

Post-pellet liquid application systems

BY TERRY STEMLER

REVIEWED AND EDITED BY ADAM FAHRENHOLZ, CHARLES STARK, AND CASSANDRA JONES

The ideal post-pellet liquid application system would expose each pellet to the proper amount of liquid by weight with a 360-degree uniform coating of material, with no over-spray or residual build-up of materials on downstream equipment. In such a system, as much of the surface area of the pellet needs to be exposed to the spray as possible in a contained environment, with enough time given for the liquid to be absorbed. The general criteria for the system would be the following:

- Accurate ingredient metering;
- Uniform ingredient distribution;
- Liquid is absorbed into the pellet; and
- Liquid and dry material contained within the coating system.

General considerations

When using ingredients in any process, it is necessary to examine the characteristics of the ingredient to ensure that the method of controlling and metering the ingredient is appropriate. These characteristics include density, viscosity, pH, percent needed to apply, desired accuracy and optimal temperature. Careful consideration should be given to the materials of construction and desired accuracy. For example, it is undesirable for copper or copper alloys to come into contact with animal fat. Tallow has a tendency to solidify at higher temperatures, so it is desirable to heat trace equipment used in the application of this ingredient.

Feeders and pumps should be sized for the appropriate flow for the desired percentage of ingredient being applied. Make sure when sizing the pumps and meters that you consider the minimum threshold for a no-flow condition. For example, if there is no way to surge product going

into the application system, then you may want to divert and ignore the material that comes from the cooler during initial start-up when the flow rate is very low. When looking at various methods for metering and measuring the flow of material, make sure that you consider the on-going cost, as well as the up-front cost.

There is a common misconception that if an ingredient is cheap, you can use a cheap method for measuring the ingredient because it doesn't cost much. If the ingredient is expensive, or if you use a large quantity of the ingredient, it can be shown that the more accurate methods of metering pay back quickly. For example, if the volumetric meter that you are using has an accuracy of +/- 1%, that means that in order to ensure that enough of the ingredient goes into the product, you could be over-formulating by 1%. It could also be true that a change in supplier or a change in the lot of ingredient that you have been using (or a change in the temperature) has caused a 1% error in the measurement that you are using because the density of the product has changed and you did not realize it. Let's suppose that you have a pellet line running at 55 metric tonnes per hour and you are applying 5% fat to the pellet. The amount that you are applying is off by + 1% of the desired flow.

$$55,000 \text{ kg} \times 5\% \text{ fat} = 2,750 \text{ kg}$$

$$2,750 \text{ kg} \times 1\% \text{ error} = 27.5 \text{ kg per hour}$$

$$27.5 \text{ kg/hr} \times 16 \text{ hr/day} \times 300 \text{ days} = 132,000 \text{ kg/yr}$$

$$132,000 \text{ kg/yr} \times \$0.50/\text{kg} = \$66,000/\text{yr}$$

$$\$66,000/\text{yr} \div 12 \text{ months} = \$5,500 \text{ per month}$$

The previous example shows that a coriolis meter that is $\pm 0.1\%$ accurate will pay for itself in about two months time (cost of meter is about \$5,000, plus installation). It really pays to be accurate.

Methods and metering

In any application system there are two issues that must be addressed—method of application and control of metering. Most commonly, the liquid application will take place at the pellet die or after the cooler. The addition of liquid immediately after the pellet process may be popular where no suitable alternative exists to install stand-alone equipment. This method uses a spray nozzle or nozzles at the pellet mill discharge and typically uses volumetric measurement of the dry flow based on the number of turns of the feeder into the preconditioner. The liquid flow is either mass flow or volumetric. The advantage of this type of system is that the liquid is being applied to the product while it is still hot from the pelleting process. It is also inexpensive and can be installed on existing equipment.

