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Evaluate Flow Equipment: **Sealless Pumps, Nozzles and Settlers**



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PRODUCT FOCUS

MEGAPRESS FITTINGS HELP REDUCE PRODUCTION DOWNTIME

For manufacturing facilities, MegaPress stainless press fittings will dramatically reduce the time required to make pipe repairs compared to other pipe joining systems, the company says. Faster repairs mean shorter periods of production downtime, reducing the potential for losses in revenue.

Designed for iron pipe size (IPS) stainless steel, the new line of Viega stainless fittings makes secure connections in seven seconds or less, reportedly reducing installation time by up to 60% compared to welding or threading. The fittings also are equipped with the Viega Smart Connect feature, which allows installers and maintenance personnel to easily identify unpressed connections during pressure testing.





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PRODUCT FOCUS

LIQUID ULTRASONIC FLOW METER MEASURES THERMAL ENERGY

The [InnovaSonic 207i](#) transit-time ultrasonic liquid flow meter is designed, built and calibrated for non-intrusive liquid flow metering, and optimized for thermal energy/ BTU measurement.

The meter offers accurate measurement of speed of sound in an ultrasonic flow meter through its Raptor OS. Because an ultrasonic flow meter detects the speed of sound in the liquid being measured, a small change in liquid density can have a big impact on accuracy and repeatability. By adding a temperature input from a transmitter, or using an external input from an existing transmitter, the 207i can calculate real-time liquid density. This ensures the highest accuracies of $\pm 0.5\%$ of reading from 0.16 to 40 ft/s (0.05 to 12 m/s), says the company.

The flow meter also calculates thermal energy / BTU flow energy by determining the amount of heat transferred between the cold and hot flow legs of a heating or cooling process. This helps end users manage energy costs.

No pipe cutting or expensive plumbing is required to install the flow meter's clamp-on sensors. With its visual sensor spacing tool on the local display, or by using the software app, end users can move the sensors together or apart to position the indicator line between the "goal posts" and ensure optimal signal strength and a correct installation. [Watch this video](#) to see how it's installed.

The flow meter comes with a software package of apps for ease of use, field upgrades, and calibration validation. [Watch this video](#) for more information.



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Select the Right Sealless Pump

Understand the advantages and limitations of the two main options

By Amin Almasi, rotating equipment consultant

Centrifugal pumps comprise over 90% of all pump installations in the chemical industry. They have proven to be the most economical pumps in various services; they require much less maintenance and operational efforts than other pump types. A centrifugal pump usually includes a casing (housing) having a cavity, a suction and a discharge; a shaft located in the cavity has an impeller (or impellers) positioned to receive liquid from the suction and exhaust that liquid to the discharge. Unfortunately, problems with shaft seals often arise — indeed, seals cause more than half of all unscheduled shutdowns of centrifugal pumps.

Many plant operations can't tolerate any leakage of liquids for safety, environmental or economic reasons. Yet, some difficult

services pose a nightmare for seal selection. This has spurred the development of sealless centrifugal pump technologies.

Sealless versions now are available for all common centrifugal pump designs: end-suction top-discharge used for single-stage pumps; top-suction top-discharge used for multi-impeller horizontal pumps; and multi-impeller vertical pumps (sometimes with 30 impellers or more) used for high-pressure applications.

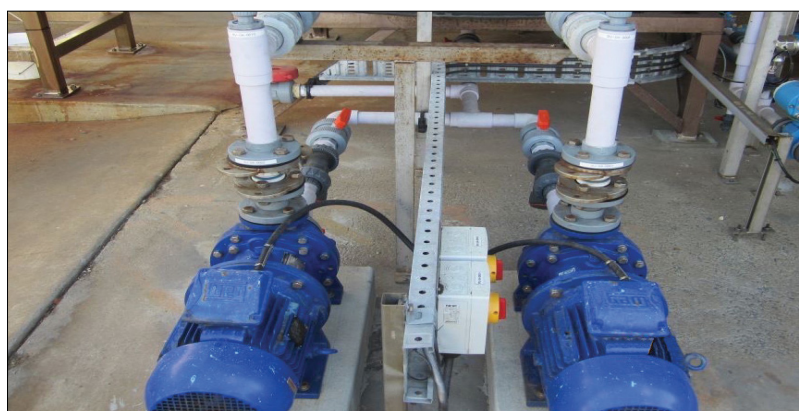
Magnetic drive units are the most common sealless pumps at chemical plants but submerged motor pumps also find wide use. Both types of pumps have proven themselves over many years in a variety of different services.

MAGNETIC DRIVE PUMPS

These are close-coupled pumps that can be quickly and easily stripped and re-built in the field; most often they don't require traditional alignment. Such units (figure 1) usually handle corrosive or difficult liquids; materials of wetted parts must suit the particular liquid.

Magnetic drive pumps have some limitations and disadvantages. For instance, they don't come in large sizes and with high power ratings. Many internally circulate the liquid being pumped for bearing lubrication and cooling; so, those pumps aren't appropriate for some applications, such as ones involving liquids susceptible to forming scale.

Magnetic drive pumps also should not run dry. While that's more or less true for centrifugal pumps in general, a magnetic drive pump is more vulnerable to damage from dry running because the pump liquid provides



MAGNETIC DRIVE PUMPS

Figure 1. Such units are the most common sealless pumps used at chemical plants.

bearing lubrication. Some manufacturers have developed bearing materials and coatings that are more forgiving of upset conditions and can run dry for a limited time; this also depends on the particular pump's details and service. Upset conditions often result in some liquid remaining in the pump; this aids in bearing lubrication and prevents the bearings from breaking during brief dry-run periods. Hopefully, advances in bearing technology eventually will allow dry running for extended periods.

