Design and Fabrication of the Mu2e Cryogenic Distribution System

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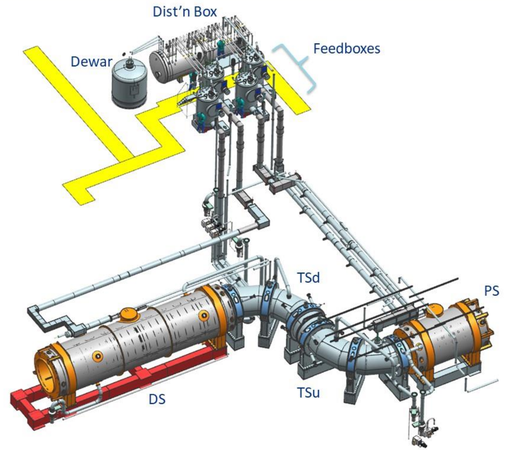
Introduction

Abstract. The muon-to-electron conversion (Mu2e) experiment at Fermilab will search for the charged lepton flavor-violating conversion of muons to electrons in the field of an atomic nucleus. The Mu2e experiment is currently in the design and construction stage and is expected to begin operations in 2022. The Mu2e experiment uses four large superconducting solenoid magnets including a Production Solenoid (PS), an Upstream and Downstream Transport Solenoid (TSu and TSd) and a Detector Solenoid (DS).

This paper will focus on the cryogenic distribution system for these four solenoid magnets. Liquid helium will be supplied from two re-purposed Tevatron satellite refrigerators. A large cryogenic distribution box is located in the Mu2e building to distribute the required cryogens to each of the four solenoid magnets. Each solenoid magnet will have a dedicated transfer line and cryogenic feedbox. The solenoid magnets each require two liquid helium circuits and two liquid nitrogen circuits.

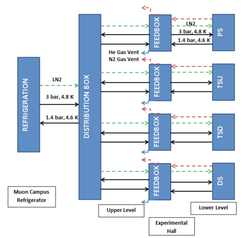
The most unique feature about this cryogenic system is that the assemblies for the start of the superconducting portion of the power leads are mounted in feedboxes that are in the range of 23 m to 31 m away from the solenoid magnets. The cryogenic feedboxes are located remotely to provide protection from radiation damage and high magnetic fields. The power leads are NbTi superconducting cable stabilized with high conductivity aluminum. The 6061-T6 aluminum grade was selected for the transfer line piping so that the piping would thermally contract at the same rate as the power lead. A major concern for this transfer line is that a small helium leak could create an electric discharge arc due to the Paschen effect. This paper includes a description of the design features and testing done to ensure that the power leads are protected from the Paschen effect while still being adequately cooled to liquid helium temperatures.



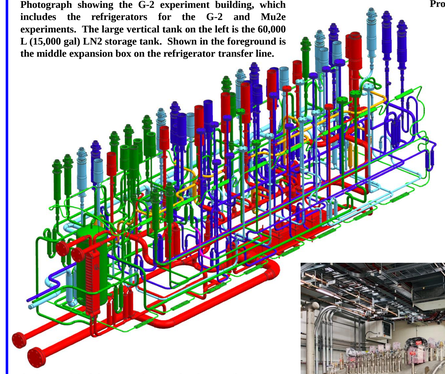
The 3-D conceptual model of the Mu2e solenoid magnets and cryogenic distribution system components located inside the Mu2e building. Typical sized people are shown next to the Feedboxes and Distribution Box to give a sense of scale.

Supply & Distribution

Photograph showing the G-2 experiment building, which includes the refrigerators for the G-2 and Mu2e experiments. The large vertical tank on the left is the 60,000 L (15,000 gal) LN2 storage tank. Shown in the foreground is the middle expansion box on the refrigerator transfer line.



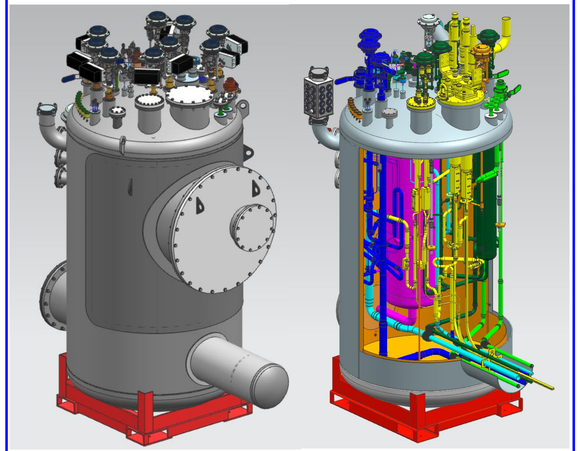
Process Flow Diagram



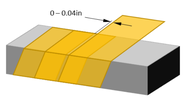
The 3-D model of the internal piping for the Distribution Box. The nitrogen supply and return are dark green and light green respectively. The helium supply and return are dark blue and light blue respectively. The piping for cooldown and warmup is shown in red. The nitrogen phase separator vessel is located in the bottom left corner.

Photograph of the distribution box and 3,000L liquid helium dewar being moved into their final installation locations. The transfer line from the refrigeration plant comes into the building through the left wall, then extends down along the wall to make the connection to the distribution box.

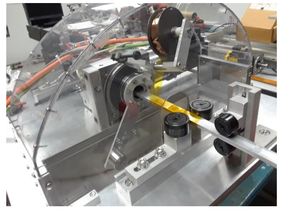
Feedboxes & Power Leads



A 3-d model showing the as-delivered state of the TSu/TSd feedboxes is shown to the left. A cut-away view of the TSu/TSu feedboxes with the power leads installed is shown on the right. The power leads and piping installed by FNAL are shown in yellow and the helium phase separator is shown in pink. The nitrogen supply and return are dark green and light green respectively. The helium supply and return are dark blue and light blue respectively.

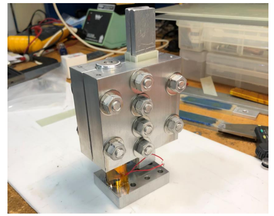


50% overlap Kapton tape wrapping of the aluminium stabilized NbTi superconductor.

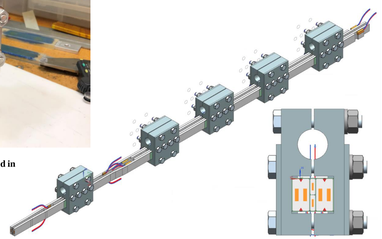


Lead wrapping machine developed for the Mu2e conductors

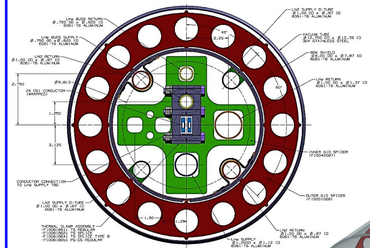
Solenoid Transfer Line



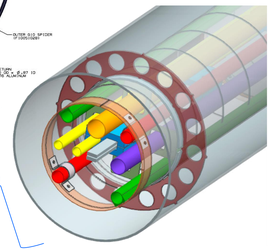
Power lead cooling clamp assembly tested in cryocooler test stand.



TS STL conductor splice clamps.



STL cross-section



Red: LN2 Supply
Green: LN2 Return
Yellow: Conductor LHe Supply & Return
Purple: Solenoid LHe Supply
Orange: Solenoid LHe Return

Summary

- Design has been completed
- Fabrication is underway

Acknowledgements

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