Oxidizer Energy Recovery Strategies

Introduction

The mainstream media today is full of allusions to *energy awareness* and *conservation*. Just as visible these days are media references to astronomical dollar figures that can boggle the mind. This article does not seek to break out of that mold, but rather to conform to it – as Oxidizer Stack Heat Recovery offers a tremendous opportunity for both energy conservation and energy cost reduction.

Consider the following:

- At any hour of the day there are likely to be more than 10,000 oxidizer systems in service, using a high temperature reaction chamber (with or without catalyst) to treat the exhaust gases from a wide range of industrial processes.
- The final component of nearly all of these oxidizer systems is an exhaust stack, where the treated exhaust gases are released to the atmosphere at elevated temperatures.
- Historically, oxidizer systems have been sized to treat exhaust airflows from 100 SCFM (Standard Cubic Feet per Minute) up to several hundred thousand SCFM. But conservatively, the average oxidizer system airflow processing capability (i.e. "size") can be estimated to be between 15,000 and 20,000 SCFM.
- Now, considering these 10,000 stacks emitting hot, treated gases to the atmosphere around the clock; if heat recovery equipment capable of dropping the exhaust stack temperature by 100 ˚F could be installed into each one of them, this would lead to an overall value of over 18 billion BTUs (British Thermal Unit) per hour of energy conservation!
- In dollars - assuming $10/MM BTU and year round operation – this equates to recovering over $1.5 billion worth of energy per year!

Taking this into account, it is no surprise that a wide range of stack energy recovery options have been developed and marketed to end-users of oxidizer systems. This article will discuss three important aspects of energy reclamation from hot oxidizer stacks:

1. Energy reclamation from oxidizer stacks is one of three potential areas of optimization for oxidizer systems.

2. There are distinct challenges that must be addressed in the process of evaluating potential energy savings options.
3. There are multiple potential equipment options for this application, each with its own benefits and limitations.

The ABC's of Oxidizer Stack Energy Recovery

Using *ABC's* in the title of this section is actually a misnomer. Truthfully, the letters *A* and *B* should be set aside and the caption should read – *The CDE's of Oxidizer Stack Energy Recovery.* The reason for this is twofold:

First of all – any plan for recovering waste heat in the exhaust stack of an oxidizer system is already a Plan C. For anyone taking a hard look at optimizing the energy efficiency of an oxidizer system as a whole, Plan A should consider 'upstream' opportunities. (For example, retrofits that reduce overall airflow to the oxidizer system and/or increase the concentration of solvents to be treated.) Plan B should focus on the internal TER (Thermal Energy Recovery) of the oxidizer system itself. After airflow reduction, maximizing the internal energy recovery of an oxidizer system will almost always lead to the best project payback.

Hence, it follows that energy recovery in the exhaust stack of the oxidizer is Plan C. Now calling it Plan C is by no means meant to downplay the opportunities associated with oxidizer stack energy recovery. The only intent is to fit the concept into the greater framework of energy usage in the oxidizer system as a whole. There are many reasons why Plan A and/or Plan B as defined above may not be attractive or even feasible – making Plan C: Energy Recovery in the Oxidizer Exhaust Stack – the best overall choice for energy conservation efforts.

The second reason that the letters *C, D* and *E* are a better fit for the title of this section is that those three letters represent the challenges associated with energy recovery efforts in oxidizer exhaust stacks, namely:

- CAPTURING the energy from the stack itself
- DELIVERING the energy back into the plant cost-effectively
- EMPLOYING the recovered energy effectively inside the plant

Following is a brief discussion of each of these challenges along with the different options for recovering oxidizer stack heat.

Challenge #1: Capturing the Energy

Of the three challenges, the first – Capturing the Energy – is usually the easiest to evaluate and estimate. By simply knowing the airflow and temperature of the exhaust gases in the oxidizer stack, suppliers of energy recovery equipment can quickly begin to model an appropriate device for reclaiming energy effectively. It is often during this first challenge that the overall opportunity for yearly savings is also quantified.

The more information that an oxidizer end-user can provide at this juncture, the more realistic the opportunity analysis can be. At a minimum, those considering stack energy recovery should gather the following before beginning this process:

- Expected airflow and average temperature in the oxidizer stack
- Expected hours of operation per year
- Current energy rates for the plant (gas or oil and electric)

The first two items are often monitored already on a continuous basis in oxidizer data recorders. If that is not the case for a particular system, the most recent EPA (Environmental Protection Agency) stack testing data can be an excellent source for this information.