The magnet system transmits all the pump power and so requires special attention. A straddle-mount-

ed design with bearings on either side of the inner magnet provides excellent stability and operation; this modern design reduces radial loading and allows the pump to better tolerate off-peak operation — and is far superior to the old-fashioned overhung inner magnet design.

RECIRCULATION FLOW

Every magnetic drive pump has a recirculation flow system — usually either discharge to suction or discharge to discharge. In the discharge-to-suction design, the fluid enters the magnetic coupling area at a high-pressure discharge point and returns to the

bulk flow at the suction eye of the impeller. In the discharge-to-discharge design, the fluid enters the magnetic coupling area at a high-pressure discharge point and returns to the bulk flow at a point behind the rear shroud of the impeller. Each design has its advantages; so, make the choice between them on a case-by-case basis. Other recirculation flow paths and designs also are available in special magnetic drive pumps.

In the discharge-to-suction design, the flow is routed to the suction through either thrust balance holes in the impeller or through a hole along the axis of the pump shaft. The differential pressure between the recirculation inlet and return locations drives the recirculated liquid at high velocity. As the differential pressure rises, the internal flow rate increases but at a decreasing rate. The internal flow will reach a maximum beyond which any additional increase in differential pressure will have negligible impact. This occurs when friction losses begin to become the dominant factor affecting flow. The observed internal pumping effects primarily are caused by the action of the inner magnet ring and thrust washers.

The differential pressure between the recirculation inlet and return locations is lower for the discharge-to-discharge design, so it creates less recirculation velocity. However, discharge-to-discharge recirculation provides a larger flow path. Moreover, its flow

pattern is characterized by high localized pressure and little interference with suction flow. Overall, the mass flows are comparable. Internal pressures in both systems prevent flashing of most liquids at the magnetic coupling interface or internal bearings.

Discharge-to-suction recirculation tends to have better impeller thrust balancing characteristics due to its routing of the flow through the impeller eye balance holes. However, this provides minimal advantage and, with the growing use of silicon carbide thrust bearings, isn't a significant factor.

Discharge-to-suction recirculation also tends to flush solids better due to its higher velocities. In general, pumps with silicon carbide bearings can handle a higher level of solids because these bearings stand up well to most commonly encountered abrasive solids. A pump equipped with discharge-to-discharge recirculation typically has a lower required net positive suction head ($NPSH_R$) because the recirculation return flow doesn't interfere with fluid flow through the suction eye.

THRUST BALANCED PUMPS

The design of such units ensures virtually no thrust-bearing load; this leads to high reliability and long pump life. One type of thrust balancing system has a valve with a ring extending from the impeller hub; this is used to define a variable-sized vent between the ring and shaft. The pump usually

includes wear rings with axially extended rings that permit the thrust balancing system to operate within a range of axial positions, with the particular one chosen based upon the operating point of the pump and specific gravity of the fluid.

Balancing axial hydraulic thrust on an impeller (or impeller assembly) reduces or eliminates maintenance of axial thrust bearings by generally maintaining spatial axial separation between members of any axial thrust bearing during normal pump operation. Moreover, the thrust balancing system increases mechanical efficiency and decreases torque-driving requirements of the pump by cutting friction associated with axial thrust bearings. In particular, the thrust balancing system may reduce the activity (for example, duty cycle) of axial thrust bearings or avoid the need for axial thrust bearing(s) altogether. However, a conservative engineering approach is to replace a conventional axial bearing with an auxiliary axial bearing intended for intermittent use in conjunction with the thrust balancing system. Nevertheless, in general, many sealless pumps (whether magnetic drive, submerged motor or another type) don't have axial (thrust) bearings.

This system also could include a radial bearing positioned in an impeller recess at or near the center of gravity of the pump upstream from the thrust balancing valve, i.e., further toward the discharge pressure or

direction of fluid flow, to improve resistance against dry running and prevent flashing of the pumped liquid.

SUBMERGED MOTOR PUMPS

In these units, the motor and hydraulic sections are directly coupled with a common shaft and fully submerged in the pumped fluid. This isolates the unit from the atmosphere and thus completely eliminates the need for seals or couplings; pumped fluid fills motor gaps and voids. There's practically no leakage. Design of bearings and their compatibility with the pumped liquid is important.

The primary reason for submerged motor pumps' popularity is their inherent safety and reliability. Another benefit is the avoidance of alignment problems normally associated with pumps that use couplings. In addition, the liquid in which the assembly is submerged acts as effective sound insulation; these pumps operate very quietly.

Some of these pumps are long multistage vertical units — e.g., one plant uses a 15-stage pump to move liquid from a high-pressure storage tank. A usual design has three radial ball bearings along the pump shaft line. This construction yields a stiff rotor perfectly guided on multiple points. Bushings in all non-bearing carrying stages provide additional damping. The stiff and damped rotor dynamics enable safe pump operation in different steady state and transient situations.

Many submerged motor pumps can't or don't use thrust bearings because of the low load capacity of these bearings or previous failures. Instead, a specially designed balance drum assembly usually compensates for axial forces. Such an assembly should meet the requirement of the axial thrust balancing in all anticipated conditions, i.e., for whole operating range considering flow, head, etc.

Submerged motor pumps come in a wide variety of power ratings and sizes. As a very rough indication, motors range from 50 kW to as much as 3.5 MW and capacities extend to 4,000 m³/h and over 4,000 m of head. The motors are a unique design. The starting current required is approximately 6 to 6.5 times the full load current because of the amount of torque required

for starting the pump. Soft starters, auto-transformers and variable frequency drives have worked very well in many different applications to reduce the starting current. However, proper setup of starting parameters in any current-reduction-type starting system is important.

