# POST PROCESS LIQUID INGREDIENT ADDITION

Heat intensive processing has created a need to add ingredients downstream from the extrusion or drying process. Some of the necessary vitamins and nutrients are heat sensitive and loose much of their effect a temperatures that are encountered in conditioning and extrusion of feeds.
The following information is an overview of methods used in our industry, as well as others, to apply micro ingredients after the extrusion process. For the purposes of this talk we will be defining micro ingredients as those ingredients that are added at a rate of less than one percent.

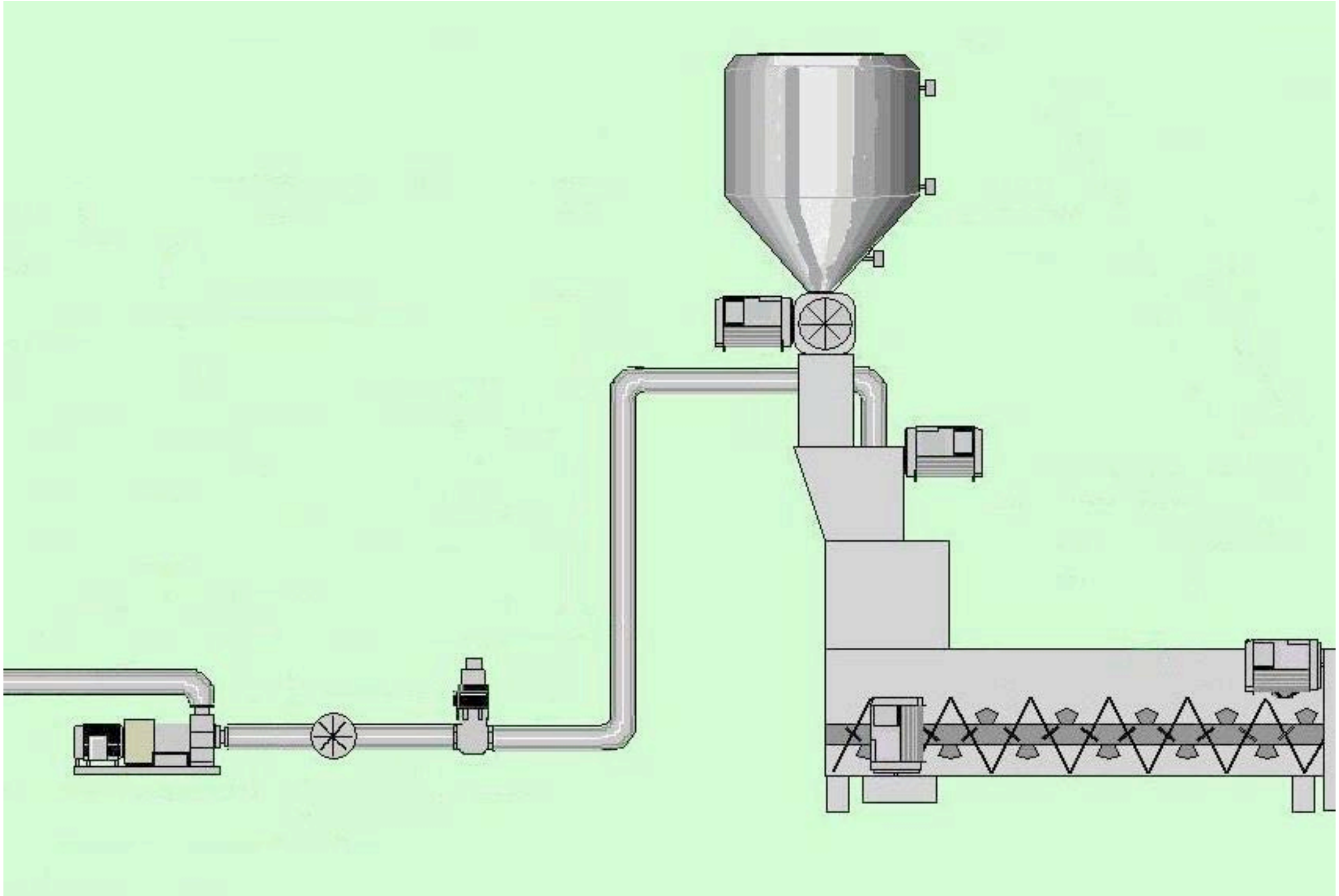
General considerations:

When using ingredients in any process it is necessary to examine the characteristics of the ingredient to insure 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. For example liquid animal digest is quite acidic and systems should be designed to withstand the corrosive nature of the ingredient. Feeders and pumps should be sized for the appropriate flow for the desired percentage of ingredient being applied. When the ingredients are being applied after the cooling process the application system should be placed as close as possible to the packaging or load out system, in order to minimize the build up of liquid ingredients on material handling equipment. In any coating system there are two issues that must be addressed; control of metering and method of application.

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 extrusion or drying 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 of material in a continuous flow. 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 extruded product, to be the master flow. All other additives are slaved from this master flow.

Volumetric (fig 1)



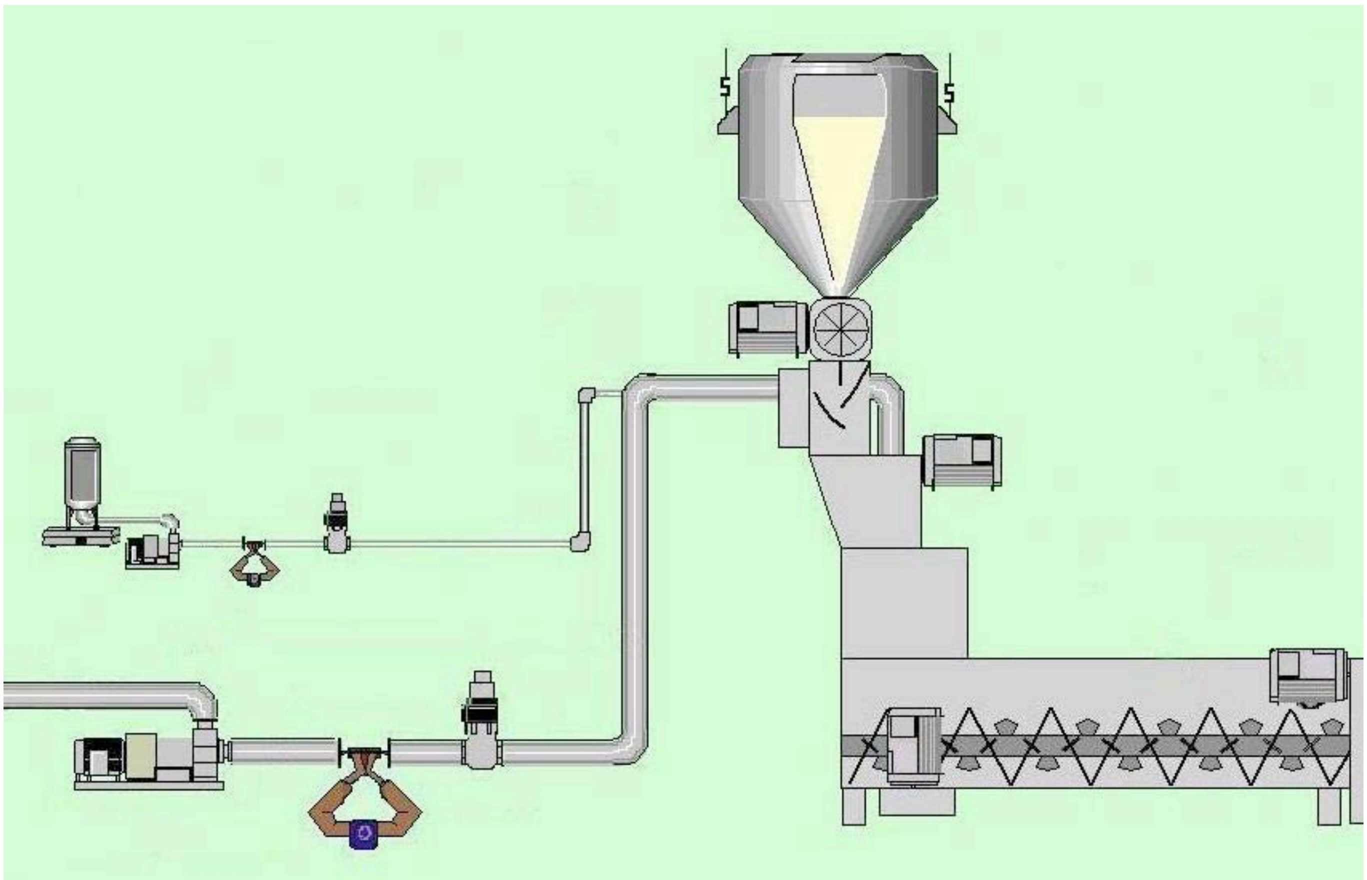
In volumetric metering the master flow of material is sensed by the number of revolutions of a screw conveyor, rotary feeder, or belt conveyor. We calibrate the material flow by measuring how much product has run through the system in a given amount of time. It is important to have a method to divert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

