# E951
# Cryogenics for
# Pulsed Solenoid Magnet

## Design, Operation, Safety
## Project Status

BNL
ESR Safety Committee
September 6, 2002

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Solenoid, Cryostat Design: MIT, Peter Titus

Magnet Design: Bob Weggel

Cryo-Design Issues: ***ACT***, G. T. Mulholland

Components

1). Pulsed Solenoid Magnet

2). $LN_2$ Storage Dewar: 5.88 kgal.

3). Vacuum Pumps, Ambient HEs

4). GHe Circulator/HE

5). $LH_2$ Storage Dewar: 14 kgal.

6). Interconnections

- a). VJ lines, valves
- b). $LN_2$ Trailer Fill station
- c). $LH_2$ Trailer Fill station
  - i). $LH_2$ P&P plumbing
  - ii). $GN_2$ Purged vent stack

7). Cryogenic Controls

- a). Physical
- b). Automatic
  - i). Alarms, pager
  - ii). Interlocks

8) Gas Sensors

- a). Oxygen (cave)
- b). Hydrogen ($H_2$ areas)

Operating Modes: Field, Cooled by,

1. 5T: $LN_2$ direct,
2. 10T: pumped $LN_2$ direct,
3. 5T: GHe cooled by $LN_2$.
4. 10T: GHe cooled by pumped $LN_2$.
5. 15T: GHe cooled $LH_2$.

Max. Dynamic Loading: 15T. $LH_2$ Operation

$LH_2$ Dynamics

1). Dynamic: 15.0 MJ/pulse (+54K)

Peak = 54*5.5j/gK*100 g/s = 29.7 kW

2). 30-minute repetition-rate (spec.)

3). 15.0/(30*60)= 8.33 kW average

4). Background ca. = 1.66 kW

5). $LH_2$ avg. dynamic consumption rate;

(10 kW/(445.4j/g))*(3600 (s/h)/71 g/l)

= 1138.4 lph = 300 gph

5). $LH_2$ Dewar use: 14 kgal., dynamic

Hrs/Dewar = 14,000/300 gph = 46.7 h

46.7/8=5.8 (8-hr op. shifts/Dewar)

6). $LH_2$ Dewar use: 14 kgal., standby

Hrs/Dewar = 14,000/50 gph = 280 h

280/8=35 (8-hr standby shifts/Dewar)

Discussion:

1) Equipment Mode Block Diagrams (3)

2) A3 Beam Line Equipment Layout (1)

3) General Arrangement (Schematic, 1)

4) Pulsed Solenoid Magnet Excerpt (1)

5) Circulator/HE Excerpt (2)

6) GOP flow diagram examples (2)

7) Safety considerations
   a) Equipment
      i) 14 k gallon $LH_2$ Dewar (140 psig)
      ii) 5.88 k gallon $LN_2$ Dewar (65 psig)
      iii) PSM Cryostat (MIT, later)
      iv) Circulator Bath (DA=300 psig, new set pressure = 4 atmos.)
      v) GHe Circuit (B31.3 DA=200 psig)
      vi) Interconnecting piping (150/200 psig)

b) Equipment Design, Siting

i) BNL OHSG, Special Precautions for Locations Containing Flammable Atmospheres 4.12.0

ii) BNL ESH, 5.1.0 Non Flammable Cryogenic Liquids, Rev.2

iii) BNL OHSG, Flammable Cryogenic Liquids 5.2.0

iv) NFPA 50B, Standard for Liquefied Hydrogen Systems at Consumer Sites, 1999 NFPA

v) CGA G-5.4-2001, Standard for Hydrogen Piping Systems at Consumer Locations, 2nd Edition

vi) CGA G-5.5-1996, Hydrogen Vent Systems, 1st Edition.

vii) Others?

(more)

8) Final System Documentation
   a) Configuration Documented
   b) Safety Issues Documented
      i) FEA
   c) Pressure Test Plans Documented
   d) Operating Procedures Complete
   e) Final CSC, ESR reviews
   f) Final System Details Documented

