Market-Driven Systems

Marknadsstyrda System

FRTN20

Lecture 3: Batch Production

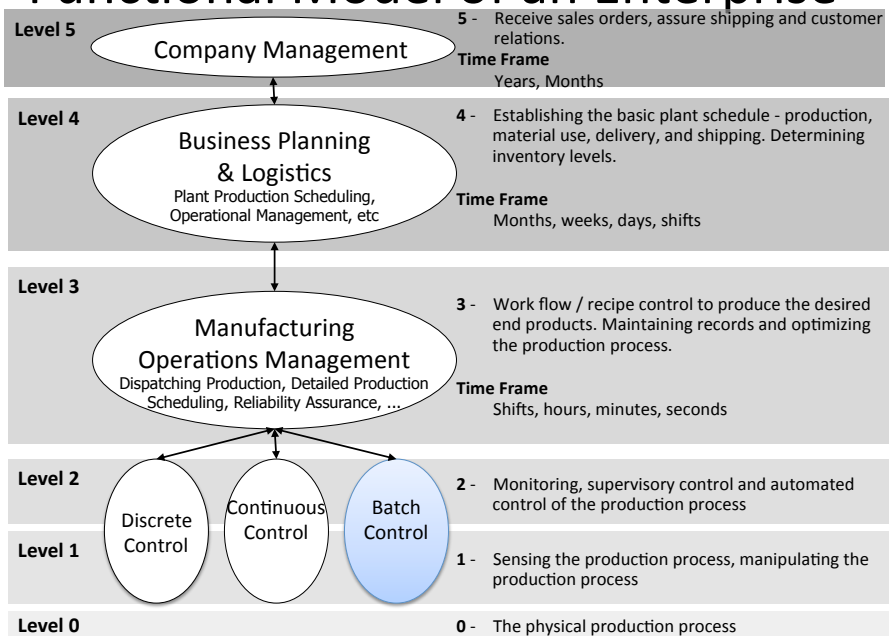
1

Outline

- **Batch Production Systems**
- S88 Batch Standard
  - Process Model
  - Physical Model
  - Procedural Model
  - Equipment Control Logic
  - Recipe – Equipment Control Separation
  - Additional Items

2

Functional Model of an Enterprise



Batch Production Processes

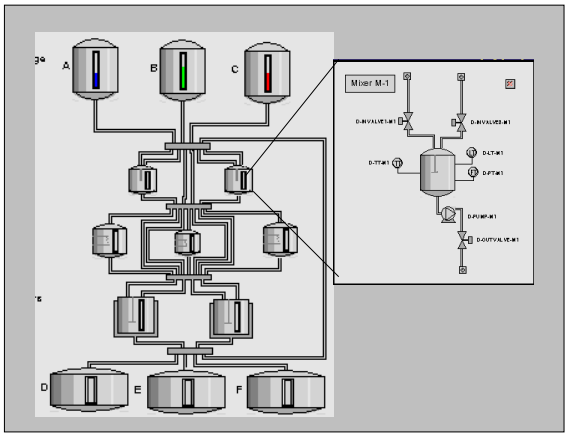
General Characteristics of batch production processes:

- Production of products in batches
- Discontinuous flow of materials.
- Production run determined by time/end point.
- Production goes through steps of operations.
- Fluid and dry processing.

4

Batch Production Processes

A batch production process produces products in batches (lots).
Production goes through steps of operations into products.

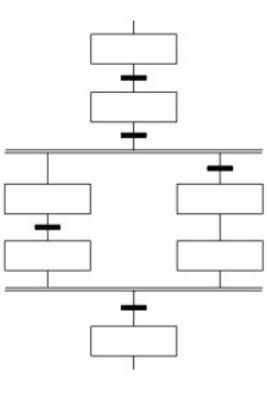


5

Batch Production

The basic functionality required in batch production is the recipe.

The recipe coordinates basic control functions with procedural control and coordination control.



Today, there is an international standard for Batch Control, IEC 61512, also known under the name ISA88 (or simply S88).

6

Making cookies

The making of cookies is an example of batch production.

The recipe defines the steps required to make the cookies:

1. Add flour, sugar and cocoa in a bowl
2. Mix and sift
3. Add butter,
4. Chop until well blended.
5. Roll very thin,
6. Sprinkle with granulated sugar,
7. Sut with cooky cutter,
8. Bake on a buttered sheet in a moderate oven.

The formula defines the quantities of the ingredients:

2 cups flour
1/4 cup cocoa
1/2 cup brown sugar
1/4 teaspoon salt
1/2 cup butter
1/2 teaspoon vanilla

7

Industrial batch production

The products can most often also be done in a continuous way BUT ….

1. A higher degree of flexibility is beneficial

OR

2. Some of the production activities require an extended time to complete

=> Batch Production is sometimes the prefered production type.

8

Industrial batch control

- Within the same process cell several products can be made.
- Within the same process cell several products can be made **at the same time**.
- Within the same process cell, the same product can be made using **different equipment**.

=> Batch control becomes **more than just a control problem**, it also becomes a system scheduling problem.

9

Industrial Batch Production

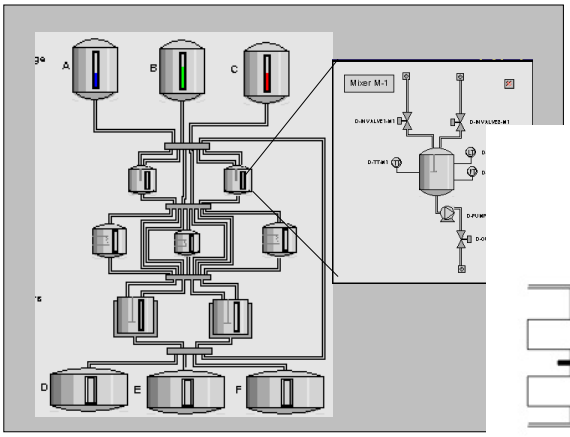
Batch control includes:

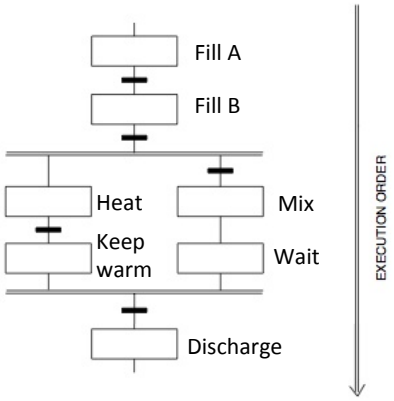
- Basic control (i.e. Classic continuous control)
- Logic control (i.e., start-stop)
- Procedural control (i.e. Sequencing)
- Coordination control (i.e. Allocation of equipment, propagating state changes)

⇒ Batch control therefore tends to be more complex than both continuous and discrete control

10

Batch Control





Outline

- Batch Production Systems
- **S88 Batch Standard**
  - **Process Model**
  - **Physical Model**
  - **Procedural Model**
  - **Equipment Control Logic**
  - **Recipe – Equipment Control Separation**
  - **Additional Items**

12

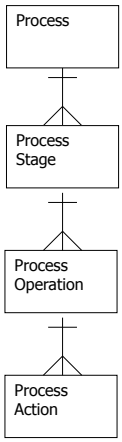
What is defined in S88 ?