Two other issues for consideration during this phase of an evaluation are:

- Constituents in the exhaust gases (and especially their dew points): Any effort to reclaim energy in the exhaust stack of an oxidizer will lower the oxidizer exhaust gas temperature, bringing with it the potential for condensation of acids. Suppliers of energy recovery equipment will typically take care to ensure that final stack temperature is above any acid dew points. Given the typical solvent laden exhaust from printing presses, this is rarely an issue of concern for oxidizer systems in the flexographic printing industry.

- Adding energy recovery equipment to an oxidizer exhaust stack will also come with a system back-pressure penalty. The existing oxidizer fan will usually be tasked with pushing or pulling air through the 'hot side' of the added heat recovery component. To keep overall project payback attractive, the goal is usually to choose energy recovery equipment that will limit the added system back-pressure to an amount that the existing oxidizer system fan can handle without major modification. Therefore, knowing the additional capacity available in the oxidizer system fan will help narrow down which cost-effective options for energy recovery are feasible.

Challenge #1 for a typical application may look like this:

Consider a flexographic printer with a ten year old 20,000 SCFM Regenerative Thermal Oxidizer (RTO). The combined exhaust from all dryers and capture hoods routed to the RTO is 20,000 SCFM at approximately 150˚F. The average exhaust temperature from the RTO is 275˚F.

Plan C - A 50% effective heat exchanger installed in the oxidizer exhaust stack to transfer the waste heat to air or fluid would drop the stack temperature by approximately 125˚F – capturing approximately 2.7 MM BTU/hr. If this energy was 100% useful inside the plant and the plant operated around the clock, this could lead to a yearly savings of up to $225,000.00. A payback of one to two years is certainly possible for a project of this nature.

By comparison:

Plan A – reducing airflow to the RTO by 10% could save approximately 0.3 MM BTU/hr or up to $25,200.00/year. This could likely be accomplished with very little capital investment at all. A payback of less than six months is possible for this option.

Plan B – for the data presented, this RTO is operating with an internal thermal energy recovery (TER) of approximately 92%. Installing additional ceramic heat recovery media to raise the TER to 95% could save approximately 1.0 MM BTU/hr or up to $84,000.00/year. A payback of less than one year is possible for this option.

Challenge #2: Delivering the Energy Back into the Plant Facility Cost Effectively

As seen in Challenge #1, sizing energy recovery equipment and estimating the overall savings opportunity with oxidizer stack energy recovery are not difficult tasks. To take an opportunity analysis and turn it into an actual payback period however, one has to determine the cost of installing the equipment and providing the infrastructure for delivering captured energy back to the plant.

For a cursory analysis, some will take the cost of the energy recovery equipment and double it, calling that the estimated cost of installation. (i.e. Total Estimated Cost = One Part Equipment Cost + Two Parts Installation Cost) This can provide for a quick check of whether a particular idea merits additional investigation. To obtain true payback numbers then a site visit by different tradespeople to estimate the overall cost of energy recovery system installation will be necessary. Fans and/or pumps, control valves, thermocouples, etc. will all need to be both mechanically installed and electrically wired to an existing or new control system. This is often the challenge where the overall project feasibility hangs in the balance.

Challenge #3: Employing the Recovered Energy Effectively inside the Plant Facility

The final challenge is also extremely important for optimizing energy recovery project payback. Ideally, the oxidizer end-user should look for ways in which recovered stack energy can be used in the same process that the oxidizer is connected to. This typically provides the best payback because there are energy demands by that process at nearly all times that oxidizer waste heat is available. In contrast, projects focused on recovering oxidizer exhaust stack energy to help heat a facility, for example, may only be useful for part of the year.

Oxidizer Stack Energy Recovery Options

Oxidizer stack heat has been recovered to perform a wide variety of functions in the plant environment.

- Air-to-air heat exchangers have been used to provide pre-warmed fresh air back to process ovens, dryers and/or plant make up air units.
- Air-to-fluid heat exchangers have been used to transfer oxidizer stack heat to boiler feed water, plant makeup water, process water, glycol and other thermal fluid loops.
- In extreme cases, waste heat boilers have been used with oxidizer stack heat to create steam.
- And on the horizon, heat-to-power systems are in development for reclaiming oxidizer stack heat and creating electricity.

