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Avoid Splitting Headaches

Ensuring proper control of parallel flow paths demands care

By Andrew Sloley, Contributing Editor

WHEN FLOW goes through parallel paths, both always have identical pressure drops. Flow rates adjust to balance the pressure drops. This often creates situations that don't meet process requirements. In such cases, plants usually install control valves to provide variable pressure drop in one or more parts of the system — to achieve satisfactory flow splits.

Figure 1 shows a typical case of split flow. Path 1 goes through a heat integration exchanger (E1). Path 2 goes through a utility exchanger (E2) to add incremental heat. The control valve on Path 1 (V1) alters the flow to meet the heat integration requirement of the other side of the service. The control valve (V2) on the utility heat adjusts flow to maintain a required downstream temperature.

The flow split between the two paths varies with the pressure drop on exchangers E1 and E2. If they differ in fouling tendencies or cleaning histories, the pressure drop through E2 quite possibly could be low enough that not enough flow would go through E1 even with V1 wide open. This means the heat integration step would remove insufficient heat.

Shifting the control valve position to V3 just may change the problem rather than solve it.

CONTROL OF PARALLEL FLOW PATH

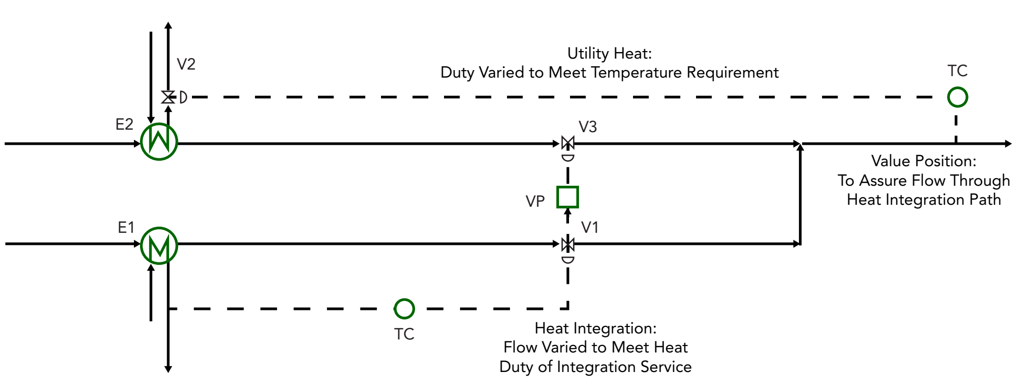

Figure 1. Adding a third valve allows the control pressure drop to be in either path.

With one valve in the V3 position, too much flow may go through E1 even if V3 is fully open. This occurs when E1 is relatively clean.

Depending upon the cleaning history and service requirements, the control pressure drop may need to be in either flow path. Keeping V1 and V2 in their original locations and adding a third valve at V3 provides the needed capability. Many different control configurations are possible. A common one relies on a split-range temperature controller on the E1 outlet to change both V1 and V3. The configuration shown uses a valve position controller. Process characteristics and objectives will determine the best choice among the different options.

Another alternative is to opt for a single three-way valve for controlling the process flow. Figure 2 illustrates two configurations. The first uses a three-way valve in splitting service upstream of the exchangers (V1a). The second puts the three-way valve in mixing service downstream of the exchangers (V1b). The better position will depend upon process characteristics including expected operating temperature, pressure and downstream disposition. The simple system shown combines the two flows. When downstream flows go to different destinations, the splitter configuration usually is used.

Buying and installing one three-way valve typically will cost less than putting in two separate single-flow valves. Nevertheless, plants often avoid three-way valves.

Historically, three-way valves generally were available with linear characteristics. So, systems needing equal-percentage or proportional characteristics weren't seen as good fits for the valves. Today, though, three-way valves come with linear, equal-percentage or proportional characteristics. They even can provide different characteristics for each path.

However, existing plant layout may work against using a three-way valve. If a single-flow valve already is in place, adding a second one

USE OF THREE-WAY VALVE

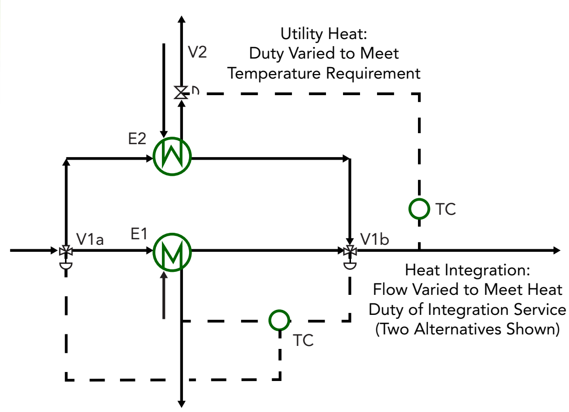

Figure 2. Valve can be located upstream to split streams (V1a), or downstream to mix them (V1b).

often is cheaper than installing a three-way valve and doing the necessary piping reconfiguration.

