Helium Operators Familiarization Program

Liquefier HYSYS Simulation

Doha, January 2013 I GRABIE Véronique I Air Liquide

324 – 325 Liquefier HYSYS Simulation

- Liquefier Design basis
- Liquefier control philosophy (reminder)
- HYSYS - Base Case
- Case studies: Lower HP
- Case study: Fouling of HX1
- Case study: Increased heat leaks to the distribution system
- Case study: Impact of adsorbers cool down

Liquefier design basis

The Liquefier has been sized according to a loading scenario proposed by Ras Gas.

Over a Week Test, the HeRU shall be able to load 31 Trucks distributed as follows:

	Cold Clean	Warm Clean (<200ppm)	Warm Dirty (>200ppm)	Warm Load (Cold Clean)
INDEX	**CC**	**WC**	**WD**	**WL**
Number	x **24** / Week	x **6** / Week	x **1** / Week	x **7** / Week

Note:
-4600 kg is loaded in mobile container (Tare is performed after pulling)
-Warm Trucks [WC&WD] are first Cooled Down and then sent to the parking lot for Soaking (Temp. Homogenization).
-WL Trucks are Warm Trucks returning from Soaking for Loading.
-The number of WL Trucks is equal to the total number of incoming Warm Trucks [WC+WD].

Liquefier design basis - Tasks

For each task an estimation of required time has been made as following :

	Cold Clean	Warm Clean	Warm Dirty	Cold Clean (From Warm)
INDEX	**CC**	**WC**	**WD**	**WL**
IP: Initial Prep	1 h	1 h	1 h	
F: Flush (Purge)	0 h	0 h	12 h	
C: Cool-Down (300K-80K)	**0 h**	**10 h**	**10 h**	
K: Cool-Down (80K-4K)	**2 h**	**2 h**	**2 h**	
LN: LIN Filling	0 h	4 h	4 h	
S: Soaking	0 h	72 h	72 h	
LN: LIN Filling	2 h			1 h
P: Pressure Pulling	**3 h**			**3 h**
L: LOADING	**6 h**			**6 h**
X: No Activities	**0 h**			**2 h**
FP: Final Preparation	1 h	1 h	1 h	1 h
Time in Bay	15 h	18 h	30 h	13 h

Liquefier design basis - Estimated Flows / bay

- For each task an estimation of required mass of helium has been made as following

Phase	Time	Mass	Flow
Flushing	12 hrs	300 kg	7 g/s
Pulling	3 hrs	200 kg	19 g/s
C: Cool Down (300K -> 80K) To Truck	10 hrs	1320 kg	37 g/s
C: Cool Down (300K -> 80K) From Truck	10 hrs	1300 kg	36 g/s
K: Cool Down (80K-> 4K) To Truck	2 hrs	930 kg	129 g/s
K: Cool Down (80K-> 4K) From Truck	2 hrs	180 kg	25 g/s
Soaking	1 week		
Loading To truck	6 hrs	4800 kg	222 g/s
Loading From truck	6 hrs	750 kg	35 g/s
LIN filling	2 hrs		1000 l/h

No accumulation in containers

Liquefier design basis - Plant Sizing

- The plant has been designed on an **average capacity**, thus the load can be higher than the plant capacity

