

How Do Regenerative Thermal Oxidizers (RTOs) Work?

Xian, Shaanxi Aug 6, 2026 ([Issuewire.com](https://www.issuewire.com)) - Thermal destruction is the most widely used technology for treating industrial volatile organic compound (VOCs) emissions. The key equipment—the [Regenerative Thermal Oxidizer](#) (RTO)—comprehensively addresses the challenges of VOC discharge faced by enterprises, enabling compliance with emissions standards and cost-effective operation.

What is a Regenerative Thermal Oxidizer?

A Regenerative Thermal Oxidizer (RTO) is a highly efficient air pollution control system designed to destroy Volatile Organic Compounds (VOCs) and Hazardous Air Pollutants (HAPs) from industrial exhaust streams through high-temperature thermal oxidation. The core principle of a regenerative thermal oxidizer is to combust these pollutants at elevated temperatures, typically between 760°C and 980°C (1400°F and 1800°F), converting them into harmless carbon dioxide (CO₂) and water vapor (H₂O). What truly distinguishes an RTO from simple [Thermal Oxidizers](#) is its innovative regenerative heat recovery system, which allows it to achieve exceptional thermal efficiency, often exceeding 95%.

Due to their high destruction removal efficiency (DRE) of up to 99%, reliability, and low operating cost, regenerative thermal oxidizers are widely employed across various industries, including chemical manufacturing, paint and coating application, printing, and pharmaceuticals, where robust and economical emission control is paramount.

How do regenerative thermal oxidizers work?

1. Two-Chamber RTO

The Two-Chamber RTO evolved from the Thermal Oxidizer (TO). The initial RTO involved connecting two TO units in parallel and adding ceramic regenerator beds at the outlet to achieve the "regenerative function." It utilized lift-type switching valves to repeatedly alternate the inlet and outlet gas paths, hence the name "Two-Chamber RTO."

The main structure of a two-bed RTO consists of a combustion chamber, two ceramic regenerator chambers, and four switching valves. The organic waste gas treatment process is as follows: When VOC-laden exhaust gas is delivered by a supply fan into Regenerator 1, this chamber releases heat, preheating the VOC gas to about 750°C before it enters the combustion chamber for oxidation and decomposition. The resulting high-temperature clean flue gas passes through Regenerator 2; this chamber absorbs heat, cooling the combusted clean gas before it is discharged through the switching valve. After a set switching time is reached, the valves switch. VOC gas then enters through Regenerator 2 (which now releases heat), enters the combustion chamber for oxidation, and passes through Regenerator 1 (which now absorbs heat), cooling the combusted, clean gas before it is discharged through the switching valve. By periodically switching in this manner, the VOCs exhaust gas can be treated continuously.

• Three-Chamber Regenerative Thermal Oxidizer

To address the issue in two-chamber regenerative thermal oxidizers, where, during the switch from heat release to heat storage, untreated gas remaining in the regenerator chamber is directly discharged, a third chamber was added to the two-chamber design. This introduced a "purging function," creating

the Three-Chamber regenerative thermal oxidizer. This represents the second-generation technology, achieving an improvement in purification efficiency from 95% to 99%.

The main structure of a three-bed RTO consists of a combustion chamber, three ceramic regenerator chambers, and nine switching valves. The organic waste gas treatment process is as follows: Exhaust gas is preheated through Regenerator 1, then enters the combustion chamber for oxidation and decomposition. Meanwhile, any residual untreated gas in Regenerator 3 is purged back into the combustion chamber for incineration using purified gas (purging function). The decomposed, clean, high-temperature flue gas exits through Regenerator 2, simultaneously heating Regenerator 2. Once the heat front penetrates Regenerator 2, the valves switch. Exhaust gas then enters through Regenerator 2 (preheated), enters the combustion chamber for oxidation, residual gas in Regenerator 1 is purged back to the combustion chamber, and the decomposed gas exits through Regenerator 3, heating Regenerator 3. When the heat front penetrates Regenerator 3, the valves switch again. Exhaust gas enters through Regenerator 3 (preheated), enters the combustion chamber for oxidation, residual gas in Regenerator 2 is purged back for treatment, and the decomposed gas exits through Regenerator 1, heating Regenerator 1. This cyclical operation allows for continuous treatment of VOCs exhaust gas.

