CORE-FLOODS ON SITE: ASSESSING THE OPTIONS FOR WATER TREAMENT IN FIELDS WITH ACTIVE EOR APPLICATIONS

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ABSTRACT

We report on a new mobile core-flood system to assess the impact on injectivity of different treatment processes for oilfield waters used in enhanced oil recovery (EOR).

Oil in water (OIW) and the amount of total suspended solids (TSS) are traditional parameters for assessing water quality, be it for secondary or tertiary recovery methods or simple disposal. Typically, these values are obtained by analysing water samples taken at discrete intervals at a water treatment plant or from process streams inside a testing facility for a novel water-treatment technology.

In our experience OIW- and TSS-values alone will provide limited information to properly assess risks and injection-well performance of chemical packages which are employed during the water treatment process. These additives can interact with traces of EOR-fluids (e.g. polymers) or the matrix of the target formation. This in turn can lead to damage and even the loss of an injection well, despite the fact, that initial screening based upon OIW or TSS content indicated good injectivity.

To directly asses the water quality in terms of actual injection performance, we employ a continuous "permeability reduction test" (PRT). A 10ft-container equipped with two identical core flood rigs allows continuous monitoring of injectivity of produced water from different stages of treatment process. The injectivity behaviour of the produced water is evaluated in terms of pressure build up across a core sample. A short latency in the order of only five minutes allows us to correlate the pressure response of the core with operating parameters and/or the chemical consumption in the upstream water treatment plant. Testing two cores in parallel (e.g. inlet vs. outlet) corrects for variations in the inlet water quality caused by unsteady operating conditions. The PRT-container is designed for road transport and can be deployed at any desired locations within an

oilfield. Once the core samples have been mounted monitoring and control can be done remotely.

We present results from a test campaign which evaluated a novel flotation technology for treating water containing back-produced polymer from a polymer pattern in the Matzen field in the Vienna Basin, Austria.

INTRODUCTION

Starting in 2010 OMV installed a polymer flood pilot in one of the horizons of the Matzen Field in the Vienna Basin, Austria. Numerous studies on polymer injectivity behaviour [1, 2] and reservoir simulation aided by tracer data [3] supported this pilot-installation. However, in order to successfully facilitate a full-field roll-out the treatment of back-produced formation water needs to be addressed. Back produced water containing polymer may interfere with oil-water separation and can negatively affect established water treatment processes.

Field trials of several months duration using test-skids of the currently installed water treatment plant (pilot WTP, [4]) or novel techniques like micro bubble floatation (MBF, [5]) were conducted.. During this stage it was determined, that the traditional characterisation of water treatment efficiency in terms of oil-in-water (OIW) or the amount of total suspended solids (TSS) should be complemented by a direct method of predicting injection behaviour. In particular, the deployment of chemical packages aiding e.g. floatation- or flocculation steps can impair injection behaviour into a well by interaction with traces of back-produced polymer, even though the water quality in terms of OIW and TSS still indicates good injectivity.

While filtration tests developed in house have long been successfully deployed in OMV's WTP in the Vienna basin, these tests would 1) rely on batch sampling and only provide a snap-shot in time and 2) use a filtration medium which is significantly different to the actual rock formation. Consequently injectivity behaviour into the formation is again only inferred rather than determined outright. The decision was thus taken to implement a core-flood system capable of continuously monitoring the water quality as a function of the operating state of any arbitrary water-treatment technology situated upstream. The method was dubbed "permeability reduction testing" (PRT) and would mimic injection into a well by means of a core flood, whereby the quality of the produced water is evaluated in terms of pressure build up across a core sample.

DESIGN PHILOSPHYAND REALISATION

The main requirements during the design phase were: Firstly, to allow continuous injection of oil-field waters in to a core at rates corresponding to the near-wellbore conditions of a typical injector and secondly, semi-autonomous operation in order to limit operator tasks to mounting/dis-mounting of cores and the occasional sampling of fluids for chemical analyses and cross-checking. Further considerations were a ruggedized construction compatible with road transportation (flatbed truck) and in terms of health, safety, security and environment (HSSE) an intrinsically safe design for the pressure bearing parts. The resulting piping and instrumentation diagram (P&ID), which also serves as the user interface on the touch panel display of the control system, provides an overview of the process and design (Figure 1).

