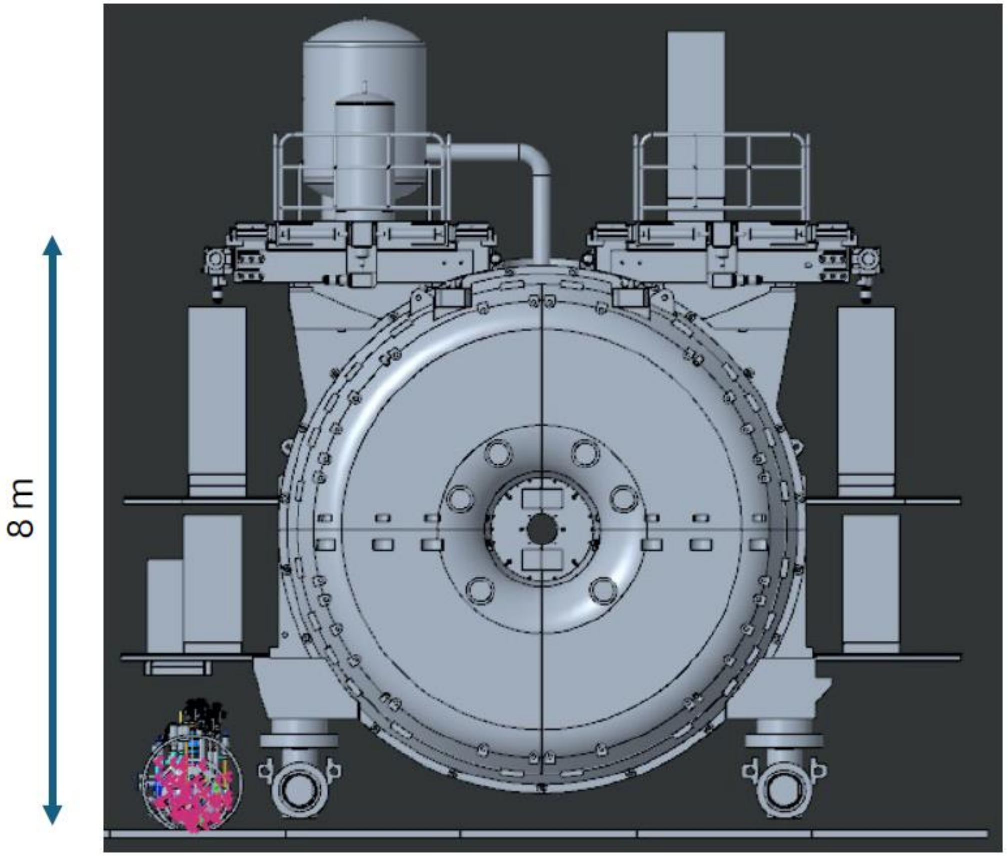
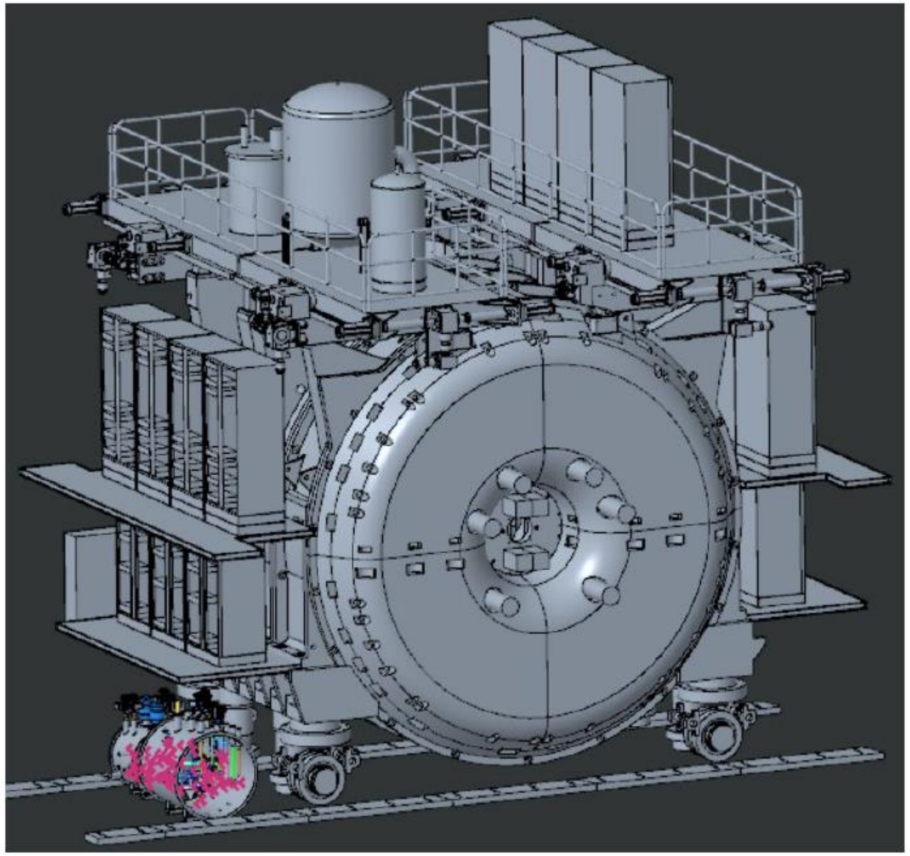
CRYOGENICS FOR GRAIN

CSN1 Review of SAND
July 11th-12th 2024

R.Pengo, G.Piazza & the cryogenic service of LNL

FNAL final destination layout





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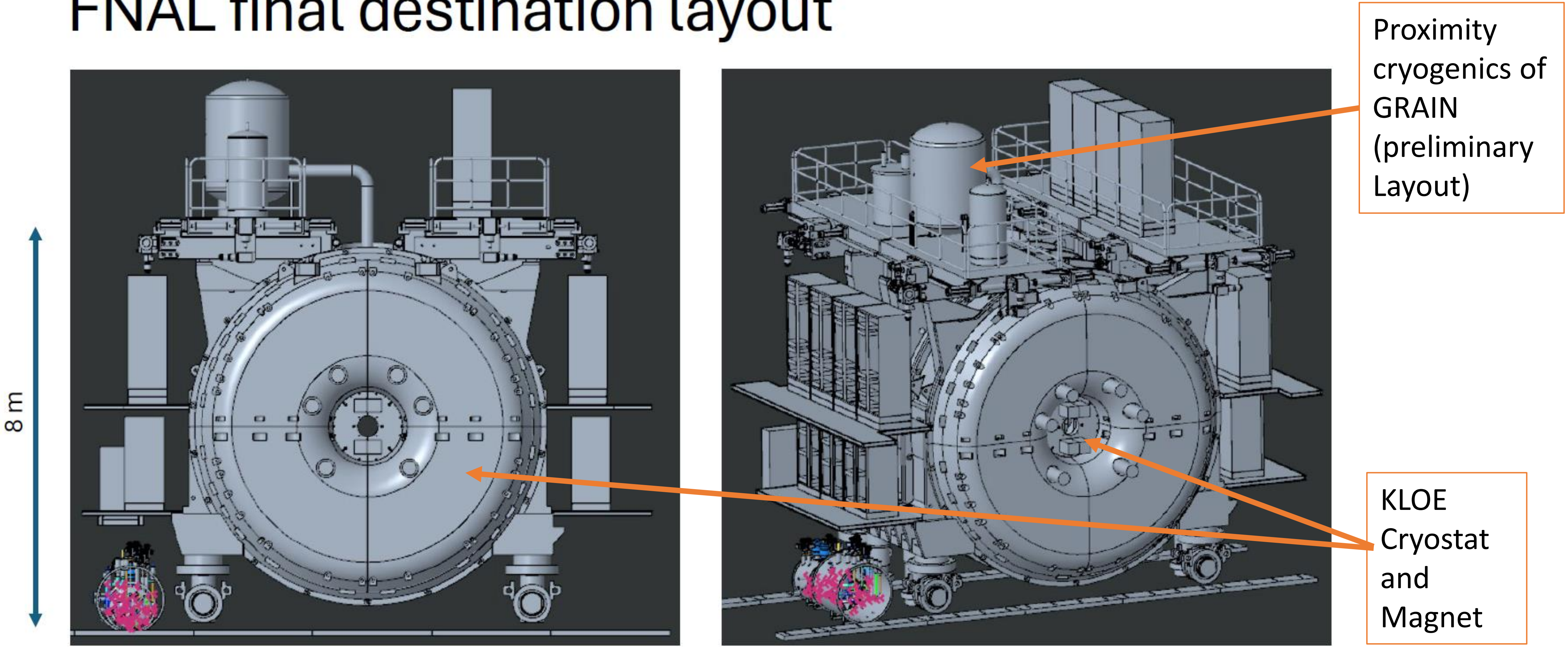


FORWARD

It has been agreed with INFN-LNL to construct a <u>dedicated test facility</u> for the experiment, prior to the installation at FNAL:

- To <u>test the final cryogenic system</u> (with a SS vacuum tank for the cryostat)
- To <u>test the detectors in the final configuration</u>

The site of LNL (Laboratori Nazionali di Legnaro) has been selected since <u>a minor refurbishing</u> for the scope is needed, taking advantage of the existing cryogenic laboratory formerly used for the test of the 22 cryostats of the local superconducting accelerator, since long in operation there.

