An oxidizer stack. All art courtesy Anguil Environmental Systems.

Take the Heat... and Reuse it

Solutions for Reducing Operating Costs Using Oxidizers

By Mike Scholz

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. 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 100SCFM (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 20,000SCFM.
- 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 Units) per hour of energy conservation!
- In dollars, assuming $10/MMBTU and year-round operation, this equates to recovering over $1.5 billion worth of energy per year!

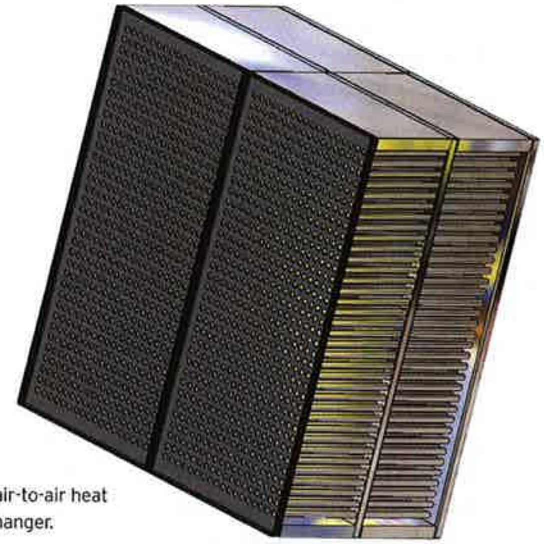
Taking this into account, it is no surprise that a wide range of stack energy recovery options have been developed and marketed to end-users of oxidizer systems. This article will discuss three important aspects of energy reclamation from hot oxidizer stacks:

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.

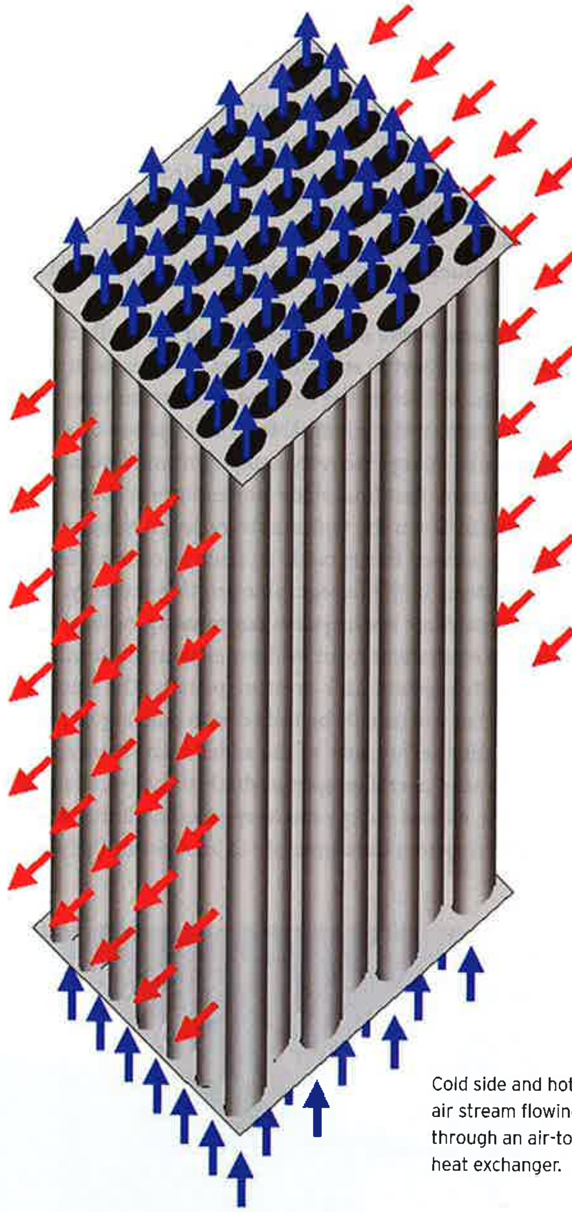
ABC'S OF OXIDIZER STACK ENERGY RECOVERY

Using *ABC*'s in the title of this section is actually a misnomer. Truthfully, it should say *CDE*'s. 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 sys-



An air-to-air heat exchanger.