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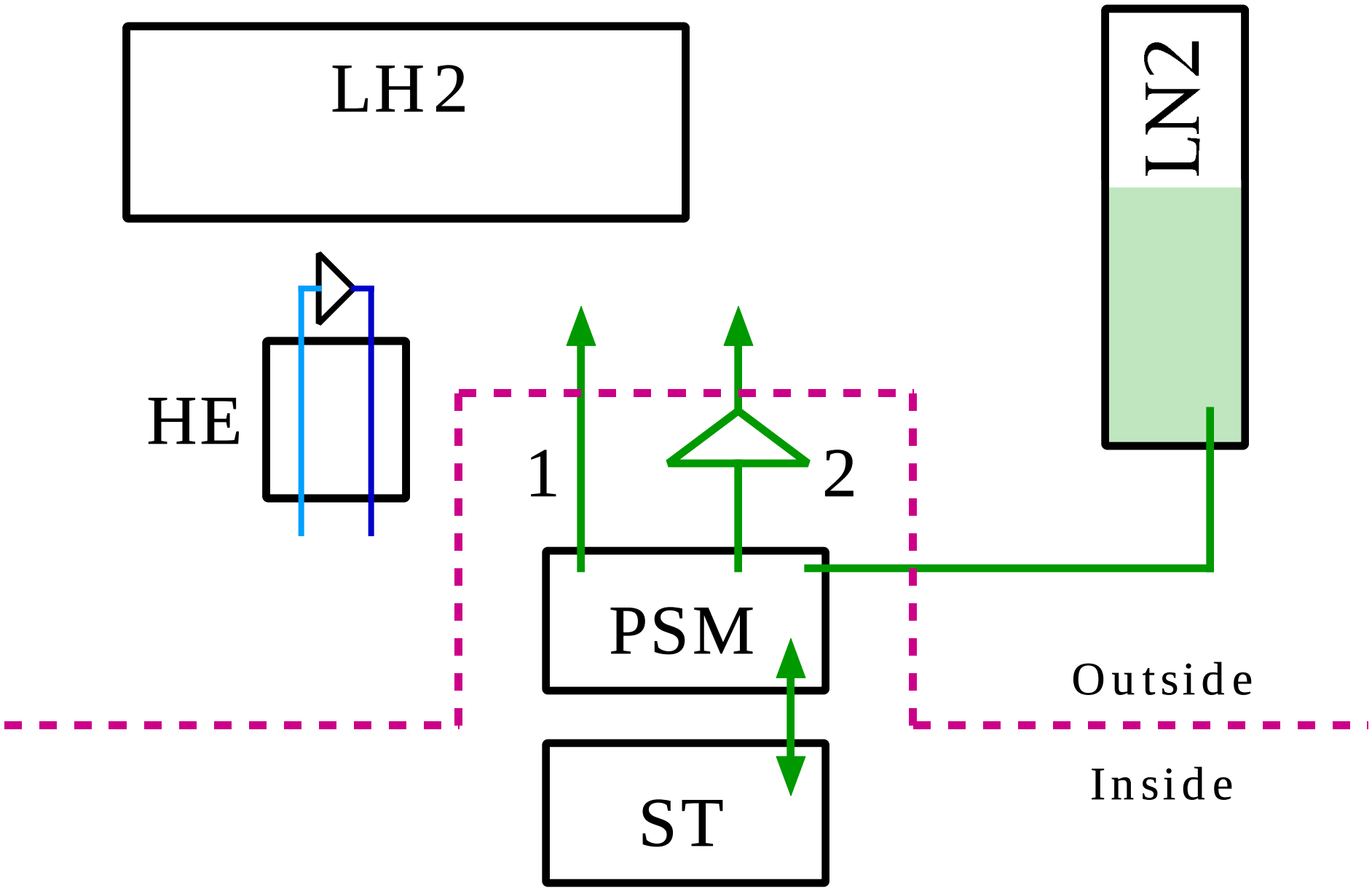
