Coldbox Documents to be Reviewed

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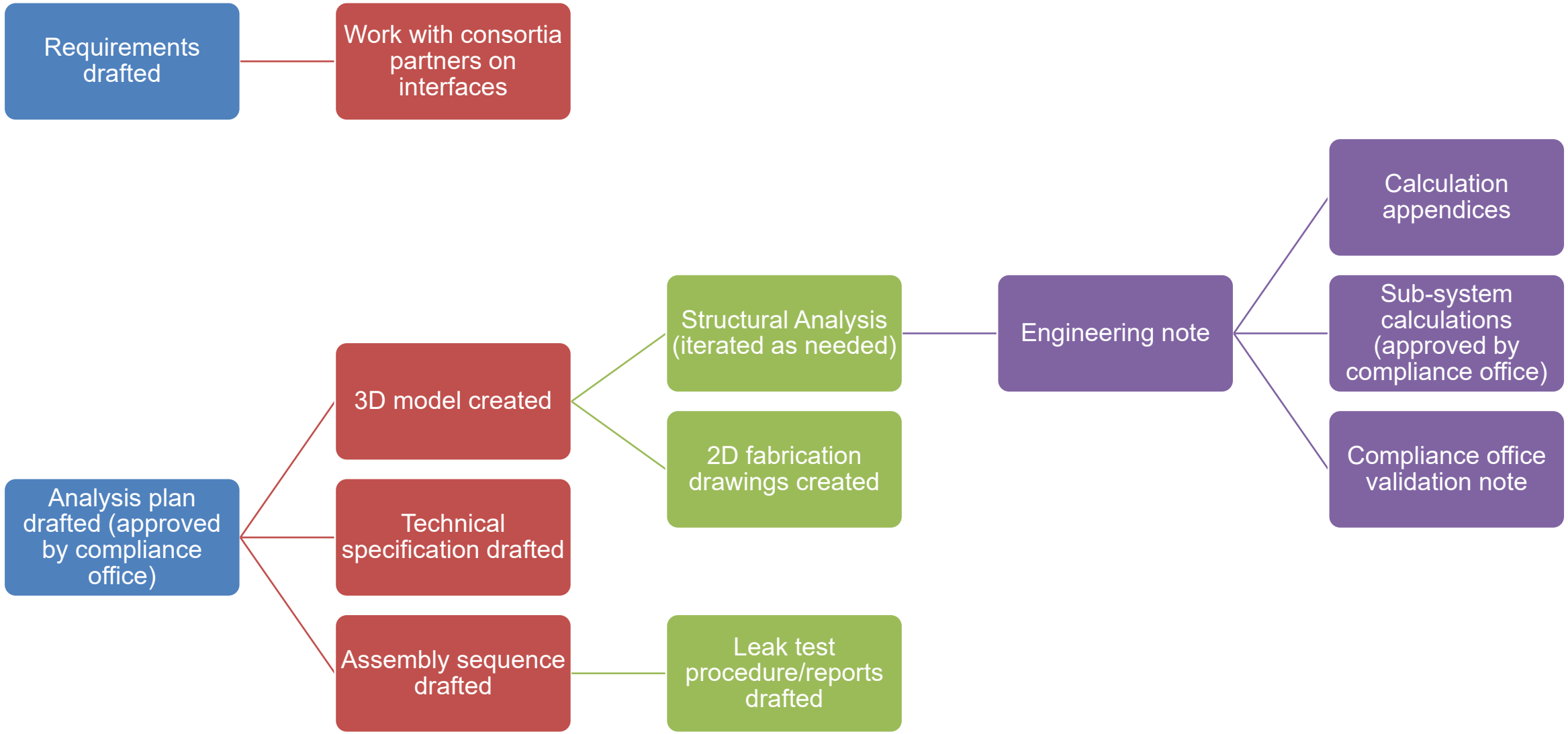
PRR: FD-HD Coldbox

