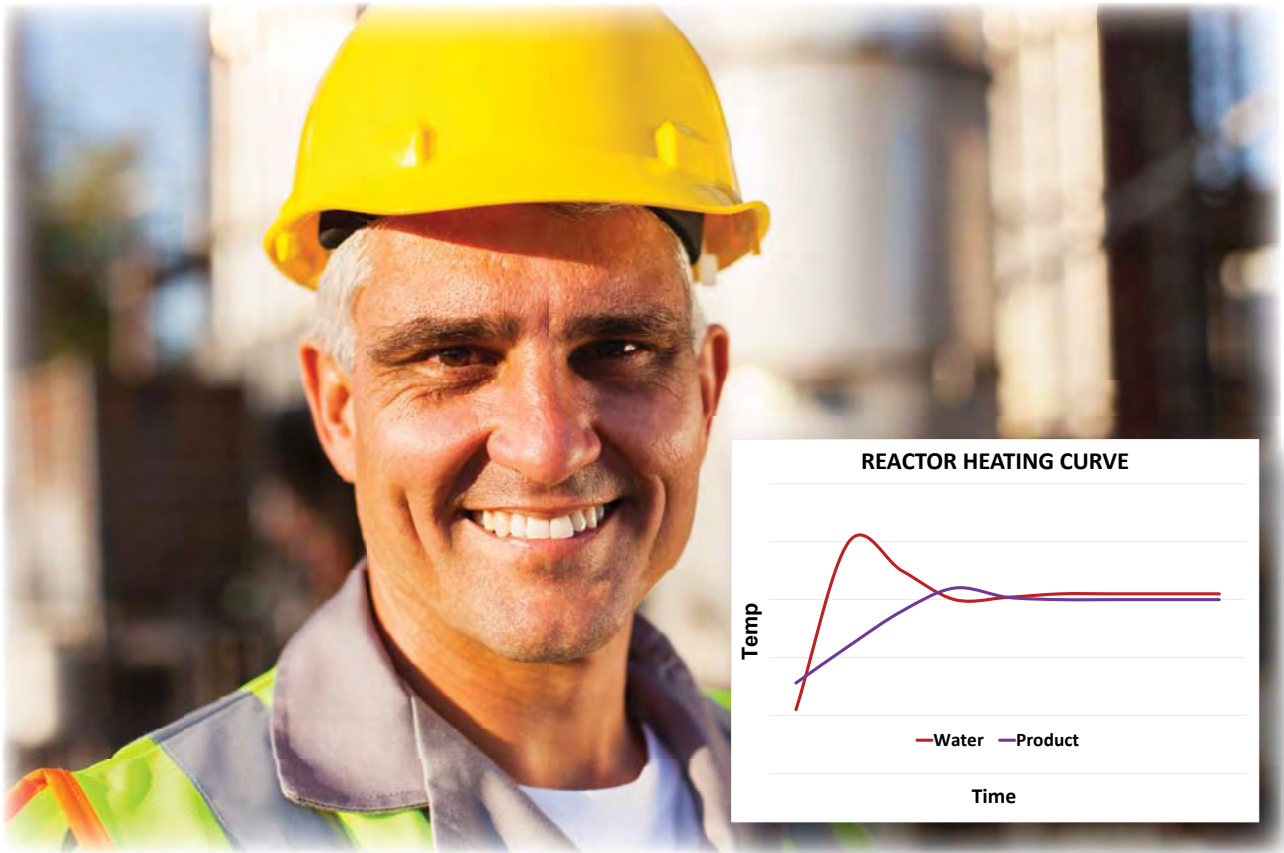


# CHEMICAL PROCESSING

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## Keep Your Cool with Heat Exchangers





# LARRY SCHUBERT FLAT LINED...

**and feels like a million bucks!**

Actually, the first thing he felt was relieved. Because Larry finally discovered absolutely precise temperature control for all his chemical processing. Thanks to Pick Direct Steam Injection Heaters, now his process temperature graphs show one, long, beautiful, flat line. That's because Pick's exceptional temperature control automatically holds jacket temperatures to extremely close tolerances – within 1°C or less, while providing rapid response to changing process conditions.

