A drain line (see arrow) on a discharged bottle failed twice due to high vibration, causing safety hazards and requiring repairs at a refinery.

SMALL-BORE PIPING FAILURES ON THE RISE

Beta Machinery says pulsation studies often overlook branch connections

Small-bore piping (SBP) can be the Achilles' heel of a compressor package.

Beta Machinery Analysis (Beta) said vibration-related SBP failures appear to be increasing due to the growing complexity and instrumentation of compressor packages.

SBP, also known as branch connections, are generally 2 in. (50 mm) or smaller in diameter.

Beta's President, Russ Barss, said SBP vibration is often overlooked because a typical pulsation study does not include the small-bore piping. API 618 guides the design of reciprocating compressor packages to avoid pulsation- and vibration-related issues, but is silent on small-bore piping (see June 2008, *COMPRESSORTech^Two^*).

Gufran Noor, general manager of Beta's field engineering group, said, "During the past few years, our company has experienced a significant increase in field audits for small-bore piping installed at refineries, compressor stations, petrochemical facilities and offshore platforms. Small bore represents the most common type of failure and the most significant risk to a facility."

SBP can include a variety of attachments to vessels and the main process piping. SBP includes temperature/pressure sensors (gauges, taps and thermowells), instrumentation lines or tubing, site glasses, pressure safety valves, blowdown lines, inspection flanges on scrubbers, and drain or vent lines.

Beta said SBP problems occur because the main process piping vibrates due to the normal operation of the machine. Any rigid SBP attached to such a pipe will also vibrate.

Although the vibration level of the main pipe or vessel may be acceptable, the vibration may be magnified for the SBP, depending on the geometry of the cantilevered attachment.

Beta noted that if the SBP is resonant, the vibration can be amplified as much as 30 times higher than the process piping. At these high amplitudes, the risk of SBP failure is high.

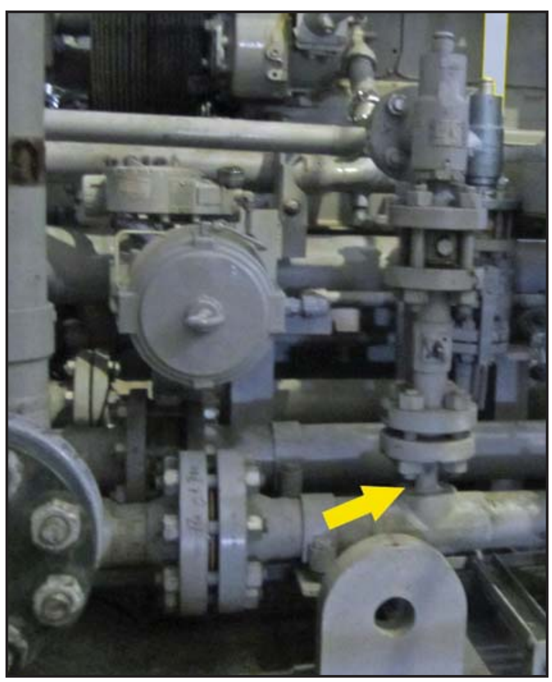
There are numerous resistance temperature detectors (RTDs), relief pipes, gauges and site glasses on a compressor or pump package; and one or more of the SBP components may be resonant sometime during the unit's operation.

The likelihood of high SBP vibration also occurs when compressors or pumps on a package are operating at different speeds, or when variable speed drives are used. And if the operating conditions of the package or the gas composition change from the initial design point, it can create a different vibration scenario.

Barss said variations in SBP fabrication can also result in vibration problems. Because branch connections are small, the installation is often left to shop employees or field installers.

"This means that minor differences can occur in the fabrication, which is why some units might be acceptable while other, so-called, 'identical units' can experience problems," he added.

When SBPs fail, volatile gases and



At a compressor station, this small-bore piping (SBP) (see arrow) failed at the connection to the main piping, causing a gas release and fire.

A field engineer performs a vibration audit, including small-bore piping (SBP), at a facility in Abu Dhabi.

fluids can escape and machinery can be damaged. "At a minimum, the equipment will immediately shut down, causing an expensive production outage while the SBP is repaired," Noor said.

