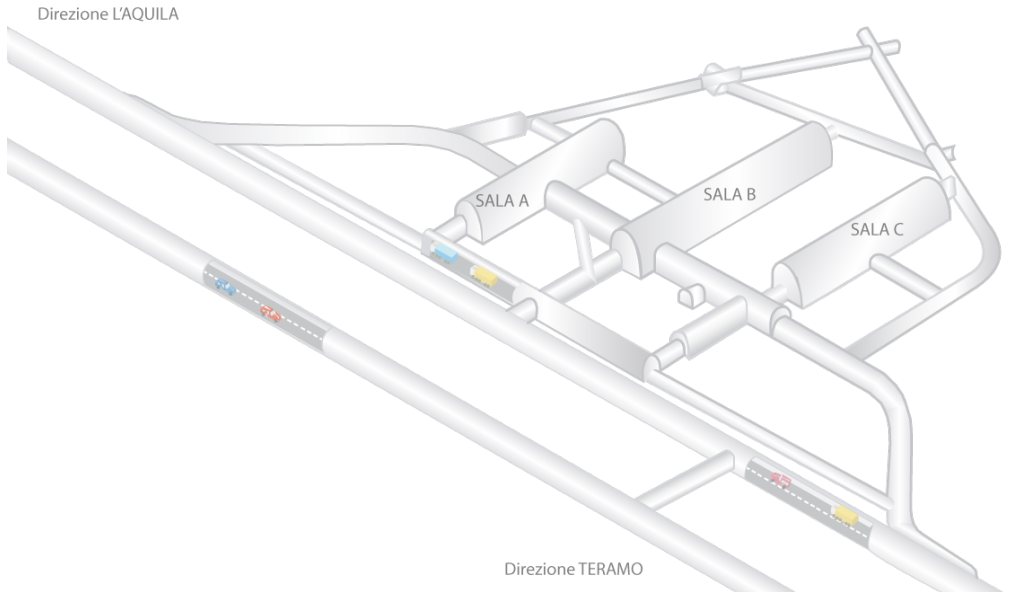
# N2 liquefaction plant for the LNGS underground site

**Paolo Gorla - LNGS**



# Goal of the project

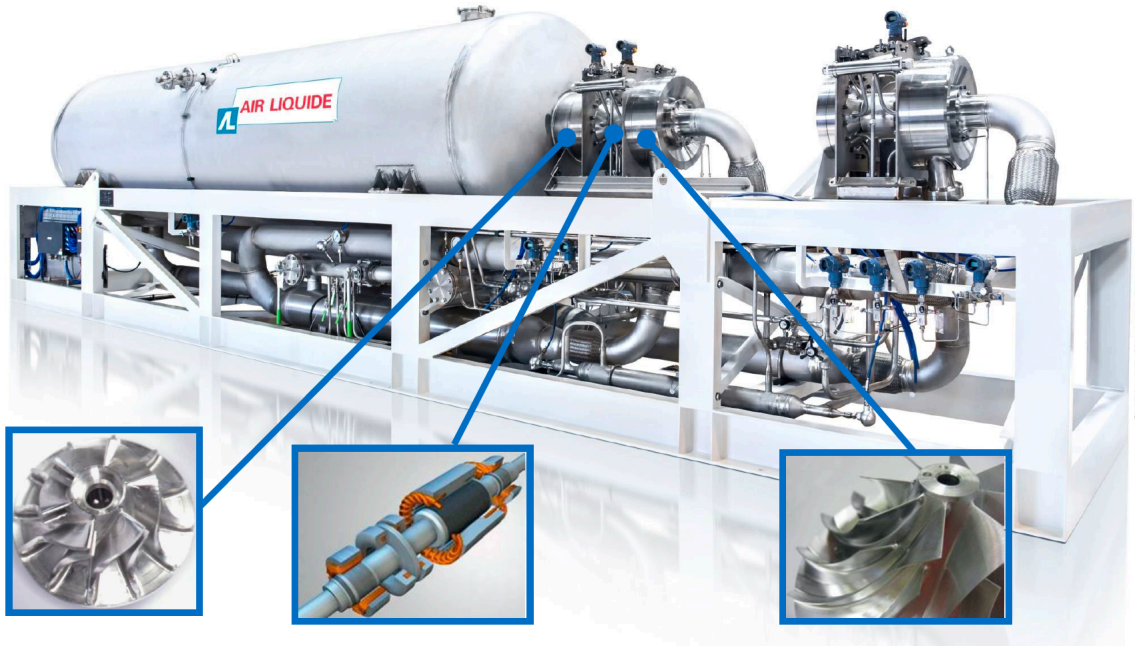
Develop, procure, and install a N2 liquefaction system for the needs of the LNGS underground Lab (operating experiments and facilities, DS20K, future projects…)

