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Particle Physics Division
Mechanical Department Engineering Note

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Project: NOvA

Title: Scintillator Fill Piping Service Selection and Inspection Criteria.

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Applicable Codes: ASME B31.3, (2010) ASM BPE (Bioprocessing Equipment) (2009) , FESHM 5031.1 current version

Abstract Summary:

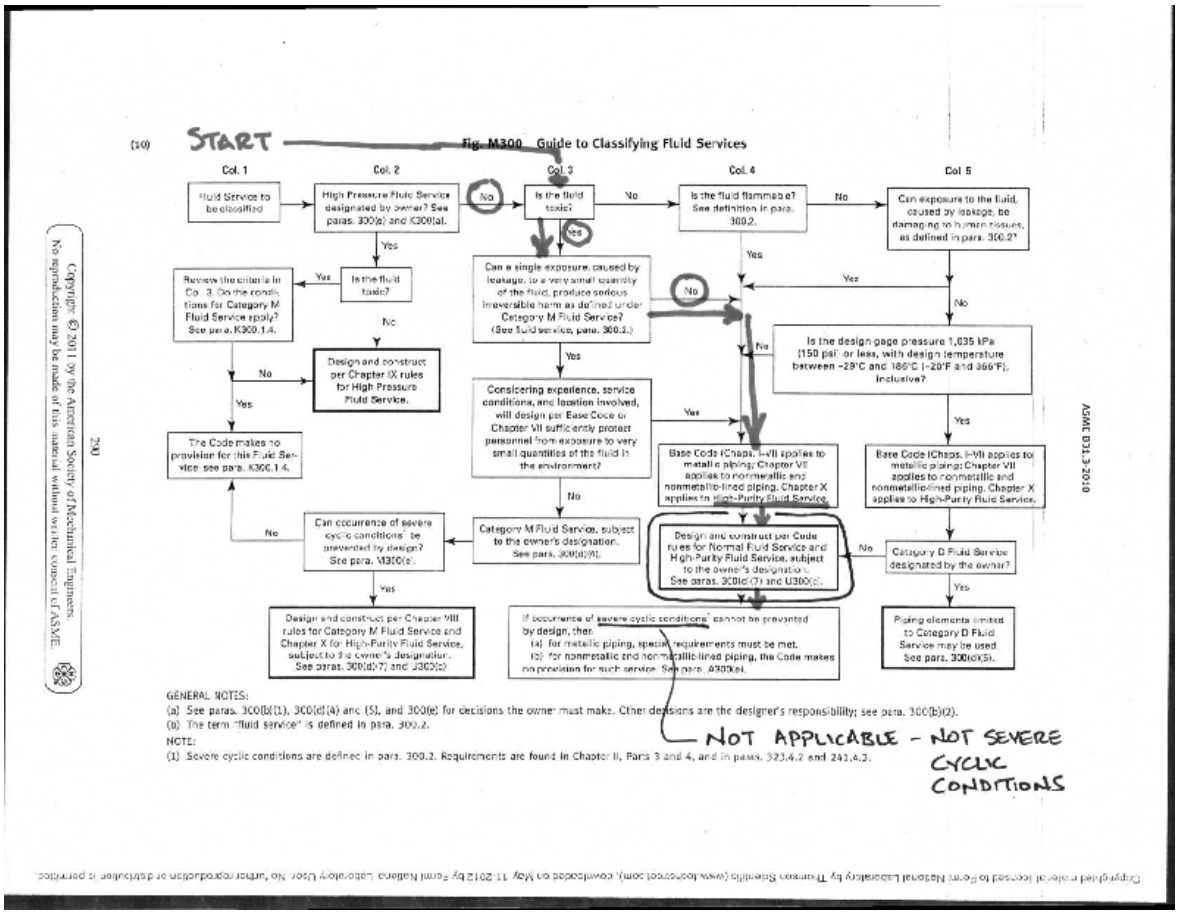
A piping system designed to transfer scintillator from a delivery truck to the NOvA far detector modules has been purchased, installed, leak tested and is in the midst of a safety review.

Discussion:

FESHM 5031.1 table 1 does not list scintillator as a fluid and does not recommend an applicable piping code of standard.

As a default, ASME B31.3 (latest edition) should be used as the piping code as stated in FESHM 5031.1, Paragraph 1.b under Policy and Requirements.

Follow Figure M300 in Appendix M in B31.3 to determine the fluid service:



The 5% pseudocumene in the scintillator is assumed to cause the scintillator to be classified as “toxic” in column 3 of figure M300.

Conclusion is shown at the bottom of column 4; “Design and construct per Code rules for Normal fluid Service and High-Purity fluid Service, subject to the owner’s designation. Paragraph 300(d) places the responsibility on the owner to assign the fluid service as Normal or High-Purity. This fluid is assigned as High-Purity because of the need to keep contamination out of

the fluid in order to meet the detector performance requirements. Therefore, Paragraph U300 (in Chapter X – High Purity Piping) applies. Specifically, paragraph U300 (e) (1).

Paragraph U311 (Welded Joints) and Paragraph U311.1 (c) General requires examination in accordance with paragraph U341.4.1

Paragraph U341.4.1 allows a weld coupon examination in lieu of the 5% random radiographic / ultrasonic examination required in paragraph 341.4.1(b) when orbital welding is used.

