FESHM 5031.1: PIPING SYSTEMS

Revision History

Author	Description of Change	Revision Date
Michael White	• Added low stress piping category	7-March-2016
Terry Tope	• Clarified 150,000 ft-lb threshold for piping engineering note generation. • Added an exclusion for piping attached to a single gas bottle. • Added guidance with respect to independent review. • Added WPS and inspection guidance in 7.0 items 6 and 7. • In-process examination form added as a technical appendix.	10-Jun-2015
Terry Tope	Updated Teamcenter posting procedure.	02-Apr-2015
Terry Tope	Required posting of engineering note to Teamcenter. Explicitly noted that amendments require Division / Section / Center approval. Provided additional guidance with respect to used piping systems.	24-Oct-2014
Thomas Page	Revised wording in Section 5.0, Item 8 to clarify the review of Amendments. Added wording in Section 7.0, Items 7, 8 and 9.	17-Sep-2012
Thomas Page	Release Chapter 5031.1 using new FESHM template. Revised wording in Section 7, Item 2. Added Non-flammable Scintillator to Table 1.	09-Jul-2012

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1.0 INTRODUCTION

This chapter defines procedures for designing, fabricating and testing piping systems.

2.0 SCOPE

This chapter applies to all piping systems fabricated and/or operated at Fermilab except those falling under the scope of FESHM 5035: Mechanical Refrigeration Systems.

3.0 DEFINITIONS

Engineering Note: A written analysis demonstrating that a given piping system satisfies the requirements of this chapter.

Qualified Person: A qualified person is a person who, by possession of a recognized degree or certificate of professional standing, or who, by extensive knowledge, training and experience, has successfully demonstrated the ability to solve or resolve problems relating to the subject matter and work.

Radioactive Water (RAW) System: Water systems containing radioactive water as defined in FRCM (Fermilab Radiological Control Manual) Article 346, *Control of Radioactivated Cooling Water.*

Appropriate Governing Code: A national, state or local piping code or standard that specifies design, fabrication, and operation requirements and practices that must be followed for piping systems within their respective scopes.

Exceptional Piping System: A piping system which cannot meet the requirements of this chapter and therefore requires a Director's exception.

Low Stress Piping: Low stress piping fluid service is when:

- The design gage pressure is less than 150 psig (1.035 MPa)
- The combined stress is less than 20% of allowable for all components
- All fittings are pressurized to less than 20% of their rating
- The maximum design temperature is less than 366 °F (186 °C)
- All materials are ASME code listed for the range of design temperatures
- The fluid handled is nonflammable, nontoxic, and, except for effects of temperature, not damaging to human tissue

4.0 SPECIAL RESPONSIBILITIES

The Division/Section/Center Head who controls the area of operation of the piping system is responsible for carrying out the requirements of this chapter. The Division/Section/Center Head, or designee, shall arrange for the review of required Engineering Notes by a qualified person and shall certify piping systems compliance with this chapter by signing the Engineering Notes. The Engineering Notes shall be placed into Teamcenter.

The Environment, Safety, Health, and Quality (ESH&Q) Section shall audit the Divisions / Sections /Centers on their compliance to this chapter.

The Mechanical Safety Subcommittee (MSS) shall serve the Division/Section/Center Heads and ESH&Q Section in a consulting capacity on all piping system matters. This includes providing recommendations regarding the applicability of a standard to a given piping system. The Mechanical Safety Subcommittee may propose appropriate modifications to this chapter as necessary. Changes in policy and responsibility shall be recommended by the Laboratory Safety Committee after consulting with the Division/Section/Center Heads.

5.0 POLICY AND REQUIREMENTS

1. *Policy:* All piping systems built and/or operated at Fermilab shall be in accordance with this chapter and the appropriate governing code. See Table 1 for guidance in the selection of the appropriate governing code for common piping systems operated at Fermilab. Note that the recommendations given in Table 1 are general. Evaluation of each specific piping system (operating parameters, fluid type, environment, etc.) is necessary to determine the appropriate governing code and category.

    a. When an appropriate governing code cannot be identified for a particular piping system or a when a piping system falls outside the scope of the appropriate governing code, accepted engineering practice (commensurate with the piping system parameters and risk factors) shall be employed. The piping system in question is still subject to the remaining requirements of this chapter.

    b. Where multiple codes apply, accepted engineering judgment shall determine the most appropriate code considering the hazards and risks of the individual piping system. At a minimum, ASME B31 Pressure Piping code series will govern for those piping systems within their respective scopes.

