Helium Operators Familiarization Program

Unit 326 – ASU

Doha, January 2013 I PICHOT Delphine, SCHULLER Audrey I Technology and Process Direction

Agenda

- Introduction
- Process Description
- Process Control
- Hazards and Safety

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- **Introduction**
- Process Description
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Introduction

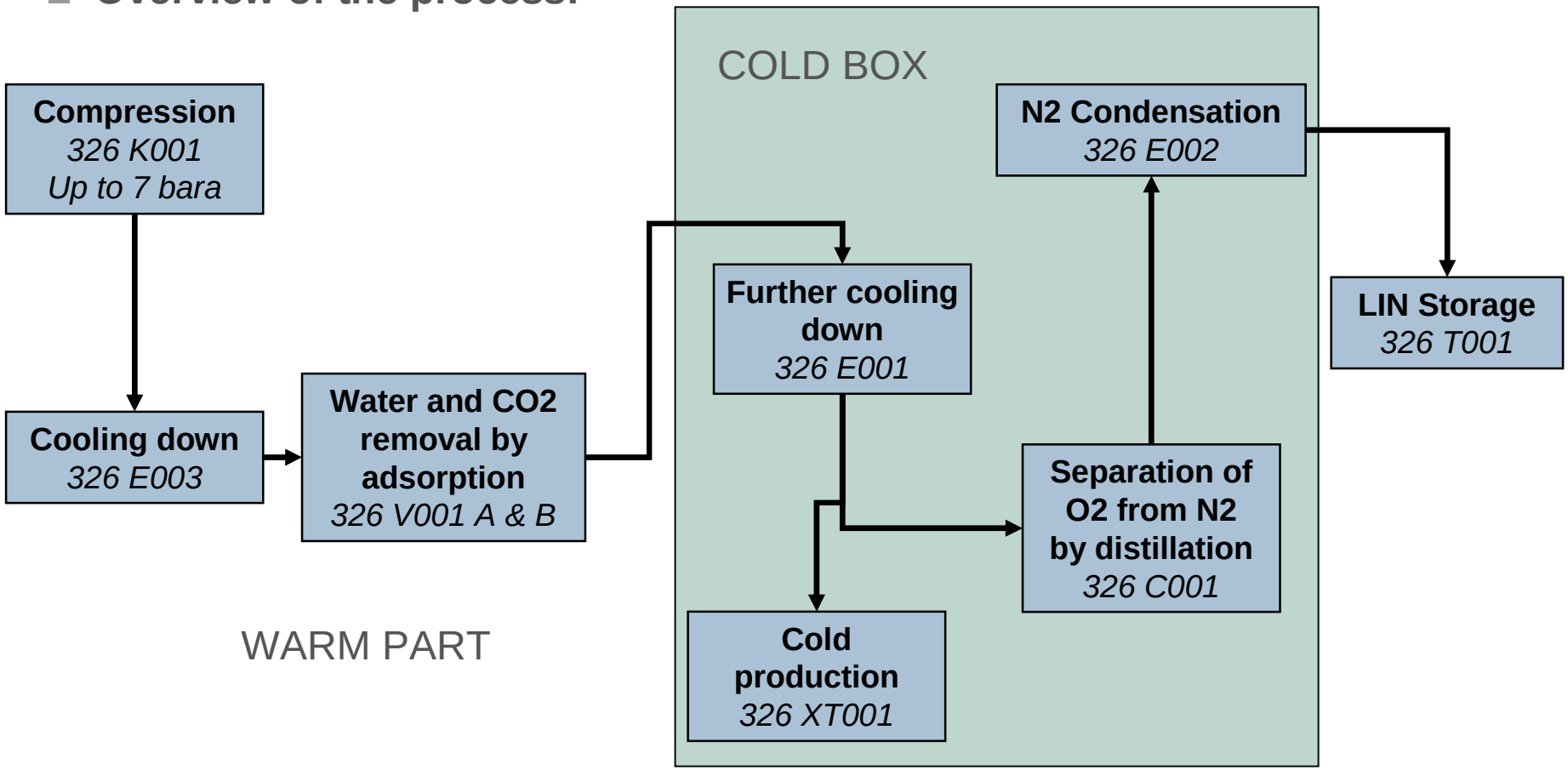
- The purpose of the ASU is to produce:
  - Liquid Nitrogen (LIN) for Helium storages and containers: the He storage's insulation is ensured by introducing liquid nitrogen in the tanks' shields
    - For He storages: 80 Nm3/day/storage (eq. 15 Nm3/h)
    - For He mobile containers: 1600 L/containers (eq. 210 Nm3/h)
  - Liquid Nitrogen (LIN) for GNI supply -> 10 Nm3/h (cold box venting)
  - Instrument air (320-K002 back up) -> 700 Nm3/h

- The ASU is designed for 15 tpd (500 Nm3/h) of LIN
  - There is extra capacity: only 235 Nm3/h of LIN is needed during normal operation

    - Note: The ASU does not provide cold for liquefier: the liquefier is self-sufficient

Introduction

- **Overview of the process:**



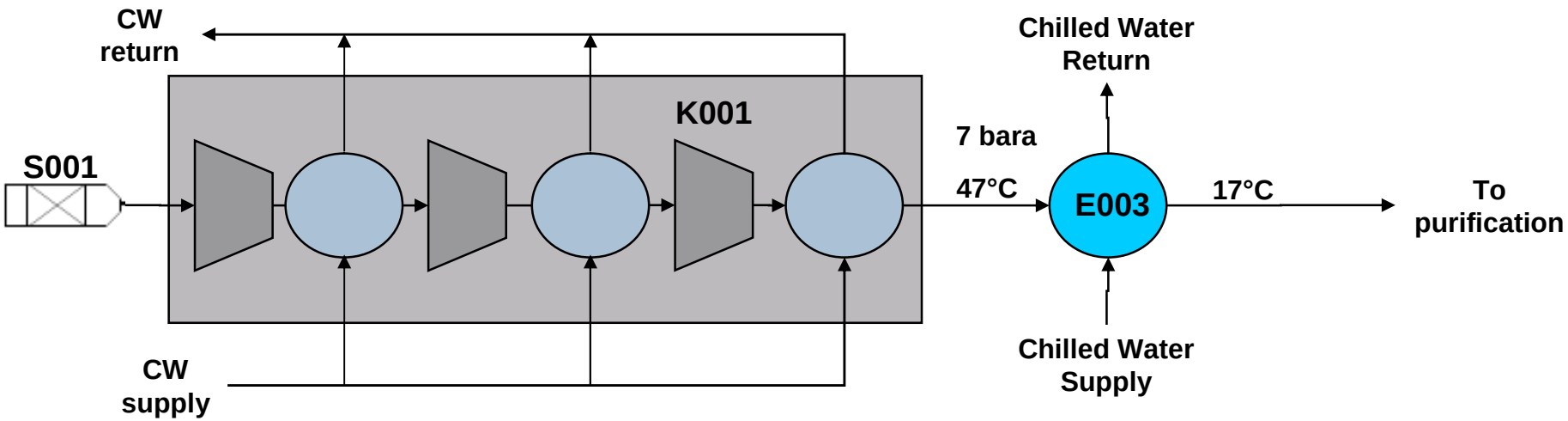
- Due to very cold temperatures and possible high hydrocarbons concentration in a O2-enriched fluid, the ASU presents specific risks.

Agenda

- Introduction
- **Process Description**
- Process Control
- Hazards and Safety

Process description – Compression and Chilling

- Air is filtered through 326 S001
- Air is compressed in ASU Main Air Compressor (326 K001):
  - 326 K001 is a 3-stage centrifugal compressor
  - Compression up to 7 bara
- Cooling down against Chilled Water in 326 E003 down to 17°C. While chilling:
  - Most of the water condensates and is removed
  - The dew point of compressed air is lowered



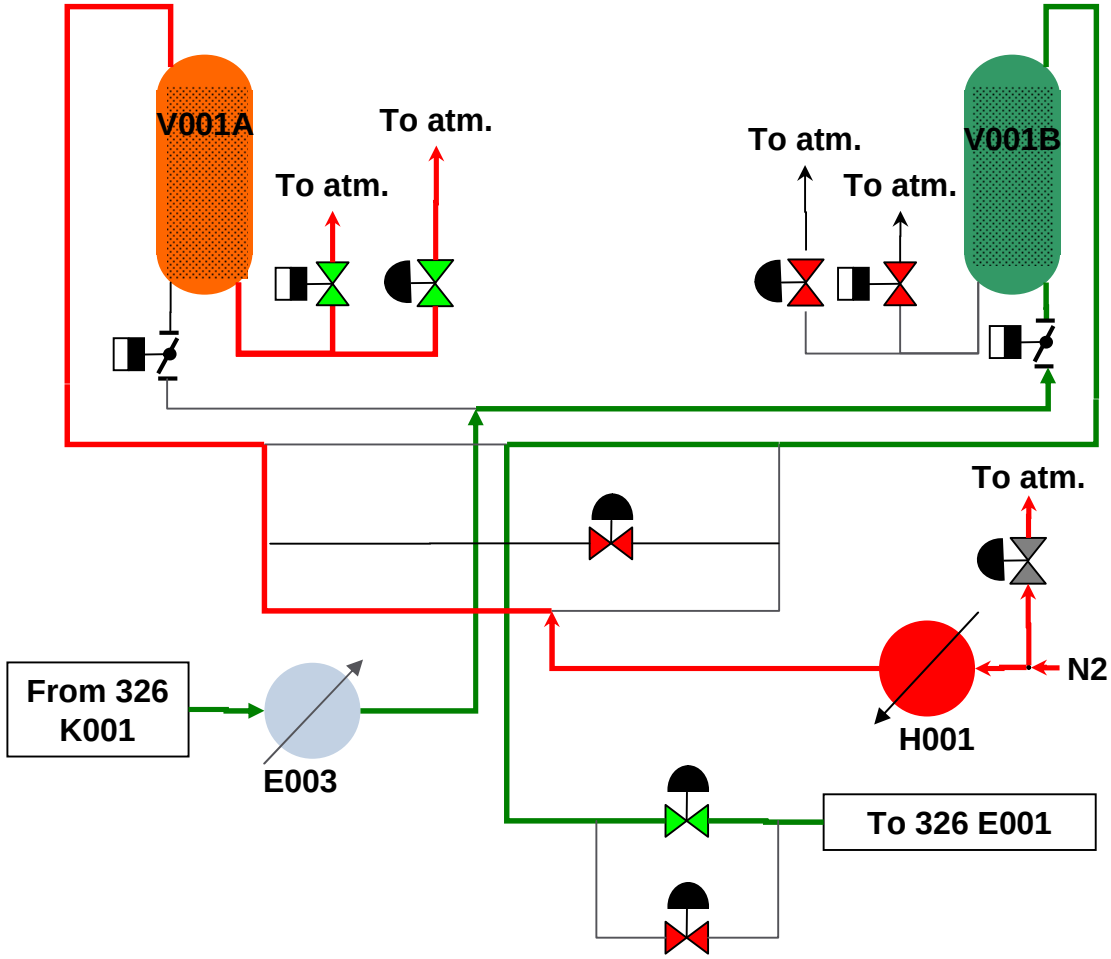
Process description – Purification

- Compressed Air must be dry and CO_2-free before being cooled down, in order to prevent water and CO_2 from freezing inside the heat exchanger 326 E001.
- The adsorbents are:
  - Aluminia to adsorb H_2O
  - Molecular sieves to adsorb CO_2
- To ensure continuous process, 2 adsorbers are used:
  - One is lined up: wet air circulates from bottom to top in the adsorber, H_2O and CO_2 is adsorbed at adsorbent surface
  - The other one is in regeneration: a regeneration gas circulates from top to bottom in the adsorber, carrying over the adsorbed impurities to the atmosphere. After regeneration is completed, the adsorber can be re-used again for adsorption.
- Regeneration is performed with Waste N_2 from 326 C001, at high temperature
- Each phase (adsorption/regeneration) lasts 2.5 hours
- Dryer operation is fully automated with a sequence of 18 steps based on physical parameters and timers: 9 steps for adsorption + 9 steps for regeneration

Process description – Purification

OVERVIEW

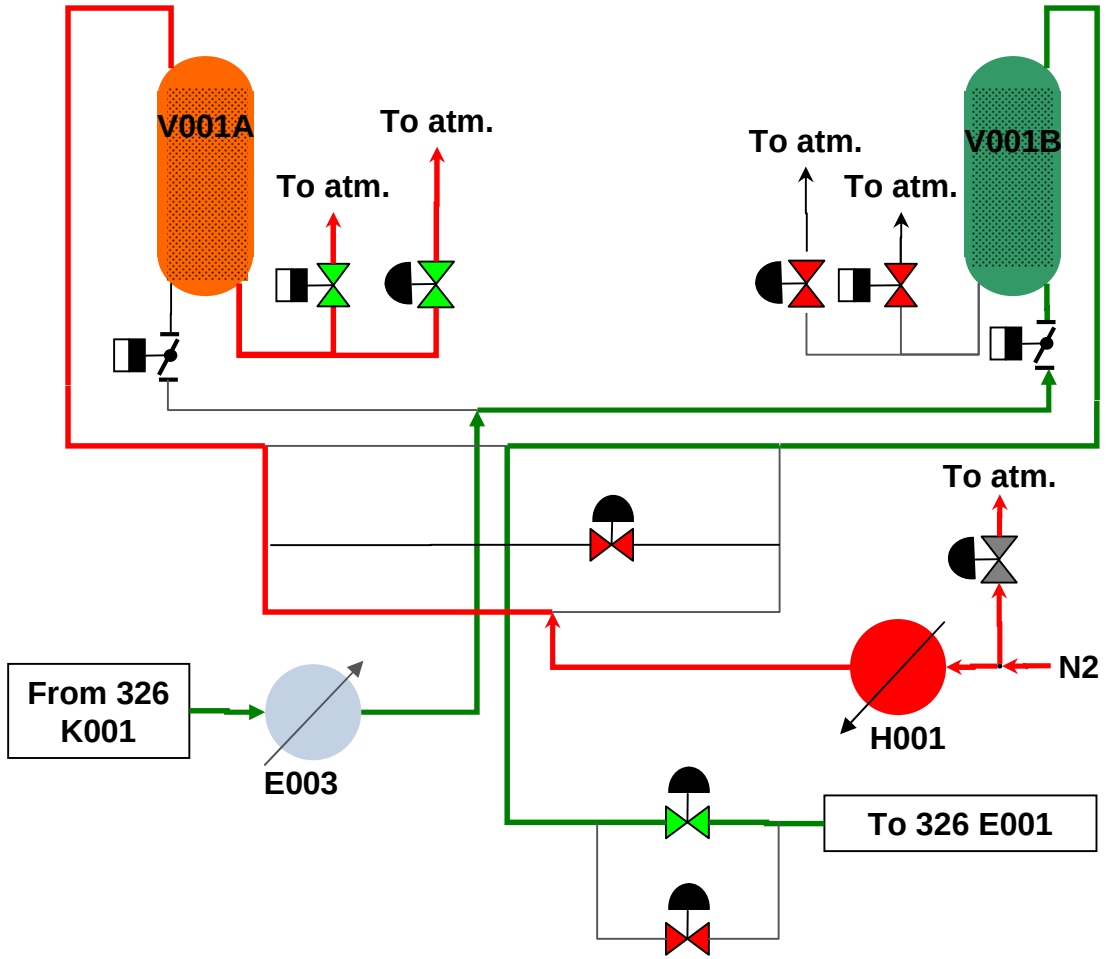
- Wet air is cooled down in 326 E003 to condense water and reduce the load to the adsorbers
- Wet air circulates from bottom to top of the adsorber in adsorption mode (V001B)
- Meanwhile, the other vessel (V001A) is in regeneration mode, to get ready for the next cycle.
- After 2.5 hours, the vessel needs to be regenerated.
  - V001A switches to adsorption
  - V001B switches to regeneration



Process description – Purification

REGENERATION

- The regeneration gas is hot Waste Nitrogen coming from 326 C001 and heated up in 326 E001 and 326 H001
- While circulating, hot N_2 carries over H_2O and CO_2 adsorbed at adsorbent surface when the vessel was in adsorption mode.
- Hot N_2 along with the impurities are vented to the atmosphere.



