Feeding Systems and the Process

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1. Introduction

Henry Ford's success with the auto assembly line indelibly imprinted on the minds of other forward-looking engineers and captains of industry the logic of having the worker stay put while the product moves. Today, in most continuous processing systems, whether in the chemical, plastics, food or any other applied area, product flows not from worker to worker, but from machine to machine — each possessing a specialized processing function just as the auto worker still has his own specialized skill and purpose.

It may be a shaky analogy to think of Ford's conception of the assembly line as an early example of a continuous processing system, but stretching the similarities does serve to underscore the system-intensive nature of processing product continuously. In reversing conventional thought, Ford effectively demonstrated the potential for more widespread application of the principles of continuous production that had been, until that time, limited to the most basic industries.

In the early years of this century, though, there were a few hitches that would slow the realization of that potential: a lack of systems methodology, and a lack of the technology required to convert method, once devised, into machinery. But, in the 74 years since the first mass produced Model T rolled off the production line, systems knowledge has grown and matured, and technology has successfully translated raw concept into reliable control throughout the developed world.

2. The Focus on Feeders

One of the weak points of the assembly line/continuous processing analogy is that in auto production thousands of pre-manufactured components 'flow' together to form a car, whereas in the more familiar and relevant context of the continuous processing of bulk materials, the 'components' are far fewer, and the term 'processing' rather than 'production' more aptly describes what goes on between the receiving door and the shipping dock.

At the center of many sophisticated, continuous, bulk material processing systems is the feeder. By the fact that feeders control the flow rate of material ingredients, they are an important and primary means by which overall processing rate and formulation is controlled.

While feeders have control over only one physical parameter — flow rate — there are nearly limitless possibilities as to how they are to control (as masters) or are to be controlled (as slaves) by other system elements. Basic process needs and considerations, in any specific instance, will reduce the possibilities to a manageable few, but, within the avenues of feasible options left to the process engineer, only experience and knowledge will bring the final system configuration into clear focus.

3. Feeders as Masters

Strange as it may seem, feeders rarely serve as masters over anything other than feeders. At first thought it appears that a feeder's flow rate signal could be picked up and used to control a variety of process equipment, but that option is not usually chosen. The reason is simple and has to do with system dynamics.

To keep a processing system working efficiently and on-spec all the time, the most slowly reacting element in the process should have control over the elements with which it interacts. An extruder is a good example. Since close control of temperature is a must in most extruder applications, it takes a while for an extruder to ramp up or down to a new operating point without allowing temperature to wander outside of acceptable limits. Extruders are constrained by their massive thermal inertia to accommodate rate changes slowly, so it is best that a quickly reacting feeder or feeding system follow the extruder's ponderous lead. A feeder, as master, simply sets a pace of reaction to change few other process elements can match. As a nearly universal result, feeders end up controlling only other feeders.

Feeders in a master role are quite common, though, because in the continuous proportioning of materials there is no better way to assure consistency of both recipe and rate. The feeder handling the main or most critical ingredient is usually singled out as master. In operation, its setpoint or flow rate signal is channeled to all slaved feeders (which can be any combination of other dry or liquid weigh-feeders, volumetric feeders or pumps). Fig. 1 shows an example of a master weigh-belt feeding a rubberized product and controlling the proportioned flow of two slaved ingredients, one delivered by a loss-in-weight solids feeder, and the other handled by a speed-controlled volumetric feeder.

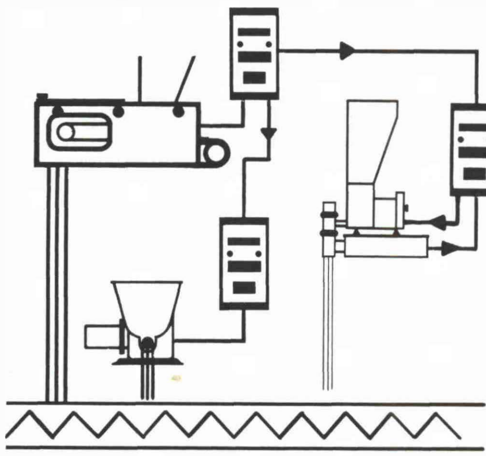

Fig. 1: Master weigh-belt feeding rubberized product and controlling two slave feeders

