Reference Manual

PlantPAx
Process Automation System

PlantPAx Batch Design Considerations





Allen-Bradley • Rockwell Software

Rockwell Automation

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Throughout this manual, when necessary, we use notes to make you aware of safety considerations.

	WARNING: Identifies information about practices or circumstances that can cause an explosion in a hazardous environment, which may lead to personal injury or death, property damage, or economic loss.
	ATTENTION: Identifies information about practices or circumstances that can lead to personal injury or death, property damage, or economic loss. Attentions help you identify a hazard, avoid a hazard, and recognize the consequence.
IMPORTANT	Identifies information that is critical for successful application and understanding of the product.

Labels may also be on or inside the equipment to provide specific precautions.

	SHOCK HAZARD: Labels may be on or inside the equipment, for example, a drive or motor, to alert people that dangerous voltage may be present.
	BURN HAZARD: Labels may be on or inside the equipment, for example, a drive or motor, to alert people that surfaces may reach dangerous temperatures.
	ARC FLASH HAZARD: Labels may be on or inside the equipment, for example, a motor control center, to alert people to potential Arc Flash. Arc Flash will cause severe injury or death. Wear proper Personal Protective Equipment (PPE). Follow ALL Regulatory requirements for safe work practices and for Personal Protective Equipment (PPE).

Notes:

This document provides guidance on selected batch implementation topics in a Rockwell Automation PlantPAx® system environment. The information helps one make informed decisions when implementing projects by using FactoryTalk® Batch, LBSM, or other batch management solutions.

This document is not a batch tutorial, product user manual, or programming guide. You need to be 'batch literate', possessing an understanding of appropriate industry practices, standards, and Rockwell Automation products.

Before You Begin

A sound understanding of the current parts of the ISA-88 batch processing control standards is necessary, including the following:

- ANSI/ISA-88.01-2010 Batch Control Part 1: Models and terminology
- ANSI/ISA-88.00.02-2001 Batch Control Part 2: Data structures and guidelines for languages

We also suggest knowledge of the following:

- How to use FactoryTalk Batch equipment editor, recipe editor, eProcedure®, and MaterialManager components.
- How to program Logix5000™ controllers with RSLogix™ 5000 software or the Studio 5000 Logix Designer™ application.
- How to use Rockwell Automation® process library objects.

Additional Resources

These documents contain additional information concerning related products from Rockwell Automation.

Resource	Description
PlantPAx Process Automation System Reference Manual, publication PROCES-RM001	Provides characterized recommendations for implementing your PlantPAx system.
PlantPAx Process Automation System Selection Guide, publication PROCES-SG001	Provides basic definitions of system elements and sizing guidelines for procuring a PlantPAx system.
PlantPAx System Application Templates Quick Start, publication PROCES-QS001	Describes how to configure controller and HMI templates to start development of your PlantPAx system.
FactoryTalk Batch User's Guide, publication BATCH-UM011	Provides a complement of FactoryTalk recipe management, component guidelines, and software installation procedures.
PhaseManager™ User Manual, publication LOGIX-UM001	Explains how to define a state model for your equipment and develop equipment phases.
Logix5000 Controllers Design Considerations Reference Manual, publication 1756-RM094	Details how to design and optimize Logix5000 controller applications.

You can view or download publications at http:/www.rockwellautomation.com/literature/. To order paper copies of technical documentation, contact your local Allen-Bradley distributor or Rockwell Automation sales representative.

Notes:

Overview

FactoryTalk Batch software enables you to develop batch control systems that support your flexible production needs. FactoryTalk Batch development tools let you define equipment configurations and then build product recipes against that defined equipment.

Key to successful batch implementation is careful design and separation of the batch process into two models:

- Equipment
- Procedural

The Equipment model is a hierarchical organization of the equipment and basic control capabilities of the plant. The Equipment model is a representation of the plant's equipment capabilities to make product.

The Procedural model describes a multi-tiered, hierarchical model that defines the process capability and automation control in relation to the physical model to perform a task. The procedural model is a representation of how to use the equipment (described by the model) to make product.

Proper design of your batch process by using these two models provides many benefits, including providing modularity to make the system easier to design, implement, and maintain. ISA-88 provides definition of these two models and there are many experts and resources available in the field to provide practical guidance of designing and implementing these models; this is not within the scope of this document.

Design Options

Once the model is developed, there are specific implementation choices that can also impact the success of the project. Unlike the modeling effort, these implementation choices are often specific to the platform being deployed. The purpose of this document is to provide technical guidance on these topics to help you make well-informed decisions when implementing projects by using FactoryTalk Batch software.

This document does not dictate the choice for you. Detailed, specific recommendations cannot be made without an understanding of requirements as they relate to the equipment capability, procedural requirements, and workflow related to respective projects.

The topics discussed in this document have been selected based on observations of hundreds of batch application projects over two decades. The design considerations presented are intended to help prevent confusion and avoid mistakes that have negatively impacted projects.

Document Format

Each chapter in this document addresses a design or implementation choice often encountered in batch development. Each topic opens with a discussion, followed by potential solutions, which are summarized in a reference table.

Here is a brief description of the selected topics:

Unit Coordination and Synchronization -- Examines how asynchronous units coordinate activity between two units to make product. Appendix A elaborates on 'who is my partner' and communication methods with illustrations.

Operator Interaction -- Defines three solutions for operator interaction to execute a batch process.

Material Management -- Describes supplemental systems that manage material consumption and supply.

Process Upsets -- Discusses upset conditions and batch recovery methods.

Transitions -- Examines configured conditions for processing a batch.

Batch Timing -- Examines techniques for establishing timing phases.

Resource Arbitration and Allocation -- Discusses how to establish rules for sharing resources among multiple entities.

Shared Phases -- Provides architectural considerations for using shared phases to reduce controller code for the batch. Appendix B shows what can happen if the host controller goes offline.

Two- or Three-layer Model -- Describes how to implement controller organization for batches.

The document closes with an Implementation Techniques chapter that contains tips and often over-looked items.

Unit Coordination and Synchronization

When a batch requires interaction between units, a mechanism must exist to determine which units can participate, of those who want to participate, and of those who are ready to participate.

Discussion

Typical scenarios of unit coordination in multi-unit batch processes include the following:

- Bulk weigh transfer from a scale unit to a mixer unit
- Content transfer from a reactor unit to a centrifuge unit
- Start mashing in the mash tun unit only after a downstream lauter tun unit has finished raking

A 'transfer-in/transfer-out' pair of phases works well when coordinating material transfer between units while 'synchronize' phases accomplish alignment.

For details on unit coordination, see Appendix A on page 41.

These phases, when configured in respective unit procedures, provide the recipe author a convenient means for specifying when actions can take place in the procedure or transfers. Now, to complete the transaction, a 'handshake' is required, between phases.

This 'handshake', managed by controller phase logic, communicates status such as the following:

- 'I'm ready to send'
- 'I have a problem, stop the transfer'
- 'We are both at procedural point 'x,' please continue'
- 'I'm ready for delivery 2 of 3'

Solutions

Two methods for 'handshaking' or communicating between phases are discussed in this section:

- Controller-based execution
- Server-based execution

Controller-based Execution

Handshaking takes place by using controller tags. Depending on the architecture, these tags are read locally or moved between controllers by using peer-to-peer communication mechanisms such as produce/consume or message read/write.

Server-based Execution

FactoryTalk Batch facilitates 'handshaking' by routing the messages between 'message partners'. Participating phases are configured as 'link groups', in the recipe. Controller-based PXRQ instructions initiate message send-and-receive requests.

Summary

Table 1 provides a comparison of the two communication methods for unit coordination.