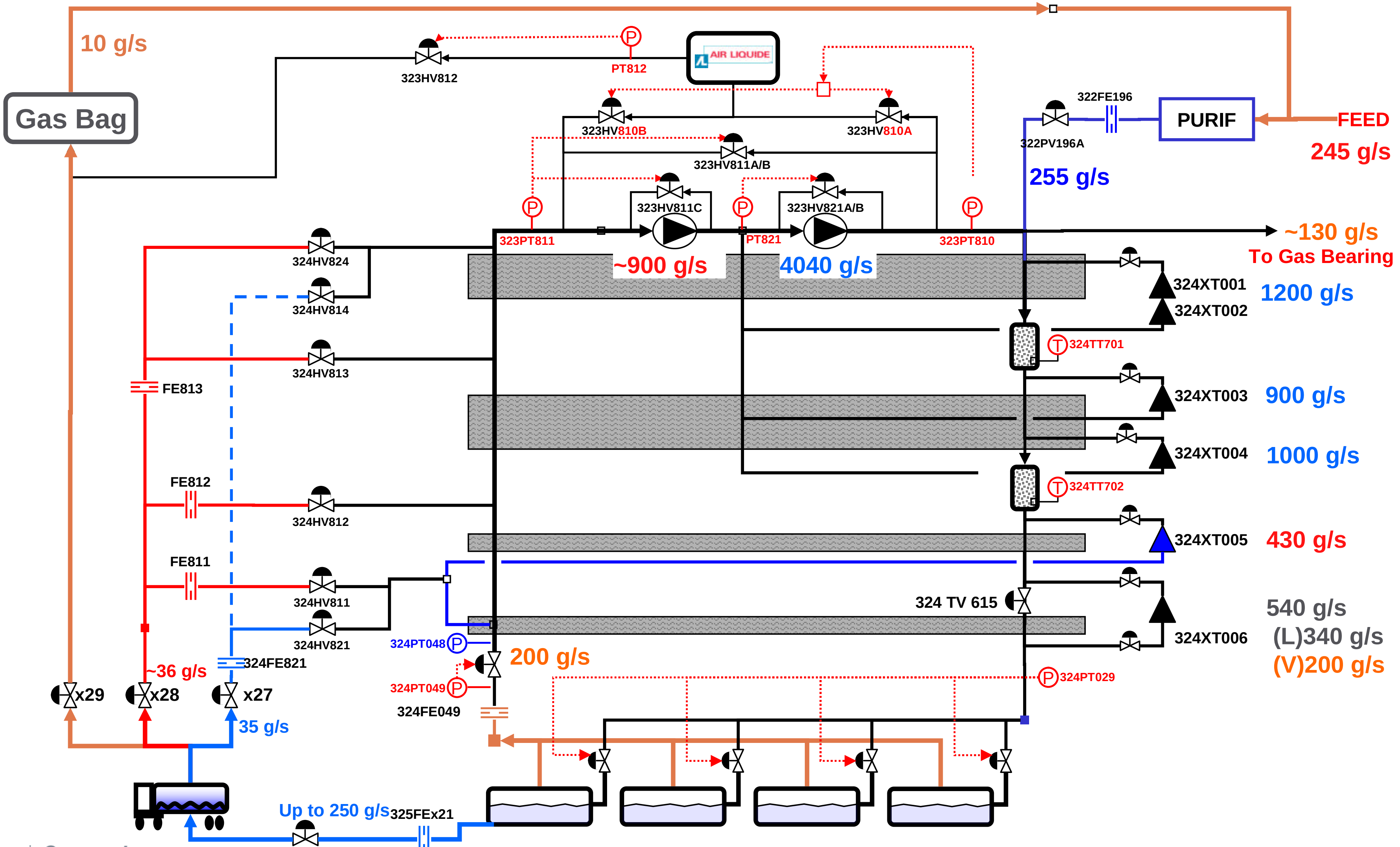
	CXXX	XXXX	KXXX	CKXX	KKXX	
Load vs Capacity	106%	**93%**	97%	**113%**	103%	
Time repartition	37%	29%	27%	6%	1%	
Load x Time	39%	29%	26%	7%	1%	100%

- Note: each letter stands for the activity in bay #1 #2 #3 #4
  - X: loading liquid helium, vapors recovered at T<7K
  - K: cooling down of a container, vapors recovered at 7K>T> 80K
  - C: cooling down of a container vapors recovered at T> 80K
  - The above table shows that overload occurs during cooldown and mainly for warm mobile container. **The warmer the vapors, the higher the plant load.**
- Main consequences are :
  - Consumption of LHe (Decrease of Dewar Level)
  - HP increases -> Excess of gas is sent to the Drum

-> Scheduling of Loading sequences is a key element to avoid venting gas !

