Typical process units control

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Outline

- ✓ Chemical Reactors
- ✓ Distillation columns
- ✓ Boilers
- ✓ Compressors
- ✓ Control structures design methodology
- ✓ Examples

Reactor control

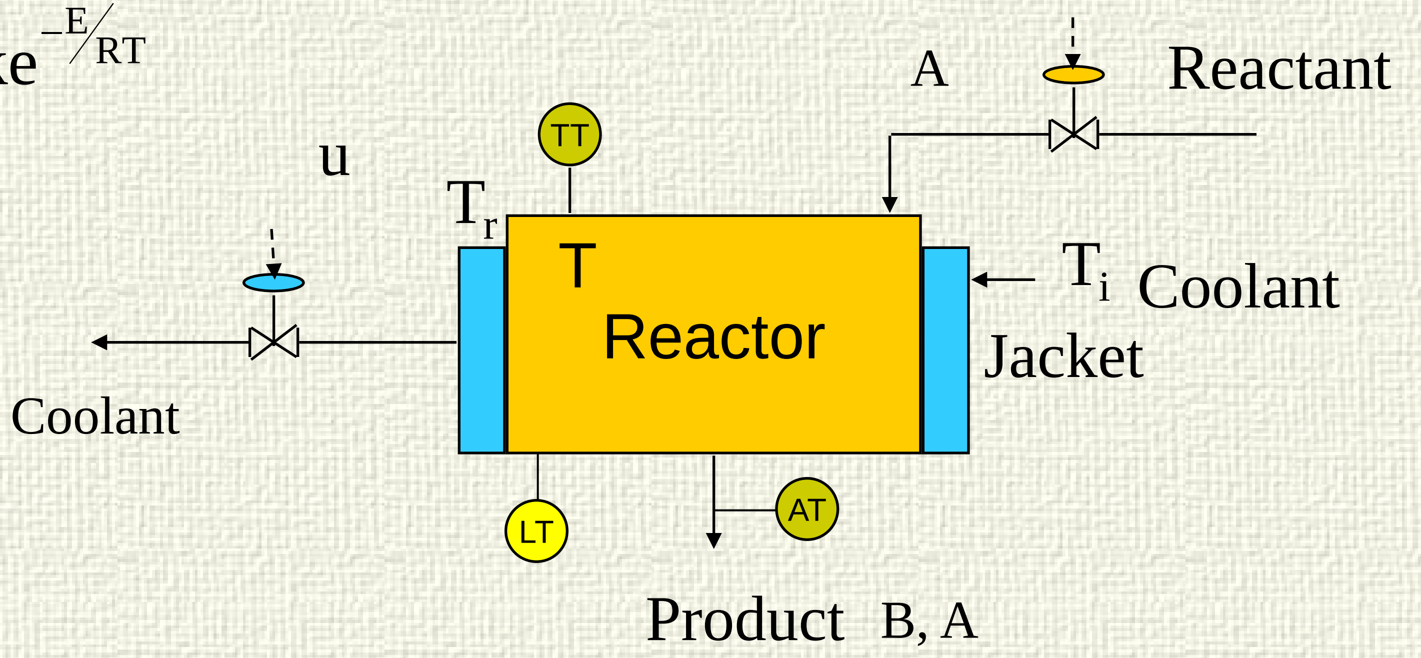
$$A \rightarrow B$$

$$c_A = (1-x)c_{Ai}$$

$$0 = Fc_{Ai} - Fc_A - Vke^{-E/RT}c_A \text{ using conversion x :}$$

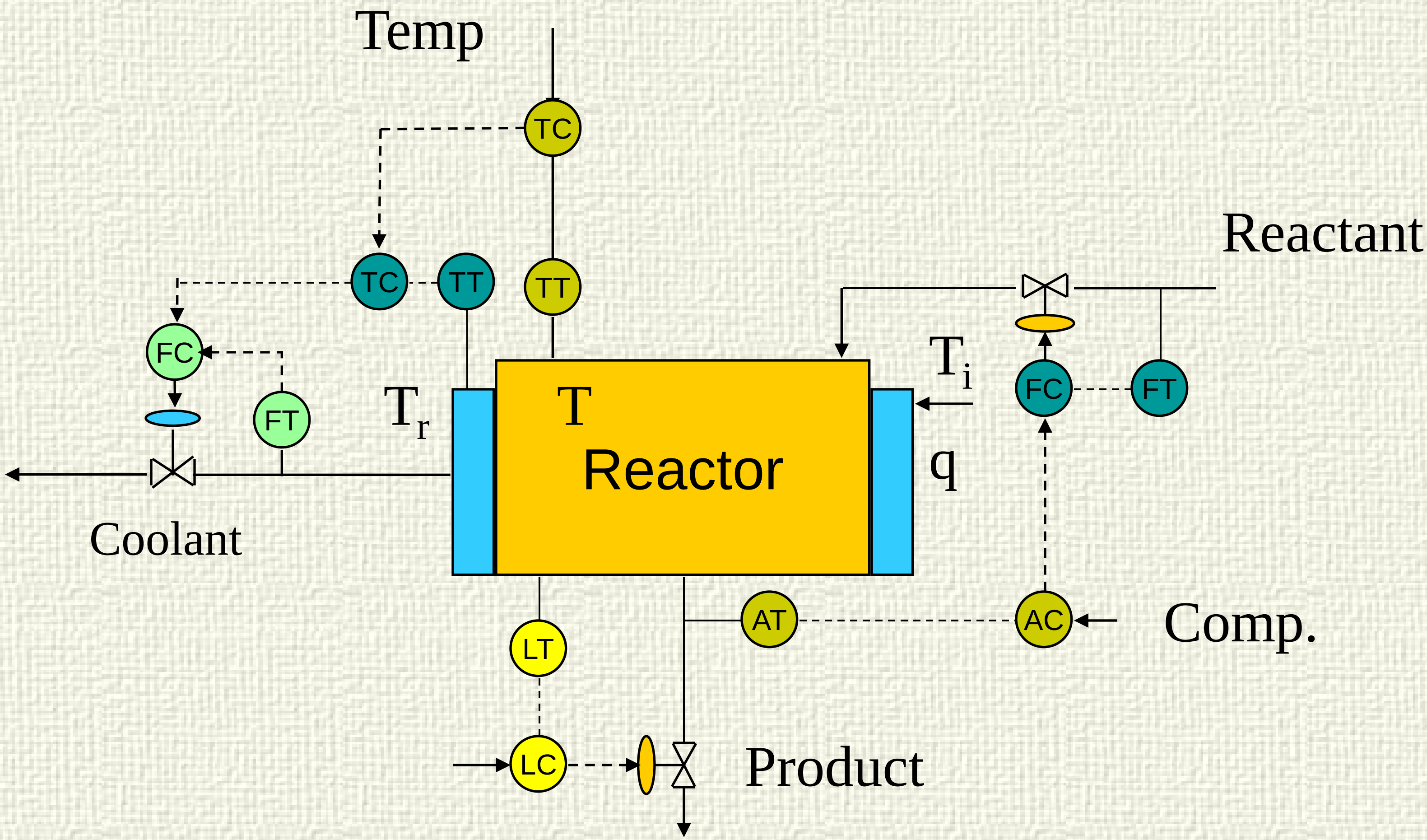
$$0 = xF - Vke^{-E/RT}(1-x)$$

$$\frac{x}{1-x} = \frac{V}{F}ke^{-E/RT}$$

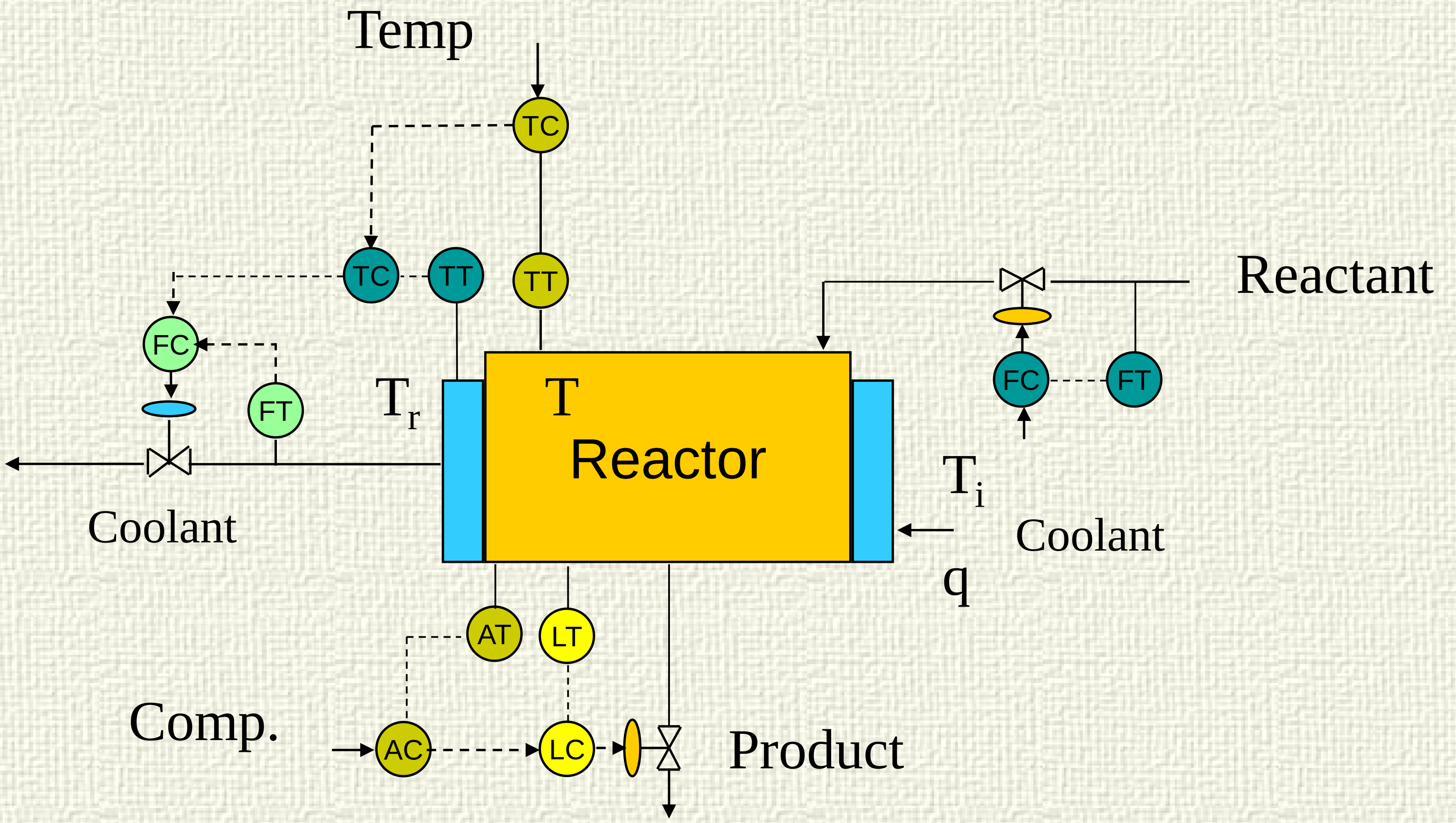


Conversion can be controlled either with the retention time or temperature

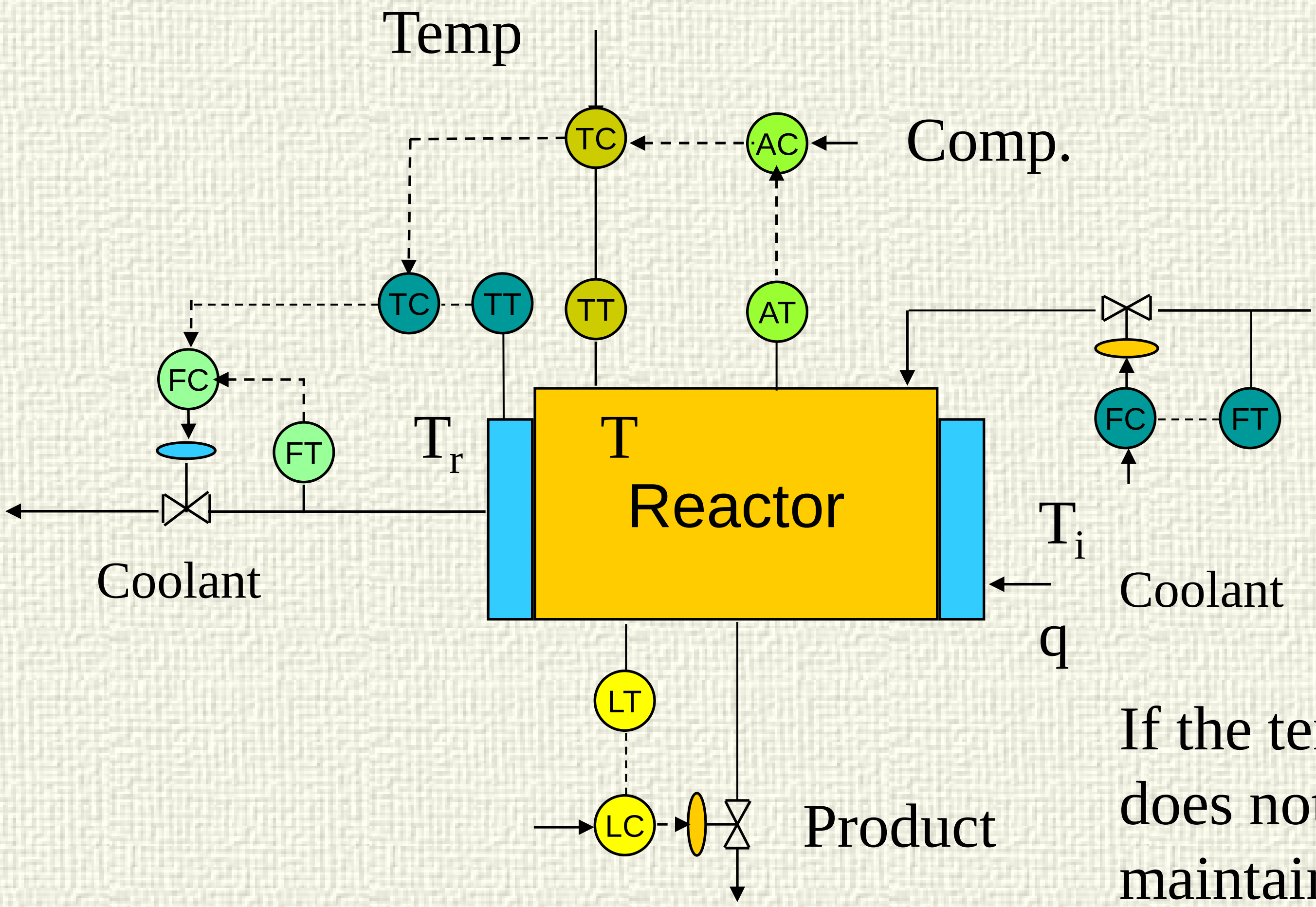
Reactor Control



Reactor Control



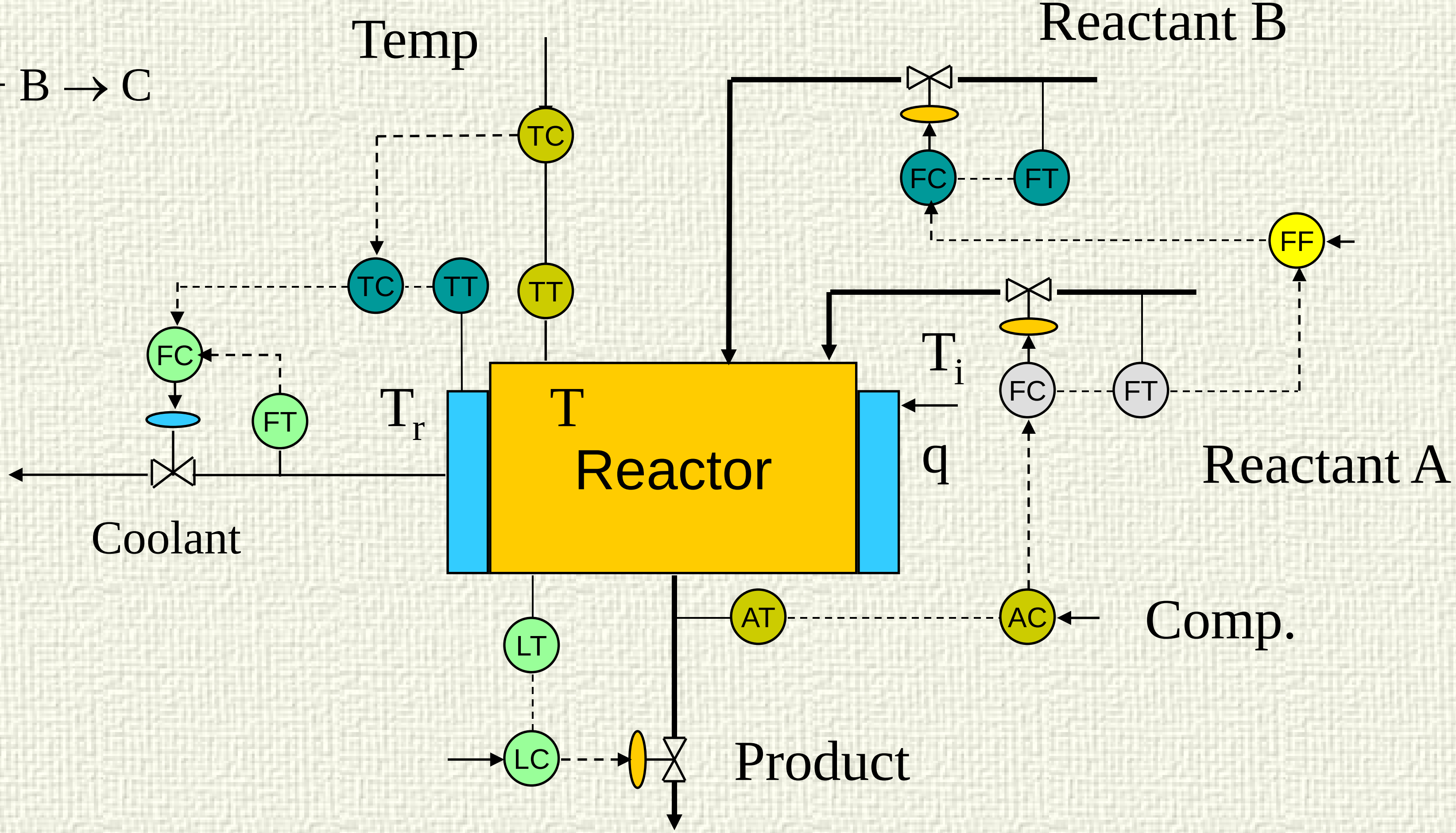
Reactor Control



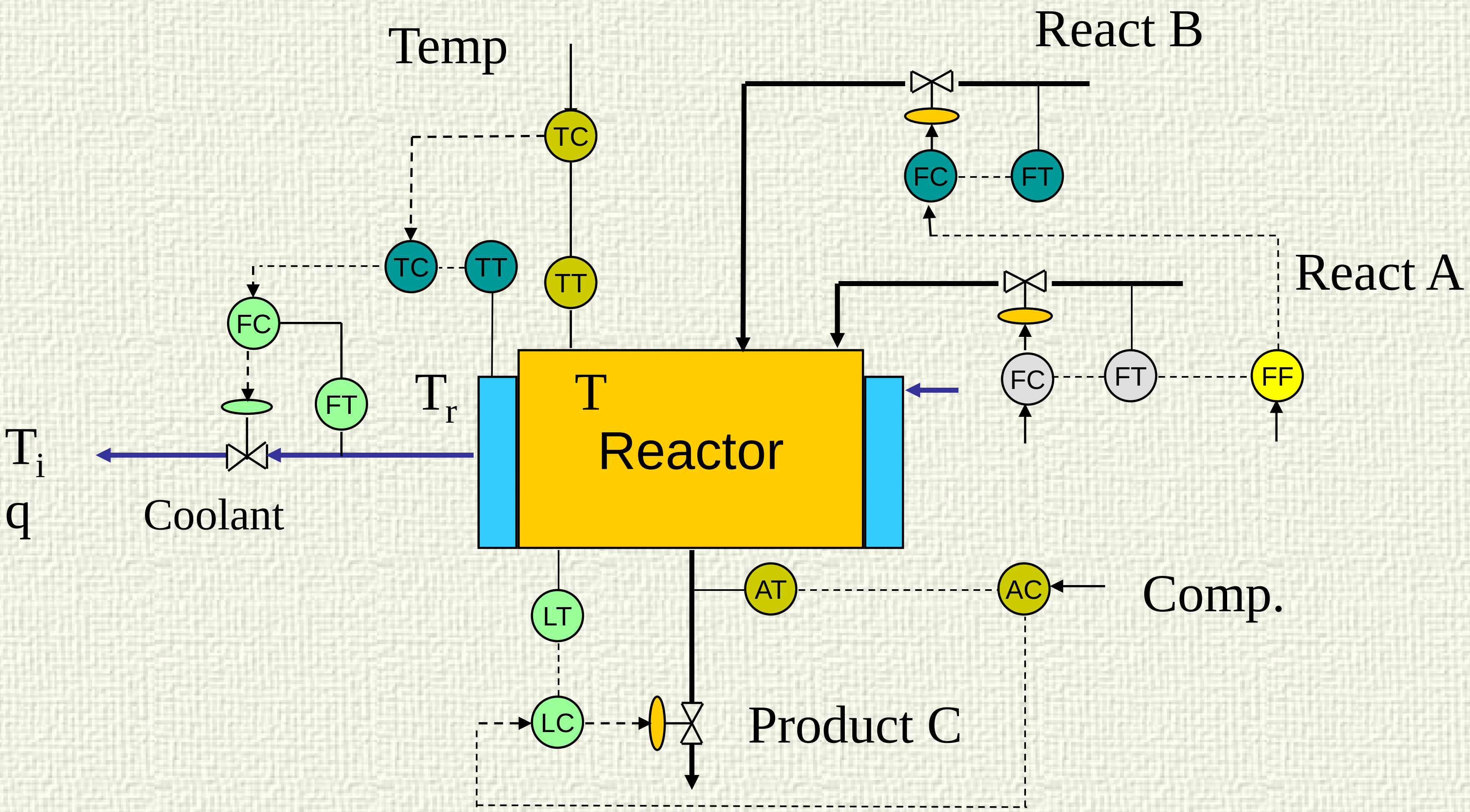
If the temperature does not need to be maintained in a fix value

