Technical White Paper on Industrial VOCs Waste Gas Treatment Technology Selection and Compliance Application

Volatile organic compounds (VOCs), as an important component of air pollution, are key precursors for PM2.5 and ozone formation. Their emissions not only damage the ecological environment, but some toxic and harmful VOCs can also cause irreversible harm to human health. Currently, national and local authorities continue to intensify VOCs treatment and control, introducing multiple emission standards and remediation requirements. Industrial enterprises face strict emission compliance pressure and demands for treatment technology upgrades.

This white paper combines current policy standards with industry practices to systematically analyze industrial VOCs waste gas emission characteristics, treatment technology selection principles, and full-process compliance key points, providing enterprises with practical and compliant treatment references to help achieve VOCs compliance discharge and green production transformation.

I. Core Characteristics of Industrial VOCs Waste Gas and Current Compliance Requirements

(1) Core Emission Characteristics of Industrial VOCs Waste Gas

Industrial VOCs waste gas sources are extensive, involving multiple industries such as coating, printing, chemical, mechanical processing, and surface treatment. Different industries exhibit common characteristics of complex composition, significant concentration fluctuations, and notable air volume variations. Among them, coating and heavy machinery industries are key VOCs emission sectors, with waste gas often accompanied by paint mist, dust, and other particulate matter;with alkanes, aromatic hydrocarbons, esters, and aldehydes as main components, mostly low-concentration, high-air-volume emissions; some chemical and precision processing industries have medium-to-high concentration VOCs waste gas emissions, some with recovery value.

Additionally, industrial VOCs waste gas emissions face challenges in controlling fugitive emissions. Fugitive leakage easily occurs during raw material storage, transfer, and process operation in production, becoming a key and difficult point in enterprise compliance remediation.

(2) Current Core Compliance Standards and Requirements

Currently, industrial VOCs treatment follows a dual system of national general standards plus industry-specific standards. Core general standards include the "Integrated Emission Standards for Air Pollutants" (GB16297-1996) and "Standard for Fugitive Emission Control of Volatile Organic Compounds" (GB37822-2019), which clearly specify VOCs emission concentration limits, fugitive emission control requirements, and monitoring specifications.

Key industries have issued specialized emission standards. For example, coating industry standards set stricter limits for VOCs emissions during spraying and baking processes, requiring enterprises to implement paint mist pretreatment plus VOCs deep treatment combined processes. Additionally,various regions have introduced local emission standards based on regional air pollution control needs. Some regions implement ultra-low VOCs emission requirements, further reducing emission concentration limits. Enterprises must strictly comply with corresponding standards based on their region and industry requirements.

At the policy level, enterprises are required to implement full-process treatment concepts of source reduction, process control, and end-of-pipe treatment, prioritizing low-VOCs content raw and auxiliary materials, optimizing production processes,deploying efficient end-of-pipe treatment facilities, and establishing comprehensive monitoring, operation and maintenance, and record-keeping management systems to achieve traceable and supervisable full-process VOCs treatment.

II. Core Technologies and Adaptation Principles for Industrial VOCs Waste Gas Treatment

End-of-pipe treatment technologies for industrial VOCs waste gas can be divided into two major categories: recovery methods and destruction methods. Recovery methods are suitable for medium-to-high concentration VOCs waste gas with recovery value,achieving VOCs recovery and utilization through condensation, adsorption, membrane separation, and other methods; destruction methods are suitable for VOCs waste gas without recovery value,decomposing VOCs into carbon dioxide and water through incineration, catalytic oxidation, photo-oxygen catalysis, and other methods. Based on industry practices, the following are the most widely applied core treatment technologies and their applicable scenarios:

(1) Activated Carbon Adsorption Purification Equipment

Core Principle: Utilizing the porous structure of activated carbon to adsorb VOCs molecules in waste gas, achieving waste gas purification. Suitable for pretreatment or end-of-pipe treatment of low-concentration, high-air-volume,no-recovery-value VOCs waste gas. Can be paired with desorption devices to achieve activated carbon regeneration and reuse.

