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Environmental

Saving energy through front end engineering

Plant Engineering
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Environmental

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Key concepts

Examine all options when considering energy conservation

An option can have a low first cost and operating cost.

The optimum time to consider energy conservation is when making modifications to process equipment to meet new manufacturing requirements. Although this is obvious, it is not always done because of the rush to get a project completed and of the internal effort to reduce engineering cost. A good example of this is in the installation of a thermal oxidizer for pollution control.

Basically a thermal oxidizer (sometimes referred to as an afterburner or a fume incinerator) is provided to destroy Volatile Organic Compounds (VOCs) and/or for odor control.

The concept of a thermal oxidizer is based on the three Ts: time, temperature, and turbulence. The three Ts depend on the type and design of the thermal oxidizer and the process exhaust being treated. Most often the temperature for destruction of VOCs and odors ranges from 1450—1550 F and the time at the destruction temperature is 0.5 to 0.7 sec. The turbulence factor depends on the design of the thermal oxidizer and is required to ensure the design destruction efficiency of the VOCs and/or odors.

Types of thermal oxidizers

- Simple flares at the process exhaust
- Combustion chambers with no heat recovery
- Recuperative, having an air-to-air heat exchanger for heat recovery
- Regenerative, having a ceramic or stoneware bed for heat recovery
- Catalytic bed

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- Software
- Tools and Welding

- Specialty variations within the above categories.

When applying a thermal oxidizer or any new modifications to process equipment, the entire system must be considered. In the case of pollution control equipment, the processes and pollution control equipment must be evaluated as a single system to ensure that system operation will be safe and the equipment selected will result in the lowest owning and operating cost. A process hazard analysis should be conducted to ensure that the system design will result in a functional and safe design.

The intent of this example is to illustrate the necessity of looking at viable options when considering energy conservation while at the same time demonstrating that energy conservation options sometimes have a low first cost along with a low operating cost.

The airflow rates, type of process equipment, combination of and percentages of solvents used in the following calculations are arbitrary and do not reflect any actual process. However, values used in the calculations do represent realistic conditions.

Assumptions for example

Total process exhaust rate is 150,000 scfm from four individual dryers. The dryers may not all operate at the same time due to product changeovers, etc. The utilization rate for the dryers is 75%. When solvents are being evaporated in a dryer, the dryer exhaust is directed to the pollution control equipment.

When the processes are online the average process exhaust airflow rate is 112,500 scfm.

The dryers are 25 years old and were installed at the time the plant was built.

The normal production schedule is 24 hr/day, 5.5 days/wk, and 50 wk/yr.

The total maximum pounds of solvent evaporation from the four dryers is 756.3 lb/hr.

The solvent evaporated is a mixture of toluene, methyl ethyl ketone, ethyl acetate and heptane. The solvent heat value is 15,120 Btu/lb.

During normal operation the process exhaust is at 3% lower flammability limit (LFL).

Process air inlet temperature at thermal oxidizer is 125 F.

Estimated yearly average outdoor air temperature is 50 F.

Natural gas cost is $3.90 per MMBtu and electrical cost, including demand charges is $0.075/kWh.

The required VOC capture efficiency is 93%. In order to achieve the required capture efficiency the pollution control equipment, i this case a thermal oxidizer, must achieve a minimum destruction efficiency of 97%.

Two options are considered in this example: Option 1 is based on leaving the dryer exhaust as is. Option 2 is based on modifyin the dryer exhaust.

So as not to confuse the issue of the energy conservation opportunity presented and to simplify the calculations for the two options, both options are based on regenerative thermal oxidizers having similar life spans, annual maintenance costs, and hot gas recirculation. The primary difference between the two options is the size and thermal efficiency of the thermal oxidizers.

Option 1:

To achieve the required destruction efficiency, the thermal oxidizer manufacturer recommends a destruction temperature (therma oxidizer combustion chamber) of 1530 F.

Thermal efficiency required for the thermal oxidizer to be self-sustaining at the above conditions is 95.3%.

