Fermilab

Particle Physics Division
Mechanical Department Engineering Note

Number: g-2-doc-2054 Date: July 10, 2014

Project: g-2 superconducting rings

Title: g-2 LN2 Shield piping engineering note

Author(s): Erik Voirin

Reviewer(s):

Key Words: Piping Engineering note B31.3 ASME 5031

Abstract Summary:

This document describes the Liquid Nitrogen tubes in the g-2 cryostat rings, which were designed and installed in the g-2 cryostat at Brookhaven National Laboratory in the early 90's. The tubes are part of the heat shield for the aluminum superconductor containing mandrel which is Aluminum T6061-T6. The tube itself is Aluminum T6063-T52 and has three relief valves set to 75 psig. This piping note analyzes the tubing and shows the system complies with FESHM 5031.1 and ASME 31.3 code for process piping for operational pressure/temperature design, as well as all relief scenarios, which include simultaneous complete loss of vacuum and magnet quench without consideration of the dump resistor.

FESHM 5031.1 PIPING ENGINEERING NOTE FORM

Prepared by: **Erik Voirin** Preparation Date: **7-10-2014**

Piping System Title: **g-2 mandrel Heat Shield LN2 Tubing**

Lab Location: **MC1 Building** Location code: **209**

Purpose of system**: Supply Two-phase Nitrogen to the Heat shield surrounding the mandrel.**

Piping System ID Number: **none assigned**

Appropriate governing piping code: **ASME B31.3**

Fluid Service Category (if B31.3): **Normal Fluid Service**

Fluid Contents: **Two-phase Nitrogen**

Design Pressure: **90 psid @ 77K**

Piping Materials: **Aluminum 6063-T52**

Drawing Numbers (PID's, weldments, etc.): **g-2 Doc 1830 - Attachment C**

Designer/Manufacturer: **Brookhaven National Laboratory**

Test Pressure: **105 psid** Test Fluid: **Nitrogen** Test Date: **TBD**

Statements of Compliance

Piping system conforms to FESHM 5031.1, installation ***is not*** exceptional: **Yes**

Piping system conforms to FESHM 5031.1, installation ***is*** exceptional and has been designed, fabricated, inspected, and tested using sound engineering principles: **N/A**

Reviewed by: ____ (Print Name)

Signature: ____Date: _____________

D/S Head's Signature: ___________________________________Date: _____________

The following signatures are required for exceptional piping systems:

ES&H Director's Signature: _______________________________Date: _____________

Director's Signature or Designee: __________________________Date: _____________

Pipe Characteristics

Size**: 0.5” x 0.0625” D-tube and standard tube** Volume: **~ 15 Liters**

Relief Valve Information: **Three identical relief valves used**

Type: **Spring Loaded Modulating** Manufacturer: **Circle Seal**

Set Pressure: not applicable Relief Capacity: **75 psig**

Relief Design Code: **ASME B31.3 – Non-Code Relief device.**

Is the system designed to meet the identified governing code? **Yes**

Fabrication Quality Verification:

Process and Instrumentation diagram appended? **Yes, Attachment C**

Process and Instrumentation component list appended? **Yes, Attachment C**

Is an operating procedure necessary for safe operation? **No**

If ‘yes’, procedure must be appended.

Exceptional Piping System

Is the piping system or any part of it in the above category? **No**

If “Yes”, follow the requirements for an extended engineering note for Exceptional Piping Systems.

Quality Assurance

List vendor(s) for assemblies welded/brazed off site: **Brookhaven Nat’l Lab**

List welder(s) for assemblies welded/brazed in-house: **Leonard Harbacek**

Append welder qualification Records for in-house welded/brazed assemblies. **Attachment F**

Append all quality verification records required by the identified code (e.g. examiner's certification, inspector's certification, test records, etc.)

Table of Contents

1. Description and Identification

These three vacuum vessels, also called the cryostats, contain the superconducting coils of the Muon g-2 magnet. Therefore they also contain cooling lines which carry two-phase helium to the superconductor containing mandrels and nitrogen to the heat shields. Figure 1 shows an external view of the 50 ft. diameter vessels and the interconnect region which connects the cryostats together into one common vacuum space. Internal dimensions of these vessels are shown in Table 1. Figure 2 shows the entire magnet cross section, where one can see the position of the three vacuum vessels and their internals. Figure 3 shows a close up view of the three vessels and their internals, where the nitrogen and helium lines are labeled and colored purple and blue respectively.

