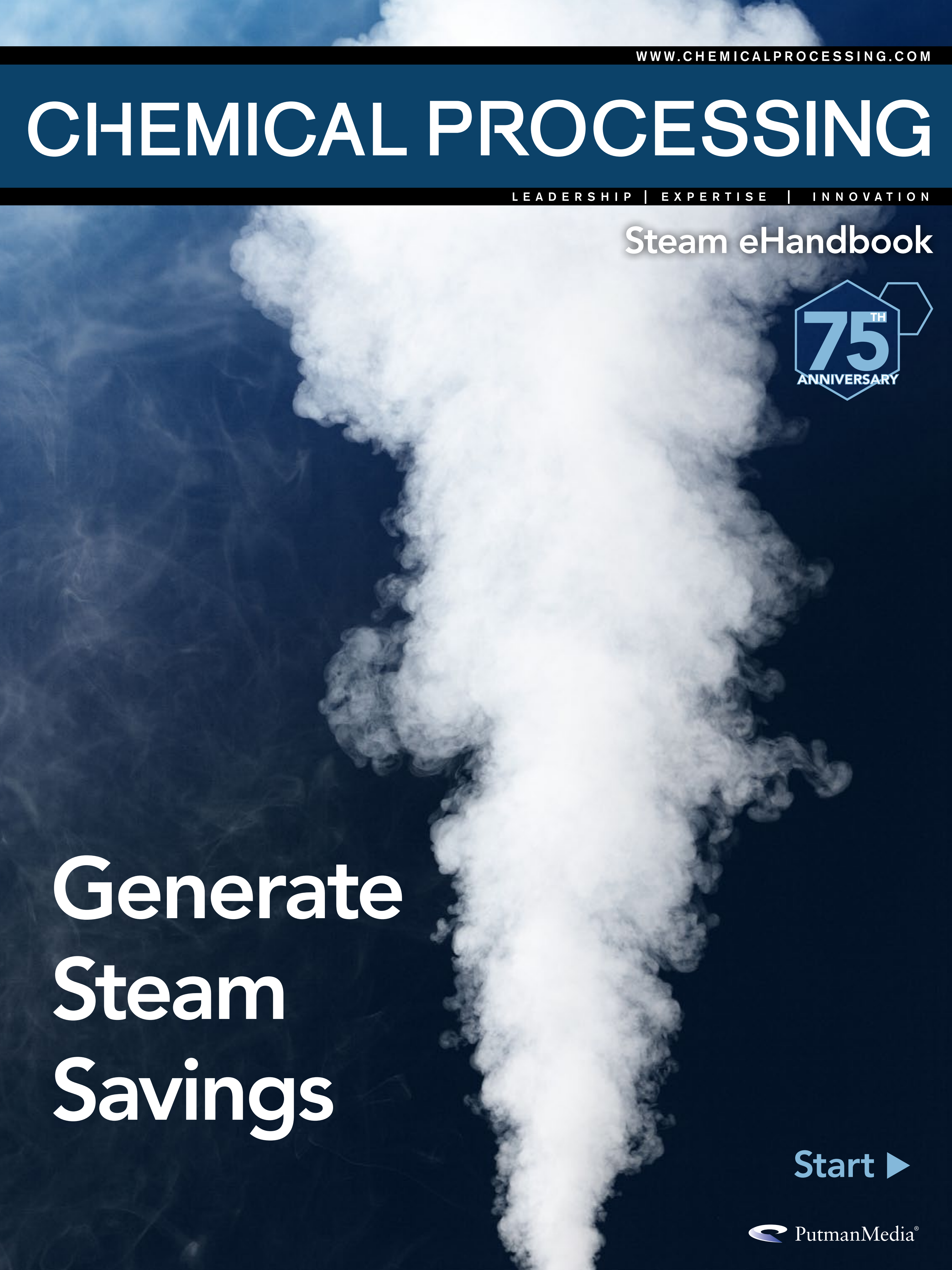

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TDI Plant Pares Steam Consumption

Thinking differently about energy management leads to substantial savings

By Donald Pferdehirt, Bayer MaterialScience

COVERING 1,700 acres along the Cedar Bayou at the Gulf of Mexico and having roughly 1,000 employees, Bayer MaterialScience's Baytown, Texas, plant is the company's largest manufacturing site in North America. The facility, which began operating in 1971, traditionally has been a focal point of the company's global manufacturing strategy.