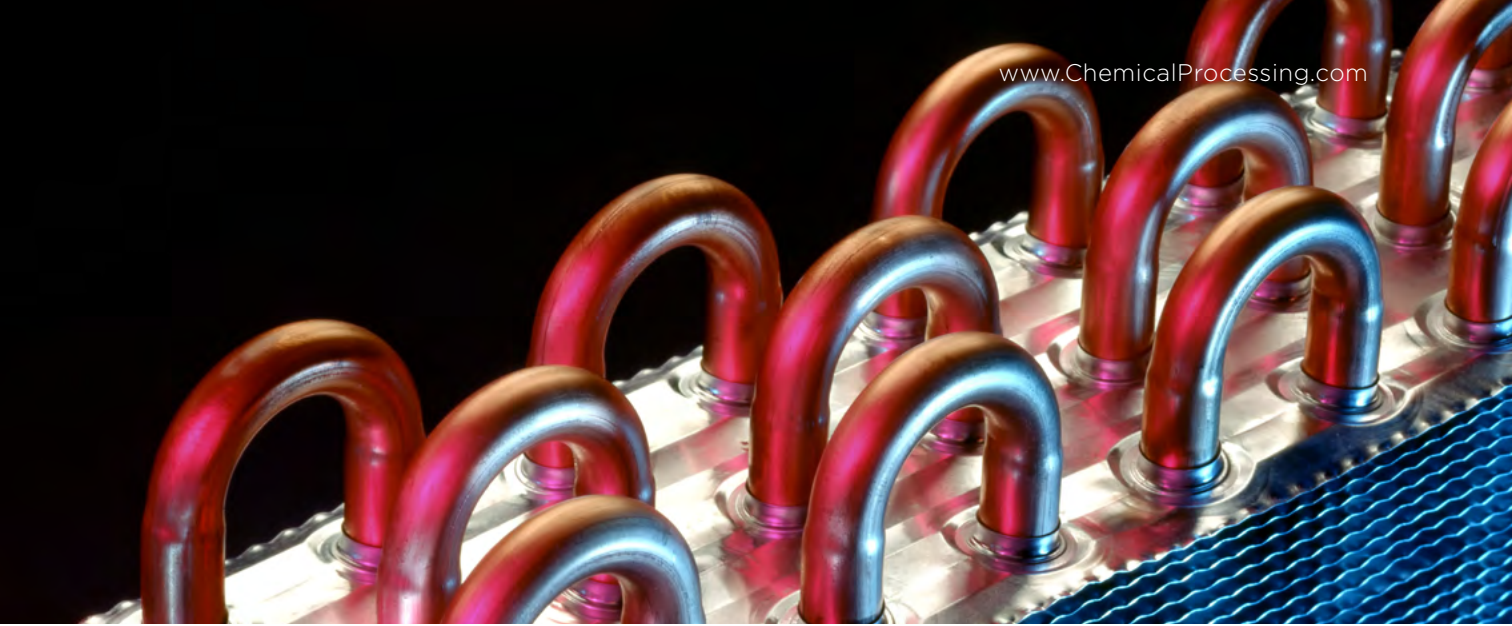
Whether you require jacketed heating or have other process liquid heating applications, Pick eliminates steam trap losses for 100% heat transfer efficiency. This alone could save Larry's company up to 20% in fuel costs. In addition, Pick's compact design along with its ease of maintenance, saves valuable space and invaluable down time. All this, combined with low water pressure drop, the lowest noise level, and the widest operating range of any direct steam injection heater is enough to make anyone's heart go pit-a-pat. Which is precisely what flat lining can do to a guy.



