Compatibility of Emerson Pressure Management Products with Hydrogen Gas

Introduction

Hydrogen is expected to play a key role as an energy carrier in the coming years as the world migrates towards a low-carbon economy. Blending hydrogen with natural gas has been proposed as a way to achieve near-term reductions in greenhouse gas emissions. Other applications using hydrogen include electrolyzers, fuel cells and fueling stations. Emerson Process Management Regulator Technologies, Inc. (Emerson) is committed to supporting our customers' needs to ensure safe and reliable progression of their critical infrastructure upgrade projects.

Hydrogen presents several challenges due to its unique properties. With respect to Emerson's Pressure Management products, the key challenges to address are material compatibility and leakage/permeation.

Material Compatibility

Exposure to hydrogen gas reduces the ductility of many metallic materials, causing an increase in fatigue crack growth rate and a decrease in fracture toughness. This phenomenon is known as Hydrogen Environment Embrittlement (HEE). The degree of embrittlement depends on the hydrogen environment, material properties and applied stress. This is frequently illustrated qualitatively using the Venn diagram shown in Figure 1. HEE occurs at the intersection of the three circles.

Hydrogen Environment

The key parameters of the hydrogen environment that affect embrittlement are temperature, pressure, concentration and gas impurities. For many materials, HEE is most severe at room temperature. HEE is also more likely to occur at a high pressure and high hydrogen concentration. Finally, some impurities, such as oxygen and carbon monoxide, have been found to reduce the effect of HEE. In contrast, other impurities, such as hydrogen sulfide, have been found to accelerate HEE.

Material Properties

Important material properties that affect HEE are strength, hardness and microstructure. In general, stronger, harder materials are more susceptible to HEE than weaker, softer materials. In addition, martensitic and ferritic microstructures are more prone to HEE than austenitic microstructures. These properties can be affected by heat treatment so a material may be suitable for hydrogen service with some heat treatments but not others.

Based on available data, low strength steels, austenitic SST, copper alloys and aluminum alloys are best suited for hydrogen applications while high strength steels, martensitic SST and nickel alloys should be used with caution.

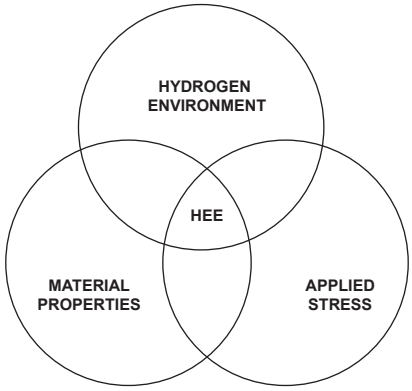

Figure 1. *Hydrogen Environment Embrittlement Diagram*

Applied Stress

In general, parts under high tensile stress are more susceptible to HEE than parts under low or compressive stresses. Additionally, the number and frequency of load cycles that a part experiences can influence the risk of HEE. Parts for hydrogen applications should be designed to minimize stress concentrations (e.g., sharp corners).

Leakage and Permeation

Due to its small molecular size and low density, hydrogen has a greater propensity towards leakage than natural gas. In addition, hydrogen can diffuse directly through solid materials such as polyethylene pipe and elastomeric diaphragms. Small leaks will generally disperse quickly but could become an issue in an enclosed space.

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Current research indicates that a joint that is leak tight with natural gas will remain leak tight with hydrogen. Research also suggests that in the event of a small leak (e.g., threaded joint) at typical residential gas pressures hydrogen will leak at a similar rate to natural gas. However, at higher pressures and/or leak rates (e.g, pipe fracture or diaphragm rupture) hydrogen can leak almost three times as much as natural gas.

Emerson has conducted leak testing with hydrogen and helium and concluded that our products can reliably seal hydrogen gas. When specially requested by the customer, Emerson offers optional helium leak testing at the factory for products intended for hydrogen applications.

Internal Relief Valves

Hydrogen is much more flammable than methane. When mixed with air, methane will burn at concentrations between 4.4 and 17% by volume. In contrast, hydrogen is flammable at concentrations between 4 and 75% by volume. Due to this wide flammability range special considerations may be needed for pressure regulators equipped with internal relief valves. It is the customer's responsibility to ensure that applicable codes are followed.

