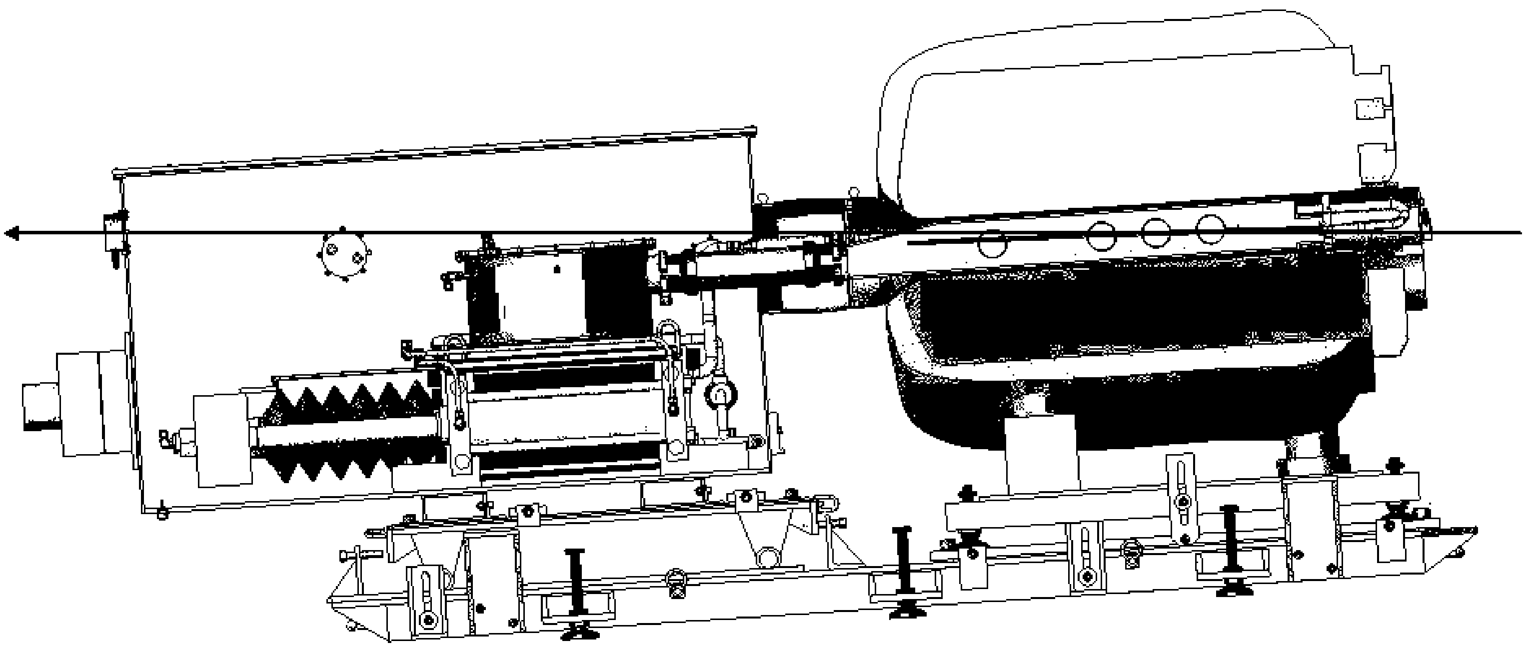
Organisation Européenne pour la Recherche Nucléaire
European Organization for Nuclear Research
Laboratoire Européen pour la Physique des Particules
European Laboratory for Particle Physics

Accelerator Technology Department

Cooling System for the MERIT High-Power Target Experiment



Haug F., Pereira H., Silva P., Pezzetti M., Pavlov O., Pirotte O., Metselaar J., Efthymiopoulos I., Fabich A., Lettry J., Kirk H., McDonald K., Titus P., Bennet R

Tucson, Arizona, USA
June 30, 2009

Summary

Introduction

Experimental Setup

Experimental Location and Layout

Operation

Results

Conclusion

Introduction

Proof-of-principle test of a target station suitable for future neutrino factory or muon colliders. Muon beams are obtained from the decay of pions produced with intense proton beams intercepted by suitable targets.

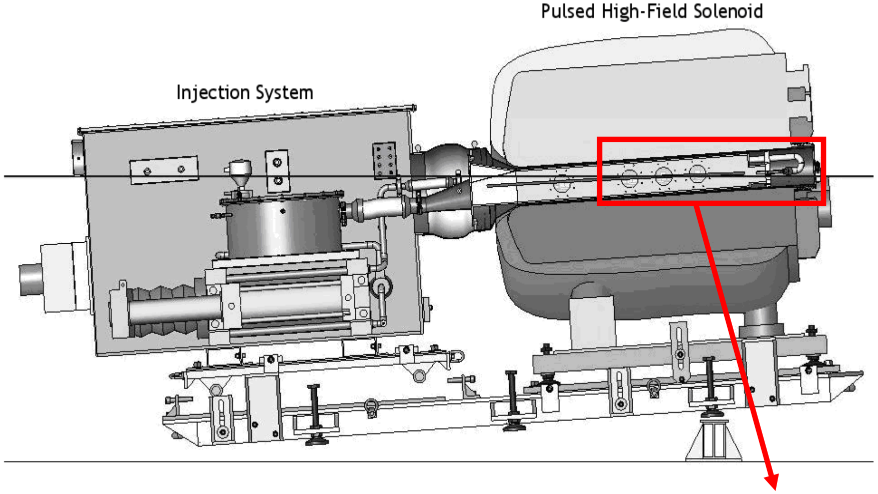
A fast extracted high-intensity proton beam intercepts a free mercury jet inside a normal conducting pulsed 15 T capture solenoid magnet cooled with liquid nitrogen.

The main objective is the optical observation of the jet target dispersal by the sudden energy deposition of the beam and the influence of the high magnetic field on the stability of the jet.

Up to 30 MJ of Joule heating is dissipated in the magnet during a pulse.
A fully automated, remotely controlled cryogenic cooling system of novel design permits the transfer of nitrogen by the sole means of differential pressures inside the vessels.

Experimental Setup

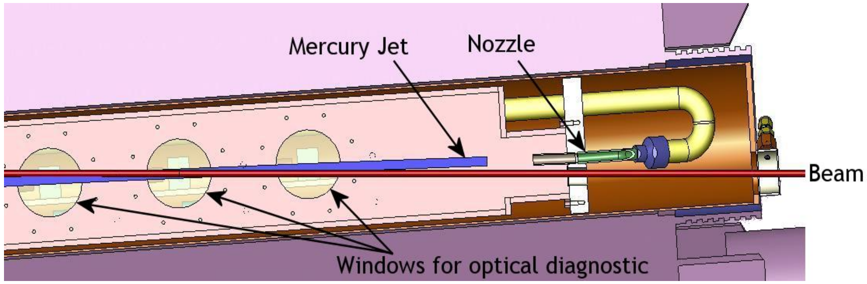
Magnet mated with the Hg injection system:



Beam, target and magnet:

Up to 24-GeV proton beam;
Free Hg jet target moving at ≤ 20 m/s;
15 Tesla capture solenoid;
Cooling to LN2 temperature.

Optical windows and beam-target interaction:



Experimental Setup

Magnet:

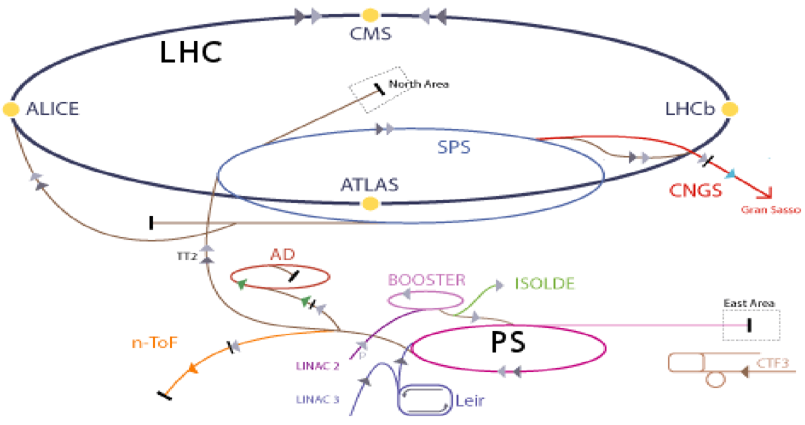
Installation:

Hg System:

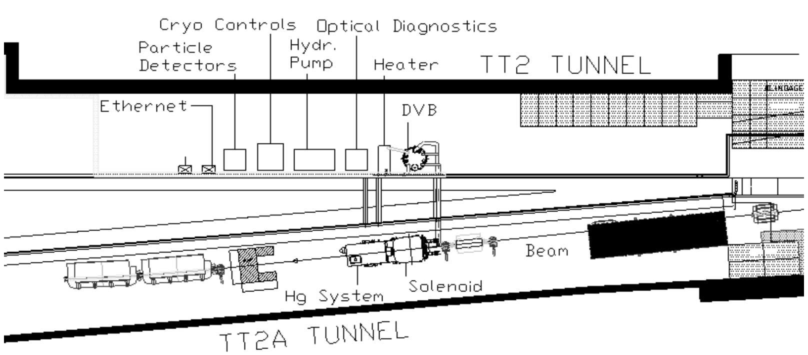
DVB:

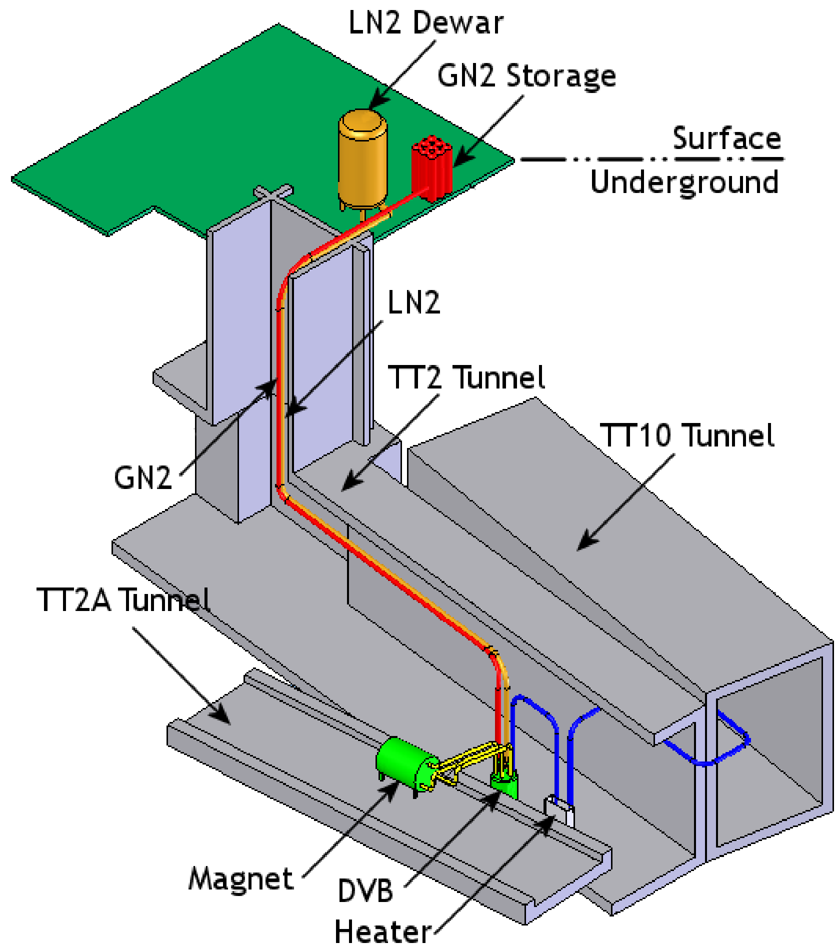
Experiment Location and Layout

CERN accelerator complex:



TT2/TT2A tunnels of CERN PS:





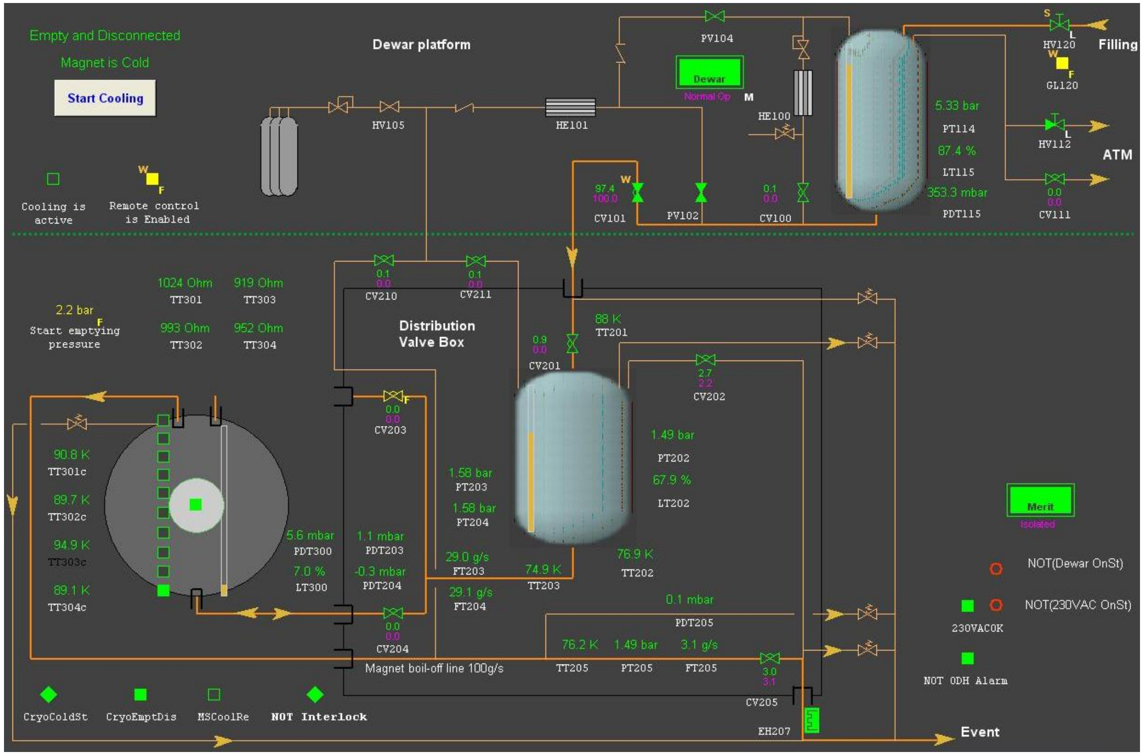
Operation

Automated remote control of the complete cryogenic process:

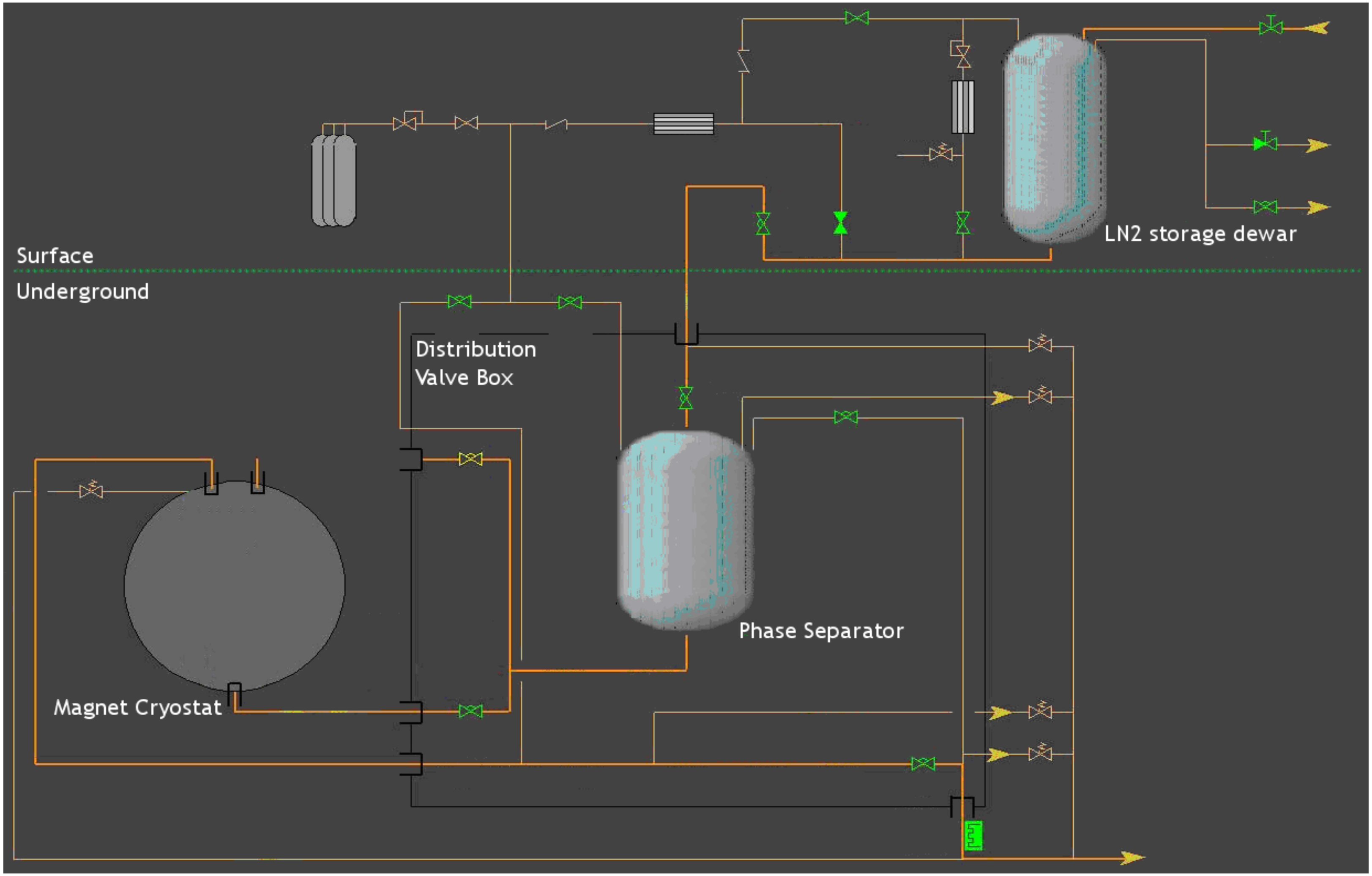
CERN Standard for Slow Controls based on a Schneider Electric PLC TLX Premium and a remote PVSS supervision station connected via Ethernet.

Operation Modes:

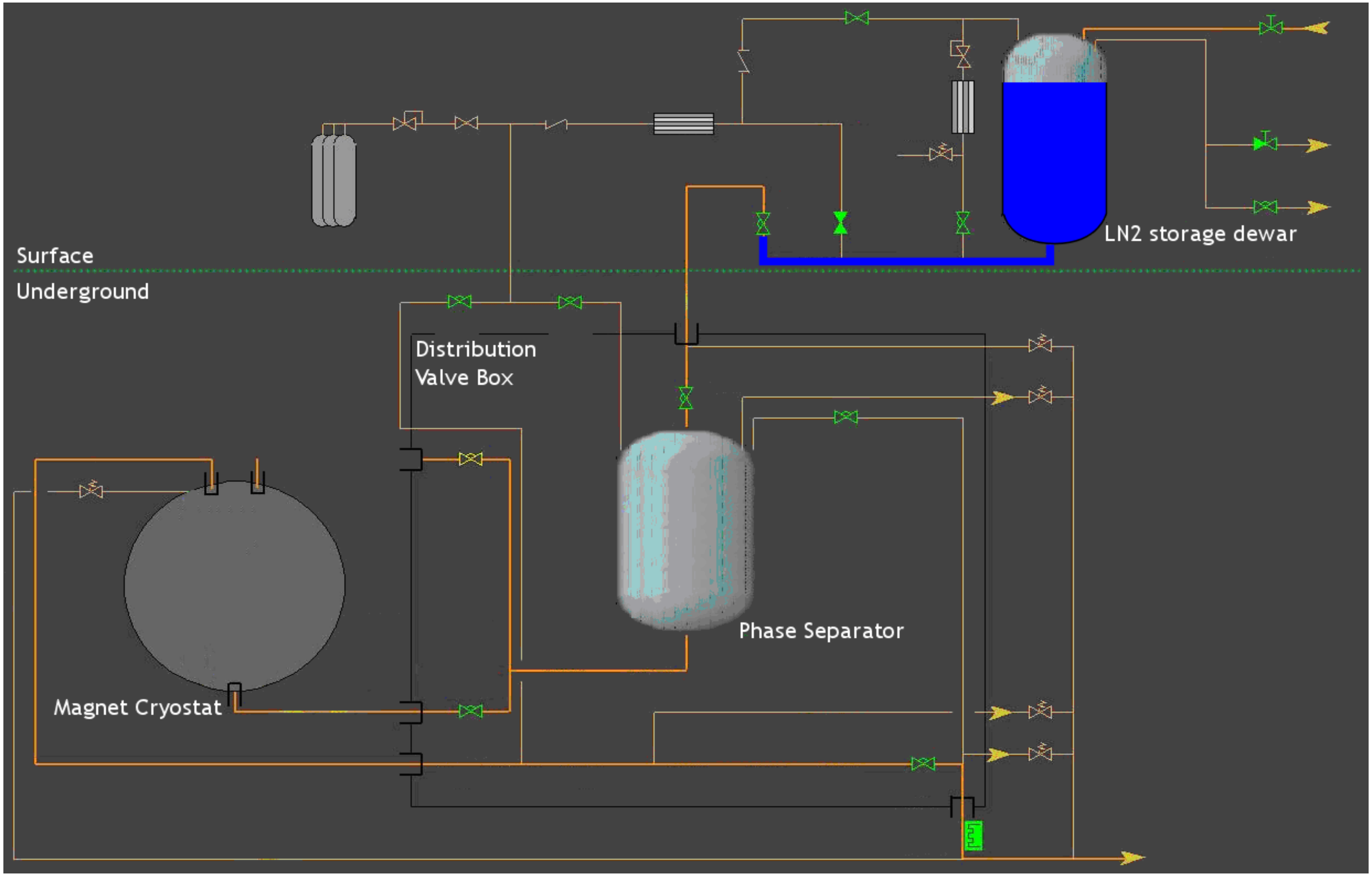
Cooling of proximity cryogenics;
Magnet cool down;
Emptying of the magnet cryostat;
Magnet pulse;
Re-cooling.