2. *Documentation*: An Engineering Note shall be prepared by a qualified person for all piping systems identified below (2.a), whether purchased or in-house built. The format

of the Engineering Note is shown section 7.0. Its purpose is to allow a reviewer to check the design and installation and to inform a future user of the piping system's parameters. The document shall include design calculations for the piping systems and manufacturer's compliance to the appropriate governing code for purchased piping systems. All code-required documentation shall be appended to the document including welding/brazing qualification records and inspection/examination records. The document shall also include precautions, diagrams, documents and operation procedures necessary for the safe use of the piping system.

a. An Engineering Note must be prepared, reviewed, and approved when:

   i. The piping system contains over 150,000 foot pounds (ft-lbs) of stored energy or the operating pressure is above 150 pounds per square inch (psi) for gas, or 500 psi for liquid, or the design operating temperature is above 366° F. The stored energy calculation should include all pressurized volumes connected to the piping such as pressure vessels. Excluding those piping systems temporarily erected for pressure testing purposes. These systems are subject to the Fermilab Environment, Safety, and Health Manual (FESHM) Chapter 5034, *Pressure Testing*. Also excluding piping systems of ½ inch Nominal Pipe Size (NPS) diameter or smaller, which are erected on the downstream side of the pressure regulator connected to a single gas cylinder and adequately protected with relief(s) below 150 psi).

   ii. The piping system falls within the scope of American Society of Mechanical Engineers (ASME) B31.3 Process Piping Code – Normal Fluid Service (excluding those piping systems containing only water).

   iii. The piping system is a hydraulic (oil) piping system (primarily hydrostatic; not used for transport of the fluid) with a design operating pressure above 10,000 psi.

   iv. The piping system falls within the scope of ASME B31.3 Process Piping Code – Category M.

   v. The piping system has the potential for an environmental release exceeding the occurrence reporting criteria of FESHM 3010, *Significant and Reportable Occurrences*. This includes RAW cooling systems.

   vi. The piping system is an Exceptional Piping System.

b. Piping systems that do not require Engineering Notes are still required to satisfy the appropriate governing code. In these cases, all code-required documentation shall be kept on file by the responsible engineer or Department Head (or their designee).

6. *Review of piping systems*: All required Engineering Notes (see 2.a above) shall be reviewed by an independent, qualified reviewer, other than the person who prepared it, for concurrence to this chapter. The review of the Engineering Note shall include review of code-required installation documentation to ensure conformance of the installation to the appropriate governing code. The engineering note reviewer should not report directly to the preparer of the note nor should he or she be able to be perceived as having a conflict of interest in reviewing the note. As a general guideline, a conflict of interest could result from the reviewer having direct involvement in the project for which the note was written.

7. *Piping Systems with Additional FESHM Chapter Requirements*: Some piping systems must comply with more stringent safety analyses. Additional Fermilab ESH&Q chapters have been written for these specific systems. The documentation and review requirements for these systems are included in the following chapters:

    a. Any flammable gas system covered and reviewed under Fermilab ESH&Q Manual Chapter 6020.3, *Storage and Use of Flammable Gases*.

    b. Any cryogenic system covered and reviewed under FESHM Chapter 5032, *Cryogenic System Review*.

8. *Modifications to a compliant piping system*: Any subsequent changes in usage or operation of a piping system (already in compliance with this chapter) shall meet the requirements of this chapter. Significant modifications impacting piping system safety shall be documented in an Amendment to the original Engineering Note (for those systems requiring Engineering Notes). This Amendment shall be reviewed in the same manner as the original note and requires Division/Section/Center Head approval. A new piping engineering note form shall be created for each revision.

9. *Director's Exception*: Exception to the provisions of this chapter shall be allowed only with the approval of the Laboratory Director or his designee and documented in the Engineering Note. The need for such exceptions is to be minimized by adherence to the provisions of this chapter. Exceptions are to be identified and submitted to the Director for review as early in the design process as possible. These exceptions shall only be allowed after the Director is assured that sound engineering practice will be followed during design, fabrication and test of the piping system. Amendments to exceptional piping engineering notes require the Director's approval if the changes documented by the amendment are in exception to the provisions of this chapter. Amendments to exceptional piping engineering notes which document changes in compliance with this chapter requires Division/Section/Center Head approval.

