Technical Note: AN-925-1
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ATEX Considerations:

The Possibility of Ignition in Installations Employing FPT-850 Near-Infrared Transmission Probes in Conjunction with Explosive Atmospheres

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FPT-850 fiber-optically coupled transmission probes are not subject to the requirements of European Union Directive 94/9/EC (ATEX). However, installations employing these probes may come under the Directive. This Technical Note addresses this possibility and provides some guidance to those responsible for installing and operating such installations.

FPT-850 probes are intended for use in the analysis of liquid chemical. In most installations, they are used in conjunction with Fourier Transform Near-Infrared (FT-NIR) spectrometers employing broad band incandescent sources of optical radiation. This mode of operation will be assumed for the discussion below.

Note that, although the probes are intended for the analysis of liquids, there is a possibility that vapors may be present in the probe sample gap during certain periods such as start-up or shut-down. We will assume this worst case condition.

Axiom drawing 13887, attached, shows a cross section of an FPT-850 along with the conduit termination housing and sealing gland normally provided and recommended for use by the party performing installation. Note that, although Axiom Analytical recommends the use of these or similar components, Axiom is not responsible for the installation or system operation.

Optical radiation is introduced into the FPT-850 probe by means of an optical fiber which is connected to an FT-NIR spectrometer or other source of radiation. A lens within the probe forms the radiation into a collimated beam with a diameter of 6 mm. This beam enters the sample gap through the first of two sapphire windows.

The international standard IEC 60079-28 establishes a safe irradiance level for hazardous locations of 5 mW/mm^2 (Table 2 and Figure B.1). The relationship between irradiance (p) and total optical power (P) is given by: $P = pA$ where "A" is the area of the optical beam. For the FPT-850 probe, the beam diameter is 6 mm, yielding an area of $A = 28.3\ mm^2$. Thus, to produce an irradiance of 5 mW/mm^2, the total optical power in the sample gap would need to be 141 mW. Furthermore, the total round trip transmission of an FPT-850 probe is always less than 30 % (0.30). So the single pass transmission will be less than $(0.30)^{1/2} = 0.55$. Thus, the maximum allowable power at the input to the probe (output of the optical fiber) would be 141/0.55 = 256 mW.

The following discussion will establish that the optical power coupled into a practical optical fiber from an FT-NIR spectrometer employing an incoherent source will always be substantially lower than 256 mW.

Instruments, such as FT-NIR spectrometers, that are used for broadband spectroscopic chemical analysis in the near-infrared spectral region employ incoherent sources of optical radiation. As we will demonstrate below, there are fundamental physical limits to the ability to focus such radiation into a small area such as the end of an optical fiber.

It should be pointed out that the studies employed to establish the limits provided in IEC 60079-28 utilized laser diodes and LEDs, which are not incoherent sources. [Ref. 1] The radiation from these sources can be focused to a much smaller spot than radiation from an incoherent source. However, the use of these sources is not compatible with the operation of an FT-NIR spectrometer.

The optical radiation source used in all FT-NIR spectrometers is a bulb with a tungsten filament. When operated under the conditions required to assure a reasonable lifetime, the maximum temperature of the filament will be approximately 2800 ^oK. However, since we must consider upset conditions, we will use the melting point of tungsten (3683 ^oK) for our calculations.

The emissivity of tungsten is approximately 0.3 in the near-IR, increasing to 0.5 in the visible region. We will use 0.5 for this discussion.

A useful quantity for our discussion is "Radiance" (L). (Ref. 2) This is defined as power per unit area per unit solid angle. For a Lambertian (diffuse) optical source, such as a tungsten filament, the Radiance is independent of direction. It is related to the Radiant Exitance (M_e), the total power per unit area radiated by the source (W/m^2), by the following:

$$L = M_e/\pi.$$

For a blackbody radiation source at a temperature T (°K), the Radiant Exitance is given by:

$$M_e = \sigma T^4,$$

Where σ is the Stefan – Boltzmann constant:

$$\sigma = 5.67x10^{-5}\ Wm^{-2}K^{-4}.$$

Substituting T = 3683 °K into this equation, we obtain M_e = 10.42 W/mm^2 for a blackbody. For the actual filament with an assumed emissivity of 0.5, this value will be reduced to 5.21 W/mm^2. The available power is further reduced by the fact that the maximum theoretical transmission efficiency of an FT-NIR spectrometer is 50%, giving us an effective value of M_e(effective) = 2.60 Wmm^{-2}. Thus, the radiance is equal to

