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High Performance Material Additions for Batching

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KEY WORDS

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ABSTRACT

Creating a control system to deliver highly accurate feeds with short feed times dictates the need for applying flexible, predictive adaptive feed cut-off algorithms that are generally complex algorithms and are not easily done in most process controllers due to memory requirements and scan time limitations. Additionally, algorithms for controlling overlap feeds are not easily implemented in most process controllers due to the need for massive “look up” tables and a great deal of code solving the “rule set” for what feeds can happen simultaneously and determining start times from historical data so that the unknown feed is always the last to finish . Any control system would also have to include reporting and handling of abnormal operation. A control system was developed that had the cut-off control including the complex algorithms embedded in the scale and flowmeter controller. This controller also includes the ability to control overlap, error handling, and alarming. The system is installed in a high capacity batching operation and provides highly accurate repeatable feeds for flowmeter and Gain-in-Weight material additions, self tuning predictive adaptive control algorithms, historical data, overlap feed capability, reporting, and error handling in a “hands off” environment with little process controller code.

CUSTOMER REQUEST

A customer wanted to install a high capacity batch mixing system. They requested a system that was:

- Easy to use
- Flexibility with System Parameters
- Capable of high rates
- Lowest possible cost

The system would consist of two identical mixing systems that would mix liquids or liquid slurries with many different viscosities, varying densities, and various delivery flow rates from bulk storage tanks.

DETAILED REQUIREMENTS

As is typical for most engineering tasks, the requests from the customer needed to be transformed into measurable process and control system requirements before option development and solution analysis can begin. The following requirements were developed with the customer:

- Easy to use
    - Common reusable software and hardware components
    - Automated Unattended Campaigning
    - Self learning…automatically adjusts to current conditions
    - Give operator ability to handle abnormal conditions & needs without engineering assistance
    - Provide operations with detailed second to second status of material movements
- Flexibility with System Parameters
    - Ability of any material in any batch at any amount
    - Ability to manipulate the product type, setpoints, batch size, campaigns and final product destinations Formula
    - Various orders of addition
    - Ability to handle varying flowrates during material additions and still maintain accuracy
- Capable of high production rates
    - No slowdown for dribble modes in material delivery
    - High reliability
    - Minimize Feed Times
    - Overlap feeds of a Gain-In-Weight and flowmeters to improve production rates
    - High capacity & high speed will eliminate the need for a 3rd System saving capital
    - Reduce batch times by at least 33% over traditional systems
- Lowest possible cost
    - Low Installed Cost
        - Use and reuse as many “Shelf” items as possible
        - Limit number of physical devices
        - Limit piping requirements
    - Inexpensive to Operate
        - “Hands Off”
        - One operator for multiple systems

        - Highly accurate feeds (reduces raw material costs)
        - High Mean Time Between Failures (MTBF)
        - Low Mean Time To Repair
        - Low Mean Time To Resume operation due to disruptions
    - Inexpensive to Maintain
        - Low training commitment (less than 4 hours)
        - "Plug and Play" concept for changes
        - No Engineering Required for formula & recipe changes
        - Limit the number of spares by limiting devices
        - Use common equipment types already in plant
        - Use "packaged" software to reduce troubleshooting

This list of requirements is what was used to develop solution options and finally a recommendation to address the customer needs.

SYSTEM DESCRIPTION

The process is a large liquid batching system for producing many different brand products. The system has the following equipment capabilities:

- Material additions using scales as the measuring device
- Material additions using flowmeters as the measuring device
- Near limitless turndown requirement/capability for material additions
- Correction for under tolerance feeds
- Variable speed mixing
- Temperature Control
- Recirculation
- Sampling and Trimming
- Transferring to storage tanks
- Filtering and backwashing of filters
- Temperature checking for "OK to Proceed"
- Pausing for operator intervention or acknowledgement
- Calibration of Flowmeters using the Scale
- Initial Checks for material availability and system ready for supply systems
- Pigging product lines to the storage tanks

The overall process requires extreme reliability with each component because the nature of the batching process. If the batching process is stopped for too long, the batch would be scrap. This is a major concern given the high disposal cost of an off-spec batch as well as the raw material costs.

