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PROCEDURE FOR CONDUCTING A COMPATIBILITY EVALUATION FOR A CLASS V INJECTION WELL

Procedure #: UICV-11
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Narrative:

The purpose of this document is to provide a listing of several common procedures for conducting a compatibility evaluation.

The well materials must be compatible with the fluid with which the material may be expected to come into contact. This is necessary to prevent failure of internal mechanical integrity. Failure of mechanical integrity is a serious threat to public health and the environment. Forms of corrosion for metal materials include uniform thinning, pitting, galvanic corrosion, dezincification, parting, cracking, erosion corrosion and crevice corrosion. Results of attack by the fluid on plastic materials include swelling, cracking, blistering, softening and delamination.

The injection fluid must also be compatible with the injection formation, material and fluids and the confining strata material. Failure of the confining zone strata could allow injected fluids to escape from the injection zone and threaten fresh or usable waters or the public health. Dissolution of limestone or dolomite injection formation material could result in the development of cavities that may result in a structural stability problem. CO_2 gas development as a result of acidic injection fluid reacting with limestone or dolomite can cause a well blowout forcing injection fluids and formation fluids to the surface and also causing damage to the well components. Gases entrapped in pore spaces resulting from phase separation can reduce permeability. Incompatibility of the injection fluid with injection formation fluids or materials can result in plugging and reduced permeability limiting the capacity of the well to accept fluids or plugging the formation completely. Severe permeability damage or reduction may not be correctable and the use of well could be lost.

Generally speaking; with increasing temperature, pressure, gas content, or total dissolved solids; corrosivity and reactivity are increased.

Suspended solids, entrained gas and oil must be removed from the waste to the highest degree feasible prior to injection because these all have the potential to plug the injection formation and reduce the capacity of the formation to accept fluid.

Procedure:

One type of compatibility evaluation is a comparison of the predicted conditions to known reactions. Listed are some of the common potential adverse reactions between various types of injection fluid and injection formation materials and fluids that have been observed in the field and in the laboratory.

Injection Fluid and Formation Material Reactions

- Acidic injection fluids will react with dolomite and limestone. The prevalent reaction is between the acid and $CaCO_3$ or Ca-Mg CO_3. This can result in the formation of CO_2 gas, potentially resulting in a blowout.

A cavern in the formation can also develop causing a potential structural stability problem, weakening of the formation and/or development of undesirable fractures through the disposal formation and/or confining strata.

- Under certain conditions gels can form when acidic injection fluid reacts with $CaCO_3$ material resulting in mechanical plugging of the formation.

- Dissolution of $CaCO_3$ by acidic injection fluid can cause over saturation of the disposal formation with CO_2 and calcium salts, decreasing permeability.

- Acidic injection fluid can dissolve clay minerals. The H^+ ion replaces the metal ions in the clay resulting in a breakdown of the clay structure and the release of particles that can plug pores.

- Acidic injection fluid can react with sandstone causing iron to dissolve. Many sandstones have a large amount of iron in the cement between the sand grains. As the acid is neutralized the iron reprecipitates, plugging the pores and reducing permeabilities.

- Acidic injection fluid can dissolve $CaSO_4$ cement in sandstone and subsequent reprecipitation can cause blocking of pores.

- Highly alkaline injection fluid can dissolve silica damaging the clay structure and releasing fine clay particles causing plugging.

- Injection fluid with a low salt concentration may cause swelling or dispersion of clays resulting in reduced permeability. The cations are released from the clay and the vacant spaces then hydrate, causing swelling. Bentonite is very reactive with water and will swell to 10 times its unreactive size. Kaolinite is the least reactive of the clay minerals.

- Polar organic chemicals are readily absorbed onto clay and silicates and may cause a reduction in permeability. This reaction is more severe in sandstone then in carbonates.

- Phenols can cause swelling of clays resulting in a reduction in permeability.

Injection fluid and Injection Formation Fluid Reactions

- Certain pressure or temperature changes may cause gas to come out of solution forming a gas phase. Above their critical temperature, some gases can not be held in solution. This can result in plugging of pores reducing permeability.