Hydrogen Tiers

Emerson has conducted an extensive literature review on the technical aspects of blending hydrogen into the natural gas infrastructure. In addition, we have tested materials, wetted components and assembled products. Our testing studied material compatibility, shutoff and external leakage in various hydrogen/methane blends up to 100% hydrogen.

Based on the literature review and the results of our testing, Emerson has established three tiers for products that are suitable for hydrogen. Products suitable for each tier are shown in Table 1.

- **10% H_2 tier —** Products in this tier have had their wetted materials of construction evaluated for compatibility with low concentrations of hydrogen.
- **25% H_2 tier —** Products in this tier have had the same material evaluation performed as products in the 10% H_2 tier. In addition, products in the 25% H_2 tier have been tested in hydrogen/methane blends.
- **100% H_2 tier —** Products in this tier have had their wetted materials of construction evaluated for compatibility with 100% hydrogen. Material upgrades have been made as necessary to assure safe and reliable service.

Note

Products must be selected and used properly according to the application. In order to ensure safety and performance, recommended maintenance intervals and procedures must be followed using Emerson authorized spare parts. Products must be regularly inspected for abnormal conditions and monitored for leakage with appropriate adjustments and/or repairs being made based upon these inspections.

Due to uncertainty of an installed product's condition and service history, Emerson cannot make a general statement on the compatibility of currently installed products with hydrogen at this time. Please consult the factory or your local sales office for guidance on specific products and applications.

Emerson reserves the right to increase or decrease a product's allowable concentration based on further test results and/or field experience.

Additional Sources of Information

- **ANSI/AIAA G-095A —** Guide to Safety of Hydrogen and Hydrogen Systems
- **ASME B31.12 —** Hydrogen Piping and Pipelines
- **ASME STP-PT-003 —** Hydrogen Standardization Interim Report for Tanks, Piping and Pipelines
- **ASME STP-PT-006 —** Design Guidelines for Hydrogen Piping and Pipelines
- **California Public Utilities Commission —** Hydrogen Blending Impacts Study
- **CGA G-5.6 —** Hydrogen Pipeline Systems
- **CEN/TR 17797 —** Gas infrastructure - Consequences of hydrogen in the gas infrastructure and identification of related standardisation need in the scope of CEN/TC 234
- **CEN/TR 17924 —** Safety and control devices for burners and appliances burning gaseous and/or liquid fuels - Guidance on hydrogen specific aspects
- **ISO/TR 15916 —** Basic Considerations for the Safety of Hydrogen Systems
- **MARCOGAZ —** Overview of Available Test Results and Regulatory Limits for Hydrogen Admission into Existing Natural Gas Infrastructure and End Use
- **NASA/TM-2016-218602 —** Hydrogen Embrittlement
- **National Renewable Energy Laboratory —** NREL/TP-5600-51995 — Blending Hydrogen into Natural Gas Pipeline Networks: A Review of Key Issues
- **National Renewable Energy Laboratory —** NREL/TP-5400-81704 — Hydrogen Blending into Natural Gas Pipeline Infrastructure: Review of the State of Technology
- **Sandia National Laboratories —** SAND2012-7321 — Technical Reference for Hydrogen Compatibility of Materials

Table 1. *Products Suitable for Hydrogen*[1][2]

