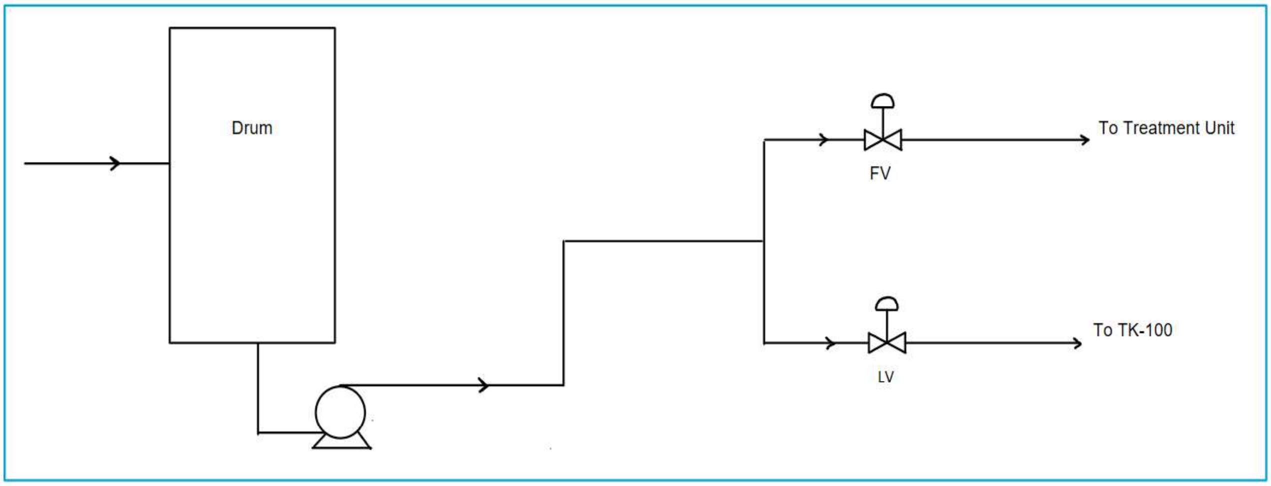
Advanced Control

Split-Range

Example 1:

Blow-down, oily water, water containing ions are always problematic to most process engineers or process plant technical managers. Therefore, before putting the unit in operation, one should take into account all aspects. Here is one example to see how most petrochemicals and process plants deals with the problem.

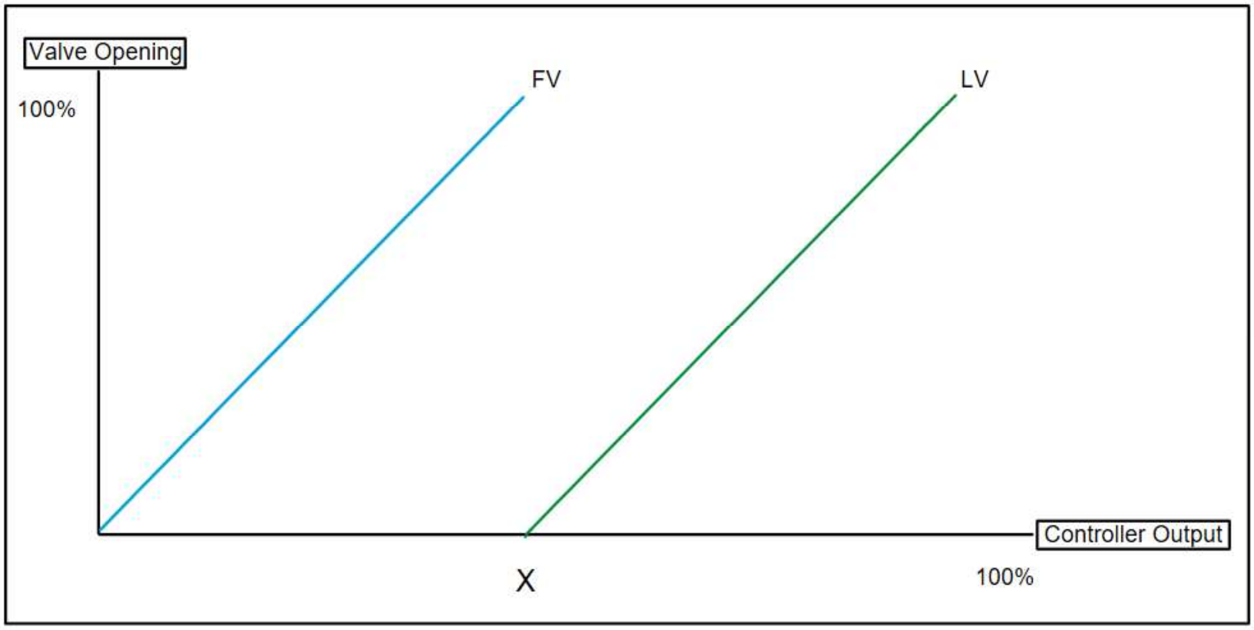


Simply the blow-down is sent to a treatment facility outside of the plant. Based on PFD-like sketch, the flow to treatment unit is controlled via FV while the flow to TK-100 is controlled by LV. Sometimes the treatment unit is out of service for say half a day and thus, cannot receive the blow-down. Therefore, the process designer should foresee a storage tank to overcome such operational problems in the future.