1. Process model
2. Physical model (Equipment model)
3. Procedural model (Control model)
4. Equipment control logic
5. Recipes
6. Recipe – Equipment control separation
7. Additional material of relevance for batch control

13

1. Process Model

A process is a sequence of activities for the conversion, transporation or storage of material and energy.



Production of Polyvinyl Chloride

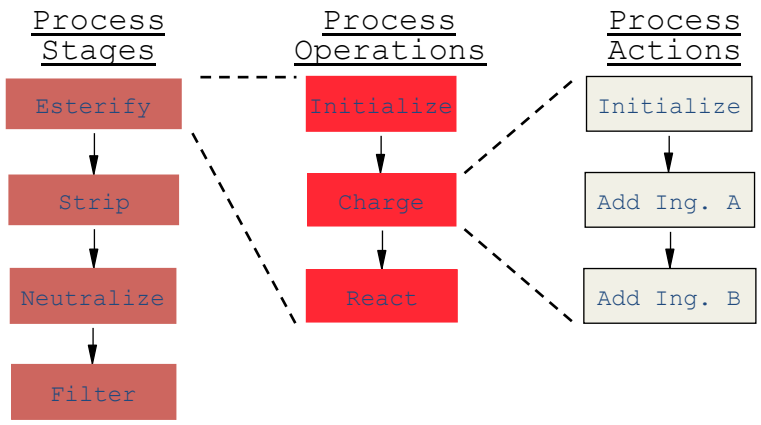
Polymerize, Recover, Dry

Prepare reactor, Charge, React

Add, Heat, Hold

14

1. Process Model - Example



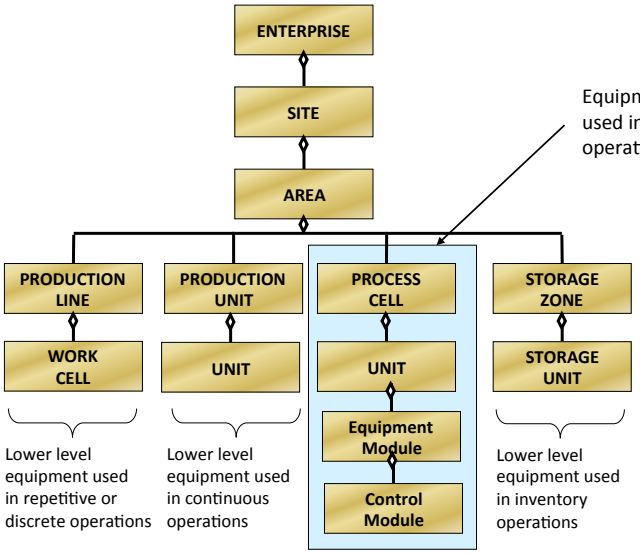
15

What is defined in S88 ?

1. Process model
2. Physical model (Equipment model)
3. Procedural model (Control model)
4. Equipment control logic
5. Recipes
6. Recipe – Equipment control separation
7. Additional material of relevance for batch control

16

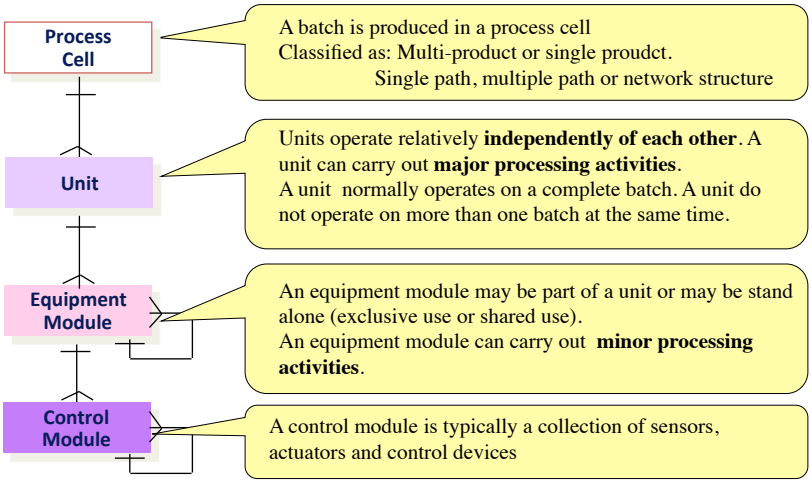
Physical Hierarchy



17

2. Physical Model (Equipment model)

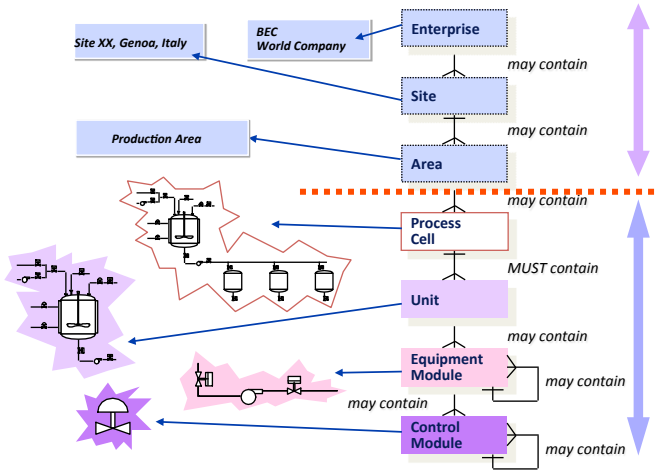
Structuring a physical plant is not a trivial task.



18

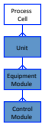
2. Physical Model (Equipment model)

The physical model defines the equipment used



19

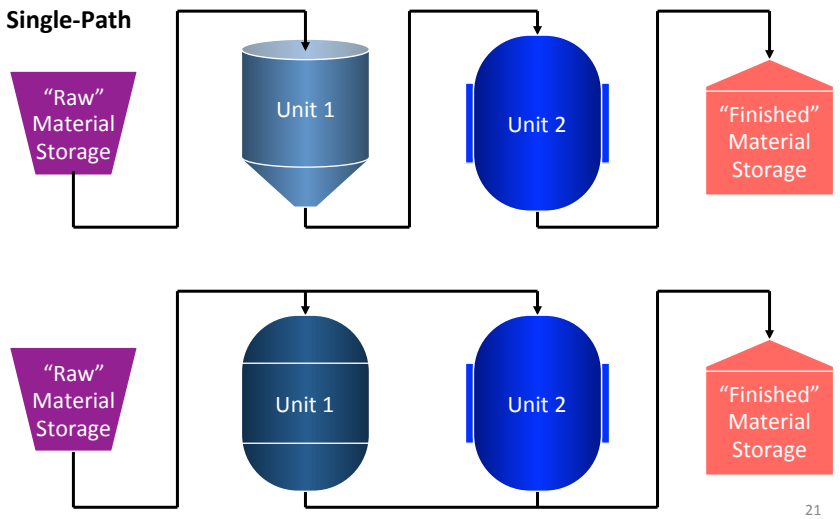
2. Physical Model (Equipment model) - Process cell



