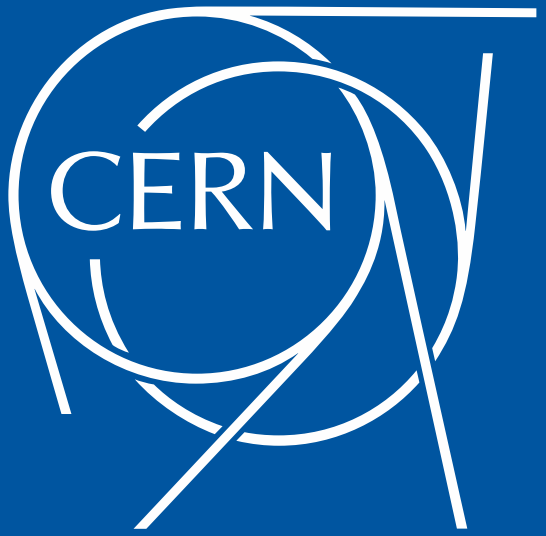

CERN

Neutrino Platform Proximity Cryogenics

Functional Design

M.Chalifour

Outline

- Intro
- Project Requirements
- Configuration management
- 3D Configuration models
- Interfaces (ICD/IS)
- Modes of Operations
- Process and Instrument Diagram (P&ID)
- P&IDs in the various modes of operations

Introduction

- The scope of the tender is the design, procurement, fabrication and installation of the following items:
  - SBN-FD (NP-01) **Proximity Cryogenics.**
  - ProtoDUNE Dual Phase (NP-02) **Proximity and External Cryogenics** (liquid storages and the LAr circulation pumps excluded).
  - SBND (NP-03) **Proximity Cryogenics (installation is optional).**
  - ProtoDUNE Single Phase (NP-04) **Proximity and External Cryogenics** (liquid storages and the LAr circulation pumps excluded).
- The tender is issued with a **Functional Specification**, (e.g. we do not supply pipe/valve sizes, etc.).
- The Internal Cryogenics is NOT part of this tender for any project.
- The warm piping is NOT part of this tender for any project.
- The P&IDs for NP-02, NP-03, NP-04 are as identical as possible. NP-01 is different: it reflects the old ICARUS P&ID as much as possible.

Applicable documents supplied for the tender

- Main document: Functional Specifications.
- P&IDs.
- 3D Configuration Models
- Interface control document (ICD), Interface sheets and drawings.

Requirements for **SBN-FD** NP.01

Required Parameter	Value
LAr purity in cryostat	**>3** ms electron lifetime (**<100** ppt O2 equivalent)
Verifiable contamination levels for LAr delivery	O2 < 1 ppm, H2O < 1 ppm, N2 < 2 ppm
Max Design Over-Pressure	**350** mbarg (~**5** psig)
Operating gas pressure	**150** mbar (~**2** psig) with +/- 5% (~0.1 psig)
Vacuum tightness	Localized leaks < 10^{-8} mbar x liters / s Global leak rate < 10^{-6} mbar x liters / s
Minimum inner dimensions cryostat	**3600** mm (Transv) x **19900** mm (Para) x **3900** mm (H) (-0 mm +10mm for all dimensions)
Cool-down rate	≈ 2 K/hr (5 days to cool to LAr temperature)
TPCs max gradients	< **70** K < **50** K (vertically)
LAr recirculation rate	1.56 kg/s per T300 module (one volume / week)
Purification Technique	Pump down to vacuum and fill with purified LAr
LAr flow speeds (convection)	< 20 cm / sec
Minimum depth of liquid argon	**3783** mm (From the floor)
Total liquid argon mass	**377** ton / T300 module
Maximum static heat leak	**<10** W/m^2 (Sides/Floor) **10** W/m^2 (Roof)

Requirements for **ProtoDUNE** NP.02

Parameter	Value	Notes
GAr purge flow rate	88 m^3/hr	From 1.2 m/hr
Maximum cool-down rate TPC	40 K/hr 10 K/m	T sensors to be defined and placed by Internal Cryogenics/Detector
Maximum Delta T between any two points in the detector	50 K	T sensors to be defined and placed by Internal Cryogenics/Detector
Design Pressure	1345 mbar	Design Pressure
Operating gas pressure	1000 mbar	Operating gas pressure
LAr filling flow rate (*)	18 l/min	Assuming 2 trucks/day (**)
Cryostat static heat leak	3.0 kW	GAr boil-off (18 g/s)
Other heat loads (estimate)	5.0 kW	Total estimate is ~ 8 kW
LAr circulation (5 days turnover)	1.63 kg/s	Nominal value (1 pump)
Max emptying (w both LAr pumps)	3.2 kg/s	Limited by size of tank/truck
Condenser size	16 kW	

Requirements for **SBND** NP.03

Required Parameter for Cryogenics	Value
LAr purity in cryostat	3 ms electron lifetime (100 ppt O2 equivalent)
Nitrogen contamination	Less than 2 ppm (to coincide with T600)
Design Pressure	345 mbarg (~5 psig)
Operating gas pressure	70 mbar (~1 psig) with +/- 5% (~0.05 psig)
GAr Piston purge rate of rise	1.2 m/hr
Membrane cool-down rate	From manufacturer (most likely < 10-15 K/hr)
TPCs cool-down rate	< 40 K/hr < 10 K/m (vertically)
Mechanical load on TPC	The LAr or the gas jet pressure shall not apply a mechanical load to the TPC greater than 200 Pascal
Nominal LAr purification flow rate (filling/ops)	1 volume change/day 0.88 kg/s
All surfaces in the ullage during operations	< 100 K
Convective currents inside cryostat	< 10 cm/s
GAr purge within insulation (From LBNF)	1 volume change/day of the open space between insulation panels
Condenser cooling power	Based on fill with LAr (~25 kW)
Grounding and noise requirement	Electrical isolation from cryostat. Approval by SBND committee supervising detector and building grounding

Requirements for **ProtoDUNE** NP.04

	Parameter	Value	Notes
	GAr purge flow rate	88 m^3/hr	From 1.2 m/hr
	Maximum cool-down rate TPC	40 K/hr 10 K/m	T sensors to be defined and placed by Internal Cryogenics/Detector
	Maximum Delta T between any two points in the detector	50 K	T sensors to be defined and placed by Internal Cryogenics/Detector
	LAr filling flow rate (*)	18 l/min	Assuming 2 trucks/day (**)
	Cryostat static heat leak	3.0 kW	GAr boil-off (18 g/s)
	Other heat loads (estimate)	5.0 kW	Total estimate is ~ 8 kW
	LAr circulation (5 days turnover)	1.63 kg/s	Nominal value (1 pump)
	Max emptying (w both LAr pumps)	3.2 kg/s	Limited by size of tank/truck
	Condenser size	16 kW	

* Value might be limited by the pressure inside the LAr storage dewar.
** We need to contact the supplier to confirm availability of 2 trucks/day of LAr.

