Using S88 Batch Techniques to Manage and Control Continuous Processes

David A, Chappell
Batch Technology Manager
Procter & Gamble
8256 Union Centre Blvd.
West Chester, OH 45069
513-634-9495/513-634-9439
chappell.da@pg.com

KEY WORDS
Continuous Process, Recipe Management, Recipe Execution, Batch Sequencing, Hybrid

ABSTRACT
Have you ever thought of using batch sequencing and S88 recipe management techniques to control a continuous process? This paper will discuss the great similarities and subtle differences found in such applications. At Procter & Gamble we have successfully created several such “hybrid” process control applications. The results of these adventures greatly exceeded expectations. These systems benefited from an adaptation of the modular approach described in the S88.00.01 standard with some significant differences in the states of their Equipment Modules and Phases. The necessary modifications will be presented in detail.
Background

Continuous systems have existed alongside of, and in competition with, batch systems throughout modern manufacturing history. Both approaches have their champions and both have advantages and disadvantages, which leads to competition between the manufacturing practices. Batch systems generally require less capital to build than continuous systems but batch systems are considered more difficult to operate which offsets the cost advantage. Batch is dominant in areas where material genealogy tracking is important, such as pharmaceuticals, with continuous dominating areas where mass production is important, such as petrochemicals.

At Procter & Gamble we apply a mix of these types of systems. Sometimes we have the same products made on both continuous and batch systems. There is continual debate as to which is the best manufacturing approach, and, based upon business requirements, the right answer is sometimes both!

The examples I present in this paper are similar to several systems that have been successfully implemented within Procter & Gamble. Some of the aspects of these systems have been generalized for clarity, but all of the significant details remain.

Batch Example

Shown in the batch example of Figure 1 is a simple system with two units and five different materials. In this example, the two batch units use weight scales to indicate the amount of material added. As such, they can only add materials sequentially, which will dictate the batch cycle time and therefore how much material can be created in a given period of time.

Continuous Example

The example continuous system shown in Figure 2 makes the same product as the batch example in Figure 1. It has all of the same processing capabilities; they are just performed in a different manner. There is significantly more processing equipment involved in the continuous system than the batch system, making equipment capital costs typically higher for continuous systems than for batch. The continuous production is controlled by a final product flow meter against which all other flow meters are proportionally controlled.
Primary Physical Differences

The continuous system requires a method to independently monitor and control the amount of materials being transferred; in this example, flow meters with control valves are indicated. While some batch systems will use this technique to improve cycle time, it is not mandatory and adds complexity and cost to the batch system.

In this example there are six materials, Recycle has been added. This is a common requirement because an indeterminate material is created during the transition times (start up, shutdown, and running product change) of the continuous system. Rather than waste this material, it is common to blend it back into the final product. The philosophy in the batch system is to make sure the product produced is right before sending it to product storage, therefore no recycle handling equipment is required.

Material handling can vary significantly between batch and continuous systems as illustrated in Figure 3. In continuous systems, recirculation lines are generally included in the material delivery systems to reduce the amount of recycle produced. The recirculation lines provide a method to fill the supply line and guarantee proper operation of the flow monitoring instruments before the full system is started. In batch systems using weight control this does not affect accuracy since material delivery to the receiving unit will only be delayed by empty lines. In both the batch and continuous systems when a material is not being used for a given product, the supply lines are cleared by using compressed gases.
Primary Operational Differences

I have heard some state that the only difference between continuous and batch is that continuous is a single batch with a long steady state.

I have heard others state that a batch is just a continuous system that is in a continual flux of start up and shutdown.

And one good friend of mine says they are “exactly the same… except for what’s different.”

People who have worked with both know that the “what’s different” is significant. The focus of continuous systems is “running”, which can be hours, days, weeks or longer. Continuous systems can generally make more product in shorter time than comparable batch systems; this is one of the primary advantages of continuous systems. The traditional focus of operations for continuous systems is the start up, which is a one-time event; these systems mostly take care of themselves after an operator has “lined out” the system. Whereas batch systems have traditionally required “continuous” attention by operations as product is made. Thus, we see a trade off in the cost of equipment vs. the cost of people.

Primary Automation Differences

The traditional approach to automation of a continuous system has been to rely on industry standard controllers that will allow the flows of materials to maintain a ratio against the total flow of finished product. This is well-understood technology and easy to successfully implement almost anywhere. If there is any automation in the start-up of the system it traditionally has been custom, leading to very complex monolithic systems that only a few people understand and even fewer can support and modify. As with older batch systems, any change in product formulation becomes difficult to manage.

Since the early 90’s batch systems have received a lot of attention because of the S88 standard and the many newly available products to automate the “continuous starting and stopping” of batch manufacturing. This has lead to many products which are designed to manage both a “recipe” for a product and the “sequencing” of a process to create that product. The “modularization” techniques recommended by S88 have proven to be extremely effective in the automation of batch systems and they have become the batch industry standard approach. Many of these automated systems now run with even less attention than their continuous counterparts.

During the early days of the S88 definition effort, it was observed that the standard could apply to all forms of manufacturing and not just batch! While most everyone agreed with this, Thomas Fisher had the wisdom to keep the focus only on batch; his point was that there never would be an S88 standard if we attempted to reach too far, and continuous was too far at that time and may still be today, but may not be tomorrow.

A Merging of Technologies
In three successful applications, P&G has been able to blend batch automation and continuous automation technologies to create systems where we automate management of product formulation and recipe management using “batch” technology, automate the start-up of a continuous system using the “sequencing” capability of “batch” technology, and retain the traditional continuous operation automation that is so comfortable to manufacturing.