From an operational standpoint, an operator selects a brand and campaign size for the batch to be made. The operator can then select to use material addition set points that are stored as part of the master recipe or can they choose to use the set points used last for the selected recipe. Additionally, the operator can choose to modify all of the set points, but the control system will always complete a final check to insure that the total "parts" chosen add up to 100%. The control system then completes some initial checks on the system to insure that the mixer is empty, the capacity of the mixer will not be exceeded, all raw materials to be used have sufficient inventory and their supply system is in a ready state. At this point,

the material additions begin. Simultaneous feeds are used extensively. This is done using the patented overlap concept imbedded in the load cell/flowmeter instrument where any number of feeds can happen concurrently as long as there is only one feed per measuring device. In this case, a large number of flowmeter feeds occur with one Gain-in-weight (GIW) feed. Although all the materials hit the scale, the system can manage the additions that are attributed to the flowmeter additions to accurately feed the GIW to its setpoint.

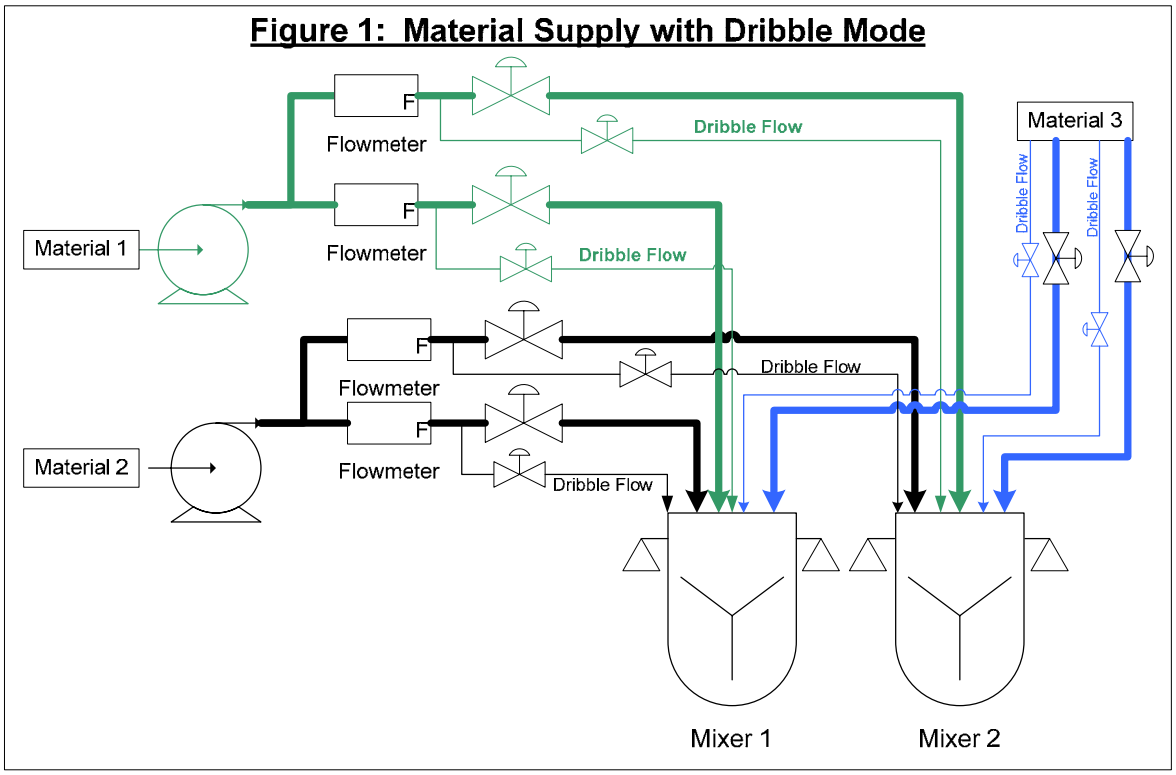
During the material additions, several process steps are also occurring which include: Recirculation, Agitation, and Cooling. The control system is also constantly monitoring the pH of the batch and making acid or caustic additions to bring the batch within limits. Once the batch has completed its cycle and all checks are met, the finished product is filtered and pumped to storage tank.