-> Cooling down of mobile container has to be limited to 7 per week

Liquefier design Basis



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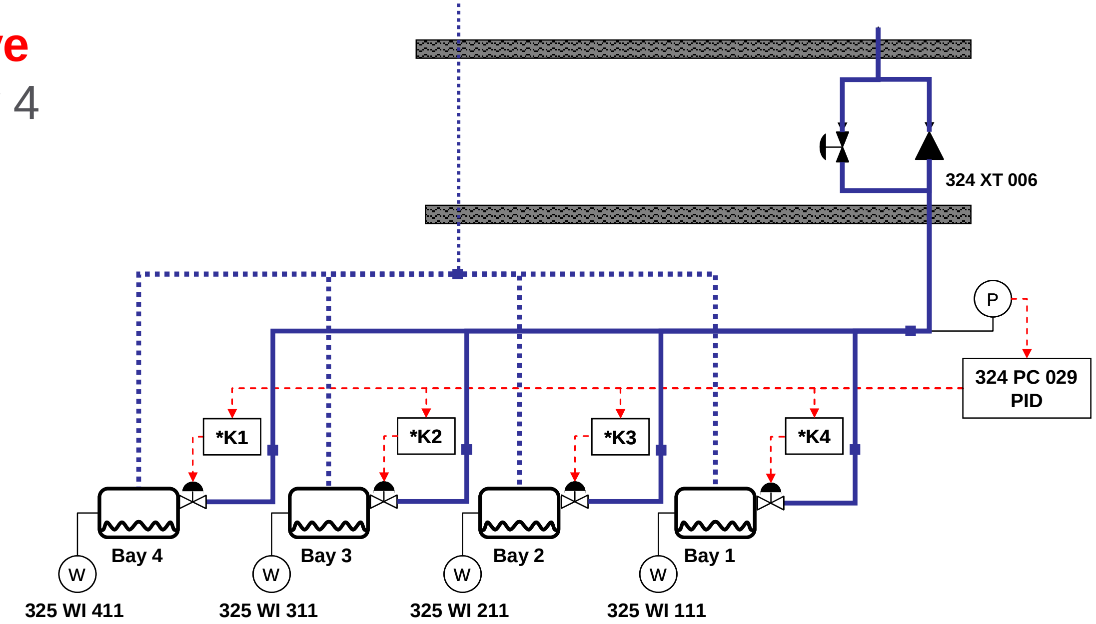
Control philosophy 324 PC 029 - T6 back pressure

- **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



Control philosophy 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 x FLOW_1 / Σ FLOW_i

LEVEL_1 (3) = MAX (325 WT 111 / 14,500kg, 10%)
LEVEL_1 Coefficient = 4 x 1 / LEVEL_1 / Σ (1 / LEVEL_i)

BAY_1 For each Bay, the user can force a coefficient, called Bay from 1 to 10.
BAY_1_Coefficient = BAY_1 / Σ 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 %