Thermal oxidizer selection for this option is a regenerative thermal oxidizer having a 95% thermal efficiency with an air pressure drop of 25 in. wc at the design airflow. An additional 5 in. wc is required for the process collection ductwork.

The minimum required airflow through the thermal oxidizer, based on a 4 to 1 turndown, is 37,500 scfm. The unit is provided with hot gas recirculation to reduce the operating cost when all processes are offline and when the process exhaust air volume is less than the minimum required airflow.

To provide for a redundant exhaust fan, three exhaust fans, each sized for 75,000 scfm, are provided and each fan is equipped with a variable speed drive and an outlet isolation damper.

The estimated total project cost to provide the thermal oxidizer, collection exhaust ductwork, controls, engineering, and installation is $13,500,000.

Hours of thermal oxidizer operation per year: 24 hr/day x 7 day/wk x 51 wk/yr = 8568.

Hours of operation per year with process exhaust = 24 hr/day x 5.5 day/wk x 50wk/yr = 6600 hr/yr.

Hours of standby operation without any process exhaust and utilizing hot gas recirculation: 8568 hr/yr – 6600 hr/yr = 1968 hr/yr.

Estimated temperature leaving the thermal oxidizer stack based on unit having a 95% thermal efficiency: 195 F.

Estimated natural gas cost:

Process exhaust:

Because the solvent loading is not always at design loading due to the process ramping up and down, infiltration, etc., it can be reasonably estimated that a minimal amount of natural gas energy will be required at all times. The actual amount of natural gas required can range from 10 to 45 times the calculated natural gas requirements. To present a reasonable example of projected energy costs, a factor of 20 times is used.

Fuel cost = (285,000 Btu/hr x 20) x $3.90/1,000,000 Btu x 6600 hr/yr = $146,718/yr.

Standby operation including the required combustion air when operating in this mode:

Btu/hr for recirculation = 37,500 scfm x 4.5 x 0.26 x 25 (Δt) = 1,096,875 Btu/hr.

Btu/hr for combustion air = 1,096,875 ÷ 106 x 0.075 x 0.26 x (1530 – 50) = 298,640.

Total MMBtu/yr for standby operation = (1,096,875 + 298,640) x 1980 hr/yr x $3.90 ÷ 1,000,000 Btu = $10,776.

Total estimated annual cost for natural gas: $146,718 + $10,776 = $157,494.

Estimated electrical cost:

Process exhaust:

Average airflow of 112,500 scfm and 50 scfm of combustion air at an average system pressure drop of 26 in. wc, exhaust fan efficiency of 75%, and a 0.9 power factor.

Total estimated fan horsepower based on the above conditions = 615 hp.

KWh = approximately 510.

Cost per year = 510 kWh x 6600 hr/yr x $0.075/kWh = $252,450.

Standby operation:

Minimum airflow of 37,500 scfm and 175 scfm of combustion air, average system pressure drop of 12 in. wc, exhaust fan efficiency of 75%, and a 0.9 power factor.

Total estimated fan horsepower based on the above conditions = 95 hp.

kWh = approximately 79.

Cost per year = 79 kWh x 1980 hr/yr x $0.075/kWh = $11,732.

Total estimated annual cost for electricity: $252,450 + $11,732 = $264,182.

Estimated total energy cost:

Total estimated energy cost per year for natural gas and electricity: $421,676.

Option 2:

Under this option the percent-LFL control will be added to the existing dryers to reduce the amount of process exhaust by increasing the percent-LFL in the process exhaust from 3% to 8%. The total air circulation rate through the dryer will remain the same so as not to disturb the existing curing process. Even though the percent-LFL will be increased, the change in percent-RH within the dryers is insignificant.

Estimated cost to add the percent-LFL control to the dryers is $750,000 each for a total of $3,000,000.

To achieve the required destruction efficiency, the thermal oxidizer manufacturer recommends a destruction temperature of 1530 F, the same as indicated for Option 1.

Thermal oxidizer selection for this option is a regenerative thermal oxidizer having an 88% thermal efficiency with an air pressure drop of 24 in. wc at the design airflow. An additional 5 in. wc will be required for the process collection ductwork.