The disadvantage to this system is that there is very little retention time for the liquid to absorb into the product. Even though the product is hot, time is still needed for the liquid to be absorbed into the product if the percentage of liquid is above 2% or 3%. When the percentage to be applied is higher, the liquid can be drawn off of the surface of the pellet and end up in the cooler and the cooler air system. If the system is not cleaned at periodic intervals, the efficiency of the cooling system will be affected. Also, the fines that are drawn off of the cooler are laden with fat, and if they are re-circulated back into the pelleting system, they can affect the formulation of the product and the ability of the pellet mill to make a pellet. The cooler also serves to pull moisture from the pellet, and the application of fat or other oils on the surface of the pellet prior to cooling may change the cooler's ability to remove water. These factors will affect the cooling of a green pellet and affect the pellet durability.

Where this type of system is used, modifications can be made in the duct work and cooler to facilitate

cleaning. A regular schedule should be maintained in order to ensure proper cooler operation. If the physical layout of the plant allows, a short conveyor can be added to increase retention time and reduce the possibility of liquid being drawn off in the cooler. If the installation is a new one, then a cooler can be chosen that will minimize the effect of liquid on the surface of the product. Because of the deeper bed depth and the lack of perforated pans, a counterflow cooler is more tolerant to this type of application. If an existing horizontal cooler is used, the perforated pans can be replaced with solid pans, which will prevent plugging. A flow indicator at the pellet discharge will help to ensure that we do not spray liquid when no dry product is flowing.

As stand-alone systems, common liquid applicators include:

- Spray in a screw (solid or cut-flight), ribbon, or paddle conveyor;
- Spray into a plenum or weir;
- Spray in a rotating drum or reel;
- Spray using a spinning disk; and
- Spray into a batch mixer.

Spray into a screw conveyor

Many times, spray nozzles are added to a screw conveyor to apply liquids to the product before packaging (**Figure 13-1**). Screw conveyors do not make good application equipment because they provide very little mixing action or retention. We can improve the performance of this type of equipment if we cut the flights, or substitute ribbons for solid flights, to achieve better mixing action. If we put paddles between the ribbon flights that are pitched to throw product back in the opposite direction of conveying, then we have even better mixing action and retention.

Figure 13-1. Example of a screw conveyor.



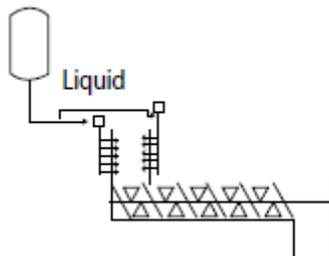
If we run the conveyor full, it will stay cleaner and give us the maximum amount of retention and less breakage. The problem with this type of system is that the spray nozzles apply liquid on a relatively

small portion of the product and count on the mixing action of the conveyor to disperse liquid onto the rest of the product. The dispersion of fats or oils can be done this way, but a water-soluble liquid like molasses can soak into the pellet almost immediately. This can cause spotty coverage where some of the product has a great deal of liquid applied and some has very little. One way to alleviate this problem is to drop the product into a plenum with spray nozzles prior to entry in a mixing conveyor.

Spray into a plenum or weir

If we take the nozzles out of the mixing conveyor and arrange the nozzles on a chute in a pattern for maximum coverage and easy cleaning, then we can spray onto the product as it is tumbling in the air. This will greatly increase the efficiency of the mixing conveyor (**Figure 13-2**). By arranging pairs of nozzles on opposite sides, we have better odds of hitting all sides of the pellet with spray. In the case of a weir (an s-shaped chute), the product is sprayed from one side and then flipped over and sprayed on the other side. After the product gets the coating of liquid, it can then drop into a conveyor or drum to get more retention. This allows higher liquid addition rates and more time to soak into the pellet.

Figure 13-2. Conveyor with a plenum.

