An Alternative Approach to Waste Gas Energy Recovery

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This article discusses the current market of heat recovery methods and technologies and analyzes gradual oxidation as an efficient, economically advantageous alternative.

With the ever-increasing discussion of climate change and the subsequent implementation of policies looking to reduce the emissions of greenhouse gases, mitigation of waste gases has become an important consideration and an economic burden for companies. According to the Environmental Protection Agency, the comparative impact of methane is more than 20 times greater than CO_2. In an effort to control emissions of volatile organic compounds (VOCs) like methane, thermal oxidizers and other combustion-based processes have been extensively used. While effective, regenerative, recuperative, and direct-fire thermal oxidizers are energy-intensive systems with very particular requirements, a well-known disadvantage of these systems is their inability to effectively destroy gases with below 15 percent methane content (approximate). Combustion-based destruction technologies, therefore, become a cost burden to the overall facility as they require supplemental fuels to destroy the lean gases they destroy.

Heat Recovery

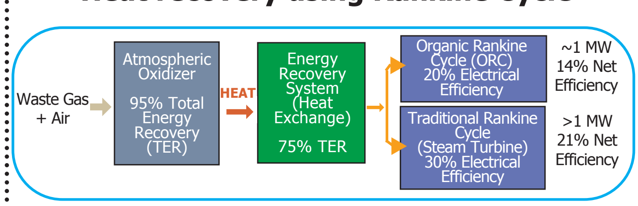
In an effort to lessen the financial drain of operating these systems, the heat generated during the destruction of the waste gases is increasingly being employed to generate electricity. The two main heat recovery technologies utilized are: the traditional (steam-based) Rankine Cycle and the Organic Rankine Cycle. These systems operate in a similar manner with one key differentiator. The Organic Rankine Cycle utilizes an organic fluid rather than water vapor (steam) in its cycle. These systems recover heat from the exhaust of the thermal oxidation process and utilize the heat to power a turbine and generate electricity. A major drawback to these systems is the losses in efficiency during the conversion process. Figure 1 outlines typical system efficiencies and total energy recovery (TER) from these processes. It is worth noting that only 14 percent and 21 percent of the original heat exhausted from an atmospheric thermal oxidizer is converted to electricity by the Organic Rankine Cycle and traditional Rankine Cycle respectively.

Gradual Oxidation

Gradual oxidation is an innovative alternative process that overcomes the inefficiencies of heat recovery with thermal oxidizers while increasing the cost-effectiveness of the overall system (Brayton Cycle). The process also can overcome the minimum energy density requirements. In other words, its intended operation range spans from 15 Btu/scf to 2,600 Btu/scf. The system simultaneously destroys contaminated gases (VOCs) and generates power.

Figure 1

Heat recovery using Rankine Cycle



Unlike combustion systems, which can emit NO_X because of high temperatures and CO because of incomplete combustion, gradual oxidation relies on a flameless chemical reaction that avoids the high peak temperatures of traditional combustion. Because gradual oxidation has a long reaction time (1-2 seconds), VOCs are destroyed from incoming gases. Without the flame and high peak temperatures, gradual oxidation can bring NO_X emissions to less than 1 part per million (ppm) and VOC destruction to a 99 percent efficiency (cooling dependent).

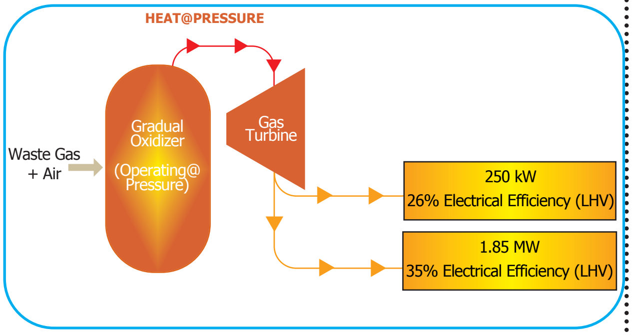
The gradual oxidation process begins with mixing VOCs and ambient air. This mixture is pressurized and introduced into the gradual oxidizer, which is heated above the auto-ignition temperature of the fuel. At this temperature, a chemical reaction releases heat energy. A turbine can harness that energy to create electricity with a generator (Figure 2).

Because the thermal oxidizer is operated at pressure, the conversion to electricity is much more efficient than an atmospheric oxidizer, which employs a steam or Organic Rankine Cycle to utilize excess heat. The conversion efficiency from heat generated is 26 percent and 35 percent for the 250 kW and 1.85 MW machines respectively. This is between 12 and 14 percentage points higher than the thermal oxidizer-Rankine Cycle combination.

With gradual oxidation, waste gases that were previously economically burdensome and environmentally harmful can now be harnessed to create energy and electricity while simultaneously maintaining low NO_X emissions. Not only is the cycle more efficient than conventional heat recovery options, it also has the added benefit of being able to run solely on low-Btu fuels (sub 15 percent methane content). Higher electrical conversion efficiencies and broader fuel flexibility lead to a faster payback and lower operating costs.

Figure 2

Heat recovery using Brayton Cycle



As industrial polluters face tighter emission standards, utilization of all waste streams becomes increasingly important. Energy recovery technologies such as Rankine Cycles and gradual oxidation are a competitive advantage for those looking for an edge in the marketplace. **APC**

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