

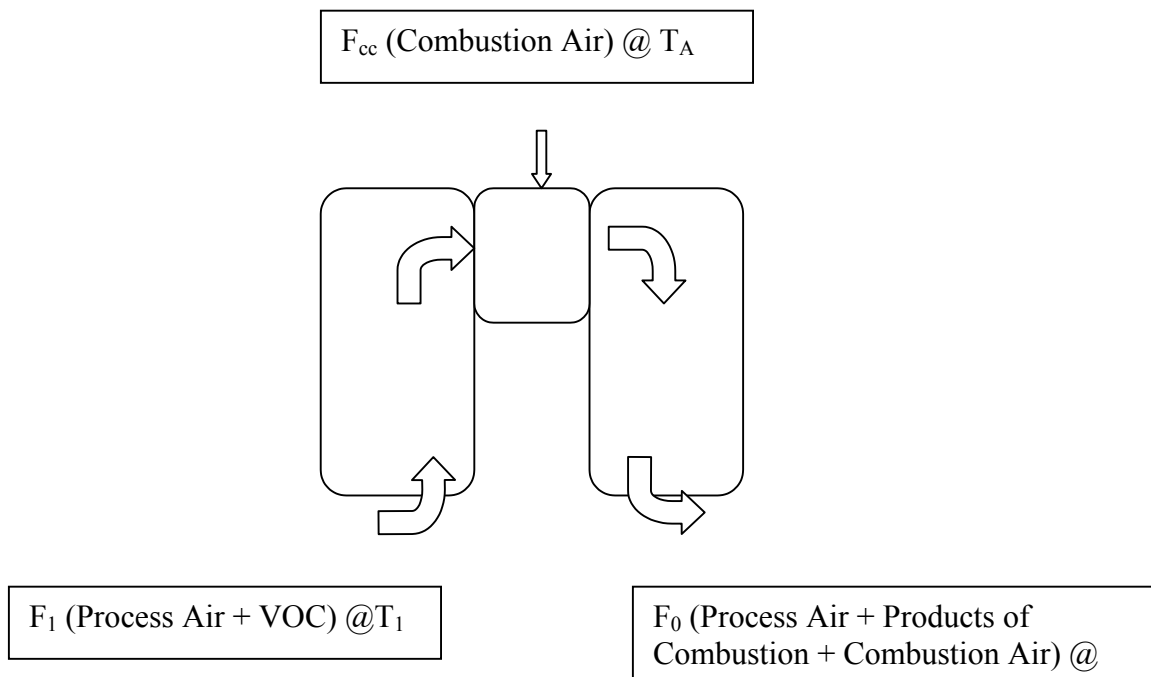
## **ICAC GUIDANCE METHOD FOR ESTIMATION OF GAS CONSUMPTION IN A REGENERATIVE THERMAL OXIDIZER (RTO)**

### 1. OBJECT AND SCOPE

Supplemental fuel consumption, typically natural gas, can be a significant consideration for the installation and operation of a regenerative thermal oxidizer (RTO). Regenerative thermal oxidizers are used in a variety of processes in the destruction of volatile organic compounds (VOC) and hazardous air pollutants (HAP). The amount of fuel required will vary by application; however, within a single application an estimate of fuel consumption should be consistent among RTO

manufacturers and suppliers. As a result, the following procedure developed by ICAC and its member companies describes an industry derived guidance method for estimating gas consumption requirements of an RTO. Once fuel consumption has been estimated, fuel as part of the operating cost can be calculated using current or projected fuel cost assumptions. Generally, this method can also be used as a reference to confirm and compare manufacturers' fuel consumption estimates. The guidance method estimate will provide a reference for gas consumption estimates.

### 2. OVERVIEW OF GAS CONSUMPTION IN A RTO



### 3. GUIDANCE ESTIMATION METHOD

Energy consumed in the RTO can be determined by performing a heat balance as follows:

$$Q_T = Q_I + Q_{CC} + Q_{RL} - Q_{VOC}$$

$Q_I$ : Heat used to raise temperature of  $F_I$  (BTU/hr)  
 $Q_{CC}$ : Heat used to raise temperature of  $F_{CC}$  (BTU/hr)  
 $Q_{RL}$ : Radiation Heat loss from RTO (BTU/hr)  
 $Q_{VOC}$ : Heat Release from oxidation of VOCs (BTU/hr)

$$Q_I = F_I \times 1.10 \times (T_O - T_I)$$

$$Q_{CC} = F_{CC} \times 1.10 \times (T_O - T_A)$$

$$Q_{VOC} = VOC \times H_C \times (\% \text{ Dest} / 100)$$

**Where:**

$F_I$ : Process air (SCFM)  
 $F_{CC}$ : Combustion air (SCFM)  
 $T_I$ : RTO inlet air temperature (°F)  
 $T_A$ : Ambient or Combustion air temperature (°F)

$T_O$ : Average RTO outlet temperature (°F)  
 1.10:  $60 \text{ (min/hr)} \times 0.075 \text{ (lb/ft}^3\text{, density of air at standard conditions)} \times 0.245 \text{ (Btu/deg F - lb, specific heat of air)}$ , where 0.245 is the average heat capacity of air over the temperature range.  
 $VOC$ : lbs/hr of VOC to the oxidizer  
 $H_C$ : Weighted Average for Heat of Combustion of VOCs  
 $\% \text{ Dest}$ : Guaranteed VOC Destruction Rate

Since  $F_I$ ,  $F_{CC}$ ,  $T_I$ ,  $T_O$  and  $T_A$  can all be determined by data supplied with proposal,  $Q_I$  and  $Q_{CC}$  can be determined.

