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Subject: Dresser™ Meters Hydrogen Compatibility

Dresser™ Measurement can confirm the compatibility of Dresser Roots Meters on systems which include the addition of Hydrogen gas to a natural gas pipeline. We have completed a review of materials and processes to determine our products have a low risk when installed in pipelines which contain up to 40% Dry Hydrogen added to dry natural gas with no Hydrogen Sulfide (H_2S) and under normal operating conditions. The determination is based on a review of safety and performance/accuracy.

The design of the Dresser Rotary Meters allows for the measurement of dry gases. Unlike other measurement technologies whose components expand and contract, slide, or have dependence on transmission of sound in the media being measured, the rigid measurement chamber of the Dresser Rotary Meter makes it specific gravity agnostic. The performance/accuracy of the meter would be materially unaffected by the addition of Hydrogen gas to the stream. Because of this conclusion regarding design robustness, the focus of our analysis was with respect to safety and Hydrogen Stress Cracking, or Hydrogen Embrittlement as it is commonly termed.

A qualitative assessment of the products was performed with respect to individual metallic component susceptibility to Hydrogen Embrittlement by exposure to Dry Hydrogen Gas added to a pipeline. Dresser used a typical natural gas composition model with Hydrogen concentrations ranging from 0% to 40%. Analysis assumes the gas will contain no H_2S nor will it contain water vapor.

In general, the makeup of the Dresser Meter pressure containing items are comprised of:

- Aluminum Alloys
- Copper Alloys (Brass)
- Low Temperature Carbon Steels.
- Stainless Steels

Aluminum Alloys are generally considered unaffected by Hydrogen gas. This is primarily due to the natural oxide layer that forms on the surface almost immediately when exposed to oxygen. This oxide layer acts as a barrier that impedes the migration of Hydrogen into the Aluminum.

Additionally, every meter's structural components are anodized prior to assembly. Aluminum is approved for use as a standard material in high pressure hydrogen tanks. (T.Michler, 2014)

The copper alloy components used in the construction of the Dresser Rotary meter (generally brass bodied Pressure and Temperature Measurement Plugs) are generally considered to have no risk of Hydrogen embrittlement. (Craig, 2019)

Regarding steels, low strength steels are generally considered resistant to dry Hydrogen Gas with susceptibility beginning with steels having yield strength greater than 100 ksi. NACE International provides guidance on steels with use in Hydrogen Environments stating that a maximum hardness of 22 HRC or 237 Brinell should be maintained. (NACE International, 2001) All of the carbon steels used in the pressure vessels of the meters meet this requirement.

The stainless steels used in the pressure vessels of Dresser rotary meters are of the Austenitic (300 Series specifically 316) stainless steel. These are considered very resistant to cracking in H_2 since they are single phase, face centered cubic structures with a high solubility for Hydrogen. (Craig, 2019)

Materials used in the construction of the Dresser rotary meters that may have risk of Hydrogen Embrittlement are those used in the manufacturing of the meters timing mechanism (Carbon Steel > 22HRc 416 Stainless Steel, and 17-4 PH Stainless Steel). As these components are subject to low stresses, the risk is generally considered low and does not affect the safety of the meter.

We are able to draw the conclusion from our research that the Dresser Roots Meters Series A, Series B, Series D, Series K, and High Pressure Cartridge meters are at low risk for use in pipelines containing up to 40% dry Hydrogen gas added to the Natural Gas.

References

Craig, B. P. (2019). *Dresser H2 Report.* Denver: MetCorr, Mettalurgy and Corrosion Consulting.
NACE International. (2001). Petroleum and natural gas industries - Materials for use in H2S-containing Environments in oil and gas production. *NACE MR0175.* Houston: NACE.

T.Michler, M. U. (2014). Gaseous Hydrogen Embrittlement of Materials in Energy Technologies. *Assessing hydrogen embrittlement in automotive hydrogen tanks*, 94-125.