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The 4 Key Hidden Causes of Filling & Dispensing Errors: Part Two

Intended Audience

- Process Engineers
- Control Engineers

Manufacturing Area

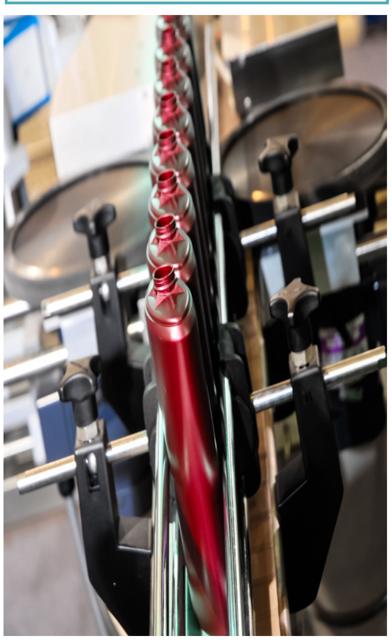
- Process & Packaging

Applications

- Batching & Blending
- Filling & Dispensing

Focus

- Weight-based Filler and Dispenser Control in Industrial Manufacturing



Part One Summary

At some stage in the manufacturing process, just about every manufacturing plant in the world makes and/or packs raw materials and finished product. In plants everywhere, the measurement and control of these raw material and finished product events happen many hundreds of thousands or millions of times a year. Even a very small error in every dispensing or filling event, adds up to a very large number at the end of 365 days. Read Part One Here

PROCESS conditions do not stay constant. By that we mean that the rate at which materials "FLOW" can change over a period of time (mins or hours, etc) or even from one cycle to the next. Changes in process conditions will influence flow rates, which in turn will adjust the amount of "over or under" fill or dispensing errors. There are 4 HIDDEN THINGS" going on, that contribute to and add up to over or under filling or dispensing errors. They are:

1. Measuring in flight materials (Materials moving at the time of shut-off)
2. Measurement delay (between the measuring instrument and the PLC)
3. Final control element let through between the signal that closes the gate and the gate closing
4. Kinetic energy impact: Finally there is the "force" of the material that impacts the scale

Part Two: The Solution

So what to do? There are 3 potential approaches. We will discuss each of these options, in depth. They encompass:

- Controlling process changes
- Constricting and adapting to process changes
- Predicting and adapting to process changes

Approach #1: Controlling Process Changes

This approach is usually only deployed when filling or dispensing slurries, liquids or gasses. Why? Because with these forms of material we can "eliminate" the effect of gravity, by controlling the pressure inside the sealed container or vessel that we are feeding the material from.

Think of a 30 foot high, 10 foot wide vessel holding a liquid with the dispensing valve located at the bottom of the vessel. When the vessel is full (30 foot column of liquid) the head pressure on the valve is at its highest and material will flow at its faster rate. When the vessel is a third full the head pressure will be significantly reduced and material will flow at a slower rate – affecting the 4 THINGS mentioned above. In fact every time material is taken from the vessel the height of the column of material gets lower, which in turn reduces the head pressure and the 4 THINGS change slightly.

What's the control engineers answer to solving this problem? Use a sealed vessel that can be pressurized and control and hold the pressure in the vessel at a constant level. A few examples of this approach would be: Color Kitchen batch applications producing inks or dyes; and multi-head rotary fillers, filling juices, oils etc. The benefit (PROs) of this approach is clear, by eliminating the process variable created by gravity we eliminate changes in the 4 THINGS.

The downsides (CONs) are:
1. That the cost to implement, automate and control the pressurized vessel can be high
2. This approach does not work for all materials e.g. aggregates, granules and powders.

Approach #2: Constricting and adapting to process changes
Now let's take a look at another widely used approach. In this case the control engineers are aware that the material flow rates are going to vary for multiple reasons – material flow characteristics changing because of moisture, temperature etc. and also head pressure. So in this case they decide to "minimize" the process changes and therefore the errors that would be created by the "4 THINGS".

How? Well they choose to control the feed rate (flow rate) of the material during each feed or filling cycle. They do this by using two pumps or two valves depending of the material types they are dealing with. This type of approach is called multi-speed feed control. As an example: consider feeding material from the same 30 foot vessel mentioned above, but this time we are not going to seal it and pressurize it. Instead we are going to have 2 outlets at the bottom on the tank – the first will be a 6 inch pipe with an on/off slide gate and the second a 1 inch pipe with an on/off slide gate.

