Zeolite Rotor + RTO Combined Process for Treating Low-Concentration High-Volume VOCs Exhaust Gas Technical White Paper

Low concentration and high volume are one of the typical characteristics of industrial VOCs exhaust gas emissions, widely present in key industries such as coating, heavy machinery, shipbuilding, wind power and nuclear energy, and electronic processing.These types of exhaust gas, due to low concentration and large volume, present challenges for single treatment processes such as insufficient purification efficiency, high operating energy consumption, and high treatment costs.High treatment costs have become difficulties in deep industrial VOCs treatment.have become difficulties in deep industrial VOCs treatment.

The combination of zeolite rotor adsorption concentration technology and regenerative thermal oxidizer (RTO) technology is an efficient treatment solution for low-concentration high-volume VOCs exhaust gas.It combines three core advantages: concentration and reduction, deep decomposition, and energy saving and consumption reduction, achieving compliant or even ultra-low emissions of VOCs exhaust gas.It has become the mainstream application process in the industry.

This white paper systematically summarizes the technical principles, core advantages, process design, application scenarios, and operation and maintenance key points of the zeolite rotor + RTO combined process.This white paper systematically summarizes the technical principles, core advantages, process design, application scenarios, and operation and maintenance key points of the zeolite rotor + RTO combined process, providing practical technical references for enterprise VOCs exhaust gas treatment.

1. Industry Pain Points in Low-Concentration High-Volume VOCs Exhaust Gas Treatment

Low-concentration high-volume VOCs exhaust gas generally refers to industrial exhaust gas with VOCs concentration below 1000ppm and exhaust gas volume exceeding 10,000 m3/h.Treatment of this type of exhaust gas faces multiple industry pain points, and single processes are difficult to meet treatment requirements.

Direct treatment has high energy consumption: If incineration-type processes are directly used for treatment, due to low exhaust gas concentration, a large

amount of auxiliary fuel is needed to raise temperature.This leads to high equipment operating energy consumption, high treatment costs, and heavy burden on long-term enterprise operations.

Adsorption-type processes are prone to saturation: If single adsorption processes such as activated carbon are used, due to large air volume, adsorption consumables will quickly become saturated.Frequent replacement/regeneration is required, which not only increases operation and maintenance costs but also easily generates large amounts of hazardous waste.Additionally, it is difficult to achieve deep treatment.

Equipment has large floor space: Low-concentration high-volume exhaust gas has high requirements for treatment equipment capacity.Single process equipment is bulky and has strict space requirements for enterprise production sites, resulting in poor adaptability.

Purification efficiency is difficult to meet standards: Some industries face regional ultra-low emission policy requirements.Single process purification efficiency is difficult to meet strict emission limits, easily causing emission exceeding risks.

In this context, the combined process of "adsorption concentration + incineration decomposition" has become the key to solving pain points.Zeolite rotor adsorption concentration can convert low-concentration high-volume exhaust gas into high-concentration low-volume exhaust gas, greatly reducing the burden of subsequent incineration treatment.RTO achieves deep oxidation decomposition of VOCs, and the two work together to achieve efficient and economical treatment goals.

2. Core Technical Principles of Zeolite Rotor + RTO Combined Process

(1) Core Technical Components

The zeolite rotor + RTO combined process mainly consists of five core parts: exhaust gas pretreatment system, zeolite rotor adsorption concentration system, RTO incineration system, hot air circulation system, and automatic control system.All systems operate synergistically to achieve full-process treatment of VOCs exhaust gas.The zeolite rotor and RTO are the core process equipment, undertaking the key roles of "concentration" and "decomposition".undertaking the key roles of "concentration" and "decomposition".

(2) Staged Process Principles

Exhaust gas pretreatment: Industrial exhaust gas often contains impurities such as paint mist, dust, oil contamination, and moisture.If directly entering the zeolite rotor, these impurities can cause zeolite adsorbent blockage and poisoning, reducing adsorption efficiency and service life.Pretreatment systems use primary, medium-efficiency filters and water/oil removal devices to remove particulate matter and impurities from exhaust gas.This ensures that exhaust gas entering the zeolite rotor meets process requirements, which is the prerequisite for ensuring stable operation of the combined process.

