CM 3310 Process Control

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Lecture 19

Charts and Diagrams used in Automation

a) Plant/Process Description
   - P & ID (Piping and Instrumentation Diagram)
   - PFD (Process Flow Diagram)
   - BFD (Block Flow Diagram)

b) Signal/Transfer Function Block Diagrams (for Process Contol)

c) Entity/Relations Diagram

d) Sequential Function Charts

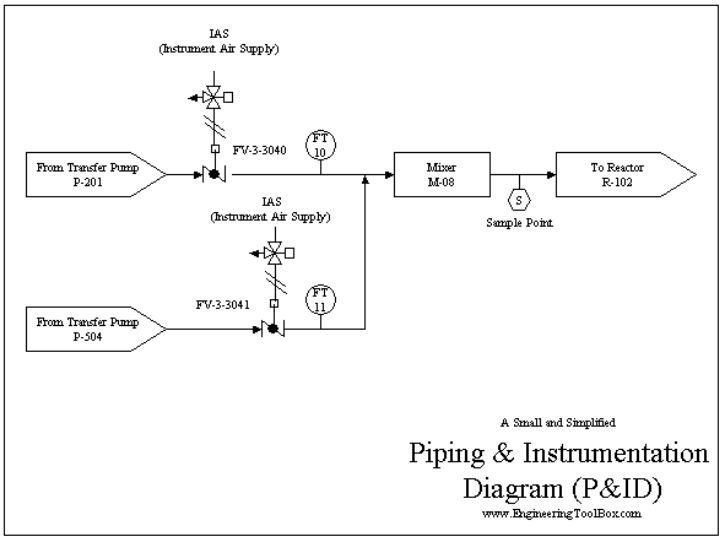
e) Ladder Logic Programs

1. P & ID (Piping and Instrumentation Diagram), PFD (Process Flow Diagram) and BFD (Block Flow Diagram)

(following notes based on http://www.engineeringtoolbox.com/)

"A P&ID should include:

- Instrumentation and designations
- Mechanical equipment with names and numbers
- All valves and their identifications
- Process piping, sizes and identification
- Miscellaneous - vents, drains, special fittings, sampling lines, reducers, increasers and swagers
- Permanent start-up and flush lines
- Flow directions
- Interconnections references
- Control inputs and outputs, interlocks
- Interfaces for class changes
- Seismic category
- Quality level
- Annunciation inputs
- Computer control system input
- Vendor and contractor interfaces
- Identification of components and subsystems delivered by others
- Intended physical sequence of the equipment"



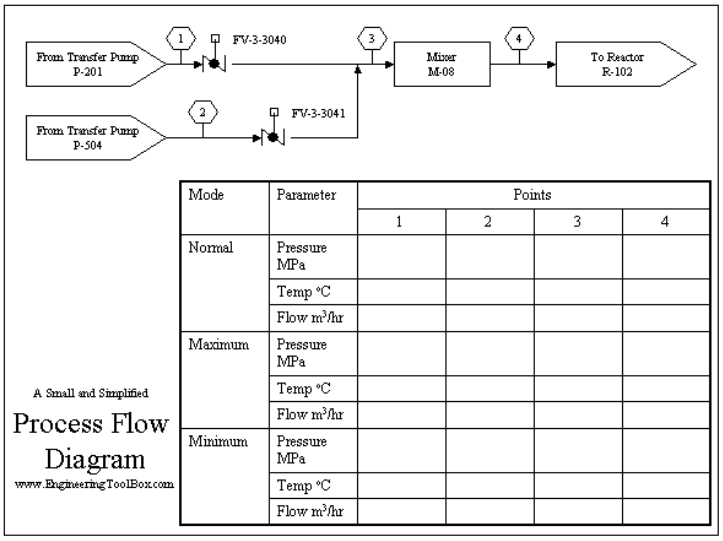
For ISA standard designations, see

https://en.wikipedia.org/wiki/Piping_and_instrumentation_diagram

"**A <u>Process Flow Diagram</u> - PFD** - (or System Flow Diagram - SFD) shows the **relationships** between the major components in the system. PFD also tabulate process design values for the components in different operating modes, typical minimum, normal and maximum. A PFD does not show minor components, piping systems, piping ratings and designations.