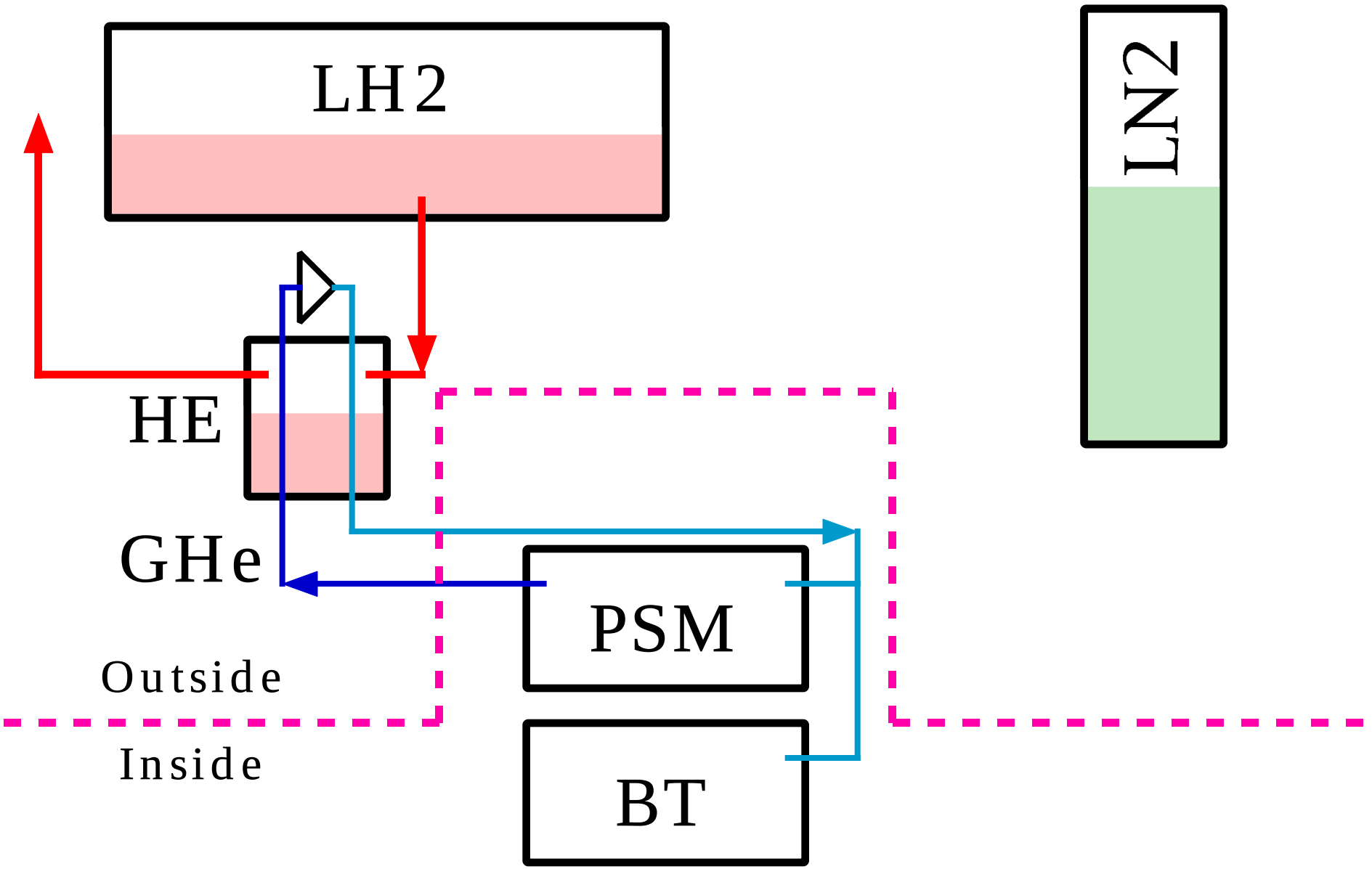
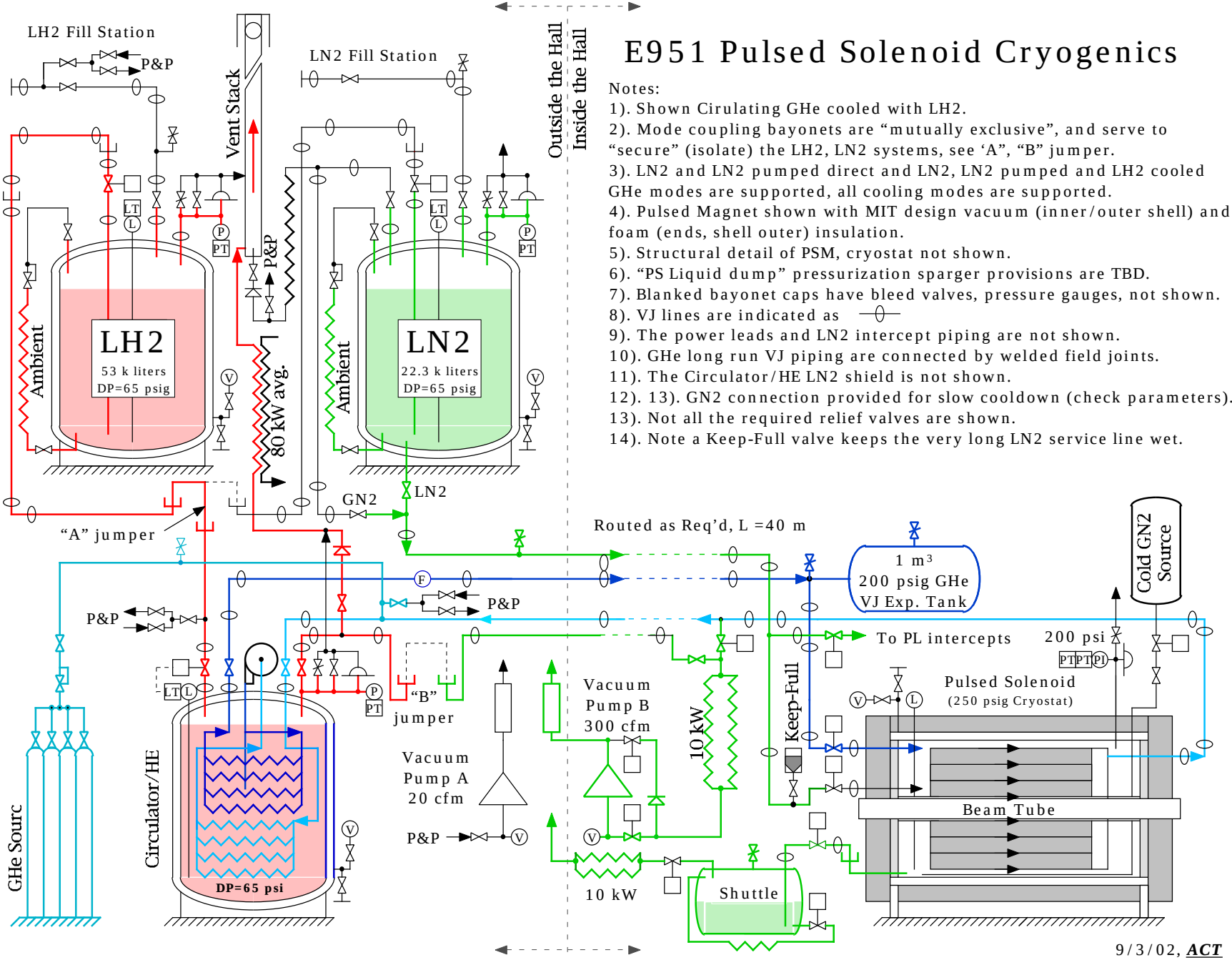
# Mode 1, 2



