A paper for automation engineers

Process Automation – a methodology

Overview

This paper describes an approach to the development of highly automated process automation systems. The methodology covers all aspects of the life cycle from requirements definition through implementation to validation, and can be applied concurrently with the project design engineering on a fast-track project.

The paper demonstrates how the use of diagrams, matrices, data classification, and databases can provide excellent documentation improve visibility of the development process and reduce errors in the final system. It discusses the advantages of software tools.

Key issues include

Involving the process engineers and the users

Using their experience and process knowledge

The value of modelling

Prototyping

The paper includes a modular diagrammatic analysis of a hygienic storage area as an example.

ControlDraw Ltd, 2002
Author Francis Lovering[1]

[1] [1] Francis Lovering has had a long a diverse career in the process control industries, working at all stages of the life cycle. He now runs ControlDraw Ltd, and concentrates on providing tools to assist suppliers and users in the automation industry, whilst still working as a practitioner of control systems design.

Contents

Introduction

This paper describes an approach for process automation engineers to use to provide process automation systems for bio/chemical/food processes.

The approach covers all aspects of the life cycle from requirements definition through implementation to validation.

The methodology described in this paper was originally developed, and could still be achieved using standard PC diagramming tools, along with spreadsheets and databases and of course word processing. The method adapts well developed software engineering practises and adds knowledge of modern process control and the capabilities of DCS and PLC systems via an IEC61113 type of structure.

Note: Production using ControlDraw is much faster and more accurate, since all the diagrams, data and matrices are stored in a single database file. There are many other benefits from using ControlDraw that this paper does not discuss.

Establishing the Requirements

The detailed requirements are to be found in several places including

Engineering diagrams such as Process Flow sheets and Piping & instrument diagrams

The Control and operability philosophy if one exists

Process descriptions

Peoples Heads

The last of these is always the most difficult to obtain. What is required is a way to elucidate this knowledge and build it into the Functional Design. This is achieved by the clarity of the design and the Review procedure, which is described later in the paper.

Functional Requirements Analysis

This includes finding out and then describing the detailed functional requirements – what the objects are and how they should be controlled.

The process should ensure that:

End users have the opportunity to input and can make sure that their requirements are considered.

Design is carried out in a rational and documented way

Important design decisions are not made by programmers whilst coding (which can be a recipe for problems)

The process includes

The decomposition of the process and recipes into the S88 physical and procedural objects

The detailed design of each of these objects

Mapping these into the standard system functions. During the system independent stage the mapping is done into generic standard modules.

The resulting design is contained in a Functional Requirements Model, hereafter just called the model.

The process uses the Models and Terminology defined in the ISA standard S88.01. There are however many interpretations of S88. Different understandings of operations versus phases are common the same sometimes applies to Equipment Modules versus Control Modules. Unless the standard is narrowed down, there is still a lot of room for inconsistencies and misunderstanding.

For this a document – the Design Principles document - is written to clarifies the extent to which the choices that are allowed in S88 apply to the particular project. It also shows the way Units, Equipment Modules, Operations are defined. The Design Principles document also provides a description of generic control mechanisms that are common to the entire process, and describes in general terms how the diagrams and tables define the required Control and Operational activities.

This includes:

Generic control requirements for both normal operation and exception handling.

The structure of the model.

The use of diagrams.

The use of matrices.

The use of tables and lists of data.

How various control objects (items such as units, equipment modules, control modules, recipe procedures etc) are defined.

HMI aspects of the model

Standard module designs

Note – The Design Principles document could also be a ControlDraw model - see also Reference models in other ControlDraw papers.

The Model

The Model comprises a collection of linked diagrams and tables.

The S88 Physical and Procedural Hierarchies are captured in the relationships between the diagrams. For example, on a process cell diagram a single symbol represents a Unit. This Unit is then detailed on a diagram containing the Equipment and Control modules in the Unit. Thus the Process Cell contains the Unit and the Unit contains the EM's and CMs exactly as per the S88 Physical model

The details of what is shown on each diagram depend on the type of diagram.