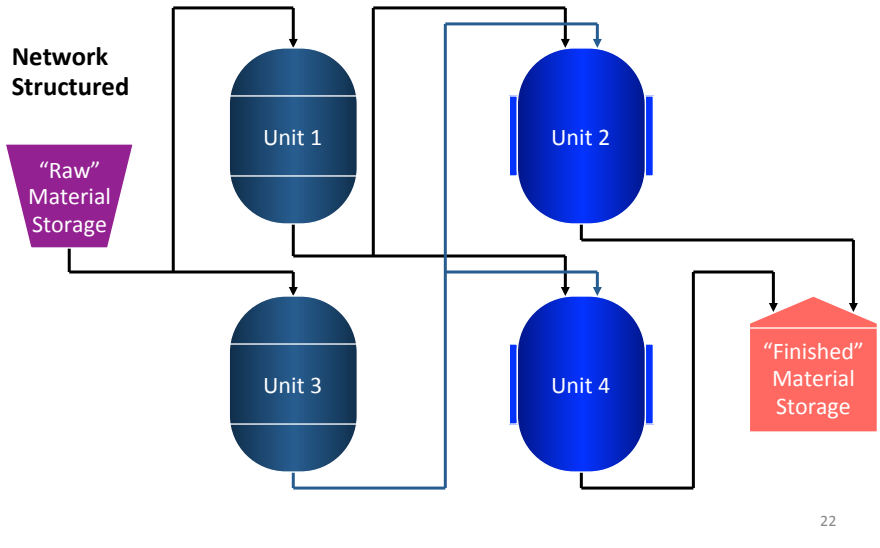
- A logical grouping of equipment required for production of one or more batches
- May contain more than one grouping of equipment needed to make a batch
- This grouping is sometimes referred to as a train
- The equipment actually used for the batch is referred to as the path
- May contain more than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

20

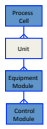
2. Physical Model (Equipment model) - Process cell



2. Physical Model (Equipment model) - Process cell



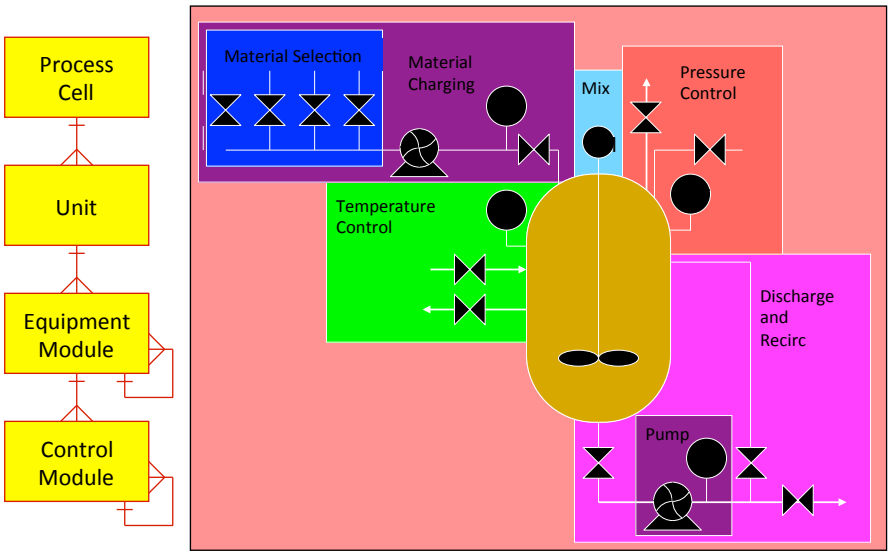
2. Physical Model (Equipment model) - Units



- Usually centered on a major piece of process equipment
- Frequently operates on or contains the complete batch
- May operate on or contain only a portion of the complete batch
- Cannot operate on or contain more than one batch at a time
- The primary S88 module for automatic control
- Making a batch often requires multiple units
  - Although a batch is allowed to be completed in a single unit
- A unit is made up of equipment and/or control modules
- Control and equipment modules can exist as:
  - Permanently attached parts to a unit
  - Temporarily attached parts to a unit
  - Totally separated from any unit

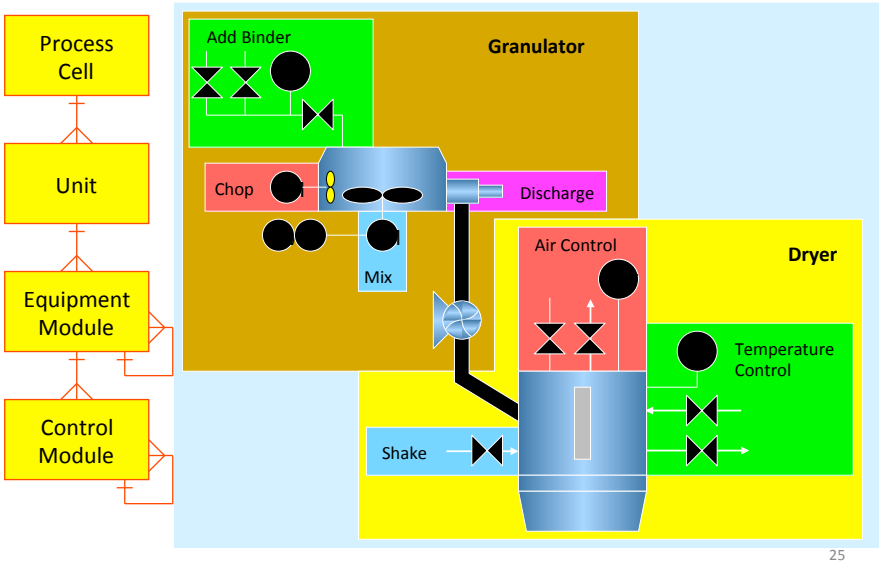
23

2. Physical Model - Example



24

2. Physical Model - Example



25

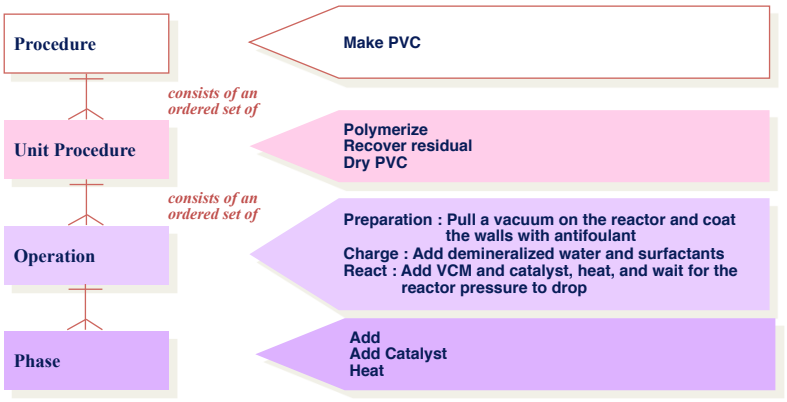
What is defined in S88 ?