Most submerged motor pumps today are vertical types whose hydraulic design evolved from that of standard American Petroleum Institute (API) vertical in-line or other API vertical centrifugal pumps. Multi-vaned diffusers rather than a volute casing usually provide diffusion. The diffusers can be axial flow (to maintain smaller diameters) or radial flow (to maintain shorter stage lengths). Impellers are of radial- or mixed-flow (Francis) type, closed shrouded design and the hydraulic

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stages are radially split. The pumps can have up to 25 stages (or sometimes more) to satisfy service requirements. Typically, the first stage is a high-specific-speed axial flow inducer, used to improve $NPSH_R$ performance.

MAKING A CHOICE

Magnetic drive pumps usually suit small- and medium-sized services involving corrosive, toxic, dangerous and other

troublesome liquids that should not contact the environment or the electric motor. On the other hand, submerged motor pumps can handle medium- and large-size applications with clean and usually non-corrosive liquids so long as the fluid doesn't cause difficulties if delivered to the electric motor. ■

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Spray Effectively

Consider new technology as well as operational issues before choosing a nozzle

By Charles W. Lipp, Lake Innovation LLC

Remaining competitive today requires achieving higher levels of process performance. At many plants, this demands optimal spray performance over a wide range of operating rates. However, most spray applications receive insufficient attention and design consideration because they are subsystems of unit operations.

Hundreds of applications in the chemical industry rely on sprays — for example, quenching or conditioning gas, injecting catalyst and washing filter cake. The sprays primarily serve to enhance heat and mass transfer or to distribute liquid material over an area or through a volume of gas. Some applications require more than one function to achieve the best process performance. For example, rapid cooling of hot gas not only depends

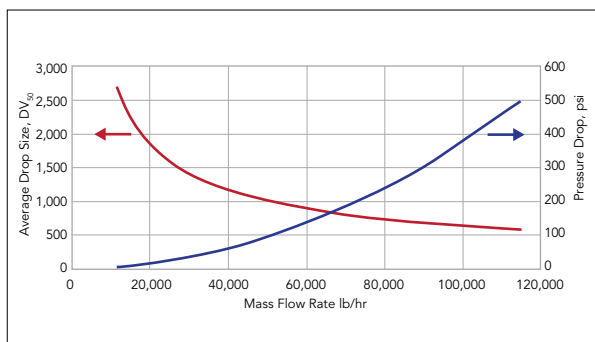
upon a fine average drop size so drops evaporate rapidly but also on drops contacting all the gas. Designs of these systems use multiple nozzles to achieve the contacting and average drops requirements.

Selecting the most-appropriate and cost-effective technology requires thorough process knowledge.

Plants most commonly turn to single-fluid and two-fluid nozzles to achieve a wide range of control. However, spill-return, pop-pet and pulsing nozzles are gaining wider usage because they offer significant advantages in some applications. So, let's look at each of these options.

GENERAL CONSIDERATIONS

Processes involve a range of operation from

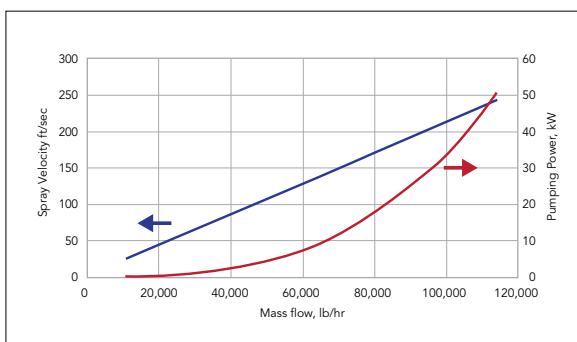


EFFECT OF OPERATING RATE

Figure 1. Mass flow rate through a single-fluid spray nozzle significantly affects both pressure drop and average particle size.

startup to full production rate. The maximum design rate is critical but high levels of performance over the entire operating envelope is valuable and, in a growing number of applications, essential. This range of operating conditions requires a range of rates of sprayed material. Most commonly, plants opt for hydraulic or single-fluid spray nozzles because of their low cost, simplicity and good performance at design rate.

Often the performance of a unit operation with a spray is optimized for full rate but the system must operate acceptably over the entire operating range of a facility. In a multi-product plant, the maximum operating rate may vary from one product to another. Consequently, the operating rate of the sprays may change. Also, the range of actual normal operations may differ from product to product. The result is a process demand for a higher level of spray performance over a wide range of operation. Many processes require sprays to operate



FURTHER IMPACTS OF RATE

Figure 2. Mass flow rate through a single-fluid nozzle also markedly alters spray velocity and theoretical pumping power.

effectively over a 1:10 range of rates. Figures 1 and 2 show the impact of operating rate on spray characteristics of a commercially available single-fluid nozzle. Running a single-fluid nozzle over a 1:10 range results in a nozzle pressure drop that varies by a factor of 100 (Figure 1). The pressure drop can be approximated as a squared function of flow rate. Often, more important to process performance is the average drop size, DV_{50} , which varies from 2,700 microns to 500 microns. The process performance of these sprays differs significantly. The drop evaporation time will be approximately 29 times longer for the larger spray (lower rate operation with 2,700-micron drops). The drop trajectory in a process vessel also changes. The high rate spray has a substantially higher velocity that, when combined with the flow rate, results in a much larger energy input as shown in Figure 2. (In a nozzle, the liquid pressure is converted into the kinetic energy of the spray drops.) The change in the energy input may impact the process dramatically. The