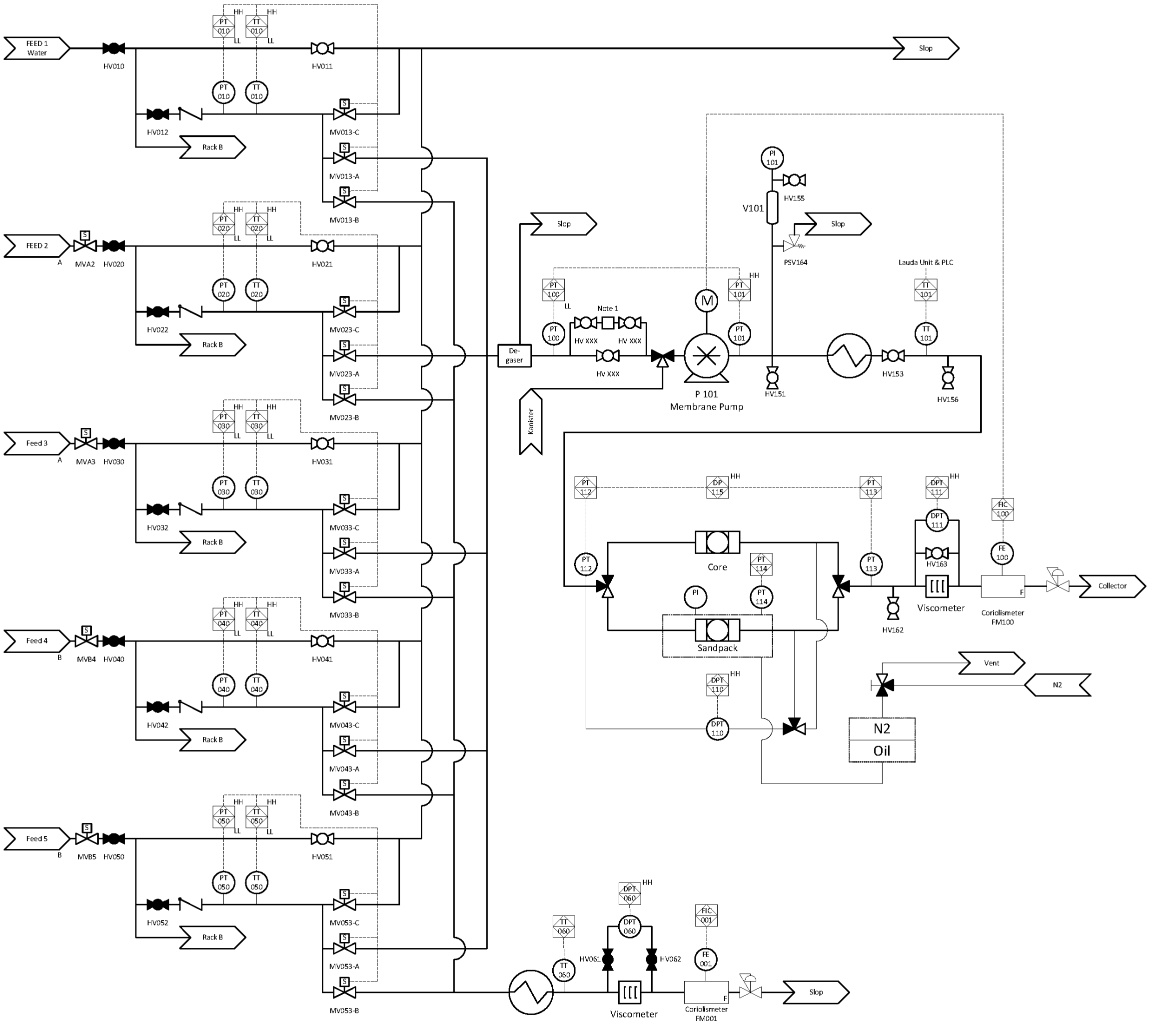

Figure 1: P&ID of the PRT. The same P&ID is used as the basis for the touch-panel controls

Up to five different water streams can be hooked up to the container and fed to two identical core flood racks via a manifold. In this way minimal modifications are required once feedlines are installed on a new testing site. This allows sampling of oilfield-waters from different (e.g. intermediate) stages of treatment process with a high degree of operational flexibility. Alternatively, the efficiency of the complete pilot skid can be compared to the “do-nothing-case” by comparing treated water with water taken directly from an inlet stream.

