Level control drain valve tuning

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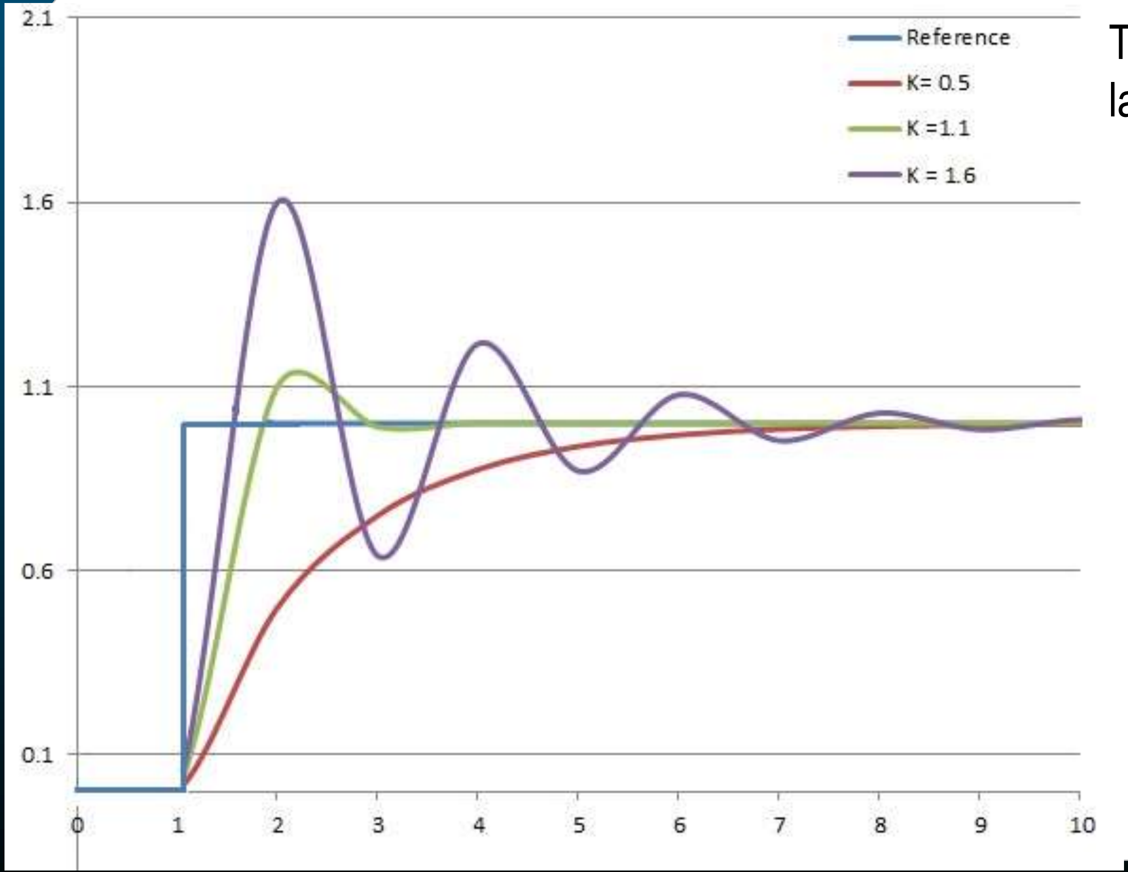
DUKE ENERGY®

Tuning Introduction – Why is it important

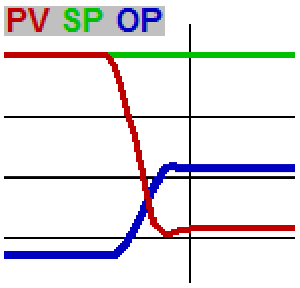
- PI and PID controllers have been accepted throughout process design and all forms of controllers.
- Everyone has a PI and/or PID controllers in their station.
- PI and PID controllers are everywhere in your station some common areas include:
  - FWHs level controllers (drains)
  - Rx level control (SULCV)
  - Drain tanks
- Tuning is an art and often hard to be a precise science – EPRI
- Improper tuning can result in system instability in response to transients, loss of efficiency, Rx level oscillations.
- For a longer duration, improper tuning will result in unusual equipment degradation rates

- Set Point (SP), Process Variable (PV), Output (OP)
- Controller: Generates a signal (output) in response to a process error detected by the feedback loop. The most common type is a PI (Proportional and Integral)
- Error (e): Difference between Set Point and Process Variable
- Proportional Response (P): The proportional response is a control response in which there is a continuous linear relationship between the output and the input. Proportional response can be obtained by multiplying the 'error' (e) by the process 'Gain' (K_c).
- Proportional Band (PB%): (Do not confuse with Gain or Proportional Term) Measured as a percent with respect to gain inverse x 100
- PB = 100 / K_c *OR* $K_c = 100 / PB$ Large gain = Large response, Large PB = Small response
- $P_{out} = K_c \times (e) * (t)$
- *For an error with a magnitude of 10 and a controller gain of 5 the response would be 50.*

Tuning basics – Gain comparison

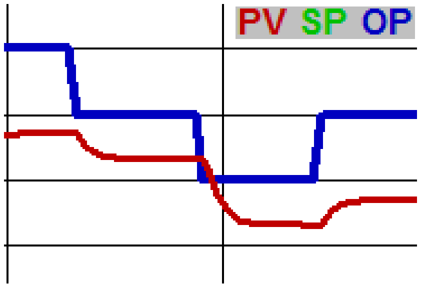


This simulation lacks offset



Gain Only Response

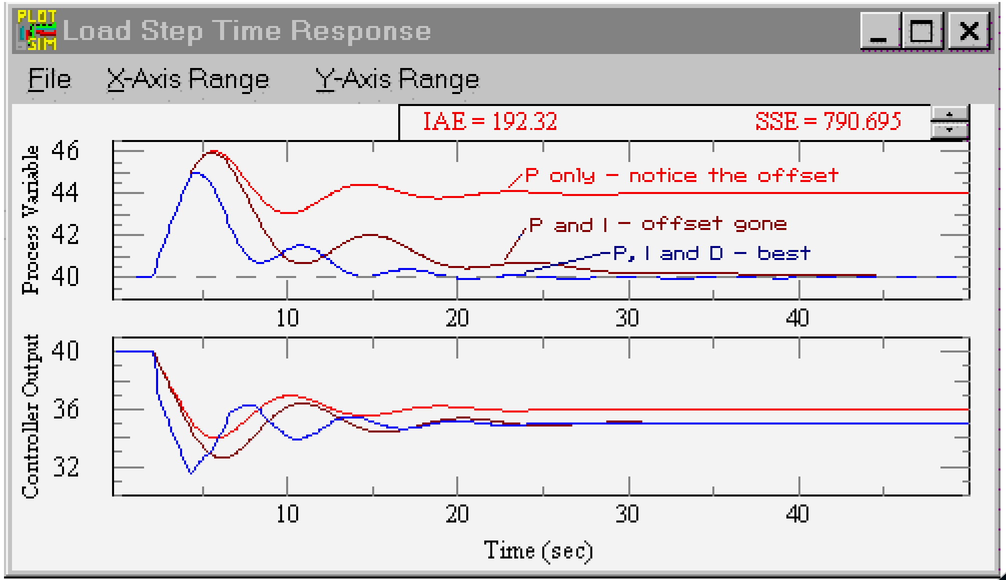
- Integral Response (I): Intended to eliminate offset. Integral sums up the error over time. When (e) = 0 controller output is likely not equal to 0. Units may be in resets/min OR minutes / reset.
- Response is based on a rate of change
- Gain alone is difficult to tune to. Excessive gain will result in overshoot, insufficient gain will result in large offset from PV and SP.
- Hysteresis: Some devices will yield a different PV for the same OP depending on whether the OP went up or down to get there. A valve might allow 25 GPM through after moving from 20% to 30%, but 30 GPM after moving from 40% to 30% (too low of gain or no integral)
- Offset: difference between set point and process variable.
- Tank with drain valve (P)
- Tank with inlet and outlet flow (I)