This has required a mind shift in “modularization” of the continuous systems by those responsible for the process and its automation. This is no small task, but once done the benefits are eventually obvious and it becomes the property and philosophy of the engineers who own these continuous systems. It is unfortunate that they do not have a method to broadly share this information since it seems to reside in small groups and is not widely accepted.

The implementations consist of three independent “managers”, one for recipe management, one for the start-up sequencer and one for continuous operations as shown in Figure 6.

**Recipe Management**

The recipe manager uses the standard S88 guidelines and is a commercially available package, which we are able to use “as is”. This has allowed all those in charge of the product specification to have their intent directly applied to the actual production, and this has had a significant positive impact on data entry mistakes.

**Start-Up Sequencer**

The start-up sequencer uses a standard S88 Equipment Phase to interface with a commercial recipe sequencer, which manages three phase types: initialization, material, and sequencer run. The phase states and actions are described in Figure 4. Each phase has interaction with components of the continuous manager. The Initialization Phase clears all pending material information and informs the continuous manager that a new recipe download is in progress. The Material Phase provides the materials that are used in this recipe with all the information necessary to be used and issues a request for those materials to proceed to their ready states, if they are not already there. The Sequencer Run Phase provides all other recipe processing information, such as temperature and residency times, and informs the continuous manager that all materials are ready for production and then terminates the Recipe Start-Up Sequencer. Functionally, the Start-Up Sequencer replaces the manual operation of bringing the material paths to a useable state. It eliminates the varying effects of different operator approaches to this, resulting in much smother operation and better quality product sooner.

---

Figure 4: Sequencer Phases
Material Equipment Modules

The physical equipment represented in Figure 3 uses the S88 “Control Module” concept to manage each individual piece of equipment, one for the pump, one for each block valve, etc. These Control Modules are in turn controlled and coordinated by an “Equipment Module” that orchestrates the Control Modules to carry out the necessary process functions. The Material EM states and actions are represented in Figure 5. The material Equipment Modules provide a “bridge” between the Start-Up Sequencer and the Continuous Production Manager as shown in Figure 6. As indicated, the Material EM can receive transition commands from three sources, the Start-Up Sequencer, the Continuous Production Manager (by operator action), and itself. The Start-Up Sequencer provides recipe information in a “pending” storage area for the Material Equipment Modules; upon production start-up, this information is transferred to a “running” storage area and will be used for production. The operator has access to all of this data and can modify it within the parameters of the recipe. By creating a single modular EM for material transfers and then reapplying it for all material transfers the engineering effort is greatly reduced over traditional approaches. It also proves to be much easier to support than previous monolithic systems, and necessary changes to the process are now more easily accomplished.

Continuous Production Operations

The Continuous Production Manager has three modes: “Full Auto” in which it will rely upon the Sequencer for “advice” and the Operator for confirmation, “Semi-Auto” in which the operator can assume direct control of the EMs (bypassing the Sequencer and Continuous Production Manager (CPM) but taking full advantage of the EM logic), and “Manual Mode” in which the operator takes direct control of all Control Modules bypassing all other control and logic.

In Full Auto during the initial start-up of a recipe, the CPM is waiting for indication that all required materials have reached the “Started” state. Once that has occurred and the operator signifies the start of production, the CPM instructs all required materials to proceed to the Run state. During this time the production “Rate” is maintained at the minimum setting and all material produced is directed to the recycle vessel. When the operator is satisfied the product quality is at target, production is redirected to product storage and the production rate is set as desired. Any system upset affecting quality will cause the rate to be set to minimum and will redirect product to the recycle vessel waiting for the operator’s decision to hold, shutdown or resume production. If the operator chooses “Hold”, all active materials are commanded to the “Started” state in which no product or recycle is produced. If the operator chooses...
“Shutdown”, all materials that are not already in “Idle” are commanded to the “Shutting Down” state which will cause all material paths to be cleared and all equipment to go to its “off” state.

There is also a “Running Recipe Change” option, while running one recipe it is possible to have the (Start-Up) Sequencer load another recipe. Materials that are not part of the current recipe are commanded to the “Starting” state and the CPM is informed when all materials and recipe information are ready for use. When the operator decides it is time to switch recipes, the CPM will switch to the minimum production rate, switch production to recycle and issue “Started” commands to all materials in the new recipe and “Shutting Down” commands to materials that are not idle and not in the new recipe. When the operator determines conditions are right, the command to switch to product storage is issued and the rate adjusted as needed. In the past, only a few operators could successfully perform this function, and, even then, it often lead to catastrophic results, shutting down production for significant periods. With the S88 modular implementation, the “Running Recipe Change” has never failed!

**Reporting**

Reporting is handled by the CPM and manufacturing operations personnel. This is accomplished by using flow totalizers during the times when material is directed to recycle or to production storage. The totalizers are captured at specific times during operations and when a product change occurs. This information is and provided to the plant information system for use by operations and plant management.

**Conclusions**

There are times and situations where continuous systems are appropriate and where batch systems are appropriate, and there are situations where either could be used. The use of the modularization recommended by the S88 standard has significantly reduced the effort and cost of the automation of batch systems. While these modularization approaches have been demonstrated to improve the automation efforts of continuous systems, as they have for batch, having this modularization approach accepted by those who do the automating is difficult, with most still following the traditional monolithic automation approach. Using the recipe management and sequencing capabilities of commercially available batch products have also greatly improved the operational management and execution of continuous manufacturing, although again gaining acceptance is difficult. There are groups that believe strongly in the superiority of continuous manufacturing and they will go to great lengths to prove it, including rejecting any automation techniques that are shared with batch systems. When the reluctance to use the S88 concepts is overcome, continuous systems realize the same improvements that batch systems have realized.

Batch and continuous are exactly the same…except for the differences.
Figure 6: The Total System