# Main features

- Reliable plant (stable over time, minimal maintenance stops, robust system)
- Tunable cooling capacity (to handle the variations over time in the underground lab)
- Minimize the environmental impact (minimise road transport)
- Minimize the truck induced disturb on the Lab activity

# Chosen technical solution: Turbo Bryton

- High efficiency, reliability and lifetime (developed for natural gas reliquefaction on boats).
- 100% Oil-free (magnetic bearings)
- Flexibility and modularity: stand-by mode with a low rotation speed and immediately subcool LN2 at order, tunable cooling power.



# Technical solution

- The TBF system cools down a closed circuit gas mixture
- N2 is cooled and liquefied trough heat exchange
- The inlet into the heat exchanger is designed for the specific application

# Requests

- LNGS users: **~16 kW @ 68 K.** LN2 is taken at 77K and lost to air.
- DS20k: Preliminary requested cooling power:
    - **11 kW @ 85.5K** (normal operation)
    - **18 kW @ 85.5K** (initial cooldown)

Closed N2 line, ~all N2 is recollected and reliquefied.

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- **17 kW + UAr @85.5K?**
- **38-56 kW @85.5K?**

**(at TBF system)**

Closed N2 line, ~all N2 is recollected and reliquefied.

# Selected system

| System name | Electrical consumption | Cooling power @68K | Water cooling | Re-liquefaction capability | Size (LxWxH) (m) | Mass | Cost |
|---|---|---|---|---|---|---|---|
| **TBF-175** | 200 kW | 17 kW | 9.3 Kg/s | ~0.2 t/h<br>~174 smc/h | 9.5 x 1.7 x 2.65 | 15 t | 2.7 M€ |
| **TBF-350** | 410 kW | 40 kW | 18.6 Kg/s | ~0.45 t/h<br>~394 smc/h | 11 x 1.7 x 2.65 | 17 t | 3 M€ |

- Very compact footprint
- Maintenance: 3-4 days each 5 years
- Delivery time: 14 months from the tender assignment
- Power: 20 kW for LNGS users, 20 kW for DS20k

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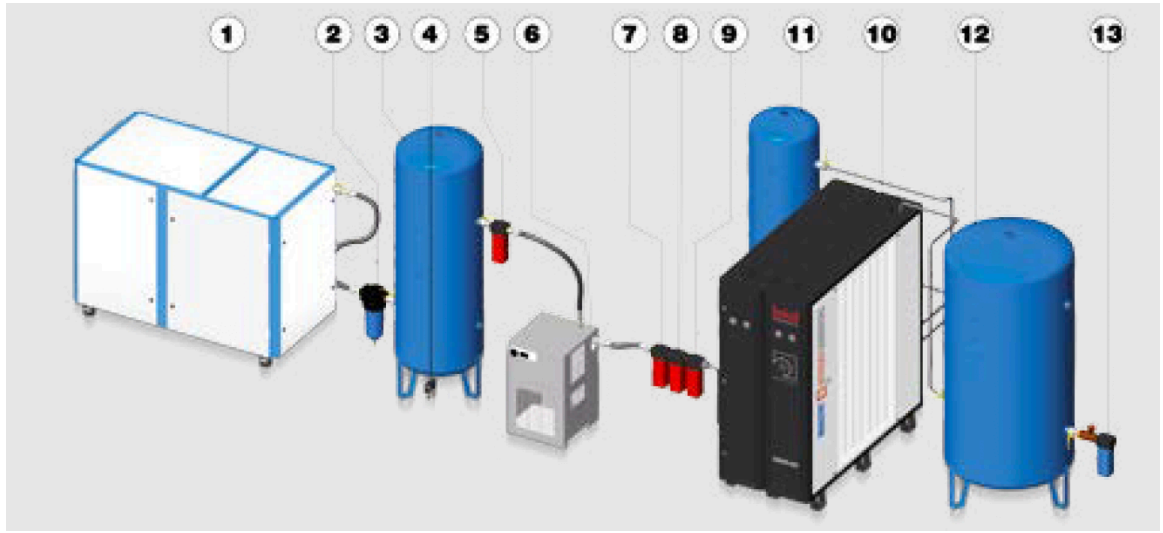
**TBF-350 is the most suitable plant**

