Title: Efficiency is in the Details
Description: THE USE OF SCALES AND METERS IN LIQUID ADDITION SYSTEMS

Introduction:
There are a variety of ways that liquid additives can be introduced into your formulation. This article will include an overview of both weighing and metering of these liquid additives.

Volumetric methods for adding liquids to a formulation do not compare well with weighing of the liquid. These volumetric meters include oscillating piston meters, nutating disk meters, magnetic meters, and vortex shedding meters. These meters measure the volume of flow of the liquid. This is accomplished by either counting the number of times that a cavity is filled and emptied, or by indirect flow measurement such as measurement of the conductivity of the liquid, or measurement of turbulence that an obstruction in the line creates. Theses types of meters range in accuracy from +- 0.5% to 1%. This is of course based on the idea that the density of the liquids do not change. Changes in density will greatly affect the accuracy of these types of meters since they are only sensing the volume of flow. A 20°F change in temperature can represent a 0.8% change in density for many of the common fats, oils, and flavorings that are used in the pet food industry. There is quite a difference between filling a cavity with a liquid that weighs 7 lbs per gallon and a liquid that weighs 7.2 lbs per gallon. Yet, a volumetric meter will not pick up this difference. These meters are also sized for a specific flow capacity, so it is important to size these meters so that the maximum and minimum flow rate can be measured. This can become difficult with low flow rates, due to slippage of the liquid through the meter.

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 your recipe, 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. This is because the density of the product has changed and you did not realize it. This is especially common when measuring fats and oils where the change in temperature can greatly affect the density of the liquid.

Let's suppose that you have a production line running at 10tph and you are applying 10% fat to your product. The amount that you are applying is off by +1% of the desired flow. 20,000 x .1= 2000lbs x .01error = 20lbs/hr x 16hrs per day x 300 days = 96,000lbs per year x 0.20 for $0.20 a lb = $19,200.00 per year. A coriolis meter that is .1% accurate will cost about $ 10,000.00 so the meter has paid for itself in less then a year. Since the cost of not metering an ingredient by weight is so high, we are going to concentrate on the metering technology that most closely resembles weighing. This is the Coriolis mass flow meter.

Coriolis Meter Accuracy

A Coriolis meter is based on the idea that a fluid will impart force on a tube when the flow changes direction. 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 80HZ. This up and down vibration has a total movement of less than a tenth of an inch 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% to 0.2% of the flow, within the meters rated flow capacity. This means if the flow rate that is called for is 10lbs per minute. the flow out of the meter will be between 9.99 and 10.01 lbs per minute. These meters are setup from the factory to be spanned for the flow capacity that you will be running. It is important when ordering this type of meter to give the representative or factory as much information as you can about the characteristics of the liquid. 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 250 degrees F 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.

If air is allowed to enter the system, the entrained air can affect the accuracy of the meter. If the liquid has a high viscosity or has more than 50% suspended solids, then you may want to go up to the next size meter to avoid plugging or excessive pressure drop across the meter. All metering systems should be setup so the amount of material flowing through the meter can be calibrated and checked. If it is possible, it is good to catch the product at a point near the destination. By doing this you can make sure that the back pressure conditions are similar.

Scale Accuracy

Procedures that you would use to scale dry product should also be used when scaling liquid products. You need to make sure that all connections to the scale are done so that the dead load on the scale is repeatable. You should also make sure that there is no obstruction that would prevent the scale from moving freely in its mounts. If the scale is discharged by pressurizing the scale, the weighing should be done when the scale is at atmospheric pressure, and after the target weight has been met. Then the scale can be pressurized for discharge.

Any scale should be setup so that as the scale is filling, the displaced air has a place to go. Proper venting will aid in the filling and discharge of the scale. It is a good idea to periodically monitor the scale after filling to make sure that it is not gaining or losing weight due to a leaky valve. This can be done by pausing the batching process, recording the weight, and holding the contents of the scale for a few minutes and then recording the weight again. If there is equipment running nearby that could affect the accuracy of the scale, then the scale should be mounted on vibration reducing pads or the vibration may be able to be electronically filtered, (if the vibration is cyclical and somewhat repeatable).

