Sustainable Emission Treatment

A holistic approach to face todays challenges

Introduction
Facing the challenges of a changing world

The global energy landscape is changing. The push for alternative energy sources is in full swing: green electricity, green hydrogen and sustainable fuels will replace fossil fuels in the combat of CO_2 emissions globally.

Another recent challenge is to reduce the deposition of nitrogen in the soil, which requires a strong reduction of reactive components such as NO_x.

The world needs to reduce emissions in order to face the global warming effects. VOCs however have a far greater global warming potential than for example CO_2.

The reduction of VOC emissions through thermal oxidation is still the most efficient method to combat the adverse effects of the release of VOCs into the atmosphere. But until now, thermal oxidisers have needed fossil fuels and released CO_2 and NO_x.

How to combine these factors in an emission reduction strategy with optimised technology?

How to choose and invest wisely and be ready for the future?

Content

1. CO_2, NO_x and VOC Reduction

CO_2 Emission Reduction

The need for change – the European Green Deal

Approved in 2020, the European Commission set goals to become climate neutral by 2050.

This ambitious goal known as the EU Green Deal is combined with the goal to reduce greenhouse gas emissions in the EU by 50 % in 2030 when compared to 1990. CO_2 is a greenhouse gas, as are methane and other hydrocarbons.

CO_2 emissions are taxed and regulated under the EU-ETS program, forcing asset owners to carefully select the type of process used and minimize the emission of CO_2.

Reducing CO_2 emissions from fossil fuel combustion is therefore an obvious requirement that plays a key role in any process heat generation and emission control project in all industries. Numerous national funding programs support conversion measures for buildings and machinery.

NO_x Deposition
A new challenge for the environment

Nitrogen oxides have long been subject to strict emission regulations. Recently, however, this has received renewed attention due to the ecological impact of nitrogen deposition, which affects soil quality and has a direct impact on biodiversity.

This has led to a renewed focus on reactive nitrogen-containing substances such as ammonia (NH_3) and nitrogen oxides (NO_x).

When fuels are oxidised in a burner, nitrogen oxides are produced when the nitrogen in the air is combined with oxygen.

In this process, the mode of operation and the performance of the burner are decisive for the level of NO_x emissions.

As part of a holistic approach to thermal afterburning of VOC emissions, minimising NO_x from the burner is a key element.
The selection of the optimal post-combustion process is crucial. If VOC emissions with nitrogen components are to be post-combusted, additional NOx reduction systems can be used. Keyword $DeNO_x$ by SCR and SNCR (catalytic systems and non-catalytic systems).

VOC Emission Reduction

Industrial air purification

VOC (Volatile Organic Compounds) is the generic term for the versatile hydrocarbon compounds used in the industrial production of paints, resins, adhesives and plastics, in surface finishing, media printing, the pharmaceutical industry and the (petro)chemical industry.

Part of the VOC escapes during manufacturing, production, drying and decanting processes. In order to prevent VOC emissions from entering the occupied zone of people and the atmosphere, they are usually captured. Newer industries such as biogas production and recycling of plastic waste also have to do with VOC emissions.

VOCs are the third largest group of air pollutants after CO_2 and nitrogen oxides. They are generally hazardous to humans and the environment and are precursor substances for ground-level ozone.

Their reduction is a success story. Since 1990, the volume of VOCs in Europe has steadily decreased.
New legislation stimulated replacement with e.g. water-based systems, recovery and more effective capture and purification.

2. The Holistic Approach
A Philosophy

The Holistic Approche

A Philosophy

The ability not to look at issues separately from each other, but to see them in context with each other has always been a challenge.

If one has these skills, it is possible to design a complex system in such a way that it works well together. The approach to the solution of a task is called holistic approach.

A real challenge for engineers when the task and the requirements are highly complex - like the task of cleaning VOC emissions sustainably and as CO_2 and NO_X neutral as possible.

Only through a holistic view of the entire process, an optimal system can be achieved with minimal emissions, an attractive business case and long-term reliability.

The Choice

Different industrial air purification systems

There are many technologies available for emission treatment. The use of thermal systems, despite of the additional CO_2 emissions generated by this process, remains one of the most versatile and energy -efficient methods of treating exhaust air and off gas streams from almost all processes.

The design of an efficient emission control system can only take place with an in-depth understanding of the production process where the emissions originate. Be it coating, printing, surface treatment, chemical production, tank storage: only by looking deep into the process and by understanding it completely an effective emission treatment system can be designed. Combined with this, the first step is always to see if an actual reduction at the source can be achieved.