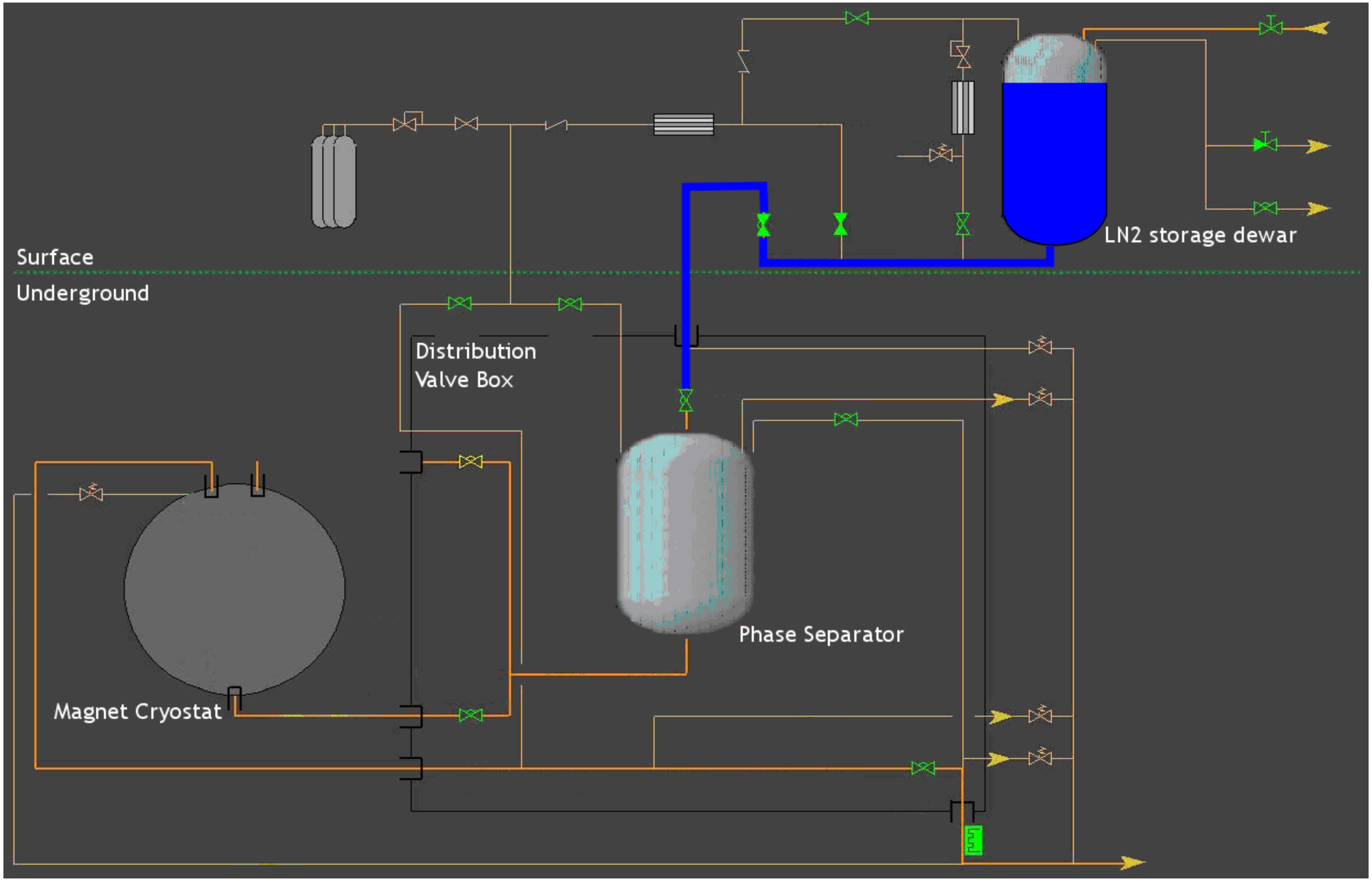
Operation - Standby



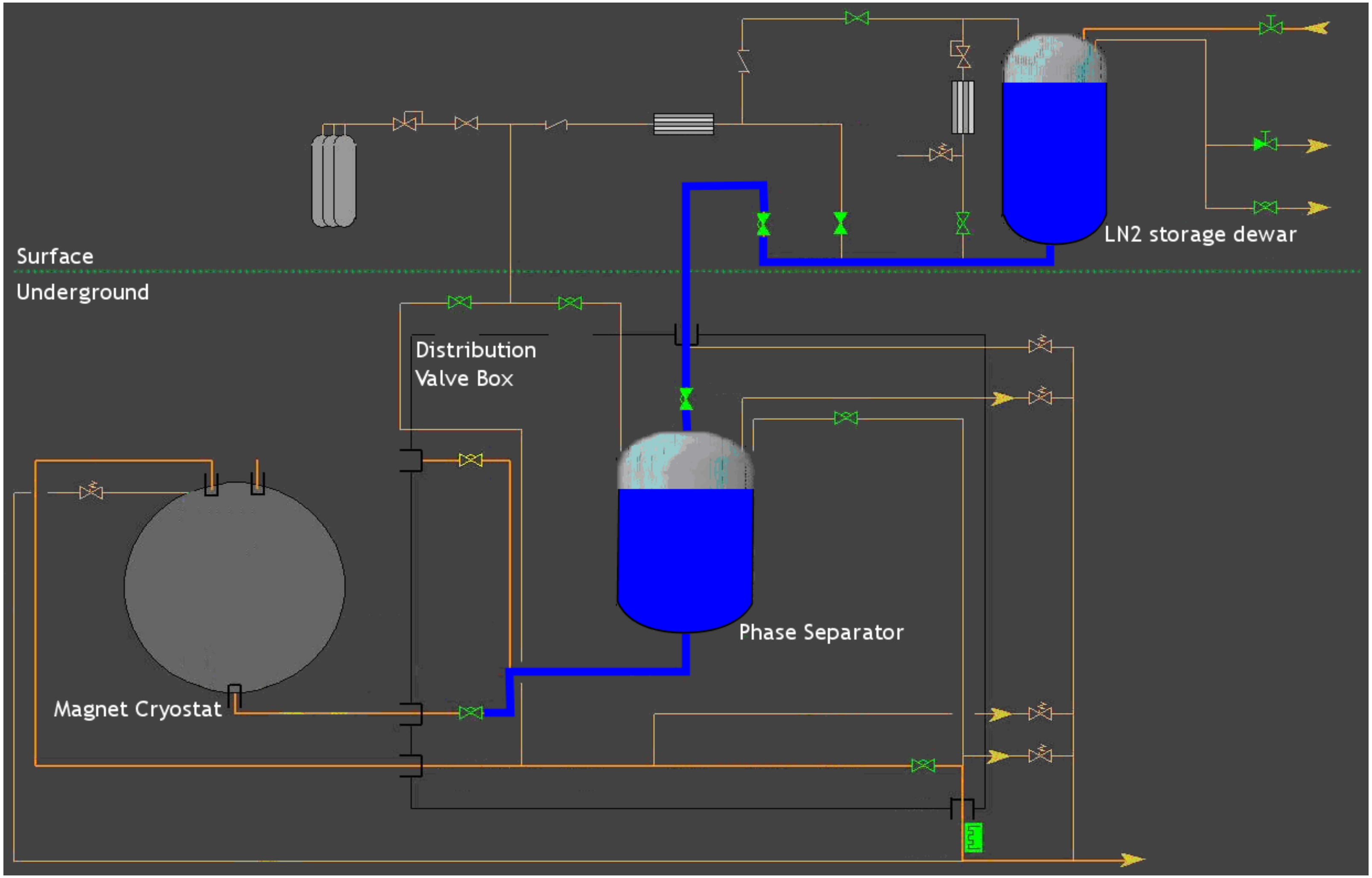
Operation - Standby



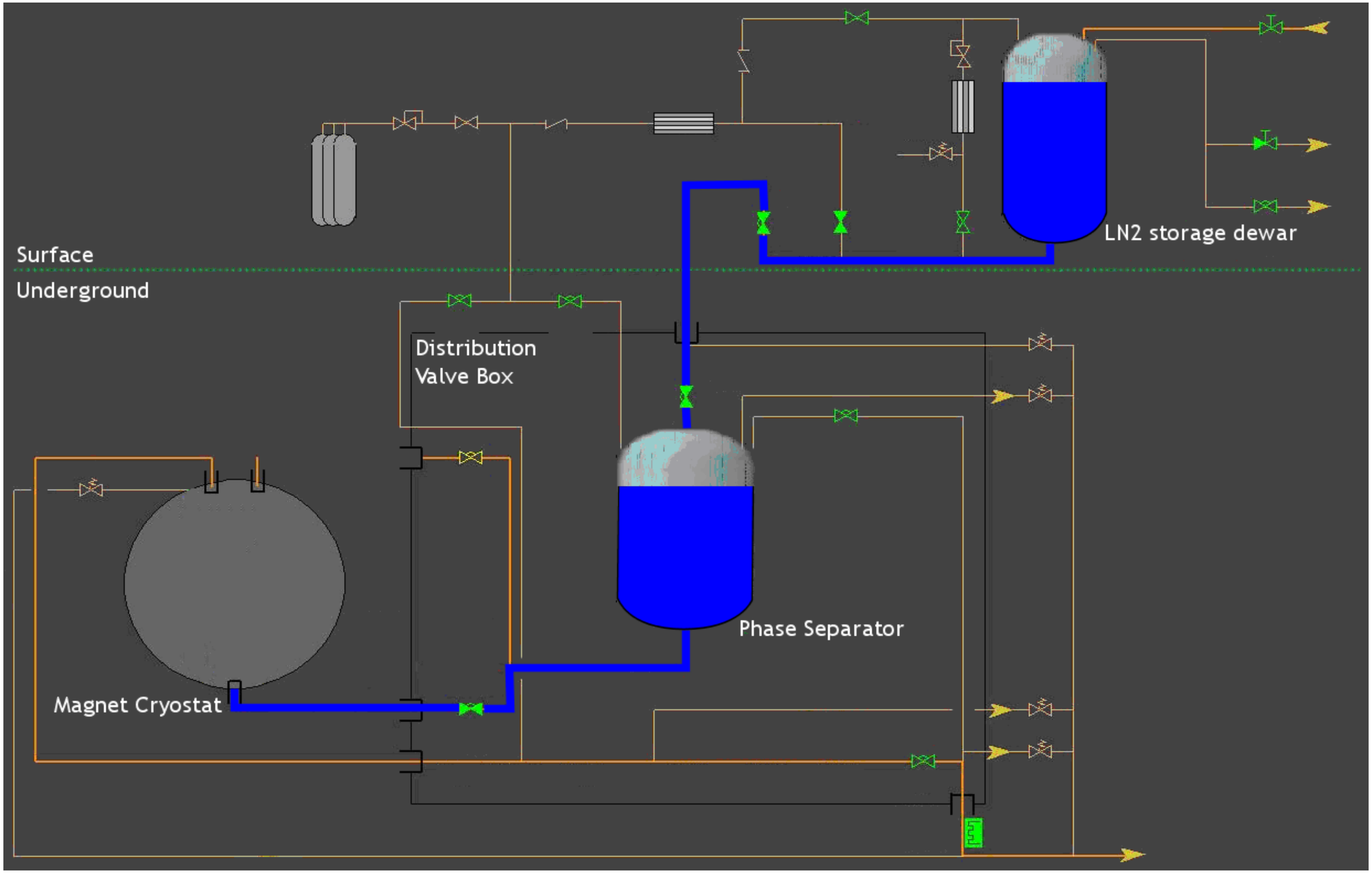
Operation – Cooling of proximity Cryogenics



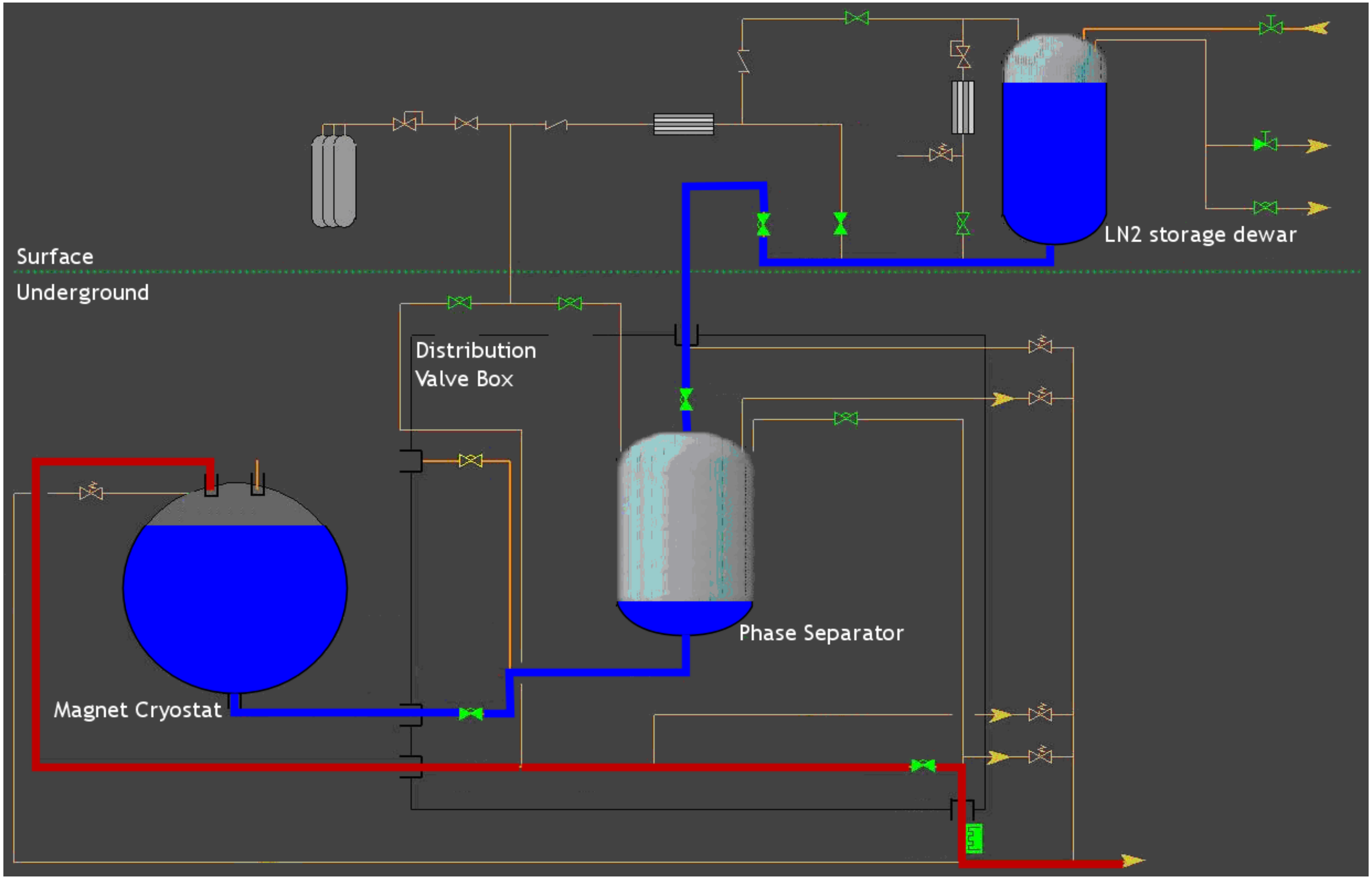
Operation – Cooling of Proximity Cryogenics