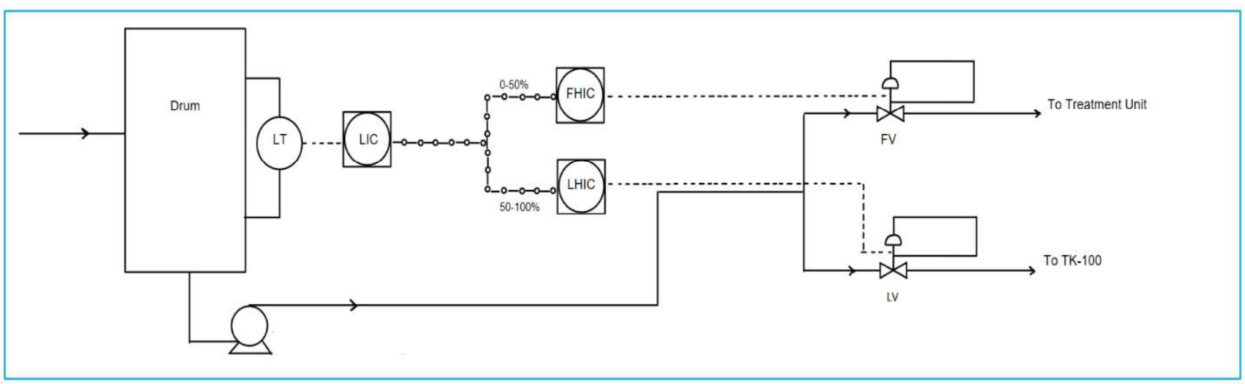
Let's view the process from another perspective. There is a surge of blow-downs because of an emergency. Imagine yourself as the controller; you open FV as much as you can but still the level in the drum is increasing. Then you as controller start opening LV and sending a part of blow-down to the tank to mitigate the problem. If we want to show the behavior of control valves on a diagram, it would be like next-page:

Just look at it. Now you can see that the controller has devided the role between the control valves. In other words, the controller has split the role between the control valves, or we professionals say, the controller splits the range of actions on control valves. That is why it is called split-range control.

The typical value of X when we have two control valves is 50% in output. So far we know that we need a LIC to control the level. We also have gained this understanding that a simple LIC is meaningless here and split-range should be used. How simple it is, right?



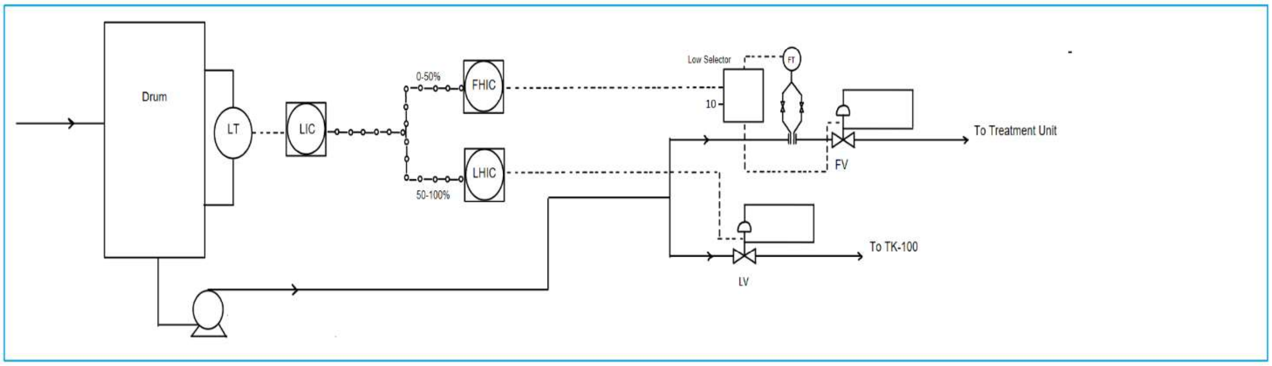
Now let's complete the PFD-like sketch by incorporating the control system.



Now there is this specification issued by the treatment facility that you can't send whatever you want when we are in operation. Our facility supports other plants as well. Therefore, you can send maximum 10 ton/hr.

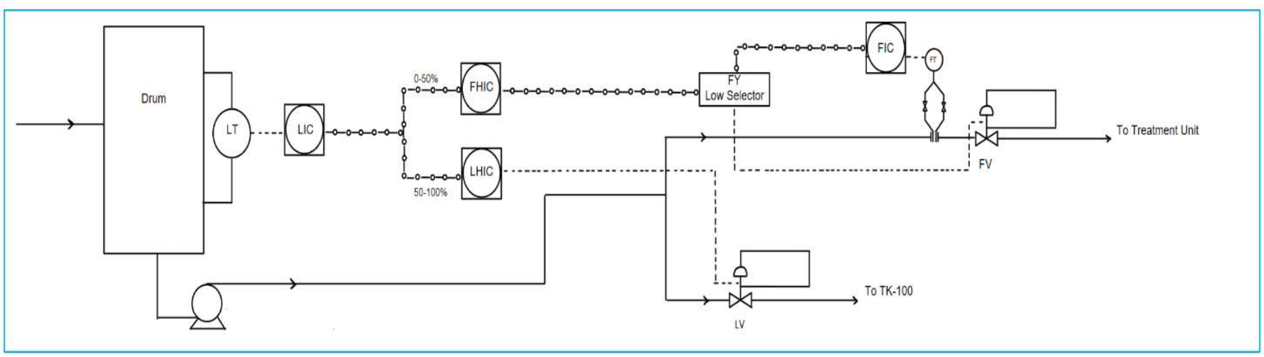
If you are thinking that we should change the design of the controllers, you are wrong since we need the controller to be split-range. Probably we should add something!