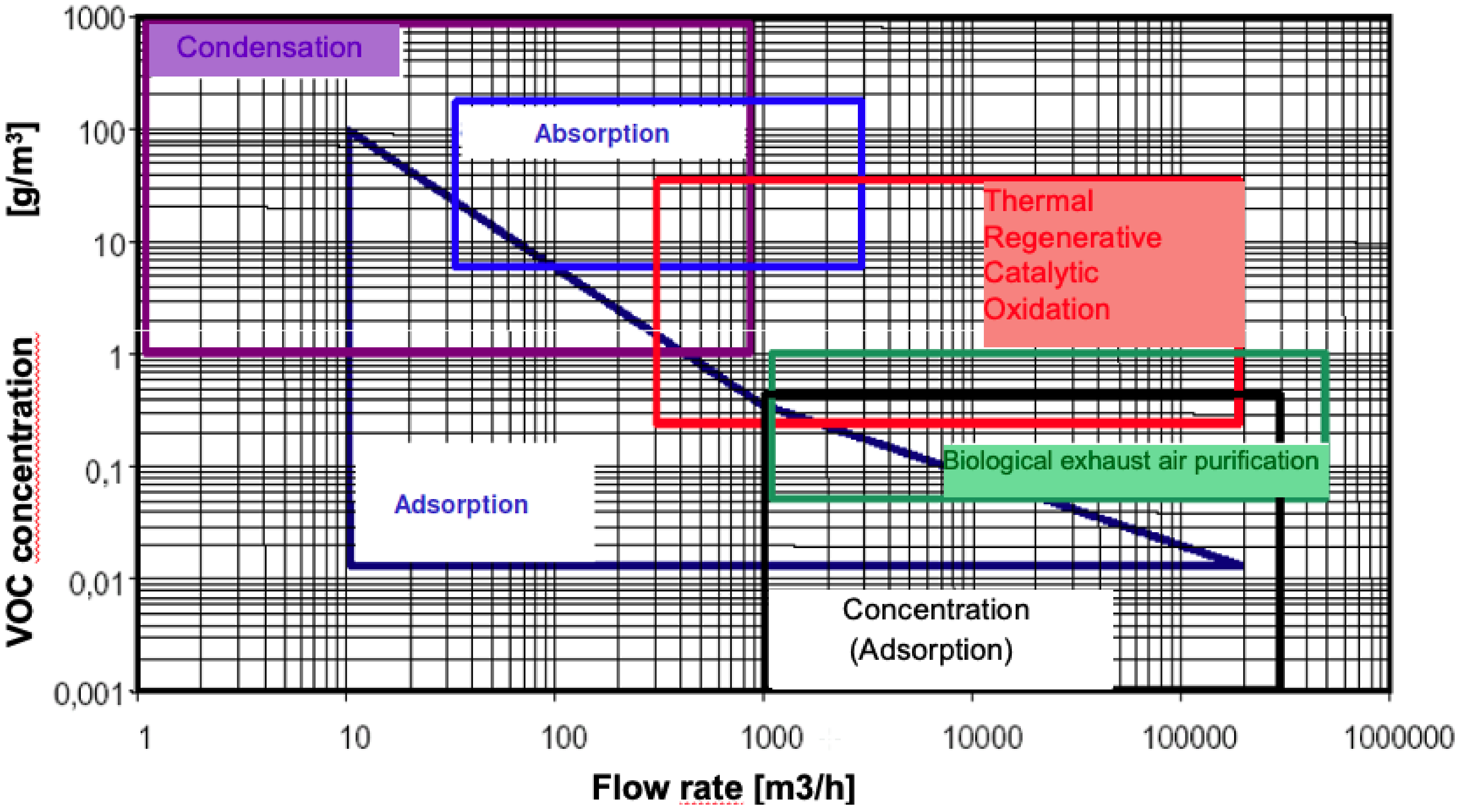
The selection of different technologies is depending on many factors. The following chapter gives an insight into the available technologies and the selection criteria.

Design of an optimized system is like a tailored suit: it only fits with good preparation, and there is no one-size-fits-all solution.

3. Industrial Air Purification Systems

Different Industrial Air Purification System

Selection diagram



The Thermal Oxidation Process

The thermal process always relies on the oxidation of hydrocarbons with oxygen to CO2, water and energy:

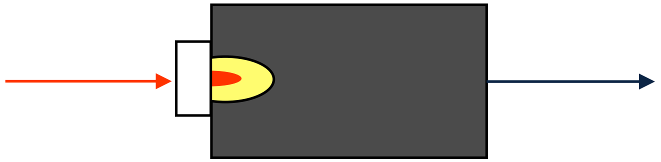
VOC (solvent) **+ Oxygen ⇨ Carbon Dioxide + Water + Energy**

$$C_xH_yO_z + (x+½ y-½ z)\, O_2 \Rightarrow x\, CO_2 + ½\, y\, H_2O + \text{Energy}$$

The difference between ‘regular’ and catalytic oxidation lies mainly in the oxidation temperature, drastically reduced by the use of catalyst as can be seen in the figure below.

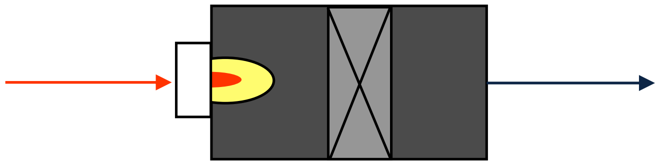
- **Thermal Oxidation**

750 °C – 850 °C



- **Catalytic Oxidation**

200 °C – 450°C



Internal Efficiency

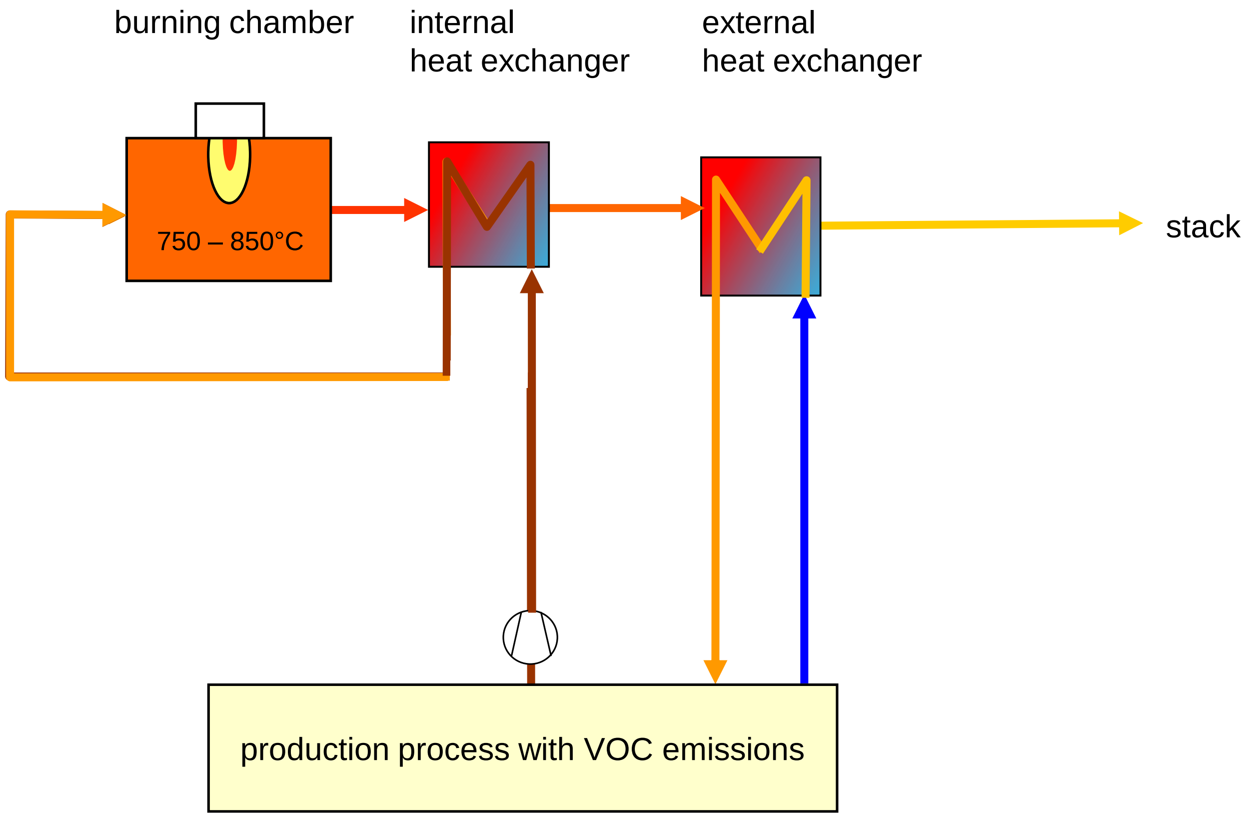
Making thermal oxidation highly energy efficient is mainly due to the two most important factors today: reducing the use of fossil energy and CO_2 emissions, while maintaining the advantages of the high conversion rate of thermal oxidation.