1. Process model
2. Physical model (Equipment model)
3. Procedural model (Control model)
4. Equipment control logic
5. Recipes
6. Recipe – Equipment control separation
7. Additional material of relevance for batch control

26

3. Procedural Model

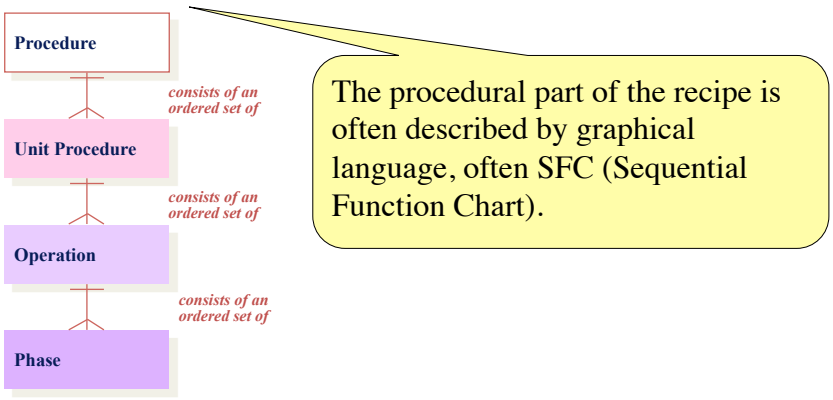
Procedural control direct equipment-oriented actions to take place in an ordered sequence in order to carry out a process-oriented task.



27

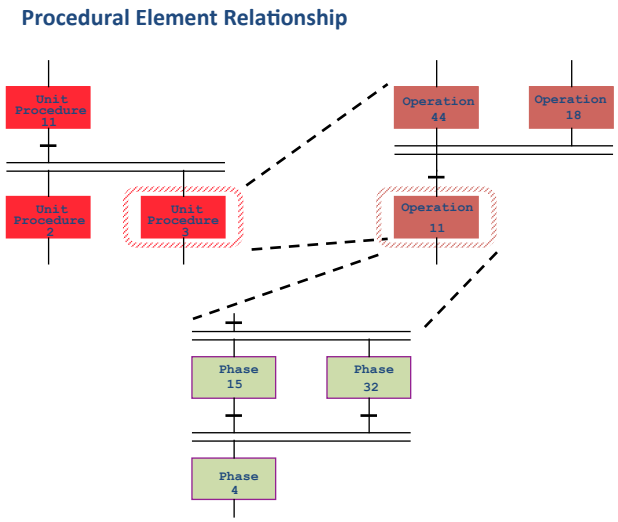
3. Procedural Model

Procedural control direct equipment-oriented actions to take place in an ordered sequence in order to carry out a process-oriented task.



28

3. Procedural Model



29

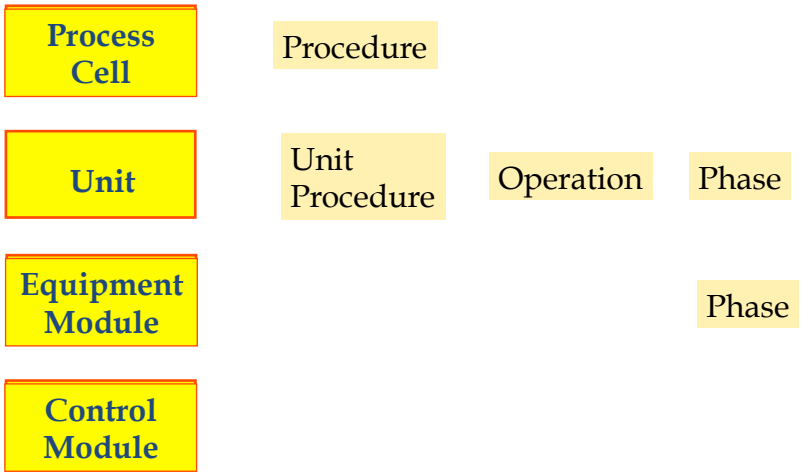
3. Procedural Model - procedure

- The highest level in the hierarchy
- Defines the strategy for carrying out a major processing action such as making a batch
- Defined in terms of an ordered set of unit procedures
- Example: "Make Product A"

30

3. Procedural Model

Equipment Entity/Procedural Element Mapping



31

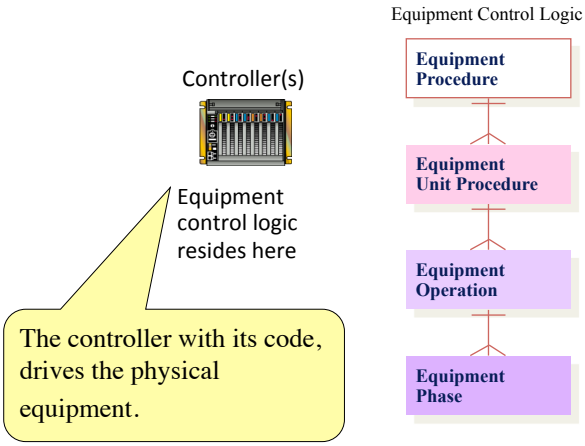
What is defined in S88 ?

1. Process model
2. Physical model (Equipment model)
3. Procedural model (Control model)
4. Equipment control logic
5. Recipes
6. Recipe – Equipment control separation
7. Additional material of relevance for batch control

32

4. Equipment Control Logic

The functionality (control logic) of the equipment is implemented in the PLCs



Note:
Not all levels in this hierarchy have to be implemented.

33

What is defined in S88 ?

1. Process model
2. Physical model (Equipment model)
3. Control model (Procedural model)
4. Equipment control logic
5. Recipes
6. Recipe – Equipment control separation
7. Additional material of relevance for batch control

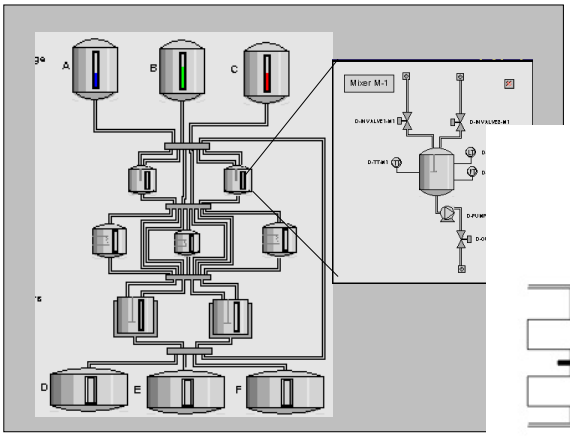
34

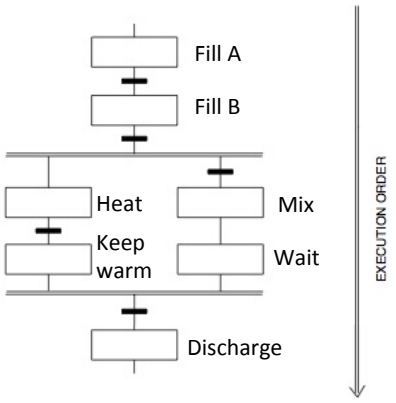
5. Recipes

- The recipe tells the batch control system how to make product
- A recipe usually exists for each intermediate or finished product that is to be produced
- Recipes provide a way to describe products and how they are produced