# N2 generation

## Pressure Swing Adsorber

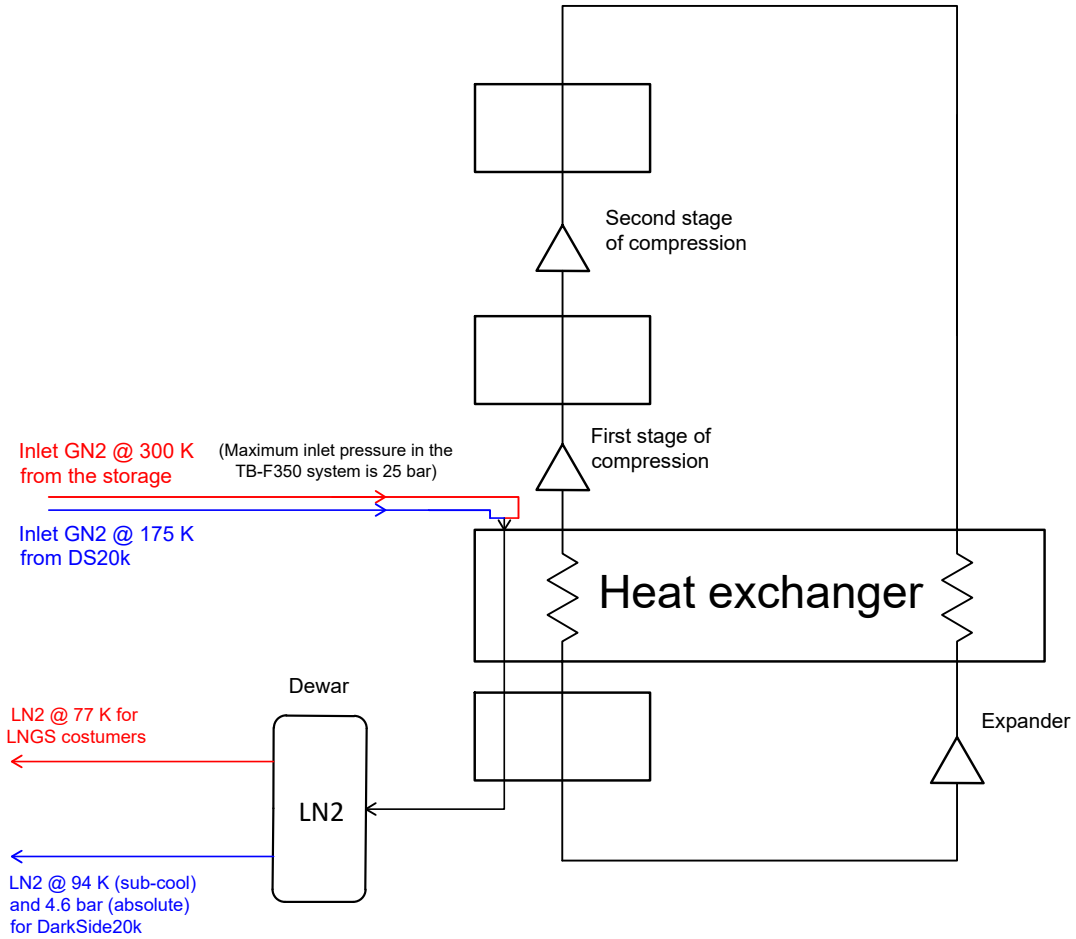
- Needed to compensate for losses due to LNGS LN2 general usage and topping up on the DS20k circuit
- Based on Pressure Swing Adsorption process
- No cryogenics needed
- Purity up to > 99.999% nitrogen (5.0)
- Modularity (multiple modules)



