

# Helium Operators Familiarization Program

## Unit 324/325 – Control Loops

Dec 2012 | Vincent HELOIN



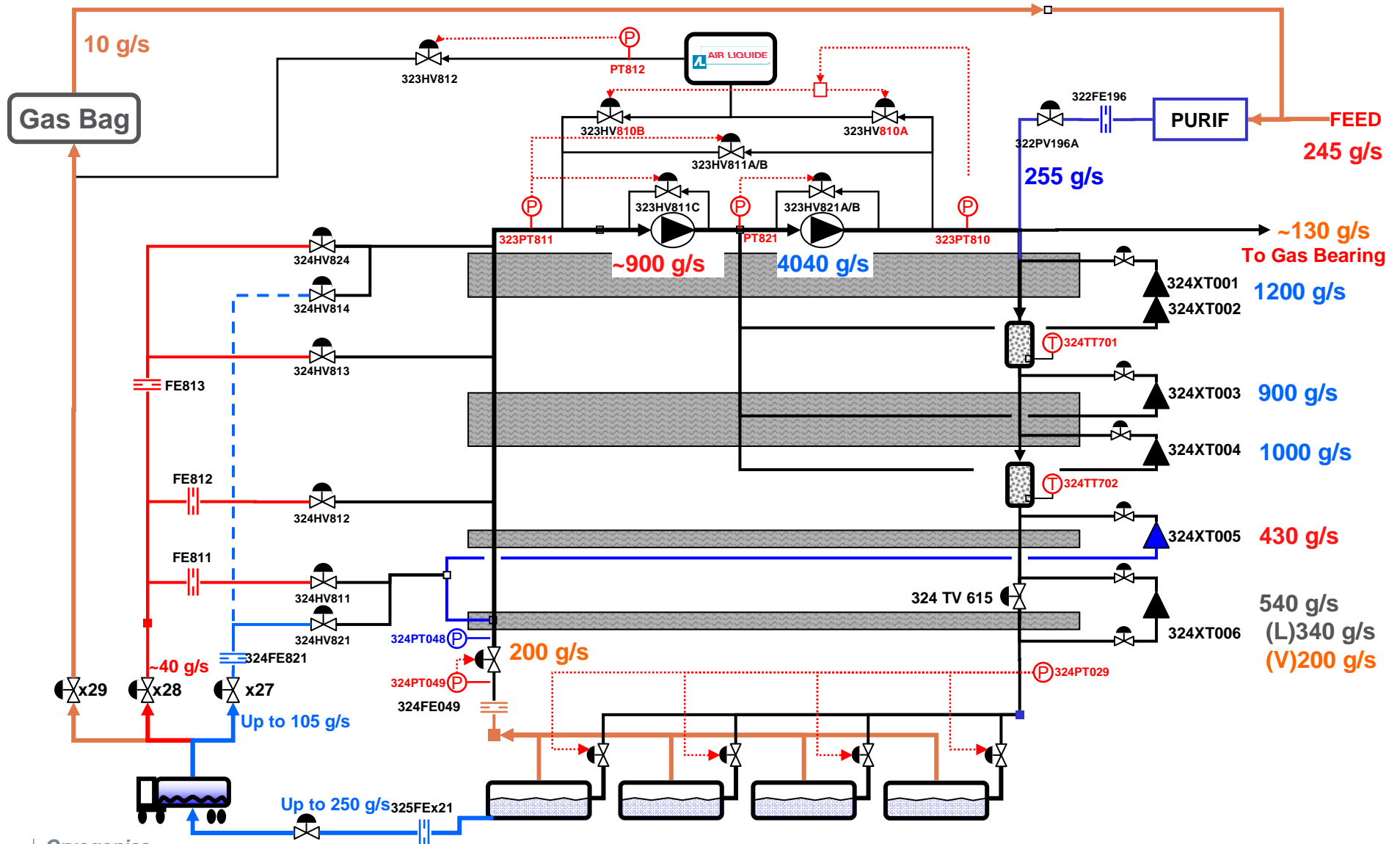
# Course Agenda

- Control Loops

- Nitrogen Loops

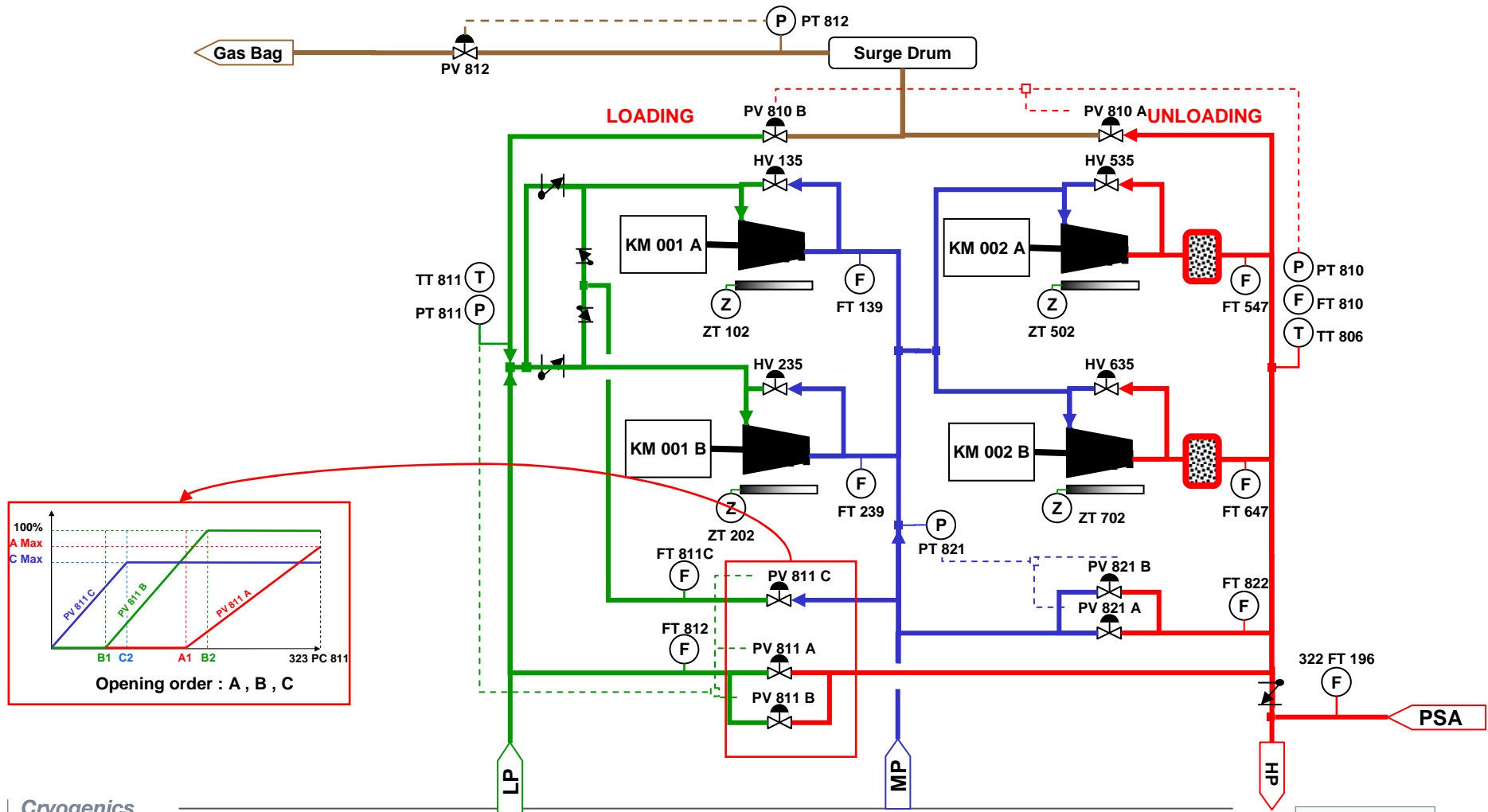
- Turbines Controls

# OVERALL



# Compressor Regulation

## ■ (Reminder)

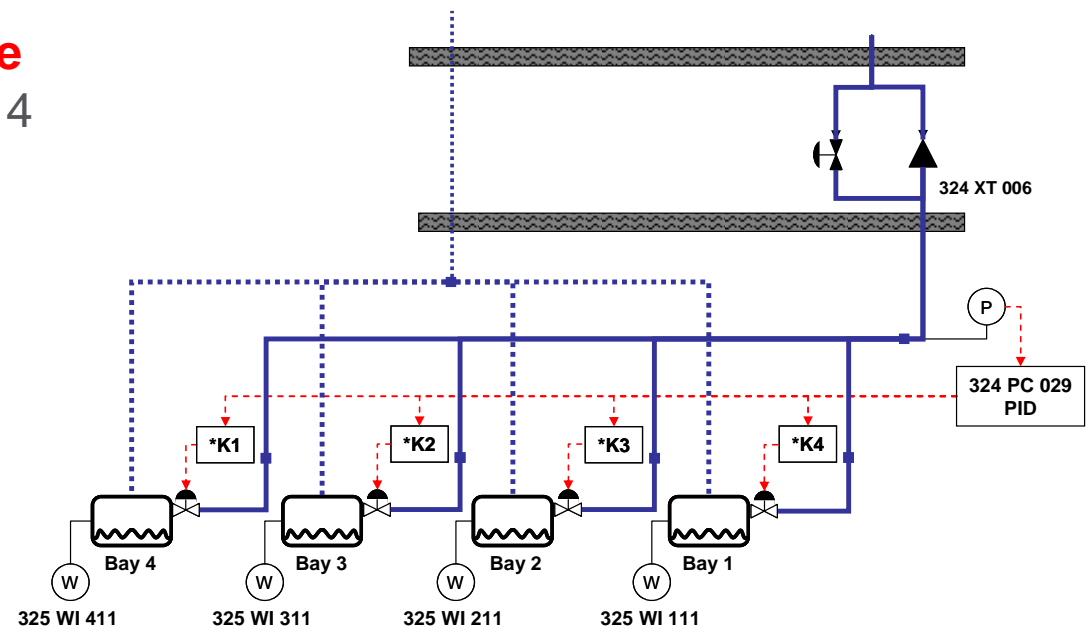


# 324 PC 029 - T6 back pressure

## ■ 324 PC 029

- ▣ Object : Turbine 6 back pressure
- ▣ Actuator : 325 PV 101, 201, 301 & 401
- ▣ Process Value: 324 PT 029
- ▣ Set Point : ~3.0 Bara\*
- ▣ Action : Direct

T6 outlet pressure maintain **above 2.25 bar a (critical Pressure)** by 4 JT valves



# 324 PC 029 - T6 back pressure

## ■ 324 PC 029

Consumption of LHe from the 4 storage tanks is not even

-> Use of factors on opening to maintain **an even level across the 4 storages.**

A MINIMUM opening applies to each of the JT Valves in order to have a continuous flow.

A MAXIMUM opening applies to each JT Valves in order to limit the flow (low pressure downstream T6)

**FLOW\_1** = MAX ( 325 FT 121 , 25 g/s )

**FLOW\_1 Coefficient** =  $4 \times \text{FLOW\_1} / \sum \text{FLOW\_i}$

**LEVEL\_1 (3)** = MAX ( 325 WT 111 / 14,500kg, 10% )

**LEVEL\_1 Coefficient** =  $4 \times 1 / \text{LEVEL\_1} / \sum (1 / \text{LEVEL\_i})$

**BAY\_1** For each Bay, the user can force a coefficient, called Bay from 1 to 10.

**BAY\_1 Coefficient** =  $\text{BAY\_1} / \sum \text{BAY\_i}$

In nominal Operating Conditions:

Opening: 15% → 30 g/s = Minimal flow.

Opening: 50% → 140 g/s = Nominal Flow.

Opening: 70% → 540 g/s = T6 Max Flow.

The Values in Green are accessible with the Operator Access.

