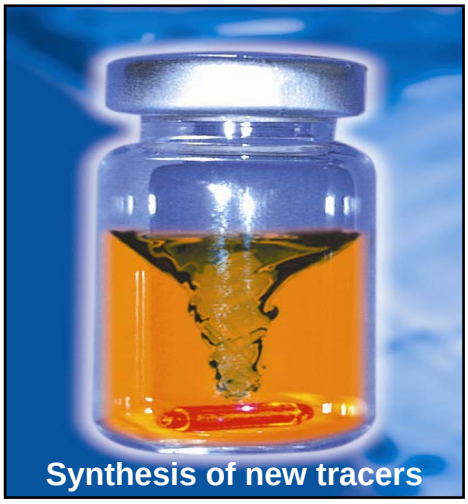
Some highlights for 2007 from Department for Reservoir and Exploration Technology

The tracer development program ResTrac

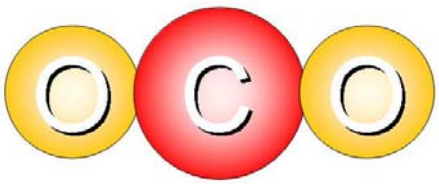
Towards the end of 2007 the 5 years tracer development program ResTrac (Reservoir Tracing), which has been a Joint Industry Program (JIP) sponsored by the petroleum industry, was completed. In this program we have worked with development of tracer technology in order to meet the demands in the petroleum industry for methods capable of monitoring and collection information of dynamic flow conditions in petroleum reservoirs. Understanding of the prevailing flow fields in a reservoir is decisive for developing optimum production strategies. There is a continuous need for more passive tracers for water and gas and tracers with phase partitioning properties with acceptable environmental behaviour for use in such examinations (well-to-well and single-well). In the ResTrac program we have developed new environmentally acceptable tracers, improved analytical methods and carried out field pilot studies of their behaviour in under various reservoir conditions. This kind of studies is mandatory for ensuring reliable tracer behaviour in field studies. The studies have been carried out in close cooperation with the oil companies Statoil, Hydro, Total, ConocoPhillips and Wintershall in a so-called Joint Industry Program (JIP). This cooperation has enabled easy access to field pilot studies.


Synthesis of new tracers

ResTrac is the 3th main phase in our ”Tracer Club” which was started in 1991, and has been preceded by the programs ITRC (IFE Tracer Research Co-operation1991-1996) and ADVISOR (Advanced IFE SOR tracing program, 1997-2002). A new phase in the Tracer Club called TracEOR is scheduled for the period 2008-2012.

CO_2 for improved oil recovery

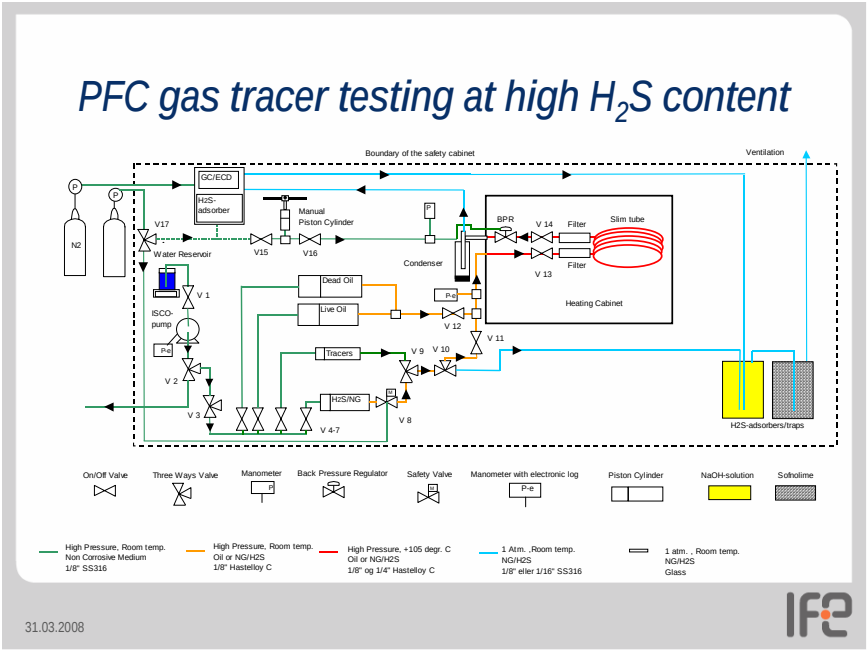
CO_2 has been applied in many field projects in order to increase oil recovery, especially in USA. So far, it has not been used on the Norwegian continental shelf. The reason for this is due both to reservoir-technical limitations and the fact that access to succicient supply of CO_2 so far has been to scarce. This may however change in the future, and development of improved technology is of interest. Under reservoir conditions CO_2 will normally have a considerably lower viscosity than the oil. This may lead to channelling of CO_2 through the reservoir, thus also to a limited sweep efficiency. Limited contact between CO_2 and the oil in place leads again to low recovery efficiency. An R&D project has investigated the possibilities of improving the volumetric sweep by chemical additions under CO_2-injection. So far, we have concentrated on performing laboratory investigations in order to create a scientific and technical basis for mathematical modelling of such systems. This again gives possibility to calculate improved recovery by simulations.



