



Batch Control Using the ANSI/ISA-88 Standard

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What is ISA/S88 ?

- An ISA (The International Society of Measurement and Control) standard S88.01 “Batch Control Models and Terminology”
- Also IEC 61512-01 standard
- SP88 is the committee charged with developing the S88 standards
- IEC 65A-WG11 is the IEC oversight committee





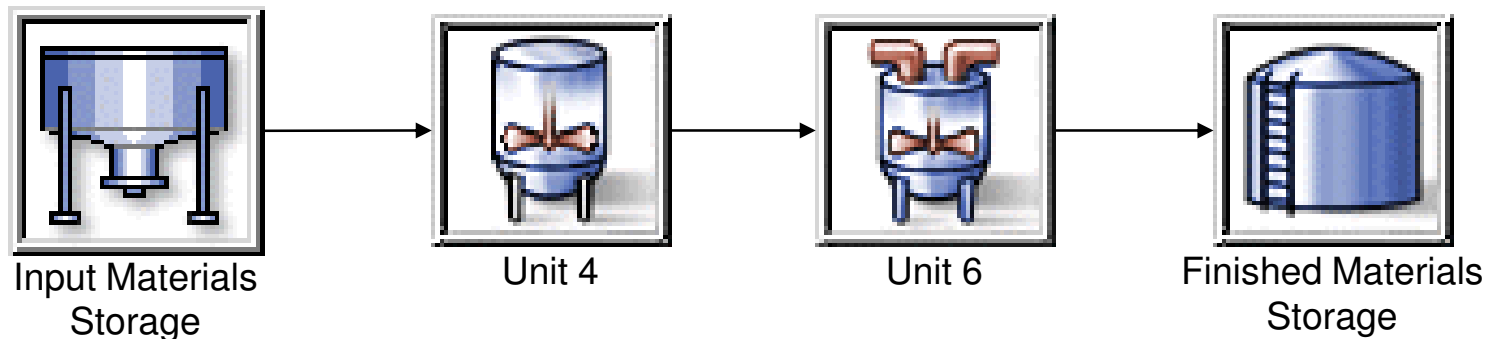
S88.01 Batch Control

- S88.01 is not about the BATCH Industries!
 - ▶ It applies in discrete, continuous, and batch industries
- S88.01 is a model and methodology for designing & operating control systems for flexible manufacturing
 - ▶ Independent of the underlying control system (PLC, DCS, or PC)
 - ▶ Independent of the underlying basic control algorithms



Where S88 Applies

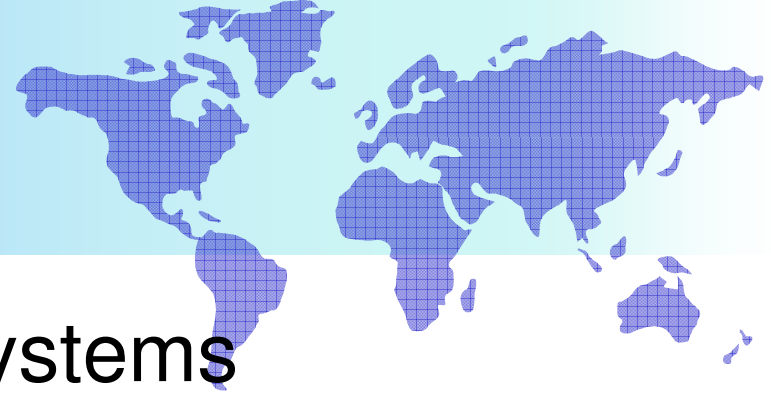
- Flexible manufacturing (including batch)
- Multiple products manufactured using the same set of equipment
- Output is a finite quantity of materials
- Built using a defined order of processing actions





What S88 Does Not Address

- Can be applied to, but does not specifically address:
 - ▶ Discrete parts manufacturing
 - ▶ Continuous processing
- But, the concepts and terms have been effectively used in these areas
 - ▶ Continuous
 - Startup - shutdown
 - Grade change
 - ▶ Discrete
 - Setup - Tear down
 - Product Change

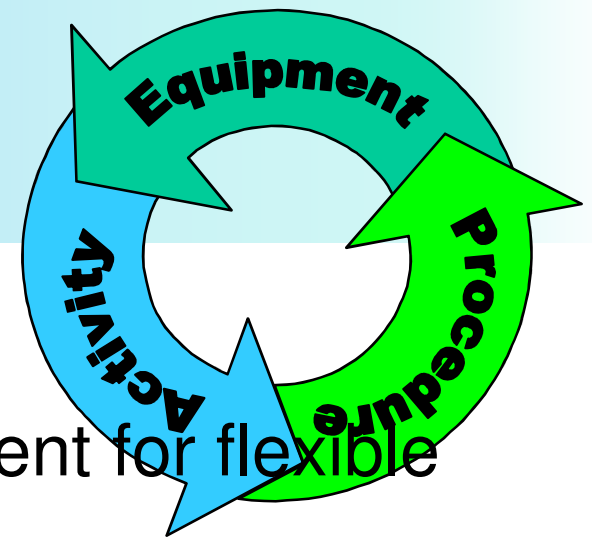


Benefits of S88.01

- Reduce cost of automating systems
- Reduced life cycle engineering effort
 - ▶ Reduced time to market
 - ▶ Improved flexibility
 - ▶ Improved process quality
- Rapid batch recipe development
- Applied today around the world, with proven and identifiable benefits



Three Models



- Equipment Model
 - ▶ How to effectively organize equipment for flexible manufacturing.
- Procedural & Process Model
 - ▶ How to effectively organize process and production rules for flexible manufacturing.
- Activity Model
 - ▶ How to effectively organize manual and automatic activities for flexible manufacturing.

Three Models

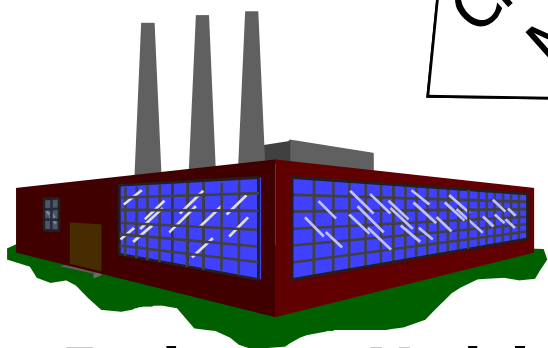
Activity Model

Defines all the activities involved in Batch Automation



Creates and Maintains

Creates and Maintains



Equipment Model

Defines the equipment capability available to manufacture a product

Executes against



Recipe Model

Defines the information required to manufacture a product



Part 1: Recipes and Equipment

- Key S88 Concept:
- Separate:
 - ▶ Product Knowledge - kept in Recipes -
 - ▶ from Equipment Capabilities
- S88.01 goal
 - ▶ Allow recipe development without the services of a control systems engineer
 - ▶ 'No control system programming' required
- Result
 - ▶ Same equipment - multiple products



Definition - Recipe

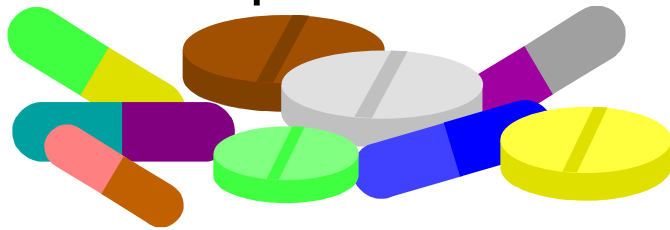
- Recipes
 - ▶ The necessary set of information that uniquely defines the production requirements of a specific product
 - ▶ The recipe tells the batch control system how to make the product
 - ▶ A recipe usually exists for each final product to be produced
 - ▶ Recipes may exist for different sets of raw materials that can be used to make the same product



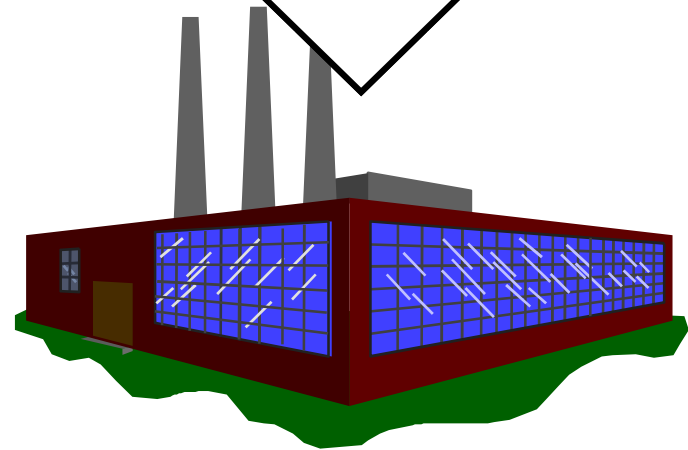
Recipes and Equipment

Recipe

Defines the information required to manufacture a product



Runs Against Equipment



Equipment

Defines the equipment capability available to manufacture a product

Provides Process Capabilities for



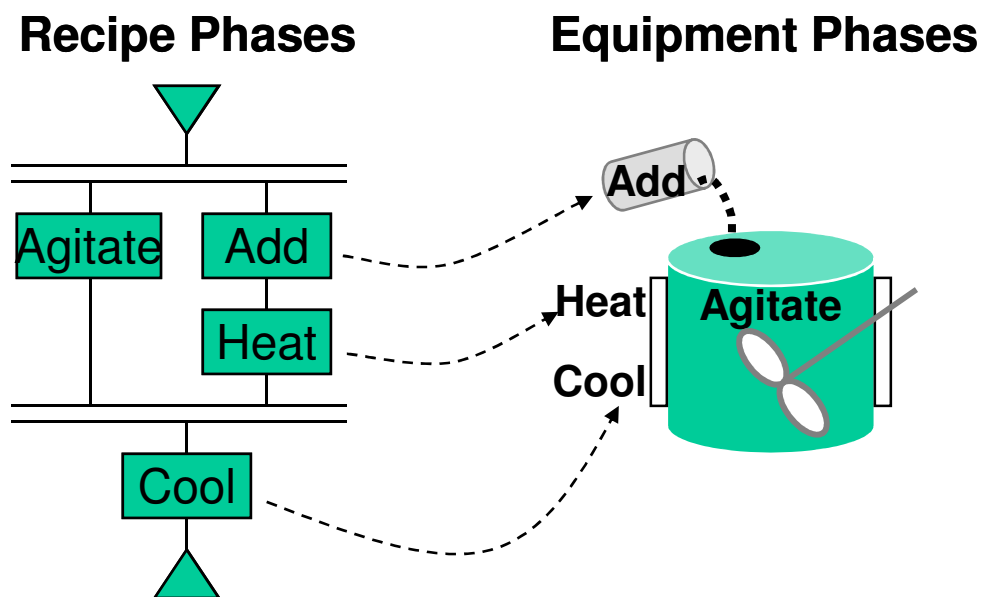
Recipe - Equipment Separation

- S88.01 explains the concept that separates the recipe, that describes how a batch is to be made, from the equipment that is actually used to make the batch
 - ▶ Improves the ability to transport a recipe from one system to another
 - ▶ Makes recipes more flexible and reusable
 - ▶ Simplifies recipe validation
 - ▶ Makes equipment control more flexible and reusable
 - ▶ Lower first cost
 - ▶ Improved long-term maintainability



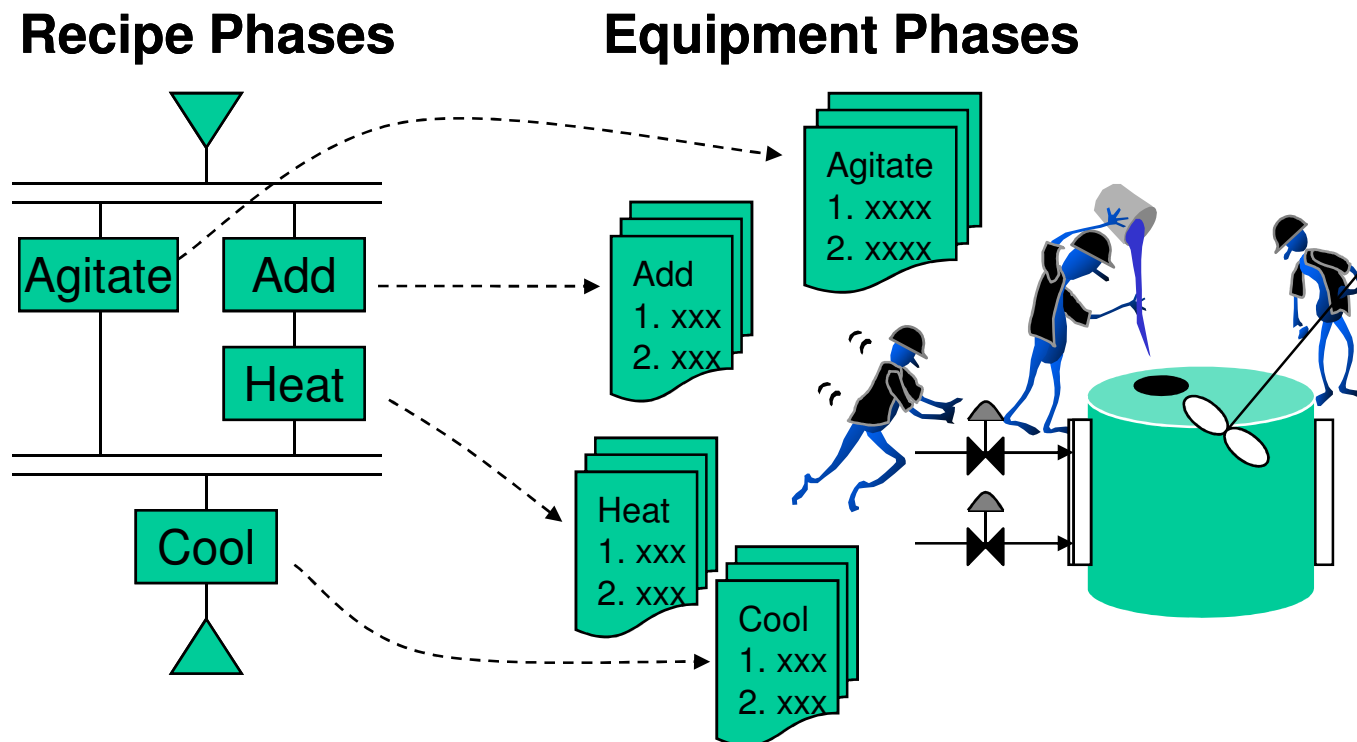
Recipe vs Equipment

- Recipes reference basic equipment capabilities
 - ▶ Independent of how the capabilities are actually implemented



