E951
Cryogenics for Pulsed Solenoid Magnet

Design, Operation, Safety Project Status

BNL
ESR Safety Committee
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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
   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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E951 Pulsed Solenoid Cryogenics

Notes:
1). Shown circulating 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). 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.

Locate VP as close as possible to PSM.
200 psi
as Req’d, L = 40 m

Pulsed Solenoid
(250 psig Cryostat)

1 m³
200 psig GHe
VJ Exp. Tank

Vacuum Pump B
To PL intercepts

Pulsed Solenoid
(250 psig Cryostat)

Inside Cave
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Cold GN2 Source

Shuttle

10 kW

10 kW

Vacuum Pump B

Vacuum Pump B
Remove "A" Jumper, cap Bayonet

Remove "B" Jumper, cap Bayonet

Cooldown the PSM with vented GN2

Fill the PSM with LN2

Continue or

Isolate, Pump LN2 to < 0.24 atm. or

Top Off the PSM

On Command, pressurize to ca. 2 atm.

Rapid Drain PSM LN2, to Shuttle Tank

Enable the Magnet Pulse

Standby

On Command, Cold Restart

Refill PSM From Shuttle Tank

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

P&P Circ. Bath, "A" Jumper, "B" stub to GN2

Remove "B" Jumper, cap Bayonet

Establish Bath Level, Initiate GHe Pump Flow

On Command, LH2 Cool, Fill Circ./HE Bath

On Command, Cold Restart

Enable the Magnet Pulse

Cool the PSM to 30 K

Standby

Pulse the Magnet

On Command, Shutdown Sequence