How to Establish a Batch Best Practice

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ABSTRACT

All over the world, small and medium sized plants in the chemical, foods and beverage industries operate in manual or "manumatic" mode. For a small batch process operation to achieve the same level of excellence as larger companies, it must establish batch best practices. Batch manufacturing is a sequential processing activity at the level of process cells. In these cells, control modules are applied to equipment modules to run a recipe in a specific unit. To establish a best practice it is necessary to link it to a determinate Process Cell and make the right choice in process modularization. An example process cell is postulated and a possible process material selection control module discussed. Some alternatives are compared and some fundamental parameters identified to be optimized in the best batch sense.
INTRODUCTION

At present, small and medium sized companies have great difficulty remaining competitive in the market place due to lower capability for innovation when compared with larger companies. Generally small or average sized companies from chemical specialties, foods and beverage operate their plants in manual or “manumatic” batch modes. Adopting an international standard like S88 for process automation can be a good alternative to manufacture their products in a competitive way, but S88.01 is not a compliance standard. It does not have a mandatory character. S88.01 is a proposal of how to organize and design a batch design philosophy. When adopted, it results in decisions about how to execute a plant control recipe. Even with no universal model for batch control, it is very interesting to establish and define a Batch Best Practice for small batch operating companies that can enable them to achieve the same level of excellence that larger companies achieve. Generally best practices are defined in larger companies to normalize the way they operate their sites all over the world. Best practices are also adopted inside an industrial sector. In Brazil SEBRAE (Support Service Brazilian Agency for Small Company) give orientation to the sector’s good manufacture procedures. When the consumer and the public interest are so fundamental, as in the health and sanitary areas, the best laboratory practices in the USA are establish by FDA and in Brazil good manufacture practices are proposed by ANVISA, the Federal Regulatory Sanitary Agency. Then let us try to formulate the parameters of a Batch Best Practice.

PROCESS MODULARIZATION

Batch manufacturing is a sequential processing activity executed in Process Cells. In these Cells, control modules are linked to equipment modules to run a recipe in a specific unit. To establish a best practice it is necessary to associate it to a determinate Process Cell, by making the right choices in process modularization. But what is the right choice in process modularization? To modularize a process we have to segment the process cell into the proper equipment entities. The S88.01 standard prudently avoids explicit or mandatory guidance in the area of low-level decomposition. It specifically says, “total explanation of process segmentation is beyond the scope of this standard”. And follows, “effective subdivision of process cell into well-defined equipment entities is a complex activity, highly dependent on the individual requirements of the specific environment in which the batch process exist”. However, it warns: “inconsistent or inappropriate equipment subdivisions can compromise the effectiveness of the modular approach to recipes suggested by this standard”. Yet proper subdivision is a necessary condition if we are to guarantee that we can create a recipe procedure linked with its corresponding steps and operations. The local characteristics of the environment and the safe operation of the batch process must be considered when this low-level decomposition is done. Then to make the right decision in the sense of getting the best choice we may consider the level of safety and the local environment of the process cell batch operation when defining the “right” equipment entities. We certainly have more restrictive operation rules for manufacturing a chemical product than when operating a food processing plant. And if we manufacture the same product in two different sites located in two different climes (USA/temperate against a Brazilian/tropical for example) some individual and particular requirements must be followed to make the best choice. Even a great world based company could have a general recipe for manufacture of its products but it has to be adapted for a local site in
different regions of the world. (In Brazil Car Assembly Companies have to “tropicalize” their production lines to adjust the product to the climate and the way that the product is manufactured).