When the feed starts both vales are opened (effectively 7 inches of flow rate is feeding material) this is called the "fast feed" stage. As the feed is approaching the set point and gets to within say 5% of the target, the control system shuts of the 6-inch slide gate. This effectively slows (constricts) the flow rate down to 1/7th of the fast feed rate – the feed is now in what is termed "slow feed" stage. What just happened? Constricting the flow effectively reduced all process variation to 1/7th and the impact of all errors created by the "4 THINGS" to 1/7th. In this case there will still be an error but it will be greatly reduced. Whatever the error was can be recorded, and a portion of it (say 50%) used as feedback to adjust a pre-act value that triggers the "slow feed" stage to stop just before the feed target is reached. Or after if the Kinetic Energy in the "slow feed" stage exceeds the other "3 THINGS". An easy way to think of what was done is to imagine you are "throttling the process changes and errors almost to death" to minimize any variations caused by moisture, temperature, head pressure etc. The benefit (PROs) of this is approach is clear:
1. It "minimizes" errors from the "4 THINGS"
2. This approach will work for ALL materials types.

The downsides (CONs) are:
1. The cost to implement, automate, control and clean multiple feeding outlets can be high
2. Slowing the process flow rate in every feed "steals time" from production – filling line and batch cycle times become longer. This reduces the number of bottles that could be filled in an hour or the number of batches that can be produced in an hour

Approach #3: Predicting and Adapting to Process Changes
This approach was developed more recently and was motivated by:
1. The high cost of implement and maintaining the control systems or loops
2. The need to maximize filling rates and batch cycle times in high performance manufacturing supply chains
3. The desire to simultaneously minimize feeds errors as much as possible. Remember the Holy Grail of feeding materials is to feed the exact amount of material, in the minimum amount of time, every time!

So is this possible? Well this time instead of "controlling or constricting" we are going to try to "measure and predict" what has changed since the feed started, then adapt for the change. Let me explain where this idea came from by switching gears completely for a moment.

Think about a gunner on a ship back in WWII trying to shoot down an enemy aircraft. The aircraft is a moving target, the shell the gunner is about to fire will take some time to reach the aircraft – so the gunner tries to anticipate where the aircraft will be when the shell gets to it by firing slightly in front. But the planes air speed could be changing, wind speed and direction both could change. The bottom line is that it is challenging for the gunner. This challenge is what motivated the invention of the missile, which is fired in the general direction of the target, but tracks any changes in the targets position down to the last second before impact. I think you get the picture.

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A similar thing is going on during a material feed. Process conditions are changing the flow rate. Now we don't have the luxury of a missile, but we have one advantage over the gunner in that we can use the weight controller to predict and track down and adapt to any process changes to the last second, and that one thing is "FLOW RATE". By measuring the weight and flow rate simultaneously we can adjust and "dial in" pre-act value throughout the feed, without having to control or constrict the flow rate.

Weight Controllers

Application Specific Dispenser/Filler Modules

By monitoring flow rate we can maintain a fast flow rate all the way through the feed down to the last second before impact, in other words all the way to the set point (target weight). The benefits (PROs) of this is approach is clear:

1. We don't have to worry about the process variability and potential errors from the "4 THINGS"
2. This approach will work for all materials types
3. That the cost to implement, automate, control and clean in most cases can can be reduced to one multispeed valve/gate and slowing the process flow rate in every feed is not required in most cases so "stealing time" from production does not happen. Filling line and batch cycle times become shorter.

This increases the number of bottles that could be filled in an hour or the number of batches that can be produced in an hour. The downsides (CONs) are

1. Feed upsets e.g. wildly varying flow rate can still create feed errors. However, this approach takes us much closer to the "Holy Grail".

If you are wondering how often each approach is deployed in the real world? A best guess (estimate) based on experience would be: Approach #1 in approximately 10% of applications; Approach #2 in approximately 70%; Approach #3 in approximately 20%.

We believe that as more and more control engineers engage in the use of advanced control methods, and discover and deploy the third approach that it will eventually reach about 50% of future applications.

The above article was written by Rodger Jeffery. who has been with Hardy Process Solutions for 11 years and in the industry for 40 plus years. He has solved simple and complex weighing related problems in many manufacturing industries and has installed thousands of INDUSTRIAL WEIGHING solutions across the globe. This is the second article in this series that he has written for Hardy

How Hardy improves OEE with Faster Installations, Calibrations and Diagnostics

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