SERIES OR TYPE	BODY MATERIAL	HYDROGEN SUITABILITY (BY VOLUME)		
		Up to 10%	Up to 25%	Up to 100%[3]
Anderson Greenwood 80	Steel, SST	X	X	X
Anderson Greenwood 90	Steel, SST	X	X	X
Anderson Greenwood 200	Steel, SST	X	X	X
Anderson Greenwood 400	Steel, SST	X	X	X
Anderson Greenwood 800	Steel, SST	X	X	X
Anderson Greenwood 9000	Steel, SST	X	X	X
Crosby J Series	Steel, SST	X	X	X
Crosby OMNI-TRIM	Steel, SST	X	X	X
Fisher 63EG	Steel, SST	X	X	X
Fisher 67CF/67CFS	Aluminum, SST	X	X	X
Fisher 133H	Steel	X	X	- - - -
Fisher 133L	Steel	X	X	- - - -
Fisher 161EB	Steel, SST	X	X	X
Fisher 289H	Aluminum	X	X	- - - -
Fisher 289L	Aluminum	X	X	- - - -
Fisher 299H	Steel	X	X	- - - -
Fisher 310A-32A	Steel	X	- - - -	X
Fisher 627	Steel	X	X	X
Fisher 630	Steel	X	X	X
Fisher 912N	Zinc/Aluminum Alloy	X	X	X
Fisher 1098-EGR	Steel, SST	X	X	X
Fisher 1301	Brass, SST	X	X	X
Fisher 6350/6360	Aluminum	X	X	X
Fisher B/25	Zinc/Aluminum Alloy	X	- - - -	- - - -
Fisher B/40	Zinc/Aluminum Alloy	X	- - - -	- - - -
Fisher BLE	Steel	X	X	- - - -
Fisher BLX	Steel	X	X	- - - -
Fisher CS400	Steel	X	X	X
Fisher CS800	Steel	X	X	X
Fisher CSB400	Steel	X	X	X
Fisher CSB600	Steel	X	X	X
Fisher CSB700	Steel	X	X	X
Fisher EZH	Steel	X	X	X
Fisher EZHSO	Steel	X	X	X
Fisher EZL	Steel	X	X	- - - -
Fisher EZR	Steel	X[4]	- - - -	X
Fisher HSR	Cast iron	X[5]	- - - -	- - - -
Fisher LS200	Steel	X	X	- - - -
Fisher MR95	Steel, SST	X	X	X
Fisher MR98	Steel, SST	X	X	X
Fisher OSE	Steel	X	X	X
Fisher OSX	Steel	X	X	X
Fisher T205/T205B	Steel, SST	X	X	X
Fisher T208	Steel, SST	X	X	X
Fisher VS100	Steel	X	X	- - - -
Fisher VSX4	N/A	X	X	- - - -
Fisher VSX8	N/A	X	X	- - - -

Note: Consult factory or your local sales office to determine appropriate hydrogen constructions.
1. For Emerson Pressure Regulator products, the information only applies to products produced after September 2022.
2. Suitability is determined by material compatibility, shutoff and external leakage. It is the customer's responsibility to ensure the product is suitable for their application.
3. Products in the 100% tier are typically a special construction with upgraded materials.
4. 232 psi / 16 bar maximum pressure
5. 60 psi / 4 bar maximum pressure

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Hydrogen

Table 1. *Products Suitable for Hydrogen[1][2] (continued)*

SERIES OR TYPE	BODY MATERIAL	HYDROGEN SUITABILITY (BY VOLUME)		
		Up to 10%	Up to 25%	Up to 100%[3]
Fisher Y692	Steel, SST	X	X	X
Fisher Y693	Steel, SST	X	X	X
Jeon FEQ	Steel	X	X	----
Jeon JEQ	Steel	X	X	----
Tartarini A/140	Ductile iron, Steel	X	----	----
Tartarini B/240	Ductile iron	X	----	----
Tartarini BM5	Steel	X	X	X
Tartarini BM6X	Steel	X	X	X
Tartarini CF/CN/CNF[4]	Steel	X	----	----
Tartarini Cronos	Steel	X	X	----
Tartarini FA	Steel	X	----	----
Tartarini FAG	Steel	X	----	----
Tartarini FL	Steel	X	X	X
Tartarini M	Steel	X[5]	----	----
Tartarini OL	Steel, SST	X	----	----
Tartarini PRX	Steel	X	X	X
Tartarini PS/79	Steel	X	X	X
Tartarini PS/79-1	Aluminum	X	X	X
Tartarini PS/79-2	Aluminum	X	X	X
Tartarini PS/80	Steel	X	X	X
Tartarini R/25	Zinc/Aluminum Alloy	X	----	----
Tartarini R/70	Aluminum	X	----	----
Tartarini R/72	Aluminum	X	----	----
Tartarini SA/2	Steel	X	X	X
Tartarini V/20-2	Brass	X	X	X
Tartarini V/50	Aluminum	X	X	X
Tartarini V/60	Aluminum	X	X	X
Tartarini VFA	Steel	X	----	----

Note: Consult factory or your local sales office to determine appropriate hydrogen constructions.
1. For Emerson Pressure Regulator products, the information only applies to products produced after September 2022.
2. Suitability is determined by material compatibility, shutoff and external leakage. It is the customer's responsibility to ensure the product is suitable for their application.
3. Products in the 100% tier are typically a special construction with upgraded materials.
4. Excludes CNF-05-AP and CNF-1-AP.
5. 232 psi / 16 bar maximum pressure

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