Table 1 - Phase Communication Comparison

Item	Topic	Controller Based	Server Based
1	Communication method	Reading/writing to user-defined controller tags	PXRQ instructions
2	Inter-processor communication	Produce/consume tags or messaging	Transparent to phase, managed by FactoryTalk Batch
3	Unit-to-unit alignment	Coded. Could require matching of 'unique batch ID'	Transparent to phase, managed by FactoryTalk Batch
4	Phase-to-phase alignment	Coded. Could require matching of a 'key' formula parameter	Transparent to phase, managed by FactoryTalk Batch
5	Adaptability	Supports any process management solution, such as LBSM or coded sequencers	FactoryTalk Batch must be active and managing the batch
6	Mode	Supports operator mode or other means of activating phases	Only functions in context of a FactoryTalk Batch executed batch, by using a recipe configured with 'link groups'
7	Display	Tag-based. Can display conditions and status on any HMI display	Requires FactoryTalk Batch BatchView™ to determine messaging status
8	Data format	Supports multiple binary, integer, and real data. No limit on size or quantity of data exchange	Single binary flag (for example, 'Ready') per PXRQ instruction
9	Data direction	Bi-directional. Phases can continuously read and write to each other	Uni-directional. A phase can only send or receive a flag in a single transaction (or PXRQ instruction)
10	Architecture	Transactions require peer-to-peer controller communication	Transactions require a functioning FactoryTalk server

Operator Interaction

Successfully engaging the batch operator is critical to system success.

Discussion

Most batch processes require operator interaction. Typical examples of operator interaction include the following:

- Operator or hand additions
- Quality checks
- Measurements

Interaction often requires the operator to manage equipment, such as starting an agitator, lining up valves, or actuating loops. But operator interaction is not limited to making product, as operators often need direction for the following:

- Disassembling/cleaning /and reassembling a pump
- Kitting or staging of materials
- Setting up or changeover of a packaging line
- Confirming non-automated valve, transfer panel, and equipment lineups

Several factors influence operator interaction solutions. These conditions include the following:

- Number of interactions or 'prompts' required to complete a task or batch
- Degree of automation
- HMI
- Recording and reporting operator interactions

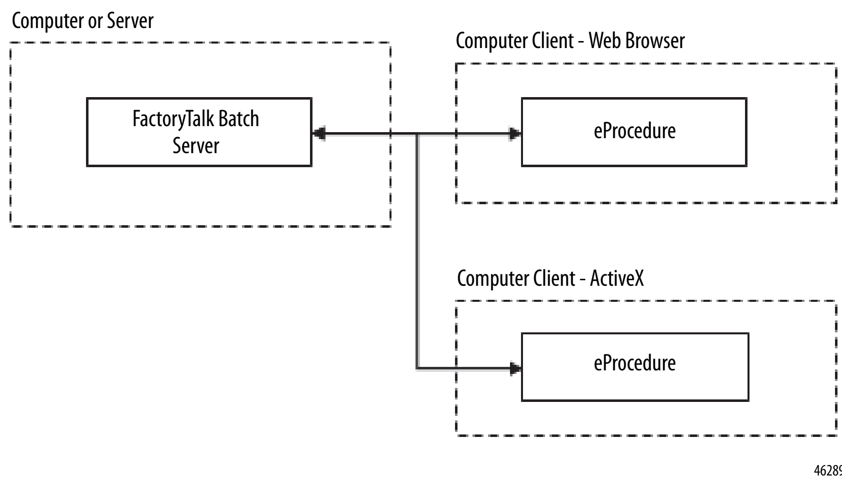
Solutions

This section defines three solutions for operator interaction and provides a diagram to show the physical relationship of each one.

eProcedure Component

The optional FactoryTalk eProcedure component displays operator instructions in a web page or browser ActiveX. eProcedure supports electronic signatures and signoffs captured in the batch journal.

Figure 1 - eProcedure Diagram



For more information, see the FactoryTalk Batch User's Guide, publication BATCH-UM011.

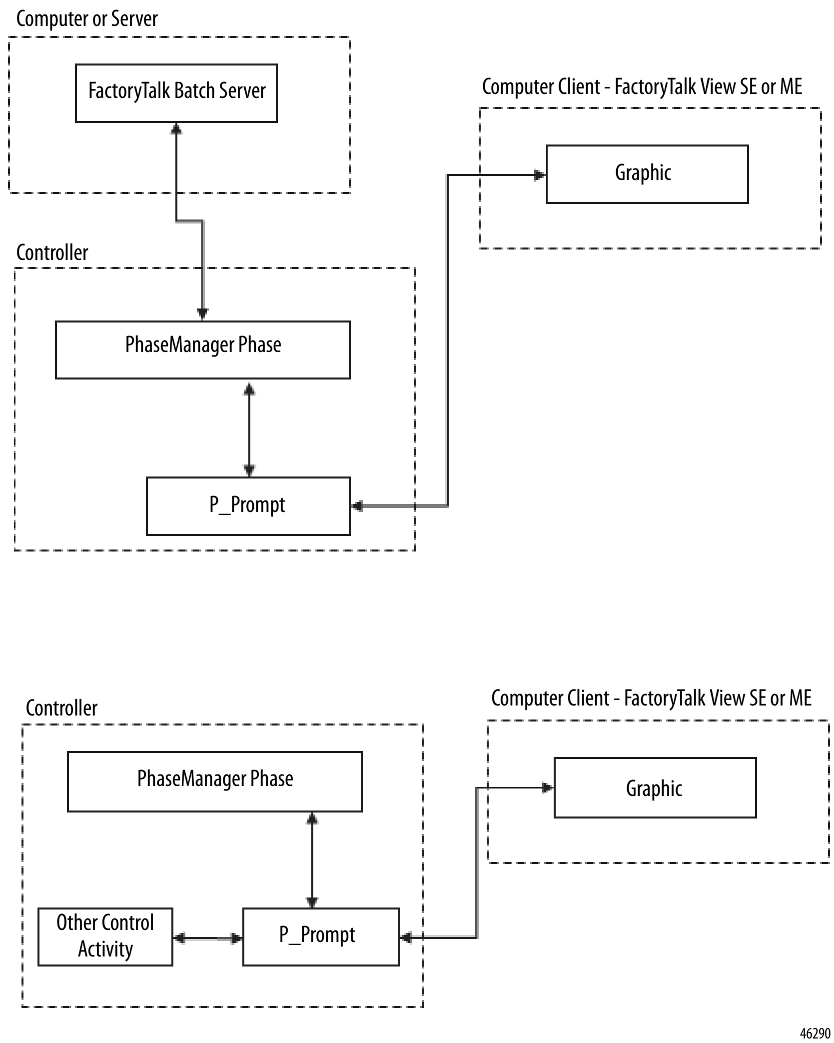
IMPORTANT	The three interactions that are discussed in this section do not have to be mutually inclusive. To solve different functional requirements, we recommend a mix of technologies as no one technology fits all.

Operator Prompt

The P_Prompt Add-On Instruction is included in the Rockwell Automation Library of Process Objects. Similar to other Process objects, the P_Prompt instruction consists of a Logix Add-On Instruction and a FactoryTalk View global object that adds interaction to any HMI graphic.

The P_Prompt instruction works with multiple platforms, including a controller or server-based batch solution.