Product Breakdown Structure

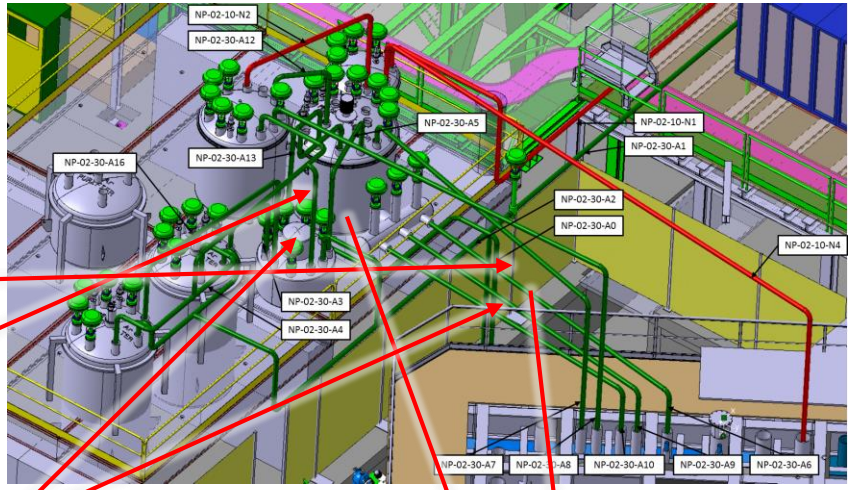
The product deliverables are breakdown into a PBS:

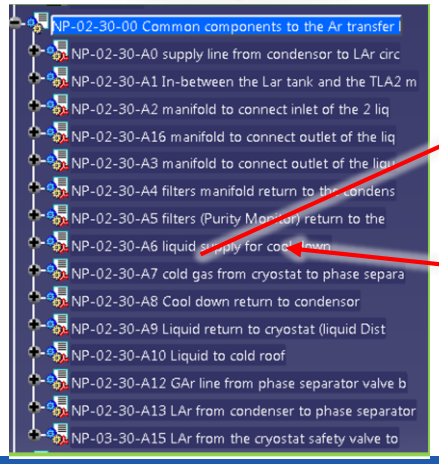
The PBS is organized in a product tree
The PBS is the support to the configuration management (P&ID, 3D, ICD)
The PBS is the support to the documentation

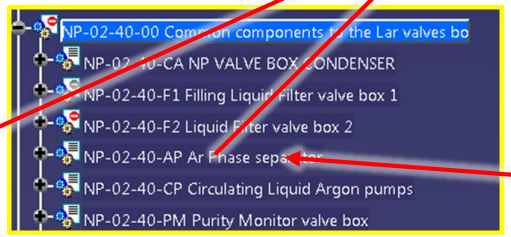
Neutrino Platform Proximity Cryogenics								
Project name/identification			PBS proposal					#
Responsible	Support	Accountable	Level 1	Level 2	Level 3	Level 4	Component name	Comments
Proximity Cryogenic NP								
			NP	00	00	00	Common	common components to the NP Proximity Cryogenics facilities
SBFD NP01			NP	01	00	00		
ProtoDUNE NP02			NP	02	00	00		
			NP	02	30	A1	Transfer Line A1	in-between the Lar tank and the TLA2 manifold
SBND NP03			NP	03	00	00		
ProtoDUNE NP04			NP	04	00	00		

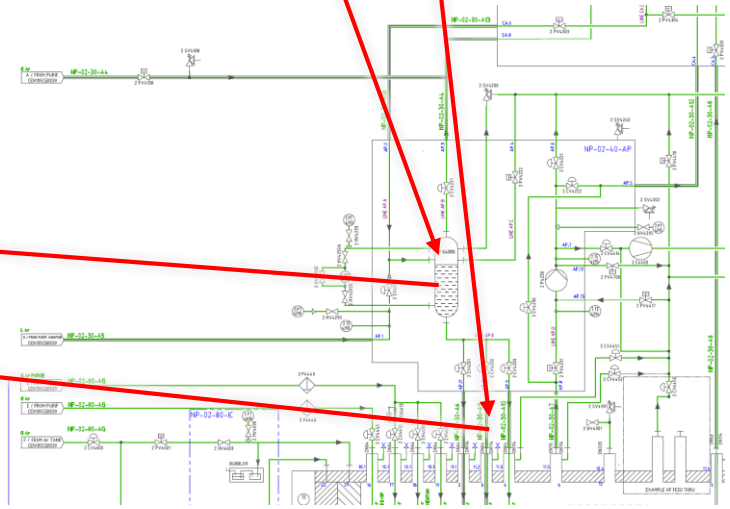
Configuration management: PBS/3D/P&ID/ICD

Proto Dune DP NP02					
Level 1	Level 2	Level 3	Level 4	Component name	Comments
NP	02	00	00	Common	common components to the NP02
NP	02	10	00	Common	common components to the Nitrogen system
NP	02	10	N1	Transfer Line N1	in-between the LN2 tank and the N2 phase separator
NP	02	10	N2	Transfer Line N2	exhaust of the N2 phase separator
NP	02	10	N3	Transfer Line N3	in-between the N2 phase separator and the condenseur
NP	02	10	N4	Transfer Line N4	in-between the N2 inlet of the condensor and the electronics manifold
NP	02	20	00	Common	common components to the storage system
NP	02	20	NT	LN2 Tank	LN2 outside Tank storage (50m3)
NP	02	20	AT	LAr Tank	LAr outside Tank storage (50m3)
NP	02	30	00	Common	common components to the Ar transfer line system
NP	02	30	A1	Transfer Line A1	in-between the Lar tank and the TLA2 manifold
NP	02	30	A2	Transfer Line A2	manifold to connect inlet of the 2 liquid filters and from pumps
NP	02	30	A3	Transfer Line A3	manifold to connect outlet of the liquid filters to the PS
NP	02	30	A4	Transfer Line A4	filters manifold return to the condensor
NP	02	30	A5	Transfer Line A5	filters return to the phase separator
NP	02	30	A6	Transfer Line A6	liquid supply for cool down
NP	02	30	A7	Transfer Line A7	cold gas from cryostat to phase separator valve box
NP	02	30	A0	Transfer Line A0	supply line from condensor to LAr circulation pumps
NP	02	30	A8	Transfer Line A8	Cool down return to condensor
NP	02	30	A9	Transfer Line A9	Liquid return to cryostat
NP	02	30	A10	Transfer Line A10	Liquid to cold roof
NP	02	30	A12	Transfer Line A12	GAr line from phase separator valve box to condenser
NP	02	30	A13	Transfer Line A13	LAr from condenser to phase separator
NP	02	40	FL	Filling Liquid Filter valve box	Mechanical Filling Liquid Filter valve box
NP	02	40	00	Common	common components to the Lar valves boxes system
NP	02	40	CA	Condenser valve box	Gas Condenser valve box
NP	02	40	F1	Liquid Filter valve box 1	Filling Liquid Filter valve box 1
NP	02	40	F2	Liquid Filter valve box 2	Circulating Liquid Filter valve box 2
NP	02	40	AP	Ar Phase separator	Ar phase separator and cold compressor
NP	02	40	CP	Circulating LA pump valve box	Circulating Liquid Argon pumps
NP	02	40	PM	Purity Monitor valve box	Purity Monitor valve box
NP	02	60	NP	N2 Phase separator	N2 phase separator
NP	02	70	F3	Gas Filter set	Warm Gas Filter set









Annex 5 ICD: Example of Interface sheet 1/5 (From NP-04)

