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Cool Down Your Fuel Bills

Get energy costs under control by optimizing your process heating systems

Ven V. Venkatesan, Energy Columnist

NEARLY ONE third of commercial energy used in plants goes to process heating. More efficient use of process heat can result in substantial fuel savings and cost reductions. Completing a detailed analysis of heating needs can help identify the following four critical items to guide optimization:

1. Useful heat needed for processing steps or process stages or by the product;
2. Heat losses associated with the processes that are unavoidable and unrecoverable;
3. Heat losses that can be controlled, reduced or avoided; and
4. Heat losses that can be recovered economically.

Industrial process heating is classified in three categories — high-, medium- and low-temperature systems. Processes such as cracking of hydrocarbons and synthesis of ammonia require high-temperature heating, while fractionation of oils and most reaction vessels use medium-temperature heating. All drying, evaporation and sterilization processes require low-temperature heating. Cost reduction and optimization opportunities exist in all three categories.

Process heating is carried out either through direct-fired heaters or through heating mediums like steam and thermal oil. For both methods, fuel is burnt in a furnace or boiler. Hence, efficient combustion is the first step to reducing costs. Operator awareness and the use of certain instrumentation at the furnace or boiler can help ensure efficient fuel combustion. Measuring stack gas oxygen and temperature is essential to improve combustion efficiency. If the furnace or boiler is small, use a portable flue gas analyzer to help track heat losses.

For instance, at a graphite electrode manufacturing plant using petroleum coke as the raw material, a carbon anode baking furnace reduced fuel oil usage by 10% when its stack gas conditions were continuously monitored and the air/fuel ratio adjusted. Because the baking process involved releasing hydrocarbon volatiles, recycling the fluegas alone with combustion air supply was enough to cut fuel supply by ensuring complete combustion.

Measuring fluegas oxygen and temperature might suffice to ensure efficient combustion, but when the stack temperature is higher than 280°F

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it's worth looking for additional heat recovery. The most-common heat recovery retrofits to furnaces and boilers are economizers, air-preheaters and additional convection coils. In some plants, additional hot water generation or process stream preheating options may be more attractive than the above retrofits.

High-temperature process heaters usually come with good instrumentation and waste heat recovery features. However, if instruments aren't working properly or not calibrated periodically, the operator is forced to run the heater far from optimal combustion conditions. Also, maintaining the fireside heat transfer surfaces is essential to sustain energy efficiency, especially when liquid and solid fuels are fired. In a petroleum refinery where vacuum processing units fired heavy residue and fuel oil, we added soot blowers to its air preheaters. The soot blowers ensured at least 1% average improvement in the heaters' combustion efficiency and avoided air preheater bypass operation for the last three to four months of operation (end-of-run condition) prior to the processing unit's routine turnaround.

Because most chemical plants take raw materials and deliver their final products at ambient temperature, inefficient process heating can lead to excess cooling. Analyzing all the process streams routed through trim-coolers and air-fin coolers could identify the heat recovery potential. If suitable incoming streams (heat sink) heated either by steam or process heaters could recover some of the heat rejected by the cooling streams, both fuel and cooling tower use would decrease, saving energy and pumping costs. Where suitable heat sinks are not available, installing vapor absorption chillers or generating power using organic Rankine cycle could allow you to take advantage of the low-temperature waste heat sources.

Many pharmaceutical and organic fine chemicals plants require areas of controlled humidity that rely on air handling units with both dehumidification and reheat coils. In such plants, the HVAC systems need considerable heating energy after the dehumidification coils. Installing heat pipes or heat recycling through a glycol system could save heat energy as well as chiller load. A heat pipe is a heat transfer device with heat flux rates over 10 times that of conventional heat exchangers. Generally, heat pipes don't have any moving parts and only require clean heat transfer surfaces. Where hot air drying is practiced, routing the hot air discharged from air compressor cooler fans to the dryer fan suction could save energy and optimize the process heating load. ●