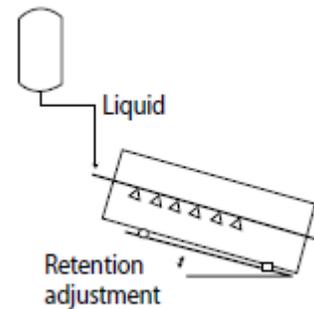


Spray into a rotating drum

The food and pet food industries quite often use a rotating drum with a variable angle of tilt on the drum (**Figure 13-3**). The product to be coated is discharged into the interior of the drum, which commonly has raised flights on the inside to tumble the product. The advantage of this type of system is that retention of the product can be adjusted. Also,

the drum eliminates pinch points that can cause product breakage, so it is very gentle. The disadvantage of this type of system is that the drum is open on two ends and mist from the atomization of the liquid can migrate out of the drum and settle on the surrounding equipment. This type of system can also benefit by putting the spray nozzles into a plenum prior to entry into the drum.

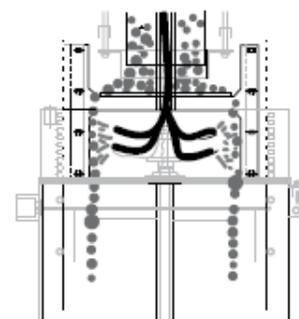
Figure 13-3. Rotating drum.



Spray using a rotating disk

One limitation to previously discussed PPLA methods is that spray nozzles have a tendency to clog when applying liquids with suspended solids. Rotating disk applicators use two spinning disks to apply liquid to pelleted products, so spray nozzles are eliminated (**Figure 13-4**). Dry material is spun from a low-RPM rotating disk and falls in a 360-degree curtain around a second disk. Liquid enters through the central bore of the dry disk shaft and drops onto the second disk spinning at a high RPM. The liquid is atomized into a fine mist that is driven by centrifugal force into the surrounding curtain of dry product. This results in a uniform coating of liquid without the need for spray nozzles.

Figure 13-4. Spinning disk.



This technology differs greatly from the traditional method of spraying, which would be to spray on a relatively small portion of the product and depend on the mixing action of a drum or conveyor to further distribute the liquid. Since the rotating disk applicator applies liquid as the product is falling past the liquid disk, you are assured of having some liquid on all of the particles that pass by the liquid disk. These systems do incorporate a mixing conveyor; however, the purpose of this conveyor is more for retention, in order to give the liquid time to absorb into the product. Another obvious advantage of the disk applicator is that since it does not require spray nozzles, any liquid capable of flowing through the delivery pipe is going to be able to flow through the machine.

This gives the user a great deal of flexibility in the selection of ingredients. Liquids that previously could not be used in coating systems because of the high percentage of suspended solids easily pass through the spinning disk applicator. Since these machines are totally enclosed, the over-spray associated with open-ended coating systems is eliminated. The top material disk spins at low RPM, so the system is very gentle. The amount of liquid that the machine can apply depends on the hardness of the product and the porosity.

Spray into a batch mixer

Another way to apply liquids is into a batch mixer. These systems are usually located just before load-out or packaging. These mixers are typically fluidized zone mixers that use paddles or a combination of ribbons and paddles. These mixers work well because they are low-shear and gentle on the product, but at the same time provide a very fast mixing cycle. This fast cycle time is necessary to keep the size of the mixer small, but still enable the mixer to keep up with the continuous flow of material. One advantage to this type of system is that a vacuum can be drawn on the mixer. The idea is that the vacuum draws the air out of the product and then when the vacuum is released, the liquid is drawn into the product to replace the vacuum. This type of system allows for very high liquid addition by weight.

The advantage of this system is the high level of liquid that can be added. Another advantage is that the amounts of each ingredient are weighed. The disadvantage of this system is that it requires more headroom and is quite expensive.

Addition of dry ingredients

The most common way to apply dry ingredients after the pellet process is to meter the dry ingredients onto the particles after the application of liquids (**Figure 13-5**). This causes the dry ingredients to stick onto the particles. In order to apply a uniform application of dust to a particle, the liquid must first be applied in a uniform fashion. The dry dusting should be applied just after liquid application, and before the retention time has given the liquid time to absorb into the particle.