28 Oct. 2024

Documentation Workflow



Documentation Summary

HD Coldbox PRR Document Review Outline		https://edms.cern.ch/project/CERN-0000252193	
Folder	**Document**	**EDMS**	**Comments**
Technical Specification	Coldbox Technical Specification	https://edms.cern.ch/document/3061760/LAST_RELEASED	
	Coldbox Requirements	https://edms.cern.ch/document/2373857/LAST_RELEASED	
	Coldbox Pressure Relief Valve	https://edms.cern.ch/document/3123703/LAST_RELEASED	
3D Model	Coldbox 3D Model	https://edms.cern.ch/document/2874217/LAST_RELEASED	.STEP / Navisworks
Structural Analysis	Coldbox Analysis Plan	https://edms.cern.ch/document/2825997/LAST_RELEASED	
	Coldbox Engineering Note	https://edms.cern.ch/document/2874218/LAST_RELEASED	
	Coldbox Calculation Appendix	https://edms.cern.ch/document/3021564/LAST_RELEASED	
Compliance Office	Coldbox Compliance Office Validation	https://edms.cern.ch/document/2883252/LAST_RELEASED	Validation document
2D Drawings	Coldbox 2D Drawings	https://edms.cern.ch/document/3061763/LAST_RELEASED	
Installation Procedure	Coldbox Assembly Sequence	https://edms.cern.ch/document/3024281/LAST_RELEASED	
	Coldbox Leak Test Procedure	https://edms.cern.ch/document/3087803/LAST_RELEASED	
	Coldbox Leak Test Report	https://edms.cern.ch/document/3089968/LAST_RELEASED	

Requirements

- Functional requirements outline specifications to be met with the design
- Main points include purpose, requirements list, and interface descriptions

1 Purpose

The integrated anode plane assemblies (APA), photon detectors, and cold electronics need to be tested at or near liquid argon temperature. This document serves as design requirements for the cold boxes, and the cryogenic refrigeration system and associated instrumentation in support of APA testing.

2 Requirements

The following table sets the minimum requirements for the HD coldboxes.

Table 1 HD Coldbox requirements

Requirement	Description
Number of cold volumes	Three independent volumes to cool down the APA doublets.
Condensation	There shall be no condensation on the outside surfaces.
Minimum internal c.o. dimensions	Internal dimensions are 108" [2.74 m] depth x 40" [1.02 m] opening width x 551" [14.00 m] high
Overall dimensions	Overall dimensions are 148" [3.76 m] depth x 80" [2.03m] wide x 591" [15.01 m] high
Internal contents	Two APAs are mounted on vertically, hung from the ceiling of the cold box. Integrated APA mass is 3133lb [1421kg]. Nearly all mass is stainless steel, electronic boards present.
Internal environment	Gaseous at 90 K and slightly above atmospheric pressure, there must be sufficient pressure relief as cold box will not withstand internal pressure, moisture must not be present in the box, nitrogen purity criteria to be provided by cryogenics.
Internal temperature uniformity	-0 K +60 K
Internal Pressure	Design pressure = 90 mbarg. Pressure relief set at ± 85 mbarg.
Cool down rate from room temperature	24 hours
Warm up rate to room temperature	24 hours with dry nitrogen gas or dry air
Operation time at cold temperature	48 hours
Operating regimes	All cold volumes capable to run cold operations simultaneously. Only one cold volume cooled at any time, with other two Cold volumes capable of cold operations. All Cold volumes capable to warm up simultaneously.

Analysis Plan

- Analysis plan is developed in combination with compliance office to determine the following for structural analysis:
  - Applicable standards/specifications (e.g., AISC)
  - Safety factors (e.g., load combinations for LRFD)
  - Manufacturing requirements
  - Material properties
  - Load cases to be analyzed
    - Load and mass tables outlining forces imposed for each load case
- Analysis plan is used as outline for the engineering note

5 Loads and Mass

The table below gives a summary of the loads and the mass of the equipment stored in the coldboxes. The mass of the structures is based on the geometry available in EDMS 2874217. The mass of the APA fully integrated is based off mass table available in EDMS 2281422.

Table 5-1 Mass and Loads

Structural Loads		Load Type	Load	
			U.S.	SI
Coldbox structure	Structure (excluding door)	Uniform distribution	27979 lbm	12691 kg
	Insulation	Uniform distribution	3500 lbm[1]	1588 kg
Coldbox door	Structure	Uniform distribution	5814 lbm	2637 kg
	Insulation	Uniform distribution	500 lbm	227 kg
Monorail Assembly	Structure	Uniform distribution	351 lbm	159 kg
Cryogenic equipment	Self-weight	Localized distribution on roof	400 lbm	181.44 kg
CE test equipment	Self-weight	Localized distribution on roof	276 lbm	125 kg
APA fully integrated	Self-weight	Remote force	3133 lbm	1421 kg
Internal pressure	Pressure	Uniform distribution	1.3 psi	90 mbar
Internal Temperature	Temperature	Target Internal	-297.7 °F	-183.15 °C
	Temperature	Temperature uniformity	-0 °K	
			+60 °K	

[1] Value calculated from Table C3.1-1a. Minimum Design Dead Loads in ASCE 7-22 and model geometry.