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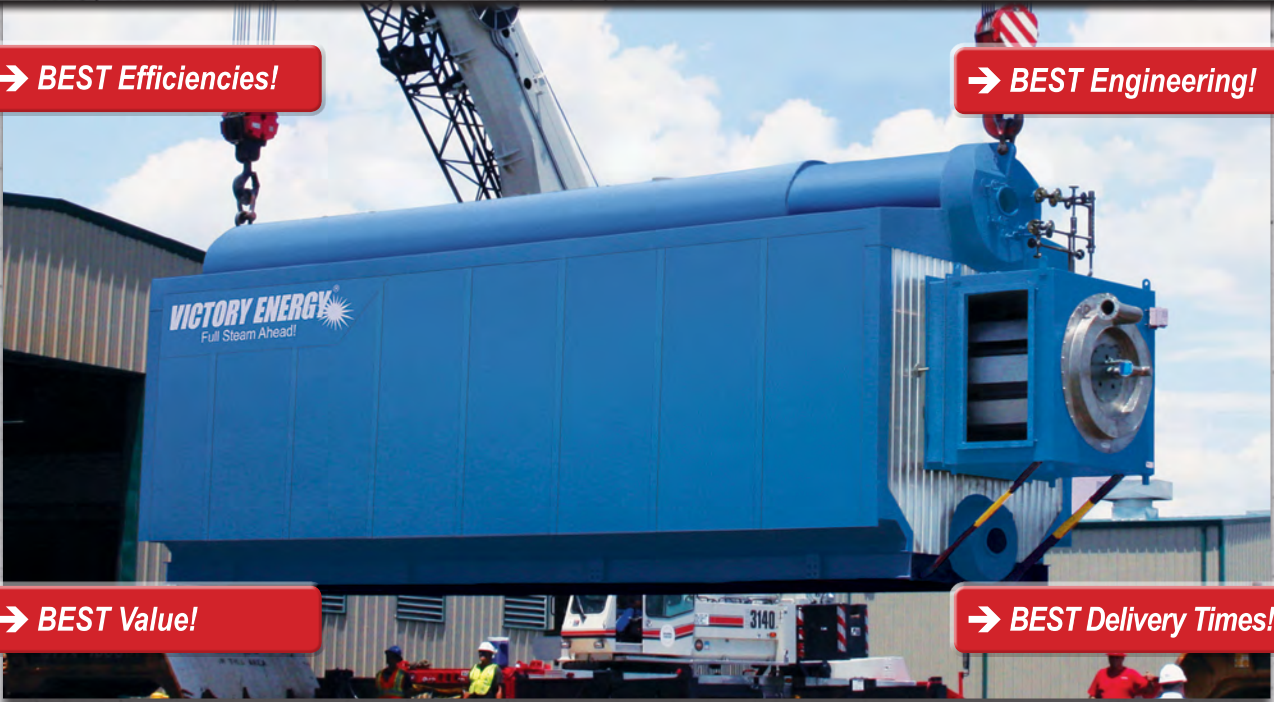

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Simulation Saves Energy

Modeling identifies opportunities to reduce energy use

By Seán Ottewell, Editor at Large

OPERATING COMPANIES worldwide are relying on process simulation and modeling to improve plant energy efficiency. "There's definitely no doubt that energy efficiency is a huge area of focus right now. There are different reasons for this and the reasons can differ according to the region of the world you are in. But wherever you are, it is a high priority," confirms Ron Beck, productivity director for the engineering product line of AspenTech, Burlington, Mass.

At BASF, Ludwigshafen, Germany, modeling sits alongside experimentation as an essential part of the company's R&D philosophy. "Most of our researchers complement their experimental work by modeling the underlying physico-chemical processes and simulating their experiments using appropriate commercial and/or in-house computational tools. The goal is to increase process knowledge about the fundamental reactions and to use the results, for example, for an optimization or for optimal experiment design," says a BASF spokesman (Figure 1). With R&D efforts focused on the development of sustainable processes and products, minimizing energy demand is central to much of the modeling work.

"There are usually many possible options to improve energy efficiency. For example, increasing yield by using an improved catalyst will, in general, reduce the effort of recycling unconverted educts [reactants] or separating unwanted byproducts. Another possibility is to optimize and compare different process concepts in terms of energy efficiency. For a sustainable process development, the whole process has always to be considered," the spokesman notes.

MULTIFACETED APPROACH

Figure 1. BASF researchers complement their experimental work by modeling underlying physico-chemical processes. *Source: BASF.*

New or improved catalysts and polymer processes are two of the key areas of interest to the company; one of the commercial tools BASF uses is gPROMS Advanced Process Modeling from Process Systems Enterprise, London, U.K., a package specially designed to handle the difficult requirements of batch and semi-batch systems.

In one project, BASF used the software to build a high-fidelity detailed kinetic model of its batch expanded polystyrene process and then applied dynamic optimization techniques. The first-principles gPROMS batch

process model included detailed reaction kinetics, with parameters estimated from experimental data. It modeled heat and material balances, geometry details, transport and thermodynamic properties, and plant operating procedures. BASF then used dynamic optimization to minimize batch time, taking into account process constraints. The company identified a 30% reduction in batch time, which, of course, provides energy savings.

SPOTTING POTENTIAL SAVINGS

AspenTech starts by running simple profitability models to discover energy-saving opportunities. Steady-state and dynamic modeling assess the demand side and Aspen Utilities Planner evaluates the supply side.

"These can be models of either facilities or operations, and we typically find that in a large plant you can improve energy efficiency by 10–25%," Beck says.

However, one challenge with turning these opportunities into reality is the lack of in-house skills on modeling software — a legacy of management consultancies convincing chemical operating companies to outsource their engineering competencies, he notes.