Figure 13-5. Powder feeder.



This can be done in any of the systems that we have looked at already. Another method for using dry ingredients is to blend the dry material with the liquids to be applied. Care must be taken that the ingredients are compatible and that the application system is capable of applying the solution or slurry. One common method for using a slurry application is to have two liquid delivery systems—one for water-soluble ingredients and one for oil-soluble ingredients.

Control of metering

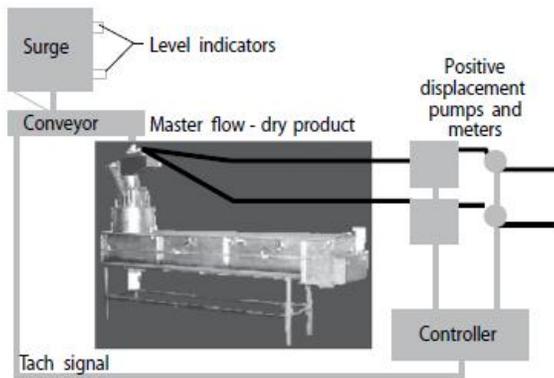
The preferred method for achieving accuracy in the proportioning of ingredients into a process is by weight. The most accurate weighing processes are batch processes. This becomes problematic in the addition of ingredients after pelleting and extrusion since these processes are continuous. The goal is to

achieve a weight for the product, without interrupting the process flow. There are three principle methods for measuring the flow rate of material in a continuous system. They are volumetric, mass flow and loss-in-weight. In all of these methods, we consider the flow of the carrier ingredients, in this case pelleted product, to be the master flow. All other additives are slaved from this master flow.

Volumetric

In volumetric metering, the master flow of material is sensed by the number of revolutions of a screw conveyor, rotary feeder or belt conveyor (**Figure 13-6**). We calibrate the material flow by measuring how much product has run through the system in a given amount of time. It is important to have a method to divert material from the process flow so that check weights can be done to confirm calibration.

Figure 13-6. Volumetric system.



The flow of liquid additives is sensed by the number of pulses we receive from a positive-displacement liquid meter (nutating disk, turbine or piston) or the number of revolutions that we see from a tachometer mounted on a positive-displacement pump. If dry additives are to be added to the product stream, then these are sensed in the same manner as the master flow.

The advantage of this type of system is that the up-front cost is low and that the overall system is simple. This type of system works quite well if the

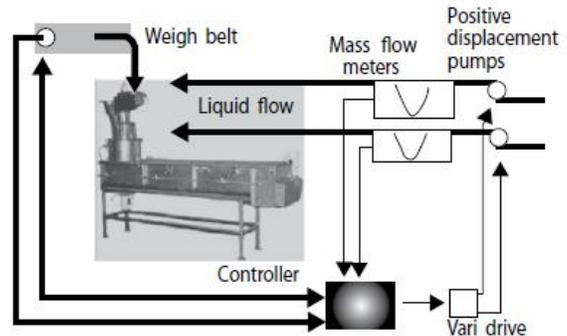
density of the products never changes and if the ratio of liquid to dry does not need to be frequently changed.

The disadvantage of this type of system is that it does not provide very good accuracy (1-2%). It also does not take into account changes in density or viscosity, so if the moisture or temperature of the product changes, the system has to be re-calibrated.

Mass flow

In mass flow metering, the master flow of product is sensed with a weigh belt, weigh feeder, impact scale or centriflow meter (**Figure 13-7**). This type of measurement integrates the weight of the product with a tach signal from a conveyor or over a specified time period.

Figure 13-7. Mass flow system.



The preferred liquid meter in this case is a mass flow coriolis-type meter. This meter measures a shift in frequency and position of a tube that is proportional to the mass flowing through the tube. This in turn tells us the mass of product flowing through a tube in a specified period of time.