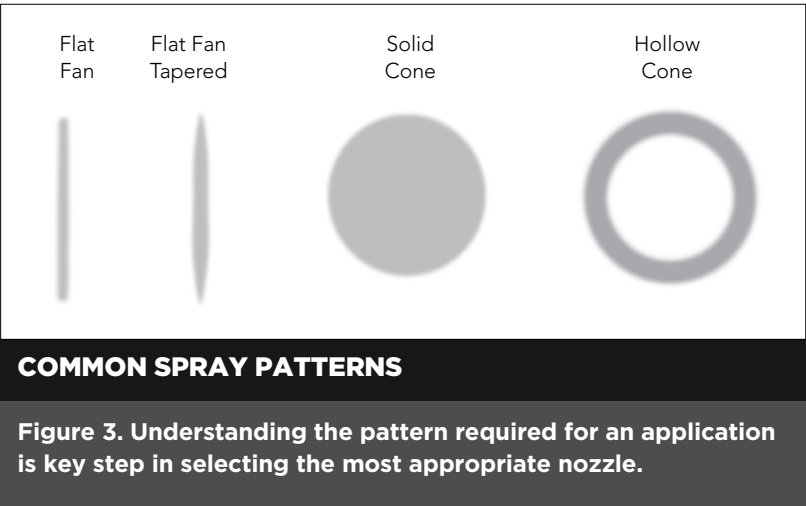
	Advantages	Limitations	Applications	Comments
Groups of nozzles	Conventional nozzles used	Not all nozzles in service at one time Issues with out-of-service nozzles — for example, cooling, flushing and purging	Gas cooling, conditioning and quenching	Turndown depends on the number of nozzles and each nozzle's ability to be independently actuated
Spill-return nozzle(s)	Nearly constant drop size and spray angle	Hollow-cone spray pattern only Spray velocity with sprayed flow	Gas cooling, conditioning and quenching	
Poppet nozzle(s)	Constant spray angle	Complex relationship between flow and average drop size Clean liquid required because of narrow passages	Deaerator for boiler feed water Condensate water feed for steam	Proprietary designs with little drop size information published
Pulsing nozzle(s)	Nearly constant drop size, spray velocity and spray angle	Low to moderate flows	Conveyorized materials	Growing application areas
Two-fluid nozzle(s)	Wide range of operation	Spray velocity changes with flow rate Independent control of atomizing media Required cost of atomizing media	Wide application	Control of average drop size

SPRAYING METHODS

Table 1. Understanding the advantages and limitations of each method is crucial to a sound choice.

high velocity sprays induce bulk gas or vapor motion. The additional gas or vapor motion may cause back-mixing and entrainment of sprays in unintended ways. An approximation of this effect can be calculated from the hydraulic power of the spray.

In contrast, selecting a nozzle with a 40-psi pressure drop for the high flow case would result in only a 0.4-psi pressure drop at the low-flow conditions, causing the spray nozzle to drizzle liquid instead of forming a spray. For any application, always



answer the following questions:

1. What process functions must the spray perform?
2. What spray pattern best matches the application hardware?
3. What spray parameters are critical for this ap-

plication?

4. What is the required and reasonable operating range?

The spray pattern is an important consideration in selecting a process spray nozzle. Figure 3 illustrates

the common spray patterns. Process applications use solid- and hollow-cone pattern sprays more often than flat fan sprays. The liquid distribution of a solid-cone nozzle is generally better for the circular cross-sections of most process vessels.

Choosing the spray pattern is only one part of the process, though. You also must select the number of nozzles to achieve the degree of spray distribution of the liquid. For example, the contacting of a spray quench is an essential part of the design to ensure a uniform outlet temperature. Distribution of spray across a filter cloth for washing or cleaning requires a specific arrangement of nozzles to attain a uniform liquid distribution or spray impact for cleaning.

Selection to produce a wider range of effective spray operation begins with understanding the differing nozzle characteristics. Choosing and designing the method best suited to the process application must integrate the process requirements and constraints. Table 1 provides an overview of five methods, some spray characteristics and the controls required. The range of operation is an approximate guide because each specific unit operation has a different sensitivity to a change in average drop size or drop velocity. The ideal spray nozzle would have the same spray angle, average drop diameter, spray velocity and other characteristics over the operating range — however, no such nozzle exists.

Understanding the differences between the options is crucial.

GROUPS OF NOZZLES

One of the most common means to expand the range of single-fluid nozzles and maintain the other parameters is to use multiple nozzles. This approach involves activating another nozzle or a group of nozzles when the process requires additional flow of sprayed material. For example, a system might use ten nozzles, each with one-tenth the total capacity, with the supply pressure controlled at a specific level. This results in the spray average drop size and spray velocity remaining nearly constant. Groups of nozzles require more complex controls to isolate individual nozzles. The issue with this is the effect of the process environment on the nozzle and supply piping not in service and perhaps, more importantly, the process impact on only one nozzle in service. Such a system needs a water flush when the nozzle is removed from service. The distribution of sprayed material in the process changes as more nozzles are put in service.

Another approach is to have three nozzles designed for low, medium and high capacity service. Only one nozzle operates at a time, starting with the low flow rate nozzle. This robust approach increases the range of the nozzles by opening or closing the valves according to the flow rate required. The control system complexity depends on the process requirements. Because the nozzles

have differing capacities, the higher capacity nozzles have a larger average drop size.

The effective operating range depends on operational characteristics, the number of nozzles and each nozzle's ability to be independently activated.

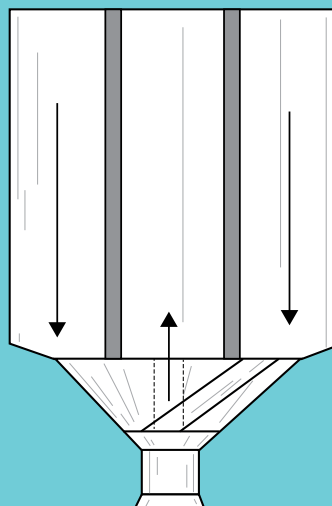
SPILL-RETURN NOZZLE

This is a modified pressure-swirl single-fluid nozzle that recirculates or spills a portion of the nozzle feed, returning it to the suction side of the feed pump (Figure 4). The nozzle produces a hollow-cone spray pattern with a nearly constant average drop size and spray angle over a range of flows. It works in this way because the flow in the swirl chamber is constant. The feed control system is designed to deliver a constant flow to the nozzle and adjust the amount of sprayed material by the back-pressure on the spill connection of the nozzle. The nozzle manufacturer provides a chart or equation describing the operating characteristics, i.e., sprayed flow dependency on nozzle back-pressure, that allows establishing control parameters for a specific nozzle.