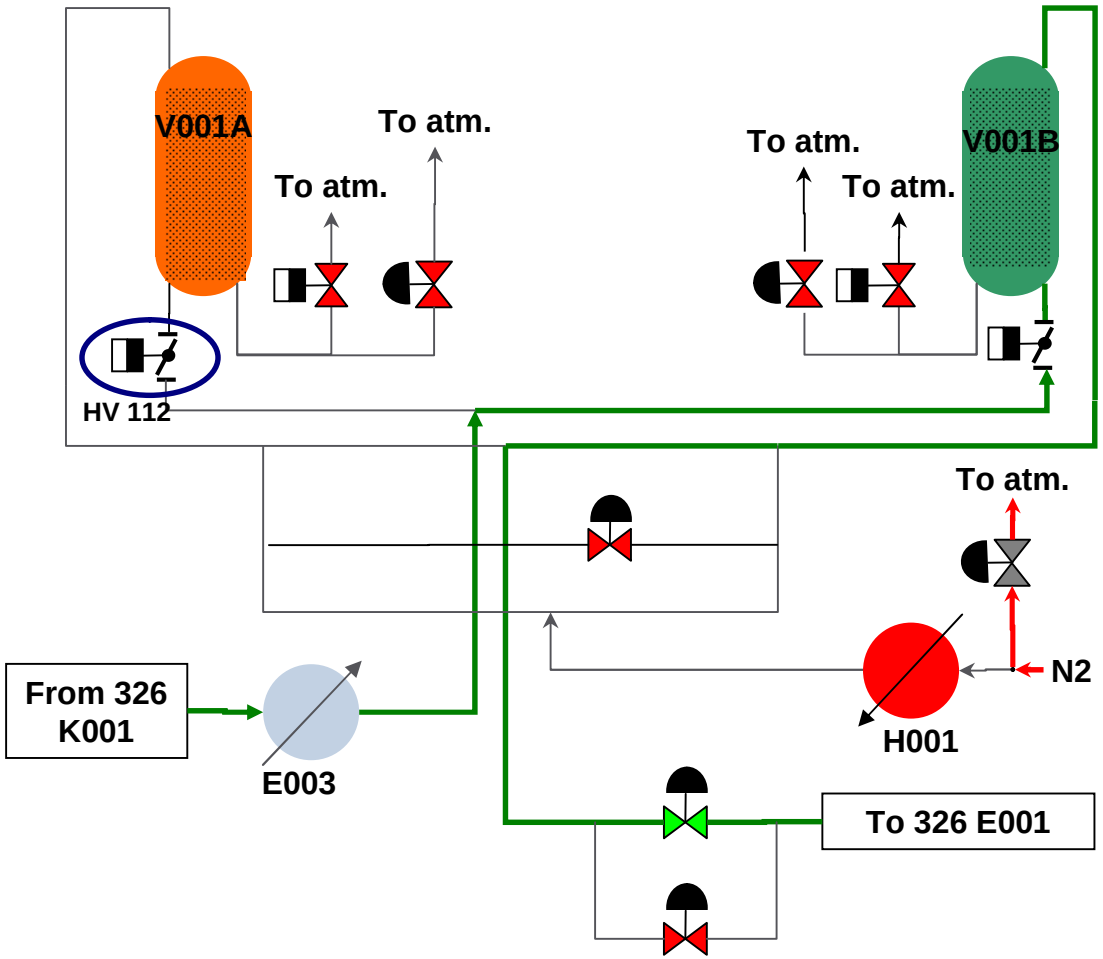
Process description – Purification

REGENERATION

STEP 1: High pressure isolation

326 HV 112 closes

326 PV 103 A is already open.



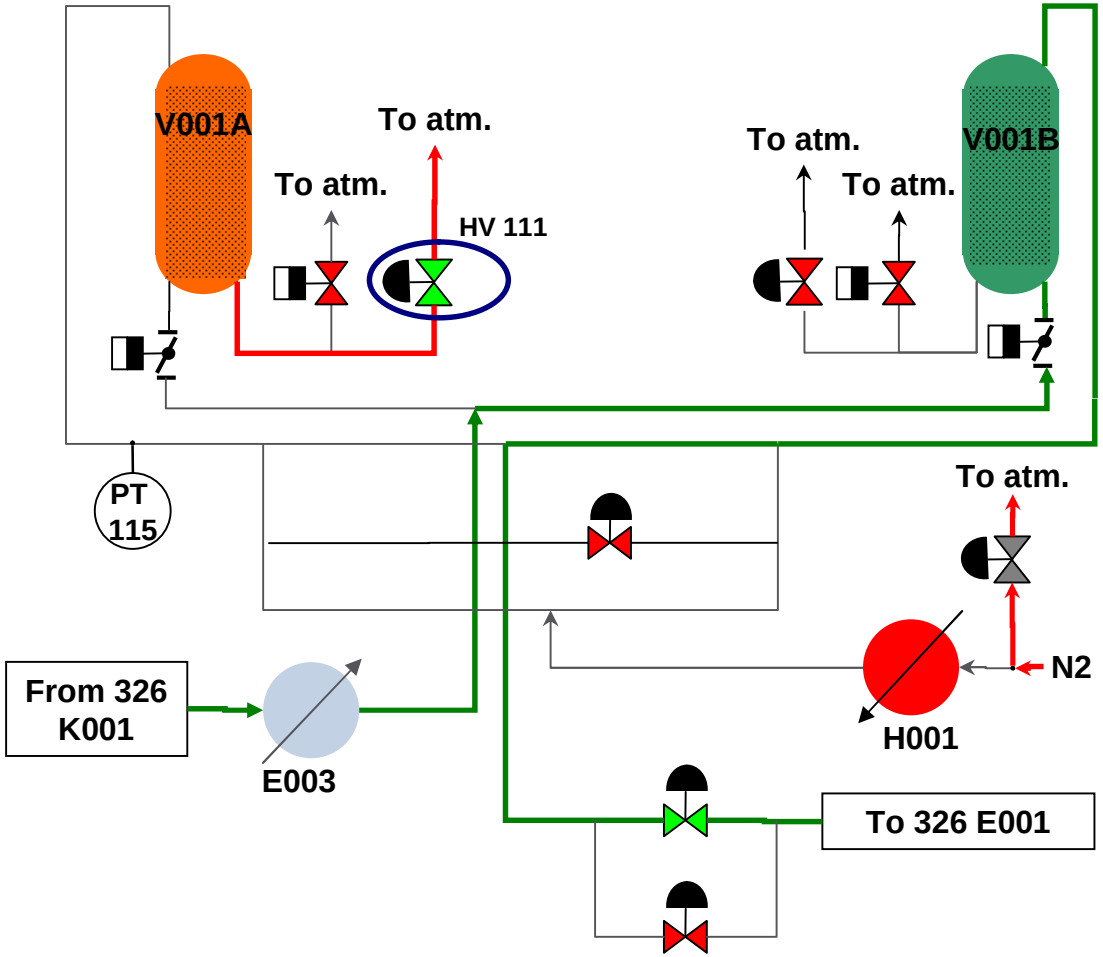
Process description – Purification

REGENERATION

STEP 2: Depressurization

326 HV 111 opens on a slow ramp up to 100%

When 326 PT 115 is low enough, the vessel is ready to move to step 3.



Process description – Purification

REGENERATION

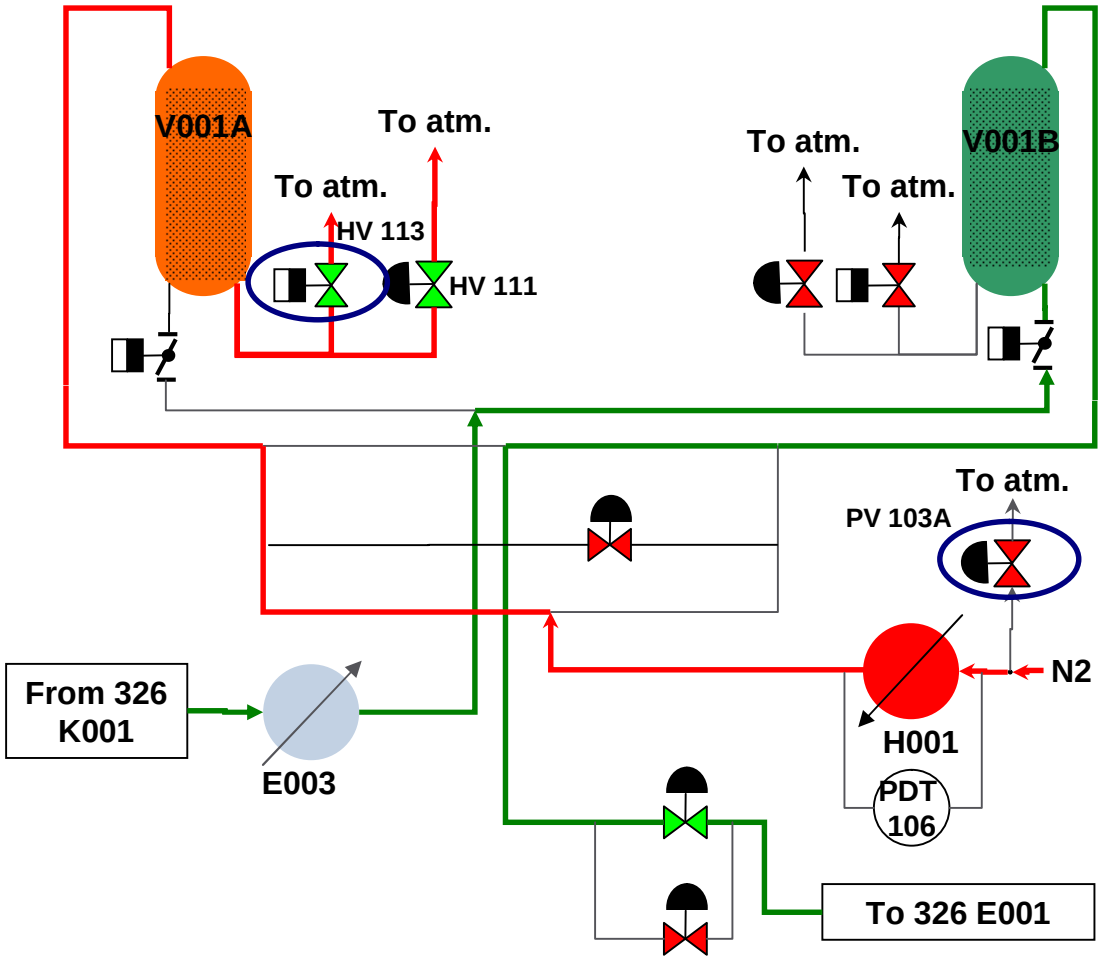
STEP 3: Blowing

326 HV 111 has reached its maximum opening in the previous step.

Vent valve 326 HV 113 opens

The Waste N_2 flow through the vessel increases by throttling 326 PV 103A.

When 326 HV 113 is fully open and the flow through the heater is high enough (PDT 106), the vessel is ready to move to step 4.



Process description – Purification

REGENERATION

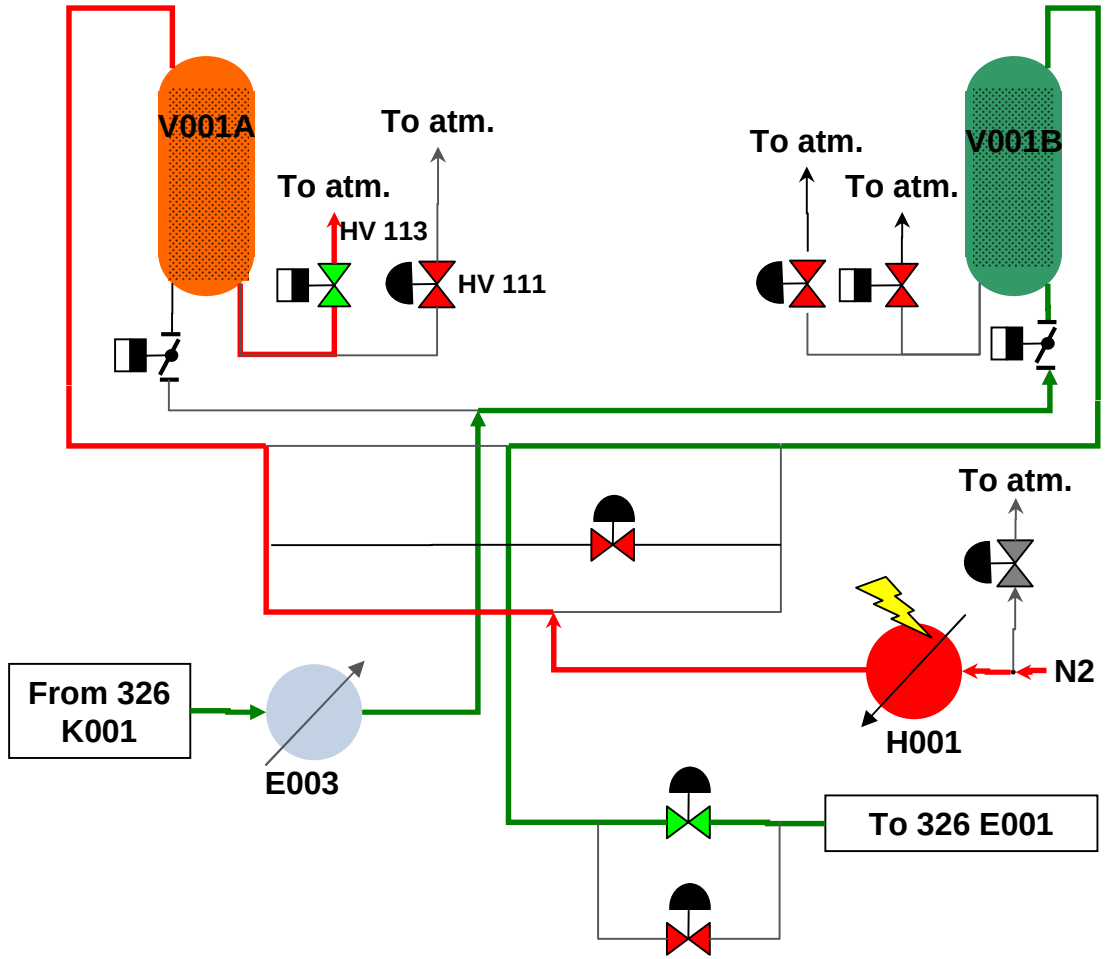
STEP 4: Heating

Heater 326 H001 starts.

