Fermilab

Particle Physics Division
Mechanical Department Engineering Note

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Project: CMS Upgrade Cooling System Test Design

Title: CMS CO_2 Test Stand Piping Note

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Abstract Summary:

The CMS CO_2 Detector test stand contains piping which runs from the storage tank suspended in Lab C to the South Clean room of Lab C and back again. This document serves to provide details on the piping system and its components. The piping could be subject to up to 1200 psi and a temperature drop from room temperature, down to -73C, (-100F). This piping note analyzes these criteria and shows stress does not exceed the amount allowed by ASME 31.3 code for process piping.

Table of Contents

Body:

Appendices:

1) Introduction

The piping in the CO2 Test stand will be used to transfer liquid, gaseous and supercritical CO2 from the storage tanks of the system to the CMS detector test stand, going thorough trim heater vessels, pumps and phase separators along the way. The closed loop piping system also returns the fluid from the Detector back to the storage tank. The piping system and all vessels are designed to 1200 psi of internal pressure, and -110F shock temperature. This design pressure was chosen so the system could sit pressurized at room temperature for extended periods of time without the need for evacuating the system. The piping will be insulated by 2" thick fiberglass pipe insulation and hung from pipe hangers throughout the building. All piping is grade 304 or 304L stainless steel, schedule 10 or thicker. Nominal Diameters range from ½" to 1- ½".

A system overview can be seem in Fig.1, which is drawn spatially similar to the piping and instrument diagram.

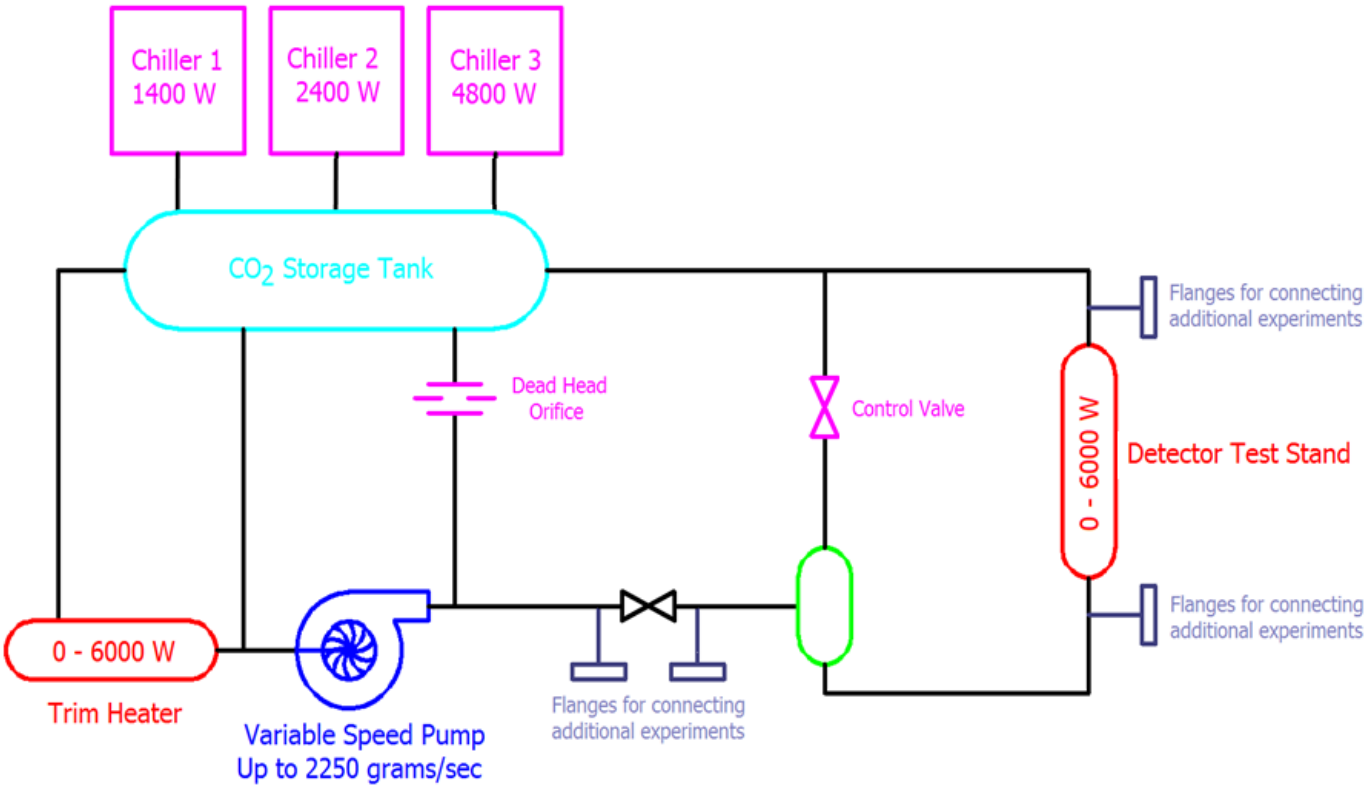

Fig.1 – CMS CO2 test stand cooling system overview

2) Piping and Instrument diagram

The piping and instrument diagram is on drawings 9212.750-ME-466879.