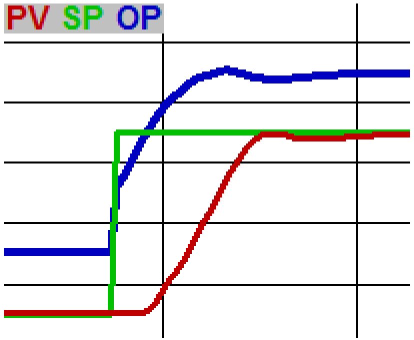
OP Hysteresis

Comparison of what an integral and proportional bands

Reset Only Response



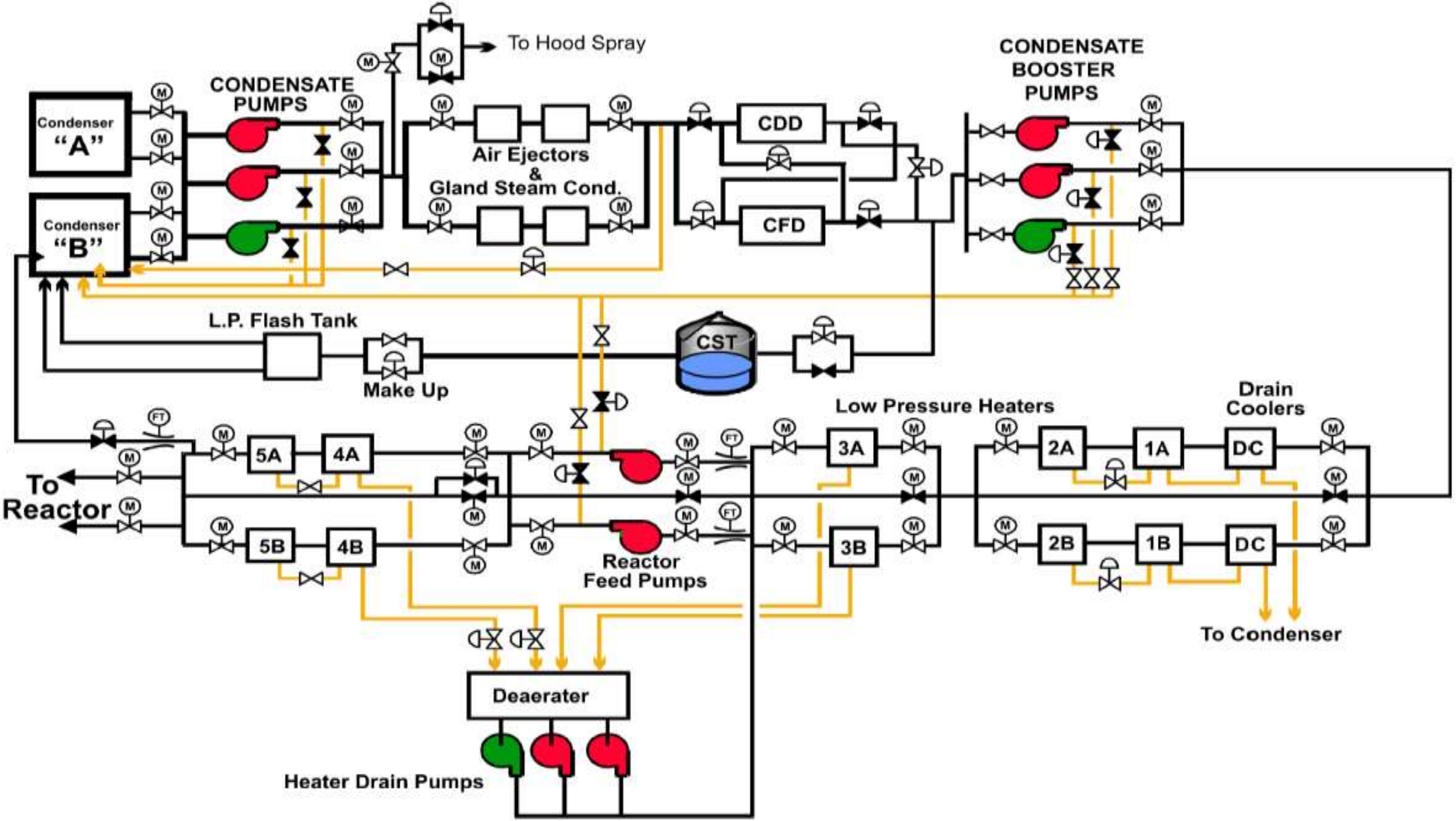
- After inducing an upset, the PV is approaches the SP.
- Proportional and Integral react in opposite directions.
- Allows PV of a well tuned loop to approach the SP without excessively overshooting or undershooting.
- In a typical reverse-acting loop, the proportional will try to lower the OP as the PV rises toward the SP. The integral response will raise the OP because PV is below SP.
- As the PV gets closer to the SP, integral action decreases resulting in the PV smoothly decelerating into the SP.



