EPA-452/F-03-021

Air Pollution Control Technology Fact Sheet

Name of Technology: Regenerative Incinerator

This type of incinerator is also referred to as a regenerative thermal oxidizer (RTO), or a regenerative catalytic oxidizer (RCO) if a catalyst is used.

Type of Technology: Destruction by thermal or catalytic oxidation.

Applicable Pollutants: Volatile organic compounds (VOC). RCO units also control carbon monoxide (CO).

Achievable Emission Limits/Reductions:

VOC destruction efficiency depends upon design criteria (i.e., chamber temperature, residence time, inlet VOC concentration, compound type, and degree of mixing) (EPA, 1992). Typical regenerative incinerator design efficiencies range from 95 to 99% for RTO systems and 90 to 99% for RCO systems, depending on system requirements and characteristics of the contaminated stream (EPA, 1995; Power, 1996; AWMA, 1992; EPA, 1991; Chen, 1996). Lower control efficiencies are generally associated with lower concentration flows (EPA, 1995).

RCO systems using precious metal-based catalyst can destroy more than 98 percent of the CO in the VOC-laden air stream (Gay, 1997). RTO systems do not reduce the levels of CO.

Applicable Source Type: Point

Typical Industrial Applications:

Regenerative incinerators can be used to reduce emissions from a variety of stationary sources. Generally, high flow (greater than 2.4 standard cubic meters per second (sm3/sec) (5,000 standard cubic feet per minute (scfm))), low VOC concentration (less than 1000 parts per million by volume (ppmv)) applications are best suited to control with regenerative incineration systems (Gay, 1997). This type of incinerator is applicable in controlling VOC from metalworking and coating operations, automotive manufacturing, and forest and wood products manufacturing. Particulate matter (PM) and condensables which can clog the incinerator's packed bed or poison the catalyst (for RCOs) would have to be removed by an internal filter or some pretreatment technology prior to entering the reactor chamber (Biedel and Nester, 1995).

The use of precious metal catalysts such as platinum and palladium have allowed VOC waste streams containing chlorides, bromides, and other halogens to be controlled with RCO systems. However, the potential for catalyst poisoning still exists if the VOC stream contains silicon, phosphorous, arsenic, or other heavy metals (Gay, 1997).

Emission Stream Characteristics:

a. Air Flow: Typical gas flow rates for regenerative incinerators are 2.4 to 240 sm3/sec (5,000 to 500,000 scfm) (Gay, 1997).

b. Temperature: An RTO uses natural gas to heat the entering waste gas to typically from 760(C to 820(C (1400(F to 1500(F), however, it is capable of operating up to 1100 (C (2000(F) for those cases where maximum destruction is necessary. An RCO uses a precious metal catalyst, which allows oxidation to occur at approximately 400(C (800(F) (Gay, 1997).

c. Pollutant Loading: Regenerative incinerators can and have been used effectively at inlet loadings as low as 100 ppmv or less (EPA, 1995). As with thermal and recuperative incinerators, for safety considerations, the maximum concentration of the organics in the waste gas must be substantially below the lower flammable level (lower explosive limit, or LEL) of the specific compound being controlled. As a rule, a safety factor of four (i.e., 25% of the LEL) is used (EPA, 1991; AWMA, 1992). The waste gas may be diluted with ambient air, if necessary, to lower the concentration.

d. Other Considerations: Characteristics of the inlet stream should be evaluated in detail, because of the sensitivity of RCO systems to PM and VOC inlet stream flow conditions, which may cause catalyst deactivation (EPA, 1992).

Emission Stream Pretreatment Requirements:

Typically, if design conditions are satisfied, no pretreatment is required, however, in some cases, PM removal may be necessary before the waste gas enters the incinerator. This is more critical for RCOs than RTOs, as RTOs tolerate PM more than RCOs. Catalysts may be “blinded” by PM. Blinding is coating of the catalyst so that the catalyst active sites are prevented from aiding in the oxidation of pollutants in the gas stream. Catalytic systems may incorporate internal filters that process the air stream before it reaches the catalyst. A sacrificial bed also can be employed to prevent PM from reaching the catalyst. Some manufacturers fluidize the catalyst beds to assist in passing the PM through the system (Biedell and Nester, 1995).

