Why is Hydrogen permeation so destructive to pressure transmitters?

Simple ways to reduce downtime and maintenance expense of pressure transmitters placed in hydrogen service.

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Yes, simple solutions do exist! However, before we discuss the solutions, it is important to understand the reasons why hydrogen permeation occurs and the challenges end users experience.

Anyone with a hydrogen rich process has probably encountered a pressure transmitter that looks like Figure 1A or 1B.

Your first thought after discovering this was probably "what in the world happened?"

Figure 1A

Figure 1B

The technical term for this condition is catastrophic membrane deformation. The more ordinary term is "jiffy pop". Any process or differential pressure transmitter with this appearance has a hydrogen permeation issue, a vacuum/temperature combination issue or all three. This paper will focus on hydrogen permeation.

What most people do not understand is why hydrogen permeation occurs or what steps can be taken to protect the pressure transmitter.

Hydrogen permeation occurs when hydrogen molecules in the process fluid migrate through your typical 316L or Alloy C diaphragm membrane. Once through the membrane, the hydrogen molecules go into solution in the cell's fill fluid.

At this point damage is not immediate. If the process exerts sufficient positive pressure on the membrane, the hydrogen molecules will remain in solution. It is only when the process pressure drops to near or below atmospheric conditions that damage occurs. With reduced process pressure, the hydrogen molecules in the fill fluid come out of solution in the form of gas bubbles. This happens very quickly and increases the fluid volume and internal pressure present in the cell or diaphragm seal. The pressure measurement cell or diaphragm seal is a closed environment, so the additional volume has no means of escape. Consequently, the thin 316L/Alloy C membrane becomes distended resulting in catastrophic damage.

Hydrogen migration can occur in a variety of applications. However, all hydrogen permeation can be categorized as one of two things; diffusion in aqueous solutions [due to a galvanic process] or diffusion in a gas environment.

Diffusion from a galvanic process in an aqueous solution

Wastewater treatment or biogas plants are the most common facilities to experience this situation. A galvanic process occurs when you have two dissimilar metals serving as your anode and cathode in conjunction with a suitable electrolyte.

Example: You have an installation in a sump with a zinc plated ladder near your pressure transmitter. The ladder acts as the anode and the 316L/Alloy C membrane of the pressure transmitter is the cathode. The water present in the sump is your electrolyte. This combination will result in a galvanic process or "battery effect".

The result of this galvanic process is a reduction of hydrogen cations to hydrogen atoms. These atoms lose electrons and can diffuse through a 316L/Alloy C diaphragm in the form of extremely small H^+ ions.

On the other side of the diaphragm the H^+ ions capture electrons and recombinate into H_2 molecules in the cell's fill fluid [Figure 2]. This type of diffusion is independent of the process pressure, but the hydrogen mass transfer depends on temperature.

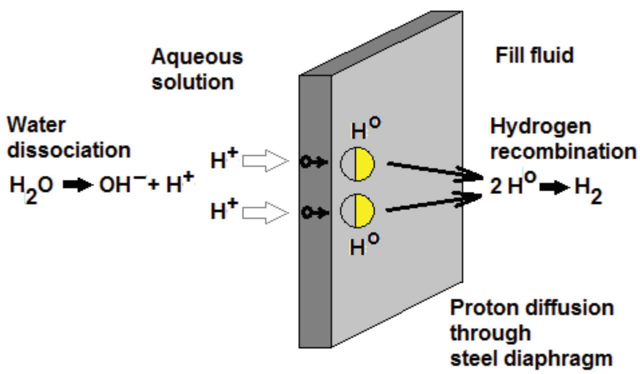

Figure 2

The standard method for combating hydrogen diffusion due to a galvanic process in an aqueous solution is to employ individual Rhodium and Gold coatings over the 316L/Alloy C membrane as a shield [Figure 3]. The Rhodium [Rh] layer promotes the hydrogen recombination into gas molecules on the aqueous solution side of the diaphragm. The gold [Au] layer is used as a diffusion barrier which impedes hydrogen permeation through the diaphragm and into your fill fluid.