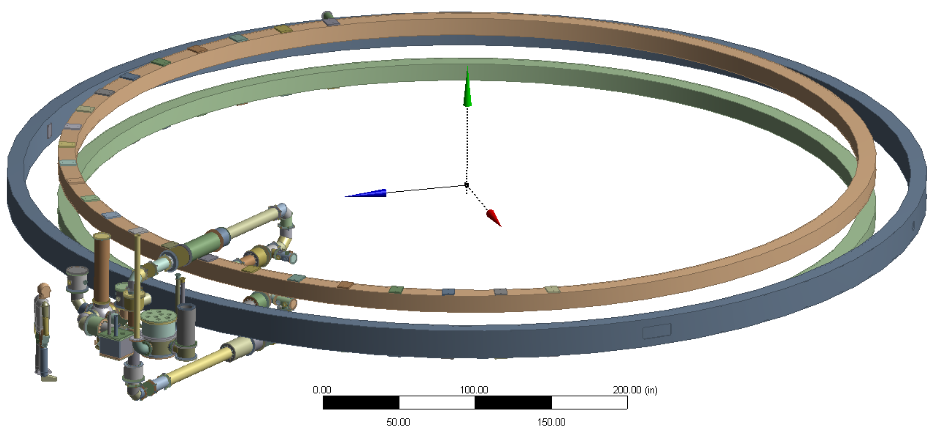

Figure 1: External view of the three cryostats and interconnect region which connects the cryostats together.

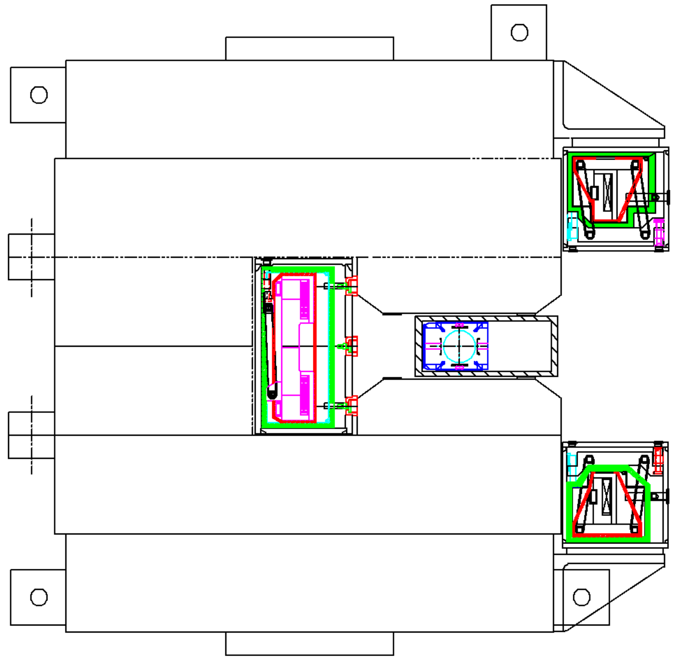

Figure 2: Entire magnet cross section containing the vacuum vessels (cryostats).