Reactor Control

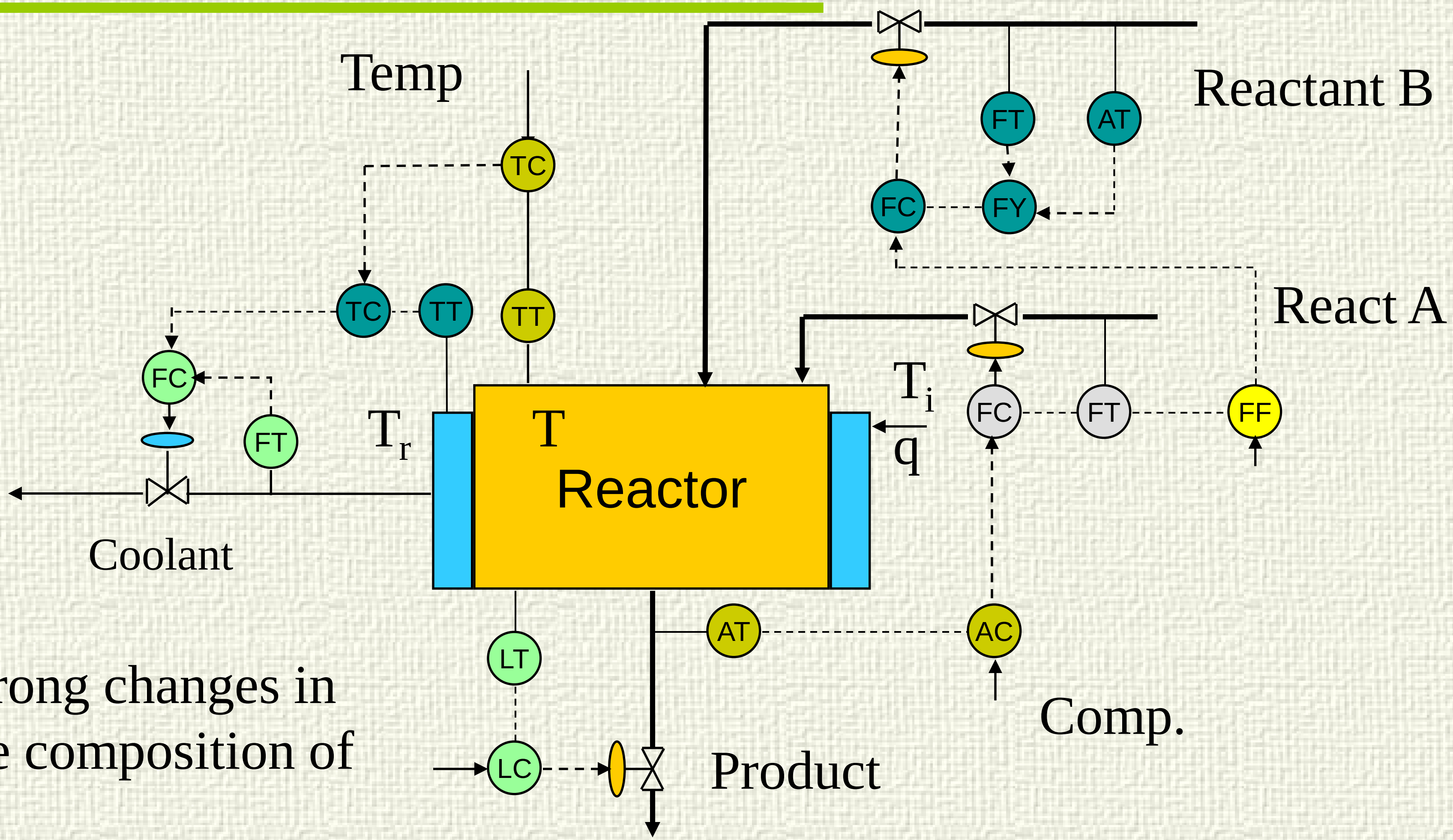
$A + B \rightarrow C$



Reactor control

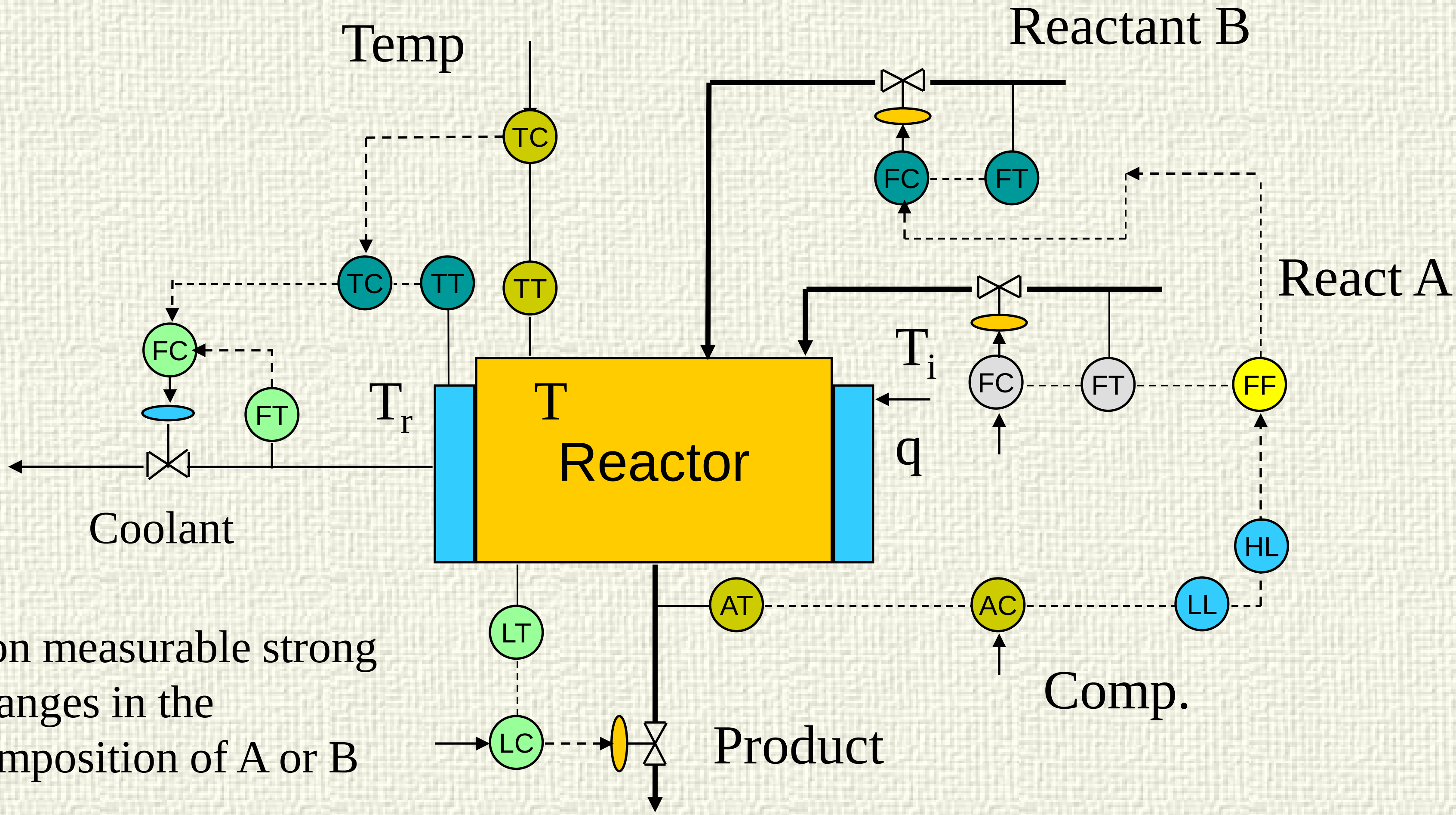


Reactor Control



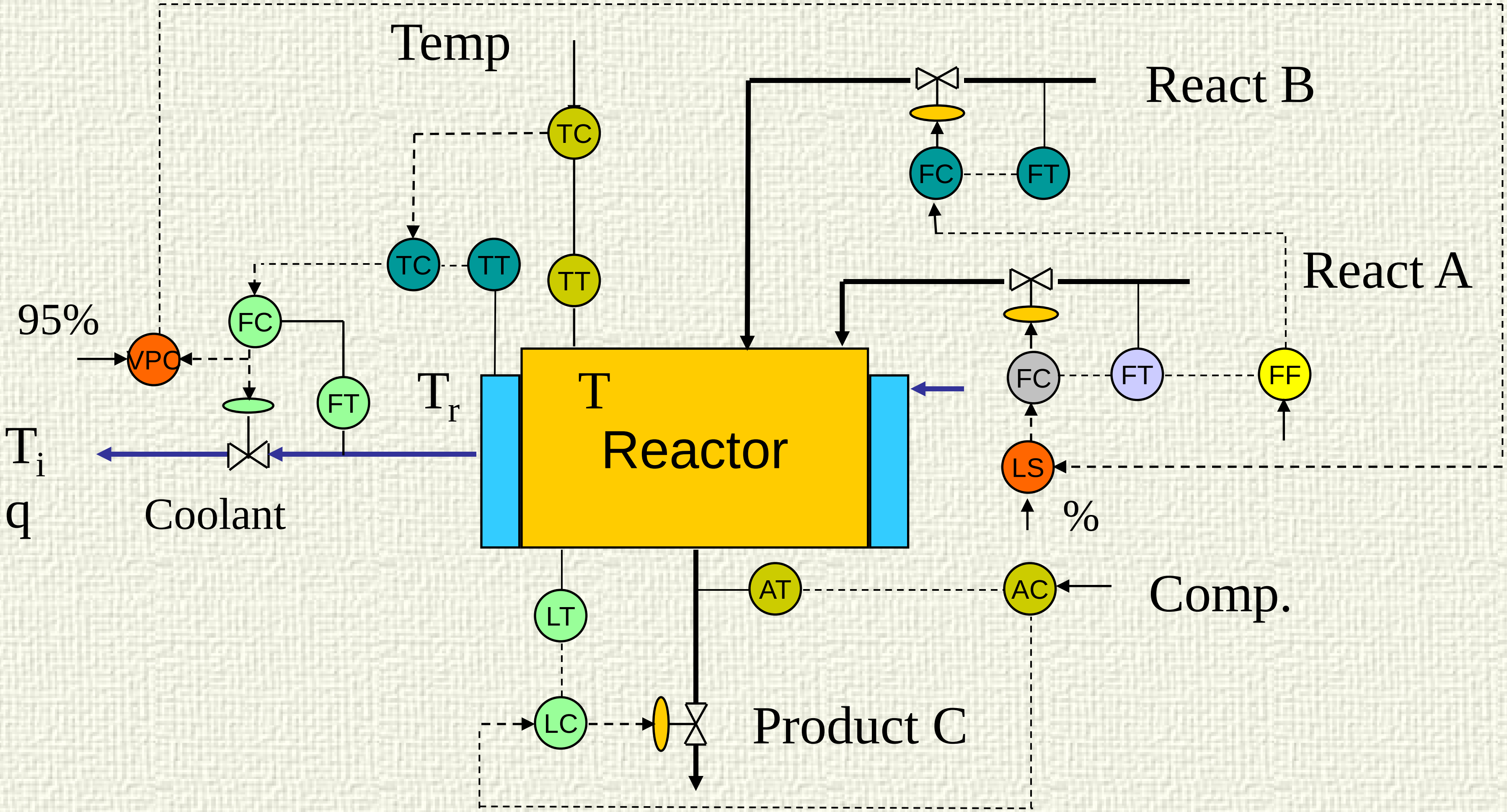
Strong changes in the composition of B

Reactor Control

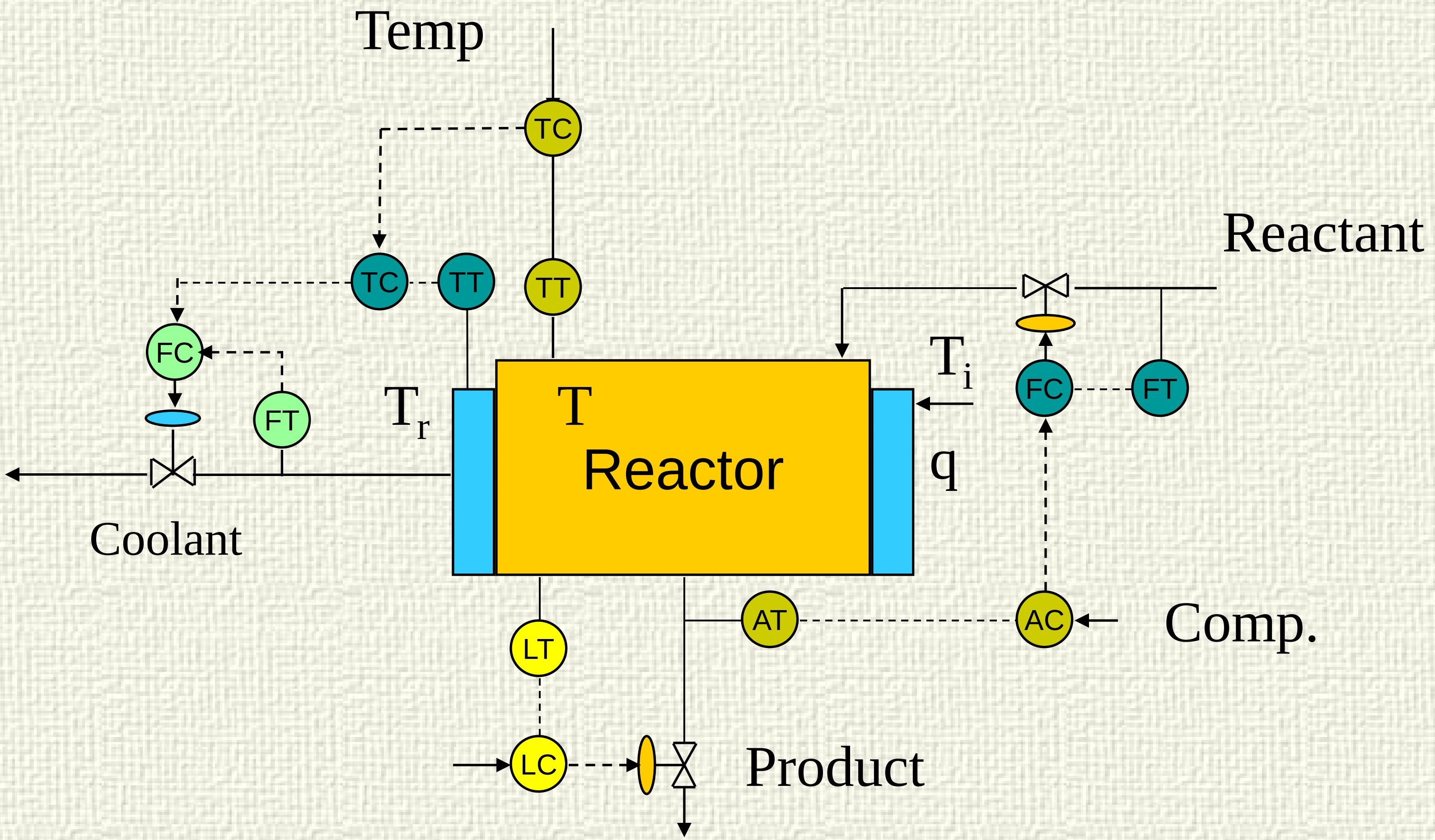


Non measurable strong changes in the composition of A or B

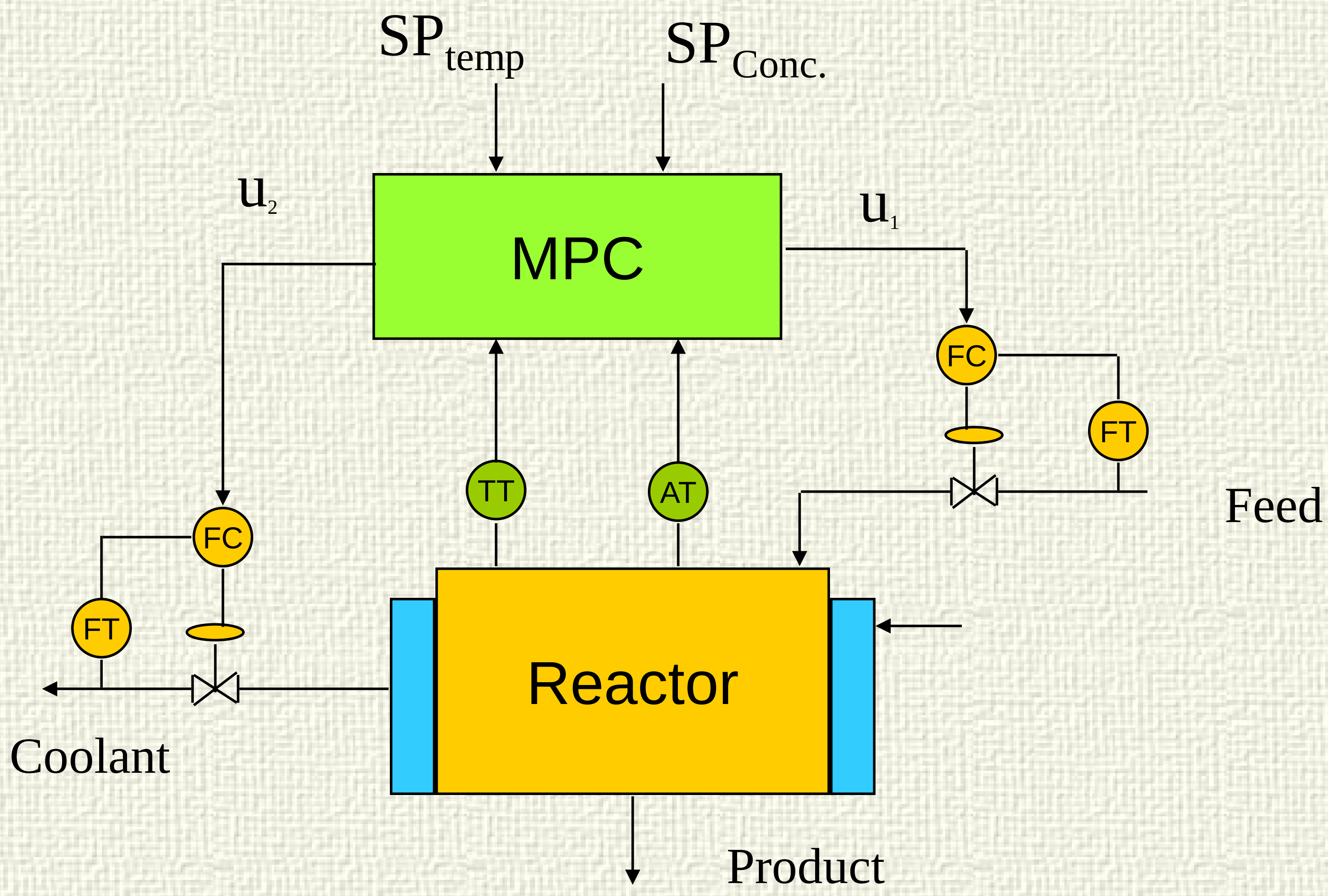
Reactor: constraining production



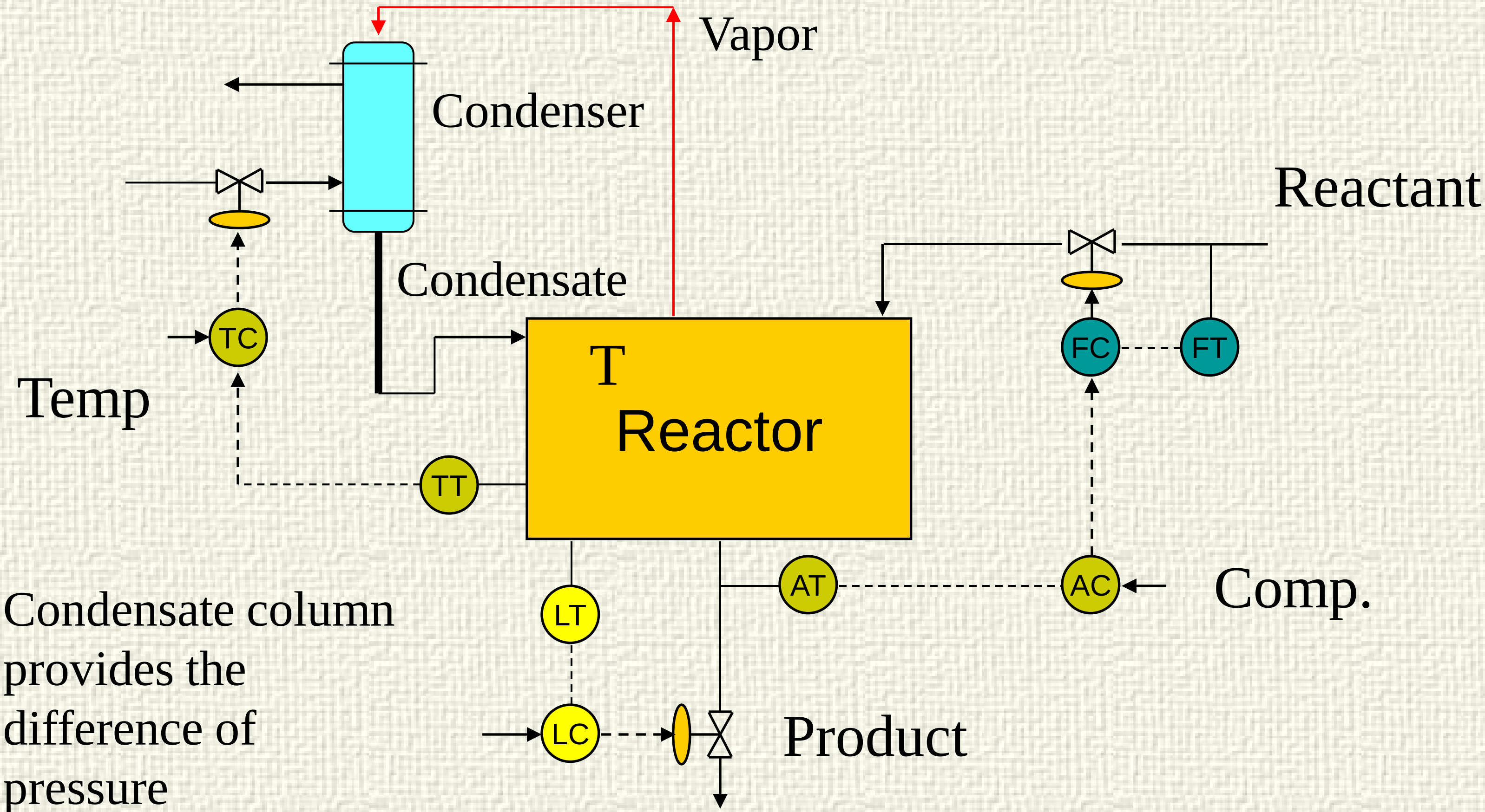
Loop interaction



Multivariable control, MPC

