Hydrogen Probe

User's Guide

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Instructions for Use of Pressure-Based Hydrogen Probes

1. Disclaimers

This document provides basic instructions for the installation and use of hydrogen probes and related equipment. Due to the nature of the equipment and the applications in which it is used, the operator may be exposed to a variety of potential safety risks. These include but are not limited to:

- Flammable media (particularly hydrogen gas)
- Pressurized equipment and media
- Hot surfaces
- Moving parts
- Welding arcs

This procedure does not attempt to address all safety concerns. It is the responsibility of the user to identify all safety concerns, and to ensure that adequate safety measures are taken while performing any part of this procedure. This includes the use of appropriate PPE.

This document contains some safety warnings, and references external documents which also contain safety warnings. At no time should these be considered to be comprehensive, nor should they be taken to supersede any established safety rules or requirements at the worksite. All local, governmental, and corporate safety requirements should be observed.

Any work conducted in accordance with this procedure should be performed by qualified personnel.

Some equipment listed is sold separately.

2. Introduction

Hydrogen is the most abundant element in the universe. On earth it exists primarily in molecular form because it so readily forms covalent compounds. However, monatomic hydrogen is a common byproduct of many industrial processes and chemical reactions. This can be a serious concern for pipeline and plant operators because individual hydrogen atoms are small enough to diffuse into metal.

Under ideal conditions, hydrogen atoms would pass freely through a metal structure and escape harmlessly into the atmosphere. Unfortunately it is common for hydrogen atoms to encounter each other as they migrate through the metal wall, at which point they combine to form hydrogen molecules. Because hydrogen molecules are too large to permeate the metal wall they become trapped in place. Over time, the continued buildup of hydrogen molecules within the metal wall causes a rise in pressure which leads to a loss of ductility and strength. This can lead to phenomenon such as hydrogen blistering, hydrogen embrittlement, or hydrogen stress cracking, any of which can result in a catastrophic failure of process equipment.

Metal Samples offers a variety of hydrogen probes which can be used to assess hydrogen permeation through a pipe or vessel wall. This can be helpful in evaluating the risk of hydrogen-induced failures in a system, as well as the effectiveness of remedial actions and treatment programs that may be implemented.

Hydrogen probes are available in both intrusive and non-intrusive styles to satisfy a wide range of industrial applications. Table 1 illustrates each of these probe types and details their basic components.

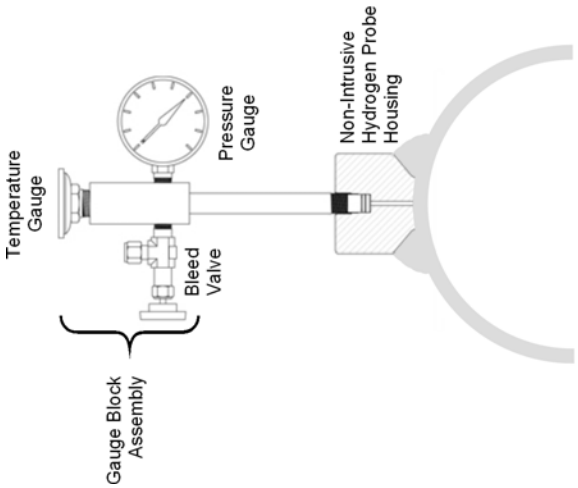
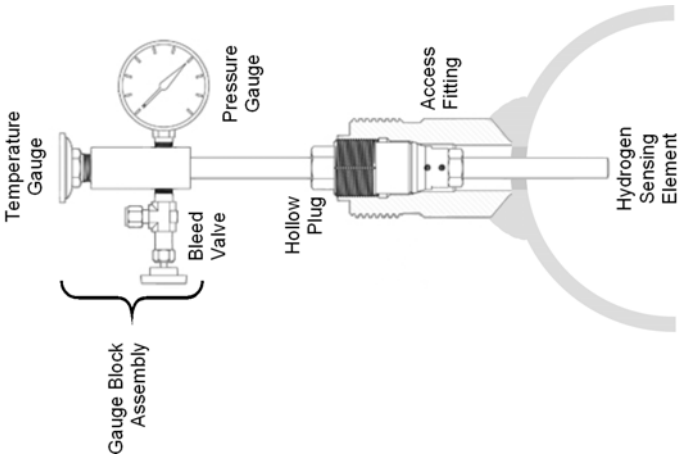
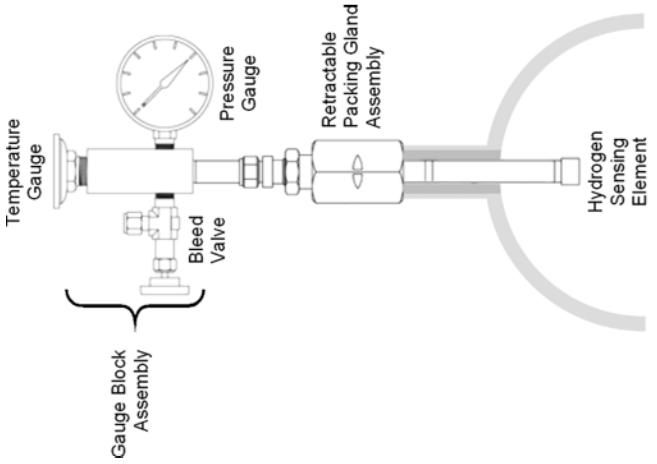
Non-Intrusive Hydrogen Probes		
Intrusive Hydrogen Probes	**Retrievable Type**	
	Retractable Type	