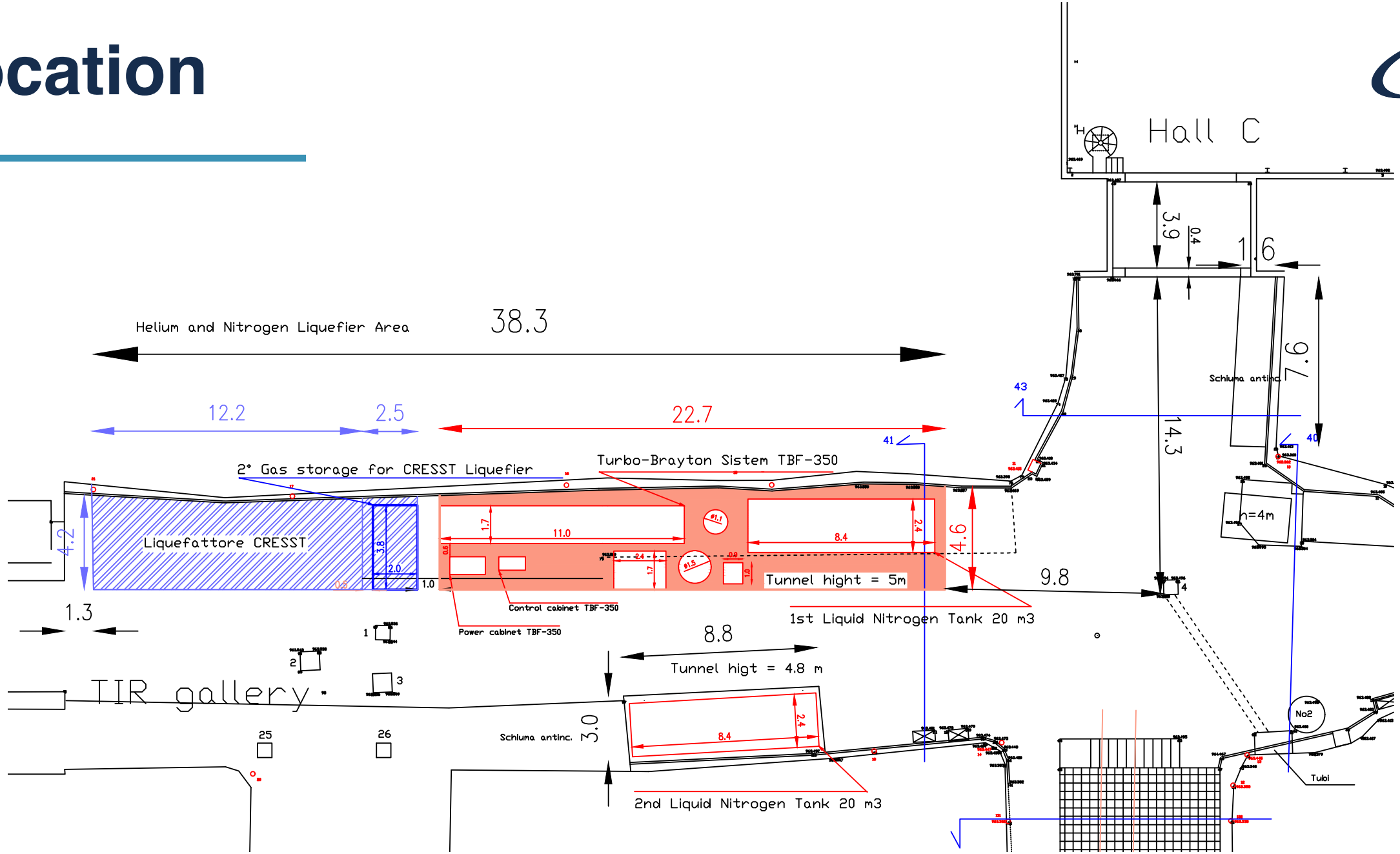

1 Compressore
2 Separatore ciclone
3 Serbatoio aria compressa
4 Scaricatore elettronico
5 Filtro universale
6 Essiccatore
7 Filtro fine
8 Micro filtro
9 Filtro a carboni attivi
10 Generatore d'azoto
11 Serbatoio di processo
12 Serbatoio di accumulo azoto
13 Filtro polvere