How about this, adding a block which receives the actual flowrate and compare it with 10ton/hr. If the flowrate is lower than 10ton/hr. then send the value issued by FHIC but if the value is more than 10ton/hr. then select the 10ton/hr. In fact, we want to give the block the name, it would be low selector since it always selects the lower value. So, the sketch would be like this:

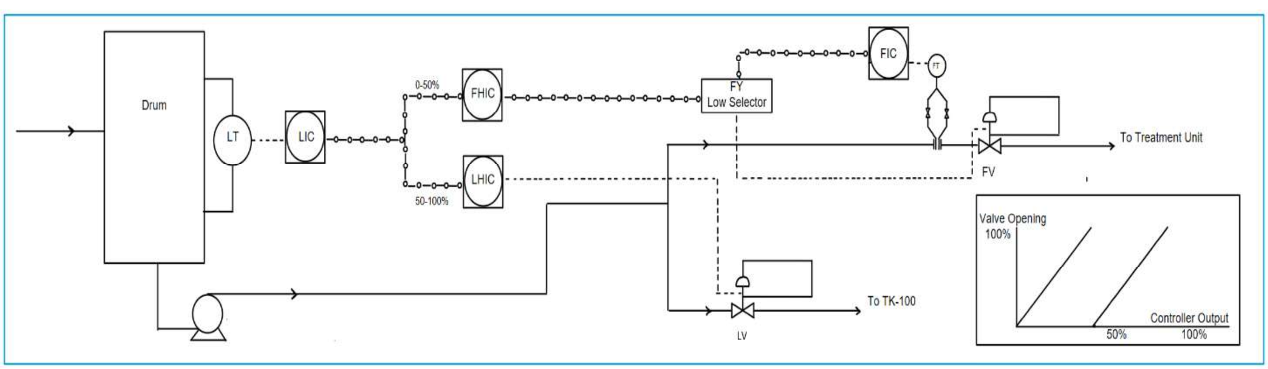


Notice: One of the inputs to the low selector is MV% while the other one is barg which can not be compared. We already know that. So don't think we have made a mistake. Just follow the chain of our perspective.

Now when we specify that we have a low selector block, it means that only instrumentation engineers have access to the calculation behind the block. So, we have to design it in a way that operation supervisor can have access to change 10ton/hr. in case the treatment facility stipulates that today the maximum flowrate which can be sent is 6ton/hr. To address the problem, we propose adding another FIC by means of which the operator can change the set point.



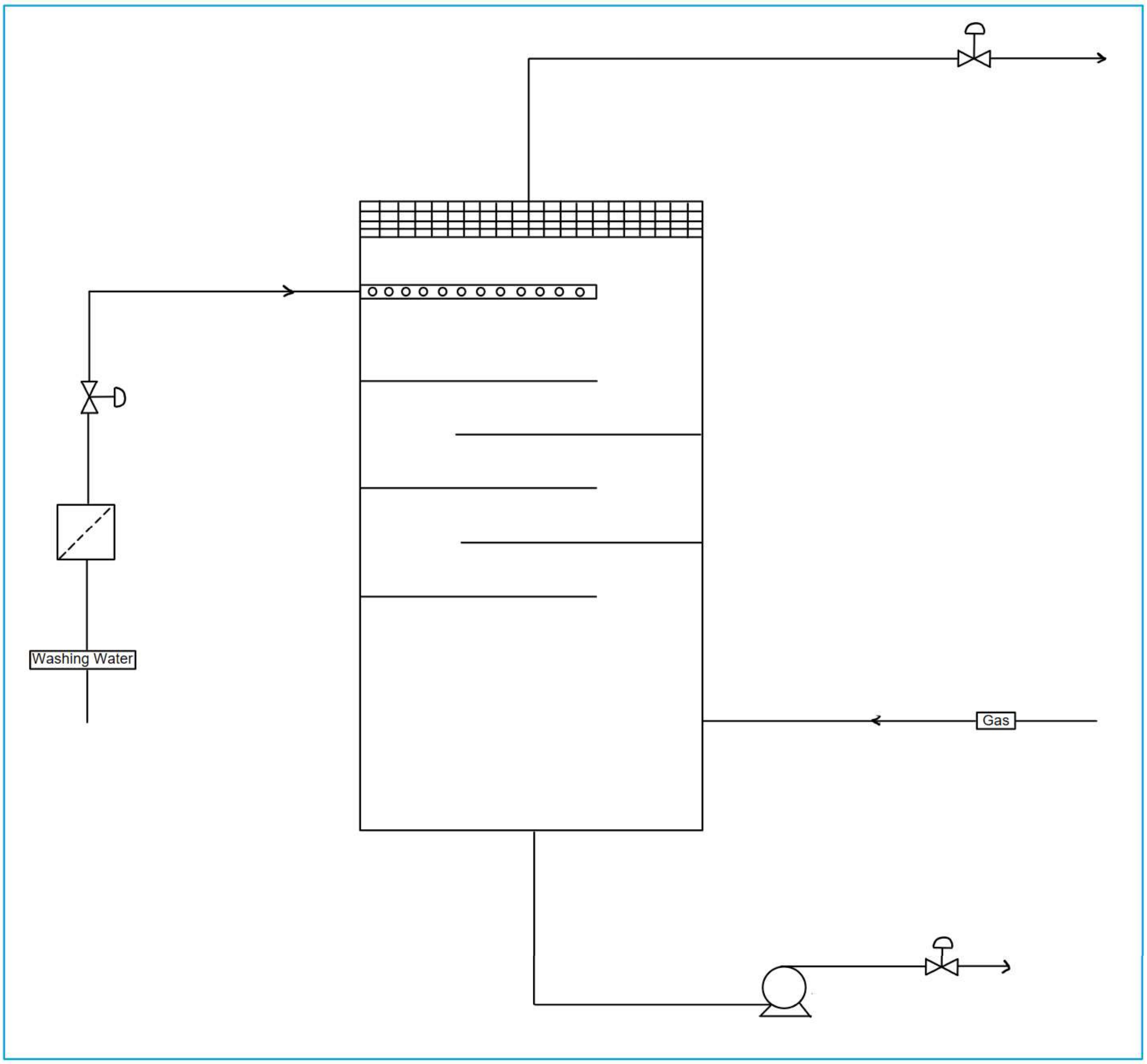
Now let's finalize it!