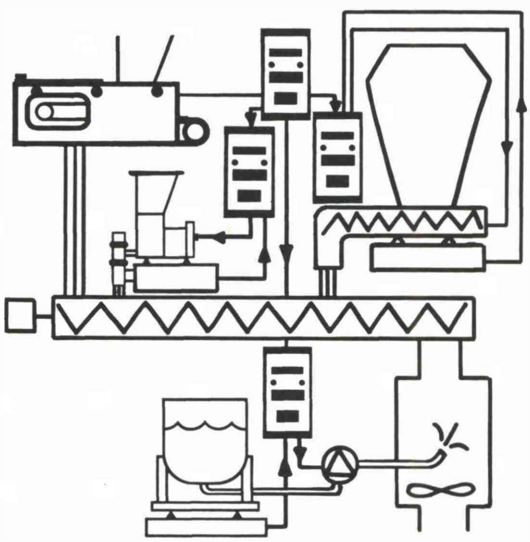

Fig. 2: Master/Slave system used in manufacture of powdered drink mix

Discharge is to a mixing conveyor. Fig. 2 illustrates one master/slave system used in the making of a powdered drink mix. Again, the main ingredient is controlled on a weigh-belt. One low rate and one high rate loss-in-weight feeder are slaved to the weigh-belt's flow signal while a third slave feeder, a liquid loss-in-weight, delivers a precisely controlled stream of molasses to a spray head.

4. Feeders as Slaves

Just as every piece of paper has two sides, we could not discuss feeders as masters in the previous section without also touching on feeders as slaves. But keep in mind that, even though we are now going to be looking at feeders in the capacity of the slave function, a slave can also be a master at the same time. A weigh-belt feeder, for example, may be taking its setpoint orders from some external source, but at the same time it may be passing along its flow rate signal to a whole family of subordinate feeders.

Aside from feeders being slaved to master feeders, there are two other ways feeders can be externally controlled: either they can be directly governed by a supervisory process control device such as a computer or dedicated programmable logic controller (PLC), or their rates can be dictated by a specifically chosen process-related variable.

Supervisory Control — Depending on the nature, size and complexity of the application, process control can manage, coordinate, audit and monitor the entire process, or just selected parts of it. Since the material feeding system is so central to the operation of the process as a whole, feeders are seldom excluded from process control's command.

Under the control of either a central computer or a PLC, the feeding system, in whatever configuration is appropriate to the application, receives its feed rate commands and, if desired, returns actual mass flow data (for all ingredients) to the computer or PLC. Depending on the desired extent of direct control, proportioning feeders can be governed by the supervisory device (where individual setpoint signals can be generated and distributed), or can be indirectly governed (via supervisory control of only the master feeder where all others are slaves).

Totalized material thruput for each controlled ingredient can either be directly supplied to process control from each feeder's flow integrator, or the process control device itself can integrate each feeder's flow signal to achieve the same result. Feeder status conditions and alarm signals are often channeled to process control for easier problem diagnosis, orderly start-up and shut-down, and better management of overall process operation.

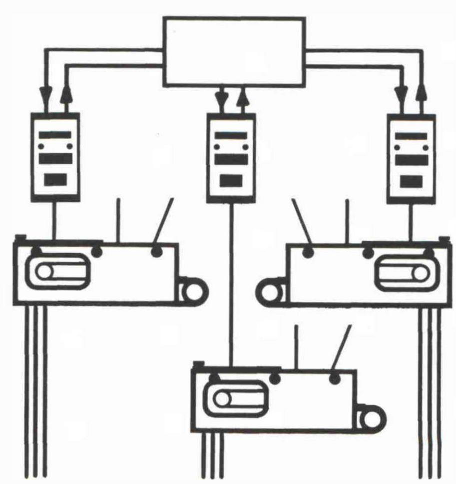

Fig. 3: Application of central computer in pet-food application

Fig. 3 illustrates the application of a central computer in one pet food application. It communicates formulation and total flow via floppy disk, and individual feeders report the totalized flow of each ingredient.