For success, the models must be up-to-date and thoroughly understood by users. For this reason, AspenTech has set up a small consulting group to help operating companies. This group typically identifies at a large site 50–100 projects to improve energy efficiency, ranging from no-investment supply-side initiatives to ones requiring large capital investment.

A recent project at LG Chem's Yeosu plant in South Korea illustrates the value of simulation technology. Here, management was charged with exploring reconfigurations to increase 1,3 butadiene production capacity and improve energy performance. Adding to the challenge, any process revamps couldn't involve major upgrades or replacements.

LG Chem used Aspen Plus to develop detailed simulation models of the plant and employed the integrated Aspen Exchanger Design and Rating models to assess existing process equipment to determine available spare capacity.

Using the simulation models, LG Chem successfully developed methods to debottleneck both the extractive distillation column and fractionator — resulting in spare production capacity increases of 13% and 17%, respectively. Overall, the plant could achieve 15% greater capacity with only a small additional capital investment.

Similarly, the detailed heat integration of process streams produced by Aspen Energy Analyzer showed that rearranging the path of a solvent stream loop would enable the energy in the loop to be recovered and used for heating purposes elsewhere in the process. Moreover, this energy recovery decreased the final temperature of the stream before it went to a final cooler to 51°C from 70°C, which ultimately reduced the required quantity of cold utility in the cooler. In addition, identification of a new use for steam in the process eliminated excessive steam venting.

The company now is utilizing AspenTech products to simulate, monitor and optimize plant performance at other sites.

AkzoNobel's Deventer site in the Netherlands relies on Aspen Plus for modeling unit operations and plants. "This tool provides us with a broad application in both R&D and process engineering, as it combines simulation of unit operations, total plant simulation, process dynamics, and heat integration studies — combined with solid physical property sets to do trustful calculations," says Jacky Ooninckx, leader of the process technology expert capability group at Deventer.

Modeling is important as the company strives to meet its strategic targets to improve energy efficiency and reduce carbon dioxide emissions, such as a goal of cutting the cradle-to-grave carbon footprint per ton of sales by 25–30% from 2012 to 2020.

"To achieve this target, we use the best available know-how; this sometimes means ensuring existing best practices are in place but for more distinctive, complicated processes we use modeling software. We see modeling as a strong enabler to achieve our broader energy efficiency improvement target. For example, for new breakthrough processes that replace existing processes, we aim for a 30–40% energy reduction in combination with reduced capital investments. For the optimization of existing processes, we focus on the processes with high energy consumption," she says.

DME INITIATIVE

A good example of this in action is a study of novel manufacturing routes for dimethyl ether (DME) jointly carried out by AkzoNobel's Deventer R&D department; the Ecole Nationale Supérieure de Chimie de Mulhouse, Mulhouse, France; and the department of chemical engineering at the University Politehnica of Bucharest, Romania.

The increasing use of DME as a clean fuel and green aerosol propellant is spurring efforts to achieve higher production rates at lower production costs.

Traditionally, high purity DME is synthesized by dehydration of methanol produced from syngas in a conventional gas-phase process that involves a catalytic fixed-bed reactor followed by two distillation columns. The main problems with this process are the high investment costs for units such as the reactor, columns and heat exchangers, the large overall plant footprint they require, and their heavy energy use.

To tackle these problems, the three organizations investigated novel process-intensification alternatives based on a dividing-wall column (DWC) or reactive distillation (RD). These promise a smaller footprint and significant savings in both investment and operating costs. These process-intensification alternatives were rigorously simulated in Aspen Plus.

BETTER ROUTE TO DME

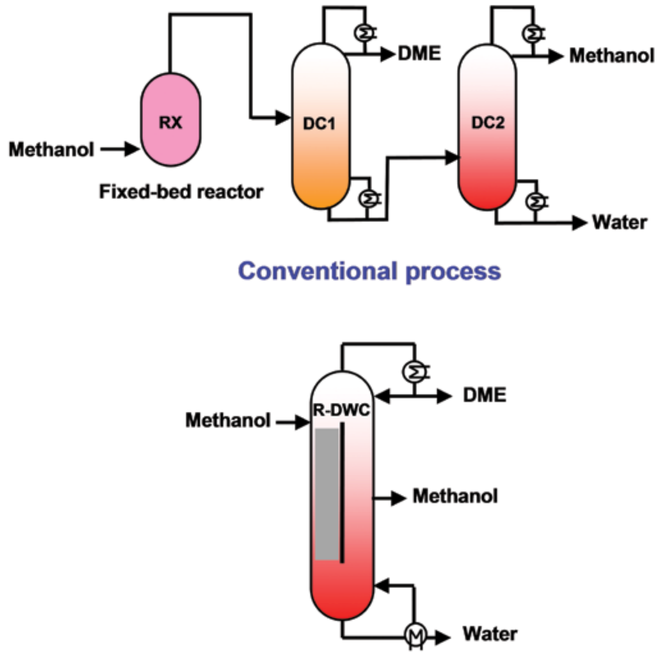

Figure 2. The R-DWC process provides energy savings of up to 60% and significantly lower investment costs compared to the existing process. *Source: AkzoNobel.*

The study showed that both DWC and RD technology can serve effectively to improve existing and new DME processes. For example, a single-step separation based on DWC can replace the conventional DME purification and methanol recovery distillation sequence. The proposed DWC alternative reduces energy requirements by 28% and equipment costs by 20% compared to the conventional direct sequence of two distillation columns.