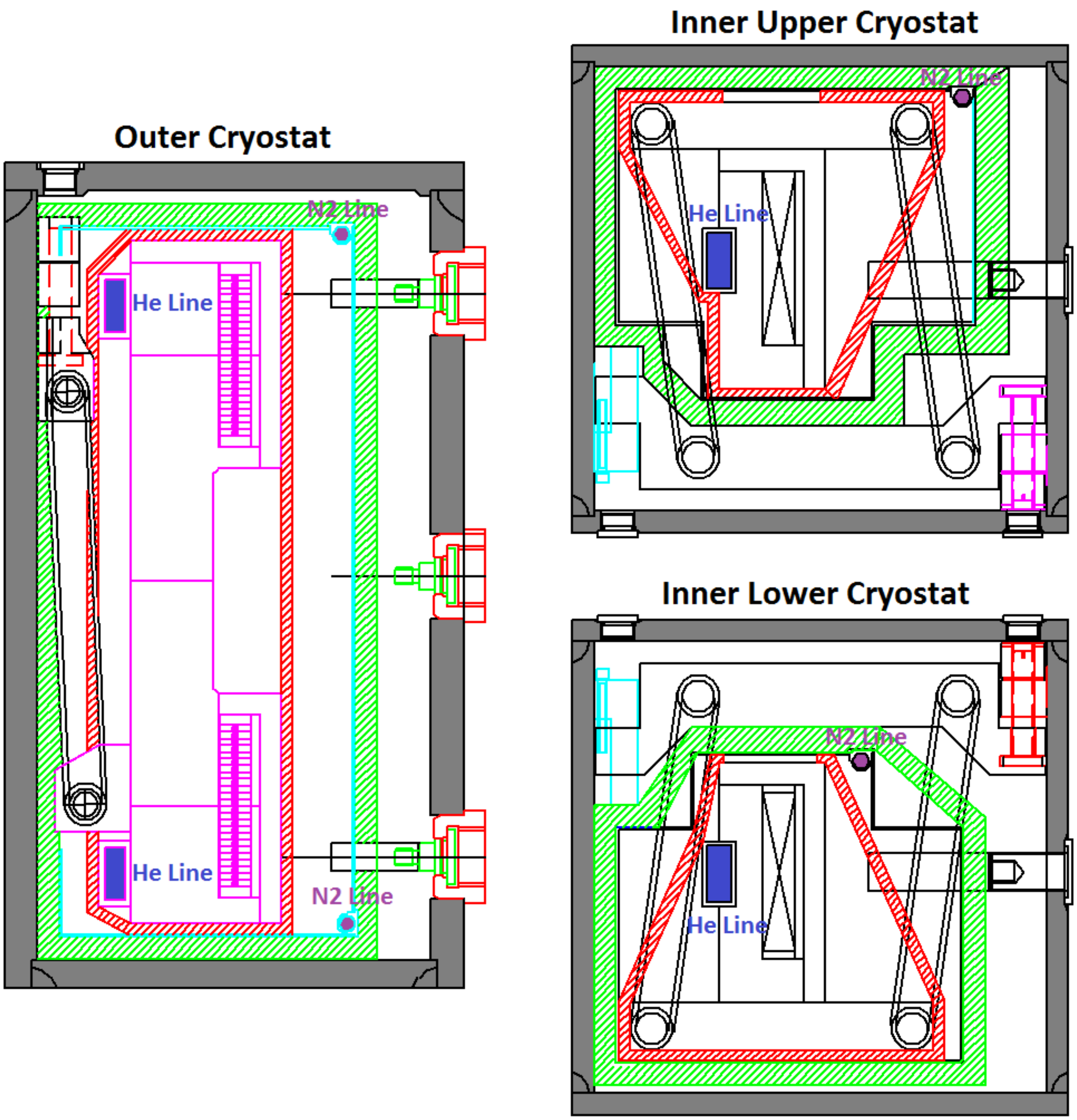

Figure 3: Close up view of the three vessels and their internals, where the nitrogen and helium lines are labeled and colored purple and blue.

2) Piping and Instrument diagram

The full cryogenic systems piping and instrument diagram is in g-2 DocDB: Doc 1830, and also shown in Attachment C, along with the Valve and instrument list for this portion of the tubing. This note only analyzes the internal nitrogen tubing inside the ring cryostats and interconnects, highlighted in Figure 4, not the entire cryogenic system.