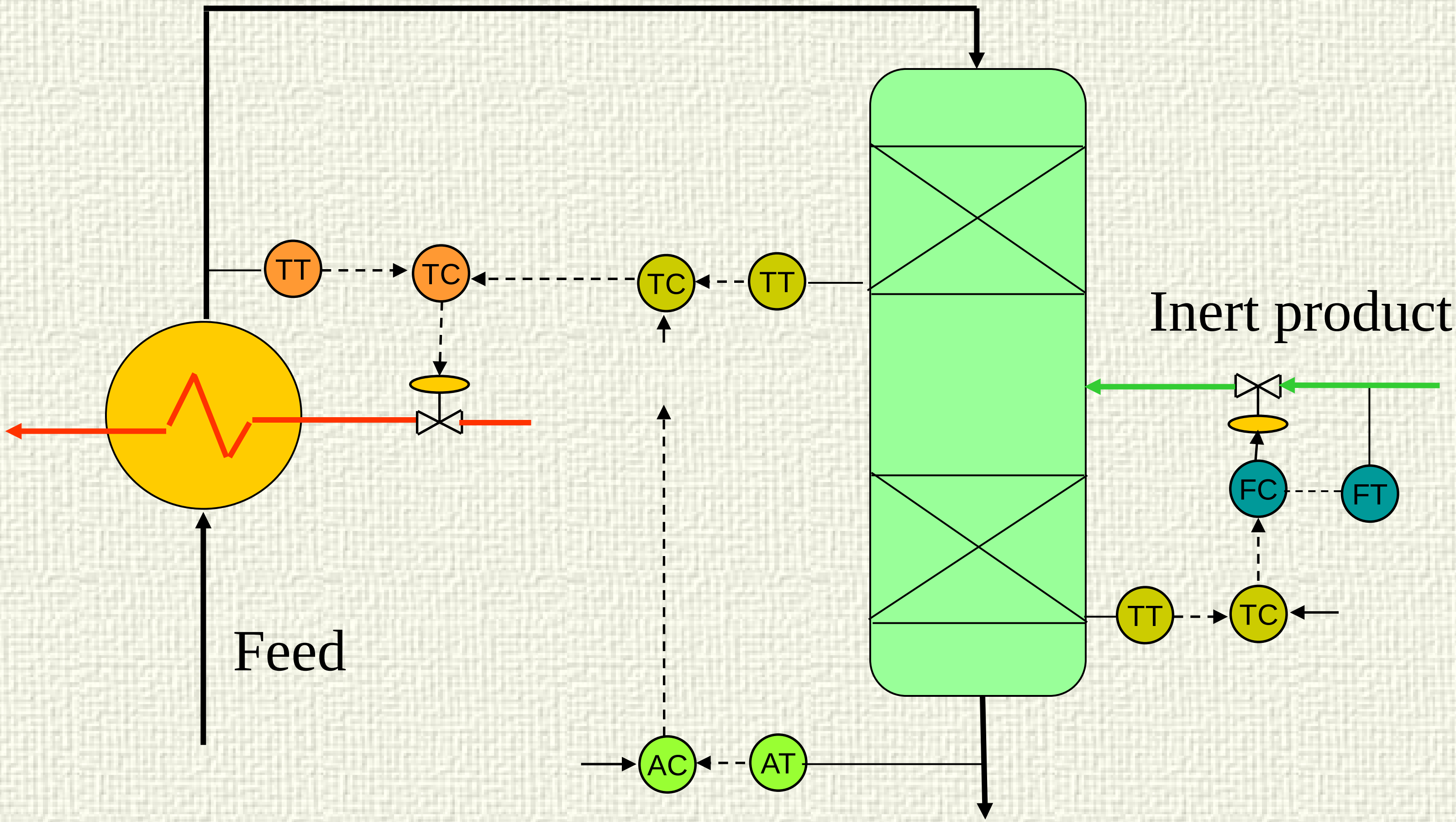


Autorefrigeration

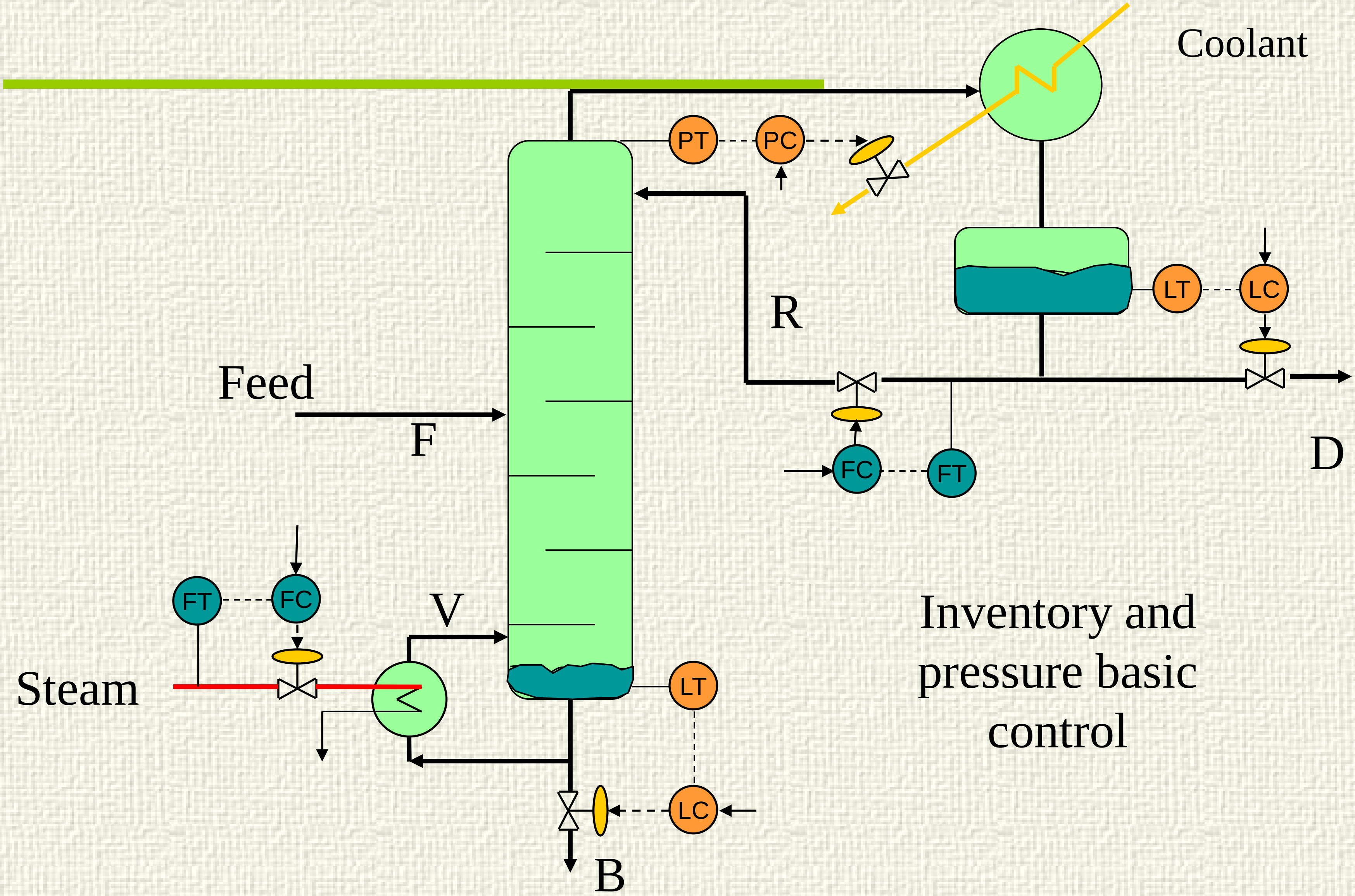


Condensate column provides the difference of pressure

Bed reactor temperature control

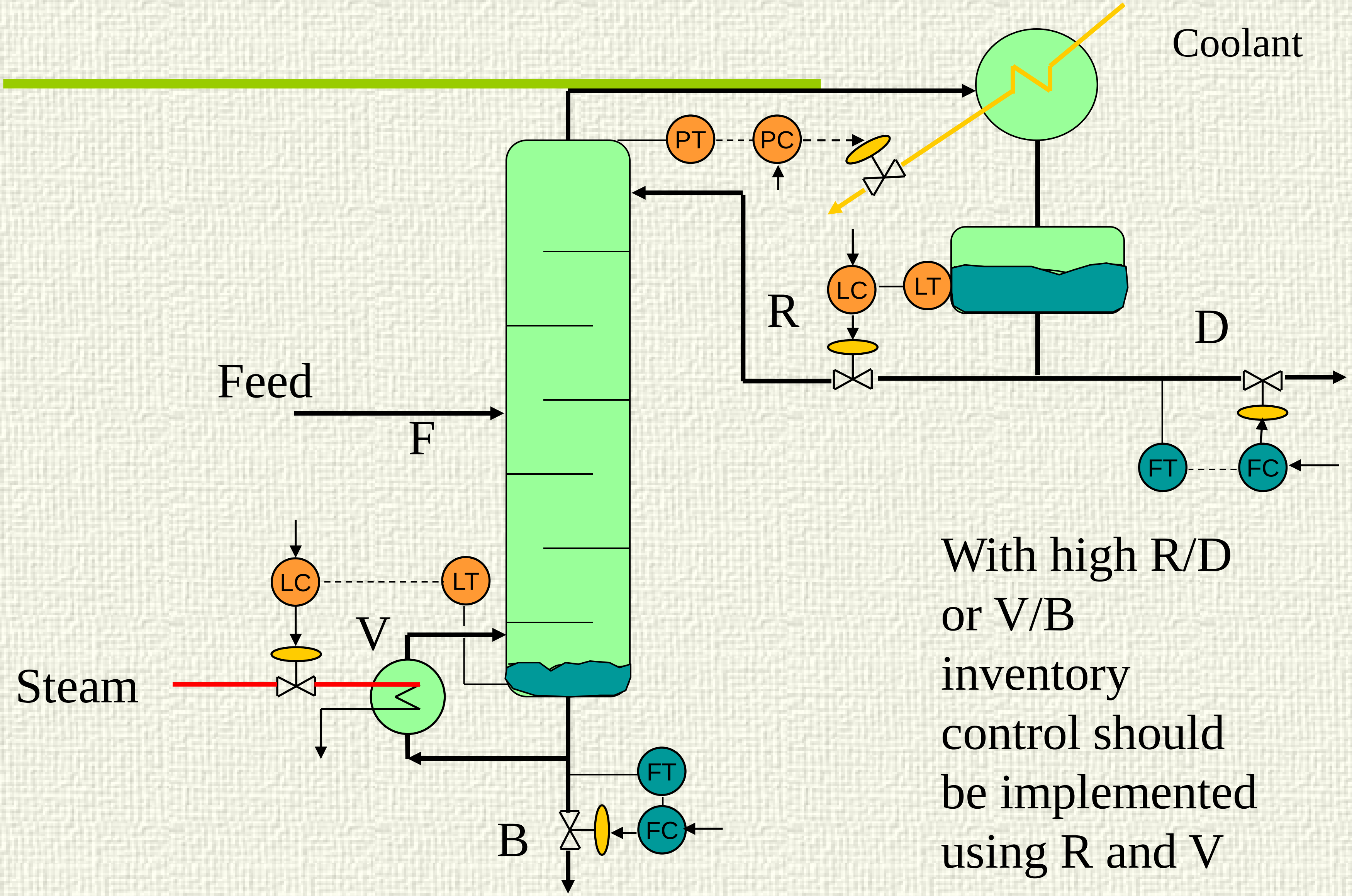


Destillation Column



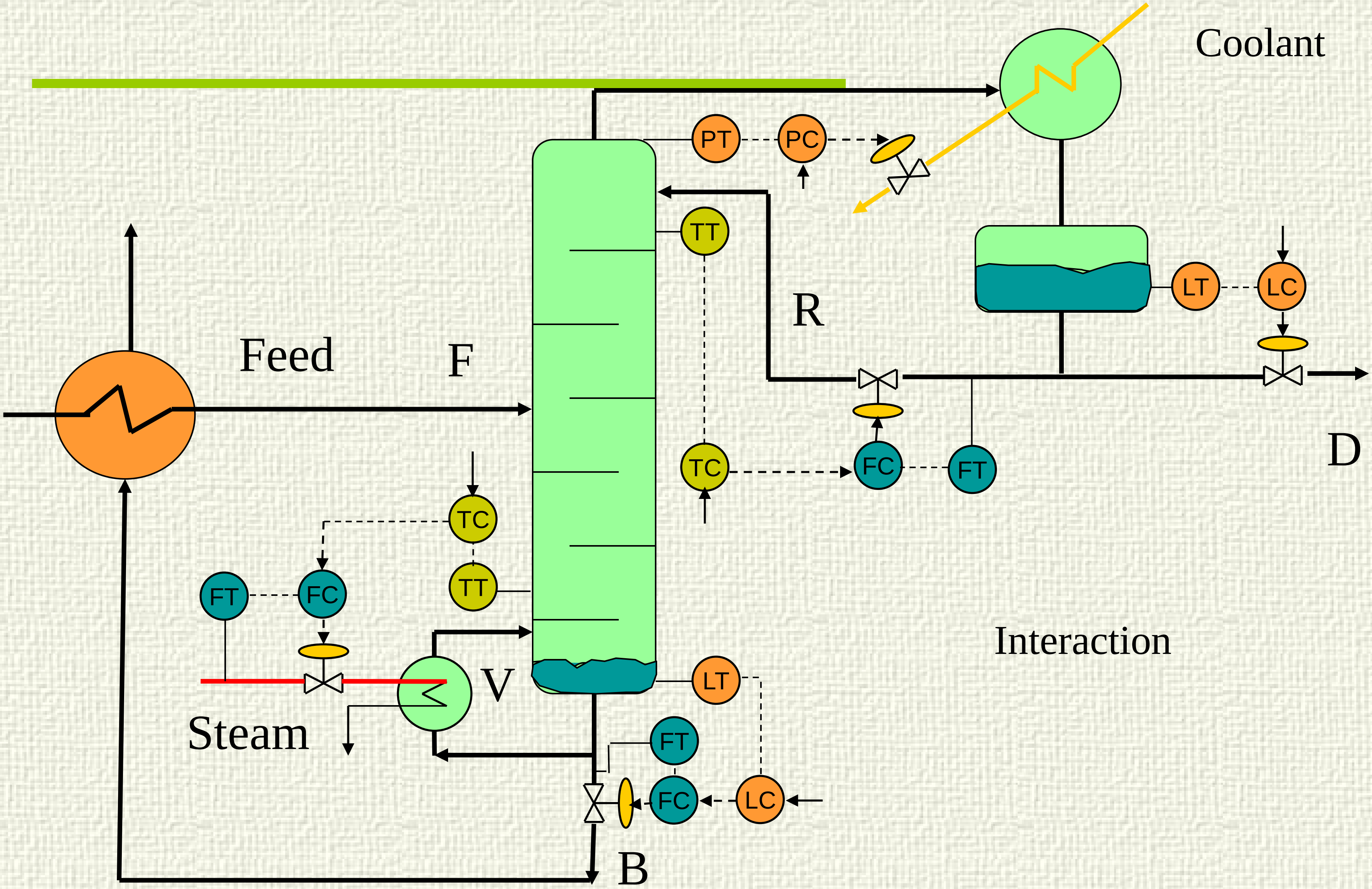
Inventory and pressure basic control

Alternatives

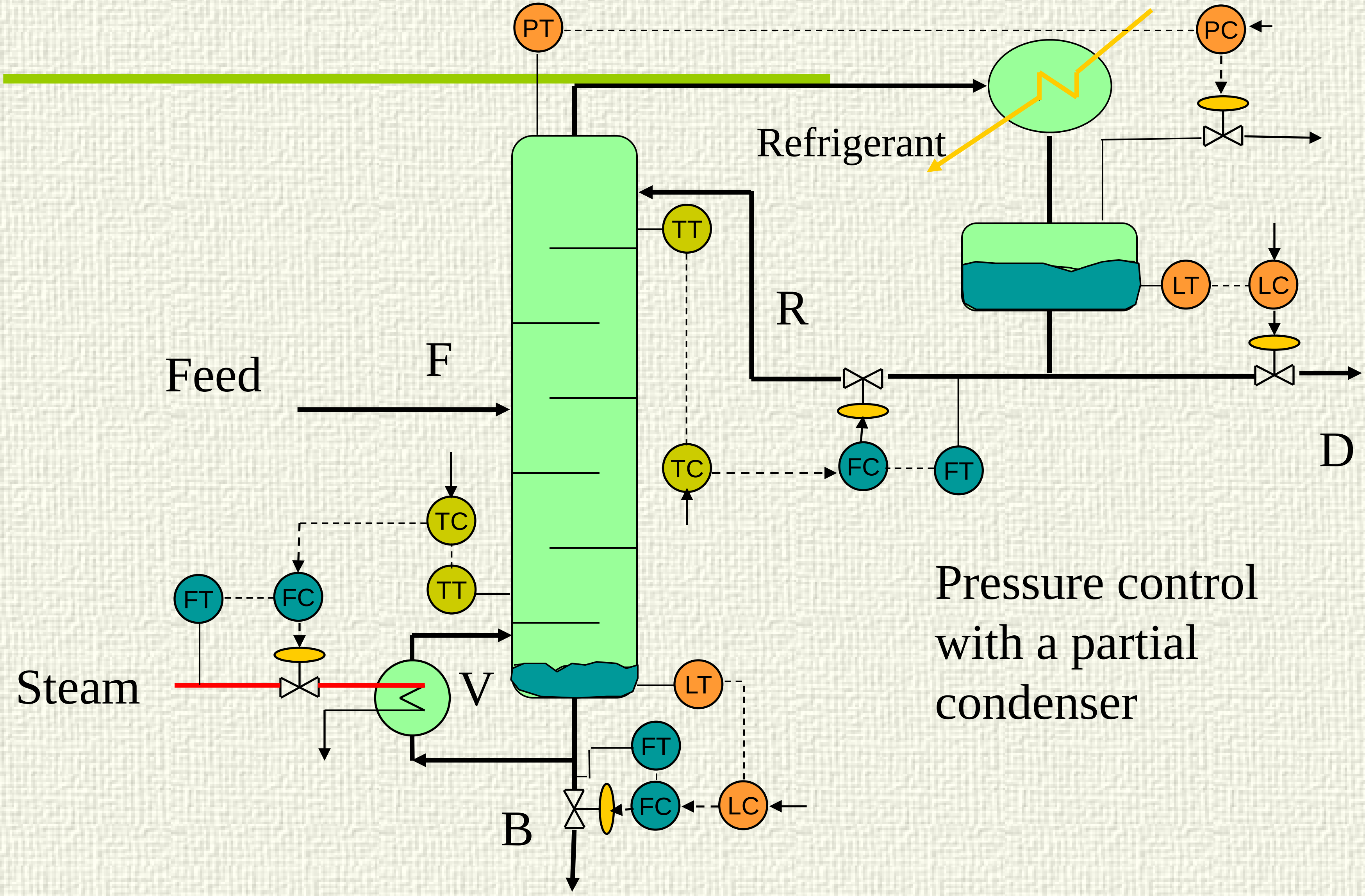


With high R/D or V/B inventory control should be implemented using R and V

Destillation Column

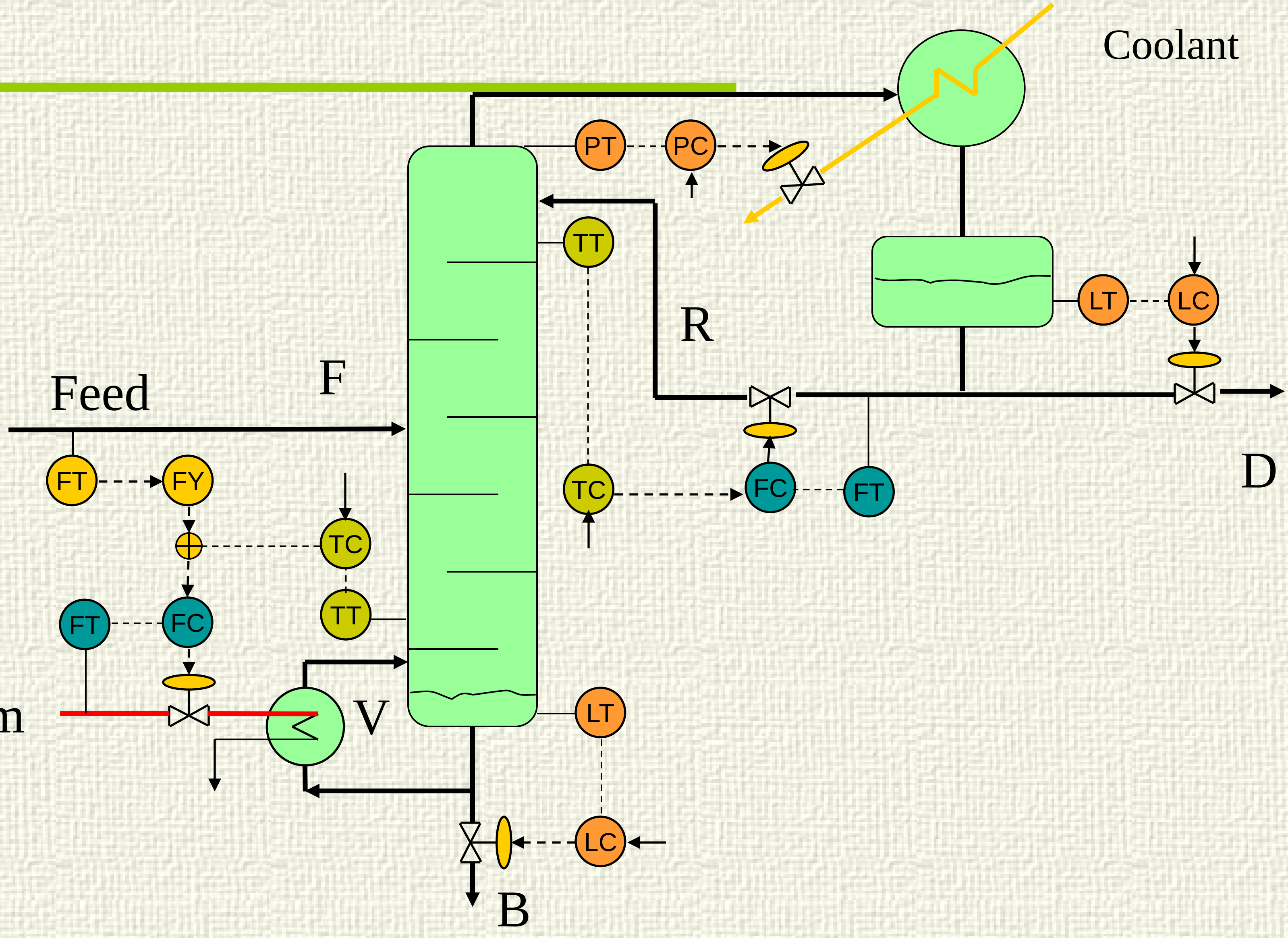