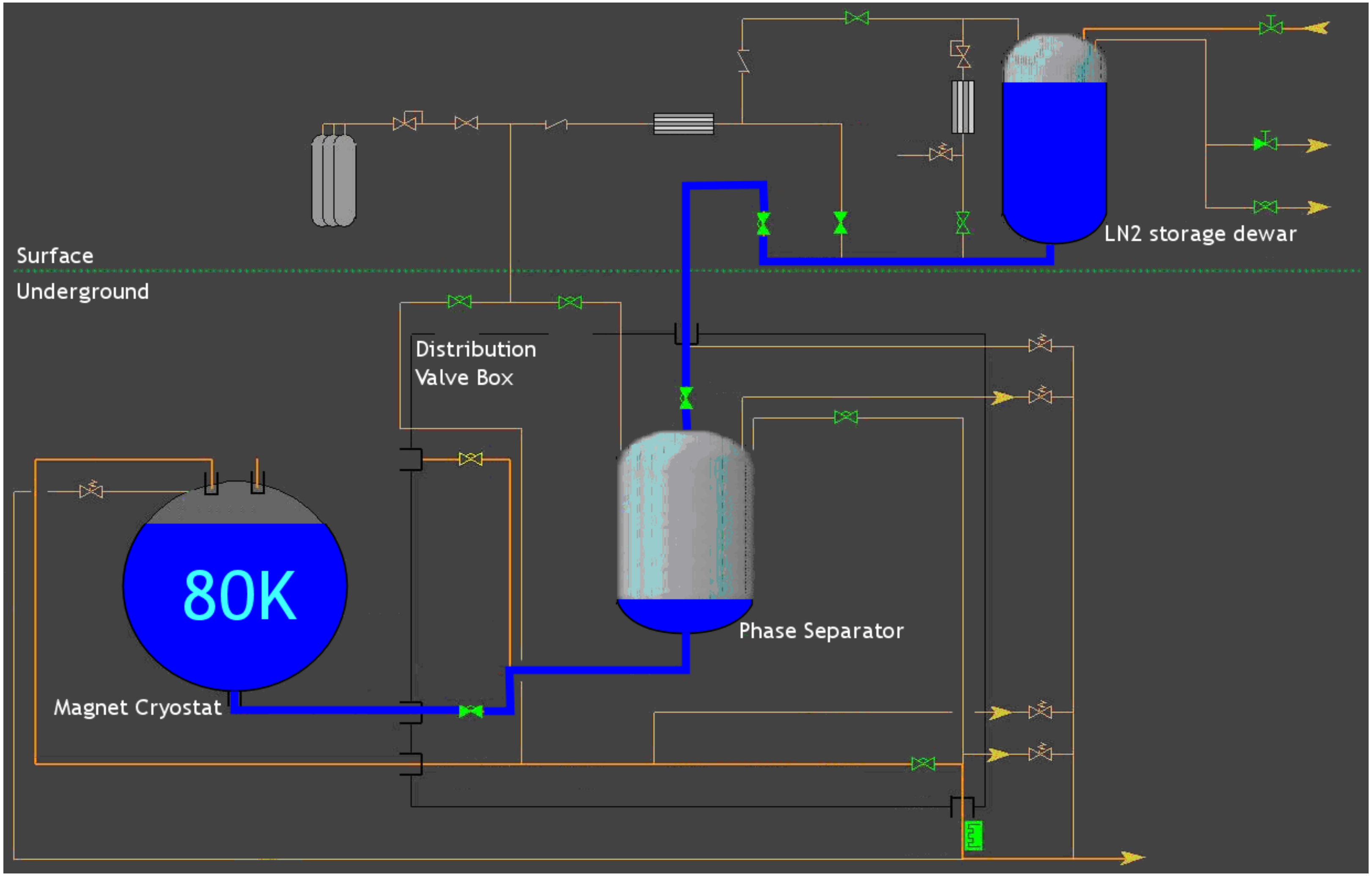
Operation - Cooldown

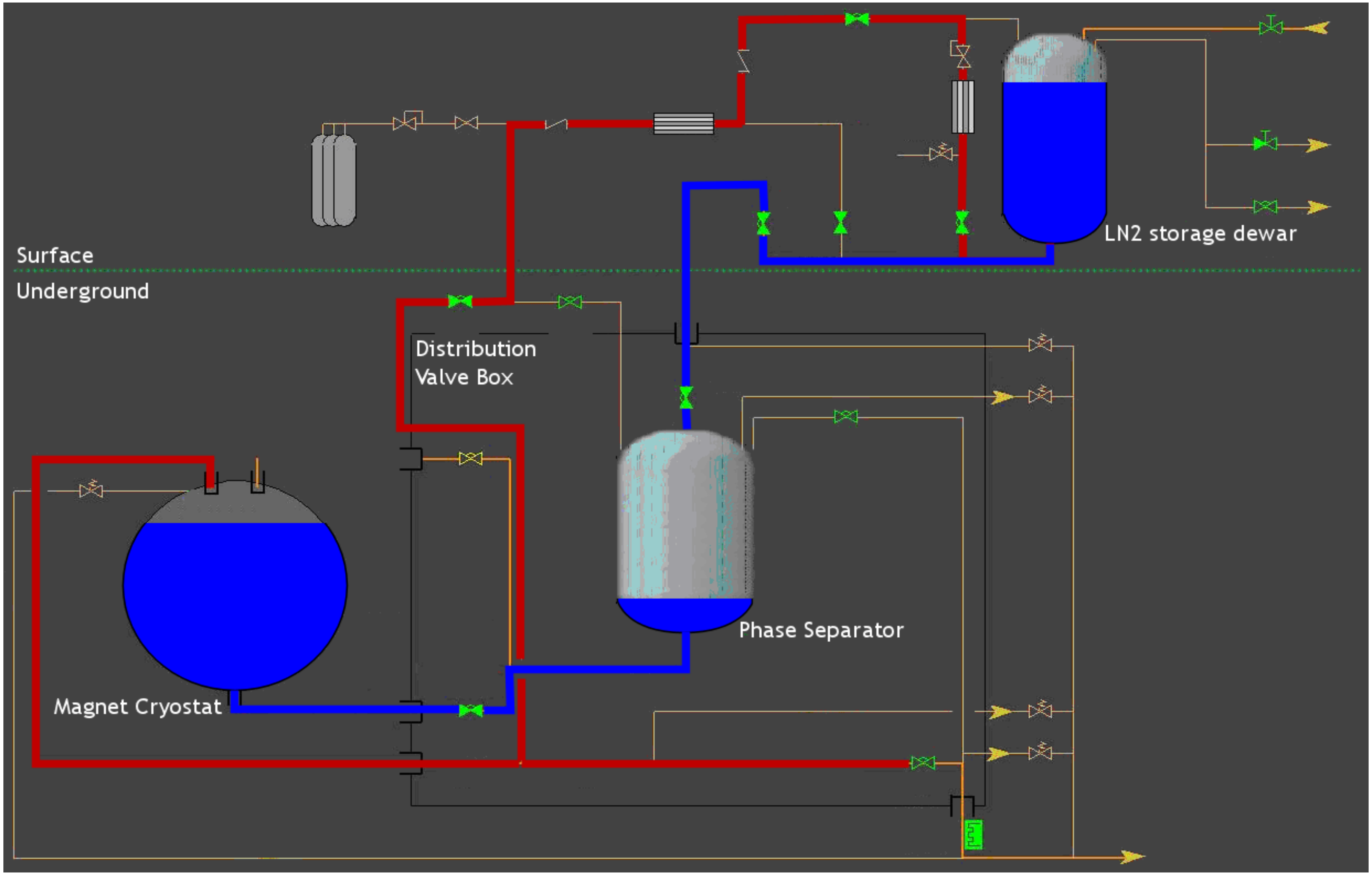


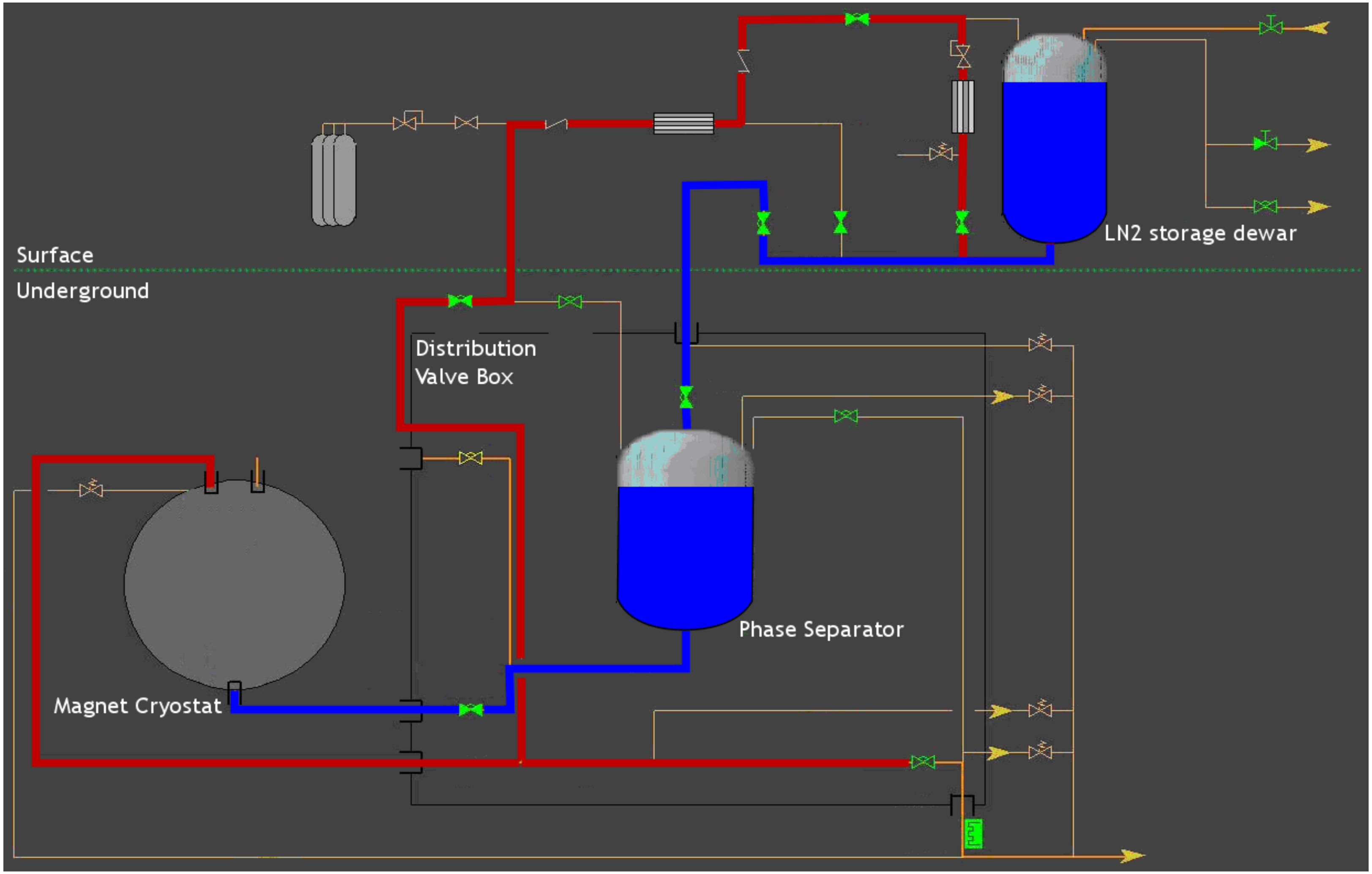
Operation - Cooldown



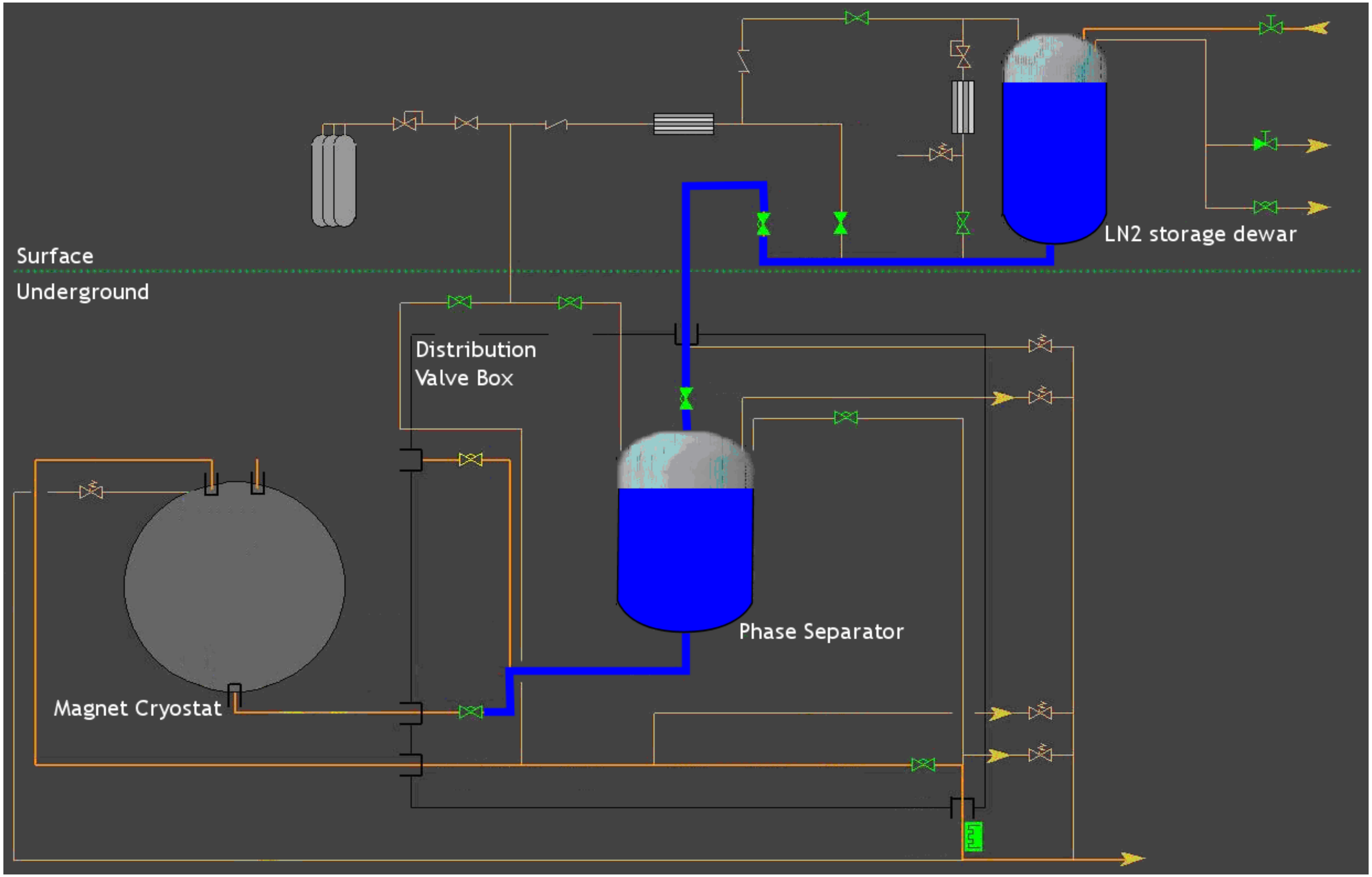
Operation – Magnet at 80K



