

CARBOTRACE

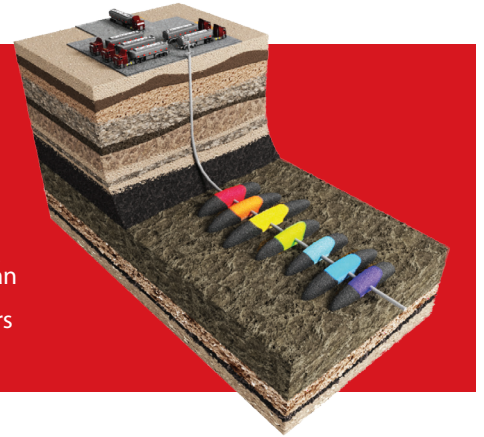
Proppant-conveyed production tracers

Features

- Economic production evaluation in multistage fractured wells
- On-demand unlimited production logging at any time
- Long-term oil, water and gas monitoring

Benefits

- Identification of producing and non-producing intervals
- Reservoir model and hydrocarbon reserves calibration
- Optimization of Field Development Plan
- Improved hydrocarbon recovery factors



Production surveillance integrated with CARBO quality proppants

Deployed with any type and size of proppant, CARBOTRACE offers a quantitative analysis of the fraction contribution of the oil, water and gas phases for each frac stage. With over 60 unique codes for each of the oil, gas and water phases. The analysis can produce a virtual PLT, at a fraction of the cost and, as often as desired by just collecting and analyzing production samples. A 3-year minimum standard surveillance period is offered. With a typical turnaround time of 1 week once the samples reach the analytical lab CARBOTRACE enables quick decision making based on reliable production data.

Production profiling—complete cycle

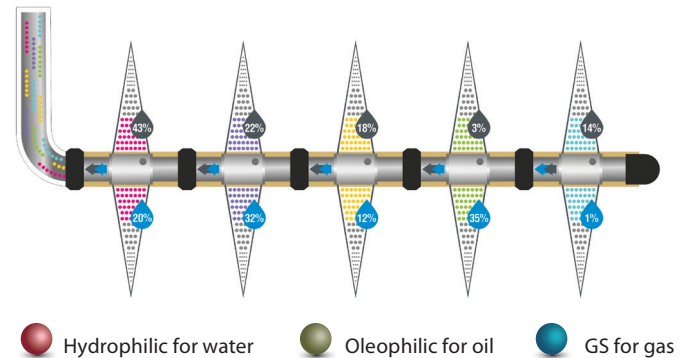
CARBOTRACE technology is based on the utilization of tracers and the implementation of machine-learning software for automated and accurate interpretation. The results provided from a CARBOTRACE evaluation are often used by the operator to manage current assets and plan for future assets.

Tracer is deployed with the fracture treatment

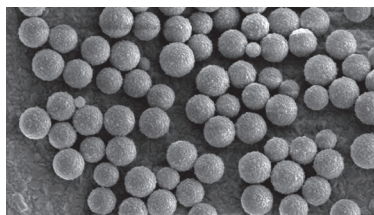
Three types of functional coating allow deploying unique tracers for oil, water and gas in over 60 individual frac stages. The tracer deployment design is tailored to the stimulation design and is typically pumped as a tail in stage deployed on the same proppant type for the main treatment. Any proppant type and size are possible.

Tracer synthesis

CARBOTRACE consists of nano-sized tracer particles, embedded into a functional coating applied to proppant. The patented coating provides both the tracer binding and release mechanisms from the proppant into the production flow stream. Coatings react differently when exposed to water, liquid hydrocarbon and gas enabling release into and tracing each phase individually.



Tracer excitation by laser



SEM microphotograph of marker-reporters

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Fluid sampling and transport

Liquid samples collected at surface are separated into water and hydrocarbon. Marker dots are extracted from the liquid hydrocarbon phase into a water solution using simple techniques while gas tracers are collected on a membrane. This eliminates the need to ship hydrocarbon flammable or pressurized samples, greatly simplifying transport logistics to a specialized lab for analysis.

Data reception and interpretation

The tracers emit a narrow spectrum that allows having more than 60 unique tracers per phase. The analysis is made applying flow cytometry and analytical chemistry to detect the various spectra and determine tracer counts. The use of machine learning and AI allow processing a large data package with a tunable accuracy in a short time period. The resulting answer product is a virtual PLT giving the quantitative contribution per phase for more than 60 frac stages individually.

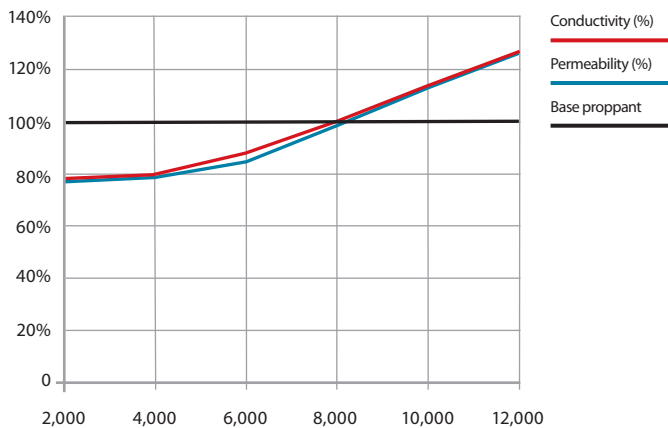
Physical properties

| | |
|---|---|
| Available sizes | As required |
| Substrate | Any CARBO ceramic or sand substrate |
| Available sizes | All sizes |
| Turbidity (NTU) | ≤ 250 |
| Temperature stability | 356° F |
| Roundness | > 0.8 |
| Sphericity | > 0.8 |
| Tracer release mechanism | Water, liquid hydrocarbon and gas activated membranes |
| Product fluid compatibility | Any frac or gravel pack fluid systems |
| Shelf-life (years) | ≥ 3 |
| Processed samples shipping requirements | Water solution / non-hazmat |
| BTEX | Free |
| PAH | Free |
| Storage conditions | Covered-exterior/warehouse |
| Answer product type | Quantitative (*) |

Long-term conductivity and permeability

The functional coating applied with CARBOTRACE has the added benefit of enhancing Long Term Conductivity (LTC) in medium to high stress environments. Conversely a slight reduction can be expected at lower stress.

CARBOTRACE vs. Base Proppant Conductivity and Permeability



CARBOTRACE LTC vs. LTC of the base substrate.
Net effect is proportional to CARBOTRACE fraction when used in blends.

CARBOTRACE application envelope

| | Oil | Water | Gas |
|------------------------|------------|------------|--------|
| Fluids | | | |
| Temperature Limit (°F) | 356 | 356 | 356 |
| Rate (min-max) | | | |
| BBL/Interval/Day | 3 - 11,000 | 3 - 11,000 | - |
| MMSCF/Interval/Day | - | - | 0 - 30 |

Talk to CARBO to find out how we can help you enhance your production.

carboceramics.com

CARBO

Production. Enhanced.