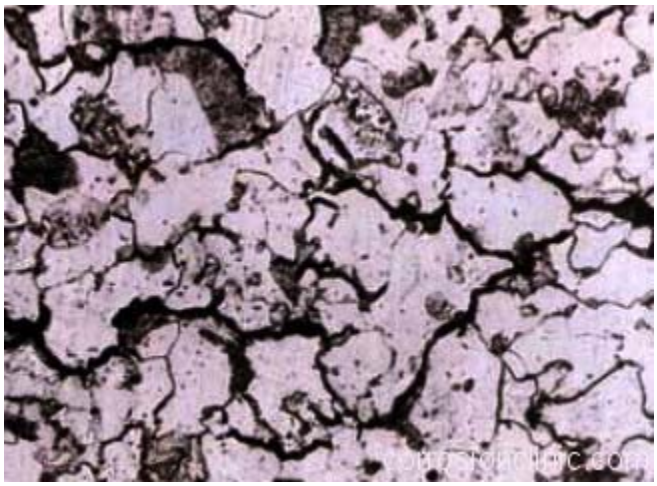
Different Types of Corrosion

- Recognition, Mechanisms & Prevention

High-temperature Hydrogen Attack (Decarburization)

Recognition of High Temperature Hydrogen Attack (HTHA)



What is high-temperature hydrogen attack?
High-temperature Hydrogen Attack (HTHA) refers to the loss of strength and ductility of steel by high-temperature reaction of absorbed hydrogen with carbides in the steel, resulting in decarburization and internal fissuring.

High-temperature hydrogen attack is also referred to as hot hydrogen attack or decarburization. It occurs in carbon and low-alloyed steels exposed for an extended period to hydrogen under high pressure and at high temperature.

This micrograph shows intergranular cracking caused by high temperature hydrogen attack in a C-0.5Mo steel.

Mechanisms of High Temperature Hydrogen Attack

What causes High-temperature hydrogen attack?
Atomic hydrogen (formed in corrosion processes or by dissociation of molecular hydrogen in a gas stream at the steel surface) diffuses into steel. At grain boundaries, crystal imperfections, inclusions, discontinuities and other defects, the atomic hydrogen reacts with the dissolved carbon or with the metal carbides, forming methane:

$8H+C+Fe_3C = 2CH_4+3Fe$ (eq.1)

Because of the pressure build-up of the methane in the steel, this results in the formation of intergranular cracks (refer to the micrograph above), fissures and blisters, often extending to the surface of the steel. This form of hydrogen damage sometimes resembles the low-temperature hydrogen blistering. Moreover, the decarburization process leads to the loss of carbon in the steel and hence a reduction in tensile strength and an increase in ductility and creep rate. Interestingly, the reverse process (Eq.1 above), carburization, can also occur in hydrogen-hydrocarbon mixtures such as that encountered in petroleum-refining operations.

Modeling, Prediction and Prevention of High Temperature Hydrogen Attack

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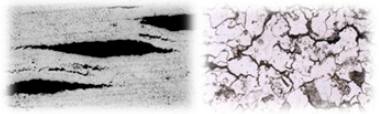
How to determine the operating temperature limits for steels in hydrogen service to avoid high temperature hydrogen attack (HTHA)?
How to select alloy steels for high temperature hydrogen services?

H2Compass: Modeling and Prediction of Low Temperature Hydrogen Damages and High Temperature Hydrogen Attack

Operating Temperature	°C	425		Material of Construction	1Cr0.5Mo	
H2 Partial Pressure	MPa	10.000		Predicted H Concentration in Steel	ppm	2.239
Low Temperature Hydrogen Damages (HB/HIC/SOHIC/SWC/HE/HSC/SSC/SZC)				High Temperature Hydrogen Attack (HTHA)		
Internal H2 Pressure at Traps in Steel upon Cooling	MPa	1.822e+3		HTHA Temperature Limit	°C	373
PWHT and Pre-Heating Requirements	C	Mo	Cr	HTHA Susceptibility	susceptible to HTHA	
PWHT is required.	0.100	0.500	1.000	Reduce operating temperature or H2 pressure or change the metallurgy to prevent HTHA.		
Susceptibility to HB/HIC/SOHIC/SWC	Mn	Cu	Ni			
Susceptible	0.450	0.001	0.001			
Susceptibility to HE/HSC/SSC/SZC	Hardness	HRC	40			
Susceptible	Equivalent Carbon Content		0.500			
Reduce hardness and/or H concentration in steel.						



$8H+C+Fe_3C = 2CH_4+3Fe$

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How to assess the susceptibility of an alloy steel to high temperature hydrogen attack (HTHA)?

H2Compass is a powerful software for modeling and prediction of high temperature hydrogen attacks. H2Compass software provides instant answers to the above questions. The software can be used to determine the safe operating limits of temperature and hydrogen partial pressure for commonly used alloy steels in hydrogen services.

How to prevent High-temperature hydrogen attack? High-temperature hydrogen attack, decarburization and fissuring can be prevented through:

- avoid high carbon steels
- use higher alloyed steels
- following the safe operating temperature and hydrogen partial pressure limits computed by

H2Compass.

For more details on High Temperature Hydrogen Attack

Where can I learn more about high temperature hydrogen attack? More details on high-temperature hydrogen attack are included in the following corrosion courses which you can take as in-house training courses, course-on-demand, online courses or distance learning courses:

Corrosion and Its Prevention (5 days)
Environmental Cracking (HB-HIC-SWC-SOHIC-SSC-SZC-HSC-HE-SCC): Recognition, Mechanisms and Prevention (5days)
API 571 Damage Mechanisms Affecting Fixed Equipment in the Refining and Petrochemical Industries (5 days)
Corrosion, Metallurgy, Failure Analysis and Prevention (5 days)
Marine Corrosion, Causes and Prevention (2 days)
Materials Selection and Corrosion (5 days)
Stainless Steels and Alloys: Why They Resist Corrosion and How They Fail (2 days)

If you require corrosion expert witness or corrosion consulting service on high temperature hydrogen attack, our NACE certified Corrosion Specialist is able to help. Contact us for a quote.