Engineering Note

- Engineering note covers results for each load case as outlined in the analysis plan
  - Descriptions of the FEM (finite element model) input parameters are outlined in the engineering note (e.g., material properties, mesh settings, boundary conditions)
  - FEA is used to extract deformations, stresses, reaction forces, and buckling analysis for each load case
  - Additional checks for bolted and welded connections
- Structural analysis conducted according to AISC 370 for stainless steel construction
  - Connection/member evaluation appendix outlines structural calculations for capacities
- Check design strength is adequate for all load cases

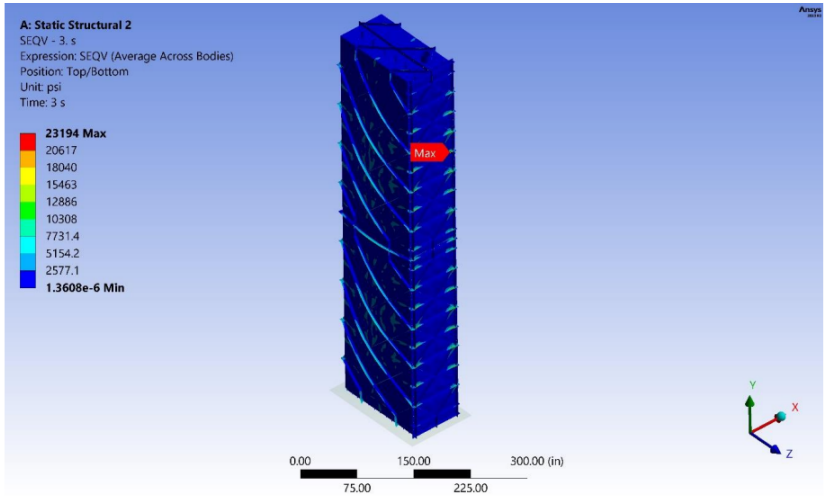
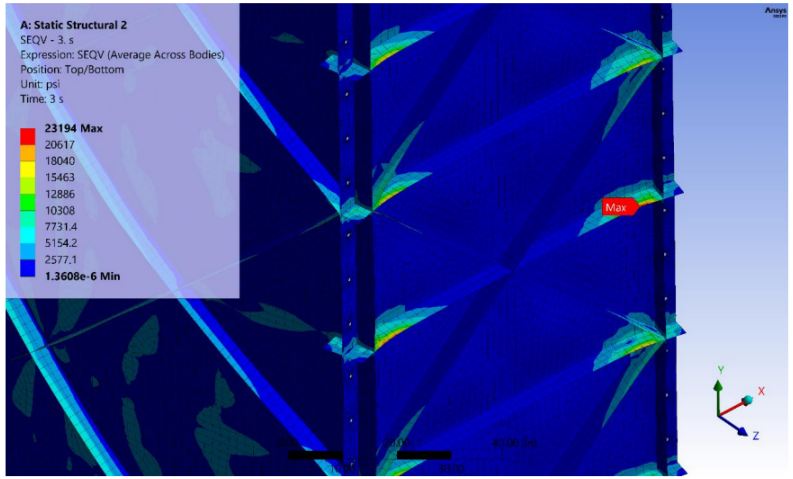
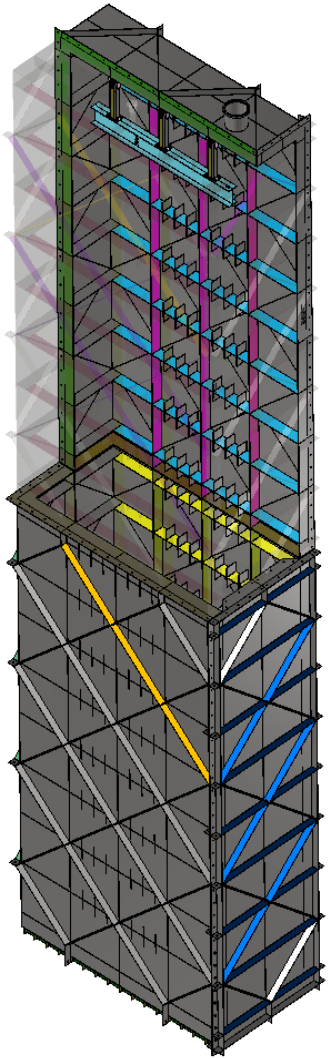