# Plant layout

## Turbo-Brayton F-350 system Operating Scheme

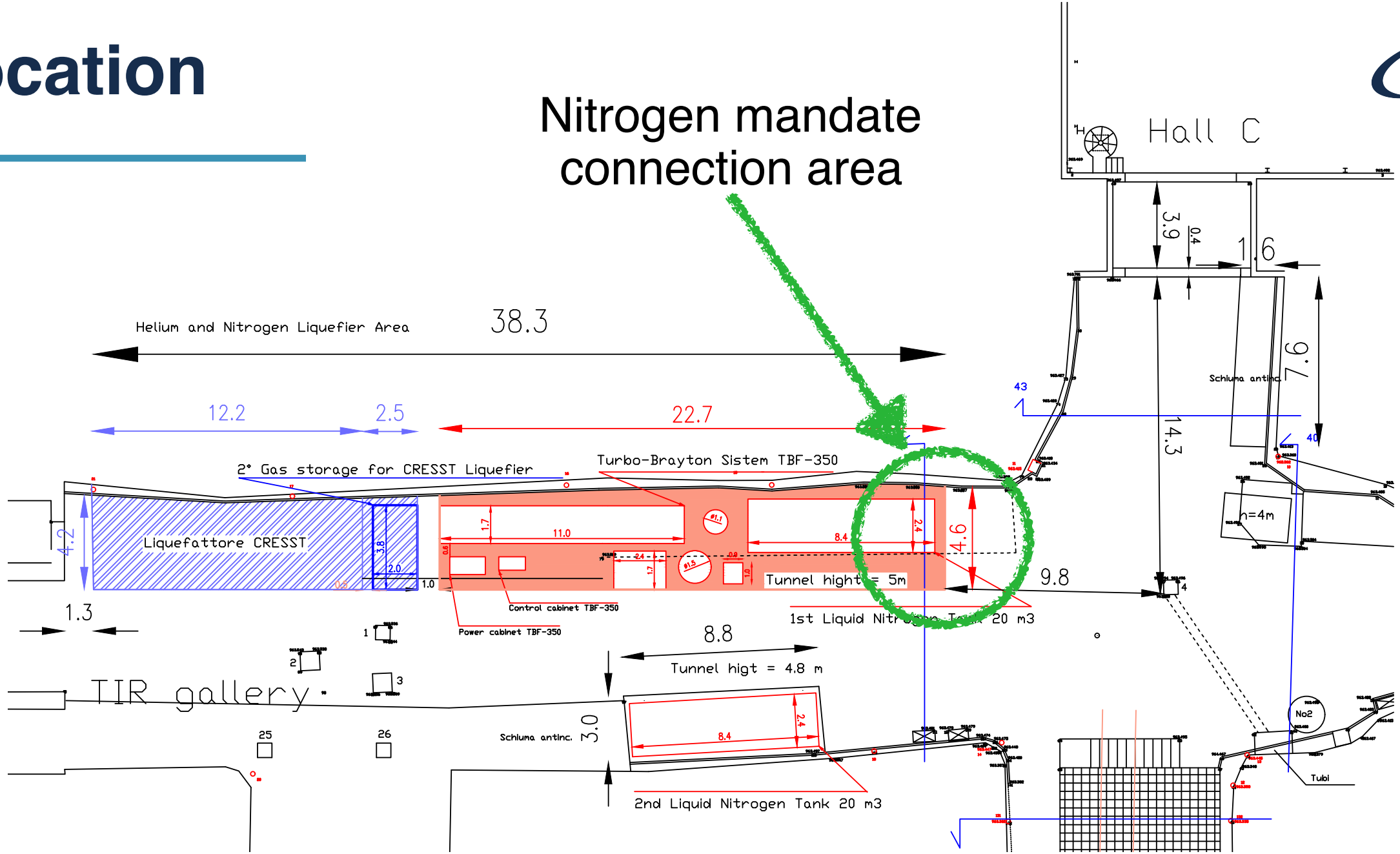


# Location


Hall C
Helium and Nitrogen Liquefier Area
38.3
12.2
2.5
22.7
2° Gas storage for CRESST Liquefier
Turbo-Brayton Sistem TBF-350
Liquefattore CRESST
Tunnel hight = 5m
Control cabinet TBF-350
Power cabinet TBF-350
1st Liquid Nitrogen Tank 20 m3
Tunnel higt = 4.8 m
TIR gallery
Schiuma antinc.
2nd Liquid Nitrogen Tank 20 m3
Schiuma antinc.
h=4m
No2
Tubi
3.9
0.4
1.6
9.7
14.3
9.8
4.2
1.3
8.8
3.0