A drastic reduction in fossil energy consumption by the burner is achieved by using internal and external heat exchangers. Every modern thermal system contains at least one internal heat exchanger, which can be combined with an additional external heat exchanger to further increase the utilization of the generated heat.

The type of internal heat exchanger used determines the type of system. Thermal oxidation without an energy recovery system is no longer practical or permissible at many sites due to emission regulations and the high cost of CO_2 emission allowances under the EU ETS.

This means that thermal emission treatment with internal heat recovery is economical: due to the low burner capacity, the system does not fall under the EU-ETS regulations.

Internal Efficiency
Scheme



Different Thermal Exhaust Air Treatment Systems

Regenerative Thermal Oxidation

Universal cleaning technology also for large air flows, up to 96 % heat recovery through internal ceramic heat exchangers

VOC-Fired Power Generation

Use of exhaust air containing VOCs as a fuel additive in micro gas turbine CHP units. Autonomous, decentralised, always simultaneous energy generation of electricity and heat for the energy needs of industrial plants.

Recuperative Thermal Oxidation

For high organic pollutant concentrations, especially from printing, coating, laminating and impregnation processes, up to 76 % internal heat recovery. External heat recovery always requested.

Catalytic Oxidation

For low combustion temperatures and low pollutant concentrations in the chemical and pharmaceutical industries, printers, painters, coaters, up to 86 % internal heat recovery. Also, in combination with regenerative heat recovery.

Concentrator

For large exhaust air volume flows with low VOC emissions. For reducing the exhaust air volume flow and increasing the VOC concentration upstream of a thermal afterburner.

4. The Holistic Approach to Exhaust Air Treatment

The Holistic Approach

Exhaust air treatment Part I

The challenge lies in the combination of high-performance thermal oxidation for VOC reduction and the requirement for CO_2 and NO_X minimisation.

Can these two goals be optimally combined to make a positive contribution to both? Yes, through a holistic approach and a good understanding of the processes.

Exhaust air capture, oxidation, heat recovery, integration of exhaust air purification into production are all parts of the whole. If you know how to influence and combine these parts, you can create a highly effective system.

Optimally, all these parts are designed in such a way that the energy provided by the VOC in the exhaust air is sufficient to generate the necessary oxidation temperature without the need for additional energy, such as fossil fuels or electricity generated with them.

If no fossil fuels are required for normal operation, no additional CO_2 and no NO_X are emitted.

The Holistic Approach

Exhaust air treatment Part II

A concept for an efficient exhaust air treatment system can only be made if one has a thorough knowledge of the production process in which the emissions are generated. Whether coating, printing, surface treatment, chemical production or tank storage, only by delving deep into the process and understanding it fully can an effective system be designed. The first step is always to check whether a reduction can be achieved at the source. This can be done, for example, through optimised emission capturing or adjustments to the production process.

The results of recorded emission measurements under representative production conditions are important: the behavior of the exhaust air volume flow, the concentration and the VOC composition are important data to be aware of.

In the case of pressure swing adsorption systems used, for example, in biogas treatment or as a gas recovery system in tank farms, the intelligent adaptation of the exhaust air purification system to the upstream process is a key element for a success story. Knowledge of the energy needs of production in the form of steam, thermal oil, hot water or refrigeration is important to develop a fully integrated and highly efficient exhaust air purification system that, in the best case, provides free energy for production from the oxidation of VOCs.

Simply implementing an "off-the-shelf" thermal system based on theoretical baseline data is a sure way to miss out on important energy and emission savings that could otherwise be achieved at no additional cost.

Regenerative Thermal Oxidation

Universal solution with high efficiency

Quality requirements, existing plant technologies and buildings limit the possibilities for optimising the collection of VOCs. The VOC-containing exhaust air still present after the optimisation steps must be cleaned.

Whether the energy contained in the VOCs is sufficient to reach the necessary oxidation temperature depends on the necessary oxidation temperature and the internal heat recovery.

In regenerative oxidiser, ceramic material with a very high heat storage capacity is used as an internal heat exchanger, acting like a "heat battery": Up to 96 % of the energy is stored and used internally. The additional energy required to reach the oxidation temperature is covered by the VOC or supplied via a comparatively very small burner. Since the installed burner capacity is usually very small, the system is not affected by the CO_2 emissions trading system. The CO_2 and NO_x emissions are equally low.

