Kraken Automation

Batching Systems White Paper

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Batching Systems

Introduction

When a specific end product is to be fabricated from raw ingredients, batching systems is one the initial process areas that formulate the end product from pre-configured recipes. The techniques used to dispense and weigh raw materials will vary depending on material type (i.e. solids or liquids), material attributes, and the amount to be dispensed. Furthermore, various industries need to comply with regulatory bodies, requiring batching methodologies that adhere to industry standards for data validation with date-time stamping.

Standards and Regulations for Batch Systems

When designing a new batch system, or improving on existing ones, following industry standards is a good starting point to characterize or model the batch process, and offer tangible deliverables such as:

- Improve new product to market production launches;
- Allow for R&D test runs without significant reconfiguration of existing systems;
- Enable qualified vendors to provide system components that can be easily integrated within the model;
- Reduce operating waste and operating costs for automated systems;
- Provide opportunities for higher equipment utilization;
- Allow recipe configuration and execution to be handled by non-engineering staff, making operating unit self sufficient; and
- Enable users to clearly define real system needs.

It should be noted that recognized industry standards are not suggesting that there is only one way to deploy batch control, abandon current methodologies, or even perceive restrictions in batch operations. Rather, standards should be used as a tool to enhance current concepts, or existing systems in operation. For the most part, the ISA-88.01-1995 batch control standards attempt to rationalize the batching process, defining models and common terminology. Furthermore, these standards help identify:

- Good practices pertaining to the design and operation of batch processes;
- Areas where improvements in batch control schemas can be realized; and
- Apply the methodologies regardless of the level of automation used;

Where standards help streamline the batch operations, industry regulations have forced manufacturing facilities to have batch systems provide validation and conformance to set operating requirements, and in some instances, incorporate upset control management. Of the more important ones are those implemented by the FDA, namely 21CFR Part 11, primarily geared for pharmaceutical industries, and HACCP (or Hazard Analysis and Critical Control Points). Both regulations are primarily focused on validation of product quality, understanding of potential hazards to the product, and in the case of HACCP, identifying the process control point(s) where the highest hazard risks are located, and providing some measure of remediation to contain, or at least, identify the suspect product.

When defining product hazards, one normally is referring to hazards pertaining to biological, chemical, or material hazards introduced to the main product stream. As an example, in batch operations that prepares meat type slurries, salmonella type pathogens are a concern, and therefore, methodologies need to be in place to ensure and validate that the manufacturing environment (i.e. temperature and residence time) are controlled to alleviate potential growth, and subsequent contamination from this pathogen. If an upset condition occurs, that is contamination, the controls must be capable to remove, contain, de-contaminate and validate these tasks for the 'in-process' vessels. Another example is product cross contamination where the contaminant product may be an allergen. In this case, hazard analysis would typically be implemented to highlight the critical control points in the batch process, and identify remedial system modifications and/or control procedures to eliminate this hazard.

Batching System Considerations

Batching is the preparation of an end product by executing a repetitive sequence of automated and/or manual tasks, typically, which includes the unit addition of raw materials. Not all batching systems, however, strictly conform to ingredient addition, but may include interjected steps for special procedures. These may include such tasks as mixing cycles, recirculation modes, hand additions, quality sampling, relaxation intervals and/or atmosphere purging. Given these variations of tasks, the batching system control may be required to provide sequence step configuration and execution flexibility. In other instances, the sequence steps are fixed, with variable recipe weight and control parameters. Whatever the customer requirement, the automation component for the batching systems control must provide a common framework of functionality, capable of being configured for either extreme of control rationale.

The main reason for utilizing a batch control system, as mentioned earlier, is to formulate a specific end product using raw ingredients from preconfigured recipes, and do so with as much inherent flexibility as possible. The salient feature of any batching system, regardless of the architecture, is the capability of repeatably dosing the required raw ingredients accurately within a pre-defined operating sequence. This ensures consistent product quality to downstream process systems, not tempered by subjective variations. Typical batching systems call for batched product accuracies to the target (required) recipe weight +/- 1.0% or better. With this kind of requirement, the techniques and devices used within the batch system architecture must be properly matched and applied.