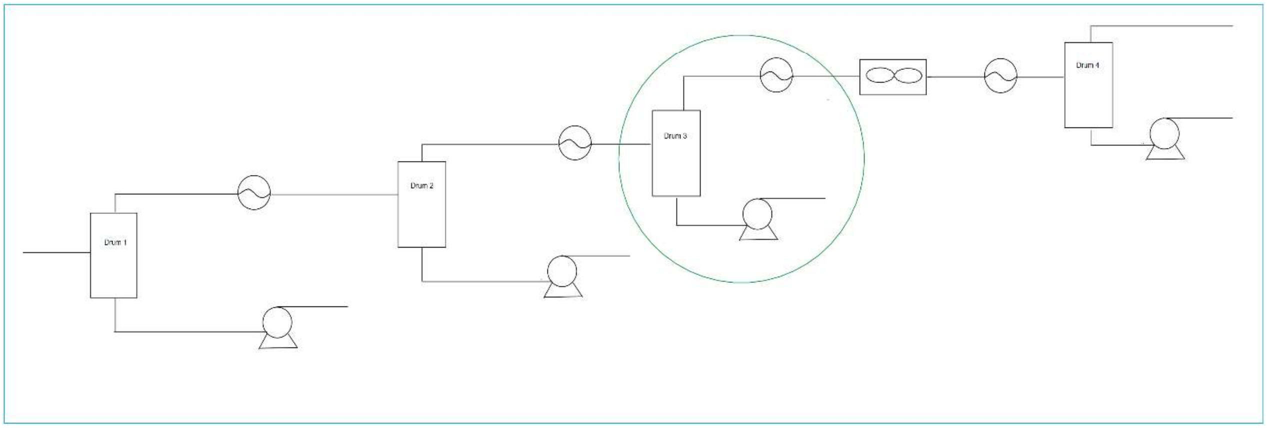
Yes, we have to show the plot in the note section of the P&ID.

Example 2:

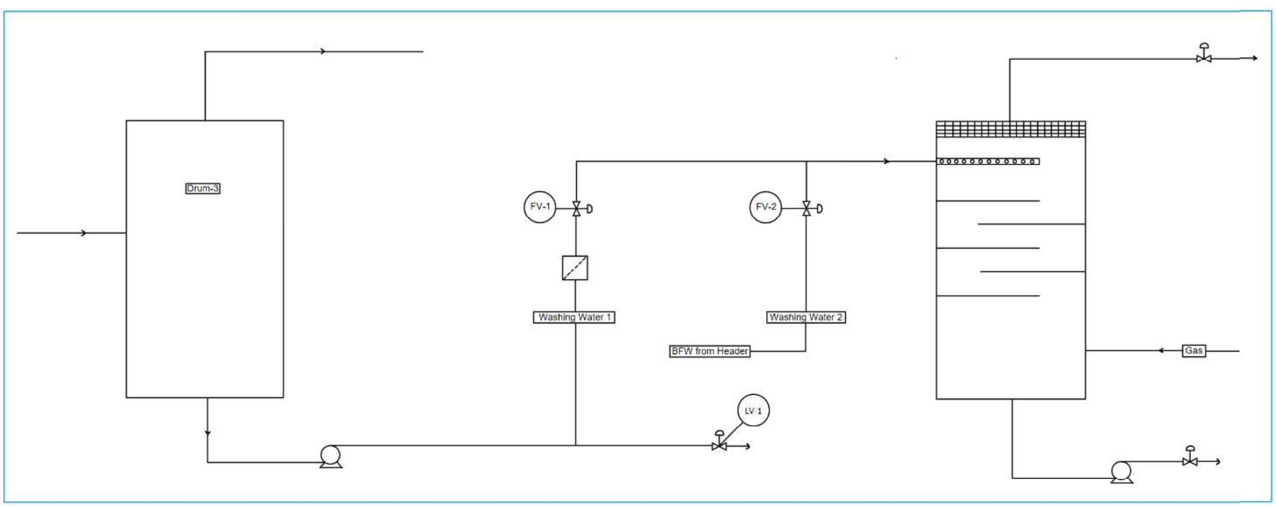
Catalysts are the heart of all processes. In fact, without them, literally all processes are meaningless. So, we should really take care of them during design and operation stages. Some catalysts such as reforming catalysts in hydrogen plants are extremely sensitive to some ions like Na^+. In this regard, to prevent carryover of such poisonous ions to the downstream catalysts, we can have a small drum-like tower in which countercurrent process happens. The gas comes from lower part and moves up while the washing water enters from upper part and goes downward. Based on simulation, mass and heat transfer principles, a good portion of Na^+ could move to the liquid phase. Here is the PFD-like sketch.



Due to surpless amount of process water and its quality and temperature, it could be used as washing water. But what is this process water?? Do you remember the following sketch when we where discussing the simple control loop?