Figure 2 - Operator Prompt Diagrams

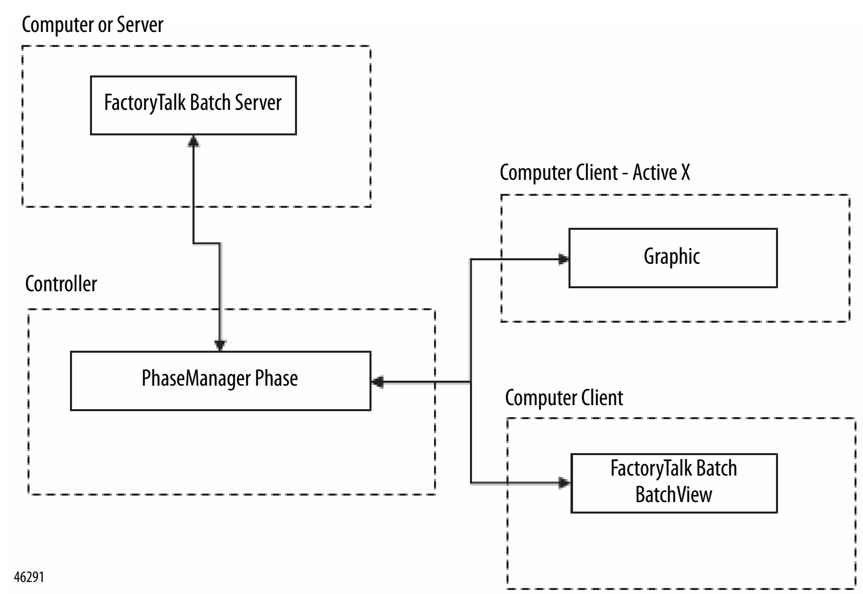


For more information, see the Rockwell Automation Library of Process Objects: Operator Prompt (P_Prompt) Reference Manual, publication SYSLIB-RM046.

Phase Request

Phase Requests are a FactoryTalk Batch product feature. Phase Requests, triggered by phase logic, wait for an operator entered formula value. Responses can be enumerated (such as yes/no) or values (such as water quantity – gallons or kilograms).

Figure 3 - Phase Request Diagram



For more information, see Tips on Using PhaseManager with FactoryTalk Batch, publication FTALK-WP001.

Summary

Table 2 provides a comparison of the operator interactions.

Table 2 - Operator Prompt Comparisons

Item	Topic	eProcedure Component	P_Prompt	Phase Request
1	HMI	Web browser	FactoryTalk View Site Edition (SE) or Machine Edition (ME) software	FactoryTalk Batch BatchView or batch Active X components in FactoryTalk View SE software
2	Parameter display per instance	No limit to quantity or data type	Limited to four REAL or four string entry and four binary selections	One parameter of any data type, including enumerations
3	Reporting	Responses automatically entered into the batch journal	Responses entered into the batch journal as phase report parameters	Responses automatically entered into the batch journal
4	Electronic signature	Supported within the FactoryTalk Batch product	Requires custom FactoryTalk View development	Not supported
5	Electronic signature	Signature signoff automatically entered into the batch journal	Signature signoff entered into the FactoryTalk View diagnostic log	Not supported
6	Display content	Text, photos, video, links	Text	Text
7	Controller requirements	No controller required	Requires controller and FactoryTalk View HMI	Supports controller-based phases
8	Annunciation	Difficult to highlight active prompt	Designed for integration into graphics, menus, bread crumbs	Can be annunciated in graphics by using phase logic and tags
9	React to live data	Not readily supported	Live data integrates into prompt display and response verification	Not applicable
10	Prompt from entity other than phase (for example, EM or CM)	Not supported	Supports any interaction with operator, batch/process/upset response	Not supported

Notes:

Material Management

All batches consume materials, therefore the system could support material inventory, storage locations, and genealogy.

Discussion

All batch process requires material additions. Minimally, each addition requires the following:

- What material to add (niacinamide, glycerin, raisins)
- How much to add (5.7 kg or 2 tablespoons)
- When to add

In many systems additional information is required, which includes the following:

- How to add (by hand or with automated controls)
- Source or storage location (for example, storage tank A, warehouse sector; C-3, silo 12)

When using materials, one encounters requirements, such as the following:

- Monitoring inventory
- Maintaining material lot and sub-lot numbers
- Storing material attributes by lot (such as fat content or percent moisture)

A recipe defines the materials, their quantities, and procedurally when they are added. However, a recipe typically doesn't include site physical data (for example, storage locations) nor individual lot attributes. Therefore, supplemental systems, beyond recipe management, are needed when encountering material management requirements.

Solutions

The following are two material management solutions:

- Controller
- FactoryTalk Batch Material Manager

Controller

A controller array that is augmented with a HMI graphic can meet many material management requirements. In general, a UDT contains needed elements for lot number, inventory, or expiration date. A 'material centric' UDT references material while a 'physical centric' UDT references a location.

The array is sized for number of either materials or storage locations depending on centricity. A user-developed HMI graphic displays and inputs desired data.

A controller-based solution requires design, development, and support by the integrator and/or end-user.

FactoryTalk Batch Material Manager

Material Manager is an optional component of the FactoryTalk Batch product suite that provides integrated material management capability. Material Manager provides storage location and material configuration from which FactoryTalk Batch managed batches retrieve or submit data

IMPORTANT	Material Manager is designed to support material usage in the batch process. This tool normally complements, but does not replace, a site-wide inventory management system.

Summary

Table 3 provides a comparison of the two material management type solutions.

Table 3 - Material Management Type Comparison

Item	Topic	Controller Design	FactoryTalk Batch Material Manager
1	Data repository	Controller	MS-SQL database
2	Interface	HMI graphic	MS-SQL queries and display
3	Maintenance	Controller/HMI knowledge	RDB tools and procedures
4	Material management	Supports any batch management in any mode (operator or program) initiated from any HMI)‘	Supports FactoryTalk Batch managed batches or phases only
5	Find current location given recipe-specified material	Coded	Product feature
6	Theoretical inventory updates	Coded	Product feature
7	Real-time inventory	Readily supported from available instrumentation	Coded by using SQL and batch API
8	Plug-flow inventory	Coded	Product feature
9	Pallet inventory	Coded	Product feature
10	Deferred material specification	Supported	Not supported
11	New material or location introduction	No constraint	Requires restart of batch service
12	Material reference	Text strings	Pull-down list
13	Reporting – lot numbers	Coded by using phase report parameters	Product feature
14	Material quantities	Material centric < 20 Physical centric — no limit	No constraint
15	Location quantities	Physical centric < 20 Material centric — no limit	No constraint

Notes:

Process Upsets

All systems, batch or otherwise, experience 'upsets'. A successful system solution provides the means to detect, inform, and respond to abnormal situations.

Discussion

A list of example upsets includes the following:

- Equipment (valve failed to open)
- Mode (operator owns and has locked a needed device)
- Process (solution fails to gel or batch fails to reach temperature)
- Materials (insufficient inventory to satisfy batch requirements)
- Quality (pH too high)
- Unknown (activity time out)
- Safety (reactor high pressure)

To avoid most upsets, be sure to use good process control, which protects life, property, and product with safety systems and interlocks.

Now, after an upset has occurred and process control has done its job—bringing the process to a safe state—what happens to the batch? Some batch responses include the following:

- Keep all batch procedural entities (phase, operation, unit procedure, procedure) in a running state, but with logic designed to respond, notify, correct, and potentially recover from the upset

- Command only an impacted phase, to the 'Holding' state where holding logic is then executed

- Command higher level batch procedural entities, such as an operation, unit procedure, or procedure to 'Hold' that drives all subordinate entities for that batch to 'Holding' then 'Held'.

Lastly, after a batch procedural entity has enacted its response, one needs to consider recovery. Some of the possibilities include the following:

- Abort batch (drastic and unfortunate but could be the only option)
- Command batch procedural entities to the 'Running' state
- Automatically resume processing once upset is corrected

Recovery methods vary and are influenced by these factors:

- Workstation capability
- Number of operator 'key clicks'
- Security or authentication (for example, 'only a supervisor can resume batch')
- Logging and reporting requirements

Solutions

Solutions are numerous and vary based on the conditions and scenarios presented above. This document describes two approaches:

- Active State Processing
- Phase Failures

Active State Processing

Active state processing detects, responds, annunciates, and recovers all within the state (running, holding, stopping) where the upset occurs.

Phase Failures

'Phase failures' leverage the FactoryTalk Batch product and associated configuration. Upsets, detected by controller phase logic, are read by the FactoryTalk Batch service. The FactoryTalk Batch service then commands batch procedural entities to 'Holding'.

FactoryTalk Batch propagation configuration determines whether a phase, the operation containing the phase, the unit procedure containing the operation, or the batch is held.