In many systems, using a three-way valve creates a new common-mode failure case. Failure of the single three-way valve affects both E1 and E2. While failure of single-flow valves in parallel piping also causes interactions, the effects often are different. In some systems, the extra failure mode is relatively unimportant — for example, when a common failure mode already exists and contingency has been designed into the system. In other cases, addressing the new common-mode failure incurs extra expense to keep the plant safe.

Other requirements such as tight shutoff and special startup, shutdown or minimum flow requirements also might make a three-way-valve application more difficult.

Three-way valves are useful devices that deserve to be considered more often in process plants. However, you always should thoroughly check the possible implications of their use in an application.

ANDREW SLOLEY, Contributing Editor
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Apply Wet Screw Compressors Wisely

The machines suit many applications but pose a number of specific issues

By Amin Almasi, rotating equipment consultant

ITS COMPACT design, relatively low cost, pressure ratio capability per stage, high efficiency and good reliability make a wet screw compressor the best choice for numerous small- and medium-size applications. Such machines, which also are called "oil-flooded" or "oil-injected," offer the same performance advantages as reciprocating compressors, mainly a constant (adjusted) capacity under varying pressures and a high efficiency. In addition, screw compressors boast the same advantages as centrifugal compressors with respect to reliability, availability and small footprint. Wet screw compressors don't have a surge limitation (which is the main restriction of centrifugal and axial compressors). Also, they don't present high pulsation amplitudes and cylinder valve issues (which can pose major problems in reciprocating machines).

A wet screw compressor contains male and female screw rotors, with the 4/6 combination (4 male lobes and 6 female flutes) traditionally popular at process plants. The compressor uses a slide-valve capacity control system to regulate the volume flow; this system can offer step-less control (usually in a 20–100% range) and excellent energy efficiency.

Because of the high volume ratio, the internal pressure ratio can be high, which is a great advantage for medium-pressure applications. For best efficiency, the volume ratio should be set so the machine's internal compression ratio matches the system compression ratio. For optimum efficiency, internal clearances within the machine should be kept as small as possible. The presence of a large quantity of oil during the compression process lessens the chance of contact between the screw rotors.

THE OIL SYSTEM

Oil injection in the compressor results in simpler, less-expensive and more-reliable operation. The oil enables control of the compressed gas temperature, which permits relatively large pressure rises across the compressor. It serves as sealant, partially filling the clearance between rotors, and the rotor and casing. The oil, which covers all the metal surfaces in the compression chamber, also acts as a significant

Figure 1. A higher length-to-diameter ratio increases capacity at a given speed but may decrease permissible differential pressure.

barrier to corrosion and thus allows the compressor to handle difficult gases. (Selecting the proper oil is critical for tough services.) Another important feature is that the oil dampens noise.

The oil is injected in the region where gas compression is taking place (the oil can also enter from the bearing). It absorbs around 70–85% of the heat generated by gas compression. Commonly, a pumped oil circuit serves the bearing and seal while a pump-less circuit supplies the suction injection. For a pump-less oil-injected machine, gas discharge temperature could remain relatively constant over a wide range of operation (for example, within 10–15°C at varying pressure ratios). With a pumped system (forced-oil injection), gas outlet temperature usually can be maintained more tightly. The forced-feed oil-injection system could be a reliable option for large (critical) screw compressors.

Always check the compatibility of the injected oil with the process gas — to avoid risks of process system deterioration or oil degradation. Examine the entire downstream system; the oil shouldn't cause problems in exchangers, reactors, etc.

Recovery of oil from the discharge gas is an important consideration. The oil separator usually uses coalescing filter technology. If vapor-phase oil carryover is a significant concern, put in two oil separators and install an after-cooler (to condense vaporized oil) between the primary and secondary oil-separator vessels. Usually, oil content (including vapor, aerosols, etc.) ranges from 1 to 5 ppm. Services requiring lower residual oil content (for example, 0.1–0.5 ppm or even less) may need a three-level oil-separator system; these systems require more-than-usual attention.

For special applications, a liquid other than oil may be injected. For instance, water-injected two-stage screw compressors are popular where gas tends to polymerize. Other types of compressors such as centrifugal ones wouldn't work in these difficult services because of rapid polymerization.

COMPRESSOR COMPONENTS

The screw rotor length-to-diameter (L/D) ratio usually falls in range of 1.1–2.2/1, with 1.5–1.9/1 most common. Using larger ratios can increase the capacity at a given speed but might reduce the permissible differential pressure — with long, slender rotors, this may be as low as 4 bar. Short (stubby) rotors can accept differential pressures of 24 bar. A single stage of compression can handle most chemical processing duties. However, for pressure ratios between 15 and

Figure 2. For small- and medium-size applications, the compressor is installed on the oil separator vessel (horizontal vessel), resulting in a compact package.

24, a two-stage screw compressor will afford better efficiency.

Screws commonly are made of carbon steel (Figure 1) but other materials can be used whenever carbon steel isn't compatible with process conditions.

The compressor usually is driven by direct coupling to an electric motor (Figure 2). Sometimes a gas or diesel engine serves as the driver (Figure 3); it usually requires an intermediate gear unit.