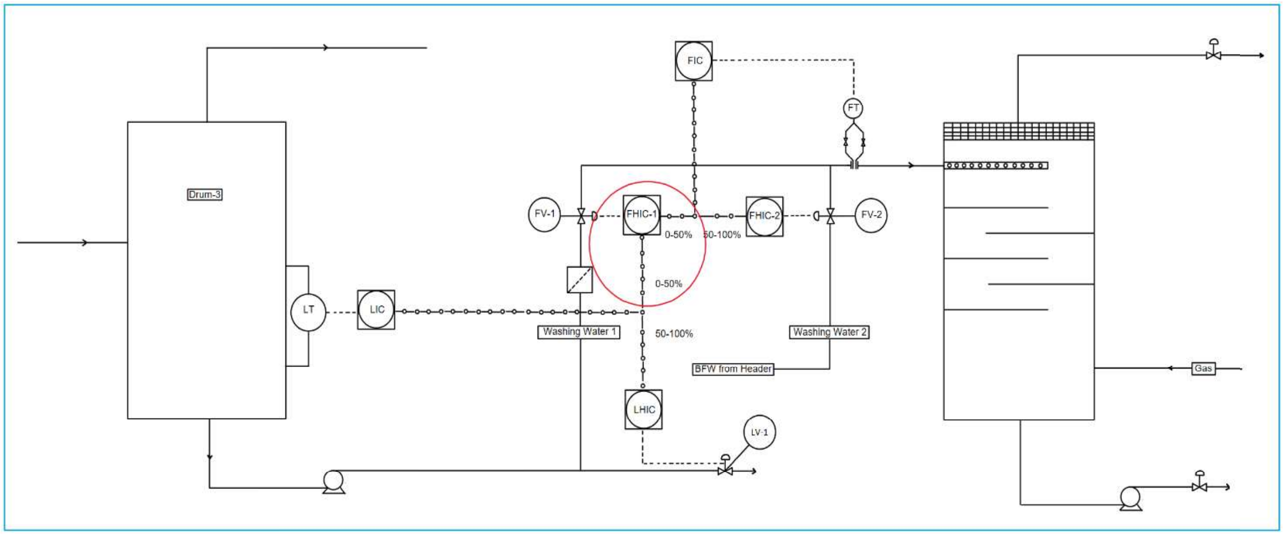


You were supposed to develop a control system for one of these drums. Anyway, let's focus on Drum 3 and re-use its separated water as its water condition approximately matches the quality of washing water. To make sure the drum-like tower operates extremely well at all conditions, BFW could be used as "stand-by" water in case some turbulences occur on Drum-3 during its operation. By the way, a part of Drum-3 separated water is also utilized in other process which needs water with such condition. To better understand what we are talking about, let's have all of them together and start analyzing its control system.



The aim here is to always maintain and keep washing water flowrate within the range. So we need a FIC for this purpose; it is also crystal clear that we should have split-range control since the controller should operate two control valves.

That is right that the flowrate of washing water to drum-like tower is very important but it should not be construed that we should ignore the separator! That is also a part of the process and should be as important as washing water flowrate in the eyes of process control specialists. Anyway, for the level control, we should also apply the split-range control since two control valves can impact the separator level.



Everything is in order except the FHIC controller part, which is shared by both Master controllers FIC and LIC. It is abnormal that the controller receives two MV at the same time; it is meaningless and the controller becomes confused which MV to take.

To overcome the issue, let’s have a look at it from our process demand. To better understand what by process demand is meant, the following scenarios are provided:

Imagine Master FIC sends a MV of 40%; it means that the FV-1 opening to be 80%. At the same time the Master LIC send a MV of 20%; it means that the FV-1 opening to be 40%. Now one of these MVs should be selected. Imagining incorporation of a high selector for a FHIC-1. Let’s see the result and consequences.

Scenario A: Adding a high selector before FHIC-1

Assumption: FV-1 current opening is 50%.

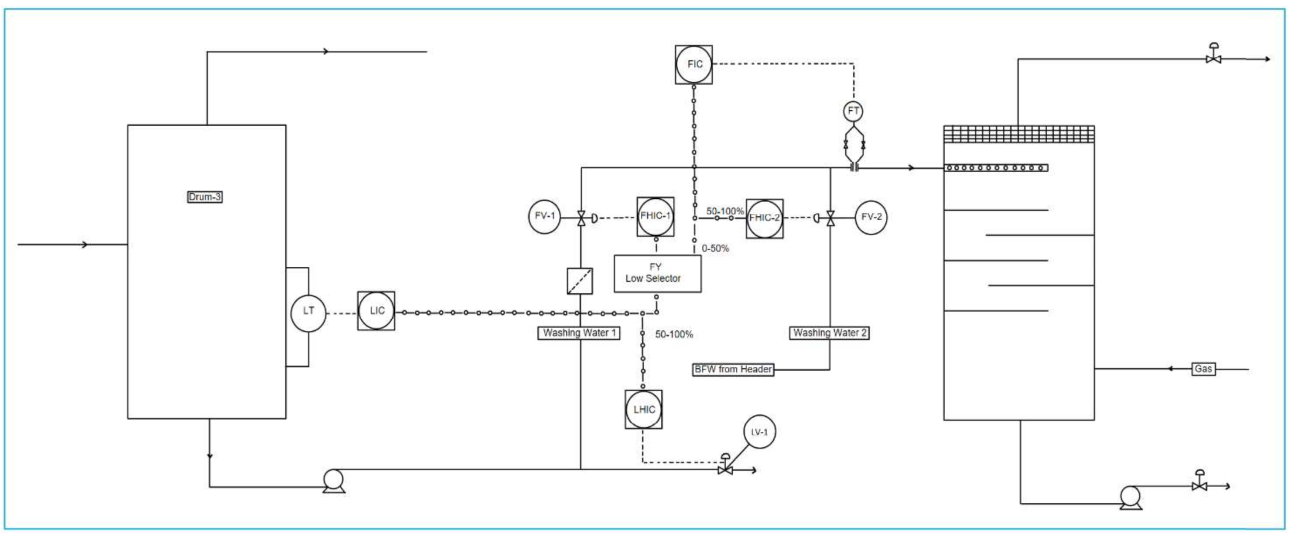
The high selector chooses 80% as the opening of FV-1 and FV-1 starts opening more and more until its opening reaches 80%. Simultaneously, since the valve opening increases, more water passes though FV-1 and the level starts decreasing. You know why? Because if wanted to keep the level within the range, the opening of the FV-1 should have been kept at 40%. The level decreases and decreases and at the same time the MV of Master LIC also decreases to 0% but its voice is going to be unheard!! Thanks to the fact that we have incorporated a high selector in our design and it is always going to choose a higher value. Finally, the separator reaches a low value and interlock is activated, stopping pumps.