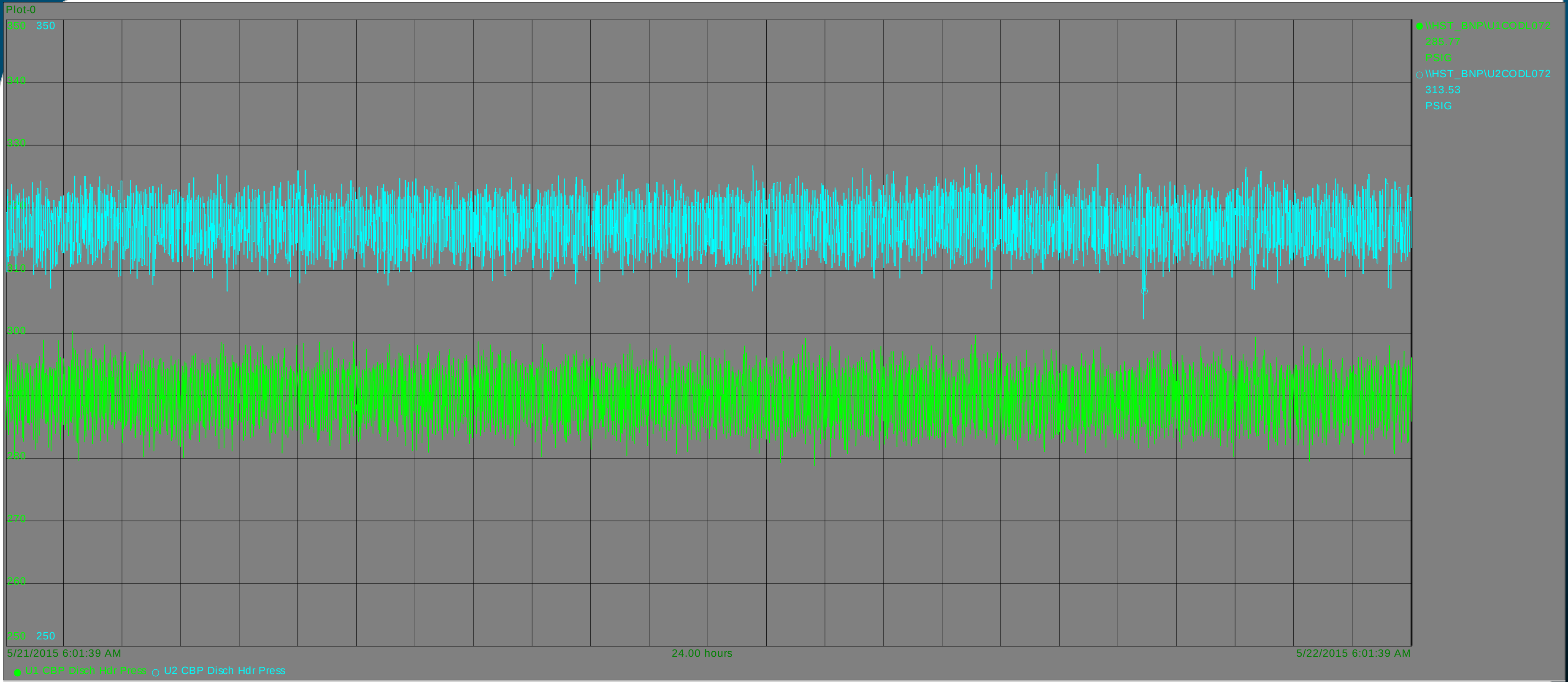
Gain and Reset Together

BNP OE event discussion

- Post EPU and satisfactory performance
- Series of inputs and outputs from the loop
- The loops is normally operated with 3 condensate pumps
- In March 2015 B222R1 refueling outage, Condensate Margin project was implemented.
  - Allows the station allowed to transition from 3 to 2 condensate pump operation.


To Hood Spray
CONDENSATE PUMPS
CONDENSATE BOOSTER PUMPS
Condenser "A"
Condenser "B"
Air Ejectors & Gland Steam Cond.
CDD
CFD
L.P. Flash Tank
CST
Make Up
Low Pressure Heaters
Drain Coolers
FT
5A
4A
3A
2A
1A
DC
5B
4B
3B
2B
1B
DC
To Reactor
Reactor Feed Pumps
To Condenser
Deaerater
Heater Drain Pumps

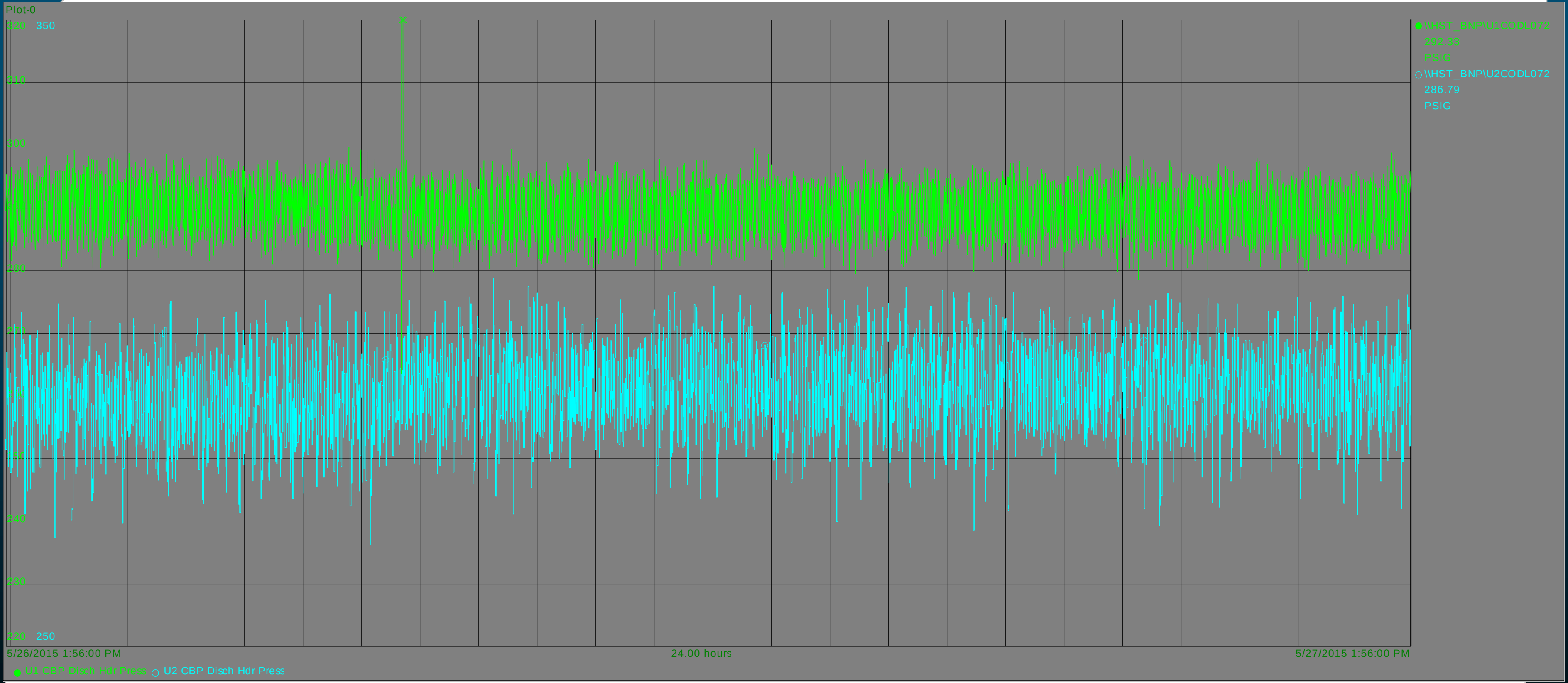
Comparison of Unit 1 (2 pumps) and Unit 2 (3 pumps) CBP discharge header