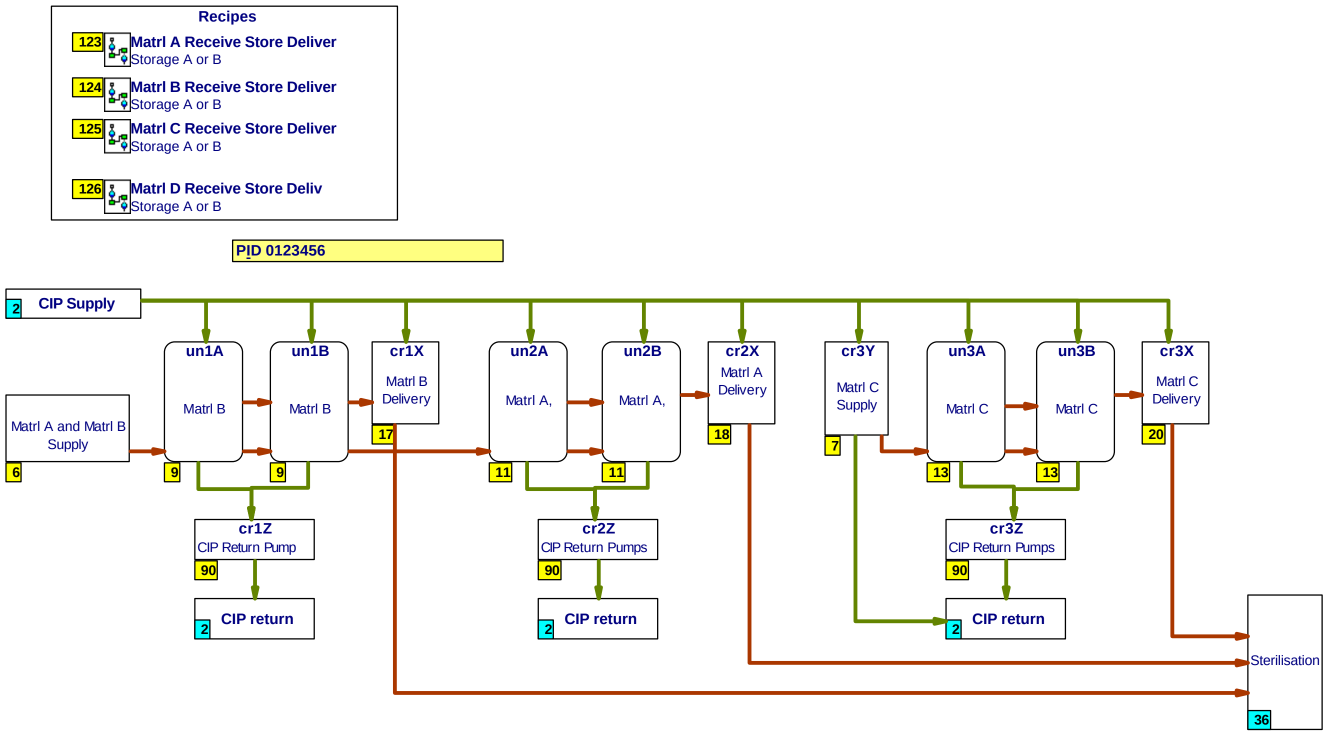
All Diagrams contain relevant references – for example the P&ID number and revision are shown on physical model diagrams, and on procedural diagram references to the process description. These helps to provide an audit trail back to the preceding documentation

The following are examples on the diagrams in a model. Note - yellow boxes with numbers in represent links to diagrams that contain the description of the particular object.