“Equipment” Includes Manual and Automated Phases

- Recipes are independent of how the capabilities are actually implemented
 - ▶ Automated in PC, PLC, DCS, ...
 - ▶ Manual documented in SOPs





Part 2: Equipment Model

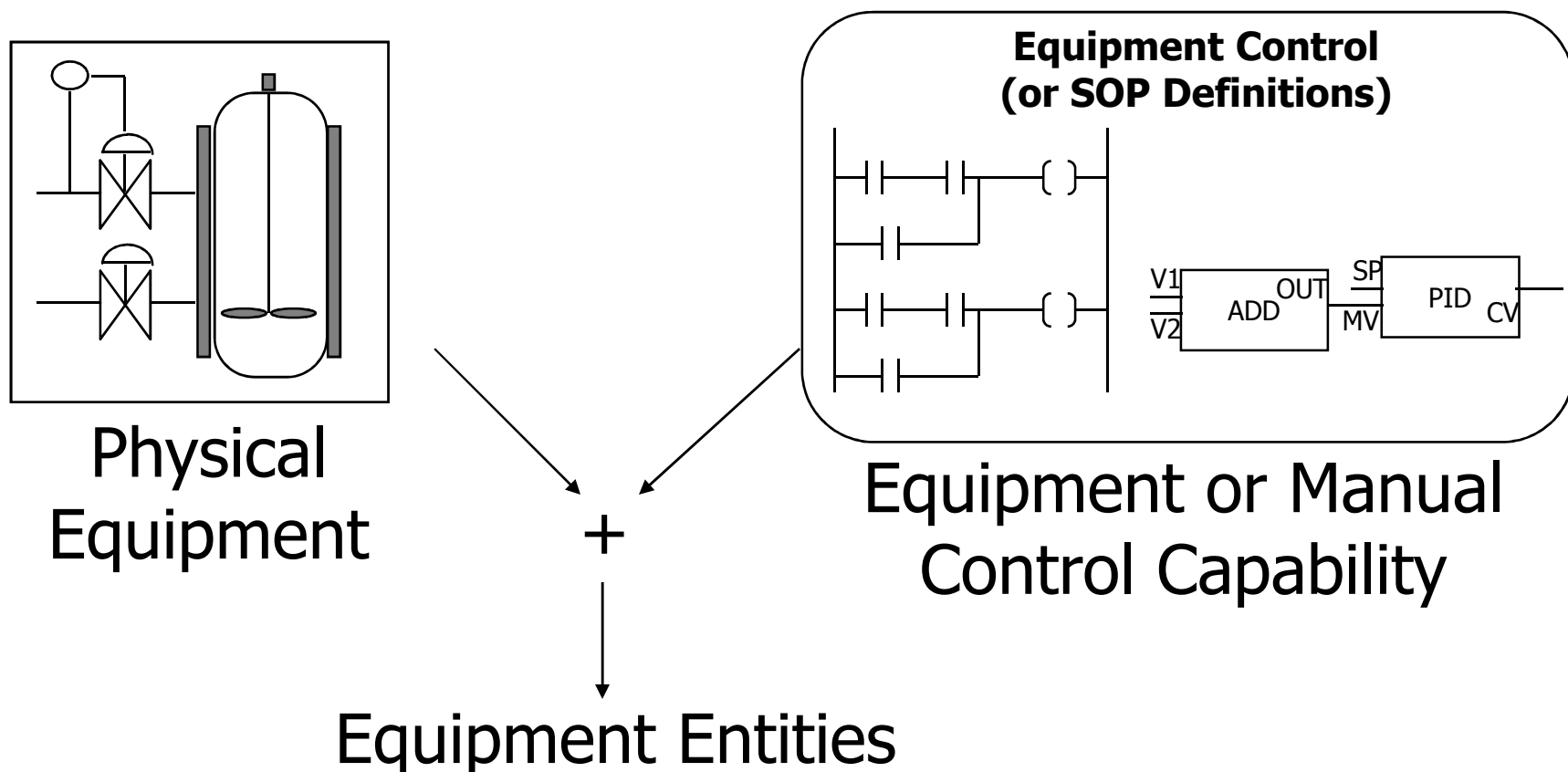
- Equipment entities
- Process Cells
- Units
- Equipment Phases





Equipment Model

- An object approach to organizing equipment
- Designed to support the required level of flexibility

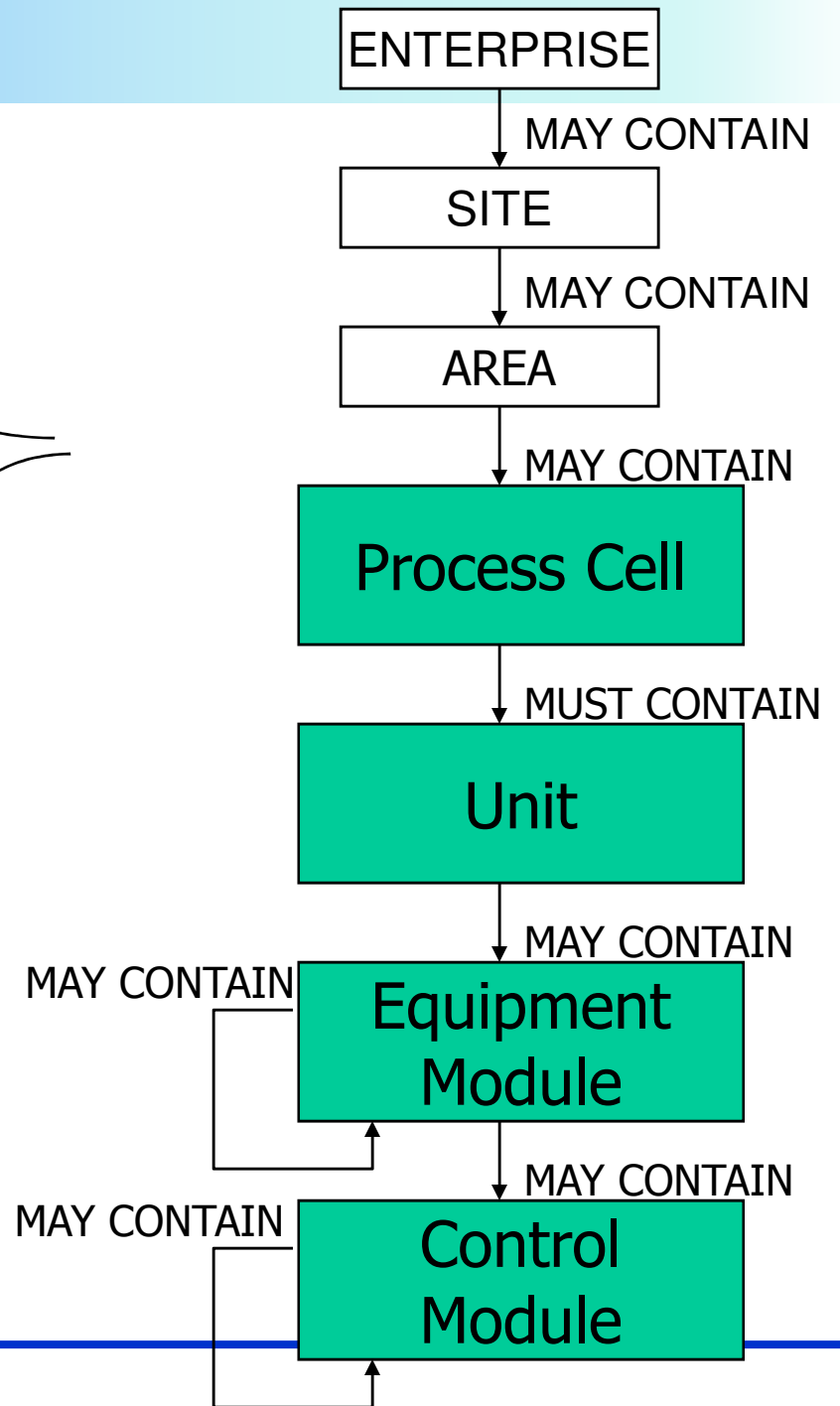




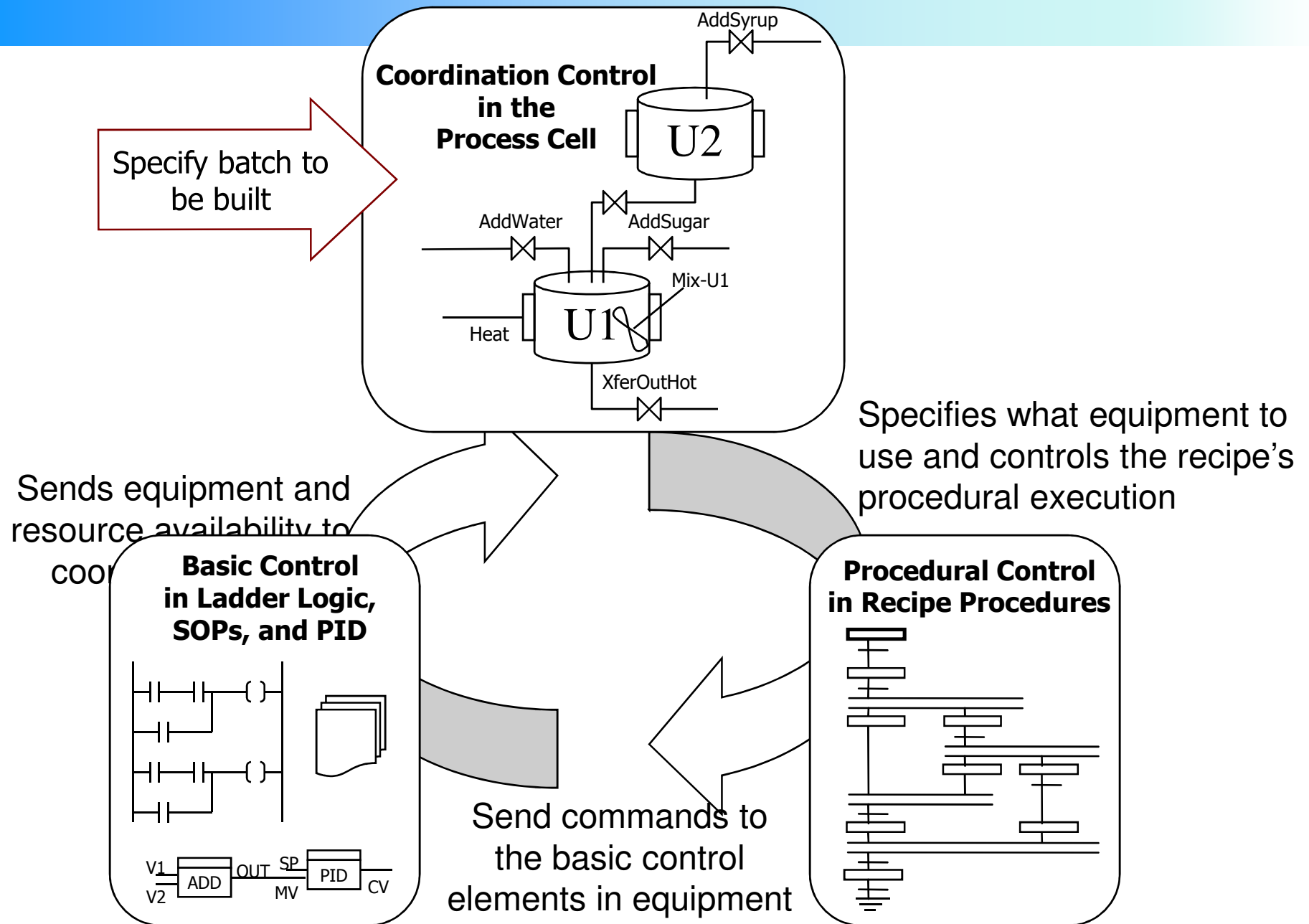
Physical Model

Only discussed to
place the Process Cell
in context within a
manufacturing enterprise