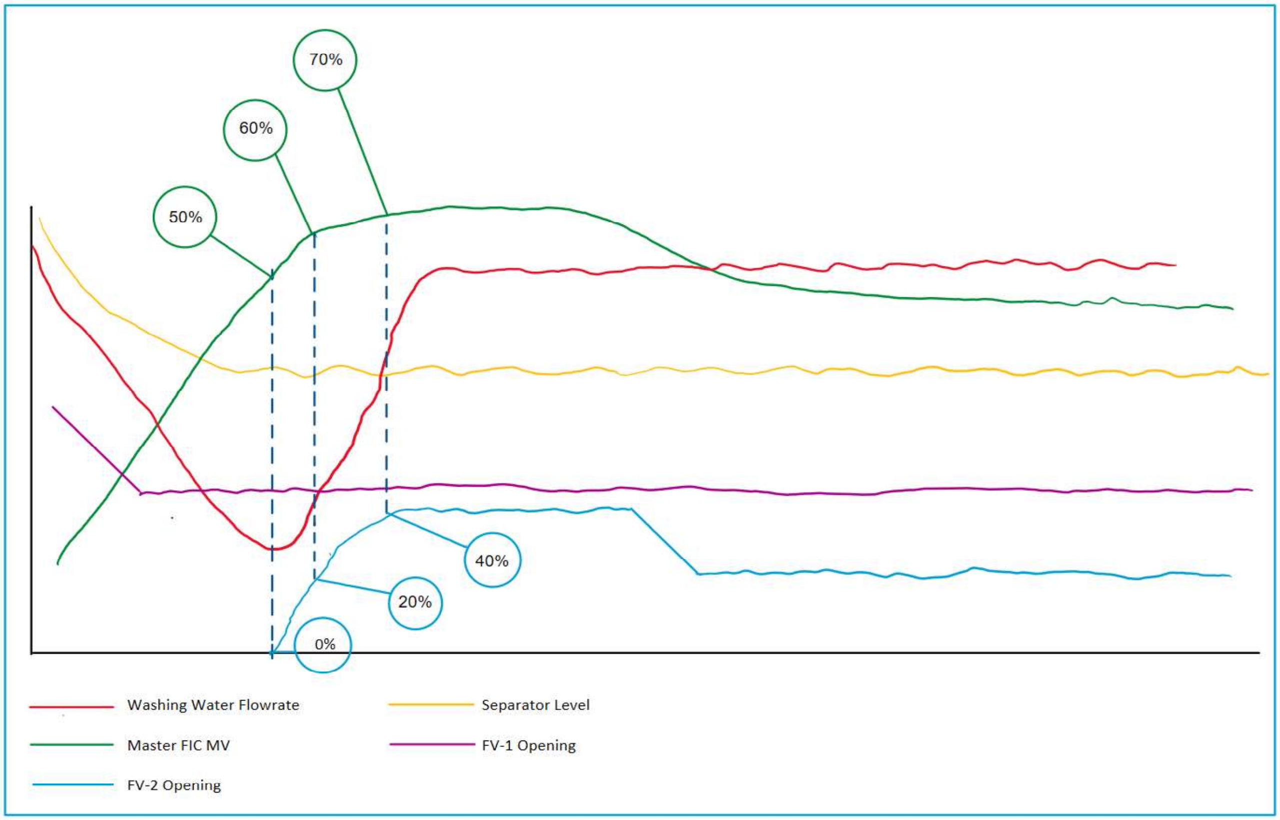
Scenario B: Adding a low selector before FHIC-1

Assumption: FV-1 current opening is 50%.

The low selector chooses 40% as the opening of FV-1 and FV-1 starts closing more and more until its opening reaches 40%. Simultaneously, since the valve opening decreases, less water passes though FV-1 and the level starts increasing. Now it sounds that the Master FIC has been ignored. So the Master FIC starts increasing its voices by increasing MV to 50%. Still ignored! Then it starts increasing its MV to 60%, which means the FV-2 opening to be 20% and start consumption of BFW. Let’s think dynamic! Then the Master FIC again increases its MV to 70% and as a result, the FV-2 opening increases to 40% and more BFW passes and added to the drum-like tower. Now the thirst of the Master FIC has been quenched and the Master FIC starts decreasing its MV to 60% and stay at this value. Therefore, the FV-2 opening would be kept at 20%. After half an hour, the operation team eliminate the cause that contributed to such turbulence and the Master FIC MV goes down to below 50% and FV-2 starts closing. That is the aim in fact. We don’t want to use BFW in continuously and it should be used only in turbulent situations like this.

You see how beautifully the Low Selector helped us to tackle the difficulty. To gain deeper understanding, let’s have a look at the next page diagrams which represents what has happened.

