ALLOCATING COMMINGLED OIL PRODUCTION

Using a simple mixing model, a single geochemical difference between oils from two zones is sufficient to allocate commingled production from those two units (e.g., Kaufman et al., 1990). Using the concentrations (not ratios) of several compounds, the commingled production from several zones (or several fields) can be allocated to the discrete units using a linear algebra approach described in detail by McCaffrey et al., 1996, 2011, and 2012.

The primary applications of this technique to conventional oil and gas reservoirs are:

- Optimizing production from multilaterals
- Identifying sanded out Intervals for fill clean out (FCO)
- Identifying competition between laterals
- Monitoring effects of water or steam injectors
- Testing if IsoSleeves are set
- Controlling water production
- Monitoring effects of initiation of artificial lift
- Quantifying zone contributions for royalty calculations or regulatory requirements

Additional applications of this technique to unconventional reservoirs include:

- Determining if hydraulically-induced fractures have propagated out of the formation containing a lateral wellbore and into an overlying or underlying pay zone, causing the commingling of oil produced from different reservoirs.
- Identifying “cross-talk” between the induced fracture networks in wells completed in adjacent formations

In brief, production allocation is achieved by identifying chemical differences between "end-member" oils (samples of oil from each of the zones or production streams being commingled). Parameters reflecting these compositional differences are then measured in the end-member oils and in the commingled oil. The data are then used to mathematically express the composition of the commingled oil in terms of contributions from the respective end-member oils.

At OilTracers®, we use geochemical methods to solve two types of production allocation problems:

- Assessing the relative production from multiple pay zones in a given well
- Assessing the contribution of multiple fields to commingled pipeline production streams

Assessing the relative production from multiple pay zones in a given well

There are many advantages to using oil geochemistry (as opposed to production logging) to allocate commingled production.
• Cost advantages: Geochemical techniques for allocating commingled production from multiple zones in a single well typically result in a >95% cost savings relative to production logging (McCaffrey et al., 2006, 2011, 2012). Geochemical techniques cost $750 to $2,250 per well per allocation, while production logging usually costs >$60,000 per well. The greater cost of the production logging approach is due not only to the costs of running the log, but also to the associated rig costs, and the costs of lost production during logging. These costs are not applicable to our geochemical approach.

• Detection of zone performance problems at any point during the life of a well: The low cost of the geochemical techniques for production allocation allows field engineers to monitor production frequently over long periods (weekly, monthly, quarterly). This ability to monitor continuously the relative performance of discrete pay zones allows early identification of zone performance problems. The much higher cost of production logging limits that technique to infrequent use; therefore, production logs typically provide only a "snap shot" of the production origin at the time the log was run, and not a continuous performance history.

• Applicability to vertical, deviated and horizontal wells: Geochemical techniques are applicable not only to vertical wells, but also to highly deviated and horizontal wells. In contrast, production logging is problematic at high deviations, and especially difficult at deviations greater than about 70 degrees.

• Applicability to pumping wells: Geochemical techniques can be applied to all types of pumping wells (including those with tubing-deployed electrical submersible pumps, and progressive cavity pumps). In contrast, most pumping wells (except those with unusual completion styles, such as Y-block completions) cannot accommodate a production logging tool because the pumping apparatus prevents access of the logging tool to the underlying perforated interval.

• Ability to quantify uncertainty: Geochemical techniques provide multiple, independent solutions to the allocation problem, allowing one to quantify accurately the uncertainty of an allocation result. In contrast, the uncertainty associated with logging results is more difficult to quantify.

• Eliminate the risk of sticking a logging tool: Because the geochemical approach relies only on produced oil samples, there is no risk of sticking a tool in the well.

Assessing the contribution of multiple fields to commingled pipeline production streams

• Ability to allocate in the absence of flow meter data: Geochemical techniques can allocate commingled production at points in the production stream where flow meter data are unavailable.

• Ability to identify problems with flow meter data: Where flow meter data are available, geochemical data provide complementary information for allocating production, because geochemical techniques measure the relative contributions of oil (instead of water + oil) to a production stream. Since geochemical production allocation cannot be impacted by entrained water, the geochemical techniques provide an independent check on allocation data from flow meters.