If the VOC concentration and thus its energy density is higher than necessary, the additional burner is switched off. The CO_2 emissions from fossil fuel and the NO_x emissions from the burner decrease to zero. If the VOC concentration is even higher, the surplus heat can be transferred to the heat transfer media for production via an external heat exchanger. Boilers normally required for this purpose can be reduced in their capacity and additional fossil energy is saved there as well, with correspondingly lower CO_2 and NO_x emissions.

Concentration

Solution in two steps to become highly efficient

In order to clean large exhaust air volume flows with low VOC concentrations, even a regenerative oxidiser would still require a lot of fossil energy. To avoid this, a concentration unit can be installed upstream.

1 Here, the VOCs in the exhaust air are adsorbed via a zeolite rotor and then desorbed again with a warm, much smaller desorption air flow. The VOC concentration in the desorption air is many times higher.

2 The subsequent thermal afterburning system only has to bring this exhaust air to oxidation temperature. If an effective internal heat exchanger is used, the energy of the VOCs in the desorption air is usually sufficient to operate the complete system without additional fossil energy. CO_2 is then only emitted from the oxidized VOCs. There are no NO_x emissions.

Often, additional surplus heat can be transferred to heat transfer media for production.

Catalytic Oxidiser

Lower oxidation temperature

The process of catalytic oxidation is basically a thermal oxidation with a clever trick: By using a special catalyst made from metal oxides or precious metal, the necessary oxidation temperature is lowered to 260 to 380 °C.

In combination with an internal plate heat exchanger with an efficiency of up to 85 %, the system is very energy-efficient to operate. If the VOC concentration in the exhaust air is sufficiently high, the burner is switched off completely and no CO_2 is emitted.

No NOx is emitted during burner operation either. The catalyst that oxidizes the VOCs also reduces the NO_x that may come from the burner.

After the internal heat exchanger, an external heat exchanger can be installed. Air-to-air heat exchangers or hot water heat exchangers are common.

A prerequisite for the trouble-free operation of a catalytic oxidizer in conformity with the limit values is the absence of components that act as catalyst poisons, such as e.g. organosilicon hydrocarbons, Sulphur and Phosphorus.

A combination of regenerative oxidation with a catalyst layer above the ceramic heat regenerator is another very energy-efficient system for exhaust air treatment that does not require additional fossil energy even at very low VOC concentrations.

Micro Gas Turbines

Electricity and heat

The use of exhaust air containing VOCs as a fuel additive in a micro gas turbine CHP unit enables the autonomous, decentralised generation of electricity and heat for the energy needs of the production.

The use of a microturbine is very efficient in terms of energy if electricity and heat are needed at the same time as the VOC emissions are emitted during production. The heat demand should be as high as the heat output of the CHP unit throughout the year.

The VOCs in the exhaust air reduce the turbine's demand for natural gas - but it is not possible to do without fossil energy altogether. But: No additional natural gas fired boiler is needed to heat up hot water for production. The hot water heat exchanger downstream of the turbines transfers the heat from the turbines' exhaust gas to the hot water.

The combustion chambers of the turbines are optimised so that they emit very little NO_x. The downstream catalytic converter reduces these NO_x emissions to zero.

Even large exhaust air volume flows can be co-combusted in a microturbine if a concentration unit is installed upstream as the first stage.

5. A Changing Energy Landscape

The Global Energy Landscape is Changing

Green Hydrogen

The push towards alternative energy sources is in full swing: green electricity, green hydrogen and synthetic fuels will replace fossil fuels worldwide.

What needs to be done during this time if a thermal oxidation system is to be introduced? What should be done with existing plants? Should they be converted to new fuels, or should an electric, flameless technology be chosen?

Using green hydrogen instead of natural gas is a reliable way to move away from using fossil fuels for thermal equipment altogether. Tests carried out at a regenerative oxidizer have shown that this is also very feasible in existing plants and leads to very positive results.

Only if the hydrogen has been produced sustainably and all tasks regarding availability have been clarified, does the use of hydrogen make sense with regard to the reduced CO_2 footprint.

The Global Energy Landscape is Changing

Green Electricity

Electrical heating of exhaust air treatment units originally designed to operate with a burner can be very daunting:

The connected loads for the power supply are large, the warm-up times are long, the temperature control in the combustion chambers is slower to respond, which is very problematic when VOC concentrations change.

The heating elements must reach very high surface temperatures, which can lead to an increase in NO_x emissions. Due to the high surface temperatures, the heating elements are exposed to high thermal loads and need frequent maintenance. For each maintenance, the complete system must be cooled down and warmed up again afterwards.

In systems that are specifically designed for electrical heating, such as an E-RTO, the disadvantage is mainly the 1- or 2-chamber design and the high cost of replacing the heating elements, which have a high probability of failure when VOC concentrations vary greatly.

All this has to be considered in conjunction with the rising cost of electricity. As with hydrogen, the only advantage in terms of CO_2 reduction is the use of electricity generated from renewable sources.

A Holistic Approach Uses the Experience

It is already available

If the technology for exhaust air/flue gas treatment is carefully selected, then this is the first step towards reducing the consumption of fossil energy. Coupled with the reduction of CO_2 and NO_x emissions.

If the chosen exhaust air treatment unit is intelligently implemented based on a deep understanding of the process, this goes even further. Combined with external heat recovery, the effect can even be reversed: Not only is continuous fossil fuel not required, but the energy contained in the VOCs to be cleaned is made available as heat and can reduce or even replace conventional process heat generation fired by fossil energy.

Many exhaust air purification systems have the option of remaining in hot standby in the event of a low load without any energy being supplied and immediately going back into operation for an extended period of time. In other words, with optimal process design and intelligent control, the energy source for initial heating is no longer important, as the use of fossil energy is reduced to an absolute minimum.

Control and regulation technology has developed enormously in recent years. Replacing old thermal oxidisers with intelligently designed and controlled systems with high energy efficiency is a wise consideration to minimise the CO_2 footprint and NO_x emissions and save significant operating costs.