As part of the Bayer Group's commitment to climate protection, the TDI (toluene diisocyanate) Train team in Baytown, in collaboration with colleagues at the Isocyanates Technology Center (ITC) in Leverkusen, Germany, undertook a major initiative to substantially reduce the train's energy consumption by optimizing the operation of equipment.

The team operates the Baytown units that produce TDI, a key raw material for polyurethane, via a three-step energy-intensive process: 1) converting toluene to di-nitrotoluene (DNT); 2) transforming DNT to toluene diamine (TDA); and 3) producing TDI from TDA. Each step involves exothermic reactions and uses distillation to purify solvents and products.

Most TDI manufacturing units at Baytown were built between 1998 and 2000. Steam supply for these units primarily comes from a high-pressure steam network utilized throughout the plant. Additionally, the TDI units can import or export steam via an intermediate-pressure steam network. While several energy-integration measures originally were built into the train, changes at the site, such as adding or shutting down other units, reduced the efficiency of these measures.

Bayer MaterialScience sees great value in sharing information globally. So, personnel from the ITC and team members from operating units worldwide participate in monthly teleconferences and annual face-to-face meetings to discuss issues related to operations at their respective sites. These discussions generated ideas for several energy-saving projects at Baytown that would:

- reduce overall steam consumption;
- allow use of lower-value steam; and
- enable recovery of waste steam.

THREE-STEP APPROACH

To spur people to think differently about the issues, the team took what we call the Energy Management System approach. It has three steps. The first consists of an energy efficiency check and improvement plan aimed at identifying potential savings, categorizing necessary measures and then implementing them. The second step, referred to as Energy Loss Cascade & Performance Indicators, involves visualizing energy losses, reporting the losses and the reasons for them, and setting targets for improvement. The third step, dubbed Online Monitoring & Daily Energy Protocol, comprises visualizing deviations from full-rate operation, optimizing energy use and creating awareness of the steps taken.

Following this approach, the team first studied individual units to identify potential opportunities for energy efficiency improvements. In doing so, it sought

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to determine if existing measures were fully utilized. If they weren't, the team determined the root cause and evaluated possible modifications. It also studied whether there were additional uses for reaction heat, and reviewed distillation efficiency and the solvents used with an eye toward seeking more-energy-efficient choices.

Furthermore, the team assessed the interactions between the TDI units and other areas of the plant. This was done to:

- determine energy needs and potential to supply across the entire site (for example, utilize the heat of the reactions);
- compare total volumes of steam sources of all pressures available for potential use in other units; and
- develop means to modify existing steam supplies to meet needs of units.

As part of this effort, the TDI energy officer monitored energy usage daily and made modifications to optimize unit conditions. In addition, for immediate optimization, operators got access to online models that were developed to compare actual to theoretical best usage.

Based on its findings, the team implemented several TDI Train energy improvement projects.

For example, one effort involved using process simulation tools to evaluate different heat-integration configurations, leading to greater energy efficiency.

The team also conducted cooling-tower load studies. The findings led to consolidating two cooling towers into a single operation, providing additional opportunities for increased efficiency.

Another noteworthy project resulted in installation of an additional steam educator on existing equipment. The original educator only could work at high operating rates; the second educator provided the ability to reduce steam usage across the entire operating rate range.

The site saved 243,000 tons of steam between 2008 and 2010 through these modifications. The reduction in natural gas consumption for steam generation equals the demand of 17,000 American households for a year. Furthermore, the site was able to decrease the amount of steam needed from an outside supplier by approximately 20%.

Besides lowering operating costs, the energy savings projects provide the equivalent of reducing CO_2 emissions by approximately 47,450 tons per year.

Additionally, the site achieved a 50% reduction of the energy intensity in one of the units.

In recognition of its efforts, the Baytown TDI Train team received the American Chemistry Council's Responsible Care Energy Efficiency Exceptional Merit award.

The ITC continues to investigate and develop energy savings measures that are applicable across many sites/units, and teams worldwide continue to gather best practices from other sites for implementation at Baytown. The site has formed the Baytown plant energy community to monitor changes to the overall energy balance and look for additional opportunities to improve.

Further, the Energy Management System approach will be fully implemented by the end of 2013 in most Bayer MaterialScience energy-intensive production facilities (those accounting for 85% of energy consumption). This should lead to additional opportunities for optimizing operations and costs. ●

DONALD PFERDEHIRT formerly was TDI production lead, Bayer MaterialScience LLC, Baytown, Texas, and now is TDI train program manager at the Bayer MaterialScience site in Shanghai, China. E-mail him at Donald.Pferdehirt@bayer.com.