The Values in Blue are accessible with Engineer Access

| JT VALVES              | BAY 1   | BAY 2  | BAY 3  | BAY 4   |
|------------------------|---------|--------|--------|---------|
| Withdraw flow →        | 200 g/s | 0 g/s  | 0 g/s  | 100 g/s |
| FLOW COEFFICIENT: X 4  | X 2.7   | X 0.0  | X 0.0  | X 1.3   |
|                        | 75 %    | 50 %   | 50 %   | 25 %    |
| LEVEL COEFFICIENT: X 1 | X 0.6   | X 0.9  | X 0.9  | X 1.7   |
|                        | 1       | 1      | 1      | 2       |
| BAY COEFFICIENT: X 1   | X 0.8   | X 0.8  | X 0.8  | X 1.6   |
| 324 PC 029 = 30 %      | X 1.35  | X 0.55 | X 0.55 | X 1.55  |
| JT OPENING             | 40 %    | 17 %   | 17 %   | 45 %    |
| MINI OPENING = 5%      |         |        |        |         |
| MAXI OPENING = 70%     |         |        |        |         |
| OK                     |         |        |        |         |

# 324 PC 049 / 809 – Dewars Pressure Regulation

## ■ LHe Storage Tanks Pressure control

- **324 PIC 049:** used in Normal Operation to maintain a constant P in the LHe Storages: ~1.30 Bara.
- **324 PIC 809:** used in Liquefier is down to avoid Pressure increase in the LHe Storages.

### 324 PC 049 (Liquefier ON)

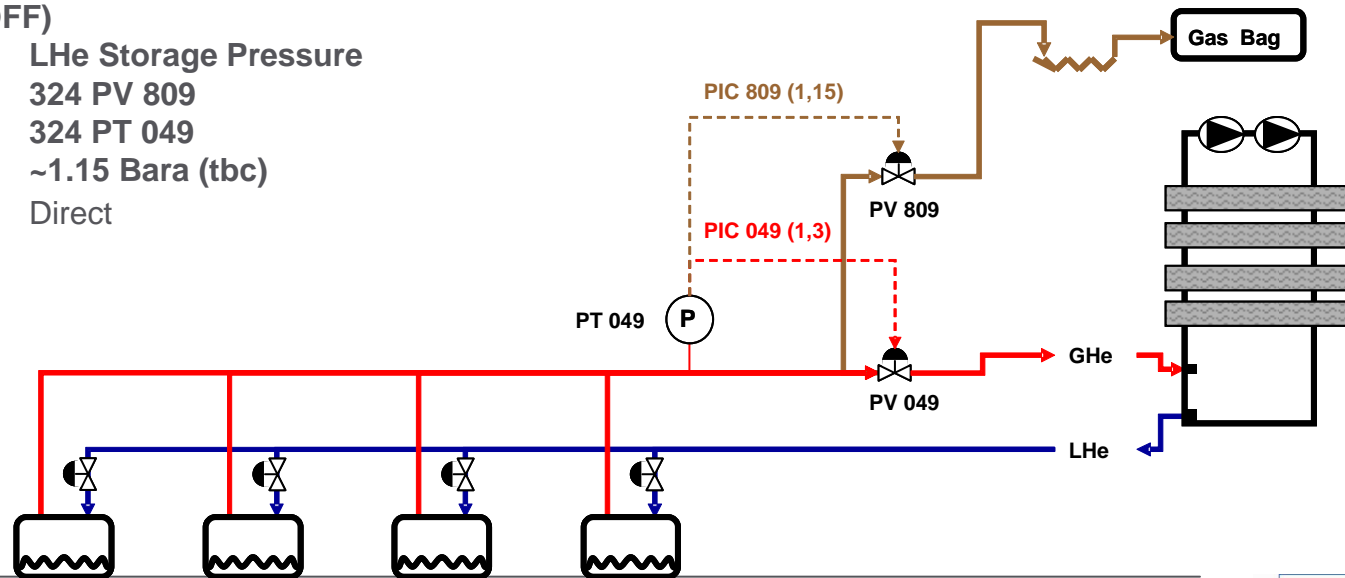
Object : LHe Storage Pressure  
 Actuator : 324 PV 049  
 Process Value: 324 PT 049  
 Set Point : ~1.3 Bara (tbc)  
 Action : Direct

### PV049 Opening boundaries

|                 |     |     |
|-----------------|-----|-----|
| MIN             |     | 15% |
| MAX 324 XT 005: | ON  | 80% |
| MAX 324 XT 005: | OFF | 50% |

### 324 PC 810 (Liquefier OFF)

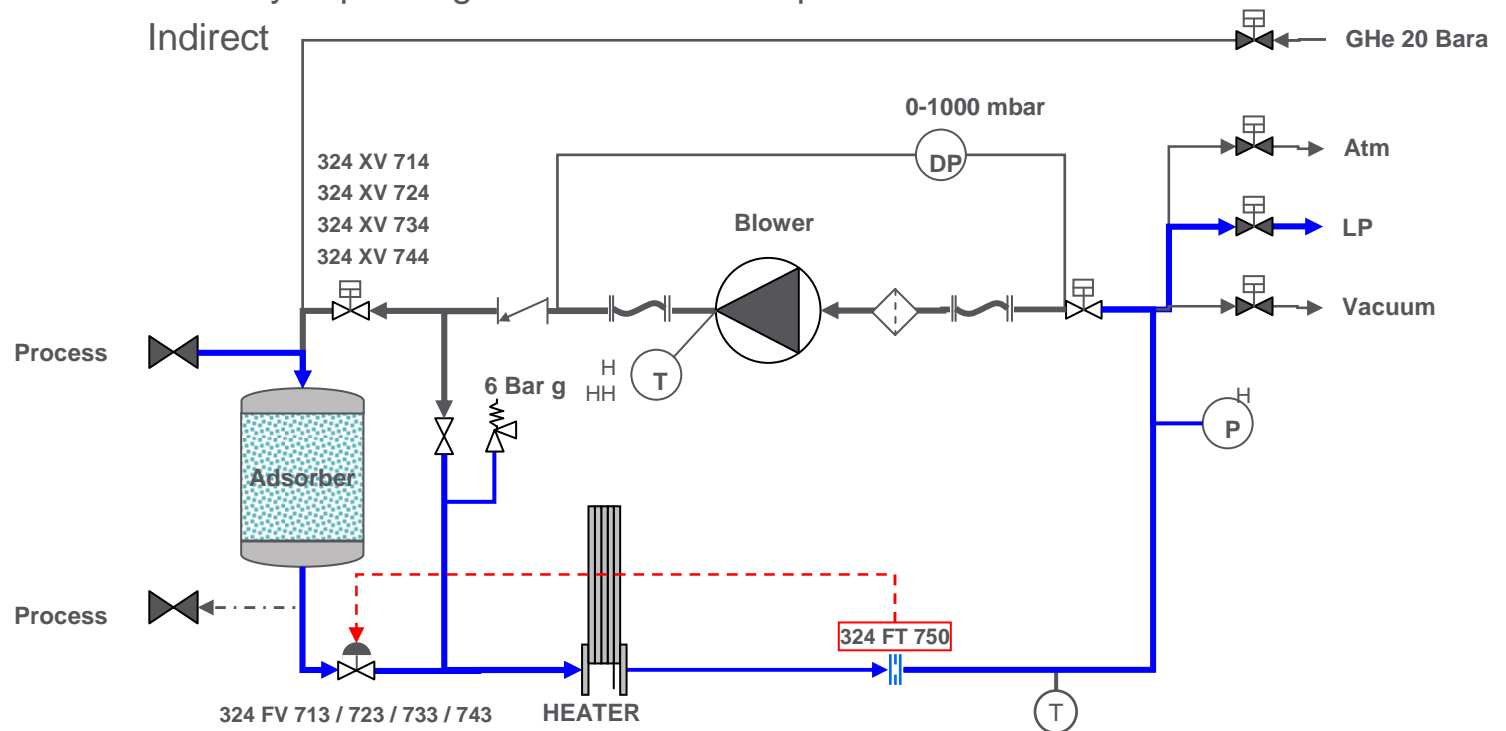
Object : LHe Storage Pressure  
 Actuator : 324 PV 809  
 Process Value: 324 PT 049  
 Set Point : ~1.15 Bara (tbc)  
 Action : Direct



# 324 FIC 750 - Adsorber Depressurization & Cool-Down

## ■ 324 FIC 750: Adsorber Depressurization & Cool-Down

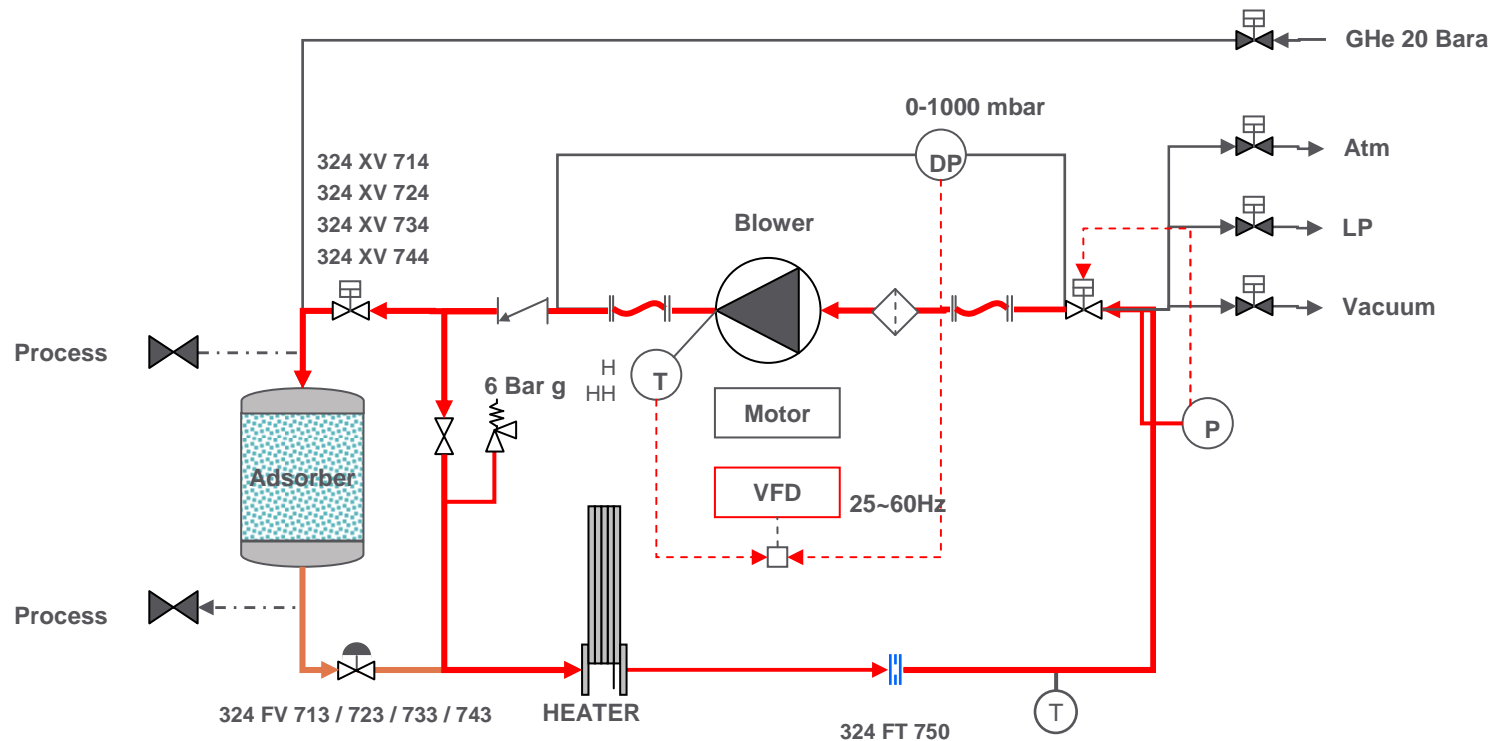
- Object : **Depressurization & Cool-Down Flow**
- Actuator : 324 FV 713 / 324 FV 723 / 324 FV 733 / 324 FV 743  
**Nota : 1 Valve at the time selected by the DCS**
- Process Value: **324 FT 750**
- Set Point : 5g/s to 20g/s  
 Will vary depending on Adsorber and Operation.
- Action : Indirect