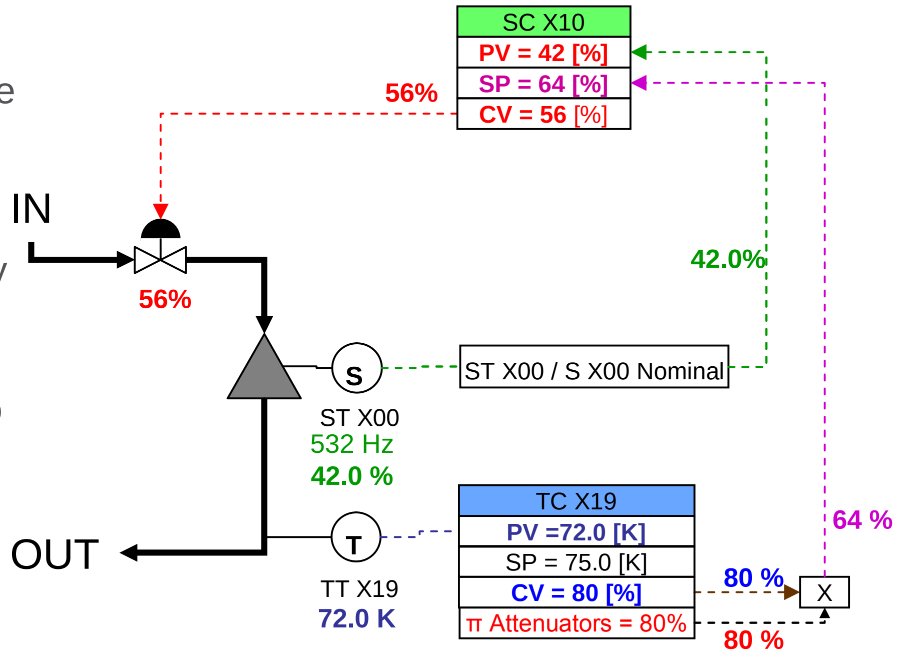
MINI OPENING = 5%
MAXI OPENING = 70%
OK

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

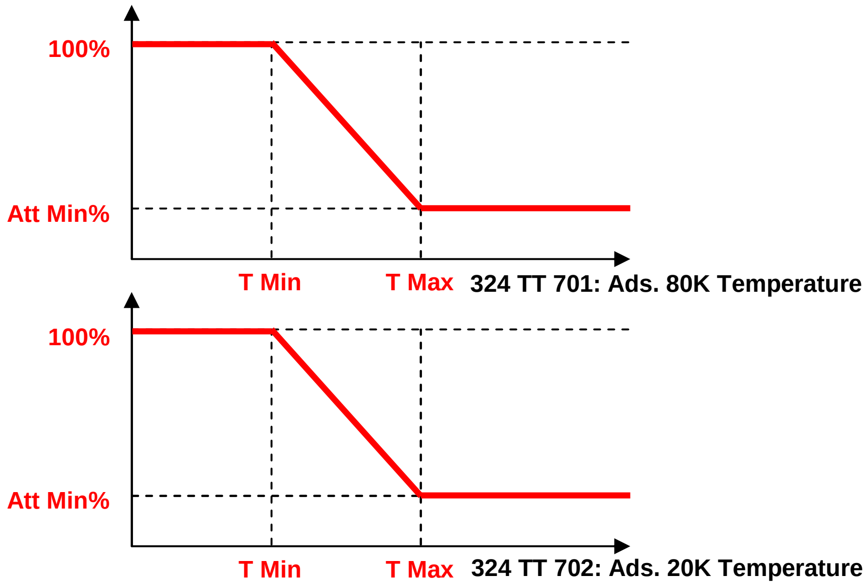
⇨ Slow down turbine before Alarms and Trips

⇨ When Turbine parameters approach extreme UNSAFE or OFF-DESIGN conditions, the Turbine Speed Set point is decreased.

Turbines - 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

Turbines – List of Speed Attenuators

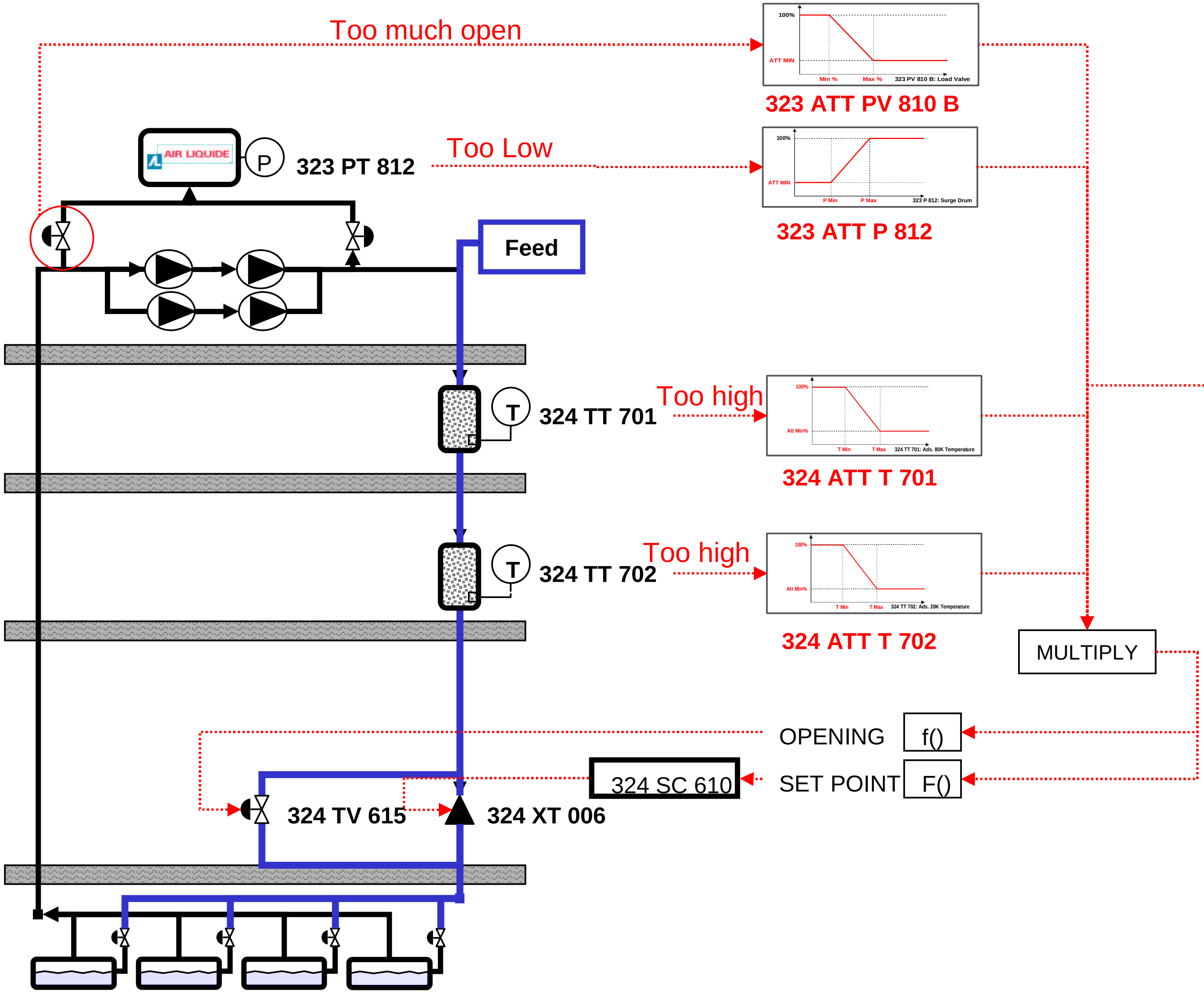
- The Turbine Speed Set Point is corrected by ATTENUATORS, which will slow down the Turbine