Vent valve 326 HV 113 is maintained open.

Vent valve 326 HV 111 closes.

When heating time is over, the vessel is ready to move to step 5.



Process description – Purification

REGENERATION

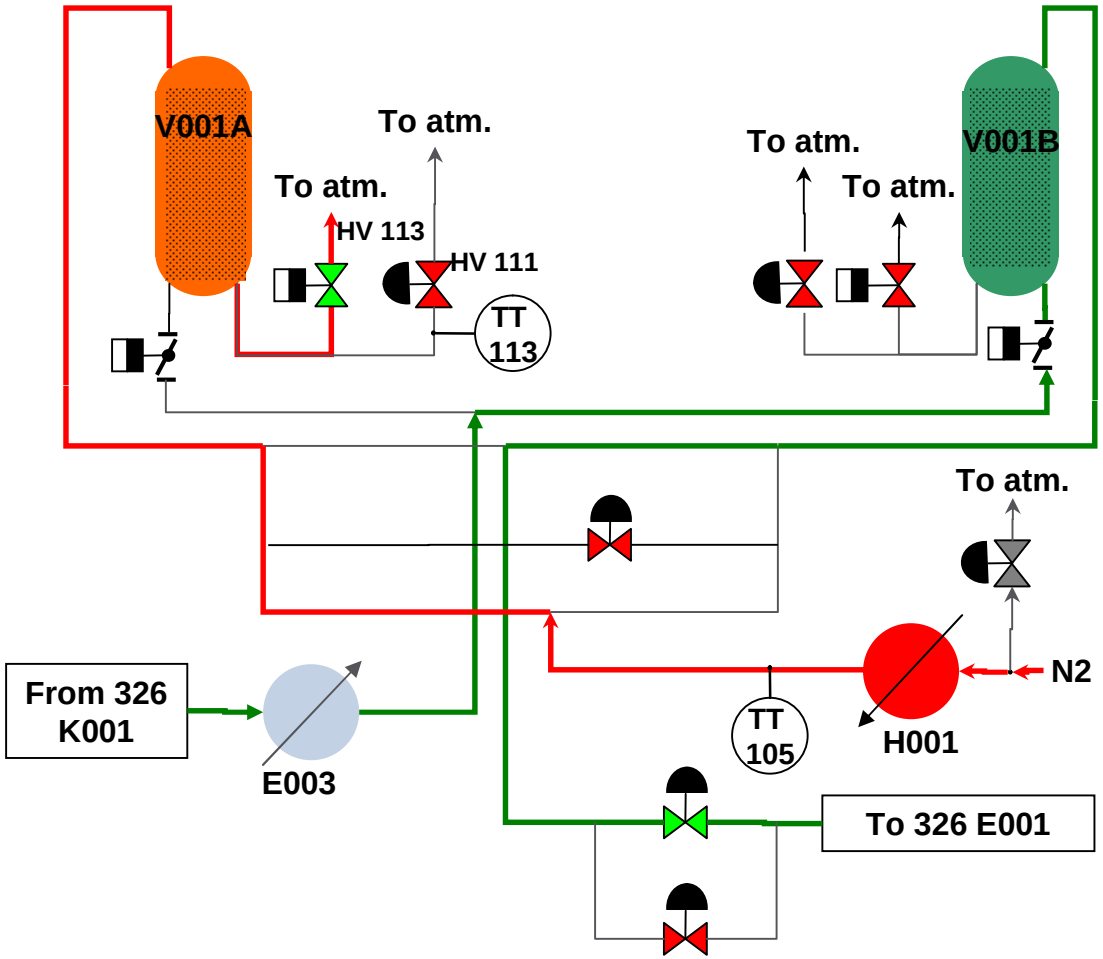
STEP 5: Cooling

Vent valve 326 HV 113 is maintained open.

The heater is stopped. The regeneration flow is now cooling down the lines.

When:

1. Cooling time is over
2. Temperature difference of the regen. gas before and after the vessel is low (TT113 – TT105), the vessel is ready to move to step 6.



Process description – Purification

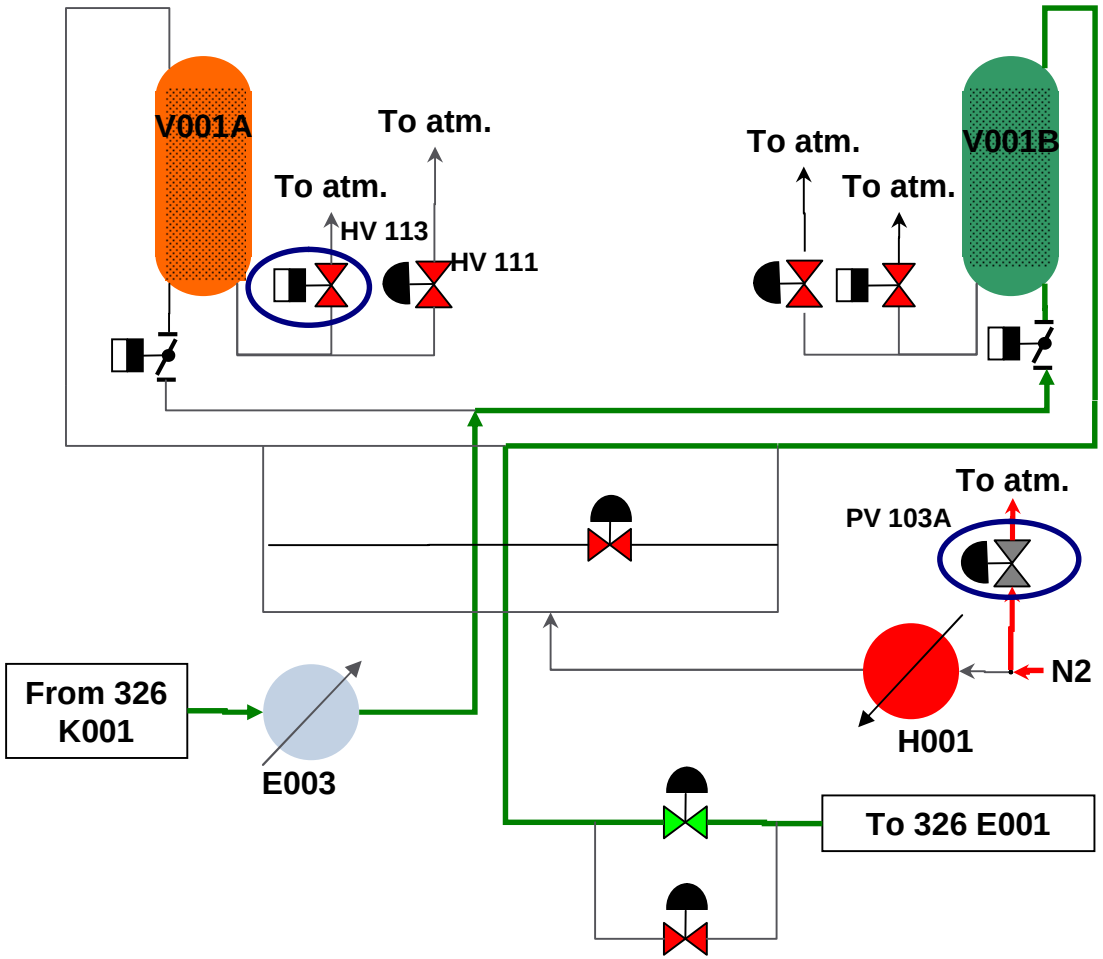
REGENERATION

STEP 6: Isolate LP

The regeneration flow stopped by opening 326 PV 103A.

Vent valve 326 HV 113 closes.

When vent valve is completely closed, the vessel is ready to move to step 7.



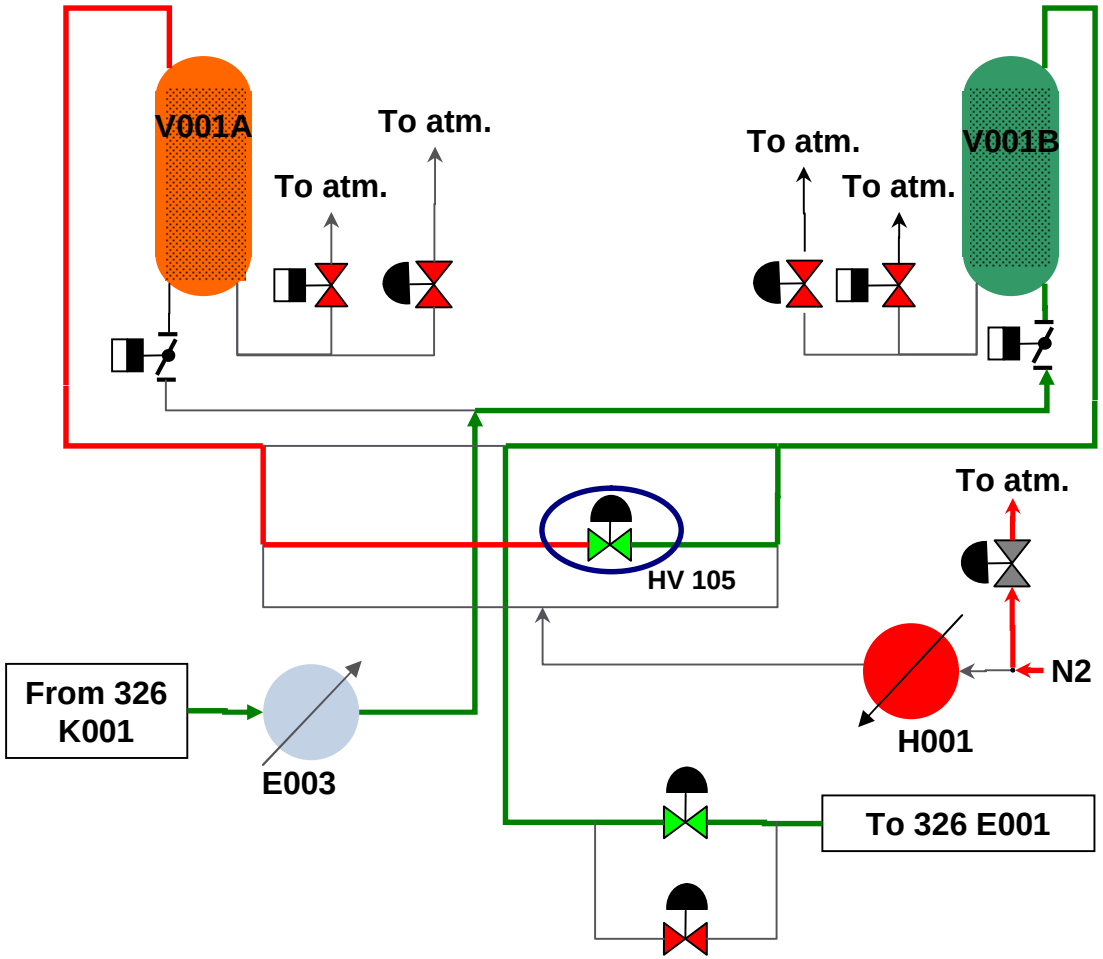
Process description – Purification

REGENERATION

STEP 7: Pressurize

Pressurization valve 326 HV 105 slowly ramps up to 100%.

When differential pressure at HV 105 limits is low enough (PDSL 105), the vessel is ready to move to step 8.



Process description – Purification

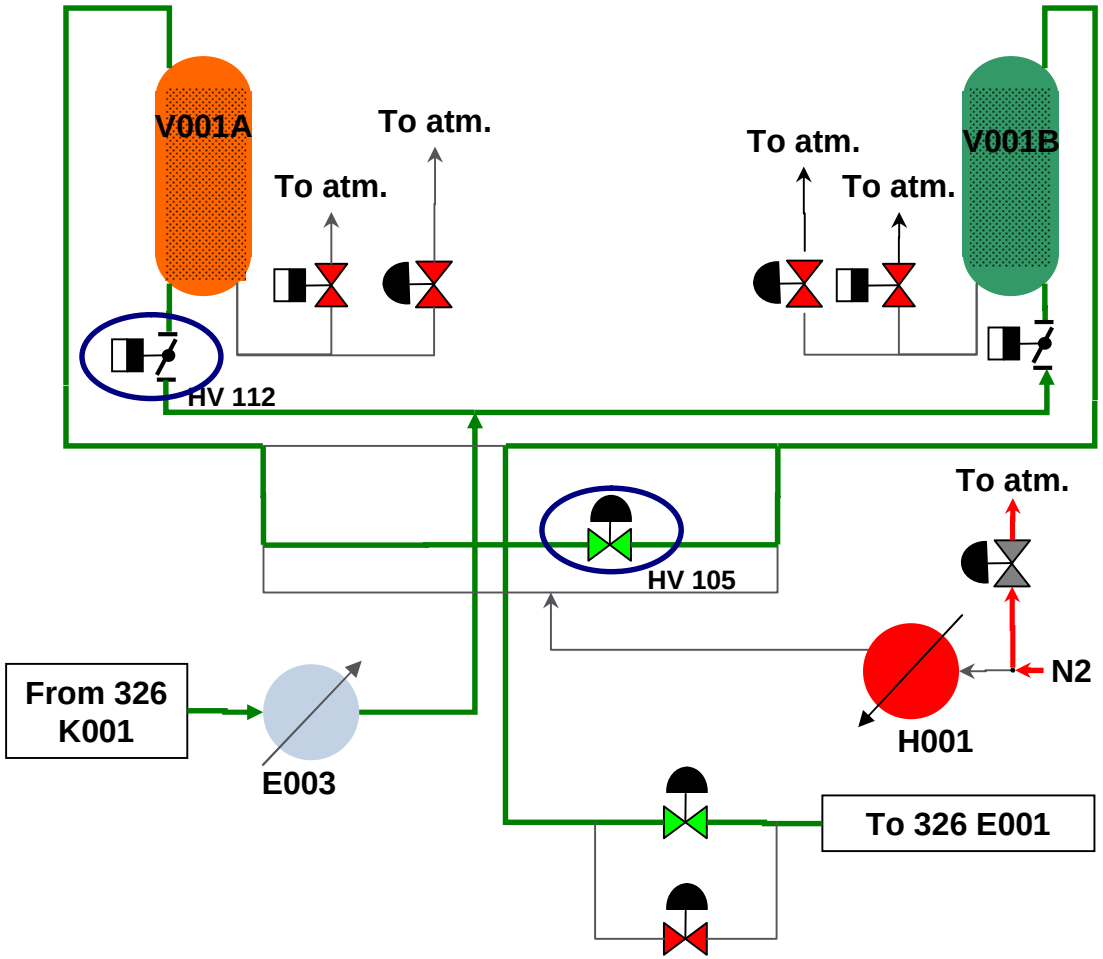
REGENERATION

STEP 8: Parallel

Pressurization valve 326 HV 105 remains open.