# 324 DPIC 759 - Adsorber Warm-Up

## ■ 324 DPIC 759: Adsorber Warm-Up

- Actuator : 324 K 001M Regeneration Blower VFD [Rotation Speed Hz]
- Process Value: **324 PDT 759**
- Set Point : **SP = ATT 324 TT 759** (Calculated from 324 TT 759, see next slide)
- Action : Indirect

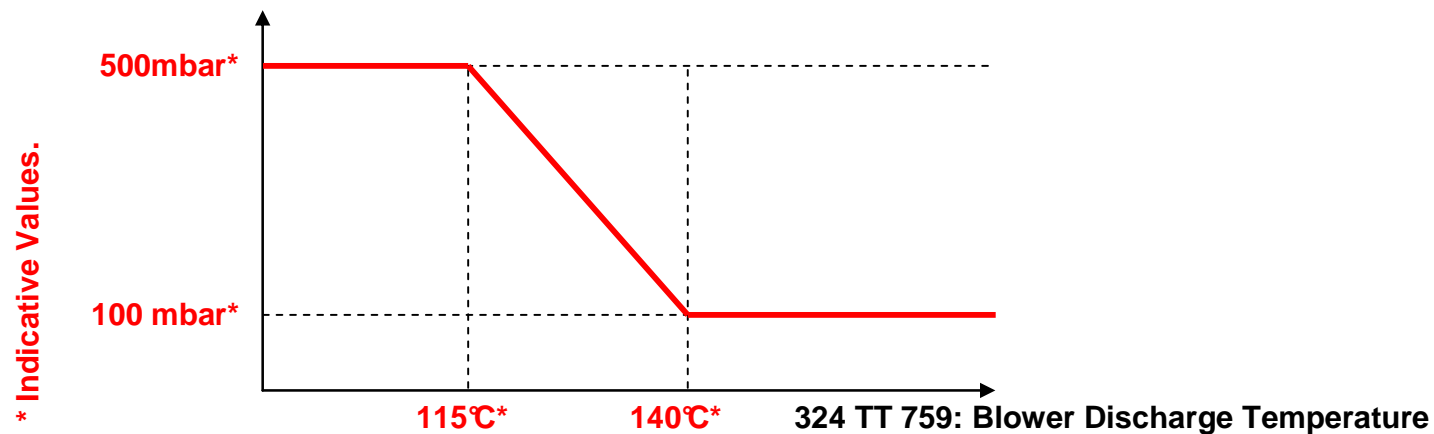


# BLOWER: ATT 324 TT 759

324 DPIC 759 controls the blower pressure rise.

Depending of the gas composition (He, Ne or N<sub>2</sub>), and inlet conditions (T &P) the discharge temperature may rise, leading to unsafe operation.

Pressure rise is then limited by ATT 324 TT 759, when  $T_{out} > 115^{\circ}\text{C}$ .



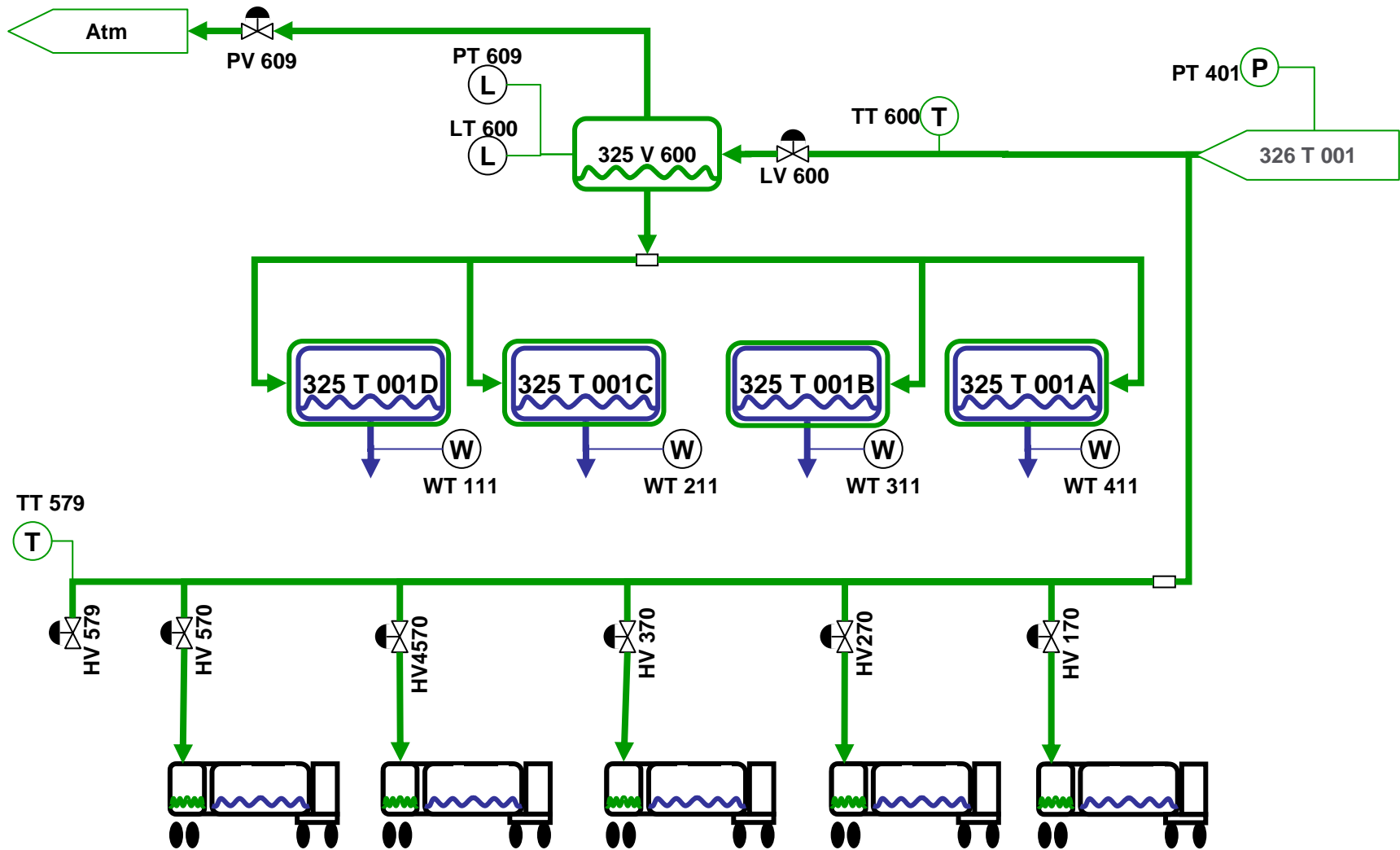
# Course Agenda

- Control Loops

- Nitrogen Loops

- Turbines Controls

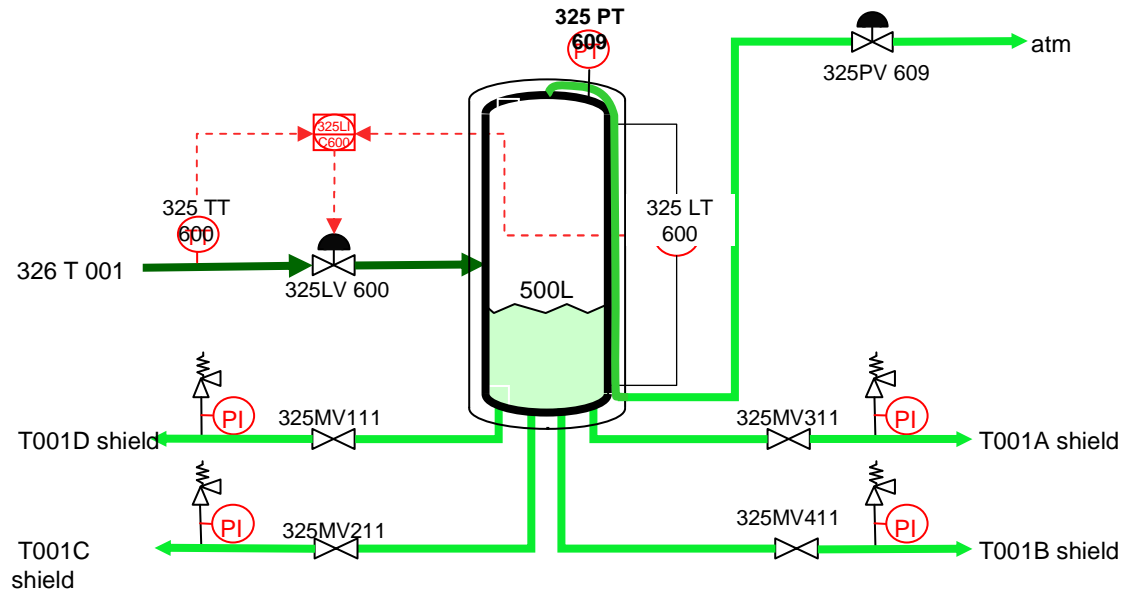
# Nitrogen Distribution



# Phase Separator Level Regulation

## ■ 324 LC 600: 325 V 006 Pressure

The control loop maintain the level between 20 and 70%, and TT600 < 100K.

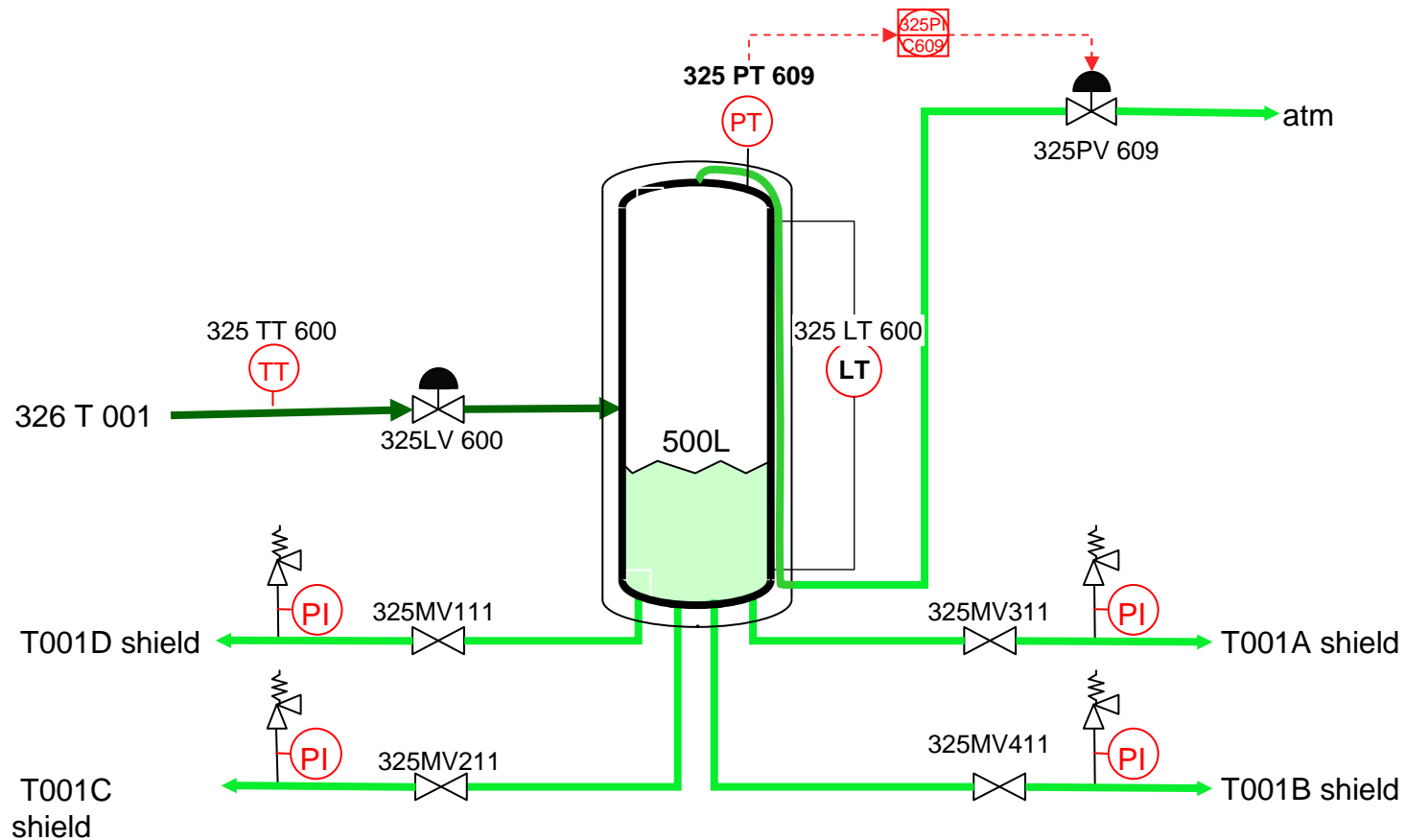


| 325 LV 600 |                  |                  |   |            |   |
|------------|------------------|------------------|---|------------|---|
| 325 PT 609 | < ~ 1.8 bar abs* | Pressure Max     | → |            | <b>OPEN 325 LV600 ~ 10%*</b><br>With RAMP 0.5% /sec<br>By Default, 325 LV 600 is Closed |
| 325 LT 600 | < ~90%*          | Safety Level     | → |            |   |
| 325 LT 600 | < ~20%*          | Minimum Level    | → | →<br>SET   |   |
| 325 LT 600 | > ~70%*          | Maximum Level    | → | →<br>RESET |   |
| 325 TT 600 | > ~100K*         | High Temperature | → | →<br>SET   |   |
| 325 TT 600 | < ~80K*          | Temperature OK   | → | →<br>RESET |   |
|            |                  |                  |   | OR ↓       | AND ↓   |
|            |                  |                  |   |            |   |