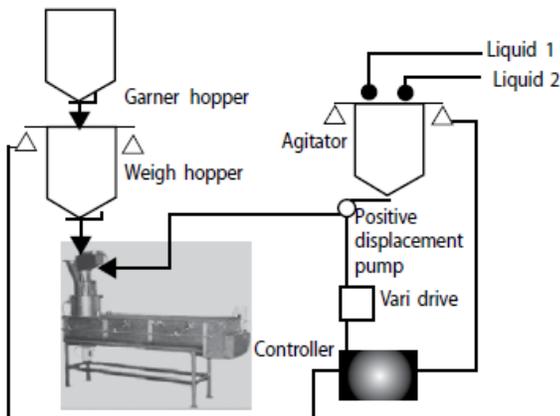
The advantage of this type of system is that the measurement is unaffected by changes in density or viscosity. The accuracy is also quite good (0.5-1%). The disadvantage is the higher up-front cost.

Loss-in-weight

In loss-in-weight metering the master flow of product is sensed by monitoring the loss-in-weight of product flowing from a weigh hopper (**Figure**

13-8). In order to accomplish this type of weighing in a continuous-flow application, a garner hopper must be used to surge product prior to entry in the weigh hopper. The system cycles drafts of product into a scale hopper and discharges the hopper at a rate that is used as the master flow. This flow is then used to signal a speed control on a positive-displacement pump for proportional discharge of a loss-in-weight liquid scale.

Figure 13-8. Loss-in-weight system.



The advantage of this type of system is that the actual weight of the product is being monitored, so changes in density are accounted for. Also, calibration of this type of system is simple, since local scale companies can check the system calibration.

The disadvantage of this type of system is that it requires a large amount of headroom to accommodate the garner hopper above the loss-in-weight scale. The up-front cost for this type of system is also greater than both of the systems mentioned before. However, if the number of ingredients being weighed is greater than three, the cost can compare well with mass flow technology using coriolis-type meters.

Principle components common problems and recommendations

1. Pellet feeder

- A. Screw conveyor—should be built with close tolerance to avoid breakage. Over sizing the conveyor also keeps the speed low and makes

for less product-on-steel contact.

- B. Belt conveyor—scrapers and brushes should be used to minimize fines carry-over onto the back side of the belt. Belt alignment sensors should be used to make sure that the belt is serviced as soon as the belt starts to drift, otherwise the belt can be damaged. Auto belt tensioning should also be used.
- C. Rotary pocket feeder—the inlet of the pocket feeder should have a flex material to eliminate the pinch point where breakage can occur. Pockets should be staggered to avoid feeding the system with a surging flow.
- D. Variable slide gate—make sure the slide gate has high resolution and a linear response.

2. Pellet meter

- A. Weigh belt—design of the weigh belt should eliminate the build-up of fines between the weighbridge and the belt. Auto tensioning can eliminate the possibility of weights changing due to changes in belt tension.
- B. Weigh screw—pivot point should have free movement. Flexible connectors should be made of material that does not shrink due to changes in temperature or moisture. Conveyor should be oversized to maximize material in the conveyor.
- C. Impact scale—avoid excessive free fall into the impact scale (no more than 1 meter). Special abrasion-resistant materials should be used on the sensing plate. Should be cleaned and inspected on a regular basis.

3. Liquid pump

- A. Gear pump or progressive cavity pump—make sure that contact surfaces are appropriate for the material that is being metered. Flood feed the inlet of the pump to make sure that the inlet is not starved. Use a dual-basket strainer so the strainer can be cleaned without shutting down the pump. Make sure that the screen in the strainer has a large surface area to avoid having to clean too often. Set a maximum Hz or RPM value in the control system so you know when the pump is starting to wear excessively.
- B. Diaphragm pump—set up schedule for replacement of pump diaphragm according to manufacturer's recommendation for number of

hours use. Use a pulsation dampener and back-pressure regulator to eliminate the pulsations from the diaphragm.