**To determine  $Q_{RL}$  the following guidelines can be used:**

1. Determine surface area of the RTO shell.
2. Multiply that area by heat loss factor (assume  $200 \text{ Btu/ft}^2$ ) to arrive at approximate  $Q_{RL}$ .

#### 4. CALCULATION OF THERMAL EFFICIENCY (*N*)

$$N = ((F_1 + F_{CC}) / F_1) \times ((T_C - T_O) / (T_C - T_I))$$

**Where:**

*N* = Thermal Efficiency

*T<sub>C</sub>* = Temperature, Combustion Chamber

*T<sub>O</sub>* = Temperature, RTO Outlet (Average)

*T<sub>I</sub>* = Temperature, RTO Inlet

$$T_O = 208^\circ\text{F}$$

$$Q_I = (15,000\text{SCFM})(1.10)(208^\circ\text{F} - 100^\circ\text{F}) = 1,782,000 \text{ BTU/hr}$$

$$Q_{CC} = (450 \text{ SCFM})(1.10)(208^\circ\text{F} - 70^\circ\text{F}) = 68,310 \text{ BTU/hr}$$

$$Q_{RL} = (900 \text{ ft}^2)(200 \text{ BTU/ft}^2) = 180,000 \text{ BTU/hr}$$

$$Q_{VOC} = 0 \text{ BTU/hr with no VOC loading}$$

$$Q_T (\text{Net}) = 2,030,310 \text{ BTU/hr}$$

Lower Heating Value of Natural Gas is 906 BTU/ft<sup>3</sup>. Net Natural Gas Requirement = 2,030,310 / 906 = 2241 ft<sup>3</sup>/hr

#### 5. EXAMPLE FOR ESTIMATING FUEL REQUIREMENTS AND COSTS

**a. Case 1**

- Process flow of 15,000 SCFM
- 100 °F process temperature
- 900 ft<sup>2</sup> of oxidizer surface area
- 95% Thermal Efficiency
- 1500 °F chamber temperature
- VOC Loading of 0 lbs/hr
- 70 °F ambient temperature (combustion air temp)
- \$5 / MMBTU fuel cost
- 450 SCFM of combustion air introduction at full flow, zero VOC loading

$$N = 0.95 = ((15,000 + 450) / 15,000) \times ((1500 - T_O) / (1500 - 100))$$

Gross Natural Gas Requirement:  
2241 ft<sup>3</sup>/hr x 1005 BTU/ft<sup>3</sup>  
(gross, as purchased) = 2,252,205 BTU/hr

$$2,252,205 \text{ BTU/hr} \times \$5 / 1,000,000 \text{ BTU} = \$11.26/\text{hr}$$

**b. Case 2**

- Process flow of 15,000 SCFM
- 100 °F process temperature
- 900 ft<sup>2</sup> of oxidizer surface area
- 95% Thermal Efficiency
- 1500 °F chamber temperature

- VOC Loading of 45 lbs/hr, with  $H_C = 12,000$  BTU/lb
- $70^\circ\text{F}$  ambient temperature (combustion air temp)
- $\$5$  / MMBTU fuel cost
- 450 SCFM of combustion air introduction
- 98% VOC Destruction Rate

$$Q_I = 15,000\text{SCFM}(1.10)(208^\circ\text{F} - 100^\circ\text{F}) = 1,782,000 \text{ BTU/hr}$$

$$Q_{CC} = (350 \text{ SCFM})(1.10)(208^\circ\text{F} - 70^\circ\text{F}) = 53,130 \text{ BTU/hr}$$

$$Q_{ROL} = (900 \text{ ft}^2)(200 \text{ BTU/ft}^2) = 180,000 \text{ BTU/hr}$$

$$Q_{VOC} = (45 \text{ lbs/hr}) (12,000 \text{ BTU/lb}) (98\% \text{ DRE}/100) = 529,200 \text{ BTU/hr}$$

$$Q_T (\text{Net}) = 1,485,930 \text{ BTU/hr}$$

Lower Heating Value of Natural Gas is 906 BTU/ft<sup>3</sup>. Net Natural Gas Requirement =  $1,485,930 / 906 = 1640 \text{ ft}^3/\text{hr}$

Gross Natural Gas Requirement:  
 $1640 \text{ ft}^3/\text{hr} \times 1005 \text{ BTU/ft}^3$  (gross, as purchased) =  $1,648,200 \text{ BTU/hr}$

$$1,648,200 \text{ BTU/hr} \times \$5 / 1,000,000 \text{ BTU} = \$8.24/\text{hr}$$

## 6. INFORMATION REQUIRED FROM RTO SUPPLIERS

- A. VOC Loading in lbs/hr
- B. Weighted Average for Heat of Combustion of VOCs (BTU/lb)
- C. Combustion Chamber Setpoint Temperature
- D. Thermal Efficiency at Full Process Flow
- E. Combustion Air to Burner at Full Process Flow and no VOC Loading
- F. Combustion Air to Burner at Process Flow Conditions with VOC Loading
- G. Heat Loss or Surface Area of RTO
- H. Combustion Air Temperature
- I. Fuel Cost in  $\$/\text{MMBTU}$
- J. VOC Destruction Rate