Moreover, the study found RD to be a feasible process-intensification alternative to produce DME by methanol dehydration using solid acid catalysts.

"The innovative reactive DWC (R-DWC) process [Figure 2] resulted in energy savings of up to

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60% and significantly lower investment costs compared to the existing process," notes Oonincx.

Consequently, she says, the R-DWC process can be considered as a serious candidate for DME production in new as well as revamped industrial plants. AkzoNobel has no immediate plans to use the new process, but the technology definitely offers an opportunity for future investment, she adds.

ENERGY EMPHASIS

Schneider Electric, which gained a portfolio of simulation products with its recent acquisition of Invensys, also is finding energy efficiency to be a driving force in business today: "Energy efficiency is a common thread across all of the industry verticals and among the different processes within each vertical. Profit margins are very tight and energy is a large portion of any plant's operating cost. Therefore, efficient usage of energy is key to remaining competitive in the global market," says Joseph McMullen, the company's Cohasset, Mass.-based product marketing manager.

Two simulation products in particular focus on energy efficiency: ROMeo process optimization software, which enhances plant performance by minimizing utility use, and SimSci APC, which allows operators tighter control of product specification and thus the opportunity to increase throughput and reduce energy use. This year, a completely revamped version of SimSci APC came out. The company also is developing its new SimCentral platform, which combines steady-state and dynamic modeling and optimization into a single user interface and delivers simulators with ergonomics and usability akin to those of today's smartphones and tablets.

"… The following units/processes are particularly energy intensive and are of specific interest to Schneider Electric customers: distillation columns; boilers; heat exchanger networks; and pump and compressor trains," he adds.

McMullen cites a project at the Star Petroleum Refining (SPR) refinery in Rayong, Thailand, as a good illustration of what process modeling can achieve.

SPR approached Schneider with a challenging list of requirements, including: diagnosing performance bottlenecks; improving decision-making capabilities; making identification of faulty instrumentation easier; monitoring, optimizing or enhancing plant yields and profitability; and automating optimization and reporting.

Using SimSci ROMeo Online Performance Suite modeling software, which is designed to show what currently is happening at the plant so users can make appropriate and timely business decisions, SPR was able to increase throughput, reduce energy usage and improve regulatory compliance at the refinery.

The modeling also revealed an interesting problem: "We optimized the plant based on a rigorous model. Normally, real-time operation will drop the pressure for improved separation but we found in one column that it increased the pressure. Then we checked and realized that this column was already flooded," notes SPR process engineer Bussarin Sapsawaipol. ●

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Increase Sustainability with Thermal Oxidation

The right emission control system can help meet compliance and reduce energy costs

By Jon Hommes, Dürr Systems, Inc.

INSTALLING NEW production processes, or upgrading and expanding existing lines today requires a review of the expected emissions. The right emission control system for Hazardous Air Pollutants (HAPs) and Volatile Organic Compounds (VOCs) can help efficiently and economically dispose of these environmentally hazardous wastes. Over the last 20 years, as emission limits have tightened and authorities have taken a more "holistic", plant-wide approach to air permits, the trend in CPI has been to collect multiple waste streams plant-wide for control in a single thermal oxidation system, despite the required additional source ducting and piping. This trend has been driven by an array of factors, including:

- Rising fossil fuel prices
- Tightening of emission limits for VOCs, HAPs, NO_x and CO
- Goals for the reduction of a plant's carbon footprint
- Increasing cost for disposal of organic waste liquids
- Minimizing the number of control systems to be maintained and points of emission monitoring and testing.