# Location

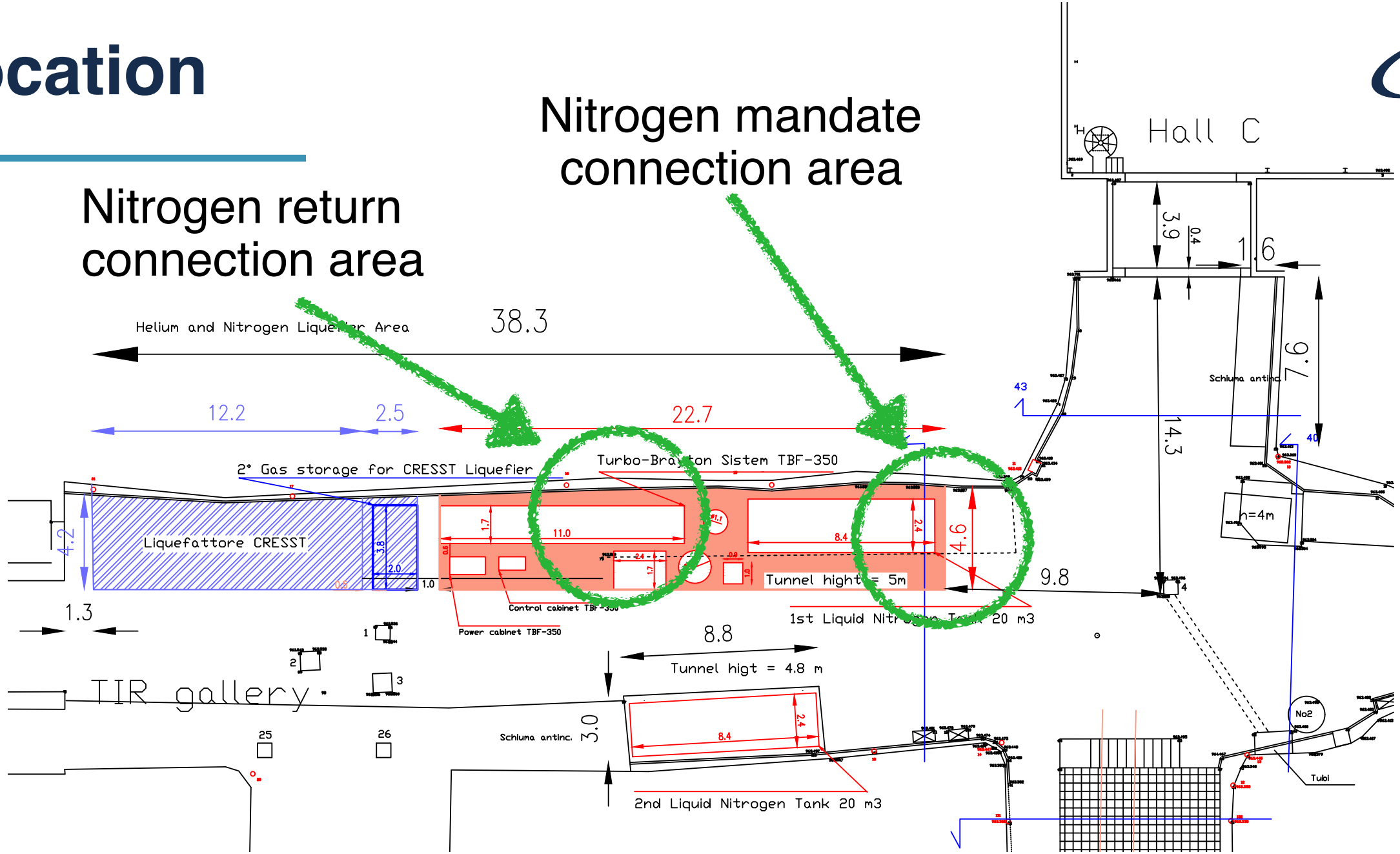
Nitrogen mandate connection area



# Location

Nitrogen mandate connection area

Nitrogen return connection area



# Status of N2 liquefier project

- Budget allocated for the TBF 350 system.
- Tender postponed to (first quarter of) 2023, final numbers from DS20k must be defined to design the heat exchanger.
- Preliminary circuit layout prepared. In 2023 tenders for final design. ~14 months for delivery.
- System at LNGS in 2024.
- Selection of the N2 separation and purification system. Tender will start as budget will be available.

