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Watch Out for Two-Phase Flow

Process performance can suffer dramatically when a liquid flashes unexpectedly

By Andrew Sloley, Contributing Editor

TWO-PHASE FLOW can present challenges. The greatest problems occur when two-phase flow shows up unexpectedly. Elevation changes with equilibrium liquids can lead to such situations. We'll look at a case where uphill piping caused major difficulties.

Proper pressure balance can make a liquid flow uphill in a pipe. However, starting with an equilibrium liquid can cause flashing when elevation changes. The increased volume boosts pressure drop. The resulting flow may either be much lower than expected or cause severe mechanical problems from surging. Proper consideration of intermediate conditions in fluid flow can avoid these problems.

At the site in question, a drum supplies refrigerant to multiple exchangers. The plant added a new service to the existing system (Figure 1a). After commissioning, the new service received only 75% of the required duty.

The design of the new service, like that of many refrigerant exchangers, called for a fully flooded condition on the refrigerant side. Field investigation showed that the level control valve on the refrigerant supply always is fully open. The exchanger doesn't have independent level taps. A neutron backscatter device monitors refriger-

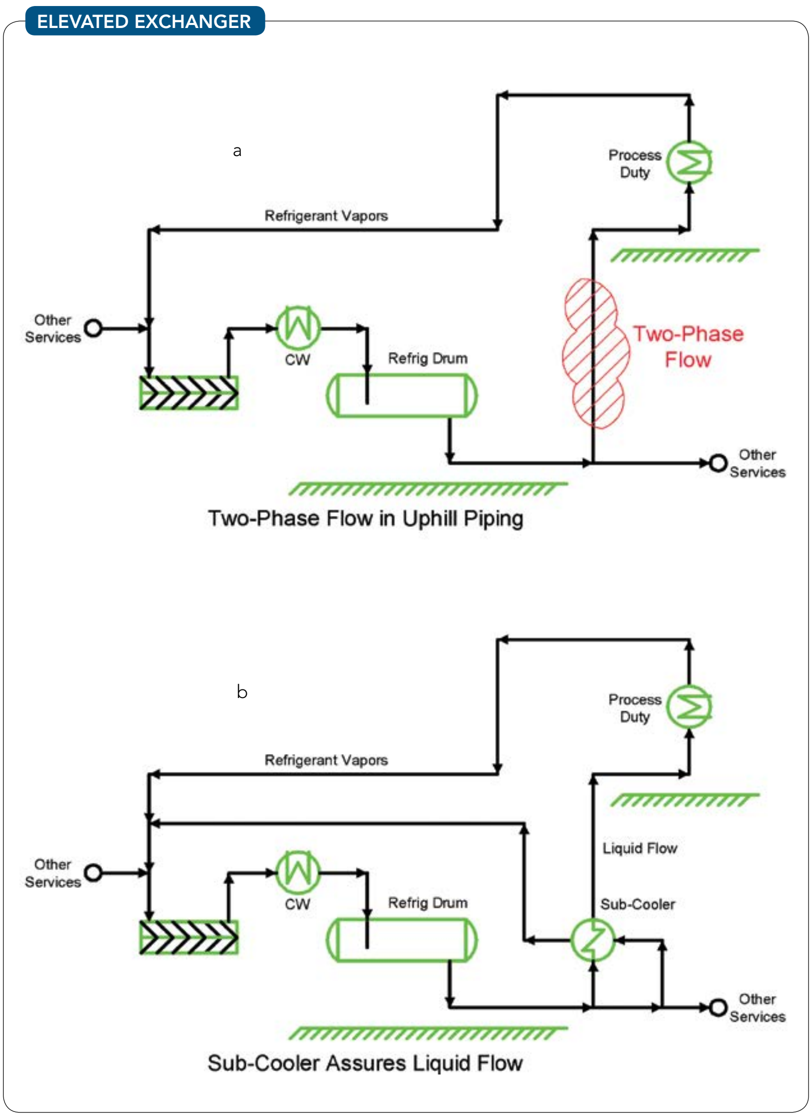

Figure 1. Original design (a) didn't consider that new service was uphill of others; addition of subcooler (b) enabled exchanger to perform properly.

ant level — and indicated that roughly one-third of the tube bundle actually is above the refrigerant level.

