



Standard Practice for Evaluation of Hydrogen Uptake, Permeation, and Transport in Metals by an Electrochemical Technique¹

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1. Scope

1.1 This practice gives a procedure for the evaluation of hydrogen uptake, permeation, and transport in metals using an electrochemical technique which was developed by Devanathan and Stachurski.² While this practice is primarily intended for laboratory use, such measurements have been conducted in field or plant applications. Therefore, with proper adaptations, this practice can also be applied to such situations.

1.2 This practice describes calculation of an effective diffusivity of hydrogen atoms in a metal and for distinguishing reversible and irreversible trapping.

1.3 This practice specifies the method for evaluating hydrogen uptake in metals based on the steady-state hydrogen flux.

1.4 This practice gives guidance on preparation of specimens, control and monitoring of the environmental variables, test procedures, and possible analyses of results.

1.5 This practice can be applied in principle to all metals and alloys which have a high solubility for hydrogen, and for which the hydrogen permeation is measurable. This method can be used to rank the relative aggressivity of different environments in terms of the hydrogen uptake of the exposed metal.

1.6 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 ASTM Standards:

G 96 Guide for Online Monitoring of Corrosion in Plant Equipment (Electrical and Electrochemical Methods)³

3. Terminology

3.1 Definitions:

3.1.1 *charging*, *n*—method of introducing atomic hydrogen into the metal by galvanostatic charging (constant charging current), potentiostatic charging (constant electrode potential), free corrosion, or gaseous exposure.

3.1.2 *charging cell*, *n*—compartment in which hydrogen atoms are generated on the specimen surface. This includes both aqueous and gaseous charging.

3.1.3 *decay current*, *n*—decay of the hydrogen atom oxidation current due to a decrease in charging current.

3.1.4 *Fick's second law*, *n*—second order differential equation describing the concentration of diffusing specie as a function of position and time. The equation is of the form $\partial C(x,t)/\partial t = \partial/\partial x D_1 \partial/\partial x [C(x,t)]$ for lattice diffusion in one dimension where diffusivity is independent of concentration. See 3.2 for symbols.

3.1.5 *hydrogen flux*, *n*—the amount of hydrogen passing through the metal specimen per unit area as a function of time. The units are typically concentration per unit area per unit time.

3.1.6 *hydrogen uptake*, *n*—the concentration of hydrogen absorbed into the metal (for example, g/cm³ or mol/cm³).

3.1.7 *irreversible trap*, *n*—microstructural site at which a hydrogen atom has a infinite or extremely long residence time compared to the time-scale for permeation testing at the relevant temperature, as a result of a binding energy which is large relative to the migration energy for diffusion.

3.1.8 *reversible trap*, *n*—microstructural site at which a hydrogen atom has a residence time which is greater than that for the lattice site but is small in relation to the time to attain steady-state permeation, as a result of low binding energy.

3.1.9 *mobile hydrogen atoms*, *n*—hydrogen atoms that are associated with sites within the lattice.

3.1.10 *oxidation cell*, *n*—compartment in which hydrogen atoms exiting from the metal specimen are oxidized.

3.1.11 *permeation current*, *n*—current measured in oxidation cell associated with oxidation of hydrogen atoms.

3.1.12 *permeation transient*, *n*—the increase of the permeation current with time from commencement of charging to the attainment of steady state, or modification of charging conditions (that is, rise transient). The decrease of the permeation current with time resulting from a decrease in charging current (that is, decay transient).

¹ This practice is under the jurisdiction of ASTM Committee G01 on Corrosion of Metals and is the direct responsibility of Subcommittee G01.11 on Electrochemical Measurements in Corrosion Testing.

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² Devanathan, M.A.V. and Stachurski, Z., Proceedings of Royal Society, A270, 90–102, 1962.

³ Annual Book of ASTM Standards, Vol 03.02.