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Experimental determination of the capillary pressure to assess hydrogen integrity in completion systems

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In order to quantify the risk of storing hydrogen in underground facilities, the materials belonging to a wellbore completion (cement and steel) are analyzed by using laboratory tests in presence of hydrogen at elevated pressures and temperatures. Penetrated and diffused hydrogen produces negative effects on materials. In steels, embrittlement is caused by hydrogen diffusing in atomic form through defects and interstitial spaces of the material's lattice. Recombined molecular hydrogen occupies more space, inducing cracking and severely affecting the mechanical properties.
On the other hand, the impact hydrogen has on the cements´ integrity can be estimated by determining the capillary effect of this gas when being in contact with the reservoir water initially present in the cement pores. It is considered a loss of integrity in the completion once the pressurized hydrogen completely displaces the reservoir water from the pores. Gas break-through tests enable to determine the capillary pressure associated with the loss of cement storage integrity. During the test program, the cement composition was continuously improved by using different additives and by being able to adjust the cement hydration process to the real situation in the field, resulting in a continuous increase of the capillary pressure, which translates into an increase of the gas tightness of the completion system. The results obtained from the tests along with their interpretation have been confirmed by additionally determining the capillary pressure from experimental data on the interfacial tension between the fluids as well as contact angles on the solid materials involved at reservoir conditions.