Destillation column

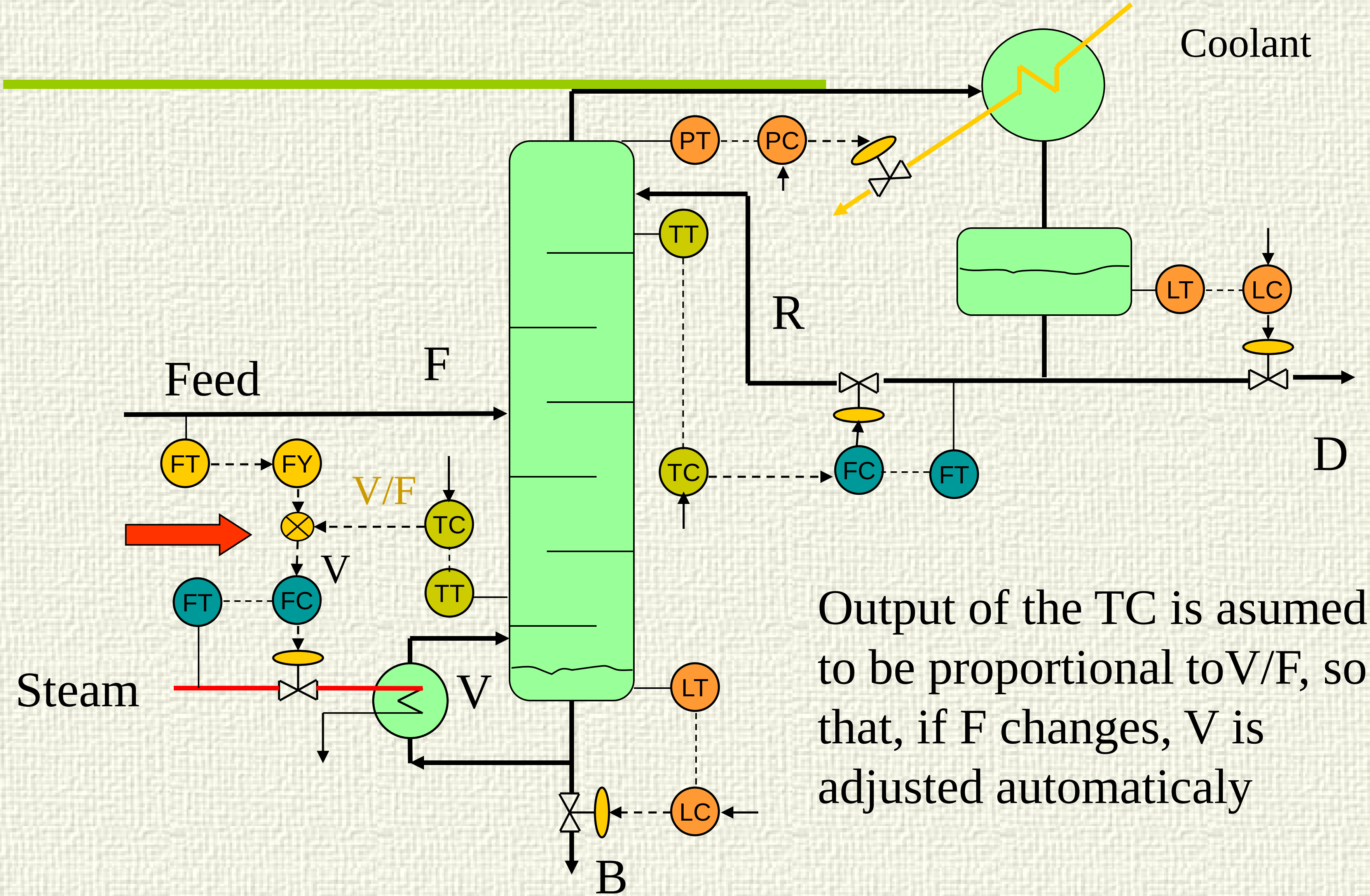


Pressure control with a partial condenser

Feedforward F

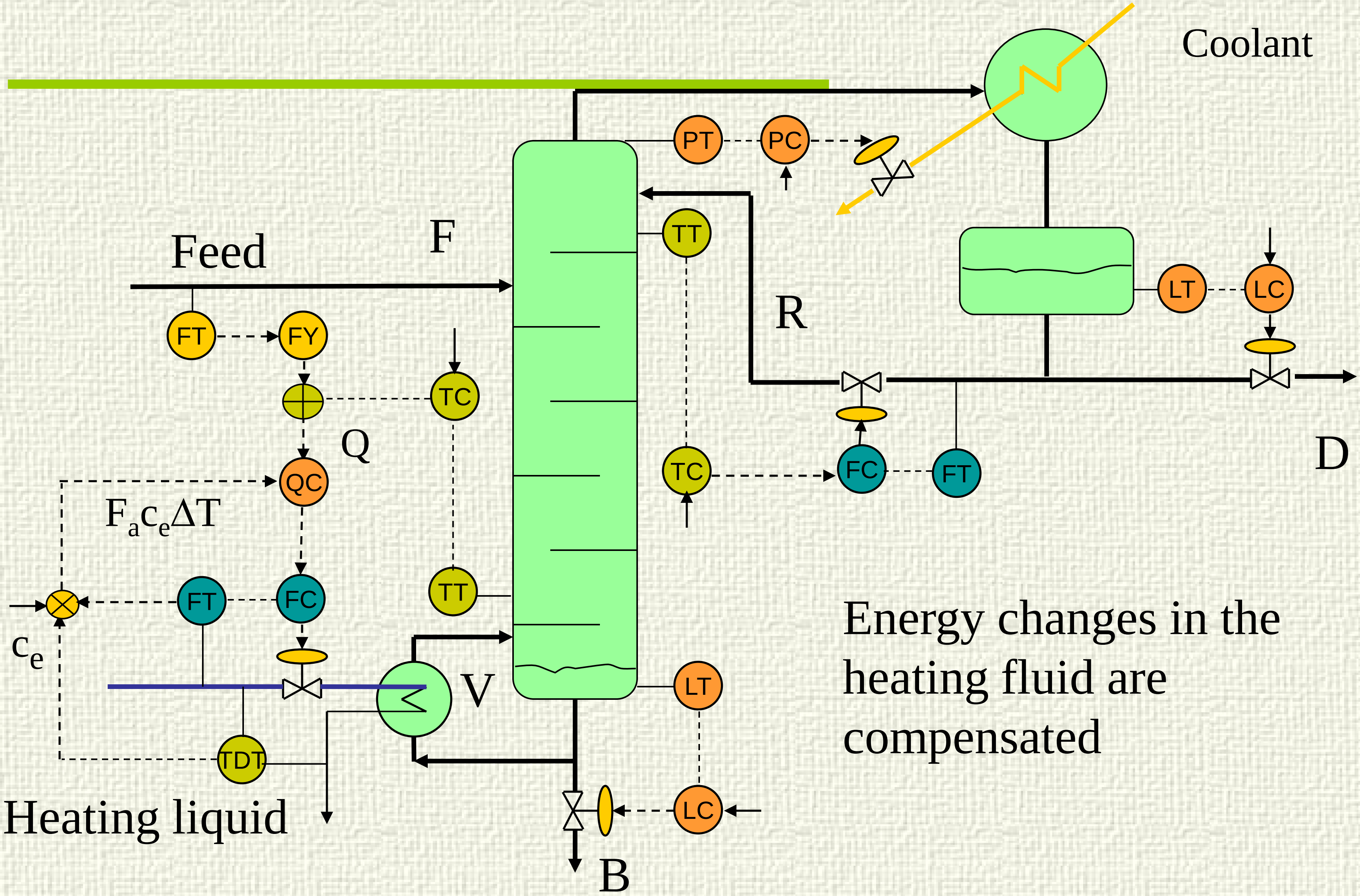


Feedforward V/F



Output of the TC is asumed to be proportional toV/F, so that, if F changes, V is adjusted automaticaly

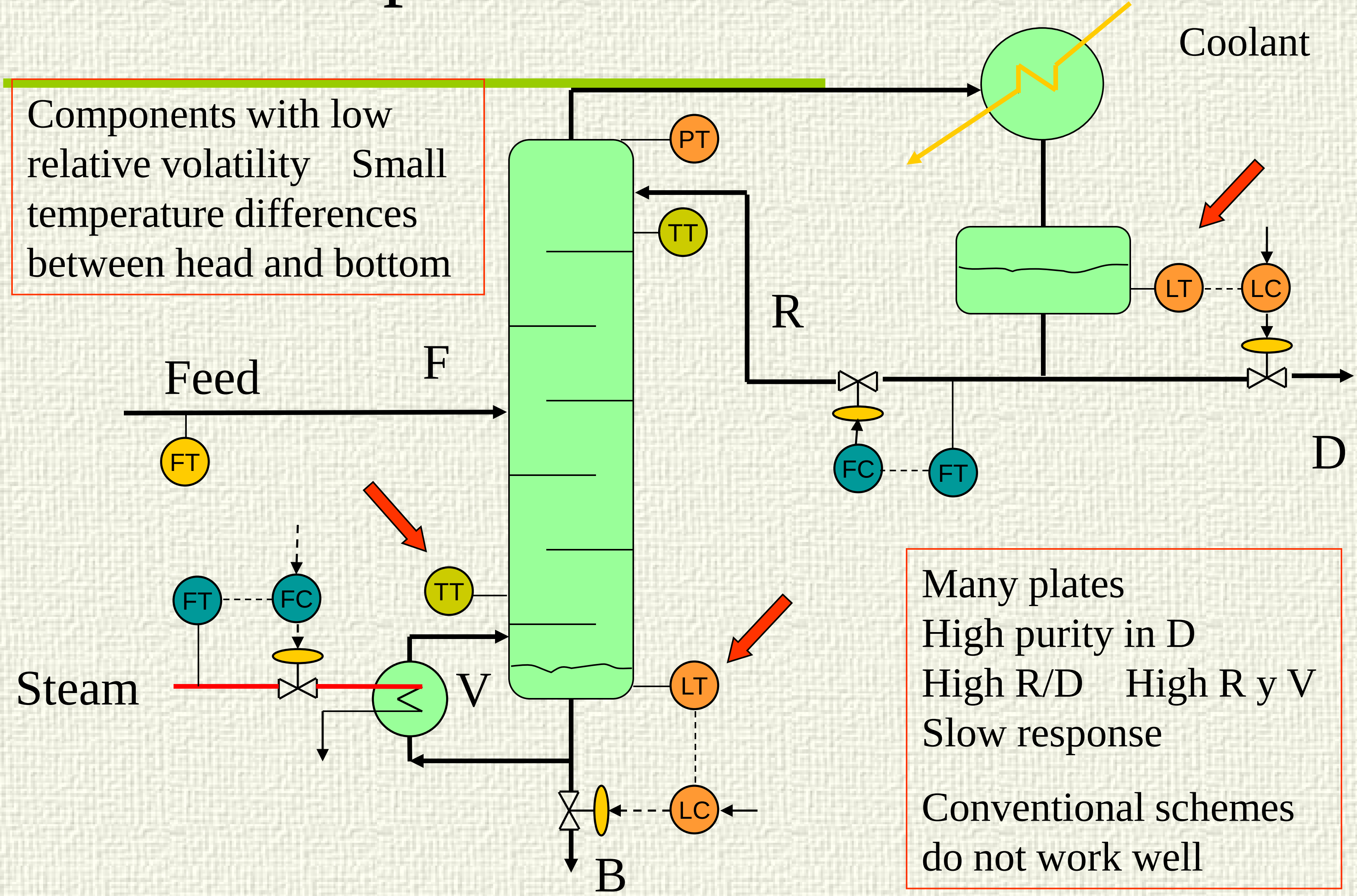
Feedforward + cascade



Energy changes in the heating fluid are compensated

Superfractionator column

Components with low relative volatility   Small temperature differences between head and bottom