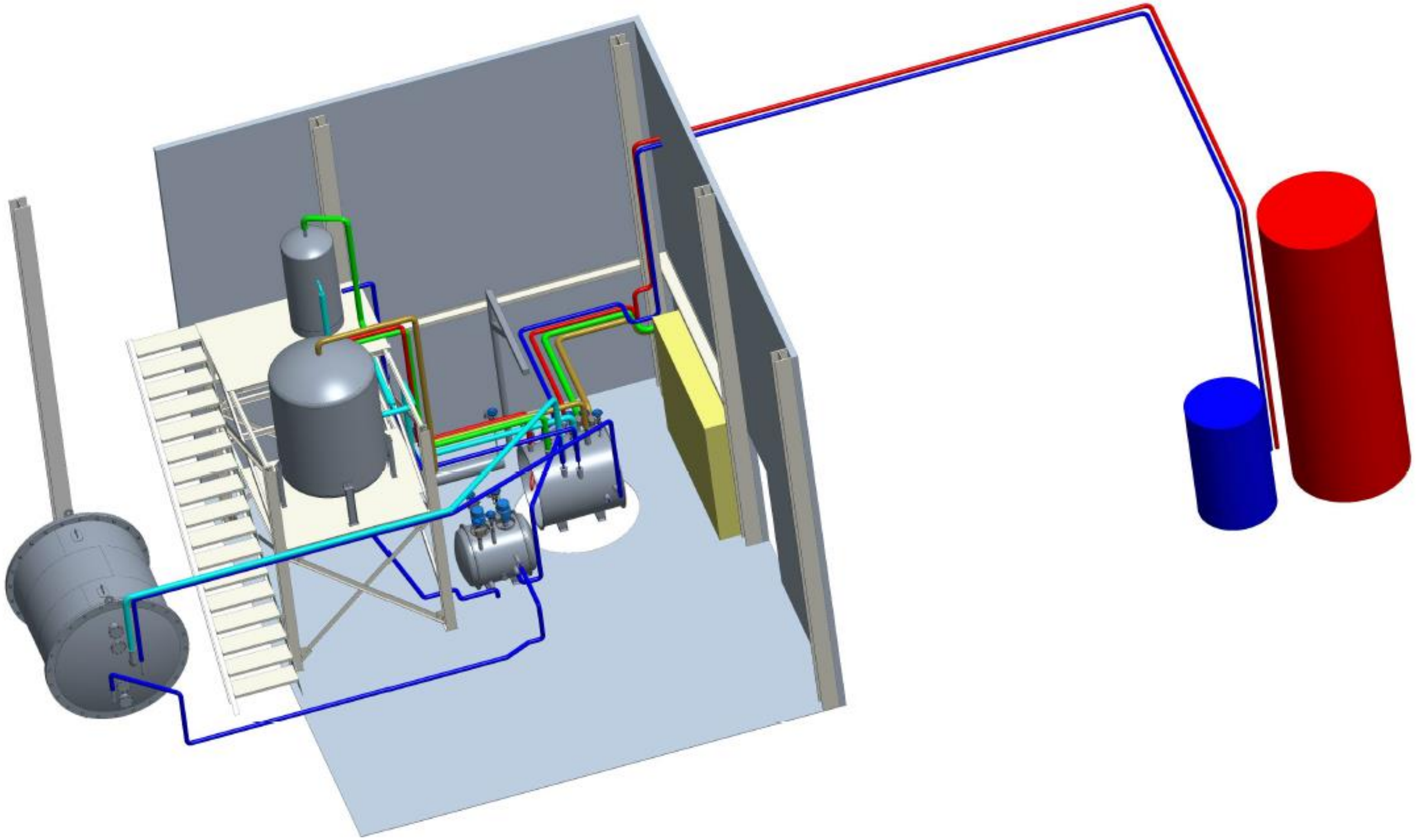
The design of the test facility will follow the requirement that <u>the maximum of the components will be installed at FNAL with the minimum adaptation</u>, in order to achieve:

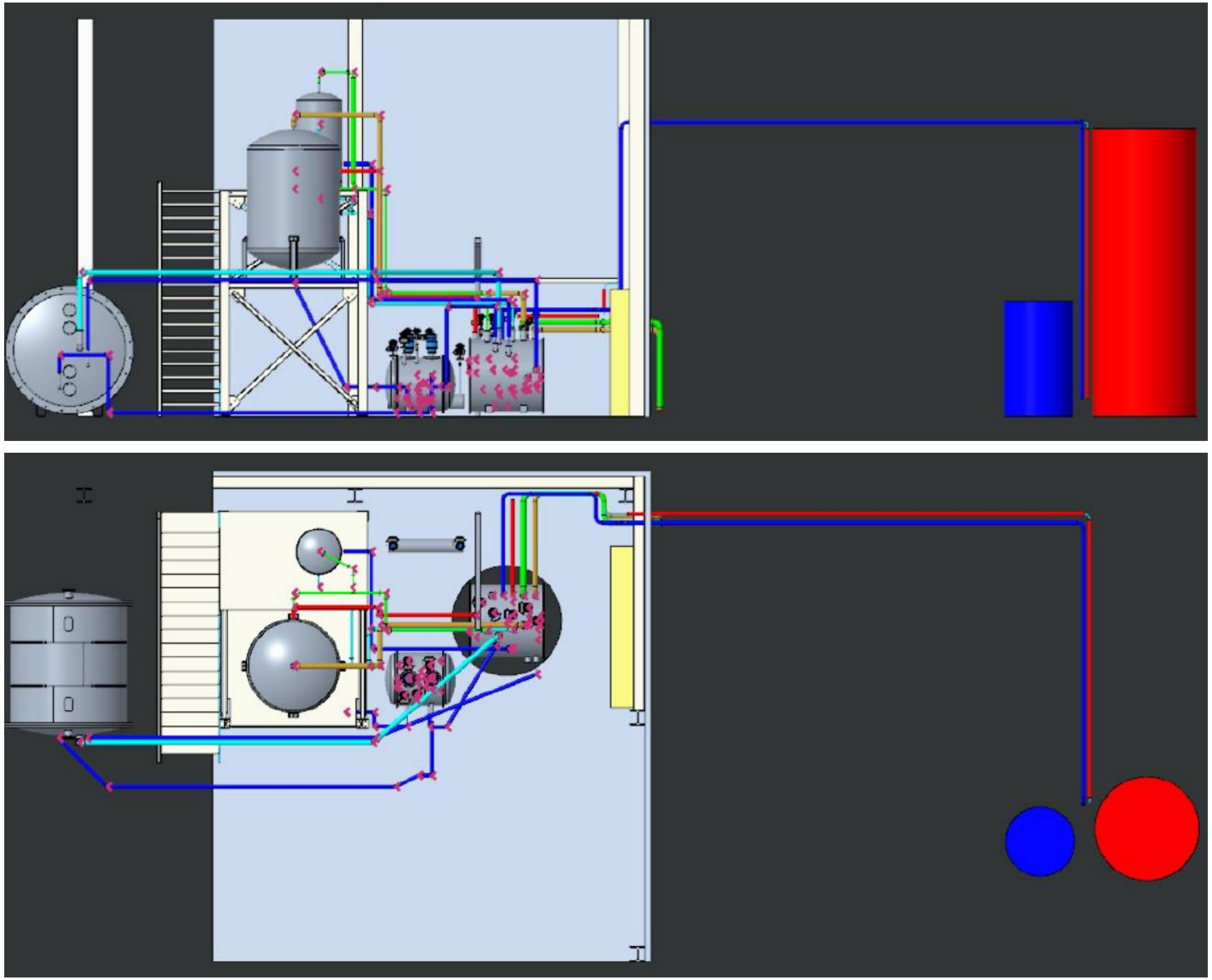
- highest reliability of the operation at FNAL
- saving costs

Refurbishment of LNL lab

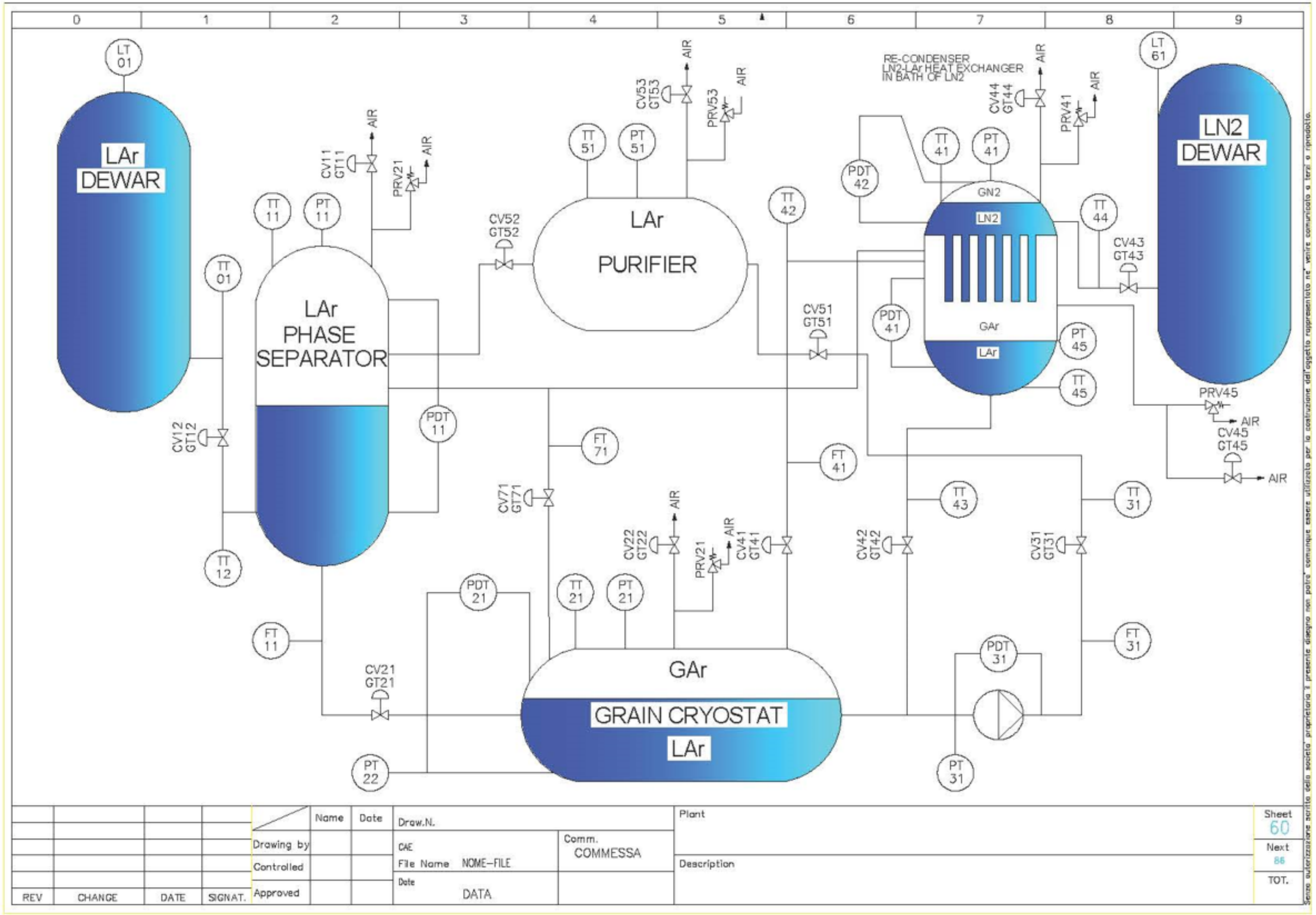
- Existing LN2 tank outside
- Four new transfer lines (vacuum insulated) are being installed:
  - IN/OUT for LN2/GN2
  - IN/OUT for LAr/GAr