Cold side and hot side air stream flowing through an air-to-air heat exchanger.

tem as a whole, Plan A should consider upstream opportunities. For example, retrofits which 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.

CAPTURING THE ENERGY

Of the three challenges, the first 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.

Air to air heat exchanger plate type.

- 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.
- **Current oxidizer main system fan capacity.** 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 No. 1 for a typical flexographic printing application may look like this. Consider a flexographic printer with a 10-year old regenerative thermal oxidizer (RTO). The combined exhaust from all dryers and capture hoods routed to the RTO is 20,000SCFM at approximately 150°F. The average exhaust temperature from the RTO is 275°F.

Implementing Plan C, a 50-percent 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 2.7MMBTU per hour. If this energy was 100 percent useful inside the plant and the plant operated around the clock, this could lead to a yearly savings of up to $225,000. A payback of one to two years is certainly possible for a project of this nature.

By comparison, in Plan A, reducing airflow to the RTO by 10 percent could save approximately 0.3MMBTU per hour, equivalent to $25,200 per 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. Alternatively, for the data presented, this RTO is operating with an internal thermal energy recovery (TER) of approximately 92 percent. Plan B would be installing additional ceramic heat recovery media to raise the TER

Installation of a secondary heat exchanger.

to 95 percent could save approximately 1.0MMBTU per hour or up to $84,000 per year. A payback of less than one year is possible for this option.

DELIVERING THE ENERGY

As seen in Challenge No. 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, a site visit by different trades people 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.

EMPLOYING THE ENERGY

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.

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

Probably the most common energy recovery product applied to oxidizer stacks—especially in the flexographic printing industry—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 No. 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.

Maximizing internal thermal energy recover. Metal heat exchanger replacement.

10 TIPS FOR MAXIMIZING HEAT RECOVERY FROM YOUR OXIDIZER AND REDUCING OPERATING COSTS

By Mike Scholz

More and more, companies operating air pollution control equipment today realize that the initial capital cost of an oxidizer system can be rapidly eclipsed by continued operating expenses if careful attention is not periodically given to the system. Below are 10 tips to ensure your oxidizer is operating at peak performance. The first five focus on parameters end-users should know about their oxidizer systems, while the last five address energy reduction projects to be considered.

1. KNOW HOW MUCH YOUR OXIDIZER IS SUPPOSED TO BE COSTING YOU TO OPERATE.

It is surprising how many facilities cannot answer the following two questions:

- How much is operating our oxidizer expected to cost?
- How close is our oxidizer operating to that expected value?

The "out of site, out of mind" approach is entirely too prevalent these days when it comes to air pollution control equipment. While that speaks highly for the reliability of systems installed today, it also hints at a blind spot around the day-to-day operating cost of oxidizer systems. With relatively minimal inputs, oxidizer vendors can run a performance model for you and give you the expected operating cost range for your oxidizer system.

2. PAY ATTENTION TO THE PERCENTAGES.

After five years of operation, a regenerative thermal oxidizer (RTO) originally designed for 95 percent TER (thermal energy recovery) may have slipped to 93 percent TER. This might not sound like a big deal, and this may go unnoticed by even the most attentive maintenance department. However, an average sized RTO (25,000SCFM) operating for a full year at 93 percent TER verses 95 percent TER could cost upwards of an additional $65,000 each year! Percentage points do count over the course of a year. Get to know the critical parameters to watch as your system ages.

3. KNOW YOUR VOC LOADS–ESPECIALLY THE AMPLITUDE AND DURATION OF PEAKS.

Often, it is peak VOC (volatile organic compound) loads that determine your oxidizer design, but average VOC loads that determine your oxidizer operating cost. When an oxidizer is specified, designed and installed, oftentimes it is the anticipated VOC loading peaks that dictate the amount of heat recovery incorporated. Typically, estimates for a future "worst case scenario" are made to ensure a conservative approach is taken. After a couple years of operation, it may be time to examine whether the design was too conservative and the peak solvent usage is much lower than originally estimated. Operating an oxidizer designed to handle a theoretical peak loading may be costing you much more than necessary for your actual day-to-day production loading.