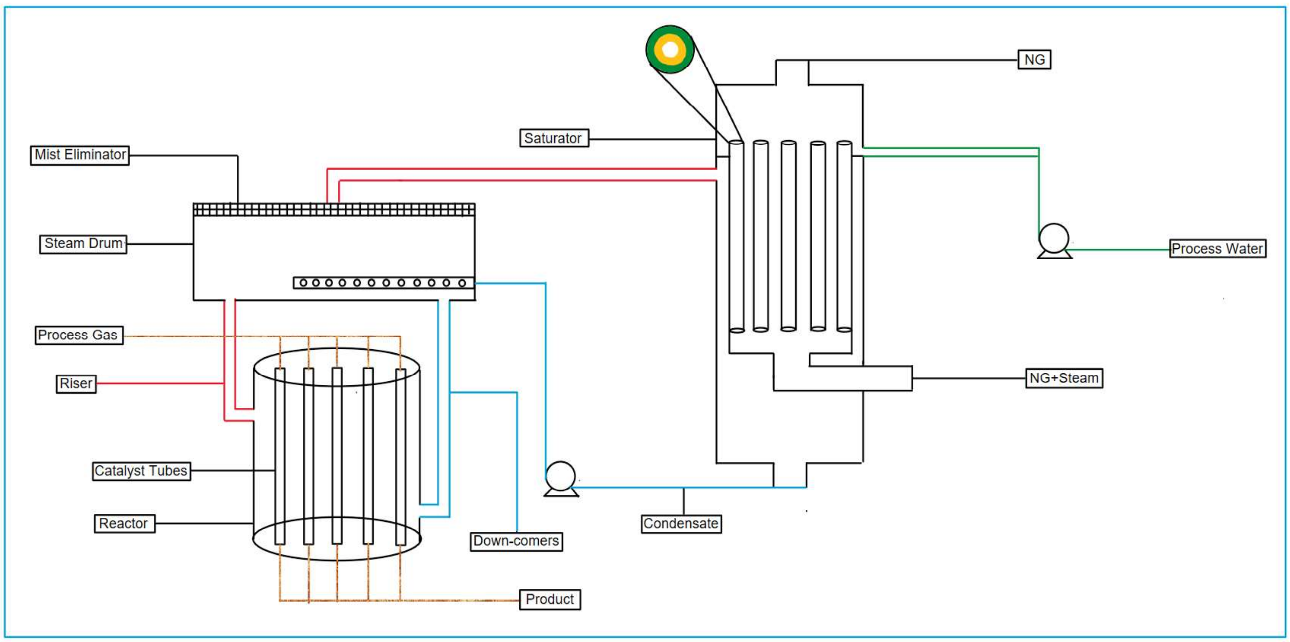




70%
60%
50%
40%
20%
0%
Washing Water Flowrate
Separator Level
Master FIC MV
FV-1 Opening
FV-2 Opening

Example 3:
You can find steam drums in almost each process plants. Understanding how they work really does not require that much process engineering knowledge since one you understand it you say of course it should happen like this. It is an act of nature.

The process gas passes through the catalyst tubes, the conversion occur, and the product is produced. Throughout the tube, while the reactants are converted to the product, immense amount of heat is produced. To optimize the process and get the best out of the heat produced, water enters the steam drum, comes around the tubes via downcomers, gets heated, via risers as saturated vapor moves up, enters the steam drum, collide with a baffle, and finally passes through mist eliminators and exits the steam drum as pressurized steam free of any water droplets.



When we as process engineer look at other side of the process, we see that we have a saturator which requires approximately the same amount of the pressurised steam. Don't be scared! The saturator is a vertical heat exchanger. Let's see what the purpose of the saturator is and how it functions. Simply, the NG is going to be cracked or reformed in a fired heater. In order to prevent the cocking on the surface of tubes in fired heater, NG is saturated with steam; to saturate NG with steam, NG comes to the saturator and becomes mixed with water with yellow color. Now both NG and process water moves downward alongside the tube. As they move downwardly, the pressurized steam which is produced in the steam drum enters the shell side of the saturator and provides a great deal of heat to the tubes. Now the heat by means of convection passes through wall of the tubes and vaporizes the process water which is moving downward in the tubes alongside NG. At the end, saturated NG with steam exit the saturator. The pressurized steam on the shell side which provided the heat, now gets cooled and becomes condensed. The condensate could be pumped to the steam drum, goes down to the reactor via downcomers, gets heated, and you get the story.

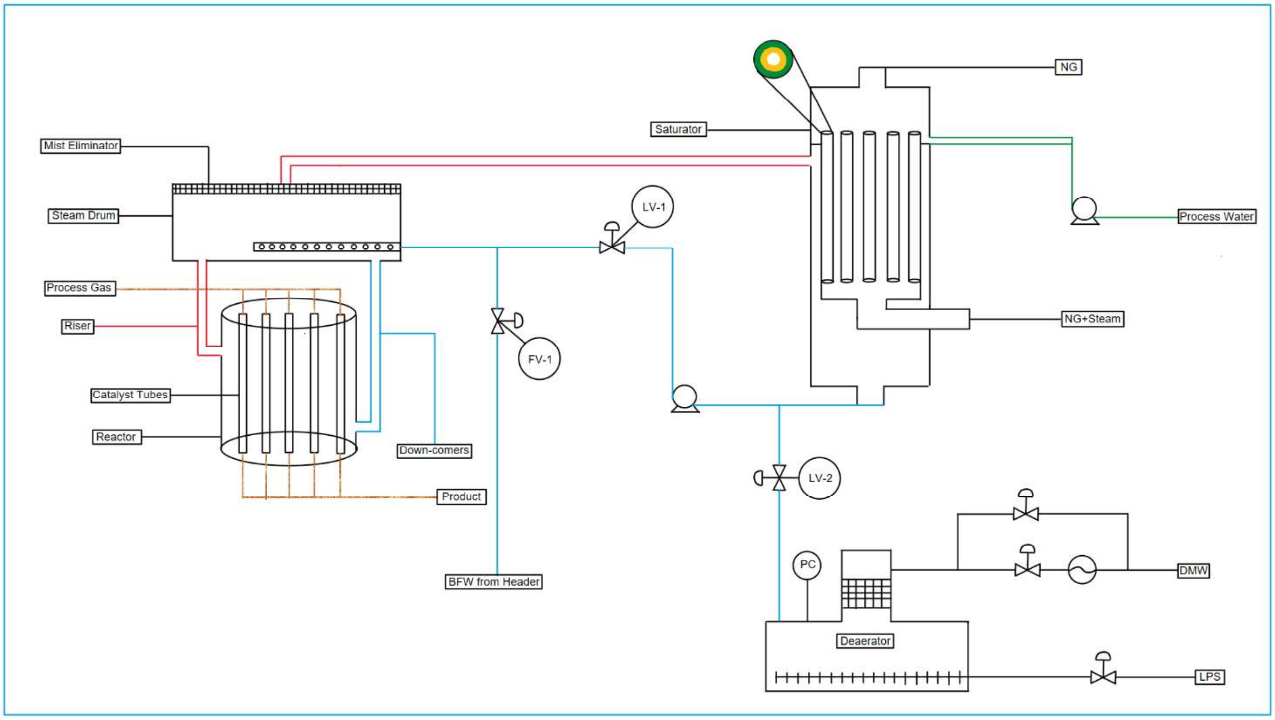
For now let's think like professionals and get out of academic contexts and environment!

