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Regenerative Thermal Oxidizer Design Considerations

Thermal Efficiency and Thermal Energy Recovery

The **thermal efficiency** (TE) of an RTO operating at steady state is defined as the percentage of preheat energy supplied by the ceramic heat-exchange media. Preheat energy is the energy required to bring process air from its inlet temperature to the combustion chamber temperature.

$$TE = \frac{(M_{inlet} + M_{burner})(T_{comb} - T_{outlet})}{(M_{inlet})(T_{comb} - T_{inlet})} \times 100\%$$

where T_{inlet} is the temperature of process air entering the RTO (°F or °C),
T_{comb} is the temperature in the combustion chamber (°F or °C),
T_{outlet} is the average stack gas temperature (°F or °C),
M_{inlet} is the flow rate of process air entering the RTO (scfm or Nm³/h), and
M_{burner} is the flow rate of unheated air entering the combustion chamber (scfm or Nm³/h).

M_{burner} is usually just the air fed to the burner in the combustion chamber, although it may also include unheated gas used to cool nozzles, etc.

In some RTOs the burner in the combustion chamber is used only for start-up, and once the oxidizer has come to steady state the burner is turned off and auxiliary fuel gas is added to the process air. In that case, if M_{burner} = 0, the thermal efficiency will be the same as the **thermal energy recovery** (TER), defined as the percentage of available heat recovered by the heat-exchange media.

$$TER = \frac{(T_{comb} - T_{outlet})}{(T_{comb} - T_{inlet})} \times 100\%$$

When referring to heat recovery, please indicate clearly whether TE or TER is being specified.

The RTO stack temperature rises and falls during each cycle. Note that its average value T_{outlet} (determined by integrating the gas temperature over an entire cycle) is not simply the arithmetic mean of the minimum and maximum temperatures observed.

For example, if an RTO treats 2,400 scfm of process air entering at 80°F, fuel gas is added as required to maintain a combustion chamber temperature of 1,500°F, 36 scfm of unheated combustion air is fed to the burner, and the average stack temperature is 151°F, then

$$TE = \frac{(2{,}400 + 36\text{ scfm})(1{,}500 - 151^\circ F)}{(2{,}400\text{ scfm})(1{,}500 - 80^\circ F)} \times 100\% = 96.4\%\,,\quad TER = \frac{1{,}500 - 151^\circ F}{1{,}500 - 80^\circ F} \times 100\% = 95.0\%$$

Operating Mode and Fuel

The valve switch time (or cycle time) must always be indicated. If auxiliary fuel is supplied through the burner during operation, please specify the burner air flow rate (if it is constant), or else the burner air / fuel gas ratio and the heating value of the fuel gas (Btu/scf or kWh/Nm³).

If a regenerative thermal oxidizer has more than two heat-recovery canisters, the air flow configuration must be indicated, including the purge air flow rate and duration (or at least the average value of the purge air flow rate).

Uniform Air Distribution

Heat-recovery calculations are performed assuming that air flows through all parts of the heat exchange media at the same mass velocity (scfm/ft² or Nm/s). Gas inlet and outlet transitions must be designed to provide uniform air flow. If local gas velocities (determined by anemometer readings above the media when cold air is blown through it) deviate from the average by more than ±15%, then heat recovery may be significantly less than predicted for uniform flow.

For example, if the superficial air velocity through the media is 300 scfm/ft², no velocity vector measured just above the media should exceed 345 scfm/ft² nor be less than 255 scfm/ft².

Moisture Content

Unless otherwise specified, calculations assume that the process air entering an RTO is relatively dry, containing <5% water vapor (v/v). Air more humid than this will have higher heat capacity, and so more heat-exchange media may be needed to heat or cool it to a given temperature. The same is true of air containing >5% CO_2.

Note that 5% is not the relative humidity, but rather the moisture content by volume. For example, process air saturated with water vapor at atmospheric pressure and 92°F (33°C) would contain 5% water vapor (v/v).

Condensable or Particulate Matter

If process air entering an RTO is expected to contain dust or other aerosols, this must be indicated in the design specification, as it may affect the choice of heat-exchange media and/or maintenance requirements.

VOC Loading Rates

When possible, the estimated VOC content of the process air and the average caloric value of the VOCs should be indicated. If the VOC load is expected to vary widely, average and maximum values should be estimated. TE and TER are measured with clean air flowing through an RTO, but VOC loading estimates can give an indication of whether the combustion chamber will tend to overheat.

Detailed Specifications for Reliable Designs

Any unusual aspects of an RTO or its operation should be noted. When in doubt, include more information. Remember that incomplete specifications can result in inadequate designs.