Cornerstone
ENVIRONMENTAL HEALTH AND SAFETY, INC
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Thermal Oxidizer Efficiency

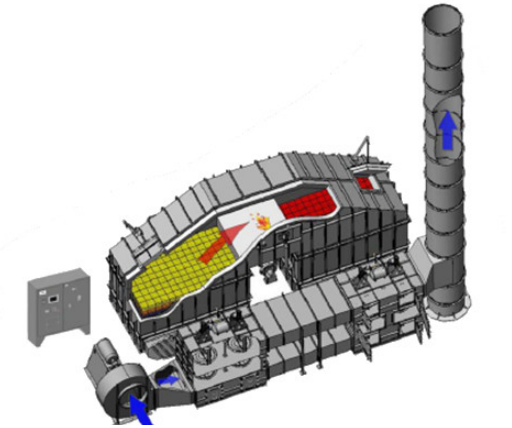
Pollution Prevention Opportunities at Existing Thermal Oxidation Installations

Indiana Partners for Pollution Prevention Conference

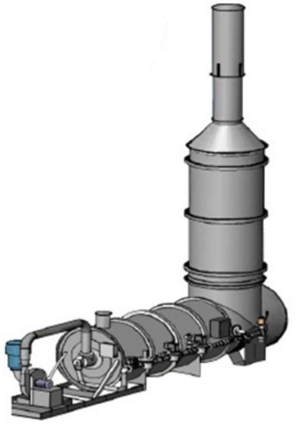
September 20, 2017

Oxidizer Technology Overview

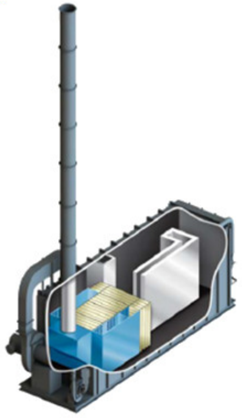
Types of Oxidizers



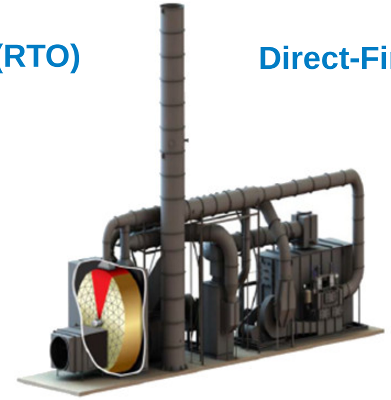
Regenerative Thermal Oxidizers (RTO)