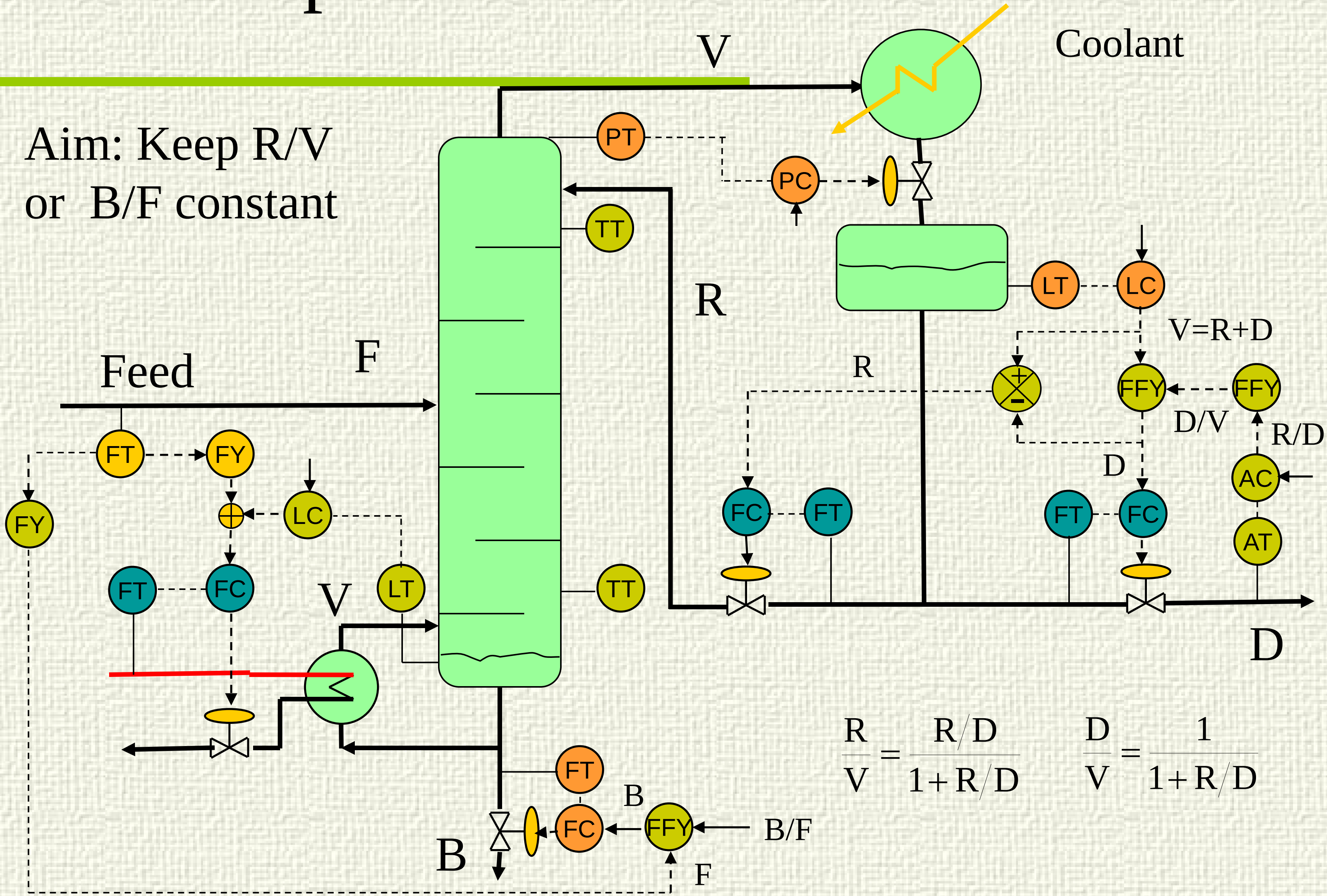


Many plates
High purity in D
High R/D   High R y V
Slow response

Conventional schemes do not work well

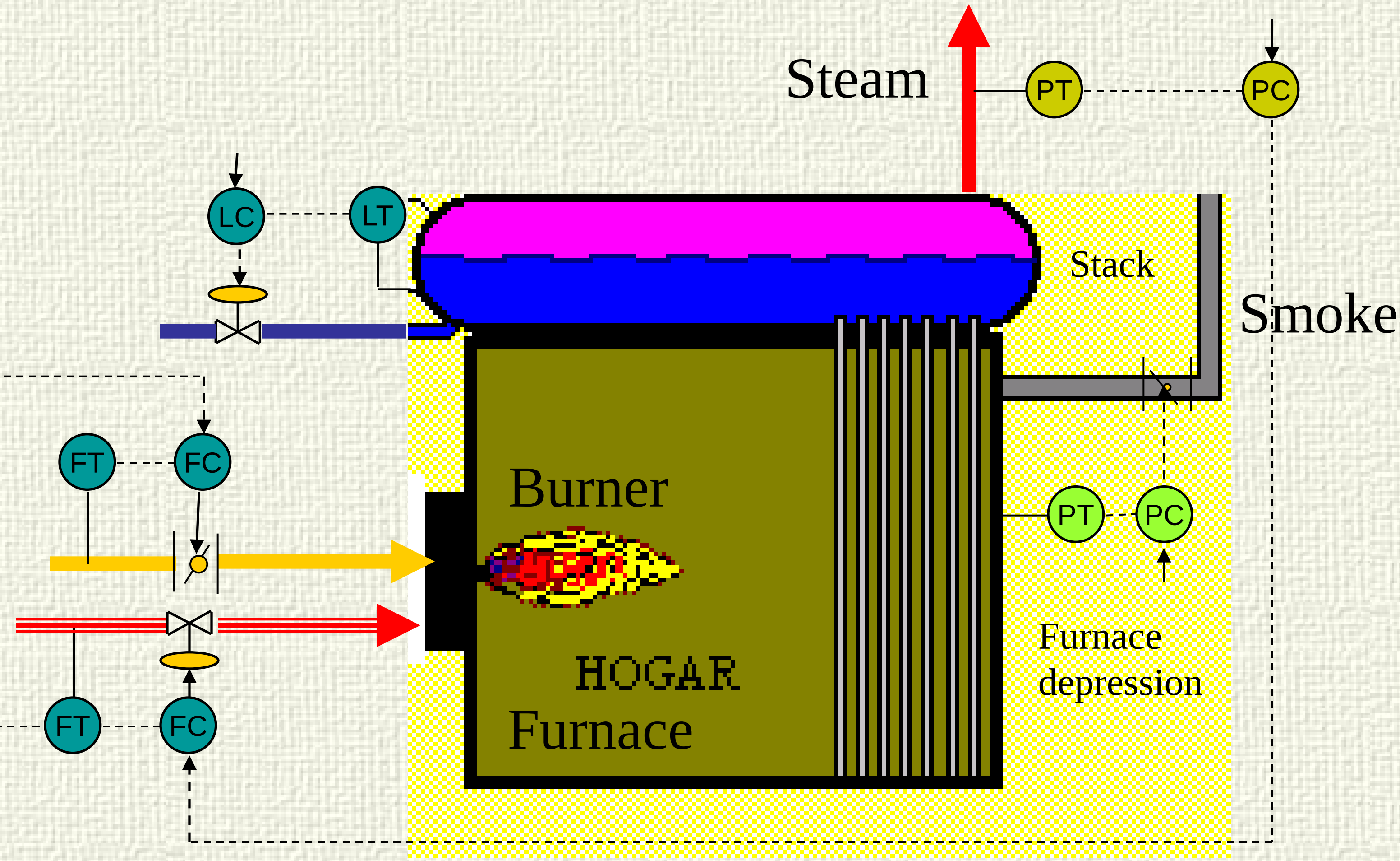
Superfractionator column

Aim: Keep R/V
or B/F constant

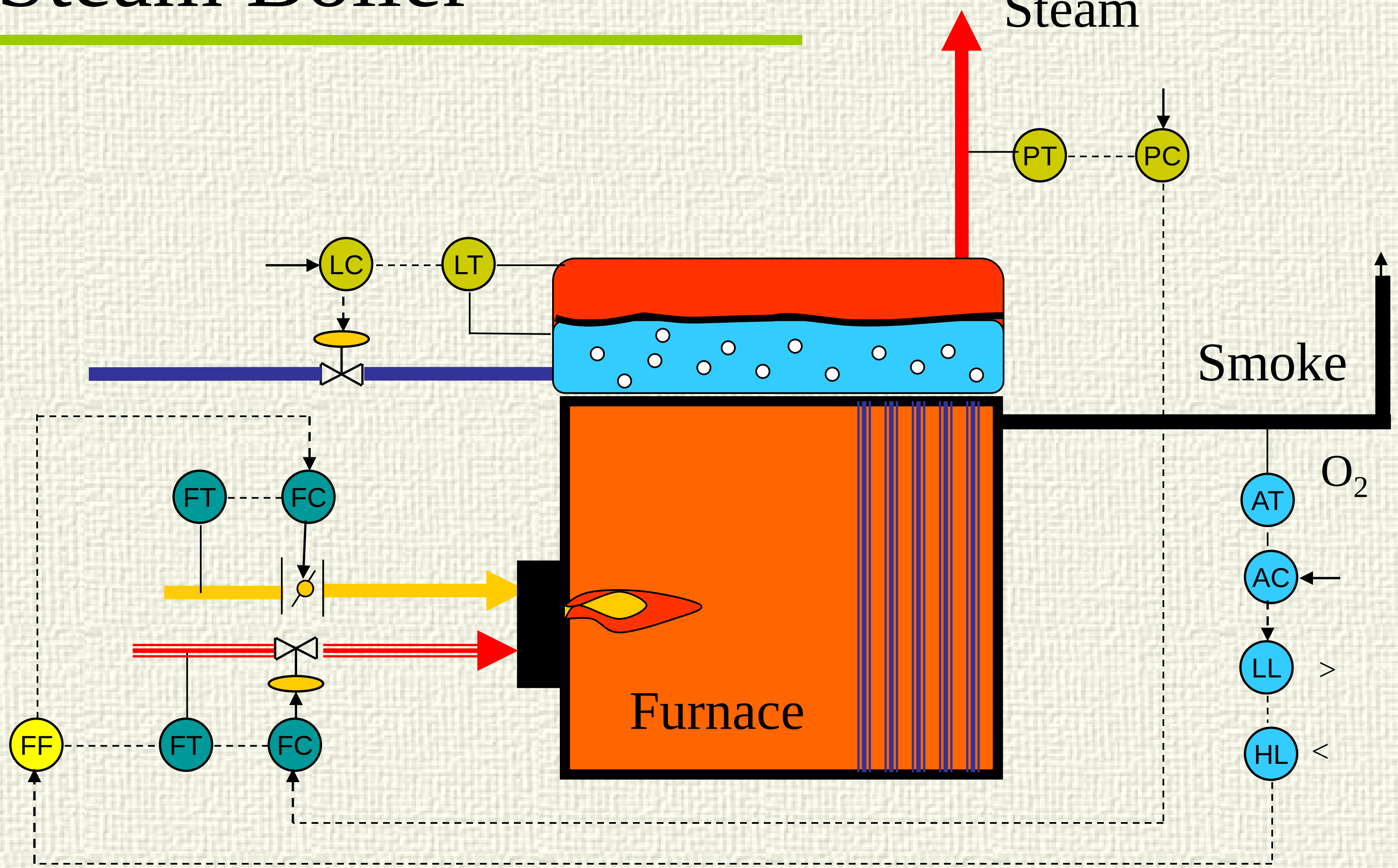


$$\frac{R}{V} = \frac{R/D}{1+R/D} \qquad \frac{D}{V} = \frac{1}{1+R/D}$$

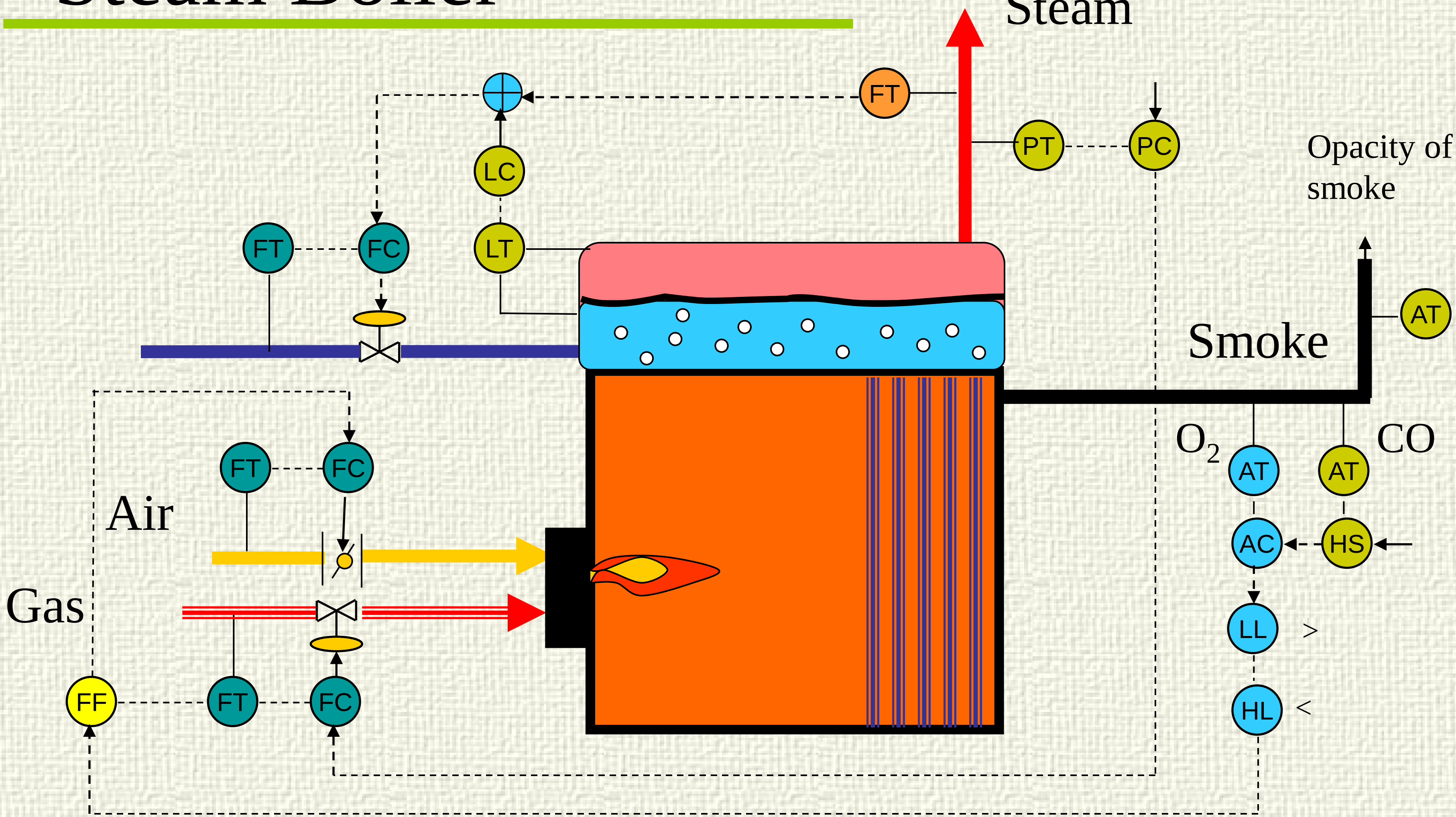
Steam Boiler



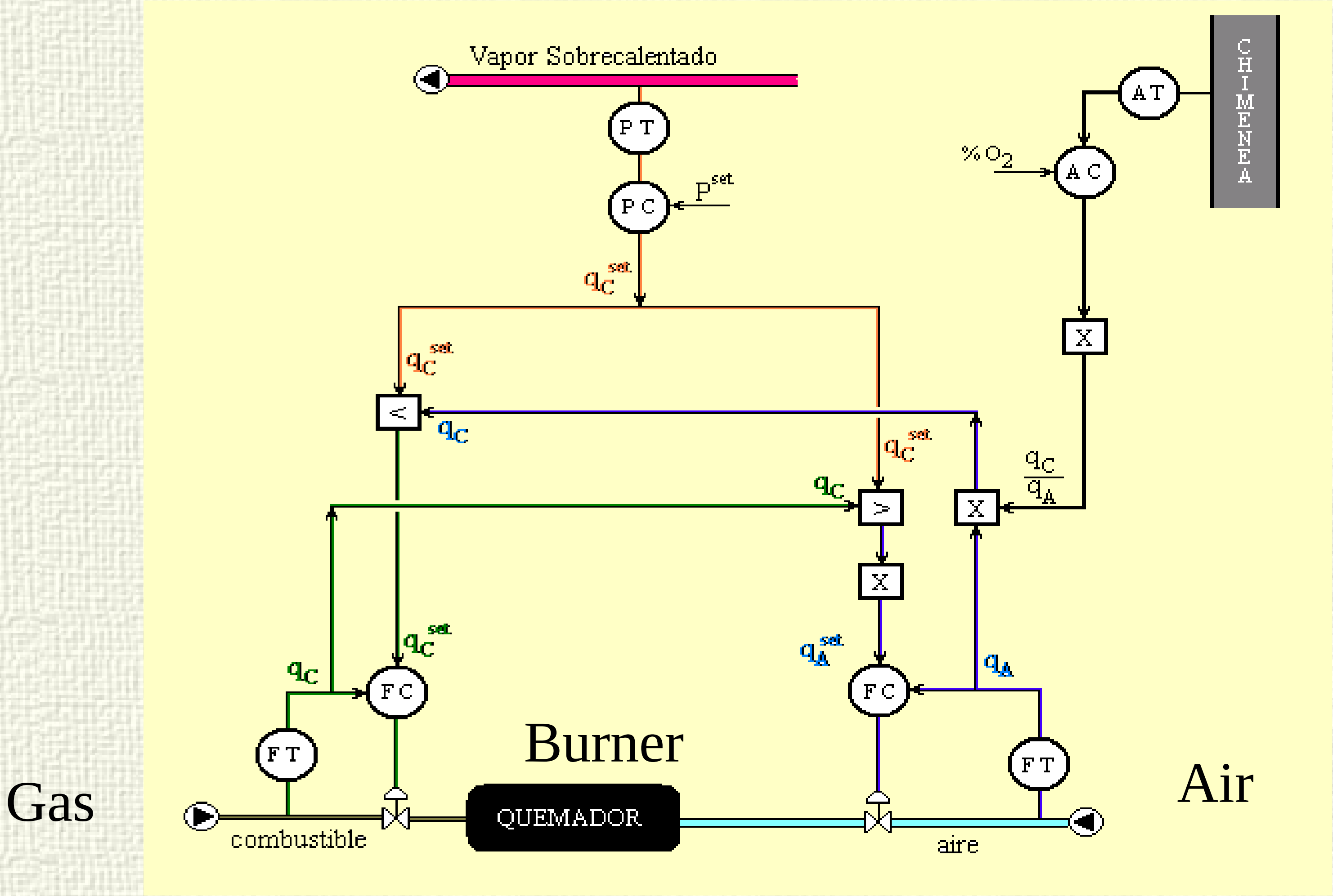
Steam Boiler



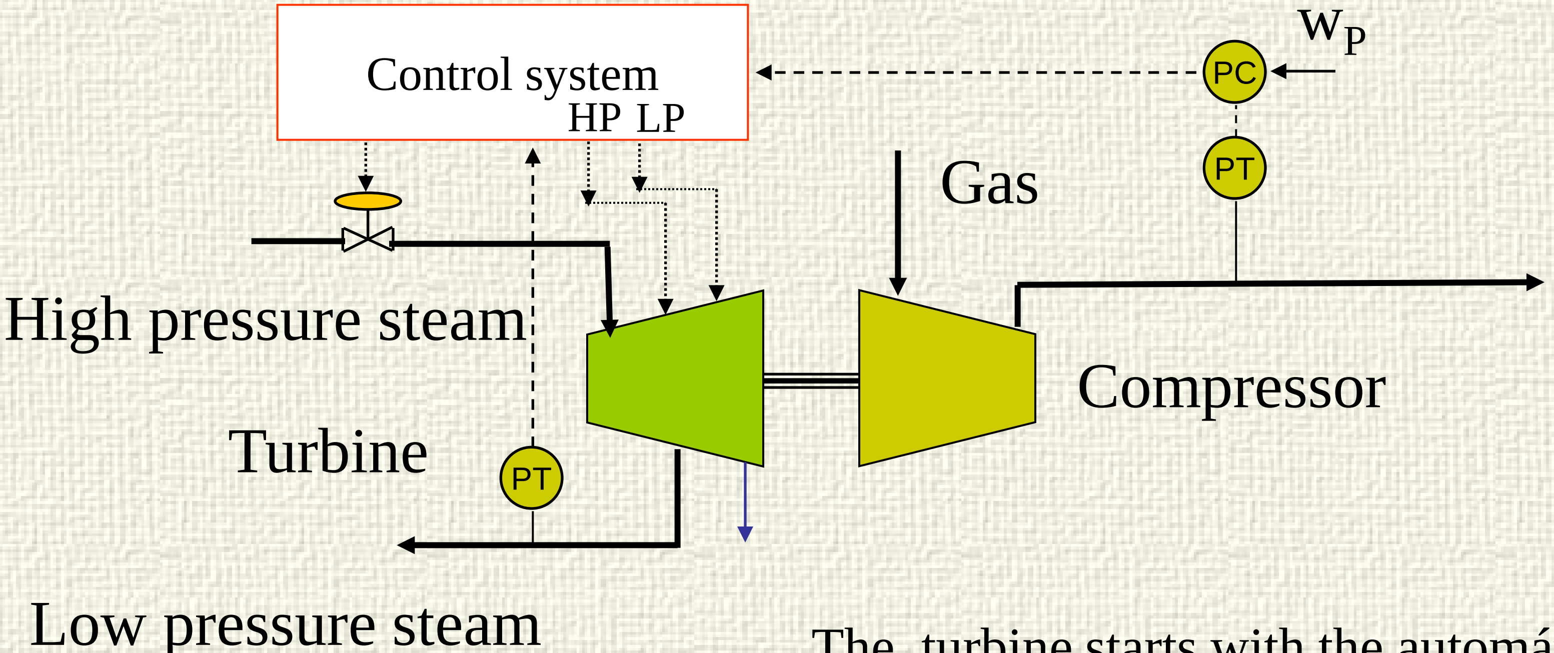
Steam Boiler



Security Fuel/Air

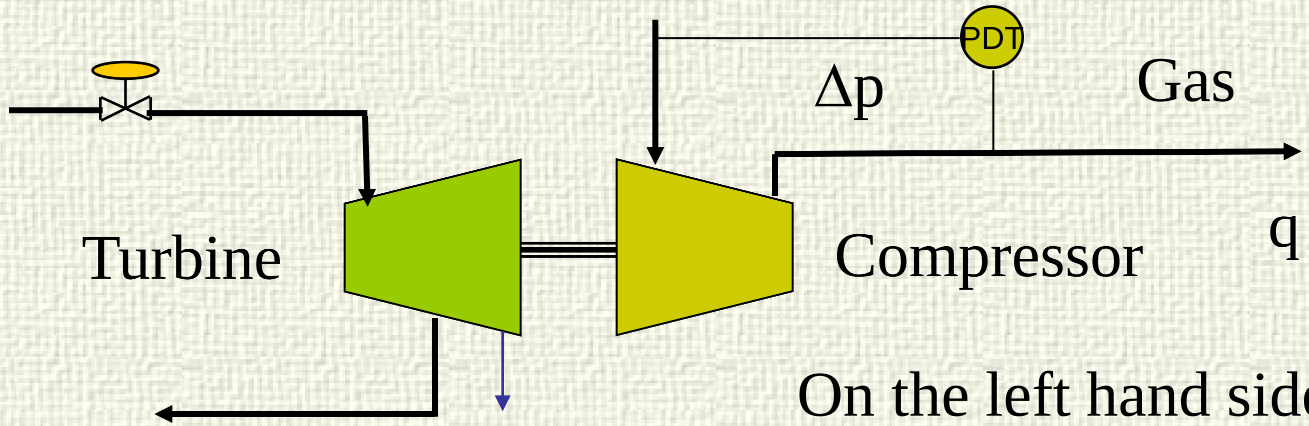


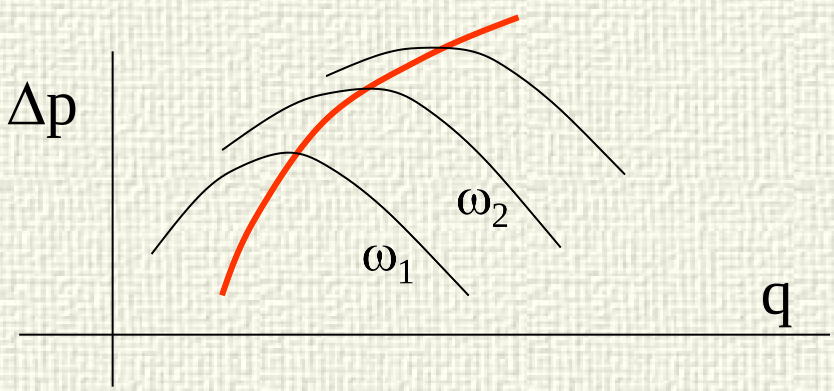
Centrifugal compressors



The turbine starts with the automátic valve then the regulation is made with the HP valve