					n.a.	Not applicable																
					(*)	Not in Process Pipe																
	Equipment	Interfacing TAG	Interfacing Port	Interfacing Type	Process Pipe	Process Description	Physical Interface			Maximum allowable		Operating conditions				Maximum allowable mechanical loads						Notes
							DN	Outer Diameter	Thickness	Pressure	Temperature	Pressure	Temperature	Nominal Mass flow rate	Max Mass flow rate	Fx	Fy	Fz	Mx	My	Mz	
								mm	mm	[Barabs]	[K]	[Barabs]	[K]	[g/s]	[g/s]	[N]	[N]	[N]	[N.m]	[N.m]	[N.m]	
	NP-04-40-CA	NP-04-10-N2	CA.1	Y	X	GN2 Vent	TBD	TBD	TBD	10	300	2.500	90.0	50.0	100	TBD	TBD	TBD	TBD	TBD	TBD	
				Y	vacuum	(*)	TBD	TBD	TBD	1.5	300	vacuum	300.0	n/a	n/a	TBD	TBD	TBD	TBD	TBD	TBD	
		NP-04-10-N3	CA.2	Y	X	LN2 Inlet to Heat Exchanger	TBD	TBD	TBD	10	300	2.500	86.0	50.0	100	TBD	TBD	TBD	TBD	TBD	TBD	
				Y	vacuum		TBD	TBD	TBD	1.5	300	vacuum	300.0	n/a	n/a	TBD	TBD	TBD	TBD	TBD	TBD	
		NP-04-30-A8	CA.3	Y	X	GAr Return from Cool down	75	76	TBD	10	300	1.070	90.0	100.0	100.0	TBD	TBD	TBD	TBD	TBD	TBD	
				Y	vacuum	(*)	TBD	TBD	TBD	1.5	300	vacuum	300.0	n/a	n/a	TBD	TBD	TBD	TBD	TBD	TBD	
		NP-04-30-A12	CA.4	Y	X	GAr Return from Cryostat	TBD	TBD	TBD	10	300	1.070	90.0	50.0	Risk Analysis	TBD	TBD	TBD	TBD	TBD	TBD	
				Y	vacuum	(*)	TBD	TBD	TBD	1.5	300	vacuum	300.0	n/a	n/a	TBD	TBD	TBD	TBD	TBD	TBD	
		NP-04-30-A0	CA.5	Y	X	LAr to Main LAr pumps	TBD	TBD	TBD	10	300	1.030	87.0	50.0	50.0	TBD	TBD	TBD	TBD	TBD	TBD	
				Y	vacuum	(*)	TBD	TBD	TBD	1.5	300	vacuum	300.0	n/a	n/a	TBD	TBD	TBD	TBD	TBD	TBD	
		NP-04-30-A13	CA.6	Y	X	LAr to Phase Separator	TBD	TBD	TBD	10	300	1.030	87.0	50.0	100	TBD	TBD	TBD	TBD	TBD	TBD	
				Y	vacuum	(*)	TBD	TBD	TBD	1.5	300	vacuum	300.0	n/a	n/a	TBD	TBD	TBD	TBD	TBD	TBD	
		NP-04-30-A11	CA.7	Y	X	LAr to Condenser Pump	TBD	TBD	TBD	10	300	1.030	87.0	50.0	50.0	TBD	TBD	TBD	TBD	TBD	TBD	
				Y	vacuum	(*)	TBD	TBD	TBD	1.5	300	vacuum	300.0	n/a	n/a	TBD	TBD	TBD	TBD	TBD	TBD	
		NP-04-30-A4	CA.8	Y	X	GAr from purification and phase separator	TBD	TBD	TBD	10	300	1.03-1.50	transient 300-88	??	100.0	TBD	TBD	TBD	TBD	TBD	TBD	The Operating Pressure during the cool down of the LAr Filters will be higher. During the cool down of the cryostat we will need to increase the pressure inside the LAr Phase Separator to be able to push the LAr through the cool down nozzles. We would need 0.7 bar, which we can provide partly with LAr head (~0.2m) and partly increasing the pressure inside the LAr Phase Separator.
				Y	vacuum	(*)	TBD	TBD	TBD	1.5	300	vacuum	300.0	n/a	n/a	TBD	TBD	TBD	TBD	TBD	TBD	
		CV4441	CA.9	X	X	Fresh GAr to Condenser	TBD	TBD	TBD	10	300	10.000	300.0	100.0	Risk Analysis	TBD	TBD	TBD	TBD	TBD	TBD	
		SV3160		Y		Safety Device LN2 Heat Exchanger	TBD	TBD	TBD	10	300	10.000	87.0	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	
		SV4300		Y		Safety Device LAr Heat Exchanger	TBD	TBD	TBD	10	300	10.000	87.0	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	
		SV4302		Y		Safety Device LAr outlet line	TBD	TBD	TBD	10	300	10.000	87.0	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	
		SV4340		Y	vacuum	safety device vacuum vessel	TBD	TBD	TBD	1.5	300	vacuum	300.0	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	
				Y	X	LAr Inlet from Condenser	TBD	TBD	TBD	10	300	layout	87.0	50.0	50.00	TBD	TBD	TBD	TBD	TBD	TBD	It is the hydrostatic height.

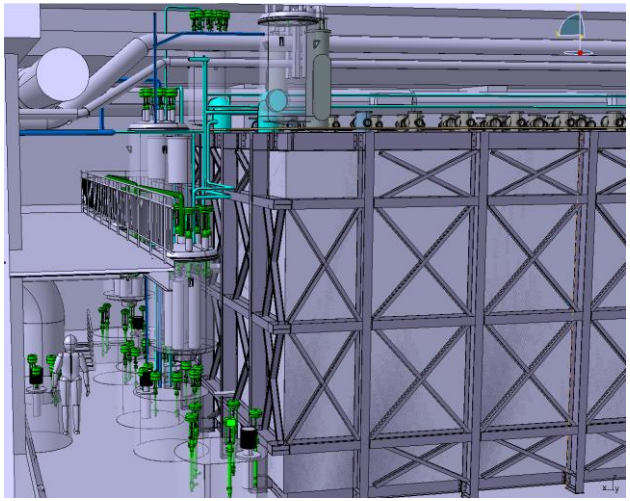
Process parameters of the lines connected to the valve boxes:

- Port name and type.
- Process pipe or not.
- Description.
- Dimensions → Vendor's task.
- Maximum allowable conditions (Pressure and Temperature).
- Operating conditions (Pressure, Temperature, Flow rate).
- Maximum mechanical loads → Vendor's task.