326 HV 112 opens.

When 326 HV 112 is fully open and parallel timer is over, the vessel is ready to move to step 9.



Process description – Purification

REGENERATION

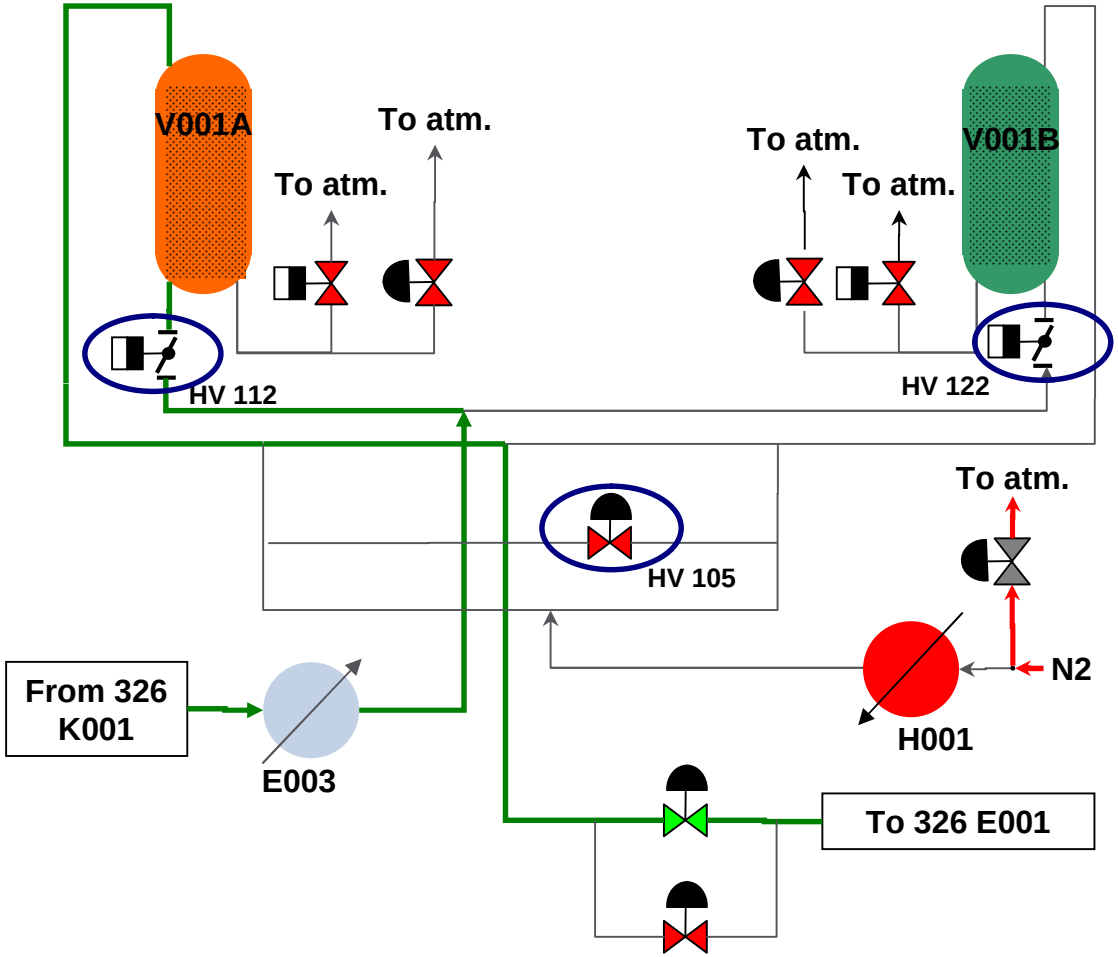
STEP 9: Start adsorption

Pressurization valve 326 HV 105 closes.

326 HV 112 opens.

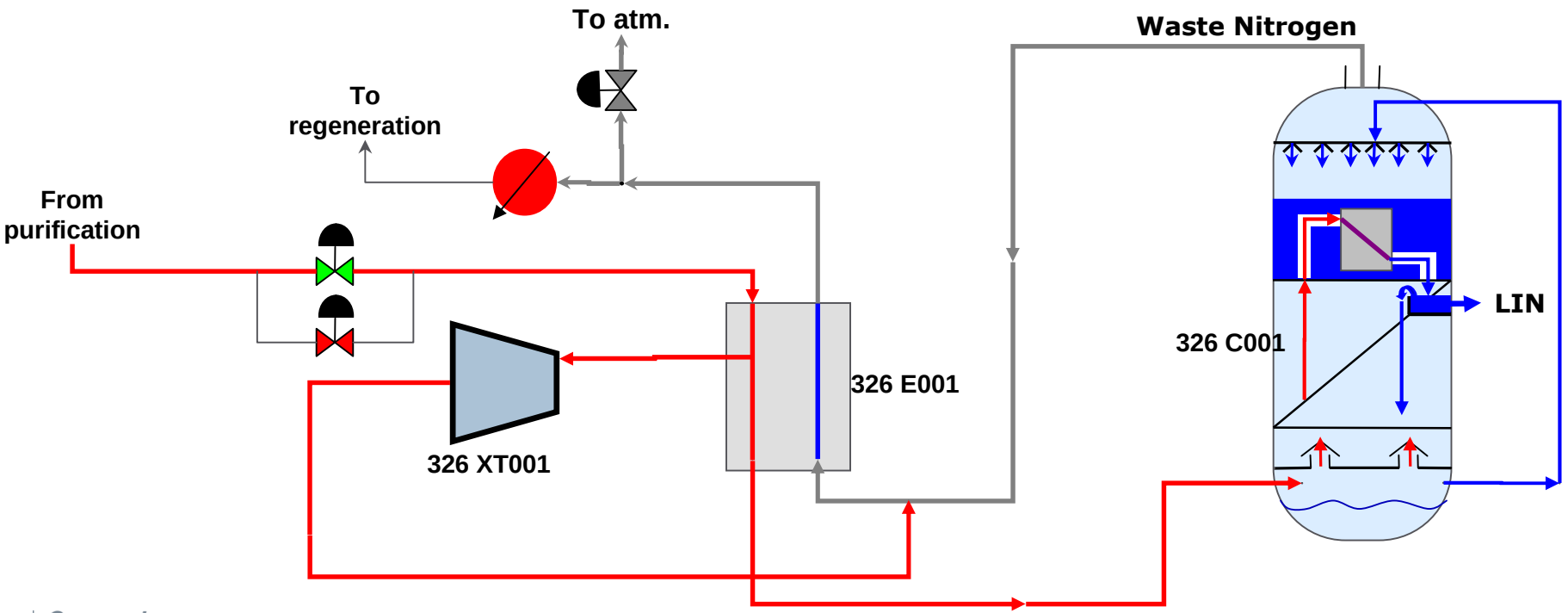
326 HV 122 closes.

V001B switches to the first step of regeneration: “isolate HP”



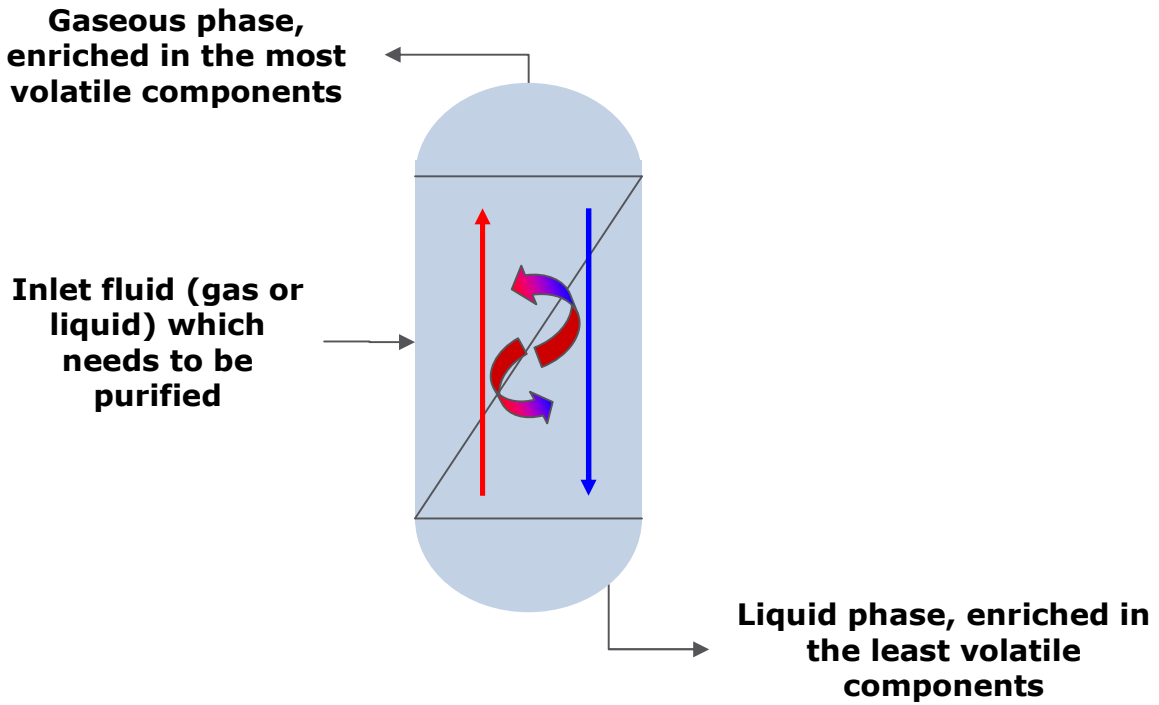
Process description – Cooling down in 326 E001

- After the purification, dry air is separated into 2 flows:
  - To the turbine 326 XT001 for cold production
  - To the distillation column 326 C001 to separate O_2 and N2
- In E001, the cold duty is brought by Waste Nitrogen from 326 C001 and expanded air.



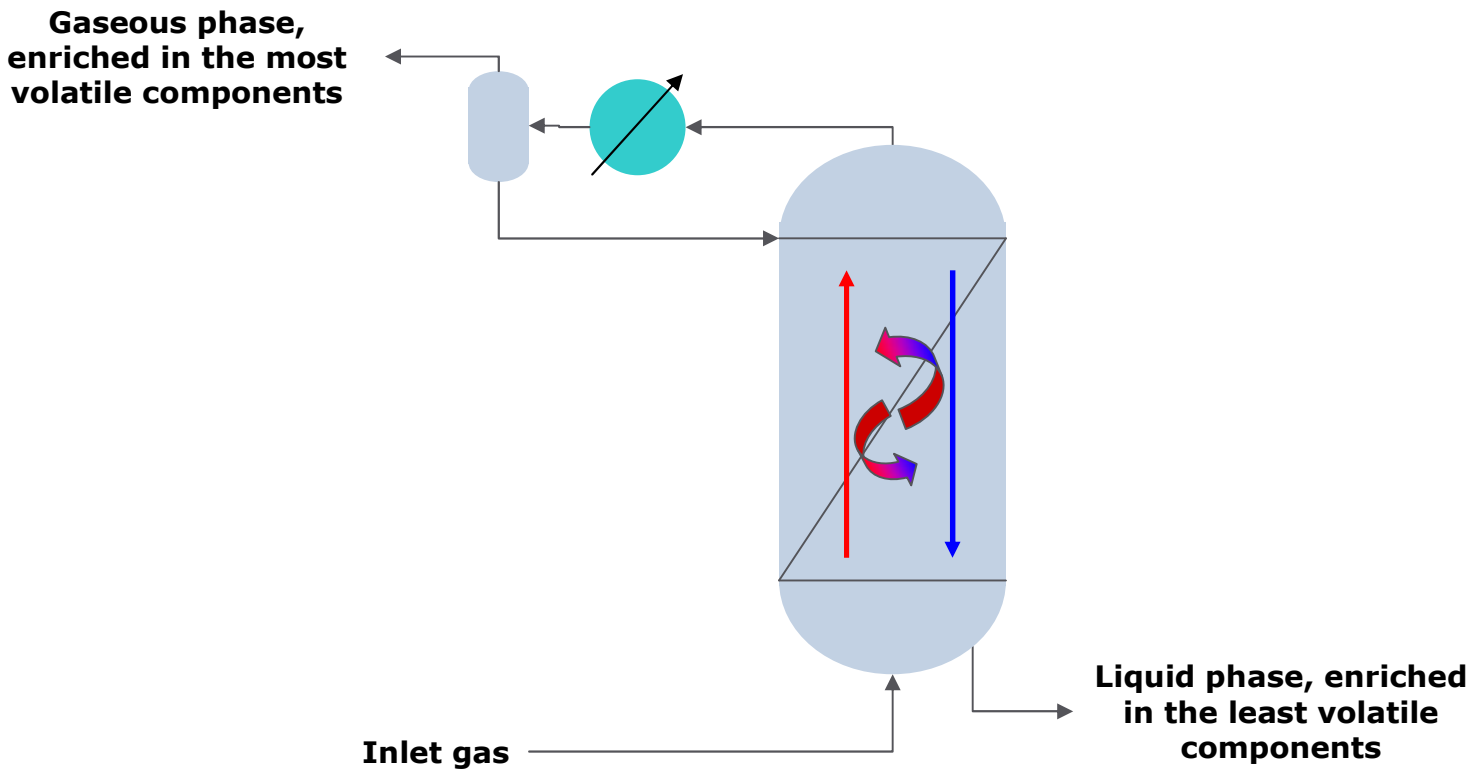
Process description – Distillation - Theory

- Distillation columns allow to separate molecules from a gas or a liquid, by getting the 2 phases in contact and then, transferring the most volatile molecules in the gaseous phase and the least volatile molecules in the liquid phase.