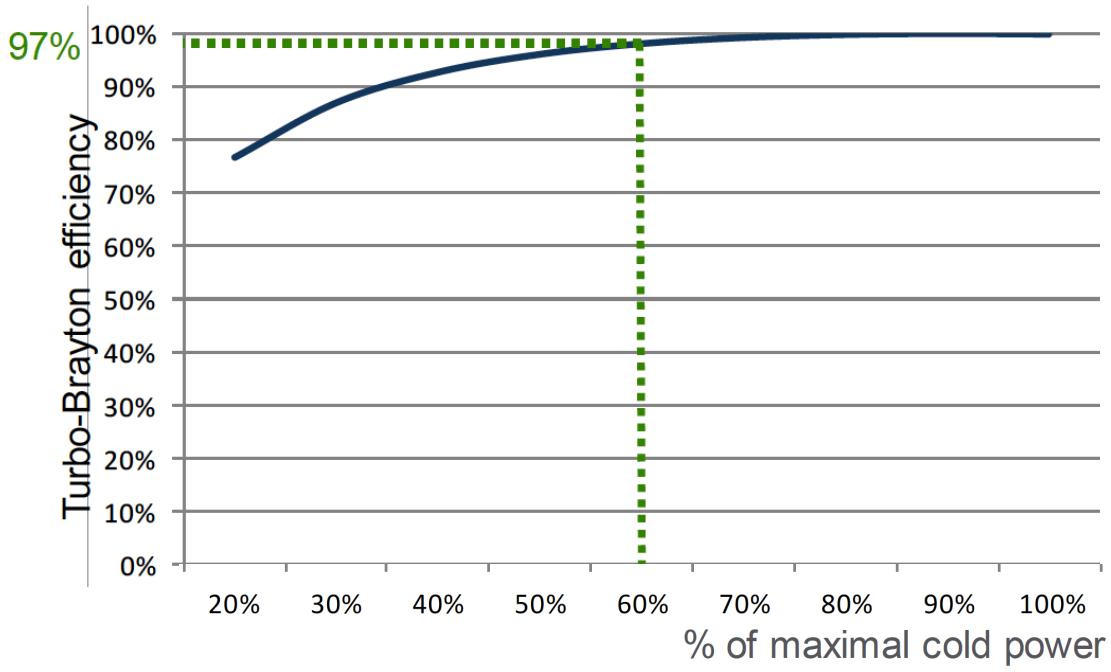
# Open issues

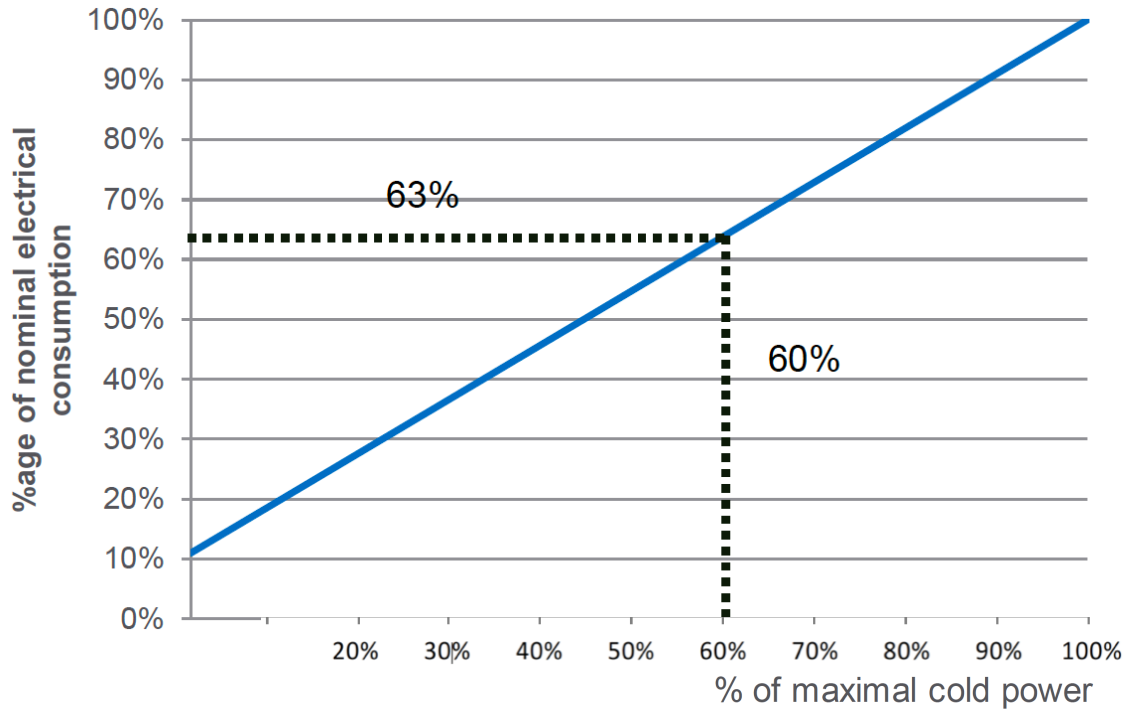
| Name | PBS number | DN | interface point | at the dewar location | | | at the mechanical interfaces | | | at the cold end return interface TB | | | modes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | P | dm/dt | T | P | dm/dt | T | P | dm/dt | T | |
| | | | | Bara | g/s | K | Bara | g/s | K | Bara | g/s | K | |
| AAr Liquid nitrogen supply | NP.DS.10.N1 | TBD | 1 | 4.6 | 10-85 | sub-cool | 4.0 | 10-85 | sat | n.a | n.a | n.a | cool-down |
| | | | | 4.6 | 60 | sub-cool | 4.0 | 60 | sat | n.a | n.a | n.a | NO |
| UAr Liquid nitrogen supply | | TBD | n.a | n.a | 50 | sub-cool | 4.0 | 50 | sat | n.a | n.a | n.a | cool-down |
| | | | | | 8 | sub-cool | 4.0 | 8 | sat | n.a | n.a | n.a | NO |
| ∑ AAr +UAr | NP.DS.10.N1 | TBD | 1 | 4.6 | 135 | sub-cool | 4.0 | 135 | sat | n.a | n.a | n.a | cool-down |
| | | | | 4.6 | 68 | sub-cool | 4.0 | 68 | sat | n.a | n.a | n.a | NO |
| AAr Gas nitrogen return | NP.DS.10.N4 | TBD | 2 | n.a | n.a | n.a | 2.2 | 10-85 | 300-175 | 1.5 | 10-85 | 300-175 | cool-down |
| | | | | n.a | n.a | n.a | 2.2 | 60 | 175 | 1.5 | 60 | 175 | NO |

- Table still incomplete
- Relevant number for the system load is the interface at TBF
- >19 kW at TBF too high for the system

# Backup

# Turbo-Bryton (TBF) systems from Air Liquide




- High efficiency also at partial load (at 60 % partial load, the overall efficiency is only decreased by 3 %)
- The cold power is automatically adjusted from 0 to 100 % by varying the speed of the motor. No valves nor heater are needed.
- Standby mode consume only 5-10% electrical power (depending on the product)

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