ICDs will be detailed by David

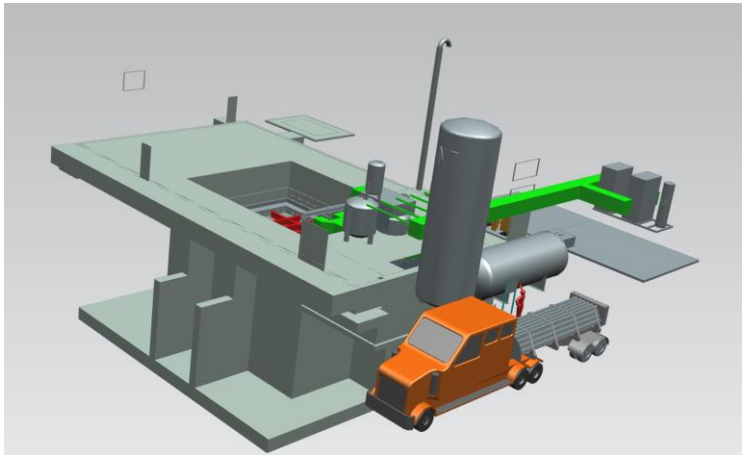
Annex 3 3D models

NP.01

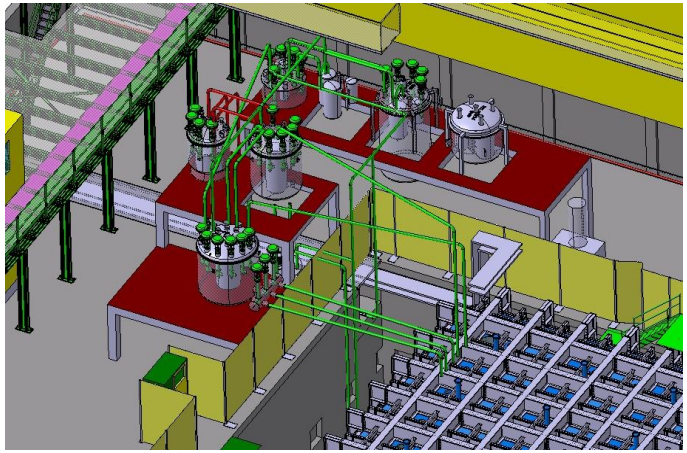


NP.02

NP.03

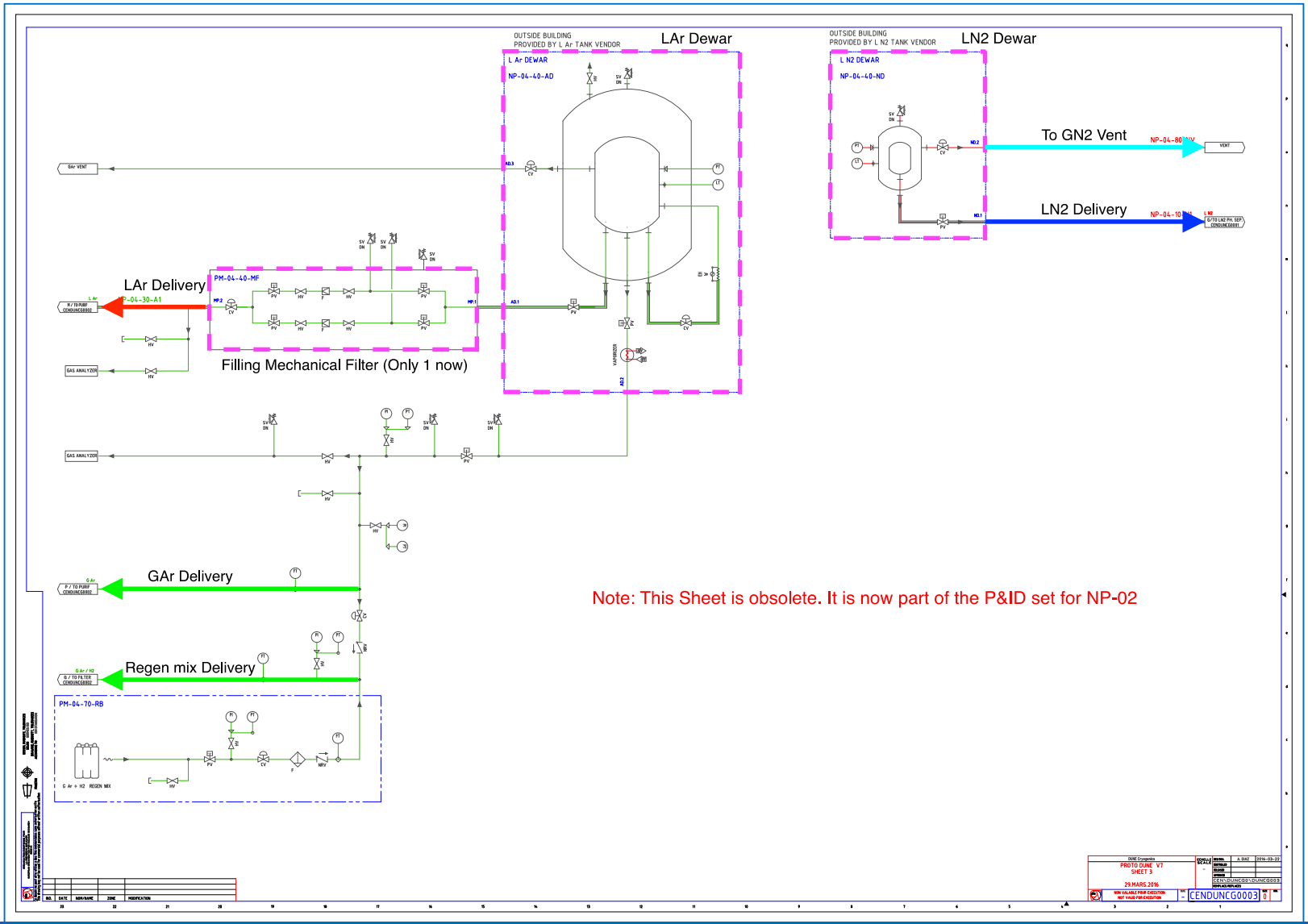


NP.04

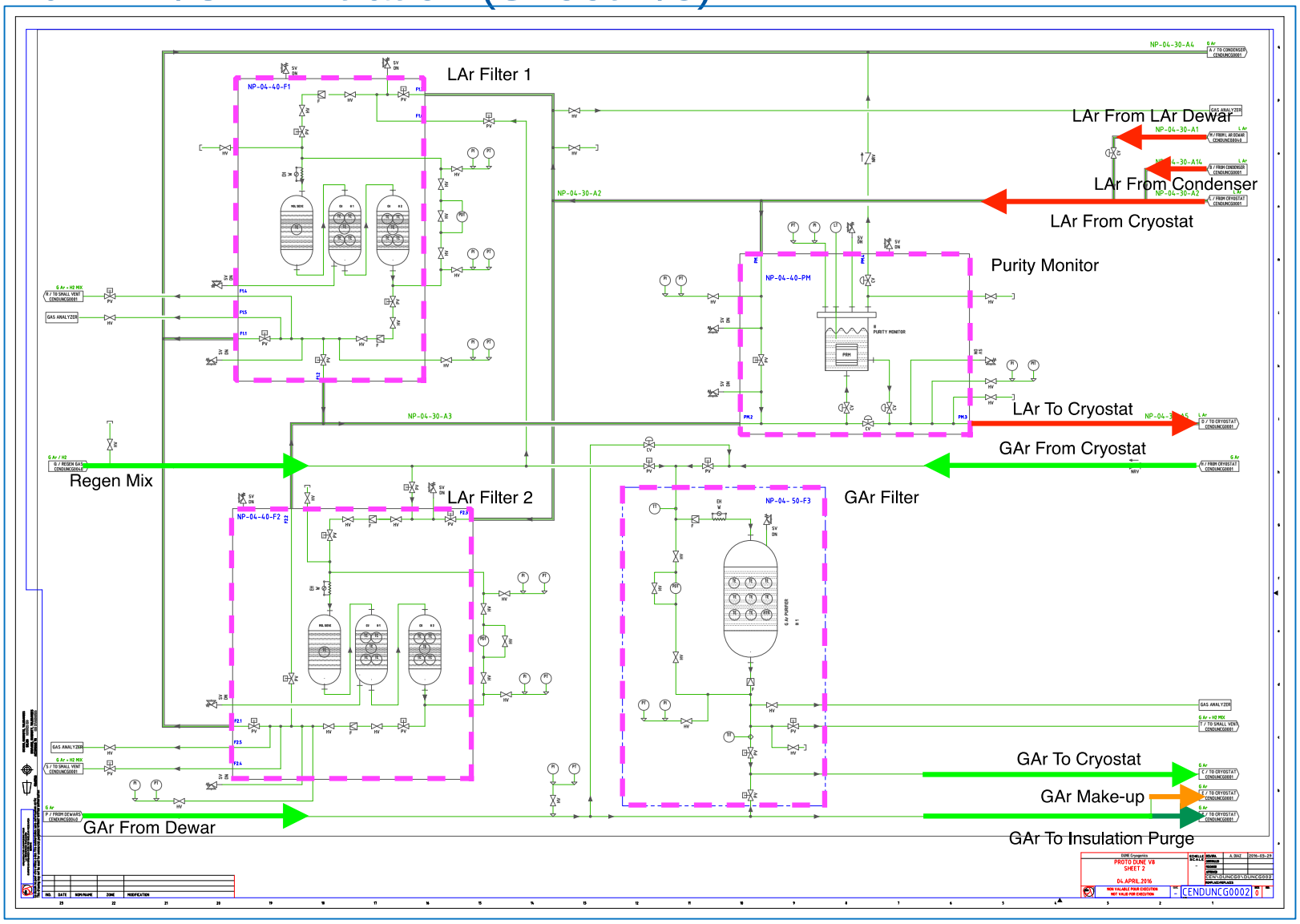


3D models will be detailed by Barry and Joaquim

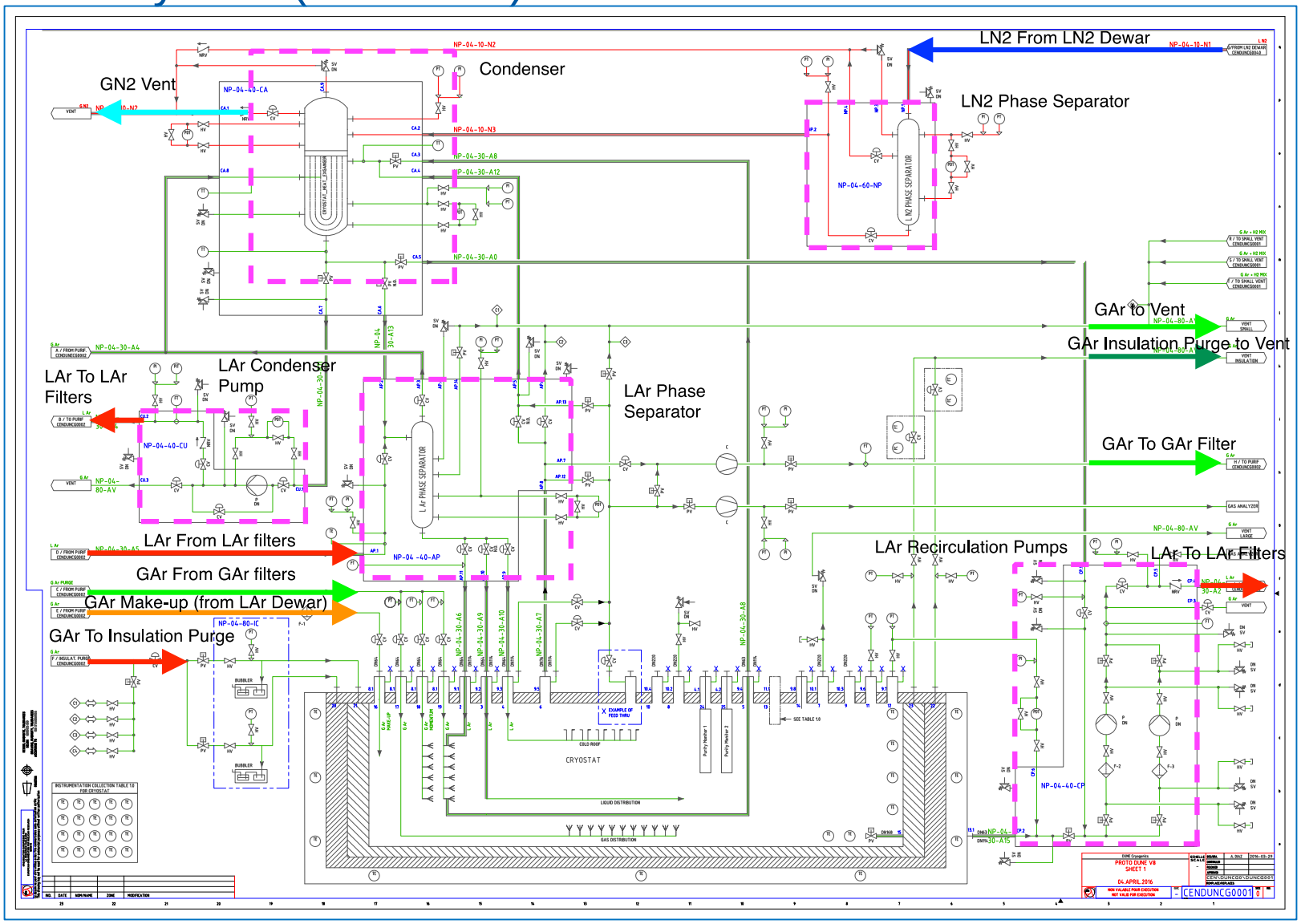
Annex 6: NP-04 Cryogen supply (Sheet 3/3)



NP-04 LAr/GAr Filtration (Sheet 2/3)



NP-04 Cryostat (Sheet 1/3)



Modes of operation for NP.01

1) **Pumping down / Purge**

- Vacuum pumps (turbo molecular pumps) are connected to the cold vessels and the argon circuit up to the Larg tank, around 2 months is needed of pumping to achieve 10-4mb, then pressurization of the cold vessels @1100mba with GAr (from liquid phase).

2) **Cool down**