Analyze Steam Trap Selection

A life cycle analysis approach can help reduce maintenance and prolong steam trap life

By Rex Scare, Armstrong Steam & Condensate Group

MORE OFTEN than not, the strategy of selecting the cheaper alternative turns out to be the most expensive decision in the long run. This is true across many industries and among a wide variety of goods and services – including steam traps.

Many organizations that aren't prepared for spikes in energy costs or capital improvement expenses often select the option with the lowest upfront cost which leads to the "pay me now or pay me later" dilemma. Over time it's discovered that these lower-priced alternatives cost much more due to higher failure rates, wasted energy and more intensive maintenance. For some organizations it feels like dumping money down the drain twice — once for the initial purchase price and then again to maintain a poor performing product. The cycle repeats itself again when the failed steam trap is replaced with yet another "inexpensive" model.

To avoid falling into this trap, facility directors and energy mangers should consider a life cycle cost analysis approach.

LIFE CYCLE COST ANALYSIS

Many organizations do not apply the life cycle cost analysis in their decision making process because it's perceived as more complex and takes greater effort. Instead, many companies opt for a simple cost/savings/payback formula:

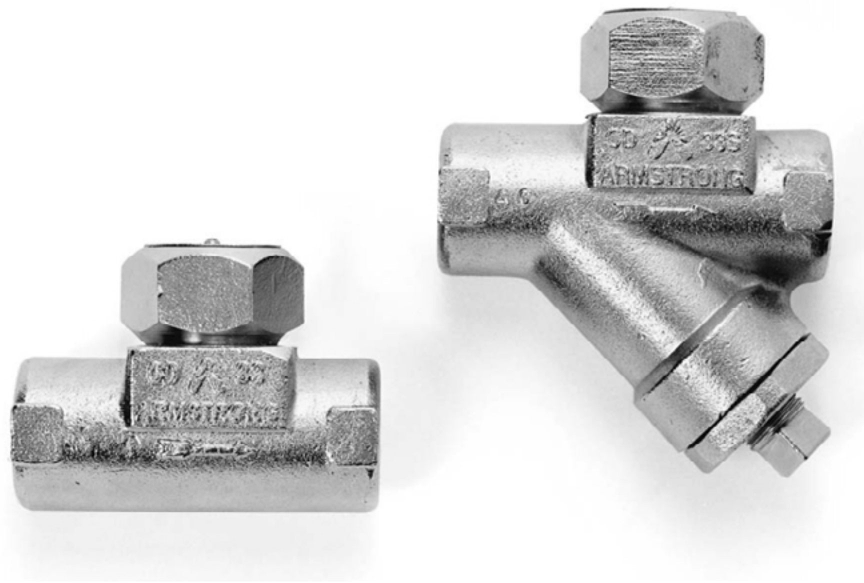
Purchase Price (including installation) + Annual Cost Savings = Payback Timeline

Unfortunately, this traditional formula doesn't reveal underlying and ongoing costs such as the costs of operating and maintaining the equipment, variable energy costs and other calculations such as depreciation of equipment over time.

Using the life cycle cost analysis model, we can evaluate the true costs involved to help lead to making the best decision possible.

Purchase Price (including installation) + Lifetime Maintenance Cost + Lifetime Operating Cost (including energy) = Total Cost

THERMODYNAMIC STEAM TRAP



INVERTED BUCKET STEAM TRAP

Figure 1 illustrates an example of the life cycle cost analysis model applied to two different types of steam traps — a thermodynamic disc (TD) steam trap and an inverted bucket steam trap.

While the TD steam trap offers a more attractive purchase price, the higher maintenance and operating costs due to the shorter expected life span (just 12 months) and more intense energy loss due to operating inefficiencies result in greater costs over its life span.

Even with the higher purchase price of the inverted bucket (IB) steam trap, the investment makes sense because of the longer expected life span (5-year guarantee for an inverted bucket trap) requiring little or no maintenance costs and more efficient operating costs over time.

STUDY REVEALS IMPACT OF LIFE CYCLE COST ANALYSIS

The value of life cycle cost analysis was proven at ICI Engineering plants in Huddersfield and Grangemouth, U.K. During this seven-year in-plant study that included monitoring and testing of various steam traps, ICI Engineering concluded that the life span of the inverted bucket steam trap was between five and seven years operating at 200 psi, while the thermodynamic disc trap was only 12 months (see Table 1).