For more information, see the FactoryTalk Batch User's Guide, publication BATCH-UM011.

Summary

Table 4 provides a comparison of the two solutions for upsets.

Table 4 - Upset Solution Comparison

Item	Topic	Active State	Phase Failures
1	Architecture	Controller handles all upset activity	Requires FactoryTalk Batch Service to detect upset and command phase to 'Holding'
2	Architecture	Phase remains active to assist with upset handling or recovery	Phase transitions to 'Held,' an inactive state
3	Architecture	Supports any batch management (example, LBSM) and phases running in operator mode	Only the FactoryTalk Batch server can detect upset and command phases to 'Holding'
4	Reporting	Can be tied to FactoryTalk Alarm and Event. Batch journal entities can be made by using a report parameter and PXRQ instruction	Upset is automatically entered into the batch journal
5	Propagation	Requires additional controller programming	Batch service propagates 'Hold' to other, configured, batch entities (phases, unit procedures, batch)
6	Recovery	Recovers from any HMI user graphic	Recovery requires BatchView Client or Batch ActiveX
7	Recovery	Automatic or single graphic button press	Can require many 'key-clicks' depending on recipe and propagation configuration

Notes:

Transitions

Batch procedure execution is dependent on configured conditions. Examining and ‘going on’ based on a condition is only part of the story. Successful solutions also consider the recipe author's effort and operator discernment during the batch.

Discussion

Process conditions are often factored into the batch process, for example, ‘Add Material y' only after the temperature is above 'x' degrees.

IMPORTANT	Recipe configurations are for conditions that change between products, not for equipment. Requirements such as ‘Never run the agitator until the lower blades are covered’ do not belong in the recipe.

Solutions

Three solutions for configuring product-related, process conditions, into a recipe are the following:
- Procedure transition expressions
- An ‘Evaluation’ phase
- A phase's recipe parameter

IMPORTANT	These solutions are not mutually exclusive and you can use more than one technique in the same project.

Procedure Transition Expressions

FactoryTalk Batch provides an expression editor for configuring transition conditions. Conditions can reference controller ‘live data’ to tie transitions to specific process events or states such as, ‘reactor temperature at setpoint’.

Evaluation Phase

An ‘Evaluation’ procedural phase is added to the system and executed by the controller (as done with most other phases). Recipe parameters such as ‘Wait until Temperature >’ or ‘Wait until Level <‘ describe the condition. The condition is then modified with parameter values, such as ‘60 °C’ or ‘35%’ respectively, to complete the expression.

Phase Recipe Parameter

If a process condition is ‘always’ or ‘nearly always’ evaluated for a given phase, then the evaluation can be done within the phase's execution logic by using a recipe configured value.

Summary

Table 5 provides a comparison of process conditions.

Table 5 - Process Condition Comparisons

Item	Topic	Transition Expression	Evaluation Phase	Phase Recipe Parameter
1	Convenience	Requires knowledge of expression editor and unit tags	Configured in same fashion as other phases (for example, Add or Heat)	Requires only parameter entry along with other phase parameters
2	Display	Expression and status viewed only in FactoryTalk Batch procedure display (BatchView or ActiveX)	Condition and status are tags that display on any HMI graphic	Condition and status are tags that display on any HMI graphic
3	Versatility	New expressions or conditions can be created as needed	Requires knowledge of process to define a flexible phase	Works for a specific phase requirement only
4	Parallelism	Many transition expressions, in parallel legs, can be evaluated simultaneously	Requires additional phase instances if simultaneous expression evaluation is required	Not applicable
5	Architecture	Evaluated within batch service	Requires a controller for evaluation	Handled within existing phase logic
6	Deferring transition parameter values	Not supported	Supported	Supported

Batch Timing

Choose a timing solution that saves you time while at the same time provides the correct time for your application.

Discussion

Most batch process has some need for 'timing', which generally appears as the following:

- Mix vessel contents for 20 minutes
- Wait 40 seconds then add ...
- Take sample every hour while reaction takes place

Generally, batch systems need a 'timing' procedural phase that can be inserted as many times as needed into the procedure, which is the focus of this section.

IMPORTANT	A timing phase does not preclude one from including timing recipe parameters as part of another phase when this concept simplifies recipe construction or matches a user methodology. For example, if one always 'agitates for time', then providing timing setpoints in the agitation phase might be better than a timing and an agitating phase configured in parallel.

Solutions

The following are two procedural 'timing' phase solutions:

- Controller-based execution
- Server-based execution

In both cases, the recipe author configures the 'wait time' as formula parameters and the phase completes when the specified time has elapsed.

Controller-based Execution

The timing phase is a controller-based phase that is implemented similar to all other controller phases, such as 'add water', or 'heat'.

Server-based Execution

The FactoryTalk Batch product supplies 'timing' phases for each unit.

Summary

Table 6 provides a comparison of two timing phases.

Table 6 - Material Management Type Comparison

Item	Topic	Controller Based	Server Based
1	Time base (for example, wait 2 hr, 23 min, 15 s, and so forth)	Configure multiple formula parameters, such as minute **and** second (2 hr, 23 min, 15 s)	Supports only one time base that can either be day, hour, minute, **or** second (for example, 8495 s)
2	Display	Tag-based, integrates into any HMI graphic	Requires ActiveX
3	'Time remaining' display	Can show multiple units (1 hr, 8 min, 12 s remaining)	Displays single unit (4092 s remaining)
4	Quantity	Generally one instance only per unit, therefore one 'wait' at a point in time	Multiple, simultaneous 'waits' can be configured at a point in time
5	Architecture	Requires controller	Managed at server level, no controller required
6	Coordination (for example, 'time while at temperature only')	Facilitates timing coordination with other process conditions or activity	No integration with process control or other phases

Resource Arbitration and Allocation

If there are shared resources, then arbitration and allocation for those resources are required.

Discussion

Resources often have limited capacity and are used by multiple entities, thus 'shared'. Examples include the following:

- Devices (tank outlet valve)
- Segments (common inlet header)
- Materials (alcohol supply)
- Equipment (dust collector)
- People (operator)

When sharing, 'arbitration' is needed to evaluate contention rules as well as an 'allocation' function for establishing ownership.

Solutions

Arbitration and allocation solutions are typically implemented as either of the following:

- Controller-based execution
- Server-based execution

Controller-based Execution

Arbitration and allocation code is written and managed in the controller. Tag-based 'handshakes' are developed to request, receive, and release shared resources.

Server-based Execution

The FactoryTalk Batch product provides resource arbitration and allocation. Shared resources can be defined at the unit or phase level.

Summary

Table 7 provides a comparison of resource and arbitration methods.

Table 7 - Resource Arbitration and Allocation Method Comparison

Item	Topic	Controller Based	Server Based
1	Development	Coded	Configured
2	Acquisition arbitration	Coded, therefore can accommodate priority batches, queue wait time, or any algorithm, in addition to 'first come - first serve'	First come-first serve allocation scheme
3	Capacity arbitration (for example, resource can supply up to three users)	Supported through code development	Supported through configuration
4	Coverage	Arbitration and allocation active and managed at all times within or outside of a batch	Supports phase activity that is only initiated and directed by active batch service
5	Communication	Requires 'handshake' protocol and possibly inter-processor communication	Transparent to phase
6	'Hold' state or similar response	Coded, therefore can release and reacquire resources	Phase retains resource unless resource management coded by using PXRQ instruction

Shared Phases

A ‘Shared Phase’ is a FactoryTalk Batch feature that reduces coding while providing arbitration and allocation. However, sometimes it is best not to share a phase. This option can provide increased availability and flexibility without reducing code.

Discussion

The FactoryTalk Batch product and PhaseManager software support a feature that is known as ‘Shared Phase’. When a phase is configured as ‘shared’, the same phase can support multiple batch units but requires only one controller instance. In addition, the FactoryTalk Batch server arbitrates and allocates this shared phase to one batch at a time.

Refer to Resource Arbitration and Allocation on page 31.