Field investigation continued with a series of pressure readings along the flow loop to the new exchanger. Based on flow rates, the pressure drop in the refrigerant return loop was as expected. However, the pressure drop in the refrigerant supply loop was much higher than expected. The immediate thought was that heat gain through the piping was causing vaporization in the refrigerant line. Inspection showed the new line was well insulated and not likely to have significant heat gain.

While inspecting the line to check the condition of its insulation, the engineer noticed that the new service was at a markedly higher elevation than most of the existing refrigerant exchangers. Review of the design of the new piping showed that elevation changes weren't considered in system hydraulics. The supply drum provided enough head to overcome friction losses but not substantial elevation changes. The height change caused significant vaporization. Even a small percent of vaporization dramatically increased pressure drop.

To get refrigerant to the new exchanger required either changing a sizable amount of piping or keeping the liquid at a pressure above its bubble point. The latter called for either pumping the refrigerant to a higher pressure or cooling it to a lower temperature.

Adding rotating, reciprocating or other machinery with moving parts, even small units, costs a surprisingly large amount after final installation has been completed. So, instead, the plant installed a small subcooler. A slipstream of refrigerant provides cooling for the stream going to the new exchanger. The net result is that refrigerant going there enters the supply line at 30 psi over the saturation pressure. The subcooling eliminates the pressure drop problem. Desired capacity was immediately achieved.

Other situations when two-phase flow can unexpectedly occur include: heat gain into cold systems; flashing across orifice plates or other head meters; mixing dissimilar streams; retrograde condensation through the two-phase region; continuing reactions in lines; internal flows in physically large equipment; and leaks. To a large extent, process analysis can identify all these potential problems, except leaks, before they are created. Remember to check intermediate flow conditions — these may be important — as well as piping inlet and outlet conditions. If you don't check for them, you risk unpleasant surprises. Proper analysis beforehand can head off such problems.

Leaks tend to be more of a troubleshooting issue. Don't forget to think about the impact of low-pressure fluid leaking into high-pressure systems. Consider, e.g., leaks into a vacuum system, process/process leaks, or process/utility leaks. Even small amounts of extra volume can create major pressure drop problems.

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Nix Nozzle Nuisances

Avoid flow problems by considering the impact of inlet losses

By Andrew Sloley, Contributing Editor

PLANTS OFTEN must move fluid from a large vessel into a pipe. For pressurized systems this rarely creates problems. However, for systems in which static head sets the available head even the small inlet losses from nozzles can restrict flow. Therefore, it's important to understand flow resistance coefficients (k) in your system to check low head flows.

The classic nozzle entrance shape is a flush connection with a $k = 0.5$. But other shapes abound, e.g.: angled flush, projecting, flush cone, flush bellmouth and projecting bellmouth (Figure 1), as well as screens and perforated plates. When limited by head available from gravity these complex pipe entrances can dramatically change system capacity. The k of these shapes are hard to find. So, here's a selection of the more useful.

Pressure drop through an outlet pipe is evaluated in height of the flowing fluid (h). The standard equation is:

$$h = k\,(v^2/2g)$$

where v is the velocity of the fluid and g is acceleration due to gravity.

Converting this to a dimensional equation gives the two forms commonly used:

$$h = 522\,(kq^2/d^4) = 0.00259\,(kQ^2/d^4)$$

where q is flow in ft.^{3}/sec., Q is flow in gal./min., d is diameter in in. and h is height in ft.

If you know k, you can easily calculate head losses for piping entrances.

I. E. Idelchik's "Handbook of Hydraulic Resistance" provides k values. Unfortunately, working with that book poses challenges. The text was complex to begin with — garbled translation coupled with missing subscripts in some equations and use of the wrong symbols in others require the reader to take extreme care.