The minimum required airflow through the thermal oxidizer, based on a 4:1 turndown, is approximately 13,400 scfm. The unit is provided with hot gas recirculation to reduce the operating cost when all processes are offline and when the process exhaust air volume is less than the minimum required airflow.

To provide for a redundant exhaust fan, three exhaust fans, each sized for 26,625 scfm, are provided, and each fan is equipped with a variable speed drive and an outlet isolation damper.

Estimated total project cost to provide the thermal oxidizer, collection exhaust ductwork, controls, engineering, and installation is $5,000,000.

Hours of thermal oxidizer operation per year = 24 hr/day x 7 day/wk x 51 wk/yr = 8568 hr/yr.

Hours of operation per year with process exhaust = 24 hr/day x 5.5 day/wk x 50 wk/yr = 6600 hr/yr.

Hours of standby operation without any process exhaust and utilizing hot gas recirculation = 8568 hr/yr – 6600 hr/yr = 1968 hr/yr.

Estimated temperature leaving the thermal oxidizer stack based on unit having a 95% thermal efficiency = 195 F.

Estimated natural gas cost:

Process exhaust:

As explained under Option 1, the actual amount of natural gas required can very easily range from 10 to 45 times the calculated natural gas requirements. To present a reasonable example of projected energy costs, a factor of 20 times is used.

Fuel cost = (125,000 Btu/hr x 20) x $3.90 ÷ 1,000,000 Btu x 6600 hr/yr = $64,350 per year.

Standby operation including the required combustion air when operating in this mode:

Btu/hr for recirculation = 13,400 scfm x 4.5 x 0.26 x 25 (Δt) = 91,950 Btu/hr.

Btu/hr for combustion air = 391,950 ÷ 106 x 0.075 x 0.26 x (1530 – 50) = 106,715 Btu/hr.

Total MMBtu/yr for standby operation = (391,950 + 106,715) x 1980 hr/yr x $3.90/ 1,000,000 Btu = $3,850 MMBtu/yr.

Total estimated annual cost for natural gas: $64,350 + $3,850 = $68,200.

Estimated electrical cost:

Process exhaust:

Assume average airflow of 56,200 scfm and 20 scfm of combustion air at an average system pressure drop of 26 in. wc, exhaust fan efficiency of 75%, and 0.9 power factor.

Total estimated fan horsepower based on the above conditions = 308 hp.

Electric power = approximately 255 kWh.

Cost per year = 255 kWh x 6600 hr/yr x $0.075/kWh = $126,225.

Standby operation:

Assume minimum airflow of 13,400 scfm and 80 scfm of combustion air, average system pressure drop of 12 in. wc, exhaust fan efficiency of 75%, and 0.9 power factor.

Total estimated fan horsepower based on the above conditions = 34 hp.

Electric power = approximately 29 kWh.

Cost per year = 29 kWh x 1980 hr/yr x $0.075/kWh = $4310.

Total estimated annual cost for electricity: $126,225 + $4,310 = $130,535.

Estimated total energy cost:

Total estimated energy cost per year for natural gas and electrical is $198,735.

Conclusion

Option 1 has a first cost of $13,000,000 for the thermal oxidizer with an annual energy cost of $421,676.

Option 2 has a first cost of $3,000,000 for dryer modifications plus $5,000,000 for the thermal oxidizer for a total of $8,000,000 with an annual energy cost of $198,735.

Clearly option 2 is the system having the lowest energy consumption while at the same time having the lowest first cost.

Additional advantages of Option 2 include:

v Additional annual energy savings resulting from reducing the amount of makeup air required for dilution (lower exhaust air volumes)

v A portion of the capital expenditure was used to upgrade the controls of the dryers, which in turn will increase the product yield and quality.

This is just one example of a viable energy conservation project. Usually a simple initial evaluation of a process can be used to determine if the process may be a candidate for energy conservation. If the initial evaluation determines the process is a strong candidate for energy conservation, then an indepth analysis should be provided to verify the magnitude of the project cost, the value of the projected energy saved, and estimated project pay back based on the value of the energy reduction.

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More info

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