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## TABLE OF CONTENTS

<b>Consider Open-Rack Seawater Heat Exchangers</b>	<b>4</b>
Such units often offer an attractive way to take advantage of the resource	
<b>Pick the Right Side</b>	<b>11</b>
Allocating fluids in a tubular exchanger demands care	
<b>Take a Closer Look at Direct Steam Injection</b>	<b>14</b>
Technology responds rapidly to changing process conditions	
<b>Additional Resources</b>	<b>16</b>

## AD INDEX

Pick Heaters • <a href="http://www.pickheaters.com">www.pickheaters.com</a>	2
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# Consider Open-Rack Seawater Heat Exchangers

Such units often offer an attractive way to take advantage of the resource

By Amin Almasi, mechanical consultant

**H**eat exchangers that use seawater are common worldwide because they provide a compelling benefit — seawater is a free heat-transfer medium that doesn't produce emissions. The units exchange heat between a process fluid (cryogenic or hot) and seawater of ambient temperature. In warm sea conditions (i.e., water at  $>14^{\circ}\text{C}$  or, better,  $>18^{\circ}\text{C}$ ), such a seawater stream can serve as the heat source in vaporizer/heater equipment. On the other hand, cold seawater (preferably  $<12^{\circ}\text{C}$ ) can handle cooling of hot process streams; even seawater in tropical climes might suffice to cool some process streams.

Many seawater heat exchangers are open-rack designs because they typically boast better economics and shorter

payback periods than other options such as shell-and-tube units. This advantage holds particularly true for large high-flow and high-capacity equipment. Another key plus is that open-rack heat exchange is considered a very safe and reliable technology. The units provide a simple and cost-efficient heat exchange process that's easy to operate and maintain. Plants usually use parallel operating exchangers with spares.

## MECHANICAL DETAILS

In an open-rack heat exchanger, the seawater enters at the top and runs downward in a film-like manner over tubes containing the process fluid. The seawater collects in a basin at the bottom of the tubes and then is returned to the sea.

## Increasing or decreasing the number of panels or blocks easily allows a design appropriate for the necessary heating/cooling capacity.

Tubes are fabricated from suitable materials with proper thermal, mechanical, corrosion and erosion characteristics. For example, in cryogenic services (vaporizers/heaters), aluminum alloys nearly always are used.

The tubes require an appropriate coating (such as a zinc aluminum alloy one for aluminum alloys) to ward off different mechanisms of seawater corrosion and erosion. Typically spray applied, the coating usually serves as a sacrificial anode to protect the base material from corrosion by seawater. As a rough indication, such a coating should have an expected life of 25,000–50,000 total operating hours (say, 3–5 years) — but this depends on seawater quality and operation pattern as well as cleaning and maintenance work. For cheap coatings or poorly maintained open-rack exchangers, recoating should take place every one or two years, particularly when polluted seawaters are involved. As a very rough estimate, a

2-block 200-t/h unit takes 2–3 weeks, excluding preparation period, to recoat.

Tubes usually have fins to increase heat transfer area. In addition, the inside of each tube most often has a cruciate profile, spirally twisted and fixed through the entire length, or another arrangement to further enhance heat transfer. Such a structure promotes turbulent flow, which improves heat exchange.

The tubes are arranged in panels. Each panel generally holds close to a hundred heat-transfer tubes. The distance between the panels often is 550–700 mm. Several of these panels (say, four to eight) are unified into a block by a manifold pipe and hung from a ceiling frame placed over a concrete structure at the installation site. A slide-type support provided under the block absorbs thermal movements. Increasing or decreasing the number of panels or blocks easily allows a design appropriate for the necessary heating/cooling capacity.

Often, it's possible to isolate each block individually using proper valving systems. For instance, a 3-block design might operate only one or two blocks at low turndown. However, some manufacturers recommend using all blocks for part-load.

The units require regular inspections and maintenance to keep the finned tube surface clean. So, it's important to ensure the seawater distribution facility over the heat exchanging panels is easily accessible, adjustable and designed to permit cleaning, via methods such as a high-pressure water jet or a rodding brush.