# Mode 5



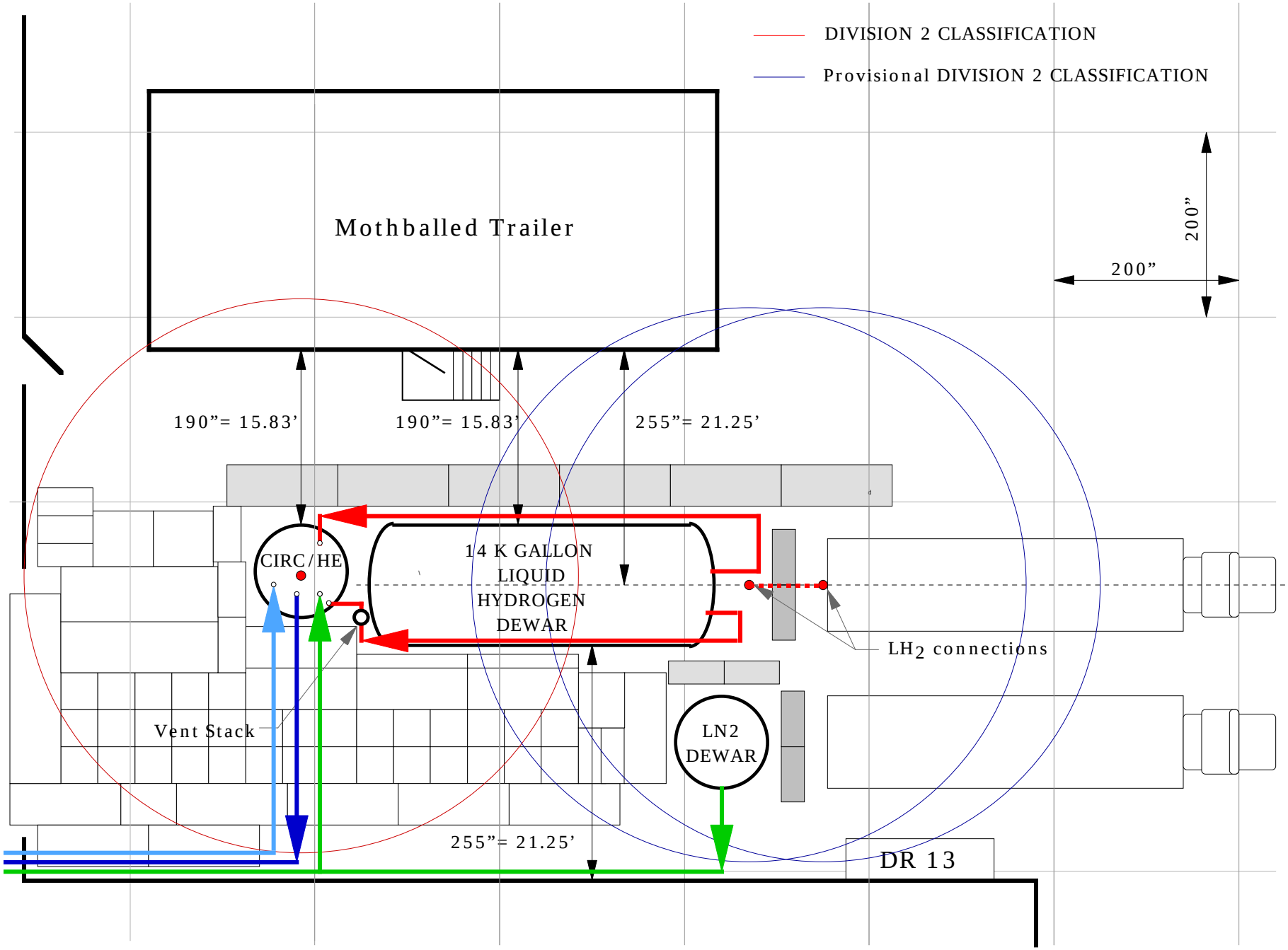
# E951 Pulsed Solenoid Cryogenics




Notes:

1). Shown Cirulating GHe cooled with LH2.
2). Mode coupling bayonets are "mutually exclusive", and serve to "secure" (isolate) the LH2, LN2 systems, see 'A", "B" jumper.
3). LN2 and LN2 pumped direct and LN2, LN2 pumped and LH2 cooled GHe modes are supported, all cooling modes are supported.
4). Pulsed Magnet shown with MIT design vacuum (inner/outer shell) and foam (ends, shell outer) insulation.
5). Structural detail of PSM, cryostat not shown.
6). "PS Liquid dump" pressurization sparger provisions are TBD.
7). Blanked bayonet caps have bleed valves, pressure gauges, not shown.
8). VJ lines are indicated as —⊖—
9). The power leads and LN2 intercept piping are not shown.
10). GHe long run VJ piping are connected by welded field joints.
11). The Circulator/HE LN2 shield is not shown.
12). 13). GN2 connection provided for slow cooldown (check parameters).
13). Not all the required relief valves are shown.
14). Note a Keep-Full valve keeps the very long LN2 service line wet.