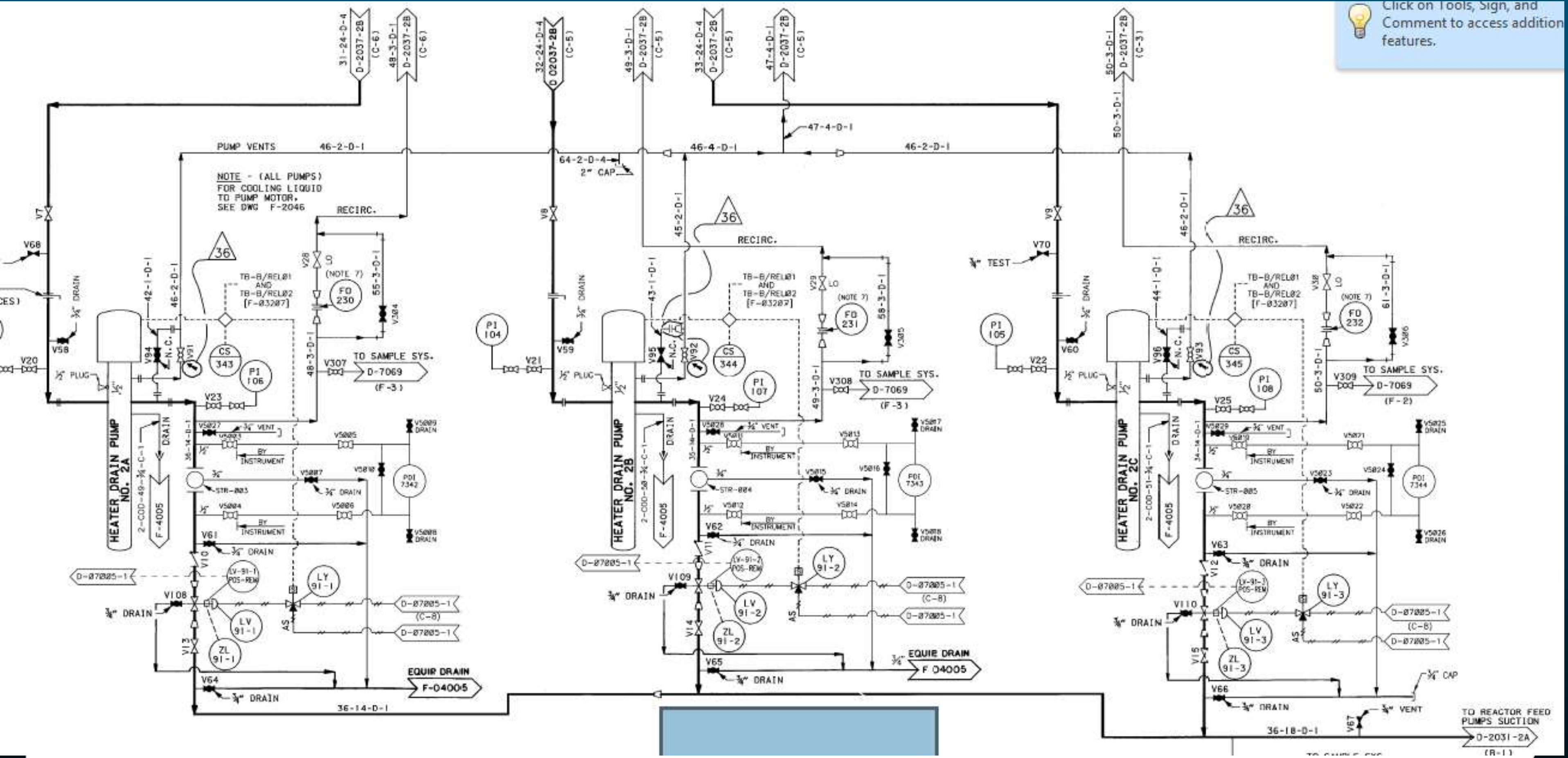


Transitioning from 3 to 2 Cond pump operation… Irregularities observed

- On 5/26/15 at 0954 Operations transitioned from three to two condensate pump operation. After securing the third condensate pump, system pressure dropped and system oscillations were observed. This shift in performance and system pressure oscillations have been present since securing the 3rd condensate pump and have not deviated.
- Booster pump discharge header pressure dropped expectedly from 320 to 260 psig.
- Unexpected 30-40 psi CBP pressure oscillations and HDD level oscillations 44 to 52 inches. Normal level is ~48 inches +/- 0.5 inches.
- Concern over opening HDD backup dump valve, HDD pump trip, CBP auto start, RFP suction pressure alarms.
- Operations started the 3rd condensate pump. Oscillations stopped and pressures returned to normal.

Comparison of Unit 1 and Unit 2 CBP discharge header in 2 pump operation




Click on Tools, Sign, and Comment to access addition features.
PUMP VENTS
46-2-D-1
46-4-D-1
47-4-D-1
NOTE - (ALL PUMPS)
FOR COOLING LIQUID
TO PUMP MOTOR,
SEE DWG F-2046
RECIRC.
HEATER DRAIN PUMP NO. 2A
HEATER DRAIN PUMP NO. 2B
HEATER DRAIN PUMP NO. 2C
TO SAMPLE SYS.
D-7069
EQUIP DRAIN
F-04005
F 04005
36-14-D-1
36-18-D-1
TO REACTOR FEED PUMPS SUCTION
D-2031-2A
¾" TEST
¾" DRAIN
¾" VENT
¾" CAP
2" CAP
STR-003
STR-004
STR-005

Heater drain pump performance

- Single controller 2-HD-LC-91 receives input from the HDD tank level element. The controller output goes to 3 individual positioners and valve actuators.
- The controller output began at 67.5% output and dropped 4% and quickly recovered by 2% output. The output continued to decline until output was 52.5%. Overall, there was a 15% decline in output with 'sawtooth' patterns.
- Once the 3rd condensate pump was restored to service, the controller output only oscillated between 54 to 57% in a stable sinusoidal.
- In two condensate pump operation, the HDD control valve position was observed at approximately 27% open.
- In three condensate pump operation, the HDD control valve position was observed at approximately 47% open.
- Known fact, the HDD discharge valves are oversized and are expected to operated more closed than open.

Corrective Actions – Performed in 2010

- In 2010 a new valve trim was installed with ‘quick opening’ characteristics. Tuning was performed for 3 HDD pumps.
- Outside contractor requested to perform evaluation and provide tuning characteristics.
- Controller tuning parameters as-left settings 3.4 Gain and 1.55 min/reset.
- Pressure oscillations were normal 10-15 psig (as seen in the first graph)
- Satisfactory performance observed.

Investigation – Performed in 2015

- Compared positioner responses between A and B HDP discharge valve positioners (equipped with feedback arm). Dissimilar outputs and valve position indicates degradation in the positioner or valve.
  - Similar responses in output and feedback observed
  - Confirmed valves were further closed
- Swapped from A and B HDPs to A and C HDPs to assess the performance in the C and B loops and determine system sensitivity.
  - No change in performance obseved
- Observed all other inputs and extractions from the loop to/from external reservoir or loop.
- Observed internal extractions and return lines such as the FWHs and RFP speed controls.
- There was NO apparent cause relating to equipment damage or externally induced.