Applicable Scenarios: Low-concentration VOCs waste gas treatment in mechanical processing and coating industries. Can be used alone or as a pretreatment step in combined processes. Timely replacement/regeneration of activated carbon must be noted to avoid emission exceedance due to adsorption saturation.

(2) Activated Carbon Adsorption - Catalytic Combustion Integrated Process (CO/RTO Desorption Catalytic Combustion)

Core Principle: Combining the dual advantages of "adsorption enrichment + catalytic combustion". First, activated carbon adsorbs and enriches low-concentration, high-air-volume VOCs waste gas into high-concentration,low-air-volume waste gas. Then, a catalytic combustion furnace oxidizes and decomposes VOCs at low temperatures of 200-400°C. The decomposition heat can achieve activated carbon desorption and regeneration, achieving energy-saving effects.

Applicable Scenarios: Deep treatment of low-concentration, high-air-volume VOCs waste gas in coating, shipbuilding, aerospace, wind power and nuclear energy industries. Purification efficiency can reach above 95%, with no secondary pollution. It is one of the current mainstream industrial VOCs treatment processes.

(3) Zeolite Rotor Adsorption Enrichment Equipment

Core Principle: Using honeycomb-shaped rotors coated with hydrophobic zeolite as the adsorption carrier, through continuous "adsorption-enrichment-desorption" procedures,enriching low-concentration, high-air-volume VOCs waste gas by 5-30 times, paired with incineration or catalytic combustion devices for end-of-pipe decomposition. Features high adsorption efficiency, low pressure drop, and low energy consumption.

Applicable Scenarios: Suitable for high-air-volume, low-concentration, complex-component VOCs waste gas treatment. Especially suitable for continuous operating

conditions such as coating production lines. Can be combined with RTO, CO and other processes to achieve efficient treatment.

(4) Regenerative Thermal Oxidizer (RTO)

Core Principle: Using ceramic regenerators to store heat generated from VOCs decomposition, preheating untreated waste gas. Oxidation temperature reaches 800-850°C, completely decomposing VOCs. Thermal efficiency can reach above 95%,with rotary RTO achieving decomposition rates above 99%.

Applicable Scenarios: Suitable for medium-to-high concentration VOCs waste gas treatment without recovery value. Can process waste gas containing corrosive or catalyst-poisoning substances. Widely applied in chemical, coating,and heavy machinery industries. High-concentration waste gas can achieve waste heat recovery, reducing operating costs.

(5) Core Principles for Technology Selection

Enterprises must follow three core principles of "demand-based adaptation, economic efficiency, and compliance achievement". Core considerations include: 1) Waste gas characteristics: determine process type based on VOCs concentration,air volume, composition, and whether it contains particulate matter/corrosive substances. Low-concentration high-air-volume applications prioritize "adsorption enrichment + combustion" combined processes; medium-to-high concentration with no recovery value prioritizes RTO; 2) Industry operating conditions: select equipment type based on production continuity,workshop layout, and site conditions. Large workpiece coating can be paired with mobile paint spray rooms and integrated VOCs treatment equipment; 3) Economic costs: consider equipment investment, operating energy consumption, and maintenance costs. Prioritize energy-saving processes such as catalytic combustion and zeolite rotor + RTO combined processes;4) Compliance requirements: select processes that meet purification efficiency requirements based on emission limits in your region and industry. Ultra-low emission requirements necessitate deep treatment combined processes.

III. Key Points for Full-Process Compliance Implementation of Industrial VOCs Treatment

(1) Source Reduction: Reducing VOCs Emissions from the Source

Source reduction is the primary link in VOCs treatment and the core direction encouraged by policies. Enterprises should prioritize low-VOCs content raw and auxiliary materials, such as water-based coatings, high-solid coatings,and solvent-free coatings, to replace traditional solvent-based coatings; optimize production processes, adopt closed and automated production equipment, reduce fugitive leakage during raw material storage,transfer, and construction, reducing VOCs generation from the source while also reducing end-of-pipe treatment pressure.