Process Cell Diagrams

A process flow diagram of the Units and Common Resource,

Icons for each Recipe



Unit diagrams

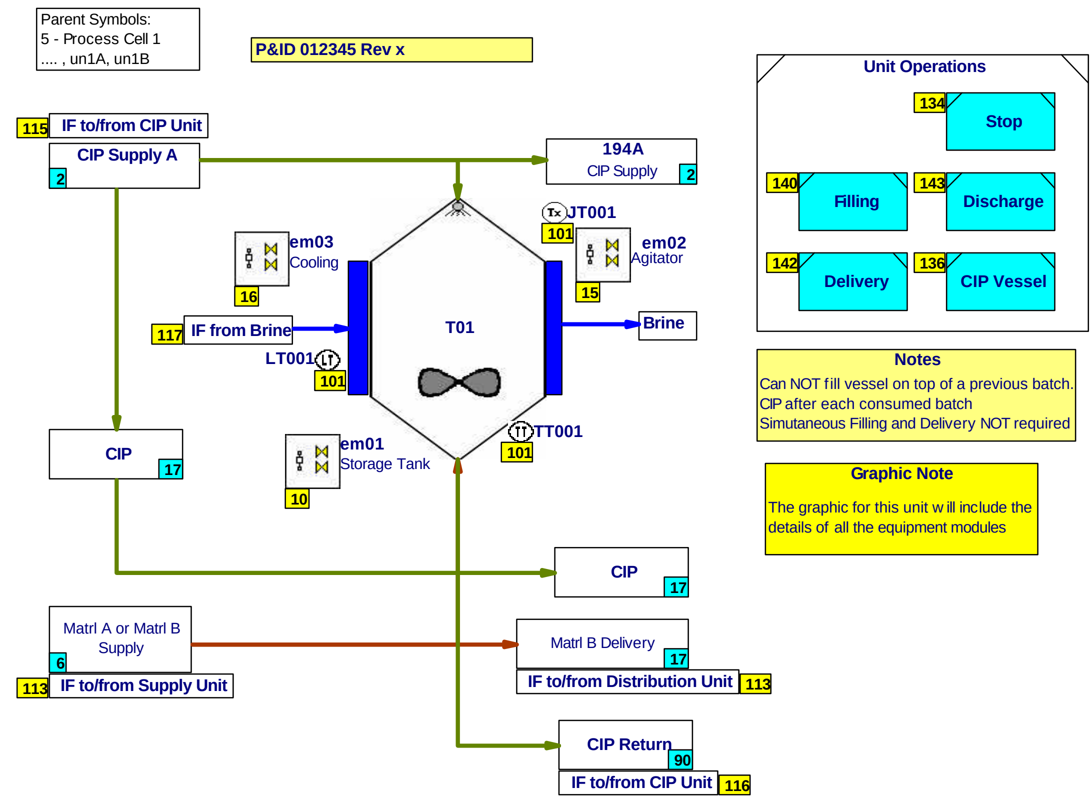
These comprise:

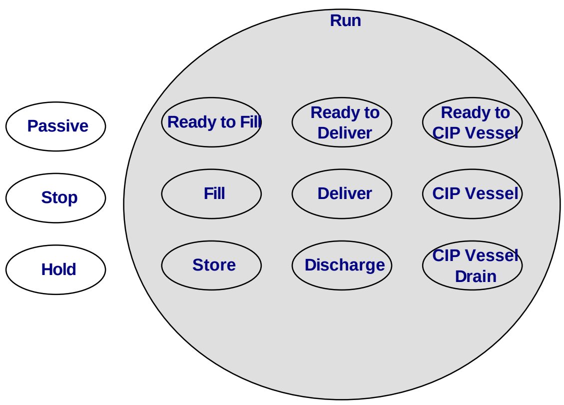
A process flow diagram of the equipment modules and control modules (such as Measurement devices) that are in the unit. Note if a control module is only relevant within an equipment module then it is shown in the Equipment module rather than in the unit diagram.

A symbol for each operation.

Interface Objects – modules that control the communication between units and common resources.

The Unit state matrix –a table that shows the settings for the equipment modules for each state that the Unit can be set to.





un StorageTank

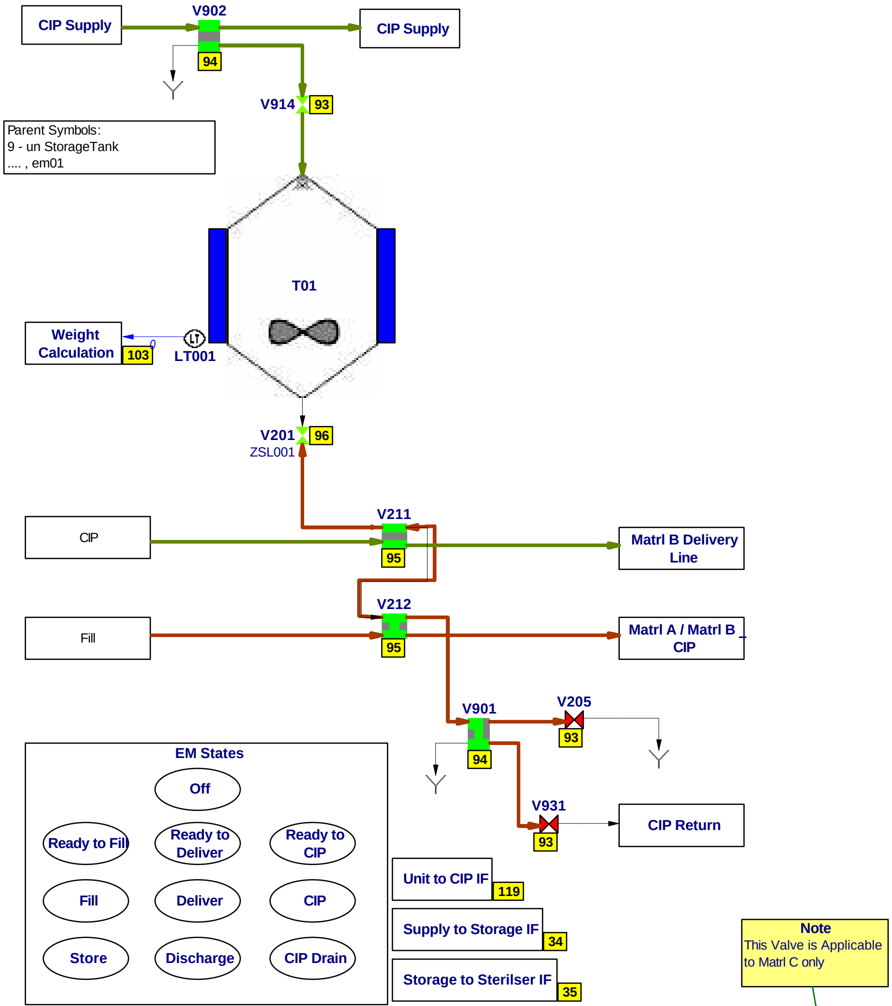
	em01	em02	em03
Passive	Off	Off	Off
Stop	Off	Off	Off
Hold	Off	Off	Off
Ready to Fill	Ready to Fill	Off	Off
Fill	Fill	Run	On
Store	Store	Run	On
Ready to Deliver	Ready to Deliver	Run	On
Deliver	Deliver	Run	On
Discharge	Discharge	Off	Off
Ready to CIP Vessel	Ready to CIP	Off	Off
CIP Vessel	CIP	Off	Off
CIP Vessel Drain	CIP Drain	Off	Off

