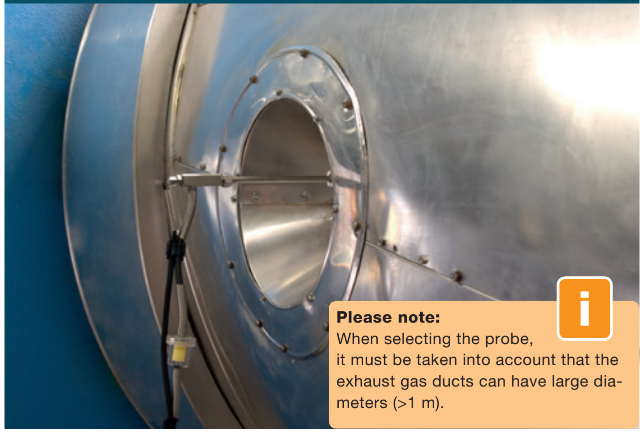
Measurement parameter	Typical values	Limit values
	M_1	M_2
O_2	15 to 18 %	15 % (reference value)
NO_X	25 to 60 ppm	300 to 350 mg/m³
CO	0 to 30 ppm	100 mg/m³
CO_2		
Dust		
Gas temperature	+300 to +400 °C	+70 to +90 °C
Gas flow		
Humidity		

Advantages of Testo sensors and dilution system:

- High measurement accuracy at low concentrations, thanks to precise CO_{low} and NO_{low} sensors
- Very large measuring range thanks to measuring range extension up to factor 40 (2x, 5x, 10x, 20x, 40x)
- Automatic switching on of dilution function protects from overload without interrupting the measurement
- Automatic sensor protection prevents damage to the sensor at high concentrations
- No additional "high sensors" (e.g. NO and CO sensor) necessary → cost savings
- Measuring range sensors:
  · O_2 sensor, 25 Vol. %
  · NO_{low} sensor, 300 ppm, 12,000 ppm*
  · CO_{low} sensor, 500 ppm, 20,000 ppm*
  · NO_2 sensor, 500 ppm

* Measuring range extension for single slot with dilution factor 40

Measurement aperture



Please note:
When selecting the probe, it must be taken into account that the exhaust gas ducts can have large diameters (>1 m).

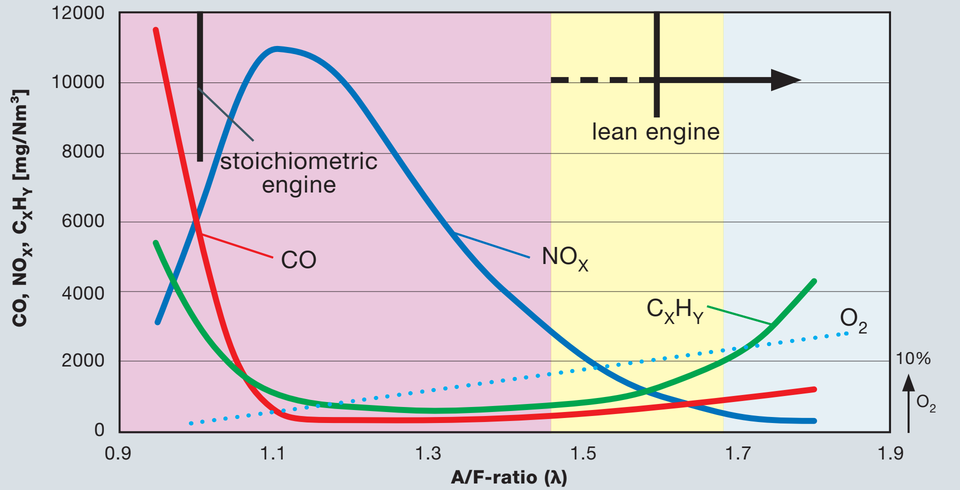
Advantages of the testo 350 flue gas analyzer:

- Ready to measure within 30 seconds
- User-guided operation with helpful instrument pre-settings
- Easy, precise test gas adjustment possible by the user on site
- Closed, robust housing, insensitive to impact and dirt
- Pre-calibrated sensors can be exchanged in the field, thus reducing downtimes
- Analyzer box with industrial standard connections and easily accessible service apertures
- Integrated gas preparation protects from dilution of the measurement values by humidity and from leaching out, e.g. of NO_2 by condensate in the exhaust gas

Application description gas turbine

Theoretical knowledge 1

Emission behaviour of gas turbines

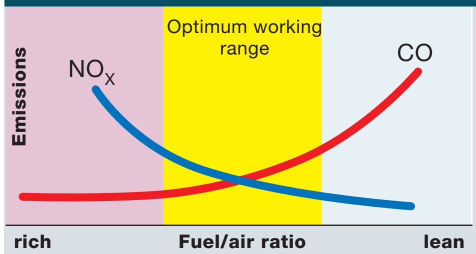


In general:
The working point on the combustion chart shifts, depending on the ratio of air to fuel.

NO_X = NO + NO_2
→ Measure NO_X separately = NO + NO_2 sensor

- Consists of fuel NO_X and thermal NO_X
- NO_2 quantity can be very low → danger of leaching very high (→ gas cooler recommended)
- NO also in very low range → NO_{low} sensor

Optimum working range



NO_X emissions in gas turbines

- Gas turbines work with a large air surplus.
- The thermal NO_X production increases quickly when the stoichiometric flame temperature is reached.
- An increase of the fuel/air ratio in the direction of "lean" (more O_2) leads to a decrease of the thermal NO_X formation, but increases the CO emissions.