9/3/02, ***ACT***

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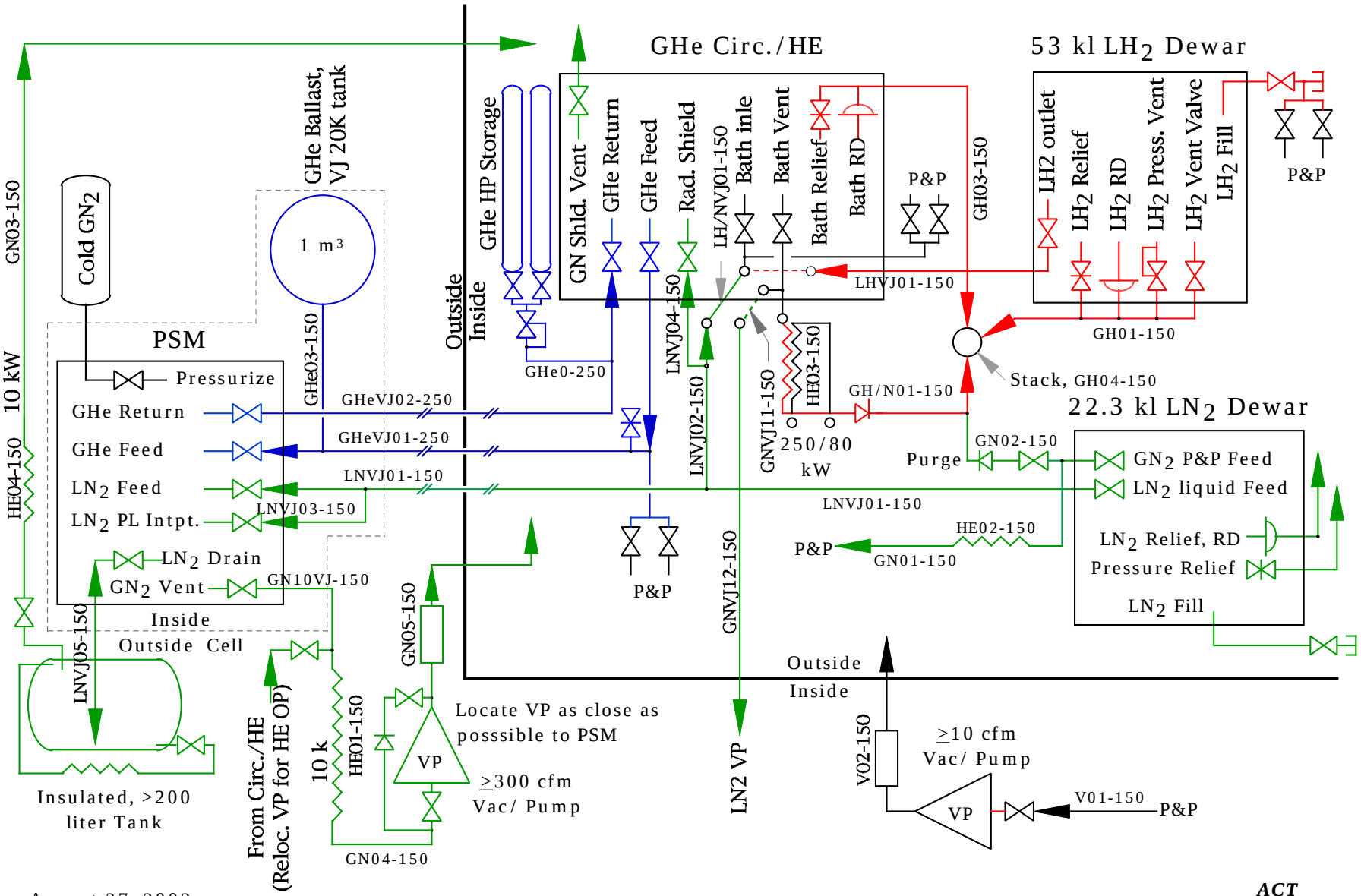
# E951 Major Interconnections and Line, Ambient Heater, Heater, Vacuum Pump Sizes, Etc.