First and foremost is to understand the type of batch class that is best suited for the application at hand. The batch class categorizes the methodology of batch formulation, from the raw ingredient handling, to batching vessels and finally, to end product handling. These classes are defined as part of known batch standards (ISA-88.01 discussed previously), and offer manufacturers with concepts that can provide the optimum flexibility to deal with needs from not only production, but also R&D, marketing and maintenance.

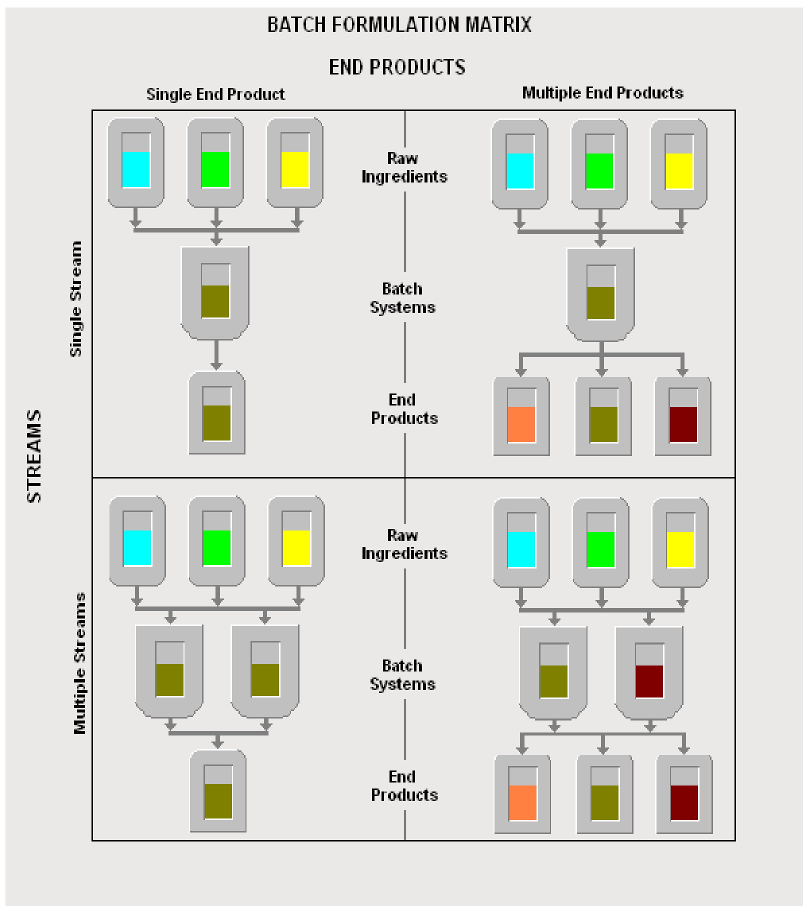
Batch classes can fall into one of four items of a formulation matrix:

<u>Single product, single stream:</u> Multiple raw ingredients dispensed into a single batch unit (vessel) to create one end product;

<u>Single product, multiple streams:</u> Multiple raw ingredients dispensed into a multiple batch units (vessels) to create one end product;

<u>Multiple products, single stream:</u> Multiple raw ingredients dispensed into a single batch unit (vessel) to create multiple end products, either contiguously, or on demand; and

<u>Multiple products, multiple streams:</u> Multiple raw ingredients dispensed into multiple batch units (vessels) to create multiple end products, either contiguously, or on demand.