LNL preliminary layout





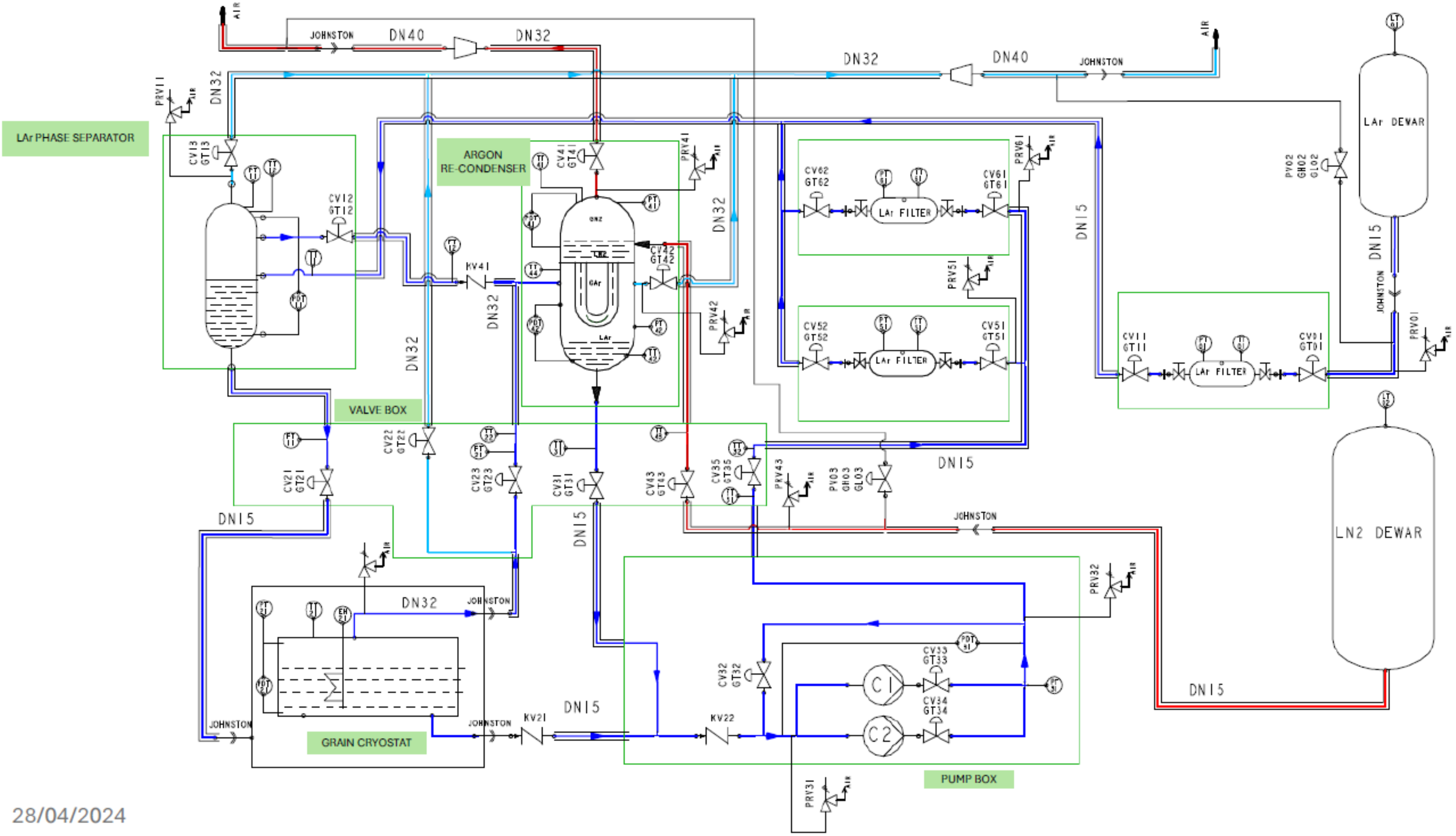
- All final (FNAL) cryogenic transfer lines are vacuum insulated and welded
- The four fixed cryogenic transfer lines at LNL have Johnston removable connections.
- The height of the PS, which determine the sub-cooling temperature margin, will be 3.5 m at LNL and 8 m at FNAL



SIMPLIFIED P&ID

TT: Temperature Transmitter
PT: Pressure Transmitter
PDT: Differential Pressure Transmitter
FT: Mass Flow Transmitter
CV: Control Vave
PV: Valve ON/OFF
PRV: Pressure Relief Valve

GRAIN Piping & Instrumentation Diagram



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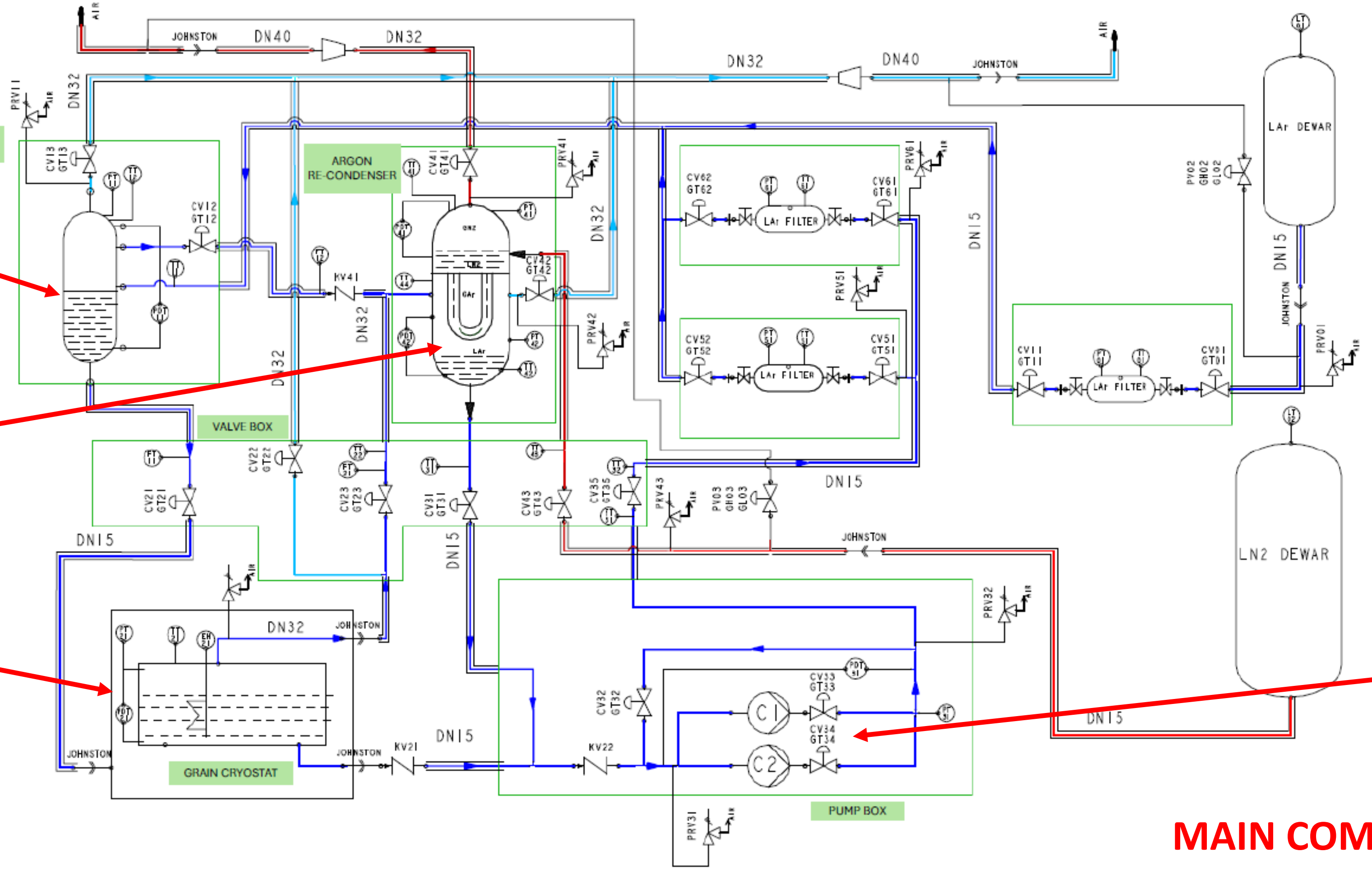
GRAIN Piping & Instrumentation Diagram



Phase Separator (PS)

GAr Re-liquefier

GRAIN Cryostat

Online LAr Purifiers/Filters

Filling LAr Purifiers/Filters

Centrifugal LAr pumps

MAIN COMPONENTS

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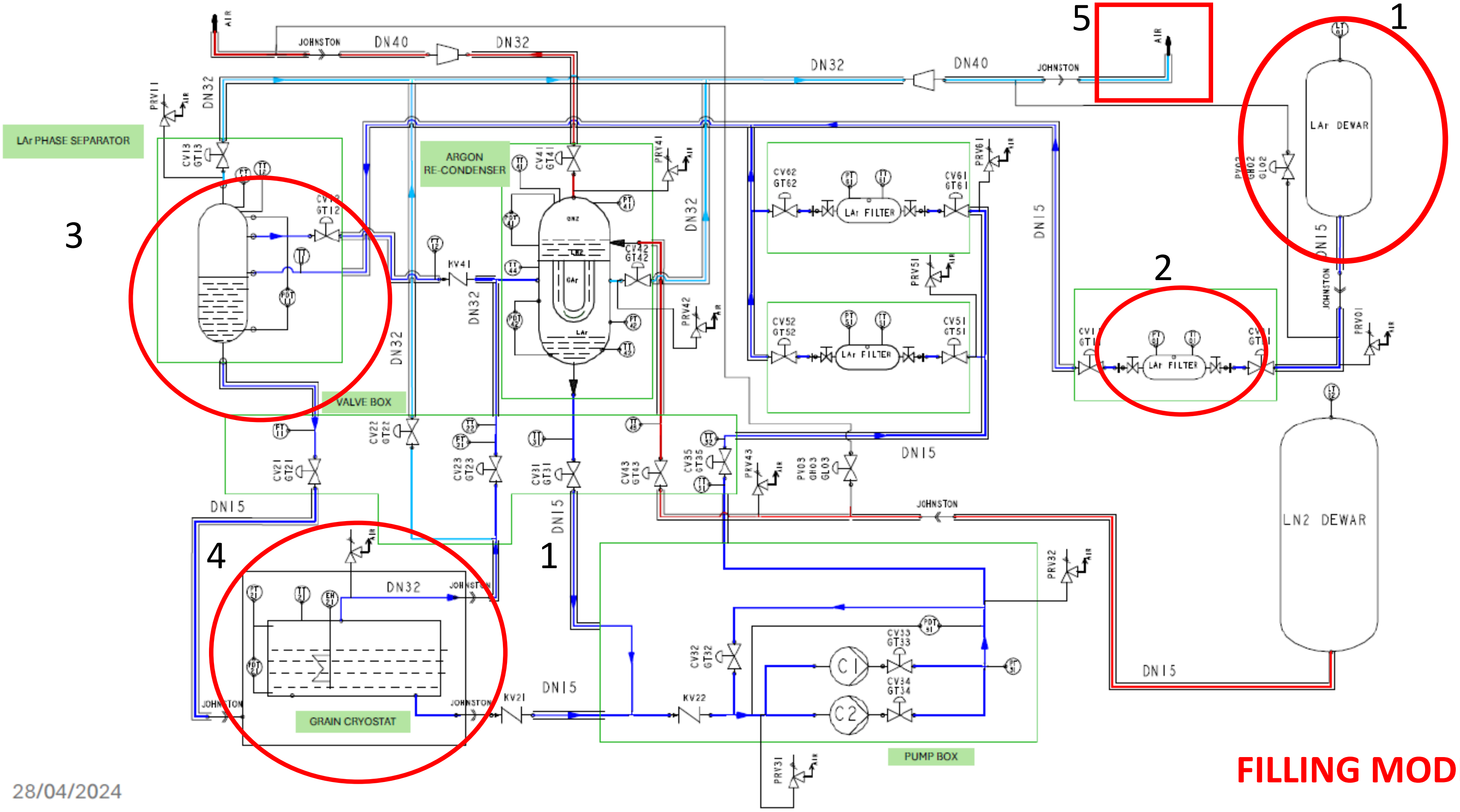
FILLING the cryostat with LAr from an outside trailer