# Phase Separator Pressure Regulation

## ■ 324 PC 809: 325 V 006 Pressure

- Actuator : 325 PV 609
- Process Value: 325 PT 609
- Set Point : **~1.6 Bara\***
- Action : Direct

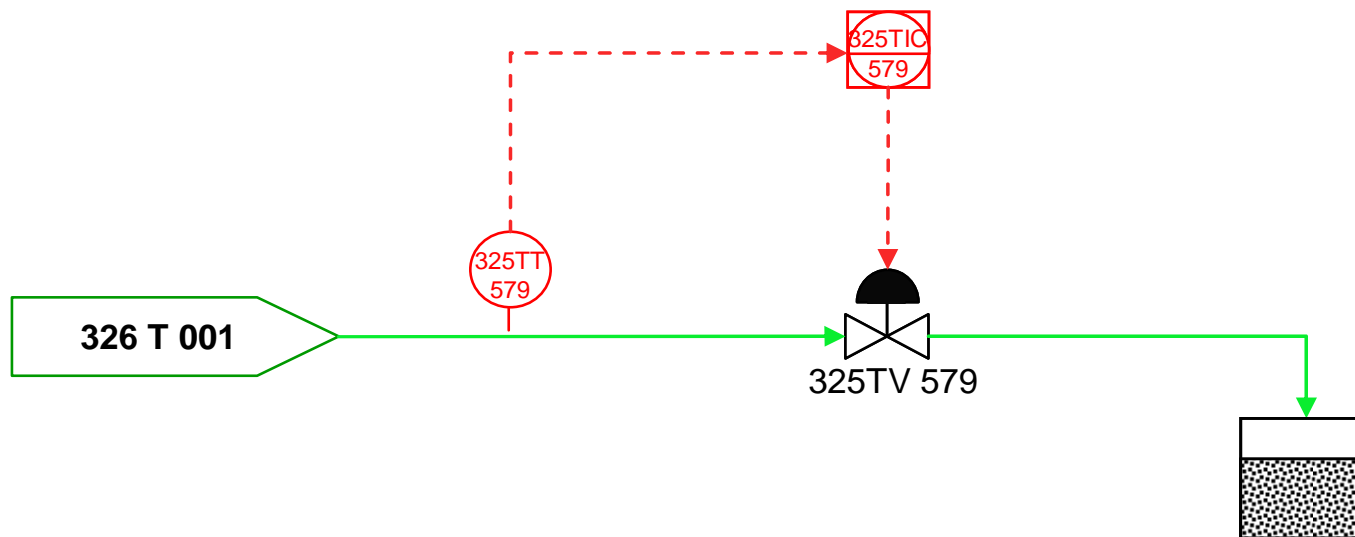


# Lower Deck Nitrogen Temperature Control

■ In order to maintain the nitrogen line cold, even if not used, a flow is forced according to the measured temperature. (Valve 324TV579 open with a ramp @ ~10%)

## ■ 324 TIC 579: LN2 Lower Deck Temperature Line

- Actuator : 325 TV 579
- Process Value: **325 TT 579**
- Set : **> 100K**
- Reset :: < 80K



# Course Agenda

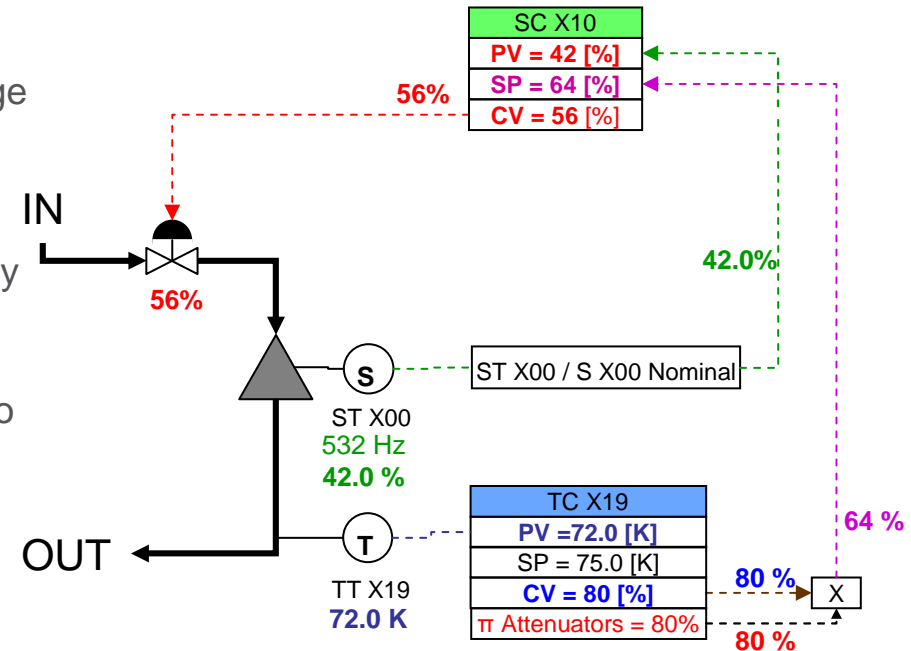
- Control Loops
- Nitrogen Loops
- Turbines Controls

# Turbines – Control Philosophy

- 2 controllers in cascade ⇒ **control the turbine discharge temperature**

- **324 TC X19** controls the turbine discharge temperature by adjusting the turbine speed set point.
- **324 SC X10** controls the turbine speed by adjusting the turbine inlet valve.

In nominal mode, cascade controller tends to keep the inlet turbine valve fully open.



- In addition, **ATTENUATORS** will slow down the turbine before it reaches extreme OFF-DESIGN or UNSAFE conditions

## **ATTENUATORS SHALL BE CONSIDERED AS SAFE GUARDS**

- ⇒ Slow down turbine before Alarms and Trips
- ⇒ When Turbine parameters approach extreme UNSAFE or OFF-DESIGN conditions, the Turbine Speed Set point is decreased.

# Turbines – List of Speed Attenuators

- The Turbine Speed Set Point is corrected by ATTENUATORS, which will slow down the Turbine

| ATTENUATOR |                           | SENSORS         | T1 & T2          | T3 | T4 | T5                | T6               |
|------------|---------------------------|-----------------|------------------|----|----|-------------------|------------------|
| 1          | Low Surge Drum Pressure   | 323 PT 812      |                  |    |    | X <sup>(1)</sup>  | X <sup>(1)</sup> |
| 2          | Load Valve too open       | 323 PV 810<br>B |                  |    |    | X                 | X                |
| 3          | LP value too high         | 324 PT 040      |                  |    |    | LP <sup>(1)</sup> |                  |
|            | MP value too high         | 324 PT 030      | MP               | MP | MP |                   |                  |
| 4          | High Discharge Pressure   | 324 PT X19      |                  |    |    |                   | X                |
| 5          | Low Discharge Temperature | 324 TT X19      |                  | X  | X  | X                 | X <sup>(1)</sup> |
| 6          | High Brake Temperature    | 324 TT X11      | X <sup>(2)</sup> | X  | X  | X                 | X                |
| 7          | High 80K Ads. Temperature | 324 TT 701      |                  |    |    |                   | X <sup>(1)</sup> |
|            | High 20K Ads. Temperature | 324 TT 702      |                  |    |    |                   | X <sup>(1)</sup> |
| 8          | Client Attenuator         | NA              | X                | X  | X  | X                 | X                |

**Note <sup>(1)</sup>:** IMPORTANT Attenuators.

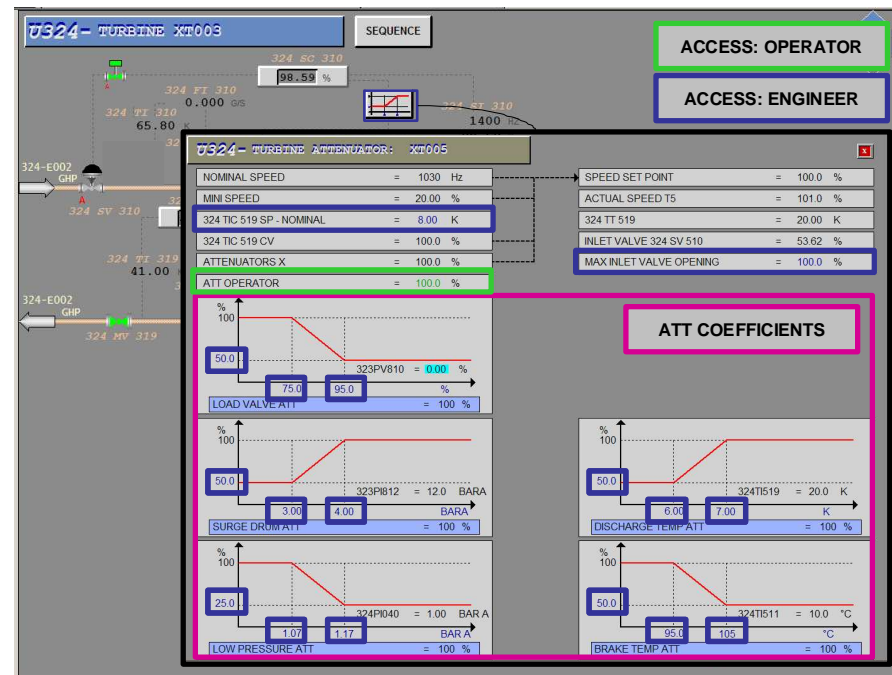
**Note <sup>(2)</sup>:** For T1&2 Brake Temperature Attenuator use Max (324 TT 111, 324 TT 211)

# Turbines – Attenuators Access

- Some Attenuators values are modifiable :

**By Operator :** The ATT OPERATOR is directly accessible to the Operator: (0 to 100%)

- By Engineer :**
- Each Coefficient Parameter can be adapted
  - Turbine Speed Set point (Internal) can be modified.
  - Turbine Inlet Valve Maxi Opening can be adjusted.