	ATTENUATOR	SENSORS	T1 & T2		T3	T4	T5	T6
1	**Low Surge Drum Pressure**	323 PT 812					**X [1]**	**X [1]**
2	**Load Valve too open**	323 PV 810 B					**X**	**X**
3	**LP value too high**	324 PT 040					**LP [1]**	
	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 [1]**	
6	**High Brake Temperature**	324 TT X11	**X [2]**		**X**	**X**	**X**	**X**
7	**High 80K Ads. Temperature**	324 TT 701						**X [1]**
	High 20K Ads. Temperature	324 TT 702						**X [1]**
8	**Client Attenuator**	NA	**X**		**X**	**X**	**X**	**X**

Note [1]: IMPORTANT Attenuators.

Note [2]: For T1&2 Brake Temperature Attenuator use Max (324 TT 111, 324 TT 211)

Turbines - Turbine T6 Controls (Production Control)



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

HYSYS Base case

- Base Case

- The most demanding case: CKXX
  - Liquid Helium is withdrawn and returned at warmer temperature
  - Feed gas is sent to buffer (29 g/s) or 1,4 bar/h
  - Liquefier load >> Liquefier capacity

- The easiest case: loading LHe in storage tanks or containers
  - Liquid Helium is withdrawn and returned at cold temperature
  - Feed gas is taken from buffer (18,6 g/s) or 0,9 bar/h
  - Liquefier load << Liquefier capacity

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HYSYS Case study: Lower HP

- Root cause
  - Cold Box Filter clogging or Turbine filter clogging
  - Heat Exchanger fouling

- Impact on liquefier
  - Lower ΔP on turbines
    - Turbine cold duty α Flow * ΔH

    Lower ΔP ⇨ Lower cold duty

  - Lower Pressure at turbine inlet
    - $\frac{\dot{m}\sqrt{T}}{P}$ is constant, if P ↘ $\dot{m}$ ↘

    Lower P ⇨ Lower Flow ⇨ Lower cold duty

HYSYS Case study: Lower HP

- Example T3

T3	Base case	Low HP (-1b)	Decrease
HP (bar)	19,7	18,7	5%
DP (bar)	14,7	13,7	7%
DH (J/g)	148,4	143	3,6%
Flow (g/s)	885	844	4,6%
Power (kW)	103	94	8,2%
Speed (Hz)	1500	1458	3 %