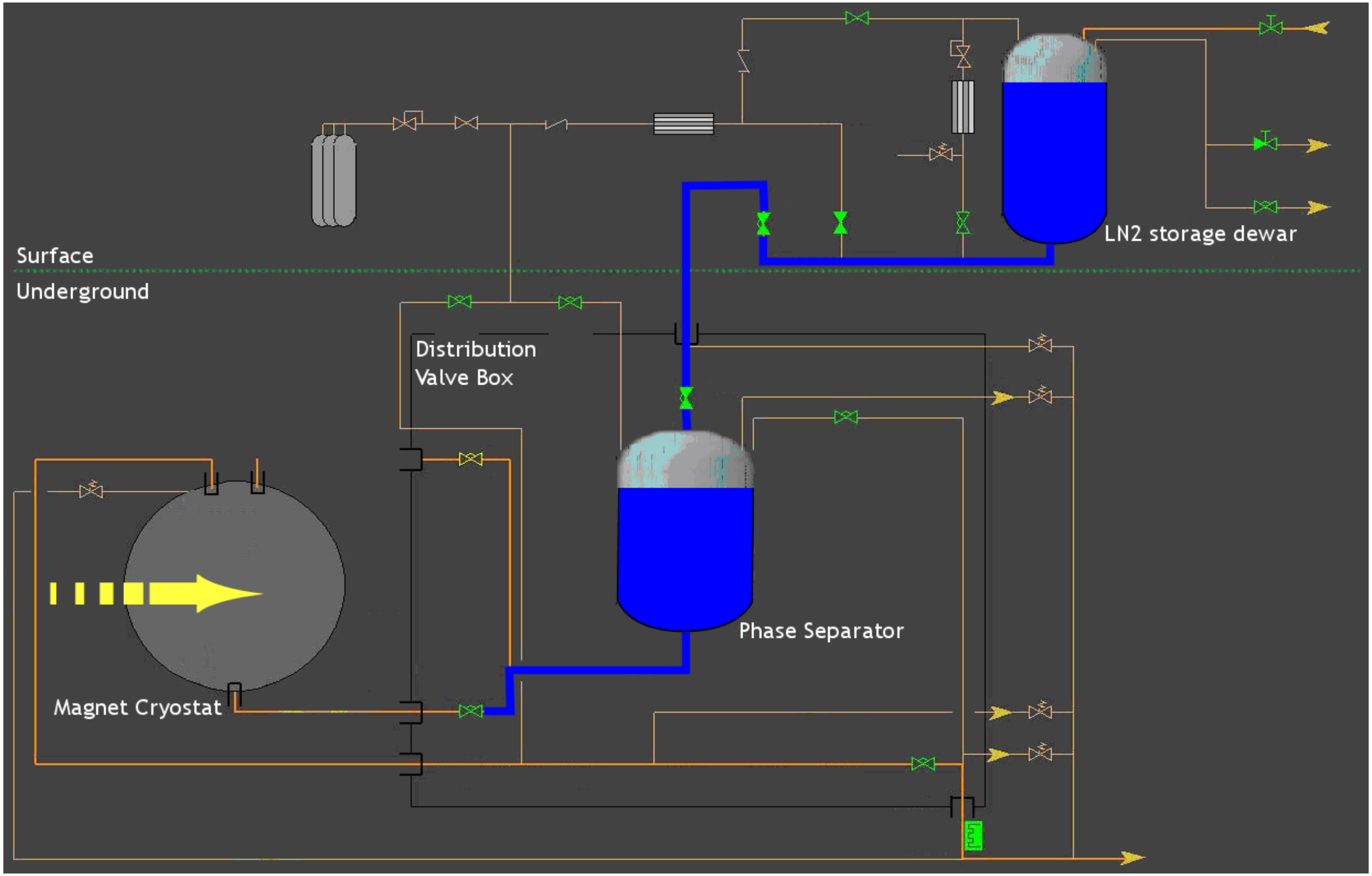

Surface
Underground
LN2 storage dewar
Distribution
Valve Box
Phase Separator
Magnet Cryostat


Surface
Underground
LN2 storage dewar
Distribution
Valve Box
Phase Separator
Magnet Cryostat