The use of a central computer in process control usually provides the user with more data recording capability and more sophisticated programming options, but computers, coming as they have from their data handling origins, have been generally found to be more difficult to program, at least from the process-oriented engineer's perspective.

PLCs on the other hand don't have a central computer's impressive capability to store, manipulate and retrieve data, but their ease of programming and ability to stand up to rigors of the process environment have made them the preferred choice in many applications. Today, though, the differences between PLCs and central computers applied to process control are becoming less distinct as PLC and computer manufacturers are drawing on each other's product strengths to produce supervisory control systems that offer the best of both approaches with the shortcomings of neither.

A computer or PLC can be instrumental in performing specialized control functions such as sequencing and pacing. In sequencing feeders, appropriate time delays are computed and executed to account for the material transport distances between feeding points. Fig. 4 shows a PLC governing feeder controllers (two weigh-belts and two volumetrics) and other processing equipment to sequence start-up and shut-down operations in addition to coordinating production rate changes.

tion with the individual feeder controllers. It provides the convenience of single point control and displays overall flow rate as well as real time mass totalization of system thruput. Where the application does not require the control sophistication of a computer or PLC, the master rate setter may provide the needed level of additional monitoring capability and convenience.

Process Parameter Control — A group of feeders tied together in a proportioning configuration can reliably produce a continuing stream of on-spec product, but the question then becomes: How does that stream relate to the rest of the process? Without total supervisory control, how can the critical process elements work in harmony to produce the right product under the right conditions at the right rate?

As pointed out earlier, feeders do not usually control other devices because of their nimbleness of response relative to other elements in the processing system. The answer to the control questions just posed lies in keying-in on a single process-related parameter to control the feeding, and, possibly, other systems. In a simple instance, conveyor belt speed may be the key selected parameter. By hinging feed rate, mixer rate and packing line speed to the speed of the conveyor, adequate coordination of the entire process may be possible.

Other examples: Fig. 5 shows that the weight signal from a belt scale can provide the 'wild flow' signal necessary to accurately proportion additional materials to the uncontrolled flow of a main ingredient.

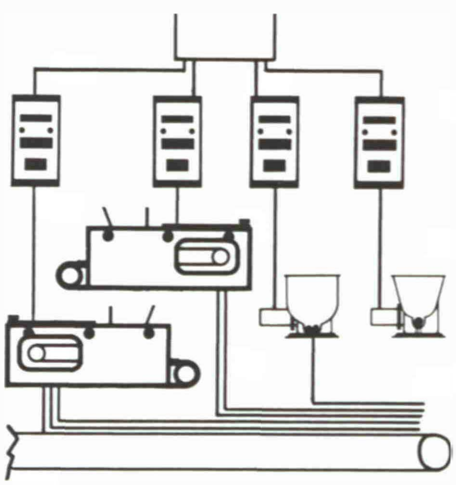

Fig. 4: PLC Governing feeder controllers and other process equipment

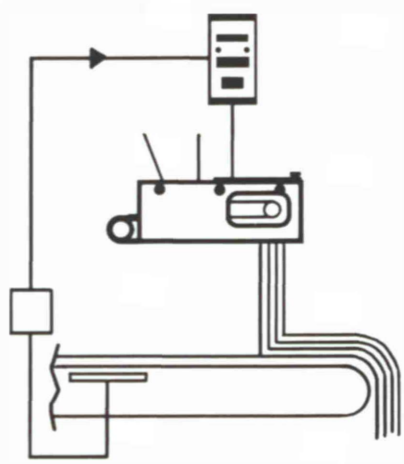

Fig. 5: Output from belt-scale controls proportion of additional materials to uncontrolled main flow

The pacing function helps prevent off-spec blends by identifying a feeder that cannot for some reason maintain its requested flow rate. Pacing brings all other feeders down in rate accordingly to preserve the desired proportions of the blend.