6.0 PROCEDURES AND REQUIREMENTS FOR DESIGN, FABRICATION, INSPECTION AND TEST

1. *Purchased Piping Systems:* All piping systems purchased by Fermilab or its experimenters shall be made (designed and fabricated) in accordance with this chapter.

2. *In-House Built Piping Systems*: All pressure piping systems built at Fermilab or experimenter's shops shall be designed and fabricated in accordance with this chapter. Welding/brazing executed at Fermilab shall be done in accordance with the appropriate governing code requirements including applicable welding qualification and inspection/examination requirements. When an appropriate governing code cannot be identified for a particular piping system or when a piping system falls outside the scope of the appropriate governing code, accepted welding/brazing fabrication procedures (commensurate with the piping system parameters and risk factors) shall be employed.

3. *Existing Piping Systems In Service*: All such piping systems must be in accordance with this chapter. Piping systems with unknown histories shall be reviewed and documented in accordance with this chapter except that they may be retested per the *Leak Test* section of this chapter (see 5 below) in lieu of detailed welding qualification records and non-visual examination/inspection records. Acceptance of this substitution is subject to the reviewer's discretion.

4. *Reclaimed Piping Systems*: Used piping systems shall be classified as an existing piping system and will have their previous service taken into account during the review process. Used piping systems or components that have been reclaimed, moved to a new location, or put into new service require either the creation of a new piping engineering note or an amendment to an existing piping engineering note.

5. *Leak Test*: All piping systems shall be pressure tested as required by the appropriate governing code. When an appropriate governing code cannot be identified for a particular piping system or when a piping system falls outside the scope of the appropriate governing code, accepted engineering practice (commensurate with the piping system parameters and risk factors) shall determine leak test requirements. Used piping systems or components that have been reclaimed, moved to a new location, or put into new service shall meet the same leak test requirements as new construction. Unmodified piping between a pressure vessel and the first flange or isolation valve need not be pressure tested provided the service is unchanged.

    a. The initial service test is considered the pressure test for ASME B31.3 Category D piping systems. No safety officer oversight per FESHM 5034 is required for pressure testing piping systems in this category.

b. Low Stress Piping may be tested with the initial service test per ASME B31.3 345.7 for Category D piping in lieu of hydrostatic or pneumatic pressure tests. The initial service test shall be done with room temperature fluid per FESHM chapter 5034.

c. Internally pressurized tests as described in ASME B31 Codes for externally pressurized pipe are not required for ASME B31.3 Category D and B31.9 vacuum jackets and vacuum piping. Standard sensitive leak tests using tracer gases satisfy the leak test requirements of this chapter. No safety officer oversight per FESHM 5034 is required for these tests.

d. All other piping systems requiring leak tests shall be pressure tested as described per FESHM 5034. In case of conflicts between the appropriate governing code and FESHM 5034, the more restrictive or conservative procedure will be followed.

6. *Component Identification*: Components on piping systems shall be labeled as required by the appropriate governing code. In addition, it is recommended that components on all piping systems that require Engineering Notes be labeled to correspond to an up-to-date piping and instrument diagram. Labels should be permanent, securely attached and easy to read. Each component label should list a unique component number for that system. Guidance may be obtained from American National Standards Institute (ANSI) A13.1 "Scheme for Identification of Piping Systems".

Table 1: Applicable code guidance for common systems at Fermilab.

Piping Service or Application	Applicable Code or National Standard											
	ASME B31.1	ASME B31.3 Normal Fluid Service	ASME B31.3 Cat. D Fluid Service	ASME B31.3 High Purity Fluid Service	ASME B31.5	ASME B31.8	ASME B31.9	NFPA 13	NFPA 24	ASME A17.1	ANSI Z223.1	Illinois Plumbing Code, Title 77 Part 890
Building Sump Pump Discharge							X					
Compressed air/inert gas							X					
Cryogenic Liquid or Gas		X										
Domestic Potable Water												X
Elevator and Lift Hydraulic Systems										X		
Fire Protection								X				
Flammable Gas		X										
Fuel Gas Piping from point of delivery to burner											X	
Fuel Gas Transmission Piping						X						
House Vacuum							X					
Industrial Cooling Water external to buildings									X			
Industrial Cooling Water internal to buildings							X					
Inner Pipe of Vacuum Insulated Cryogenic Piping		X										
Low Conductivity Water		X	X									
Non-flammable Scintillator				X								
Pond Water Cooling Systems							X					
Radioactive Water		X										
Refrigerant for HVAC					X							
Refrigerant for Process Systems		X										
Sewer Piping												X
Steam for Heating Applications							X					
Steam for Power Generation	X											
Vacuum Jacket of vacuum insulated piping			X									