Large and medium (above 500 kW) screw compressors generally use sleeve bearings. Small screw compressors employ rolling-element (anti-friction) bearings. The compression of gas in screw compressors can result in considerable axial force; this force should be resisted by an axial (thrust) bearing. The thrust bearing is a critical component in a screw compressor.

Mechanical oil seals are most common. Shaft seals should be accessible for inspection and replacement without opening the casing.

SELECTION FACTORS

The wet screw compressor originally fit the area between centrifugal and reciprocating compressors. However, its application areas have expanded. Large wet-screw compressors (say, above 3.5 MW) now cross into the centrifugal compressor area. The smaller ones completely overlap reciprocating compressors in capacity and power.

Advantages. Potential benefits of a wet screw compressor compared to a centrifugal machine include:

- considerably reduced sensitivity to gas molecular weight changes;
- higher efficiency;
- for medium sizes (up to 4 MW), lower cost and better performance;
- high ratio pressure capability; and
- direct connection to the electric motor driver, eliminating speed-increasing gear units.

Compared to a reciprocating machine, a wet screw compressor boasts:

- capability to accept more liquid and entrainment;
- considerably less maintenance;
- higher reliability and availability;
- smaller size (for a compact design);
- lower cost; and
- the possibility of doing without a spare machine.

Wet screw compressors commonly are used in range of 100 kW to 3.5 MW. Capacities typically

Figure 3. Large screw compressor is mounted on package skid (heavy-duty baseplate) near the suction drum and the oil separator vessel (vertical vessels).

range from around 400 m^3/h to approximately 18,000 m^3/h. The compressors usually are applied for discharge pressures up to around 50 barg (for vertically split casing designs). Some very large screw compressors (usually with horizontally split casings) are available for capacities as high as around 50,000 m^3/h — but they have limited pressure capabilities (say, below 17 barg).

Operational flexibility is another advantage. Starting-up a wet screw compressor with nitrogen and then gradually bringing in the process gas mixture doesn't change the performance (if the selected oil is suitable for all the compressed gases). This is a great advantage compared to dynamic compressors such as centrifugal ones.

Disadvantages. Although horizontally split casing screw compressors can provide high capacity, they only are made by a few companies and rarely are used. So, realistically, the maximum capacity of a wet screw compressor is 10,000–20,000 m^3/h, depending upon the application. (Above these limits, use a centrifugal machine.) The biggest frame that many screw compressor manufacturers can offer is limited to 2.5–4.5 MW, depending upon the service. In other words, a wet screw compressor only can cover small and medium ranges. There also are some pressure capability limits, say, 25–55 bar, depending upon the application.

Oil carryover is the biggest problem. It has afflicted a wide variety of services. If an application requires a dry gas, don't consider a wet screw compressor.

It also might not make sense for handling complex process gases that may change composition over time — unless at least two successful references exist for the application. For example, process gases containing a considerable amount of relatively heavy hydrocarbons that can dissolve into the oil can cause breakage of the oil film at the bearings and could lead to wear and other problems. Advanced synthetic oils can lessen this issue but are expensive. (A reciprocating compressor probably is the best option.) Flare gas recovery applications also pose challenges in selecting an oil that can operate successfully in the wide range of gas compositions encountered. (A liquid ring compressor is a better choice.) Gases containing corrosive or sour traces, particularly gases that can contaminate the oil, can create problems for the compressors.

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Many processors still prefer low-speed, long-stroke reciprocating compressors to wet screw compressors for various small- and medium-size applications — feeling the proven track record of reciprocating machines outweighs the first cost advantage of wet screw compressors. The reality is that reciprocating compressor technology is more mature than that of wet screw compressors. There's lots of accumulated knowledge and experience in the design, fabrication, operation and troubleshooting of reciprocating machines. (Reciprocating compressors are the best choice for some specific applications — such as ones involving small flows, light gases and high-pressures.)

Always consider the capacity, the pressure and the service (particularly successful references for it) in compressor selection. Carefully evaluate all plant-specific requirements and all aspects of offered compressors.

PERFORMANCE

Because of their high availability and reliability, screw compressors built by reputable manufacturers (particularly machines manufactured according to API 619) are popular for single stream installation, i.e., without a spare. However, straying far in operating pressure or — in particular — temperature from design conditions can lead to deformations that generally exceed the specified manufacturing tolerances. In other words, off-design operations could result in screw rotor rubbing, permanent material loss and efficiency reduction.

To more realistically evaluate the behavior of a wet screw compressor package, the shop performance test should use the application's gas and oil. If using these isn't feasible, perform the test with a gas (usually a mixture of inert gases) of molecular weight and isentropic index value (known as the "k") equivalent to the job gas across the specified operating envelope, and carefully note the characteristics of the oil.

Critical issues with the performance test are:

- the guaranteed power (usually a 3–4% allowance is acceptable); and
- covering the full operating envelope, particularly the low and high suction pressures.

The oil flush prior to start-up is critical. A wet screw compressor is sensitive to particulates in the oil. Monitoring of oil pump discharge pressure is important; it should be set to around 3 bar above the compressor gas discharge pressure.

AMIN ALMASI is a rotating equipment consultant based in Brisbane, Australia. E-mail him at amin.almasi@ymail.com.