Equipment modules diagrams

A process flow diagram showing the control modules that are in the equipment

A symbol for each state of the equipment module

An Equipment state matrix that shows the settings for the control modules for each state that the EM can be set to.



em01 SDOS Storage Main

	V902	V914	V201	V211	V212	V901	V931	V205	V210
Off	Thru	Close	Close	Through	Through	Thru	Close	Close	Close
Ready to Fill	Thru	Close	Open	Through	Mix	Thru	Close	Close	Close
Fill	Thru	Close	Open	Through	Mix	Thru	Close	Close	Enable
Store	Thru	Close	Open	Through	Through	Thru	Close	Close	Enable
Ready to Deliver	Thru	Close	Open	Mix	Through	Thru	Close	Close	Enable
Deliver	Thru	Close	Open	Mix	Through	Thru	Close	Close	Enable
Discharge	Thru	Close	Open	Through	Through	Thru	Close	Open	Close
Ready to CIP	Divert	Open	Open	Through	Through	Divert	Open	Close	Close
CIP	Divert	Open	Open	Through	Through	Divert	Open	Close	Close
CIP Drain	Thru	Open	Open	Through	Through	Thru	Open	Close	Close

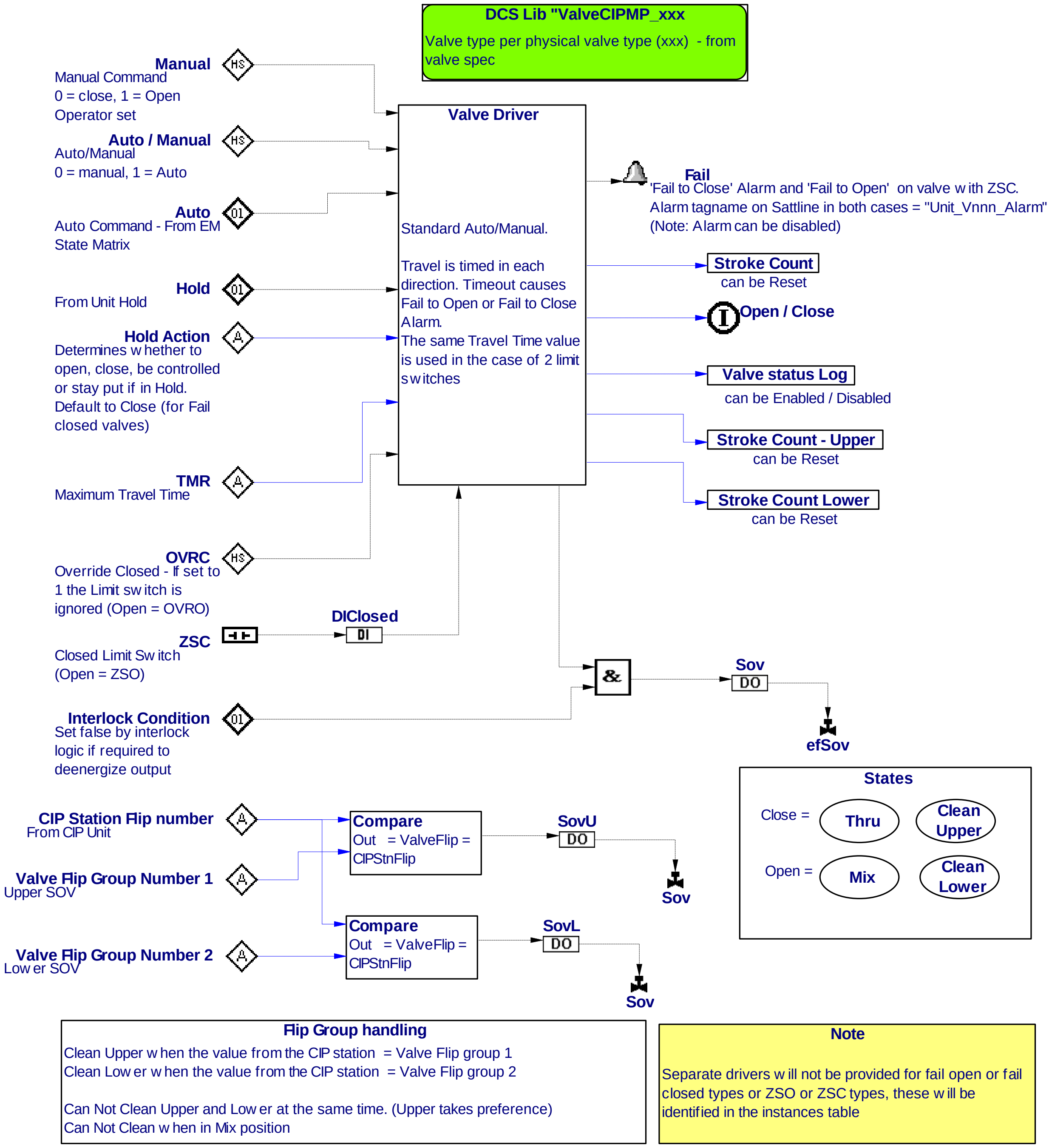
Note – in this particular model the equipment modules do not have their own operations or phases. They are set to the required state by the Unit Operations. This is not the only way that the methodology can be organised.

Control Modules diagrams

A symbol for each operator interface, such as auto-manual switches

A symbol for each control system input and output

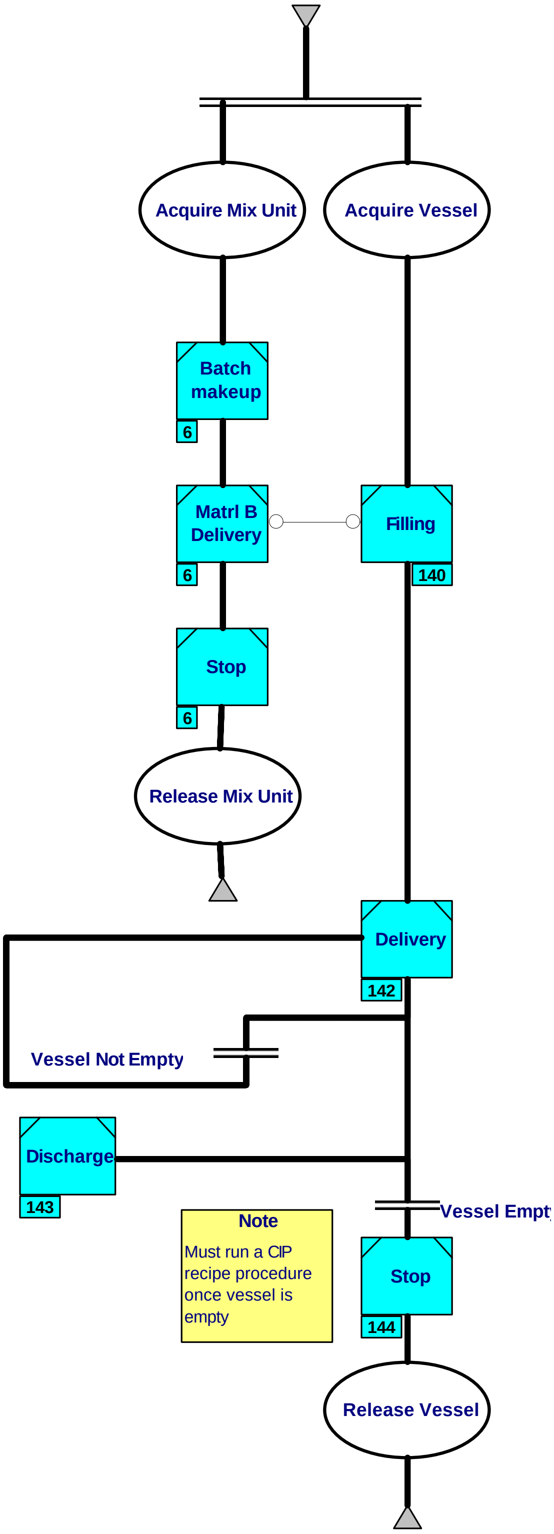
A definition of the control logic of the module