4. KNOW WHAT OXIDIZER SYSTEM WOULD BE SPECIFIED FOR YOUR PROCESS TODAY.

Finding out exactly what would be specified to treat your process exhaust today is a valuable exercise—especially if your existing equipment is in need of significant repairs or upgrades. Knowing what would be specified in today's energy conscious market can serve to illuminate cost effective upgrades to your existing equipment.

For instance, five to 10 years ago, an RTO with 90 percent heat recovery may have been specified to treat your process exhaust. Today, oxidizer vendors may prescribe an RTO with 95 or 96 percent heat recovery and a hot gas bypass damper to deal with high VOC loading periods. If your existing oxidizer system is due for repairs, one can also determine whether it would be cost effective to upgrade to today's standards at the same time.

Alternatively, it may be a completely different oxidation technology specified today. With today's control schemes, RTOs have expanded their applicability greatly over past years, while also dropping significantly in initial capital cost. Knowing exactly what would be specified today can save you from sinking too much money into an outdated oxidizer system.

5. KNOW WHAT GRANT MONEY IS AVAILABLE TO YOU.

Energy reduction upgrades to existing equipment will have an associated initial capital cost. This can be significantly reduced with grant money from local utility companies. Across the country, money has been earmarked for the specific purpose of funding energy reduction projects. Know what grant money is available to you, whom to contact, when and how to apply. The main intent of these programs is to take upgrade projects that you (or your management) may be on the fence about and contribute the funds necessary to make them very attractive.

6. CONCENTRATE HIGH VOLUME, LOW VOC AIRSTREAMS PRIOR TO OXIDIZER.

If a significant portion of the air entering your oxidizer is at or near ambient temperature with low levels of VOC loading, a VOC concentrator may be applicable for reducing the heat input required by your oxidizer system.

As a result of recent regulations, many facilities around the country have been forced to improve localized VOC capture as well as prove high destruction efficiency in their oxidizer

Maximizing internal thermal energy recovery.

Concentrators reduce the air volume being sent to an oxidizer, increasing the capacity and efficiency of an existing oxidizer system. Large air volumes with low VOC concentrations are absorbed into a concentrator then desorbed in a condensed, smaller volume before being sent to the oxidizer.

Secondary heat recovery installation.

system. In many cases this has lead to the installation of additional capture hoods or enclosures and increased the amount of air to be treated by a particular oxidizer system. A concentrator can take exhaust air at or near ambient temperatures and concentrate it so that what is actually sent over to the oxidizer system is reduced by a factor of eight to 15 times. This greatly reduced airflow is typically fuel-rich with VOCs and much less of an operating cost burden on the oxidizer system.

7. FOCUS ON COMBUSTION AIR.

Combustion air, both in your oxidizer system or in your process burners, is often overlooked as a potential area for operating cost savings. Next to main oxidizer system fans, the smaller combustion fan supplying high-pressure air across the oxidizer burner can seem insignificant. However, these smaller fans, more often than not, are supplying fresh air at outdoor temperatures directly into the oxidation chamber where it must be heated to full oxidation chamber temperature. At a temperature difference usually over 1,400 °F, it does not take much airflow over the course of a year to add up to significant operating cost dollars.

Making sure burners are tuned properly and not firing on excess combustion air can make a big difference. With RTOs, there is the additional opportunity to install a flameless fuel injection system where combustion air is not needed at all. Finally, even with a perfectly tuned burner, combustion air can be preheated using a heat exchanger or a blend with stack air.