It's not 100% clear from the text but Idelchik seems to have force-fitted his curves to meet theoretical boundary-limit conditions for known special flow cases. This leads to some apparent contradictions in k values that aren't immediately obvious in the published k graphs. Despite these problems Idelchik is still the best one-stop reference for k. (Checking published values in supposedly authoritative sources deserves a future column.)

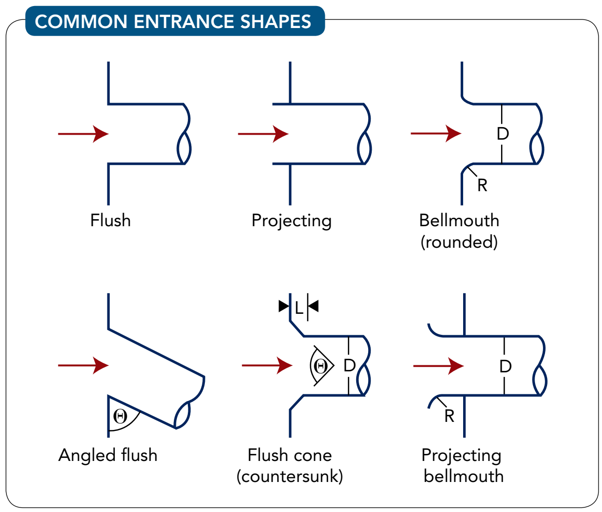

Figure 1. Each of these types of entrance provide a different flow resistance.

For angled flush entrances:

$$k = 0.5 + 0.3\cos\theta + 0.2\cos^2\theta$$

Figure 2 graphs k for bellmouth or rounded entrances. The boundary limit for a bellmouth entrance is a radius-to-diameter (R/D) ratio of zero, which equates to a sharp-edge entrance. "Crane Technical Paper 410 — Flow of Fluids through Valves, Fittings and Pipe" only provides a value ($k = 0.78$) for a sharp-edge entrance for a freestanding or projected entrance. In comparison, Idelchik gives the entire curve but with a 1.0 value for a sharp-edge entrance. Its k values are higher for the freestanding entrance because they've been force-fit to boundary conditions of an infinitely thin pipe. Crane's

BELLMOUTH FLOW RESISTANCE

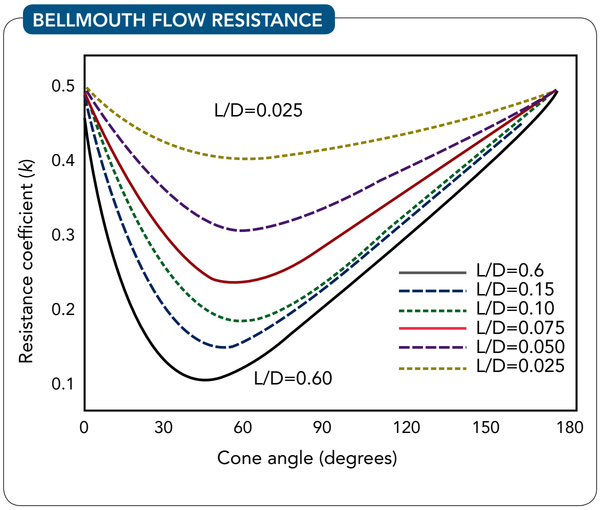

Figure 2. Two references give different *k* values for both projecting and flush entrances.

FLUSH CONICAL ENTRANCE

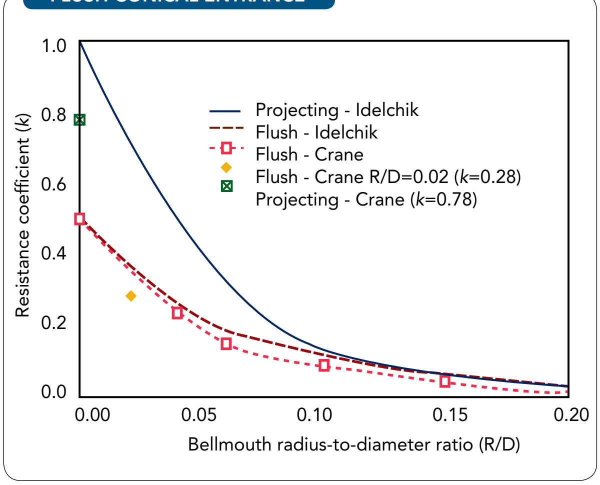

Figure 3. Values depend on cone angle as well as its length/diameter ratio.

values stem from experiments with relatively thick commercial pipe; the thick pipe entrance reduces the effect of inlet losses. The Crane tables also show an unexpectedly low *k* when R/D = 0.02.