The ICI Engineering study also revealed steam losses from various traps, indicating higher energy costs to operate the thermodynamic disc trap over the course of its lifetime (see Table 2).

LIFE CYCLE COST ANALYSIS MODEL

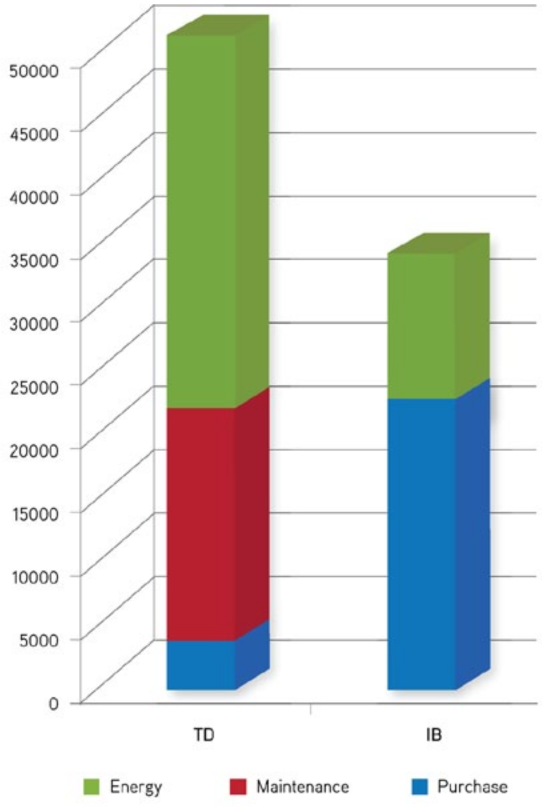


Figure 1. Analysis of a thermodynamic disc (TD) steam trap and an inverted bucket steam trap shows the TD steam trap results in greater costs over its life span.

TABLE 1: AVERAGE SERVICE LIFE FOR DIFFERENT TRAP TYPES

Trap Type	HP 650 psi (45 bar) (g)	IP 200 psi (14 bar) (g)	LP 30 psi (2 bar) (g)
Thermodynamic Disc	10 - 12 months	12 months	5 - 7 years
Float and Thermostatic	—	*1 - 6 months	*9 months - 4 years
Inverted Bucket	18 months	5 - 7 years	12 - 15 years
Balanced Pressure Thermostatic	—	6 months	5 - 7 years
Balanced Thermostatic	*3 - 12 months	2 - 3 years	7 - 10 years

* Model dependent

Table 1: Life cycle analysis reveals the life span of an inverted bucket steam trap is between five and seven years operating at 200 psi, while the thermodynamic disc trap is only 12 months.

TABLE 2: LIVE STEAM LOSSES - KG/HR.

Trap Type	IP	LP
Thermodynamic Disc	1.09	0.84
Inverted Bucket (average of 2 supplier traps)	0.44	0.42
Balanced Pressure Thermostatic	Not Tested	0.1
Balanced Thermostatic	NIL	NIL
Subcooled Bimetallic Thermostatic	NIL	NIL

Table 2: Steam losses from various traps reveal higher energy costs to operate the thermodynamic disc trap over the course of its lifetime.

TABLE 3: LIFE CYCLE COST ANALYSIS COMPARISON

INVERTED BUCKET TYPE		THERMODYNAMIC TYPE
Energy Costs		
0.44kg/hr.	- ICI Steam Loss	1.09kgs/hr.
17,424 kgs/5 years	- 5 Year Steam Loss (New Disc Trap every 12 months. No change of I.B.)	43,164 kgs/5 Year
$219	-$ Steam Loss (Per 0.7 per 1,000 kgs of steam)	$542.67
$219	Total energy costs	$542.67
Maintenance Costs		
None	- Trap Cost (Disc Trap cost $62.86 x 4 changes = 251.44)	$251.44
None	- Labor of Trap Change Cost (1 Hour x 4 changes @ $55.00/hr. (Labor) = ($220)	$220
$0	Total Maintenance Costs	$471.44
Installation Cost		
$339.29	- New Trap Cost	$62.23
Same	- New Installation Labor & Fittings Cost	Same
$339.29	Total Installation Costs	$62.23
$558.35	- TOTAL COST OF ONE TRAP (5 years)	$1,076.34
	- Total $ Cost Difference (5 years)	+$517.99
	- Total $ Cost Difference, Per Month	+$8.63

Footnote: Steam Pressure @ 14kg/cm2

Table 3: Comparison of inverted bucket and thermodynamic disc (TD) traps over a 5-year period illustrates the higher maintenance costs for TD traps.

