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QUALIFICATION OF SPECTROSCOPIC PROBE DESIGNS TO INDUSTRY STANDARDS FOR PROCESS PIPING AND VESSELS

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Faced with the need to tighten quality standards, reduce waste, and increase processing speeds, the chemical process industry is increasingly turning to molecular spectroscopy, in its various forms, as a means for providing real-time chemical process analysis. Key to many such installations is the use of one or more fiber-optically coupled in-situ probes to provide the interface between the analyzer and the chemical process. As compared to older extractive methods, in-situ (or in-line) analysis offers a number of advantages. These include, much faster response, more representative sampling, elimination of the sample conditioning components required for extractive systems, compatibility with high pressure and temperature, and the ability to withstand aggressive chemical environments.

One problem with installing any on-line device is insuring that such device does not diminish the integrity of the process system as a whole. Many early installations of process probes involved processes with minimal safety issues. In other cases, the installations were carried out with some form of variance from standard plant requirements. As process probes are more widely applied to chemical processes such probes will be required to meet higher standards of construction. In a previous technical note (AN-919) we discussed the progress made in insuring the reliability of process probes under extreme conditions. The purpose of the present article is to illuminate the general requirements for meeting industry standards in so far as they relate to process sampling probes. Axiom Analytical's FPT-850 Near-IR Transmission Probe has been analyzed in detail based upon the criteria outlined in this article. It is our belief that these probes comply with the stated requirements. A similar analysis is just being completed on our RFP-480 Process Raman Probe.

Fiber optically coupled probes are intrinsically safe devices from a NEMA, UL, and CSA standpoint. Therefore, the principal design requirements for such probes are that they meet or exceed the highest mechanical quality of construction standards. At this writing the most widely accepted standards are those of the American Society of Mechanical Engineers, ASME.

Based upon our review and understanding of the various ASME Code Sections we believe that the design criteria for the Fiber Optic coupled process probes is covered by the following specific Code Section:

I. ASME CODE FOR PRESSURE PIPING, B31.1-1998 Edition -- Code section 114.2.3.

II. ASME CODE FOR PROCESS PIPING. B31.3-1999 Edition -- Code section 304.7.2.

III. ASME BOILER AND PRESSURE VESSEL CODE, Section VIII -- Rules For Construction of Pressure
Vessels, Division I and Division 2 - Alternative Rules.

ASME Code sets forth engineering requirements deemed necessary for the safe design of pressure vessels and pressure/process piping. The Code DOES NOT provide instruction on how to design such devices.

It should be further noted that ASME has not and does not certify pressure vessel or piping designs of any kind.

The choice of a Code to comply with for new pressure vessel and pressure/process piping, lie for the most part, with the plant owner. With exception of a few states in the U.S. and the Canadian Provinces, ASME Code is not mandated by law.

ASME B31.1 - 1998 -- Code Section 114.23

"114.2.3 Threaded connections for insertion type fluid temperature determination, flow measurement, and sampling devices are not subject to the temperature limitations stated in para. 114.2.1 and Table 114.2.1 provided that the design and installation meet the requirements of paras. 104.3.1 and 114.1. At temperatures greater than 925 F (495 C) or at pressures greater than 1500 psi (10 350 kPa), these threaded connections shall be seal welded in accordance with para. 127.4.5. The design and installation of insertion type fluid temperature determination, flow measurement, and sampling devices shall be adequate to with-stand the effects of the fluid characteristics, fluid flow, and vibration."

The underlined portion of Code Section 114.2.3 appears to be the guiding principal of design for sampling devices under B31.1.

ASME B31.3 - 1999 Edition -- Code Section 304.7.2

"304.7.2 Unlisted Components and Elements. Pressure design of unlisted components and other piping elements, to which the rules elsewhere in para. 304 do not apply, shall be based on calculations consistent with the design criteria of this Code. These calculations shall be substantiated by one or more of the means stated in paras. 304.7.2 (a), (b), (c), and (d), considering applicable dynamic, thermal and cyclic effects in paras. 301.4 through 301.10, as well as
thermal shock. Calculations and documentation showing compliance with paras. 304.7.2 (a), (b), (c) or (d), and (e) shall be available for the owner's approval:

(a) extensive, successful service experience under comparable conditions with similarly proportioned components of the same or like materials;

(b) experimental stress analysis, such as described in the BPV Code, Section VIII, Division 2, Appendix 6;

(c) proof test in accordance with either ASME B16.9, MSS SP-97, or Section VIII, Division I, UG-101;

(d) detailed stress analysis (e.g. finite element method) with results evaluated as described in Section VIII, Division 2, Appendix 4, Article 4-1. The basic allowable stress form Table A-1 shall be used in place of Sm in Division 2. At design temperatures in the creep range, additional considerations beyond the scope of Division 2 may be necessary.

(e) For any of the above, the designer may interpolate between sizes, wall thicknesses, and pressure classes, and may determine analogies among related materials."