ISA 88.01 Model



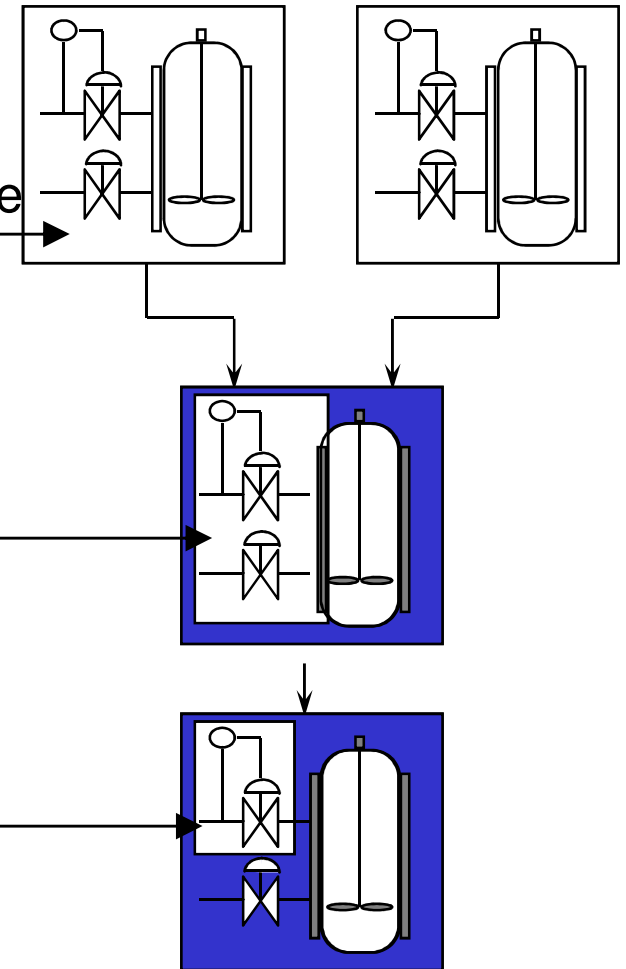
A Control View





Equipment Entities

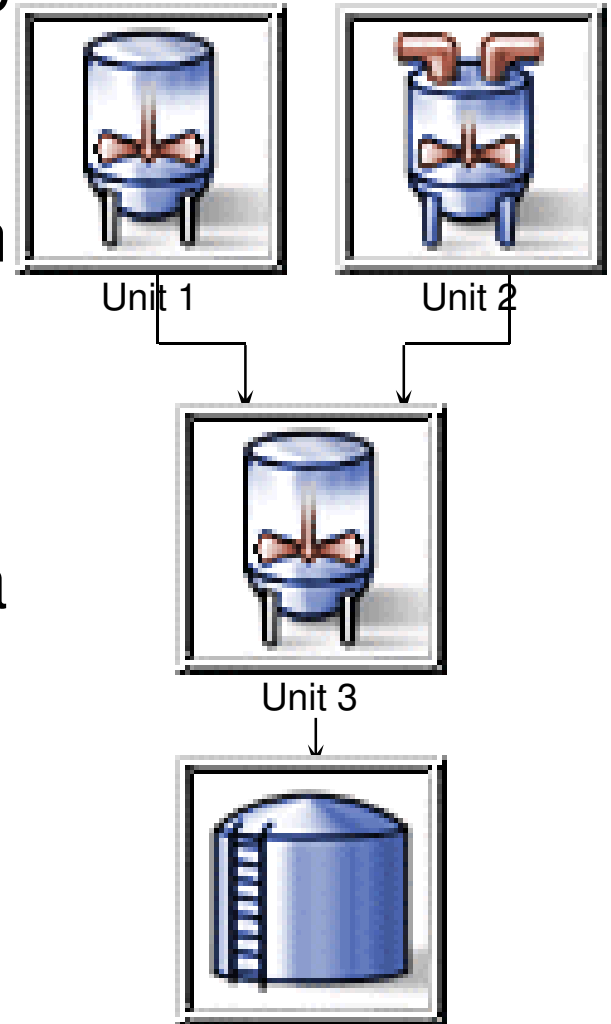
- Process cell
 - ▶ A logical grouping of equipment required for production of one or more batches
- Units
 - ▶ A collection of related control modules and equipment modules that can carry out one or more processing activities
- Equipment modules
 - ▶ A functional group of equipment and/or control modules that can carry out a finite number of specific processing activities
- Control modules
 - ▶ A regulating device, a state oriented device, or a combination of both that is operated as a single device





Process Cell

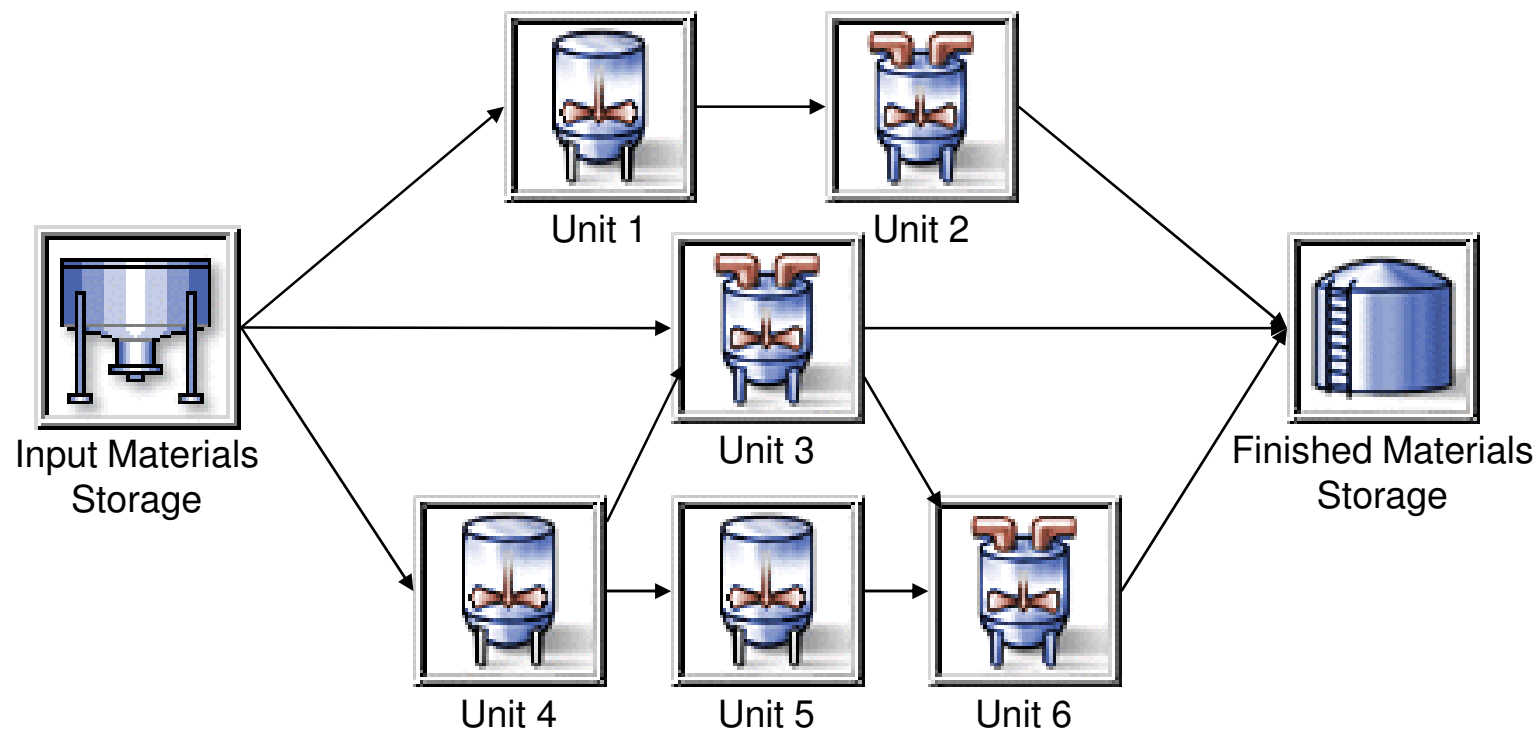
- A logical grouping of equipment required for production of one or more batches
- May contain more than one grouping of equipment needed to make a batch
- The equipment actually used to complete a batch is referred to as the *path* or *stream*
- May contain more than one batch at a time





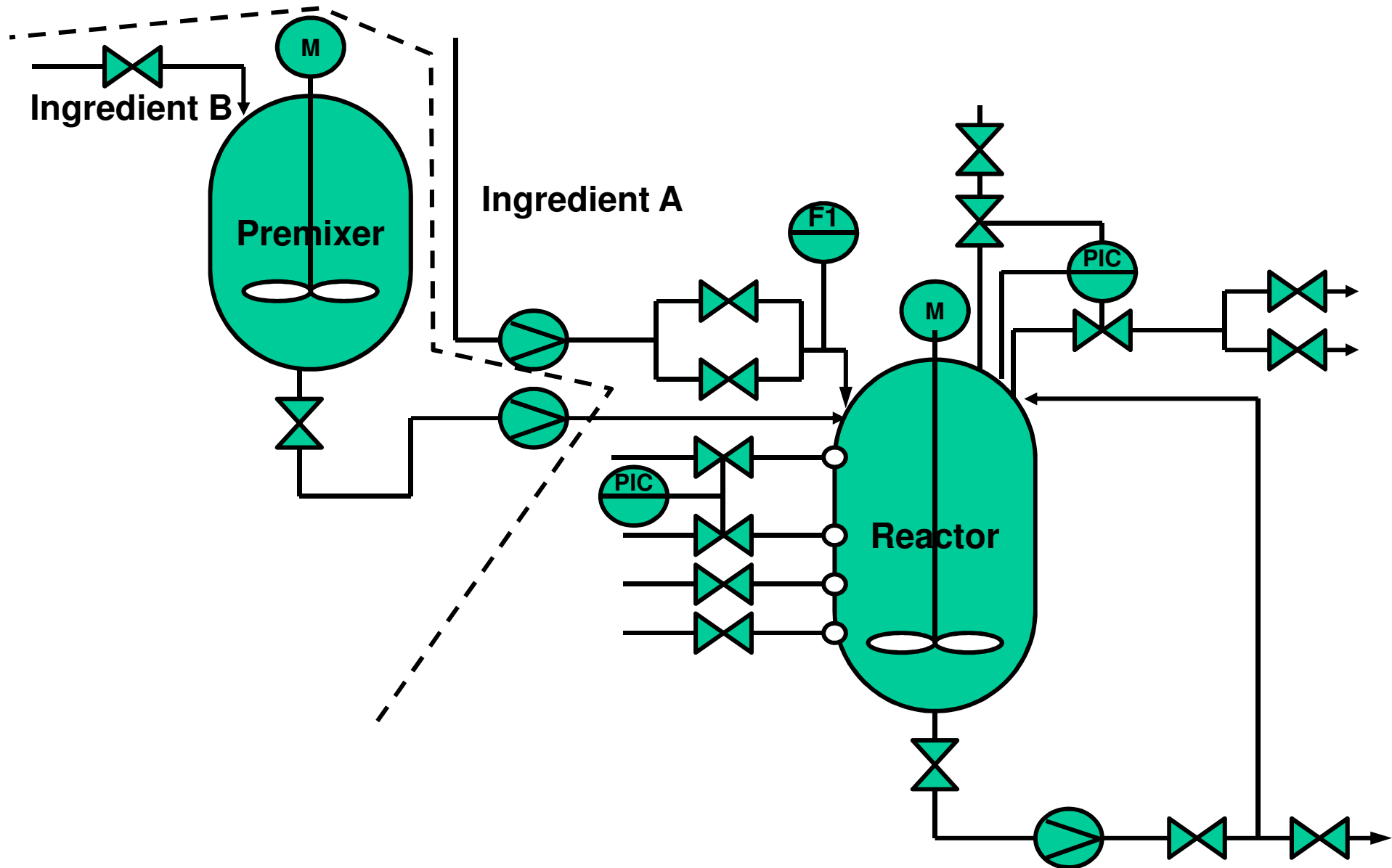
Process Cell Scope

- Defined where the batch maintains its identity
- Or, defined for the scope of a recipe
- Or, defined for a scope of operator control





Example of a 2-Unit Process Cell





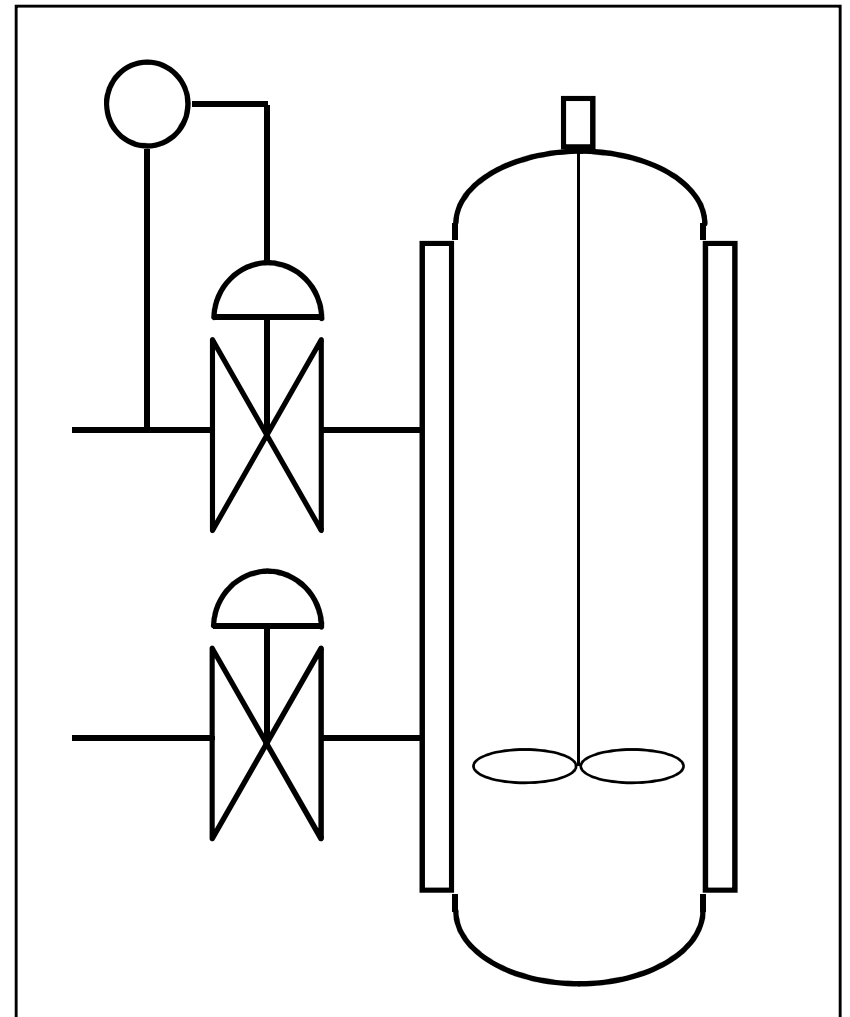
Units

- Usually centered on a major piece of process equipment
- Frequently operates on, or contains the complete batch
- Cannot operate on, or contain more than one batch at a time
 - ▶ One batch per unit
- May operate on, or contain, only part of the complete batch
 - ▶ Multiple units per batch are possible
 - ▶ Multiple units during transfers



Unit

- A collection of related control modules and equipment modules that can carry out one or more processing activities
- Operates on only one batch at a time