Direct-Fired Thermal Oxidizers/Flares



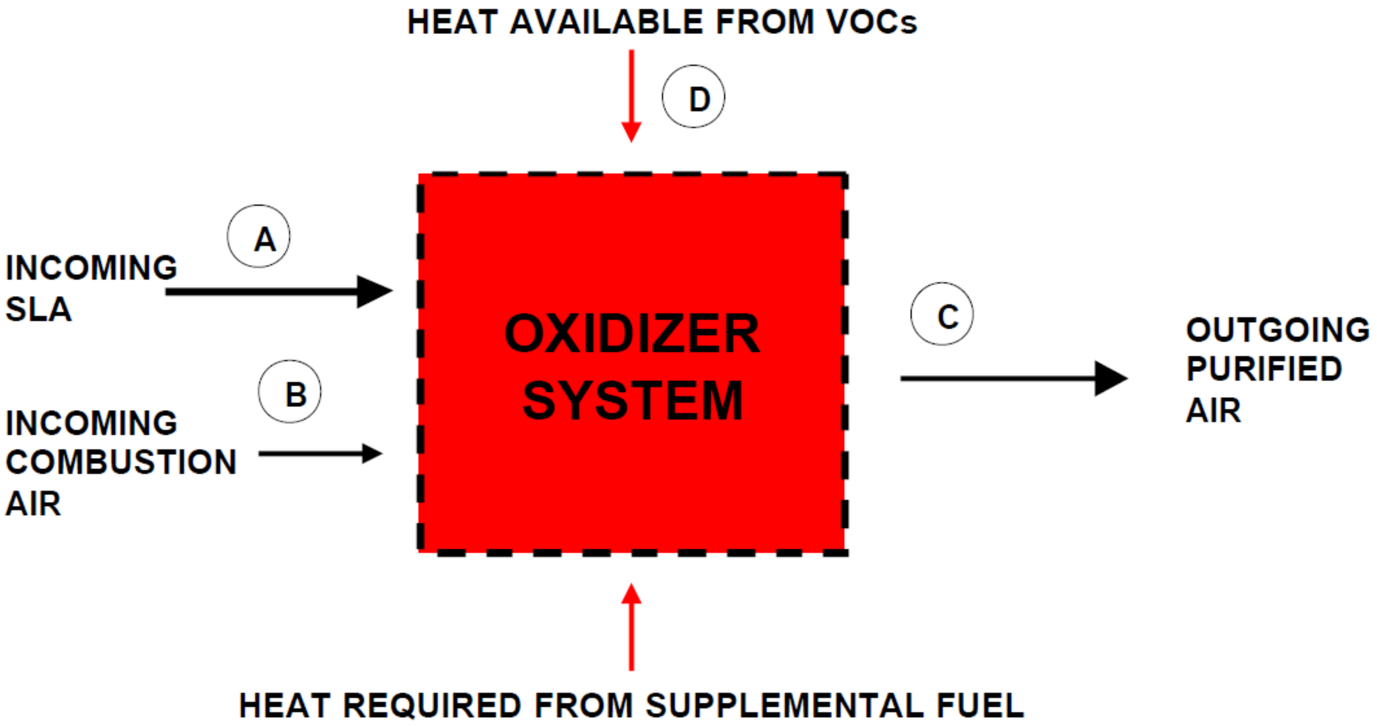
Thermal Recuperative Oxidizers



Concentrators

Catalytic Recuperative Oxidizers

Basic Thermal Oxidation



Point	Airflow (SCFM)	Temperature (F)		Point	VOC Load (lbs/hour)	VOC Heat Value (BTU/lb)
A	40,000	150		D	500	16,000 (MEK=14,500, Toluene = 18,250)
B	1000	60				
C	41,000	275				

Understanding Oxidizer Efficiency

- Oxidizers become “self-sustaining” at a certain level (measured as lb/hour) of VOC input (and airflow/temperature)
- Reducing inert airflow and decreasing oxidizer temperature promotes self-sustained operation
- Lower temperatures and airflows can dramatically reduce maintenance costs as well as natural gas usage
- Hoods and capture systems are important components of efficient design - minimizing the amount of air the oxidizer must handle improves efficiency and performance

Indiana Air Permit Compliance Requirements

D.1.X Thermal Oxidizer Temperature

(a) A continuous monitoring system shall be calibrated and maintained on the thermal oxidizer OX-1 for measuring operating temperature. For the purpose of this condition, continuous means no less often than once per fifteen (15) minutes. The output of this system shall be recorded as 3-hour average. From the date of startup until the stack test results are available, the Permittee shall operate the thermal oxidizer at or above the 3-hour average temperature of 1,400°F.

(b) The Permittee shall determine the 3-hour average temperature from the most recent valid stack test that demonstrates compliance with limits in Conditions D.1.1 (if the thermal oxidizer OX-1 is used to comply with the VOC limitation under Condition D.1.1), D.1.2, and D.1.6.

(c) On and after the date the stack test results are available, the Permittee shall operate the thermal oxidizer at or above the 3-hour average temperature as observed during the compliant stack test.

Indiana Air Permit Compliance Requirements

326 IAC 3-6-3 Emission testing
Authority: IC 13-14-8; IC 13-17-3-4; IC 13-17-3-11
Affected: IC 13-14-4-3; IC 13-15; IC 13-17

Sec. 3
(b) The owner or operator of a source or emissions unit shall conduct all emission tests as follows:

(1) The emissions unit being tested shall be operating according to clause (A) or (B), except as allowed under clause (C), as follows:

(A) At a minimum, ninety-five percent (95%) of the permitted maximum emissions unit operating capacity description.

(B) Under conditions of worst case emissions, and if the worst case emission condition is not known, then the worst case emission condition shall be assumed to be the maximum process or operating rate of the emissions unit as listed in the permit's emissions unit description.