MATERIAL SELECTION SAFE OPERATION

When talking about safe operation we must take into account the work of Rhone Poulenc group (now Rhodia) and the ongoing work of the “Flow Analyses” WBF working group. They are essential to define good engineering practices compatible with the S88 standard. The ASTRID Rhodia methodology introduces Operation Specifications for Multi-Product Process Cells. Operating a process cell with optimized resource utilization means manufacturing with flexibility. When resources are dynamically allocated for making different products one after the other or simultaneously - if it has more than one batch unit working in parallel - the safety issue is a major concern to prevent products from being mixed by opening a wrong valve for instance. We can reduce the risks in the charge ingredient or transport reagent phase implementation by applying basic concepts of flow analysis. Here we will consider an idealized material selection control module and a material charging equipment for only one unit batch mix tank represented in figure 1 (based on Jim Parshall’s The Secret Life of S88)

Fig. 1 – A Batch Mix Unit with Idealized Material Charge Equipment Module
In this example we have to transfer four ingredients (A, B, C and D) to the batch mix tank. We can identify six Equipment Entities (EEs):

- Silos A, B, C and D (not represented in fig.1 but Equipment Modules in this Process Cell)
- Manifold Transfer Line between A, B, C and D ingredients silos and the Batch Unit (the Material Charge Equipment Module)
- Batch Mix Tank (the Unit of this Process Cell)

We can get the following Charge Ingredients Phases by assembling these EEs into Flow Paths:

- TA: Transfer Ingredient A to the Mix Tank
- TB: Transfer Ingredient B to the Mix Tank
- TC: Transfer Ingredient C to the Mix Tank
- TD Transfer Ingredient D to the Mix Tank

The flow analysis is the key to establish the safe operation of the control devices (blocking valves) in the material transfer procedure. The main rule is to transfer one ingredient at a time and that the valves situated at the boundary of a Flow Path must be locked to prevent any wrong operation.

TA phase transfers ingredient A to the Process Cell Unit and by doing this operates (open) VOA (output valve at silo A) and VIU (input valve at unit). The valves at the boundary of this flow path are locked because the upstream and downstream of these control devices are allocated in different phases. VOB (output valve at silo B), VOC (output valve at silo C), VOD (output valve at silo D) and VOU (output valve at unit) will be locked. An occupation status for each valve needs to be considered in the implementation of the basic control logic algorithm at the local device driver control layer (PLC or DCS). Based on ASTRID Rhodia methodology, only valves with upstream and downstream occupied by the same phase will be unlocked and then could be opened or closed by manual or automatic (logic code based) commands.

If you are designing the process cell and want to safely transfer two or more ingredients simultaneously in some proportion to prevent a reactor from blowing up, for example, you can get independent transfer lines with their pumps and flow transmitters aggregated. Otherwise you can write better basic control code. If a less restrictive level of security is allowed (like in a food application) you can have a simpler basic control code for driving the valve without considering its occupation status. For this situation a basic device driver control module is presented by Jim Parshall and Larry Lamb in their *Applying S88*. They considered in their simplest code automatic and manual modes, a simulation mode for logic verification, a permissive mode for locking the device if allowed conditions are not true and a alarm mode that could provide feedback on the device operation.

**LOCAL ENVIROMENT CONSIDERATIONS**

In Brazil industrial buildings are large and high, providing comfortable working conditions, probably because of the climate and the less expensive modularity of construction or even due to cultural aspects. The typical industrial layout used is to have three or more floors round the equipment assemblage with process flow from up to down by gravity flow. The raw materials simply come in on the top floor if the construction allows or are pumped to the top of the materials silos. The low floor is used for
manufacturing the final products. In fig.2 we represent a batch mix tank with an idealized gravity transport equipment module.

Fig. 2 – A Batch Mix Tank with gravity material charge equipment module
Here we have to pump the raw material to the top of silos that are controlled by a load cell assembly (WT) associated with a weight comparative control actuator that drives the blocking valves.

Let us apply the concepts of safety operation according to ASTRID recommendations.

In this second example we have to transfer three ingredients (A, B and C) to the batch mix tank and we have to fill the three silos by pumping corresponding materials to them. We can identify again six Equipment Entities (EEs):

- Inlet feed manifold (Equipment Module with its aggregated pump and totalizer)
- Silos A, B, C (Equipment Modules in this Process Cell)
- Manifold Transfer Line between A, B, C ingredients silos and the Batch Unit (the Gravity Material Charge Equipment Module)
- Batch Mix Tank (the Unit of this Process Cell)

By assembling these EEs into Flow Paths, we can get the following generic Move_Ingredients Phases:

- FA: Fill Ingredient A Silo
- FB: Fill Ingredient B Silo
- FC: Fill Ingredient C Silo

- TA: Transfer Ingredient A to the Mix Tank
- TB: Transfer Ingredient B to the Mix Tank
- TC: Transfer Ingredient C to the Mix Tank

TA phase transfers ingredient A to the Mix Tank and operates (open) VOA (output valve at silo A) and VIU (input valve at unit). We can see that using gravity transfer we can close first VOA and after a delay time close VIU to clean the transportation pipe in phase execution code. The valves at the boundary of this flow path are locked because the upstream or downstream of these control devices are allocated to other phases. Then VIA, VOB, VOC and VOU will be locked but VIB and VIC will be free because they aren’t at the boundary of that flow path. Then we can execute FB or FC phases while TA phase executes if the silos B or C have been emptied after some batch.

This proposed layout provides independent transfer lines with their weight transmitters aggregated but to get real simultaneous safe transfer operations we have to aggregate two more valves at the input side of the batch tank, following ASTRID recommendation. In this situation executing FA, FB and FC phases can be done during the Mix phase execution after the all Transfer phases have been executed.

For transferring only one ingredient at a time, a better choice is to change the proposed layout to have only one load cell assembly (WT) at the batch unit associated with a weight comparative control module that drives the blocking valves at the output side of the silos and at the input side of the batch unit. In this case we will have to install high and low level sensors at the three silos to conduct the Fill phases. This is certainly a less expensive solution.

Again, if a less restrictive level of security is allowed (like in a food application) you can have simpler code for basic control logic that drives the valves without considering its occupation status for simultaneous operation like in ASTRID solutions.
PARAMETERS FOR ESTABLISHING A BATCH BEST PRACTICE

Let us talk a little about working with an optimization problem. Complex problems like development of global non-linear optimization algorithms can be likened to a kangaroo searching the top of Mt. Everest. Everest is the global optimum, the highest mountain in the world, but the top of any other really tall mountain (a good local optimum) would be satisfactory. On the other hand, the top of a small hill (a bad local optimum) would not be acceptable.

This fable of a kangaroo searching should be applied to our complex problem. We must understand that a Best Practice must be constructed from Good Practices that can overcome today’s (bad) working practices.

The great novelty from S88 is its modular organizational concept. This makes working with object oriented software modularization possible. Darrin Fleming and Philip Schreiber remind us that the children’s toy LEGO® bricks represent one of the best examples of modularity. Like a child’s activity when working with bricks we can use our creativity to formulate a set of modules with very good functionality for our purposes of beauty and pleasure.

Making an analogy of the fundamentals for a good project are the basic modules (the basic bricks) and our creativity. Basic control modules that drive the devices like actuators, blocking valves; alarms, etc. will be fundamental for safety and local optimized batch operation.

FINAL RECOMMENDATIONS

Even restringing our methodical approach to the material selection control module, there are a lot of fundamental recommendations that a best practice must identify. Following are only some of them:

- For safety purpose the equipment control must be kept as local a device as possible to reduce the dependence and the complexity of the supervisory layers and when connection to the higher levels is lost.
- Maintain your creativity (be optimistic) to find a good solution respecting your restrictive conditions
- Compare the known alternatives to do your work. Don’t forget to consider new ones like using peristaltic pumps for your transfer and meter devices.
- When writing phase logic, like Charge_Ingredients, think of the five S88 transients states: Running, Holding, Restarting, Stopping and Aborting
- Consider what happens when the entire control system loses power. The shut down and the restart process must guarantee a safe procedure
- Validation testing during start-up must be planned and followed. Don’t skip steps.
CONCLUSIONS

The importance of good methodology development is crucial to the establishment of Batch Best Practices. Fundamentals like "Flow Analysis" from WBF and the French group as well as successful implementations like "Applying S88" from ISA are basic for someone involved in implementing a S88 solution.

Fixing the principal points:

• Try to develop best batch operation code
• Be satisfied with one good solution
• Establish a consensus about the fundamental “bricks”
• Be creative in building the “puzzle” to form the picture (An S88 solution)
• Establish a consensus of basic recommendations and follow them.

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