



FloShell™: Encapsulated Chemistries for Oil and Gas Production

Improving efficiency of new and existing wells

Value Proposition

Increased oil production

With deeper penetration of chemicals into the reservoir, more oil can be released from the rock and recovered, improving per well profitability.

More efficient and environmentally friendly use of chemicals

Oil field chemistries are not diluted or contaminated by bore hole or drilling mud fluids, requiring lower volumes of chemicals to be released into the environment.

Customizable drilling and chemical delivery programs

Encapsulation parameters can be customized to meet a specific reservoir need.

Technology applications

- Fracturing
- Enhanced Oil Recovery (EOR)
- Cementing
- Corrosion Control

The Problem

The oil and gas industry estimates that between 50% and 75% of oil and gas reserves are left behind or remain in reservoirs due to the ineffectiveness or cost prohibitive nature of current extraction technologies and processes. A relatively small increase in percent of oil extracted from the Bakken, Eagle Ford, or Permian formations could result in significant value for exploration and production (E&P) operations (for example, as much as a 1% increase in the Bakken corresponds to roughly 4 billion barrels of oil in 2016). Since drilling new wells is marginally economical in comparison to extracting more hydrocarbons from existing wells, operators are placing a greater emphasis on exploring methods to tap this valuable resource.

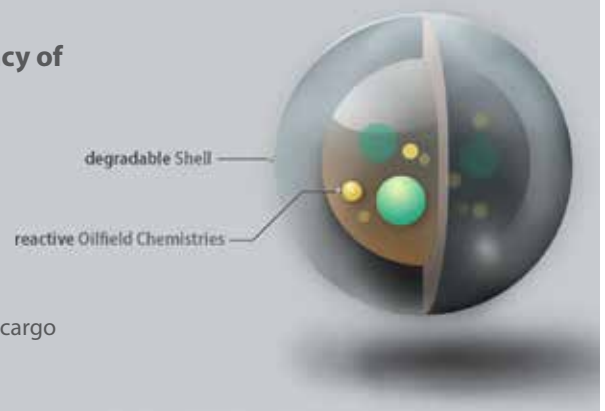
The Solution

RTI has developed FloShell™, a proprietary encapsulation technology platform that enables controlled, inside-out release of chemicals intended to improve oil and gas production and well profitability. Customizable nano- and micro-sized core-shell particles enable delivery of oil field chemistries with the ability to optimize for particle size, timing and mechanism of release and cargo load. Target application parameters will influence choice of cargo and shell chemistries.

RTI's FloShell™: Improving efficiency of new and existing wells

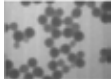

FloShell™ offers oil and gas producers:

- increased well production potential
- improved efficiency of chemical use
- customizable drilling programs
- deeper well penetration of encapsulated cargo



Core-Shell Particles for Engineered Delivery

RTI's nano- and micro-sized core-shell particles are optimized according to cargo volume, chemistry, desired delivery mechanism, and location for varying well conditions. Technical specifications will change based on cargo and shell chemistries due to variations in formulation compatibility. The following table includes a comparison of nano- and micro-particle sizes, coordinating chemistries, and advantages offered by each.

Particle Type	Size Range	Coordinating Chemistries	Advantages
Nano 	50-500nm	breakers, cross linkers, surfactants, emulsifiers, tracers (e.g. fluorescent dyes, other nanoparticles), bactericides	finer placement control targeted delivery deeper permeability into the reservoir
Micro 	500nm - 100µm	strong acids/acidizing agents, surfactants, lubricants, viscosifiers, tracers, scale inhibitors, corrosion inhibitors	higher cargo volume delivery higher core to shell ratio optimized for in or near-well bore

FloShell™: Delivery of encapsulated chemistry for downhole oil and gas applications

Well Conditions
Depth: 7,500 - 10,000 ft
Temperature: 40° F to 300° F
Pressure: 10 psi to 15,000 psi
Salinity: 60,000 PPM to 200,000 PPM

Zone 1: Cased Zone
 Corrosion inhibitors, fines control
Chemistries used in the cased zone may be used to protect metal drill string components and in-line filters.

Zone 2: Non-Perforated Zone
 Drilling lubricants, tracers
Chemistries used in the non-perforated zone may be used to protect drilling components or monitor progress.

Zone 3: Perforated Zone
 Acids, surfactants, polymers, catalysts
Chemistries used in the perforated zone are intended for reservoir management and EOR.

Notable FloShell™ Development Efforts

Encapsulated HCl

Strong (6M) hydrochloric acid was successfully encapsulated in polymer microparticles. The particles demonstrate delayed release versus conventional acidizing treatments for carbonate dissolution in 60°C and API Brine.¹

Chromium Crosslinker

Nanoscale particles containing chromium are deployed to delay polymer crosslinking mechanisms in waterflood applications for improved product placement and efficacy. Particles average 300nm in diameter and have been evaluated in up to 50°C in API Brine.^{2,3}

- Johnson, L. M., Shepherd, S. D., Rothrock, G. D., Cairns, A. J., & Al-Muntasher, G. A. (2016). Core/Shell Systems for Delayed Delivery of Concentrated Mineral Acid. *SPE Productions & Operations*, 32, doi:10.2118/173734-PA
- Johnson, L., Norton, C. A., Huffman, N. D., Mecham, J. B., & Rothrock, G. D. (2016). Nanocapsules for Controlled Release of Waterflood Agents for Improved Conformance. *Society of Petroleum Engineers*, doi:10.2118/181547-MS
- Johnson, L. M., Ledet, E., Huffman, N. D., Swarner, S. L., Shepherd, S. D., Durham, P. G., & Rothrock, G. D. (2015). Controlled degradation of disulfide-based epoxy thermosets for extreme environments. *The International Journal for the Science and Technology of Polymers*, 64(1), 84-92. doi:10.1016/j.polymer.2015.03.020

RTI International is an independent, nonprofit research institute dedicated to improving the human condition. Clients rely on us to answer questions that demand an objective and multidisciplinary approach—one that integrates expertise across the social and laboratory sciences, engineering, and international development. We believe in the promise of science, and we are inspired every day to deliver on that promise for the good of people, communities, and businesses around the world. For more information, visit www.rti.org.

RTI International is a registered trademark and a trade name of Research Triangle Institute.

For More Information

RTI is presently seeking co-development and partnership opportunities for FloShell™. Contact Ginger Rothrock at grothrock@rti.org or 919.541.6025 to learn more about our encapsulated chemistries for oil and gas production.