August 27, 2002

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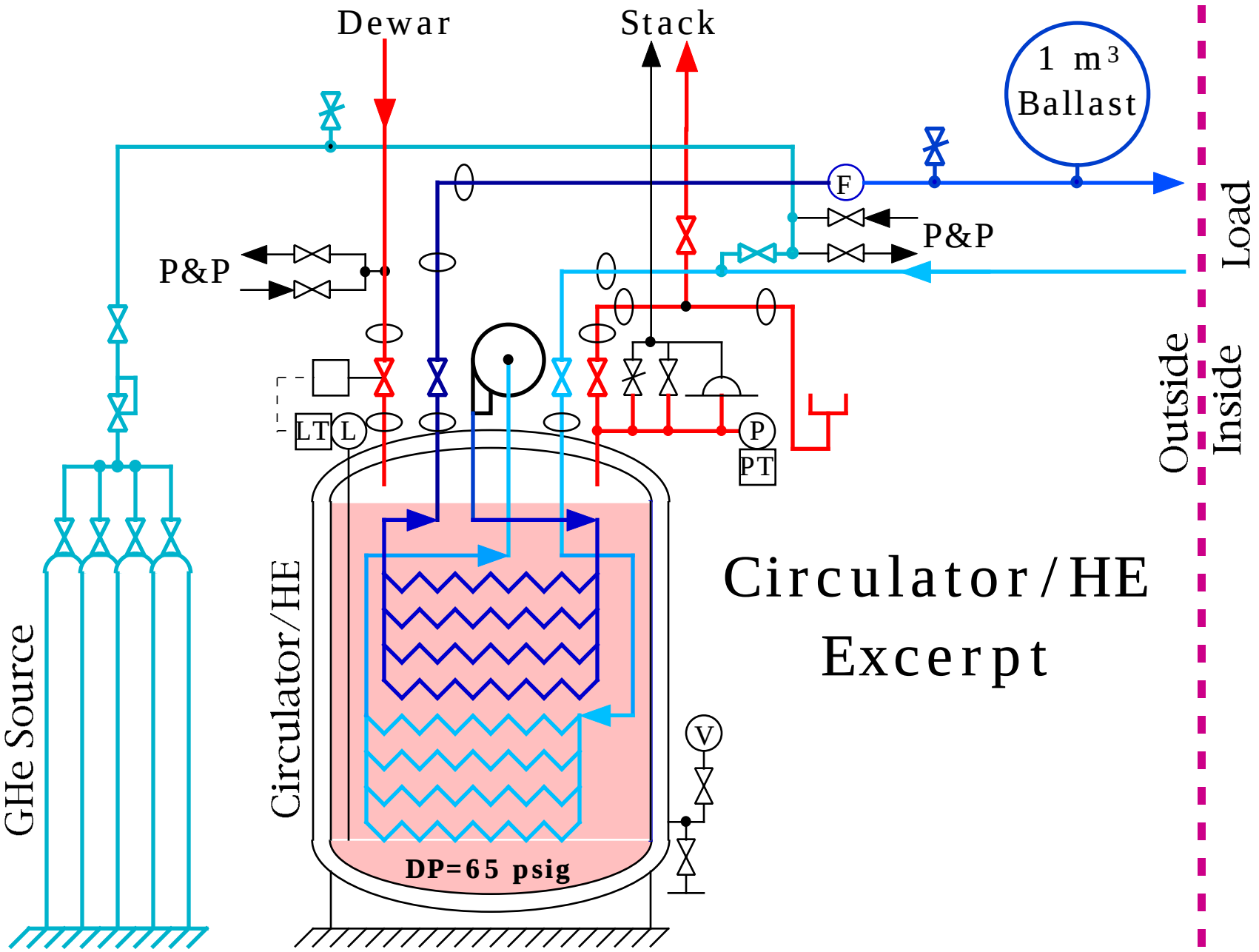