Shared phases arise when a phase class with multiple instances requires an exclusive-use shared resource. An ‘Add-X’ phase, where ‘X’ is added to multiple units, but dosed through a single flow meter is an example.

Solutions

Shared phases and their counterpart, ‘Unshared Phases’, are contrasted below.

Unshared Phases

Unshared phases are defined, developed, coded, and configured the same as other unit phases such as ‘heat’ or ‘agitate’. There is a unique code instance of the phase in each unit.

Shared Phases

A shared phase has one code instance, therefore leverages common phase activity. For example, within the 'Add-X' phase one could find common logic for all units with minor changes, such as an inlet valve, to accommodate different owners.

For example, common logic in the 'Add-X' phase could be

- opening the source outlet valve,
- zeroing the flow meter,
- checking tolerances,
- logging actual quantities,

while only V101, V201, or V301 needs to be opened depending on unit.

See Appendix B on page 49 for illustrations of shared phases.

Summary

Table 8 provides a comparison of shared and unshared phases.

Table 8 - Shared and Unshared Phases Comparison

Item	Topic	Controller Based	Server Based
1	Development and maintenance	Each unit requires a code instance that needs to be created and maintained	One code instance to develop and maintain for all units
2	Architecture	Phase placement with unit's other phases	Single phase placement requires consideration, particularly in distributed controller systems
3	Phase owner	Single unit, inherent to phase	Defined by allocation. FactoryTalk Batch in 'program' mode, user in 'operator' mode
4	Shared resource capacity	Multi-use resource capability	Exclusive use resource only
5	Shared resource arbitration	Requires other arbitration means	Inherent to phase
6	Arbitration scheme	Coded, can support priority batches and other rule sets	First-in – First-out (FIFO), maintained by FactoryTalk Batch server
7	Shared resource allocation	Requires other allocation means	Inherent to phase
8	Allocation relinquishment	Phase can release allocation (for example, in phase hold state)	Allocation maintained until phase returns to idle
9	Unit idiosyncrasies	Needed when encountering many variations (for example, alarm handling)	Minimal differences between units (for example, one or two valves)

Two- or Three-layer Model

Too little modularization is bad. Too much modularization is also bad. So how much modularization is good?

Discussion

This section pertains only to controller implementation and organization. This section is independent of batch management, servers, or services.

The following two architectures are prevalent in today's batch design:
- Two-layer Model
- Three-layer Model

The three-layer design was popular and needed prior to the release of PhaseManager software. PhaseManager software eliminated the PLI and associated phase interfaces, which then opened the door for a practical two-layer implementation.

A mixed approach can be used in the same project, leveraging either two- or three-layer advantages as needed.

Solutions

These two solutions have the following contrasts:

Two-layer Model

In a two-layer application, PhaseManager software hosts the Equipment Phase (EP) and Equipment Module (EM). This is one 'layer,' the other 'layer' being subordinate control modules (CM) and perhaps other EM's that are needed to support the phase's activity.

Three-layer Model

PhaseManager software hosts the Equipment Phase (layer 1), which directs Equipment Module(s) (layer 2), that commands subordinate CM's (layer 3).

Summary

Table 9 provides a comparison of architectural methods.

Table 9 - Controller Organization Comparison

Item	Topic	Two-layer Model	Three-layer Model
1	Maintenance	Two code layers to understand and troubleshoot	Three code layers to understand and troubleshoot
2	General interface	Same phase interface for batch, operator, or other users	Two interfaces, one for the EP and another for the EM
3	Batch interface	Batch interfaces need to be skipped when running in non-batch modes	Batch interfaces found only in EP leaving EM free of any batch constructs
4	Structure	EM activity must conform to phase state model	EM's can be developed in any style or by using a state model that best suits the application
5	Integration	Skid OEM needs to understand and provide 'batch centric' solution with phase focus	Skid OEM provides 'equipment centric' EM's that are referenced by SI developed batch phases

Chapter 11

Implementation Techniques

This chapter provides some hints and tips for implementing FactoryTalk Batch.

Standard Phases

Every unit typically includes an instance of the following phases:

- Initiate
- Timing
- Prompt

Initiate

Typically, the 'Initiate' phase is the first phase in any unit procedure.

Functions for this phase include checking equipment states (example, clean or dirty) or device mode verification (example, operator or program). Improper conditions can be flagged and corrected or the batch aborted before any process activity takes place on the unit.

'Initiate,' being the first phase in the Unit Procedure, is a good location for the PXRQ instructions that are necessary to download the Unique and User Batch ID's to the controller.

Timing

We recommend that all units have at least one instance of a timing phase that provides the recipe author a mechanism of adding a 'wait for time' into the procedure.

For more information, see Batch Timing on page 29.

Prompt

We recommend that all units have at least one instance of a general prompt phase that gives the recipe author the means of interacting with the operator anywhere in the procedure. A general prompt phase is configurable and includes the following capabilities:

- Display text to the operator only and wait for an acknowledgement. (For example, 'Confirm that the tank is clean and ready for the next batch'.)
- Display a question that can be answered with a button selection. (For example, 'Has the lab approved the batch?')
- Prompt for data and accept either a numeric or string response. (For example, 'Sample the batch and enter the pH'.)

  For more prompt details, see Operator Interaction on page 13.

Process Control/Device Ownership

Architect the system so that a single equipment module (EM) directly controls all devices (for example, valves, pumps) to complete its assigned task. Doing so, minimizes handshaking that can be complex and problematic.

Consider, for example, a transfer between two units A and B, which utilizes the outlet valve of 'A' and inlet valve of 'B'. Rather than assign ownership of the outlet valve to 'A' and ownership of the inlet valve to 'B' and then handshake between A and B and the EM, assign ownership and control of both valves to the EM (or phase) and eliminate handshaking.

Mode

Mode indicates ownership. There can be one owner only and the owner only can issue commands. For example, if a valve is in 'operator mode', then the operator 'owns' and has the exclusive right to send commands, such as open and close, to the valve. A device often has multiple users but one owner only at a time.

Because there are multiple users (for example, operator, maintenance, or program) but one owner only, rules must be established regarding ownership acquisition, retention, release, and override.

Rule definition can be difficult because these rules establish the system's operating methodology and require agreement from a number of parties including operations, quality, safety, maintenance, and engineering. Proceeding beyond the requirements stage without rules in place can result in chaos, rework, and unsatisfied system users.

Batch ‘process management’ and ‘unit supervision’ are additional users that can be considered in the rule set. We recommend these design considerations:

- What unit resources can be acquired by an operator when a batch has begun on the unit?
- What phase or equipment module resources can be acquired by the operator when the phase is in the 'Running' state? Or in the 'Held' state?

Naming Conventions

We recommend the following naming conventions:

Recipe and Report Parameters

It’s essential that if you are using the PlantPAx web-based reporting package, certain report and parameter names must follow the naming convention outlined in the Event Archive’s User Guide as part of the FactoryTalk Batch User's Guide, publication BATCH-UM011.

Recipe parameters are sorted alphabetically when displayed in the recipe editor (regardless of order entry in the equipment editor). Preface parameters with a letter (for example, a_setpoint, b_flowrate, or P01_xxx, P02_yyy) if ordering is desired.

Phase

Because a phase is a ‘process action’, it is recommended that the name be a verb. Remember, phases are configured and generally viewed in context so unit descriptions are not needed in the phase name. Maintaining a consistent verb_noun arrangement improves usability.

Some examples include the following:
- Transfer
- Add_water
- Prompt
- Agitate

Class phase names are to be short and descriptive. Short, so that the phase name is clearly displayed on batch displays and descriptive enough that one can easily follow the procedure.

Recommended	Not Recommended	Comment
Transfer	Transfer_Mixer_to_Product_Storage	Name is too long. Information not needed or redundant when in context. Name displays incorrectly.
Add_Water Add_Sucrose Add_Fructose	Water_Add Sucrose_Add Fructose_Addition	Inconsistent verb-noun arrangement; inconsistent verbs
Add_Alchohol	ADAL	Not intuitive

Procedure, Unit Procedure, Operation

Recipe entity naming conventions improve development, maintenance, and display of recipes.