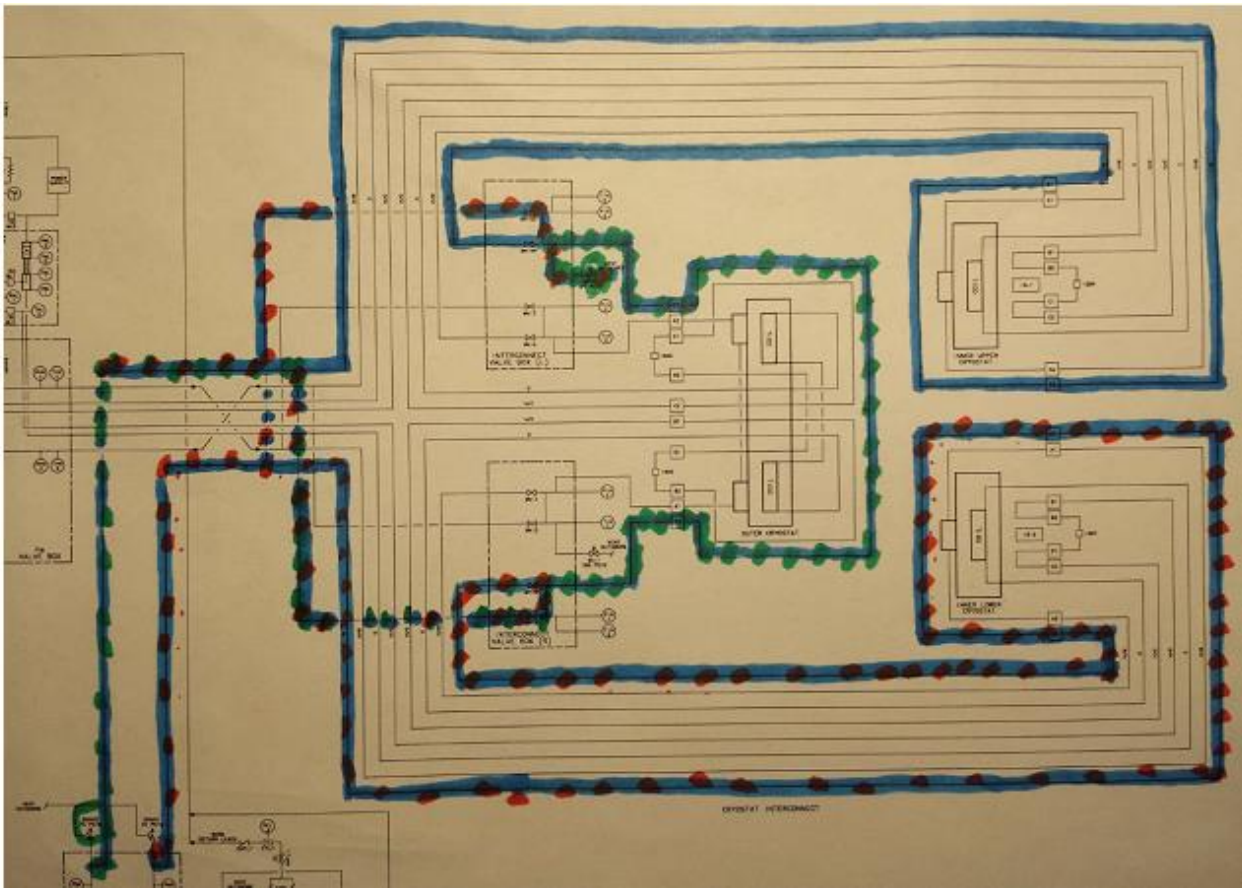

Figure 4: Portion of Nitrogen tubing this note documents, see Full P&ID for more detail.

3) Design Codes and Evaluation Criteria

These Nitrogen tubes meet the requirements of section 5031.1 of the Fermilab ES&H Manual, which states that this piping system falls under the category of Normal Fluid Service. This means it shall adhere to the requirements of the ASME Process Piping Code B31.3. Section 5032 contains additional requirements for cryogenic system components.

4) Materials

The tubing for the helium and nitrogen lines is fabricated from 6063-T52 aluminum. The allowable stress for this temper is not listed in ASME B31.3, though it can be seen by the values for aluminum in the ASME Table that they use 1/3 the minimum specified strength; so 1/3 of the 27 ksi listed for this material would be 9 ksi allowed by the code for this material/temper.

The piping will be operated at 77K (-321 ^{o}F). This is above the minimum temperature listed for this material (-452K)

5) Pipe Design / Internal pressure design

The Nitrogen piping which connects to the shield is D-Tube with one flat side, and has dimensions 0.5" OD x 0.0625" wall, shown in Figure 4. The interconnect tube is nearly identical, except it is standard circular tube, not D-tube. Calculations were done for stress due internal pressure, which shows the allowable stress is reached at an internal pressure of 2500 psi. Therefore stress due to internal pressure is not of concern as the design pressure and relief valves are 90 psid.

Pressure Rating Calculations:

The minimum tube thickness for seamless or longitudinally welded piping for t<D/6 is given by the equation shown below. Using this, we show the wall thickness is many times more than adequate, so internal pressure should be of no concern on these tubes.