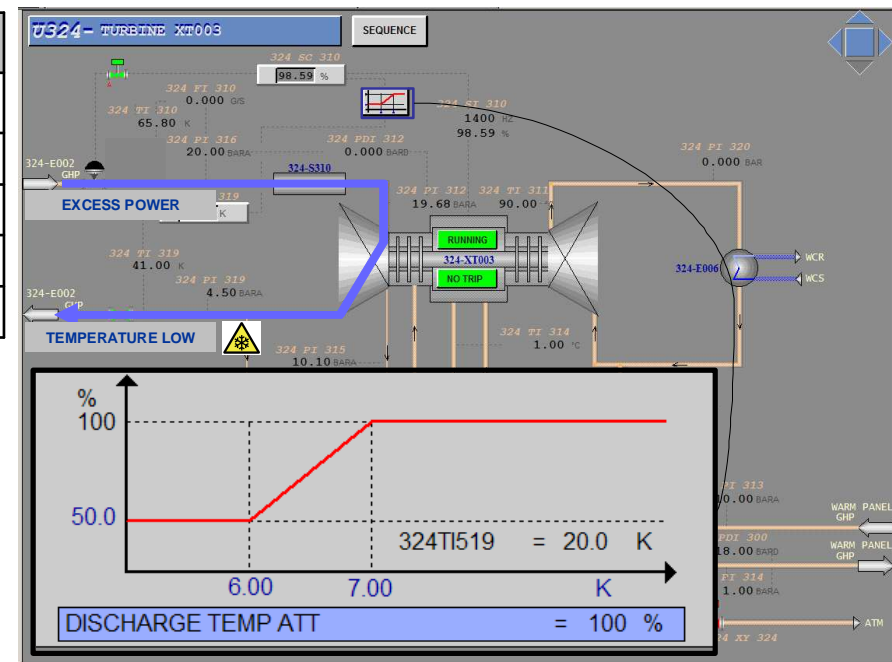


# Turbines - ATT 324 TT X19: Discharge Temperature

As said before, Outlet Temperature is controlled by cascade loop. Nevertheless, Liquefier Temperature can drop very quickly. Thus, for fast action Discharge Temp Attenuators have been implemented.

| TURBINES | CTRL LOOP  | SENSORS    | Nominal [K] | T Min [K] | T Max [K] | Att Min [%] |
|----------|------------|------------|-------------|-----------|-----------|-------------|
| 1        | 324 SC 110 | 324 TT 219 | 100 K       | 70 K      | 80 K      | 50 %        |
| 2        |            |            |             |           |           |             |
| 3        | 324 SC 310 | 324 TT 319 | 45 K        | 25 K      | 35 K      | 50 %        |
| 4        | 324 SC 410 | 324 TT 419 | 20 K        | 10 K      | 15 K      | 50 %        |
| 5        | 324 SC 510 | 324 TT 519 | 9 K         | 6 K       | 7 K       | 50 %        |
| 6        | 324 SC 610 | N/A        | 5 K         | N/A       | N/A       | N/A         |

**Example on the right**  
if T5 Tout = 6,5K, then ATT = 75%



# Turbines - ATT 324 TT X11: Brake Temperature

Brake Temperature can increase because of:

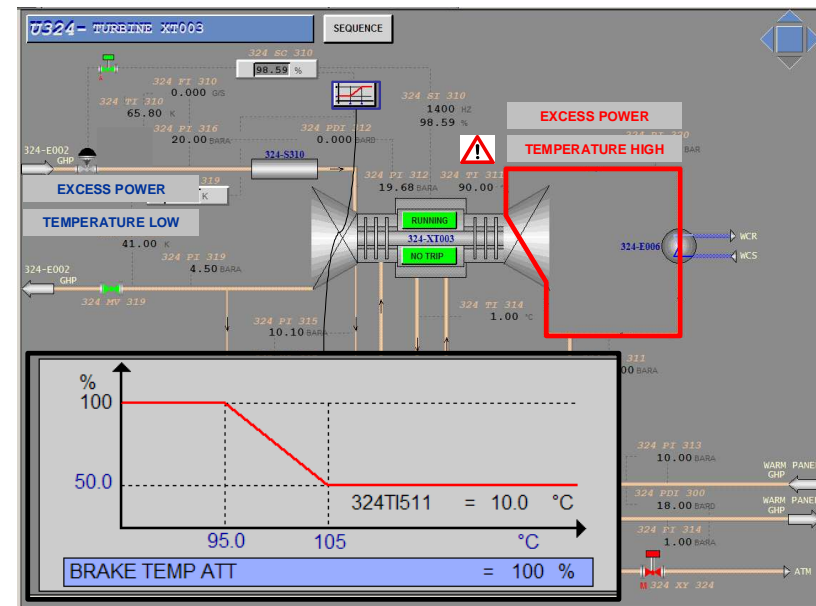
- Turbine Over Capacity
- Lack of Cooling Water.

High Brake Temperature can result:

- Brake Wheel failure (Aluminum Characteristics).
- Turbine Trip.

To avoid such situation, a Brake Temp Attenuators will reduce the Turbine Power when the Brake Temp is high.

| TURBINES | CTRL LOOP  | SENSORS              | Nominal [°C] | T Min [°C] | T Max [°C] | Att Min [%] |
|----------|------------|----------------------|--------------|------------|------------|-------------|
| 1        | 324 SC 110 | MAX(324 TT 111/2111) | 76           | 95         | 105        | 50 %        |
| 2        |            |                      |              |            |            |             |
| 3        | 324 SC 310 | 324 TT 311           | 85           | 95         | 105        | 50 %        |
| 4        | 324 SC 410 | 324 TT 411           | 76           | 95         | 105        | 50 %        |
| 5        | 324 SC 510 | 324 TT 511           | 82           | 95         | 105        | 50 %        |
| 6        | 324 SC 610 | 324 TT 611           |              | 95         | 105        | 50 %        |



# Turbines - ATT 324 PT 0X0: Low & Medium Pressure

LP or MP can increase because of :

- Turbine Excess Flow
- Compressor Lack of Flow (One LP or HP Compressor Down)
- Too much vapor return from mobile Dewar to process

High LP or MP Pressure can result in:

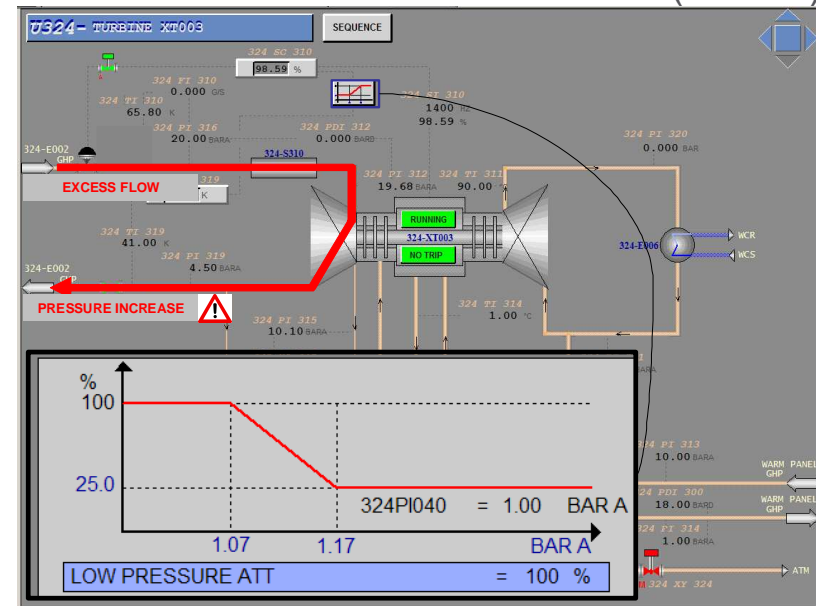
- Turbine High Discharge Pressure and Turbine Trip.
- Compressor High Suction Pressure, High Current and Trip.

To avoid such Situation, LP & MP Attenuators will reduce the Turbine Flow when the LP (PT040) or MP(PT030) is High.

| TURBINES | CTRL LOOP  | SENSORS    | Nominal [b] | P Min [b] | P Max [b] | Att Min [%] |
|----------|------------|------------|-------------|-----------|-----------|-------------|
| 1<br>2   | 324 SC 110 | 324 PT 030 | 4,90b       | 5.10b     | 5.50b     | 75%         |
| 3        | 324 SC 310 | 324 PT 030 | 4,90b       | 5.10b     | 5.50b     | 75%         |
| 4        | 324 SC 410 | 324 PT 030 | 4,90b       | 5.10b     | 5.50b     | 75%         |
| 5        | 324 SC 510 | 324 PT 040 | 1.05b       | 1.07b     | 1.17b     | 25%         |
| 6        | 324 SC 610 | -          | -           | -         | -         | -           |

**Note:** T5 is the only turbine on LP.

T5 flow ~ 50% of the LP compressor flow.



# Turbines - ATT 324 PT X19: Discharge Pressure

When too much gas is processed by the turbine, Pout increases.

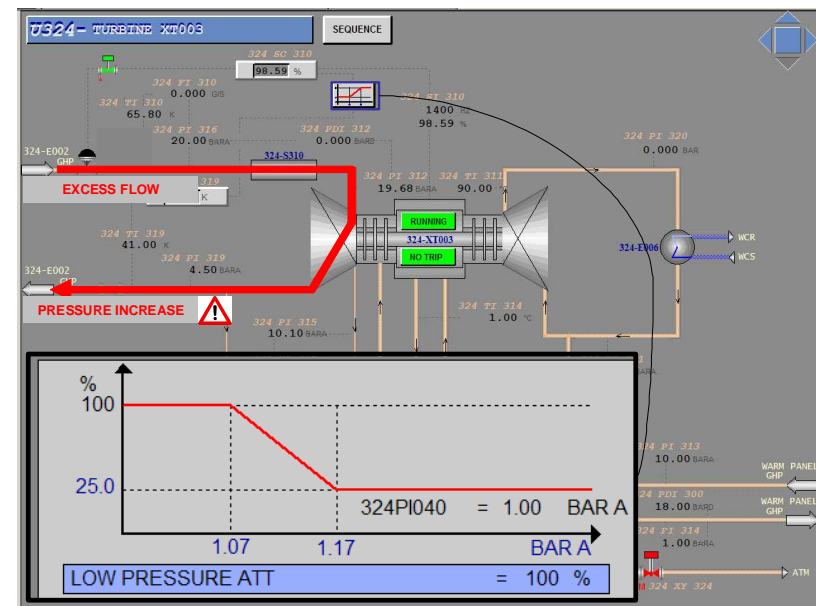
To avoid back-pressure on the turbine wheel an attenuator slows-down the turbines

NOTA : This is already covered by the previous attenuators for T1 to T5

| TURBINES | CTRL LOOP  | SENSORS    | Nominal [b] | P Min [b] | P Max [b] | Att Min [%] |
|----------|------------|------------|-------------|-----------|-----------|-------------|
| 1        | 324 SC 110 | 324 PT 119 | 12,7b       | -         | -         | -           |
| 2        | 324 SC 110 | 324 PT 219 | 5,00b       | -         | -         | -           |
| 3        | 324 SC 310 | 324 PT 030 | 5,00b       | -         | -         | -           |
| 4        | 324 SC 410 | 324 PT 030 | 5,00b       | -         | -         | -           |
| 5        | 324 SC 510 | 324 PT 040 | 1.20b       | -         | -         | -           |
| 6        | 324 SC 610 | 324 PT 619 | 3.00b       | 3.50b     | 4.50b     | 25%         |