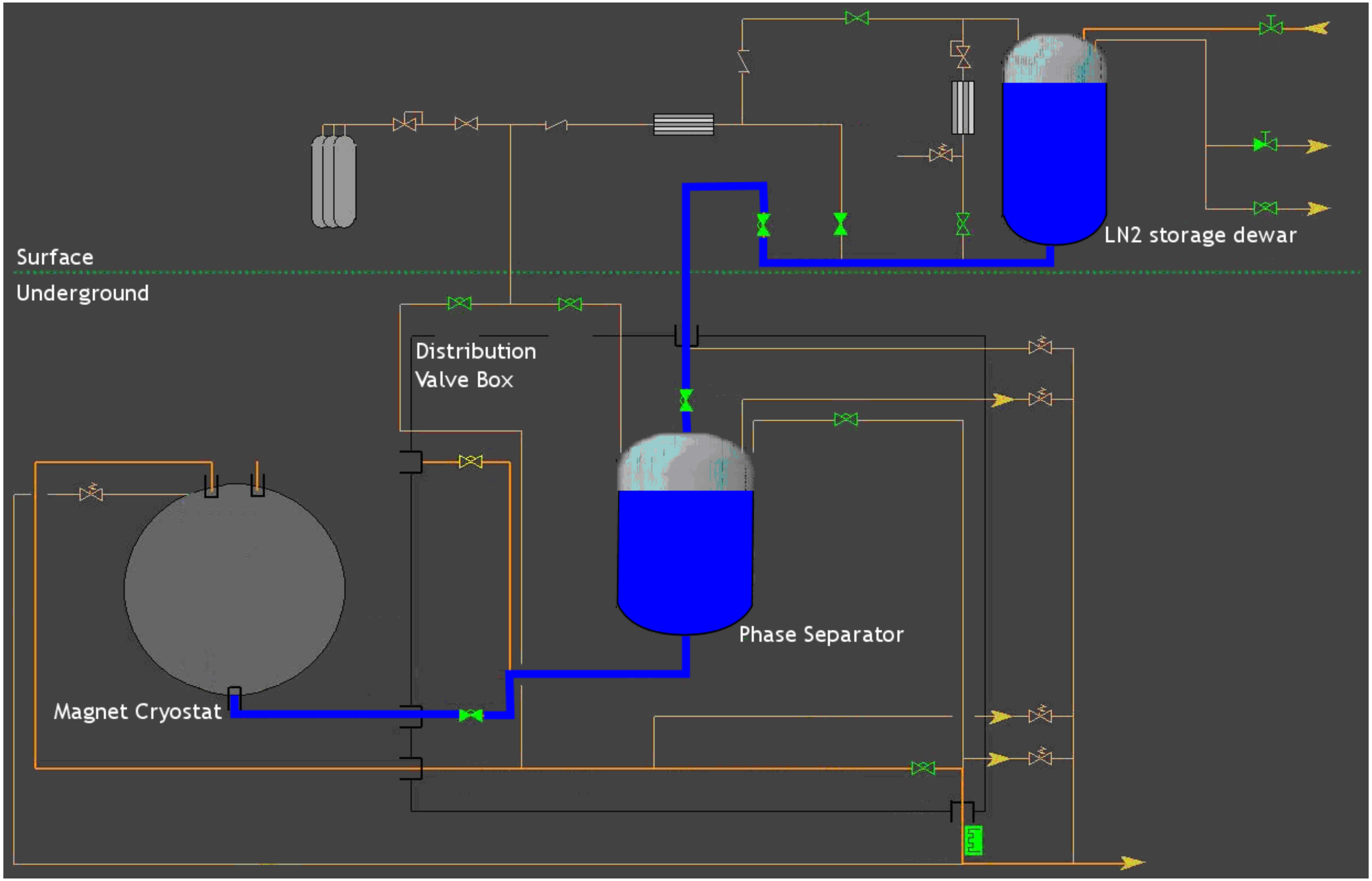
Operation – Magnet Cryostat is Empty



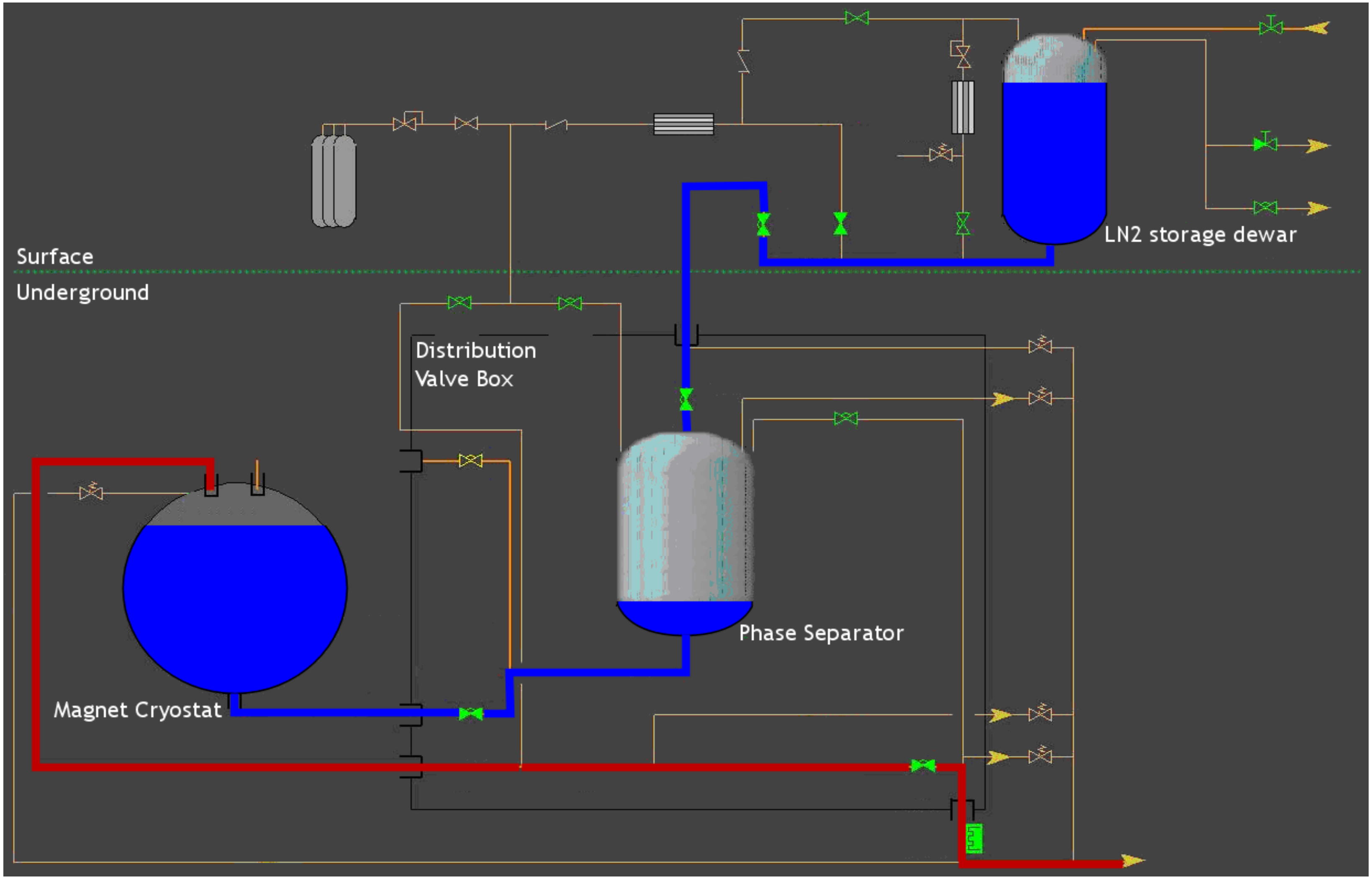
Operation – Magnet Pulse



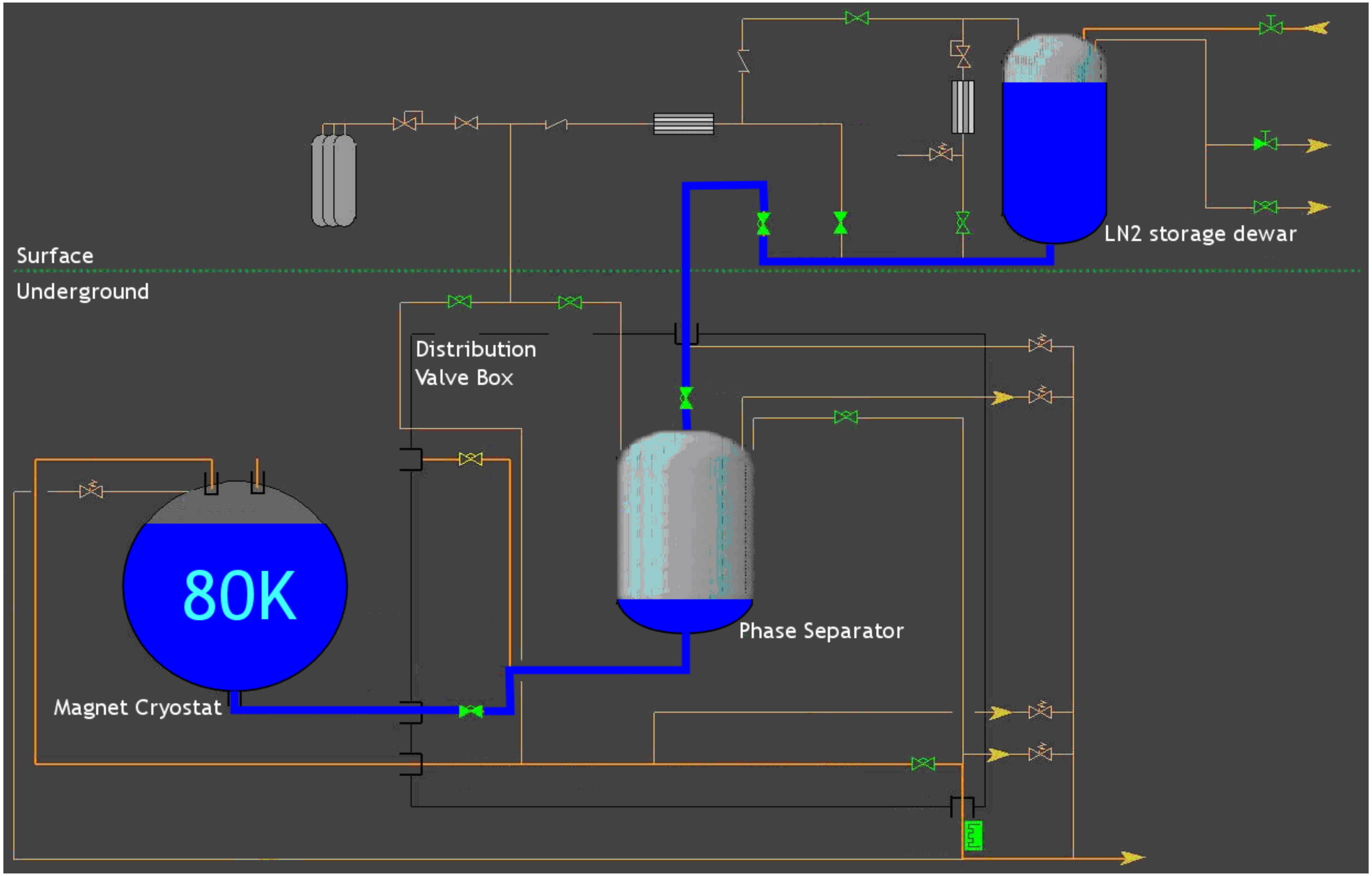
Operation – Re-cooling



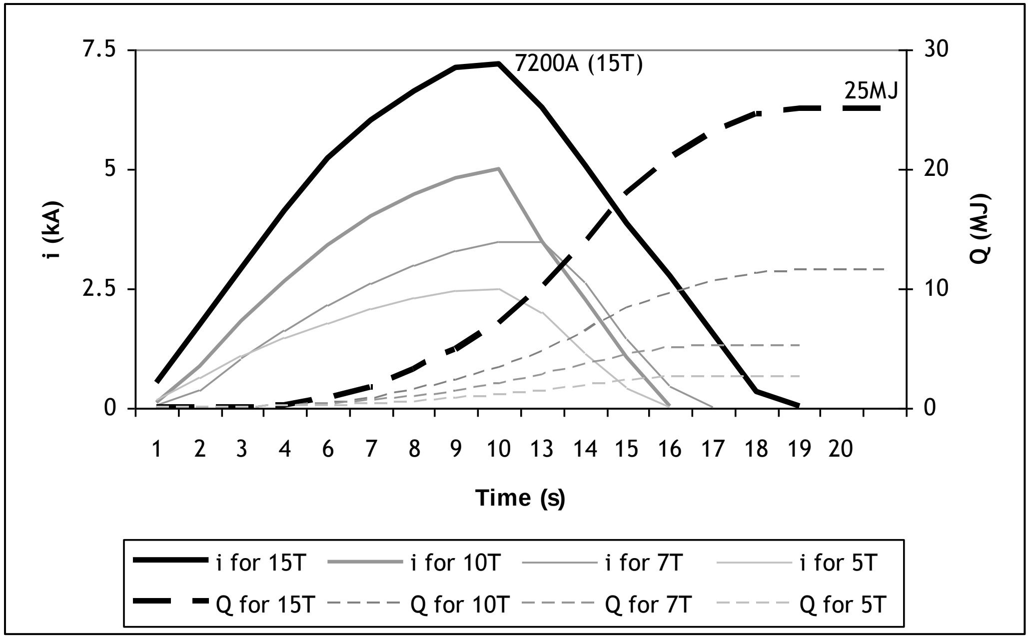