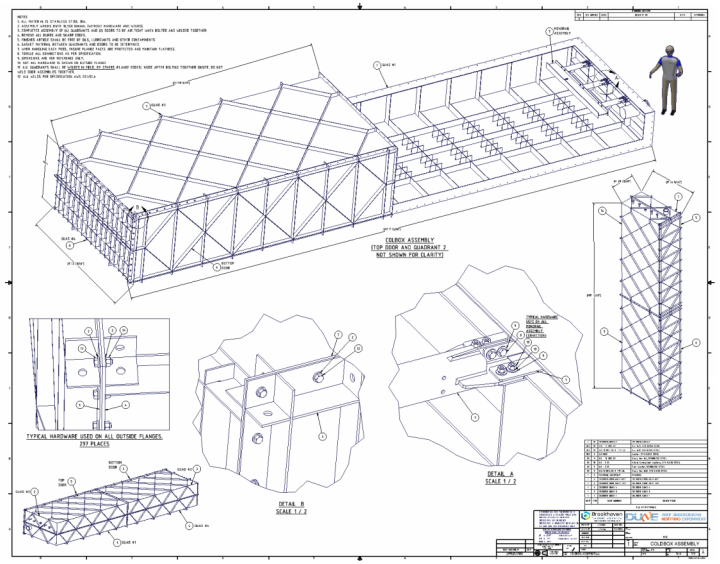
Figure 6-13 Von-Mises Stresses (LC2)

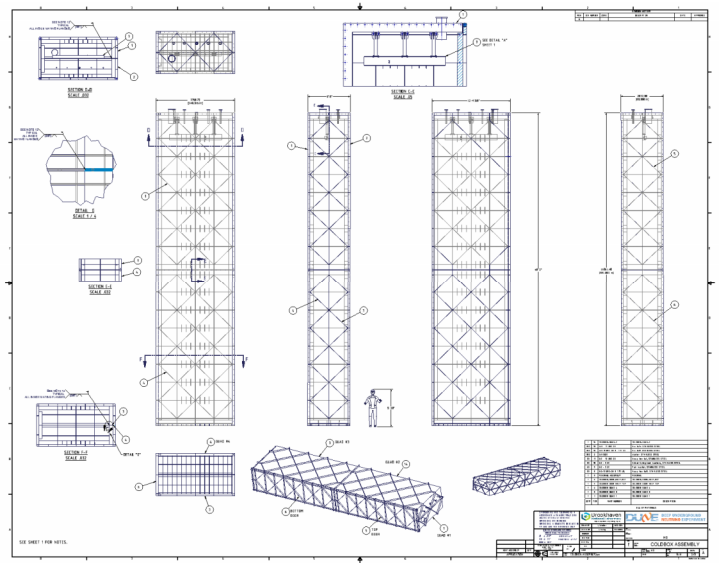


3D Model & 2D Drawings

- 3D model is developed to satisfy functional requirements, optimization and iteration is conducted during the structural analysis
- 2D drawings are constructed from the 3D model and prepared for fabrication







Technical Specification

- The technical document serves as the precursor to procurement specification
- Contains scope of work, delivery and quality requirements for vendors

3 Scope of Work

The vendor shall procure all materials, fabricate, assemble, test, package and deliver the complete individual components as shown in Table 1 HD Coldbox Assemblies. FRA provides to the vendor detailed contractual 3D models and 2D drawings of all components and assemblies at the following link locations:

- 2D drawings in .DXF, .PDF formats [2]: https://edms.cern.ch/project/CERN-0000252347
- 3D models in .STP format [3]: https://edms.cern.ch/project/CERN-0000252254

All models and drawings can be used for construction, once signed as released by FDC LBNF/DUNE.

The main contractual detailed drawings are listed in Table 1 HD Coldbox Assemblies. The BOM contains all relevant components that make up this assemblies with their material and quantities specified. All tolerances shown on drawing shall be achieved.

Table 1 HD Coldbox Assemblies

Assembly Name	Drawing Number	Part Identifier (PID)	Quantity
TOP LEVEL COLDBOX ASSEMBLY	COLDBOX-ASSEMBLY	D-086-002-00001-0000#[1]	3
QUADRANT1	COLDBOX-QUAD-1	D-086-002-00002-0000#	3
QUADRANT2	COLDBOX-QUAD-2	D-086-002-00003-0000#	3
QUADRANT3	COLDBOX-QUAD-3	D-086-002-00004-0000#	3
QUADRANT4	COLDBOX-QUAD-4	D-086-002-00005-0000#	3
DOOR HALF TOP	COLDBOX-DOOR-HALF-TOP	D-086-002-00006-0000#	3
DOOR HALF BOTTOM	COLDBOX-DOOR-HALF-BOT	D-086-002-00007-0000#	3
MONORAIL SUBASSEMBLY	COLDBOX-MONORAIL-ASSEMBLY	D-086-002-00008-0000#	3

All components must be packaged to ensure materials will conform to specifications upon shipment, delivery, and storage at SDWF.