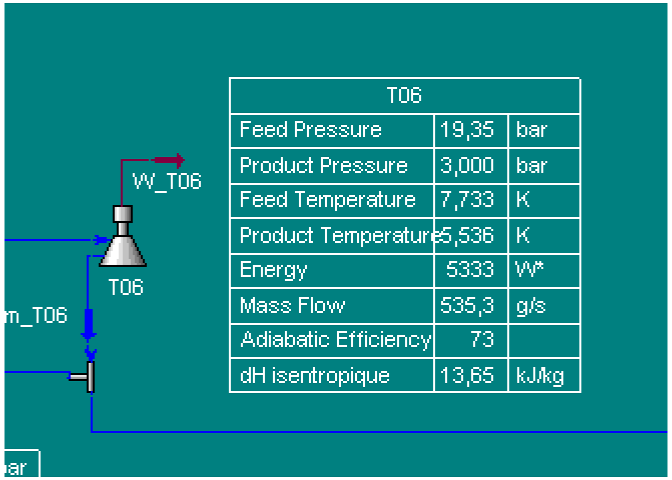
$$Power \propto Speed^{3}$$

- Small variation in speed ⇨ high variation in power
- If the HP is 1b too low, the production in decreased by 9%
- Proceed with filter cleaning, deriming.

Case study : Fouling of HX1

- Root cause
  - Contamination (oil, water, pollutants)

- Impact on liquefier
  - Delta T on warm end ↗
  - Warmer temperature chart
  - T6 limits the flow through the liquefier
    - T6 temperature increases (7,4K to 7,7K)

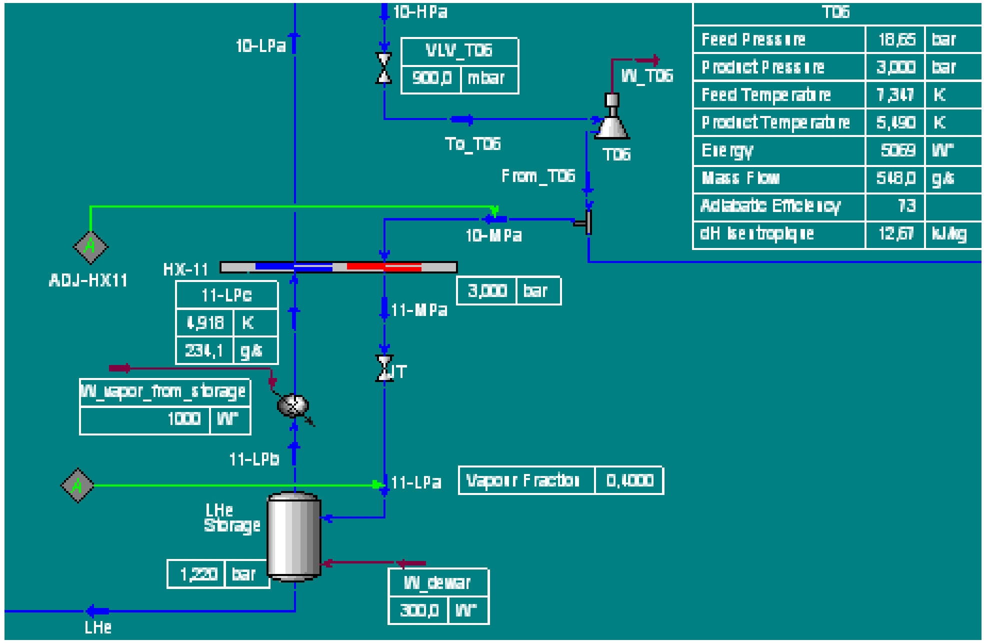


- As $\frac{\dot{m}\sqrt{T}}{P}$ is constant at turbine inlet, if T↗ $\dot{m}$ ↘

- If HX 1 is fouled, (DT warm end = 6K, the production in decreased by 10%)