7.0 ENGINEERING NOTE

1. Engineering Note: An Engineering Note shall be prepared by the designer addressing the topics below for the piping system. Its purpose is to allow the reviewer to check the design and installation and to inform the future user / re-tester of the system parameters. The note shall be deposited in Teamcenter as noted in Chapter 5031.1 under "Special Responsibilities" using the procedure outlined below.

    a. A New Item shall be created in Teamcenter with the type chosen as Engineering Note
        i. The New Item Name shall use the Piping System prefix followed by a meaningful Name which briefly describes the contents of the note
        ii. A full Description shall be entered for the New Item
    b. If applicable the Division Legacy Number shall be entered
    c. The appropriate Engineering Note category of Piping System shall be chosen
    d. The Revision Author, Revision Comments, Lab Location Code, Exceptional Status, and Division\Section\Center shall be entered
    e. The Engineering Note and supporting files shall be added as Data Sets. All documentation required for independent review of the Engineering Note must be included.
    f. Approval
        i. The Teamcenter Workflow may be used to electronically obtain the required approvals and release the Engineering Note.
        ii. Approvals may also be obtained by physical signature, scanned, and included with the Engineering Note. A Teamcenter Workflow must still be completed so that the Engineering Note is released. This workflow need not involve the required approvers in the case of physical signature.
    g. Amendments to existing Engineering Notes shall be entered as a Revision to the original Item in Teamcenter.

2. Description and Identification: Describe the system, its purpose, fluid contents, piping materials, site location, and how the design pressure and temperature were established. All documents deemed pertinent to the safety shall be listed and included.

3. Design Verification: Identify the applicable Code and provide design calculations.

4. Pressure Containment / Relief System: If required, describe any system features which prevent design pressure from being exceeded.

5. Welding / Brazing Information: Welding / brazing executed at Fermilab shall be done in a manner according to the Code. In-house procedures shall be appended to the Note for welded and brazed systems built at Fermilab. Purchased systems shall be welded according to the Code. (Weld procedures for purchased piping systems need not be included in the Engineering Note but should be provided by the contractor to the Inspector if requested.)

6. Welder's Qualification:

    a. Attach welder's qualification records if welded / brazed in-house.

    b. Qualification of a new in-house WPS should include any examinations required by the inspection plan.

7. Inspection Plan:

    a. Attach a copy of the system's inspection plan. This should specify how the system was inspected: radiography, in-process, etc.

    b. The inspection plan should be shared with the welders and/or brazers prior to the start of fabrication.

    c. The technical appendix contains the in-process examination form for typical stainless steel piping butt welds performed in-house.

8. Examiner's Report: Attach a copy of Examiner's report. This should include the examination reports: radiography reports, in-process examination forms, etc.

9. Inspector's Certification: Attach a copy of Inspector's certification of this system. This applies to purchased systems and will be a report or statement on vendor's certification that the piping system conforms to the appropriate Code.

10. Component Identification: Attach the Process and Instrumentation Diagram (PID) and the associated component and instrumentation list.

11. Leak Test: Attach a copy of the leak test plan, including test pressure, and results, if available, at the time of review. The test permit and test results should be appended to the approved Note as soon as they become available.

12. Extended Engineering Note for Exceptional Piping Systems: In addition to the items listed above, the Note shall include the following information:

    a. *Reason for Exception:* Division/Section/Center Head or designee shall provide a statement showing the necessity for a Director's exception.

b. *Exception Protocol:* The Division/Section/Center Head or designee shall provide a written record of the decisions, judgment, tests, administrative controls, and hazard analysis that were necessary to approve this type of system.

c. *Proof Test:* Proof tests of unlisted components in the system shall be performed in accordance with ASME Boiler Pressure Vessel Code Section VIII, Division 1, UG-101 or ASME B16.9.

d. *Fabrication:* The system designer shall provide a fabrication procedure, a list of planned and completed inspections and any other quality control procedures taken.

e. *What-if Analysis:* The system designer shall provide a description of personnel hazards associated with system operation and the methods used for protection. The What-if Analysis shall address application, operating limits and controls, possible effects in the event of failure and inherent safeguards provided.