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, or the number of cycles from a diaphragm type 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 stays constant and if the formula 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 (fig 2)

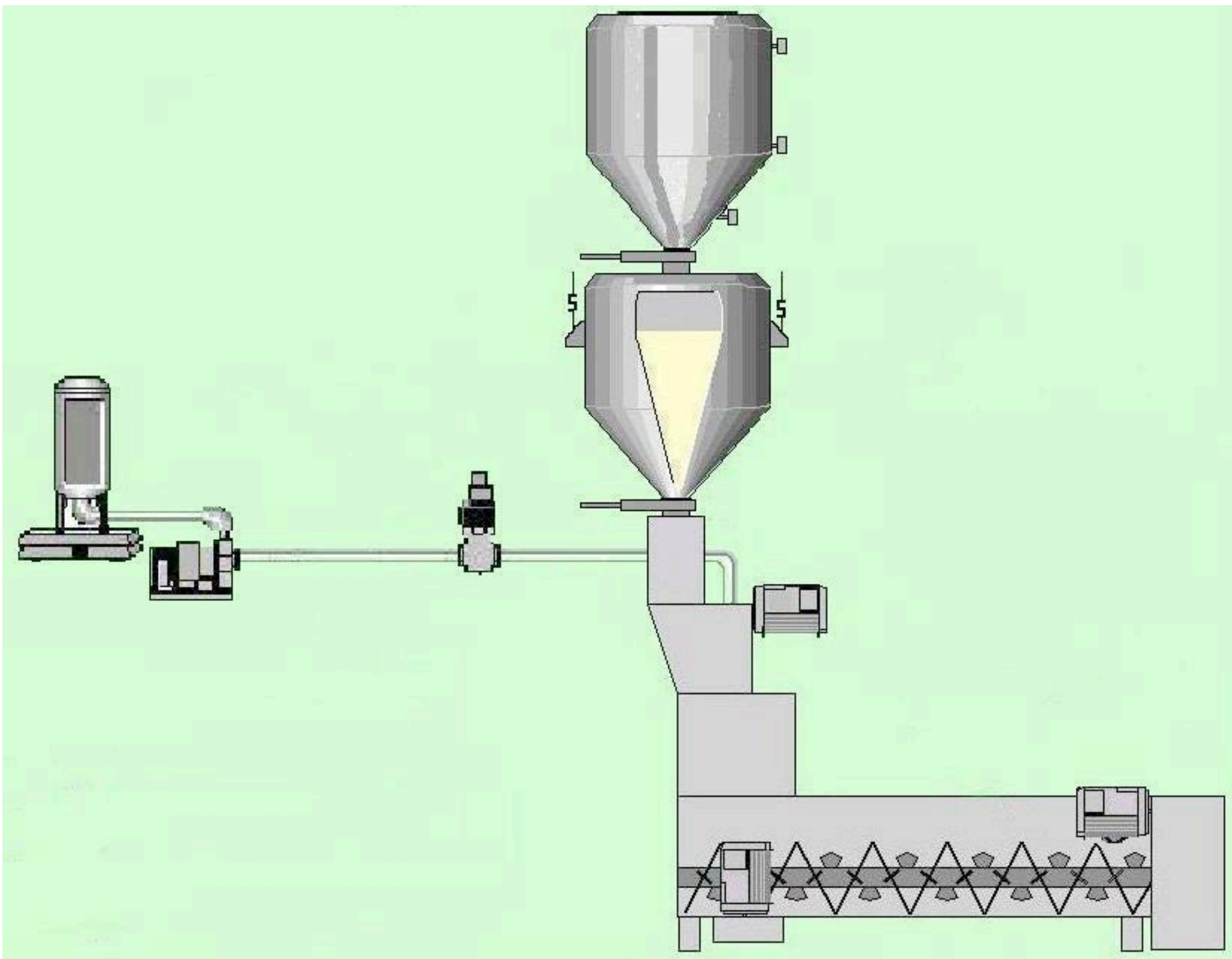


In mass flow metering the Master flow of product is sensed with a weigh belt, weigh feeder, impact scale, or centriflow meter. This type of measurement integrates the weight of the product with a tach signal from a conveyor or over a specified time period.

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 quite good (.5-1%) The disadvantage is the higher up front cost.

Loss in Weight (fig 3)



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. 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.

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 head room to accommodate the garner hopper above the loss in weight scale. The up front cost for this type of system is also greater then either of the systems mentioned before. However, if the number of ingredients being weighed is greater then three, then the cost can compare well with mass flow technology using coriolis type meters.

Methods of Metering

Delivery of the micro ingredient in a liquid form needs to be done in a repeatable fashion. This is accomplished with a positive displacement pump. There are several types of positive displacement pumps available and each has its advantages and disadvantages. A piston pump uses one or more pistons to draw in and expel liquid. Some of these pumps use two pistons alternately drawing in and expelling fluid. By alternating discharging of the pistons, the amount of pulsation to the liquid delivery is reduced. These types of pumps can have very close tolerances, so the liquid should be filtered so suspended solids do not exceed the tolerance of the pump. A diaphragm pump uses a flexible membrane that moves in and out to move