Operation – Re-cooling



Operation – Re-cooling



Results – Current Pulse and Energy Input

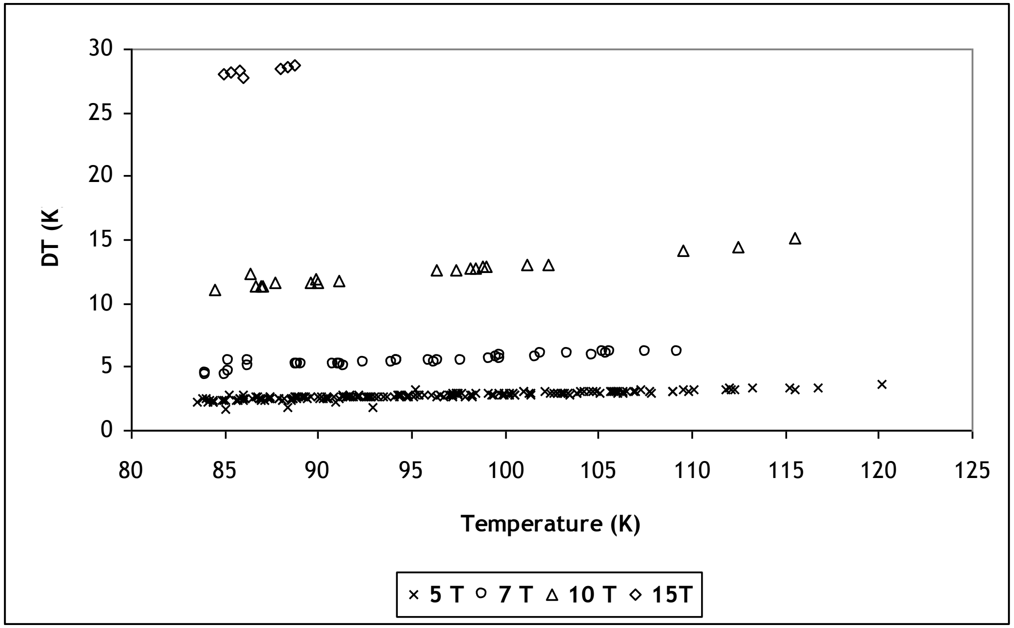


Typical magnet current input profile:

Ramp-up: 9s;
Flat-top: 1s;
Ramp-down 5s.