The selection of a specific formulation matrix item will be dependent on the end user's product family requirements (single or multiple products), along with speed, redundancy and/or contamination requirements (single or multiple stream)

Second, to attain ingredient addition accuracy, is the design of the weighing system(s) to match the batch weight ranges of the additive raw materials. For most batch applications, the weighing instruments must be ranged such that they can not only account for the weight of the batch vessel in which the raw materials are dispensed, but the weight range of the largest batch amount, with safety factors. Given these three criteria, the weight sensors need to provide a weighing accuracy to notice the smallest amount of detectable weight change. If the noticeable amount of weight change is too large, the weighing instruments will not be able to resolve the batch weight in a timely manner, resulting in raw ingredient weights exceeding standard batch accuracies. To alleviate this, some batch systems have been designed such that the raw ingredient dosing is grouped into dedicated batch weighing vessels, each sized for the batch range required. This allows the selection of more sensitive weighing systems for medium to small batched ingredients. Another technique, although not often used, is the counterbalancing of the vessel weight, thereby allowing the weight sensing instruments to be sized for the weighing range of the complete batch only, as opposed to the complete batch weight plus the weight of the weighing vessel. Smaller weighing ranges realized by this technique increase weight accuracies.

Selection of the weighing instrument is as important as defining the weighing system schema. Many instruments have been implemented in weighing applications, such as LVDTs (Linear Voltage Differential Transformers), resolvers, strain gauge devices, and more recently, intelligent digital transducers. Weighing systems are most responsive when the weighing instrument delivers an accurate representation of the weigh instantly and repeatably. The term instantly is important as some weighing devices used such as LVDTs and resolvers require position change, or motion to detect weight change. To accurately measure weight instantaneously, the instrument must refrain from motion and stabilize before a weight capture is performed. Incurring this time to stabilize and capture weight injects delays in assessing when to control a batch dosing cycle, and consequently the batch accuracy. Repeatability is also important, as some weighing instruments, such as standard strain gauges for example, do not necessarily display full linearity throughout the weighing range, but incur hysteresis. Hysteresis is a characteristic of the weighing instrument that could cause an instrument weight reading to display different data for the same physical weight, as the weighing vessel weight is increasing vs decreasing. As such, alternative devices can be selected to minimize this effect (such as using shear beam strain gauge weighing devices).

Another consideration to achieve accurate batch dosing of raw ingredients is the selection of the raw ingredient feed mechanism. For solid ingredients, feed screws or vibrating tubes are typically used for dispensing. The selection of the type of feed screw (open wire, solid or twin concave) will depend on the feed rates required, and the solid material characteristics. For example, open wire screws would not be appropriate in applications where the raw ingredient is highly aeratable (free flowing when aerated), or twin concave screws would not be appropriate for friable or delicate type products. Furthermore, the screw design, even with speed control, is important to minimize dosing pulsations on each turn of the screw flight. Having a dosing flow as smooth as possible aids in accurate feed cutoffs, and therefore accuracy for the batched ingredient. In some instances, automated valves are incorporated on the discharge of the solid feed mechanism to aid in fast material flow cutoff. As for liquids, liquid characteristics such as viscosity and temperature can affect delivery and dosing into a batch vessel. Since downstream production rates are determined by batch makeup frequency, in which accurately dispensing of individual liquid ingredients must conform to a given time window that is dependent on the characteristics mentioned, it is essential in these cases that the correct pumping system is selected for the viscosity of the liquid, or the proper thermal conditioning is used on the delivery piping for temperature sensitive liquids. In some instances, liquid recirculation is employed when temperature critical liquids are not being batched to maintain liquid consistency and homogeneity.

Add Weigh vs Loss in Weight

The selection of the weighing technique, for the most part, will depend on the user defined batching architecture. In most batch applications, one batching vessel is utilized, and must have a weighing range to accept two to three major ingredients, and yet accommodate, perhaps, two to three minor ingredients as well. As mentioned earlier, one of the batch system considerations is the grouping of ingredients by batch amounts, thereby optimizing on weighing system accuracy for a given batch size. This approach, however, may not be realistic for some applications using a limited number of raw ingredients.