Recipe Procedure diagrams

The recipe logic in S88.02 Procedure Function Chart format

A symbol for each Unit Procedure, Operation, Synchronisation etc

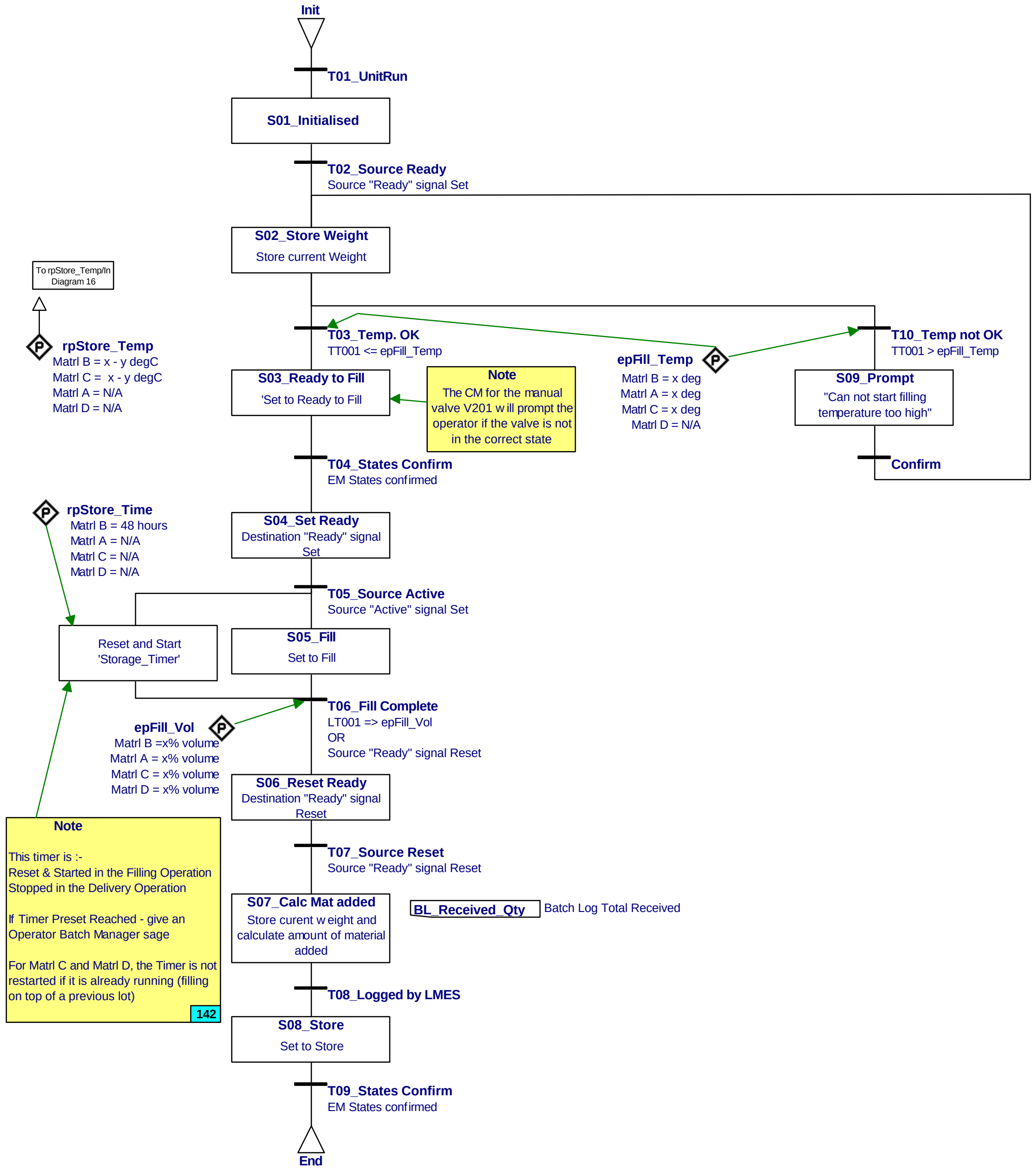


Operation and Phase diagrams

The phase logic in SFC format

A symbol for each Recipe parameter and equipment parameter

Note that the steps in the operation act by setting the Unit to one of the unit states.