Figure 3 shows *k* for flush conical or countersunk entrances. Here, you must specify both the cone's angle and length/diameter (L/D) ratio. Flow resistance approaches a minimum between 40° and 60° depending on the relative depth of the cone.

Another common entrance uses a perforated plate (generally with sharp-edge holes) as a screen or anti-vortex device. To evaluate this we must know the fraction open area of the plate compared to the downstream pipe:

f = (*flow area open in plate*) /(*flow area open in downstream pipe*)

For turbulent flow:

$k \approx [(1.707 - f)/f]^2$

For rounded entrances into plates we must know the fraction open area ratio plus the radius of curvature of the opening and the opening diameter. From the radius and opening diameter we calculate a resistance loss correction factor *k′*:

$k' = 0.03 + 0.47 \times 10^{-7.7(R/D)_{opening}}$

$k = \{[1 + (k')^{0.5} - f]/f\}^2$

We can estimate *k* for cast shapes with noncircular or complex openings using the equations here by substituting hydraulic diameter ($D_{hydraulic}$) for diameter:

$D_{hydraulic}$ = (4 × *flow area of opening*)/(*wetted perimeter of opening*)

These curves and equations enable estimating losses for many of the more common shapes of piping entrances. For extremely complex flow configurations as well as laminar and transition flow regimes, go to the standard references to find what you need. But double-check the assumptions behind the values and understand how they apply to your situation. ●

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Case Study: Speed Pipe Installation

Pipe-joining system eliminates need to weld or thread connections

VIP PLUMBING of Cleveland, Ohio, used press fittings to make water- and air-tight connections when installing a stainless system at Royal Chemical's Macedonia, Ohio plant. VIP installed approximately 3,000 ft of 316 stainless steel pipe for use with chemical processing equipment.

VIP Plumbing specializes in residential and commercial service, new construction and remodeling throughout northeastern Ohio. The ability to easily press stainless steel opened the door for VIP to install new chemical transport lines for Royal Chemical. The company had worked with Royal Chemical to install plumbing for a new bathroom as well as water and gas lines at its Twinsburg location. When Royal Chemical wanted to replace existing process piping for chemical transport between its storage tanks and mixing tanks