Where target weights for each batch additive ingredient are large and somewhat equally portioned to the total batch, add weighing is the technique commonly used. In this arrangement, the batch vessel is resting on a weighing system, and all connected infeed and discharge ports are attached to external systems with flexible links. Raw ingredients, be it solids or liquids, are dosed into the batch vessel in a sequential manner until the total batch formulation is completed.

In other batch configurations, some ingredients added into the batch may only constitute a small portion of the batch (total less than 10%). Adding and weighing these small amounts against a large weighing range and achieving the required accuracies would be very difficult. For these configurations, combinations of add weigh and loss-in-weight techniques would be more appropriate. In this arrangement, major ingredient would be batched using add weigh techniques, whereas small, or minor, ingredients would be dispensed using loss-in-weight methods. These devices are discrete weigh feed systems, each with a feed mechanism and product storage container, which dispense individual products by measuring the loss of product weight from the feed system's integrated storage hopper (or tanks where liquids are used). The advantages of these devices are that each unit can accurately dispense a minor batch quantity accurately into a larger weigh vessel. Thus, critical or expensive additives can be carefully metered. The only thing to note with these devices is that the integrated storage hoppers (or tanks where liquids are used) require refilling when the device's low weight level is reached. Refilling can be either an automatic or manual operation.

Further still, some batch configurations may employ solely the use of loss in weight systems (no add weigh). In these systems, the batch container may be fixed, with several loss-in-weight batch devices dispensing product into the container, or the container is positioned under the loss-in-weight batch device. In the fixed vessel arrangement, the main advantage of this batch configuration is the increase in batch makeup speed. All loss-in-weight batch feeders can dispense products simultaneously into the vessel, or sequentially in groups. This determination is dependent on the user's end product formulation. The positioned container system provides a benefit in that sequential, discrete batch formulations can be made on a vessel-by-vessel basis. Thus each vessel entering the batch system can be designated to receive a specific batch formulation, unique to that vessel. Such systems may contain a number of loss-in-weight batch feeding devices, to contain all possible batch ingredient formulations. Similarly, the batch vessel may stop at all, or only a specific combination of loss-in-weight batch feeding devices, this dependent of the active formulation designated to that vessel.

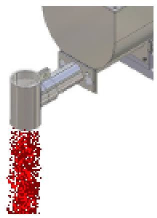
Ingredient Dosing Control

Dispensing products into a batch vessel, or vessels, using either add weigh or loss-in-weight methods, requires some form of control to dispense the raw ingredient batch amount as quickly as possible, and yet be sensitive to maintaining batch accuracy. These two requirements play against each other when dispensing several raw ingredients, each potentially having different feed characteristics. Typically, an ingredient dispensing sequence follows a preset series of steps, namely:

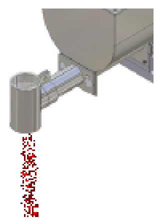
- Fast Feed Cycle
- Dribble Feed Cycle
- Jog Cycle

Within each step, control parameters are used to characterize each cycle. They are:

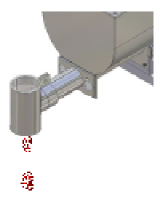
- Fast Feed Cycle
  - Ingredient Fast Feed Rate
  - Ingredient Fast Feed Cutoff Weight
  - Ingredient Fast Feed Tolerance



- Dribble Feed Cycle
  - Ingredient Dribble Feed Rate
  - Free Fall Weight
  - Ingredient Dribble Feed Cutoff Weight
  - Ingredient Dribble Feed Tolerance



- Jog Feed Cycle
  - Jog Feed Cycle Rate
  - Jog Feed Cycle Pulse Time
  - Jog Feed Cycle Dwell Time
  - Overall Ingredient Batch Target Weight
  - Overall Ingredient Batch Tolerance



The first step, or the fast feed cycle, dispenses as much of the ingredients target batch weight as quickly as possible. Typically, this may constitute 80% – 90% of the ingredient's target weight. The control parameters for this cycle manage the following:

<u>Ingredient Fast Feed Rate:</u> The material feed rate of the raw ingredient feed mechanism, be it a screw conveyor, or liquid pump. This is normally set at as high a rate as possible.