Although the design might seem simple, some components need great care and proper choice. For example, the type of connection for the process fluid inlet to the equipment is critical because this point experiences the highest thermal gradient (temperature difference) at startup.



### SEAWATER EXCHANGER

Ideally, opt for flange connections instead of transition joints; for maintenance and panel re-coating (if you don't plan on in-situ recoating), choose panels that are removable without cutting. Flange leakage at the inlet for very low or very high temperature applications usually is a concern. In such cases, consider the use of a one or two class higher ASME flange or any other suitable alternative to eliminate the potential leakage.

Many open-rack heat exchangers for cryogenic

or very hot temperature are designed with a weld connection using a transition joint between the inlet piping and the pressure part of the exchanger (which usually are made from dissimilar materials) because of fast rampup requirements at startup. However, the design and fabrication of a successful transition joint to weld dissimilar metals are complex and difficult tasks.

Installations usually include standby units, with an "N+1" (one operating exchanger and one



## A stress analysis can ensure a design provides proper flexibility and minimizes loads on panel connections and other critical components.

spare) or “N+2” (two spares) configuration common. Plants requiring high reliability and availability usually opt for a N+2 arrangement. You should maintain standby exchangers in operating condition, ready for startup when required.

### **AVOIDING PROBLEMS**

The exchanger should operate stably, reliably and safely without any vibration or problem within its specified operating range. You usually should expect the manufacturer to guarantee continuous operation from 10% to 110% of capacity. Some open-rack units have experienced high vibration during transient or part-load operation. So, consider studies and proper measures to avoid high vibration when operating under transient conditions and within the entire part-load range.

To prevent induced vibration, reinforce the support of the piping around equipment (upstream and downstream) to increase the natural frequency above the typical 10 or 12 Hz. In addition,

these applications always benefit from high-stiffness piping designs. Of course, accurate simulations and dynamic studies are the best ways to determine potential risks of component failure from vibration, fatigue from thermal cycling and other damage mechanisms.

Operation in very cold or very hot applications often results in complex phenomena such as the icing of seawater (for cryogenic applications) or the boiling of seawater (for hot fluids) on the external surface of the initial section of tubes (where the maximum temperature difference exists). This can cause difficulties in design, mechanical analysis and operation. Because the heat exchanger usually handles a significant difference in temperature and needs a rapid startup or shutdown, thermal stresses and transient operations require appropriate consideration. A variety of studies (such as those by finite element methods) and tests can lead to highly durable structures. Today’s methods enable design of the most suitable tubes (e.g., sizes and internal/

external surface shapes). Design pressures of 50, 75 or 100 barg or more aren't uncommon for such exchangers.

A stress analysis can ensure a design provides proper flexibility and minimizes loads on panel connections and other critical components. Most often, the magnitudes of thermal stresses depend on the deformation of the inlet header, which has a higher cross-sectional rigidity than that of the heat transfer tubes. Based on different studies and observations, maximum thermal stresses often appear during peak running and immediately after process fluid flow is stopped. Thermal stresses at welded (including transition) joints and heat affected zones of heat transfer tubes should remain within allowable limits.

You also must consider possible thermal stresses of the panels due to different malfunction scenarios. For instance, poor seawater distribution can result in some unexpected thermal stresses. So, finite element studies for the panel design to check the stresses at the transition joints and headers usually are needed.

## MODERN DESIGNS

During operation, the highest tube temperature gradient occurs on the outer wall at the initial part of each tube. As already noted, in vaporizer/heater units, the temperature could be lower than the freezing point of seawater, prompting ice

buildup on the tubes. Especially in cold climates, the ice thickness and height could increase significantly, causing substantial resistance to heat transfer. On the other hand, for open-rack coolers, the temperature might exceed the boiling point of seawater. Use advanced designs to avoid this icing/boiling problem and the ensuing degraded performance.