Real World Example

VOC to power and heat

At a manufacturer of car parts such as bumpers, trim strips, etc., an energy-efficient exhaust air treatment system of large exhaust air volume flows with low VOC concentrations, as they occur in manual painting processes, was realised. Through a holistic approach and a comprehensive process consideration, an optimal solution could be realised.

In a first step, the exhaust air volume flow from the painting booths was reduced by a **partial air recirculation**. An air-to-air heat exchanger transfers the heat from the exhaust air to the supply air of the painting booths and reduces the additional heat requirement, which is covered by hot water.

The exhaust air volume flow of the paint booths is **reduced to 1 : 20** via a concentration rotor, and the VOC concentration is increased accordingly. The desorption air flow is fed to six microturbines in which the calorific value of the VOCs is used as additional fuel gas. The microturbines generate both electricity and waste heat.

At a catalyst, the small amount of still unburnt VOC and CO emissions are **completely oxidised to CO_2 and H_2O** at a comparatively low oxidation temperature. The heat in the clean gas after the catalyst is transferred to the hot water system and used internally to heat the desorption air. The hot water heats the paint booth supply air.

All parts of the entire system are controlled via a central PLC. In this way, the individual processes can be optimally coordinated with each other. Ultimately, the system has drastically reduced the consumption of natural gas for hot water generation, eliminates the need for gas-fired production building heating, and also covers part of the plant's electricity needs.

Conclusion 1

1 One way of treating exhaust air containing VOCs from various processes in accordance with legal requirements is thermal exhaust air purification. Various processes are available, as well as the combination with concentration and co-combustion in micro gas turbines.

2 Ideally, the necessary oxidation temperature is generated exclusively by utilizing the calorific value of the solvents contained in the exhaust air. The higher the VOC concentration, the higher the energy density of the exhaust air. By optimizing the collection of exhaust air from the various plant and production areas, the exhaust air volume flow can be reduced, and the solvent concentration increased. The goal is to completely and reliably capture the VOC emissions with as little exhaust air as possible.

3 Process understanding into the production process is imperative for selecting the most suitable energy-efficient exhaust air treatment unit. For pressure swing adsorption processes or chemical production processes, complete integration is also important.

Conclusion 2

4 The most important parameters are the VOC concentration in the exhaust air, the type of VOC, the temperature, the volume flow, the energy demand of the emitting system and the type of energy and heat generation for this system.

5 A holistic approach to finding the optimal, energy-efficient and CO_2-neutral exhaust air treatment for the process in question encompasses almost everything that influences the above-mentioned parameters.

6 Today's possibilities for monitoring and influencing the control and regulation of plants and exhaust air purification systems allow optimisation and adaptation to changing production parameters, even in existing plants.

7 In the end, the additional step in emissions treatment is almost always worthwhile: the holistic approach will pay off in the end.

Process Design – FAQ

What relevant information is needed for the first development of a good process design?

- Exhaust air volume flow
- Exhaust air temperature
- Concentration of VOC
- Kind of VOC
- Emitting process / production
- Safety aspects
- Limit values cleaned gas
- Heat transfer medium for production
- Special company requirements and regulations
- Installation location: indoor or outdoor installation

6. About Krantz Clean Air Solutions

The History of Krantz

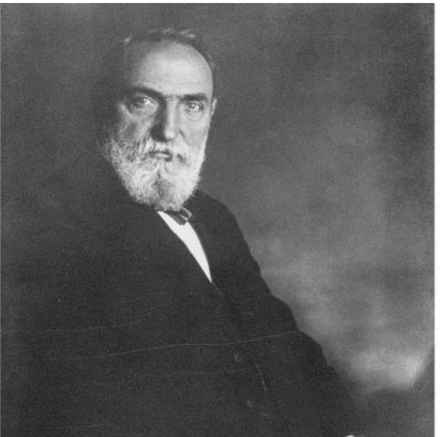
A solid base for the future

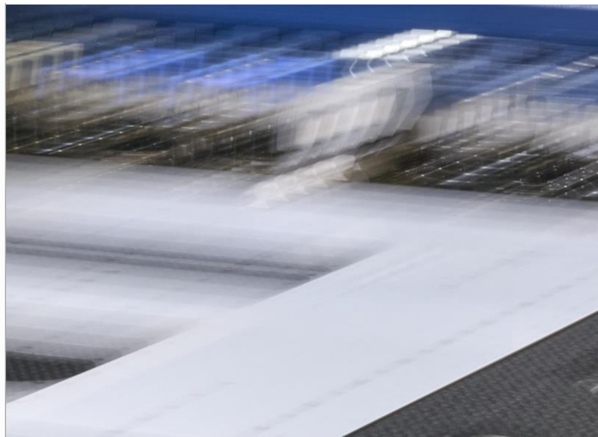
Located in Aachen, Germany, Krantz is part of IQONY Solutions and has 260 employees that work in the business units of Krantz: Filter & Damper systems, Air & Climate Solutions, Air Technologies, Clean Air Solutions and Research & Development.
Air is the common value in all business units: The air we breathe is our DNA.

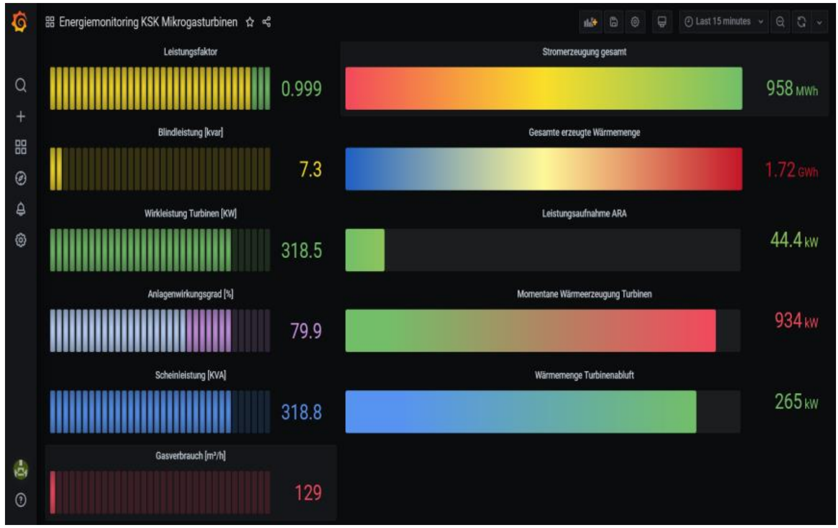
Krantz Clean Air Solutions is a company existing of engineers. Engineers with a passion for clean air. Your benefit? Our engineers always take that extra step in achieving the optimal solution for you, the end user. And in the end the environment benefits from this approach as does your business.