Ingredient Fast Feed Cutoff Weight: The weight as measured from the weigh vessel, relative to the start weight of the batch, when the material feed rate is lowered to the dribble feed rate from the fast feed rate. This weight level indicates that the majority of the ingredient's target batch weight has been dispensed into the batch vessel.

Ingredient Fast Feed Tolerance: The fast feed tolerance is a measurement window around the fast feed cutoff weight to determine if the stabilized weight has settled within an acceptable range to proceed to the next ingredient feed sequence. If a determination is made such that the stabilized weight has either exceeded or not achieved the proper fast feed cutoff weight range, then alternative automatic or manual action may need to be taken to continue the batch sequence to a successful resolution, or abort the batch and determine root causes for weight deviations.

The second step, or the dribble feed cycle, dispenses as much of the remaining ingredient's target batch weight as quickly as possible. Typically, this may constitute 10% – 20% of the ingredient's target weight. The control parameters for this cycle manage the following:

Ingredient Dribble Feed Rate: The material feed rate of the raw ingredient feed mechanism, be it a screw conveyor, or liquid pump. This is normally set to a low rate, and is determined to achieve the required batch rate cycle, yet achieve the desired batch accuracy.

Free Fall Rate: In add weigh systems, the free fall weight is a factor to account for weight of material free falling into the weigh vessel during the dribble feed cycle. This factor is used in conjunction with the ingredient dribble feed cutoff weight to anticipate when to disable product feed, so as not to overshoot the dribble feed cutoff weight limit.

Ingredient Dribble Feed Cutoff Weight: The weight as measured from the weigh vessel, relative to the start weight of the batch, when the material feed rate is forwarded to the jog feed rate from the dribble feed rate. This weight level indicates that the remaining amount of the ingredient's target batch weight has been dispensed into the batch vessel, and is at a point for final batch assessment.

Ingredient Dribble Feed Tolerance: The dribble feed tolerance is a measurement window around the dribble feed cutoff weight to determine if the stabilized weight has settled within an acceptable range to accept the batch, or proceed to the next ingredient feed sequence. If a determination is made such that the stabilized weight has either exceeded or not achieved the proper dribble feed cutoff weight range, then alternative automatic or manual action may need to be taken to continue the batch sequence to a successful resolution, or abort the batch and determine root causes for weight deviations.

The final step, or the jog feed cycle, is used only if the stabilized weight after the dribble feed cycle has fallen short of the raw ingredient's batch target weight tolerance. This feed cycle dispenses raw ingredients in short bursts, followed by a dwell period to allow weight stabilization and assessment. The control parameters for this cycle manage the following:

Jog Feed Cycle Rate: The material feed rate of the raw ingredient feed mechanism, be it a screw conveyor, or liquid pump. This is normally set to the lowest rate possible, and is determined to achieve the required batch rate cycle, yet achieve the desired batch accuracy.

Jog Feed Cycle Pulse Time: The duration of the ingredient feed pulse prior to batch weight reassessment.

Jog Feed Cycle Dwell Time: The minimum duration of time after a jog feed cycle pulse to allow batch weight stabilization and assessment prior to another jog feed cycle pulse (if required).

Overall Ingredient Batch Target Weight: The weight as measured from the weigh vessel, relative to the start weight of the batch, which indicates the required batch target weight for the dispensed ingredient.