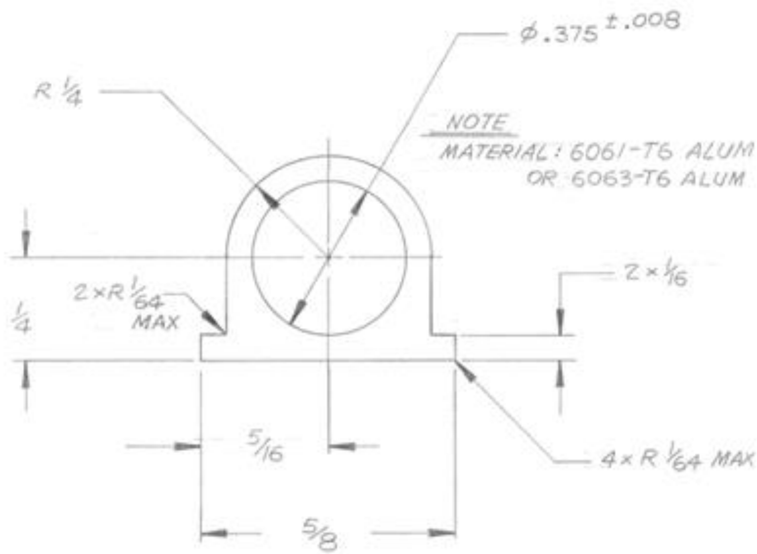

Figure 5: Drawing and dimensions of aluminum D-tube

$$t_m = \frac{P_1 \cdot D_1}{2 \cdot (S_1 \cdot E_1 \cdot W_1 + P_1 \cdot Y_1)} \text{ solve}, P_1 \rightarrow \frac{2 \cdot E_1 \cdot S_1 \cdot W_1 \cdot t_m}{D_1 - 2 \cdot Y_1 \cdot t_m}$$

$D_1 := 0.5in$	D =	outside diameter of pipe as listed in tables of standards or specifications or as measured
$E_1 := 1$	E =	quality factor from Table A-1A or A-1B
$Pressure_{rating}$	P =	internal design gage pressure
$S_1 := 9ksi$	S =	stress value for material from Table A-1
$t_m := 0.0625in$	t_m =	minimum required thickness, including mechanical, corrosion, and erosion allowances
$W_1 := 1$	W =	weld joint strength reduction factor in accordance with para. 302.3.5(e)
$Y_1 := 0.4$	Y =	coefficient from Table 304.1.1, valid for $t < D/6$ and for materials shown. The value of Y may be interpolated for intermediate temperatures. For $t \geq D/6$,

$$Pressure_{Rating} := \frac{2 \cdot E_1 \cdot S_1 \cdot W_1 \cdot t_m}{D_1 - 2 \cdot Y_1 \cdot t_m} = 2500\,psi$$

6) Relief Valves

The piping is protected from overpressure by three 1" Circle Seal relief valves, model number: 5120-B-8MP, set to 75 psig.

Relief valve calculations for the internal nitrogen tubes were performed for the most severe case, catastrophic loss of vacuum due to a helium leak. Detailed calculations are shown in Attachment A.

There are no system sources of pressure that can supply Nitrogen at a pressure greater than 75 psig, as upstream relief valves are set at this value maximum.

Fire is not considered credible due to the lack of combustible material in the vicinity of the piping, which is encased inside cryostats and surrounded by steel yoke pieces. Also, the long length of the piping makes it unlikely a significant portion could be involved in a fire.

7.) Welding Information

Nearly all welding was done during manufacture in the early 90's by BNL. Several nitrogen tubes in the interconnect region had to be cut to prepare for transport. These tubes will be re-welded here at Fermilab by Leonard Harbacek, qualifications attached, but all these welds will be socket type welds, meaning no radiography or in-process weld inspection is required by ASME B31.3.

8) References

1. NIST Material Measurement Laboratories; Cryogenic Material Properties.
   June 21, 2014 <http://www.cryogenics.nist.gov/MPropsMAY/material%20properties.htm>

2. g-2 document # 1586 – v1, June 21, 2014.
   < http://gm2-docdb.fnal.gov:8080/cgi-bin/RetrieveFile?docid=1586&filename=309%20Jia.pdf&version=1>

3. g-2 document # 1830 – v1 , June 21, 2014.
   <http://gm2-docdb.fnal.gov:8080/cgi-bin/ShowDocument?docid=1830>

4. g-2 document # 1892 – v1, June 21, 2014.
   <http://gm2-docdb.fnal.gov:8080/cgi-bin/ShowDocument?docid=1892>