8. IMPROVE PRIMARY HEAT RECOVERY.

Oxidizers are typically designed with some form of internal heat recovery. Usually the hot purified gases leaving the combustion chamber are used to pre-heat the incoming solvent laden airstream. This is referred to as the primary heat recovery of an oxidizer system. Projects that improve the primary heat recovery of an oxidizer system often offer the quickest payback because they provide additional heat recovery at all times the oxidizer is in service. For recuperative thermal and catalytic units this typically consists of adding additional passes to the internal air-to-air heat exchanger. For RTOs and RCOs this would be handled with increasing or changing the type of ceramic heat recovery media or changing the control scheme that dictates how often beds are switched from inlet to outlet.

9. CONSIDER SECONDARY HEAT RECOVERY.

If improving primary heat recovery is not cost effective—or oxidizer operating conditions do not allow it—secondary heat recovery may be the best option for conserving the heat input to an oxidizer system. Heat exchangers can be added to the exhaust stack of an existing oxidizer to capture excess stack heat in air, water, or even steam. There is a wide variety of low back-pressure designs that can be added to an oxidizer's stack without requiring a replacement of the oxidizer system fan.

Payback for these projects is greatly improved if the captured heat can be used back in the exhaust generating process itself, because again—it is assumed that the process is operating at all times the oxidizer is operating. For example: fresh air is passed through a secondary heat exchanger in an oxidizer exhaust stack and supplied back as base loading for the oven zones the oxidizer is treating. Every time the oxidizer is on the oven zones require heat, so this heat recovery project pays back all year long. If the same fresh air was supplied back to the plant as tempered makeup air, this may only provide payback during the heating season.

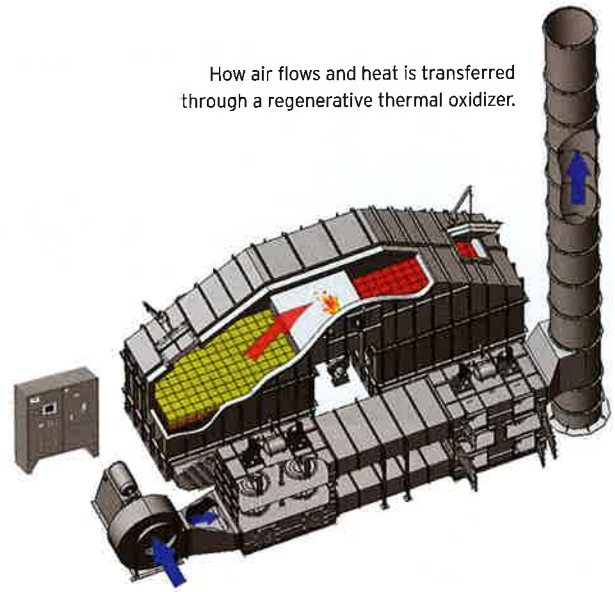
Following this logic, in the past comfort heat applications may have been ignored. But considering today's unstable and rising fuel costs, coupled with the energy recovery grants available to facilities, these projects deserve attention.

10. PROPERLY MAINTAIN EXISTING SYSTEMS.

Finally, no matter how well an overall system is designed, it cannot continue to operate at a high efficiency level without proper maintenance. A handful of small inefficiencies in system operation can lead to large operating cost bill over the course of a year. At today's energy prices, regular calibration of feedback instruments and control loops can pay for itself many times over.

All too often, production facilities take the "no news is good news" approach to their air pollution control equipment when they really should be chasing the benefits of "Company Stays Green and Saves Green" headlines instead.

How air flows and heat is transferred through a regenerative thermal oxidizer.



Oxidizer with secondary heat recovery system.

AIR TO FLUID

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 No. 2. However, unless the heated fluid is used directly back in the process that the oxidizer is connected to, Challenge No. 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.

For typical flexographic printing applications, fluid circulation between a coil in the oxidizer exhaust stack and a coil in the supply air ductwork for press between color and overhead tunnel dryers is a setup that deserves consideration.

AIR TO STEAM

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 multipass configurations. Oxidizers in the flexographic printing industry rarely have the solvent loading—and corresponding exhaust stack temperatures—necessary 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.

For the flexographic printing industry, 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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