Indiana Air Permit Compliance Requirements

(1) The emissions unit being tested shall be operating according to clause (A) or (B), except as allowed under clause (C), as follows:

…….

(C) Under <u>other capacities or conditions as specified in an applicable requirement or approved by the department</u>. As used in this clause, "capacity" means the design capacity of the emissions unit or other operating capacities agreed to by the owner or operator of the emissions unit and the department, including, but not limited to, process conditions when the department believes that changes in the operating capacities or operating conditions have the potential to affect emission levels.

2015 Compliance Test Results

At Maximum Ink (Average of Two RTOS)

Inlet Solvent Loading	633 lb VOC/hour
Destruction	99%
Average Combustion Zone Temperature	1,627°F
Total Outlet Flow Rate	70,601 DSCF

2017 Compliance Test Results

At Normal Ink (Average of Two RTOS)

Inlet Solvent Loading	296 lb VOC/hour
Destruction	98% +
Average Combustion Zone Temperature	1,576°F
Total Outlet Flow Rate	71,329 DSCF

Natural Gas Usage

RTO operated at self-sustaining conditions during both tests

Under “normal 2017 solvent loadings”, additional natural gas would be needed to increase combustion temperature from 1576^{o}F to the 2015 compliance temperature of 1627^{o}F

Leading to:

- higher costs
- increased NOx, CO and GHG

Natural Gas Usage

Heat Necessary to Increase Temperature from 1,576°F to 1,697°F:

71,000 DSCFM	=	4,260,000 DSCFH
4,260,000 DSCF	=	320,000 lb/hour
320,000 lb/hour X 0.27 Btu/lb/°F X 51°F	=	4.4 MMBtu/hour

Fuel-related Savings

Fuel Monetary Cost: $154,000 per year

4.4 MMBtu/hour X 8,760 hour/year X $4/MMBtu

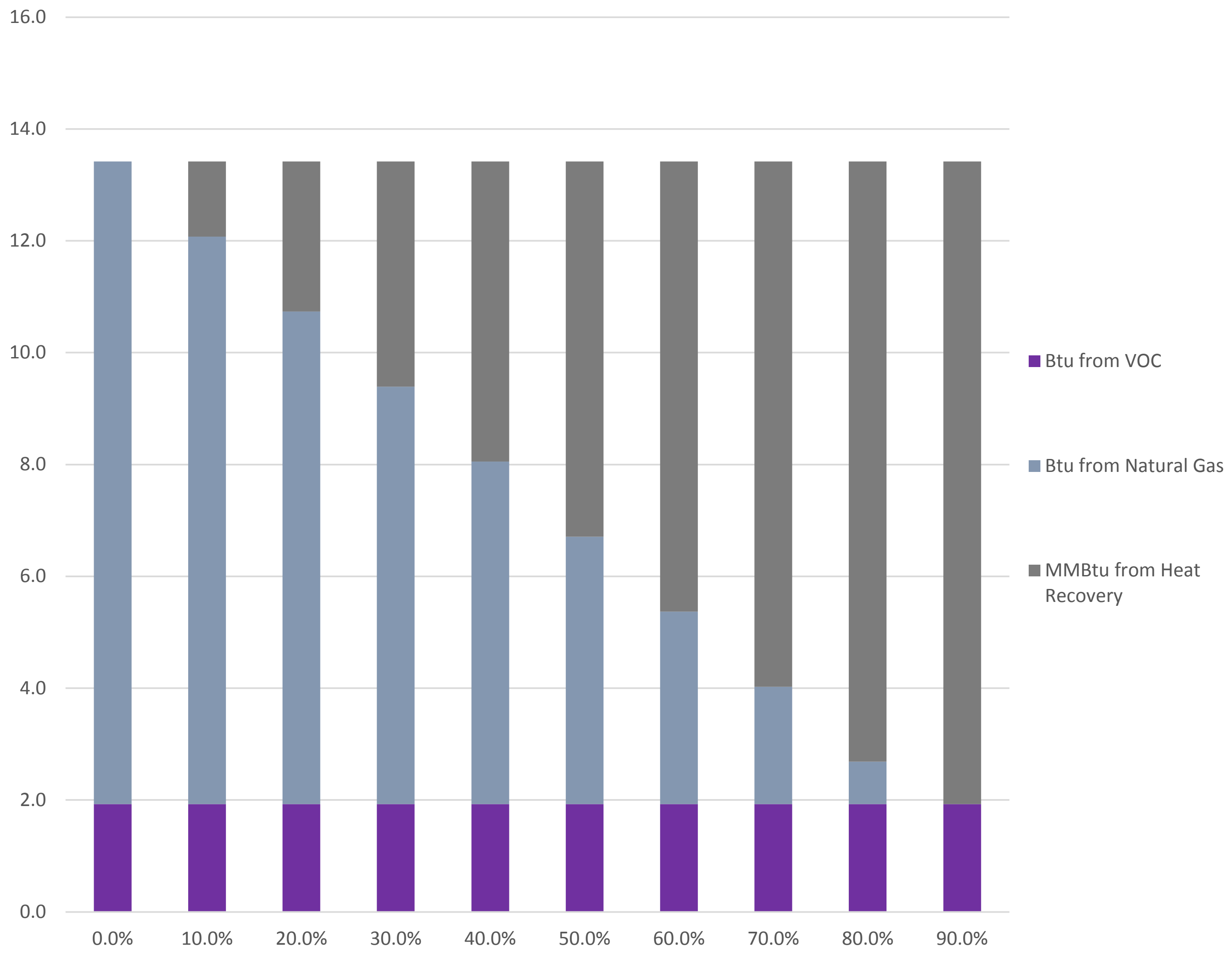
Air Emissions:

NOx – 1.9 tpy

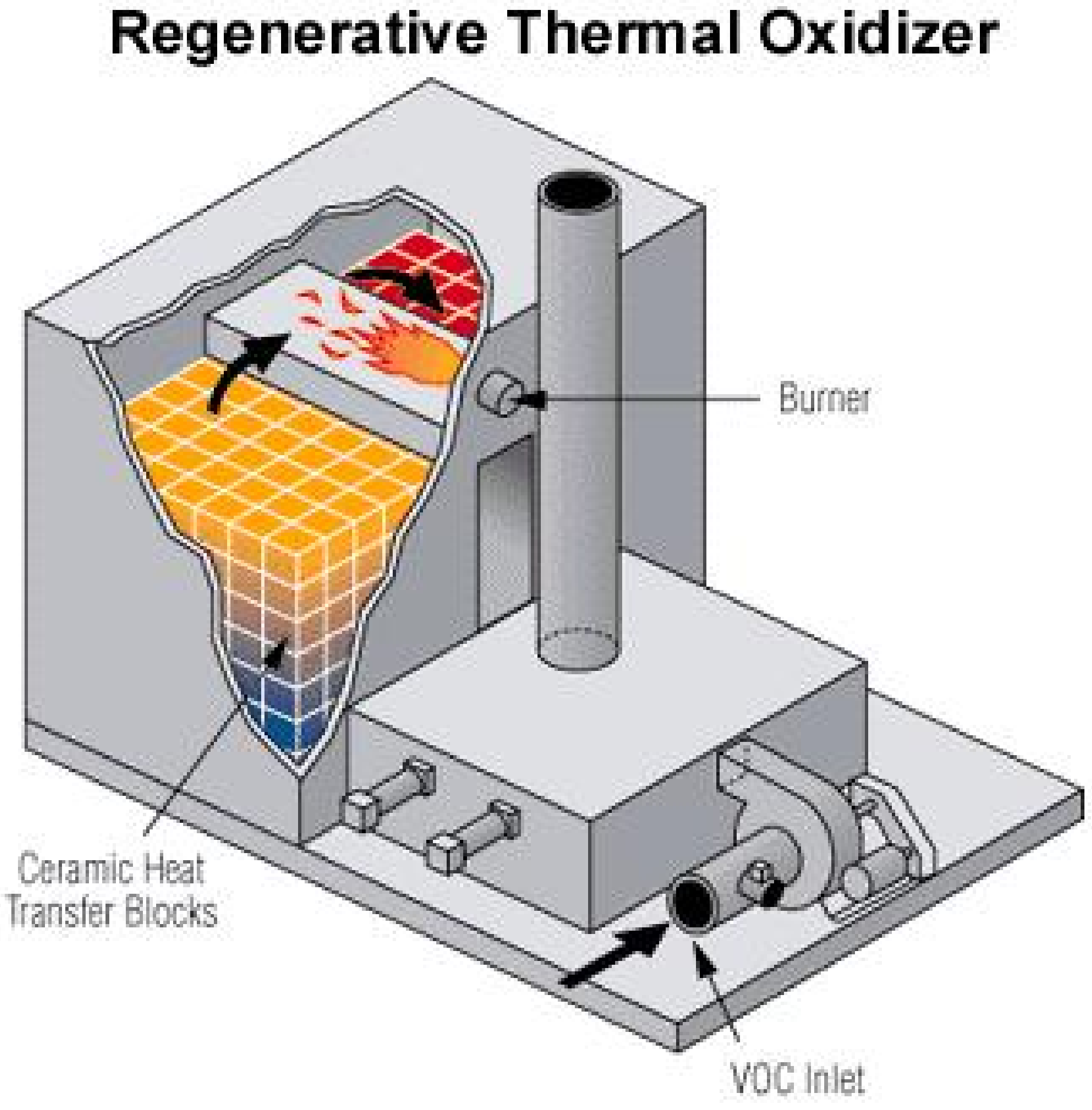
CO – 1.5 tpy

CO2e – 2,700 tpy

Impact of Heat Recovery on Fuel Use



Thermal Oxidizer Efficiency

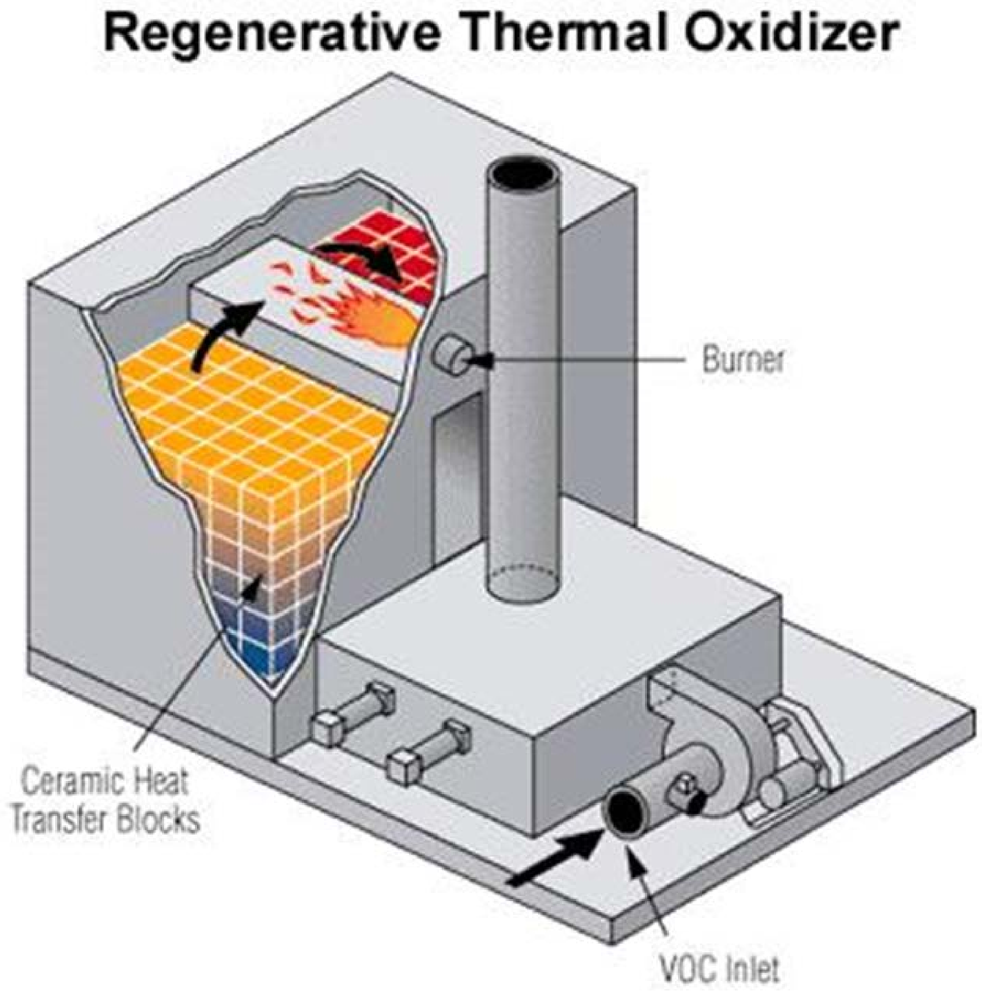


Thermal Oxidizer Efficiency

Fuel Cost: $154,000/year

Thermal Efficiencies:

Direct Fired T.O. – 0%	$ 154,000
Recuperative T.O. – 50%	$ 77,000
Catalytic T.O. w. Recup – 70%	$ 46,000
Regenerative T.O. – 95%	$ 7,700



RTO Heat Transfer Media

Media Replacement = $320,000/bed

Life Expectancy at 1,625ºF = 6 years

Life Expectancy at 1,575ºF = 10 years

Client Example of Replacing an RCO with an RTO

- Costs were developed for justification of a client's replacement of an old, poorly performing RCO

- A cost analysis was conducted to determine natural gas savings that would result from replacing a 30% thermally efficient unit with a 90% thermally efficient RTO style oxidizer

- This example is a high airflow and low VOC loading that did not reach self-sustaining operation

Input Conditions

Temperature at standard conditions	68°F