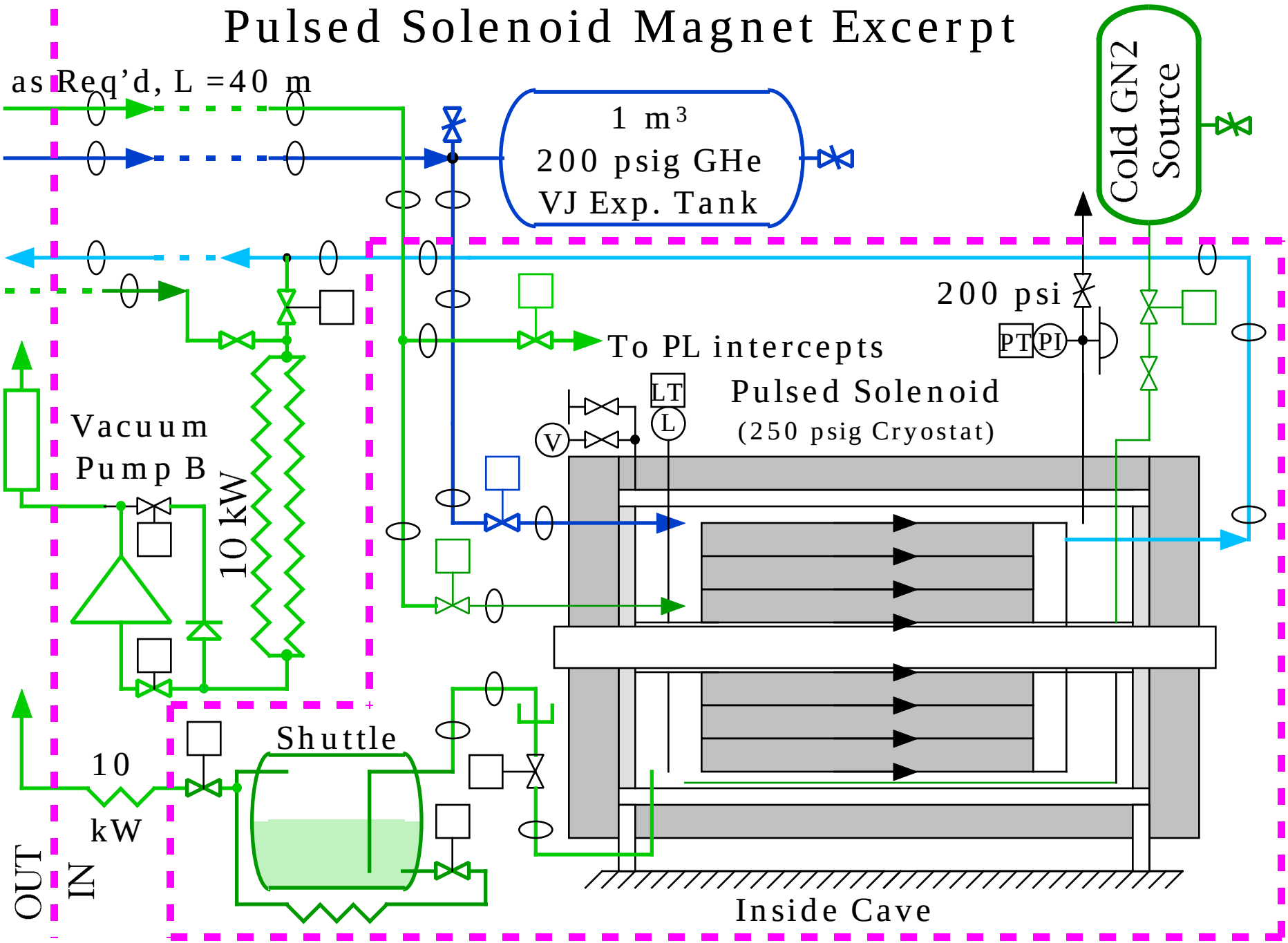
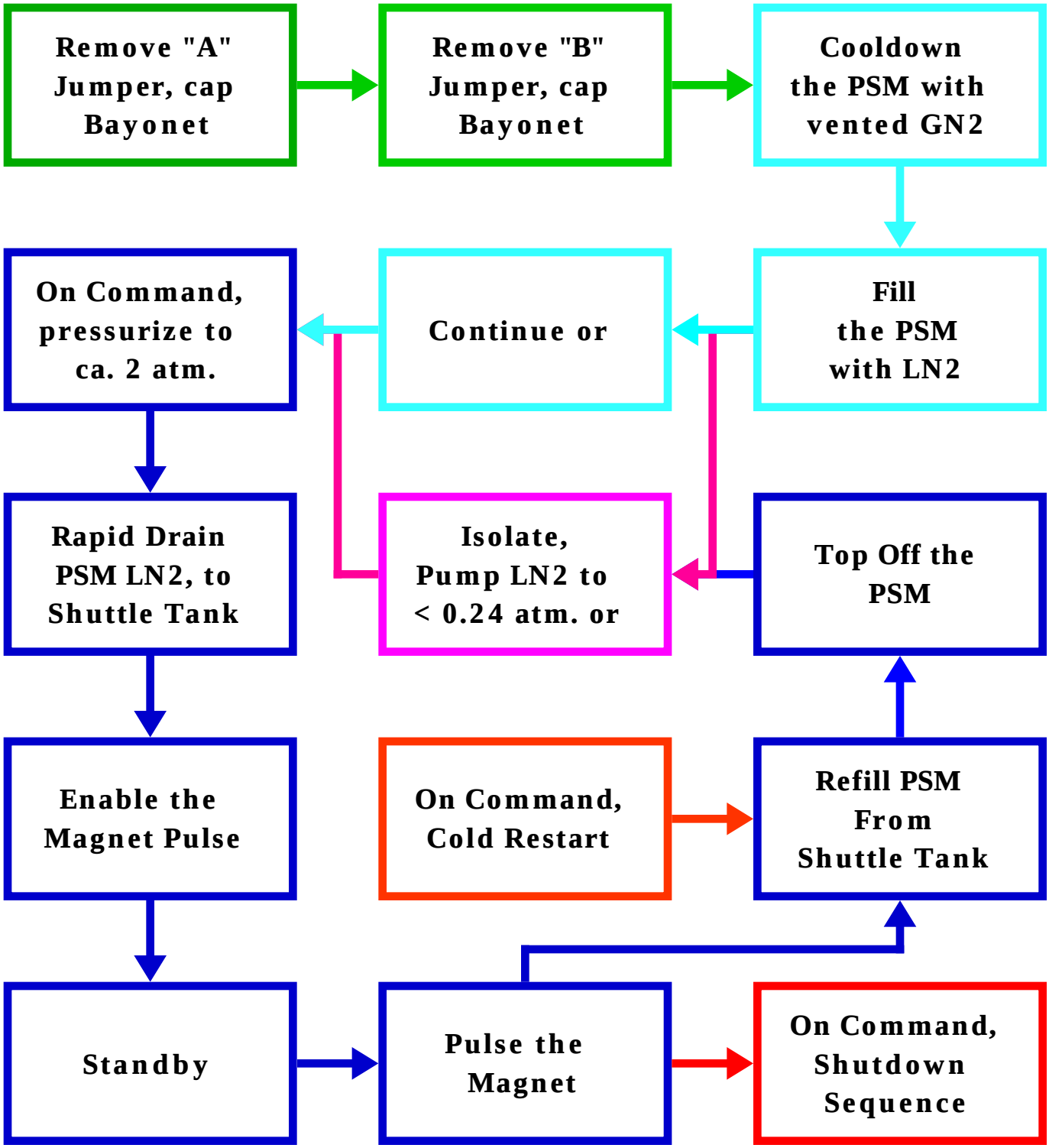
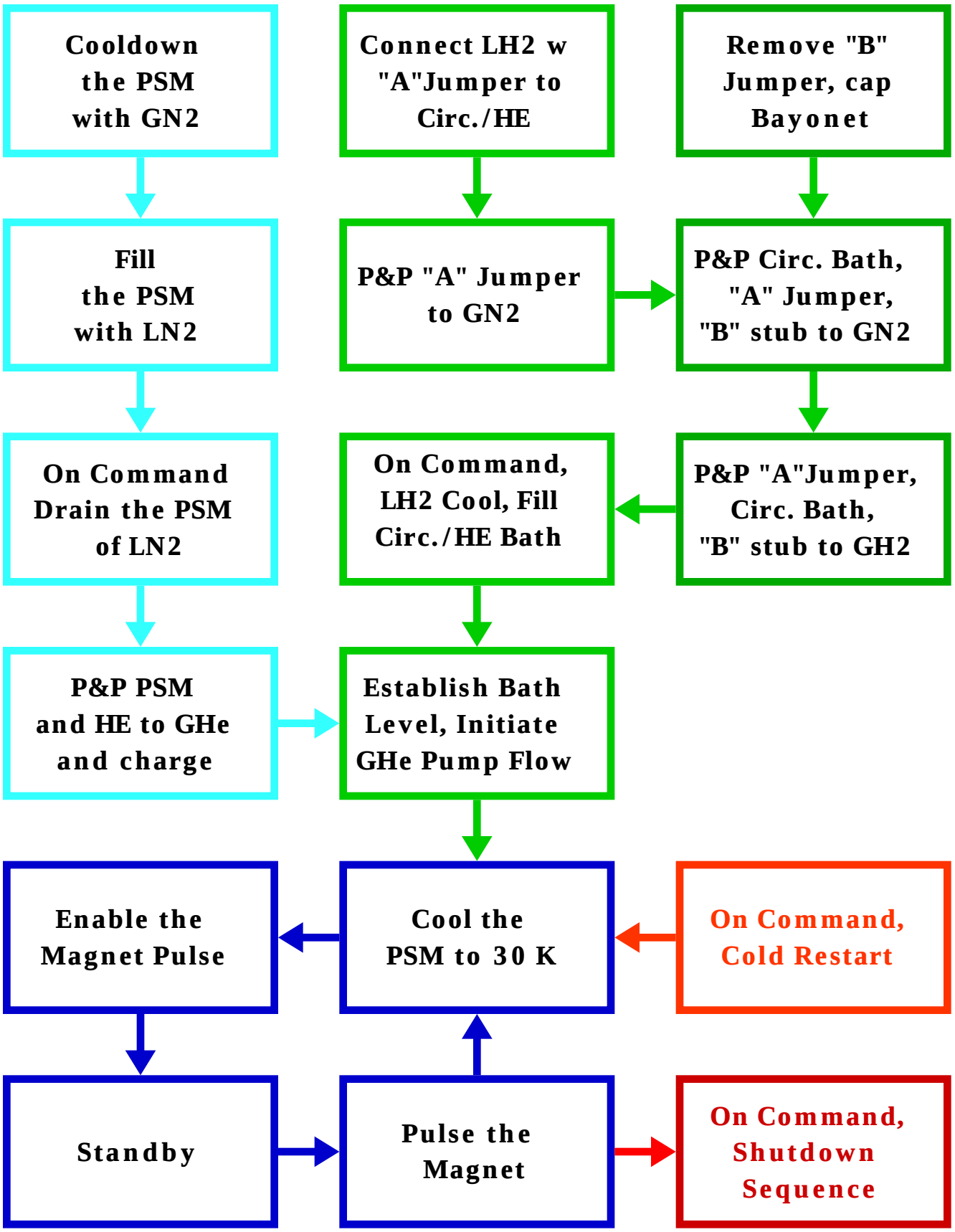