- The thermal screen is cool down with LN2 circulating pump forced flow, the cold vessels and the detectors are cool down in free convection flow. The pressurization of the cold vessels are regulated with the LArg Tank.
- In addition at around 180K the filters and the condensers are cool down with the second LN2 circulating pump.

3) **Filling**

- Once the cryostats and TPC are cold, LAr is introduced in the cryostat.

4) **Normal operations**

- LAr is continuously passed through a purifier by means of an external LAr pump (1 per module but inter-connected).
- Boil-off GAr is recondensed outside of the cryostat and purified before being reintroduced as LAr.

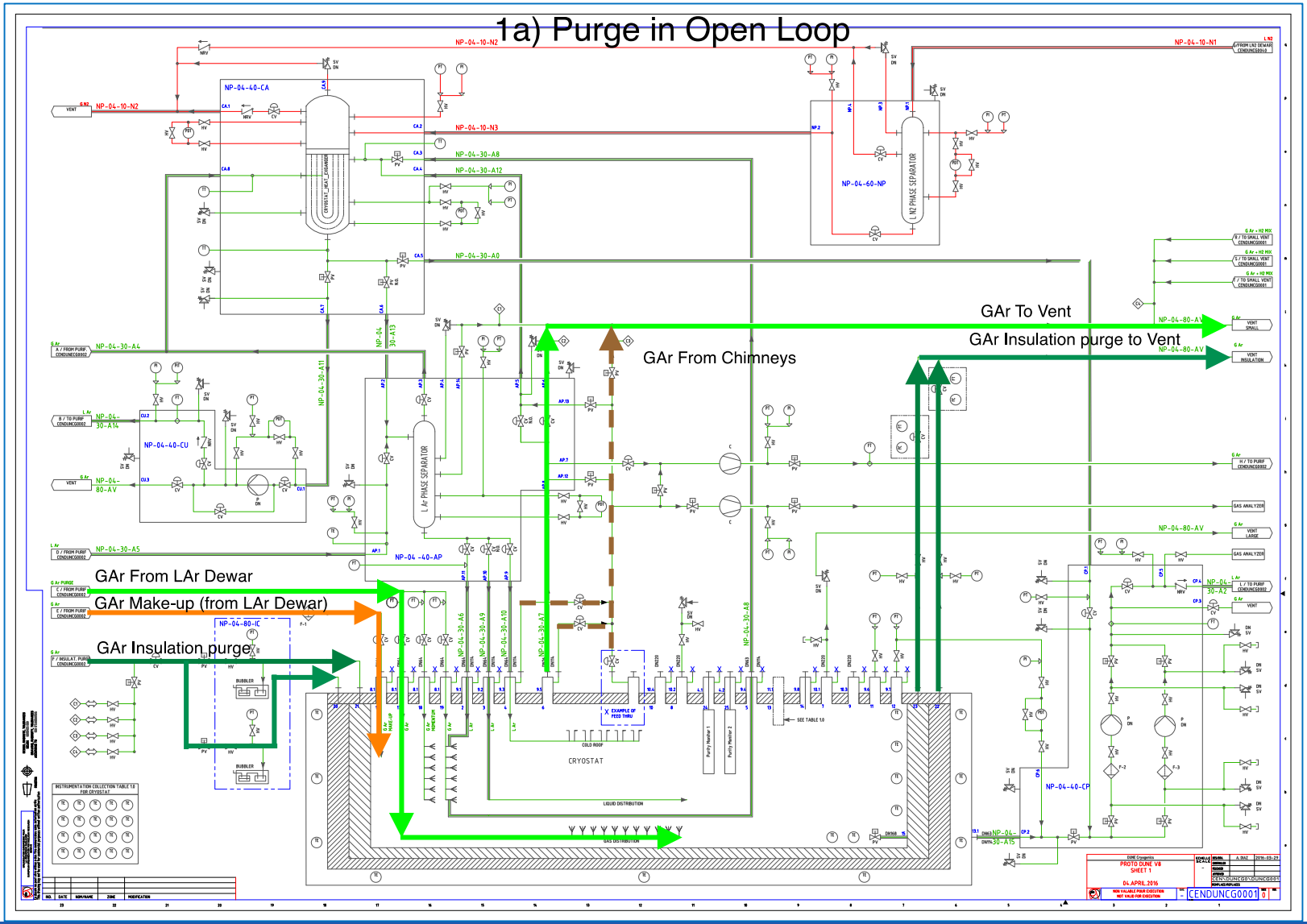
5) **Emptying**

- At the end of the operations (or if/when maintenance on the tank is needed), the tank is emptied and the LAr removed.