While not a process control device per se, the master rate setter deserves a passing mention here. A master rate setter governs only the feeding system and is used in conjunc-

The liquid flow counterpart to slaving a feeder to a belt scale simply involves the addition of a flow meter to the liquid line. The waffle premix application shown in Fig. 6 highlights the simplicity of the approach. Waffle premix is proportioned to the flow of water which is controlled by a simple manually operated valve. Water flow is sensed by a turbine meter whose output is scaled to provide a master signal for the weigh-belt feeder to follow. Discharge is to a continuous mixer.

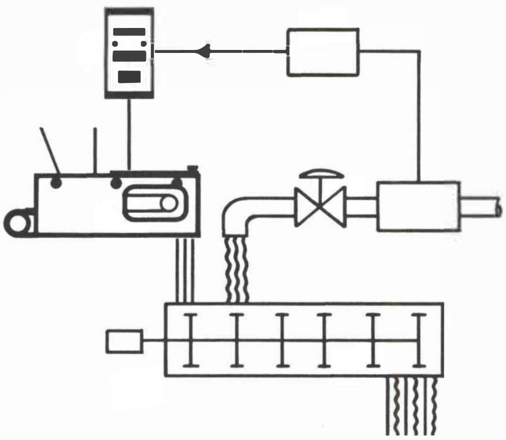

Fig. 6: Analogous situation to Fig. 5, proportioning liquids

Motor loading is still another candidate process-related parameter, but in controlling a feeding system with the motor load signal from, say, a mixer, increased motor load may well indicate that too much material is flowing through the mixer. The needed control action would then be to lower the proportioned flow rate, not increase it as would be the case if the proportioning system were slaved in the conventional sense.

Feeding and proportioning systems can be slaved to other, not-so-commonly considered process parameters such as the output of a level gauge, a moisture meter's output, the temperature of a continuous freezer, measured viscosity, dryer rate, or the number of production or packaging lines in operation at any given time. In one specialized application even the sound level within a crusher was used successfully to control the feeding system.

5. System Considerations

By appearances, many if not most processing systems look fairly simple and straightforward when they are nothing but symbols, arrows, lines and numbers on paper. Even though process hardware (feeders included) possess greater capability and higher reliability today than ever before, assembling a process system from its component parts still leaves few people unhumbled by the experience.

Assuming the hurdle of proper equipment selection has been cleared, other obstacles still stand between the blueprint and the satisfaction of a smoothly operating process:

Ranging — One of the most easily by-passed tripwires in system design, improper ranging or sizing of equipment carries with it many obvious problems. Mismatches among process elements in terms of capacity and effective operating range can be almost totally avoided at the outset if minimum and maximum capacities and flows are worked out at all critical process points, under all possible process conditions.

Response — How quickly process equipment responds to imposed control changes will, as mentioned earlier, give an indication as to which process element could or should be controlled by another process elements. Also, total system response rate should be analyzed separately for start-up, on-line changes and shut-down, as conditions and considerations will be different for each situation.

Interfacing/Interlocking — The type and extent of data to be made available for use will depend on the desired level of control over the particular elements in the process. In many cases, control is handled via single-bit connections for interfacing and interlocking. If there is informational data to be passed, BCD/binary, analog (4—20 ma, 10—50ma, various voltages), or frequency transmission may be appropriate. These inputs relate particularly well to a PLC environment.

For more sophisticated applications, RS 232/RS 449, IEEE 488 or IEEE 583 interfaces may be appropriate. Here one typically sees significantly more data being passed between devices. The sophistication of protocol allows data verification, checking, and, in some cases of error, retransmission for correction. Because of the large number of process interfaces, I.S.O. is presently developing some badly needed standards.

6. Conclusion

Like so many pieces of a jigsaw puzzle, the available configurations of feeding systems may seem more confusing than clarifying. But to meet the unique and very specific needs of a great diversity of industries, all of which must handle, control and process an equal diversity of bulk materials, such a vast array of feeding system possibilities is critically necessary. By clearly defining process needs, and conferring with all 'system element' suppliers, the pieces to your current process puzzle will fall neatly into place.

Acknowledgement

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