Quantifying reservoir inflow contribution with RESMAN's Arrival Time model

The Arrival Time model

RESMAN employs two patented techniques to determine the inflow distribution any time the well is started up: the Flush Out model* and the Arrival Time model.

The Arrival Time model interprets the arrival of the concentration peaks of each tracer signature to determine the percent of inflow that occurs between tracer locations.

In contrast, the Flush Out model interprets the rate of decline of the tracer concentration profiles from each tracer location to determine the percent of reservoir inflow from each reservoir compartment.

The Arrival Time model applies when the reservoir interval provides sufficient distance between the sections being monitored, such as long horizontal wells.

How it works

In the Arrival Time model, RESMAN Intelligent Tracers are installed in purpose-built carriers that hold the tracer material against the inside wall of the production tubing (Fig. 1).

The Intelligent Tracers are designed to release molecules in controlled rates independent from flow conditions. This feature allows a small volume of oil with a high concentration of molecules (tracer shots) to form inside the tubing of each carrier during a shut-in period (Fig. 2).

When the well is started, initial production from the zone displaces the tracer shots to the surface in series (Fig. 3). Several samples of the production fluid are taken at the surface to capture the arrival of each tracer shot.

The samples are analyzed and the results are compared with software simulations to determine the inflow distribution. The volume between the arrival of each tracer peak is proportional to the inflow that occurs upstream of each tracer.

The software simulator uses an iterative technique that assumes a specific scenario of inflow distribution, simulates the arrival time of the tracer peaks, and compares the simulated results to the actual peak arrivals. After several iterations, the simulator converges on a solution that provides an inflow distribution that best fits the actual data.

Fig. 1 - RESMAN intelligent tracers are deployed in the well using purpose-built carriers.

Fig. 2 - During a shut-in, the intelligent tracers in each zone (zone 1 blue, zone 2 red) release their unique molecule signature into the fluids inside the tubing, creating tracer shots.
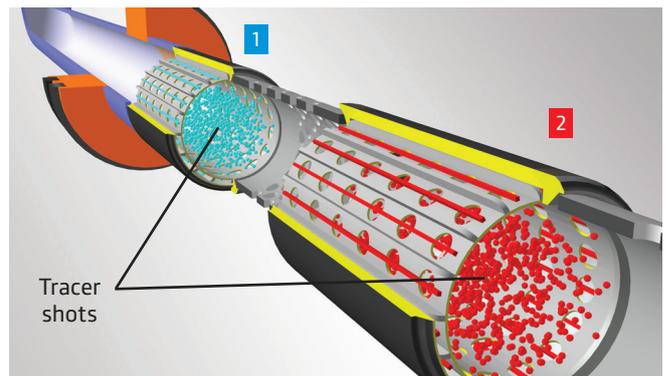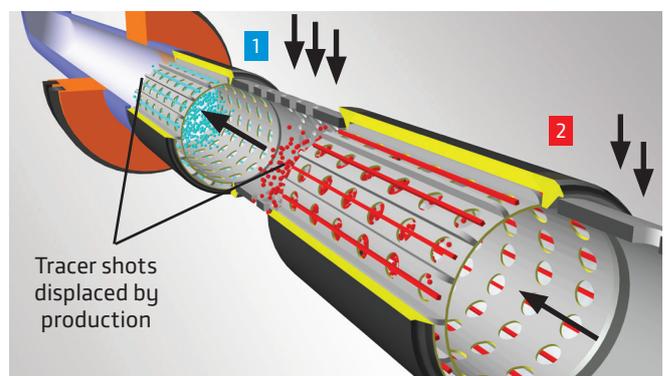
Tracer shots

Fig. 3 - Initial production from the zones displaces the tracer shots 1 and 2 to surface. The arrival time of each is dependent on the inflow upstream of each tracer location.

Tracer shots displaced by production

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In this two-zone example, the early arrival time of the blue tracer concentration peak (location 1, Fig. 4) and the separation between the red (location 2) and blue peaks indicate that significant inflow occurred between these two zones.

Arrival Time modeling of this data set revealed that the zone between tracer location 1 and 2 contributed 65% of the well's production and the zones upstream of tracer 2 contributed 35% of the total production.

Field proven

The Arrival Time model has been successfully applied in several projects with RESMAN Intelligent Tracer systems, providing operators with valuable understanding about zonal inflow performance.

The technique is comprehensively described in SPE paper 151241 (Interventionless Surveillance in a Multi-lateral Horizontal Well).

For more examples of field data, see the RESMAN case studies and papers at www.resman.no/knowledge.

Fig. 4 - Arrival Time model best simulation fit between predicted (dashed lines) and actual arrivals (peaks). The resulting inflow distribution for each zone is shown on the right.
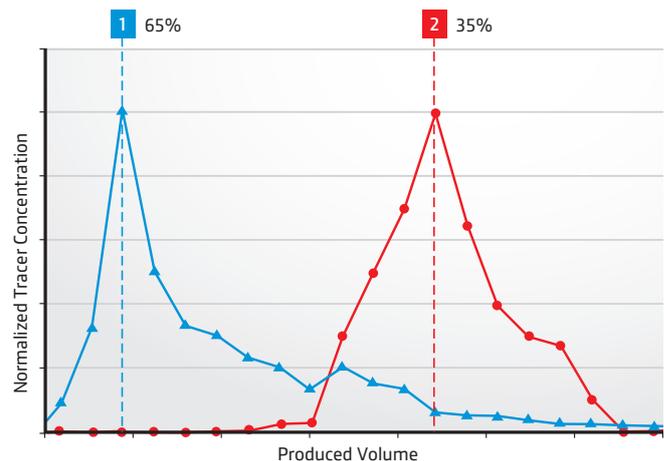
* Refer to Technical Bulletin 2 for more information about RESMAN's Flush Out model.