For example, last year U.S. officials ordered an oil pipeline to temporarily shut down following two vibration-related SBP failures. In the same month, a 1 in. (25 mm) pipe cracked at one pump station and a 0.5 in. (13 mm) nipple failed on a pressure transmitter manifold at another station. Both incidents resulted in spills. There are many other examples of SBP failures that occur at gas compressor stations.

Beta said a two-step approach should be taken to proactively address SBP vibration. "Before the compressor package is built, a vibration consultant should evaluate the SBP design. After the unit is commissioned, a vibration check should be conducted to evaluate the SBP as well as the main piping and vessels."

Noor said detecting SBP vibration requires a specialized testing procedure, which is more detailed than the usual API 618 pulsation study.

Jordan Grose, manager of pump services, said, "Of course, small-bore failures are nothing new to the industry. But we're seeing more machines running at higher speeds, which means there are more chances that small-bore piping will be resonant. Another factor is that equipment operators are taking advantage of advances in technology and instrumentation in order to more closely monitor what's happening in their systems. They want more data about pressures, temperatures, flow levels and all sorts of things. These control systems require more sensors and ports — and more small-bore piping."

Grose said, "Unfortunately, industry and industrial standards are not sufficiently equipped to handle the growing SBP vibration problem. The issue certainly deserves to be given much more attention at the design phase."

During the design phase, Beta engineers can work with the equipment owner, the engineering consultant and the compressor packager on techniques to avoid SBP vibration. The problem is that often this service is not specified by the owner or engineering consultant.

Beta's first tenet is that the use of SBP appendages should be avoided whenever possible. If they are necessary, then the unsupported cantilevered mass should be minimized by installing vent and drain valves as close as possible to main piping and bracing the cantilevered mass of the valves to the main pipe. SBP should be made of heavy-wall pipe with reinforced connections. Beta recommends the use of studding outlets if inspection openings are necessary.

Beta field engineers are experienced in SBP vibration problem solving. "This team has analyzed hundreds of compressor and pump sites using specialized test equipment and post-processing analysis techniques," said Noor.

Evaluating the SBP on a typical gas compressor package takes about a half day in the field. The company uses an analysis and modeling technique that it has developed based on actual operational data.

In one such study, Beta evaluated two acid gas (75% H_2S) compressors at a remote location. It found that vibration levels for the compressor frame, cylinders, bottles, scrubbers and piping were acceptable.

But a vibration assessment of small-bore appendages (including blind flanged sets, nozzles, tubing, indicators, etc.) found seven places on the

An oil pipeline is wired for a SBP analysis.

A Beta Machinery Analysis field engineer performing an SBP vibration study.

compressors where vibrations were 200 to 300% higher than the industry guidelines. If any of the SBP connections had failed, a lethal release of poisonous gas could have occurred.

"The company's operations and maintenance staff couldn't check this vibration because they lacked the right type of equipment, software, experience and measurement techniques," Noor said.

Solutions to SBP problems are not always easy to solve. Many barriers exist including end-user equipment specifications that limit what types of equipment are useable and what is not. Unfortunately, some specs create inherently poor SBP vibration designs, Beta said.

One example is to have redundant control system philosophies. In one case, a refinery had tertiary backups to its control system instrumentation, which ended up multiplying every SBP attachment vibration problem by three. The increased complexity, and increased amount of SBP connections, dramatically increased the risk of failure on every poorly designed connection.

Beta estimated that it performs about half of the vibration design studies undertaken in the compression industry. It has worked with customers on these types of issues for 45 years. Beta doubled its workforce in the past five years and has moved to larger quarters in Calgary, Alberta, Canada. It also has staff in Houston, Texas, U.S.A.; Kuala Lumpur and China.

Barss said, "Our expertise includes acoustical and mechanical design, torsional analysis, foundation design, package piping layout, vibration troubleshooting and predictive maintenance for the gas compression, energy, and pulp and paper industries."

The company said its Dynamic Structural Analysis services are also in high demand for offshore production facilities. "Structural vibration can result when large compressors or pumps experience resonance and vibration problems on platforms or FPSOs. These issues are generally costly and complicated to resolve," Barss said. "Most vibration issues, whether structural or small bore, are a lot more affordable, and safer, for our customers if taken care of at the design stage."