This technology currently is gaining wider usage, especially in gas quenching and conditioning applications.

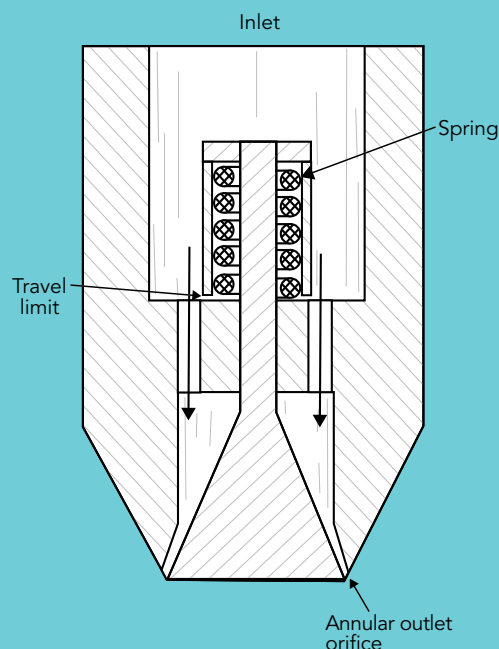
POPPET NOZZLE

Such a nozzle uses a spring-loaded element, known as a pintle, to discharge a



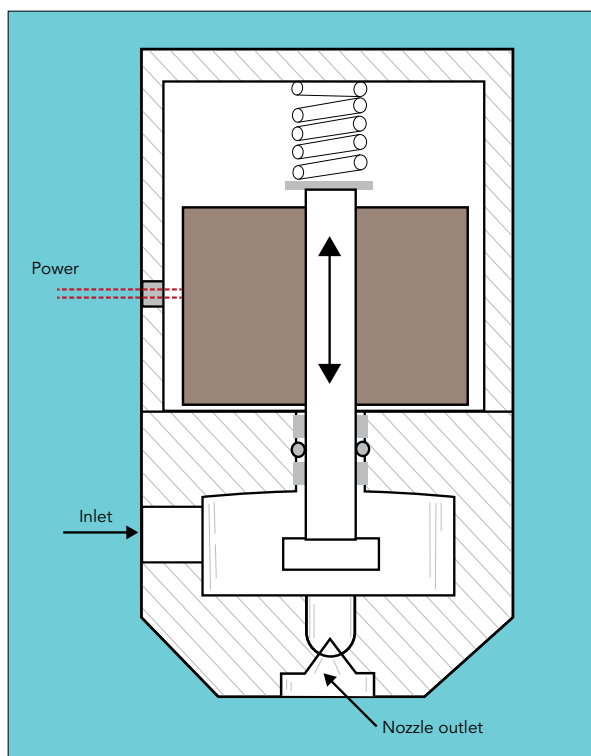
SPILL-RETURN NOZZLE

Figure 4. This nozzle gives a hollow-cone spray pattern with a nearly constant average drop size and spray angle over a range of flows.



POPPET NOZZLE

Figure 5. This nozzle uses a spring-loaded element to provide a hollow-cone spray pattern and offers reasonable performance over a high turndown ratio.



PULSED NOZZLE

Figure 6. A close-coupled solenoid enables rapid opening and closing of the outlet to control the fraction of time spraying occurs.

hollow-cone spray pattern (Figure 5). The pressure of the liquid counteracts the spring to open or close the annular outlet orifice. The nozzle's key advantage is a reasonable level of performance over a range of operation up to 50:1. The drop size and velocity vary over the operating range. However, the spray angle doesn't change.

The wide operating range is possible because the spring increases the annular opening around the pintle with increasing flow to the nozzle. When the poppet travel limit is reached, the unit behaves as a fixed-orifice pressure nozzle. However, the poppet nozzle provides a larger drop size at higher flow

rates until the travel limit is reached — unlike the fixed-orifice pressure nozzle, which gives a smaller drop size with larger flows.

Proper sizing of the nozzle to achieve the required performance and flow characteristics includes selecting the spring constant and the travel limit.

Nozzles of this design are used on condensate deaerators that remove dissolved oxygen from water fed to a steam boiler.

PULSED SINGLE-FLUID NOZZLE

Pulsing a single-fluid nozzle — that is, rapidly activating and deactivating the nozzle to control the fraction of time it is spraying — enables independent control of flow rate and pressure. A close-coupled solenoid valve acts on the nozzle (Figure 6). When the solenoid retracts the plunger, liquid can spray. The frequency of pulsation varies between the products and manufacturers; it can range from 10 to 200 times per second. The actual flow rate as a percentage of the maximum flow is set via a control unit that supplies the pulsing power to the solenoid valve. The supply pressure must be controlled to set the sprayed flow.

This technology is a relative newcomer to spray options — introduced less than ten years ago. The pulse-width-modulation (PWM) system of spray nozzles (Figure 7) is rapidly gaining traction. It provides a means to maintain the average drop size, spray

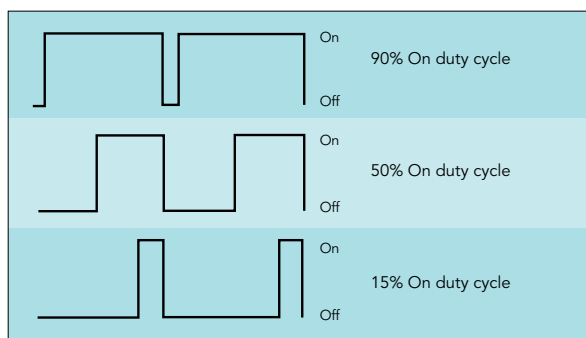
angle and spray pattern at reduced flows. PWM nozzle systems with controllers provide many advantages for certain applications. For example, adjusting the duty cycle can control the amount of material sprayed onto a conveyor as its speed changes while maintaining the spray parameters.