(2) Process Control: Strengthening Fugitive Emission Control

In accordance with the "Standard for Fugitive Emission Control of Volatile Organic Compounds", implement full-process closed-loop control of production: raw material storage uses closed tanks and sealed containers;transfer uses closed pipelines or enclosed conveying equipment; process operations use closed production equipment equipped with exhaust collection devices to improve waste gas collection efficiency,ensuring collection efficiency is not less than 90%; workshops are equipped with negative pressure ventilation systems to prevent fugitive waste gas escape, while establishing fugitive emission inspection systems to promptly identify and address leakage points.

(3) End-of-Pipe Treatment: Deploying Efficient Treatment Facilities and Standardizing Operation and Maintenance

Deploy treatment facilities as needed: select appropriate end-of-pipe treatment processes based on waste gas characteristics and compliance requirements, ensuring purification efficiency meets emission limits. Coating and other industries must first pretreat waste gas for paint mistand dust before deep VOCs treatment, avoiding particulate matter blocking treatment equipment;

Standardize equipment installation and commissioning: treatment facilities must be designed, constructed, and commissioned simultaneously with production equipment.

Install locations should be reasonable, exhaust collection and pipeline design should meet fluid dynamics requirements to ensure waste gas treatment effectiveness; equipment must complete commissioning before operation, testing purification efficiency,emission concentration and other indicators, and can only officially operate after meeting standards;

Establish normalized operation and maintenance systems: formulate daily operation, maintenance, and upkeep procedures for treatment equipment. Regularly inspect the condition of core consumables such as activated carbon,catalysts, and zeolite rotors, and promptly replace/regenerate them; regularly inspect components such as fans, valves, and PLC control systems to ensure normal equipment operation and avoid emission exceedance due to equipment failures.

(4) Monitoring and Records: Achieving Full-Process Traceability

Deploy monitoring equipment: key polluting enterprises must install VOCs online monitoring equipment, connected to local ecological environment department monitoring platforms to monitor emission concentration,air volume and other indicators in real time; non-key enterprises must be equipped with portable monitoring equipment for regular self-monitoring and data retention;conduct regular self-monitoring and retain monitoring data;

Improve record management: establish full-process VOCs treatment records including raw and auxiliary material procurement and usage records, waste gas collection and treatment volume records,treatment equipment operation, maintenance, and consumable replacement records, monitoring data records, etc. Records must be retained for no less than 3 years to ensure traceability and verifiability.Records must be retained for no less than 3 years to ensure traceability and verifiability.

IV. VOCs Treatment Solutions Reference for Typical Industries

(1) Heavy Machinery/Heavy Shipbuilding Industry

Waste gas characteristics: mainly low-concentration, high-air-volume VOCs waste gas from coating, welding, and grinding processes, accompanied by paint mist, welding fumes, and metal dust;

Treatment solution: adopting "paint mist pretreatment (dry/wet filters) + activated carbon adsorption-catalytic combustion integrated process". Large workpiece coating is paired with retractable mobile/total mobile paint spray roomsto achieve on-site waste gas collection and treatment. Simultaneously deploying workshop centralized smoke and dust purification equipment to address both VOCs and dust treatment.

(2) Aerospace/Wind Power and Nuclear Energy Industry

Waste gas characteristics: precision production processes, complex VOCs waste gas composition, high requirements for treatment equipment stability and purification efficiency, with some conditions requiring continuous operation;

Treatment solution: adopting "zeolite rotor adsorption enrichment + rotary RTO" combined process to achieve efficient enrichment and deep decomposition of low-concentration high-air-volume VOCs waste gas.Purification efficiency reaches above 99%, meeting ultra-low emission requirements. Equipment is equipped with PLC fully automatic control systems to achieve unattended continuous operation, adapting to precision production conditions.

V. Conclusion

Industrial VOCs treatment has shifted from "end-of-pipe treatment" to full-process control of "source reduction, process control, end-of-pipe treatment". Enterprises face dual challenges of technology upgrades and compliance implementation. VOCs treatment technology selection is not a "one-size-fits-all" approach - it requires comprehensive consideration of industry characteristics, waste gas operating conditions, compliance requirements, and economic costs to select appropriate processes and equipment.

This white paper data and content are for reference only for industrial enterprise VOCs treatment. Specific treatment solutions require customization based on actual enterprise operating conditions and local ecological environment department requirements.