Some manufacturers have developed duplex pipe structures at the initial part of tubes to suppress icing/boiling on the outer surface of the tube. The process fluid feeds into both an inner tube section and annular channel between inner and outer sections of the tube. The process fluid's flow rate in the inner tube usually equals that in the annular channel. Inside the annular channel, process fluid directly exchanges heat with the seawater. However, because of lower mass rates, this doesn't cause thermal shock and boiling/freezing. Meanwhile, process fluid in the inner tube exchanges heat with the fluid in the annular channel. These gradual heat exchanges allow better control of temperature and prevent ice forming or boiling on the surface of the heat transfer tube.

Modern duplex pipe structures provide significantly improved thermal performance; they reduce the volume of seawater required by 10-15%. In addition, they decrease area requirements to 30-45% of those of conventional



## You also must consider the impact of the unit on marine life.

exchangers, and cut operating cost by 10–20%.

### THE SEAWATER SIDE

The steel frame and all surfaces in contact with seawater require proper material selection and coating. Usually this means choice of an appropriate grade of stainless steel. For some applications with “clean” seawater, duplex or other common stainless steels suffice. Other applications relying on polluted or dirty seawater demand better materials such as super duplex stainless steels.

It’s sensible to install side panels to prevent any projection of seawater to the outside of the equipment.

To control algae growth within the system, inject sodium hypochlorite, chlorine or similar chemicals into the seawater before it passes to the exchanger.

Seawater contamination and pollution can degrade the operation and reliability of the exchangers. For instance, seawater containing significant amounts

of heavy metal ions can shorten the life of the protective coating of tubes; the metal ions attack such coatings. Seawater loaded with sand and suspended solids can lead to sediment jamming the water trough and the tube panel. The design of the seawater intake filtration system should prevent silts, sands and sea life from reaching the seawater pumps and exchangers. (For an unusual case of exchanger plugging, see “Don’t Neglect Spring Cleaning Duties,” <http://bit.ly/2JbeEE7>.)

You also must consider the impact of the unit on marine life. The large volumes of seawater used could have an adverse effect. In addition, the cooled/heated and treated seawater discharged back to the source potentially could impair marine life and overall seawater quality. Any open-rack heat exchanger system also poses several minor environmental issues, including seawater intake and seawater outfall. Improper design could prompt a major breach of environmental rules with serious consequences. Good design can forestall such issues. Seawater discharge temperature

## Improper design could prompt a major breach of environmental rules with serious consequences.

should comply with local regulation; most jurisdictions limit the temperature change to 5°C or 10°C. Also, pay attention to the locations of the seawater intake and outfall to avoid cold/hot seawater recirculation.

### A CASE STUDY

A plant needed a 400-t/h capacity open-rack vaporizer for a cryogenic service. This led to a design that uses 90 tubes per panel, four panels per block, and four blocks per unit. Each panel block has a capacity of 100 t/h. Normal inlet pressure of the cryogenic liquid to this vaporizer is around 48 barg. The design pressure is considered 80 barg. The vaporizer requires around

8,000 t/h of seawater. As a rough indication, the estimated heat exchanged is 90 MW. In other words, this open-rack vaporizer system is a massive unit to exchange 90 MW.

Empty weight of each panel block is around 8 t; empty weight of the equipment unit with the four blocks and including manifolds, headers, seawater troughs, inner maintenance deck, etc., is approximately 65 t. Operating weight of the unit is around 110 t. ●

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# Pick the Right Side

Allocating fluids in a tubular exchanger demands care

By Andrew Sloley, Contributing Editor

**W**hen designing a shell-and-tube exchanger, one of the first issues is deciding which fluid should go on the shell side and which on the tube side. So, let's look at some rules-of-thumb for several key factors, realizing such rough guidelines won't cover all cases.

*High pressure.* Put a high-pressure fluid on the tube side. This usually minimizes exchanger cost. The smaller tube diameter has a higher pressure rating for the same metal thickness compared to the larger diameter shell.

*Fouling.* A fluid with a tendency to foul generally should go on the tube side. Cleaning straight tubes normally is easier than cleaning the shell — even if a relatively large tube pitch or a square tube pattern is used to make the shell side easier to clean.