the liquid. This pump is more tolerant of solids, as a mater of fact, a variation of this pump is used to pump sand. Like the piston pump, the diaphragm pump delivers the liquid in a pulsating flow. The peristaltic pump uses a roller or rollers contacting a hose to pump liquid. The advantage to this type of pump is that none of the pump parts come in contact with the product. The disadvantage is that the hose needs to be changed on a regular basis, since the compressing and decompressing of the hose causes the hose to wear out quickly. In each of these pumps the pulsation can be minimized by the addition of a pulsation dampener. These devices are like a pressure accumulator that even out the flow of liquid. In order for the pulsation dampener to work, there must be enough pressure in the system for the accumulator to build up pressure. If the piping run and back pressure for nozzles is not sufficient to build this pressure, then a pressure regulator valve should be added between the pump and the liquid meter. A gear pump and progressive cavity pump use a rotating gear or screw to move the fluid. These pumps deliver liquid with little or no pulsation and can create great pressures. They can also have close tolerances so the proper size filter should be used. These pumps do not tolerate running dry, so safe guards must be put in place to make sure this doesn’t happen. Piston, peristaltic, gear, and progressive cavity pumps can be controlled by using an AC speed control or a DC speed control. In the past the DC drives were used when more turn down was necessary, but now AC drives have comparable turn down, if a vector type drive is used. The speed control for the diaphragm pump is a controller that controls the speed of an oscillating cylinder. This is accomplished by either actuating a solenoid on an air cylinder, or by energizing a coil directly surrounding the cylinder that moves the cylinder back and forth electro-