Injection pressure is provided by two industrial-grade metering pumps (diaphragm pumps) capable of delivering up to six litres per hour at pressures up to 100 bar. This pump type is also tolerant of a certain loading of the water with solids. During operations the pressure is monitored in the feed lines. Upon detection of a leak, solenoids valves automatically close the supply of the fluid under investigation at the source. Together with spill trays in the container this minimizes any possible loss of containment and provides high operational flexibility even in environmentally sensitive areas. All pressure bearing parts have a minimum rating of 140 bar, rendering the system intrinsically save.

The injection rate is set primarily via the pumps’ stroke length and then fine-tuned using a frequency converter. A Coriolis mass-flow-controller as input parameter will control and compensate for any changes in injection rate by thermal fluctuations. Fluids are brought to the simulated injection temperature by means of a tube-in-tube heat exchanger controlled by laboratory heating-cooling thermostats. Several pressure transducers continuously monitor the system and record various absolute pressures as well as the main-value of interest, the differential pressure across the core sample. Loss of pressure in the feed lines or high pressures downstream of the pump (i.e. caused by imminent core blockage) will lead to an automatic shutdown. Some details of the setup are presented in Figure 2.

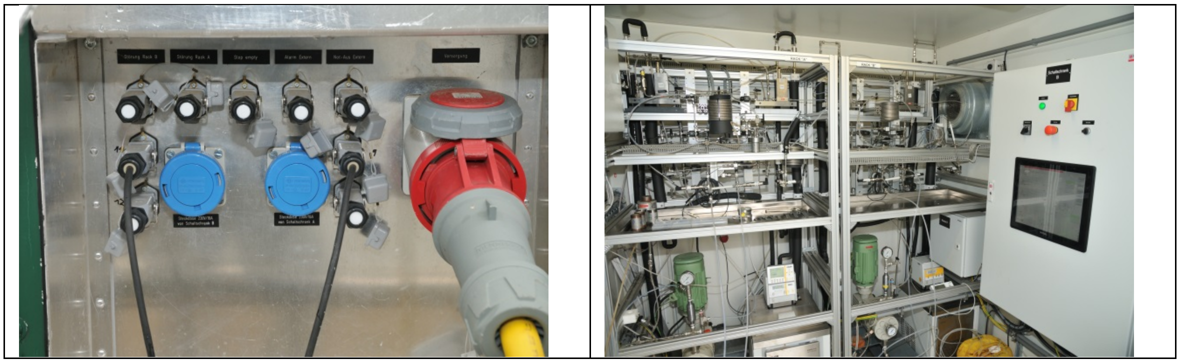

Figure 2: external connection to power supply and control for solenoid safety valves on feed lines (left) and interior view of the two racks (right)

Contrary to more elaborate setups used in a typical laboratory setting, cores are jacketed in steel sleeves by means of an epoxy without option for applying overburden pressure. Mounting occurs via a plug-and-play type core holder simply by screwing the core into custom made endplates. By this method, a large number of cores can be prepared in advance of a campaign and kept in stock until use. However, piping and instrumentation are in place to also mount Hassler sleeves for investigation of loosely consolidated formations (sand-packs).

Once a core has been mounted a baseline pressure-drop for the targeted injection rate is recorded by using synthetic brine. Upon connection to the test-medium, the system will then proceed with the test automatically. A GSM-antenna on top of the container allows for remote control of the PRT. The test ends, when either a certain amount of pore volumes (PV) was injected or a predetermined loss of injectivity is observed. Alternatively, a new core will be mounted when the operating state of the water treatment plant upstream is significantly changed.

For the last test campaign, the latency (i.e. transfer time of the fluid between sampling and injection into the core) was of the order of five minutes. This provided a good correlation of the operating state of the water treatment process with any observed pressure response of the core. Sampling rates can be as high as 1 Hz, but yield unwielding amounts of data. Typically, lower data acquisition rates of 3 data-points per minute are sufficient.

OPERATIONAL HISTORY

Over the course of summer 2017 a micro-bubble floatation (MBF) unit was field tested at one of the life-oil metering stations in the Matzen field. The test plan included spiking of produced water with various concentrations of polymer solutions of various molecular weights. Lower molecular weight was to mimic the effect of shear imparted on the polymer as it travels through the reservoir. Treated water volumes are of the order of 10 m^3/hr. Various chemical packages were identified beforehand to potentially assist the floatation process. The PRT-container was deployed for the entire test campaign, supplementing discrete sampling for OIW and TSS as well as assessing droplet size distributions via a visual process analyser.

Berea sandstone of approximately 800 mD and 20% porosity was used as analogue core in all cases. This is motivated firstly by the scarcity of reservoir rock samples, and secondly by the fact that the homogeneity of the outcrop rock allows to better isolate sample-to-sample variation from changes in the water quality and MBF-operation and its chemical consumption.