PWM nozzles usually are restricted to low-capacity applications, up to 1 kg/min. A second limitation is the design nozzle pressure generally is less than 150 psi; however, some nozzles are available with pressures up to 600 psi and flows up to 25 gpm.

TWO-FLUID NOZZLE

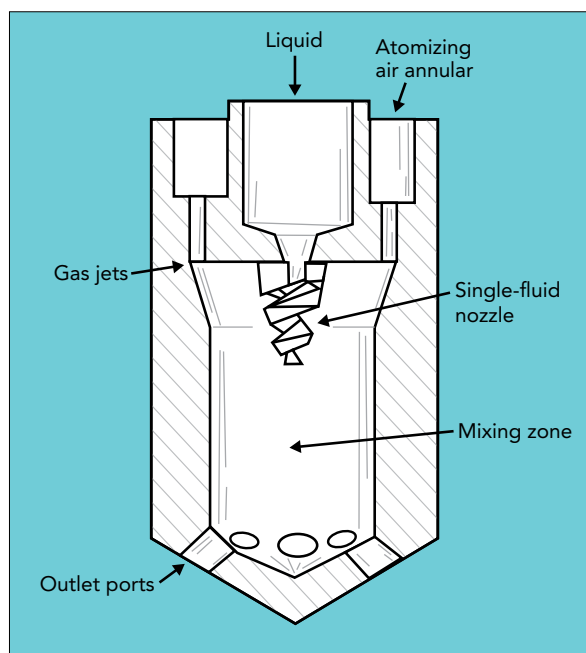
The second most popular option after the single-fluid nozzle, this unit internally mixes the liquid with a gas to intensify atomization (Figure 8). Process applications often rely on nitrogen, steam or other compatible gas instead of air. Adding the atomizing gas can cause process problems because it may need to be removed downstream. The energy cost of the atomizing gas also is a factor to consider.

Air-atomized nozzles can achieve a very wide range of liquid throughputs, 20:1 or higher. However, these nozzles are inherently more complex because of the requirement to control both the liquid feed and the atomizing gas. Directly or indirectly controlling gas-to-liquid ratio (GLR) is essential for tight control of drop size. The spray velocity varies significantly with



CONSISTENT PERFORMANCE

Figure 7. Even at lower duty cycles a pulse-width-modulation nozzle system maintains the average drop size, spray angle and spray pattern.



INTERNAL-MIX TWO FLUID NOZZLE

Figure 8. Air intensifies atomization in this nozzle with multiple outlets but other gases also can be used.

different nozzle designs and GLR. Back-flow prevention is a critical issue due to the direct connection of the atomizing gas with the process liquid. “Practical Spray Technology: Fundamentals and Practice” describes a number of control practices.

Type	Spray Pattern	Spray Angle	Spray Velocity	Range of Operation	Range of Feed Rates	Controls Required	Usage
Groups of nozzles	Depends on nozzle chosen	Depends on nozzle chosen	Varies with rate	Unlimited	Depends on design	Multiple feed control valves with controller to activate and deactivate nozzles	Common approach
Spill-return nozzle(s)	Hollow cone	Constant	Varies somewhat with rate	1:10	Depends on primary nozzle but multiple nozzles may be used	Pressure control on re-cycle to control sprayed flow rate of nozzle	Growing usage
Poppet nozzle(s)	Hollow cone	Constant	Varies with rate	1:50	Generally high capacity and clustering of nozzle common	None	Limited application
Pulsing nozzle(s)	Flat fan or hollow fan	Constant	Slight variation with rate	1:10	Modest capacity nozzles	Controller matched to nozzle	Growing usage
Two-fluid nozzle(s)	Solid cone	Narrow but may be expanded with compound nozzle outlet	Highly variable	1:10	Depends on primary nozzle but multiple nozzles may be used	Control of atomizing-gas-to-liquid ratio	Common approach

OVERVIEW COMPARISON

Table 2. Proper selection of a nozzle ultimately depends upon in-depth process knowledge.

(For more details on this book, go to: www.lakeinnovation.com/book_PST.html.)

ENSURE EFFECTIVE PERFORMANCE

We have covered five available methods to expand the operating range of spray nozzles and achieve tight control over a wide range of throughputs. Each method has unique features that must be carefully considered. Table 2 compares the five options.

Selection of the most-appropriate and cost-effective technology requires in-depth process knowledge. Unfortunately, many applications lack adequate monitoring and control instrumentation. Making the economic case for improvements requires understanding both the cost of a nonoptimal operation and the cost of implementing monitoring and control instruments.

Always define turndown of spray nozzles in a specific process context. The generally used values of turndown may be too liberal or too conservative. The number of nozzles needed to achieve the dispersion or the contacting necessary in the process is a crucial aspect of any system.

Besides the spray nozzle, effective operation requires the integration of spray nozzle control with overall process control. ■

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Be Clear About Clarifiers

Understand the design and uses of different types of settlers

By Amin Almasi, rotating equipment consultant

Removing suspended solids from liquids is necessary in many processes. Plants generally use clarifiers for this. Clarifiers are settling tanks and, thus, often also are called settlers. In addition, the devices sometimes serve for thickening — in these cases, they are termed thickeners.