35

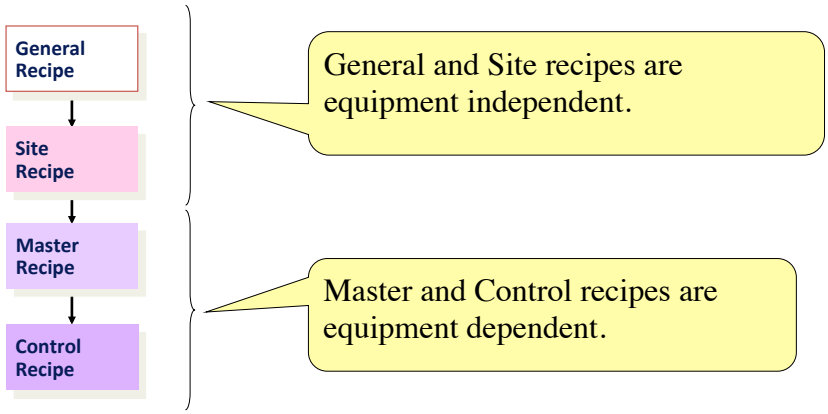
Batch Control





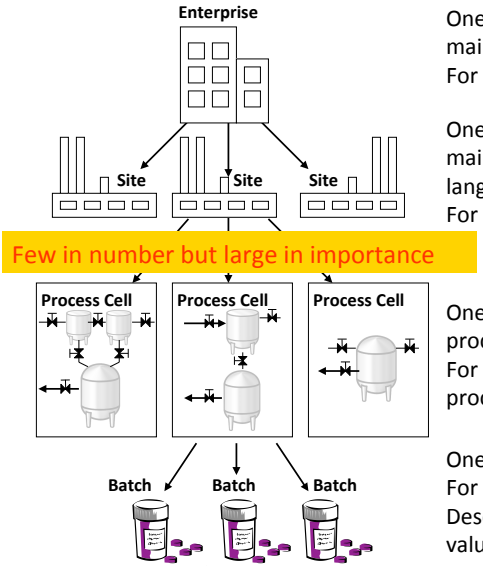
5. Recipes

The necessary set of information that uniquely defines the production requirements for a specific product. Different parts of the organization need different information about the making of the products.



37

5. Recipes
- General and Site Recipes



Few in number but large in importance

One **General Recipe** per produced material, maintained at the enterprise level.
For example, 1000 company wide products

One **Site Recipe** per site and produced material, maintained at the site for local materials, language, or segment of production.
For example, 10,000 site recipes for 10 sites

One **Master Recipe** per Process Cell and produced material.
For example, 50,000 master recipes for 5 process cells per site.

One **Control Recipe** per batch.
For example, 1,000,000 batches per year.
Describes the custom options and formula values for one specific batch of product.

38

5. Recipes

The necessary set of information that uniquely defines the production requirements for a specific product

Header: Contains administrative info about, e.g., who created the recipe and when

Formula: Contains all the parameters necessary for execution of the recipe.

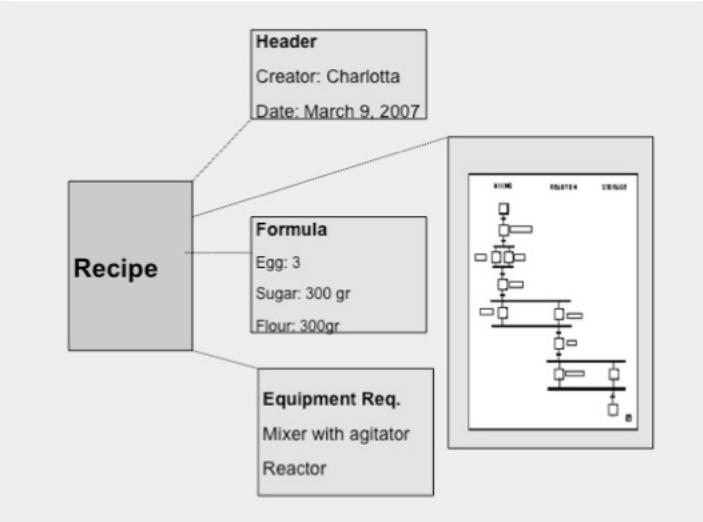
Equipment Requirement: Contains info about what equipment is necessary for the execution of the recipe.

Procedure: Contains info about the sequential order in which the recipe should be carried out.

Other Information: Contains any other info.

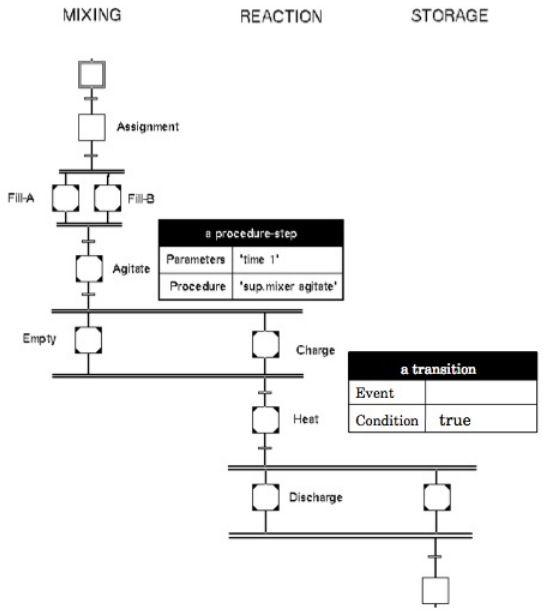
39

5. Recipe



40

5. Recipe



41

What is defined in S88 ?

1. Process model
2. Physical model (Equipment model)
3. Control model (Procedural model)
4. Equipment control logic
5. Recipes
6. Recipe – Equipment control separation
7. Additional material of relevance for batch control

42

6. Recipes – Equipment control separation

The recipe that describes how the batch is to be made *is separate from* the equipment and control that is actually used to make the batch

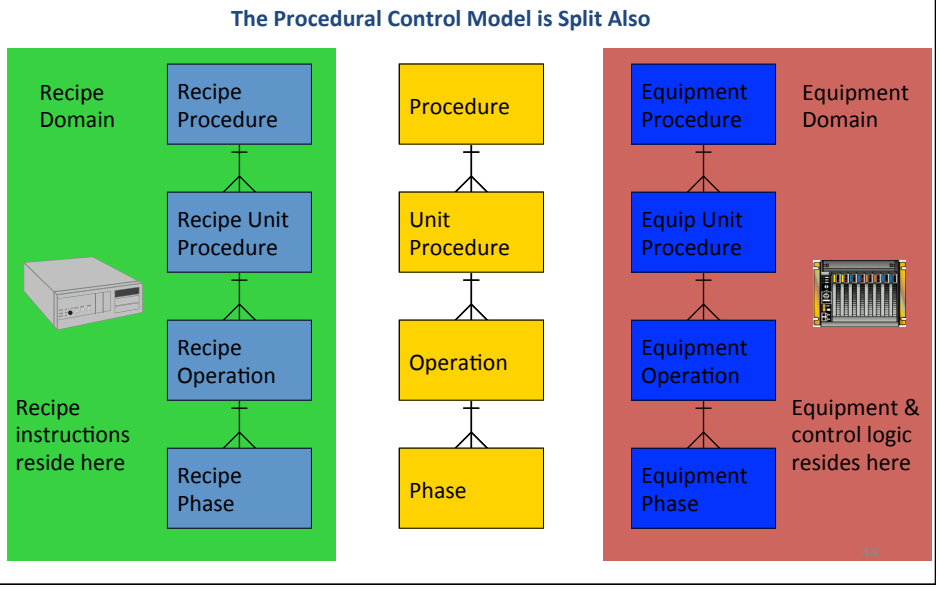
- –Makes control more flexible
- –Makes multiproduct plants easier to control
- –Simplifies recipe and equipment control validation
- –Enhances ability to reuse software