GRAIN Piping & Instrumentation Diagram



FILLING MODE

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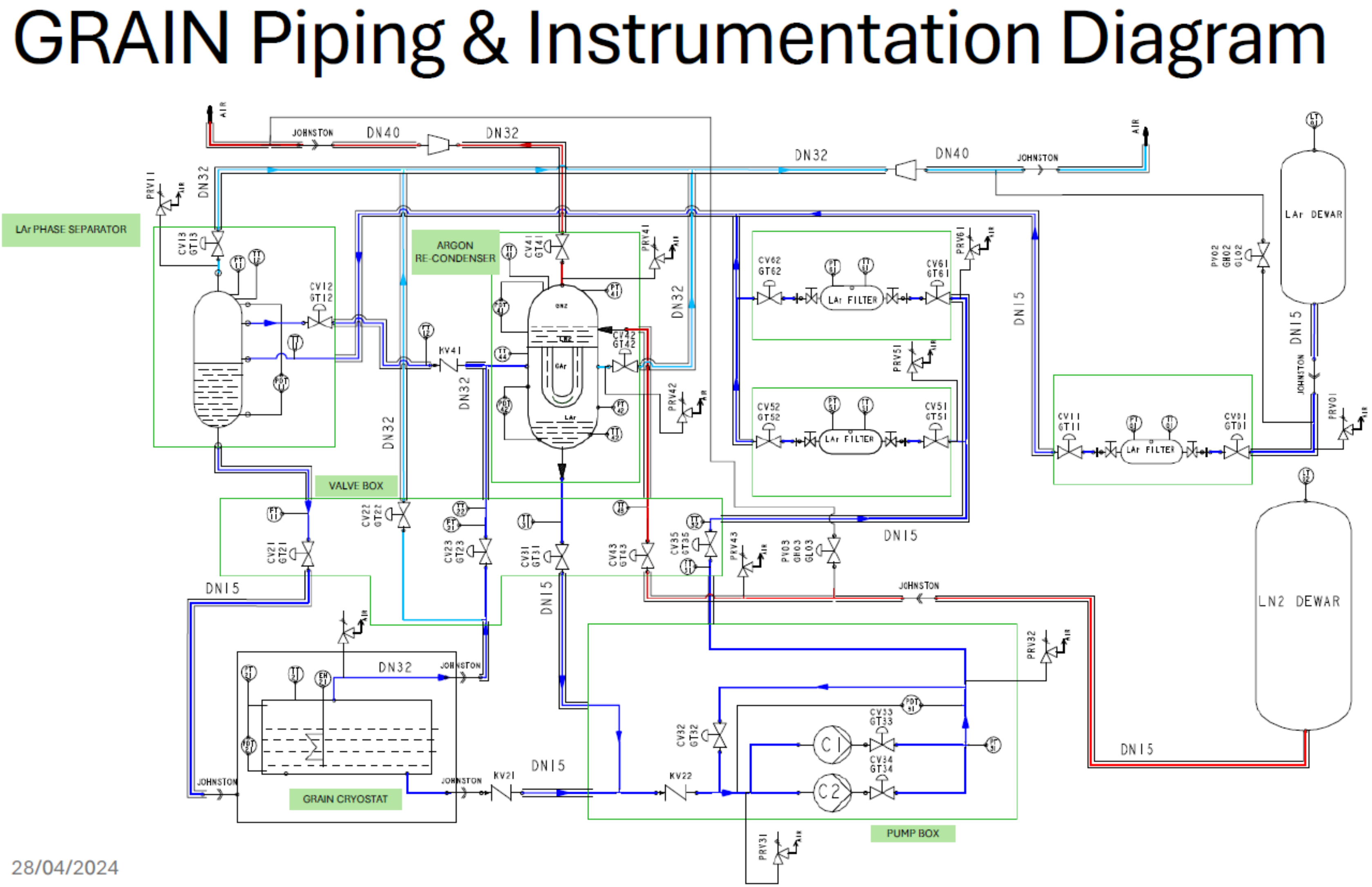
Normal operation



1) *Centrifugal pump* is circulating the LAr:

- through the purifier
- to the phase separator (PS)

2) The GAr boil-off of both the cryostat and of the PS enter the *re-liquefier*, where it is liquefied with the *aid of LN2* at the pressure corresponding to LAr (ca. 2.8 bar)

Cryogenic specifications

- Recirculation of LAr will be provided by *centrifugal pumps*: one at LNL, two at FNAL (one redundant)
- *Maximum heat* load 1500 Watt (800 liters LN2 for 24 hours of operation)
- *Mass flow* of LAr max. 20 g/s (one GRAIN volume in 20-24 hours)
- Maximum head (Delta P) necessary: 0.5 bar (3.5 m) at LNL and 1.1 bar (8 m) at FNAL
- Two filters needed (*copper spheres*): one dismountable/replaceable for regeneration
- Control system according to *UNICOS CERN* (WINCC OA) (see scheme)

Cryogenic specifications (status)

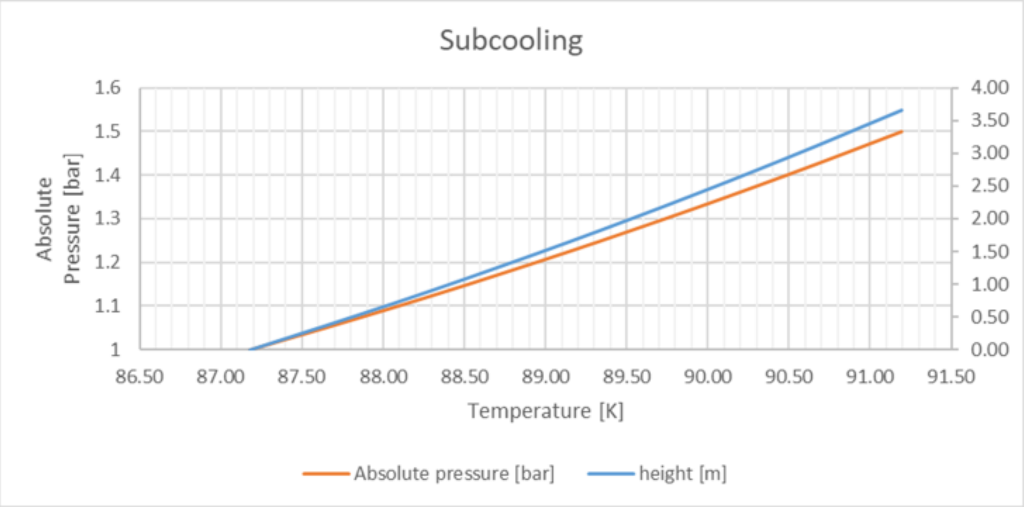
- Recirculation will be provided by centrifugal pumps (one at LNL/two at FNAL, one redundant)
- Maximum heat load 1500 Watt (800 liters LN2 for 24 hours of operation)=> To Be Confirmed
- Mass flow of LAr max. 20 g/s (one GRAIN volume in 20-24 hours)
- Maximum head (Delta P) necessary: 0.5 bar (3.5 m) at LNL and 1.1 bar (8 m) at FNAL=> contacts with Barber&Nichols ongoing
- Two filters needed (copper spheres): one dismountable/replaceable for regeneration => C. Montanari
- Control system according to UNICOS CERN (WINCC OA), the same for LNL and FNAL =>(see detailed scheme prepared by LNL cryogenic service, order placed)

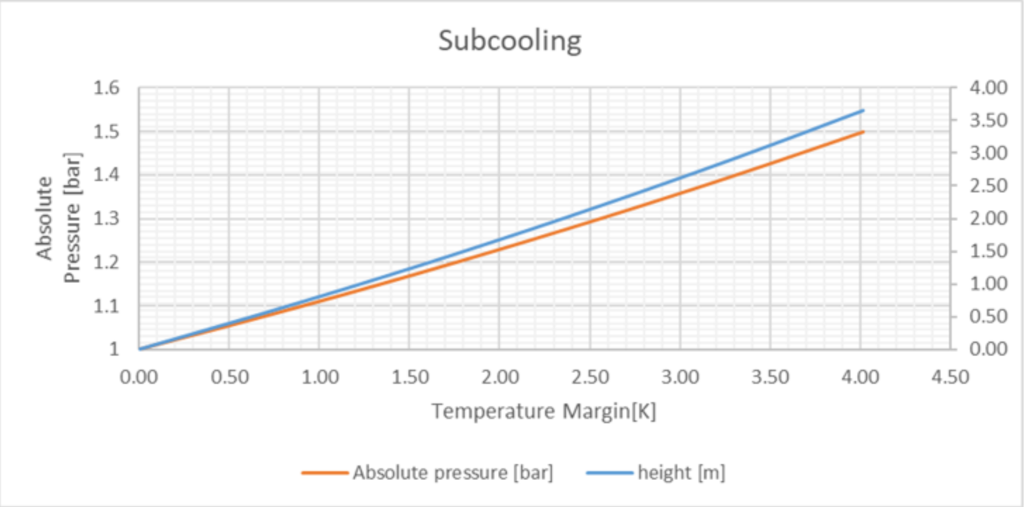
How the sub-cooling of LAr works

Temperature margin [K]

Hydrostatic height

margin[K]	(m)	Temperatu (K)	Pressure (bar)	Liquid Density (kg/m^3)	Vapor Density (kg/m^3)
0.00	0.00	87.18	1	1396.2	5.7043
0.91	0.73	88.09	1.1	1390.5	6.2253
1.76	1.46	88.94	1.2	1385.3	6.7426
2.55	2.19	89.73	1.3	1380.3	7.2566
3.31	2.92	90.48	1.4	1375.6	7.7678
4.02	3.65	91.19	1.5	1371.1	8.2763





R. Pengo

In the table above and in graphs on the right it is shown the obtainable temperature margin by means of the hydrostatic height of the LAr. The sub-cooling is necessary in order to reduce/avoid the production of Ar bubbles coming from the electronics immersed in LAr.