The economic impact of life cycle cost analysis is illustrated again in Table 3 comparing the inverted bucket trap with a thermodynamic disc trap over a 5-year period. The need for the maintenance department to change disc traps every 12 months results in much higher maintenance costs, while the inverted bucket type trap saves the owner $8.63 per month for each trap.

Utilizing the life cycle cost model demonstrates the true value of the investment because it not only accounts for savings such as fuel used, but also for costs associated with increased productivity resulting from less downtime due to system failures and cost avoidance from having the right equipment for the application.

REX SCARE, PE, is Vice President of Sales, the Americas, for Armstrong Steam & Condensate Group. He is a member of ASHRAE and serves as committee chair of the handbook committee for the steam and hydronic technical group. He can be reached at rexs@armstronginternational.com.

Review Steam Requirements

Use this simple formula to determine the proper steam demand for DSI heaters

By Phil Sutter, Pick Heaters, Inc.

ADVANCED DESIGN direct steam injection (DSI) heaters can be selected rather quickly for water heating service, but they are typically engineered pieces of equipment and a certain level of engineering review is needed when estimating the steam requirement.

First, some information should be collected about the application. Will the heated water be used at a constant flow or variable flow rate? Next, you must gather some data regarding the process conditions (e.g. water flow rate (gpm) [minimum and maximum]; temperature rise (°F hot outlet temp minus °F cold inlet temp); steam pressure; water pressure).

For operational purposes, most advanced DSI heaters require the steam pressure be at least 20 psi (or more) above the water pressure; however, some units have an added requirement that the water pressure must be 50% of the steam pressure to maintain their effectiveness.

Pick Heaters, Inc has developed a simple formula for estimating the steam requirement when heating water.

$$\text{(W) Steam Demand} = \frac{\text{Heat Load (Btu/hr)}}{\text{Usable Btu/lb of steam } (h_g \text{ enthalpy})}$$

For example assume steam pressure equals 125 PSIG saturated and cold water inlet temperature is 60°F.

$$\text{(W)} = \frac{\text{gpm x 8.34 lb/gallon} \times \text{60 minutes/ hour} \times {}^{\circ}\text{F temp rise}}{\text{Net usable Btu/lb (from steam table) 1,193 Btu/lb} - (60\text{–}32)}$$

$$\text{(W)} = \frac{\text{gpm x } (500.4) \times ({}^{\circ}\text{F temp rise})}{\text{1,165 Btu/lb}}$$

(W) Steam Demand = .43 (sizing factor) × (gpm) × (°F temp rise)

If you have a hot water requirement of 100 gpm heated from 50°F to 150° (100°F temperature rise) the steam demand would be:

(W) Steam Demand = .43 × 100 gpm × 100° temp rise
= 4,300 lb/hr.

We are able to use the .43 sizing factor over a range of steam supply pressures because the total enthalpy h_g (Btu /lb) doesn't vary much between 50 psig and 150 psig. (h_g for 50 psig saturated

steam is 1,179 Btu/lb and h_g for 150 psig saturated steam is 1,195 Btu/lb.) A difference of 16 Btu/lb or 1.3% isn't significant. However, some factors to consider that will affect the sizing formula (Figure 1) include:

1. Is the steam superheated? Superheated steam above the saturated temperature will contain some additional energy. This added energy must be taken into consideration and will usually reduce the steam demand.
2. Is the entering water temperature elevated (100°F or above)? This must also be taken into consideration because the higher inlet water temperature will generally result in a higher steam demand.

Other factors to consider when selecting the DSI heater are material of construction, pipe sizes, controls and instrumentation, noise level requirements, pressure drop requirements, and minimum piping distances.

PHILIP SUTTER is a Vice President with Pick Heaters, Inc., West Bend, Wis. He has more than 30 years of experience designing, engineering and selling liquid process heating systems for the food, chemical and pharmaceutical industries. He can be reached at psutter@pickheaters.com.