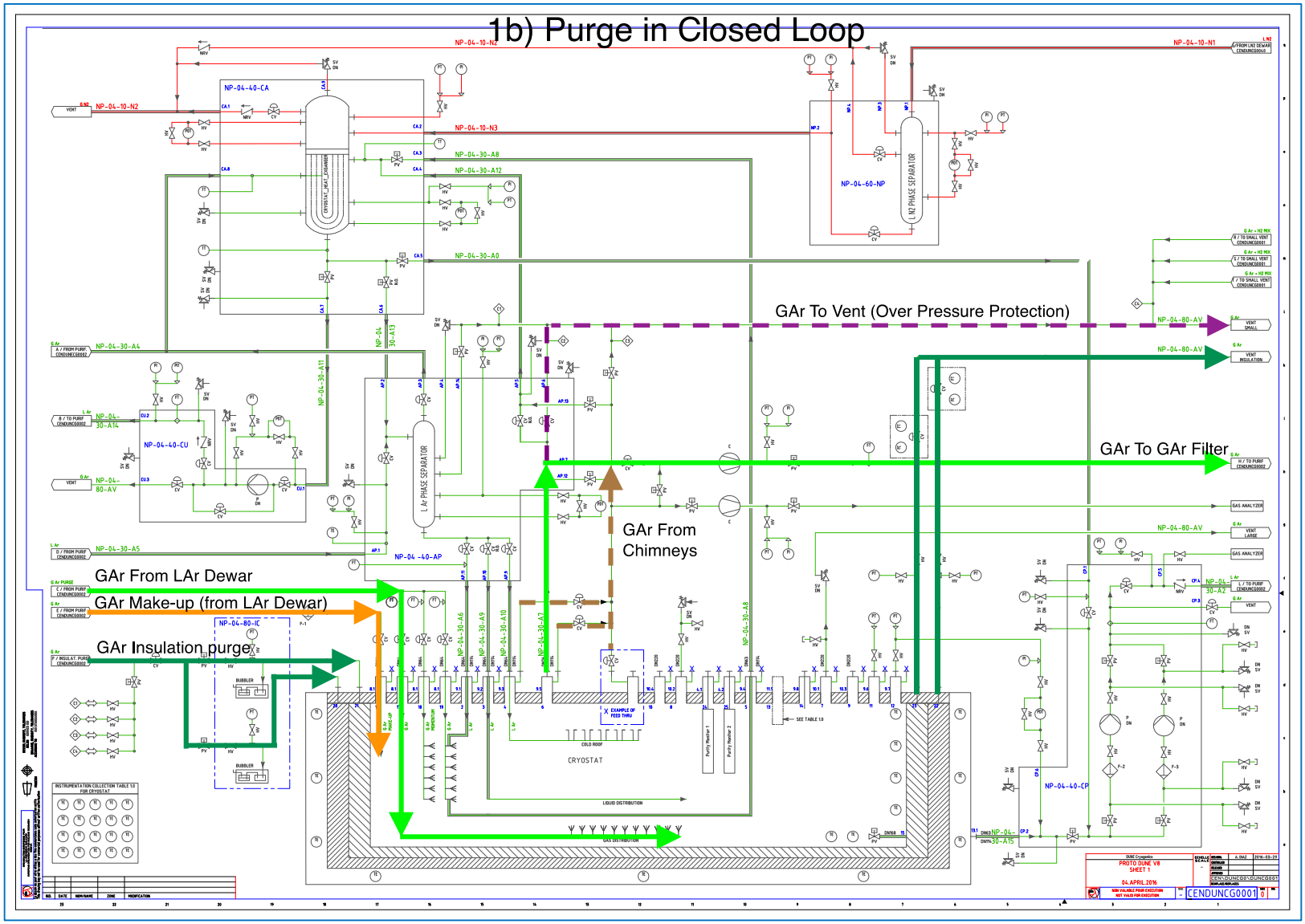
NP.02, NP.03, NP.4 Modes of operation

1) **Piston Purge**
   - GAr is slowly flown from the bottom of the tank to push the impurities out from the top.
2) **Cool down**
   - A mix of GAr and LAr is flown into sprayers to generate a mist of small liquid droplets that are moved around by another set of sprayers flowing GAr only.
3) **Filling**
   - Once the cryostat and TPC are cold, LAr is introduced in the cryostat.
4) **Steady state operations (normal and abnormal)**
   - LAr is continuously passed through a purifier by means of an external LAr pump (2 are installed for redundancy, but only one is in use).
   - Boil-off GAr is recondensed outside of the cryostat and purified before being reintroduced as LAr.
5) **Emptying**
   - At the end of the operations (or if/when maintenance on the tank is needed), the tank is emptied and the LAr removed.