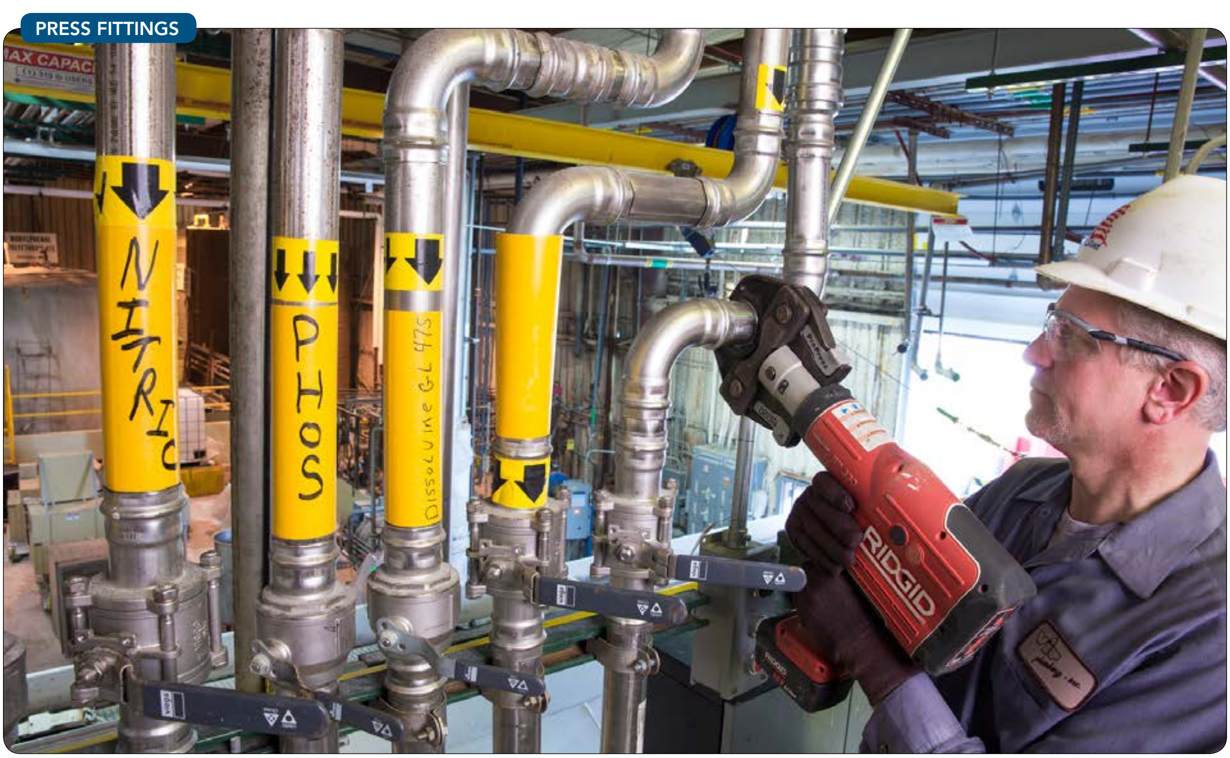

Figure 1. VIP Plumbing used press fittings to make water- and air-tight connections when adding and replacing process lines in a chemical facility.

Figure 2. The pressing tool could get into smaller spaces where welding would not have been an option.

with stainless steel pipe, as well as add additional processing lines to its facility, VIP was able to offer quick, flameless installation using Viega ProPress.

Viega ProPress uses press fittings to make water- and air-tight connections. The system comprises stainless steel pipe, valves and fittings in sizes up to 4 in. It takes less than seven seconds to make a pressed connection, compared to more than an hour for some threaded and welded connections. Its Smart Connect feature helps installers easily identify unpressed connections.

"If Royal Chemical had wanted welded stainless steel, we wouldn't have been the ones to do the installation. VIP Plumbing would not have even submitted a bid on the project if it had to be welded," says Paul Episcopo, president of VIP Plumbing. "By using pressing to join the piping, the labor was cut at least in half. Royal Chemical didn't have to shut down its operation and it was easier to get the pressing tool into smaller spaces where welding would not have been an option."

The process line installation at Royal Chemical was the first project where VIP used Viega ProPress for stainless. The company previously had rented the pressing tool for various copper tubing installation projects to increase time savings or use in environments where water couldn't be shut off for long periods of time.

"For this project, purchasing the pressing tool was a good investment for us and it's also opened up our capabilities to include work on stainless steel systems," explains Episcopo. "It's convenient now that we have the tool — we have done other projects with pressing and we can use the same tool on multiple kinds of pipe."

MATERIALS MATTER

VIP installed 2-in. to 2½-in. Viega 316 stainless steel lines for five mixing tanks and used approximately 130 fittings including tees, 90º and 45º fittings, couplings and 12 three-piece ball valves which are a new addition to the Viega ProPress for stainless product line. The valve features a three-piece construction with a full-port ball that can be removed for repair and maintenance

without removing the press ends from the system. It also features an ISO pad for actuation.

"The original valve that we installed on the nitric acid line didn't work correctly. Our Viega rep introduced us to the new three-piece ball valve that worked perfectly," says Rocky Iammarino, the plumber who performed the work at Royal Chemical. "The three-piece ball valve was perfect for the corrosive chemicals, like the nitric acid. It can be locked and if any of them ever need to be fixed, the valves won't have to be taken out."

For the installation, VIP used a combination of fittings with the standard EPDM sealing element and the FKM sealing element for increased resistance against corrosive chemicals.

