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Microscopy of Heat Exchanger Fouling During SAGD Operations

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The extraction of bitumen from oil sands by SAGD (steam assisted gravity drainage) operation requires the drilling of two parallel horizontal wells through the oil bearing formation. Into the upper well, steam is injected creating a high pressure chamber. The increased heat loosens the heavy oil causing it to flow downward into the second well. This heated low viscosity bitumen is pumped to the surface from the production well into a series of heat exchangers before further processing. Hydrocarbon deposition, scale formation, and mineral accumulation contribute to fouling of the heat exchangers.

Fouling can be defined as the deposition of undesirable materials on the surface of processing equipment preventing further operations. Fouling mechanisms are complex and involve several stages such as asphaltenes precipitation, thermal decomposition and polymerization, nucleation on inorganic particles, and heavy oil incompatibility. At elevated temperatures, mineral scaling and coking can occur. However above 280^{o}C, pyrolytic reactions occur within the hydrocarbon product to produce free radicals, some of which decompose into low molecular weight components, while others yield large molecules. These pyrolytic reactions continue until coke appears on the surfaces, bridging to other produced fluid components until fouling prevents efficient heat transfer, making the heat exchangers less efficient.

The use of light and field emission scanning electron microscopy allowed us to identify both the optical properties and elemental composition of the feedstock and fouling material in order to determine the fouling mechanism. By using correlative microscopy the same field of view in the sample allowed us to provide complementary information, which could not be gain by using a single microscopy technique. The microscopical characterization of these particles attached to the tube surface allowed us to differentiate between mineral scale and coke buildup. Based on the optical properties of the isolated particles, it is possible to identify inorganic and organic solids present in the fouling material. We were able to show that components of the bitumen were being coked when they came into contact with the metal surfaces of the heat exchangers and act as initiators to further fouling. Once a layer of solids had formed on the tube surface, they promoted the precipitation and deposition of more particles from the bitumen fluid phase. The purpose of this study is to gain an understanding of premature fouling of heat exchangers and provide options for mitigation in the future.