ASME BOILER AND PRESSURE VESSEL CODE SECTION VIII - Rules For Construction of Pressure Vessels, Division 1 and Division 2 - Alternative Rules

For purposes of design analysis it is our opinion that spectroscopic Probes would technically fall outside of the scope of BPV Code Section VIII. The U-1 Scope of Code Section VIII. Division 1 and AG-121
paragraph (e) of Code Section VIII, Division 2 would seem to indicate that the ASME piping codes would take precedence for devices such as spectroscopic Probes. Accordingly our analysis will focus on the B31 Code Sections. It should be noted that BPV Code Sections VIII and IX are referenced in the B31 Code sections and must be considered where referenced.

GENERAL ASME DESIGN CONSIDERATIONS

A critical first step performing a design analysis under B31 Code guidelines is to define the class of fluid service for which your products (probes in our case) are to be designed to handle.

In B31.3, Code Section 300.2, four levels of fluid service are defined. A brief description of each follows:

1. Category D Fluid Service - This is the least restrictive class of fluid service. To qualify for Class D status ALL of the following must apply: the fluid handled is nonflammable, nontoxic, not damaging to human tissue (as defined in B31.3, paragraph 300.2), design pressure not to exceed 150 psi. and design temperature range - 29 C through 186 C.

2. Category M Fluid Serive - This is the most restrictive class of fluid service. It is defined by Code as a fluid service in which the potential for personnel exposure is judged to be significant and in which a single exposure to a very small quantity of a toxic fluid, caused by leakage, can produce serious irreversible harm to persons on breathing or bodily contact, even when prompt restorative measures are taken.

3. High Pressure Service - This is also a very restrictive class of service. High pressure is defined in Chapter IX of B31.3, as pressure in excess of that allowed by the ASME B16.5 PN 420 (Class 2500) rating for the specified design temperature and material group.

4. Normal Fluid Service - This is the most common class of fluid service and includes any and all service not covered by Category D, M or High Pressure Service.

In performing design analysis on spectroscopic probes Axiom has generally assumed full Fluid Service in Categories D, M, and Normal, with limited compatibility in High Pressure Service. Except for Class M Service we have further assumed that all forces exerted on the probe are external. A more detailed discussion of Class M follows.

ASME B 31.3 CLASS M SERVICE

Class M Fluid Service is defined in Chapter VIII of the B31.3 Code. Chapter VIII follows the base Code requirements outlined in Chapter I on a paragraph for paragraph basis expanding and modifying the requirements it considers necessary for Class M Service. Points of interest for Class M Fluid Service include the following:

1. The classification of a Fluid Service as Class M is the responsibility of the plant owner.

2. Consideration shall be given to the possible need for Engineered Safeguards (as per appendix G of the Code) in addition to the safeguards already provided by Code.

3. Sealing via tapered pipe threads would seem to be expressly forbidden.

4. Brazing or Soldering is expressly forbidden by Code (Section M317).

5. Expanded testing is mandated over and above Section 345 requirements. Radiographic testing is required on at least 20% of all welds and a "high sensitivity" leak testing procedure is required in addition to the standard Code testing methods.

When Axiom prepares detailed structural engineering analysis for process probes we always consider Class M Fluid Service requirements. When probes are specified for operation in a Class M Fluid Service Axiom performs the following specific tests (in addition to our standard testing):

1. At 100% radiographic examination is performed on all welds. A copy of these reports is sent to the customer and a copy is retained in the permanent job file by Axiom.

2. All probes under go a full helium leak check. In our standard leak testing the maximum allowable leak rate on a probe used in Normal Class Service is 1 x 10-6 cc/sec. For probes used in Class M Service the maximum allowable leak rate is 1 x 10-7 cc/sec.

SAFEGUARDING

Appendix G of the B31.3 Code defines and strongly recommends Engineered Safeguards (G300.3) as means to protect people and property against harmful consequences of possible piping failure, such as confining and safely disposing of escaped fluid.

The Axiom FPT-850 Fiber Optic Transmission Probe is the only commercially available NIR transmission probe to offer full secondary containment as an option. In the unlikely event of a primary seal failure at the sapphire window metal body interface, the secondary containment assembly is designed to withstand the full process pressure and temperature until such time as the probe can be repaired or replaced.

The ASME Code has no specific requirements for secondary containment. We however, believe that Appendix G of the B31.3 Code would strongly suggest that in demanding application, such design enhancements should be considered.

TESTING

The B31.3 Code clearly spells out testing and inspection parameters for any and all piping system components. While the complete testing and inspection parameters are outside the scope of this general discussion, it is important to note that BOTH the manufacturer of the probe, and the customer, are required to perform specific testing consistent with the class of Fluid Service for which the probe is intended.

In addition to the standard ASME testing methods Axiom makes extensive use of Helium Mass Leak Detection techniques to insure its products exceed even the most demanding ASME requirements.

CONCLUSION

As demand for fiber optic probes for in-line applications continue to grow in both the Near-IR and Raman fields so to will the demands that such probes meet ASME design standards. Axiom has an ongoing program to insure that its process probe designs meet or exceed ASME standards.