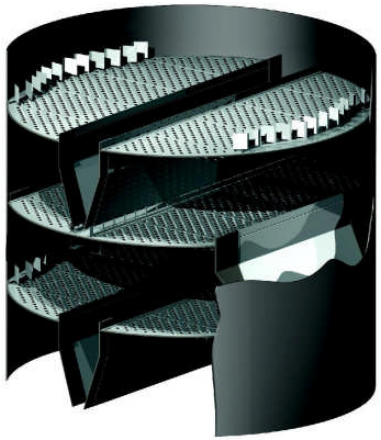
Process description – Distillation - Theory

- If the inlet fluid is a gas, a fraction (or all) of the outlet gas is condensed to provide a liquid to the distillation.
  - This requires a condenser at column's top



Process description – Distillation – Theory

- 2 technologies:
  - Trays/plates: liquid and gas phases are put in contact in trays/plates.
  - Packings: distillation columns are filled in with random or structured packing. The mass transfer is then continuous. Each packing is caracterized by a HETP (height equivalent theoritical plate).
- A performing packing limits the pressure drops during gas and liquid circulation.



Trays

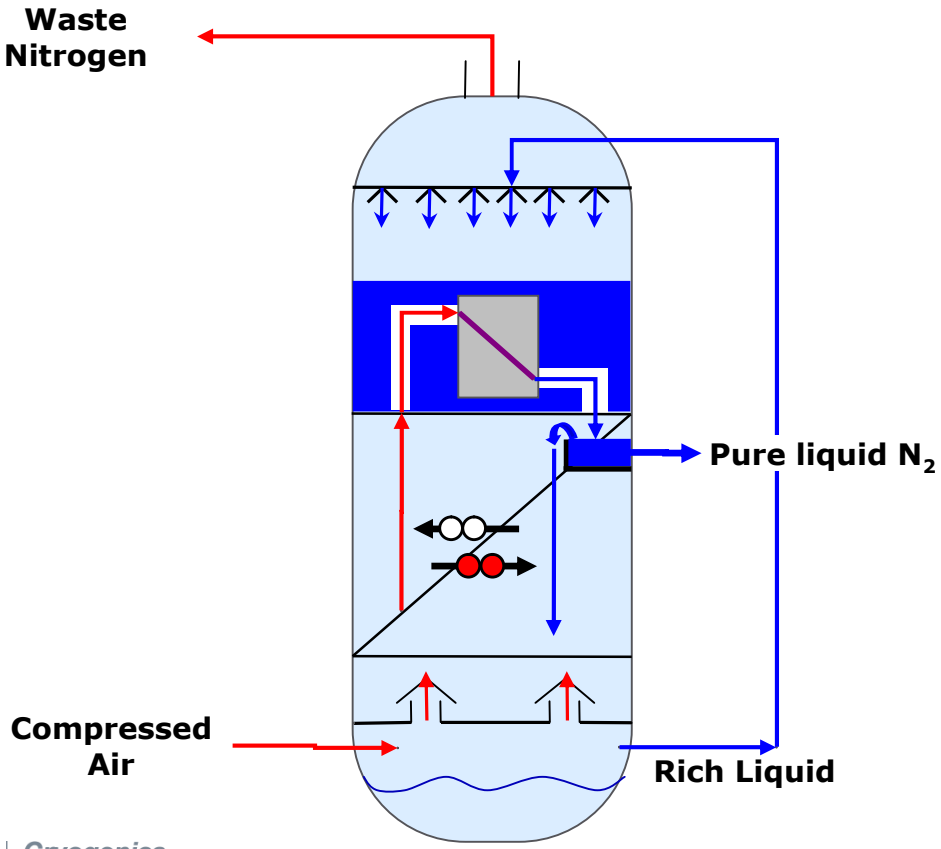
Structured packing

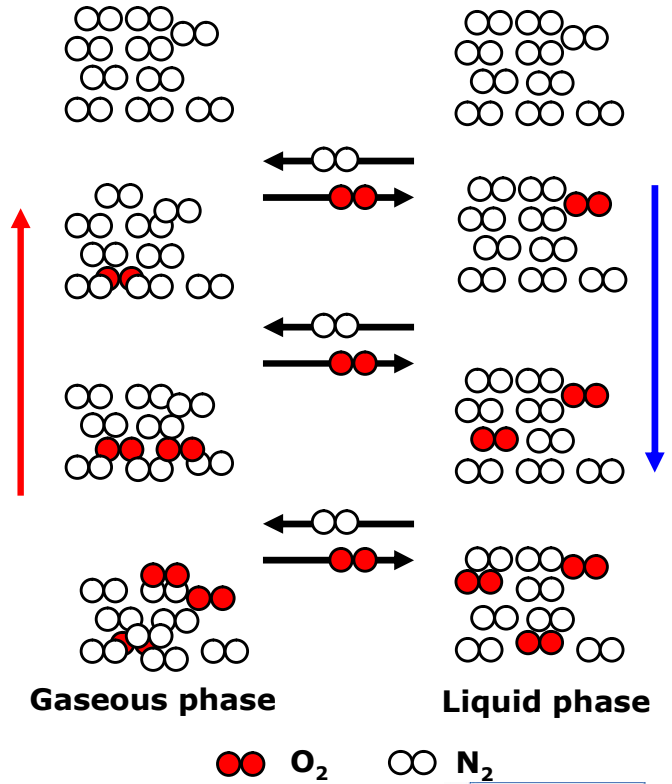
Random packings

Source: Sulzer

Process description – Distillation

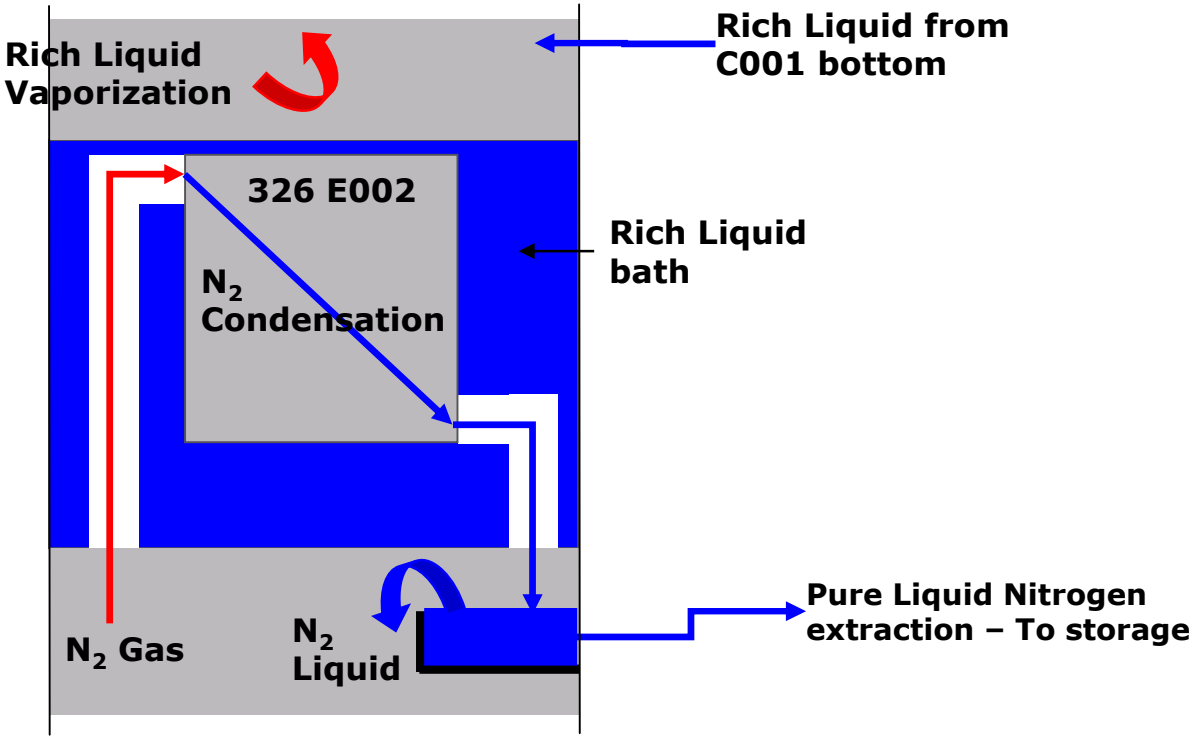
- Compressed air is introduced at 326 C001 bottom.
- The ascending gas is in contact with a N_2 + O_2 liquid mixture. While ascending, the O_2 molecules are transferred into the liquid and the N_2 molecules contained in liquid are transferred into the gas





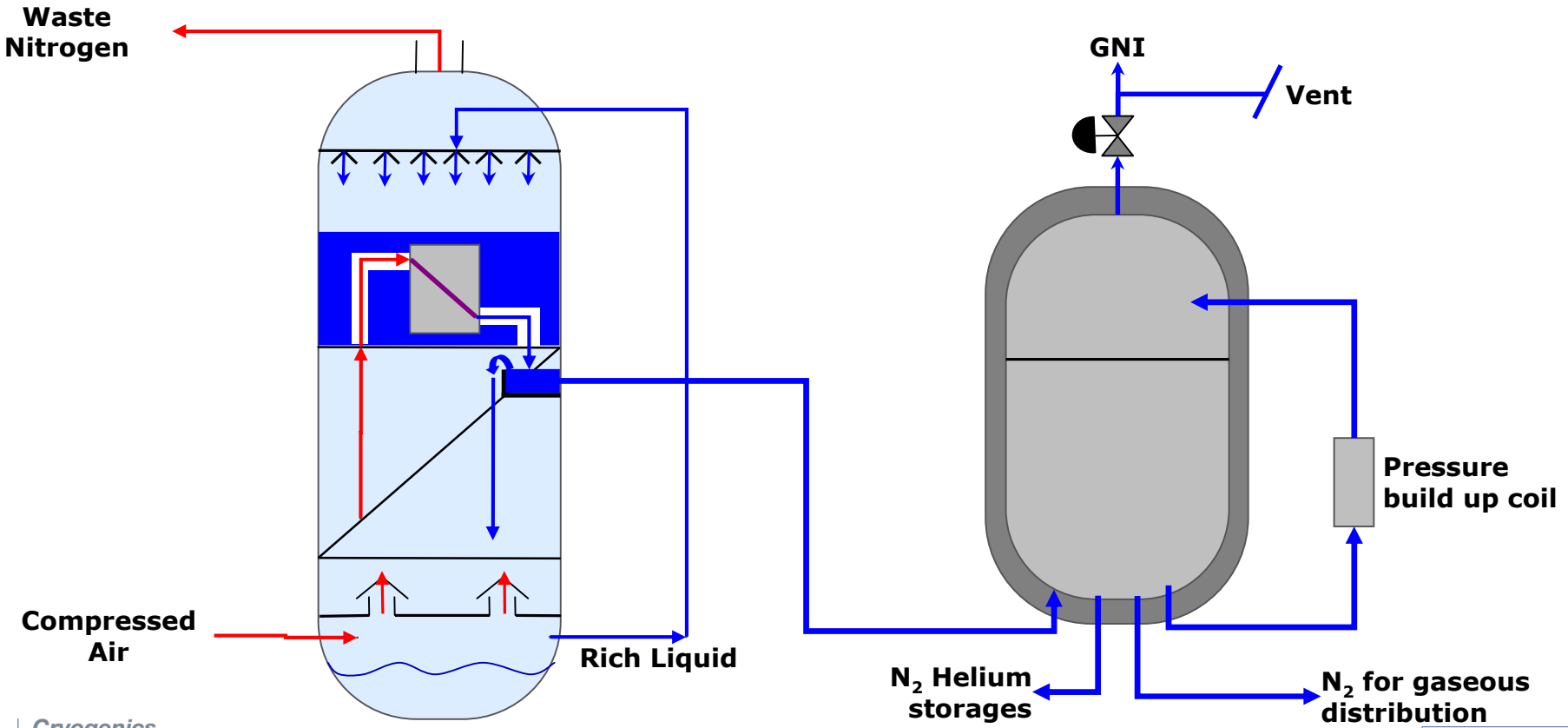
Process description – Vaporizer

- The vaporizer allows:
  - Forming the liquid phase needed for distillation
  - Producing Liquid Nitrogen for Helium storages
- The nitrogen gas is totally condensed in 326 E002.
  - The cold duty is provided by the vaporization of the rich liquid
  - The rich liquid is brought from 326 C001 bottom to 326 E002



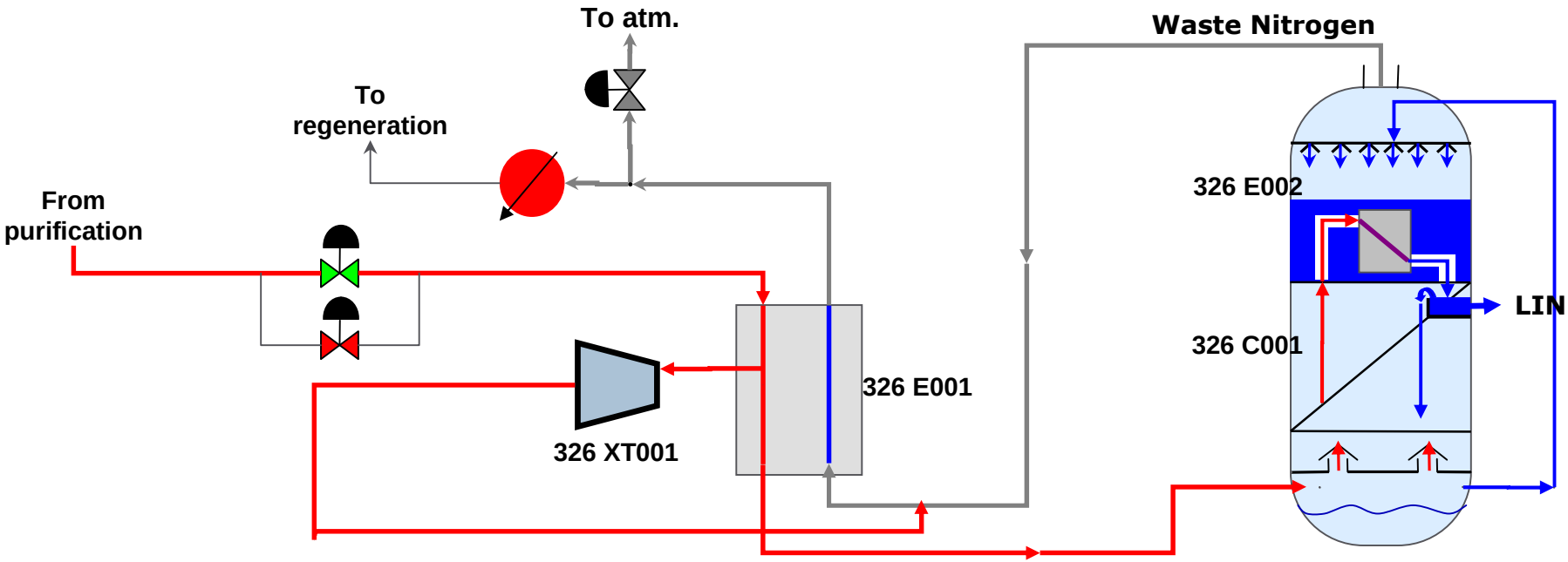
Process description – Liquid Nitrogen production

- N_2 ascending gas at column top is condensed in the vaporizer 326 E002, producing liquid Nitrogen.
- A fraction of this liquid goes back into the ditillation column while the other fraction is sent to the liquid Nitrogen storage tank.