"Because Royal Chemical transports caustic chemical through the lines, we knew that they needed fittings with highly chemical-resistant sealing elements," says Episcopo. "We worked with our Viega representative to make sure that the sealing elements were approved for use with the specific chemicals used on those lines."

FLAMELESS INSTALLATION

Viega ProPress for stainless proved to be ideal for Royal Chemical's needs due to the chemical resistance of the materials, as well as the safety and time-savings the flameless aspect of the system offered.

"By using Viega ProPress on this project, we kept Royal Chemical from having to shut down for long periods of time and avoided the need for hot permits that would have been required if the pipe had been installed with welding," notes Episcopo.

During the first phase of the installation, Iammarino installed support brackets and five new lines to replace the original welded stainless steel lines as well as sagging PVC lines. In other phases of the project, approximately 12 lines were installed.

"With all of the supports in place, installing the stainless steel piping is extremely quick," says Iammarino. "We could work around everyone at Royal Chemical and they were able to keep their facility running during the entire process. With the caustic chemicals, a welding installation was out of the question, and threading the pipe would have been much less flexible and more time-consuming."

"Royal Chemical looked into a variety of different materials for their lines. Since the plant is composed of primarily stainless steel for its other systems, it was an easy decision to select 316-grade stainless pipe and fittings for the new lines," Iammarino adds. "Even though it was our first time using Viega ProPress on stainless pipe, we had used it on other pipe material and knew how it worked."

"The security against leaks that the system provides is extremely important with chemical transporting," notes Iammarino. "I was alerted to a fitting that hadn't been pressed yet with the Smart Connect feature that ensures no fitting is left unpressed, and after that fitting was pressed, we pressure tested the lines and there weren't any leaks."

The flameless pipe-joining system allowed VIP to not only complete the installation of the chemical transport lines but also established the company's capabilities in the industrial market. "We are looking forward to getting involved with additional commercial and industrial projects that involve stainless and may not have been in our repertoire prior to our experience with Viega ProPress for stainless," says Episcopo.

VIEGA, headquartered in Wichita, Kan., manufactures press technology that provides an alternative to traditional pipe joining methods such as soldering, welding and grooving. For more information, visit www.Viega.us or call 800-976-9819.

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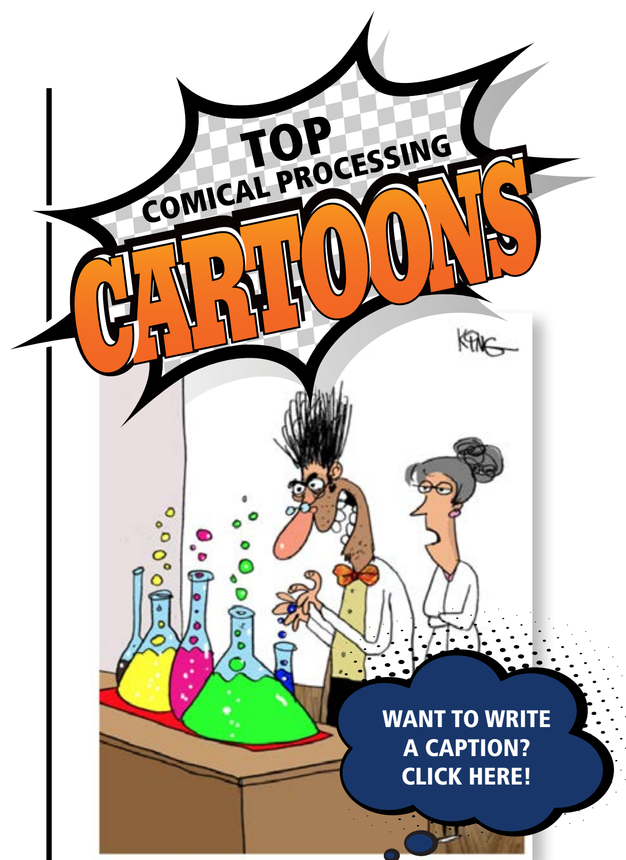

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