Hydrogen Permeation Flux Through a Steel Wall

Steady hydrogen permeation flux through a metal wall from Sieverts solubility and diffusivity with hydrogen pressures on both sides, and the time lag.

Method: Sieverts' law and Fick's first law

Input parameters

Unit system: SI

Parameter	Value	Unit
Hydrogen partial pressure, high side	100.00	bar
Hydrogen partial pressure, low side	0	bar
Hydrogen diffusivity in the metal	1.0000e-05	cm²/s
Sieverts constant (mol H_2/(m³·Pa^½))	9.4000e-06	
Wall thickness	10.000	mm

Calculated results

Parameter	Value	Unit
Dissolved hydrogen at the high-pressure face (mol/m³)	0.029725	
Permeation flux (mol H_2/(m²·s))	2.9725e-09	
Mass flux	5.1776e-04	g/(m²·d)
Permeation time lag	4.6296	h

Notes for this case

• Hydrogen dissolves as atoms, so its concentration follows Sieverts' law c = K_s√p; Fick's first law then gives J = D·K_s(√p_1 − √p_2)/L (as H_2). The time lag $L^2/6D$ is how long the flux takes to build up. Traps (inclusions, dislocations) cut the effective D at room temperature by orders of magnitude; electrochemical charging (corrosion, cathodic protection) can give much higher surface concentrations than the gas pressure suggests.

Formula and method

$$c = K_s\sqrt{p}, \quad J = \frac{DK_s(\sqrt{p_1} - \sqrt{p_2})}{L}, \quad t_L = \frac{L^2}{6D}$$

Variables

p_1	Hydrogen partial pressure, high side	Pa
p_2	Hydrogen partial pressure, low side	Pa
D	Hydrogen diffusivity in the metal	m²/s
K_s	Sieverts constant (mol H_2/(m³·Pa^½))	-
L	Wall thickness	m
c_1	Dissolved hydrogen at the high-pressure face (mol/m³)	-
J	Permeation flux (mol H_2/(m²·s))	-
J_m	Mass flux	kg/(m²·s)
t_L	Permeation time lag	s

Method and standards

Permeation.

Assumptions and limits

- Steady state; surface equilibrium (no surface-limited entry); constant D.

References

Sieverts' law and Fick's first law

Report details

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Release checks	3 reference cases of this calculator, computed independently, are checked on every release

Results are for engineering estimation. Verify critical designs against the referenced standards and your own data.

This calculator online

https://calc.firecad.com/materials/corrosion/hydrogen-permeation-flux

Open this case on calc.firecad.com →

Reopens the calculator with the inputs of this report.