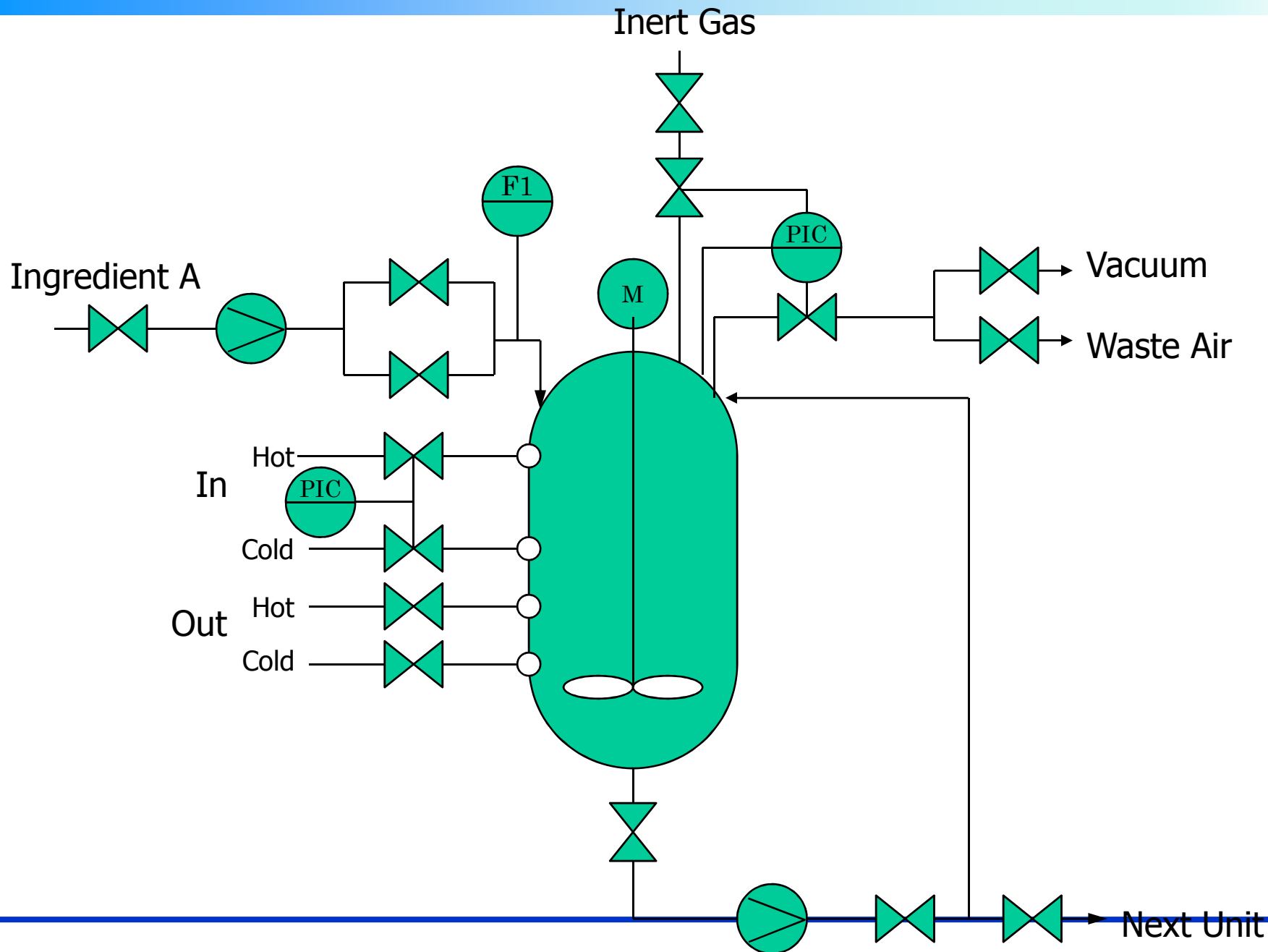


Units

- The primary object for automatic control
- There will often be multiple units involved in making a batch
- A unit is made up of equipment modules and control modules
- Provides a direct relationship to unit procedures and associated operations

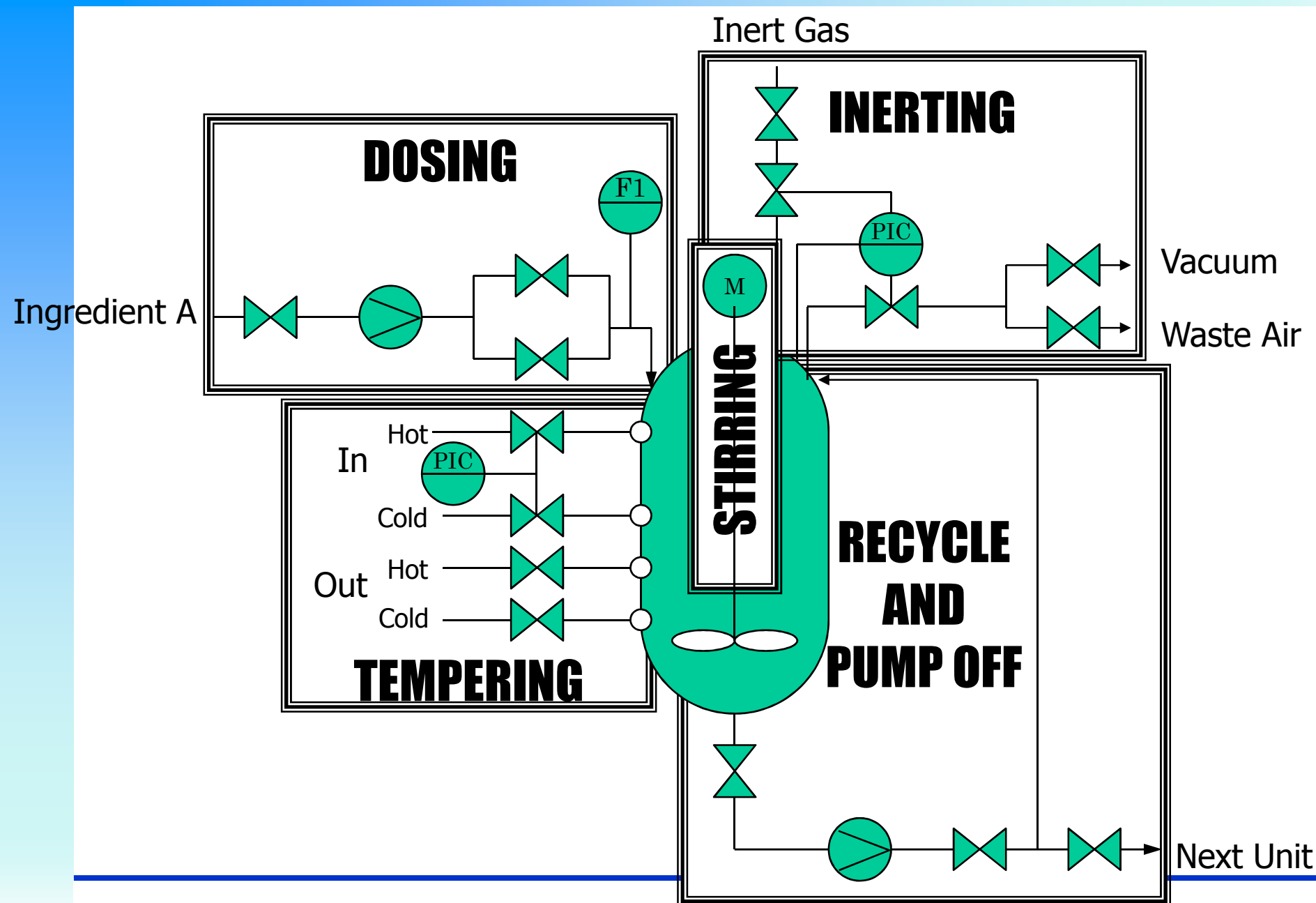


Example of a Unit



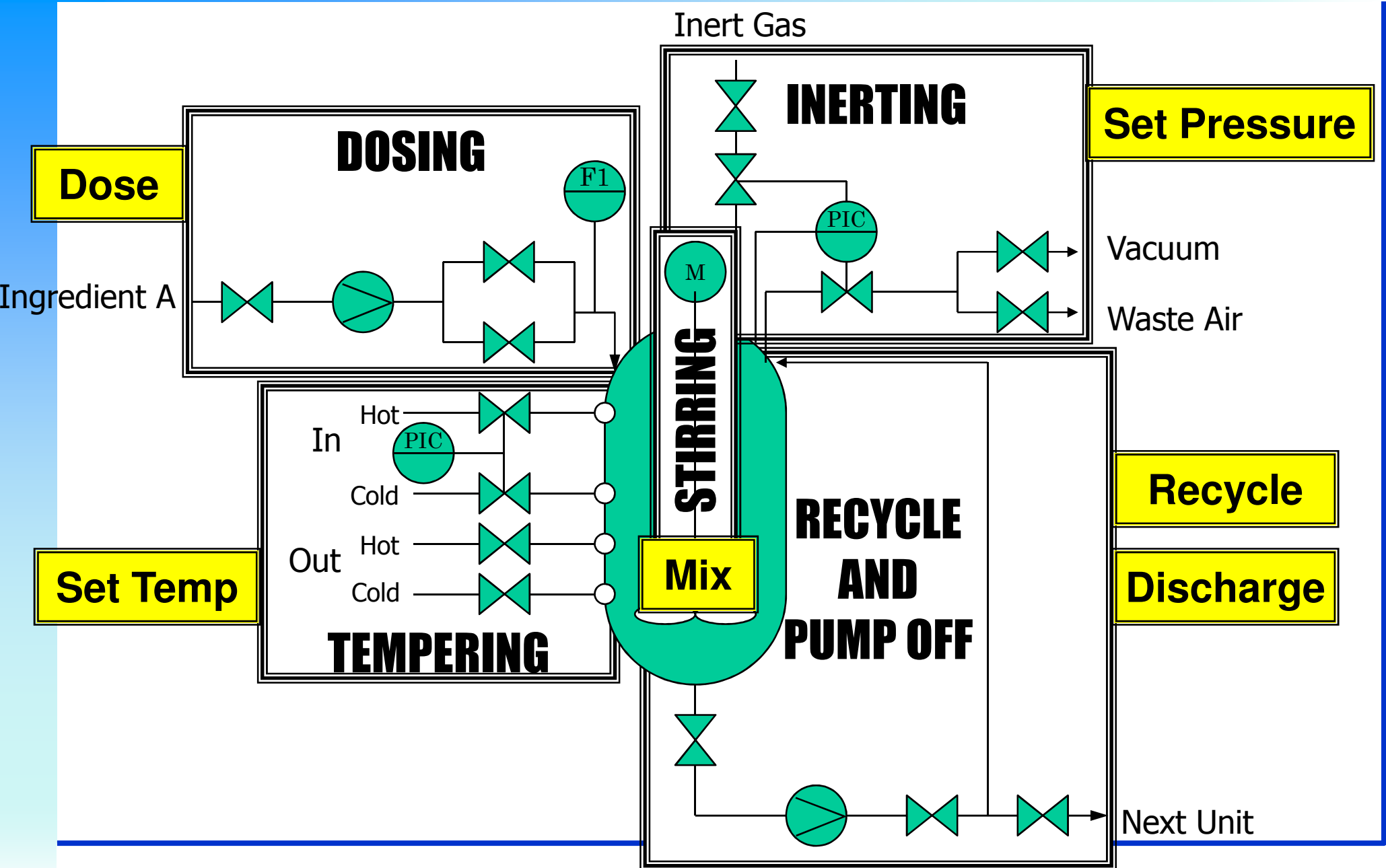


Equipment Modules





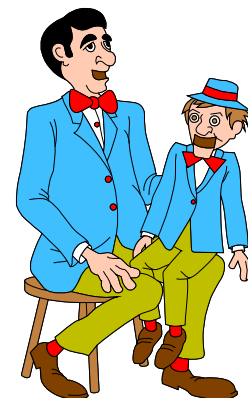
Equipment Modules – Equipment Phases





Equipment Phases

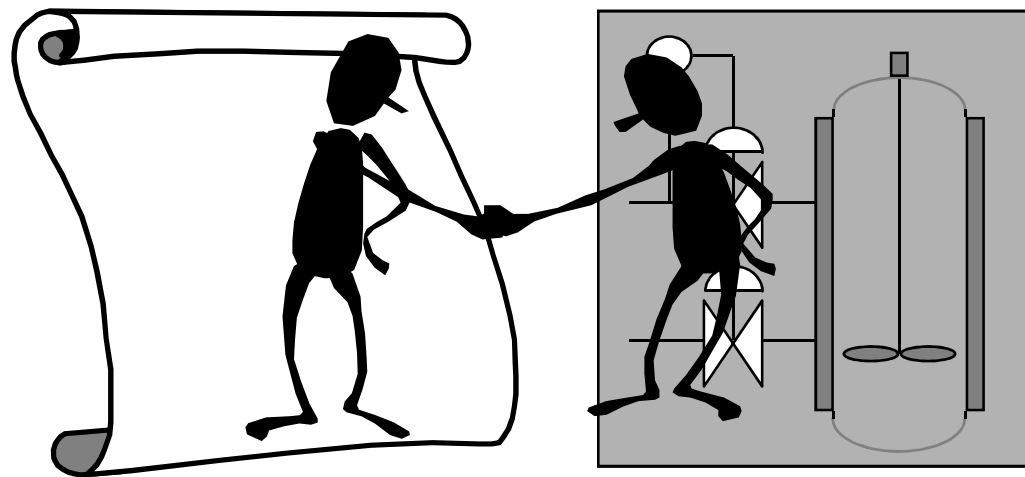
- Equipment phases are the link between the recipes and the equipment
- Equipment phases are the actions that the equipment can perform for a recipe
 - ▶ Charging materials, transferring materials, heating, cooling, agitating, blending, separating, ...