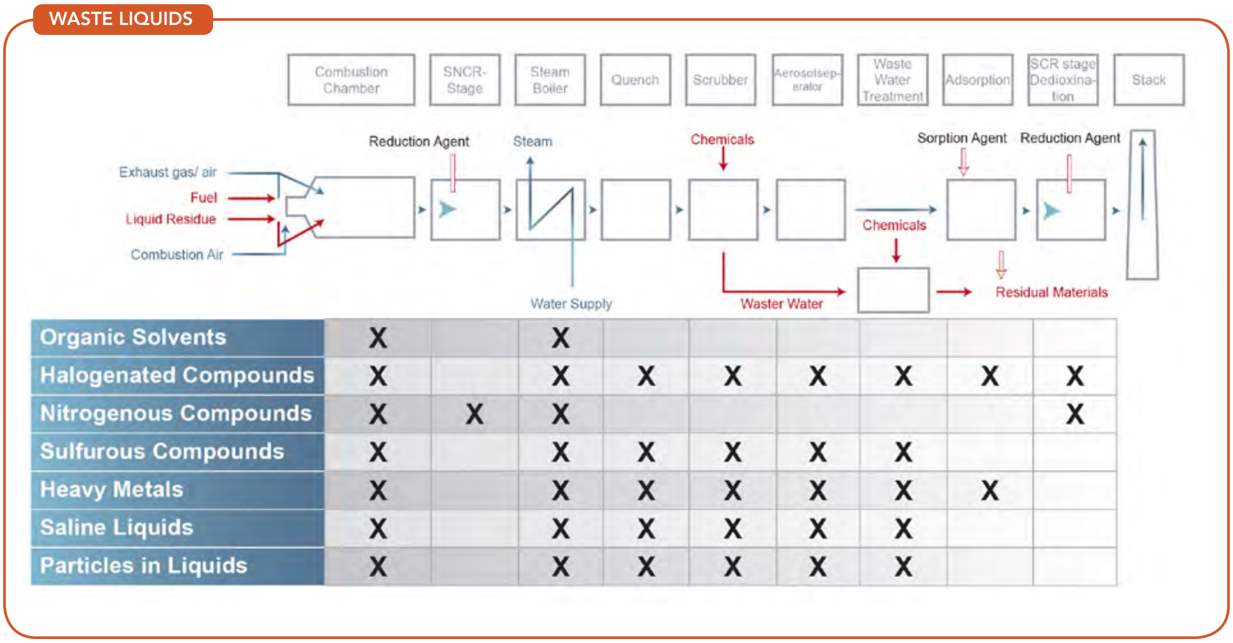
All of these are key for companies increasingly committed to energy efficient, sustainable production. The benefits of a single, centralized thermal oxidation system can be best illustrated with a case study of a plant that recently added emission controls to many existing production processes.

Two types of thermal oxidizers are most frequently applied in the chemical process industry: Regenerative thermal oxidizers (RTOs) and direct fired thermal oxidizers (DFTOs), also known as afterburners. RTOs offer high thermal efficiency and very low fuel requirements for plants that generate dilute air streams contaminated with low concentrations of VOCs and HAPs. However, a DFTO is the best choice when:

- Production processes demand steam energy
- Required destruction efficiency is greater than 99.5%
- Highly caloric off gases with low oxygen must be handled
- High loading of halogenated or sulfurous compounds are expected (acid generators)
- Destruction of waste liquids is needed.

Many excellent guides and articles address the selection process between different types of oxidizers. This paper focuses on the DFTO exclusively.

A company manufacturing organic intermediates for the pharmaceutical and fertilizers industry decided to install a DFTO system to handle all liquid and gaseous waste streams from their many small to mid-size process reactors and storage tank vents. The DFTO is designed to handle a wide range of wastes including organic compounds containing halogens, sulfur and nitrogen.



	Combustion Chamber	SNCR-Stage	Steam Boiler	Quench	Scrubber	Aerosolseparator	Waste Water Treatment	Adsorption	SCR stage Dedioxination	Stack
Organic Solvents	X		X							
Halogenated Compounds	X		X	X	X	X	X	X	X	
Nitrogenous Compounds	X	X	X						X	
Sulfurous Compounds	X		X	X	X	X	X			
Heavy Metals	X		X	X	X	X	X	X		
Saline Liquids	X		X	X	X	X	X			
Particles in Liquids	X		X	X	X	X	X			

Table 1. Components in a modular direct-fired thermal oxidizer system can be selected based upon the waste stream contaminants.

The system consists of the required liquid pipe trains and storage tanks, process off gas pipe trains including explosion protection equipment, oxidation chamber, fire tube waste heat steam boiler, economizer, scrubber for acid gas removal, selective catalytic reduction (SCR) system for NO_x removal, an induced draft system fan and stack including emission monitoring system.

WASTE LIQUIDS AND OFF GAS SOURCES

The liquid wastes are accumulated from a number of sources across the plant and collected in a storage tank. The small storage tank was sized to accommodate the effluents from periodic tank cleaning processes. At this particular plant, all of the waste liquids are purely organic and have a consistent high caloric value which allows them to be fired directly through the thermal oxidizer's dual fuel burner system. After start-up, these systems can run entirely on the waste liquid fuel. Although not needed at this facility, a second system is sometimes used to collect liquid wastes with low or inconsistent caloric value or high water content. These wastes are atomized into the oxidation chamber adjacent to the burner through secondary injection lances.