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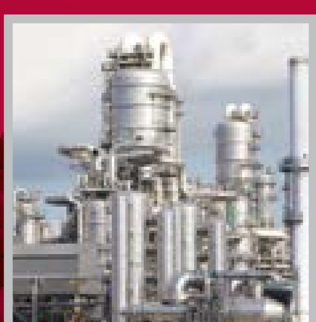

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Case Study: Speed Pipe Installation

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 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

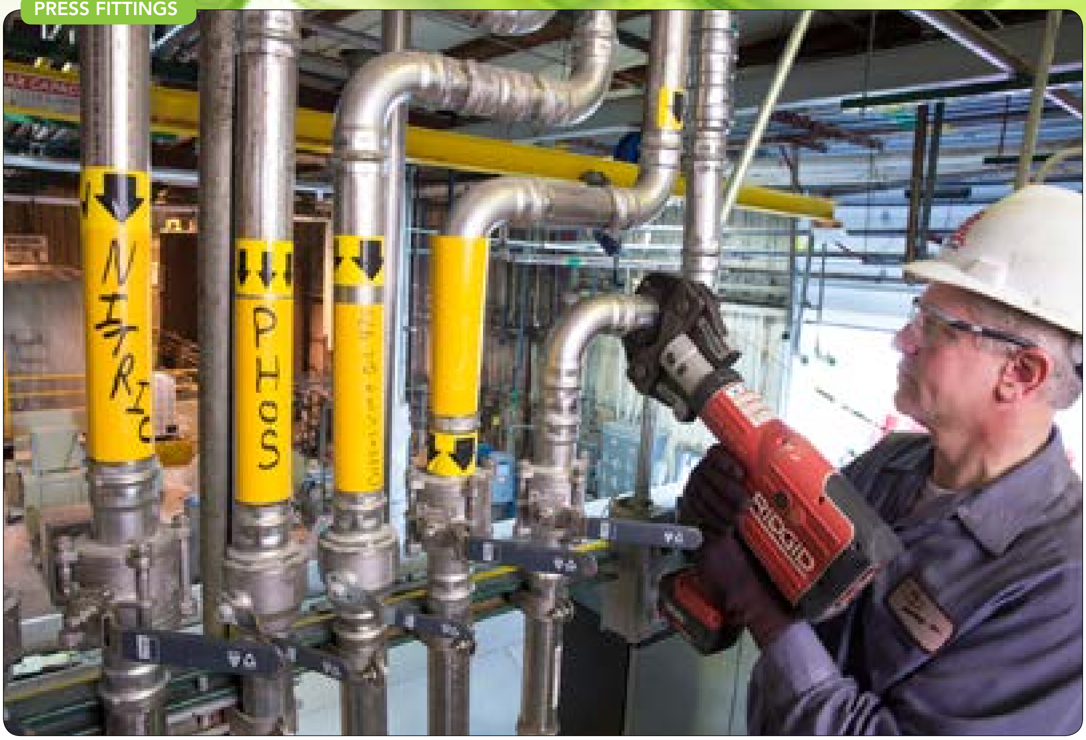

Figure 1. VIP Plumbing used press fittings to make water- and air-tight connections when adding and replacing process lines in a chemical facility.

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, 90° and 45° 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.

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

"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.ViegaProPress.us or call 800-976-9819.

Overcome the Challenges of Changing Gas Composition

New technology addresses need for more accurate and efficient biogas measuring

By Scott Rouse, Sierra Instruments

AS OIL prices remain high, we are in the midst of a nation-wide initiative to seek renewable sources of energy to increase energy efficiency and energy security. Renewable energy accounted for 13.2% of the domestically produced electricity in 2012.

Among the sources of renewable energy is the production of biogas from landfill gas (LFG) or digester gas. The production of biogas is an anaerobic process in which micro-organisms break down (digest) biodegradable material in the absence of oxygen. This biogas is then processed and used as fuel for cogeneration engines or sold to the national energy grid.

To monetize biogas and create the most efficient fuel sources, it is critical to accurately measure how much biogas is produced in each stage of the process. Accurately measuring biogas is an inherently challenging application with its changing gas composition, low pressure, and dirty, wet gas. Finding an accurate mass flow meter measurement solution for this challenging application increases a facility's efficiency and revenue stream due to increased biogas and energy production.

SOURCES OF BIOGAS

Many large wastewater treatment plants have digester tanks that use sewage sludge as the biodegradable material. During the process, the microorganisms in the air-tight digester tank transform sewage into a mixture of primarily methane (CH_4) and carbon dioxide (CO_2), producing renewable energy that can be used for heating, electricity or to fuel internal combustion engines.

Harnessing biogas from landfills is a quickly growing source of biogas. The Environmental Protection Agency estimates that there are approximately 6,000 landfills in the United States contributing an estimated 650 billion cubic feet of methane per year. Landfill gas, containing mostly CH_4 and CO_2, is produced by wet organic waste, decomposing under anaerobic conditions in a landfill which is covered and mechanically compressed by the weight of material deposited from above.