Equipment Phase - Recipe Phase

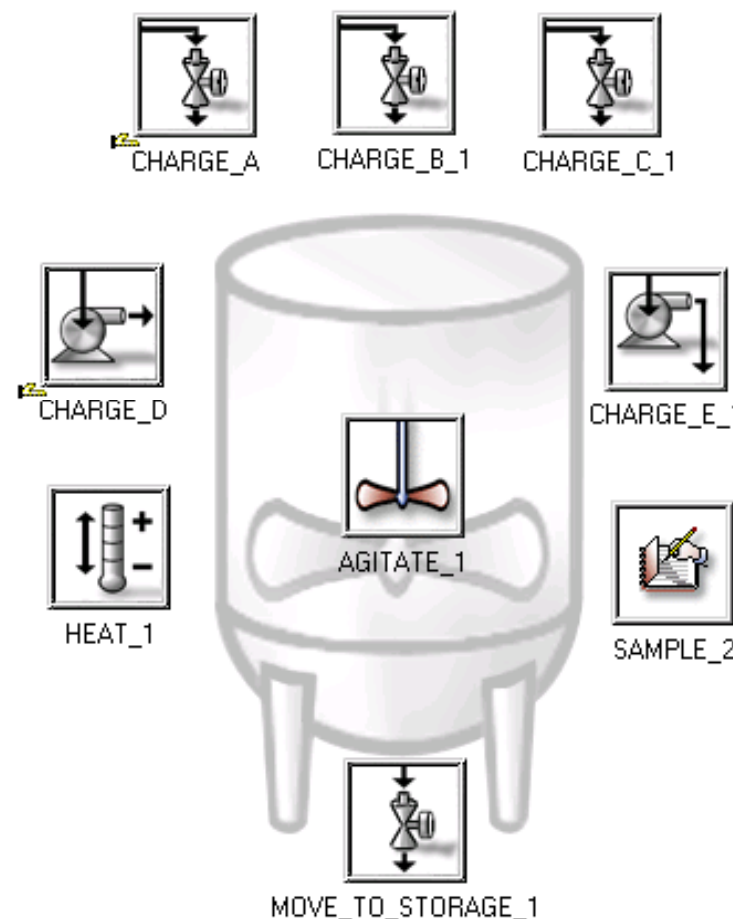
- Recipe phases command equipment phases
- Equipment phases are where the work is actually done
- Anything a recipe 'does', it does through an equipment phase





Equipment Phases

- The equipment phases of a unit (or equipment module) define the basic processing capabilities of the unit, that are available to recipes
- The details of how the equipment phases are programmed is hidden from the recipe
- Equipment phases are (generally) product independent





Section 3: Recipes

- General
- Site
- Master/Control Procedure
- Unit Procedure
- Procedure Logic

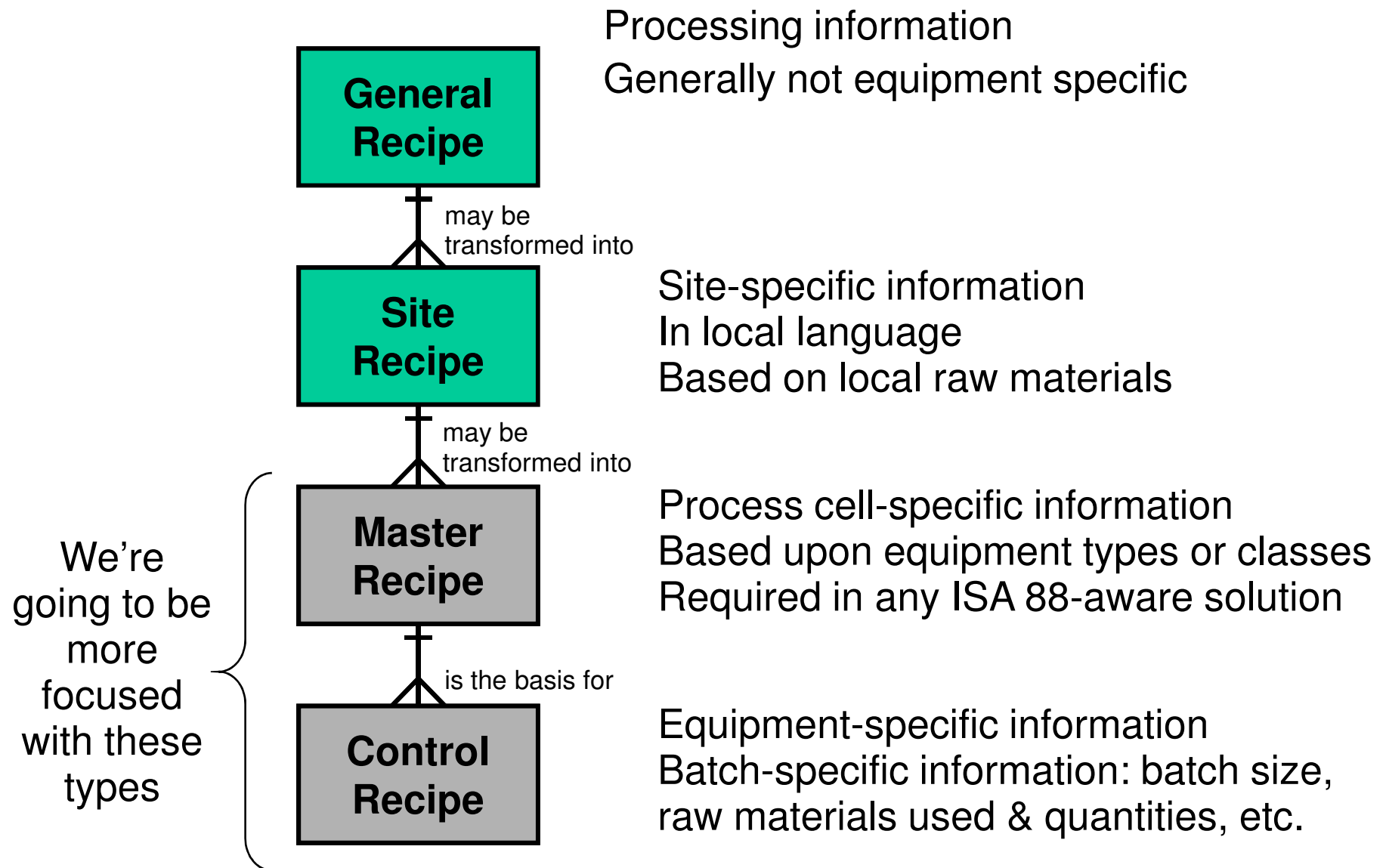




Recipe Types

- General Recipe
 - ▶ Recipe with equipment independent processing descriptions
- Site Recipe
 - ▶ Recipe with site specific modifications from the general recipe
- Master Recipe
 - ▶ Recipe with process cell specific information
- Control Recipe
 - ▶ Recipe with batch specific information.

Recipe Types





A Recipe Explosion

**General
Recipe**

**Bright White
Toothpaste**

**Site
Recipe**

Madrid

Chicago

**Master
Recipe**

Line A

Line 1

Line 2

**Control
Recipe**

Lot Mxxx

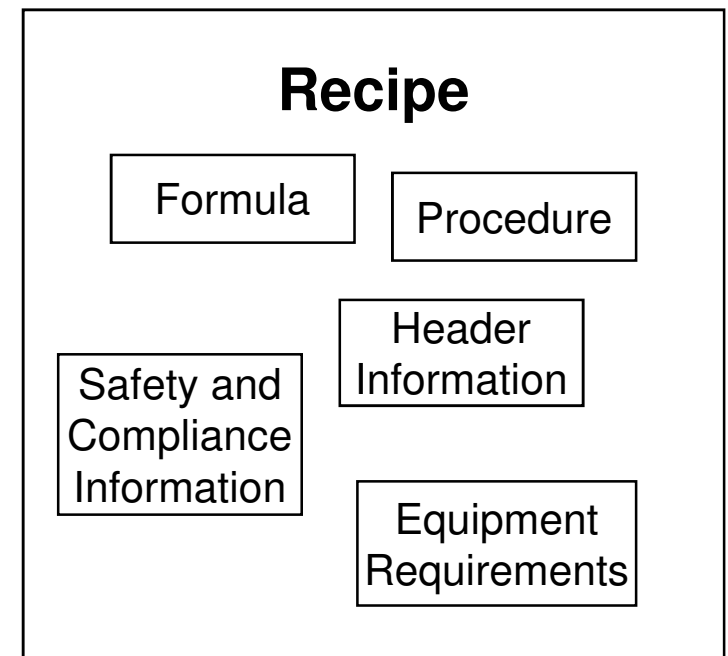
Lot C1xxx

Lot C2xxx



ISA 88 Recipes Recipe Composition

- Formula:
 - ▶ Process inputs
 - ▶ Process outputs
 - ▶ Process parameters
- Procedure
 - ▶ Control definition
- Equipment needs
- Header information
 - ▶ Identification, version control
- Safety & compliance information



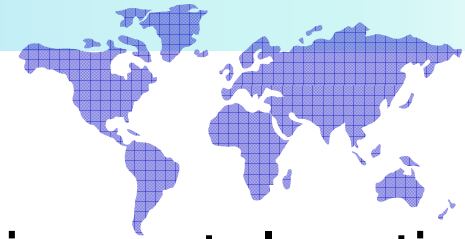


Header Information

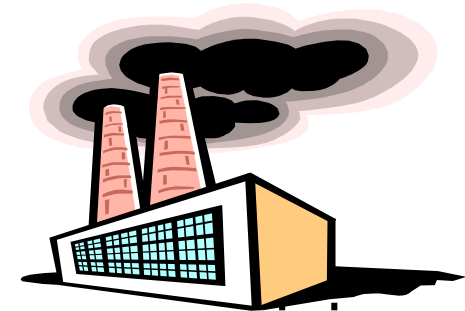
- Administrative information
 - ▶ Recipe identification and product identification
 - ▶ Originator
 - ▶ Issue date
 - ▶ Approval status
- Process summary



General and Site Recipes



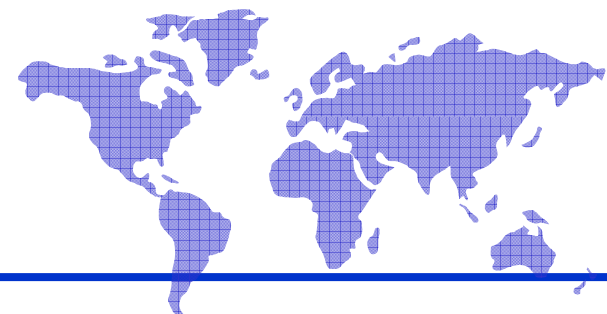
- General recipe
 - ▶ A type of recipe that expresses equipment, location, and site independent processing requirements
 - ▶ Separates product knowledge from specific equipment knowledge
- Site recipe
 - ▶ A type of recipe that is site specific
 - ▶ May be derived from *general recipes* recognizing local constraints, such as local languages, available raw materials, and site processing capabilities
 - ▶ Separates product knowledge from specific equipment knowledge





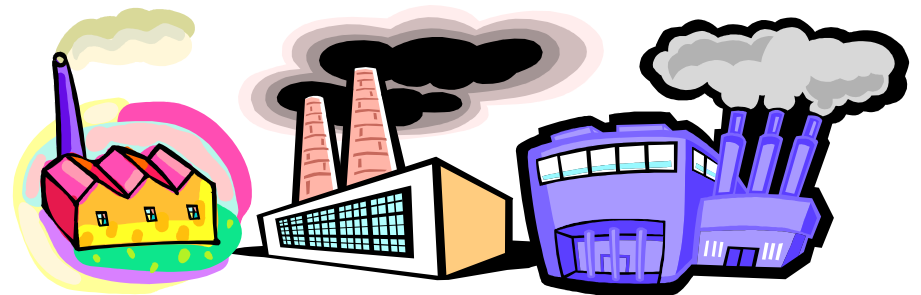
Why General Recipes ?

- Centralized control and global distribution of product information
 - ▶ Is the way to unambiguously communicate processing requirements to multiple manufacturing locations
- When you must make the same product in different sites, regions, and countries
 - ▶ Manufactured where ever is most economical



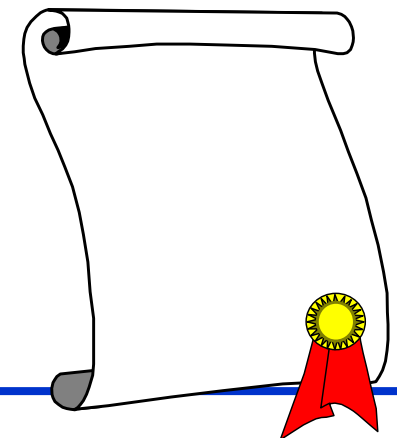
Why Site Recipes ?

- Site control of product information
- Process cell independent product formulation
- For heterogeneous sites; different control equipment, processing equipment, processing capabilities
 - ▶ Yet all must make the same product
 - ▶ Separates product knowledge from process cell details



Master Recipe

- A type of recipe that accounts for equipment capabilities and may include process cell specific information
- Is the “template” for executed control recipes
- A “required” recipe type in the ISA 88 model
- Master recipes may be derived from site recipes



Control Recipe

- A type of recipe, which through its execution, defines the manufacture of a single batch of product
 - ▶ One control recipe per batch
- A “required” recipe type in the ISA 88 model
- Derived from a master recipe



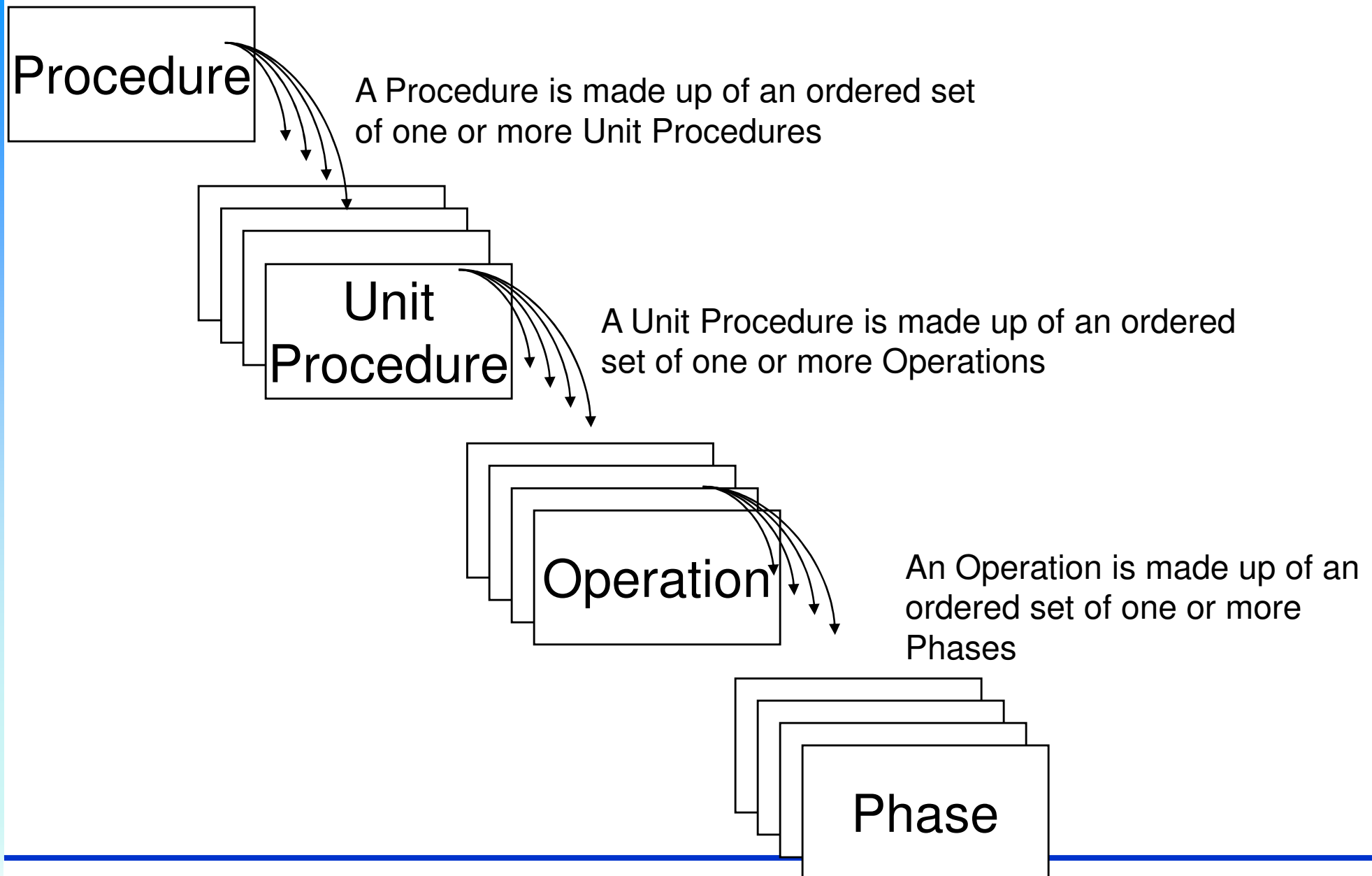


Master/Control Recipe Procedure

- Derived from a general or site recipe
- Based on the procedural model
- Creation of Master Recipe from a Site Recipe may be quite complex!
- Contains process cell specific information and equipment specific information