In addition to the liquid wastes, a total of six process off gas streams are controlled by the thermal oxidizer system. Each off gas is handled by an independent control train and injected separately into the oxidation chamber (Figure 1). One stream is drawn from nitrogen-blanketed storage tanks using a blower, designed to handle potentially explosive gases, to maintain a slight negative pressure. The remaining streams come from process reactors under pressure and can be routed to the oxidation chamber without blowers. The volume of off gas and VOC caloric content of each stream is highly variable, especially for several batch reactors and for the storage tanks which

vent the most VOC during filling operations. These large variations of flow and loading lead to the first major benefit of a single, centralized DFTO system.

During preliminary engineering of the emission controls, consideration was given to multiple, smaller DFTO systems installed local to each process gas source. This arrangement has the advantage of minimizing the cost of the off gas collection system duct work and keeping each process fully independent. However, as the off gas sources were analyzed, it was determined that each DFTO would need to be designed for the peak off gas volume and caloric content required for that source under startup or upset conditions resulting in large oxidizer size. Furthermore, the much lower "normal" off gas flow is then difficult to handle efficiently in the large oxidizer. Designing for this high turndown is especially challenging for the several batch reactor processes.

Bringing all of these off gas streams to a single, centralized DFTO makes it possible to design for the peak VOC loading on several, but not necessarily all, processes simultaneously, reducing overall system size and capital cost, while improving turndown and DFTO efficiency under normal operation. The availability of the organic waste liquids to the centralized DFTO also has a stabilizing effect on operation as the storage tank allows injection of liquids to cease during periods of maximum off gas loading (while collection in the tank continues) and to resume providing supplemental heat during periods of low off gas loading. The overall impact of the centralized DFTO is a significant reduction in natural gas (or other supplemental fuel) usage and thus the plant's utility budget. By minimizing supplemental fuel usage, a corresponding reduction in the plant's carbon footprint is achieved. Whether greenhouse gas (GHG) emission reductions are mandated, as they are in Europe, or whether they are voluntary, this is an increasingly important consideration for many companies.

PROCESS STEAM

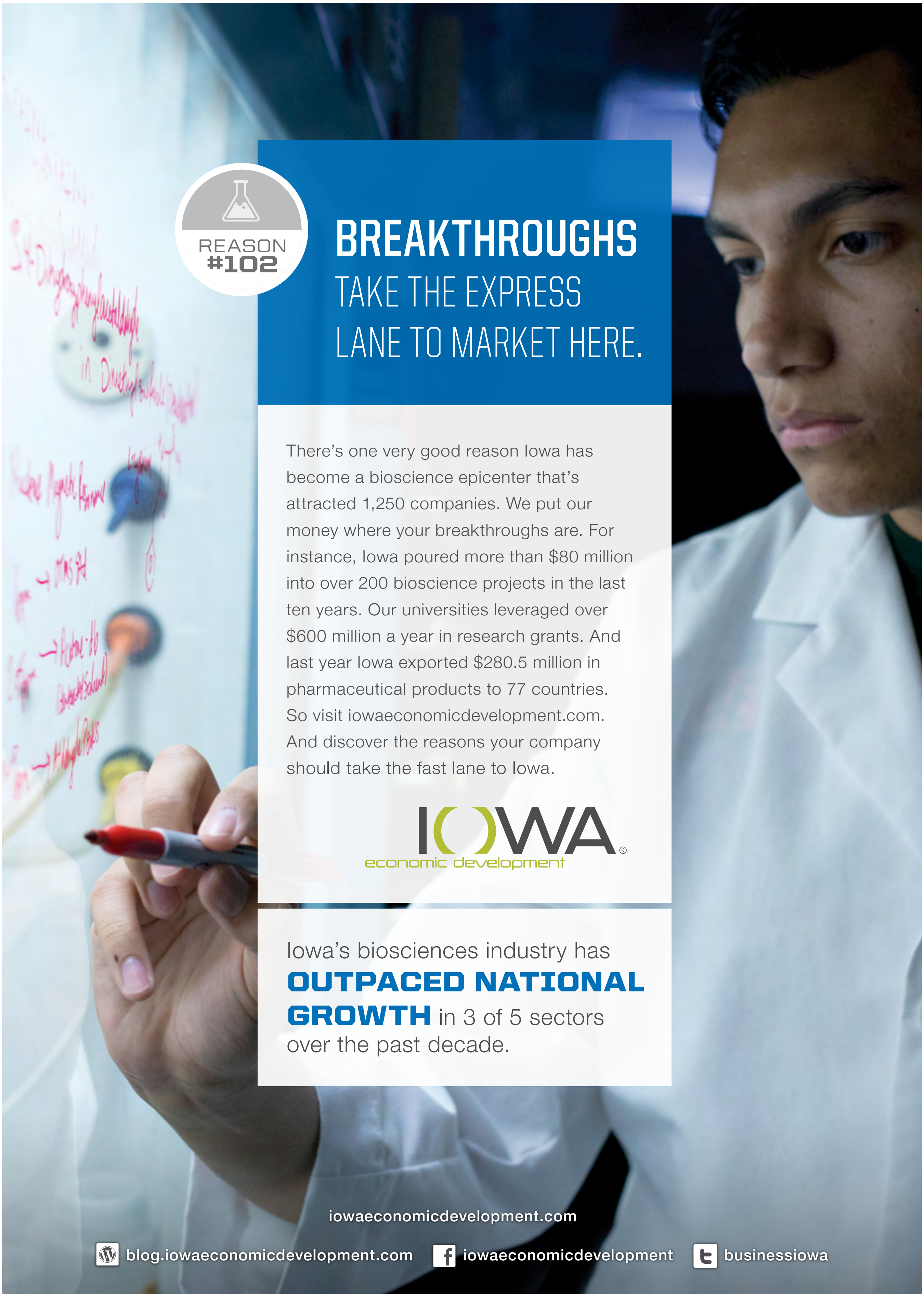
Many chemical plants generate and use steam on site for various process and heating requirements. The flue gas from a DFTO oxidation chamber is a source of high quality waste heat at 1,600 to 2,200°F that's easily convertible to saturated or superheated steam to supplement the facility's gas, oil or coal-fired boilers and reduce their fossil fuel usage. To do this, the refractory-lined oxidation chamber of the DFTO is simply transitioned to mate up to the boiler inlet. Numerous considerations affect the boiler design and selection including:

- The desired steam pressure
- Requirement for superheated steam
- Presence of halogens or sulfur that generate acid gases
- The presence of silicon, phosphorous, metals and other dust-forming compounds.

In this case, the system includes a fire tube waste heat boiler to generate medium pressure-saturated steam, followed by a super-heater and an economizer

CONTROL TRAIN

Figure 1. The thermal oxidizer system controls six process off gas streams, each handled by multiple skid-mounted off gas piping control trains.



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for preheat of boiler feed water (Figure 2). High concentrations of hydrochloric and hydrobromic acid in the oxidizer flue gas result in a design that limits the heat recovery in the economizer to keep the outlet temperature above acid dew point under all operating scenarios. In addition, due to the distance from the facility's main boiler house, the system included a boiler feed water tank with redundant pumps and a deaerator for returning condensate.

Once again, a single, centralized DFTO when compared to multiple local units is significantly more beneficial. To achieve the same steam production, the capital cost is much lower for a single waste heat boiler system with high utilization than for multiple boilers connected to localized DFTOs. Waste heat boilers for localized DFTOs must be designed and sized for the peak flow and heat load from each oxidizer but will normally operate at just a fraction of that design capacity. It's obvious the boilers themselves are capital intensive, but a single centralized waste heat boiler also minimizes installation costs associated with piping for boiler feed water, steam supply and blow down. The number of boiler startup and shutdown cycles is reduced, increasing the longevity of the equipment, and minimizing the time demands on boiler operators. The net effect is an improvement in the pay back that justifies waste heat recovery as steam. By choosing to recover waste heat, the plant further reduced their overall fossil fuel consumption and carbon footprint.

ACID SCRUBBER

After exiting the economizer, the flue gas is directed to a quench and acid scrubber (Figure 3). The quench cools and saturates the flue gas stream with water spray nozzles and flooded walls. The quench discharges the flue gas and water into the base of a vertical flow, packed column scrubber where HCl, Cl_2, HBr, Br_2, HF and SO_2 are absorbed and neutralized with NaOH solution. The scrubber removes over 99% of these contaminants; however,

FIRE TUBE STYLE BOILER

Figure 2. The system includes a fire tube, single pass waste heat boiler to generate medium pressure saturated steam.

QUENCH AND ACID SCRUBBER

Figure 3. After exiting the economizer, the flue gas is directed to a quench and acid scrubber, much like this one.

taller columns and multiple stages can be used to achieve greater than 99.9% removal. This facility includes 50% NaOH as a utility and feeds a day-tank from which redundant pumps dose it into the recirculated scrubber wash water to control the pH.

The waste liquid and three of the six off gas streams currently contain halogens requiring scrubbing downstream of the oxidizer with the vast majority coming from methylene chloride in the waste liquid. Prior to installation of the new DFTO system, these halogenated liquids were transferred to tanker trucks and disposed of offsite at significant expense ($0.20 to $0.50 per gallon). As with the waste heat boiler, adding a scrubber to the single centralized DFTO system has a significant capital cost advantage over scrubbing on multiple smaller units.