Former and new valve curve with new trim

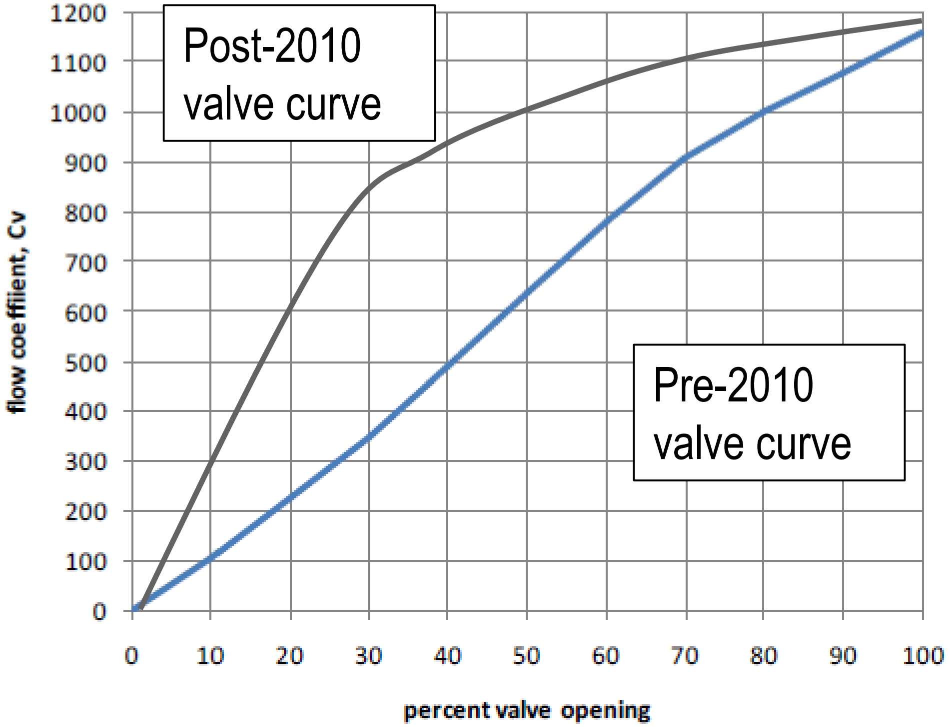
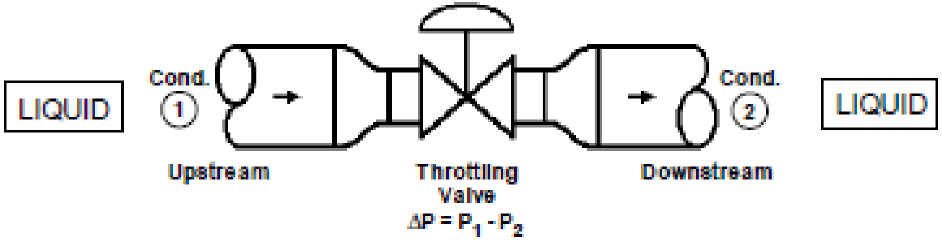


Figure 2 Flow coefficient versus travel of the HD 91 control valves

Corrective Actions – Performed in 2015

- The new valve trim was changed to a quick opening trim.
- Throttling valves operate as a steady state, steady flow device. The entering and exiting mass flow rates are the same; i.e. flow is “continuous”, and the Continuity Equation is applicable