Model Review Process

The model is subject to regular and detailed reviews with all the parties involved in the project.

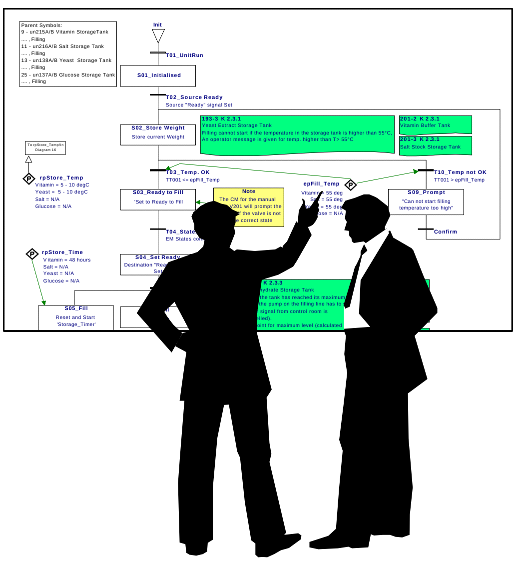
Typically this process is organised to work through the process cells and the units and into the operations and phases. Prior to the review an Archive copy is taken of the model, and the review is carried out using the Archived copy. The model is not generally changed during the review, instead minutes are taken of the required changes and these are then implemented prior to the next review.

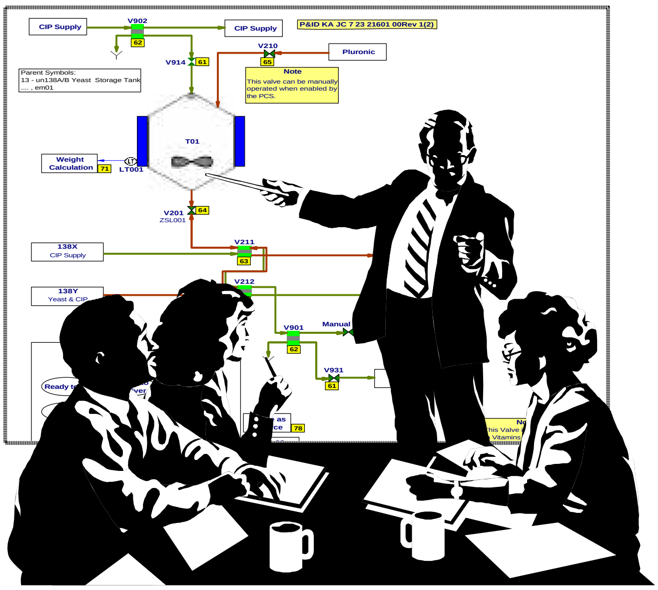
The reviews begin with an introduction to the model, and a review of the Design Principles document.

Generic Control Modules such as motors and valves are reviewed next. Since these provide much of the manual operation facilities in the plant it is important that the functionality available through these modules is understood before going into the details of the operations and phases.

Then the reviews move into the actual detail of the various process cells, unit's etc. This can include simple simulations where the valves are opened and closed, motors started etc to show dynamically the states of the equipment.

In fast track projects this is often timed to reflect the development of the process itself. It also helps to start with some of the simpler areas so that by the time the more complex areas are developed everyone has a good understanding of the methodology.