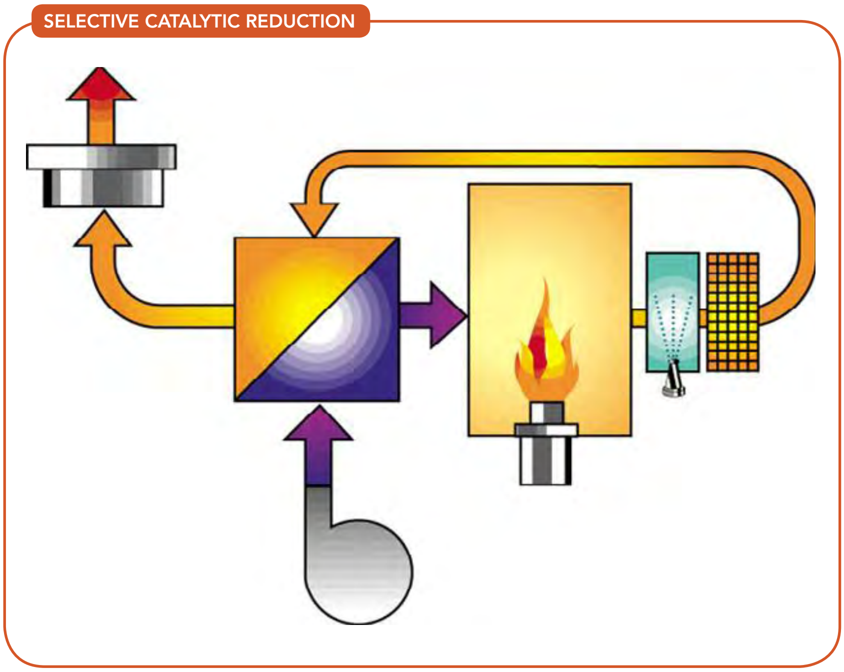

Figure 4. This diagram highlights the process flue gas takes in a selective catalytic reduction (SCR) system for NO_x control.

SELECTIVE CATALYTIC REDUCTION

In recent years, regulatory authorities have focused more and more on reducing NO_x emissions from combustion processes, and oxidizers are no exception. In the case of a boiler or process heater, the majority of NO_x emissions form as "thermal NO_x" from N_2 in the flame front of gas and oil-fired burners. In the case under study here, the vast majority of the expected NO_x comes from the oxidation of amines and other VOCs containing nitrogen in the plants off gases and waste liquids. Several alternative approaches for NO_x reduction were evaluated, including non-catalytic reduction in the oxidation chamber, before SCR was selected based on the high conversion efficiency required to meet the very low emission targets. SCR also offers the advantage that the catalyst used to reduce NO_x also favors the destruction of trace dioxins and furans formed during the oxidation of chlorinated compounds.

Because the flue gas exiting the scrubber is saturated and contains trace acids, the SCR system begins with a pre-heater module to raise the flue gas temperature above its dew point by mixing a small volume of hot air recirculated from downstream. This module is constructed in alloys resistant to chloride corrosion. The DFTO system's redundant draft fans follow the pre-heater and are operated on variable frequency drives to maintain a pressure in the oxidation chamber slightly negative to atmosphere. The flue gas then enters a recuperative heat exchanger that recovers heat from the SCR outlet (the reduction process is exothermic) to

bring the flue gas up to reduction temperature. Finally, an aqueous ammonia reducing agent is sprayed into stream, metered precisely to match the measured incoming NO$_x$, before the flue gas enters the catalyst beds where greater than 95% of the NO$_x$ is converted to N_2 and H_2O. The flue gas then passes through the other side of the heat exchanger on its way to the system stack where it exhausts to atmosphere at about 200°F. Continuous emissions monitoring equipment in the stack, as required by the plant's air permit, tracks exhaust concentrations of total hydrocarbon, hydrochloric acid and NO$_x$ to confirm proper operation of the system.

COMPLETE DFTO SYSTEM VIEW

Figure 5. This DFTO system helped reduce fossil fuel use in boilers and eliminate offsite waste disposal costs.

The low NOx emission required was another factor in the selection of a single, centralized DFTO system over a multiple system. The SCR system is capital intensive, including expensive precious metal catalyst, heat exchanger, and flue gas analyzers and strongly favored installing just one.

MEETING COMPLIANCE

For this manufacturer of organic chemicals operating many smaller processes, a single centralized thermal oxidizer system was the most cost-effective path to expand production while meeting new emission controls requirements. The resulting DFTO system benefited them by:

- Maximizing the destruction efficiency of VOCs and HAPs
- Reducing NO$_x$ emissions well below their permit limits
- Eliminating operating expenses for offsite waste liquid disposal
- Reducing plant-wide fossil fuel demand by using the caloric value of their wastes to generate steam
- Minimizing maintenance costs by installing just one system.

Taken all together, the plant's annual savings by reducing fossil fuel use in their boilers and eliminating offsite waste disposal costs actually exceed the operating costs of their new emission control system. Over its design life, the DFTO system provides a net pay back to the plant, proving that "being green" does not have to come at the expense of the bottom line. ●

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