Entity	Convention	Example	Comment
Operation	Product_Unit_OP	LightRanch_MX_OP LightRanch_PM_OP	Use a short, two- or three-letter representation for unit
Unit procedure	Product_Unit_UP	LightRanch_MX_UP LightRanch_PM_UP	
Procedure	Product	LightRanch	Top level (1)does not carry an appendix

(1) The top level entity does not have a '_level,' identifier. Therefore, if an operation or unit procedure is released as the 'top level' entity, then drop the _OP or _UP appendix.

Reset/Idle State

PhaseManager phases require an 'Initial' state configuration, the default is 'Idle'. During controller powerup or transition from 'Program-to-Run,' the Logix firmware sets all phases to the 'Initial' configured state, skipping all intermediate states in the state model.

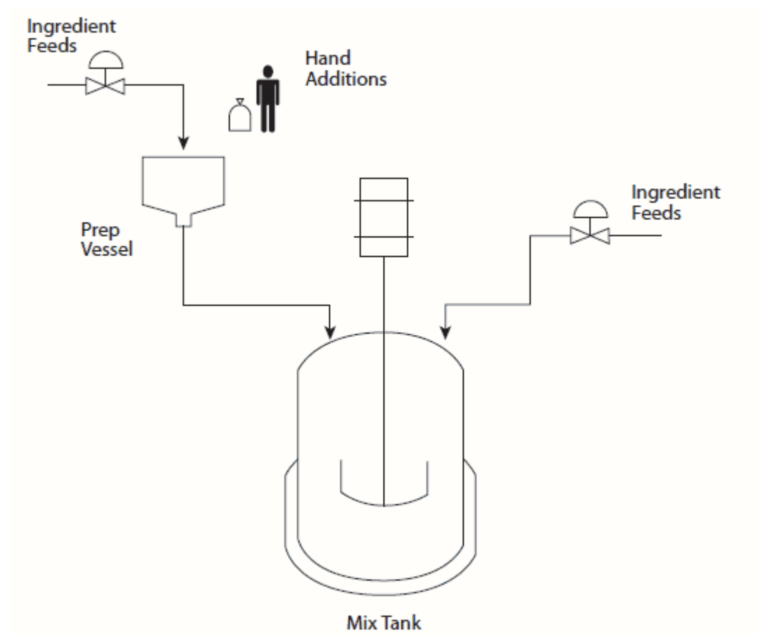
Therefore, a phase configured for 'Initial' state = 'Idle' is set to 'Idle' without executing 'Resetting' logic, if in the 'Running' state when a 'Program -> Run' transition occurs. The clean-up or resetting logic, expected to occur following the 'Running,' 'Stopping', or 'Aborting' states, is not executed and can cause the next instance of 'Running' state logic to not behave as designed.

Unit Coordination - Material Transfer

This section examines the coordination between asynchronous units in a batch process. Unit coordination can consist of material transfers and synchronization among units.

Figure 4 illustrates a common batch process scenario that includes a Prep Vessel and a Mix Tank. In general, two (or more) major pieces of equipment (known as units) are required to manufacture a product. Typically, part of the batch is started in one unit and completed in another unit to require a material transfer between the two units.

Figure 4 - Prep Vessel and Mix Tank



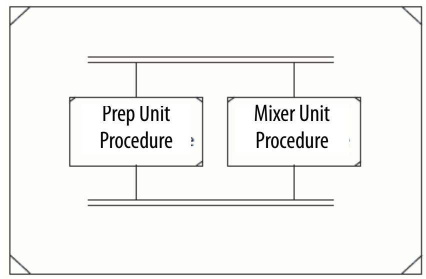
Unit Transfers

Procedural control of automated and manual processes involves coordinated material transfers between units.

Referring to Figure 4, assume the process requires material weighs in Unit A, the Prep Vessel, and primary batching (add material, heat/cool, agitate) in Unit B, the Mix Tank. Furthermore, the weighed material in Unit A is transferred to Unit B at some point in Unit B's process. Lastly, as soon as the prepped material in Unit A is transferred to Unit B, then this Prep unit is available for weighs to begin for a subsequent batch (sometimes referred to as 'pre-weigh' or 'pre-batching').

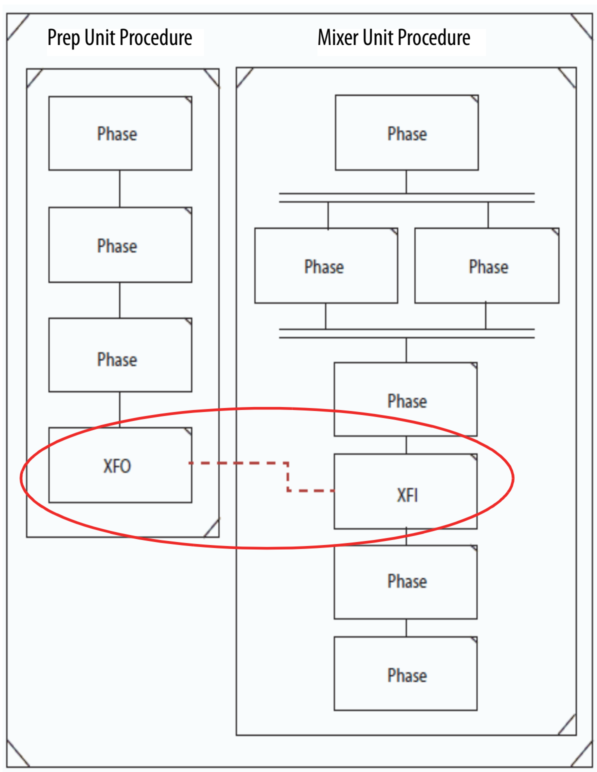
This arrangement requires two units since two different batches are being processed simultaneously (Batch 1 still is in Unit B while Batch 2 has begun on Unit A). The procedure for this batch corresponds with Figure 5.

Figure 5 - Batch Procedure



The 'Procedure' must consist of two 'Unit Procedures' and the 'Unit Procedures' must be **in parallel**. This structure is the only way to describe the need for two units to make the product and handle the requirement of multiple batches in the Process Cell at one time.

Figure 6 - Batch Phase Handshake



The next consideration is coordinating the material transfer. The material cannot be transferred to Unit B until B's process is ready for the material and the transfer cannot begin until Unit A is ready.

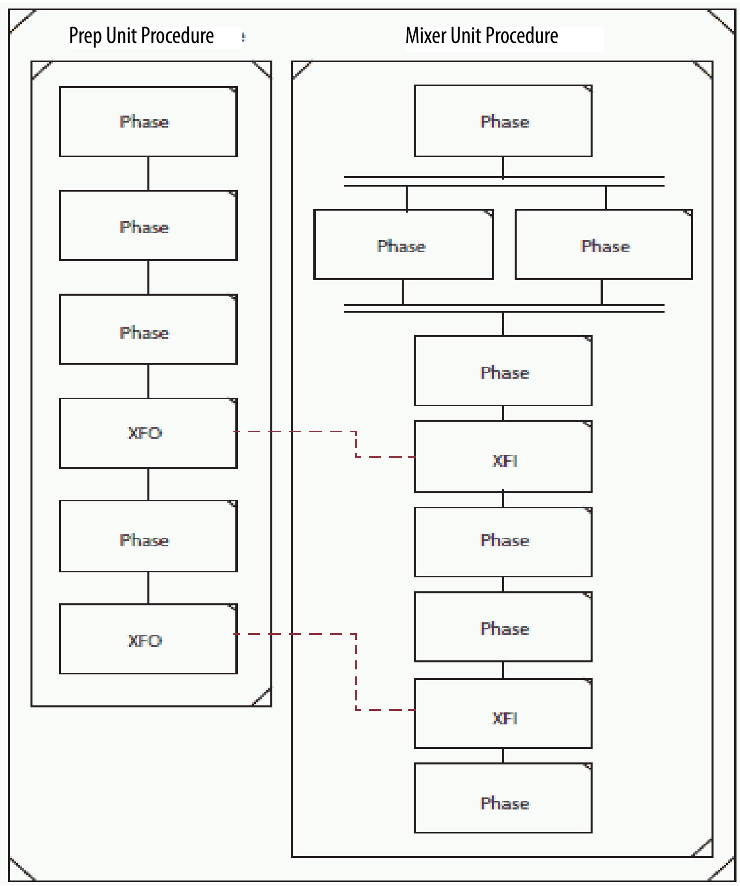
This is best handled with a Transfer Out (XFO) – Transfer In (XFI) pair of phases. The XFO phase is part of Unit A's phase set while XFI is part of B's. The two phases 'handshake' between themselves to coordinate the transfer, as indicated by the dotted line in Figure 6.