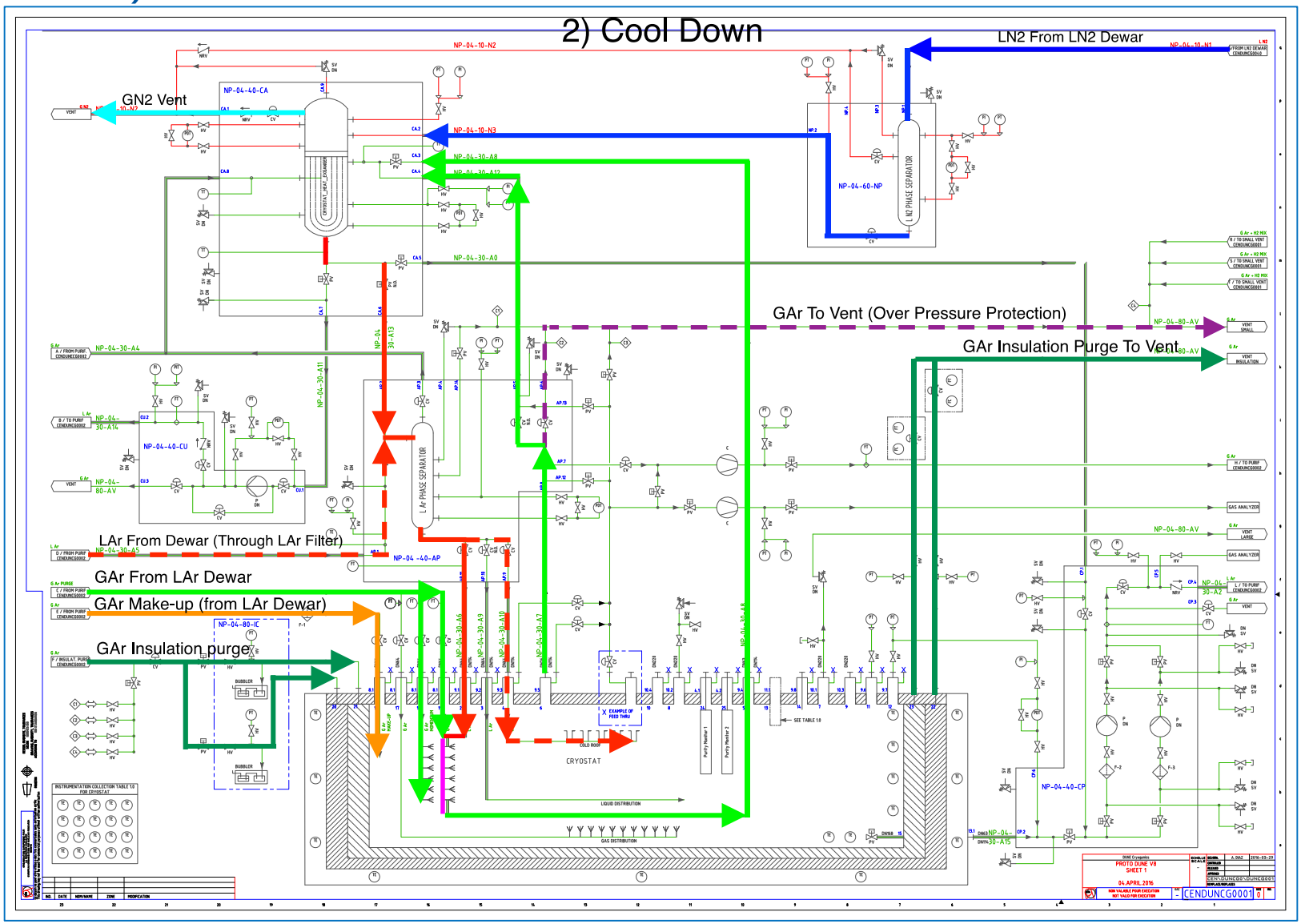
NP-04 1a) Purge in Open Loop



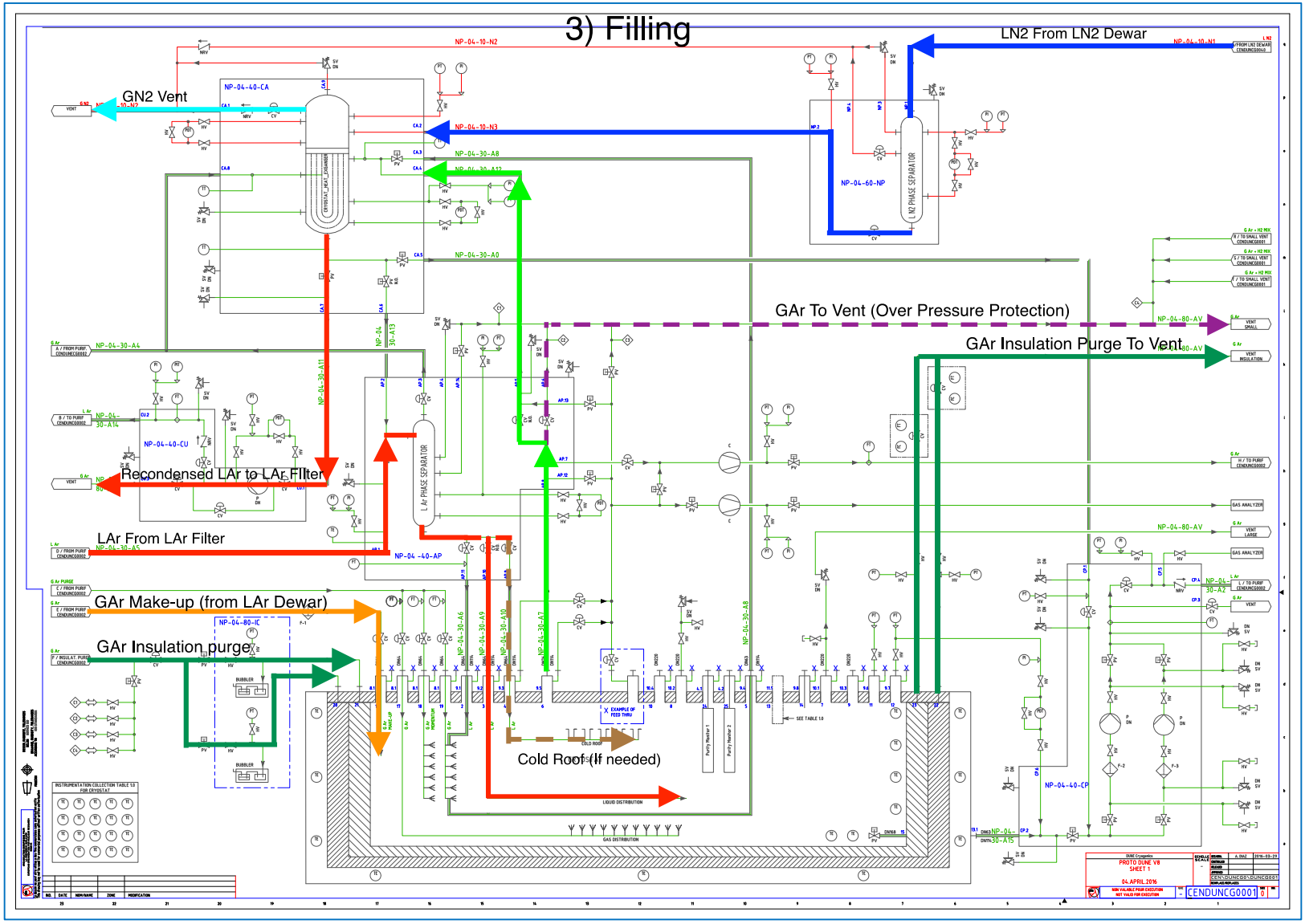
NP-04 1b) Purge in Closed Loop



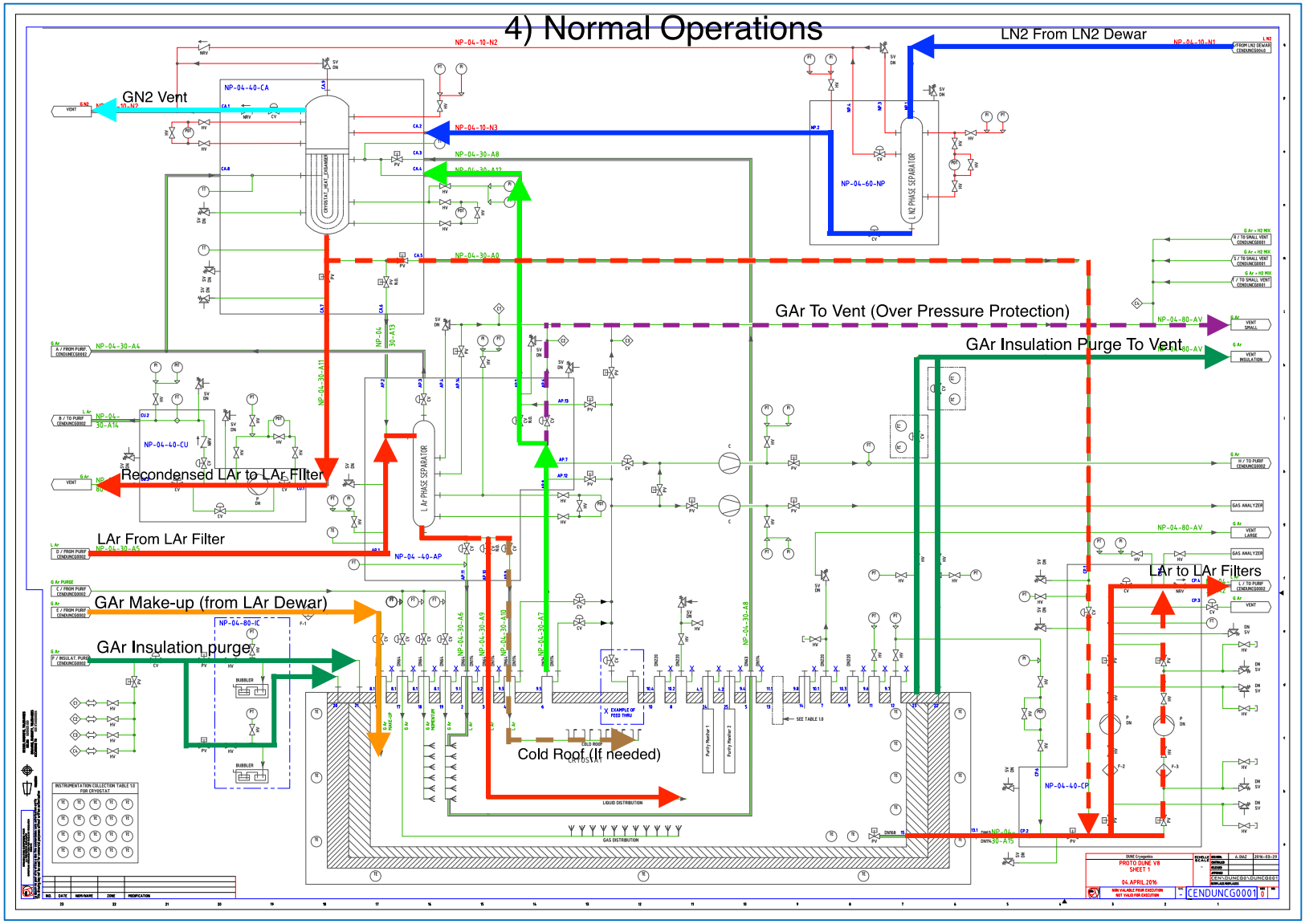
NP-04 2) Cool down



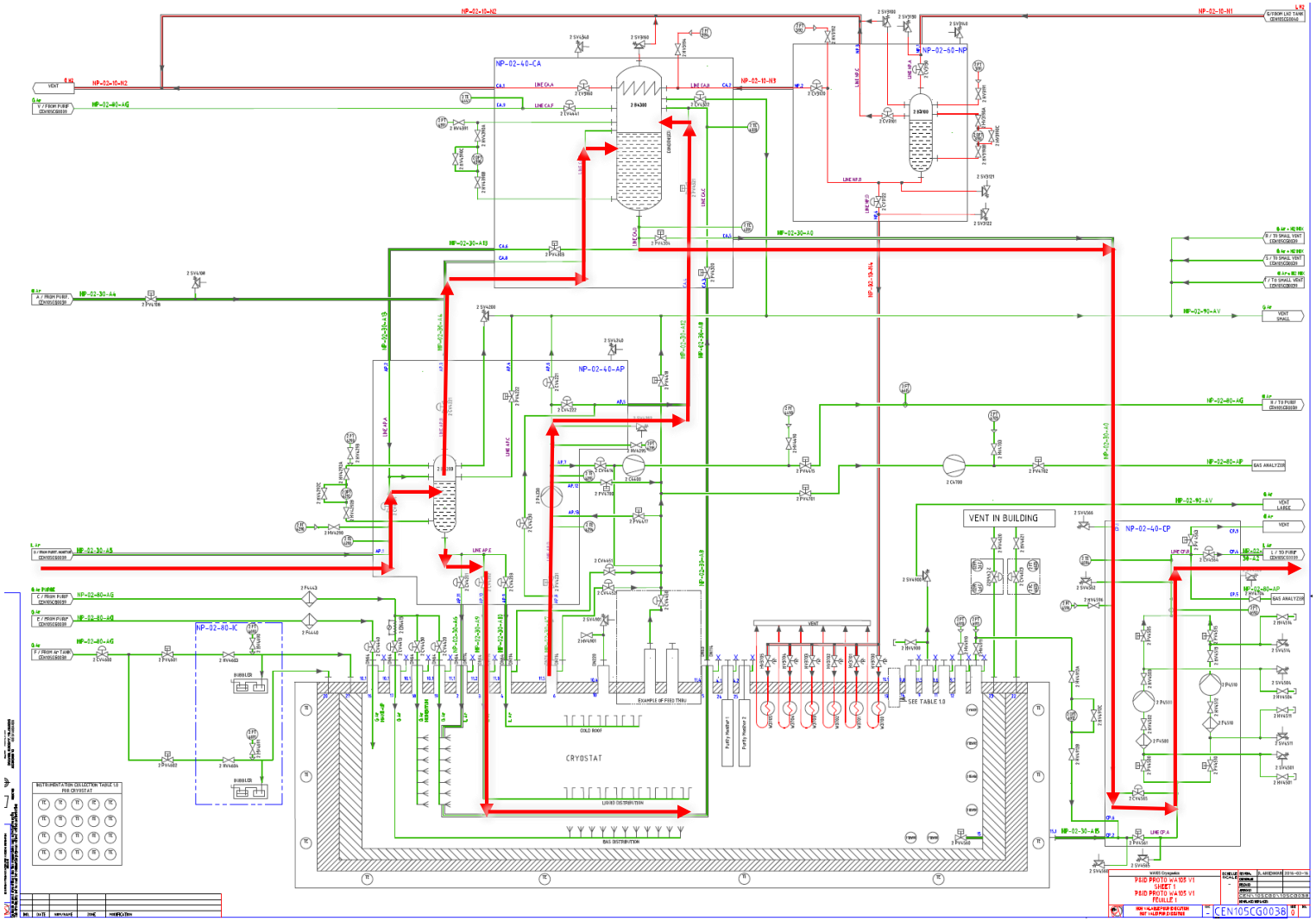