Overall Ingredient Batch Tolerance: The overall ingredient batch tolerance is a measurement window around the overall ingredient batch target weight to determine if the final stabilized weight has settled within an acceptable range in order to proceed in batching the next required ingredient. If a determination is made such that the stabilized weight has either exceeded or not achieved the proper target weight range, then alternative automatic or manual action may need to be taken to continue the batch sequence to a successful resolution, or abort the batch and determine root causes for weight deviations.

Each ingredient dispensed within a batch may use all or a subset of the above parameters to achieve the best possible batch rate and yet achieve the highest accuracy.

In focused applications of batch controls, for example the manufacturing of liquid detergents, cleaners and the like, batch production rates have been significantly increased through the use of new technology and adaptive control algorithms. This approach has eliminated the need for the dribble and jog feed dosing control steps, reducing overall batch make up time (conversely increasing production rates). This control method not only monitors the weight of product accrued in the batch tank, but the current raw ingredient flow rate as it is batching. Using predictive control algorithms, fast flow cutoffs with repeatable, good batch accuracies achieved. It should be cautioned, however, that this type of approach is attractive for use on specific raw ingredients (predominantly liquids), as material flow instrumentation is cost effective.

Other Batch Functions

Throughout the course of a complete batch cycle, some batch steps may not specifically deal with dispensing raw ingredients, but may provide another function necessary as part of the batch makeup. These interjected steps are typically specialized for the end product being formulated. As an example, some of these tasks may be:

Mixing cycles: Providing an interim period between raw ingredient additions to mix the pre-batched ingredients for specific durations at specific rates;

Recirculation cycles: Similar to mixing cycles, but re-circulating pre-batched ingredients (typically liquids) for specific durations at specific rates;

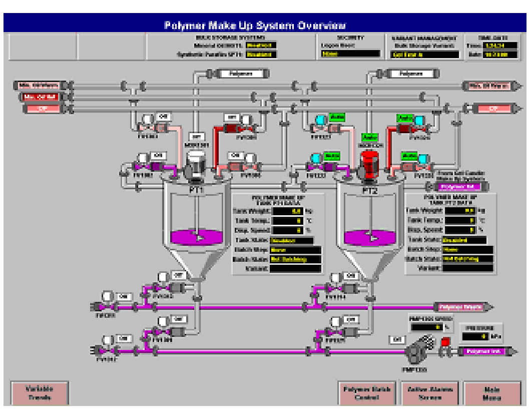
Relaxation cycles : Providing an interim period between raw ingredient additions to allow the currently batched ingredients to properly activate (typically liquids), or return to specific handling states (e.g. letting a batch charge cool);

Hand additions: A pause in the batch sequence to allow hand additions of small or micro ingredients into the batch vessel. These are pre-weighed charges, which may not be economical to dispense automatically, and typically require operator input to note the lot/type number of the ingredient being added, and verification of addition;

Purging cycles: In some specialized batch sequences, the atmosphere within the batch vessel may require purging with an inert gas. This is mostly employed where ingredients being dispensed are highly flammable, or are susceptible to oxidation.

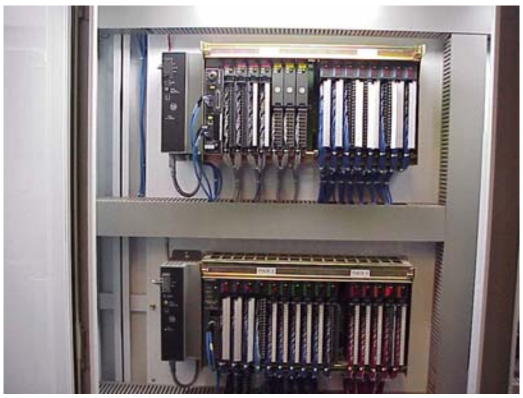
Batch Automation Systems

Given the various considerations presented, dealing with material attributes, the types of instruments to use, and the techniques of dispensing raw ingredients, the automation systems integrated with the physical hardware play an important component. It is one thing to provide the right feed, handling and measuring environment, but knowing when to sequence, how to sequence, and how to record key data is paramount in providing not only an accurate batch, but also one that can be verified and validated. With a host of government and internal plant regulatory bodies (e.g. quality control), substantiation of batch formulation data is becoming more prevalent in many manufacturing facilities, and as such, conformance to known standards.