Example of calculations:

Given:

- 1 mc of Lar at 87 K
  - (density ca. 1400 kg/mc,
  - density at 293 K is 1.64 kg/mc at 1 bar,
  - density at 293 bar is 347 kg/mc at 200 bar
- 2000 W total dissipation

Pump:

- Mass flow is 2000/161= 12.4 g/s
- Head for 5 m is 0.69 bar or 68670 Pa
- Pump dissipation for 5 m head (0.0124 x 68670)/1400 = 0.6 W
- If efficiency is 30% the dissipation is 2 W, plus static heat load from cryostat

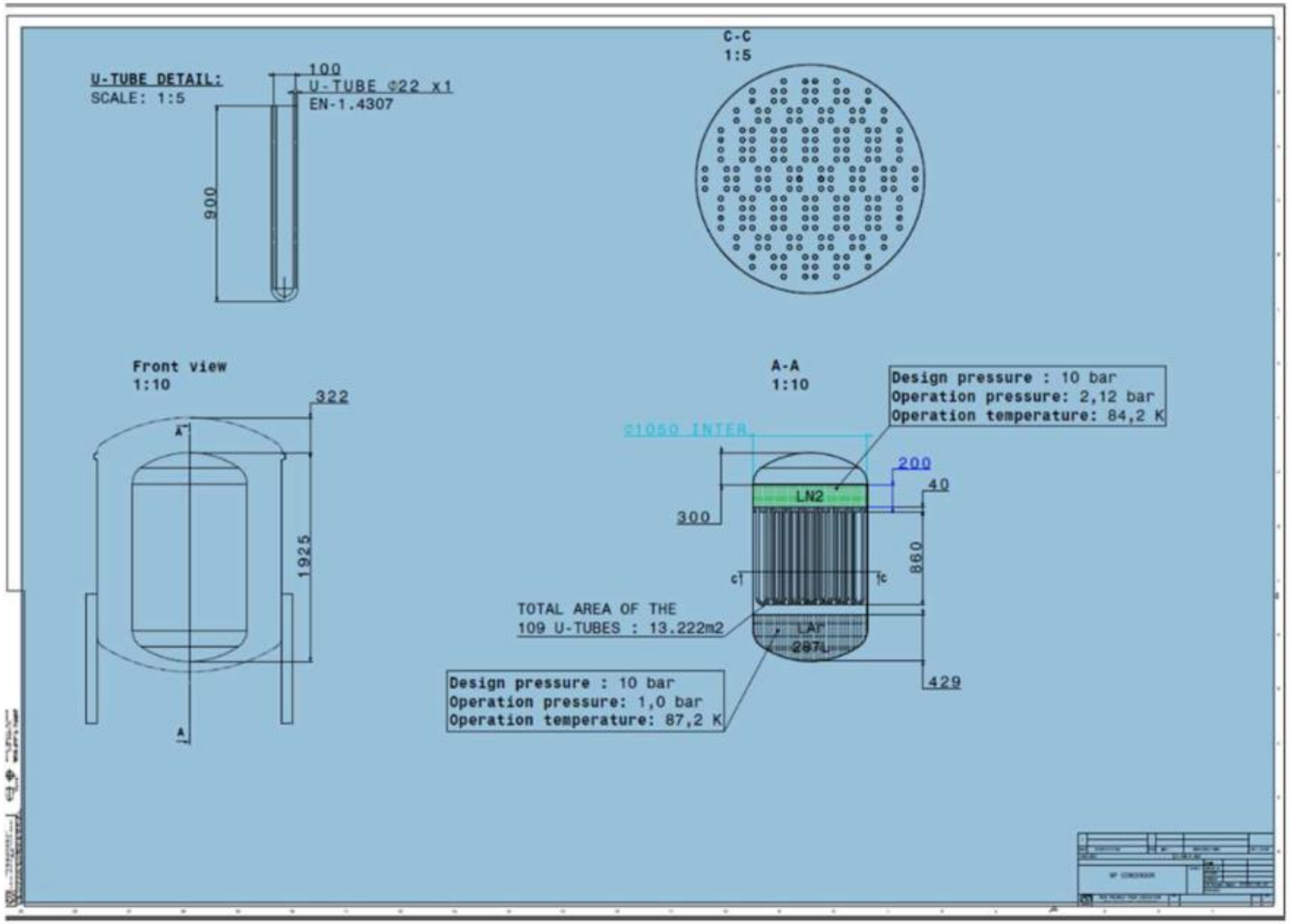
Recovery as GAr:

- Volume in gas at 200 bar is 1400/347= 4 mc at 200 bar
- If a cylinder is 50 liter 4mc/0.05 = 80 cylinders
- I packet is 12 cylinders so 80/12= ca. 7 packets

Summary of the design status of the cryogenic components

- Inner vessel (SS): designed completed
- Vacuum tank for the test facility (SS): designed completed (see G.Piazza talk)
- Vacuum tank for FNAL in Carbon fiber reinforced polymers (CFRP): design advanced
- Centrifugal pumps for LNL (head 3.5 m): design available (B&N)
- Centrifugal pumps for FNAL (head 8 m): new design to be agreed with B&N
- Phase separator: design available
- Re-condenser: design available
- Filters/purifiers: specifications available
- Control system: design ready and order placed for hardware
- Functional logics: to be prepared (UNICOS)

Re-condenser



This U-tube heat exchanger is dimensioned for 1500 W.

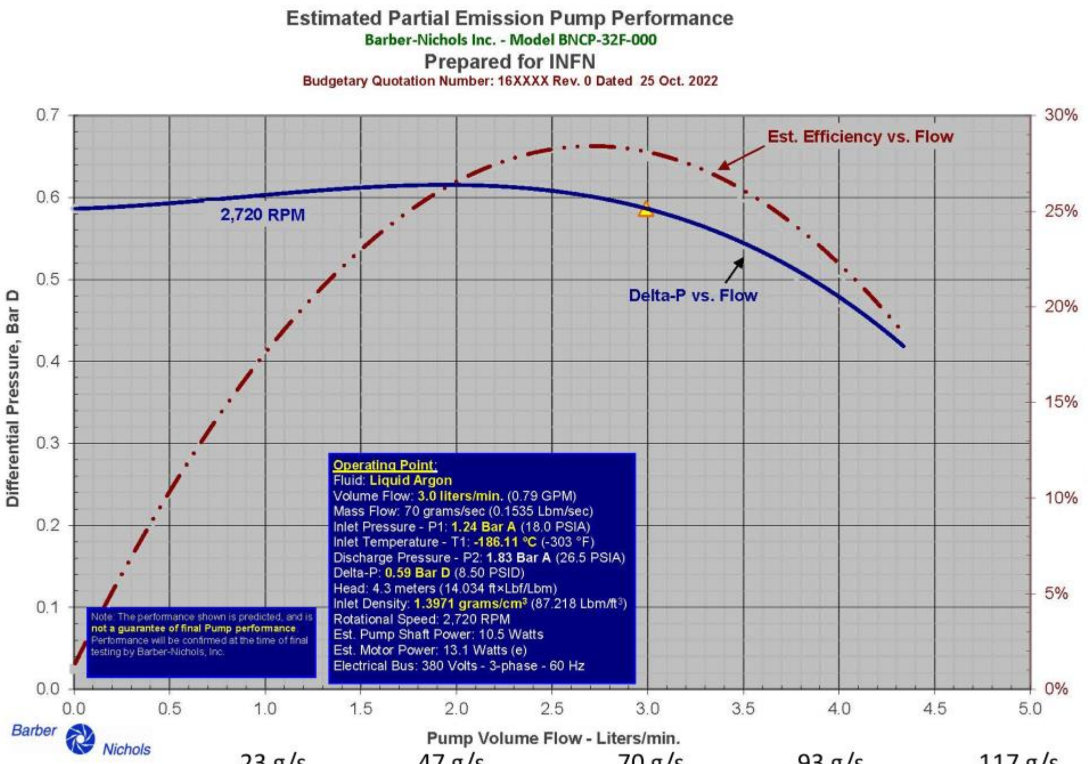
The boil off is produced by the static heat load, detectors heat load and feedthroughs.

The GAr formed has to be re-condensed and sent for gravity to the recirculation pump