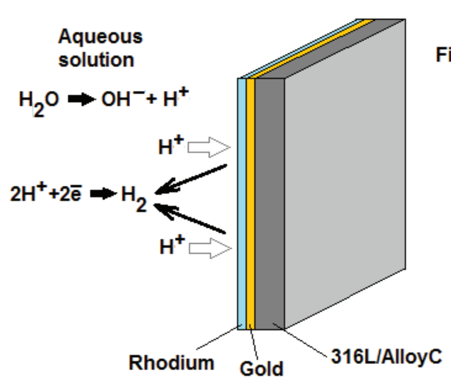

Figure 3

Diffusion from gas environment

The second possibility for hydrogen permeation of pressure cells occurs in direct hydrogen gas service. Unlike diffusion in a galvanic process, permeation in hydrogen gas service is strongly impacted by the pressure/temperature of the process. The hydrogen molecules dissociate on the diaphragm surface, then hydrogen atoms lose electrons and the subsequent H^+ ions diffuse through the 316L/Alloy C diaphragm in the same manner it was described for aqueous solutions [Figure 4].

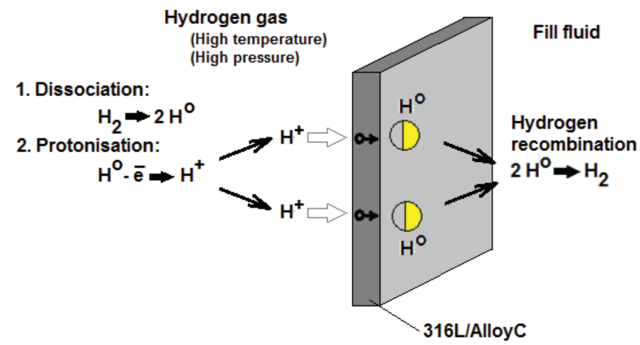

Figure 4

Your solution to counter permeation from a hydrogen gas environment will be different than what is employed for galvanic reduction in an aqueous solution. You DO NOT use a Rhodium/Gold coated diaphragm membrane. A Rhodium/Gold shielding will prove ineffective, especially at high temperature and pressure. Instead you use a straight gold coating over the 316L/Alloy C membrane. A gold coating with a thickness of 15-25 µm decreases the hydrogen permeability up to 10^6 times due to very low diffusion coefficient. Therefore, a gold coating works like a diffusion barrier for hydrogen permeation [Figure 5].

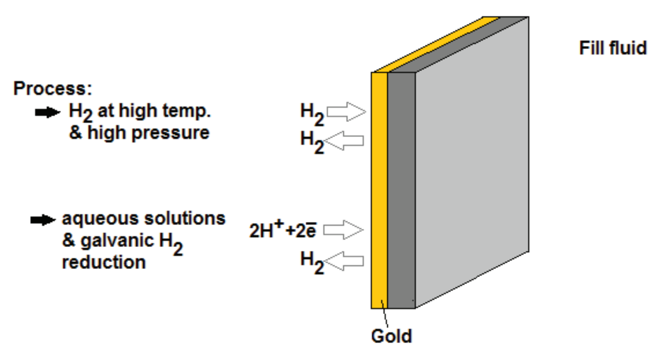

Figure 5

Hydrogen permeation in metals is relentless. Consequently, no solution will prevent it from occurring. However, if properly employed, either a Rhodium/Gold or straight Gold shielding are cost-effective methods to significantly reduce hydrogen permeation and extend the life of your sensor or diaphragm seal.

Figure 6

There is one additional solution that can be applied to diffusion from either a galvanic process or a hydrogen gas environment. A pressure cell with a ceramic membrane [Figure 6].

Hydrogen molecules will not directly diffuse through a ceramic membrane. Even if hydrogen permeates the O-ring seal employed by ceramic cells it will not matter. A ceramic cell is dry [no fill fluid] so hydrogen cannot go into a solution and accumulate. Ceramic is significantly more durable than SS or Hastelloy gold coated membranes as well. Consequently, the integrity of the cell will be unaffected.

Depending upon the specific process conditions [pressure/temperature] ceramic can be the best long-term solution for hydrogen migration.

For more details on how to properly employ these solutions, please contact your local Endress+Hauser representative. They will be more than happy to discuss your application in detail and ensure you receive the best solution for your individual needs. Visit www.us.endress.com/en/contact to find the name and contact information of your local representative.

About the Author

Keith Riley has been a Product Business Manager with Endress+Hauser since April 2008. Prior to this, he was a Product Manager and Regional Sales Manager with L.J. Star Incorporated, as well as a Product Manager for Penberthy (Tyco Valves). Overall, he has over 20 years of sales, marketing and instrumentation experience in the process industries.

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