$$L = M_e(\text{effective})/\pi = 0.828\ Wmm^{-2}sr^{-1}.$$

The maximum power that can be delivered to the optical fiber is equal to $P_f = \tau_f L$ where τ_f is the Throughput (or Etendue) of the fiber. (Ref. 3 & 4) This is given by:

$$\tau_f = \pi A_f \sin^2\alpha_f,$$

where A_f is the area of the fiber core and $\sin\alpha_f$ is the "numeric aperture" of the fiber. The largest core fibers typically used in near-IR installations have a core diameter of 0.6 mm and a numeric aperture of $\sin\alpha_f = 0.22$. For these conditions, $\tau_f = 0.043$ and the power delivered to the fiber is

$$P_f = \tau_f L = 0.043 \times 0.828 = 0.0356\ W\ (35.6\ mW).$$

This is approximately a factor of seven lower than the limit for "Inherently safe optical radiation" when using an FPT-850 probe.

If we had used a more practical operating temperature of 2800 °K for the tungsten filament rather than its melting point, the power delivered to the fiber would be 11.9 mW, more than an order of magnitude below the safe limit.

Conclusions: The optical power delivered to an optical fiber having a core diameter of no greater than of 0.6 mm and a numeric aperture of 0.22 by an FT-NIR spectrometer will always be substantially less than 256 mW. As shown above, this power level will result in a power density of less than 5 mW/mm^2 in the sample gap of an Axiom FPT-850 transmission probe. The operation is thus inherently safe (op is).

As a further conclusion, we should note that, if we consider the reflection loss at the entrance to the optical fiber, the total power at the output of the fiber would be less than 35 mW. Thus, referring to IEC 60079-28, Figure B.6, the total power would be inherently safe (op is) even in the case of two simultaneous failures, excess power during burn out of the source filament and failure of the conduit termination protection.

References:

1. H. Bothe, M. Graube, and U. Johannsmeyer, "Ignition risk due to optical radiation", Ex-Magazine 2008, Page 47.

2. W. L. Wolf, (Ed.), *Handbook of Military Infrared Technology*, Office of Naval Research, Washington DC. 1965, Page 22.

3. W. L. Wolf and G. J. Zissis (Eds.), *The Infrared Handbook*, prepared by the Environmental Research Institute of Michigan for the Office of Naval Research.
   Washington DC. 1978, Pages 20-8, 20-15, & 20-50.

4. W. M. Doyle, Axiom Analytical, Inc. Technical Note AN-916, "Signal Level Considerations for Remote Diffuse Reflectance Analysis", Page 2.