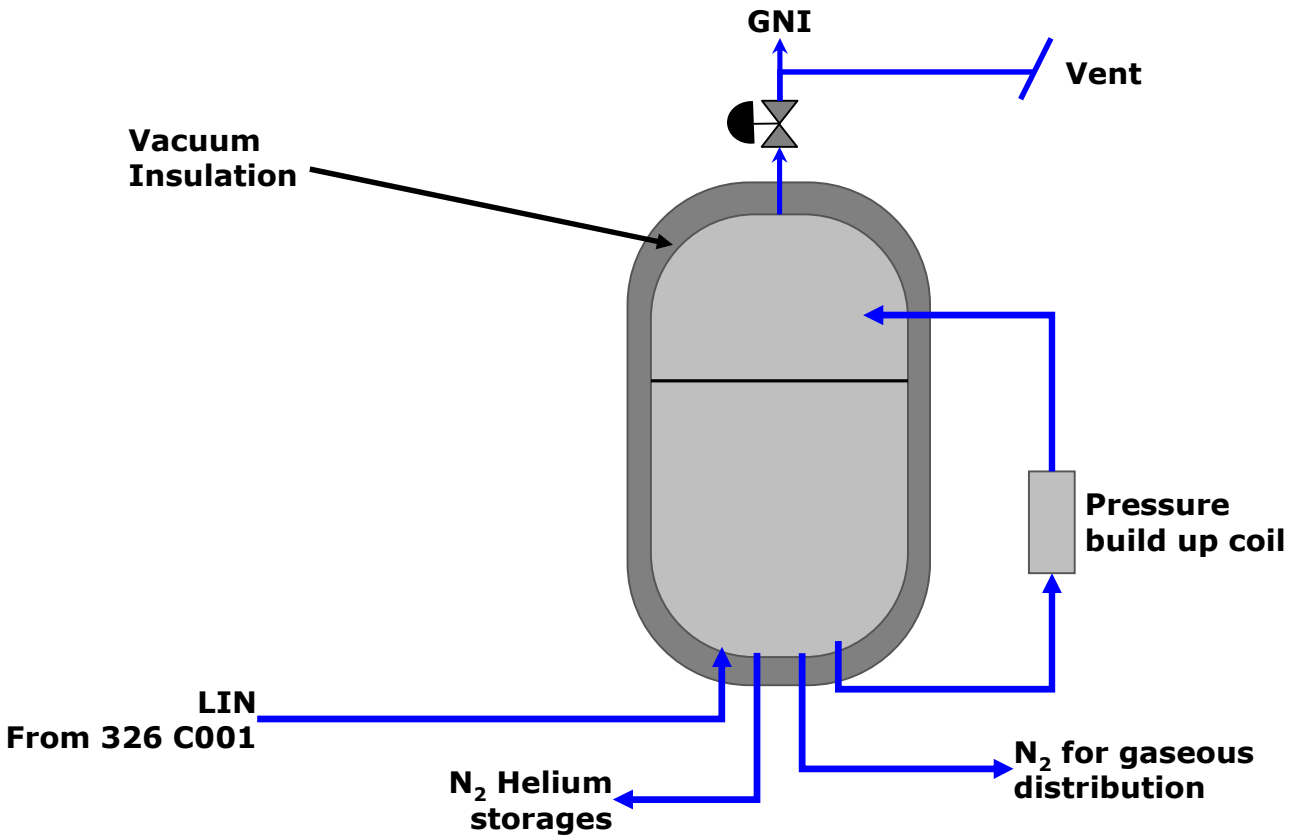
Process description – Regeneration gas

- The outlet gas from 326 E002 is cold (~-186°C).
- It is warmed up in 326 E001 where the cold is recovered to cool down the inlet air.
- Depending on the step of the purification sequence, the waste nitrogen is either sent to the vessel in regeneration, or vented to the atmosphere through 326 PV 103 A.



Process description – Liquid N2 storage

- Cold insulation is ensured by vaccum insulation.



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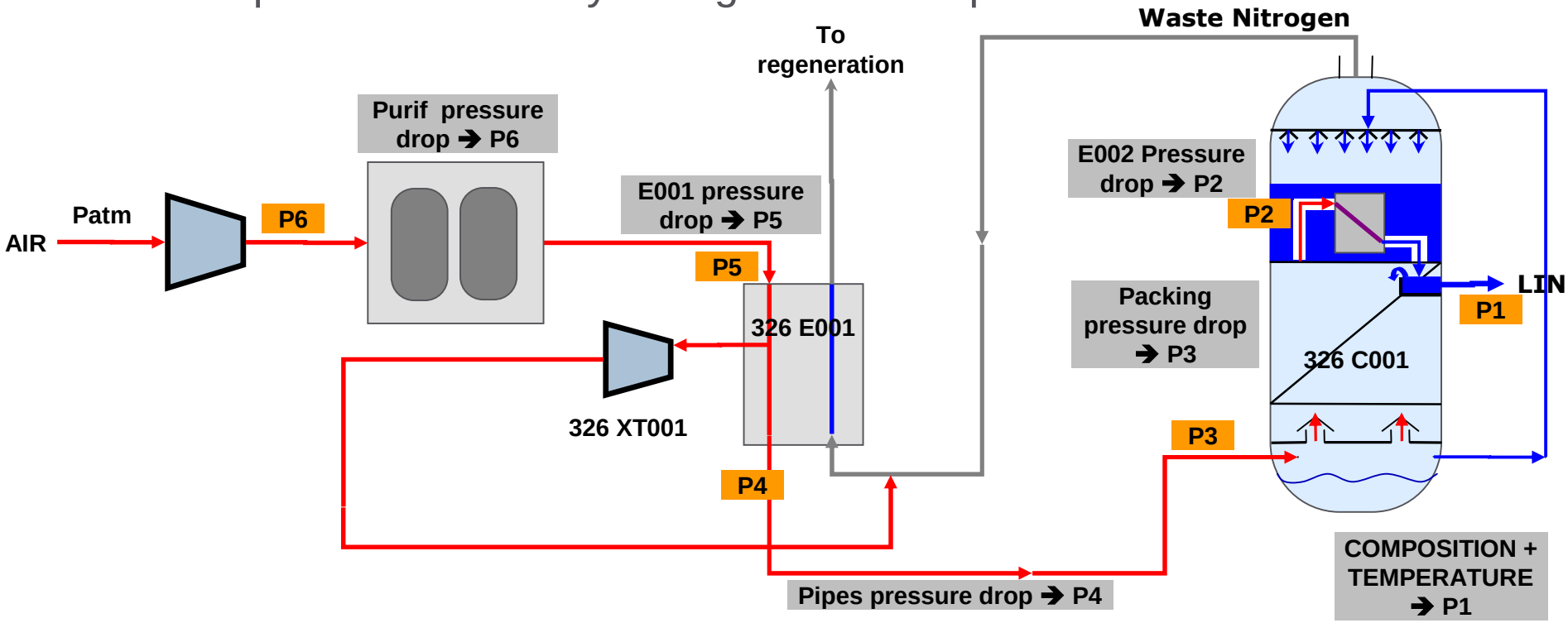
- Introduction
- Process Description
- **Process Control**
- Hazards and Safety

Process control – Compressor 326 K001

COMPRESSOR OUTLET PRESSURE (1/3)

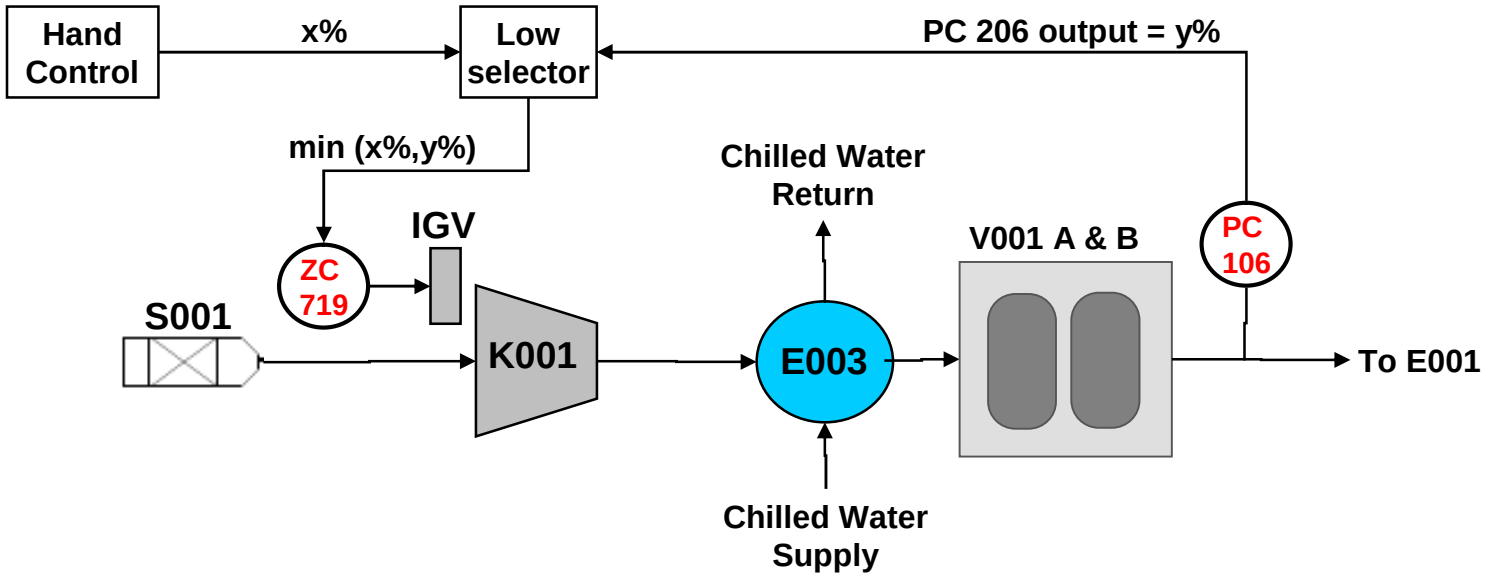
- The production of LIN is totally known:
  - Purity = 99.98% - Quantity = 501 Nm^3/h - T° = -186 °C – P = 2.9 bara
- The compressor outlet pressure is controled by 326 PC 106 at the outlet of the purification unit by acting on the compressor IGV.



Process control – Compressor 326 K001

COMPRESSOR OUTLET PRESSURE (2/3)

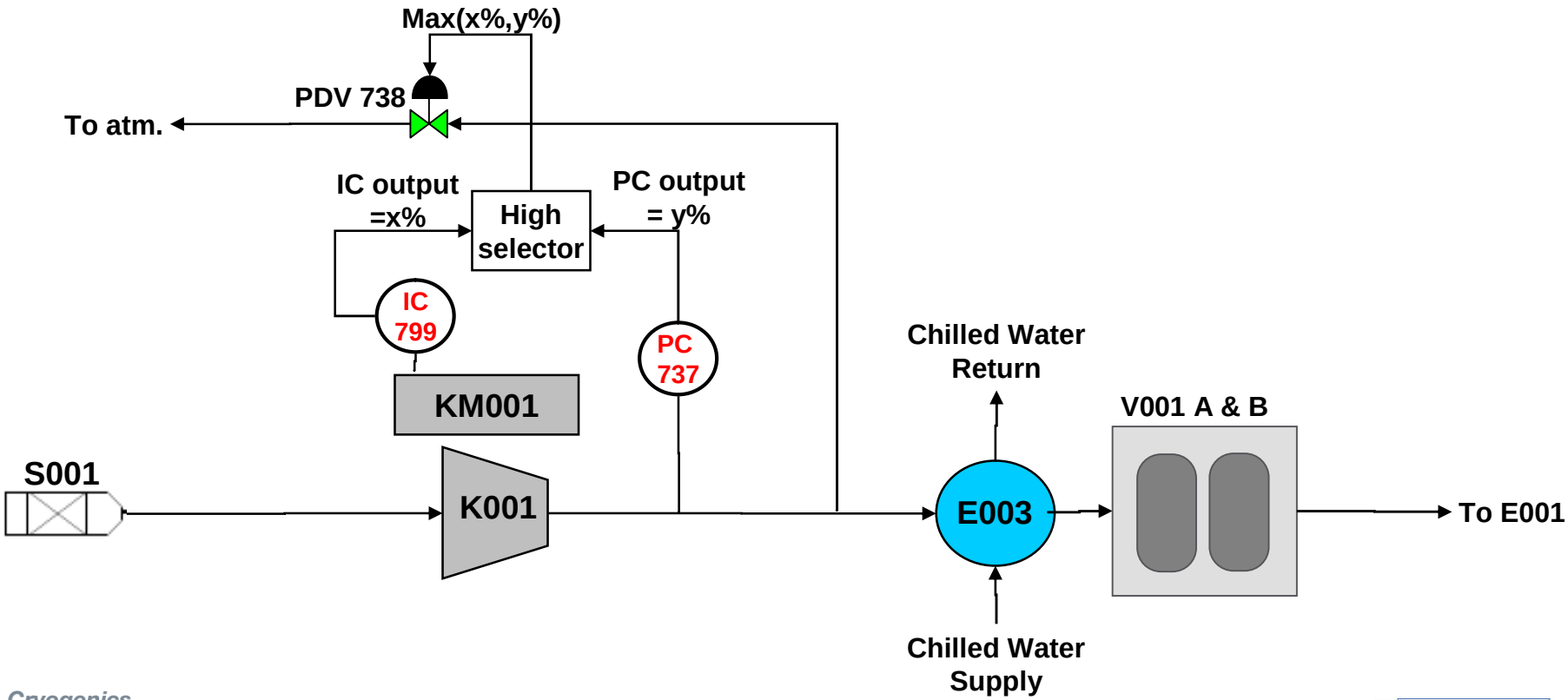
- IGVs' opening is controlled by a pressure controler at the purification outlet (326 PC 106).
  - During start up, operators can take control of the IGV with 326 HIC 719
  - **Note**: as pressure drops are known in pipes, chiller and adsorption, 326 PT 106 is the image of compressor outlet pressure.



Process control – Compressor 326 K001

COMPRESSOR OUTLET PRESSURE (3/3)

- The blow off valve is controlled with a high selector between;
  - Anti-surge control with motor current intensity (326 IC 799)
  - Compressor outlet pressure at compressor outlet: 326 PC 737



Process control

RATE OF DRY AIR SENT TO EXPANDER 326 XT 001

- After purification, the flow is sent to :
  - 326 XT 001
  - 326 C001
- The split is manually controlled:
  - The more flow is sent to the expander, the colder is the exchanger. The flow sent to both equipments is controled in manual: hand controller 326 HIC 201 and 326 HIC 302

LEVEL IN 326 C001

- Bottom level is controlled by 326 LC 202, which commands the opening of 326 LV 202. To adjust 326 C001’s level, this valve sends rich liquid to 326 E002.