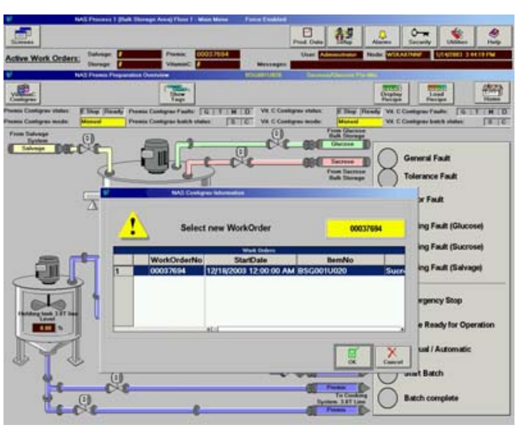
It is with this in mind that the automation systems must employ technology and programming techniques, which provide the tools to not only stage production runs, monitor work in progress and raw materials usage, but provide verification that the manufactured product specifications are achieved at the time they were to be made. Moreover, the automation system must provide the mechanisms to divert and/or recover from abnormal operating conditions, and again, have the means to record this.

In moderate to highly automated facilities, batch system automation, typically, is integrated into a larger plant SCADA system (see KAI SCADA system architecture). This automation architecture will include PLCs as the field end controls, with one or more HMIs (Human Machine Interfaces), linked onto a plant network, connecting data historians and sometimes, upper level business systems. PLCs contain much of the batch sequencing control, compartmentalized into specific routines or tasks, and called upon to execute based on the batch sequence configuration.

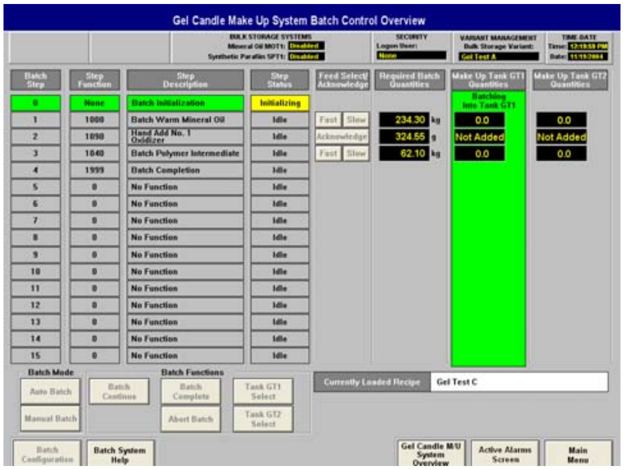


HMIs perform not only the process visualization functions, but provide much of the transactional and configuration tasks associated with single, or multiple, batch executions. More specifically, a sample of tasks normally encompassed in this level of automation is:

<u>Production work order handling:</u> The ability to acquire production work order information from business level systems, schedule production and execute the work order. Selection of a production work order automatically references the recipe, or recipes, needed to complete the work order and stages their execution accordingly. Once initiated, the additional handling may be required to pause and resume production work orders (to execute another short-run production work order), abort, or finish a production work order run.



Recipe handling: The secured loading, configuration and archiving of recipe related information, be it recipe sequence or parameter configuration;



Recipe sequence configuration: The configuration of the batch sequence steps, typically based on selection of pre-configured batch step functions. These steps functions can be categorized by material addition, tank preparation, and pre/post batch functions;

Recipe parameter configuration: The configuration of the batch step parameters based on the particular batch step function;

Batch alarm handling: Monitoring, displaying and control handling of alarm conditions/events. These can be done on a group, or individual alarm basis. For example, if a batch can be recovered after a severe tolerance deviation, then this can be completed in a manual batch mode;

Batch mode control: Asserting a specific operating control mode for a batch sequence execution, such as automatic sequencing or manual control; and

Work in progress tracking (WIP): The ability of the batching automation system, in conjunction with business system applications and databases, to accrue material usage and track completed/waste batches against required quantities presented by the production work order system.