NP-04 3) Filling



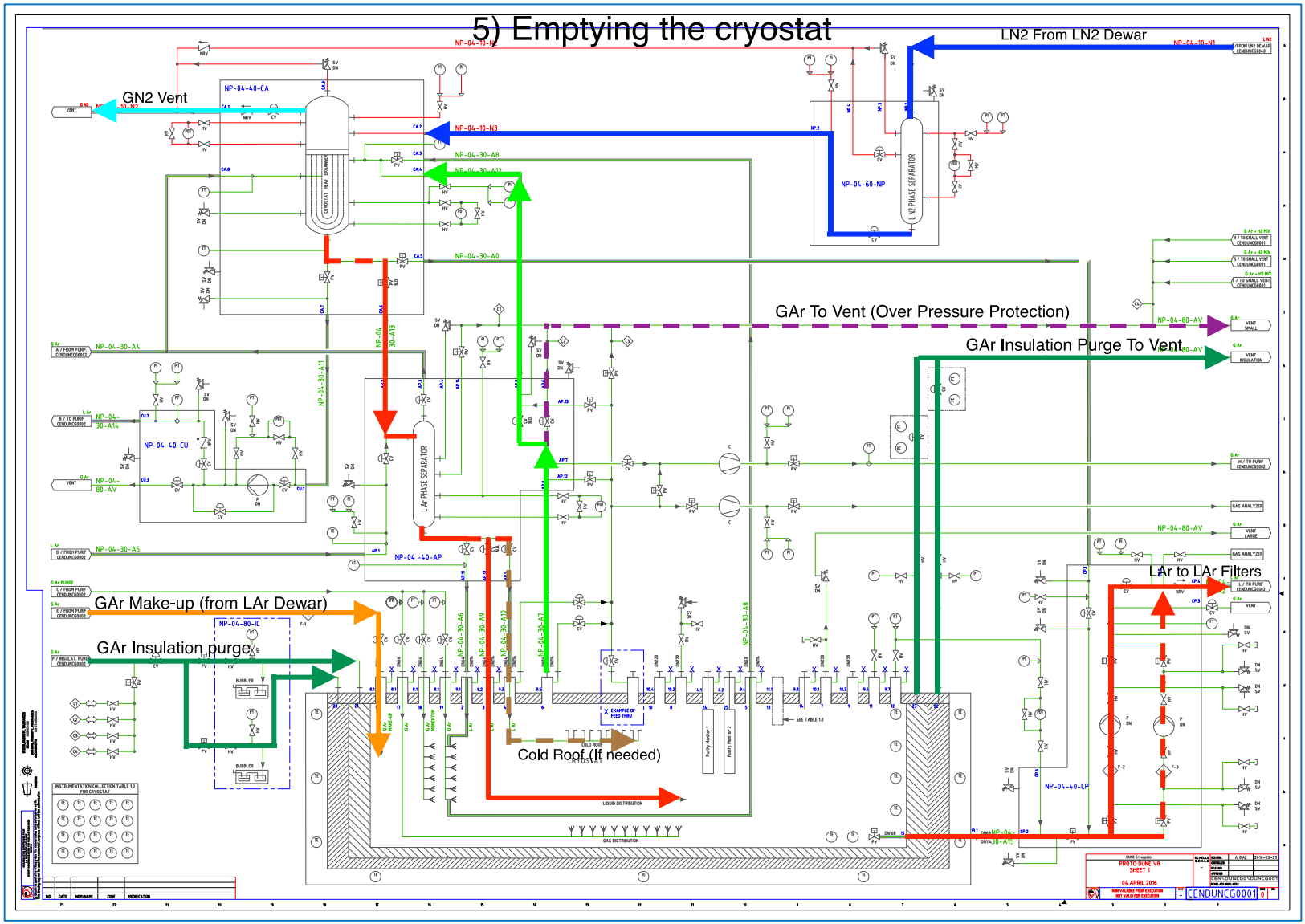
NP-04 4) Normal Operations



NP-02 4) Normal Operations with a Cold Compressor



NP-04 5) Emptying



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