Multiple Transfers between Units

The XFO-XFI pair phase combination is versatile and able to handle nearly all transfer requirements. Often there are multiple transfers, between units, within a given batch.

For example, if Unit A is a prep vessel and Unit B is a mix tank, there are two different prep transfer activities between the units as shown in Figure 7. If Unit B is not ready, Unit A holds until its partner is ready before the transfer occurs and the next phase is completed.

Figure 7 - Multiple Unit Transfers



See Connections and Controllers on page 44 to determine partnership in a unit transfer.

Connections and Controllers

The dotted line in Figure 7 shows two unit transfers that occur at different stages of the batch. This section elaborates on the dotted line by explaining how the partners communicate with each other and specifically what is being communicated to complete the transfer.

One degree of complexity comes from the number of partners and the distribution of those partners within controllers across the architecture. For example, a 1:1 (one-to-one) transfer represents one source going to only one destination while a 3:1 (many-to-one) transfer represents three sources going to one destination. The latter is more complex because the more possible participants in a transfer requires aligned connections so the correct partners are interacting.

Another degree of complexity includes the number of controllers that are involved with the transfer. Table 10 shows how the combined number of connections and controllers can change the dynamic of the transfer process within your architecture.

Table 10 - Connections and Controllers

Model	Connection	Controllers	Total(1)
1:1	1	1	2
1:1	1	2	3
3:1	3	1	4
3:1	3	2	5
3:1	3	3	6

(1) Total is a simplified measurement of complexity.

Regardless of the number of participants or controllers, any unit transfer uses a basic concept:

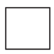
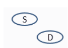
a. Who are my partners?
b. How do they communicate?

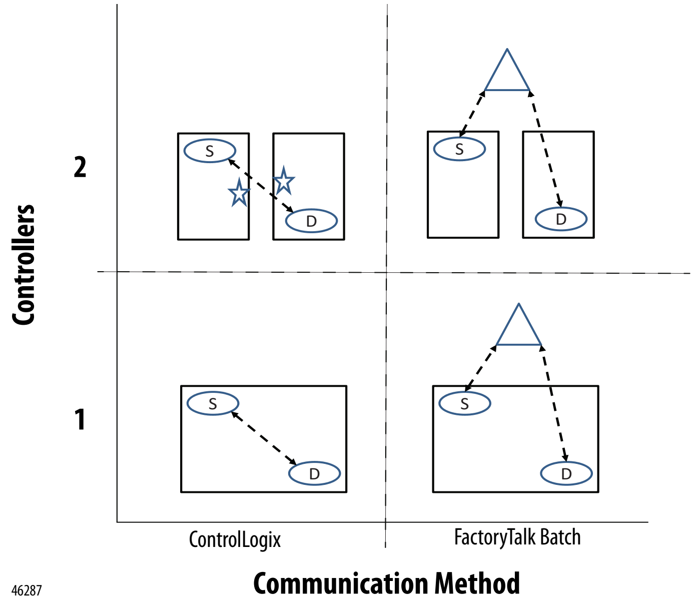
'Who' is doing the transfer and 'how' the message is conveyed between the source and destination units is orchestrated by two suggested communication methods:

- ControlLogix® tags
- FactoryTalk Batch message partners

Figure 8a and Figure 8b use a quadrant to show differences between the number of partners, controllers, and methods of communication.

Figure 8a - 1:1 Source/Destination Configuration

Diagram Key		
Shape	**Object**	**Notes**
	Controller	ControlLogix controller
	Triangle	FactoryTalk Batch server
	Transfer units	S => Source => 'XFO' D => Destination => 'XFI'
	Communication	ControlLogix = Controller tags FactoryTalk Batch = Message partners
	Inter-processor communication	Produce/consume tag



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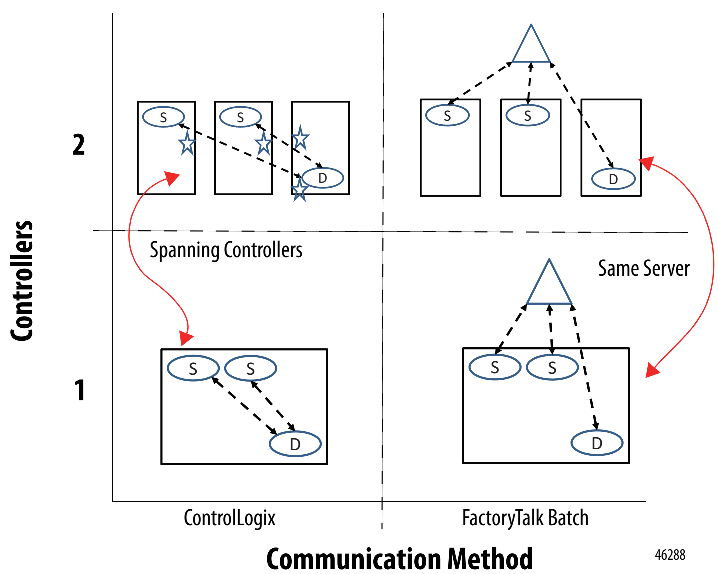
In the left side of the quadrant, ControlLogix tags are being used for the source and destination units to transfer data between one and two controllers. Spanning multiple controllers (see below, upper left corner) typically requires inter-processor communication to coordinate which source units are transferring to the destination unit.

In the right side of the quadrant, both architectures use the FactoryTalk Batch server regardless of the number of controllers. The server-based approach is useful when a greater number of controllers are added because FactoryTalk Batch uses out-of-box functionality for associating and arbitrating partners. However, if the server becomes unavailable, none of the units can communicate.

Figure 8b - 2:1 Source/Destination Configuration

Same Diagram Key applies as shown in Figure 8a.



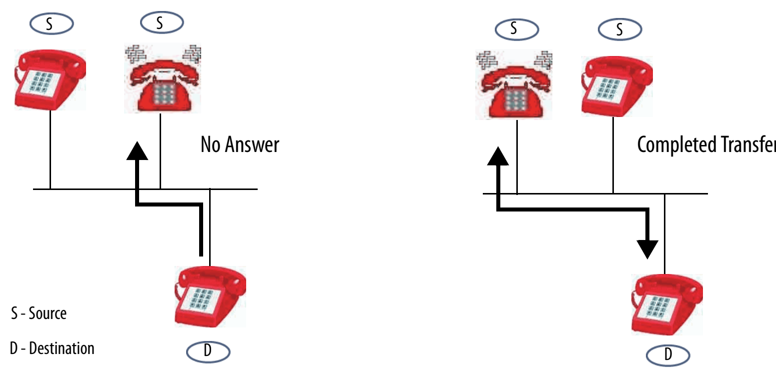
46288

Up to this point we have discussed how infrastructure is used to facilitate communication. Mode, handshake, and dialog are factors for pairing the units to complete a task.

Mode determines 'who' is the owner that is responsible for making the transfer (operator or program) and the degree to which those partners synchronize their efforts.