It should be noted that not all of the above mentioned tasks are applicable to small batch operations, but are used in highly regulated production environments (specifically food and pharmaceuticals).

As the level of industrial automation increases, batch systems have of late, adopted 'soft PLC' technology, and integrated with the applications for operator control interfaces and process visualization, data historians and business level applications. Although this may initially require more effort to establish robustness and redundancy, it has other advantages from a secured management standpoint, regarding algorithm modifications, and deployment.

Furthermore, integrated diagnostics and maintenance are becoming more prevalent within field instrumentation, which allows for predictive maintenance, resulting in proactive remediation and significantly reduced system downtime, versus reactive maintenance resulting in noticeable system downtime. For example, many weighing instruments are coming equipped with integrated, microprocessor based diagnostic and maintenance firmware, monitoring weighing elements and can anticipate issues before they become problems. As to maintenance, weight instrument calibration and sensor parameterization can be performed without the need of large test weights, typically used in mature weighing systems, and for some applications, significantly reducing the test weights and measure validation process.

Kraken Automation Offering for Batching Systems

Having reviewed a synopsis of information pertaining to batching systems, it is obvious that the implementation of a batching system may appear to be daunting at first, but in reality, can be accomplished fairly systematically if a proper approach is taken.

Kraken Automation Inc. has over 18 years of automation experience in the area of batching systems. The team of engineers and design technicians has been in industries that have utilized solid and liquid batching processes, and have a sound knowledgebase on equipment and automation specification, design and implementation. Furthermore, Kraken can integrate batching processes with associated material handling systems to transport and acquire raw materials from bulk storage, or forward formulated products to downstream processes (i.e. mixing, cooking, extrusion, etc.). All concepts developed at Kraken are designed with industry standards and regulations in mind.

More specifically, Kraken has the capabilities to deliver the following:

Batching System Evaluation: Review and evaluation of new or existing batch system architectures to define client needs, and propose alternate technologies to optimize system performance while conforming to budget and schedule requirements.

Batch System Design: Conceptualization, design, assembly and commissioning of any type of batch system architecture, including procurement of hardware and software to client standards, configuration of various control and HMI packages, and final commissioning.

Batch System PLC Programming Services: Program development, documentation, testing and commissioning for a variety of PLC families such as Allen Bradley, Modicon, GE Fanuc, Mitsubishi, Siemens and others, with code compartmentalized into phase/function logic groups.

Batch System Operator Interface (OI) Configuration: Configuration, testing and commissioning of local operator interface systems for a variety of brands such as Nematron, EXOR Uniop, Allen Bradley Panelview and Panelview Plus, Eaton/DT Panelmates, and others.

Batch System SCADA Design and Configuration: Conceptualization, design, assembly and commissioning of batch SCADA systems, including procurement of hardware and software to client standards, configuration of various industry packages (WW Intouch, GE iFIX, Rockwell RSView32), and final commissioning.

Batch Business System Integration: Conceptualization, design, configuration and commissioning of batch business system integration schemas, including procurement of hardware and software to client standards, configuration of industrial data historians (WW InSQL, GE iHistorian, Rockwell RSSQL), interface configuration to production scheduling and material tracking systems, and final commissioning.

Batch System Support: Comprehensive post-commissioning site or web-enabled support in process and software troubleshooting, including affordable service support plans, or on an “as required” basis, available 24 hours, to address any customer’s batch control system needs.

Other Related Expertise and Services: Electrical, Control and Instrumentation, and Materials Handling.