A PFD should include:

- Process Piping
- Major equipment symbols, names and identification numbers
- Control, valves and valves that affect operation of the system
- Interconnection with other systems
- Major bypass and recirculation lines
- System ratings and operational values as minimum, normal and maximum flow, temperature and pressure
- Composition of fluids"

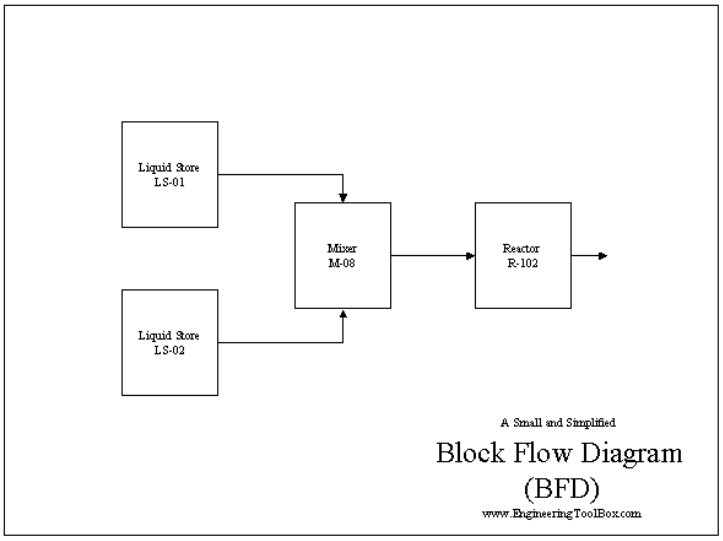


Mode	Parameter	Points			
		1	2	3	4
Normal	Pressure MPa				
	Temp °C				
	Flow m^3/hr				
Maximum	Pressure MPa				
	Temp °C				
	Flow m^3/hr				
Minimum	Pressure MPa				
	Temp °C				
	Flow m^3/hr				

BFD (Block Flow Diagram): "The block or rectangles used represent a unit operation. The blocks are connected by straight lines which represent the process flow streams which flow between the units. These process flow streams may be mixtures of liquids, gases and solids flowing in pipes or ducts, or solids being carried on a conveyor belt."

"… a number of rules should be followed:

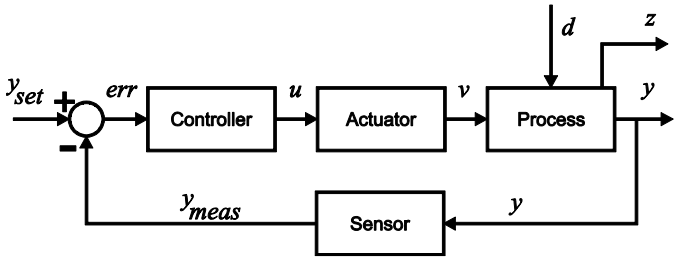
- unit operations such as mixers, separators, reactors, distillation columns and heat exchangers are usually denoted by a simple block or rectangle.
- groups of unit operations may be noted by a single block or rectangle.
- process flow streams flowing into and out of the blocks are represented by neatly drawn straight lines. These lines should either be horizontal or vertical.
- the direction of flow of each of the process flow streams must be clearly indicated by arrows.
- flow streams should be numbered sequentially in a logical order.
- unit operations (i.e., blocks) should be labeled.
- where possible the diagram should be arranged so that the process material flows from left to right, with upstream units on the left and downstream units on the right."



2. Signal/Transfer Function Block Diagrams (for Process Contol)

- Used for design of control system
- Basic Components
  a) Processes that transform an input signal to an output signal are represented by boxes
  b) Signals transmitted are represented by arrows to indicate flow
  c) Branching points : signals are split but assumed to yield the same information in all branches
  d) Summing junction : signals are added (or subtracted as indicated) prior to releasing information

Typical Feedback Loop:



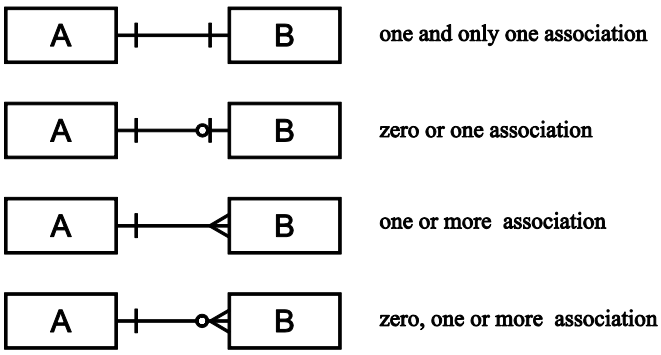
where

$$y_{set} = set\ point$$
$$y = controlled\ variable$$
$$y_{meas} = measured\ signal$$
$$err = error\ signal$$
$$u = controller\ output\ (decision\ variable)$$
$$v = actuator\ signal\ (\ manipulated\ variable)$$
$$d = disturbance$$
$$z = uncontrolled\ variable$$

3. Entity-Relation Diagrams

(based on http://www.batchcontrol.com/s88/e-r_diagrams.shtml)

"**Entity-Relationship (E-R) diagrams** are a common way of describing objects in a system (entities) and how they correlate to one another (relationships)."



