Comprehensive guidelines on the suitability criteria of cementitious materials for carbon capture and storage (CCS) in oil wells

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In order to reduce atmospheric greenhouse gases, capturing and storing of carbon dioxide underground is considered as the most effective, low-cost, long-term and safer approach. Depleted oil and gas wells are a suitable geologic site for storage and can offer stability and effective CO_2 trapping. However, cement used in oilwell drilling, under CCS applications, is exposed to extreme conditions as high temperatures, high pressures and acid, salt and CO_2 attack. There have been many reports of leakage incidents associated to cement degradation and failure of the integrity of the cement sheath. On the other hand, as a systematic retrieval of samples is impossible and lab-scale simulation is extremely difficult, there are very few representative studies reported in the literature that firmly address the key features for a long-term cement integrity on wells operating in supercritical conditions.
In addition, once possible, experiments carried out on real samples extracted directly from exhausted oil wells and laboratory experiments provide conflicting data due to mismatch between the simulated lab scale conditions and the real well conditions.
A comprehensive literature survey highlights that the type of cement providing an effective long-term barrier for CO_2storage underground is Portland cement of Class H or G according to API and ISO specification, whilst Portland Class A and B cements are usually used for pipe housing near the surface as they are not sufficiently compacted to withstand high temperatures and pressures. To withstand extreme conditions and high depths, class G and H cement can be profitably modified by adding additives, such as pozzolan.
One of the main methods of effectively increase the strength of cement subjected to HTHP conditions is to add silica fume in 20% wt. Extreme and harmful conditions for cementitious binders, however, are not only high temperatures and pressures, but also the ground level temperature (there are oil fields in extremely cold areas) and the need of cement formulation to bear these environmental conditions as well as the temperature gradient in depth. For these conditions, special cements with a gypsum/Portland mix and the addition of sodium chloride (12%) are commonly used. A pozzolanic additive, Type F Fly ash, is the most common additive used in cement for well-sealing in oil-gas field operations. Other kind of problems can occur due to the presence of brines containing sulfates. Salt brines are among the most destructive agents for Portland cements and when NaCl is present, corrosion phenomena also involve the steel pipeline. Concerning CO_2, the best method to face its attack is related to the reduction of porosity and permeability by adding pozzolanic material to the cement matrix, mixing with lower water/binder (w/b) ratio (w/b = 0.4) and promoting the use of cements with more aluminate

phases, giving a decrease in sulfate phases, lower carbonation reaction and less wear of the cement matrix.