The project is carried out in co-operation with IRIS (International Research Institute of Stavanger) and is financially supported by the Research Council of Norway and the oil companies Shell, ConocoPhillips and Dong.

Tracers in reservoirs with high content of H_2S

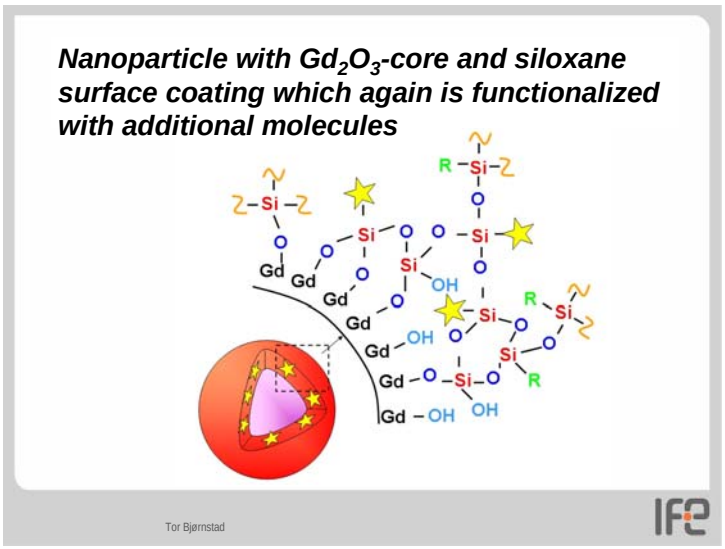
Some petroleum reservoirs, especially in the Middle East and the former Sovjet republics, have high concentration of the poisonous gas H_2S in the produced natural gas. Some of the reservoirs have, in addition, high temperature and exceptionally high pressure. These conditions create problems of different kinds (health, reservoir-technical,, environmental etc.) during operation. One of the problems related to improved reservoir description is: How do perfluorocarbon (PFC) gas tracers behave under such conditions? These tracers are today industry standards for tracing of gas movement in petroleum reservoirs under more normal conditions, but have not been tested in combination with high H_2S-concentrations in field experiments.



In order to study this problem in detail, dynamic (core-flooding) experiments have been carried out at simulated reservoir conditions with a maximum pressure at 600 bar and with a H_2S-concentration of > 20% in the natural gas. The dynamic behaviour for the PFCs was as expected and no degradation was detected. We have, in addition, developed an ultrasensitive analytical method for PFCs in natural gas with up to 50 % H_2S concentration in the natural gas. It is based on catalyst-assisted removal of H_2S from the gas sample before detection of the tracers with GC/ECD- or GC/MS-methods. Based on these laboratory examinations we therefore consider the mentioned PFC gas tracers ready for large-scale pilot tests in H_2S-containing reservoirs for final qualification.