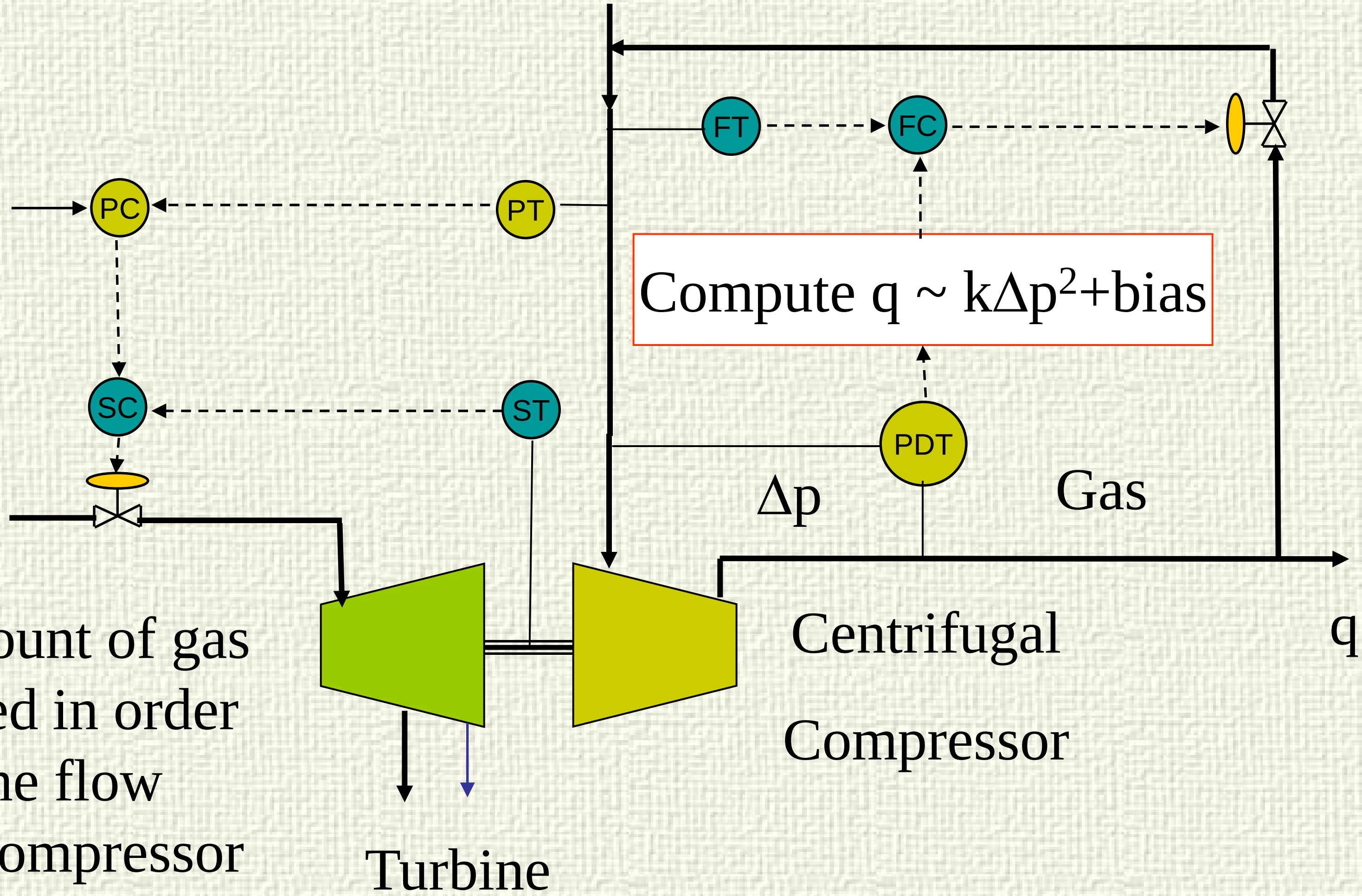
Anti-surge Control





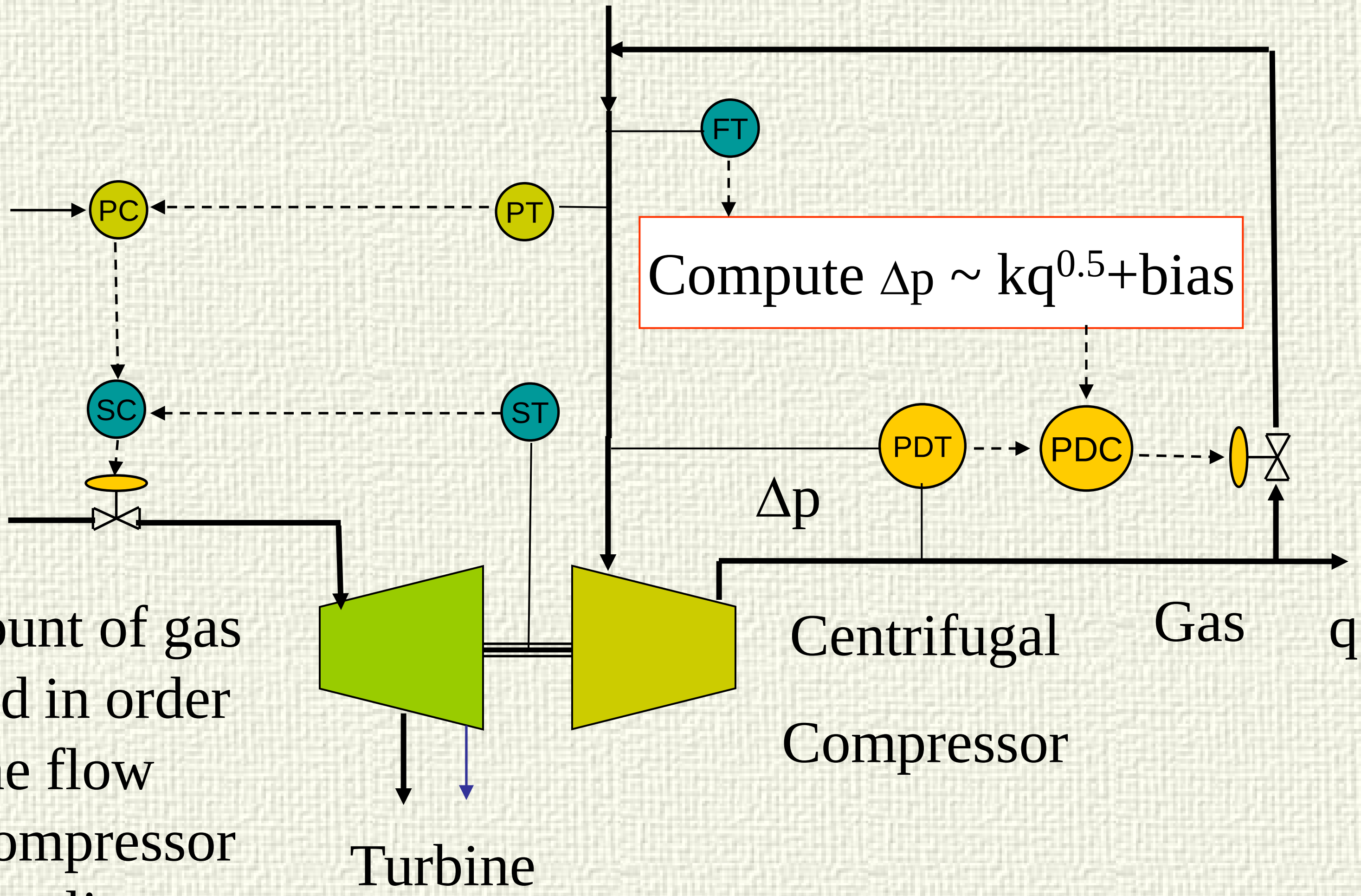
On the left hand side of the surge line, operation is unstable: if the flow q decreases, then Δp decreases too, which, in turn, decreases q

Anti-surge Control



A certain amount of gas is re-circulated in order to maintain the flow through the compressor below the surge line

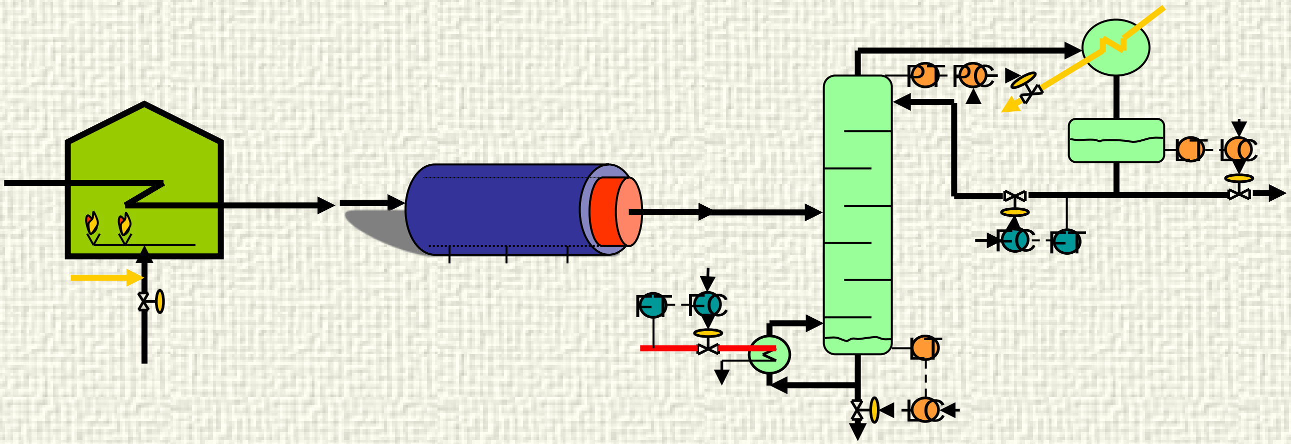
Anti-surge Control



A certain amount of gas is re-circulated in order to maintain the flow through the compressor below the surge line

Unit / Department control

- ✓ Control loops do not work in isolation. They should not disturb the operation of other control loops and must cooperate in fulfilling the overall aims



Methodology

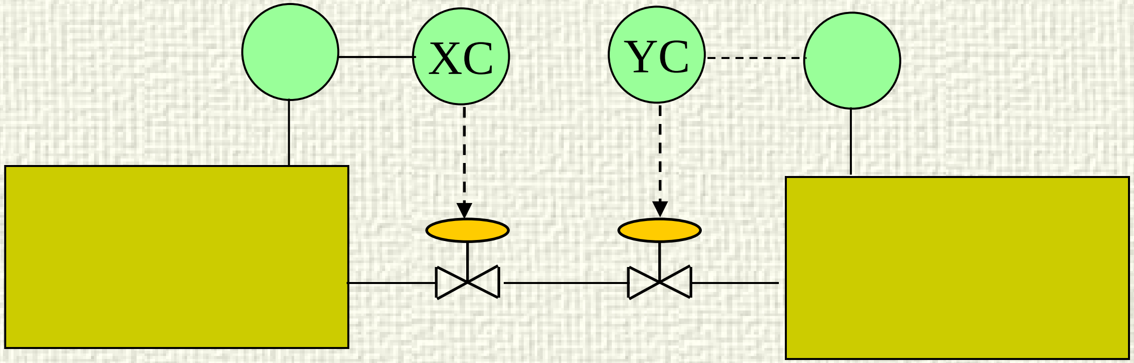
The number of automatic valves, other actuators, ... Can be considered as the number of degrees of freedom that can be used in order to maintain a given production level, product quality, security, etc.

Order:

1 Choose first those loops that fix production level
2 Then, design the security and quality loops
3 Inventory control loops
4 Check that the balances (mass, energy) can be satisfied
5 The remaining degrees of freedom can be used to optimize the plant behaviour
6 Validate the design using dynamic simulation

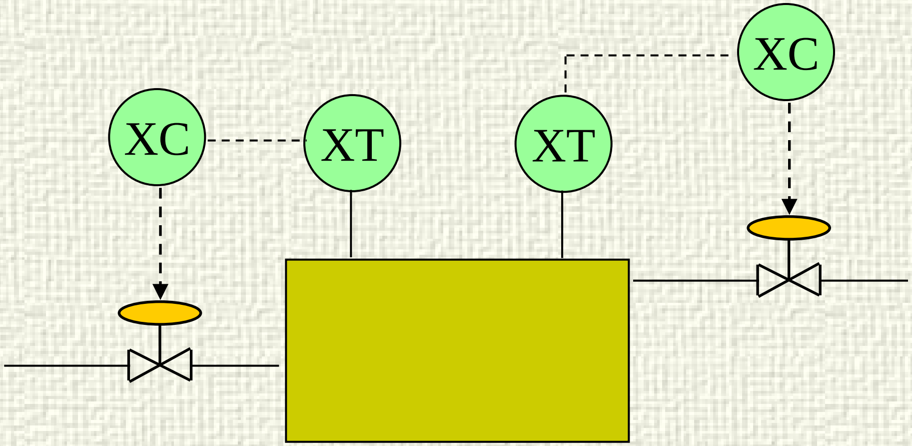
Interactions

Plant Wide Control



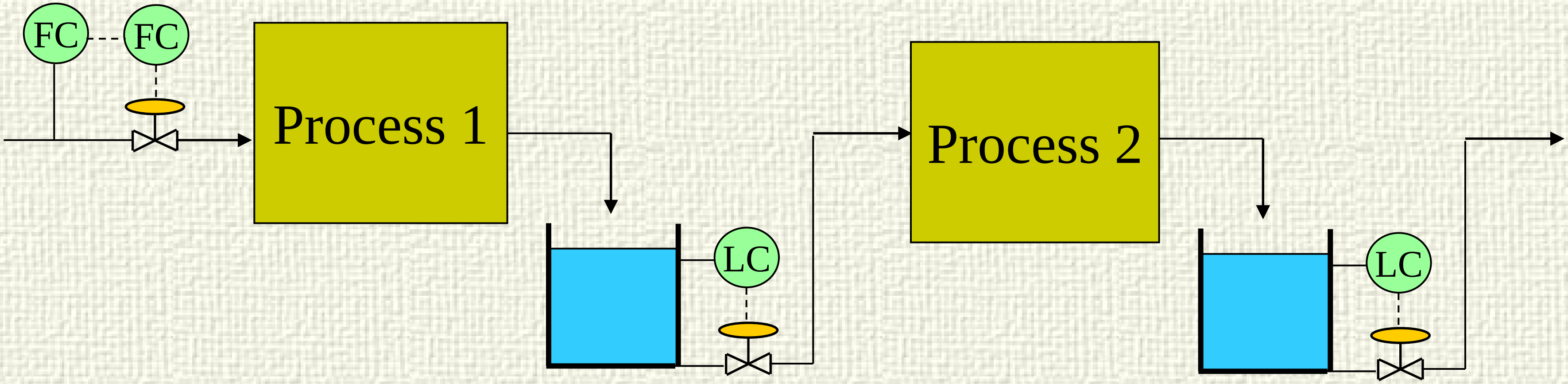
Only one automatic valve is allowed in a pipe

Interactions



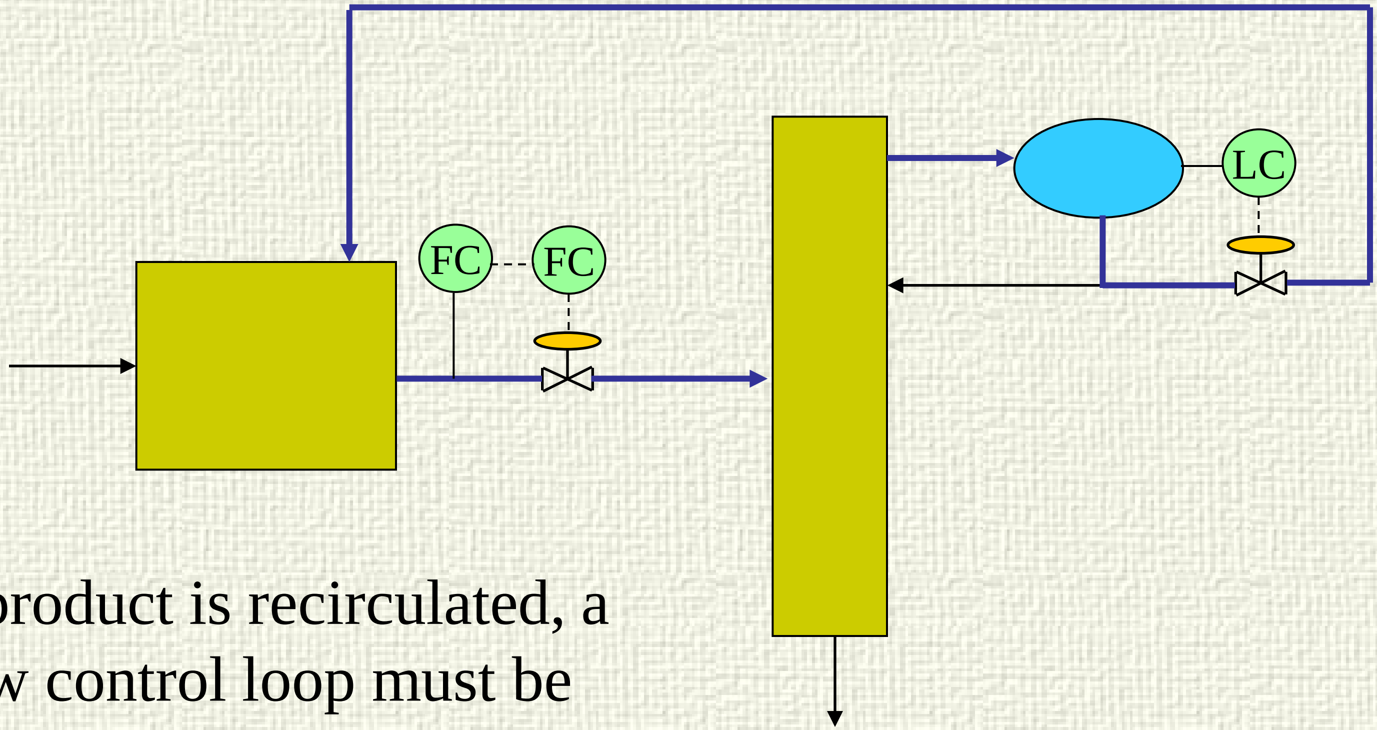
One variable should be controlled using only one controller