Process control

326 E002 PRESSURE

- The pressure in 326 E002 is adjusted by 326 PC 205.
- This controler acts on 326 PV 205 A, and on 326 PV 205 B in case of over pressure.

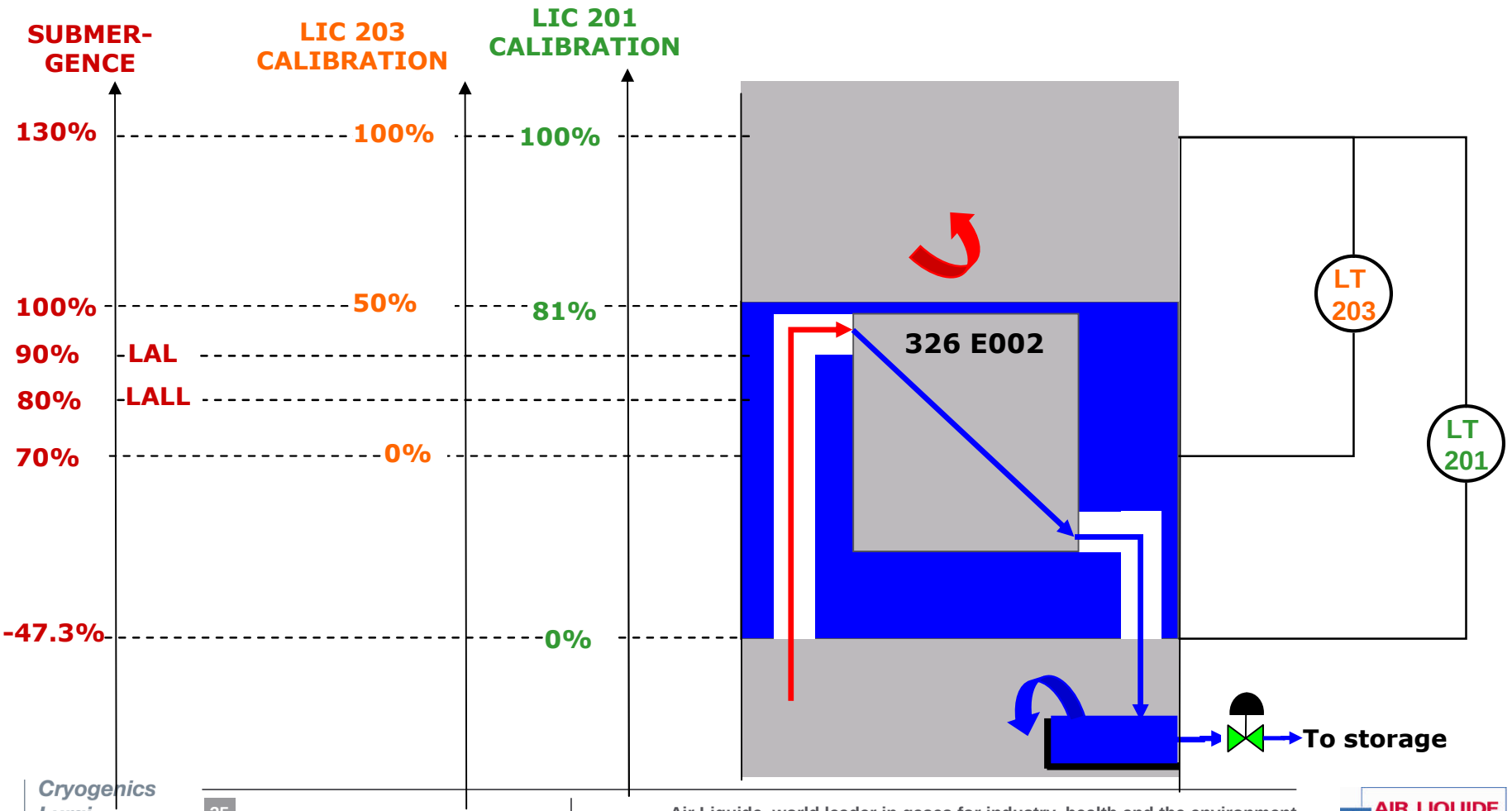
LEVEL IN 326 E002 (1/3)

- Due to safety reasons, the level of submergence of 326 E002 must always be above 100%. A too low level can lead to the explosion of the condenser.
- The rich liquid level is adjusted by 326 LC 201 A, acting on production valve 326-LV201A to the LIN storage.

Process control – Vaporizer

LEVEL IN 326 E002 (2/3)

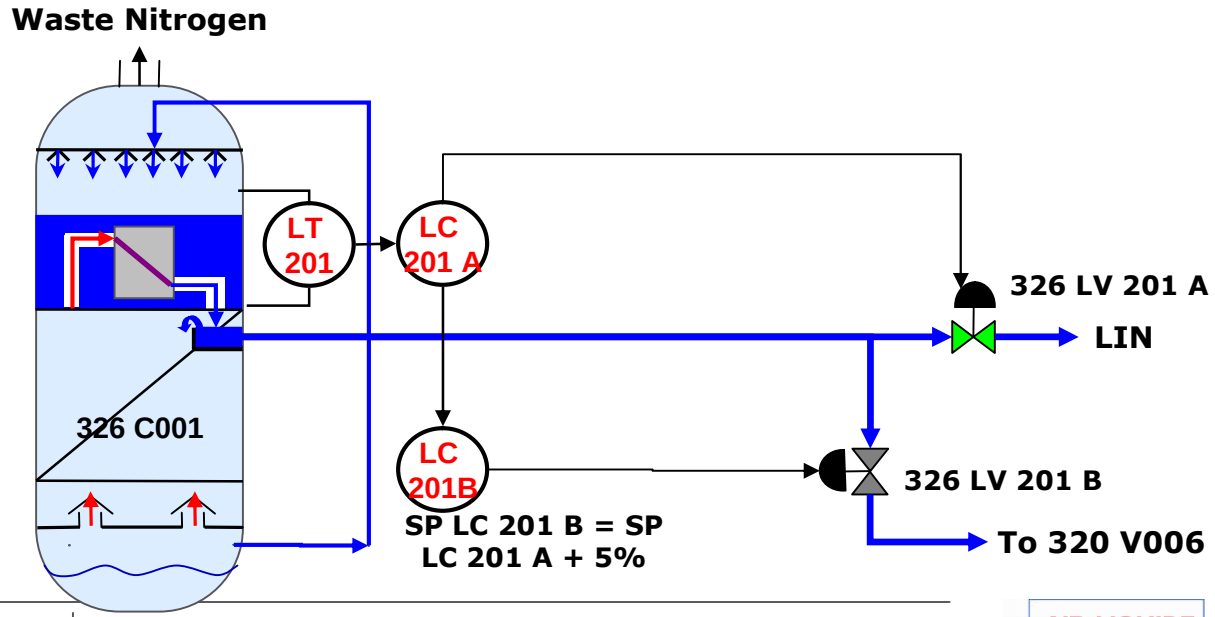
2 level transmitters to calculate the level of submergence



Process control – Vaporizer

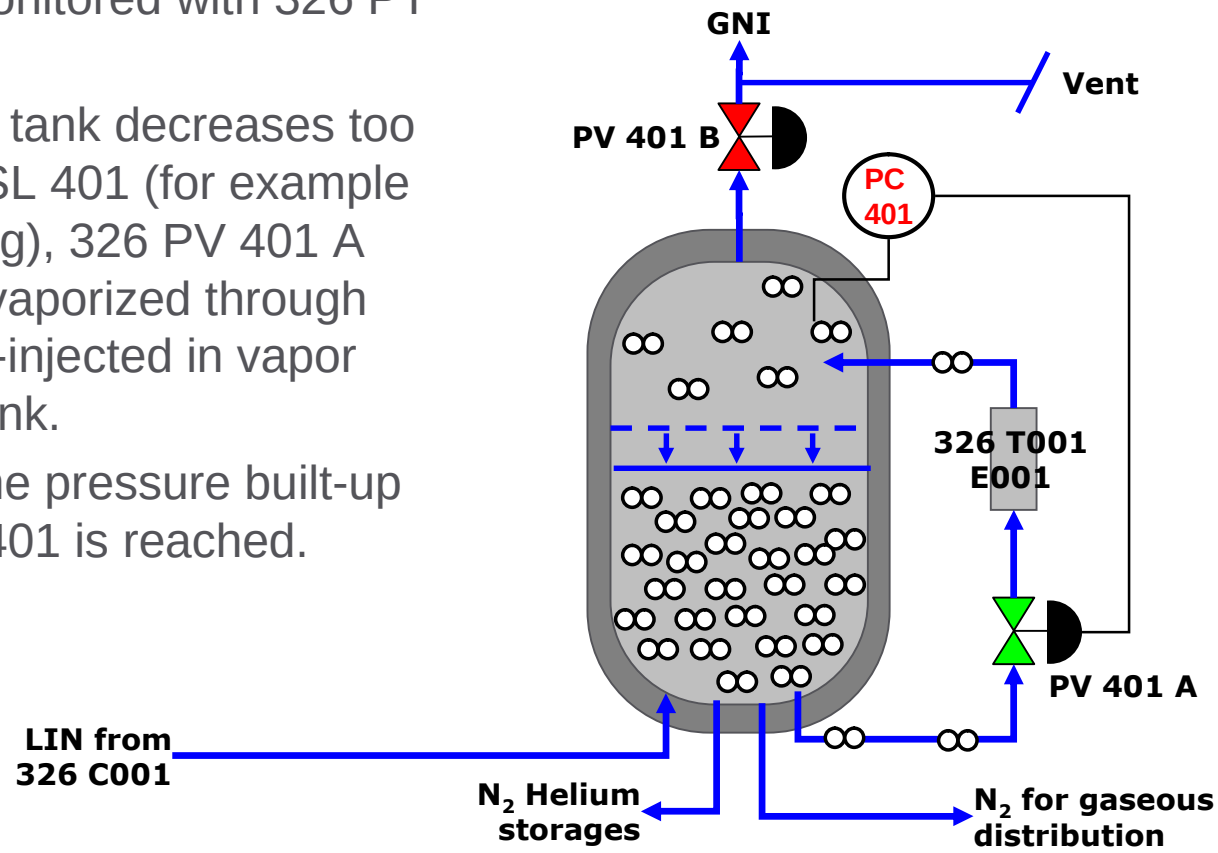
LEVEL IN 326 E002 (3/3)

- Level in E002 commands LIN production:
  - If LT 201 increased above its set point, LC 201 A commands the opening of LV 201 A.
  - LIN production increases ➔ liquid relux in C001 decreases ➔ Rich liquid at the bottom of C001 decreases ➔ LC 202 output decreases ➔ LI 201 decreases.
- As a safety measure, the SP of LC 201 B is set at LC 201 A + 5%.



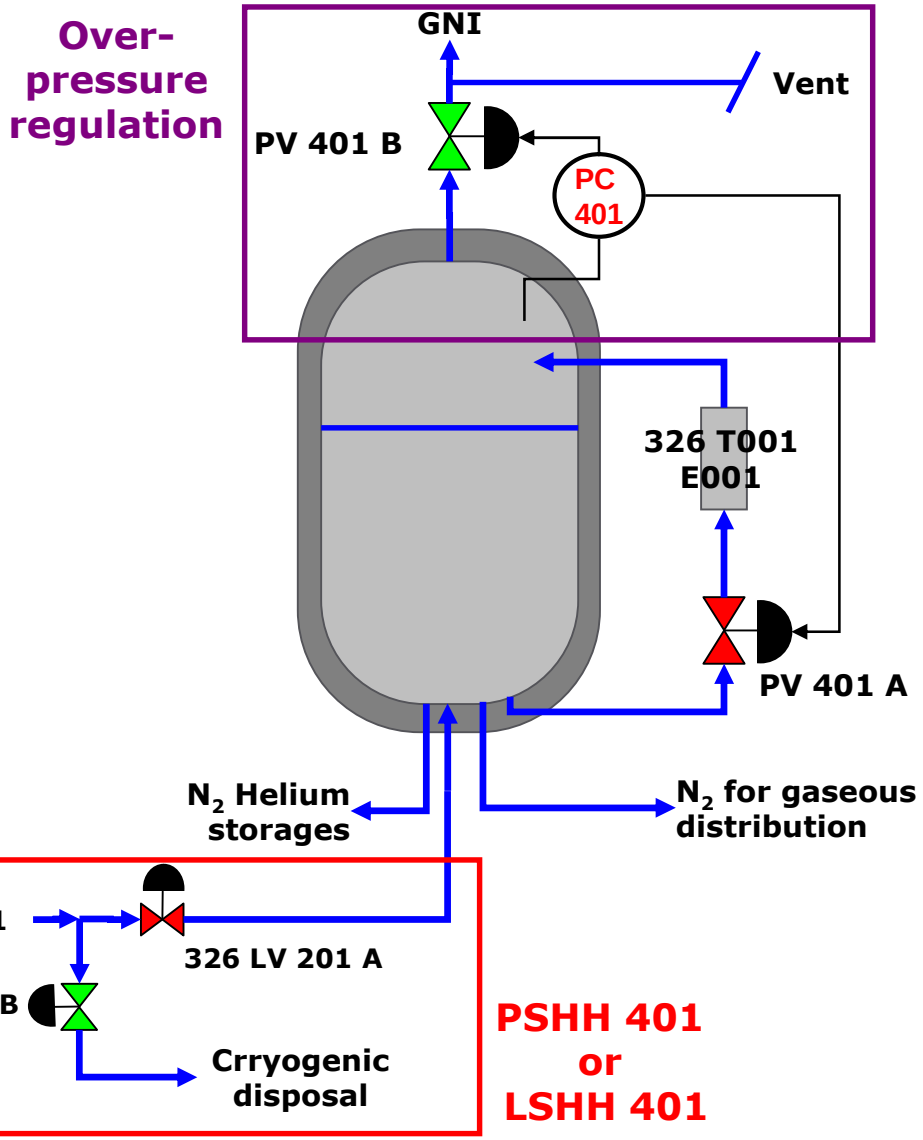
Process control – Storage tank

- The storage tank 326 T001 maintains its pressure (326 PI 401) with:
  - A Pressure Build Up Coil 326 T001 E001 ➔ Underpressure protection
  - A Vent valve 326 PV 401 B ➔ Overpressure protection
- The tank's pressure is monitored with 326 PT 401
- If pressure in the storage tank decreases too much and goes below PSL 401 (for example because of tank unloading), 326 PV 401 A opens, liquid nitrogen is vaporized through 326 T001 E001 and is re-injected in vapor phase at the top of the tank.
- The valve closes when the pressure built-up is high enough i.e. PSH 401 is reached.