Zeolite rotor adsorption concentration: Low-concentration high-volume VOCs exhaust gas after pretreatment enters the treatment zone of the zeolite rotor.The hydrophobic zeolite molecular sieve coated on the rotor surface, with its porous structure and strong adsorption properties, adsorbs VOCs molecules from the exhaust gas onto its surface.onto its surface.Purified exhaust gas is directly discharged up to standard. The rotor rotates slowly at a constant speed, and the area with adsorbed VOCs moves to the regeneration zone.A small amount of high-temperature hot air (200-220 degrees C) is used for desorption, causing the VOCs adsorbed by the zeolite to quickly release.This forms high-concentration low-volume VOCs exhaust gas with 5-30 times concentration, achieving exhaust gas reduction treatment.After desorption, the rotor area enters the cooling zone, is cooled to working temperature by normal-temperature air, and then returns to the treatment zone for continued adsorption, completing the continuous cycle of "adsorption-desorption-cooling".

RTO incineration decomposition: High-concentration low-volume VOCs exhaust gas generated from zeolite rotor desorption is sent to the RTO incineration system.Under high-temperature oxidation environment of 800-850 degrees C, VOCs molecules are completely decomposed into carbon dioxide and water.Decomposition rate can reach over 99%, achieving deep treatment of VOCs.The ceramic regenerator inside the RTO stores a large amount of heat generated from VOCs decomposition and uses it to preheat subsequent exhaust gas for treatment.This greatly reduces the use of auxiliary fuel, and thermal efficiency can reach over 95%.

Hot air circulation and energy saving: High-temperature waste heat from RTO incineration can be partially recycled to the zeolite rotor regeneration zone as desorption hot air through the hot air circulation system.This achieves waste heat

recovery and reuse, further reducing the overall operating energy consumption of the combined process.This forms a process closed loop of "waste heat recovery and energy saving".

Automatic control: The entire process is equipped with PLC fully automatic control system, which can monitor key parameters such as exhaust gas concentration, air volume, rotor speed, RTO oxidation temperature, and regenerator temperature in real time.This achieves linked start-stop and automatic parameter adjustment of all equipment.Over-temperature, over-pressure, leakage, and other alarm devices are set up to ensure safe, stable, and unmanned operation of the process.

3. Core Advantages of Zeolite Rotor + RTO Combined Process

Compared with single treatment processes or other combined processes, the zeolite rotor + RTO combined process has significant advantages for treating low-concentration high-volume VOCs exhaust gas.It meets enterprise treatment needs and production reality.

High purification efficiency, meeting strict emission standards: Zeolite rotor adsorption efficiency can reach over 90%, and RTO decomposition rate exceeds 99%.The coordinated effect of both enables the overall VOCs removal rate of the combined process to reach over 98%.This can meet VOCs emission standards across all regions and industries in China, and can even achieve ultra-low emissions, completely solving enterprise emission compliance difficulties.

Low energy consumption, controllable operating costs: Zeolite rotor concentrates exhaust gas by 5-30 times, greatly reducing RTO treatment air volume.This avoids high fuel consumption from direct incineration of low-concentration exhaust gas.Meanwhile, RTO waste heat is recycled to zeolite rotor desorption, achieving energy recycling.The overall operating energy consumption of the entire process is much lower than single incineration process, greatly reducing long-term enterprise operating costs.

Small equipment footprint, adapting to industrial production sites: Zeolite rotor uses modular design with compact structure and small floor area.After concentration, the exhaust gas greatly reduces RTO equipment specifications, making the entire combined process equipment layout more flexible.It adapts to

limited production space in enterprise workshops, especially suitable for old factory renovation projects.

Stable operation, low maintenance costs: Zeolite molecular sieve has chemically stable properties with strong temperature and corrosion resistance.It has large adsorption capacity and long service life, and the rotor operates in continuous cycle without frequent consumable replacement.RTO equipment has simple structure, and core components such as ceramic regenerators can have service life of over 5 years.Daily maintenance of the entire process only requires regular inspection of filter cartridges, rotors, valves, and other components, with small maintenance workload and low costs.