- C. Centrifugal pump—use for refill applications. Most centrifugal pumps are not appropriate for metering because of internal slippage. They lack repeatability and usually cannot generate higher pressures.

4. Liquid meter

- A. Nutating disk, piston meter, gear meter—meter should be sized for maximum and minimum flow. If a large amount of solids is in the fluid, a nutating disk meter is more tolerant. Make sure the transmitter that is selected is compatible with the automation system. Make sure that the fittings that are supplied with the meter are compatible with the plumbing in the plant. Disk, piston and gear meters are volumetric, so you can help the accuracy of the meter by keeping the liquid at a constant temperature.
- B. Coriolis meter—the coriolis meter is comprised of a U-shaped tube, an electromagnetic drive coil and two sensing coils. The U-shaped tube is made to vibrate at a set frequency, usually around 80 Hz. This up-and-down vibration has a total movement of less than 2.54 mm, and is stable when no fluid is flowing through the tube. When fluid flows through the tube, the direction of the fluid flow resists the up-and-down motion of the U-shaped tube. As the fluid flows around the bend of the tube, the other side of the U-shaped tube also resists the up-and-down motion of the tube. This resistance causes a twist in the tube, and the sensing coils on either side of the tube pick up the difference between the two sides of the tube, and translate this into the degree of twist in the tube—which is directly proportional to the mass flowing through the tube. Coriolis meters have an accuracy range from 0.1-0.2% of the flow, within the meter's rated flow capacity. This means if the flow rate that is called for is 4.5 kg's per minute, the flow out of the meter will be between 4.5 and 4.55 kg's per minute. These meters are very stable, so once the meter has been calibrated, they rarely go out of calibration. There are

some guidelines that have to be followed in the installation of these meters. The meters should be mounted so that they are being supported by the pipe that is supplying the fluid to be measured. If the meter is rigidly mounted on its own surface, separate from the pipe, then when the pipes move during expansion or contraction, the meter can be subjected to force that could damage the meter. If the weight of the meter causes the pipe to sag, then the pipe on either side of the meter should be supported. If the meter is to be located in an area where excessive vibration is present, then vibration-dampening mounting adapters are available from most manufacturers. The vibration dampening is to protect the internal sensing elements, which could be damaged from long-term exposure to excessive vibration. If a fluid such as tallow is being used, and the lines need to be heat traced, most manufacturers have trace kits that allow the meter to be electrically or steam heated. In many applications, the lines into and out of the meter will be traced, and the residual heat is enough to keep the meter warm. In any case, the maximum temperature rating for the meter should not be exceeded (this is around 121°C for the actual fluid temperature, with much higher temperatures available when specified). Most applications will have the sensing element mounted horizontally, with the inlet and discharge pipes also running horizontally. If it is necessary to mount the meter vertically, you need to make sure that the direction of flow is up through the meter, not down through the meter. The meter should always be kept full, so it is a good idea to have a short vertical run after the meter, rather than discharging out of the end of a horizontal pipe.

6. Mixing conveyor, spray plenum, weir or rotating drum

- A. Spray nozzles plug—make sure that the liquid is filtered through a basket strainer and that the filter is sized smaller than the smallest orifice opening on a spray nozzle. Make sure that the strainer arrangement is a dual-basket strainer so that when the strainer is plugged it can be cleaned out without interrupting production.

Arrange the spray nozzles so that they can easily be replaced and swapped out. Some systems have dual spray bars so that while one system is being cleaned, the other system takes over. Compressed air purging of nozzles is sometimes used, as well as a solenoid-actuated needle that periodically cycles in and out of the orifice.