In 2022, Krantz celebrated its 140th anniversary. Our philosophy has remained unchanged for over more than a century: quality, service, efficiency and total customer-orientation.

Pictures: Ing. Hermann Krantz, Founder of H. Krantz GmbH and the first factory building 1895







Customer-oriented

Planning and realisation of holistic customised individual solutions – From exhaust air capture to heat recovery

CO_2 optimised

Combined heat recovery for the generation of production heat and cold – Warm water, hot water, thermal oil and steam

Service guaranteed

Krantz Clean Air App

IIoT - Cloud-based display, storage, comparison and optimization of plant data

The Krantz Clean Air Philosophy

Sustainable Exhaust Air Treatment by a Holistic Approach

Contact

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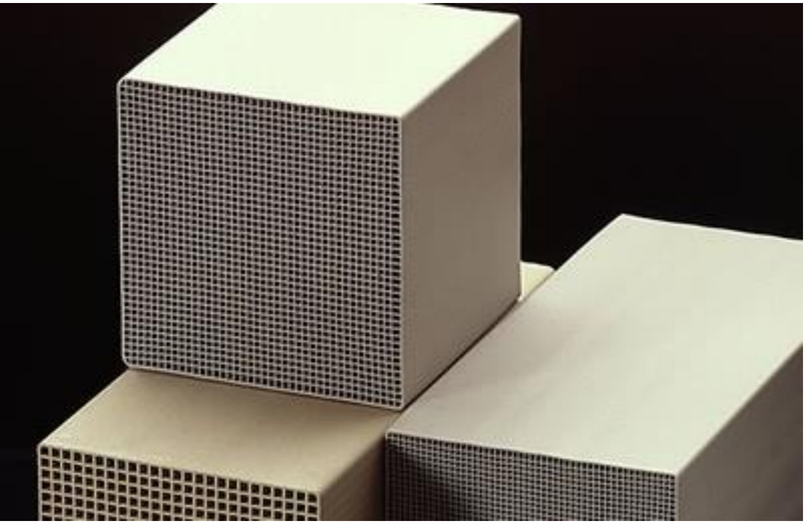
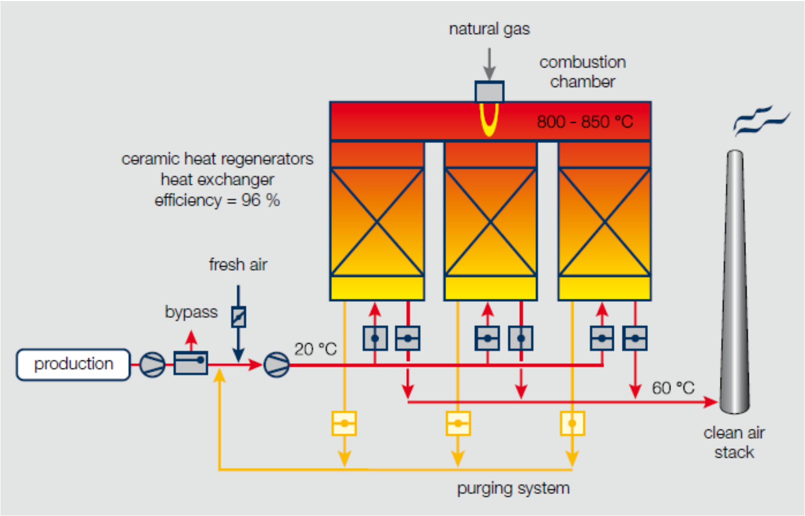




Regenerative Thermal Oxidiser

By using ceramic heat regenerators and alternating flow directions of hot clean air and cold exhaust air, up to 97 % of the thermal energy can be used to preheat the exhaust air.

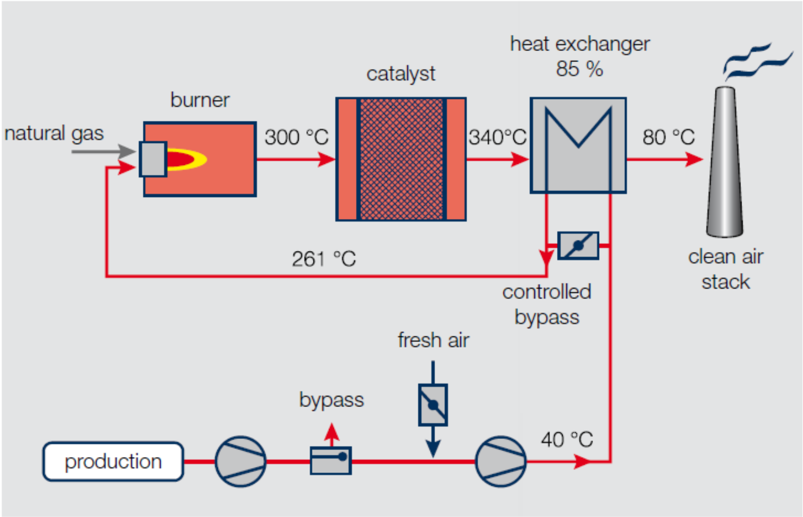
This means that RTO units can be operated autothermally from a VOC concentration of approx. 2 g/Nm³ and no additional fuel is required. If the concentration is higher, heat can be coupled out at a high level and used to generate process heat.