Wide applicability, adapting to multi-industry conditions: The combined process can treat most types of VOCs exhaust gas including alkanes, aromatic hydrocarbons, esters, aldehydes, and ketones.It is not affected by complex exhaust gas composition, and process parameters can be flexibly adjusted according to actual enterprise exhaust gas volume and concentration.It is widely applicable to industries producing low-concentration high-volume VOCs exhaust gas such as coating, heavy machinery, shipbuilding, wind power and nuclear energy, and automotive parts processing.such as coating, heavy machinery, shipbuilding, wind power and nuclear energy, and automotive parts processing.

High safety performance, no secondary pollution: The zeolite rotor desorption process uses small-volume high-temperature desorption, avoiding accumulation of high-concentration VOCs.RTO operates under negative pressure and is equipped with explosion-proof, pressure relief, over-temperature alarm, and other safety devices.Effectively preventing explosion, fire, and other safety accidents. VOCs are ultimately decomposed into CO_2 and H_2O, with no secondary pollutants generated.No secondary pollutants generated, meeting green environmental protection treatment requirements.

4. Key Design and Selection Points for Combined Process

The treatment effect and operational stability of the zeolite rotor + RTO combined process depend on the rationality of process design and equipment selection.Customized design is required based on actual enterprise exhaust gas conditions, production sites, and compliance requirements.Core design and selection points are as follows.

Zeolite rotor selection: Select rotor specifications according to exhaust gas volume, VOCs concentration, and composition.Core considerations are adsorption area, rotor speed, and concentration multiple.For larger air volume and lower concentration, rotors with larger adsorption area need to be selected. Concentration multiple is generally set at 10-20 times to balance adsorption efficiency and desorption effect.Meanwhile, according to whether exhaust gas contains moisture or corrosive substances, select appropriate hydrophobic zeolite molecular sieve types.

RTO equipment selection: Select RTO type according to concentrated exhaust gas volume and concentration after zeolite rotor desorption.For low-concentration concentrated exhaust gas, rotary RTO is preferred as it has higher thermal efficiency and better decomposition rate, with small air pressure fluctuation having minimal impact on front-end zeolite rotor operation.If exhaust gas contains corrosive substances, anti-corrosion treatment inside the RTO is required.At the same time, ceramic regenerator filling quantity is reasonably designed to ensure heat exchange efficiency.

Pretreatment system design: Pretreatment system filtration precision is determined according to particulate matter content in exhaust gas.Exhaust gas in coating industry requires additional paint mist filtration devices, and oily exhaust gas requires additional oil removal devices.Ensure exhaust gas particulate matter content entering the rotor is below 1 mg/m3 to avoid blocking zeolite adsorbent.At the same time, design reasonable duct airflow velocity to prevent impurity accumulation in pipes.

Hot air circulation system design: Reasonably design RTO waste heat recovery air volume and temperature.Desorption hot air temperature is controlled at 200-220 degrees C. Too low temperature leads to incomplete desorption, while too high temperature increases energy consumption.Auxiliary heating devices are equipped to ensure stable desorption process when exhaust gas concentration is extremely low and waste heat is insufficient.

Piping and layout design: Process piping design follows the principle of "short, straight, low resistance" to reduce exhaust gas residence time and pressure loss in pipes.Equipment layout should be combined with enterprise production sites, placing pretreatment system and zeolite rotor near exhaust gas collection points.RTO equipment can be reasonably arranged outdoors to save workshop interior space.

5. Daily Operation and Maintenance and Common Problem Troubleshooting for Combined Process

(1) Daily Operation and Maintenance Key Points

The core of the entire combined process operation and maintenance is to ensure stable operation of the zeolite rotor and RTO.Normalized operation and maintenance systems need to be established, with focus on the following work.

Pretreatment system: Regularly check blockage of primary and medium-efficiency filters, and replace filter cartridges promptly according to pressure differential.General filter cartridge replacement cycle is 1-3 months, specifically adjusted according to exhaust gas impurity content.