BIOGAS COLLECTION AND USE

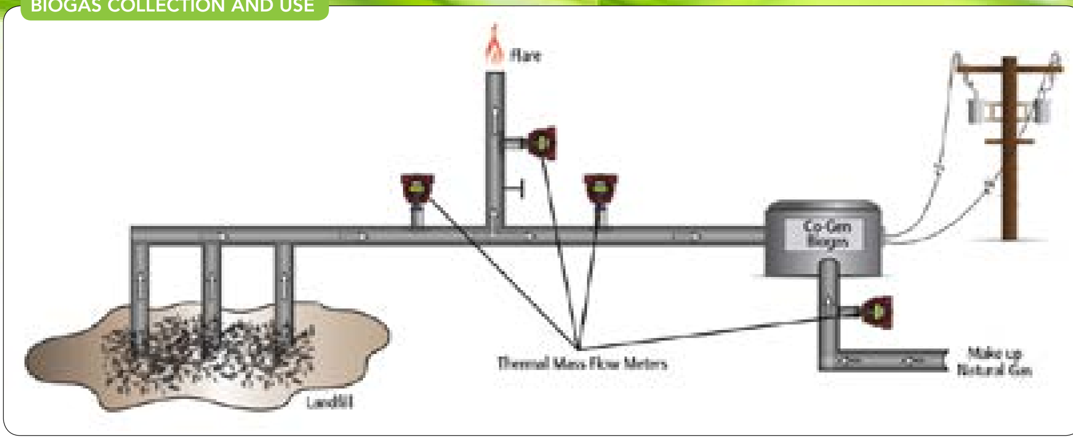

Figure 1. Facilities managers must accurately measure the flow rate of the biogas and natural gas to get the optimal heat value and energy potential from their biogas production facility.

This material prevents oxygen exposure thus allowing anaerobic microbes to thrive.

As seen in Figure 1, this gas builds up and is slowly released into the atmosphere.

Much like digester gas at wastewater treatment plants, large landfills collect and use biogas for energy. Its heating value is around 600 BTU per cubic foot (21 BTU per liter), depending on its composition.

In contrast, natural gas contains about 80% methane, with a heating value of around 1,000 BTU per cubic foot (35 BTU per liter). Filtering biogas, or "scrubbing" it, can remove the carbon dioxide and other impurities, raising the heating value. As shown in Figure 1, natural gas may be added to the biogas in order to raise its heating value. In all parts of this process, facilities managers must accurately measure the flow rate of the biogas and natural gas to get the optimal heat value and energy potential from their biogas production facility.

DIFFICULT TO MEASURE

The flow measurement challenge in biogas applications is the fact that the composition of biogas varies depending upon the source. Biogas typically contains about 55%–65% methane, 30%–35% carbon dioxide, and some hydrogen, nitrogen and other impurities. However, a representative compositional analysis (in volumetric percentage), shown in Table 1, shows the wide ranges in methane composition between 50%–75% and carbon dioxide between 25%–50%. This represents how the biogas composition can change over time with changing conditions in the landfill or in the digester tank. Such variable composition makes biogas very difficult to accurately measure.

Most flow meters are calibrated for one specific gas mix composition; thus they can't provide accurate mass flow meter readings if the composition changes without sending the meter back to the factory for recalibration.

The driver for capturing and measuring biogas from landfills and wastewater treatment plants is to produce efficient energy sources if used for co-generation or to meet EPA requirements if flared.

In co-generation, facilities managers are dependent on accurate flow measurements of biogas produced, even with its varying gas composition, so they know exactly how much natural gas to add to the biogas, creating fuel with the highest heat value or BTUs. If biogas heat values are too low due to gas composition changes and other factors,

COMPOSITION OF BIOGAS OVER TIME

Typical Composition of Biogas

COMPOUND	MOLECULAR FORMULA	PERCENTAGE
Methane	CH_4	50–75
Carbon Dioxide	CO_2	25–50
Nitrogen	N_2	0–10
Hydrogen	H_2	0–1
Hydrogen Sulphide	H_2S	0–3
Oxygen	O_2	0–0

Table 1. Varying gas compositions make accurate measurements difficult.

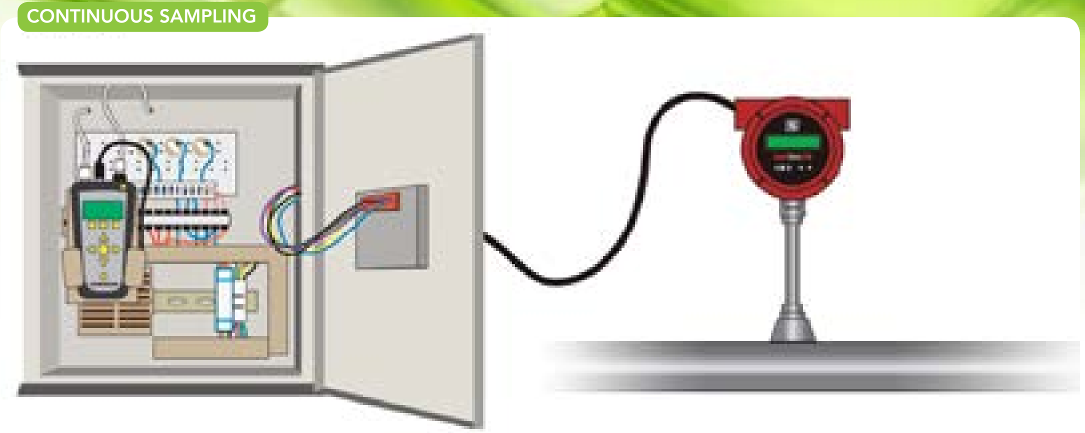

Figure 2. In this complex system, the landfill gas is sampled (using a chemical cell) and the CO_2 content is analyzed and a mini computer uses this compositional data to correct the flow rate.