Magnetic Field (T)	∫Energy Input (MJ)	Number of shots
5	3	119
7	5	35
10	12	22
15	25	7

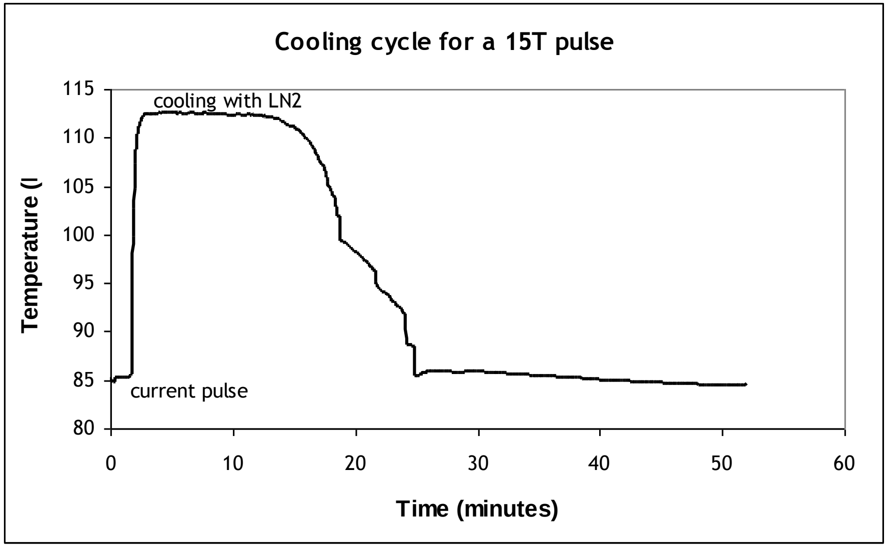
Results – Temperature Increase for Current Input

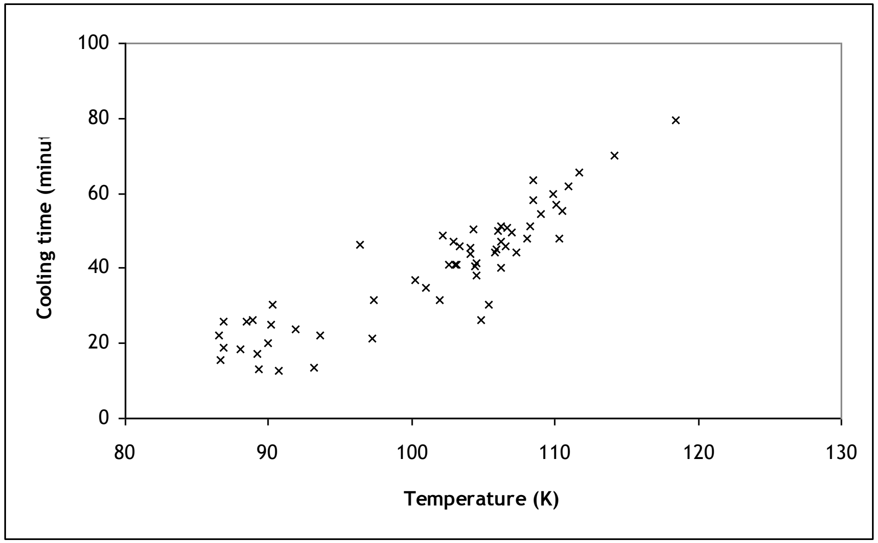


>250 current input pulses performed.

Magnetic Field (T)	ΔT (K)	Number of shots <110K
5	3-4	9
7	5-6	5
10	11-15	5
15	28-29	1

Results – Cooling Cycle

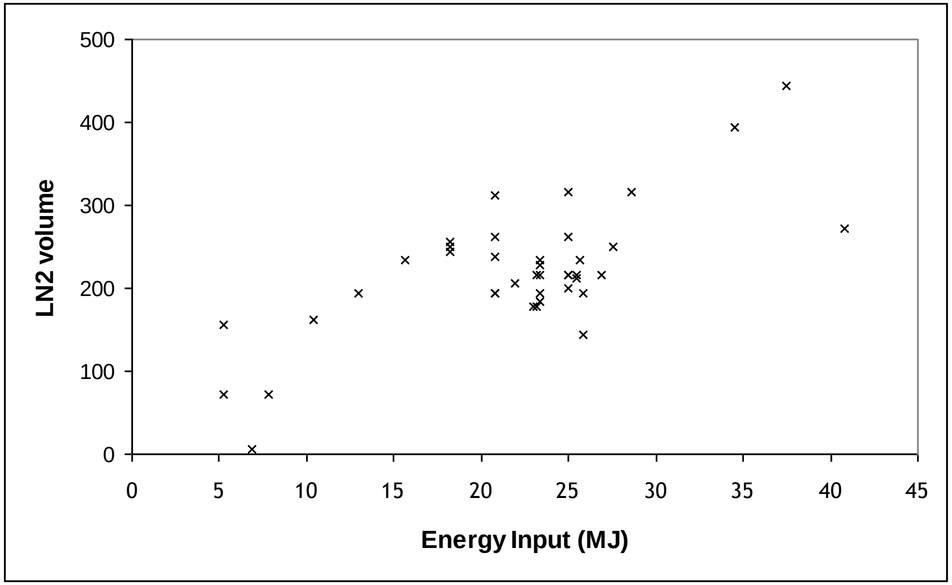




60 cooling cycles performed.

Average cryostat emptying time is 4min24s.

Temperature (K)	Cooling Time (minutes)(*hours)
110	40
125	80
180	*21
293	*54

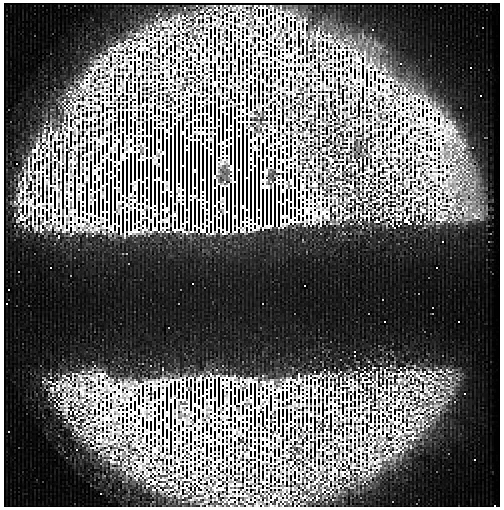


Predicted consumption: 6.2 l/MJ

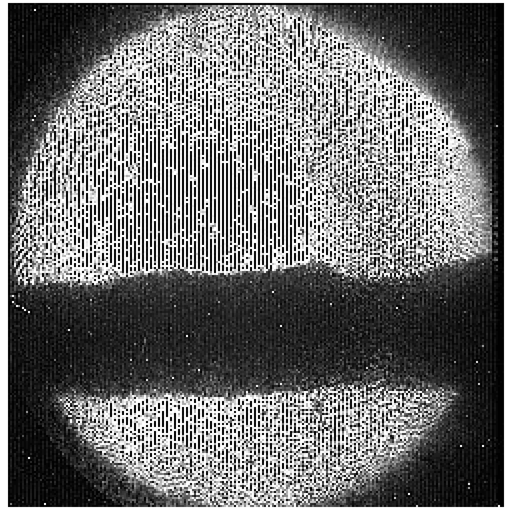
Experimental consumption: 10 l/MJ

Magnetic Field (T)	Energy Input (MJ)	LN2 Consumption Theoretical (l)	LN2 Consumption Experiment (l)
5	3	19	27
7	5	31	54
10	12	75	119
15	25	156	258

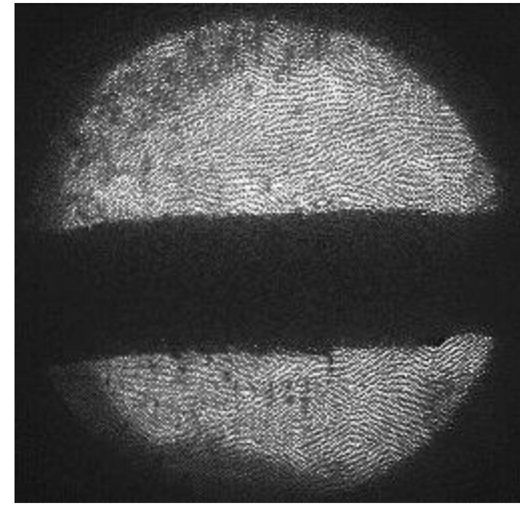
Jet-Target Interaction



14 GeV/c
$1.6*10^{13}$ protons/pulse
B-field 5 T



14 GeV/c
$1.6*10^{13}$ protons/pulse
B-field 5 T



14 GeV/c
$1.2*10^{13}$ protons/pulse
B-field 10 T

Images were recorded at 2000 frames/second.
Play-back is about 400 times slower.
Splash velocities up to 60 m/s observed.

Conclusions

Physics requirements fulfilled:

Established the proof-of-principle of a proposed system for generating an intense muon beam;
Hg jet can be injected into a high-field solenoid field without serious consequences;
Disruption of Hg jet is mitigated by high magnetic field;
Increase in threshold for disruption coupled with a delay in the onset of the observable jet breakup.

Cooling requirements fulfilled:

Cooling of magnet cryostat with LN2 flow by sole means of differential pressures;
Operation automatisms worked properly;
Magnet cooling cycle time takes 40 minutes;
Cryostat emptying time is 4min24s;

LN2 consumption:

Experimental LN2 consumption is of 10.2 l/MJ (1.64 x more than theoretical estimative);
Average 258 l of LN2 for a 15T shot;
Overnight cooling LN2 consumption: 1.2 kW