Process control – Storage tank

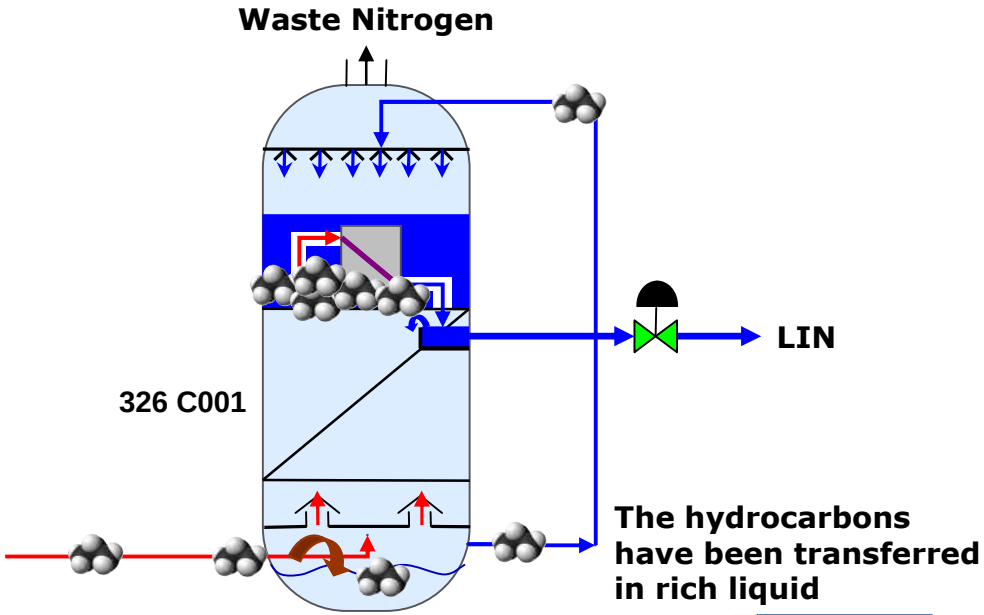
- The pressure in the storage tank is regulated with 326 PC 401: if the pressure increases too much, i.e. above PC 401 set point, the vent valve 326 PV 401 B opens to release the overpressure and regulate the pressure.
- In case of a storage tank overpressure (326 PSHH 401) or very high level in storage tank (326 LSHH 401), Liquid Nitrogen production is routed to cryogenic drain 320 V006 through bypass 326 LV 201 B.



Process control – Deconcentration valve

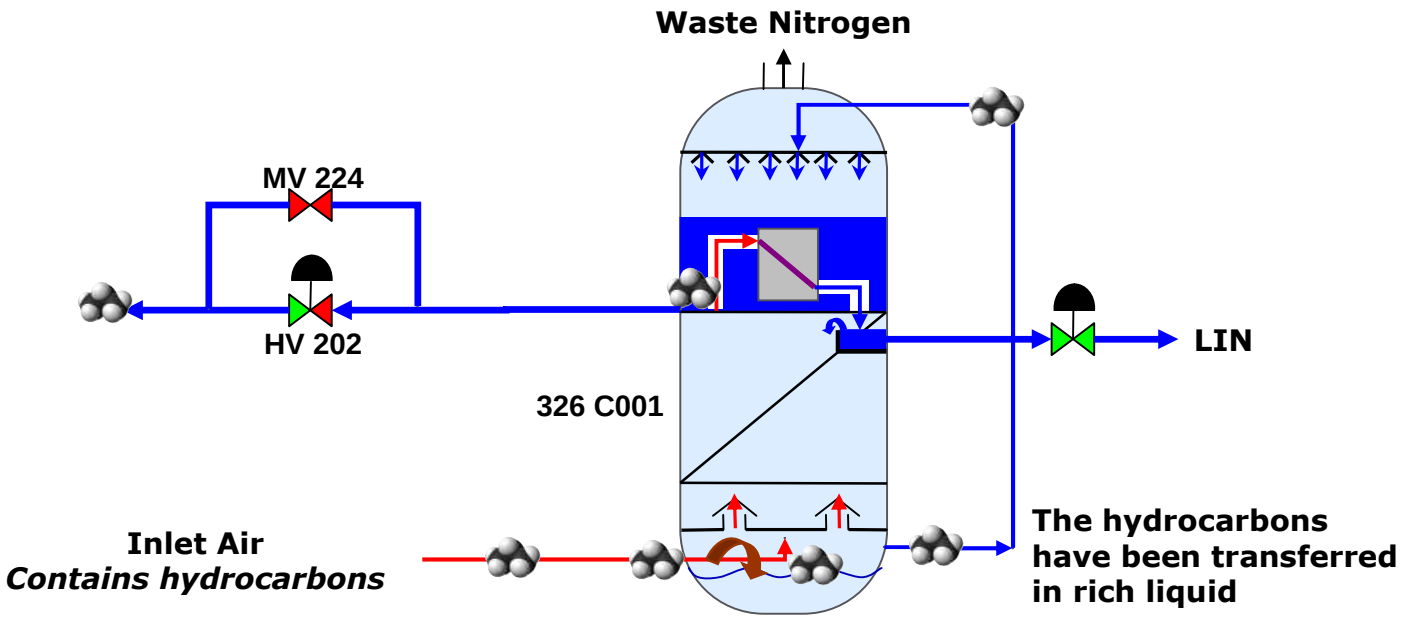
- Inlet Air contains a small amount of hydrocarbons:
- As very low volatile molecules, hydrocarbons remain in liquid state within compressed air and are therefore transferred along with the rich liquid at C001 bottom and then up to E002 bath.
- Unlike O_2, hydrocarbons do not vaporize in E002 ➔ They tend to accumulate in E002 bath, in contact with O_2.

Heavy risk of explosion!



Process control – Deconcentration valve

- To avoid explosion risks, every 5 minutes, HV 202 opens at 50% during 30 seconds. This allows deconcentrating the hydrocarbons
- If a malfunction of 326 HV 202 automatic opening is detected, MV 224 must be opened on site (one turn).



Agenda

- Introduction
- Process Description
- Process Control
- **Hazards and Safety**

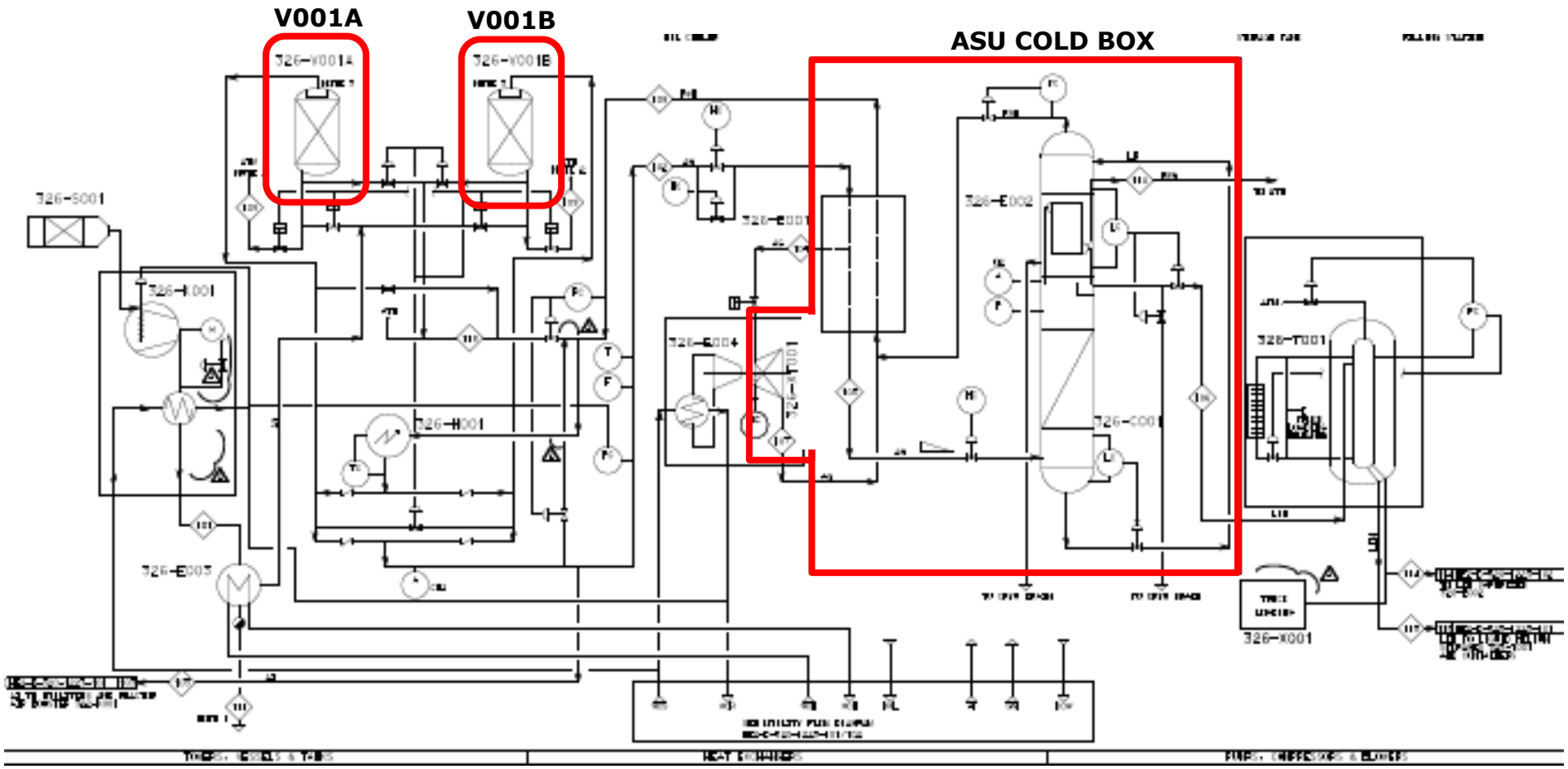
Hazards and safety – General

- Regular EPI are mandatory on site:
  - Coverall
  - Safety boots
  - Helmet
  - Eye protection
  - Ear protection
  - Toxic Clip
  - Gloves.

Hazards and Safety – Main risks

- Perlite
  - Risk of drowning
  - All measures to prevent falls in the Cold Box filled with perlite must be taken, for example, if the top plate of the Cold Box is removed to check the perlite level.
  - If perlite has to be emptied from the ASU Cold Box (for maintenance reasons for example), do not empty from the bottom of the Cold Box.
- Confined spaces:
  - In the ASU, there are several confined spaces:
    - Adsorbers V001 A and V001 B
    - C001 Cold Box
  - The main risk is anoxia
  - Confined spaces' O_2 level must be monitored.

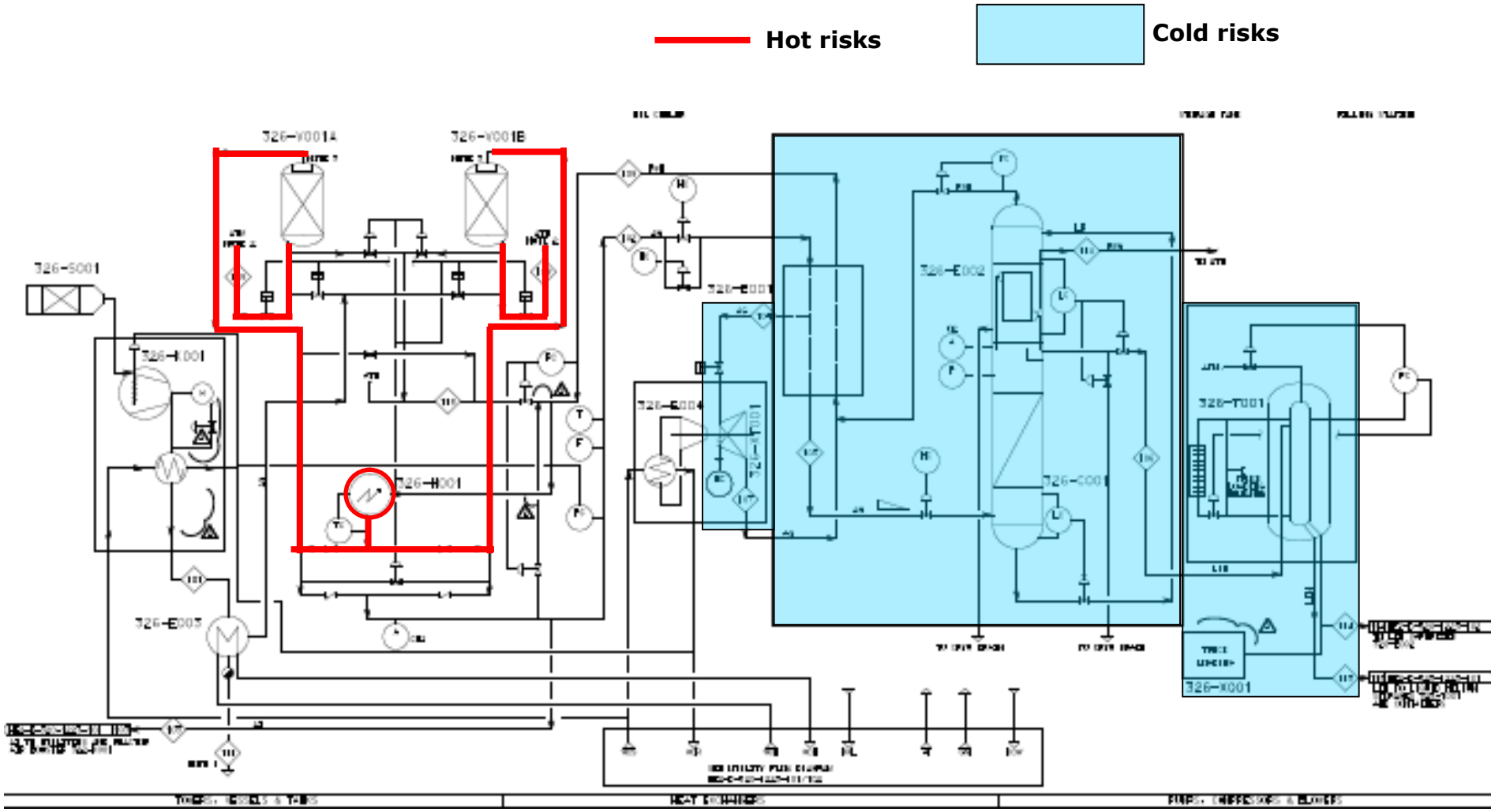
Hazards and Safety – Main risks – Confined Space



Hazards and Safety – Main risks

- Hydrocarbons concentration:
  - The risk is located in 326 E002
  - Hydrocarbons' high concentrations + O_2 rich liquid ➔ Explosion
  - 326 HV 202 must be daily checked
  - If any malfunction is detected, 326 MV 224 must be immediately opened on site (1 turn).
- Cryogenic burns:
  - Leaks on cryogenic pipes can lead to cryogenic burns.
- N_2:
  - Pure or highly-concentrated N_2 can lead to anoxia (< 19.5% O_2)
  - An O_2 analyzer should always be worn on site.
- Heat:
  - In case of leaks on hot pipes, hot burns can occur.

Hazards and Safety – Main risks



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Thank you for your attention
Questions?