3) Design codes and evaluation criteria

The CMS piping meets the requirements of Section 5031.1 of the Fermilab ES&H Manual. This section states that this piping system falls under the category of Normal Fluid Service and shall adhere to the requirements of the ASME Process Piping Code B31.3.

4) Materials

The piping is fabricated from 304 or 304L stainless steel tube and pipe. The lowest allowable stress for both of these materials from Table A-1 of ASME B31.3 is 16,700 psi. The CO2 lines are primarily made of schedule 10 pipe.

The piping will be operated at -40C (-40F) minimum. This is above the minimum temperature listed for 304/316 stainless steel pipe or tube (19 K). According to Table 323.2.2 of the Code, impact testing is not required for these austenitic stainless steels. (Reference "Bo LarTPC Cryostat Piping System Engineering Note" by T. Tope)

The minimum possible temperature would happen under a pipe rupture, where the pipe could reach temperatures down to -73C (-100F) due to the sudden expansion of the CO2 and flashing of the fluid down to this Temperature. This is above the minimum temperature listed for 304/316 stainless steel pipe or tube (19 K). According to Table 323.2.2 of the Code, impact testing is not required for these austenitic stainless steels. (Reference "Bo LarTPC Cryostat Piping System Engineering Note" by T. Tope)

5) Pipe Design

Calculations were done for pressure and stress due to thermal contraction. The design uses standard tubing and fittings, which meet specifications of ASTM A403, and are therefore rated to the same temperature and pressure as the same pipe size and schedule number according to ASME 31.3.

6) Internal pressure design

The minimum thickness of the pipes is evaluated using the procedures in 304.1.2(a) of ASME B31.3. All trapped volume relief valves are set at 1200 psig.

The minimum tube thickness for seamless or longitudinally welded piping for t<D/6 is given by:

$$t = \frac{PD}{2(SEW + PY)}$$

where: t = wall thickness,

P = internal design pressure

D = outside diameter (manufacturers nominal value is used)

S = allowable stress from table A-1

E = quality factor from table A-1B = 1 for seamless, 0.8 for clamshell

W = weld joint strength reduction factor = 1 for seamless tubing, 0.8 for clamshell per 302.3.4.
Y = coefficient from Table 304.1.1 = 0.4

7) Other Piping components

- The system contains 4 flex hoses rated to a minimum of 1200 psi. The purpose of these hoses is to allow the pump to vibrate more freely, and attached to unknown detector attachments. The braided hoses are two at 1.5" x 60" (to and from detector), one at 1.5 x 12" (pump inlet), and one at 1.5 x 16" (pump outlet). The hoses were purchased from Janco Process Control.
- The Valves used in the system are stainless steel valves rated to 1480 psi. The valves are Sharpe series 99 valves.
- Strainers are class 600 strainers manufactured by Keckley, they are rated for 1480 psi
- The check valves are cryogenic swing type check valves class 600 rated
- The manual control valve is a Triad valve rated to 2000 psi
- Flanges are class 600 rated
- Hart Unions are rated to 3000 psi

Descriptions / specifications are shown in Appendix B

8) Relief Valves

Each of the six applicable piping areas are equipped with a trapped volume relief valve. These relief valves are set to open at 1200 psig. All relief valves are Anderson Greenwood Trim KT with a size '4' orifice area equal to 0.049 in^2. For specific valve numbers and locations see the Piping and Instrument Diagrams in section 2.1 above.

9) Welding and inspection

The transfer line was assembled in two phases due to the long lengths and bends would be impossible to move through doorways and such. Maneuverable sections of the piping were fabricated in Lab F. These sections were then joined and connected either by welding, Hart Unions, or flange once in place. According to B31.3 Section 341, all piping in Normal Fluid Service shall be examined. Normally radiographic examination of at least 5% of the welds is required but in certain cases where the use of radiographic examination is difficult or impossible in-process examination is allowed in lieu of radiography. The shop fabrication was done by multiple Fermilab welders. Their qualifications are in Appendix C along with the in process weld inspections.