Methods

Allocation of commingled oil: Methods for using oil compositional differences to allocate commingled production from two zones are detailed in Kaufman et al. (1987; 1990; 1997), McCaffrey et al.(1996), and Nicolle and Boibien (1997). Similar methods for allocating the contribution of multiple fields to commingled pipeline production streams are discussed by Hwang et al., (1999; 2000). These allocation techniques were refined further by OilTracers to allow allocation of commingled production from two to eight zones (McCaffrey et al., 2011, 2012). In brief, production allocation is achieved by identifying
chemical differences between "end-member" oils (samples of oil from each of the zones or production streams being commingled). Parameters reflecting these compositional differences are then measured in the end-member oils and in the commingled oil. The data are then used to mathematically express the composition of the commingled oil in terms of contributions from the respective end-member oils.

**Allocation of commingled gas:** Schoell et al. (1993) and McCaffrey et al (2011) describe techniques for allocating gas production. Gas allocation is conceptually similar to oil allocation; the techniques differ primarily in the types of geochemical parameters measured, as discussed here.

**Background**

The geochemical approach described here is based on the well-established proposition that oils from separate reservoirs tend to differ from one another in composition (e.g., Slentz, 1981; Kaufman et al., 1990; Hwang and Baskin, 1994; Hwang et al., 1994). Depending on the field, these compositional differences exist for one or more of the following reasons:

- Processes that affect oil composition after oil enters a reservoir (e.g., biodegradation, water washing, and evaporative fractionation) do not operate to exactly the same extent in separate compartments.
- Oil that a source rock generates at a given time differs slightly both from subsequently generated oil and previously generated oil due to continuous, subtle changes in the maturity of the source rock and changes in precisely which part of the source rock is in the oil window. Since no two compartments are of identical geometry, and since no two compartments have exactly the same filling history, it is difficult to achieve precisely the same homogenized composition in two separate compartments—even with oil from the same source.
- More than one source rock may contribute oil to an accumulation, and the oils from different sources differ in composition. Since oils from different source rocks have different times of generation and/or different migration paths, the presence of more than one source may cause different compartments to fill with different mixes of oil from the respective sources. For example, Prudhoe Bay oil is known to be a mixture of petroleum from three source rocks (Masterson et al., 1997 and 2001), and source variations are therefore a significant cause of the compositional differences in that field.

When oils from discrete zones are commingled, chemical differences between the oils can be used to assess the contribution of each zone or each field to the commingled production.

**OilUnmixer™ software**

OilTracers® geoscientists use a proprietary software package to allocate production. OilUnmixer™ software, part of the Weatherford ChromEdge® Suite, can process geochemical data and allocate production from 2 to 8 zones. The allocation process is based on a sophisticated version of the linear algebra method first published and later refined by McCaffrey et al. That publication showed how commingled production from several sands or fields can be allocated to discrete units using a linear algebra manipulation of the concentrations (not ratios) of several compounds (typically 150 to 250 compounds) in the end members and the commingled oils.

OilUnmixer software utilizes more advanced methods for:

- dealing with analytical uncertainty
- assessing the validity of end member (zone specific) calibration samples
- finding and mathematically removing contamination in end members or commingled oils
- testing the validity of the allocation results (in a graphical, easy to understand form)
OilUnmixer software has been subjected to blind tests by numerous petroleum companies. These blind tests use an outside laboratory to prepare artificial mixtures of multiple oils (with OilTracers having no advance knowledge of what the "answer" is). OilTracers experts use OilUnmixer software to determine the contribution of each oil to the mix. The blind tests consistently show the OilUnmixer solution typically yields allocation results that are within 1-5% of the actual result, even when the oils being commingled are extremely similar in composition (McCaffrey et al., 2011, 2012). Results of the OilUnmixer software blind tests are available.

This software is available for licensing from Weatherford Laboratories.

For more information on the techniques described here, or to discuss a specific project, e-mail us at oiltracers@weatherfordlabs.com, or call us at U.S. (214) 584-9169.

References


