LABORATORY STUDIES OF ORGANIC AND INORGANIC GEOTHERMAL TRACERS AT SUPERHOT AND SUPERCRITICAL CONDITIONS

Jiri Muller[1], Sissel Opsahl Viig and Helge Stray
[1] Institute of Energy Technology, P.O. Box 40, NO-2027 Kjeller, Norway
e-mail: jiri@ife.no

ABSTRACT

Laboratory studies have been performed at testing stability of organic and inorganic tracers at super-hot and supercritical conditions. Both static and dynamic tests have been performed at specially constructed equipment which can tolerate such hard conditions. In some cases these tests indicate no rapid thermal degradation of the tested tracer candidates within the time frame of the performed stability test (2 months). In other cases the experiments indicate interactions between the rock material and the tracer candidates.

Keywords: paper title, abstract, format, authors, keywords, main text, conclusion

1. INTRODUCTION

Tracers are molecules which behave like sensors when injected in small quantities. By monitoring their behaviour, we can study processes which they are part of. The tracer field tests in geothermal reservoirs are useful e.g. when monitoring development of preferential flow paths, and preparing reinjection strategies in order to maintain sustainability of the reservoir.

Prior to field studies, behaviour and characterization of such tracers is conducted under static and dynamic laboratory conditions. The static experiments reveal thermal and chemical stability as well as partitioning properties of tracers amongst different phases (vapor and liquid phase), whereas dynamic flow experiments tell us about property of tracers with respect to adsorption on rocks and degree of anion exclusion (for anionic tracers) during the fluid flow. Understanding of these laboratory experiments is essential if we wish to interpret tracer production curves in large field studies.

Recently there has been an interest in developing superhot and supercritical geothermal fields with temperatures and pressures above 374 °C and 218 bar respectively. Therefore it would be useful to have knowledge of the behaviour (*e.g.* thermal stability, matrix interaction, chemical stability) of tracers used in such geothermal fields.

2. SELECTION OF TRACERS

Perfluorinated cyclic hydrocarbons (PFCs) were selected as organic tracer candidates for supercritical water conditions. The structural formulas for some common PFCs are given in Figure 1. Using PFCs as conventional gas tracers is a well-established technique for monitoring the movement of gas in a hydrocarbon reservoir. According to literature they are stable at temperatures > 400°C /1/

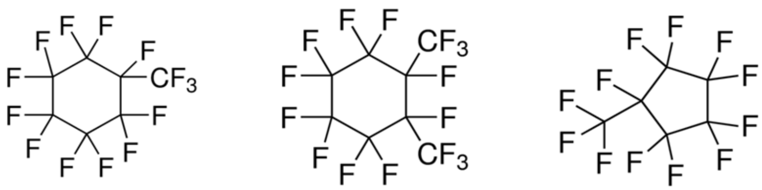

Figure 1*. Structural formula for three common PFCs; perfluoromethyl cyclohexane (PMCH), 1,2-perfluorodimethyl cyclohexane (1,2-PDMCH) and perfluoromethyl cyclopentane (PMCP)).*

In this work several PFCs have been selected for testing at supercritical water conditions. The tracers were selected to cover a relevant range of chemical and physical properties. An overview of the selected tracers is given in Table 1.

Table 1*. Overview of perfluorocarbons selected for testing.*

	Abbreviation	**Molecular weight**	**Boiling point (°C)**
Perfluoro dimethyl cyclobutane	PDMCB	300	45
Perfluoro methyl cyclohexane	PMCH	350	76
Perfluoro ethyl cyclohexane	PECH	400	101.7
Perfluoro-1,2-dimethyl cyclohexane	1.2-PDMCH	400	102
Perfluoro trimethyl cyclohexane	1.3.5-PTMCH	450	127

The selected PFCs can easily be analyzed and detected using GC-MS or GC-ECD.

Anionic metal complexes as inorganic water tracers were tested for their thermal stability and flow properties. One advantage when analysing metal ions in water is the high detectability that can be achieved using advanced analytical instrumentations like inductively coupled plasma mass spectrometry (ICP-MS) or neutron activation analysis. The following tracers have been investigated:

Tracer A: $MoO4^{2-}$
Tracer B: $WO4^{2-}$
Tracer C: $ReO4^{-}$
Tracer D: $RhCl6^{3-}$
Tracer E: $PdCl6^{2-}$
Tracer F: $IrCl6^{2-}$
Tracer G: VO^{3-}

3. THERMAL STABILITY OF TRACER CANDIDATES

Testing of tracers under supercritical conditions requires experimental set-up which tolerates harsh conditions with respect to high temperature and pressure (temperatures > 374 °C and pressures circa 218 bar). In our laboratory we have built a state-of-the art experimental setup for both static and dynamic experiments taking into consideration strict safety requirements. A schematic sketch and a photo of the experimental setup constructed for testing of thermal stability of the tracer candidates is given in Figure 2.