- B. Spray nozzles dribble—many times spray nozzles are sized for the maximum flow and then when the minimum flow is tried there is not enough hydraulic pressure to get a good atomization. Again, the system should be arranged so that nozzles can be easily changed and swapped out, with one set of nozzles for high flows and one set for low flows.
- C. Over-spray of liquid on surrounding area—one problem that is most common with a drum-type coater is the problem of atomized mist migrating out of the drum and settling on the surrounding equipment. One way to alleviate this problem is to decrease the level of atomization. Often atomization of the liquid is accomplished by combining the flow of liquid with compressed air. The compressed air can cause too fine a droplet and will increase the possibility of the liquid becoming airborne. Whenever possible, it is better to use hydraulic pressure rather than pneumatic pressure to atomize the liquid.
- D. Build-up of liquid on downstream equipment—adjust angle of tilt on the drum for more retention. Slow down mixing conveyors for more retention. Make sure that the dry flow-sensing threshold and sequencing are set correctly so that the liquid is being sprayed onto dry product flow.

7. Rotating disk

- A. Spotty spray coverage—if the dry flow is too low to cover the dry disk or liquid goes through gaps in the curtain of material and runs down into the mixing conveyor, slow down the dry disk until it is throwing a 360-degree curtain.

Micro-liquid dosing

The principles that have been presented so far also

apply to the metering of small liquid additives such as enzymes, antioxidants, mold inhibitors and other micro-additives. These ingredients are quite often temperature-sensitive, so the most common application point would be after the pellet mill.

There are also other considerations that are unique to small additives. Small additives are usually quite concentrated, which usually makes the price per kilogram higher than most other ingredients. This increases the need to be accurate in the metering of not only the liquid or powder that is being applied, but also the accurate measurement of the pellet flow into the coating system. When these micro-additives are going to be used, it is always best to use a system that takes the weight, or at least the density, into consideration.

Since these ingredients can be applied at levels as low as 50 grams per tonne of feed, it is usually not necessary to have a bulk storage and receiving system set up for these ingredients. These ingredients are usually received in plastic totes or drums, so the pumping system should be designed to easily change out a tote or drum so that when one gets empty the next one can easily be brought on-line for production. Most systems use another tote or small tank that allows some surge capacity so the main tank can be run empty without interrupting the flow. It is quite common for the storage tank to sit on a platform scale so that inventory reconciliation can be easily accomplished.

These systems quite often have a transfer pump at the main tote in the warehouse that will pump ingredients to a dosing station close to the application point. This allows the temperature of the main storage tank to be more easily controlled by keeping the bulk of the ingredient in the warehouse and not in the process area, where the temperatures can be significantly higher. A diaphragm, gear pump or other positive-displacement pump can be used for these ingredients, and they are rated in liters per hour instead of liters per minute.

These micro-liquid systems may also have a separate dilution system that is used to dilute the ingredients prior to the blending system. This helps

spread the ingredients over more surface area and increases the mixing efficiency. When a dilution system is used, then it may be necessary to use a static mixer to pre-mix the ingredients prior to blending. This is especially true when the carrier liquid is not compatible with the micro-liquid.

Choosing the correct system

The type of system that is employed depends on the required accuracy of the ingredients and how expensive the ingredients are. Even though mass flow systems and loss-in-weight systems have a greater up-front cost, a very short payback may be realized in eliminating the need to over-apply an ingredient due to worst-case errors. Regardless of which system is employed, regular cleaning, maintenance and calibration of the system should be scheduled to ensure accurate and trouble-free operation.

Mr. Stemler is President at Automated Process Equipment Corp. His past experience has been as an applications engineer for Dukar Limited and EPE. Email: terrys@apecusa.com

This content was edited and reviewed by Dr. Adam Fahrenholz, Assistant Professor of Feed Milling at North Carolina State University, Dr. Charles Stark, Jim and Carol Brown Associate Professor of Feed Technology at Kansas State University, and Dr. Cassandra Jones, Assistant Professor of Feed Technology at Kansas State University.