Installation Procedures

- Draft coldbox assembly sequence document in addition to the leak test procedures
- Steps through high level assembly points and procedures for underground work
- Leak test procedures will serve to verify welds for leak tightness

Table of Contents

Dimensions	148" [3.76 m] deep x 80" [2.03m] wide x 591" [15.01]
Cold Box steel weight w/o doors	30,671 lbm
Cold box internal volume (no Insulation)	3,371 ft³ [95.5 m³ or 95,500 liters]
Cold box door steel weight	5,832 lbm
Door Bolts	(168) 5/8" bolts
Cold Box roof penetrations:	
CE Flange	DN250CF
Cryostat Flange 1	2 inch tube
Cryostat Flange 2	2 inch tube
Cryostat Flange 3	1 ½ inch tube
Cryostat Flange 4	1 ½ inch tube
Cryostat Flange 5	1 ½ inch tube
Nominal operating Pressure	60 mbar
Pressure relief valve rating	85 mbar 1.3 PSIG
Allowable leak rate	1 SCFM (478 mBar l/s)

Table 1-1
Coldbox Parameters

The pressure test setup is shown in Figure 4-3. An air compressor with a low pressure regulator is uses to supply 60mBar air. The pressure test unit is attached to the cold box using the last open port on the cold box roof. The pressure in the cold box is increased to the nominal pressure rating of 60 mBar. The air feed valves are then closed and the pressure on the Test Pressure gauge recorded.

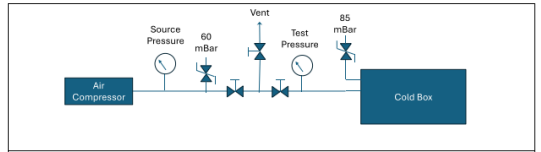


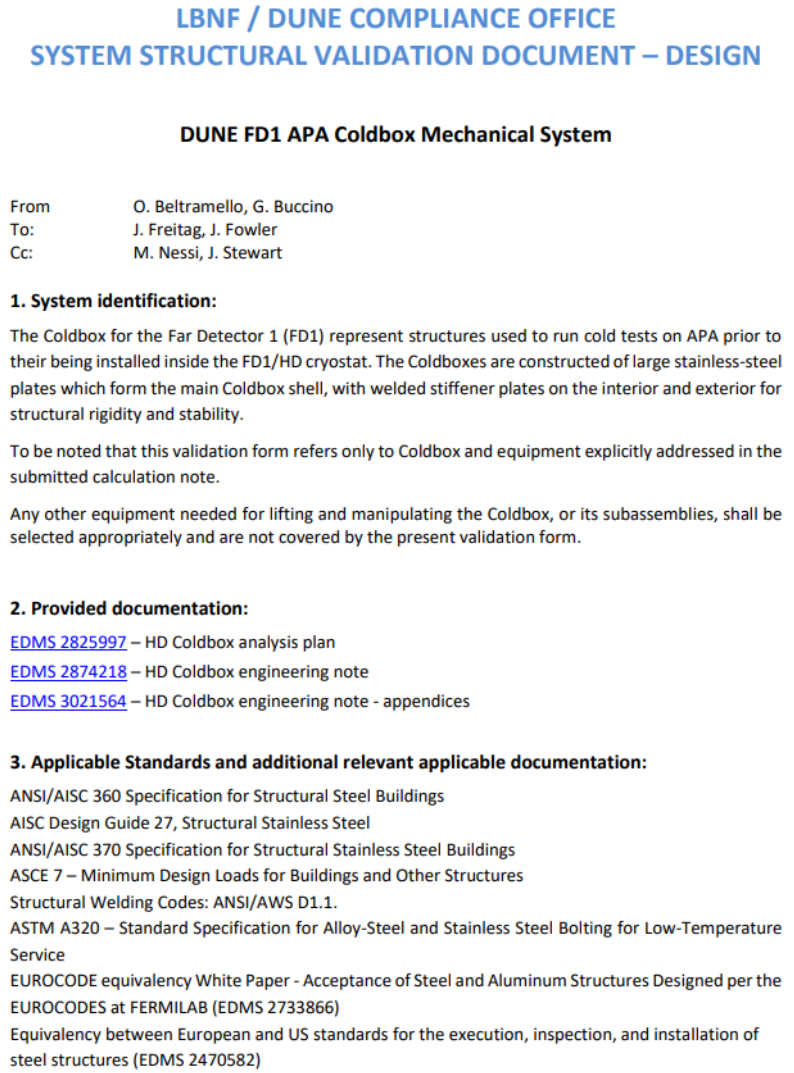
Figure 4-3 Pressure test setup.