Cost Information:

The following are cost ranges (expressed in 2002 dollars) for regenerative incinerators of conventional design both with and without a catalyst, under typical operating conditions, developed using EPA cost-estimating spreadsheets (EPA, 1996) and referenced to the volumetric flow rate of the waste stream flow treated. RTOs and RCOs are field-erected and not available as packaged units. The costs do not include costs for a post-oxidation acid gas treatment system. The upper level costs in the ranges shown apply when the control device is used for very low-VOC concentration streams (less than around 100 ppmv) at very low flow rates (around 2.4 scm/s or 5,000 scfm). As a rule, smaller units controlling a low concentration waste stream will be much more expensive (per unit volumetric flow rate) than a large unit cleaning a high pollutant load flow (EPA, 1996).

a. Capital Cost:
RTO: $85,000 to $320,000 per sm^3/sec ($35 to $140 per scfm)
RCO: $74,000 to $297,000 per sm^3/sec ($35 to $140 per scfm)

b. O & M Cost:
RTO: $8,500 to $21,000 per sm^3/sec ($4 to $10 per scfm), annually
RCO: $13,000 to $42,000 per sm^3/sec ($6 to $20 per scfm), annually

c. Annualized Cost:
RTO: $17,000 to $70,000 per sm^3/sec ($8 to $33 per scfm), annually
RCO: $23,000 to $89,000 per sm^3/sec ($11 to $42 per scfm), annually

d. Cost Effectiveness:
RTO: $115 to $21,000 per metric ton ($100 to $17,000 per short ton), annualized cost per ton of pollutant controlled
RCO: $137 to $23,000 per metric ton ($124 to $21,000 per short ton), annualized cost per ton of pollutant controlled

Theory of Operation:

RTOs use a high-density media such as a ceramic-packed bed still hot from a previous cycle to preheat an incoming VOC-laden waste gas stream. The preheated, partially oxidized gases then enter a combustion chamber where they are heated by auxiliary fuel (natural gas) combustion to a final oxidation temperature typically between 760(C to 820(C (1400 to 1500(F) and maintained at this temperature to achieve maximum VOC destruction, however, temperatures of up to 1100(C (2000(F) may be achieved, if required, for very high control efficiencies of certain toxic VOC. The purified, hot gases exit this chamber and are directed to one or more different ceramic-packed beds cooled by an earlier cycle. Heat from the purified gases is absorbed by these beds before the gases are exhausted to the atmosphere. The reheated packed bed then begins a new cycle by heating a new incoming waste gas stream.

An RCO operates in the same manner as an RTO, however, it uses a catalyst material rather than ceramic material in the packed bed. This allows for destruction of VOC at a lower oxidation temperature. An RCO uses a precious metal catalyst in the packed bed, allowing oxidation to occur at approximately 400(C (800(F). The lower temperature requirement reduces the amount of natural gas needed to fuel the VOC abatement system and the overall size of the incinerator. Catalysts typically used for VOC incineration include platinum and palladium (Gay, 1997; Biedell and Nester, 1995).

Advantages:

Advantages of regenerative incinerators over other types of incinerators include the following (Gay, 1997; Stone, 1997; Biedell and Nester, 1995; Yewshenko, 1995):

Advantages of RTOs:
a. Lower fuel requirements because of high energy recovery (85 to 95 percent);
b. High temperature capability (up to 1100(C (2000(F)) provides better destruction efficiency over recuperative incinerators, which are generally limited to 820(C (1500(F) due to heat exchanger limitations, and catalytic incinerators, which are generally limited to 600(C (1100(F) due to catalyst limitations;
c. Less susceptible to problems with chlorinated compounds; and
d. Generally lower NOx emissions than thermal oxidation (except when operating temperatures are above approximately 760 (C (1400(F)).

Advantages of RCOs:
a. Lower fuel requirements than RTOs because of lower temperature;
b. Catalyst also destroys CO in waste stream; and
c. Lower NOx emissions than RTOs.

Disadvantages:

Disadvantages include the following (Gay, 1997; Stone, 1997):

Disadvantages of RTOs:
- a. High initial cost;
- b. Difficult and expensive installation;
- c. Large size and weight; and
- d. High maintenance demand for moving parts.

Disadvantages of RCOs
- a. High initial cost;
- b. Difficult and expensive installation;
- c. Large size and weight;
- d. High maintenance demand for moving parts and catalyst monitoring;
- e. Catalyst poisoning is possible, however, precious metal catalysts are more resistant;
- f. PM often must first be removed; and
- g. Spent catalyst that cannot be regenerated may need to be disposed

Other Considerations:

Regenerative incinerators offer many advantages for the appropriate application. High flow, low concentration waste streams which are consistent over long time periods can be treated economically with either RTO or RCO systems, depending upon the waste stream composition. For either system, pretreatment to remove PM may be necessary to prevent the packed bed from clogging and/or the catalyst from poisoning. In RCO units, precious metal-based catalysts generally have a longer service life and are much more resistant to poisoning and fouling than less expensive base metal catalysts (Gay, 1997).

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