- Reactions of alkaline earths and heavy metals with carbonates and bicarbonates are caused by changes in the equilibrium between CO_2, HCO_3 and CO_3. Such changes can result in the precipitation of the carbonate or bicarbonate of Ca, Mg, Fe, or Mn.

- Oxidation of H_2S by chromium can form a precipitate. Oxidation of ferrous iron by dissolved oxygen or changes in pH can cause the formation of insoluble ferrous hydroxide.

- Sulfate reducing bacteria in the formation can reduce sulfate and sulfur to insoluble sulfides and sulfur.

- The growth of iron bacteria or other type of bacteria can clog the borehole face.

- Other common precipitations are 1) alkaline metals such as Ba, Ca and Sn typically as carbonate, sulfates, 2) metals such as Al, Cd, Cr, Fe, Mn, Ni, Zn, As, Hg, Pb as carbonates, hydroxides, or sulfides, 3) organics through polymerization. These can all cause plugging of the injection formation.

- Dissolved iron and H_2S can result in precipitation of sulfides.

- Above a pH of 10; Ca, Ba, Sr, Mg and Fe can all form gelatinous hydroxide precipitates.

Other evaluations of compatibility between the injection fluid and injection formation material and fluids and can consist of one or more of the following procedures:

- Batch tests in which various percentages of the injection fluid are mixed in a series of reactors with either actual or simulated formation waters. The solutions are then allowed to react. The reactors are opened in sequence at regular time intervals and the fluids analyzed and evaluated for the type and amount of precipitate formed, gas evolution and other reactions. The test should be conducted under reservoir temperature and pressure conditions.

- Batch tests in which injection fluid is mixed with disaggregated formation samples or formation cores to determine gas evolution and other injection fluid/injection zone mineral reactions. The test should be conducted under reservoir temperature and pressure conditions. The injection fluid and formation materials are mixed in the same proportion as expected in the field. The reactors are opened in sequence at regular time intervals and the fluid analyzed.

- Dynamic Coreflood Tests use undisturbed cores or packed columns. The same core is used throughout the experiment and the outflow end is monitored at specified intervals to observe changes in chemistry. If precipitation-dissolution reactions occur, pressure changes caused by clogging or increased permeability can be monitored. The test should be conducted under reservoir temperature and pressure conditions. The dynamic coreflood test yields the most representative data.

- Chemical equilibrium models can be used to predict theoretical activities of aqueous species and to calculate the saturation indices for selected minerals.

- The saturation or stability index can be used as a means to anticipate instability in a system affected by more than one variable. A common index is the Stiff and Davis (1952) which is intended for use with concentrated solutions. The index is used to determine if a precipitate will form or if the fluid is corrosive.

Evaluations of compatibility between the injection fluid and well components can include the following:

- To test compatibility between the injection fluid and metal well components, the use of coupons of material identical to those used in construction of the well are placed in contact with the injection fluid under pressure and temperature conditions expected at the wellhead. The material is then checked for loss of mass and thickness. The coupon is also visually observed for pitting, cracking, or other signs of corrosion. For compatibility with plastic type material the material is observed for swelling, cracking, blistering, softening, delamination or other signs of attack on the material.

- The saturation or stability index can be used as a means to anticipate instability in a system affected by more than one variable. A common index is the Stiff and Davis (1952) which is intended for use with concentrated solutions. The index is used to obtain if the fluid is corrosive.

Summary

This procedure document describes several methods for conducting a compatibility evaluation. Each disposal project is unique and has its own degree of complexity. The study should be as detailed and as site specific as feasible. The evaluation must be suited to the physical and chemical characteristics of the injection fluid and the geology, geochemistry, and operational conditions of the proposed project. If available, actual fluids and materials should be used for actual testing. A proper compatibility evaluation will require the use of experienced and qualified professionals who have access to the necessary testing equipment and are knowledgeable of proper testing procedures.

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