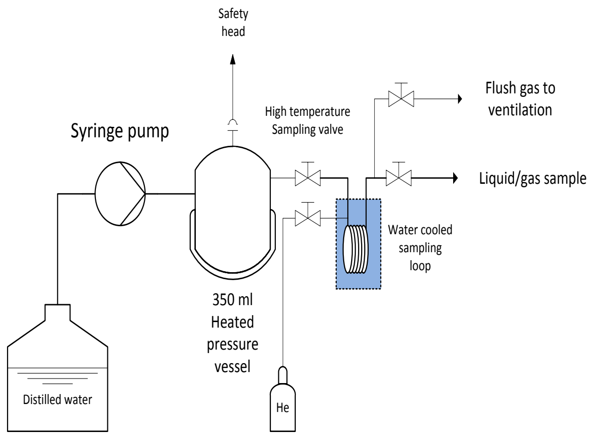

***Figure 2**. Experimental setup for thermal stability experiments at supercritical water conditions.*

4. DYNAMIC TESTING OF TRACER CANDIDATES

Flooding experiments were performed to test the dynamic properties of the selected tracers. A setup for performing dynamic flow experiments at high temperatures and pressures reaching supercritical conditions, was constructed in our laboratory and is displayed in Figure 3.

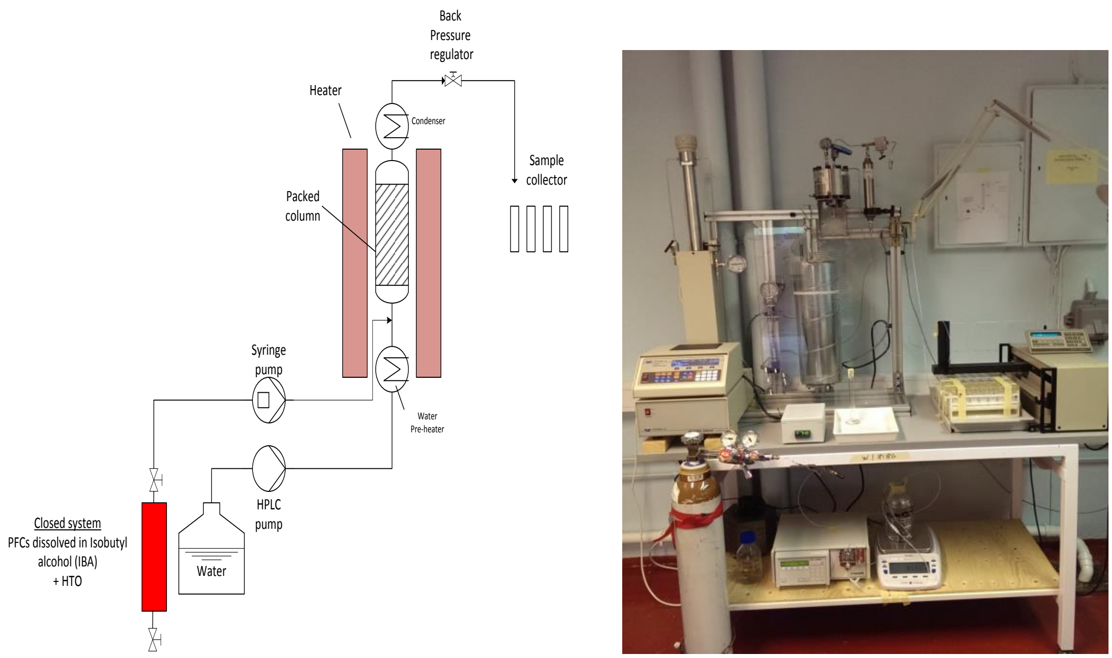

Figure 3. *Experimental setup for dynamic experiments with selected tracer candidates. The system consists of a piston cylinder containing the tracer mixture, a pump, a packed column inside a heating unit, a coil for cooling water prior to sampling, a backpressure regulator and a sampling unit.*

5. RESULTS

During the lecture we shall present the latest results on static and dynamical behavior of both organic and inorganic tracers under superhot and supercritical conditions.

Acknowledgements

This work was supported by the EC FP7 project IMAGE under grant agreement No. 608553 and EC Horizon 2020 project GEMex under grant agreement 727550.