Dewar
Stack
1 m³
Ballast
F
P&P
P&P
Load
Outside
Inside
LT
L
P
PT
GHe Source
Circulator/HE
DP=65 psig
V
Circulator/HE
Excerpt

# Pulsed Solenoid Magnet Excerpt




Remove "A" Jumper, cap Bayonet
Remove "B" Jumper, cap Bayonet
Cooldown the PSM with vented GN2
Fill the PSM with LN2
Continue or
On Command, pressurize to ca. 2 atm.
Rapid Drain PSM LN2, to Shuttle Tank
Isolate, Pump LN2 to < 0.24 atm. or
Top Off the PSM
Enable the Magnet Pulse
On Command, Cold Restart
Refill PSM From Shuttle Tank
Standby
Pulse the Magnet
On Command, Shutdown Sequence


Cooldown the PSM with GN2
Fill the PSM with LN2
On Command Drain the PSM of LN2
P&P PSM and HE to GHe and charge
Connect LH2 w "A"Jumper to Circ./HE
P&P "A" Jumper to GN2
On Command, LH2 Cool, Fill Circ./HE Bath
Establish Bath Level, Initiate GHe Pump Flow
Remove "B" Jumper, cap Bayonet
P&P Circ. Bath, "A" Jumper, "B" stub to GN2
P&P "A"Jumper, Circ. Bath, "B" stub to GH2
Enable the Magnet Pulse
Cool the PSM to 30 K
On Command, Cold Restart
Standby
Pulse the Magnet
On Command, Shutdown Sequence