8.0 FORM

The Piping System Engineering Note Form, Form 5031.1, can be found on the ESH&Q website or the ESH&Q document management database.

9.0 TECHNICAL APPENDICES

1. In-process examination form

Rev: 0
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Fermilab
In-Process Weld Examination Form

Filled by engineer:

Project: _____ Weld Type: _____ WPS #: _____

Drawing #: _____ Pipe #1 Size: _____ Engineer: _____

Weld #: _____ Pipe #2 Size: _____ Date: _____

Filled by inspector:

Welder: _____ Inspector: _____

WPQ Qualified? YES ☐ Other ☐

Filled by examiner in field:

Date: _____ Examiner: _____

In-Process Visual Examination (see more info on the next page)	***Check if OK***
a) joint preparation and cleanliness Joint surfaces are free of chips, particles, dust, rust, scale, oil, grease, etc.	
b) pre-heating: (N/A if ambient temperature ≥ 50° F [10° C]) ambient temp._____ pre-heat temp._____	
c) AWS Filler Metal Specification_____ Manfacturer_____ Filler rod: Class_____ Diameter(s)_____ Is filler certified?_____Is a copy of CMTR or COA available_____ Heat #(s)_____Lot#(s)_____ gap_____ type of purge gas_____ purge flow-rate & duration_____ or O_2 reading _____	_____ _____ _____
c)(1) for butt welds: confirm ID at end preparation is within ± 1/32" and OD is aligned properly	
d) for brazing: position, flux, brazing temperature, wetting, and capillary action	
e) for welding: condition of root pass (after cleaning) – external and/or internal	
e)(1) for SMAW (stick welding): slag removal and weld condition between passes	
f) appearance of finished joint: No visible cracks, lack of fusion, porosity, obvious imperfections, incomplete penetration Filler material is fused to edges of parent material Depth of undercut (< 1/32", N/A if non-existent)_____	 _____ _____ _____

Best welding practices

a) Joint Preparation and Cleanliness:

Use scotch bright or Aluminum oxide to clean the joint. Use only wire brushes dedicated for stainless steel on stainless steel. Carbon steel brushes can leave carbon particles in the joint.

b) Preheating:

Minimum temperature for P1 (carbon steel) and P8 (304/316 stainless steel) is 50° F [10° C]. For all other materials or atypical stainless steels, refer to para. 330 of B31.3.

c) Variable specified by WPS (Welding Procedure Specification):

* Welding Machine:
  Remote foot pedal required
  DC straight machine required.
* Filler rod must be AWS A5.9 designation (for stainless)
* Record diameter and class (308SS or 304LSS ... etc.) of filler rod
* Required Filler Rod Class

If connecting	304SS to 304SS	use 308 filler rod
If connecting	304SS to 304LSS	use 308L filler rod
If connecting	304LSS to 304LSS	use 308L filler rod
If connecting	316SS or 304 SS to 316SS	use 316 filler rod

For any other combination consult with the Fermilab weld shop.

* CMTR--Certified Material Test Report, COA-Certificate of Analysis, COC-Certificate of Conformonce

* Purge Gas
  Purge gas must be 99.995% pure welding grade Argon. Boil off gas from a liquid argon dewar is acceptable.
* Purge Flow
  Purge gas must flow through the pipe, past weld joint to remove oxygen. As a general rule the pre-weld purge should give 5-6 volume changes.
* Oxygen concentration
  Oxygen concentration must be less than 1%. If available, use an oxygen monitor to measure the O2 concentration of the exhausting purge gas.
* Joint Clearance (gap)
  Butt weld: per WPS
* Socket weld: 1/16" (+1/16", -none) clearance between socket base and adjoining piece.
  End Preparation: Align inside surfaces of joint within ± 1/32" or WPS requirement (whichever is smaller). For unequal pipe diameters or thicknesses, refer to design drawing.
* Internal Alignment:
  Butt Weld: If the two pieces have the same OD and wall thickness, alignment can be confirmed using a straight edge on the OD.

(e) Inspection:

Repeat inspection after every pass (does not need a separate form)