The leak rate is determined by measuring the pressure change over a fixed time. The leak rate equation is:

$$Q = V\frac{\Delta P}{\Delta T}$$

Validation

- Compliance office reviews engineering note and calculations, ensuring analysis was conducted correctly with respect to the load cases outlined in the analysis plan
  - Worked with compliance office through the process to iterate/optimize as necessary



LBNF / DUNE COMPLIANCE OFFICE
SYSTEM STRUCTURAL VALIDATION DOCUMENT – DESIGN

DUNE FD1 APA Coldbox Mechanical System

From O. Beltramello, G. Buccino
To: J. Freitag, J. Fowler
Cc: M. Nessi, J. Stewart

1. System identification:

The Coldbox for the Far Detector 1 (FD1) represent structures used to run cold tests on APA prior to their being installed inside the FD1/HD cryostat. The Coldboxes are constructed of large stainless-steel plates which form the main Coldbox shell, with welded stiffener plates on the interior and exterior for structural rigidity and stability.

To be noted that this validation form refers only to Coldbox and equipment explicitly addressed in the submitted calculation note.

Any other equipment needed for lifting and manipulating the Coldbox, or its subassemblies, shall be selected appropriately and are not covered by the present validation form.

2. Provided documentation:

EDMS 2825997 – HD Coldbox analysis plan
EDMS 2874218 – HD Coldbox engineering note
EDMS 3021564 – HD Coldbox engineering note - appendices

3. Applicable Standards and additional relevant applicable documentation:

ANSI/AISC 360 Specification for Structural Steel Buildings
AISC Design Guide 27, Structural Stainless Steel
ANSI/AISC 370 Specification for Structural Stainless Steel Buildings
ASCE 7 – Minimum Design Loads for Buildings and Other Structures
Structural Welding Codes: ANSI/AWS D1.1.
ASTM A320 – Standard Specification for Alloy-Steel and Stainless Steel Bolting for Low-Temperature Service
EUROCODE equivalency White Paper - Acceptance of Steel and Aluminum Structures Designed per the EUROCODES at FERMILAB (EDMS 2733866)
Equivalency between European and US standards for the execution, inspection, and installation of steel structures (EDMS 2470582)

Pressure Relief Valve Data

- Cryogenics engineer prepared pressure relief valve calculations and analysis
  - Main analysis document with appendix documents for reference and part selection

Analysis Setup

System Description

The overpressure protection and relief system design is based on a single APA Testing Cold Box. The system's P&ID close up is presented on the next page.

Overpressure Scenarios

In the process of ensuring the safety and reliability of our pressure relief system, it is crucial to accurately determine the required capacity of safety valves. This analysis will focus on one overpressure scenario: **blocked discharge.** By evaluating this scenario, we can ensure that the selected safety valves will provide adequate protection against overpressure conditions, thereby safeguarding our equipment and personnel. The following sections will detail the step-by-step calculations and considerations involved in sizing the safety valves for these specific scenarios, based on the guidelines provided in API Standard 520.

Data

General Data

$P_{atm} := 14.7\ psi$ - Barometric pressure

$MAWP := 90\ mbar = 1.305\ psi$ - Cold Box MAWP (gauge)

$a := 2699\ mm$ $b := 950\ mm$ $h := 13628\ mm$ - Cold Box internal dimensions

$m_q := 0.028\ \frac{kg}{s}$ - Cold Box system cooldown flow rate

$R := 8.314\ \frac{J}{K \cdot mol}$

$\nu_{N2} := 0.23788\ \frac{m^3}{kg}$ - nitrogen specific volume (@90K, MAWP)

$\mu_{N2} := 6.31 \cdot 10^{-6}\ Pa \cdot s$ - nitrogen dynamic viscosity (@90K)

$M_{N2} := 28\ \frac{gm}{mol}$ - nitrogen molecular weight