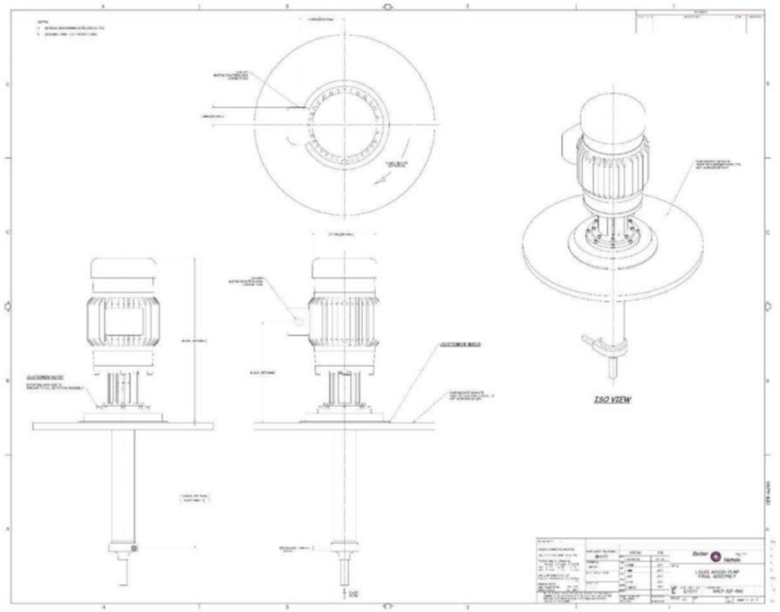
H = 5.0 m

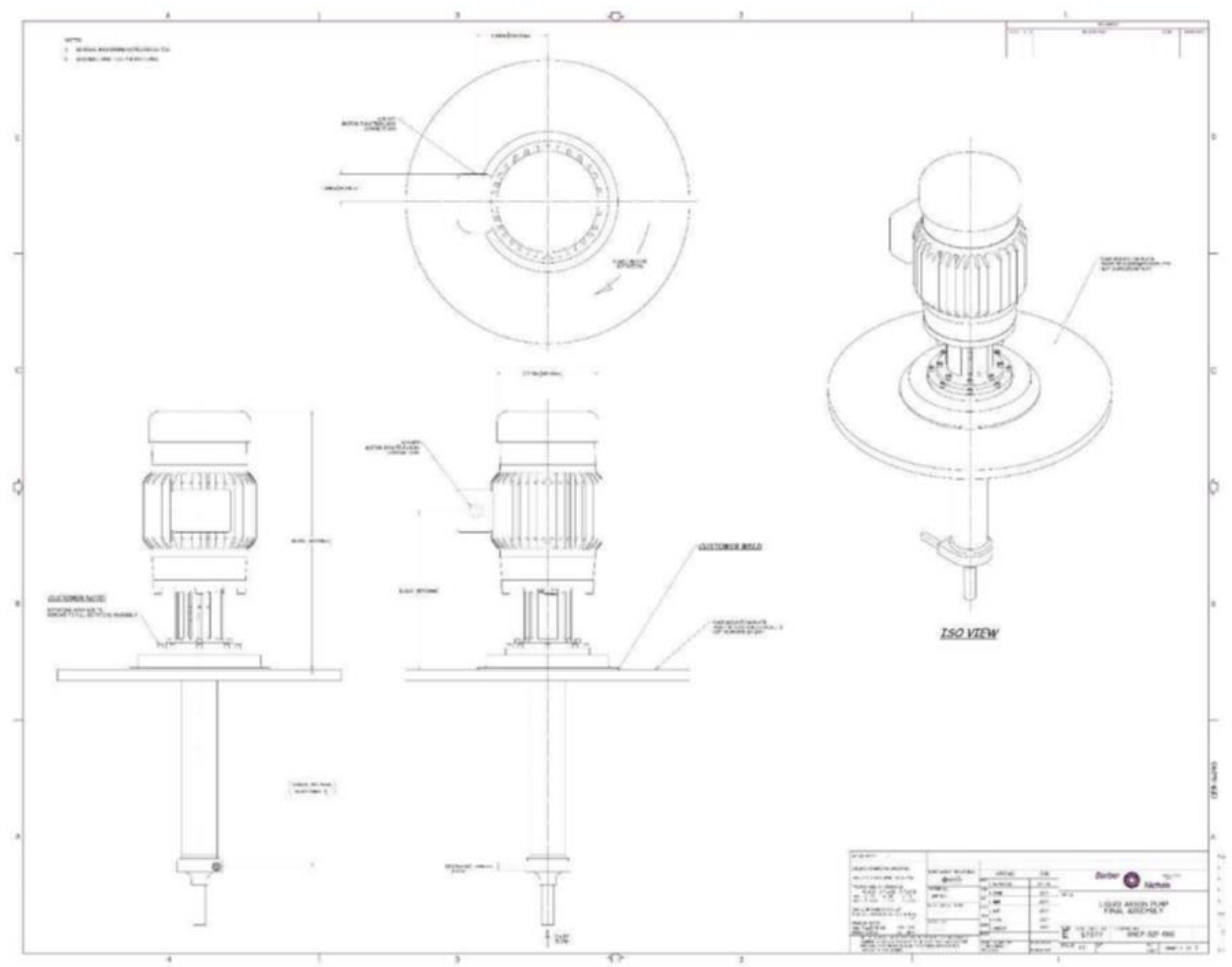
H = 4.3 m

H = 3.6 m



23 g/s 47 g/s 70 g/s 93 g/s 117 g/s



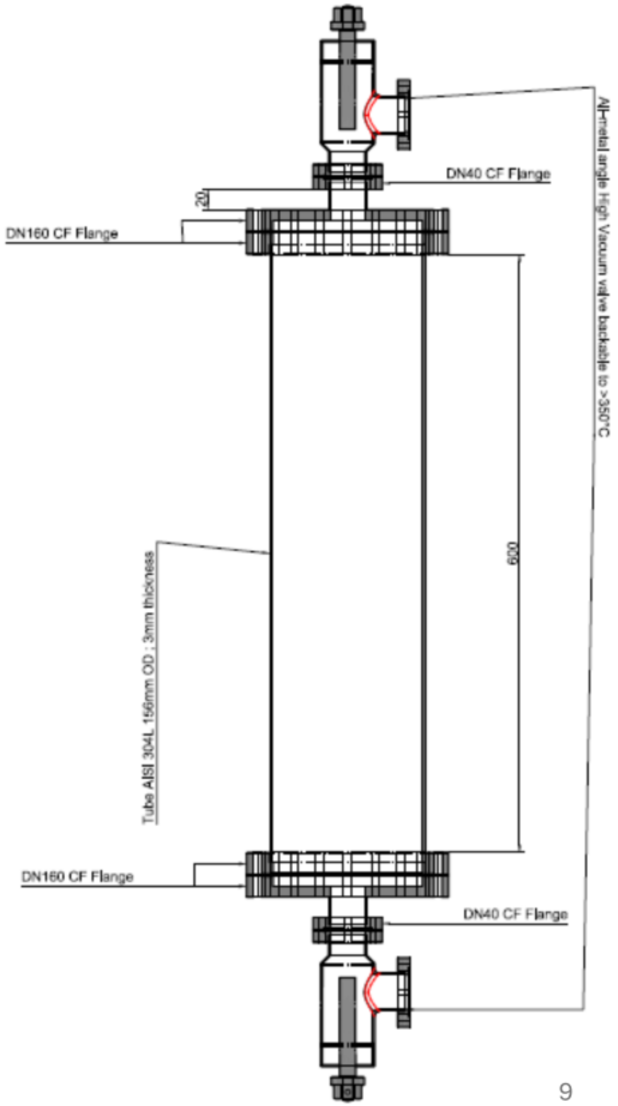

ISO VIEW
LIQUID ARGON PUMP
FINAL ASSEMBLY

Purification filters

Made of molecular sieve (sintered disk) and small spheres of Al2O3 coated with Cu
One purifier for the filling and two in parallel for the recirculation

The filters have not been sized and designed yet.

In order to dismount and regenerate the filters there will be placed a CF flange and a manual shut-off valve on both sides;
in this way the filter can be removed and installed, preventing air from entering.



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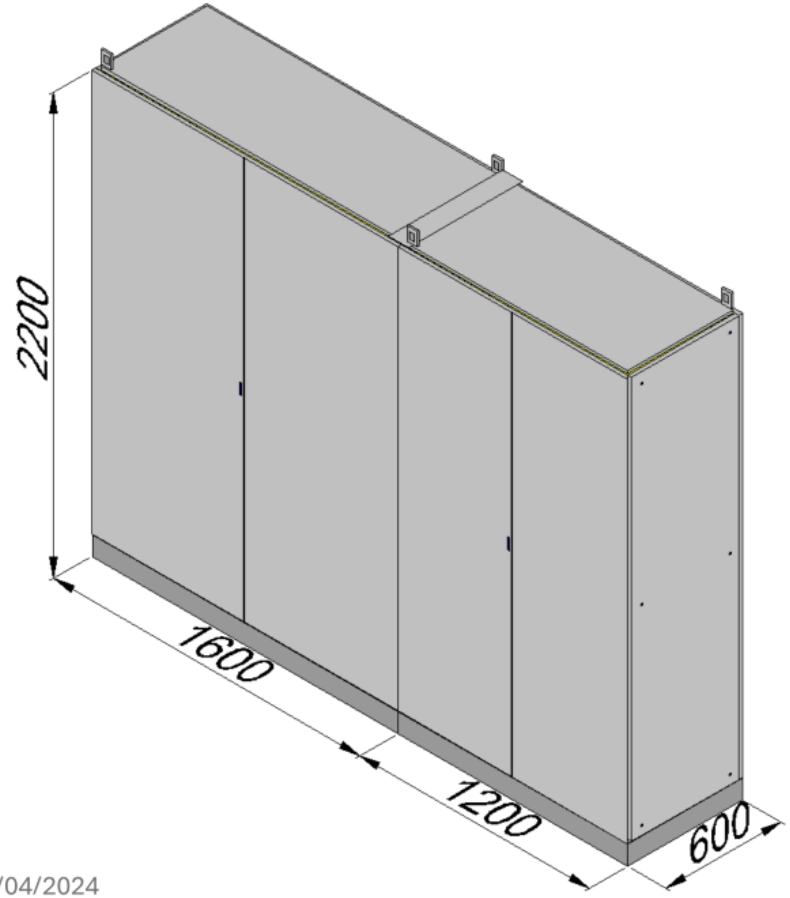
Electric control panel



The project has been completed with the help of LNL cryogenic division staff, and all the material has been delivered to LNL.

Analog Input: 52
Analog Output: 21
Digital Input: 14
Digital Output: 9

Plus some spares

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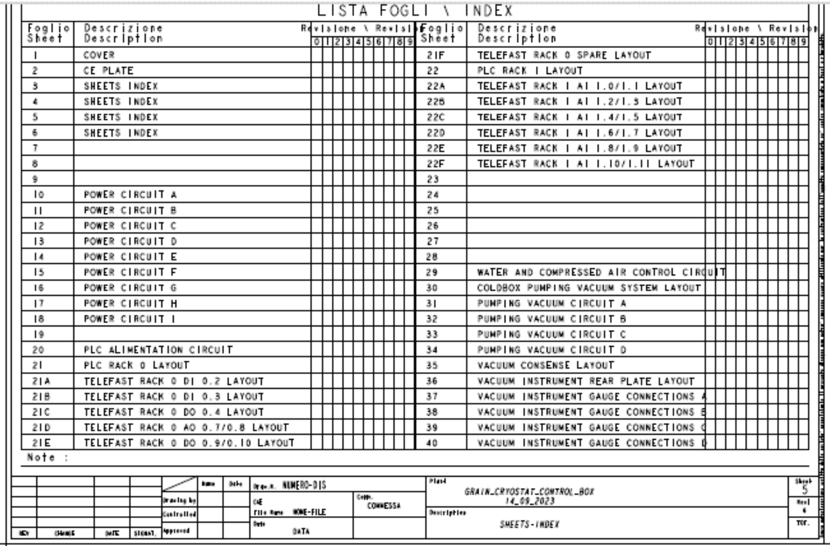
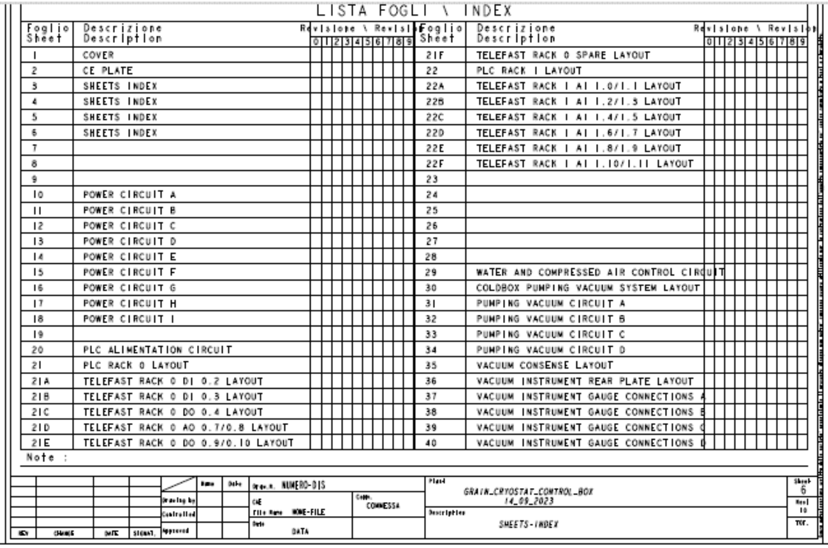