Table 1: Hydrogen Probe Types

3. Installation

A. Intrusive Probes

Intrusive hydrogen probes are designed to be inserted into a pressurized system. They consist of a thin-wall sensing element through which monatomic hydrogen can easily migrate, a probe body, and a gauge block which indicates a rise in pressure due to hydrogen permeation into the probe. An intrusive hydrogen probe is installed through some type of pressure fitting with the sensing element placed directly into the pipe or vessel. This provides good sensitivity and a fast response to hydrogen permeation. The method of installation is based on the fitting type and system used.

i. Retractable Hydrogen Probes

Hydrogen probes may be installed into a pipe or vessel using the Metal Samples Retractable System. This allows the device to be installed and removed in pressurized systems at pressures up to 2000 psi. For retractable hydrogen probes, mounting and installation should be done in accordance with the Retractable System Operation & Maintenance Manual.

For system pressures under 150 psi the retractable hydrogen probe can be hand-inserted.
NOTE: Do not push directly on the gauges or bleed valve. Doing so could cause damage, resulting in impaired performance or an unsafe condition.

For system pressures over 150 psi the retractable hydrogen probe must be installed with the Metal Samples Easy Tool, and requires a special adapter. Please contact Metal Samples Sales if your retractable hydrogen probe does not have the necessary adapter.

Once the retractable hydrogen probe has been installed into the system you may proceed to section 3.

ii. Retrievable Hydrogen Probes

Hydrogen probes may be installed using the Metal Samples HP Access System for use at pressures up to 3600 psi. Initial installation of the access system should be done in accordance with the Metal Samples' High Pressure Access Systems Manual. Once the access system has been installed:

1) Thread the Hydrogen Sensing Element into the bottom of the Hollow Plug Assembly, ensuring that the probe seal is in place, and tighten securely.
2) Install the Hollow Plug Assembly into the Access Fitting in accordance with the Metal Samples' Retrieval Tool Manual and Service Valve Manual.
3) After the Hollow Plug Assembly and Hydrogen Sensing Element have been installed into the system, thread the Gauge Block Assembly into the top of the Hollow Plug Assembly.
   NOTE: It is important to hold the top of the Hollow Plug Assembly stationary using a wrench to prevent it from rotating while you tighten the Gauge Block Assembly. DO NOT loosen the Hollow Plug Assembly as doing so could unseat the primary packing which would result in process leakage. DO NOT overtighten the Hollow Plug Assembly as doing so could damage the primary packing, which would result in process leakage.
4) Once the gauge block has been installed you may proceed to section 3.

B. Non-Intrusive Probes

Non-intrusive hydrogen probes are used in applications where there is no access point for direct-insertion into the line, or where an intrusive device is not allowed. A non-intrusive hydrogen probe is mounted on the exterior of the pipe using a special housing which creates a precise cavity to trap and measure the buildup of hydrogen as it permeates the pipe wall. Measurements are facilitated using a gauge block similar to that of the intrusive probes. To install a non-intrusive hydrogen probe:

1) Weld the housing to the pipe or vessel at the desired monitoring point. General welding instructions can be found in the Metal Samples High Pressure Access Systems Operations and Maintenance Manual.
   NOTE: The referenced welding instructions are provided for general information and may be adapted as required by the end user. Further, these instructions are not intended to supersede local welding codes or procedures.
2) Allow the housing and weld bead to cool to ambient temperature.
3) Thread the gauge block assembly into the housing. Once the gauge block has been installed you may proceed to section 3.

4. Initial Setup

Regardless of the type, the procedure to operate a pressure-based hydrogen probe is the same. The basic steps are detailed below.