Handshaking and dialog are types of communication to facilitate some type of action for a transaction. The handshake is necessary so the recipient of the transfer can verify its readiness. It also can be extended to the number of partners that need to perform a single transaction (for example, two sources supplying simultaneously to the same destination.) The source and destination units also need to maintain a 'dialog' during the whole transfer process in the event of an unintended consequence of a transfer.

For example, imagine several telephones on a network connection. One telephone rings to indicate an incoming call from another telephone. If the receiving telephone is not ready for the transmission, a busy single is exchanged.



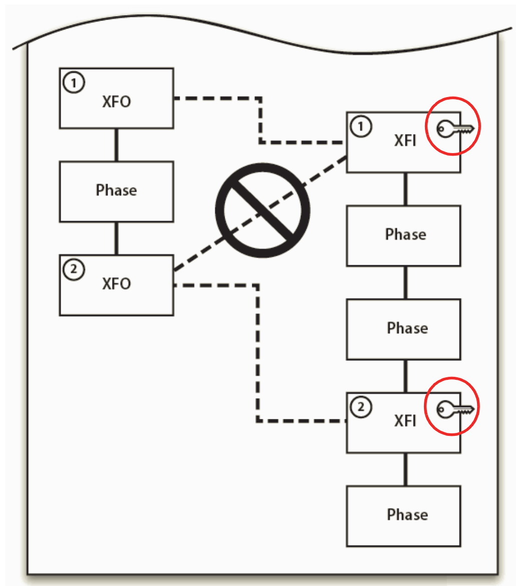
The call is then placed to another receiver and an interaction occurs when both parties communicate.

A batch transaction can be initiated either manually (operator) or by a program (batch server). Typically, controller tags require unique batch IDs to make sure the right partners are aligned at the right time. The batch server approach automatically coordinates the partnership process.

Misalignment

In Figure 9, the dotted lines show XFO 1 is paired with XFI 1, and XFO 2 is paired with XFI 2. Who and what safeguards against XFO2 transferring material to XFI 1 (indicated by the null sign).

Figure 9 - Key Symbolizes Partnership



In Operator mode, the operator is responsible for determining the unit alignment. In Program mode, the alignment is dependent on the selected communication method. See Unit Coordination and Synchronization on page 11.

If the communication method is 'controller-based' then a formula parameter, called 'key', can be configured in both the XFO and XFI phases. The recipe author configures the 'key' parameter with an integer that matches both sides of the coordinated transfer. Lastly, controller code verifies that the key's values match before beginning a transfer.

If the communication method is 'server-based' then alignment is managed through Link Group configuration.

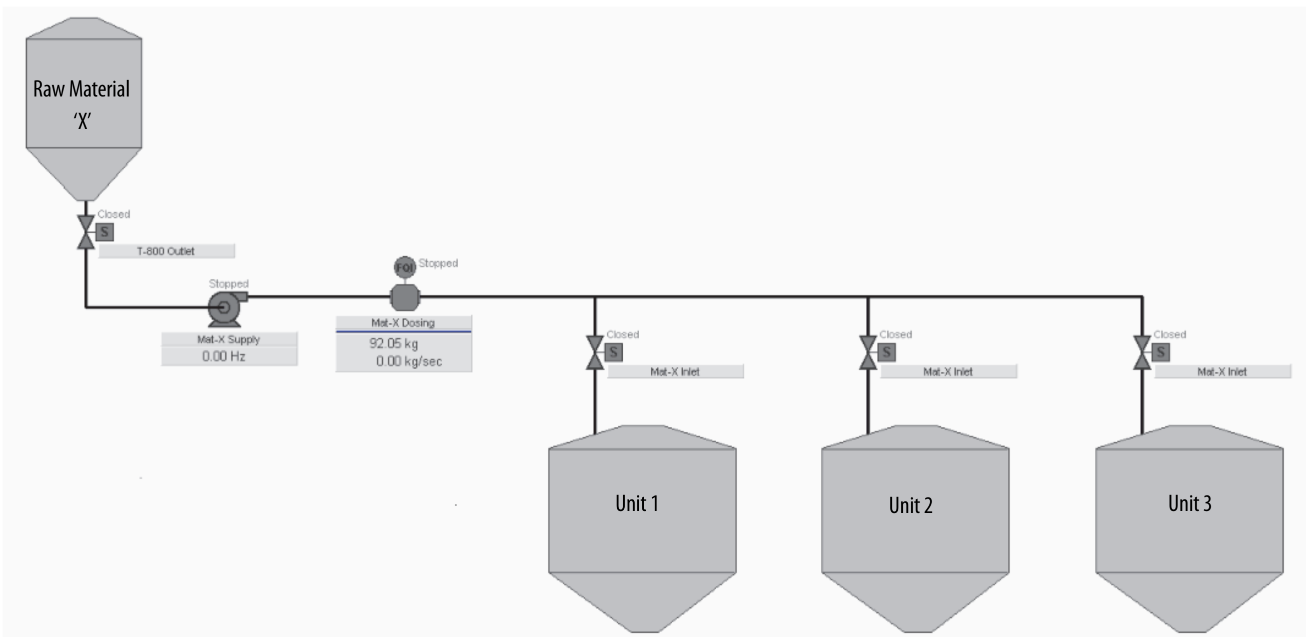
Notes:

Illustrated Shared Phases

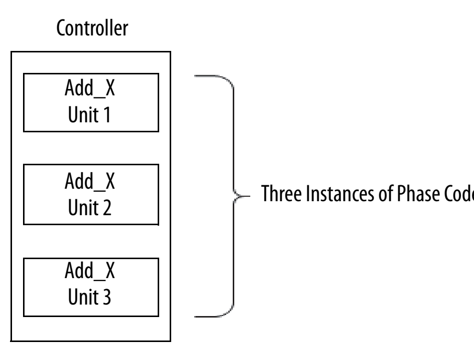
This appendix includes additional information and illustrations for shared phases.

In Figure 10, there is one raw material that is being consumed by many units (1, 2, 3). Even though transfer from the raw material source to any destination unit is possible, in our example one transfer only can occur at a time because of one flowmeter device.

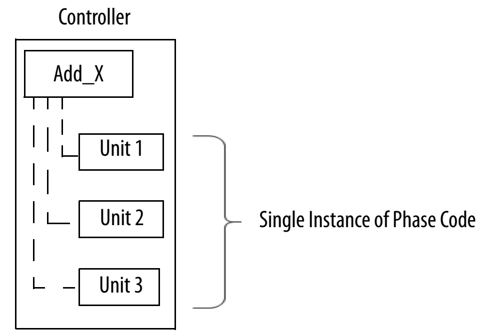
Figure 10 - Shared Phase Example



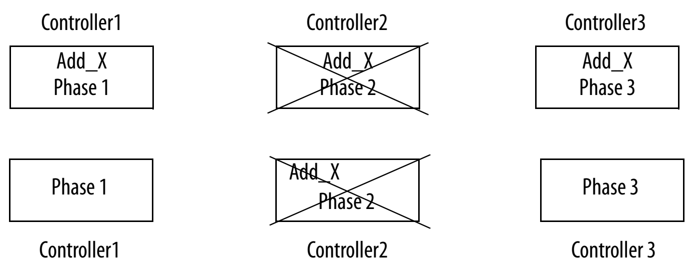
One method for the transfer process is to create a raw material (Add 'X') addition phase in each unit. This method results in three separate instances of phase code in the controller.



A shared phase reduces the controller code because one instance of code only is required.



However, there are architectural considerations. If a shared phase is in a distributed system, you must determine the impact if the host controller with the shared phase goes offline.



If controller 2 is offline in the first set, controllers 1 and 3 still can add because they each have a phase code. But, if controller 2 in the second set with the shared phase is offline, controllers 1 and 3 cannot add.

We recommend that you consider the architecture and process requirements (that is, process segmentation) to make an informed decision for the task that is being performed.

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