## Note:

T6 Back-pressure is controlled by the 4 JT Valves  
325 PV 101,201,301 & 401

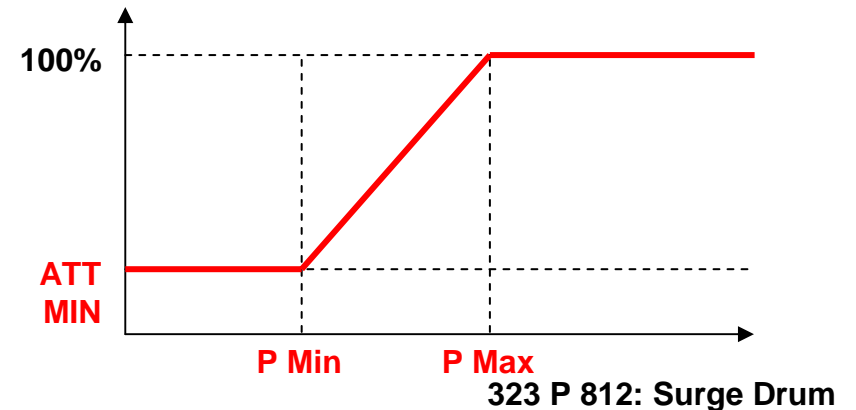


# Turbines - ATT 323 PT 812: Surge Drum Pressure

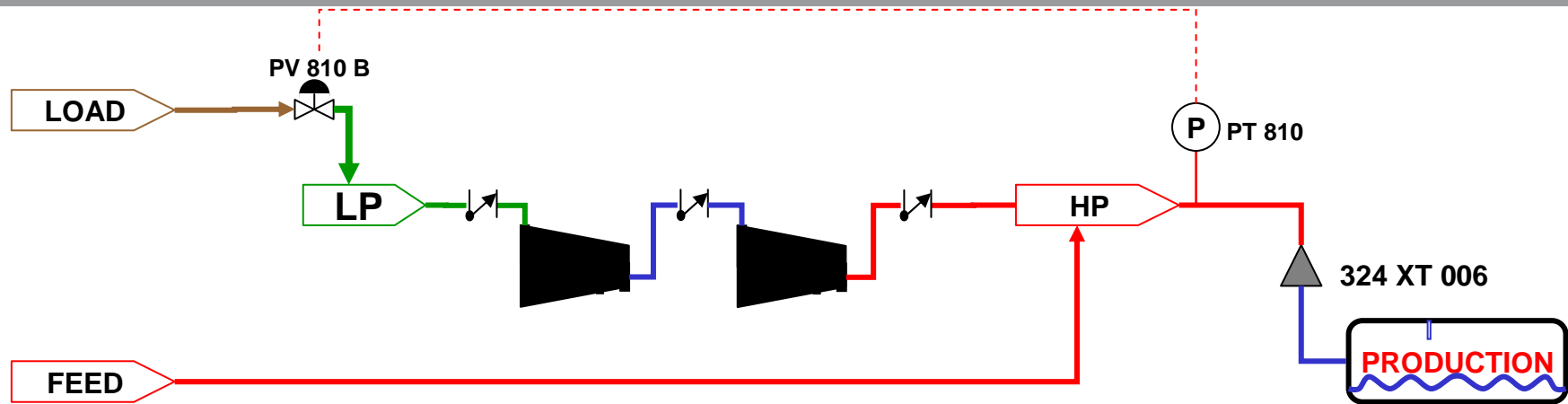
In case the DRUM pressure becomes too low, the production rate has to be reduced.

**Note:** Considering a Density of 0.150 kg/m<sup>3</sup> @ 1 atm and 50°C, a fluctuation of 1 Bar in the Buffer Tank is equivalent to a mass of 60 kg, i.e. 5 min of production

| TURBINES | CTRL LOOP  | SENSORS    | Nominal [b] | Min [b] | Max [b] | Att Min [%] |
|----------|------------|------------|-------------|---------|---------|-------------|
| 1        | 324 SC 110 |            |             | -       | -       | -           |
| 2        | 324 SC 110 |            |             | -       | -       | -           |
| 3        | 324 SC 310 |            |             | -       | -       | -           |
| 4        | 324 SC 410 |            |             | -       | -       | -           |
| 5        | 324 SC 510 | 324 PT 812 | 3-18 b      | 3.0     | 4.0     | 50%         |
| 6        | 324 SC 610 | 324 PT 812 | 3-18 b      | 3.0     | 4.0     | 50%         |

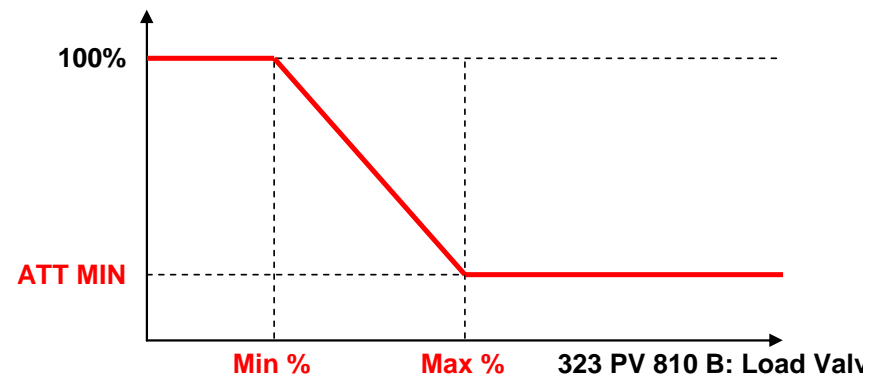


# Turbines - ATT 323 PV 810 B: Load Valve



In case the loading valve is widely open, this indicates an over liquefaction capacity.  
 The LOAD valve cannot compensate for the lack of FEED : **LOAD + FEED < PRODUCTION**  
 The Production Rate is then reduced by slowing down T5 and T6

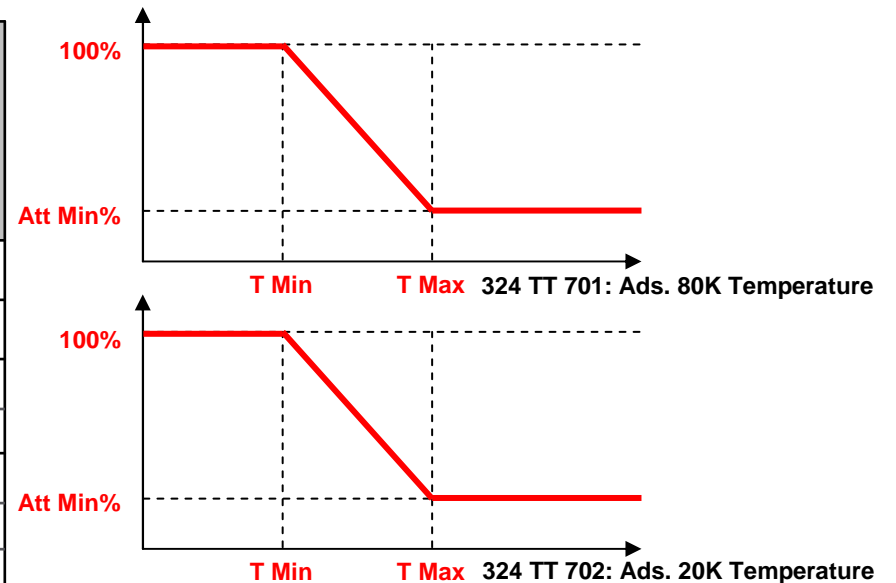
| TURBINES | CTRL LOOP  | SENSORS    | Nominal [%] | Open. Min [%] | Open. Max [%] | Att Min [%] |
|----------|------------|------------|-------------|---------------|---------------|-------------|
| 1        | 324 SC 110 |            |             | -             | -             | -           |
| 2        | 324 SC 110 |            |             | -             | -             | -           |
| 3        | 324 SC 310 |            |             | -             | -             | -           |
| 4        | 324 SC 410 |            |             | -             | -             | -           |
| 5        | 324 SC 510 | 324 PV 810 | 0-75%       | 75%           | 95%           | 50%         |
| 6        | 324 SC 610 | 324 PV 810 | 0-75%       | 75%           | 95%           | 50%         |



# Turbines - ATT 324 TT 70X: Adsorbers Temperatures

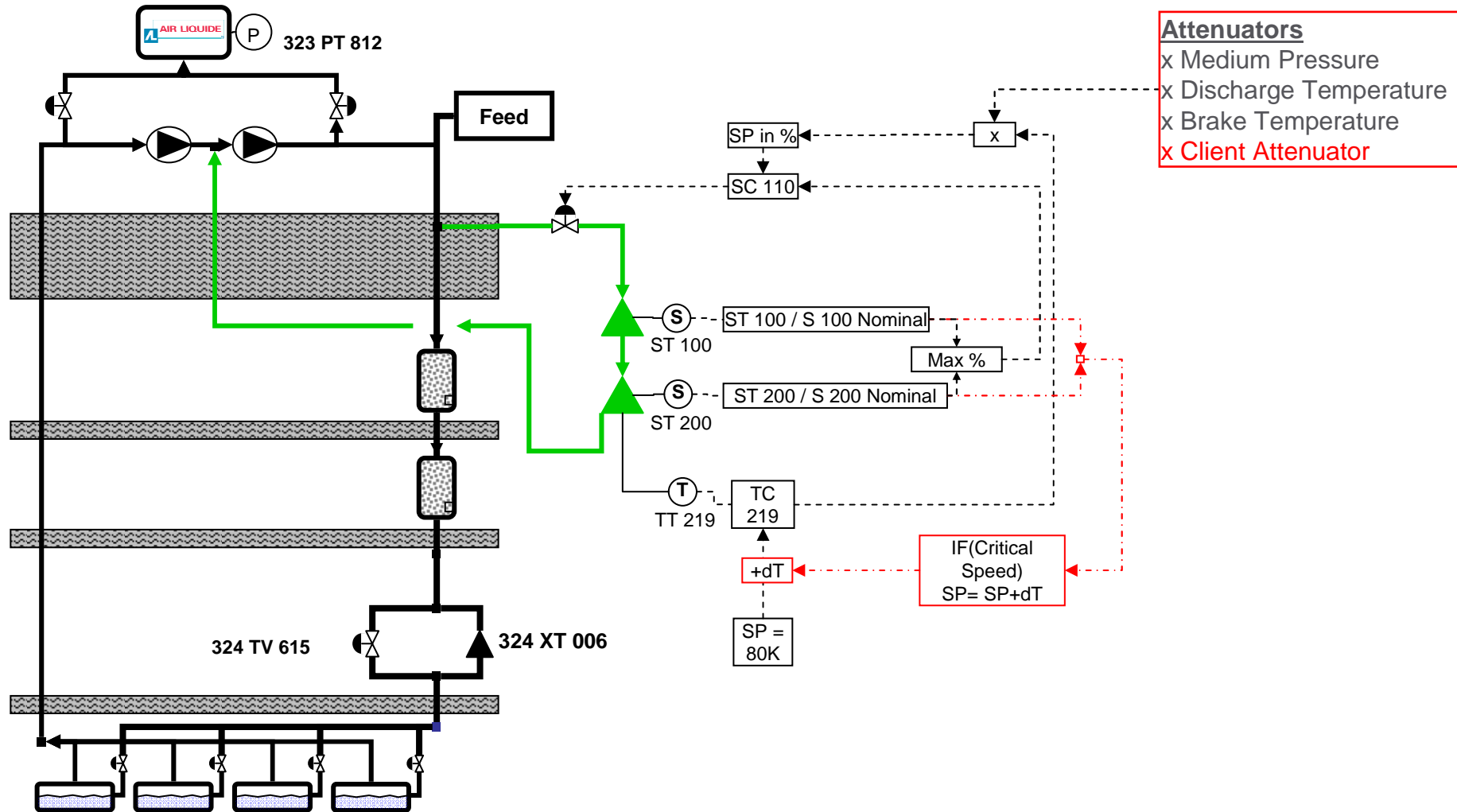
In case of adsorbers temperature increase (too much production vs capacity), the Production Rate is decreased by Slowing T6 in order to avoid release of contaminants in the process.

| TURBINES | CTRL LOOP  | SENSORS    | Nominal [K] | T Min [K] | T Max [K] | Att Min [%] |
|----------|------------|------------|-------------|-----------|-----------|-------------|
| 1        | 324 SC 110 | -          |             | -         | -         | -           |
| 2        | 324 SC 110 | -          | -           | -         | -         | -           |
| 3        | 324 SC 310 | -          | -           | -         | -         | -           |
| 4        | 324 SC 410 | -          | -           | -         | -         | -           |
| 5        | 324 SC 510 | -          | -           | -         | -         | -           |
| 6        | 324 SC 610 | 324 TT 701 | 65K         | 75 K      | 85 K      | 50%         |
|          |            | 324 TT702  | 19K         | 20 K      | 25 K      | 50%         |