Master/Control Recipe Procedure





Procedure

- The highest level in the master/control procedure hierarchy
- Defines the detailed strategy for carrying out the processing actions required to make a batch
- Defined in terms of an ordered set of unit procedures
- Example: “make product phenalfree”



Unit Procedure

- Consists of an ordered set of operations that cause a continuous production sequence to take place within a unit
- One unit procedure is presumed to be active in a unit at any time
- A unit procedure is carried to completion in a single unit



Unit Procedure

- Multiple unit procedures or one procedure may run concurrently, each in different units
- Examples of unit procedures are:
 - ▶ Esterify
 - ▶ Strip
 - ▶ Neutralize
 - ▶ Filter



Operation

- An ordered set of phases that defines a major processing sequence
- Takes the material being processed from one state to another
- Usually involved a chemical or physical change to the material
- Operation boundaries are often at points where normal processing can be safely suspended



Operation

- Only one operation is presumed to be active in a unit at any time
- An operation is carried to completion in a single unit
- Examples for the *Esterify* unit procedure are:
 - ▶ Initialize
 - ▶ Charge
 - ▶ React
 - ▶ Transfer



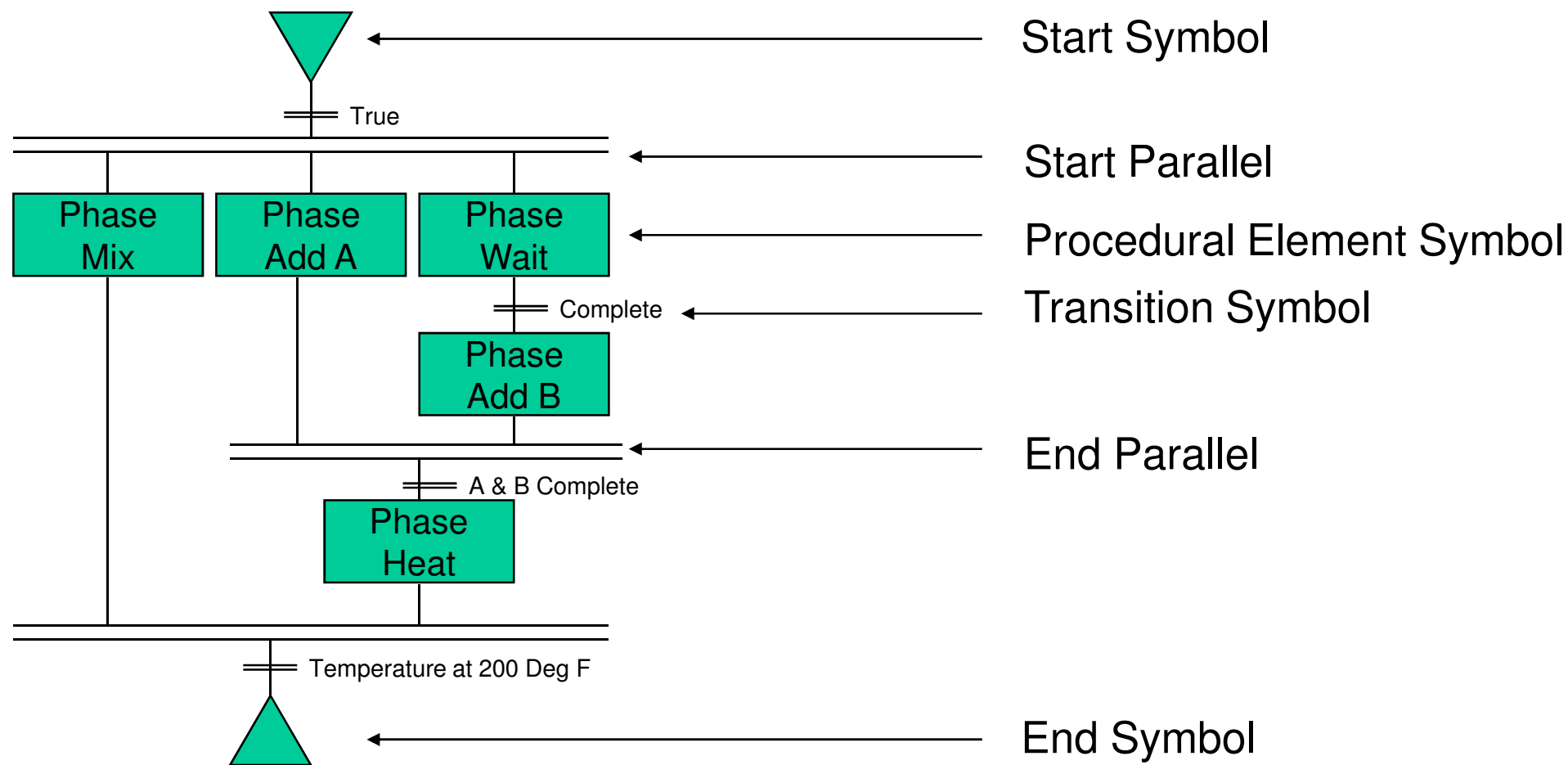
Phase

- The smallest element of procedural control that can accomplish a process-oriented task
- The logic or set of steps that make up a phase is equipment specific, and not part of the recipe
- Phases for the charge operation are:
 - ▶ Initialize
 - ▶ Add material A at 20L/min
 - ▶ Add material B at 20L/min
 - ▶ Mix for 20 minutes
- **USUALLY THE LINK TO EQUIPMENT**
 - ▶ Commands the equipment





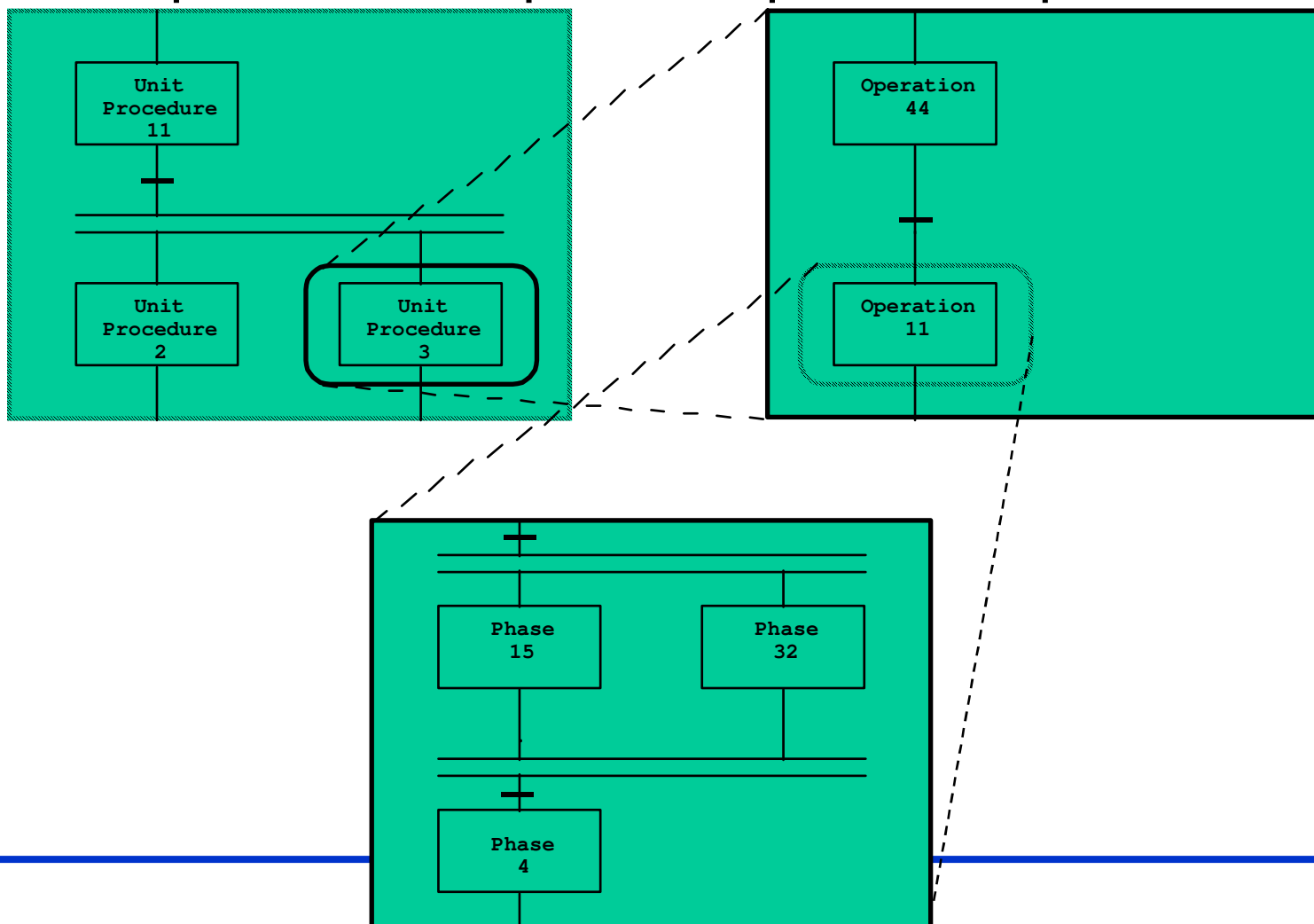
ISA 88 Part 2 - Recipe Representation





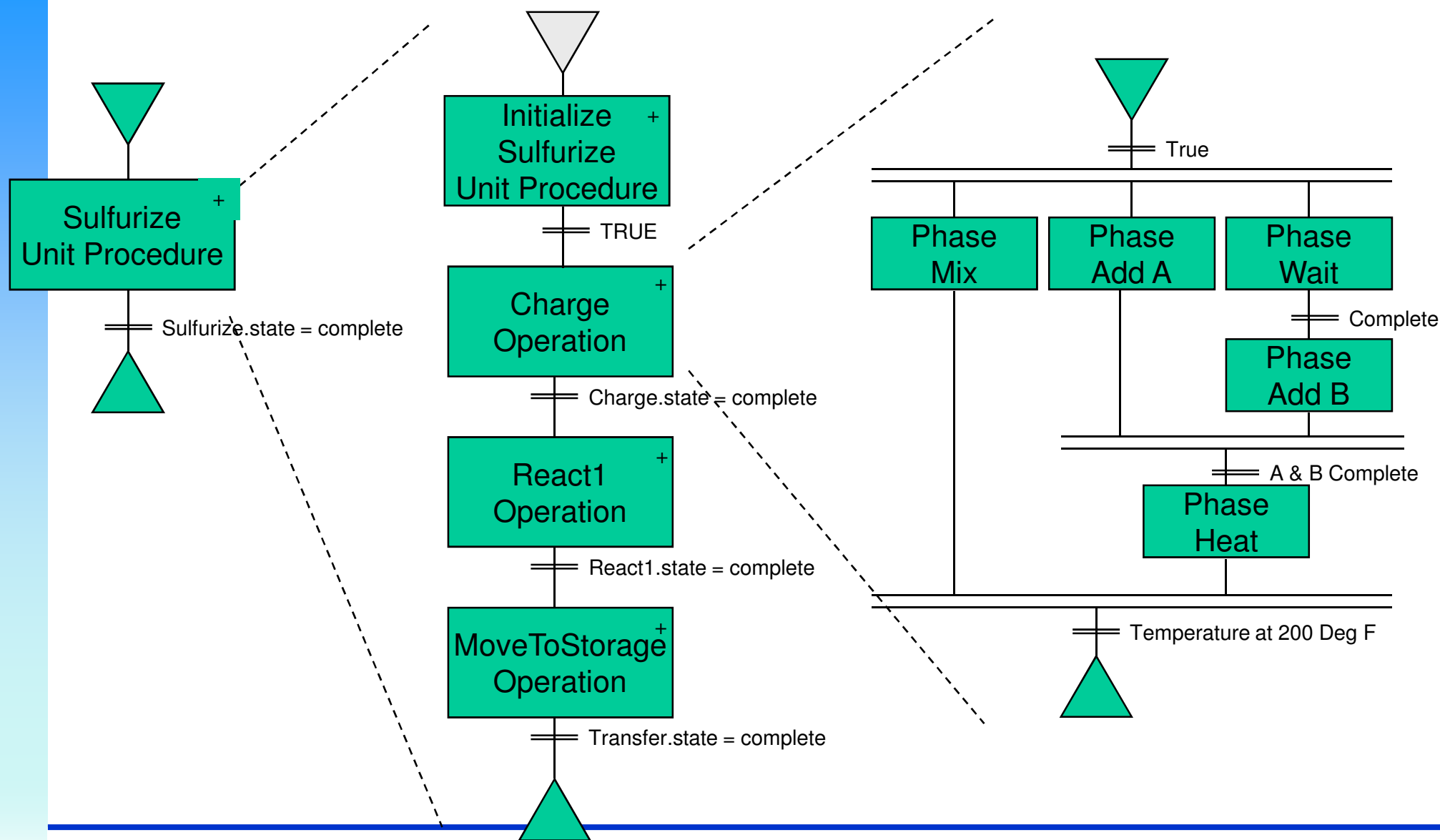
Procedural Element Relationship

- Three levels defined, for three reasons
 - ▶ Batch to unit associations, operations of products, manipulations required to perform operations



