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To:	All Surveyors/Auditors
Applicable to flag:	All Flags
Subject:	**Hydrogen Blistering and Hydrogen Embrittlement**
Reference:	**Corrosion**

Hydrogen Blistering and Hydrogen Embrittlement: Causes and Preventive Measures

The presence of atomic hydrogen is extremely dangerous and can cause serious damage to materials.

The term "hydrogen damage" refers to the mechanical damage of metal caused by interaction with or the presence of hydrogen. Atomic hydrogen has a radius of 1.1 and is capable of diffusing through many metals and steels. Hydrogen atoms are very reactive and combine with almost all elements. The molecular form of hydrogen cannot diffuse and is stable.

Hydrogen damage can be classified into four types:

1. Hydrogen blistering. Atomic hydrogen diffuses inside the metal and causes localized deformation, or even destroys the walls of the vessel.
2. Hydrogen embrittlement. Involves the penetration of hydrogen, which results in enhancing brittleness and decreasing tensile strength.
3. Decarburization (high-temperature process). Also known as the removal of carbon from steel, this can take place in moist environments at high temperatures. It decreases the tensile strength on the steel.
4. Hydrogen attack (high-temperature process). The interaction between hydrogen and any constituent of an alloy at high temperature.

Sources of Nascent Hydrogen

Atomic hydrogen is dangerous and harmful to many materials. It is created under the following conditions:

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- High temperature, moist atmosphere
- Corrosion process
- Electrolysis of water

These are the main sources of atomic hydrogen. So, to prevent hydrogen damage, we have to control these sources. The reduction of hydrogen ions produces atomic hydrogen, which subsequently forms a hydrogen molecule. If the latter step, the formation of molecular hydrogen, is slow, then the concentration of atomic hydrogen builds up and there are more chances of hydrogen damage.

Hydrogen Blistering

In hydrogen blistering, atomic hydrogen diffuses in the materials that have some voids and empty spaces inside them. Inside these voids, atomic hydrogen can combine to form a hydrogen molecule. Because molecular hydrogen cannot diffuse, tremendous pressure builds up inside these voids. The equilibrium pressure of molecular hydrogen in contact with atomic hydrogen is sufficient enough to rupture any material.

Hydrogen blistering is one of the forms of corrosion and is dominant in the petroleum industry. It can take place during refining and in storage tanks.

Preventive Measures Against Hydrogen Blistering

Use of Coatings

Metallic, organic and inorganic coatings are often used to prevent the hydrogen blistering of steel containers. The coatings and liners must be impervious to hydrogen penetration and resistant to the medium inside the container. Rubber, plastic coatings and brick linings are frequently used. Nickel and steel cladding is often employed with austenitic steels for this purpose.

Use of Inhibitors

Inhibitors reduce the rate of corrosion and rate of hydrogen ion reduction. Generally, inhibitors are used in closed systems.

Use of Clean Steels

Hydrogen blistering occurs when the hydrogen molecule forms inside of voids. We should use the material with minimum voids. So, killed steel should be used instead of rimmed steel because it has fewer voids.

Removal of Poisons

Some poisons hamper the formation of the hydrogen molecule, causing the concentration of atomic hydrogen to rise, and making components more prone to hydrogen blistering. Hydrogen

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blistering is very rare in pure corrosive systems. Corrosion, electroplating and cathodic protection are a few sources of hydrogen in metal. Certain substances like phosphorus compounds, sulfide ions and arsenic compounds hamper hydrogen ion reduction, which in turn raises the concentration of atomic hydrogen. These poisons should be removed.

Substitution of Alloys

Hydrogen blistering can be prevented by using nickel-containing steels or nickel alloys, as they have very low hydrogen diffusion rates.

Hydrogen Embrittlement

Hydrogen embrittlement involves the penetration of hydrogen. Strong, hydride-forming metals react with dissolved hydrogen to form brittle hydride compounds, such as titanium. Most of the mechanisms that lead to hydrogen embrittlement involve the slip interference with dissolved hydrogen. This slip interference may be due to a higher concentration of hydrogen near micro-voids and dislocation sites.

Hydrogen embrittlement tends to occur at stress-concentrated regions. In addition, the higher concentration of hydrogen increases the chances of hydrogen embrittlement. A few ppm of absorbed gas can be sufficient to induce cracks. Generally, the tendency toward hydrogen cracking decreases with increasing temperature.

The Difference between Stress-Corrosion Cracking and Hydrogen Embrittlement

Stress-corrosion cracking (SCC) and hydrogen embrittlement are differentiated by their responses to the applied current and mode of cracking. If applied current makes the specimen more anodic and accelerates cracking, it is a case of stress-corrosion cracking. Here, the anodic dissolution process contributes to the progress of cracks. Similarly, if applied current increases the rate of hydrogen evolution, these cases are considered to be hydrogen embrittlement. Here's how to prevent stress-corrosion cracking and hydrogen embrittlement:

Reducing the Rate of Corrosion

Corrosion of metal leads to the evolution of hydrogen. Thus, reducing the corrosion rate decreases the rate of hydrogen evolution.

Baking

A common way of removing hydrogen from steels is by baking at relatively low temperatures. Hydrogen embrittlement is almost a reversible process for steel. In other words, the properties of treated steels are close to hydrogen-free steel.

Altering Plating Conditions

Careful choice of plating baths and control of plating current is very significant. If electroplating is performed under conditions of hydrogen evolution, hydrogen embrittlement and poor deposits are the result.

Proper Welding
Dry conditions should be maintained during welding since water and water vapors are a source of hydrogen. Welding rods with low hydrogen content should be used if materials are susceptible to hydrogen embrittlement.

Substituting Alloys
Very high-strength steels are more prone to hydrogen embrittlement. Alloying with molybdenum and nickel reduces susceptibility.

The most basic step to controlling hydrogen damage is to carefully inspect potential sources of hydrogen and reduce them.

REFERENCES:

- Corrosion

ATTACHMENTS: No.

Kindest Regards,
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