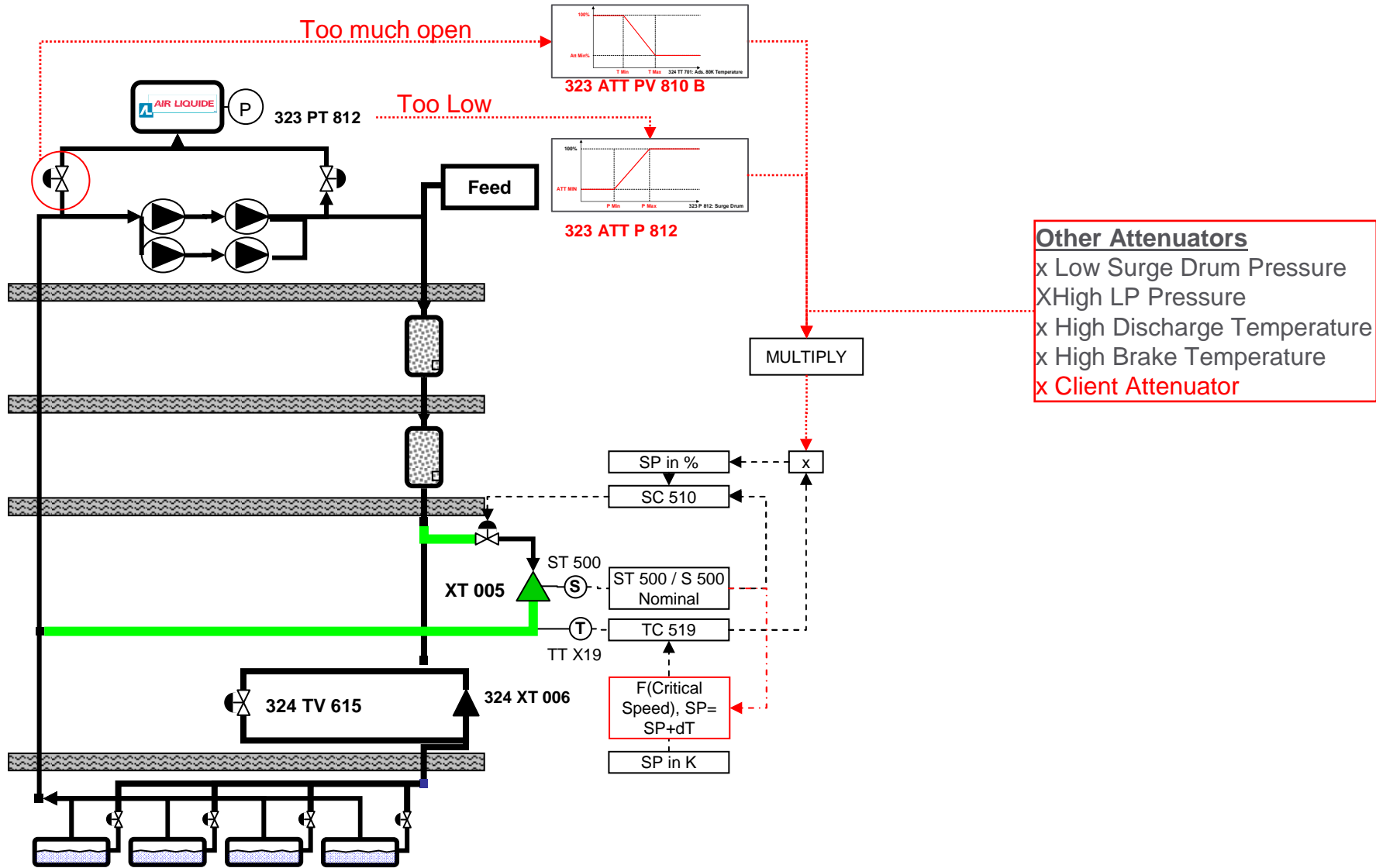


Nota: This attenuation will also be activated during cool down

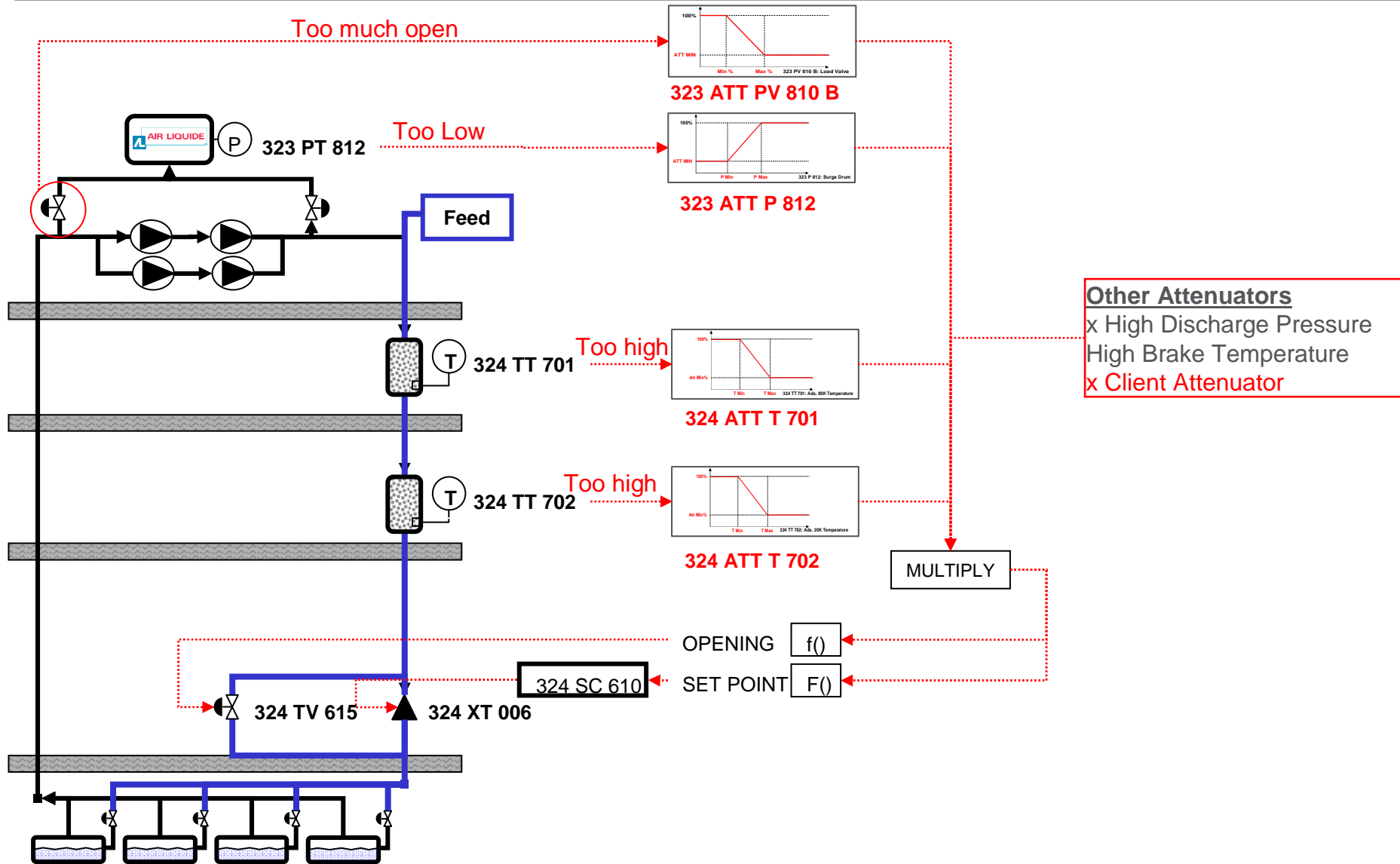
# Turbine T1&T2 Controls



# Turbines - Turbine T5 Controls

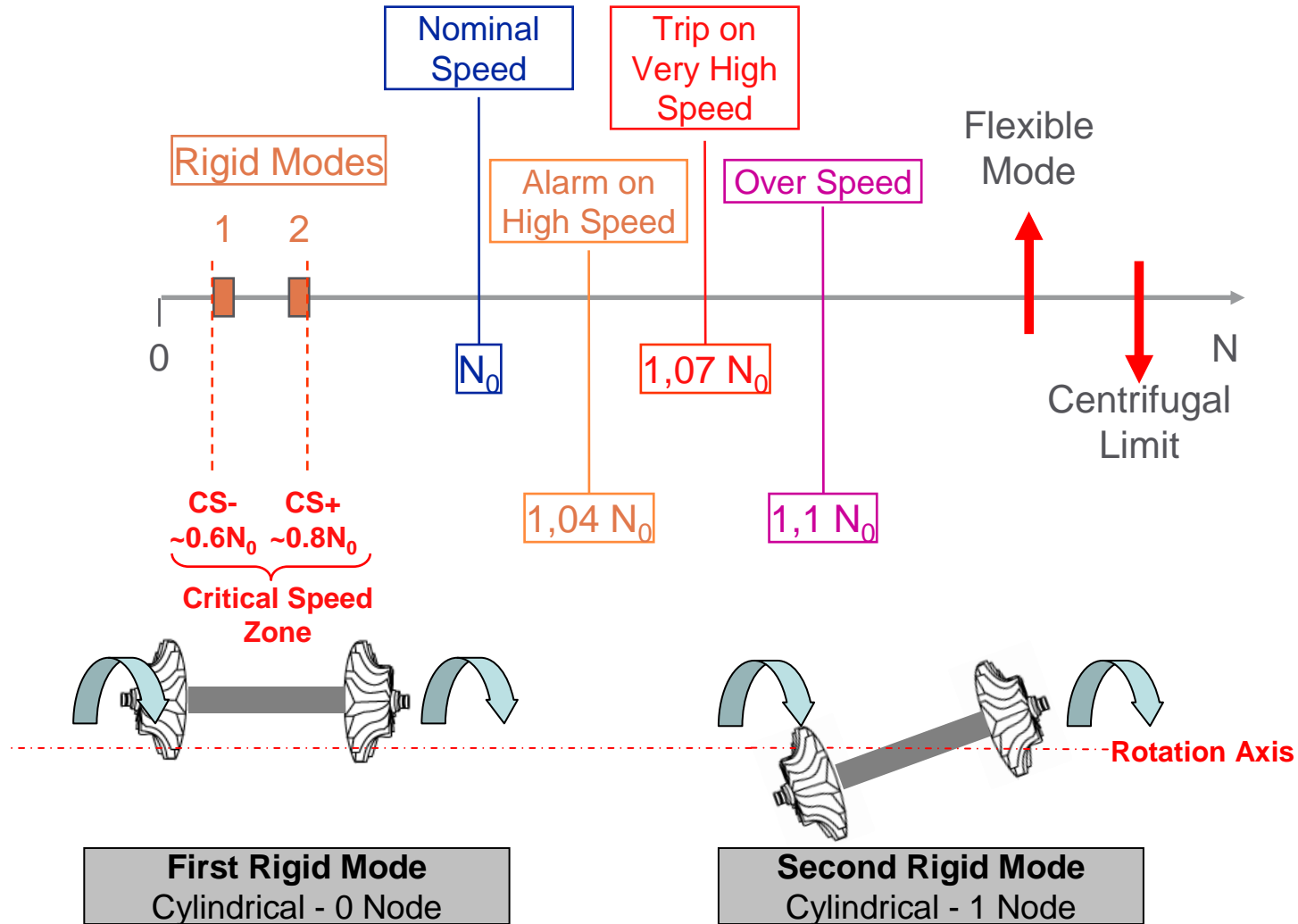


# Turbines - Turbine T6 Controls (Production Control)



**Other Attenuators**  
 x High Discharge Pressure  
 High Brake Temperature  
 x Client Attenuator

# Turbines – Critical Speed Zone



**!/\** The above values are just given as an example ! And could be very different!

# Turbines – Critical Speed Zone

In case Turbine is in critical speed (cooling down, liquefier load modification ...) the Temperature Set point is modified to escape from the critical speed zone by adding an offset (**dT**) to the Set Point (**TCX19**)

- When **TCx19 SP increases** , Turbine **slow down** (valve opening decreases)
- When **TCx19 SP decreases**, Turbine **accelerates** (valve opening increases)

## T1 & T2

If T1 **or** T2 in critical Zone, and Speed < **90%** then  $SP = SP + dT$  (dT ramp from 0 to **-5K**)  
If T1 **or** T2 in critical Zone, and Speed > **90%** then  $SP = SP + dT$  (dT ramp from 0 to **+5K**)  
Then, if T1 & T2 are not anymore in Critical Zone for 5 minutes, dT goes to 0.

