4.4 **Post-retort upgrading of shale oil by alkali metal-mediated hydrogen treatment**

Mukund Karanjikar, Javier Alvare, Dolly Chitta, Dennis Larsen, John Gordon

Ceramatec Inc, Salt Lake City, UT, United States

In the past, alkali metal upgrading was investigated for use with heavy petroleum. Results indicated that hydrogen requirements for upgrading in the presence of alkali metal are reduced by half. However the primary challenge has been economic recovery and recycling of the alkali metal. Such a process has not been investigated for shale oil until now. The purpose of this project is development of an economic upgrading technology for shale oil utilizing alkali metals for removal of nitrogen, sulfur, and heavy metals incorporating efficient separation and regeneration of the alkali metals using novel and selective membrane reactors. The methodology involves putting shale oil in contact with a combination of sodium and lithium at high temperature and pressure in the presence of hydrogen in a stirred tank reactor. The alkali metal reacts with sulfur and nitrogen to form sulfides and nitrides. The nitrides are further converted to sulfides by addition of hydrogen sulfide. These sulfides are separated using a filter and are subjected to electrochemical conversion back to alkali metal and sulfur. The alkali metal is recycled to feed into the upgrading reactor. Shale oil samples before and after treatment have been characterized by elemental analysis (CHNS) to determine nitrogen and sulfur content. Heavy metal (Hg, As, V, Cr, Fe, and Ni) and polysulfide concentrations in the oil were also measured using inductively coupled plasma atomic emission spectroscopy (ICP-AES). Polysulfides were measured to assess changes in the alkali metal concentration. In early, non-optimized laboratory experiments, 70% of sulfur and 40% of nitrogen were removed from shale oil by the alkali metal treatment. The unique recovery process uses alkali ion conducting ceramic-based electrochemical reactors. Economic recovery of the alkali metal has been demonstrated. The proposed process is modular in nature and can be adapted for field and refinery applications.