Clarifiers usually feature a built-in mechanism for continuous removal of the solids deposited by sedimentation. Concentrated impurities discharged from the bottom of the tank are known as sludge while the particles that float to the surface of the liquid are called scum. Most commonly, a clarifier comes in a circular design but rectangular and other configurations also are available.

Usually before a fluid goes to a clarifier, it

undergoes coagulation and flocculation processes. These cause finely suspended particles to clump together to form larger and denser particles that settle more quickly and stably — easing the separation, improving efficiency and, thus, conserving energy. Such treatment also promotes the settling of colloids. In addition, isolating particle components first using these processes may reduce the volume of downstream treatment operations like filtration.

After coagulation, flocculation by large mechanical paddles allows coagulates to form denser particles or flocs that settle more easily. The stream then goes to the clarifier where separation of clarified liquid from the solids and flocculated coagulate occurs by permitting the heavier and larger particles to settle to the bottom. Particles form a

layer of sludge requiring regular removal and disposal. Clarifiers usually incorporate mechanical solids-removal devices that move as slowly as practical to minimize re-suspension of settled solids. Clarified liquid often is pumped to filters to eliminate any residual particles; filtered liquid then flows to the next process.

Tanks are sized to give liquid an optimal residence time. Economy favors using small tanks but if the liquid flow rate through the tank is too high, most particles won't have sufficient time to settle. Considerable attention is focused on reducing liquid inlet and outlet velocities to minimize turbulence and promote effective settling throughout available tank volume. Baffles prevent fluid velocities at the tank entrance from extending into the tank; overflow weirs uniformly distribute flow from liquid leaving the tank over a wide area of the surface to minimize re-suspension of settling particles.

DESIGN AND OPERATION

Control of liquid flow into a clarifier is important. Reducing the velocity increases the hydraulic retention time inside the clarifier for sedimentation and helps to avoid excessive turbulence and mixing, thereby promoting the effective settling of suspended particles. The inlet flow also should be distributed evenly across the entire cross-section of the settling zone inside the clarifier; as a very rough indication, the settling zone's volume often is around 30–40% of

total capacity of a clarifier.

The sludge formed from the settled particles at the bottom of the clarifier, if left for an extended period, may become gluey and viscous, creating difficulties in its removal. Using gas (or other means) to free the sludge can cause the re-suspension of particles and the release of dissolved materials throughout the liquid, reducing the effectiveness of the clarifier. This sludge should be drained properly from the bottom of the tank — usually this involves using specially designed positive-displacement pumps.

Two dominant forces act upon the solid particles in clarifiers: gravity and particle interactions. Too high a flow can lead to turbulence, hydraulic instability and potential flow short-circuiting. Improvements and modifications made during the last few decades, particularly for improving the separation process, have enhanced clarifier performance. For instance, installation of specially designed perforated baffle walls (based on advanced hydrodynamic simulations) promotes flow uniformity.

The clarifier mechanism is designed for constant operation. Therefore, reliability of its components, particularly mechanical and moving parts, is crucial. A clarifier should include an access walkway to the platform in the center of the basin where the mechanism is mounted. That mechanism generally is of the center drive type. Flow

usually enters the center draft tube through a horizontal influent pipe extending from the tank sidewall, although peripheral and other feed designs sometimes are used. The drive unit should be capable of producing and withstanding peak momentary torque for the rake drive. As a minimum, the system should be able to provide two or three times the running torque; this is necessary particularly for starting.

Large applications that would require a single basin with a diameter in excess of 70 m instead commonly use multiple clarifiers in an “n+1,” (e.g., 2+1 or 3+1), “n+2” or similar configuration because of operational, process, reliability or layout reasons. In such arrangements, the system is designed so that flow diverted to other clarifiers when taking one clarifier (for +1) or two (for +2) out of operation doesn’t increase the surface overflow rate and the solids loading rate beyond the normal acceptable levels.

RECTANGULAR CLARIFIERS AND TUBE SETTLERS

The removal of accumulated solids sometimes is easier with conveyor belts in rectangular tanks. In addition, elongating and narrowing of the tank can stabilize flow. As a result, rectangular clarifiers may provide high efficiency and low running cost.

A commonly used design is the tube settler. It increases the settling capacity by reducing the vertical distance a suspended parti-

cle must travel. High efficiency tube settlers use a stack of parallel tubes, rectangles or flat pieces separated by several centimeters and sloping upwards in the direction of flow. Such a design creates a large number of narrow parallel flow pathways that encourage uniform laminar flow.

Tube settlers can provide a large surface area onto which particles may fall and become stabilized. In addition, flow temporarily accelerates between the plates and then immediately slows down, which helps to aggregate very fine particles that can settle as the flow exits the plates. Structures usually are inclined between 45° and 60°. This may allow gravity drainage of accumulated solids but shallower angles of inclination typically require periodic draining and cleaning (or possibly use of a backwash system in special cases). Tube settlers may permit the use of a smaller clarifier and may enable finer particles to be separated with residence times less than conventional ones — even sometimes 10–30 minutes. Typically such designs handle difficult-to-treat liquids, especially those containing colloidal materials.

Tube settlers capture the fine particles, allowing the larger ones to travel to the bottom of the clarifier in a more uniform form. The fine particles build up into a larger mass that then slides down the tube channels. The decrease in solids present in the outflow enables a reduced clarifier footprint.

Some applications use tubes made of polyvinyl chloride or another plastic; this affords cost savings and also sometimes improves performance.

INCLINED-PLATE CLARIFIER

An inclined-plate or “lamella” clarifier uses inclined plates for the settling process and solid separation. These inclined plates provide a large effective settling area for a small footprint.