A typical data-set obtained on water taken directly from the three phase separator (‘do-nothing-case’) is shown in (Figure 3). In this case water with approximately 1000 ppm OIW can be injected for almost 48 hours until slug formation causes rapid core blockage. This can result from either uneven well production or accumulation of oil at high or low points in a pipeline system. Spikes in the trace for mass flow (measured downstream of the core) typically indicate that oil has become mobile in the core. At constant volumetric flow, the lower density of the oil is registered as a spike in mass flow. First moveable oil is recorded after 12 hours into the test, corresponding to approximately 450 injected pore volumes.

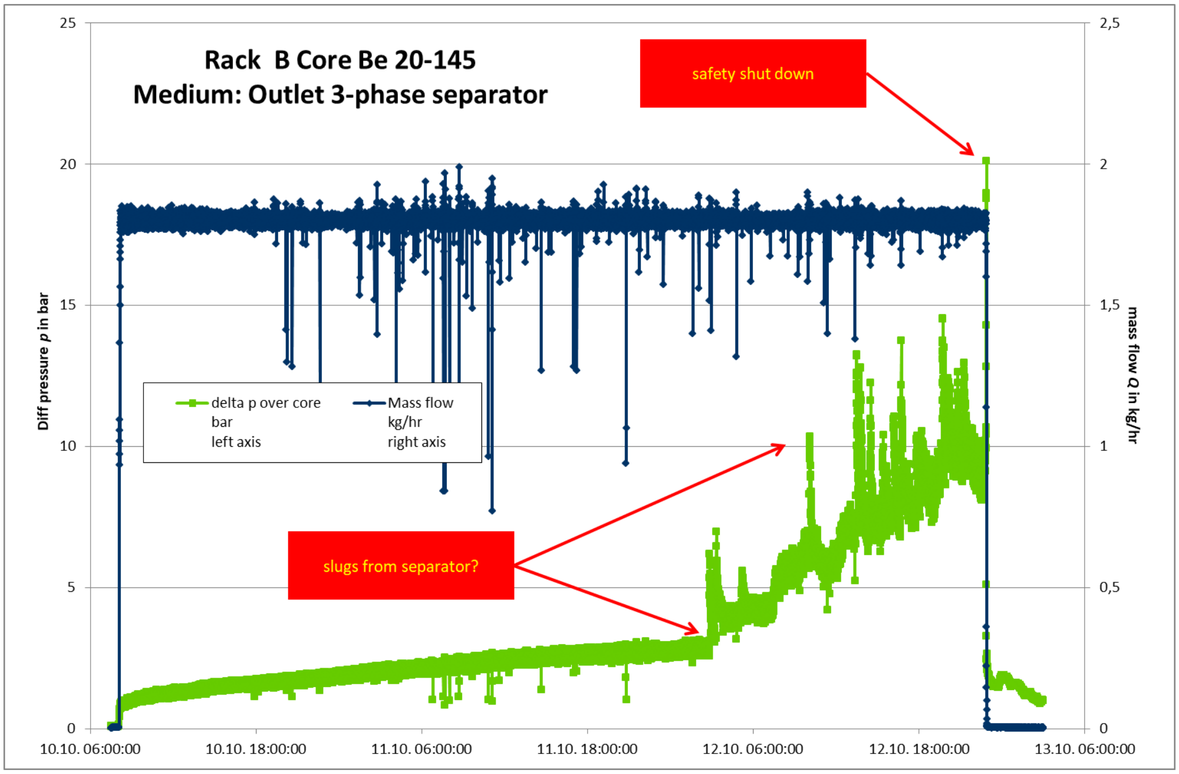

Figure 3: evolution of pressure and rate for injection of untreated oilfield water into a Berea core

The same water as in Figure 3 was subsequently fed as inlet stream to the MBF. It was observed that even though nominally the water quality was excellent in terms of TSS and OIW, blockage of the core occurred rapidly just three to four hours into the test. To demonstrate the usefulness of the PRT and its ability to relate chemical dosage and operational state to injectivity in particular, one dataset is shown (Figure 4) that led to the identification of the "impairing" component of the chemical package.