Temperature entering the oxidizer (average hoods, ovens, etc.)	70°F
Temperature exiting the oxidizer	1,550°F
Temperature exiting the stack	300°F
Moisture	5%
Air input requirement (hoods, ovens, etc.)	20,000 acfm
Solvent (blowing agent pentane heptane avg.)	19,250 Btu/lb
Loading of VOC	100 lb/hour
Fuel value	1.925 MMBtu/hour

Enthalpy Calculations

Gas flow with moisture	20,000 acfm
Temperature adjustment (acfm to scfm)	19,924 scfm
Hourly = scfm * 60 = scf/hour (includes moisture addition)	1,260,000 hourly
scf-hour/385.4 scf/lb-mole x 29 lb/lb-mole = lb/hour exhaust gas	94,811 scf-hour
Change in Enthalpies	361 Btu/lb
lb exhaust gas x Btu/lb = Btu/hour	34,231,951 Btu/hour
Heat recovery (percentage)	90%
Heat recovery (Btu/hour)	30,808,756 Btu/hour
Heat Loss (required hourly heat input)	3,423,195 Btu/hour
Natural Gas Required (@ 1000 Btu/scf)	3,423.20 scfh

Oxidizer Loading to Self-Sustain

Fuel Use for 100 lb/hour feed of 19,924 Btu/lb VOC feed at 90% Thermal Efficiency

Self-sustain	177.8 lb/hour
Natural gas	57.1 scfm/min
Natural gas (include VOC fuel)	25.0 scfm/min
Scf Natural gas (cost / 1,000)	$ 6.50
Natural Gas (cost per hour)	$ 9.74

Schedule:
8 hours per day
250 days per year
2,000 hours per year
$ 19,477 per year

Oxidizer Loading to Self-Sustain

Fuel Use for 100 lb/hour feed of 19,924 Btu/lb VOC feed at 95% Thermal Efficiency

Self-sustain	1,333.7 lb/hour
Natural gas	427.9 scfm/min
Natural gas (include VOC fuel)	395.8 scfm/min
Scf Natural gas (cost / 1,000)	$ 6.50
Natural Gas (cost per hour)	$ 154.37

Schedule:
8 hours per day
250 days per year
2,000 hours per year
$ 308,737 per year

Recommendations

- Review “max VOC loading” during compliance testing against “normal VOC loading”
- Compare TO manufacturer’s recommended temperature against “temperature established by most recent performance test”
- Conduct desk top estimate of cost savings
- Consider stack test protocol requesting test at normal loading
- Coordinate with TO manufacturer, stack test vendor, in-house production staff, and IDEM
- Establish more reasonable set point temperature to realize Natural Gas savings

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