A typical design consists of a series of inclined plates inside a vessel. The liquid stream enters from the top of the vessel and flows down a feed channel underneath the inclined plates; liquid then flows up inside the clarifier between the inclined plates. During this time, solids settle onto the plates and eventually fall to the bottom of the vessel. At the bottom of the vessel, a hopper or funnel collects these particles as sludge. Sludge may be continuously or intermittently discharged. Above the inclined plates all particles have settled, producing clarified liquid that is drawn off into an outlet channel by weir. The clarified liquid exits the system in an outlet stream.

Inclined-plate clarifiers are ideal for applications involving fine-sized solids whose loading varies. Such units are more common than conventional clarifiers at certain industrial sites due to their smaller footprint and better overall cost. The units also often are favored for revamp and renovation projects.

One specific application is at the pretreatment stage for liquid entering some filters. Indeed, inclined-plate clarifiers are considered one of the best options for pretreatment ahead of membrane filters. Their all-steel design means the chance that part of the inclined plate will chip off and be carried over into the filter is low, especially compared to tube settlers constructed of plastic or large concrete body conventional clarifiers. Moreover, lamella clarifiers can maintain the required liquid quality to the membrane filters far better than other designs.

In general, a key advantage of inclined-plate clarifiers over other clarifying systems is the large effective settling area created by the use of the inclined plates. This improves the operating conditions of clarifiers in a number of ways. The unit is more compact, usually requiring only 60–75% of the area of clarifiers operating without inclined plates. Therefore, a lamella clarifier system is preferred where site footprint constraints are a concern. The reduced required area may allow the clarifiers to be located inside, avoiding the common problem of clogging faced by outdoor equipment due to blowing debris accumulation. This is a great advantage for some applications. Operation within an enclosed space also enables better control of operating temperature and pressure as well as overall operating conditions. The inclined plates mean the clarifier can operate with an overflow rate two to four times that of

traditional clarifiers — allowing a greater influent flow rate and, thus, a more-time-efficient clarification process.

Inclined-plate clarifiers boast a simple design without any moving parts. Thus, the units have a much lower propensity for mechanical failure than other clarifiers, which results in safer and more reliable operation. In addition, these devices usually don't require use of chemicals for the clarifications and solid separation. So, they can act as pretreatment for delicate filter processes.

While inclined-plate clarifiers can overcome many difficulties encountered by the use of more traditional clarifiers, they do pose some disadvantages. Lamella clarifiers can't treat most raw liquid mixtures, which need some pretreatment (e.g., fine screening) to

remove materials that could decrease separation efficiency. In addition, the layout of the clarifier creates extra turbulence as the liquid turns a corner from the feed to the inclined plates. This area of increased turbulence coincides with the sludge collection point and the flowing liquid can cause some re-suspension of solids while simultaneously diluting the sludge. This results in the need for further treatment to remove the excess moisture from the sludge. Clarifier inlets and discharge should be designed to distribute flow evenly.

Regular maintenance is required because sludge flows down the inclined plates, leaving them dirty. Frequent cleaning helps prevent uneven flow distribution that reduces the efficiency of the process. The closely packed plates make the cleaning difficult.

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However, removable and independently supported plates can be installed. A number of proprietary inclined-plate clarifier designs exist. Inclined plates may be based on circular, hexagonal or rectangular tubes. As a rough guideline, plate spacing typically is around 50 mm and plate length is 1–2.5 m. The minimum plate pitch is about 10°. Pitches between 45° and 70° allow for self-cleaning. Lower pitches require cleaning via backwash of liquid flow.

Overall, while inclined-plate clarifiers may offer cost, footprint or performance advantages for specific applications, they are not as good an option as conventional clarifiers for most services.

A SPECIFIC APPLICATION

Let's consider a brine clarifier (brine settler) for a chemical plant. The density

of brine was around 1.18 times that of water; feed solid was around 1,000 ppm; liquid feed flow was estimated at about 50 m³/h. This led to the selection of a circular-type conventional clarifier. It was targeted to produce overflow liquid with around 30 ppm or less of solids. In other words, 97% of solids should settle in the clarifier and only 3% (or less) of solids should leave with the treated overflow liquid. The brine clarifier has a 17-m diameter, around 5.5-m elevation, about 10-m overall elevation, and a 6° bottom slope. It was fabricated from carbon steel and lined with 5 mm of rubber for corrosion protection; its roof was made from fiber-reinforced polymer. It provides a retention time of around 17 hours. ■

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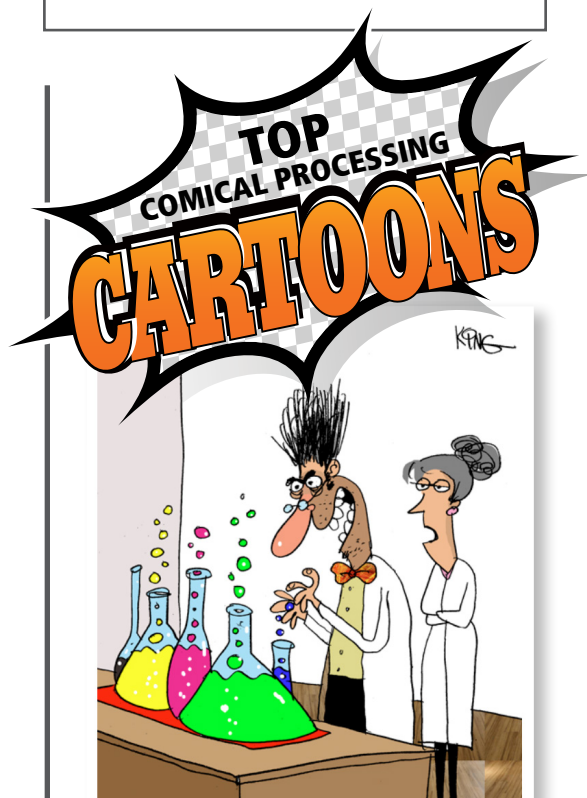
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