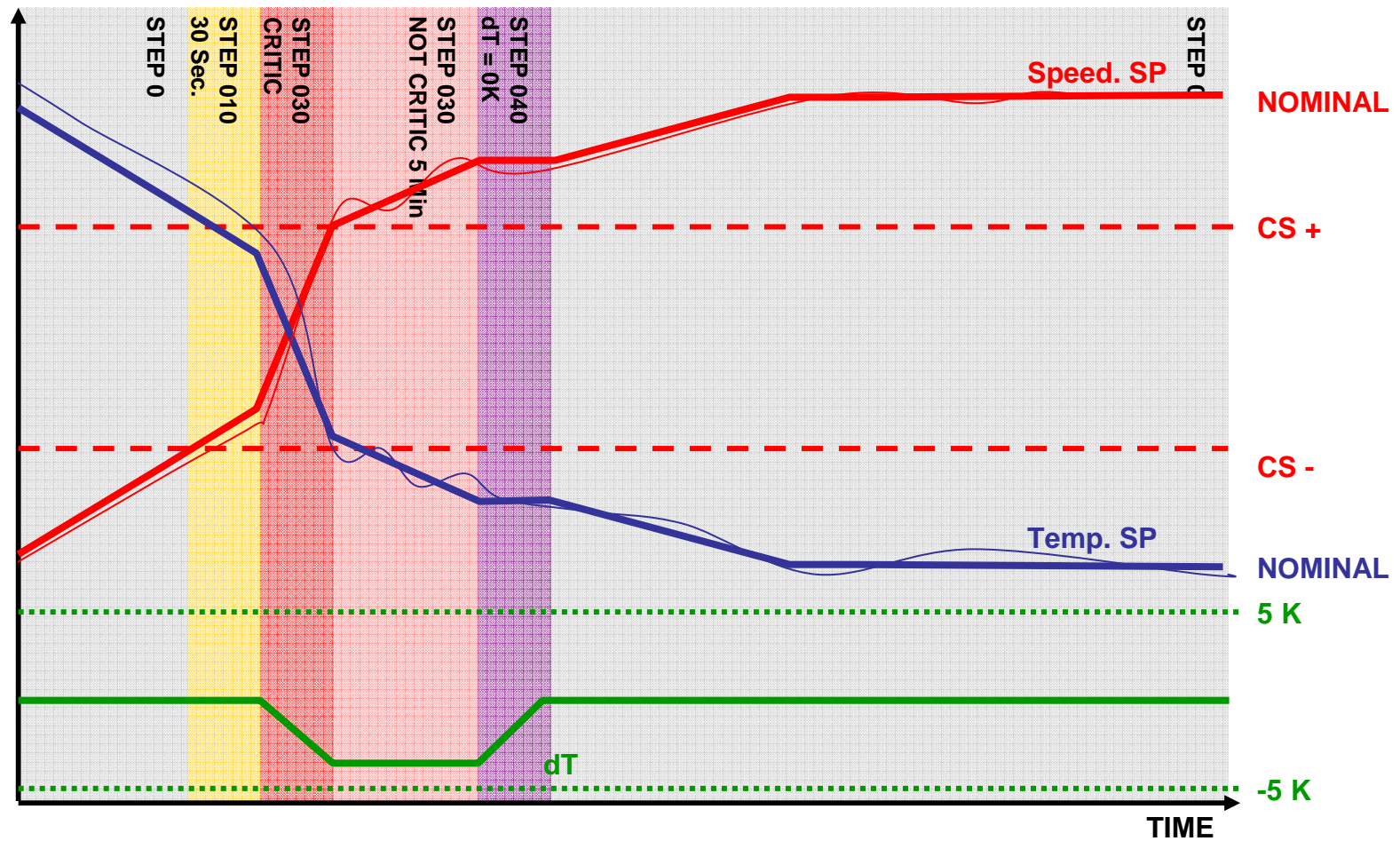
## T3, T4, T5

If Tx is in critical Zone, and  $TTx19 < TAL + dT$  then  $SP = SP + dT$  (dT ramp from 0 to **-5K**)  
If Tx is in critical Zone, and  $TTx19 > TAL + dT$  then  $SP = SP + dT$  (dT ramp from 0 to **+5K**)

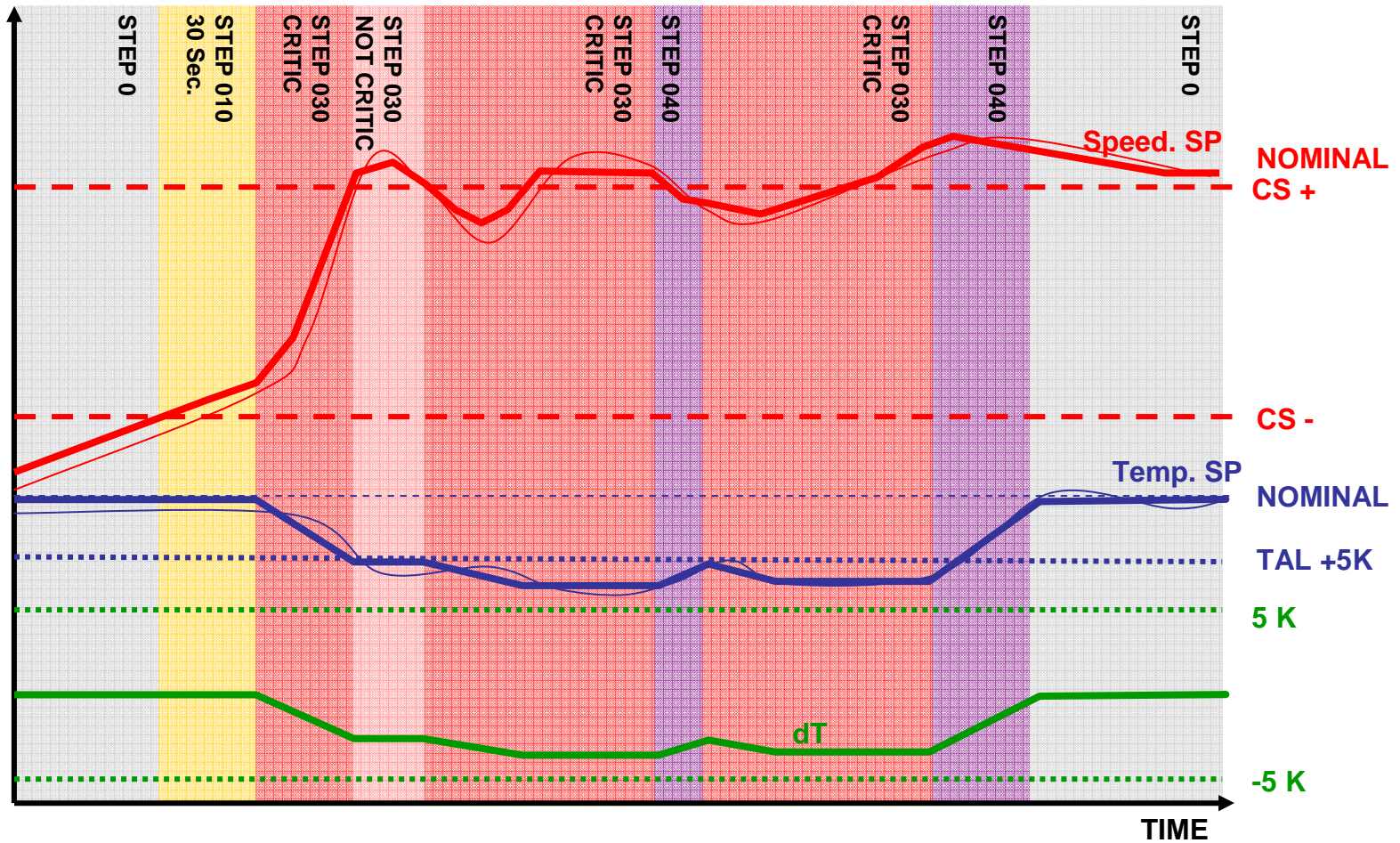
## T6

T6 philosophy is different. In case the Speed Set Point calculated from the loop is in critical region, it is modified to be 10 Hz below critical region.

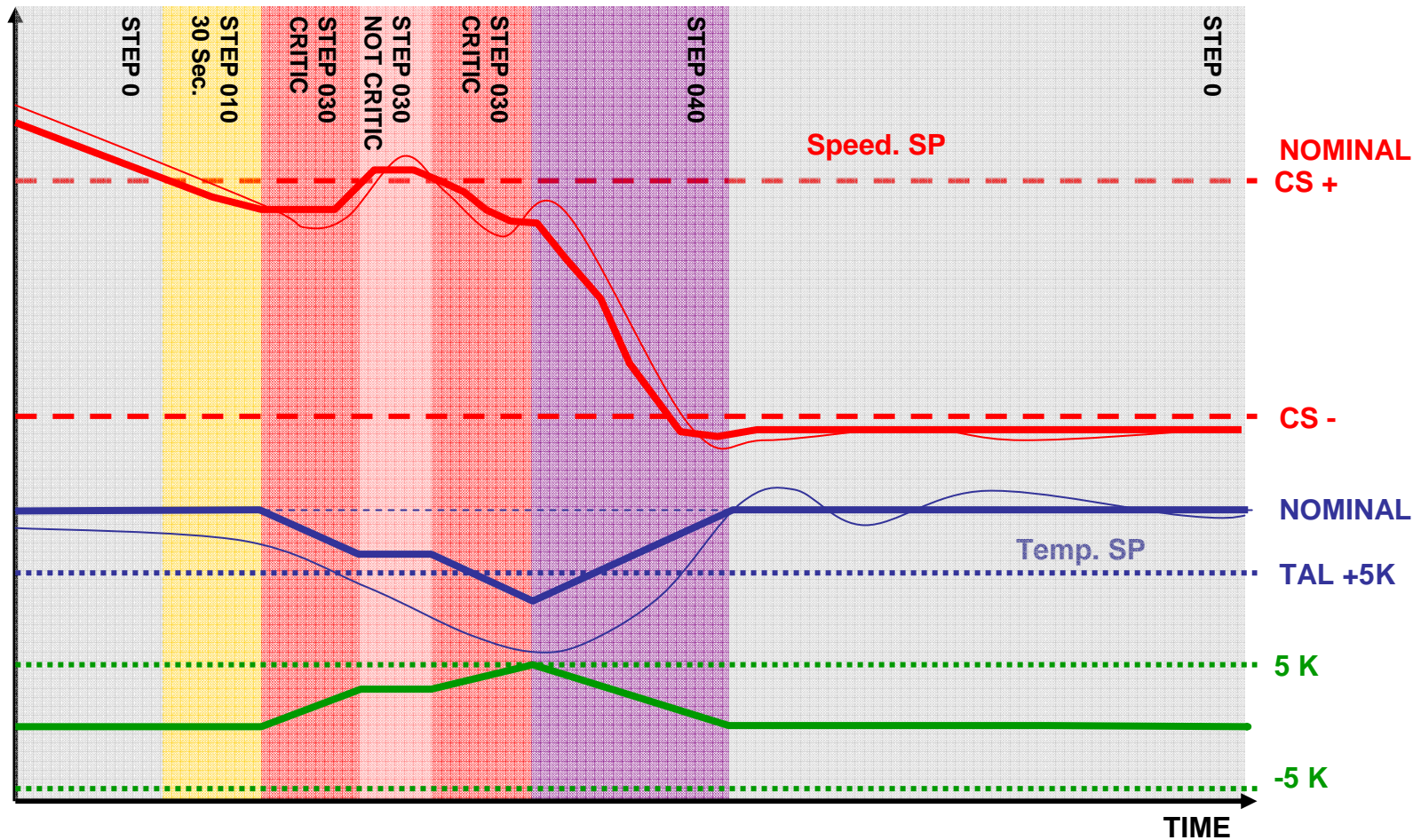
# Turbines – Critical Speed Zone – Cool Down



# Turbines – Critical Speed Zone – Load Increases



# Turbines – Critical Speed Zone – Load Decreases



# Turbines – Critical Speed Zone – Turbine 6

Set point is calculated from the attenuators product.  
If it belongs to Critical Speed Region, it is moved to 10Hz below the CS Zone.  
SP is restored as soon as the ATTENUATORS product is out of the CS Zone