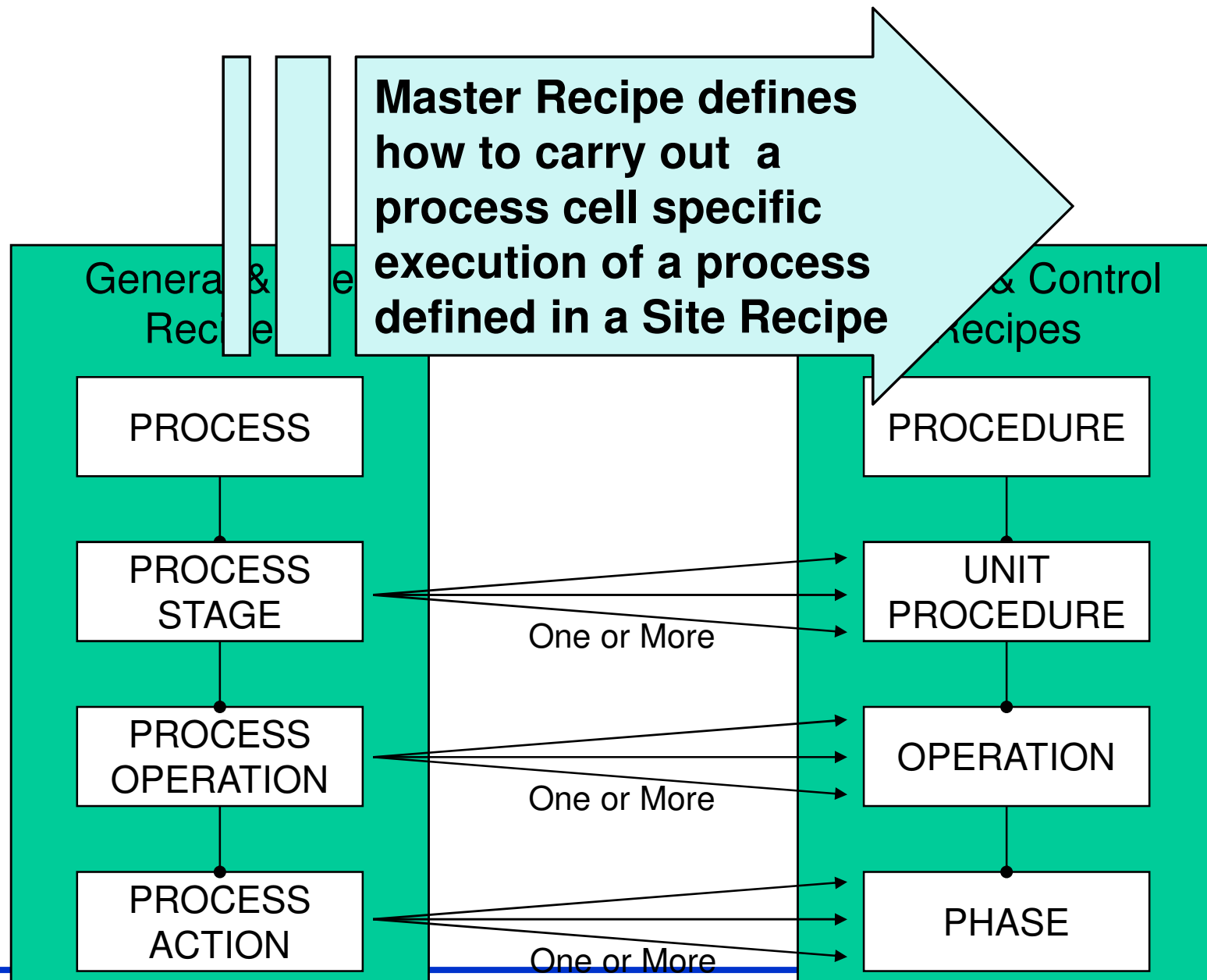


Sample Recipe – S88 Part 2 Standard





Batch Manufacturing Methodology



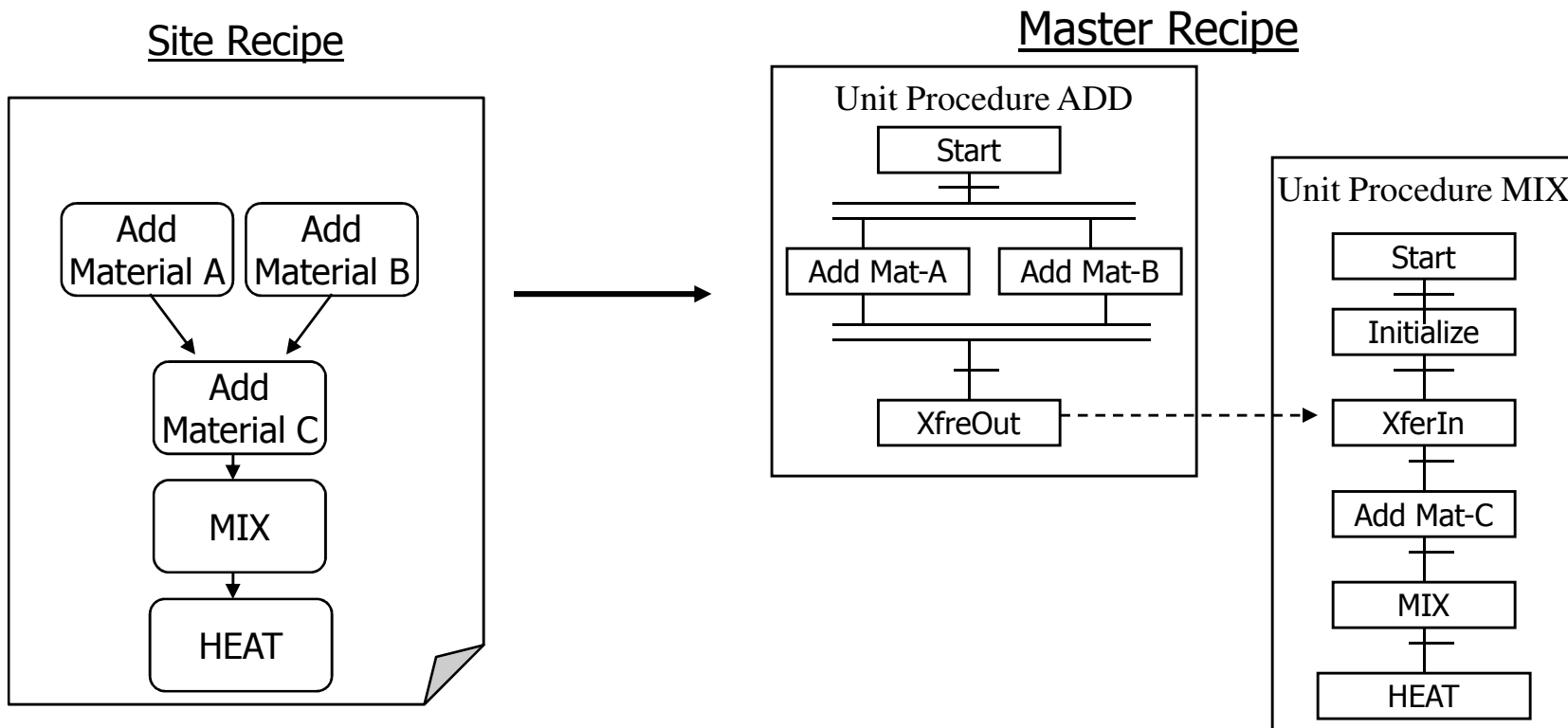


Why a Major Transformation?

- General and site recipes only describe processing technology
- General and site recipes do not reference any target equipment in the plant
 - ▶ But they may specify requirements on the equipment
- General and site recipes do not have to deal with initial conditions and startup checks
 - ▶ Unless they are vital to the product definition
- General and site recipes do not have to deal with material transfers between units

Why a Major Transformation?

- Material may have to be transferred between units
- One action may map to several phases
- Initial and exceptions phases may have to be added



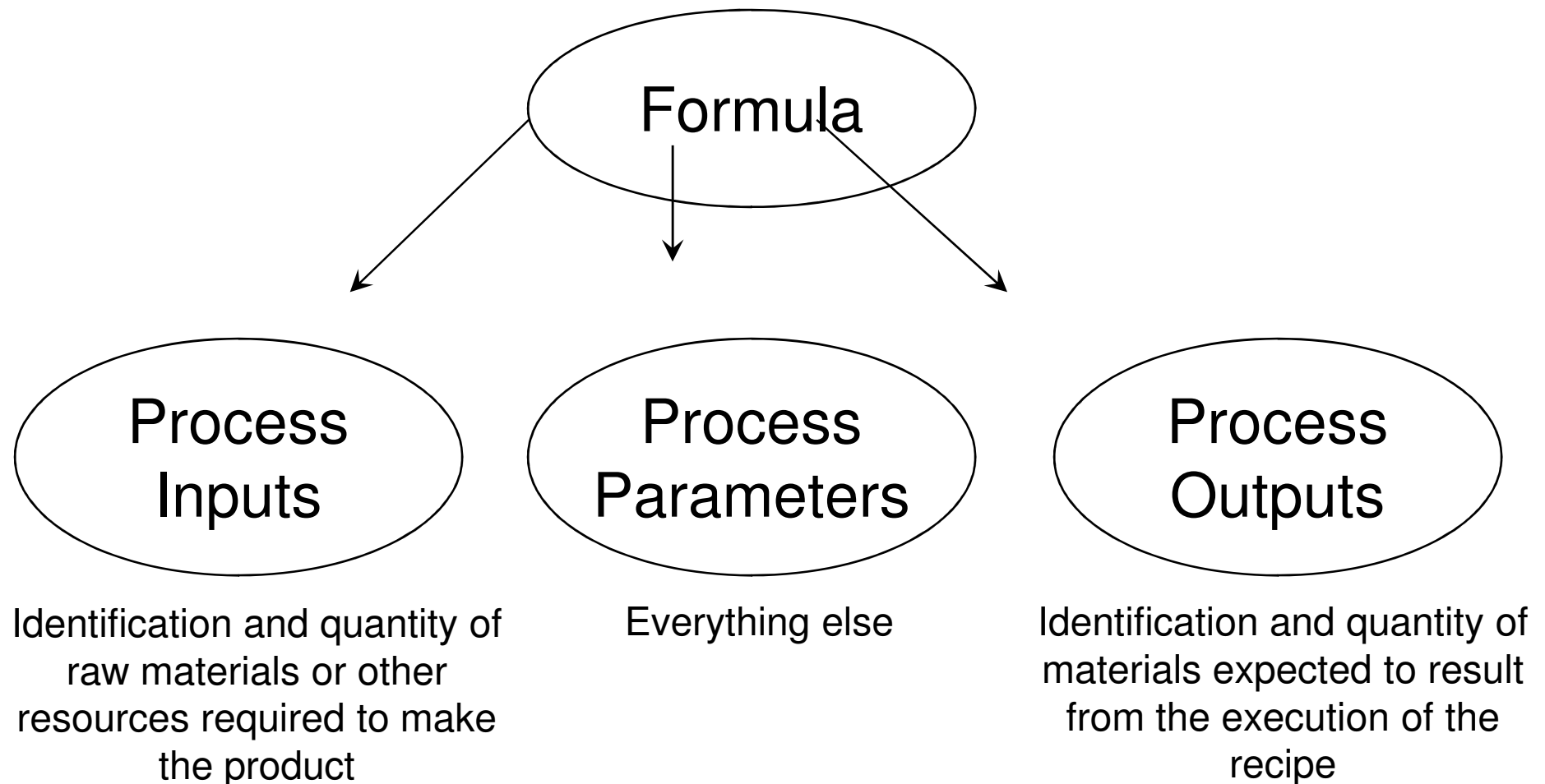


Formula

- The information of a recipe used by the procedure
- The formula is used to distinguish the products defined by procedures
- The formula concept simplifies generating different products using an established and proven procedure
 - ▶ The term 'grade' is often used to describe the recipes using the same procedure logic, but with different formula values



Formula Information





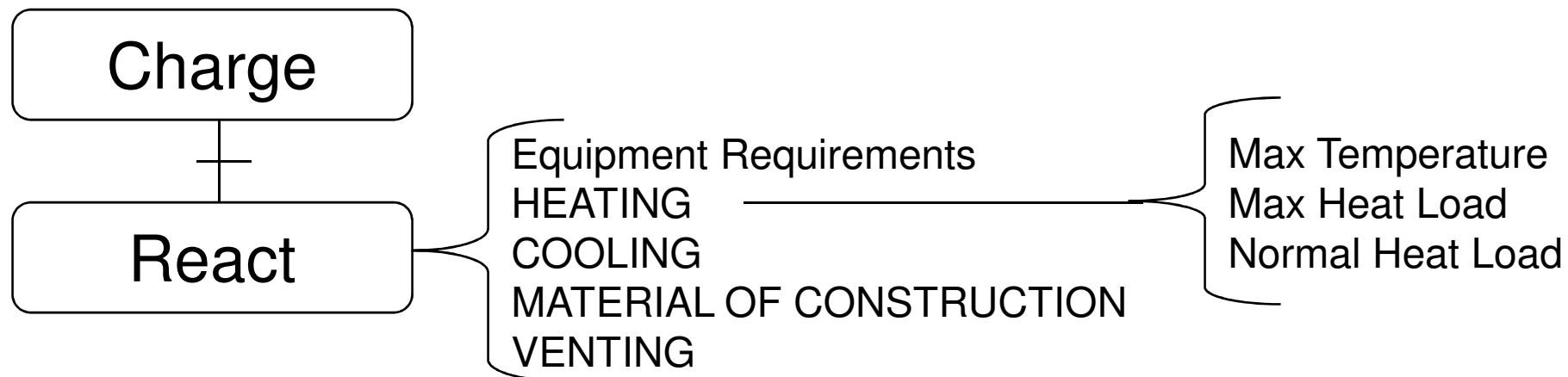
Equipment Requirements

- Define the attributes of the equipment needed, such as:
 - ▶ Type of equipment needed
 - ▶ Materials of construction
 - ▶ Equipment (tag) name
- Specific information may vary depending on the recipe level
 - ▶ Master and control may be very specific, identify the specific equipment or class
 - ▶ General and site may just identify equipment characteristics