When an RTO needs to handle air volumes exceeding 50,000 cubic meters per hour, the volume of each chamber in a three-chamber RTO becomes very large, leading to drawbacks such as uneven flow distribution, high purge air volume, high energy consumption, excessive idle regenerator volume, and high manufacturing costs. To address this, second-generation RTOs are sometimes constructed with multi-chamber structures like 5, 7, or 9 chambers, ensuring each chamber handles less than 50,000 m³/h. However, as the number of regenerator chambers increases, the number of lift valves also increases, significantly raising the probability of failure.

• Rotary Regenerative Thermal Oxidizer

To solve the problems of numerous switching valves, unreliability, and high investment associated with chamber-type RTOs, RTO engineers invented the "Rotary Gas Diverter Valve," or simply the "Rotary Valve." A single rotary valve can perform the inlet, outlet, and purge switching functions of several or even dozens of lift valves, with a simpler structure and greater stability and reliability. Multi-chamber RTOs equipped with a rotary valve are called "Rotary RTOs," representing the third-generation Regenerative Thermal Oxidizer technology.

During normal operation, the inlet and outlet cycles for the regenerator chambers are as follows:

Stage 1: When fixed bed sectors 2~6 are in the inlet state, the supply fan delivers exhaust gas to the rotary valve for distribution. The gas then flows upward through the hot packing bed, where it is preheated to approximately 750°C before entering the top combustion chamber for oxidation and decomposition. The decomposed, clean, high-temperature flue gas flows downward through fixed bed sectors 8~12, storing heat in the regenerator material, and is then discharged to the stack via the rotary valve. Simultaneously, fixed bed sector 1 is in the purge state. A purge fan extracts purified tail gas or fresh air to sweep upward through the voids of the regenerator material, removing any residual exhaust gas and ensuring it completely enters the combustion chamber for decomposition. After purging, this chamber transitions to the outlet state. Fixed-bed sector 7 is used to isolate the inlet and outlet streams.

Stage 2: As the rotary valve rotates uniformly, the supply fan delivers exhaust gas to fixed bed sectors 3~7. The gas flows upward through the hot bed, is preheated to about 750°C, enters the combustion chamber for oxidation, and the decomposed flue gas flows downward through sectors 9~1, storing heat before being discharged via the rotary valve. Fixed bed sector 2 transitions from the inlet state to the

purge state, where the purge fan sweeps residual exhaust from the chamber back to the combustion chamber. Fixed bed sector 8 transitions from the outlet state to the isolation state.

Under the uniform rotation of the rotary gas distribution valve, the 12 fixed bed sectors sequentially enter Stage 3, Stage 4, Stage 5..., enabling each chamber to cyclically and continuously perform the sequence: Inlet -> Purge -> Outlet -> Isolation. The rotary valve operates at a speed of 120 seconds per revolution, meaning each regenerator bed undergoes a "heat storage - heat release" mode exchange approximately every 50 seconds.

Conclusion

- When selecting end-of-pipe treatment equipment, considerations should include the inherent characteristics of the waste gas itself, the performance indicators of the technologies, construction investment and operating costs, and the applicable emission standards, among other factors.
- The new generation Rotary Regenerative Thermal Oxidizer technology offers significant technical advantages over three-bed RTOs in terms of reliability, energy efficiency, safety, ease of operation and maintenance, and investment cost, tailored to VOCs exhaust from different industries.
- In the selection of waste gas treatment technologies, there are some common principles and standards to follow. Regenerative Thermal Oxidizer is not a one-size-fits-all technology covering all application scenarios for waste gas treatment.

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