Interactions



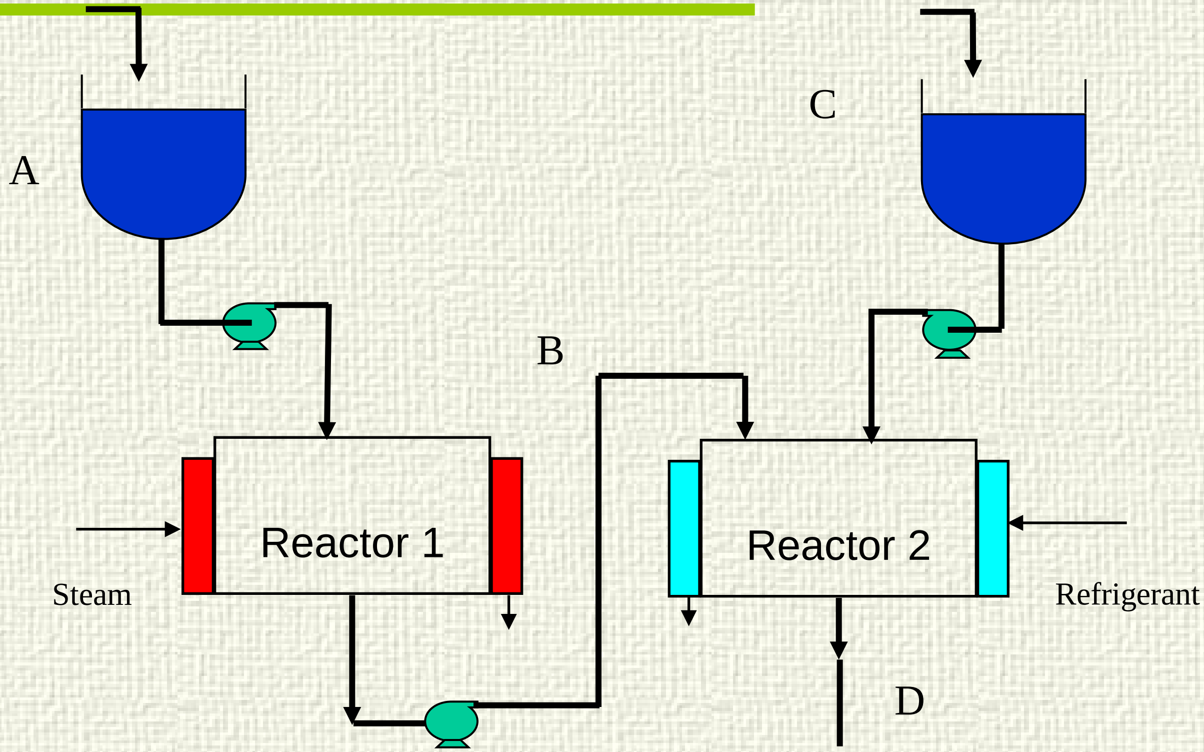
Level control loops must operate in the same direction (backward, forward) according to the point that fix the flow

Interactions



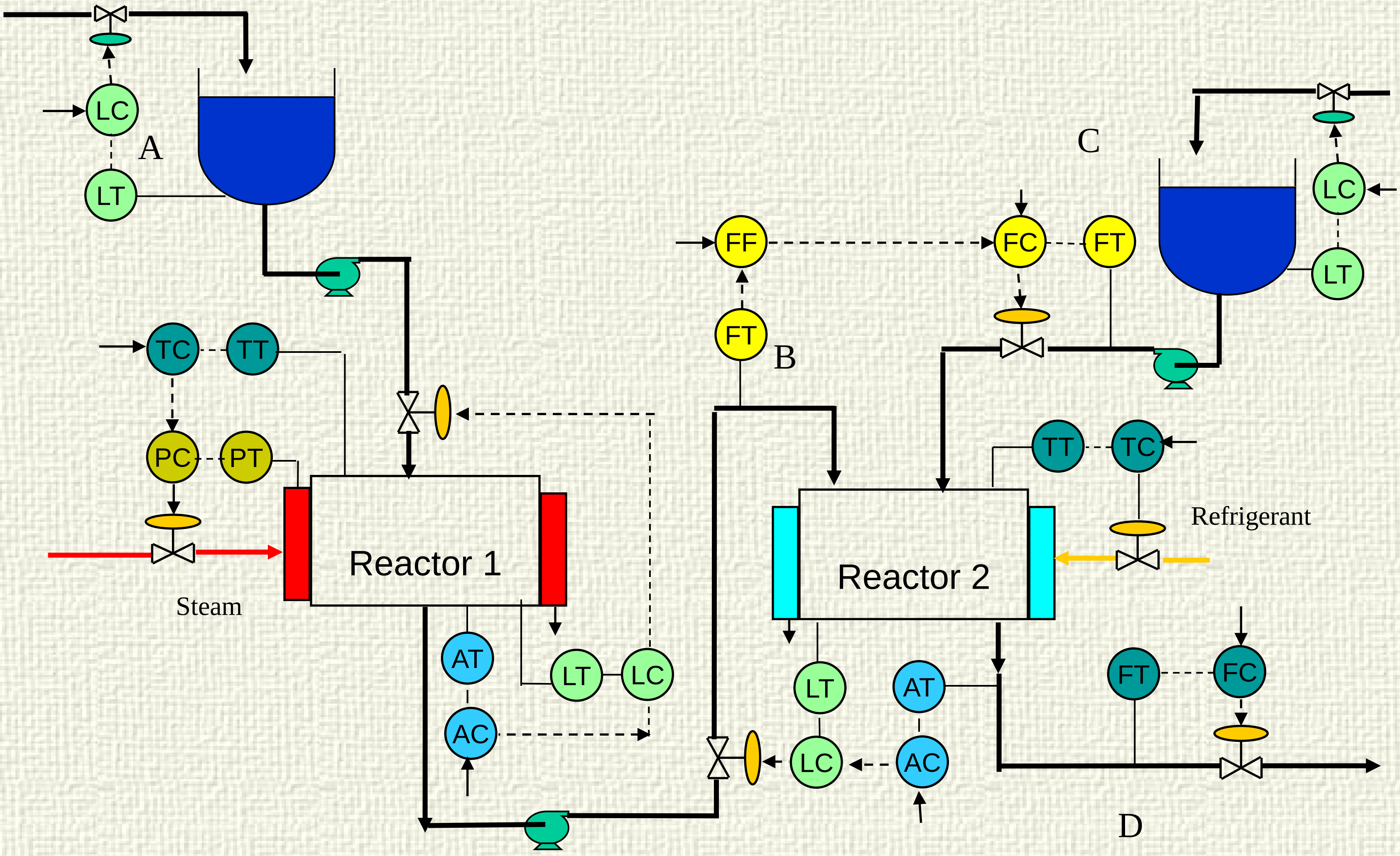
If a product is recirculated, a flow control loop must be placed somewhere in the loop

Reactors in series

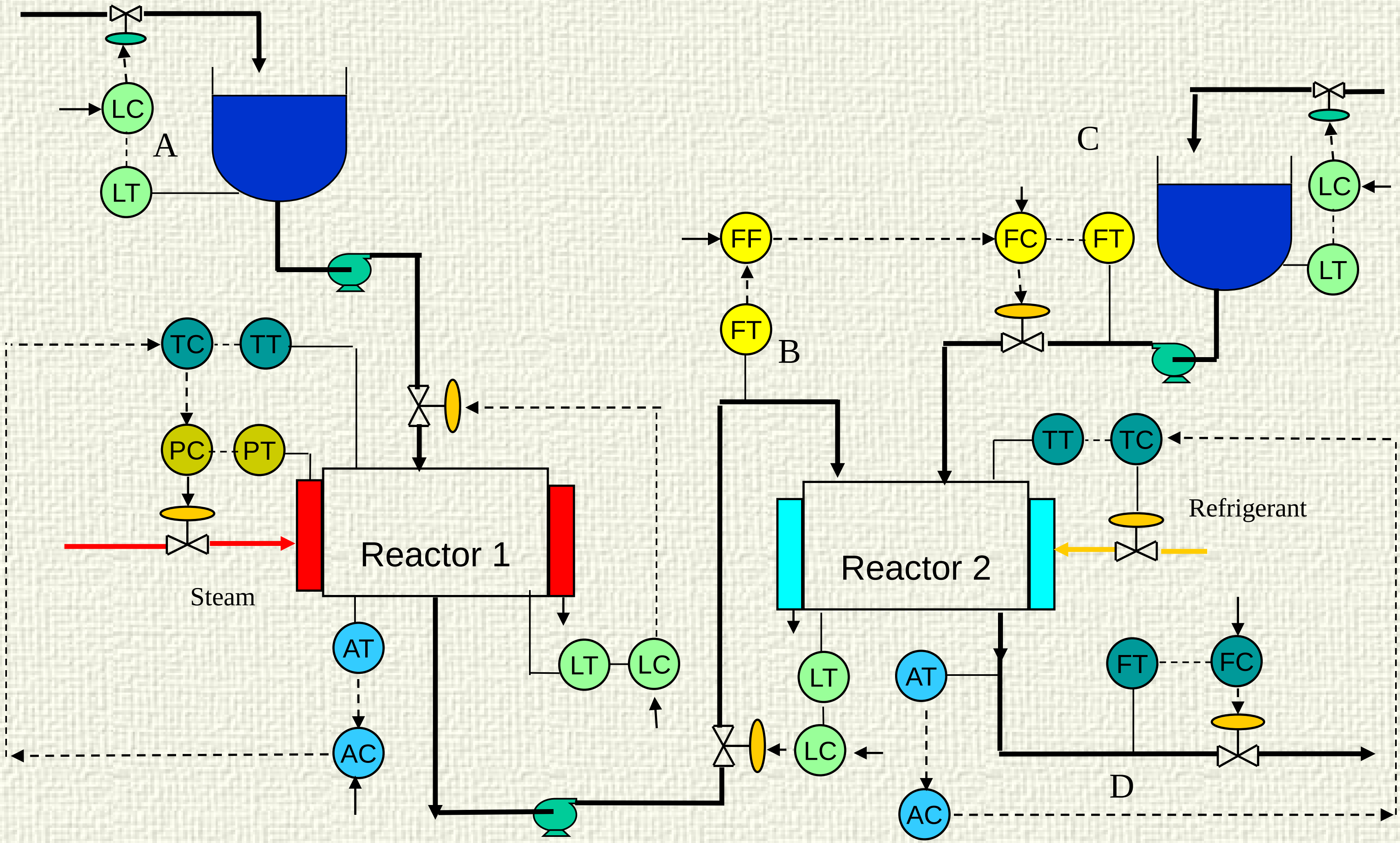


Product A reacts in the endothermic reactor 1 providing a product B to the exothermic reactor 2. Here, B reacts with C in order to obtain the desired product D. A and C are obtained from two storage tanks. The level of both reactors depends on the inputs and outputs flows while the speed of reaction is quite sensitive to their temperature. Also it is known that steam flow is affected by big changes in the supply pressure. A control structure should be drawn that it is able of maintaining with precision D product concentration as well as other possible requirements.