However, the exchanger configuration significantly influences the choice. Using a fixed tubesheet mandates putting a clean fluid on the shell side; unless expected fouling is easily removed by chemical cleaning, the fixed tubesheet makes the shell side impossible to clean. In contrast, U-tubes are more difficult than straight tubes to clean. So, sending a normally fouling service through the shell side may be better if fouling reduction steps, such as installation of helical baffles, are suitable.

*Expensive materials.* Put a corrosive fluid on the tube side. That way, only the tubes, tubesheets, heads and channels will need expensive corrosion-resistant alloys. In contrast, a corrosive fluid on the shell side requires the entire exchanger to use the materials.



## For fouling services, the exchanger configuration significantly influences the choice.

*Low pressure drop.* The fluid should go on the shell side. An appropriate combination of baffle cut, spacing and type (segmental, double segmental, rod-baffle, etc.) can accommodate nearly any pressure-drop requirement. Services under vacuum almost always are on the shell side because of pressure drop sensitivity.

*Vapor services.* Because a vapor normally has a higher volume and lower heat-transfer coefficient than a liquid, allocate it to the shell side. This reduces pressure drop for a given volume and typically provides a higher heat-transfer coefficient.

*Condensing services.* A condensing fluid most often goes on the shell side — but the choice demands careful evaluation. If the shell-side velocity is low enough, the vapor and liquid can separate inside the exchanger. The liquid dropping out makes the vapor leaner, reducing the temperature required to get more liquid to condense from the remaining vapor. For relatively pure mixtures, this effect is unimportant.

For wide-condensing-range mixtures, ensure the overall flow pattern inside the exchanger keeps the liquid and vapor mixed. This may necessitate having the shell-side fluid leave from the bottom (forcing the liquid and vapor to mix) or determine the choice of baffling inside the exchanger (horizontal versus vertical or 45° baffle cut).

*Viscous services.* Here, the tradeoffs are complex. A viscous fluid on the tube side tends to have high pressure drop and low heat transfer. That favors shell-side allocation. However, high pressure drop on the shell side can prompt significant flow by-passing around baffles, reducing heat transfer. A shell side with a high pressure drop also may suffer from vibration damage; shell-side modifications (assuming the user is aware of the need for them) can reduce such damage.

*Solidifying services.* Generally avoid a shell-and-tube exchanger for any service with a high risk of solidification or freezing. However, if you must use such an exchanger, I suggest putting the fluid with a risk of solidification in the tubes. If the fluid solidifies,

If the solid is on the shell side, it's often impossible to remove the tube bundle. The entire exchanger may require replacement.

you usually can pull out the tube bundle and replace it. In contrast, if the solid is on the shell side, it's often impossible to remove the tube bundle. The entire exchanger may require replacement.

However, allocating to the shell side a fluid that may freeze may offer advantages. In some cases, externally heating the shell with electric tracing may enable melting the fluid enough to get the exchanger back into service.

In either allocation, a freezing fluid can create local plugs. If its velocity drops,

the fluid may approach the temperature of the other side of the exchanger, which may cause the fluid to set solid. This can occur on the shell side next to baffles on the shell edge. It also can happen in tubes. Tubes may differ in flow rates. A tube with a low flow rate may reach a lower temperature, making it more likely to freeze or set up. Often, exchangers with freezing fluids may have large areas where the exchanger has set solid. ●

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# Take a Closer Look at Direct Steam Injection

Technology responds rapidly to changing process conditions

By Paul Pickering, Pick Heaters Inc.

Online heating of liquids or slurries is a requirement in many chemical and pharmaceutical operations as numerous industrial applications need an unlimited and instantaneous supply of hot water.

While choices for heating water, liquids and slurries abound, direct steam injection (DSI) heaters (Figure 1) should be at the top of the list of options for these challenging applications.