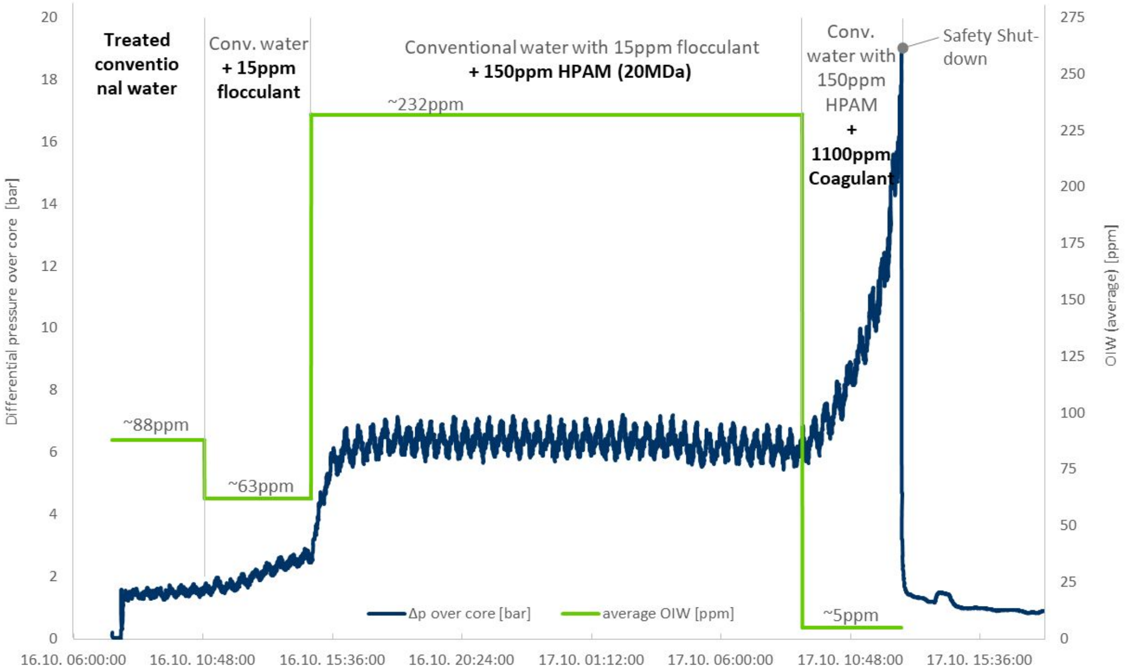

Figure 4: evolution of pressure and rate for injection of treated oilfield water into a Berea core as a function of various chemical dosages

Without chemical dosage the plant upstream of the PRT delivered water with approximately 88 ppm OIW. The pressure drop across the core remained stable safe the fluctuations caused by the feedback loop of the thermostat. Upon addition of the first part of a chemical package (a flocculant) the OIW in the effluent reduced slightly and a gentle increase in pressure drop is observed. Upon spiking the inlet feed of the MBF with additional 150 ppm of polymer the pressure drop roughly doubled due to the increased viscosity. No further interaction of the flocculant with the core is observed; the pressures remain stable for the next twelve hours. Addition of a coagulant drastically improves the performance in terms of OIW (reduced to 5 ppm), but injectivity is dramatically impaired. Within minutes of adding the coagulant the pressure drop across the core rises. Shut-down pressure is reached after four hours.

CONCLUSION AND OUTLOOK

Efficient and cost-effective water treatment will be a crucial economical constraint for the application of EOR in mature oil-fields. In particular, existing water treatment infrastructure may be affected by EOR-chemicals. As well, certain EOR-processes (e.g. alkali surfactant polymer flooding - ASP) have more stringent requirements on water quality than historically required for the operation of a given reservoir. Permeability reduction testing (PRT) via two ‘in-field’ core flood rigs in addition to a dedicated sampling campaign for OIW and TSS and supplemented by particle/droplet size distribution allows the effective online evaluation of a water treatment process in the field. Injectivity is measured directly in terms of pressure and rate, rather than being inferred from OIW- or TTS-values. Changes in operating conditions, chemical consumption or tied-in wells can be monitored in real time. Here in particular, the ruggedized setup in a mobile container provides of high flexibility under field conditions with minimal latency, as laboratory-based core floods are 1) in most cases not equipped to pump several thousands of pore volumes and 2) would rely again on repeated batch-sampling by canisters to provide the necessary fluid volumes.

As of writing, one test-campaign is ongoing with a particular focus on optimisation of an existing water treatment process; two additional test campaigns are scheduled for 2018 and 2019. Scheduled experimental upgrades include the permanent incorporation of dedicated visual process analyser and upgrade of the capillary viscometers.

ACKNOWLEDGEMENTS

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