magnetically.  These controls have a timing circuit that determines the number of times the cylinder is energized.
Spray nozzles must be selected based on minimum and maximum flow rate of the ingredient and minimum and maximum particle size of any suspended solids that might be in the liquid.  It is always better, whenever possible, to use hydraulic pressure to atomize the liquid rather then an air assist atomization nozzle.  An air assist nozzle has more of a tendency to cause the product to become air born, and using compressed air requires more energy.

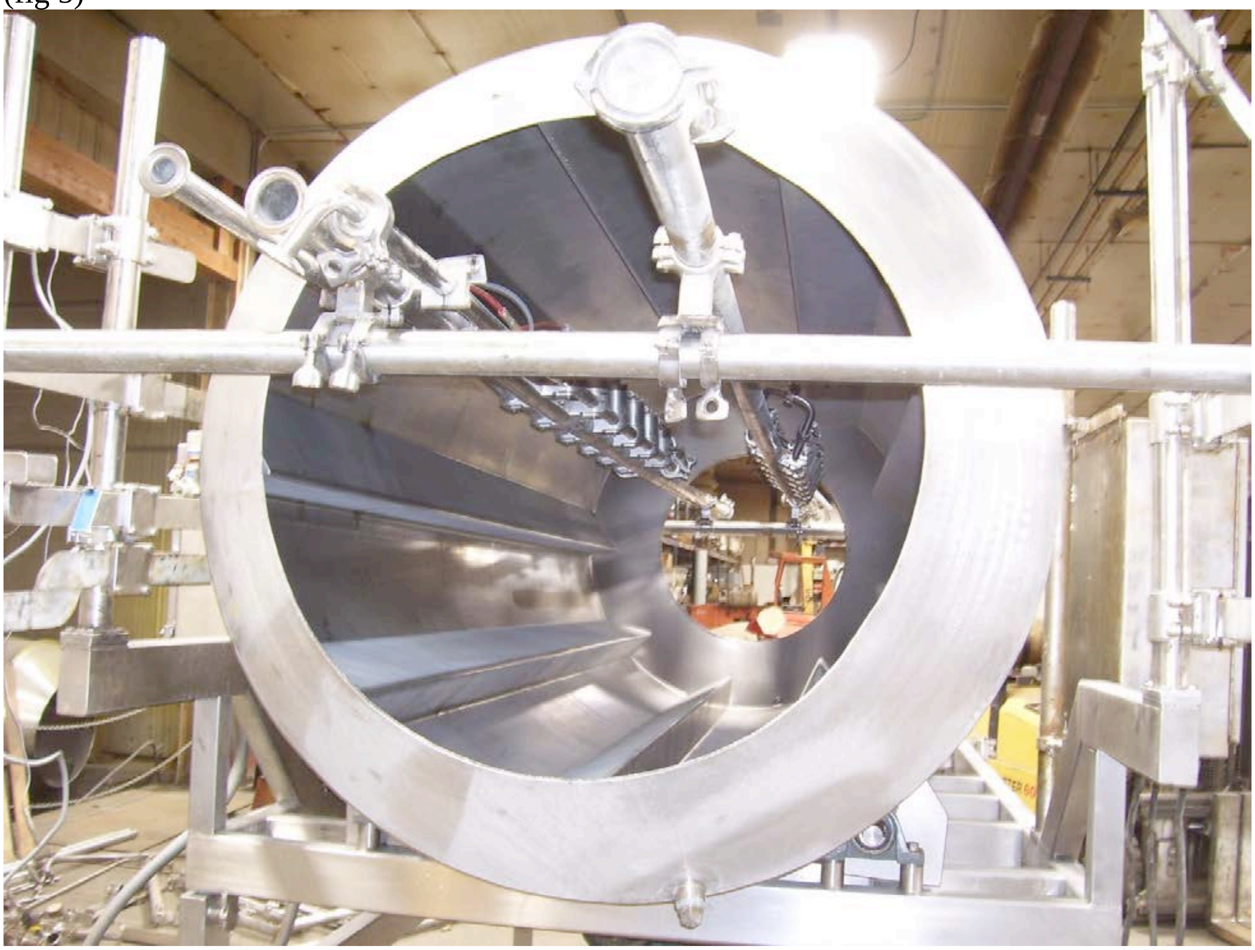
Method of Application
After we have chosen a method to control the ingredients that we are going to apply, we need to choose where and how we are going to apply these ingredients.  The most common methods of application are:

Spray in a screw, ribbon, cut flight, paddle, conveyor
Spray in a rotating drum or reel
Spray using a spinning disk

Spray into a screw conveyor:
(fig 4)

Spray nozzles can be added to a screw conveyor to apply liquids to extruded product before load out or packaging.  Screw conveyors provide very little mixing action or retention.  If we cut the flights or substitute ribbons for solid flights then we get 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.  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.  This can cause spotty coverage where some of the product has a great deal of liquid applied and others have very little.  One way to alleviate this problem is to drop the product into a plenum or weir with spray nozzles prior to entry in a mixing conveyor.

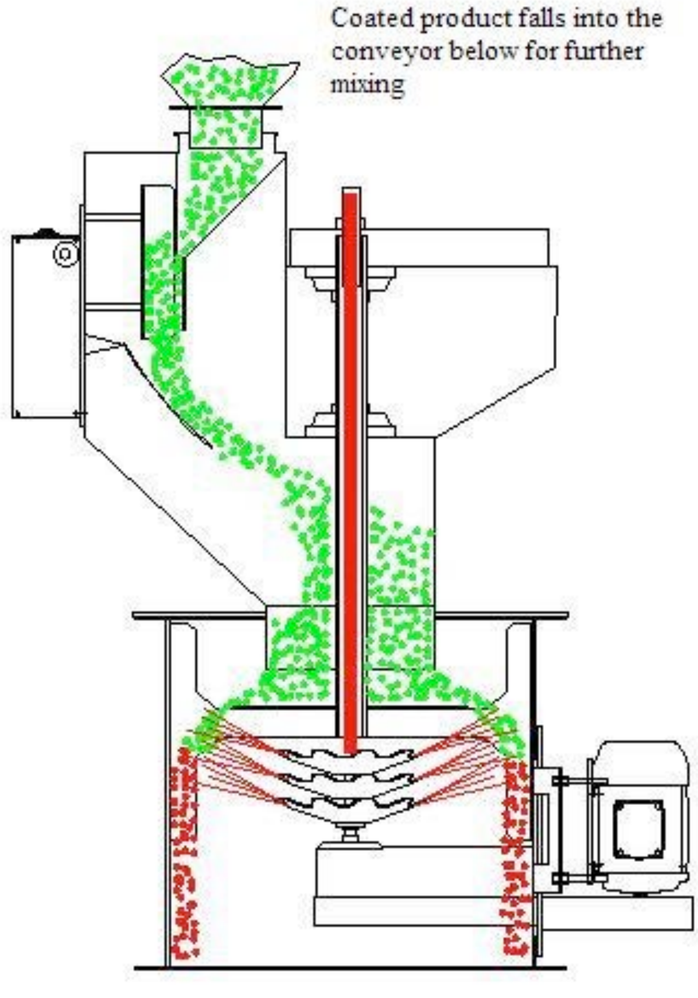
Spray into a rotating drum:
(fig 5)



The food and pet food industries quite often use a rotating drum with a variable angle of tilt on the drum.  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 spray action can migrate out of the drum and settle on the surrounding equipment.  As with the mixing conveyor, the spray contacts a small portion of the product and the tumbling action of the drum is used to intermix the liquid. This type of system can also benefit by putting the spray nozzles into a plenum prior to entry into the drum.