Zeolite rotor: Regularly check rotor sealing performance to prevent exhaust gas short-circuiting.Test zeolite adsorbent every six months. If adsorption efficiency declines, promptly perform cleaning and regeneration.Regularly clean dust accumulation on rotor surface to ensure adsorption effect.

RTO system: Regularly check ceramic regenerator blockage and damage, promptly clean or replace.Check burner ignition performance and fuel supply to ensure oxidation temperature is stable at 800-850 degrees C.

itching valve sealing and operational flexibility to prevent heat efficiency decline from air leakage.

Automatic control system: Regularly calibrate various sensors and monitoring instruments to ensure accurate parameter monitoring.Check alarm devices and linkage control logic to ensure timely start-stop and alarm when equipment fails.

(2) Common Problem Troubleshooting

Zeolite rotor adsorption efficiency decline: Mostly due to poor pretreatment system filtration effect, zeolite adsorbent blockage/poisoning.Replace filter cartridges promptly and clean and regenerate zeolite.If rotor sealing parts are aged, promptly replace sealing parts to prevent exhaust gas short-circuiting.

Large RTO oxidation temperature fluctuation: Possible causes are concentrated exhaust gas concentration fluctuation, unstable fuel supply, or switching valve air leakage.Check zeolite rotor desorption parameters to stabilize concentrated exhaust gas concentration.Calibrate fuel supply system and check switching valve sealing for timely maintenance.

Overall combined process removal rate decrease: If zeolite rotor adsorption efficiency is normal, it is mostly due to incomplete RTO decomposition.Raise RTO oxidation temperature and check ceramic regenerator heat exchange efficiency.If RTO operates normally, check if adsorbent is failing and replace promptly.

Sudden increase in operating energy consumption: Mostly due to RTO waste heat recovery system failure or zeolite rotor concentration multiple decrease.Check if valves in hot air circulation piping are normal and calibrate rotor speed and desorption hot air parameters to improve concentration multiple.

6. Typical Industry Application Cases of Combined Process

(1) Heavy Machinery Coating Industry

A heavy machinery enterprise coating workshop generates VOCs exhaust gas with air volume of 80,000 m3/h and VOCs concentration of about 300-500 ppm.Containing paint mist, dust, and other impurities, with VOCs removal rate requirement of at least 98%.The combined process of "paint mist filter + primary/medium-efficiency filtration + zeolite rotor (concentration multiple 20x) + rotary RTO" is adopted.After pretreatment, exhaust gas enters zeolite rotor for adsorption concentration, and desorbed high-concentration exhaust gas with air volume of 4,000 m3/h and VOCs concentration of 6,000-10,000 ppm is sent to rotary RTO for incineration decomposition.After process operation, VOCs emission concentration is below 20 ppm, and removal rate reaches over 99%.Regional ultra-low emission requirements are met, and RTO waste heat is recycled to zeolite rotor desorption.Auxiliary fuel consumption is only 1/10 of direct incineration, greatly reducing operating costs.

(2) Wind Power and Nuclear Energy Parts Processing Industry

A wind power parts production enterprise has exhaust gas air volume of 100,000 m3/h, VOCs concentration of 200-400 ppm, and complex composition.Production operates 24 hours continuously with requirements for stable and unmanned equipment operation.The combined process of "multi-stage filtration + zeolite rotor + rotary RTO" is adopted, equipped with PLC fully automatic control system.This achieves linked operation and automatic parameter adjustment of all equipment.

After process commissioning, VOCs removal rate reaches 98.5%, equipment operates continuously without malfunction, and waste heat recovery rate reaches over 80%.

7. Conclusion

With core advantages of efficient concentration, deep decomposition, and energy saving and consumption reduction, the zeolite rotor + RTO combined process has become one of the optimal solutions for low-concentration high-volume VOCs exhaust gas treatment.It perfectly solves industry pain points in this type of exhaust gas treatment and aligns with the national VOCs treatment policy direction of "source reduction and efficient end-of-pipe treatment".aligns with the national VOCs treatment policy direction of "source reduction and efficient end-of-pipe treatment".

The technical content of this white paper is for reference only.Specific process design and equipment selection require customization based on actual enterprise conditions.