Case study : Heat leaks on cold end

- Root cause
  - Poor vacuum in Distribution system



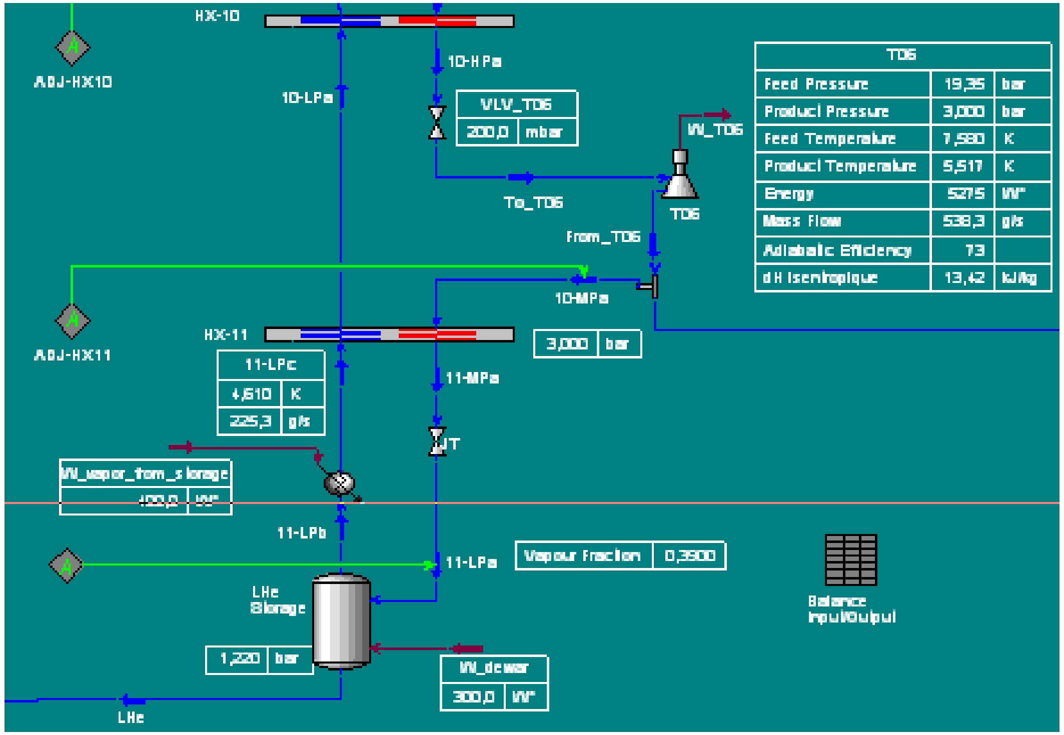
- Impact on liquefier
  - Turn to a refrigerator mode
  - Colder temperature chart
  - Higher flow from storage tanks
  - Higher temperature from containers (13,5K versus 7K)

- If the heat in-leaks to the cold end increase (+ 2kW), the production is decreased by 4%

Case study : Loading versus cooling

- Impact on liquefier

	CKXX	XXXX
T6 flow	538,3 g/s	540,7 g/s
T6 inlet temp	7,58 K	7,34 K
T6 ioutet temp	5,5 K	5,49 K
Power	5,28 kW	5,17kW
/ Average	93%	113%



- Cooling a warm container reduces the liquefier capacity by more than 10%

Case study : Adsorbers cool down

- 80K Adsorbers cool down
  - Impact on the production while cooling down : - 4%

- 20K Adsorbers cool down
  - Impact on the production while cooling down : - 3%

- Avoid to cool down adsorbers when a warm container is cooled down from 300 to 80K

Case study : Turbines OFF

- T1 T2 OFF
  - Keep the liquefier cold
  - No production
  - Turbines attenuated
- T5 OFF
  - Turbines attenuated
  - Estimated impact on the production -50%
- T6 OFF
  - Turbines attenuated
  - Estimated impact on the production -20%

Case study : 25% Plant turnodown

- Impact on liquefier

  - Pressure in compressor station are kept constant
  - T6 OFF
  - All turbines attenuated
  - Other cases\RHEA - DESIGN - EX8 2.1.2 - SANS LN2(7) - 2 TURBINES CHAUDES - 25%.pdf

Reminder: link between PSA - Liquefier

- 322 PV 196 is closed if
  - Adsorber 80K bypass is open
  - Or Adsorber 20K bypass is open

  - If 80K adsorber has been catching impurities
    - T<85K
    - and connected full fore more than 2 hours,

      ⇨The adsorber status is moved to « NOT CLEAN »

      ⇨ If temp rises in 80K adsorber > 90K and it is not clean then the bypass opens

  - If 20K adsorber has been catching impurities
    - T<25K
    - and connected full fore more than 2 hours,

      ⇨The adsorber status is moved to « NOT CLEAN »

      ⇨ If temp rises in 20K adsorber > 27K and it is not clean then the bypass opens