Recipe Domain

Equipment and Control Domain

43

6. Recipes – Equipment control separation



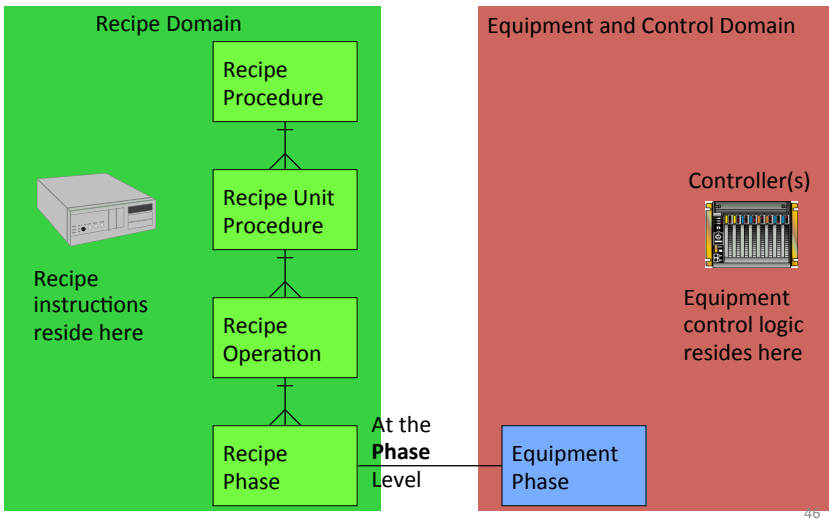
6. Recipes – Equipment control separation

- **In order for the execution to take place, there must be a link between the recipe domain and the equipment and control domain.**
- **The recipe directs the equipment control logic**
  - **To run**
  - **In the proper order**
  - **In the proper unit**
  - **With the proper formula values**

45

6. Recipes – Equipment control separation

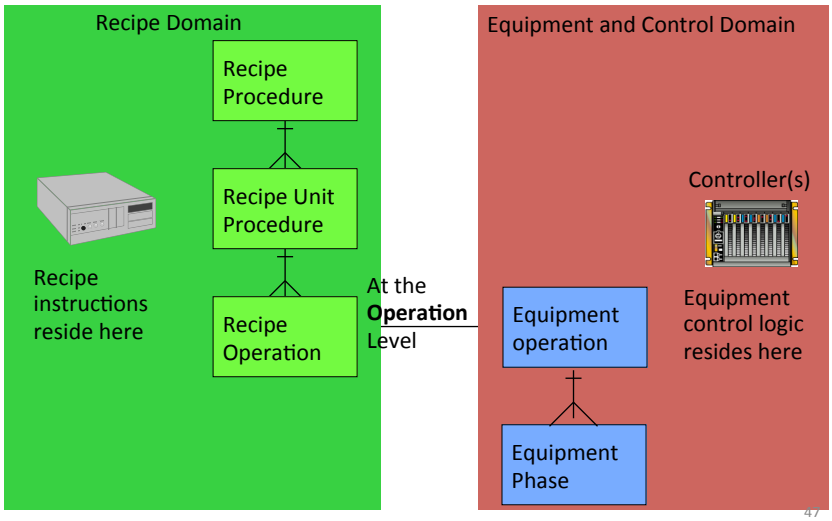
The linking is most often done at the phase level ...



46

6. Recipes – Equipment control separation

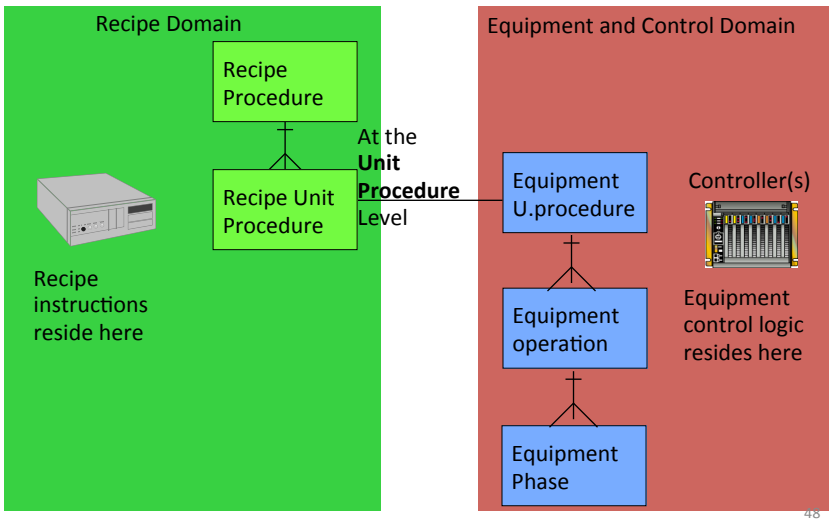
...but it can also be done at the operation level ...



47

6. Recipes – Equipment control separation

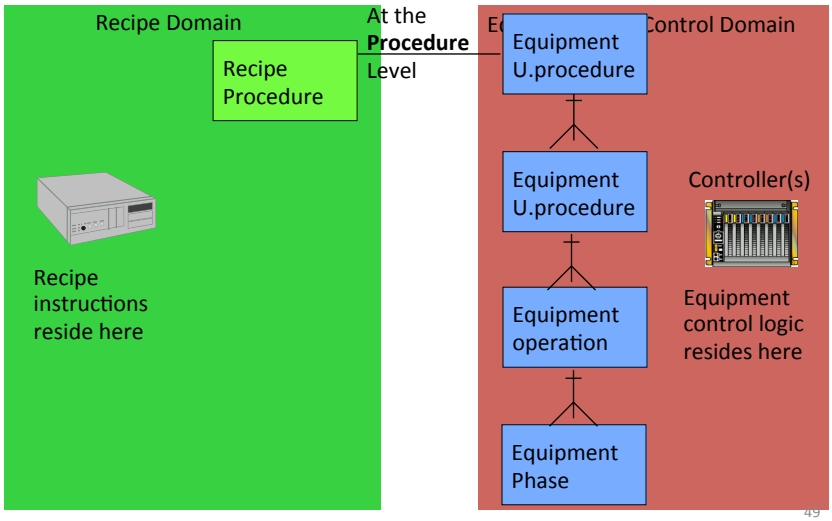
... or at the unit procedure level ...