the optimal amount of natural gas won't be added and co-generation won't be efficient. This heating value of the biogas, thus the gas composition, is also critical in combustion systems — boilers, turbines, or fuel cells-for producing space heating, water heating, drying, absorption cooling and steam production. The composition of the gas used in gas turbines and fuel cells to produce electricity is directly related to the efficiency of such devices and thus to the profit at which the electricity produced can be sold. The same is true of stationary or mobile internal combustion engines where composition is related to shaft horsepower, electricity cogeneration efficiency and vehicle MPG. Finally, if the biogas is sold to the natural gas grid, custody transfer is based on the composition.

MEASURING VARIABLE COMPOSITION

Because biogas composition is critical to its energy producing value, facilities need to assess the best flow meter measurement technology to manage compositional changes. Many companies with varying technologies are interested in measuring the biogas as it leaves the landfill or digester tank, but this is a challenging application for many reasons:

Varying gas compositions (see Table 1) make accurate measurements difficult because most meters are calibrated for one gas or mixture; when the composition changes, the flow measurements are no longer accurate and the meter must be recalibrated.

Low pressure makes differential pressure (P) devices such as orifice plates unsuitable since they require a fairly large differential pressure to operate.

Biogas is often very dirty with a high moisture and particulate content, which can clog up devices such as annubars and orifice plates, and gum up turbine meters and similar instruments that have moving parts.

Traditionally, thermal mass flow meters have been the instrument of choice. They offer reasonable accuracy for the price (2% of reading) and use a convenient insertion design that eliminates pressure drop. They also have no moving parts and can measure both high and low flows with a 100:1 turndown.

While such meters do many things well, one thing they can't do is account for changes in biogas composition. These flow meters must be calibrated for a specific biogas mix and rapidly lose accuracy if gas composition changes, which means the instrument must be sent back to the factory to recalibrate for the changing gas composition, wasting time, resources and money.

One way to account for variable composition would be with a continuous real-time sampling system integrated with a flow meter. A few systems are available with more in development, but integrating such a system into a flow measurement system is typically expensive and high-maintenance.

Figure 2 shows the complexity of such a system. The landfill gas is sampled (using a chemi-

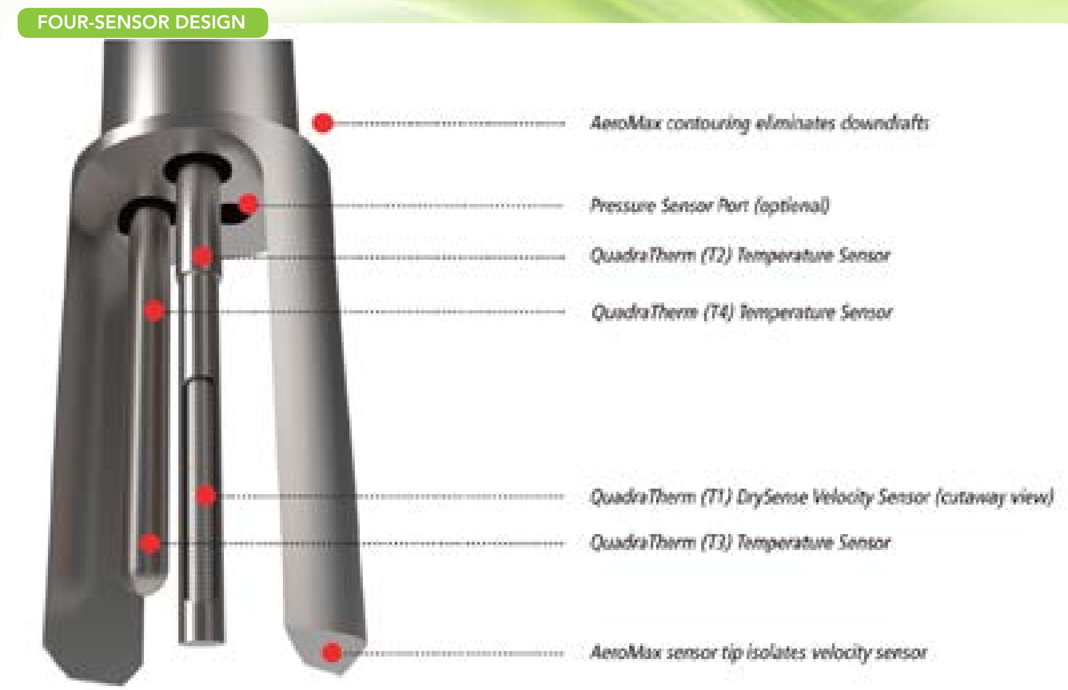

Figure 3. New four-sensor quadratherm technology accurately measures and manages biogas even with its changing gas composition.

cal cell), the CO_2 content is analyzed and a mini computer uses this compositional data to correct the flow rate.