OPTION DEVELOPMENT

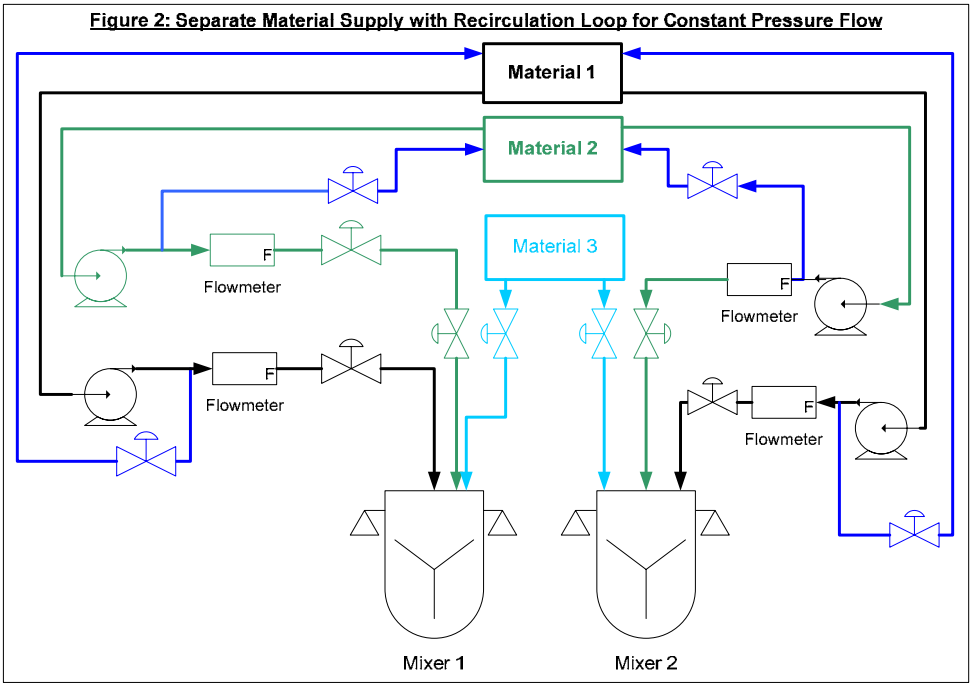
Based on the customer request and detailed requirements, several options initially seemed viable. They are as follows:

Option 1: Material Supply with Dribble Mode using either VFD on the pumps or control valves – This is a traditional approach this issue.

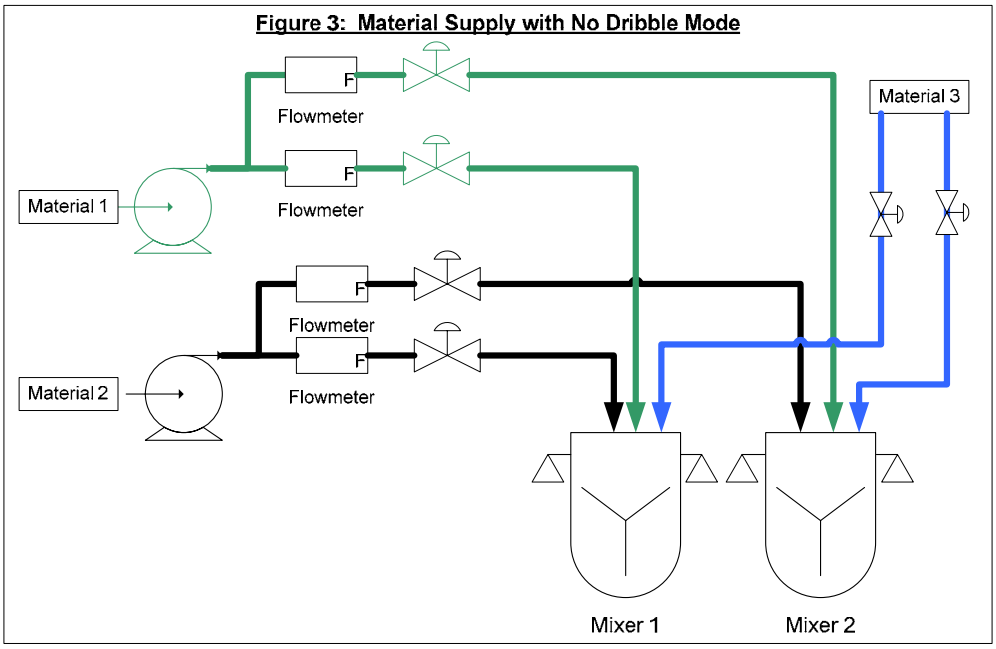
Figure 1: Material Supply with Dribble Mode



Option 2: Separate Material supply with Recirculation Loop for Constant Pressure and Flow with Overlapping feeds



Option 3: Custom software with Algorithms for predictive adaptive control



Option 4: Custom software with Algorithms for predictive adaptive Control and Custom software for Overlapping feeds (same process diagram as Figure 3)

Option 5: Standard weigh controller and PLC with shared supply and no dribble modes (same process diagram as Figure 3)

OPTION EVALUATION

Each of the options was evaluated against the detailed requirements. The following table provides a summary of this effort:

Table 1: Summary of Option Evaluation

	Option 1	Option 2	Option 3	Option 4	Option 5
Easy to use					
Common reusable software and hardware components	Maybe	Maybe	No	No	YES
Automated Unattended Campaigning	No	No	Maybe	Maybe	YES
Self learning…automatically adjusts to current conditions	No	No	YES	YES	YES
Give operator ability to handle abnormal conditions & needs without engineering assistance	Maybe	Maybe	Maybe	Maybe	YES
Provide operations with detailed second to second status of material movements	No	No	Maybe	Maybe	YES
Flexibility with System Parameters					
Ability of any material in any batch at any amount	Maybe	Maybe	Maybe	Maybe	YES
Ability to manipulate the product type, setpoints, batch size, campaigns and final product destinations Formula	Maybe	Maybe	Maybe	Maybe	YES
Various orders of addition	Maybe	Maybe	Maybe	Maybe	YES
Ability to handle varying flowrates during material additions and still maintain accuracy	Maybe	Maybe	Maybe	Maybe	YES
Capable of high rates					YES
No slowdown for dribble modes in material delivery	No	No	Maybe	Maybe	YES
High reliability, no down time	No	No	No	No	YES
Minimize Feed Times	No	No	No	Maybe	YES
Overlap feeds of a Gain-In-Weight and flowmeters to improve production rates	No	No	No	YES	YES
High capacity & high speed will eliminate the need for a 3rd System saving capital	No	No	Maybe	Maybe	YES
Reduce batch times by at least 33% over traditional systems	No	No	Maybe	Maybe	YES
Lowest possible cost					
Low Installed Cost					
Use and reuse as many “Shelf” items as possible	YES	YES	YES	YES	YES
Limit number of physical devices	No	No	YES	YES	YES
Limit piping requirements	No	No	YES	YES	YES
Inexpensive to Operate					
	Option	Option	Option	Option	Option

	1	2	3	4	5
"Hands Off"	No	No	Maybe	Maybe	YES
One operator for multiple systems	Maybe	Maybe	Maybe	Maybe	YES
Highly accurate feeds (reduces raw material costs)	No	No	Maybe	Maybe	YES
High Mean Time Between Failures (MTBF)	Maybe	Maybe	Maybe	Maybe	YES
Low Mean Time To Repair	Maybe	Maybe	Maybe	Maybe	YES
Low Mean Time To Resume operation due to disruptions	Maybe	Maybe	Maybe	Maybe	YES
Inexpensive to Maintain					
Low training commitment (less than 4 hours)	Maybe	Maybe	No	No	YES
"Plug and Play" concept for changes	No	No	No	No	YES
No Engineering Required for formula & recipe changes	No	No	Maybe	Maybe	YES
Limit the number of spares by limiting devices	No	No	Maybe	Maybe	YES
Use common equipment types already in plant	YES	YES	Maybe	Maybe	YES
Use "packaged" software to reduce troubleshooting	YES	YES	No	No	YES

Based on the evaluation, Option 5 (Weigh Controller and PLC with shared supply and no dribble modes) met all of the requirements and was selected to be implemented.

IMPLEMENTATION RESULTS

The new system was installed and is currently operational. The project achieved each of the customers' requests:

- Easy to use
  - o Operator Training done as part of 2 day Factory Acceptance Test
  - o Operator runs other systems concurrently
  - o Plant technicians can develop new recipes in less than ½ hour
  - o Operation can be monitored off-site by product development
  - o Maintenance techs were already familiar with new PLC
- Flexibility with System Parameters
  - o Any or all materials used in a batch
  - o Material additions in any amount required by formulation
  - o Material additions in any order
  - o Material additions at any rate
  - o System handles operator adjustments
  - o Ability to correct feeds during a batch
- Capable of high rates
  - o Batch time reduced over 1/3 from similar application
  - o As many feeds as possible can happen simultaneously as the process demands
  - o Reduce number of operator touches due to high accuracy of delivery system

  - Highly repeatable feeds allowed formulation to create tighter tolerances which results in very few "trims" to adjust the batch characteristics
- Lowest possible cost
  - No Recirculation Loops or Dedicated feeds
  - No Dribble Modes
  - Minimal Field Devices
  - Used "off the shelf" components
  - Two systems run by one part-time operator
  - Product Development embracing the "minimum target" philosophy
  - No formal training was required
  - No additional spares were purchased
  - Adding additional feeds consumes about 8 hours of engineering for the base system
  - Web-based interface requires no additional software or training

BENEFITS

The implementation of this application was a success for the customer and met or exceeded all of their requirements. The system is in continuous operation and is now being used more by R&D than any previous manufacturing system.