$$C_v = \dot{Q}\sqrt{\frac{SG}{\Delta P}}$$



$\dot{m}_1 = \dot{m}_2$ $A_1 = A_2$ $T_1 = T_2$ — no phase change

$\bar{v}_1 = \bar{v}_2$ $\varnothing_1 = \varnothing_2$ $\rho_1 = \rho_2$

fluid = water

$\Delta P = P_1 - P_2 = 1.00$ psid

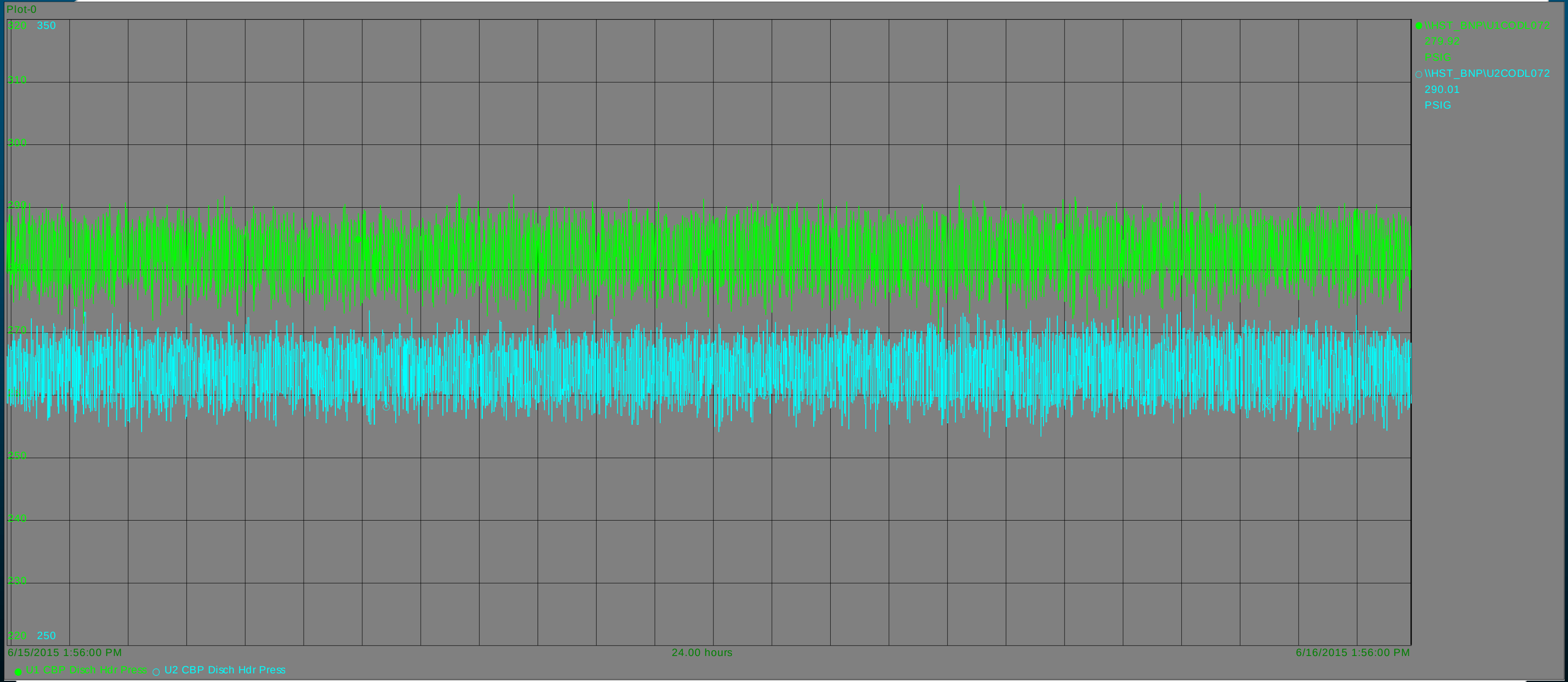
$\dot{Q} = 1.00$ US GPM

$T = 60°F$

$SG = 1.00$

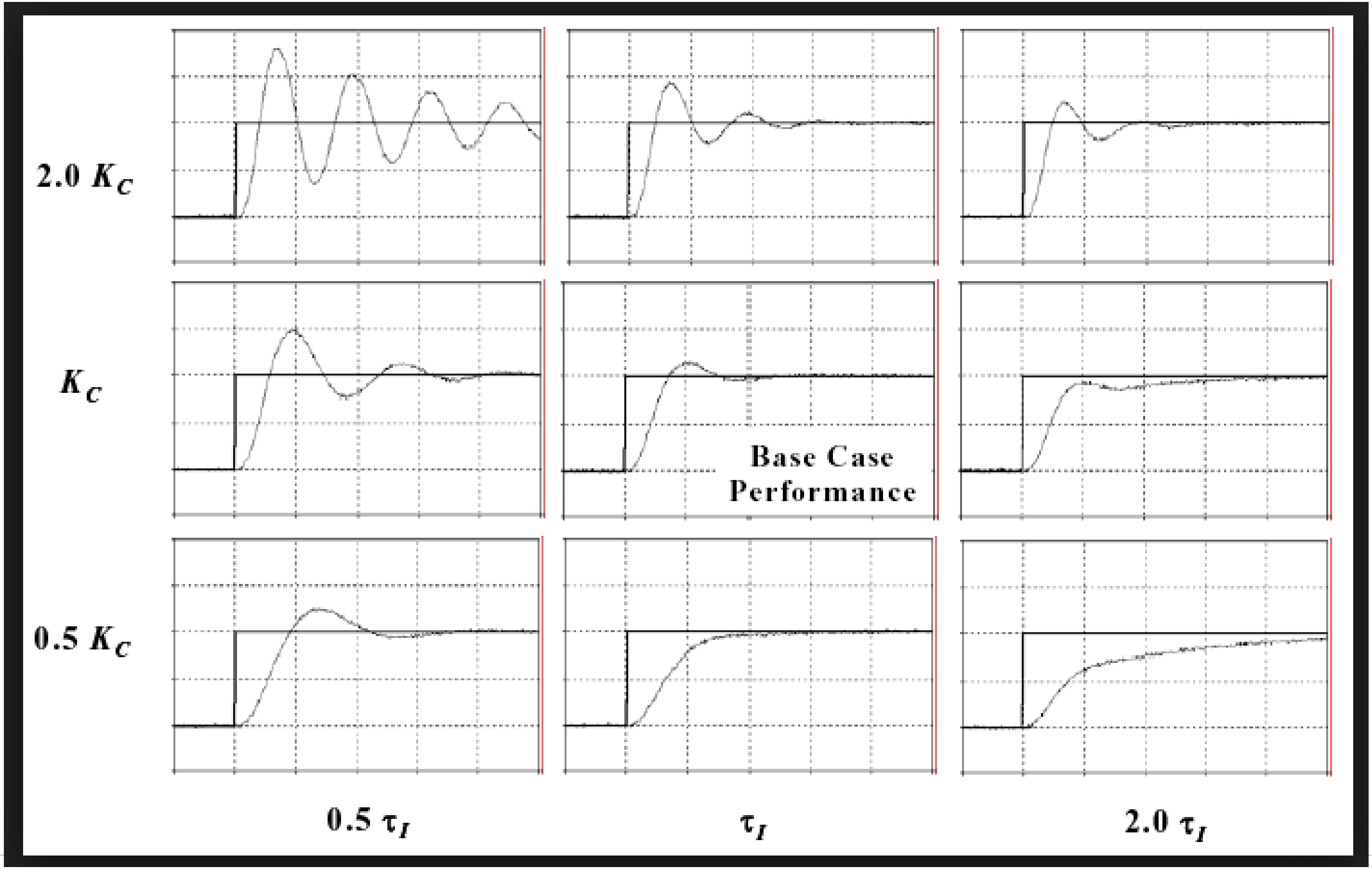
} $C_v = 1.00$

Post Tuning results



Closer look at finding tuning issues

- Component changes… Make sure your EC package contains tuning evaluation and basis.
- Tuning should only be performed ONLY when all other plausible failure modes have been ruled out. Maybe you have a latent failure mode?
- Following a new plant mod or change operations. Did you:
  - Install a new component such as a valve?
  - Transition from a 2(3) pump operation to 3(2) pump operation?
  - Implement EPU?
  - ANYTHING that may affect flowrates
  - Or maybe no one has ever noticed it



2.0 K_C
K_C
0.5 K_C
Base Case Performance
0.5 τ_I
τ_I
2.0 τ_I

- Requires access to adequate trending parameters especially Set Point, Controller Output, and Process Variable.
- Most controllers start with a gain of 1.0 (PB 100%) and a reset of 1.0 rpm.
- Tuning should be performed with a simulator or when there are no margin concerns such as auto pump starts, trips, and no impact on reactivity.
- Approximation: Loops where the PV changes quickly due to a change in Output (flow, or pressure or level in vessels with fast turnover) should have low Gain (Higher PB) perhaps 0.2 (20%) and higher reset (1.5 – 10 rpm). Loops where the PV changes slowly, or changes its direction of movement due to change in Output (temperature and level in vessels with slow turnover) typically need high gain (3 – 100) and low reset (0.05 – 0.3).

How to tune…

- Several approaches. However it is your choice of what method you use. All have advantages and disadvantages.
- Tuning methods include:
  - Ziegler-Nichols Method
  - Trial and error
  - Cohen-Coon method
  - Process Reaction Curve
  - Quarter wave dampening (preferred)

How to tune…Process reaction curve

	K_c	T_i	T_d
P	K_0		
PI	$0.9K_0$	$3.3\tau_{dead}$	
PID	$1.2K_0$	$2\tau_{dead}$	$0.5\tau_{dead}$

$$R = \frac{\tau_{dead}}{\tau}$$

$$K_o = \frac{X_o}{M_u}\frac{\tau}{\tau_{dead}}$$

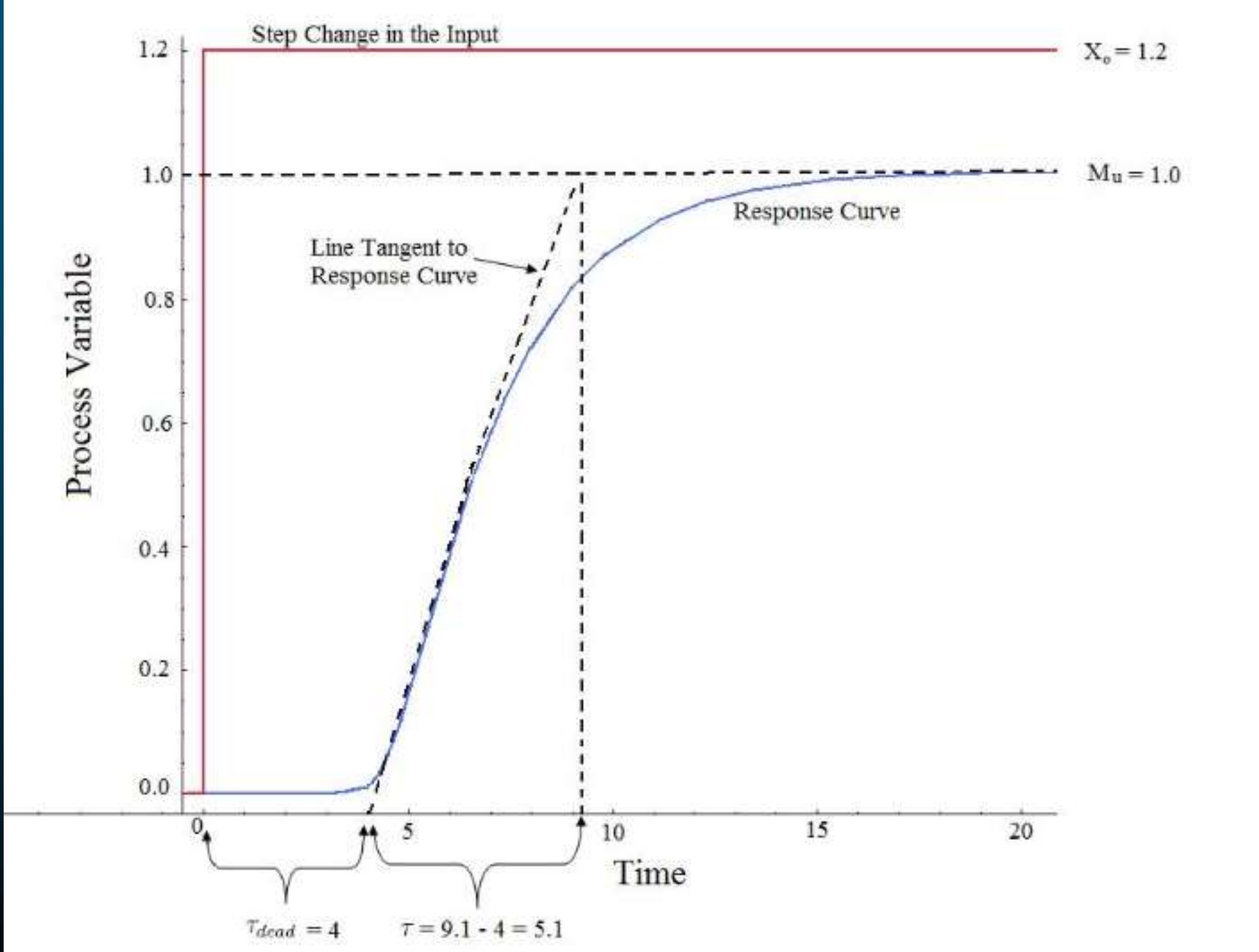
τ_{dead} = transportation lag or dead time: the time taken from the moment the disturbance was introduced to the first sign of change in the output signal