LISTA FOGLI \ INDEX

Foglio Sheet	Descrizione Description	Foglio Sheet	Descrizione Description
1	COVER	21F	TELEFAST RACK 0 SPARE LAYOUT
2	CE PLATE	22	PLC RACK 1 LAYOUT
3	SHEETS INDEX	22A	TELEFAST RACK 1 AI 1.0/1.1 LAYOUT
4	SHEETS INDEX	22B	TELEFAST RACK 1 AI 1.2/1.3 LAYOUT
5	SHEETS INDEX	22C	TELEFAST RACK 1 AI 1.4/1.5 LAYOUT
6	SHEETS INDEX	22D	TELEFAST RACK 1 AI 1.6/1.7 LAYOUT
7		22E	TELEFAST RACK 1 AI 1.8/1.9 LAYOUT
8		22F	TELEFAST RACK 1 AI 1.10/1.11 LAYOUT
9		23	
10	POWER CIRCUIT A	24	
11	POWER CIRCUIT B	25	
12	POWER CIRCUIT C	26	
13	POWER CIRCUIT D	27	
14	POWER CIRCUIT E	28	
15	POWER CIRCUIT F	29	WATER AND COMPRESSED AIR CONTROL CIRCUIT
16	POWER CIRCUIT G	30	COLDBOX PUMPING VACUUM SYSTEM LAYOUT
17	POWER CIRCUIT H	31	PUMPING VACUUM CIRCUIT A
18	POWER CIRCUIT I	32	PUMPING VACUUM CIRCUIT B
19		33	PUMPING VACUUM CIRCUIT C
20	PLC ALIMENTATION CIRCUIT	34	PUMPING VACUUM CIRCUIT D
21	PLC RACK 0 LAYOUT	35	VACUUM CONSENSE LAYOUT
21A	TELEFAST RACK 0 DI 0.2 LAYOUT	36	VACUUM INSTRUMENT REAR PLATE LAYOUT
21B	TELEFAST RACK 0 DI 0.3 LAYOUT	37	VACUUM INSTRUMENT GAUGE CONNECTIONS A
21C	TELEFAST RACK 0 DO 0.4 LAYOUT	38	VACUUM INSTRUMENT GAUGE CONNECTIONS B
21D	TELEFAST RACK 0 AO 0.7/0.8 LAYOUT	39	VACUUM INSTRUMENT GAUGE CONNECTIONS C
21E	TELEFAST RACK 0 DO 0.9/0.10 LAYOUT	40	VACUUM INSTRUMENT GAUGE CONNECTIONS D

Note :

NUMERO-DIS · GRAIN_CRYOSTAT_CONTROL_BOX 14_09_2023 · COMMESSA · NONE-FILE · DATA · SHEETS-INDEX · Sheet 5



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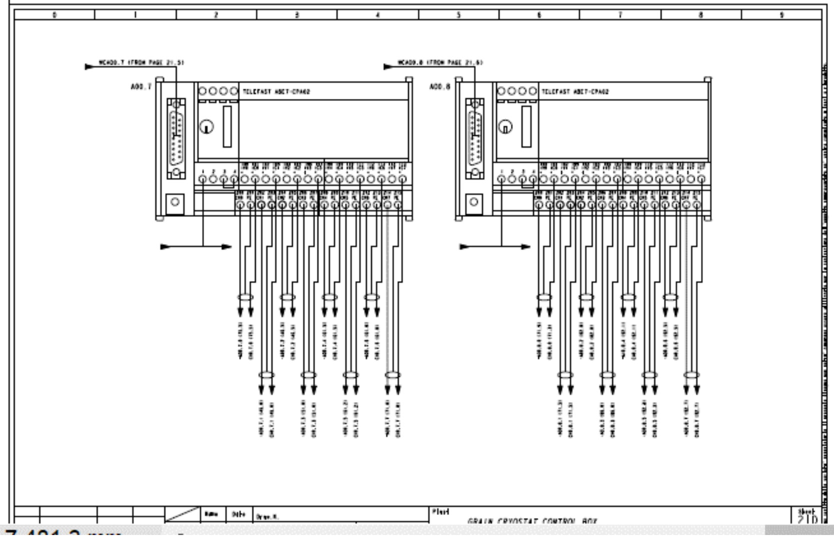
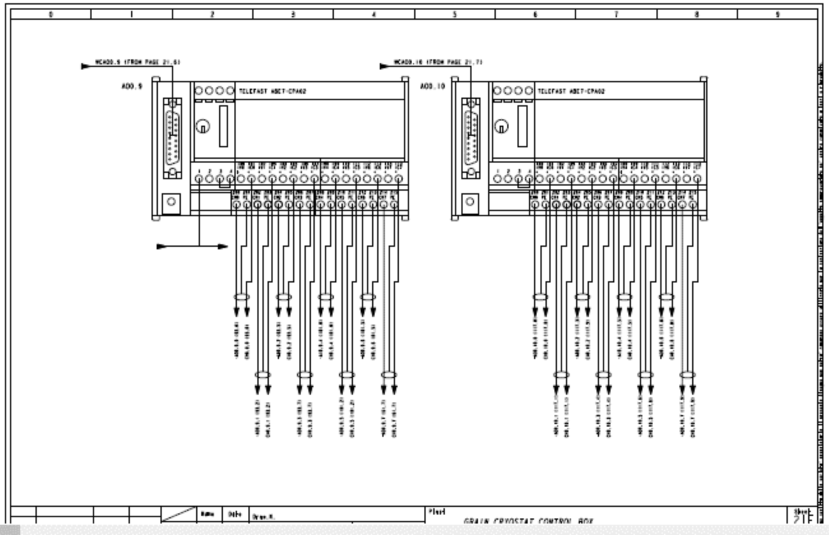
Note :

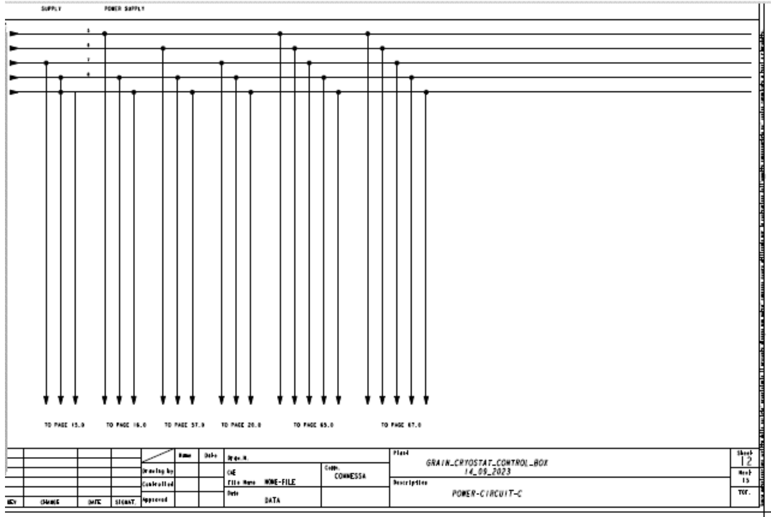
NUMERO-DIS · GRAIN_CRYOSTAT_CONTROL_BOX 14_09_2023 · COMMESSA · NONE-FILE · DATA · SHEETS-INDEX

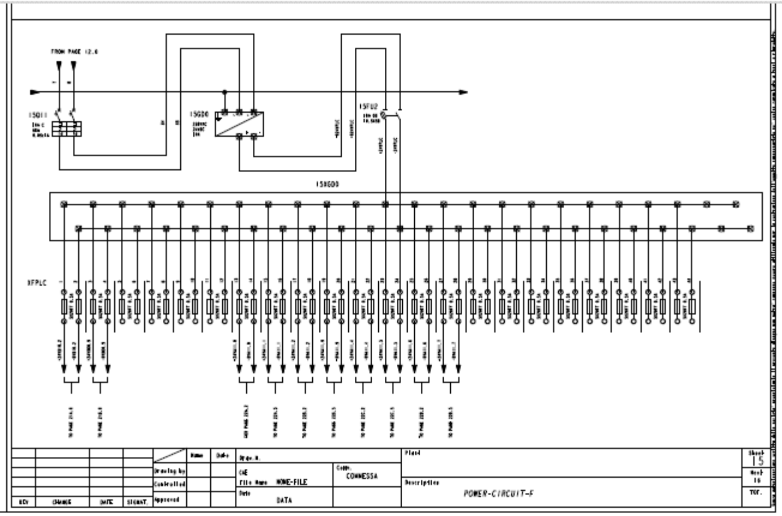
Sheet 6

Prepared by Cryogenic Service of INFN-LNL









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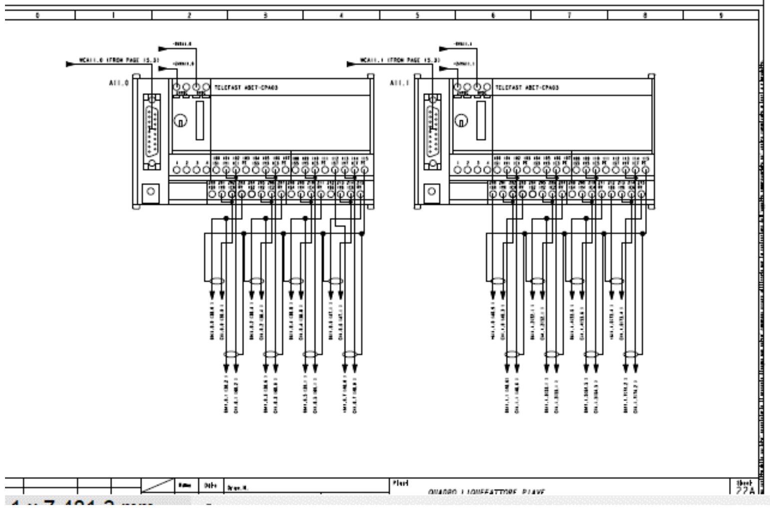