RTO units with two, three or more chambers are used in all industries that emit VOCs. They can be used for a wide concentration range and operate very economically, even without additional external heat recovery.

Picture left: ceramic honeycombs for heat recovery

Picture middle: scheme

Picture right: RTO unit with 5 chambers and steam generation



Catalytic Incinerator

The oxidation of the VOC's, depending on their composition, takes place by means of a catalyst – mixed oxide or precious metal type - at a temperature of 200 ° to 450 °C.

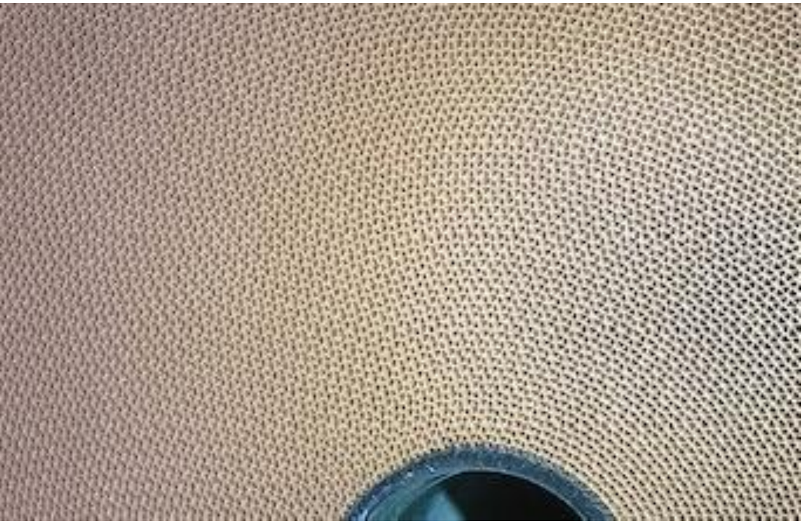
Up to 85 % of the heat energy can be used for preheating the exhaust air by the use of high efficiency, plate-type heat exchangers. The subsequent low clean air temperature enables catalytic incinerators to function economically without any secondary waste heat recovery system.

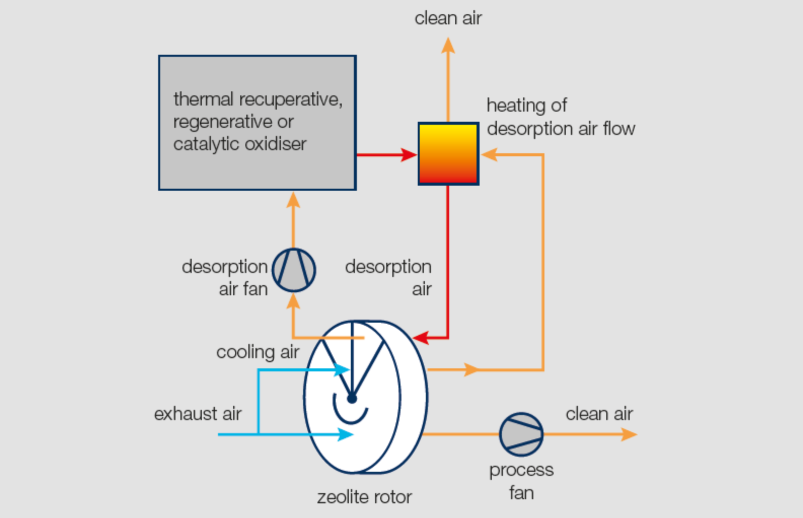
Catalytic incinerators are used to treat exhaust air, for example from the print, chemical and pharmaceutical industries as well as from various painting and coating systems.

Picture left: catalyst as extrudate / honeycomb

Picture middle: scheme

Picture right: catalytic oxidiser with upstream filter unit





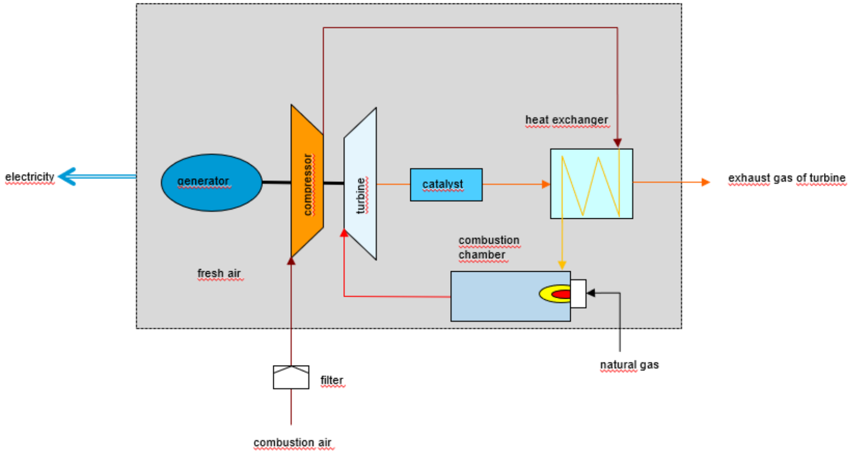
Concentrator Units

By adsorption on hydrophobic, non-combustible zeolites at low temperatures and subsequent desorption with a smaller desorption air flow, large exhaust air flows are reduced and low VOC concentrations are increased.

Depending on the type of VOC, the composition and operation mode a concentration ratio of up to 1:50 is possible. In a second process step, the desorbed air is treated in a thermal, regenerative or catalytic oxidation system.

Due to the high VOC concentration in the desorbed air, the oxidiser is usually operated autothermally without additional fossil fuel consumption. Often, additional surplus heat can be used through the operation of an external heat exchanger.

Picture left: zeolithe rotor surface
Picture middle: scheme
Picture right: concentrator unit



Micro Gas Turbines

The use of exhaust air containing VOCs as a fuel additive in a micro gas turbine CHP unit enables the autonomous, decentralised generation of electricity and heat for the energy needs of industrial plants.