τ = the time for the response to occur

X_o = the size of the step change

M_u = the value that the response goes to as the system returns to steady-state

.Process reaction curve

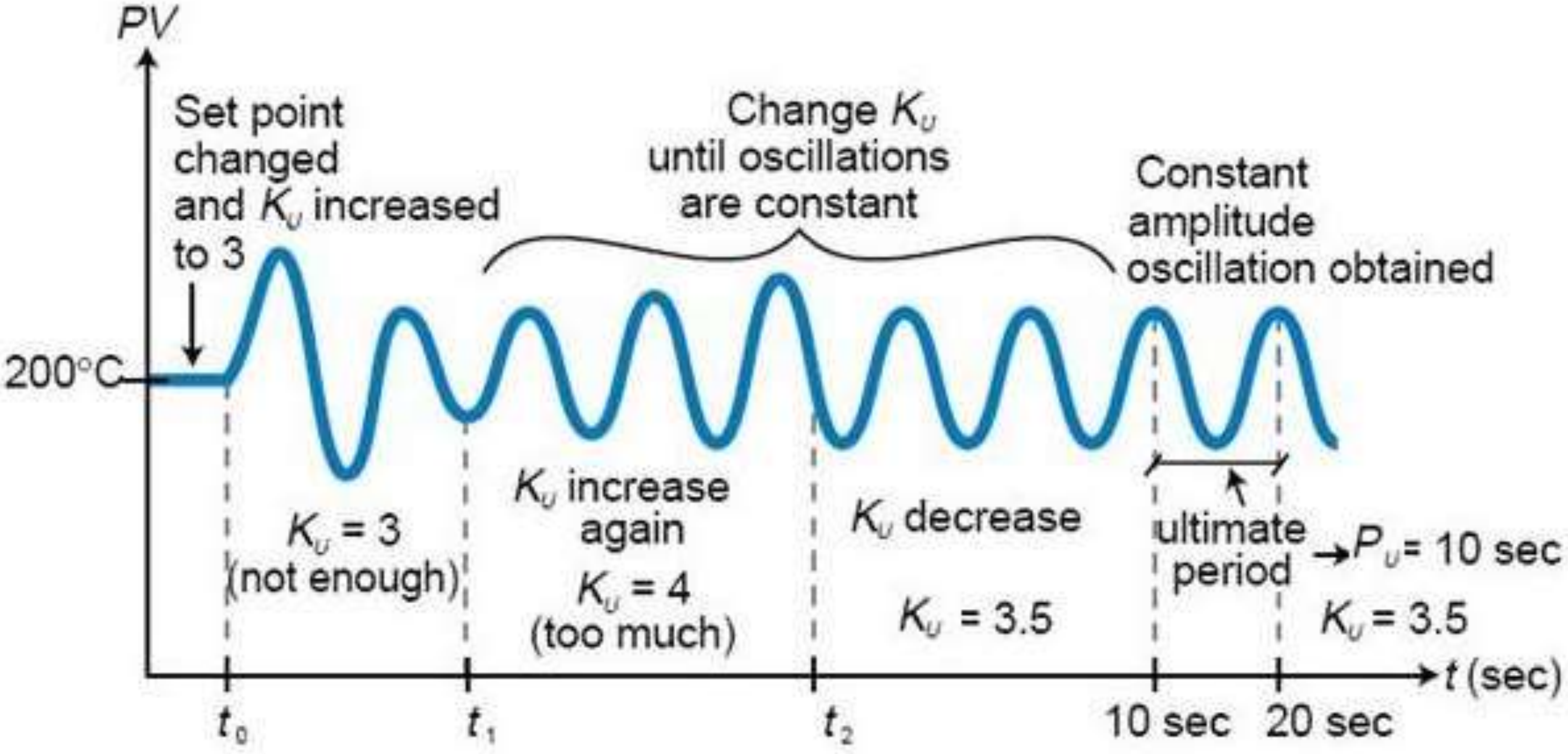


How to tune… Ziegler-Nichols Method

- Remove integral and derivative action. Set integral time (T_i) to 999 or its largest value and set the derivative controller (T_d) to zero.
- Create a small disturbance in the loop by changing the set point. Adjust the proportional, increasing and/or decreasing, the gain until the oscillations have constant amplitude.
- Record the gain value (K_u) and period of oscillation (P_u).
- Use the following table to obtain new settings

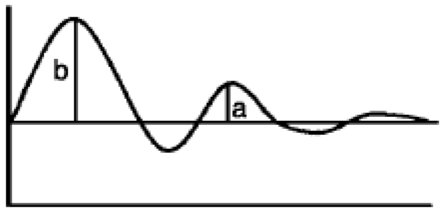
	K_c	T_I	T_D
P	$K_u/2$		
PI	$K_u/2.2$	$P_u/1.2$	
PID	$K_u/1.7$	$P_u/2$	$P_u/8$

How to tune… Ziegler-Nichols Method



- Quarter wave dampening approach.
- A good method to determine a decent setting.
- Induce an upset and ideally try to obtain this result
- No basis for the 0.25 ratio. However it has been successful and recognized in the industry including EPRI documents.