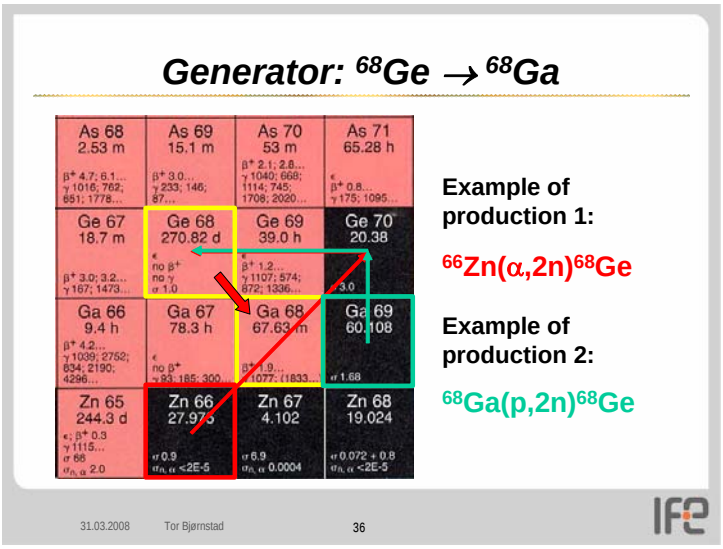
Functional tracers

IFE has started work on a new tracer concept which we call *functional tracers*. These are compounds with a built-in smart function, and are classified as so-called *active* (although not necessarily radioactive!) tracers. They may, for instance, react on natural external stimuli like change in temperature and pH or on purposely added stimuli like special ions, complexation agents etc. These compounds may be built as large molecules (dendrimers) or as nano-sized particles which have been specially functionalized on the particle surface. The main aim with this first development phase is to study their dynamic behaviour in porous simulated reservoir rock. The longer-term goal is to develop smart (functional) tracers for application in studies of reservoirs, near-well zones, well operations and process units with properties which, to a considerable degree can be tailor-made.



Radiotracer generators

Radioactive tracer semitting gamma radiation are useful tools in non-destructive examination of processes, for example during separation o foil, water and gas. In many cases, sampling is not needed. Gamma radiation may penetrate confining walls of steel, and detectors may be placed on the outer surface of the process vessel. It is, however, important that the applied radiotracers have a reasonably short half-life so that they will not constitute an additional waste problem after use because they will decay away automatically.



In order to make available short-lived radiotracers for industrial purposes, for example offshore, we may utilize the so-called radionuclide generators as a source of short-lived radiolabels. These are small “minifactories” which consist of a longlived mother radionuclide fixed on a solid support, for instance an ion exchanger column. The mother radionuclide will produce continuously short-lived daughter radionuclides. These daughter radionuclides can selectively be removed (eluted) from the column and transformed by chemical reactions into tracers for different purposes. In 2007 we started a Strategic Institute Program (SIP) for development of new industrial radiotracer generators. In this connection we participate in an international network organized by IAEA in Vienna where 15 laboratories in 15 different countries participate.

Field studies with tracers

IFE’s engagement in full-scale field tracer studies for national and international oil companies increases. Methods developed through our tracer R&D projects find application in field studies worldwide. Our last experience is studies in nthe world’s largest oil field, the Ghawar-field in Saudi Arabia. This oil field stretches over 3260 km^2 with estimated reserves on 11 billion Sm^2, which is, for example, 20 times larger than the Norwegial Statfjord field. Several water tracers were injected in a section of this reservoir towards the end of 2007 with the purpose of mapping the fluid connection between injector wells and production wells. Such experiments will provide useful information for optimalization of the pressure balance in the reservoir in order to improve the sweep efficiency and improve oil production. Saudi Arabia experiences at the time being a rapidly decreasing oil production in existing fields which have been under production for some time. Therefore, advanced technology is needed to remediate the described problem. Tracer technology is one such advanced, but still fairly simple, monitoring technique for this purpose.

Fig.:Tracer sampling

Tracer modelling

Tracers are widely used to increase the understanding of fluid flow in oil reservoirs, but are typically underexploited as a means to improve reservoir models and planning. To improve modelling and planning, the ensemble Kalman Filter (EnKF), where an ensemble of models are used to represent model uncertainty, has now been recognized as the most promising method for history matching. In the project, tracers are used for the first time to improve reservoir models using EnKF. In the project RELE collaborates with leading international experts on reservoir modelling at Texas A&M university and IRIS. A paper summarizing methodology development from the project has recently been accepted for presentation at SPE's main conference on improved oil recovery in Tulsa, USA in April, 2008 (read more in SPE-113440).