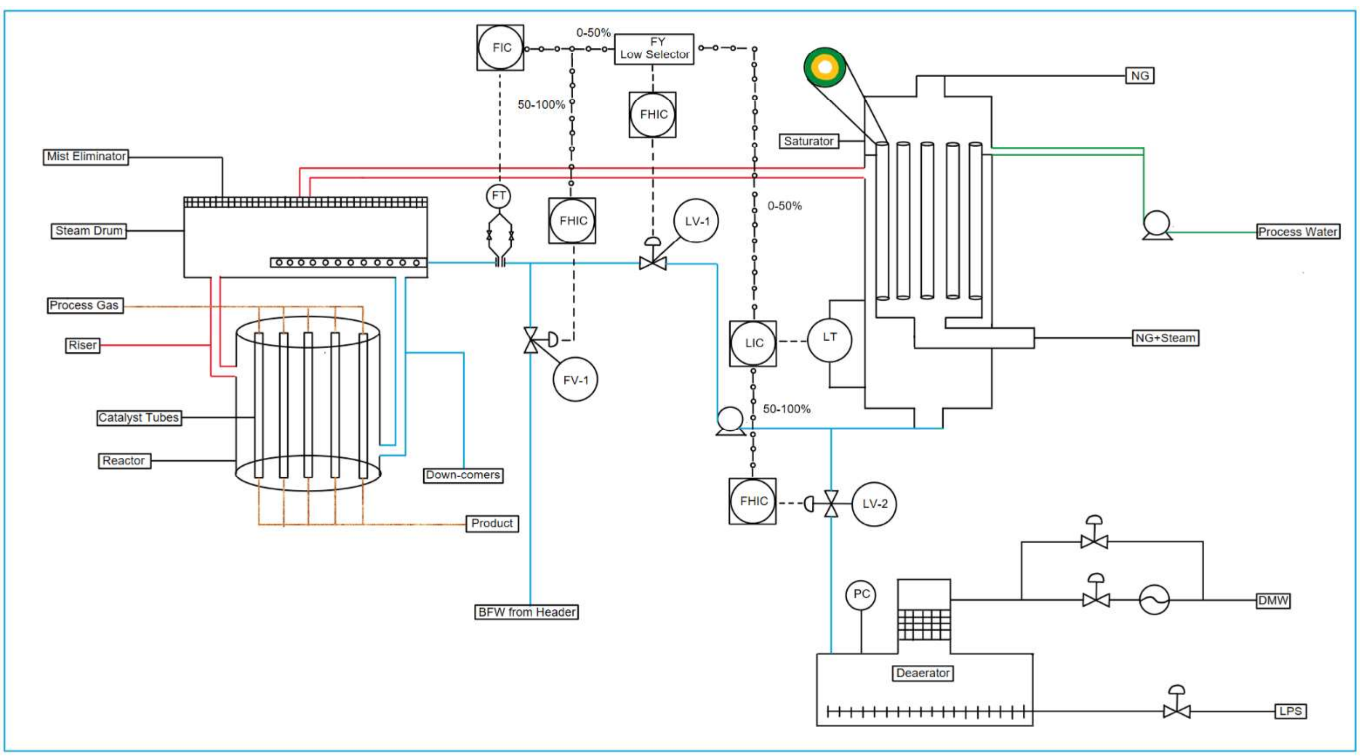
That was the normal operation of the loop and to the extreme point, you might think that even we don't need a control system to control the loop since everything happens mechanically and naturally!

We professional process and advanced control designers also take into account other parameters and conditions. Here are some to mention:

1. Each steam drum has a blow-down flowrate. Simply, the blow-down purpose is to get concentrated chemicals and particles out of the loop so that the quality of the water is kept within the range. From mass balance perspective, there is a loss and thus, make-up water should be added.
2. There are some times that the steam drum and reactor, due to some turbulences, might demand more water to dissipate the heat produced. So additional source of water is a must.
3. During start-ups, at first the saturator is put to the operation, then after one day, the reactor and steam drum assembly is brought to service. It means during start-up we should have another source of pressurised steam. To address the issue, we purchase pressurised steam from a utility plant, add it to the steam header, and finally connect the header to the shell side of the saturator. To be honest, it is not a big deal! The problem is somewhere else. The problem is that when we are at normal operation, we could use the condensate produced in the saturator and send it to the reactor and steam drum assembly. But during start-ups we don't have the steam drum and reactor assembly in operation, and hence, can't send the condensate to the assembly. In order to tackle the problem, we can use the deaerator as the receiver of the condensate during start-ups as the deaerator is the first unit to be put in service in most petrochemical start-ups.
4. If we consider the deaerator route, there is another advantage. Thanks to some turbulences, the reactor and steam drum assembly requires less boiler feed water. In case this happens, the excess water could be sent to the deaerator.

Here is the new sketch and what we should focus on:


NG
Saturator
Mist Eliminator
Steam Drum
LV-1
Process Water
Process Gas
Riser
FV-1
NG+Steam
Catalyst Tubes
Reactor
Down-comers
LV-2
Product
PC
DMW
BFW from Header
Deaerator
LPS


FIC
0-50%
FY
Low Selector
NG
50-100%
FHIC
Saturator
Mist Eliminator
FT
0-50%
Steam Drum
FHIC
LV-1
Process Water
Process Gas
LIC
LT
NG+Steam
Riser
FV-1
50-100%
Catalyst Tubes
Reactor
Down-comers
FHIC
LV-2
Product
PC
DMW
BFW from Header
Deaerator
LPS