When load cells are specified it is a good idea to get cells that are calibrated for 10,000 DIV. Even though the scale is a process scale and you may not be using it for trade, it is a good idea to have a setup that matches a legal-for-trade arrangement. A legal-for-trade scale is set up to match the load cells resolution of 1 part in 10,000. Scale resolution is one part in 10,000 of the scale rated full load capacity. This means that if a scale is rated for 20,000 lbs the resolution will be 2 lbs. If the scale is rated for 100 lbs the resolution will be 0.01.

Resolution does not equal accuracy. For example if you wanted to weigh 0.1 lbs you would not want to weigh this amount in a 100 lb scale, because if you are off by 1 increment of the scale, then you are off by 10%. For most applications a variation of 10% would be unacceptable. So if you wanted to weigh 0.1 lbs and you wanted to be within 1%, the maximum size scale that you could use is a 10 lb scale. 10/10,000= 0.001 x 100= 0.1.

Other factors effecting accuracy include the feeding equipment into the scale. Is the automation system capable of stopping the feeding device in a timely fashion? Does the pump and supply valve react quickly enough to allow the desired accuracy? Another factor can be environmental. Is the vibration in the area excessive? Are there air currents that can affect the accuracy of the scale? The scale should be setup so the calibration of the scale can be easily checked. This means that hanging test weights and spanning the scale should be easily achieved. How frequently you check the calibration will be based on your standard operating procedures, but most companies will check process scales at least once a year.

General considerations:

Whether the liquids are going to be used in the batch mixer, or after extrusion, there will almost always be a dry substrate that the liquid is being applied to. When using ingredients in any process it is necessary to examine the characteristics of the liquid and dry ingredients 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. A chart can be created so that the various vendors of the liquid system can properly size and select the equipment.

	Maximum	Minimum	Nominal	Density
Dry Flow Rate	________	________	_______	_______
Dry Material Particle Size	________			
Dry Material Angle of Repose	________			
Desired Dry Material Accuracy	________			
Liquid Flow Rate	________	________	_______	_______
Liquid Operating Temperature	________			
Liquid Viscosity at Operating Temperature	________			
Liquid PH	________			
Desired Liquid Accuracy	________			

These characteristics will determine the materials that come in contact with the liquid. For example, it is undesirable for copper or copper alloys to come into contact with animal fat. Some additives such as animal digest and phosphoric acid can be quite corrosive and would require stainless or plastic contact piping. Tallow has a tendency to solidify at higher temperatures so it is desirable to heat trace equipment used in the application of this ingredient. Since some types of fats are solid at room temperature, you may have to actually melt the fat before it can be used in your process.

Feeders and pumps should be sized for the appropriate flow for the desired percentage of ingredient being applied. This can be a challenge if both the liquid percentage and dry flow have a wide range. For example, if the dry flow varies from 2 to 10 tph and the liquid addition varies between 5% and 15%, then we would need to find a pump that can go from 200 to 3,000 lbs per hr. In order to achieve this turn down you might have to combine a VFD speed control on a pump and a proportioning valve with a return to the supply tank.

Lines going to the equipment where the liquid is being used should be setup so they can be easily accessed for cleaning. It is important to have the correct type of filter before the pump to make sure that the pump is not damaged by foreign material that could be in the liquid, or may drop into the supply tank accidentally. Check valves should be put into position so that the lines do not drain back to the tank and cause the lines to run empty.

It is important to know and record the normal operating conditions of your liquid system, so that you can know when an upset condition occurs. For example, if the normal pressure in the system is 30 PSI, then when the pressure starts to climb. Then, you may have a filter that is becoming plugged or a buildup of product in the piping.

When measuring liquids going into a process it can be weighed in a scale, like any dry material in the formula might be, or it can be metered into the process. It is more common to see liquids batch weighed into a process when the ingredients are going into a batch mixer. This can be especially cost effective when there are multiple liquids that need to be measured in a formula.