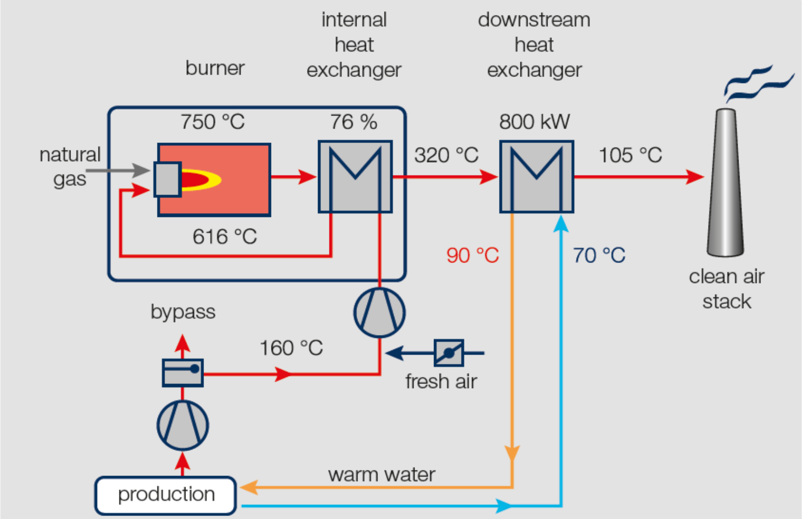
The use of a microturbine is very efficient in terms of energy if electricity and heat are needed at the same time as the VOC emissions are emitted during production. The heat demand should be as high as the heat output of the CHP unit throughout the year.

Even large exhaust air volume flows can be co-combusted in a microturbine if a concentration unit for exhaust air treatment is installed upstream as the first stage.

Picture left: six mirco gas turbines

Picture middle: scheme

Picture right: concentrat unit and turbinehouse



Thermal Recuperative Thermal Oxidiser

The VOCs are oxidised at a combustion chamber temperature of approx. 750 °C. For optimal energy efficiency, initially the heat content of the hot clean air is used to pre-heat the exhaust air.
This takes place in an integrated tube type heat exchanger, in which each individual pipe is fitted with its own expansion joint, enabling a waste heat recovery efficiency of up to 76 %.

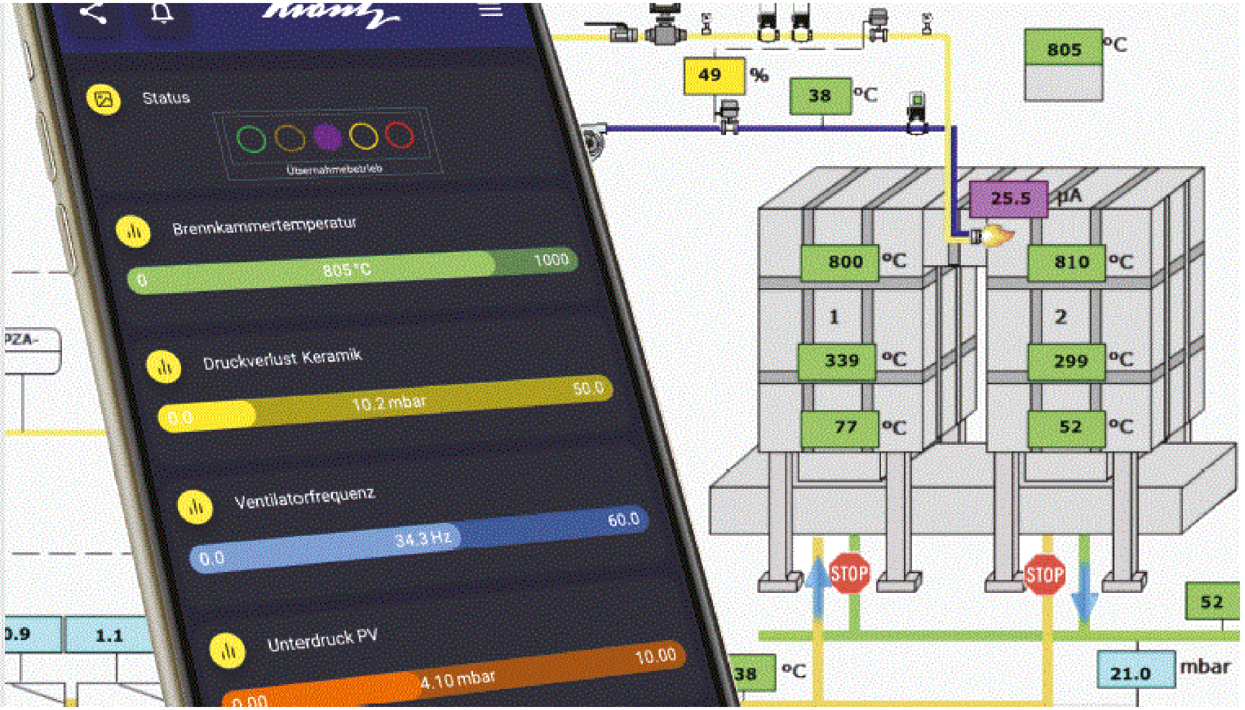
In order to further improve efficiency, additional heat recovery systems for the generation of hot oil, steam, hot and warm water or warm air can be installed downstream.

The compact thermal recuperative oxidisers are the preferred units for the cleaning of industrial exhaust air with high concentrations of VOC's which occur mainly in printing, coating, laminating and impregnating processes.

Picture left: integrated tube type heat exchanger

Picture middle: scheme

Picture right: compact unit downstream of a CDP



Monitoring and After Sale Service

Not only a good design is important. Accurate and efficient monitoring of the exhaust air treatment system is equally important to optimize energy consumption and emission levels.

For this, the IOT is the ideal platform, providing insights on all platforms such as PCs, tablets and smartphones anywhere, anytime. This provides the possibility to view plant data stored in a cloud, archive it and evaluate it for optimization purposes.

Thorough training of the staff on site enables trouble-free operation. Proactive annual maintenance is required to ensure that the system runs as reliably as on day one for many years to come.

Available for ios and Android

iOS

Android