One additional option that has been used sparingly is taking hot oxidizer stack air directly back for use in production processes. This is sometimes referred to as *Direct Heat Recovery*, while the options mentioned above would be termed *Indirect Heat Recovery*. Direct Heat Recovery from oxidizer stacks is generally shied away from due to the risks of introducing products of incomplete combustion back into a plant environment or the risk of oxidizer "oven dirt" contaminating product, but there are limited cases where this form of oxidizer stack energy recovery has been used effectively.

Each of these options for recovering heat from oxidizer exhaust stacks can be considered within the framework of the three challenges discussed previously.

Air-to-Air Heat Recovery

Probably the most common energy recovery product applied to oxidizer stacks is an air-to-air heat exchanger. Be it a shell-and-tube or plate type heat exchanger, there is a *cold side air stream* (typically fresh air) and a *hot side air stream* (typically the oxidizer exhaust) that are used for heat transfer.

Air-to-air heat exchangers have been integral to oxidizers themselves for decades so it is a well-known technology for oxidizer manufacturers to incorporate into an overall system. The programs for sizing air-to-air heat exchangers are quick and easy to use. There are a wide variety of footprints and physical layouts for ease of installation. There are also many low-backpressure models that work well with existing oxidizer system fans.

The limiting factor for air-to-air heat recovery in oxidizer exhaust stacks is Challenge #2: Delivering the Energy Back into the Plant Facility Cost Effectively. With air-to-air heat recovery, insulated ductwork is required to transport captured heat back into the facility. Costs for running ductwork in a plant vary widely and can also add up very quickly. The best applications are those with short duct runs for returning heated air.

Air-to-Fluid Heat Recovery

Air-to-fluid heat exchangers are the second most common energy recovery product for oxidizer stacks. As the name implies, heat is transferred from the hot oxidizer exhaust air (again the hot side air stream) to a circulating fluid (the cold side stream). This is typically accomplished by passing the hot air over a coil containing the fluid to be heated. As with air-to-air heat recovery there are a variety of low-backpressure designs that can allow installation into an oxidizer exhaust stack without adversely affecting the oxidizer system.

Because piping is less expensive than ducting, air-to-fluid heat recovery has a definite advantage over air-to-air heat recovery when considering Challenge #2: Delivering the Energy Back into the Plant Facility Cost Effectively. However, unless the heated fluid is used directly back in the process that the oxidizer is connected to, Challenge #3: Employing the Recovered Energy Effectively inside the Plant Facility, can be more difficult to address with air-to-fluid heat recovery. Meeting this challenge requires a detailed analysis of the demands for energy in the fluid system verses the availability of waste heat in the oxidizer stack. For example, in some plants the biggest hot water demands come in shutdown situations when the oxidizer is not running.

Air-to-Steam Heat Recovery (Waste Heat Recovery Boilers)

When the solvent laden air sent to an oxidizer system is sufficiently rich, the oxidizer's internal heat recovery component may need to be partially bypassed or forgone completely. This leads to higher than normal oxidizer stack temperatures and allows for additional options in heat recovery equipment. One such option is a waste heat recovery boiler to recover oxidizer exhaust stack heat and produce steam. Waste heat recovery boilers are custom sized for a particular exhaust gas capacity as well as required steam pressure. A variety of systems are available in vertical, horizontal, single or multi pass configurations.

Oxidizers on most applications rarely have the necessary solvent loading and corresponding exhaust stack temperatures to sustain this option.

Heat-to-Power

Sometimes referred to as cogeneration, heat-to-power is an emerging technology that is capable of sending kilowatts directly back into a facility for electrical power. The concept has been implemented on different applications throughout the world but is only now being integrated with combustion devices such as oxidizers. Heat-to-power systems can currently generate up to 100kw per hour from a modest heat source. However, the payback is normally greater than three years, the value most companies use for acceptable capital investment. As electricity costs increase and greater efficiencies are achieved with the technology it will be a very attractive option in the near future. Today, heat-to-power is not necessarily a cost reduction strategy but rather a green initiative that could be used to promote a company as a leader in energy conservation.

Oxidizer stacks represent a significant opportunity for the reclamation of energy. This applies to all oxidizer systems – including both the aging catalytic oxidizers popular in the industry years ago as well as the newer, high efficiency regenerative thermal oxidizers (RTOs) being supplied today. Achieving a cost-effective installation of energy recovery equipment with an attractive payback is not without challenges, but those challenges are being met today in a variety of ways.

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