Optimal Stability
(Quarter Wave Damping)

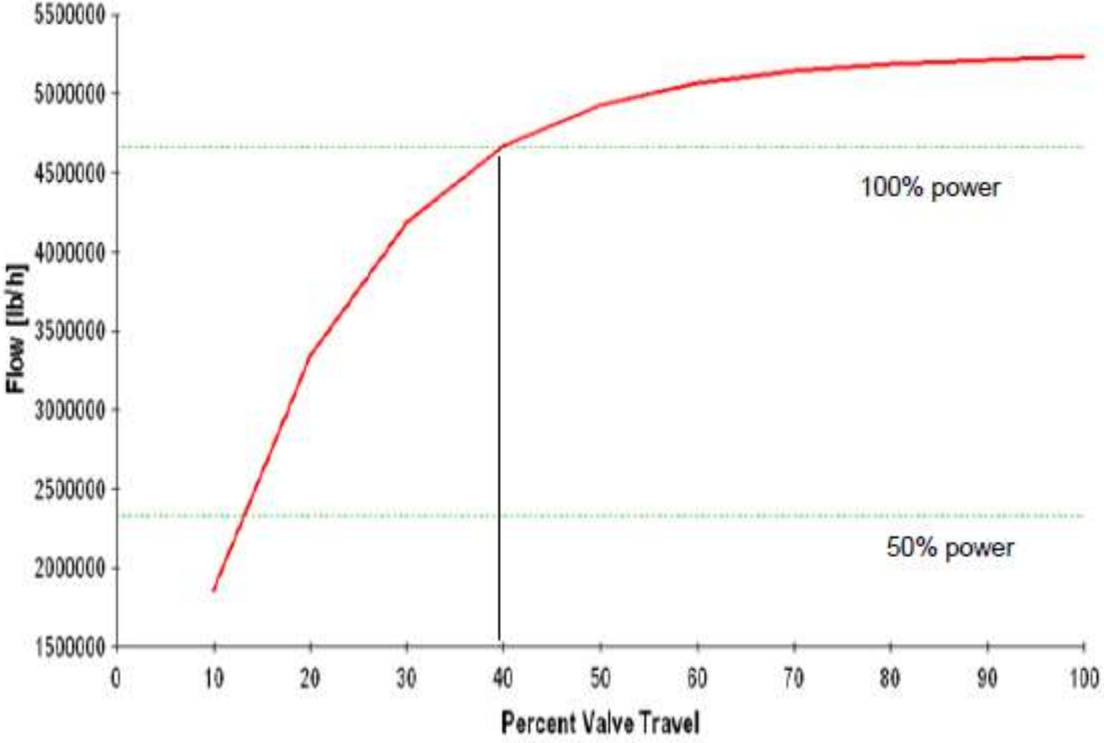


Stable if a/b = 0.25

- At BNP management challenge denied original tuning plan to combination Ziegler-Nichols Method / QWD approach.
- HDD trip would trip the 3, 4, and 5 FWHs (6 total) on Hi-Hi level… OR trip all HDPs on Low-Low level (both would result in a major power reduction)
- Talk of taking the integral band to the max AND inducing an upset is very uneasy given the already unstable controller.
- Tuning plant equipment while in service and connected directly to feedwater and reactivity is high-risk.
- Tuning should be performed when you are at full power operation. Do not tune at 50% power and ride up to 100% expecting similar results.
- Consider using the plant simulator to tune. Verify the accuracy of the simulator before attempting to tune. Most simulators you can tune equipment

Do not tune at reduced power

Observed flowrates during start up

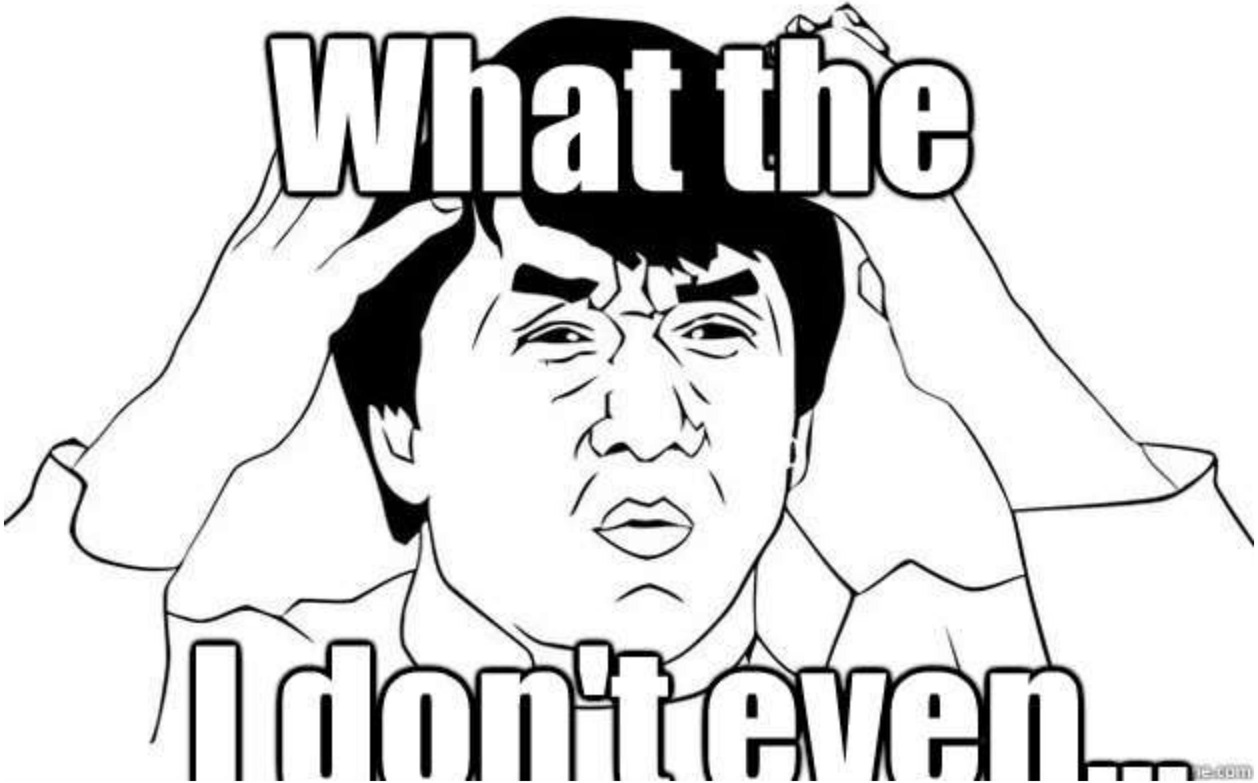


How to tune… tips

- Apply Engineering Judgement (that term everyone is so afraid of)
- Be patient and watch the controllers, outputs and Process Variables. The Control valves on the HDD had response times (to respond, overshoot, settle) of over 5 minutes.
- Compare performance across units and across trains.
- If the valve was properly tuned in the past and plant conditions change tuning the gain alone should be sufficient.
- At BNP the Gain on the HDD controller was reduced by half.
- Induced a set point change and achieved the Quarter wave dampening performance that was desired.
- There are likely multiple tuning parameters that will deliver satisfactory performance. Do not look for one specific set of parameters

How to tune… tips

- Quarter Wave dampening is important to verify you did not over dampen the controller. At steady state a dampened controller will appear stable. However if there is a plant transient, the controller may not be quick enough to recover.


What the
I don't even...

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