ADJUSTED FORMULAS

CORRECTION FOR SUPERHEATED STEAM

Steam = 200 psig @ 500°F (115°F Superheated)
Flowrate = 100 gpm
Temperature rise = 100 °F (60–160)
Useable Btu/lb = 1,267 – (60–32) = 1,239

$$W = \frac{100 \text{ gpm } (500)\ (100°\text{F})}{1{,}239} = 4{,}035 \text{ lb/hr}$$

vs.

$$W = .43\ (100)\ (100) = 4{,}300 \text{ lb/hr}$$

$$\text{ERROR} = \frac{4{,}300 - 4{,}035}{4{,}300} = 6.2\%$$

CORRECTION FOR ELEVATED WATER TEMPERATURE

Steam = 200 psig, Saturated
Flowrate = 100 gpm
Temperature Rise = 30°F (170–200)
Useable Btu/lb = 1,193 – (170–32) = 1,055

$$W = \frac{100 \text{ gpm } (500)\ (30°\text{F})}{1{,}055} = 1{,}421 \text{ lb/hr}$$

vs.

$$W = .43\ (100)\ (30) = 1{,}290 \text{ lb/hr}$$

$$\text{Error} = \frac{1{,}421 - 1{,}290}{1{,}290} = 10\%$$

Figure 1. Superheated steam and elevated water temperatures are factors to consider that can affect the sizing formula.

Generate Power Using Waste Heat

Partnering could benefit process plants looking to recover low-level heat

By Ven V. Venkatesan, Energy Columnist

MANY ENGINEERS reject low-level heat from process operations because they can't find suitable heat sinks to effectively utilize the recovered heat. It's not uncommon for plants to reject either the excess heat directly or vent the low-pressure steam generated from the waste heat. So, plants with excess low-level heat rejection should find the success story of a new technology implemented by a natural gas pipeline company, in collaboration with three partners, an eye opener for recovering wasted energy.

Kinder Morgan owns the 436-mile Trailblazer natural gas pipeline that winds through parts of Wyoming, Colorado and Nebraska. Booster compressor stations located at appropriate intervals maintain gas pressure as it travels along the pipeline. These compressor stations are often run by turbines, which exhaust waste heat during the compression process. There's no steam demand, as these stations require only a small amount of electricity for instrument control panels, lighting and minor needs that are usually supplied by the local utility company.

Because Kinder Morgan alone couldn't find suitable utilization opportunities, it looked for partners to help save the wasted energy. A few years ago, the company implemented a project in collaboration with the local utility company, Highline

Electric Association, and M/s. Ormat Corporation, a vendor specializing in Organic Rankine Cycle (ORC) power generation modules. The generated electricity from the ORC plant is upgraded to higher voltage and fed to the utility grid.

One of the company's compressor stations has two 14,500-hp gas turbines with exhaust temperatures of 900°F. Ormat added its ORC technology to capture and turn the heat into electricity. A heat exchanger in new exhaust stacks recovers the heat from the turbines. The heat is then transferred to a working fluid of pentane in a second heat exchanger, or "vaporizer." Heating the working fluid vaporizes and expands it, causing it to drive another turbine generator. After the fluid has passed through the turbine, it's air-cooled and condensed back to a liquid. No water or additional fuel is used and there are no emissions in the heat recovery process. The 12.47-kV electric output is transformed and interconnected to a new 69-kV transmission line. While the generator could have been interconnected to an existing 12.47-kV 3-phase distribution line, the area's occasional summer lightning storms made a 69-kV line a higher reliability choice.

This project was a result of a successful collaboration between four organizations:

Partner 1: Ormat built, owns and operates the system.

Partner 2: Highline Electric Association buys the electric output of the system and uses it to meet a 10%-by-2020 standard required by the state of Colorado.

Partner 3: Tri-State, the generation and transmission provider for Highline and 43 other rural electric co-ops, supported the project through its Member Local Renewable Project program that provides financial assistance for local clean energy projects.

Partner 4: Kinder Morgan owns the natural gas pipeline and compressor station; Ormat pays the company for use of its waste heat.

All four partners consider the project successful and recommend this application to other pipelines and process plants that reject excess heat to atmosphere. At present, ORC modules with capacity as low as 100 kW are commercially available.

Not all such process plants have sufficient waste heat recovery and utilization capabilities. I have come across a chemical plant with a sulfuric acid manufacturing unit in coastal Alabama that generated about 15,000 lb/hr of excess steam. A good portion of the excess steam was exported to a neighboring plant. When the neighboring plant closed a few years ago, steam was vented continuously as it couldn't be utilized within the plant. In this plant, not only is heat energy wasted, but also good quality boiler feed water.

Low natural gas prices and the higher investment costs of ORC units could be an initial challenge. Once natural gas demand increases, availability of low-cost natural gas may disappear. Chemical processing plants should consider collaborating with partners to recover and utilize the wasted heat to reduce emissions and remain profitable. ●

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