In general, while biogas composition does change over time, it doesn't change that quickly. In current practice, the composition of the biogas is calculated by periodic manual sampling of the various digesters or landfill collection points, avoiding the need for an expensive system shown in Figure 2.

Ideally, composition management would be moved into the flow meter itself. Recent advances in the field of thermal technology make this possible for the first time.

MANAGING CHANGING COMPOSITIONS

Thermal technology has undergone significant advancements, moving from two-sensor to four-sensor technology (see Figure 3) which yields unprecedented accuracy for thermal insertion flow meters of ±0.75% of reading (far better than the 2.0% reading possible previously with other thermal technologies). New four-sensor quadratherm technology, developed by Sierra, offers accurate measuring and managing of biogas even with its changing gas composition.

Along with this four-sensor technology, traditional analog measurement circuits, like the Wheatstone bridge, have been superseded by more powerful hyper-fast microprocessors that run comprehensive flow-measurement algorithms to compute mass flow. This proprietary algorithm set serves as the “brain” of the mass flow meter, using inputs from the four sensors to solve the first law of thermodynamics for the sensor in the biogas flow stream. This allows for precise calculation of heat convected away by biogas mass flow, thus providing accurate mass flow measurements in a fraction of a second. This algorithm also allows for management of gas composition because recalibration every time the gas changes is no longer required.

By combining four-sensor technology with

Figure 4. The four-sensor quadratherm mass flow meter manages changes in multiple biogas measurements including composition, mass flow rate, temperature and pressure.

this algorithm set, the meter has the capability to change gas and compositions without losing accuracy. This new technology creates many benefits:

The meter can hold up to four user customizable gas mixtures onboard and store biogas composition in a proprietary gas library, easily accessed through user software.

Engineers and operators have access to this gas library which contains all the gas properties needed to make algorithmic gas mass flow rate calculations.

Once sampling has determined the biogas composition, operators can use a simple software tool to create and name a proprietary biogas mixture. This tool uses the internet to download the gas properties of new mixtures and then uploads the new mixture into the meter in the field.

This allows operators and engineers to use just one meter with one calibration for varying gas compositions. This offers a major cost savings over expensive continuous sampling devices.

FOUR-SENSOR THERMAL TECHNOLOGY

The four-sensor quadratherm mass flow meter pictured in Figure 4 meets the criteria for successful biogas measurement by managing changes in:

- Gas composition
- Gas mass flow rate
- Gas temperature
- Gas pressure
- Outside temperature
- Pipe conditions (size and roughness)
- Flow profile

These changing conditions can all be managed with accurate readings without sending the flow meter back to the factory for recalibration, reducing downtime and saving money. Traditional two-sensor thermal flow meters need to be sent back to the factory for recalibration each time the gas composition changes or the application specification changes, so over the lifetime of the product, thousands of dollars will be saved in calibration costs, shut downs and loss of gas monetization through loss of accuracy.

In the effort to harness biofuels such as biogas, the demand for accurate flow measurement for varying gas compositions is growing. Finding the best flow meter for this biogas measurement technology is critical for optimizing the energy yields of biogas production. With these new advancements in four-sensor quadratherm technology, operators now have higher accuracy with changing gas composition and more field flexibility. This allows operators to monetize biogas and use it to get the top efficiency out of cogeneration gas engines and enables highly accurate custody transfer of gas to the collection system.

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Increase Process Availability

Coriolis mass flow meters provide reliable indication of gas entrainment

ENTRAINED GAS can disturb the sensitivity of mass flow measurement of liquids, decreasing accuracy or even stopping measurement completely. New Coriolis mass flow meter technology has come on the market that ensures both stable and uninterrupted measurements with high gas content. The new meters, including KROHNE's Optimass 6400, offer reliable indication of gas bubbles in the process by using a combination of various measurements to detect a two-phase flow. With values between 0–100% gas or air content in the line, it maintains continuous mass density measurement and provides measured values at all times. At the same time, it can report the two-phase status and output a preconfigured alarm, in accordance with NAMUR NE 107 requirements.

CAUSES OF GAS ENTRAINMENT

What is gas entrainment and why does it matter? Gas entrainment refers to the presence of gas bubbles in a process. It can occur for many reasons and — particularly in terms of sensitive dosing processes — cause aggravation and headaches for users. Gas bubbles can form, for example, due to degassing; leaks upstream of, or in, a negative pressure area; excessive cavitation and levels falling below the minimum in supply containers, as well as agitators in tanks or long drop distances for media into tanks. However, they can also occur due to status transitions in process control, such as when starting or shutting down the system, or cleaning it.

Other examples include production processes in which gas bubbles are introduced deliberately and the gas flow is measured upstream of the sprayer. This can happen, for example, in the production of shower gels, or processes in which the bubbles are used for control purposes.