Remark: we will use these when we explore various models used in S88

4. Sequential Function Charts (SFC)

- Often used for recipes or modern PLC programs
- Components:
  a) Initial Step : double-lined rectangular box
  b) Termination : multiple horizontal segments
  c) Process Steps : rectangular boxes
  d) Transitions : short horizontal segment (yielding a cross)
  e) "OR" Condition → Choice Steps : pair of long single horizontal header (divergence) and bottom (convergence) line
  f) "AND" Condition → Parallel Synchronous Steps : pair of long double horizontal header (divergence) and bottom (convergence) line
  g) Tokens : Bullets (or color change) indicates step is active

Note: The transition conditions (aka "receptivities") could include conditions of process variables ($T > 130°C$), state of other processes (agitation step finished), timing events (1 hr has elapsed), override control and other safety considerations.

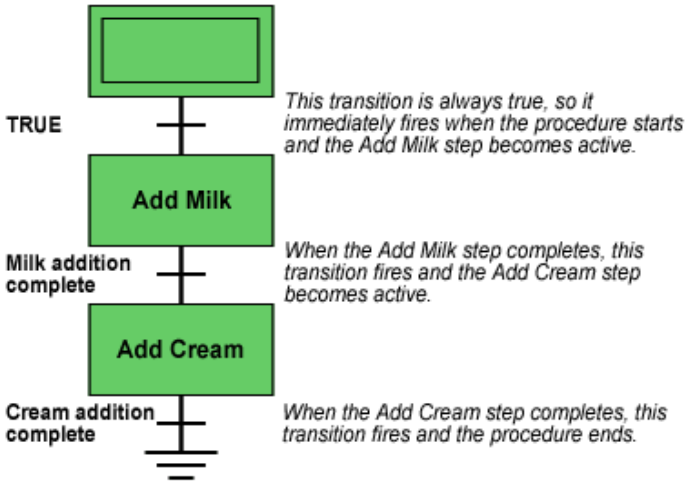
"***Firing***" Rule:

a) A transition condition require that the preceding process steps are active (all steps involved in AND lines need to be active)
b) Once the conditions are met, the transition deactivates the preceding steps and then activates the subsequent steps

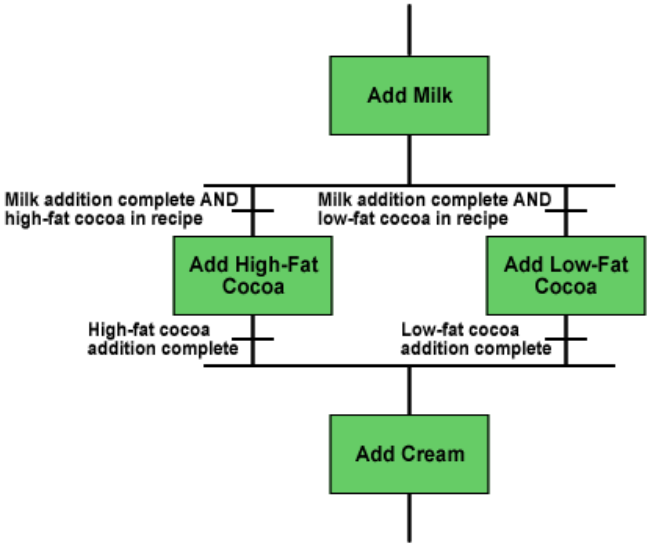
Note: Tokens are moved (or colors changed) to signify active or inactive process steps

Examples from http://www.batchcontrol.com/s88/sfcs.shtml :

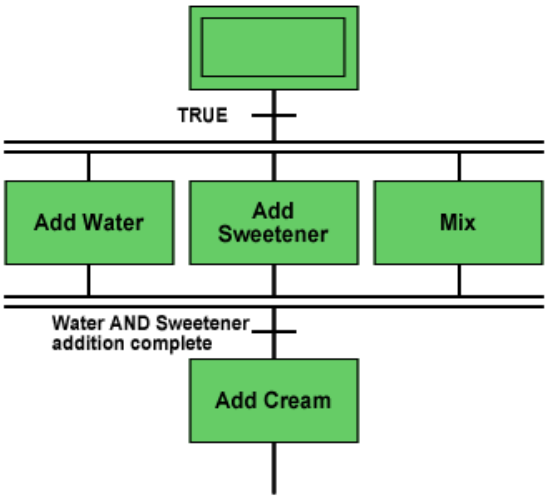
a) Simple sequential steps.



b) Divergent Paths (conditions preferably allow for exclusive activation).



c) Simulatneous (Synchronous) Paths



d) Skipping Steps