Equipment Required

- Inert gas tank with low-pressure regulator (Helium is recommended, but other inert gasses may be used)
- Connecting hose and fittings
- Basic hand tools

Procedure

1) First, bias the needle of the pressure gauge off-zero. This will help provide a faster indication once internal pressure begins to rise due to hydrogen permeation.
   a. Connect the inert gas tank to the bleed valve on the Hydrogen Probe's Gauge Block Assembly using a suitable hose and fitting.
   b. Set the pressure regulator to approximately 15 to 20 psi (1 to 1.4 Bar.)
   c. Open the bleed valve and charge the probe's internal cavity until the pressure gauge reads between 15 and 20 psi. NOTE: Do not over-charge the internal cavity of the probe as this may impair performance, or cause damage to probe components.
   d. Once the pressure gauge has been biased, close the bleed valve and disconnect the hose.
2) Next, observe the pressure gauge to ensure that pressure is not dropping. A drop in pressure may indicate a leak. In this case:
   a. Ensure that the bleed valve is completely closed.
   b. Check each of the threaded joints of the probe assembly for leaks.

c. Once the source of the leak has been identified, open the bleed valve to vent the pressure within the probe, then re-tighten the leaking joint.
d. Reconnect the hose from the gas tank and repeat steps 1 and 2 until no further leaks are found.

3) Once the gauge has been biased and the system has been verified to be leak-free, observe and record the exact pressure and temperature on the gauge array, along with the time and date (see section 4 below for suggestions on data recording.)

5. Operation

Over time, hydrogen permeation into the probe will cause an increase in its internal pressure which will be indicated on the pressure gauge. However, the internal pressure will also vary in relation to temperature. The temperature gauge is provided as a means of correcting for the influence of temperature on the pressure measurements.

Pressure and temperature measurements should be recorded on a regular interval, along with the time and date. It is recommended to record the observed values, then correct the pressure to a standardized temperature using Gay-Lussac's Gas Law:

$$\frac{P_1}{T_1} = \frac{P_2}{T_2}$$

It is important to note that this assumes an ideal gas. It is also important to note that temperatures T_1 and T_2 must be converted to an absolute scale for this calculation. Temperatures in Celsius (°C) can be converted to Kelvin (K) by adding 273.15.

For example, if the current pressure value is observed to be 2.96 Bar at 30°C, this can be corrected to a standardized temperature of 21°C (294.15K) as follows:

$$P_2 = \frac{P_1 * T_2}{T_1} = \frac{2.96\ Bar * 294.15K}{30℃ + 273.15} = 2.87\ Bar$$

Where:

T_1 = Observed Temperature,
P_1 = Observed Pressure at Observed Temperature T_1,
T_2 = Standardized Temperature, and
P_2 = Corrected Pressure at Standardized Temperature T_2

Table 2 provides an example template for recording data. This can be modified by the user as desired. It is recommended to use consistent units of measurement for all readings, and to record the units of measurement.

With continued use the pressure within the hydrogen probe will eventually reach the gauge's maximum. In this case the bleed valve should be used to bleed some of the internal pressure off and reset the gauge reading to around 15 to 20 psi. If all pressure is accidentally vented it will be necessary to re-charge the probe's internal cavity as described in section 3.

Location:						
Process:						
Date	Time	Technician	Observed Pressure	Observed Temperature	Corrected Pressure at 21°C (69.8°F)	Notes

Table 2: *Example Recording Template*

6. Removal

If it becomes necessary to remove the hydrogen probe for repair or replacement, the procedure for removal is based on the fitting type and system used.

i. Retractable Hydrogen Probes

1) Retract the Hydrogen Probe in accordance with the Retractable System Operation & Maintenance Manual.
2) Close the process isolation valve.
3) Open the process bleed valve to release any trapped pressure.
4) Open the bleed valve on the gauge block assembly to release any pressure within the probe.
   NOTE: The probe may contain hydrogen gas which is flammable. Take any necessary precautions.
5) Once the probe has been vented, the Hydrogen Probe may be un-mounted from the system.

ii. Retrievable Hydrogen Probes

1) Open the bleed valve on the gauge block assembly to release any pressure within the probe.
   NOTE: The probe may contain hydrogen gas which is flammable. Take any necessary precautions.
2) Wait until the probe has completely vented and the flow of gas out of the bleed valve has stopped.
   NOTE: If the flow of gas does not stop after an extended time, or if process medium issues from the bleed valve, this indicates that the hydrogen probe has lost integrity and is leaking. Close the bleed valve immediately and stop at this point. The retrievable hydrogen probe cannot be removed until the system has been depressurized.
3) After the probe has been vented, unthread the Gauge Block Assembly from the top of the hollow plug.
   NOTE: It is important to hold the top of the Hollow Plug Assembly with a wrench to prevent the plug from rotating while you loosen the Gauge Block Assembly. DO NOT loosen the Hollow Plug Assembly as doing so could unseat the primary packing which would result in process leakage.
4) Once the Gauge Block Assembly has been removed, mount the Service Valve and Retrieval Tool onto the Access Fitting.
5) Remove the Hollow Plug Assembly and Hydrogen Sensing Element from the system following the instructions in the Retrieval Tool and Service Valve manuals.

iii. Non-Intrusive Hydrogen Probes

1) Open the bleed valve on the gauge block assembly to release any pressure within the probe.
   NOTE: The probe may contain hydrogen gas which is flammable. Take any necessary precautions.
2) Once the probe has been vented, unthread the gauge block assembly from the housing.