Sanitary piping is welded using orbital welding methods.

Paragraph U341.4.5 requires weld coupon examinations to be performed at several times:

(a) Beginning of a shift
(b) Change of the purge gas
(c) Change of the power supply
(d) Change of equipment
(e) Anytime there is a weld defect.

The vendor (Holland Applied Technologies, Burr Ridge, IL 60527, 800-800-8464) who made each pipe section did not perform these tests as required by code. Code conformance was not verified by Indiana University prior to paying the invoice for delivered material.

So, because the appropriate inspections were not performed at the time of fabrication, the possible means to comply with the code intent include:

1. Perform 5% random radiography (RT)
2. Perform 5% random ultrasonic examination (UT)
3. Perform a destructive weld coupon examination of a sample of the piping previously fabricated.

A discussion of the defects and examinations methods used to find them follows.

Weld defects include (See Table 341.3.2) :

Defect	Identification Method
Cracks	Visual
Lack of Fusion	Visual
Incomplete penetration	Visual
Internal porosity	Radiographic (RT)
Internal Slag or tungsten inclusions	Radiographic (RT)
Undercutting	Visual
Surface porosity or exposed slag	Visual
Surface finish	Visual
Concave root surface	Visual
Weld reinforcement or internal protrusion	Visual

All of the piping has been visually inspected. Defects not yet inspected for include only internal porosity, internal slag inclusion, and internal tungsten inclusions.

This piping has been welded using tungsten inert gas (TIG) methods. A flux is not used in this process; therefore, slag inclusions are not possible.

Remaining defects to be inspected for include internal porosity and tungsten inclusions.

All piping used in this system is shown on the drawings as 304 stainless steel tubing, 0.065 inch wall thickness, 1 inch and 2 inch outside diameter. Such thin wall thicknesses are welded with single pass, 100% penetration welds. Since these are not multiple pass welds, internal porosity cannot be hidden by subsequent weld passes. If internal porosity were to exist, surface porosity would also exist and would be discovered by visual inspection.

Tungsten inclusions occur when the weld current is too high, or when the tungsten electrode is allowed to dip into the weld pool. Tungsten inclusions cause metal discontinuities that under high metal tensile stress conditions can initiate a crack to develop, leading to a piping containment failure.

A269 type 304L stainless steel tubing at a temperature of less than 200 degrees Fahrenheit has an allowable tensile stress of 16,700 psi. (S = 16,700 psi).

B31.3 paragraph 304.1.2 calculation for the required wall thickness of straight pipe is as follows:

$t = PD / 2*(SEW + P\gamma)$

P = 100 psi, the internal design gage pressure
D = 2.0 inches, the outside diameter
S = 16,700 psi from table A-1
E = Quality factor from Table A-1B = 1.00 for seamless tube
W = Weld strength reduction factor from 302.3.5 = 1.0 for austenitic stainless steel at T < 950 F
γ = 0.4 from Table 304.1.1 for austenitic stainless steel at T < 900 F

$t_{required} = 100 * 2 / (16700*1.0*1.0 + 100*0.4) = 0.012$ inches

$t_{actual} = 0.065$ inches

Solving for hoop stress:

$\sigma = DP/t = 2.0*100/0.065 = 3077$ psi.

So, the tensile stress is not very large, and a tungsten inclusion is unlikely to initiate a crack.

Therefore, the two types of defects not identifiable with visual inspections are not likely to be possible (slag inclusions, internal porosity without surface porosity) and not likely to cause a leak (tungsten inclusion) if they were present. So, effort to perform these two inspections is only useful to satisfy the code requirements and not likely useful to eliminate a failure mechanism.

In fact, the above conclusions are consistent with paragraph MJ-7.2.3 of the Bioprocess Equipment Code. Paragraph MJ-7.2.3 and MJ-7.2.4 both include the statement:

> "….This standard does not require radiography unless specified by the owner /user or other applicable code".

FESHM does not specifically require radiography for piping. The project (acting on behalf of the owner) does not require radiography. No applicable codes other than B31.3 have been identified as applicable to this work. And lastly, B31.3 offers alternatives to radiography to meet the inspection requirements in Chapter X.

B31.3 paragraph 300 (b) (3) allows a designer capable of a more rigorous analyses the latitude to do so. In this case, the more rigorous analysis of the possible defects identifiable using RT, or UT do not provide a significant benefit.

Therefore, perform the proposed actions to show due diligence in performing the inspection of the received material is as follows:

1) Document the visual inspections already performed by Mark Gebhard of IU.
2) Repeat and document the visual inspections using an experience engineer from Fermilab.
3) Perform destructive weld examination tests on at least one pipe weldment with multiple welds. Section, polish and examine all welds on this sample. Examine for internal porosity and tungsten inclusions as well as the other visually observable defects. Use code criteria for grading the defects as acceptable or un-acceptable. Document the results.
4) Should no unacceptable defects be found, conclude the examination.
5) Should unacceptable defects be found, repeat step 3 on one additional weldment, until no unacceptable defects are found.
6) Write up a lessons learned summary to show how these additional costs could have been avoided with adequate oversight of the collaborating institution engineering effort.