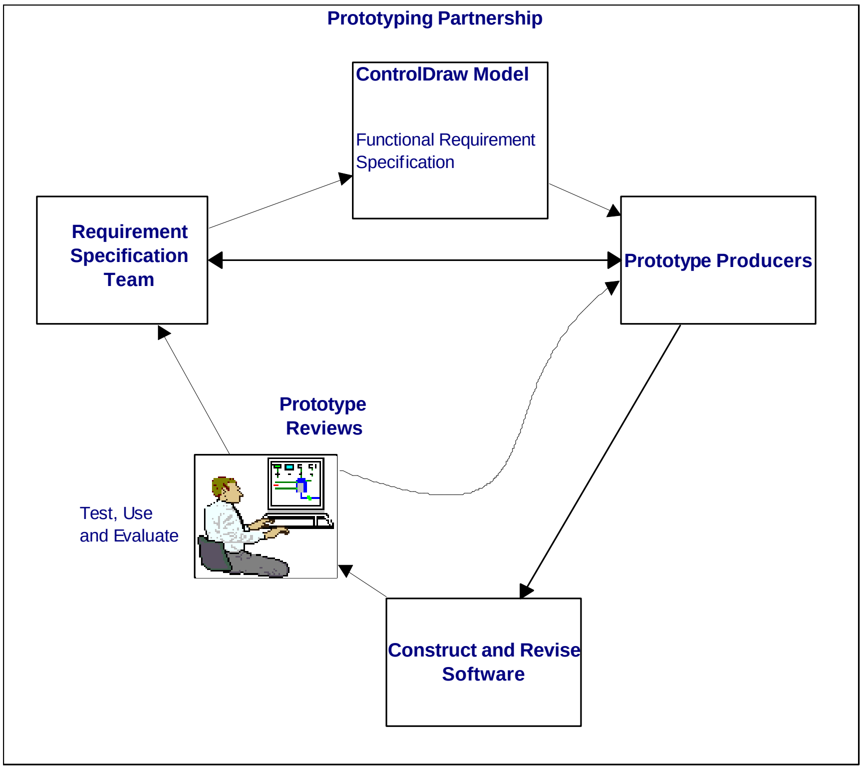
The Diagram reviews are conducted by displaying each diagram on a screen using the ControlDraw Reviewer and if there are any comments to be recorded then these are added as Yellow notes during the meeting.

This automatically builds an MS Access database of the comments. If preferred reviewers can make comments in the same way and send their comments database back to the modellers

Prototyping

Software should be implemented in exact accordance with the design!

So they say. But programmers need some freedom, and direct influence; the following diagram shows how Prototyping helps



Recommendation - Build a prototype for a subset of the Model.

Use it:

Test the Functional Requirements Specification

Get Metrics about how long different tasks take

Test the Testing

Start code level standard modules.

Try Alternative software designs

Agree the User interface early on

Get the programmers to improve the model

Get the right team

The project team should consists of the stakeholders in the whole life cycle - representatives of the key areas. The following lists the ideal collection of team members:

The End users

> They review the model for operational aspects, and often have detailed knowledge that can help.

The Process Experts

> Process engineers are needed to provide the process know how, often from Engineering Contractors
>
> They review the model in particular to look at the process aspects
>
> They are also able to liase with other process engineers to ensure that the system design is integrated with the process design.

The Model Builders

> They have detailed knowledge of Process Control, S88, the methodology and the tools
>
> Their primary role is to gather the available data and build the model, to conduct the model reviews and ensure that the expert's comments are taken on board.

The System Programmers

> They have detailed knowledge of the target system.
>
> Their primary role is to program the system according to the model. In the early stages, when prototyping they have a key input into developing the methodology in order to ensure that the resulting model will be easily programmed.

The Test and Validation Experts

> They have knowledge of the requirements for FDA validation and experience of testing.
>
> Their primary role is to review the model for testability and the carry out the test and validation work.

It should noted that in fact all the team members contribute in their role but that they can also contribute outside their official role if they have relevant knowledge. Often this is the case.

Succeeding at speed

The implementation of successful Control Systems depends on having accurate detailed information about the process under control. If the detailed process design could be completed before the control system is started then there would not be a problem. However, it is in the nature of fast track projects that changes occur, information arrives late and detail continues to develop late in the detailed engineering phase.

For example:

Development of P&ID's still continuing into the detailed design.

Valves and instruments get added during Hazops

Changes of scope removing and adding equipment

Details of process packages become available late in the detailed design

The users who are going to have to run the plant do not get involved until late, and then they wish to make changes and improvements to what they find.

On fast track projects the sheer speed of the project development forces the Control Systems programming activity into a short time period. That is only possible if the information is present,

Consequently in order to provide the systems on time the development process must support

Rapid progress

The ability to cope with frequent change.

A data store that can be added to as soon as the information becomes available

The means to identify information and its validity - for example its release status.

Key points of the methodology that results in fast progress are:

The Functional Design is detailed, reviewed and approved before code is fully implemented.

The design, review and implementation activities are carried out almost concurrently. This is of course phased so that the activities are serial for each small part of the project, such as one Unit.

The closeness of the modellers to the Users and experts. Expertise and detailed requirements are captured in developing the model before code is generated. It is far quicker to modify a model than it is to change actual code.

The proximity of the modellers to the programmers. This greatly reduces the time spent by for example the programmers trying to understand what was meant.

The Model forms the basis of the testing and validation.

Find out more

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- skilled staff to help on your project

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