Equipment Requirements

- Master recipe
 - ▶ Reactor class 1
 - ▶ Stripper class 2
 - ▶ R-502 reactor
 - ▶ S-503 stripper
- General recipe





Other Information

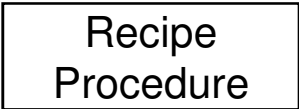
- Recipe dependent safety comments (Not MSDS)
- Recipe dependent compliance comments
- Data collection requirements
- Reporting requirements



Control Separation

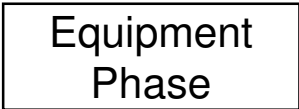
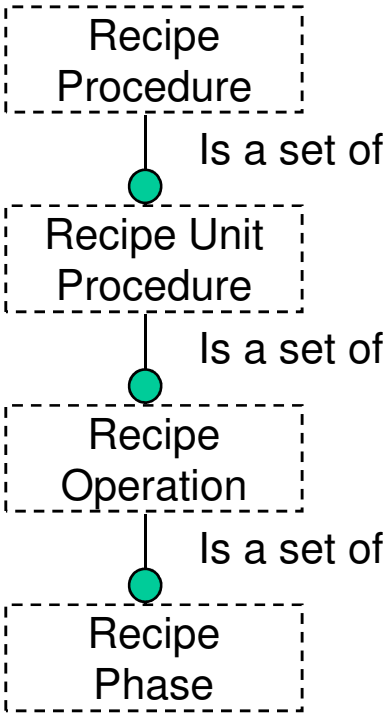
- ISA 88 model describes alternate places to put the recipe logic, depending on needed flexibility

Control Recipe Procedure



[Must always exist]

Equipment Control



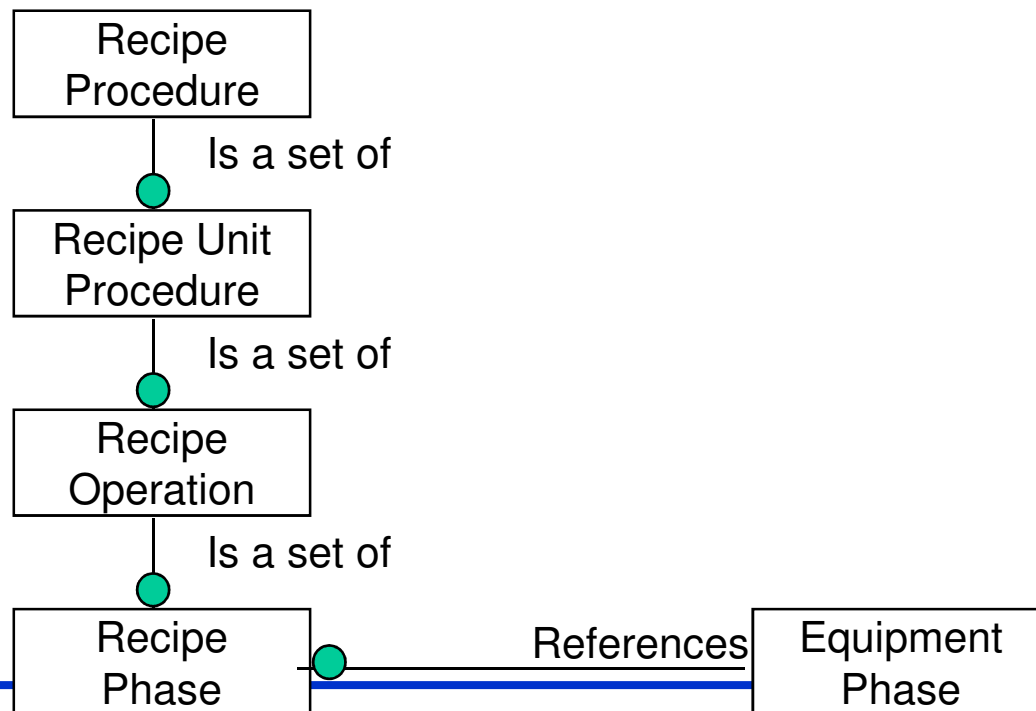


Procedure Logic in the Recipe

- Typical use
 - ▶ Recipe procedure logic in the recipe
 - ▶ Equipment phase logic in equipment
 - ▶ Maximum flexibility

Control Recipe Procedure

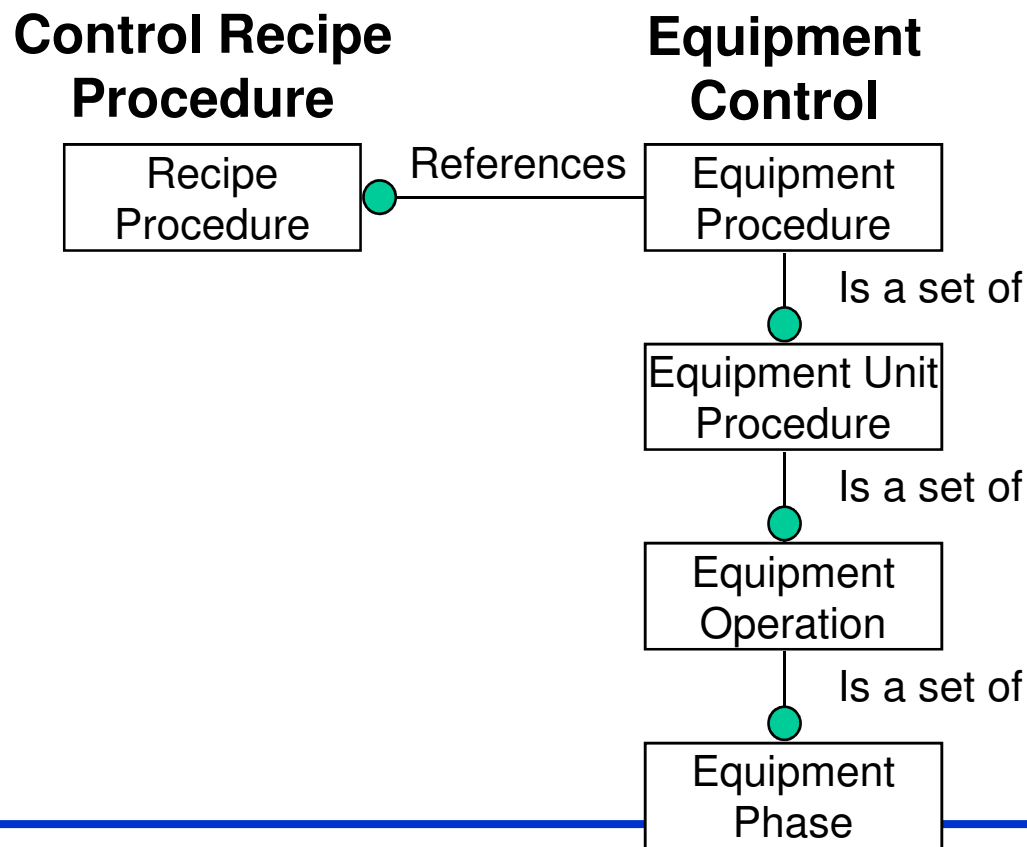
Equipment Control





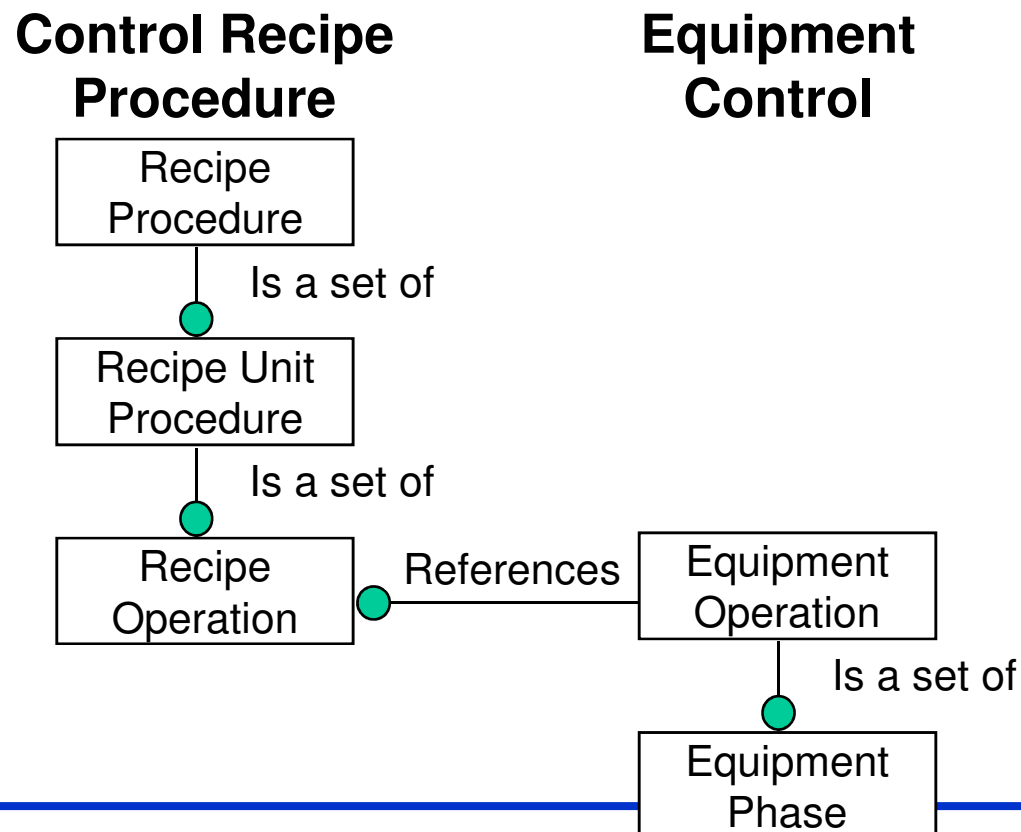
Procedure Logic in the Equipment

- Procedure “hard-coded” into the equipment
 - ▶ Recipe authors can only use pre-defined equipment procedures
 - ▶ Less flexibility, but may be required by equipment



Alternate Separation

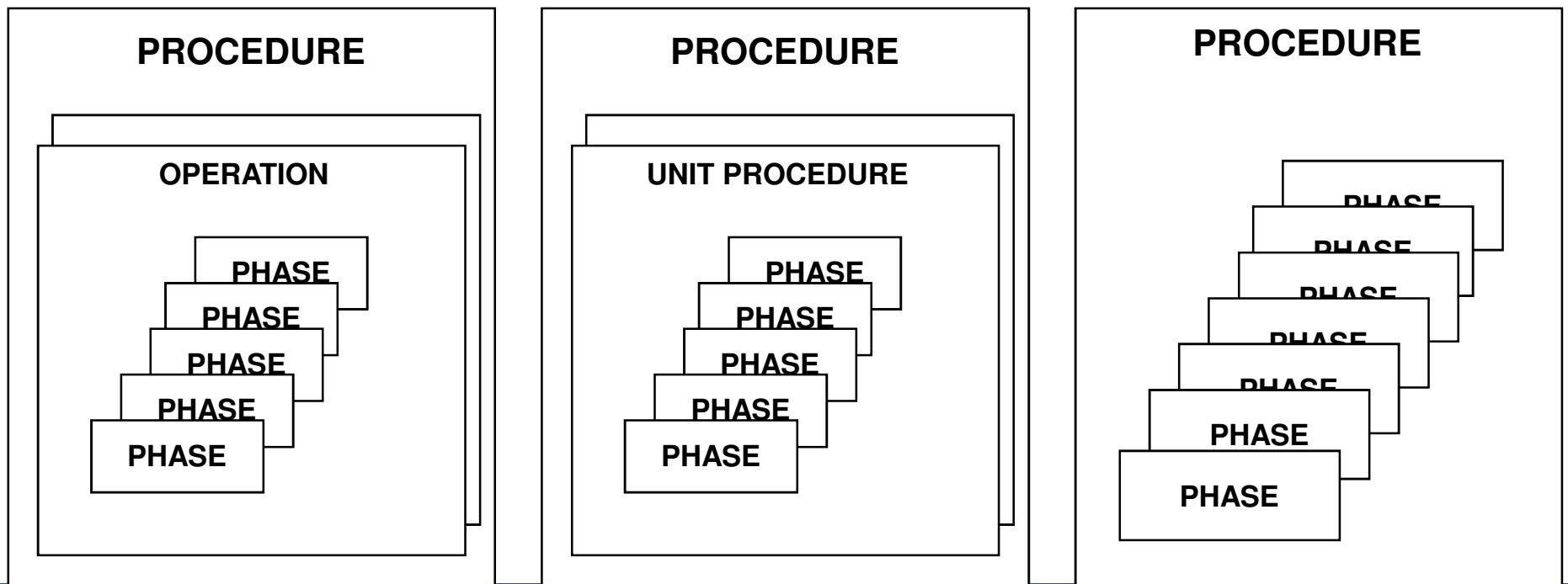
- Operations 'hard-coded' into equipment logic
 - ▶ Recipe authors may only use a set of predefined operations
 - ▶ Intermediate flexibility, but may be required due to equipment restrictions





Procedure Model Collapsibility

- Any part of the ISA 88 model may be collapsed or expanded
- E.g. expanded model may include “macro phases”
- Different “collapsed” recipes





Summary: Recipes

- General
- Site
- Master/Control Procedure
- Unit Procedure
- Procedure Logic



Summary

- S88 (ANSI/ISA-88) provides an excellent basis for developing batch systems
- The concept of separation of product information (recipes) from equipment capability is key to designing flexible systems
- S88. applies to any level of automation, and any type of automation equipment
- Defines a 'design pattern' for the architecture of batch systems that works for complex or simple problems