48

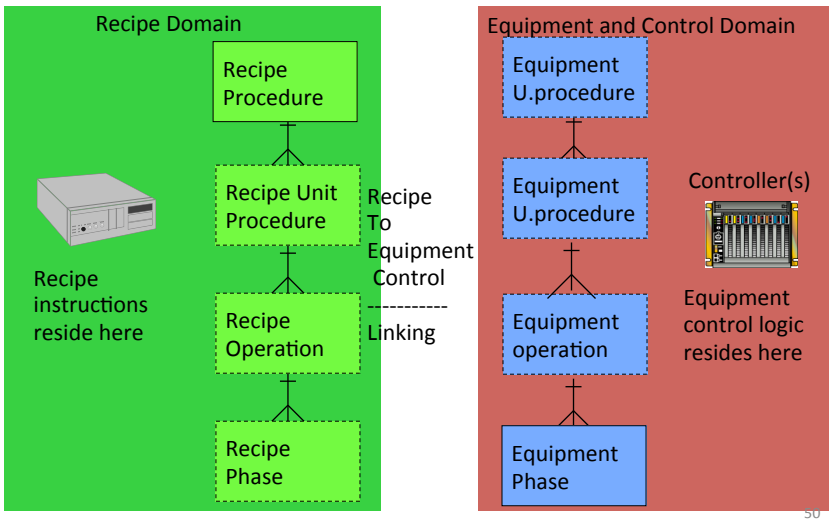
6. Recipes – Equipment control separation

... or at the procedure level.

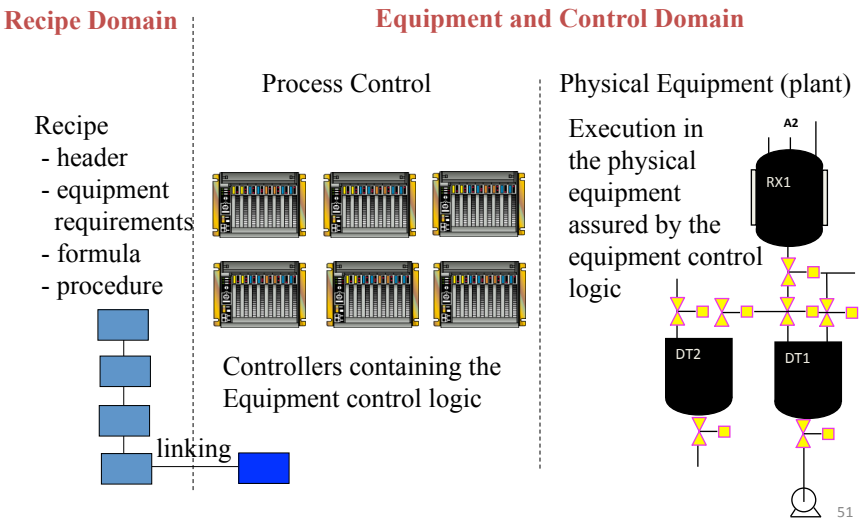


6. Recipes – Equipment control separation

One or more hierarchical levels are allowed to be left out



What is defined in S88?



What is defined in S88 ?

1. Process model
2. Physical model (Equipment model)
3. Control model (Procedural model)
4. Equipment control logic
5. Recipes
6. Recipe – Equipment control separation
7. Additional material of relevance for batch control

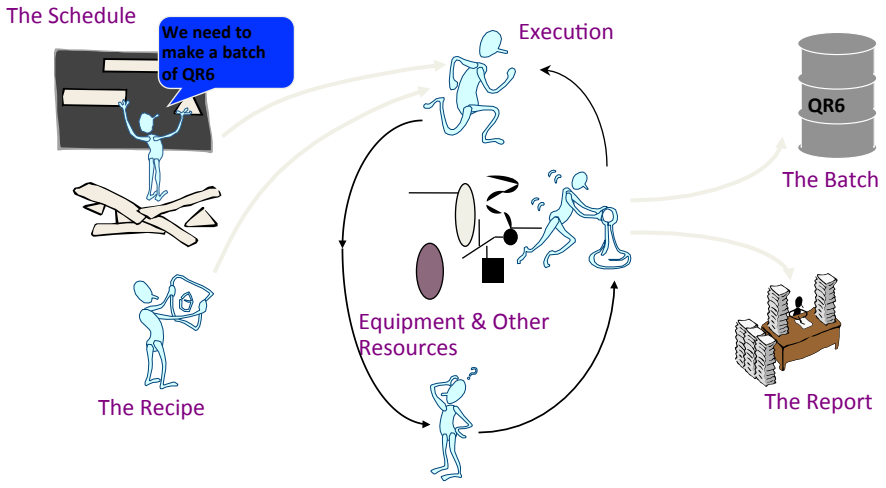
52

7. Additional material of relevance for batch control

- How to make the product –
  recipes
- The equipment control -
  equipment control logic
- **What products to make in what order –**
  batch schedule
- **How the batch was executed –**
  batch history

53

7. Additional material of relevance for batch control

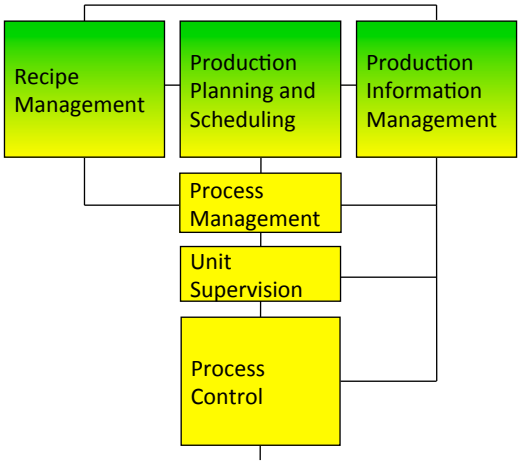


54

7. Additional material of relevance for batch control

The Control Activity Model :

- provides an overall perspective of batch control
- shows the main relationships between the various control activities required to successfully manage batch production



55

7. Additional material of relevance for batch control - Allocation and Arbitration

- Allocation - a form of coordination control that assigns a resource to a batch or unit
- Arbitration - a form of coordination control that determines how a resource should be allocated when there are more requests for the resource than can be accommodated at one time