Spray using a rotating disk:

(fig 6)




All of the systems mentioned before use spray nozzles. Spray nozzles have a tendency to clog when applying liquids with suspended solids. Rotating disk applicators use two spinning disks to apply liquid to extruded products. 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.

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 many times do incorporate a mixing conveyor, however the purpose of this conveyor is more for retention of the product, in order to give the liquid time to absorb into the product. Since the system does not require spray nozzles, any liquid capable of flowing through a half-inch pipe is going to be able to flow through the machine. This means that the user has a great deal of flexibility in the selection of ingredients. Liquids that could previously not be used in coating systems because the high percentage of suspended solids clogged the spray nozzles easily pass through the spinning disk applicator. Since these machines are totally enclosed we eliminate the over spray sometimes associated with open ended coating systems. The top material disc spins at low RPM so the system is very gentle. The amount of liquid that the machine can apply really depends on the hardness of the product and the porosity.

Addition of dry ingredients:

The most common way to apply dry ingredients after the extrusion process is to meter the dry ingredients onto the particles after the application of liquids. This causes the dry ingredients to stick onto the particles. In order to apply a uniform tack 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 before the retention time has given the liquid time to absorb on the particle. 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.

Conclusion

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 system and loss in weigh 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 insure accurate and trouble free operation.

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Principle Components Common Problems /Recommendations

Kibble Feeder

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.

Belt Conveyor

Scrapers and brushes should be used to minimize fines carry over on to 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.

Rotary Pocket Feeder

The inlet of the pocket feed 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.

Variable Slide Gate

Make sure the slide gate has high resolution and a linear response.

Kibble Meter

Weigh Belt

Design of the weigh belt should eliminate the build up of fines between the weigh bridge and the belt.  Auto tensioning can eliminate the possibility of weights changing due to changes in belt tension.

Weigh Screw

Pivot point should have free movement.  Flex should be material that does not shrink due to changes in temp. or moisture.  Conveyor should be oversized to maximize material in the conveyor.

Impact Scale

Avoid excessive free fall into the impact scale (no more then 3ft or 1 meter). Special abrasion resistant materials should be used on the sensing plate.  Should be cleaned and inspected on a regular basis.

Liquid Pump

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.

Diaphragm Pump

Set up schedule for replacement of pump diaphragm according to manufacturers recommendation for number of hours use. Use a pulsation dampener and back pressure regulator to eliminate the pulsations from the diaphragm.

Centrifugal Pump

Use for refill applications. Most centrifugal pumps are not appropriate for metering because of internal slippage they lack repeatability and usually can not generate higher pressures.

Liquid Meter

Nutating Disk, Piston Meter, Gear Meter

Meter should be sized for max and min 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.

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 80hz. This up and down vibration has a total movement of less then 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 .1% to .2% of the flow, within the meters rated flow capacity. This means if the flow rate that is called for is 10lbs per min. the flow out of the meter will be between 9.99 and 10.01 lbs per min. 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 ridgedly 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 then discharging out of the end of a horizontal pipe.

Mixing Conveyor, Spray Plenum ,Weir, or Rotating Drum

Spray Nozzles Plug
Make sure that the liquid is filtered through a basket strainer and that the filter is sized smaller then 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.

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.

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 air born. When ever possible it is better to use hydraulic pressure rather then pneumatic pressure to atomize the liquid.

Build up of Liquid On Down Stream Equipment

Adjust angle of tilt on drum for more retention.  Slow down mixing conveyors for more retention.  Make sure that dry flow sensing threshold and sequencing is set correctly so that the liquid is being sprayed on to dry product flow.

Rotating Disk
Spotty Spray Coverage
Dry flow too low to cover dry disk. Liquid goes through gaps in the curtain of material and runs down into the mixing conveyor.  Slow down dry disk until it is throwing a 360 degree curtain.  Lower the adjustment spout to choke feed the dry disk.