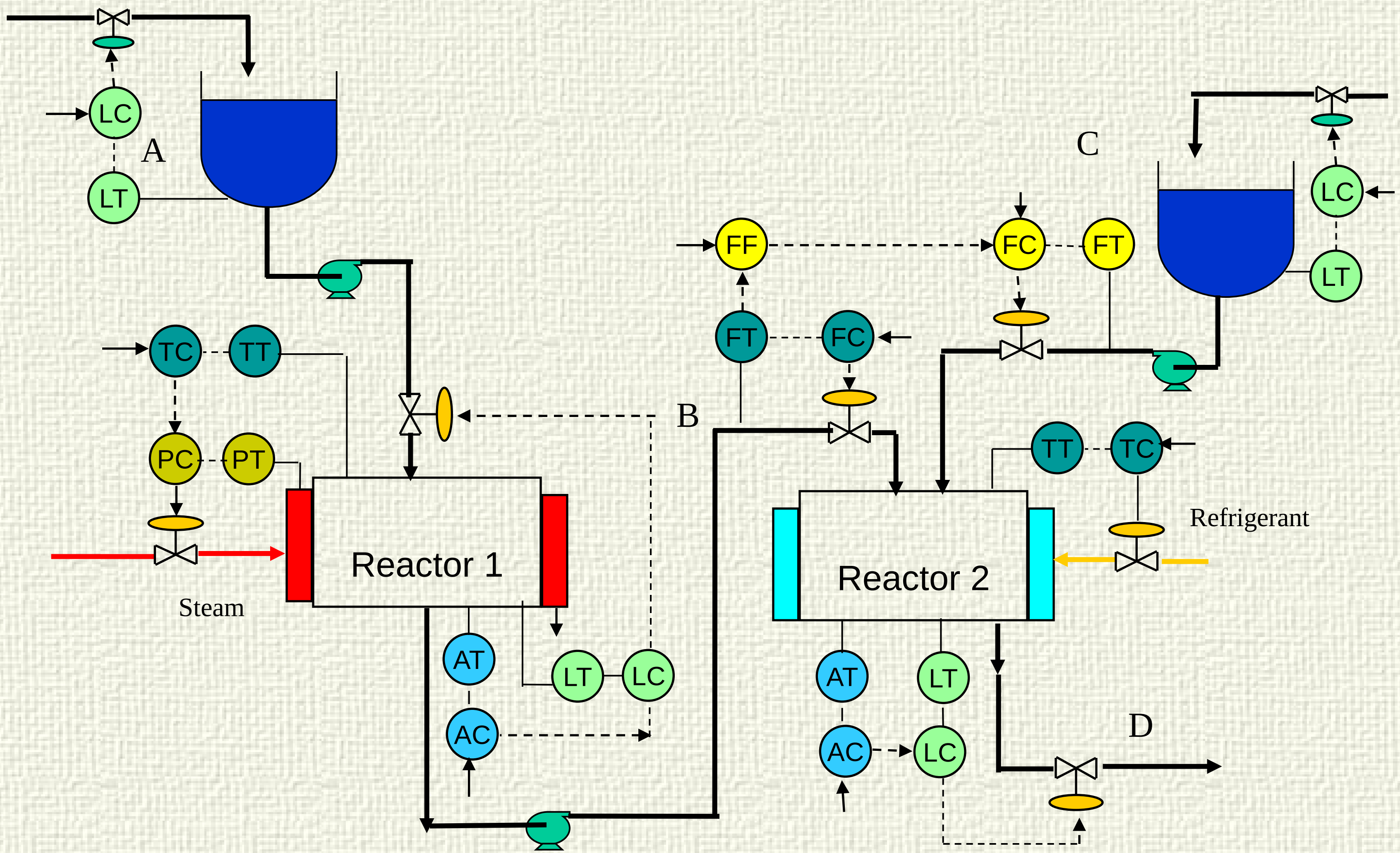
Reactors in series



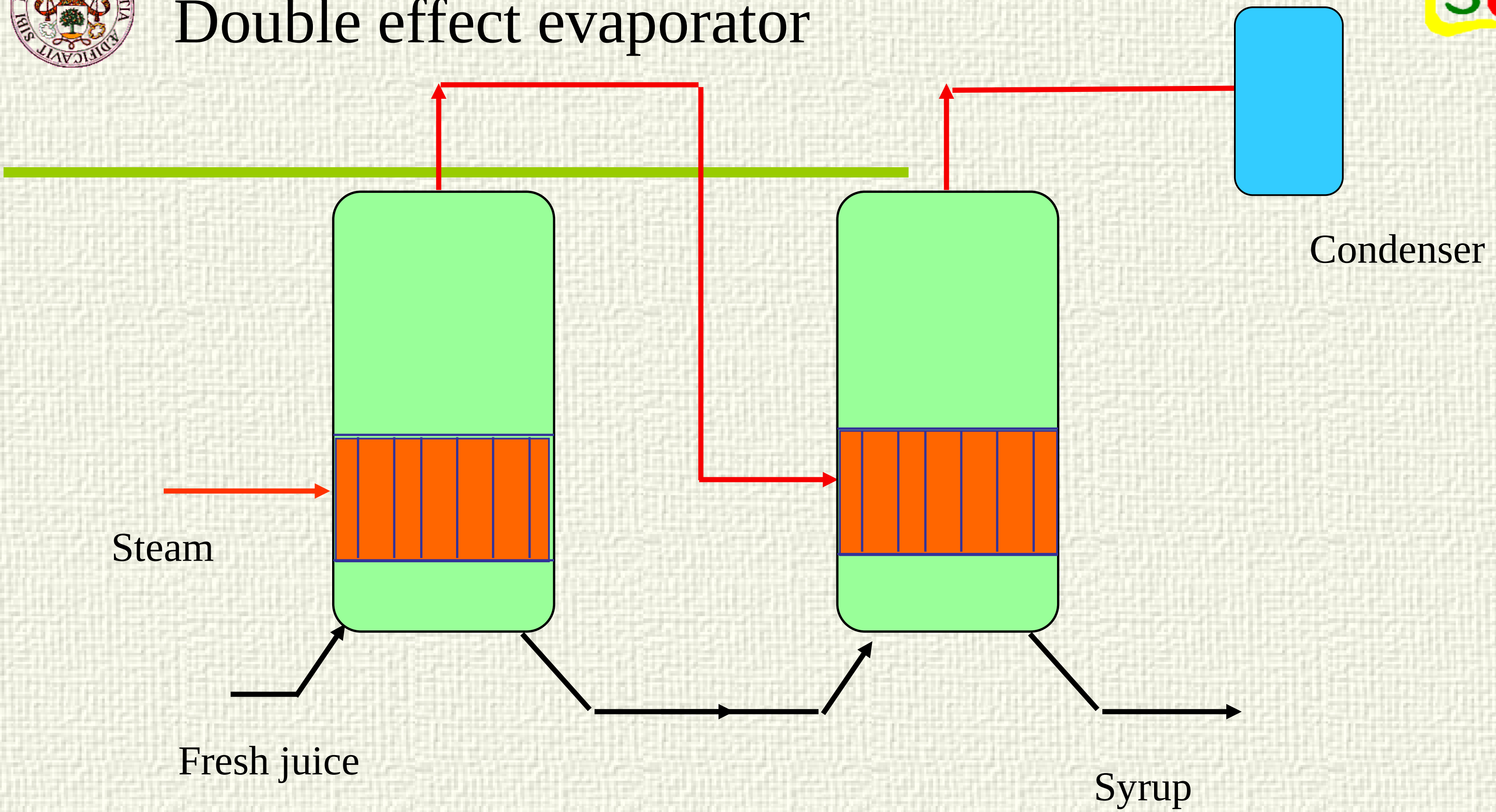
Reactors in series



Reactors in series

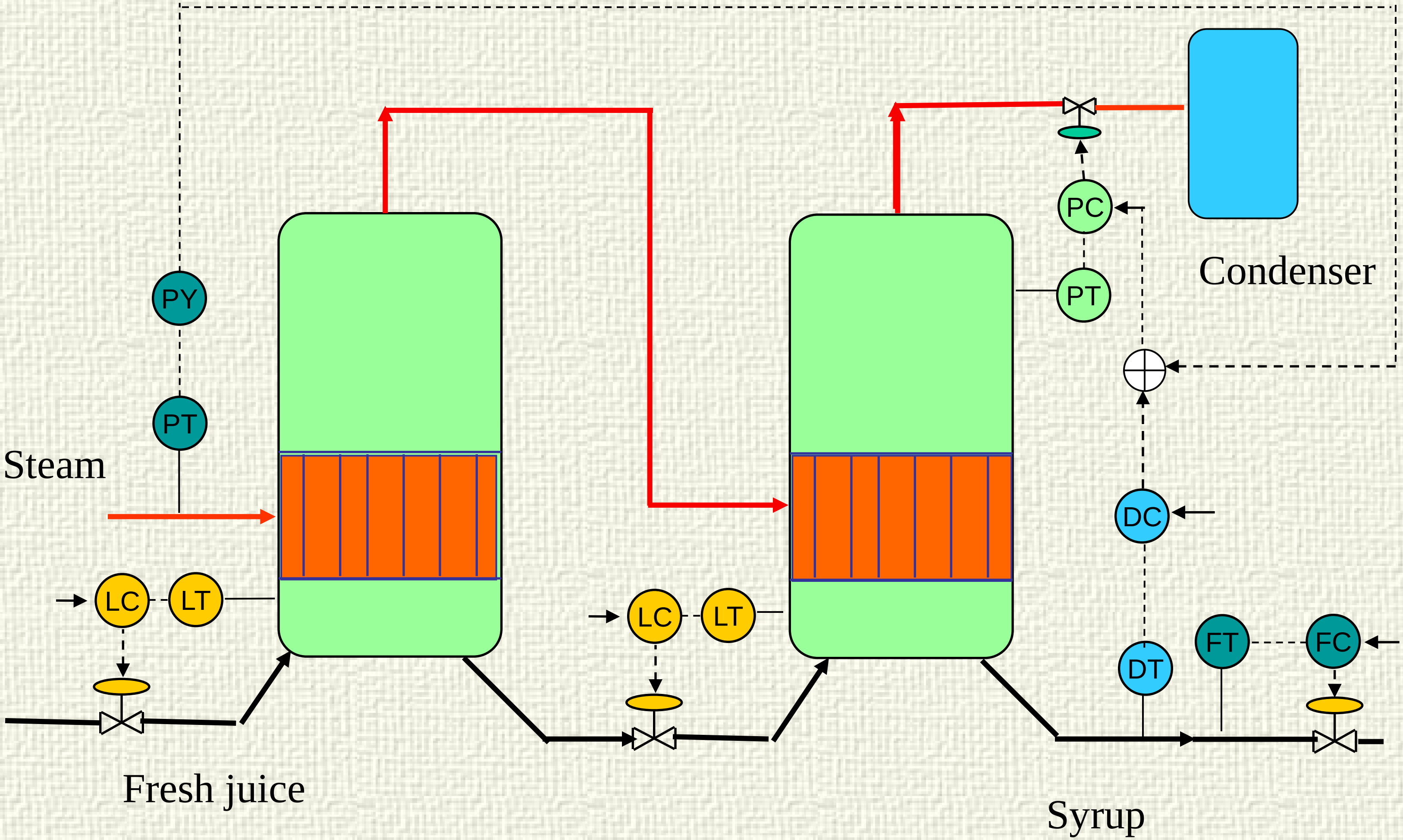


Double effect evaporator

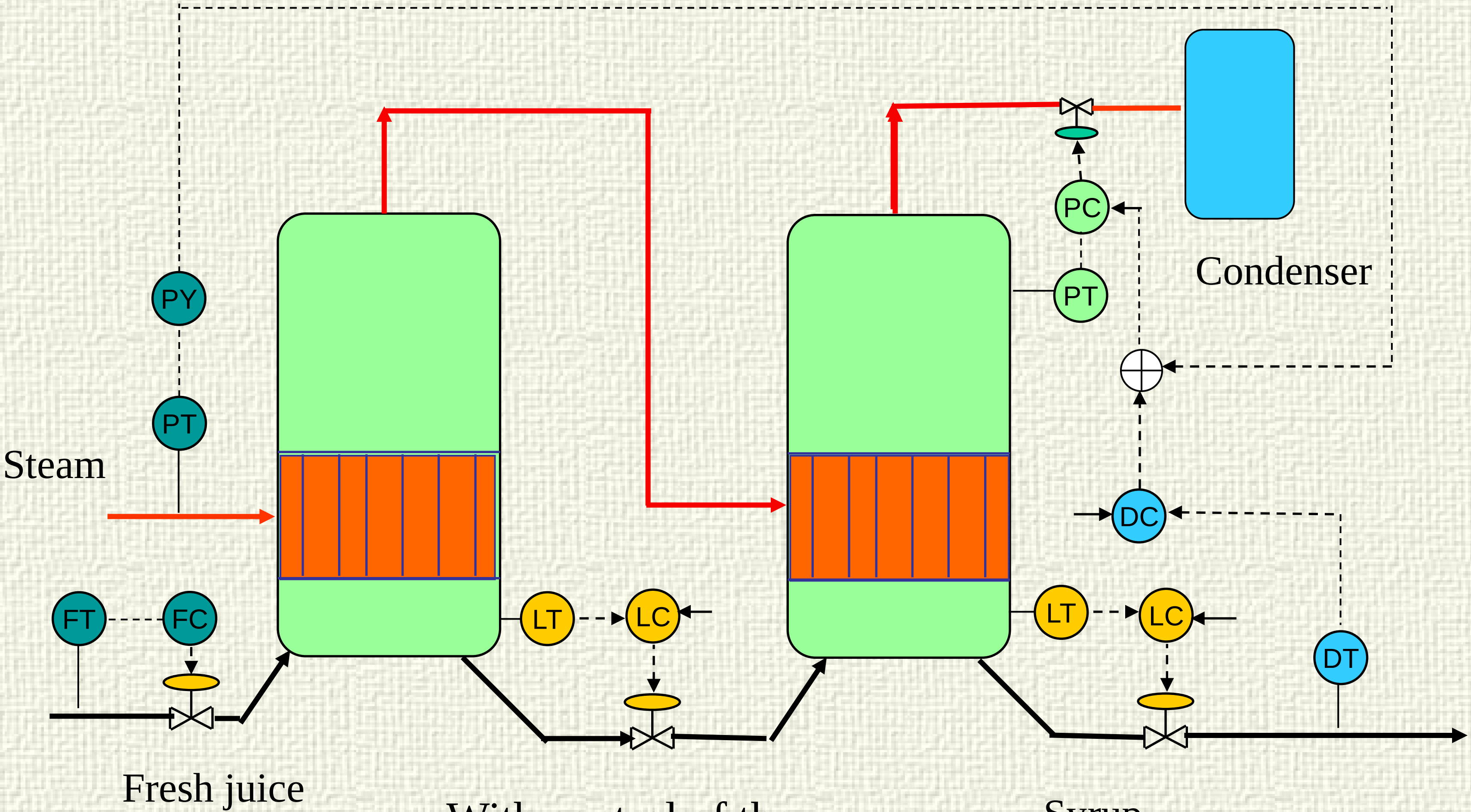


The schematic of the figure shows a double effect evaporator that processes a fresh juice in order to convert it into a syrup. The evaporator is heated using steam that comes from a previous process that experience changes in pressure and cannot be manipulated. The steam flowing out of the second effect goes to a condenser that can experiment some changes too. A control system must operate the process being the main aims maintaining a desired production of syrup of a given density in spite of the disturbances acting on the process and taking into account other possible control aims that must be implemented.

Double effect evaporator

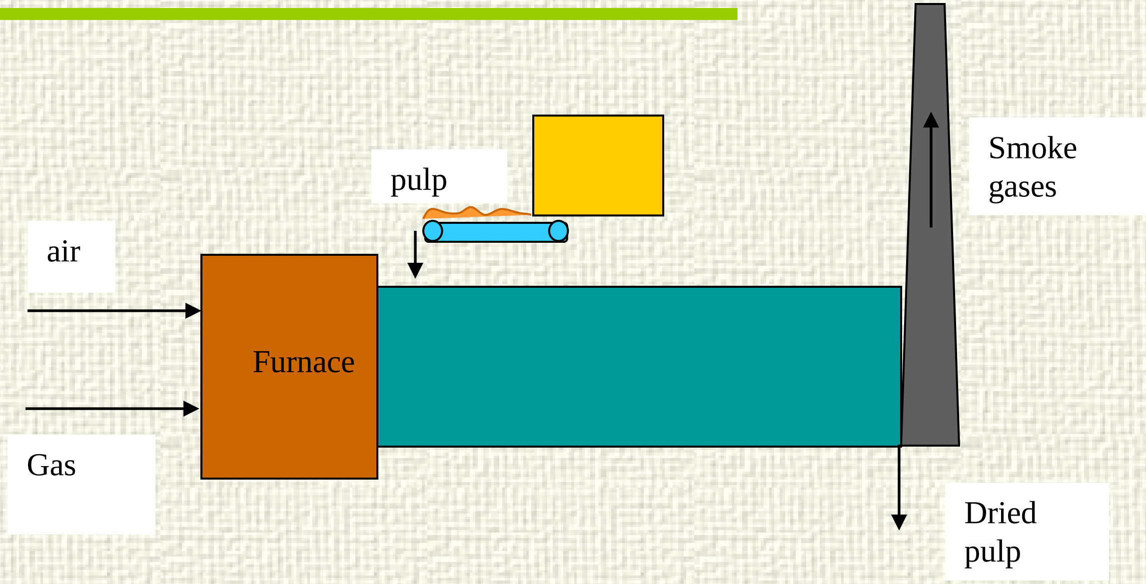


Double effect evaporator



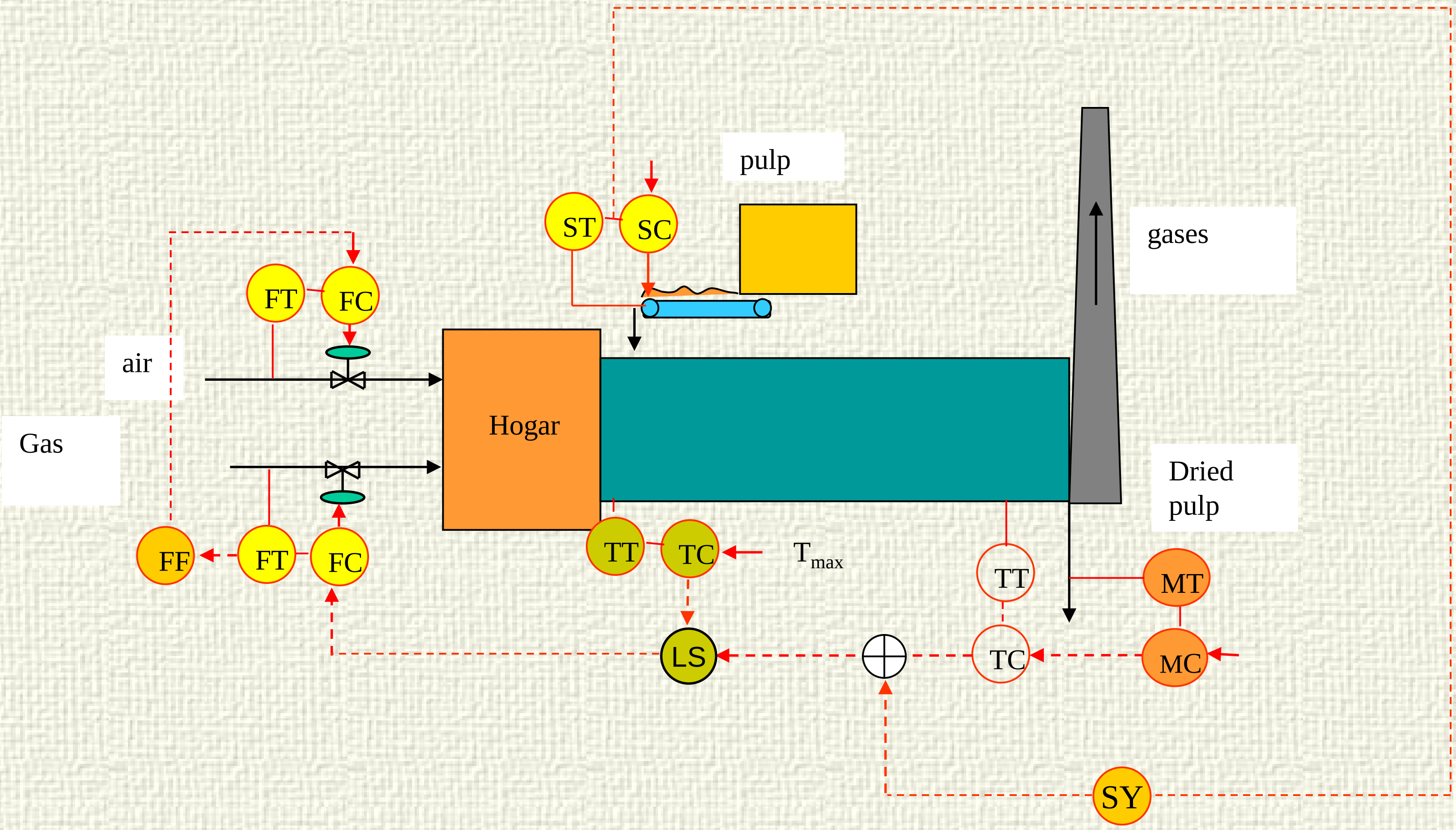
With control of the fresh juice processed

Pulp Dryer

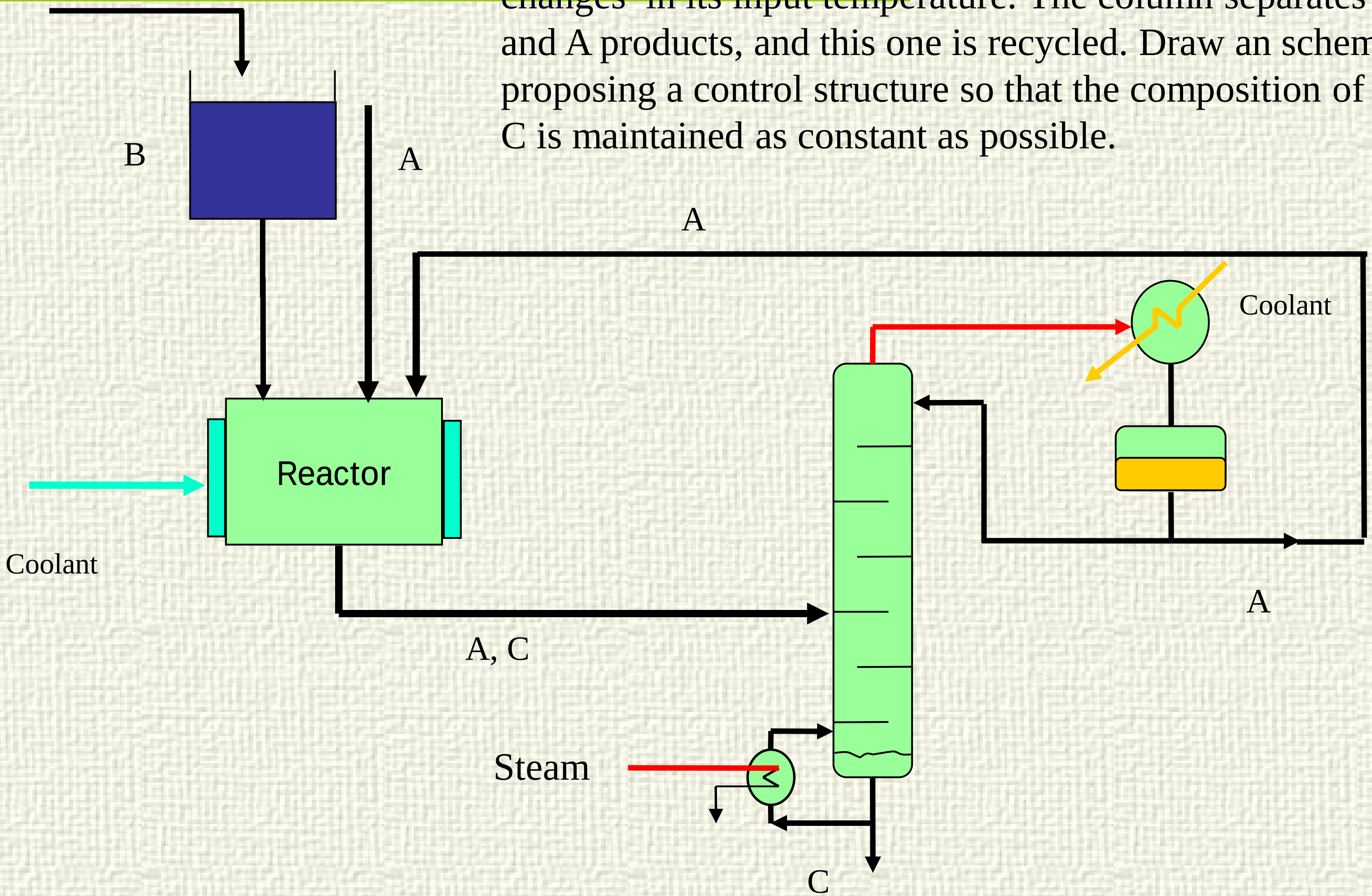


The schematic represents a pulp dryer in which a certain flow of wet pulp must be dried up to a specified value that must be maintained in spite of possible disturbances. The amount of pulp entering the dryer is proportional to the speed of the belt conveyor, which is fed from an storage tank and must be fixed according to the production needs. The dryer has a combustion chamber (where a mixed of natural gas and air is burned in order to produce a flow of hot gases) and a main body, which is a cylinder rotating at constant speed. The pulp, push by the hot gases, moves along the cylinder and, at the same time, loses water by evaporation. Smoke goes out by a chimney while the dried pulp leaves the dryer at the end of the cylinder. For security reasons, it is desired that the temperature at the furnace output is below a given upper limit. It is also known that the feeding pressure of the natural gas changes frequently.
Design a control structure that is able to cope with the above mentioned requirements.

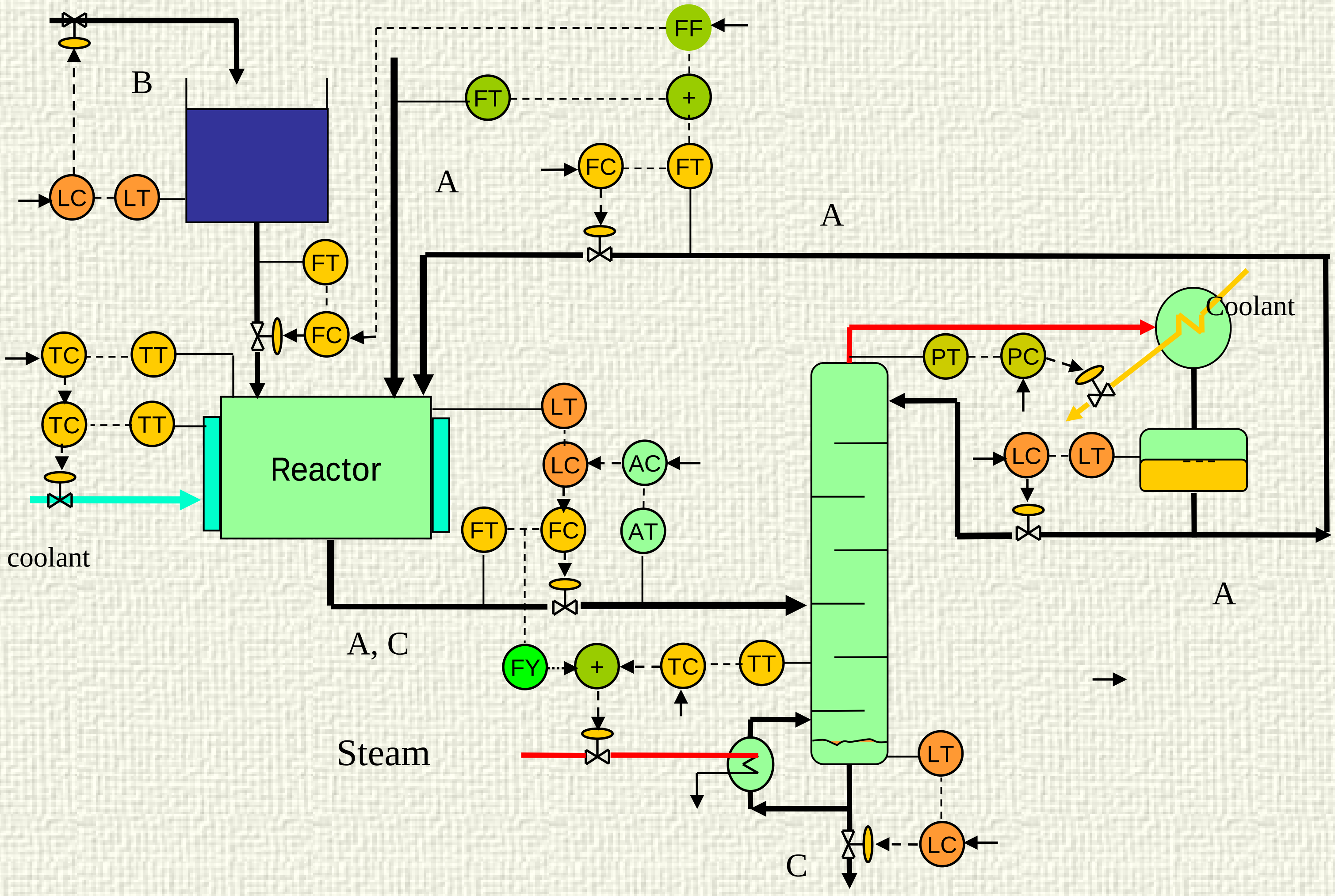
Pulp Dryer


pulp
ST
SC
gases
FT
FC
air
Hogar
Gas
Dried
pulp
FF
FT
FC
TT
TC
T_{max}
TT
MT
LS
TC
MC
SY

The plant represented in the schematic receives from other part of the factory a flow of product A, that cannot be manipulated. The exothermic reactor combines A and B (with a small excess of A) in order to produce C. The reactor coolant suffers from changes in its input temperature. The column separates the C and A products, and this one is recycled. Draw an schematic proposing a control structure so that the composition of product C is maintained as constant as possible.



Reaction-separation with recycle



Reaction-separation with recycle