## WHY CHOOSE DSI?

DSI has certain characteristics that are beneficial or even necessary depending on the process:

- It offers precise temperature control within  $\pm 1$  °C.



**DIRECT STEAM INJECTION HEATERS**  
Figure 1. These units are an ideal choice when a well-controlled, instantaneous supply of water is needed.

- It is easy to install and can be used wherever medium- to high-pressure steam is available.



## DSI provides a rapid response to changing process conditions and enables precise temperature control within a single degree Celsius.

- Precisely machined variable orifice injector with spring-loaded piston eliminates damaging vibration and steam hammer.
- Compared to alternatives such as tank steam sparging or indirect heat exchangers, DSI heaters can cut fuel costs by as much as 28% because the liquid absorbs 100% of the available energy (BTUs) from the steam instantly.
- It features a low liquid-side pressure drop — less than 2 psi.
- It is environmentally safe and nonflammable, unlike heat transfer fluids that require special handling and constant monitoring.

### EXAMPLES OF DSI IN INDUSTRIAL PROCESSES

DSI is better than indirect exchangers for heating water in industrial applications because it provides a rapid response to changing process conditions and enables precise temperature control within a single degree Celsius. As such, DSI heating is suitable for a variety of industrial processes as illustrated in the following examples:

- Many processes in the chemical industry require water temperature to be controlled precisely before adding it to a batch process. A DSI system provides instant temperature control, reducing the cycle time and increasing productivity.
- DSI also is ideal for heating large-capacity, closed-loop jacketed vessels, tanks and blenders; mixing two condensate steams; or even dispersing gas into a liquid.
- Applications such as plant sanitization, clean-in-place (CIP) and washdown hose stations require hot process water. Instantaneous and accurately controlled hot water must be available to meet stringent plant demands.
- In pharmaceutical processing, DSI technology is used in such applications as the continuous-flow heat treatment of bio-waste. The precise temperature control enables wastewater with living cells to be killed or inactivated and then cooled before disposal. For example, one waste steam inactivation system required the waste from multiple reactors to be heated to 140 °C, held for a period of time and then cooled to 60 °C. Read more [here](#). ●

**PAUL PICKERING** is a writer for Pick Heaters Inc. Pick Heaters produces DSI heaters in 10 standard sizes for liquid flow rates up to 5,000 gpm, and steam flow rates from 150 lb/hr to 50,000 lb/hr. For more information, visit [www.pickheaters.com/Products.htm](http://www.pickheaters.com/Products.htm).

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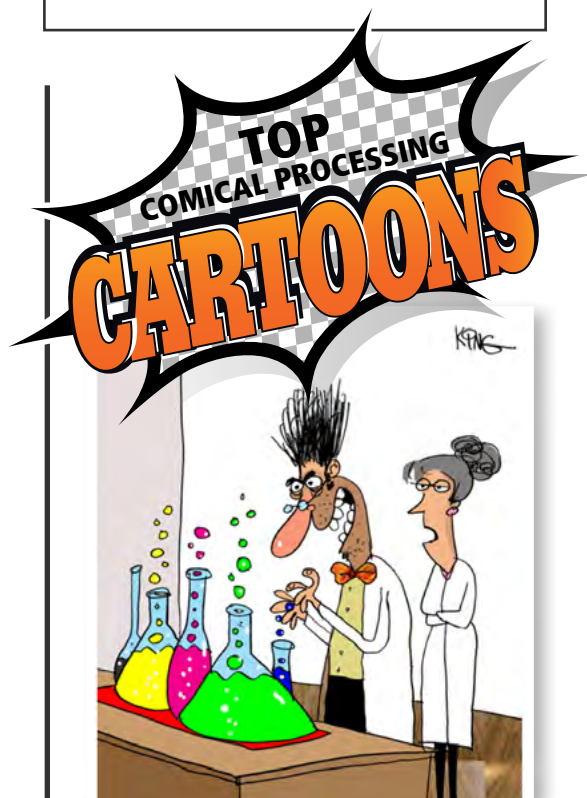
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