The effect of gas entrainment shouldn't be underestimated, because it affects process control measurements and thus results in unreliable product quality. Because of this, NAMUR recommendation NE 107, "Self-monitoring and diagnosis of field devices" for smart flow measurement processes classifies the presence of entrained gas

as an error condition in the highest category, Category 1.

On the other hand, some in the industry caution against making this a bigger problem than necessary, arguing that gas entrainment actually occurs in significantly fewer processes than measurement devices might suggest. "Gas bubbles in chemical processes are one of the most frequent reasons that system operators call service employees to test a supposedly faulty device," explains Frank Grunert, global product group manager for Coriolis mass flow meters at KROHNE. "The user is often astonished to find that the meter is measuring according to specifications and the unexpected gas content can be discovered based on the saved density changes."

MEASUREMENT CHALLENGES

The reason for these measurement difficulties stems in part from the gas measurement technology used. From a measuring technology standpoint, gas entrainment is considered a liquid-gas flow, one of the most frequently observed forms of two-phase flows. Many measured values are required to characterize a two-phase flow, including the percentage volume of the dispersed phase in the continuous phase, the densities of both phases, the morphology (size, shape, distribution) of the dispersed phase that occurs, the viscosity of the continuous phase, the operating pressure and the surface tension of the continuous phase.

Liquid-gas flows demonstrate very different characteristics, and currently there's no measuring principle that can measure all of the parameters. A combination of various measuring principles helps to create a better description of these flows, but the technical effort and expense for such a system would be quite high.

The Coriolis mass principle is very well suited for detecting gas entrainment because it precisely recognizes mass and density changes in the measurement substance. However, until recently gas entrainments posed a great challenge for Coriolis mass flow meters. The relative movement of the different phases damps the vibration of the measuring tube, and this damping leads to inconsistent vibration amplitudes of the measuring tube. These inconsistent amplitudes then interfere with the electronics' capability to determine the actual resonant frequency of the measuring tube.

In addition, the damping effect caused by the gas content in the liquid in the electro/mechanical driver system of the Coriolis mass flow meter can be larger than the driver input power. If the vibration of the measuring tube can't be maintained, the result, in an extreme case, is the interruption in measurement.

NEW MEASUREMENT TECHNOLOGY

Fortunately, new technology now is coming on the market to counteract both these effects. For example, KROHNE recently developed the Optimass 6400, which detects and signals gas entrainment reliably and maintains the active measurement in all measuring conditions with gas content from 0–100% by volume. The device is "gas bubble resistant." The measuring sensor and signal converter were designed to offer complete digital signal processing, from the production of the drive oscillation of the measuring tube to the

evaluation of the sensor signals. In this way, it's possible to reliably detect changes in the process and accurately indicate the actual conditions in the production line.

For many years, digital signal processing has been used in Coriolis mass flow meters, but initially, it was used only in the evaluation of the sensor signals. Until recently, an analog signal circuit was used for drive vibration that amplifies the measured resonant frequency of the measuring tube and returns it to the measuring tube as an impulse signal.

In the case of gas bubbles, the vibration signal is disturbed due to the transients in the damping and the density of the medium. With the analog drive system disturbance recorded and amplified, the impulse signal is disturbed as well. This means a loss in output because the excitation only occurs in the resonance of the measuring tube, which is not efficient, and also leads to a fault in the frequency measurement. Both end up increasing deterioration of the measurement of the tube oscillation and, as a result, the mass flow measurement. They also risk losing control of the driver system, which requires a restart of the meter before measurement can be restored.

The new technology used in the Optimass 6400 has a synthetic driver oscillation and high resolution digital signal processing. The oscillation is produced using a digitally generated — and therefore known — impulse frequency. The measuring tube oscillation occurs due to this impulse, so the frequency of the measuring tube is known precisely. This connection doesn't change, even with gas bubble disturbance. The control loop remains "clean" and isn't disturbed by interspersed and amplified frequencies. In this way, the Optimass 6400 can accurately measure amplitudes and phases, even in disturbed conditions, and regulate them in the resonance. The device remains in continuous measuring operation, even if there's gas content or air pockets of 0–100% by volume in the medium.

Different indicators for gas bubbles are set in the signal converter, which use cross-sensitivities to combine two or more indicators for a reliable diagnosis. According to NAMUR NE 107, the most important requirement is that the results of the diagnosis be reliable, so that the user can take the correct actions.

For many users, a crucial criterion for selecting a measuring device is the accuracy with which it measures the occurrence of gas bubbles. Despite the advances in technology, practice demonstrates that even with these devices, gas bubbles cause changes in the processes. This results in variations of accuracy with mass flow measurement, depending on the process conditions and the system operation of interest to the customer. In addition, gas bubbles can vary widely in size and frequency of occurrence. Likewise, changes in temperature, pressure or viscosity need to be considered. Therefore, users still have to be cautious regarding accuracy of the various available measurements in indicating the occurrence of gas bubbles and changing process conditions.

KROHNE, INC., Peabody, Mass., is a manufacturer and supplier of industrial process instrumentation. For more information, visit http://us.krohne.com.