Coming from "rich"	Optimum working range	Coming from "lean"
Characteristics: **NO_X (nitrogen oxides):** Increased air supply leads to lowering of combustor temperature. The NO_X emission is reduced, as less thermal NO_X occurs. **C_XH_Y or HC (hydrocarbon, e.g. methane):** A good fuel-air mixture can lead to very low C_XH_Y values. **CO (carbon monoxide):** Excess oxygen in the combustion process leads to the CO molecules being able to react with O_2 to CO_2 and thus to only low levels of CO being emitted.		**Characteristics:** **NO_X (nitrogen oxides):** Through a further lowering of the combustion temperature, the emission of thermal NO_X is largely eliminated. **C_XH_Y 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) –> C_XH_Y level in exhaust gas rises. **CO (carbon monoxide):** A too low combustion temperature leads to an incomplete oxidation of the CO and thus to a new increase of CO.

Practical tip:

When starting turbines:
High CO concentrations can occur when starting up. In combination with the dilution function (measuring range extension), high concentrations can be measured with the CO_{low} and NO_{low} sensors, in addition to the high accuracies obtained.

Optimally adjusted gas turbines:
In an optimally adjusted turbine, the CO and NO values can be very low (NO_X values <10 ppm). Systems with gas preparation prevent a dilution of the measurement values by humidity, as well as NO_2 absorption by condensate in the exhaust gas. This allows performance and measurement accuracy to be maintained at a constant level.

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Application description gas turbine

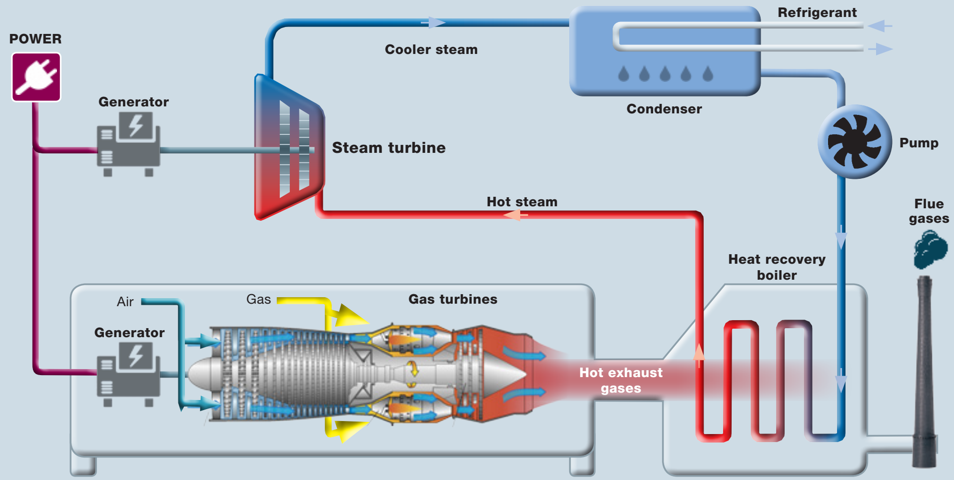
Theoretical knowledge 2

Difference between gas and steam turbine

Turbine	Fuel	Temperature range
Gas turbine	Gaseous and liquid fuels (e.g. natural gas, gasoline, propane, diesel fuel and kerosine).	High temperature range of over +1000 °C during combustion.
Steam turbine	Hot steam (usually water vapour), the heat from e.g. nuclear reactors, coal-fired combustors or gas turbines can be used. → **Important:** Steam turbines only ever come into contact with the produced water vapour, not with the fuel used.	Lower temperature range from approx. +450 to +600 °C (exhaust gas temperature of the primary combustion process produces the necessary water vapour).

Increasing energy efficiency with a combination of gas and steam turbines:
→ A high electrical efficiency is achieved by combining a gas turbine with a steam turbine. In a combined gas and steam power station, the hot exhaust gases of a gas turbine power station are used to heat a steam boiler. This considerably increases the effectiveness, since as a rule the downstream steam turbine achieves half the performance of the gas turbine again.

Principle of a combined gas and steam turbine power station



Combination measuring range extension and low-sensors

Instrument setting:
Dilution function (factors 2, 5, 10, 20, 40) of sensors is activated independently of application → the testo 350 automatically checks whether relevant gas sensors are fitted in the intended dilution slot (slot 6).

How it works:
1. Define switch-off threshold for the sensors
2. For slot 6: Activate measuring range extension → select dilution factor 2, 5, 10, 20, 40
3. When the switch-off threshold is reached, the measurement gas for the sensor in slot 6 is automatically, controlledly diluted with environmental air (other possibility: nitrogen). → The diluting gas is drawn through a separate dilution air inlet by a pump and a valve operating on the principle of pulse width modulation. → A filter is installed to protect the gas path against dust.
4. If, in spite of dilution, the switch-off threshold is again reached, the sensor protection automatically switches on, in order to protect the sensors from destruction.

Example of calculation: x40

Exposed sensor and instrument display in comparison	Measuring range CO_{low} sensor	Measuring range CO_{low} sensor with dilution factor 40*	Sensor protection: Measuring range CO_{low} sensor with dilution 40**
Instrument display	500 ppm	10,000 ppm	20,000 ppm
CO_{low} sensor	500 ppm	250 ppm	500 ppm → Sensor protection through fresh air rinsing when 20,000 ppm are exceeded

*Additional measurement uncertainty when using single slot dilution 2 % of m.v.
**Measuring range CO_{low} sensor: 20,000 ppm

Practical tip:

- If the surrounding air contains interfering gases, push the hose onto the dilution inlet and place in a clean atmosphere.*
- If gas from a gas cylinder is used (e.g. nitrogen), observe a max. pressure of 30 hPa
- Dilution also changes the resolution of the reading display. Example: Without dilution resolution 1 ppm, with factor 10 resolution 10 ppm.

* Observe diameter and length restrictions.