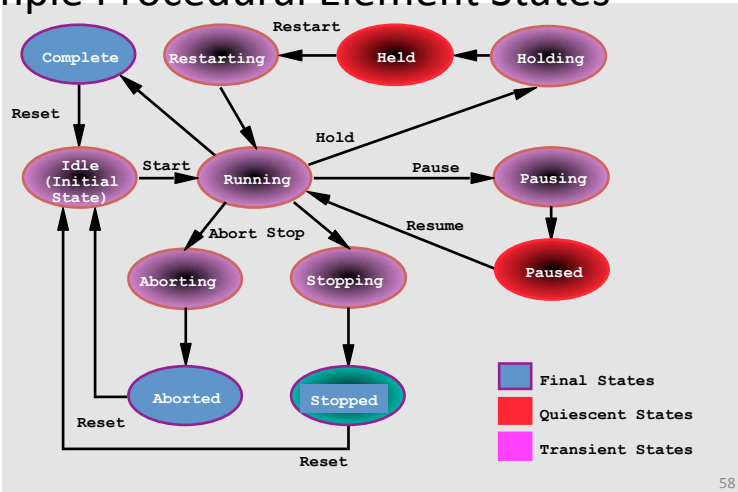
56

7. Additional material of relevance for batch control - States

- Examples of states for equipment entities include on, off, closed, open, failed, travelling, tripped, 35% open, and available
- Examples of states for procedural elements include running, holding, paused, stopped, aborted, and complete

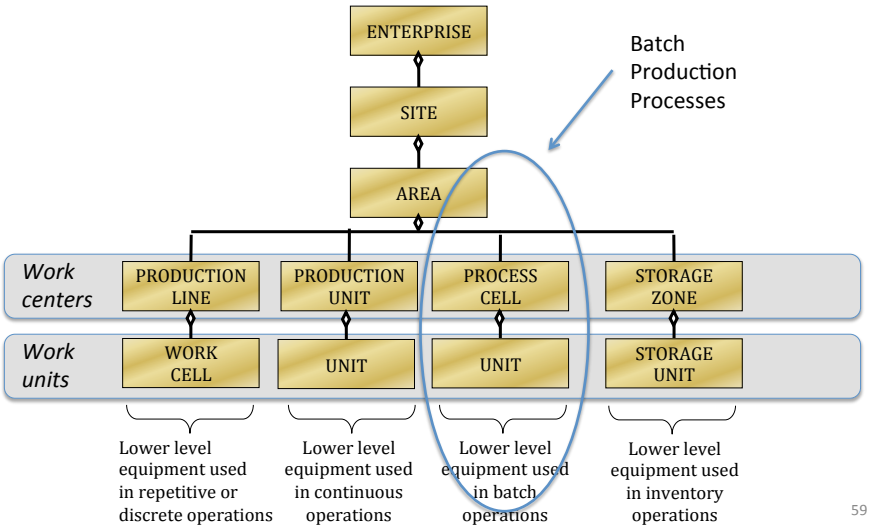
57

7. Additional material of relevance for batch control - Example Procedural Element States



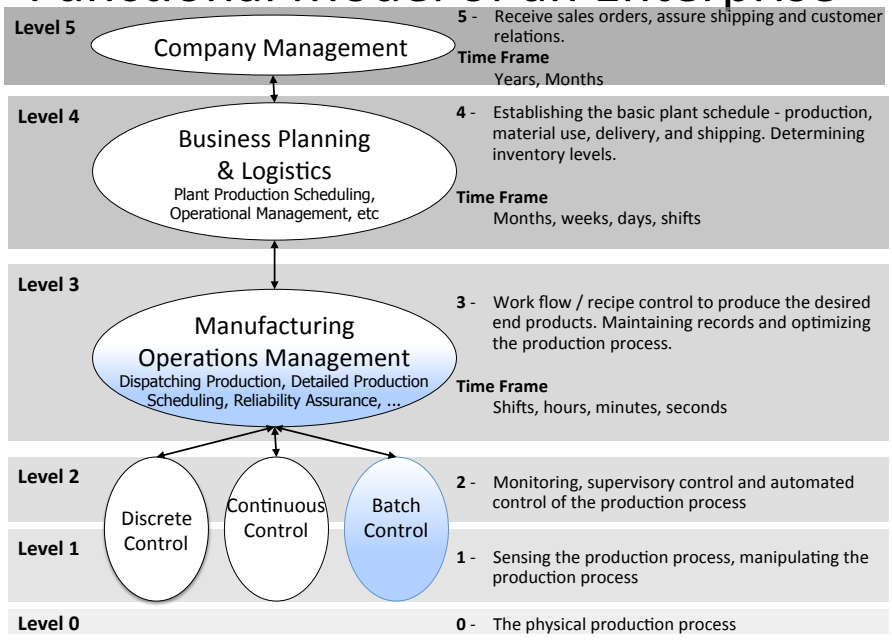
58

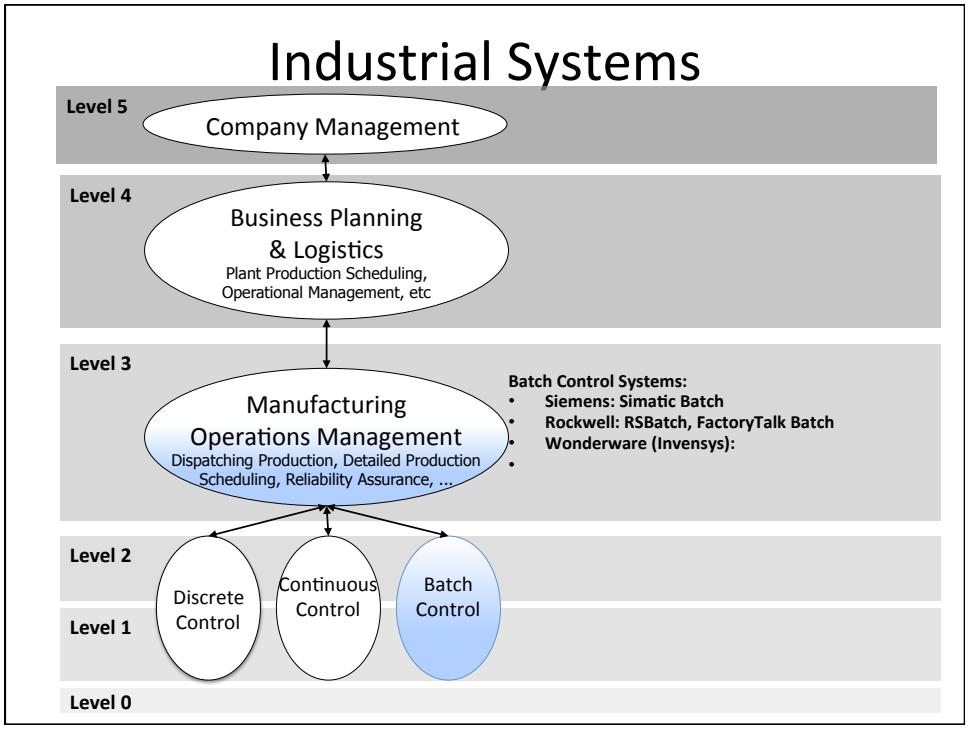
Physical Model of an Enterprise



59

Functional Model of an Enterprise




Industrial Systems
Level 5
Company Management
Level 4
Business Planning
& Logistics
Plant Production Scheduling,
Operational Management, etc
Level 3
Manufacturing
Operations Management
Dispatching Production, Detailed Production
Scheduling, Reliability Assurance, ...
Batch Control Systems:
Siemens: Simatic Batch
Rockwell: RSBatch, FactoryTalk Batch
Wonderware (Invensys):
Level 2
Discrete
Control
Continuous
Control
Batch
Control
Level 1
Level 0