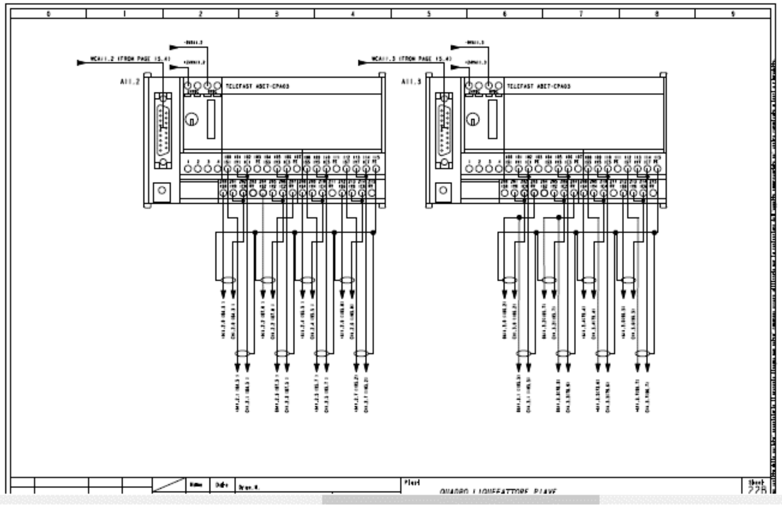

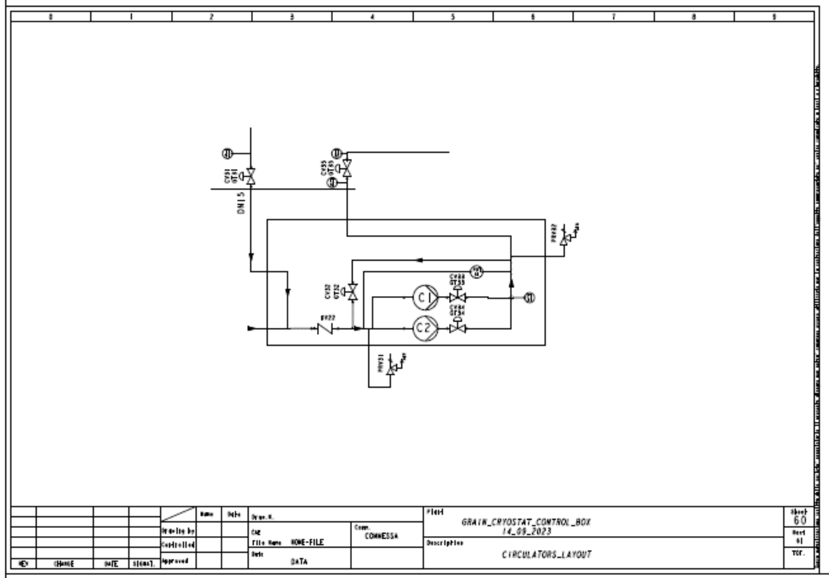

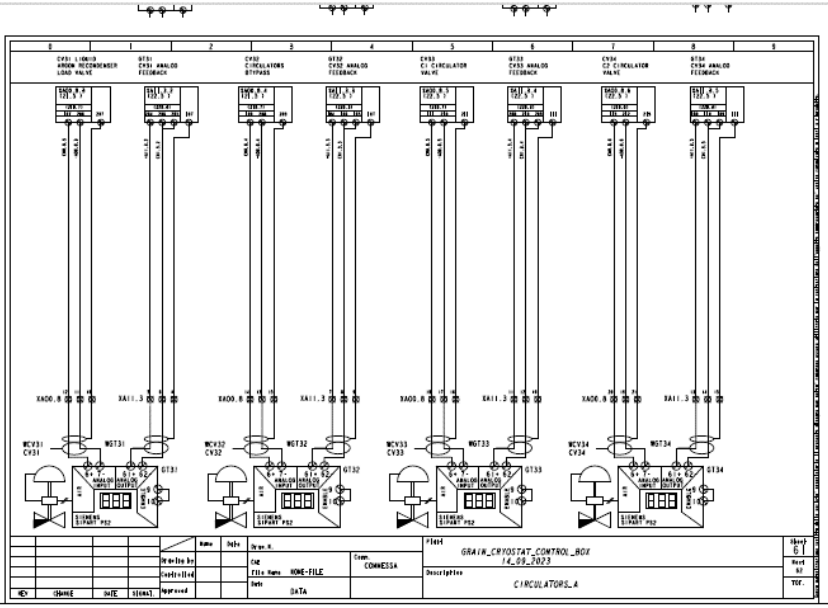

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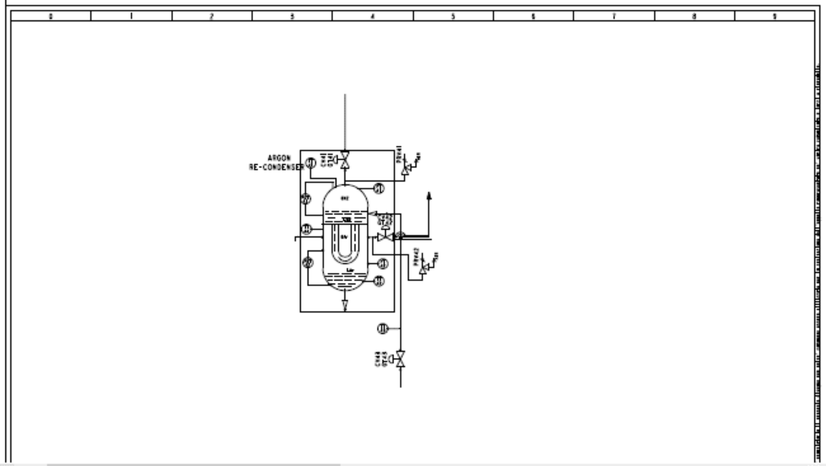

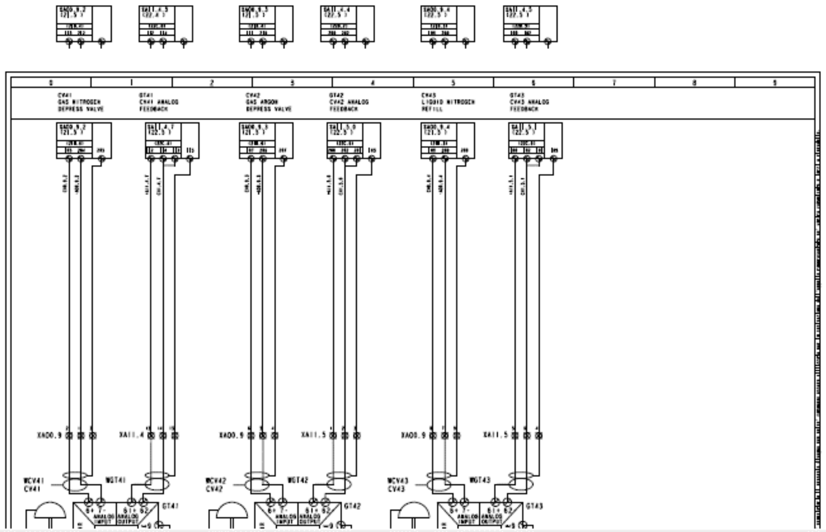

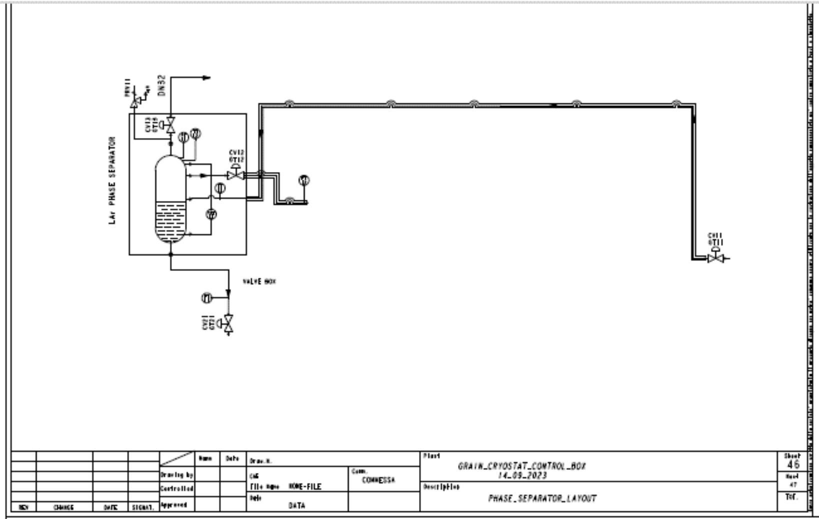

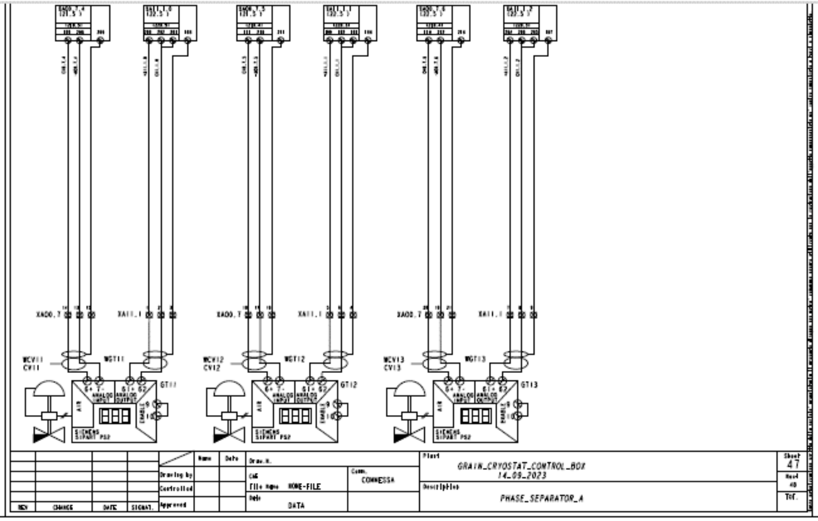

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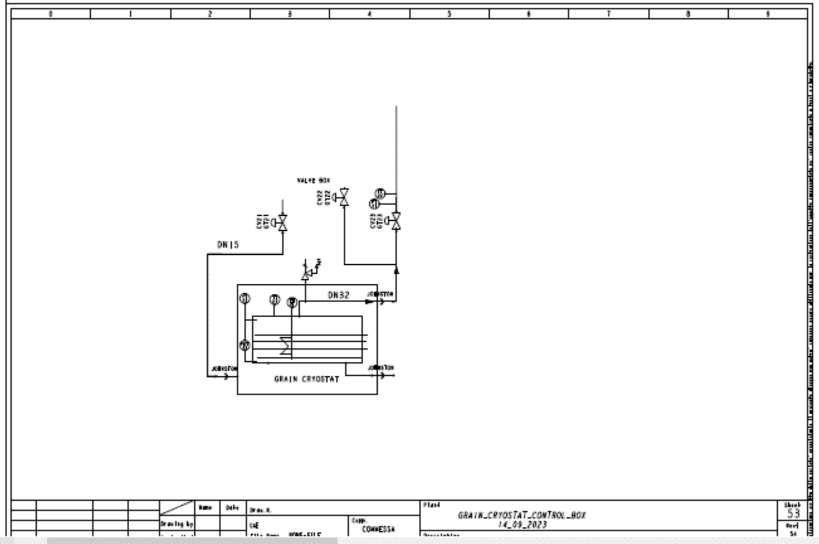

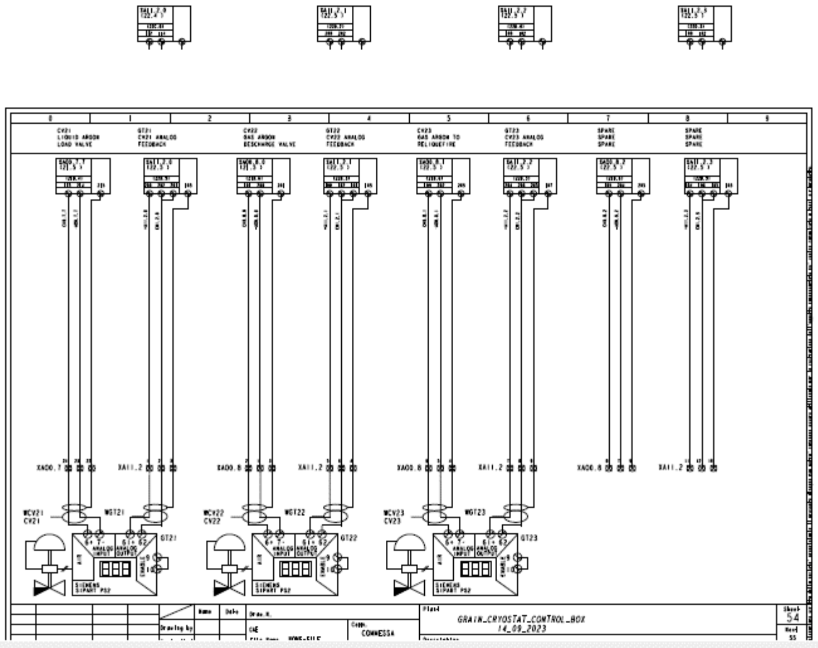

Thank You