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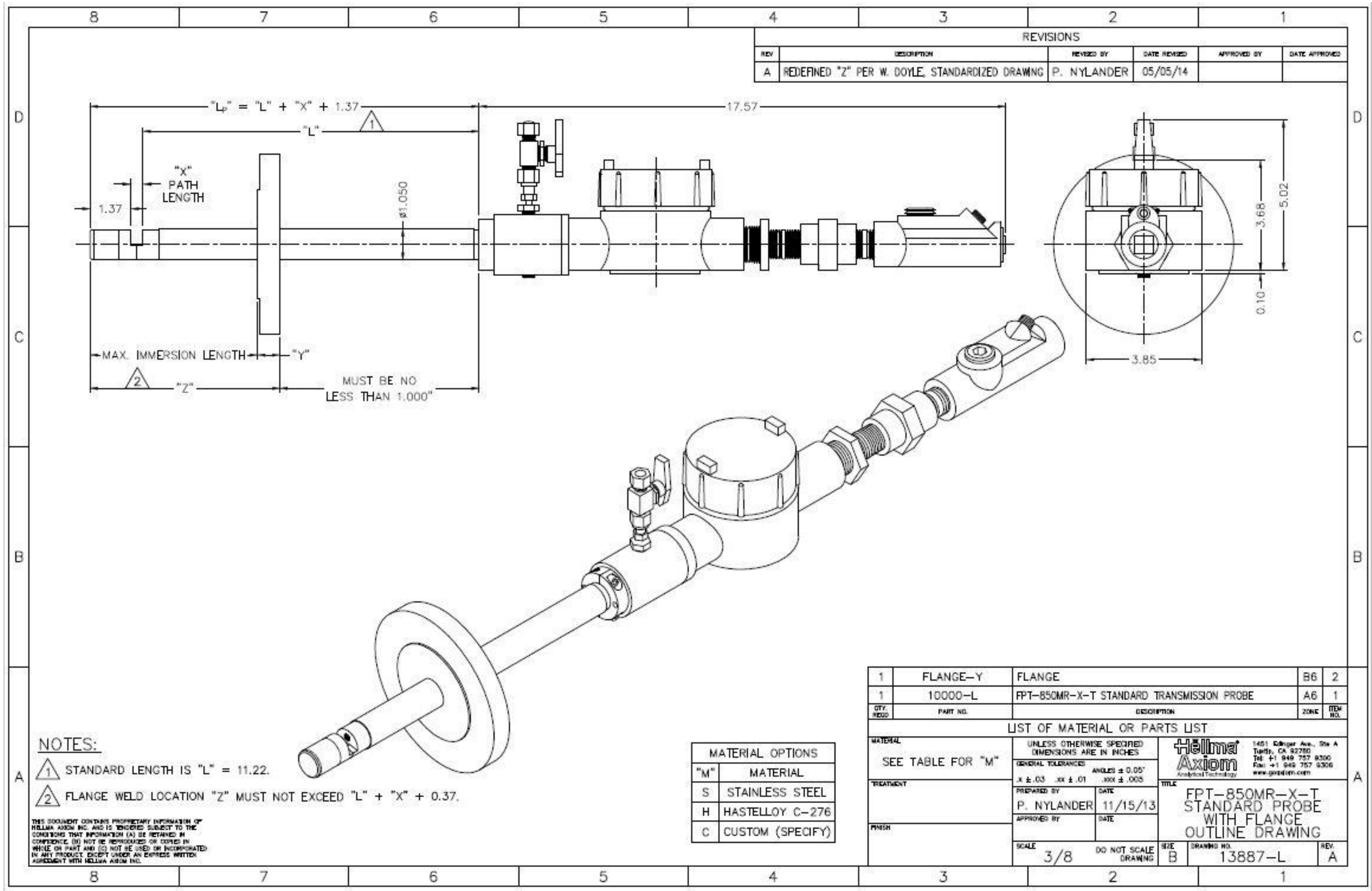
REVISIONS
REV | DESCRIPTION | REVISED BY | DATE REVISED | APPROVED BY | DATE APPROVED
A | REDEFINED "Z" PER W. DOYLE, STANDARDIZED DRAWING | P. NYLANDER | 05/05/14
"LP" = "L" + "X" + 1.37
17.57
"L"
"X" PATH LENGTH
1.37
ø1.050
MAX. IMMERSION LENGTH
"Y"
"Z"
MUST BE NO LESS THAN 1.000"
5.02
3.68
0.10
3.85
1 | FLANGE–Y | FLANGE | B6 | 2
1 | 10000–L | FPT–850MR–X–T STANDARD TRANSMISSION PROBE | A6 | 1
QTY. REQD | PART NO. | DESCRIPTION | ZONE | ITEM NO.
LIST OF MATERIAL OR PARTS LIST
NOTES:
1 STANDARD LENGTH IS "L" = 11.22.
2 FLANGE WELD LOCATION "Z" MUST NOT EXCEED "L" + "X" + 0.37.
MATERIAL OPTIONS
"M" | MATERIAL
S | STAINLESS STEEL
H | HASTELLOY C–276
C | CUSTOM (SPECIFY)
MATERIAL
SEE TABLE FOR "M"
TREATMENT
FINISH
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
GENERAL TOLERANCES
ANGLES ± 0.05°
.x ± .03 .xx ± .01 .xxx ± .005
PREPARED BY P. NYLANDER
DATE 11/15/13
APPROVED BY
DATE
Hellma Axiom
TITLE
FPT–850MR–X–T STANDARD PROBE WITH FLANGE OUTLINE DRAWING
SCALE 3/8
DO NOT SCALE DRAWING
SIZE B
DRAWING NO. 13887–L
REV. A