Scale and Meter at the Batch Mixer

A convenient place to add liquids is at the batch mixer. The amount of dry product is known because the batching system has weighed the product up before it went into the batch mixer. We will look at weighing and metering a liquid into the batch mixer. A 10,000 lb batch requires 3% fat. That means that the dry matter weight will be 9,700 lbs and the fat addition will be 300lbs. The fat is weighed in a 500 lb liquid scale and we stop the flow within 2 scale increments so the final weight was 300.1 lbs. The accuracy of the scale is 1 part in 10,000 so the most error has occurred in the over draft in the scale which is 0.1, which equates to 0.04% We take the same amount of fat and add it to the mixer and it takes 1min. The rate is 240 lbs per min. and the coriolis meter is accurate to

+- 0.1% of flow, so 300 lbs x 0.001= 0.3 lbs, which equates to 0.1%. This of course assumes that we can stop the flow through the meter instantly.

A good control system could compensate the time it takes to shut off the flow of liquid in both cases. Overall, the scale is a slightly more accurate way to add ingredients to the mixer. There are some other considerations regarding the scale. The scales themselves require inlet ball valves and discharge valves and also alarm level detectors in case the inlet valve fails to close. It is difficult to totally seal a scale hopper, since it should be vented in order to fill and discharge properly. If the scale system valves malfunction, then you could have the scale, or the scale surge over flow, which is messy.

The meter on the other hand is totally enclosed and if the shut off valve leaks, the meter should detect the flow, and sound an alarm, if the leaky valve is not detected, the fat runs into the mixer and not on the floor.

Scale and Meter Post Extrusion

Scale
Since extrusion systems are continuous flow operations, it is difficult to batch weigh the product. This means that if we want to weigh the product in a post extrusion application, we have to have a way to surge the flow of material coming in, while the weighing process is taking place. This type of system is a loss-in-weight system and requires a garner hopper to hold the product while the weighing process is taking place, or it requires a duplex scale arrangement so that one scale if discharging while one scale is filling.

Continuous liquid application systems work best when you minimize the starting and stopping of the flow and minimize the possibility of the dry and liquid products not being timed properly as they arrive at the liquid applicator. In order to maintain a continuous flow into the application machine while operating in a loss in weight mode, the system can be made to go into a weight exception mode during the refill cycle. When this happens, the system maintains the discharge rate that it was set at before the refill cycle began. After the refill cycle is complete the system returns to a loss in weight discharge mode for the measurement of the liquid and dry flow.

Meter
The continuous flow of kibble into the liquid application equipment, when using mass flow technology is usually monitored with a device that takes density changes into account. This device can be a weigh belt, impact scale, or other dry mass flow meter. This flow is then used as the master flow of material, and all other additions are slaved to this rate. The flow of liquid is controlled by a modulating valve or VFD on the pump or both. In this case the liquid flow is fed back to the controller from a coriolis meter. If the dry flow of product slows down or speeds up, the flow of liquid is adjusted accordingly.

In a continuous flow system, the most variation will be found in stopping and starting of the system. Anything that can be done to minimize the starting and stopping will benefit the uniformity of the final product. It may be possible to monitor the flow of product coming into the system, and adjust the flow coming out of the system to match the production flow. This can be done with a surge hopper and feeder that can be used to slow down or speed up the flow into the continuous blender. This can be especially valuable when the system that feeds the system has a piece of equipment that is subject to great swings in output such as a counter-flow cooler.

Micro Liquid Additives

More and more additives are being used that represent less than a percent of the final product. These additives can present special challenges. These include antioxidants, probiotics, and enzymes. Some antioxidants such as vitamin E will be extremely viscous at lower temperatures, and raising the temperature too high could affect the performance of the ingredient. In that case, the pump, meter, and piping that is used should be carefully chosen to compensate for the high viscosity. As mentioned before, the ingredient characteristics should be taken into account when selecting the equipment, since these ingredients are quite often highly concentrated and can be corrosive.

When a small amount of liquid is used, consideration should be given to whether or not there is enough liquid to spread across the surface of the kibble. When the ingredient amount is very small then you may want to consider whether the ingredient is water soluble or oil soluble and use another ingredient in the formula as a carrier for the additive, so it can be spread out over the surface area of the kibble. Even a relatively small amount of dilution can have a major change in the variation found on the surface of the kibble. Many of these ingredients are expensive, and as we have already seen, being accurate by selecting the right measurement system upfront will payback consistently throughout the life of the system.

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