



TIORCO CAPABILITIES AND OVERVIEW

INTRODUCTION

TIORCO's corporate goal is to improve oil recovery and, as a result, to increase oil reserves and profit for our customers. The goal is met by applying a combination of engineering, technology, products, services, and equipment to an oil reservoir.

TIORCO's strength lies in the technology it provides operators for improved oil recovery. Our focus is on improving waterflood performance, which includes mobility processes and polymer gel systems. The objective of polymer gel injection is to reduce water channeling and force it to move through previously unswept areas.

Behind TIORCO's success is the ability to bring the right blend of four key ingredients to each IOR project:

Technology • Products • Service • Equipment

TIORCO TECHNOLOGY/PRODUCTS

Choosing the *right* technology and products for individual reservoirs and applying it at the *right* time is extremely important in maximizing oil recovery.

TIORCO's project engineers and field technicians bring to IOR projects extensive experience in improved oil recovery technologies gained from working with diverse reservoirs worldwide. This extensive experience is supported by proprietary software, reservoir modeling capabilities and in-house laboratory services.

Volumetric Sweep Improvement Using Flowing Gel Technology - UNIPERM[®]

Oil producing reservoirs contemplated for secondary recovery must be studied prior to waterflooding to characterize the rock properties and determine how efficiently the reservoir will flood. Many exhibit a non-uniform permeability contrast that results in rapid water breakthrough at the offset producing well(s), with resulting inefficient oil recovery. If a reservoir shows a Dykstra-Parsons factor greater than 0.55, has a fresh water (< 20,000 ppm TDS) injection supply source, and is relatively deep, then a long-term injection application of colloidal dispersion polymer gel should be considered early in the life of the waterflood.

The TIORCO UNIPERM[®] colloidal dispersion gel (CDG) is a flowing polyacrylamide gel formed after it enters the reservoir. These gels are formed from low concentration polymer augmented drive fluids, capable of entering matrix rock and flowing in-depth, while being adsorbed onto the rock surfaces. Thus, high permeability flow paths are physically altered to reduce permeability. Following treatment, the reservoir becomes more uniform to the drive fluid, and more low permeability oil bearing rock is contacted. Case history data indicates one may expect recovery improvements up to 10% of original-oil-in-place, with less water injected over a shorter flood life (Figure 1).

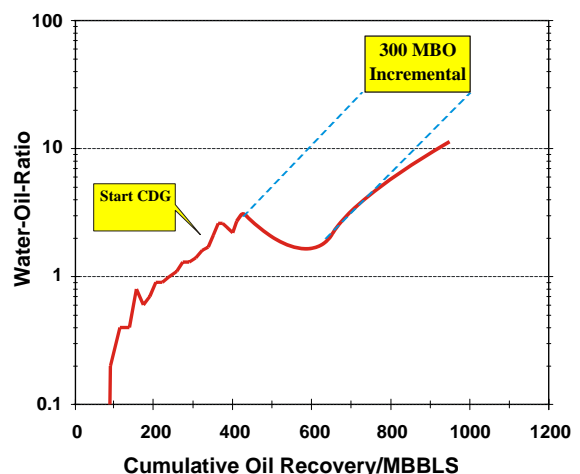


FIGURE 1. Impact on WOR of CDG project resulting in incremental oil.

Improved Oil Recovery



Additional technical literature describing this volumetric sweep improvement technology is found in:

- SPE 62610 - *Laboratory Studies of In-Depth Colloidal Dispersion Gel Technology for Daqing Oil Field*
- SPE 89460 - *Successful Field Pilot of In-Depth Colloidal Dispersion Gel (CDG) Technology in Daqing Oil Field*

Conformance Improvement and Water Shut-off Technologies - WATER-CUT[®]

TIORCO Water-Cut[®] represents the next generation of gelled polymer technology developed specifically for water shut-off in producing wells and redirection of drive water at injection wells. The gel formulations offer significant improvements over older first generation technology. First, the crosslinker is non-hazardous to field personnel; secondly, the gels are very robust, able to form under harsh reservoir conditions, including high H₂S, CO₂, TDS injection water, and high temperatures (<130C). Thirdly, polymer mixing and application in the field is straight forward and does not require tedious, complicated crosslinker chemistry.

If mature waterfloods exhibit recovery efficiencies less than 35% of original oil in place, channeling of drive fluids, high rate - low pressure injectors, or high water cut at producing wells, the TIORCO Water-Cut[®] technology may be the best approach to correct these problems (Figure 2). Natural waterdrive producing wells respond particularly well to this water shut-off technology; reducing water-cut and lowering fluid levels that enhance better oil inflow.

For a more thorough technical description of this technology, please refer to the following:

- SPE/DOE 27779 - *Applications and Results of Acrylamide-Polymer/Chromium (III) Carboxylate Gels*
- SPE 29475 - *Water Shutoff Through Fullbore Placement of Polymer Gel in Faulted and in Hydraulically Fractured Producers of the Prudhoe Bay Field*
- SPE 99379 - *Improving Volumetric Sweep Efficiency with Polymer Gels in the Cuyo Basin of Argentina*
- SPE 94096 - *The Kansas Arbuckle Formation: Performance Evaluation and Lessons Learned from More Than 200 Polymer-Gel Water-Shutoff Treatments*

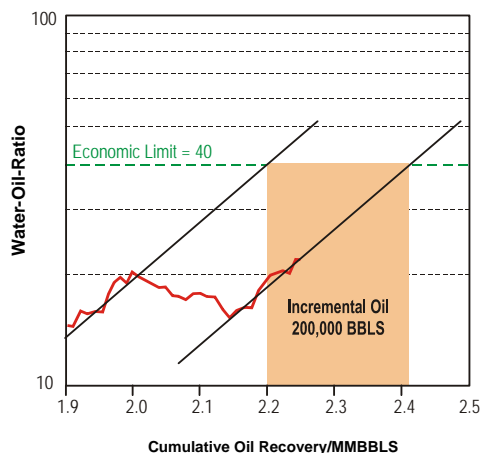


FIGURE 2 Effect on WOR of water-cut gels injected into injection wells.

Permanent Clay Stabilization at Injection Wells - TIOR-KOH[®]

Many low permeability sandstone reservoirs contain clays that swell and migrate upon flooding with fresh water. When this happens, injection of drive fluid is restricted and damage to the near well-bore area occurs. Thus, waterflood efficiency is greatly reduced and incremental oil recovery cost increases because oil production is directly proportional to the water injection rate. Manufacturing a synthetic brine for long-term injection is too costly, and cationic clay stabilization treatments are sacrificial - lasting only a short time before damage begins to occur.

The TIOR-KOH[®] process, however, reacts liquid potassium hydroxide with the near wellbore rock of the injection well to permanently stabilize the clays, rendering them immobile and non-swelling. In affect, the alkaline treatment has increased the injection well radius, and allows the fresh injection water to penetrate deeper into the reservoir where reduced velocity does not cause clay damage.

Additionally, imbibition chemicals added continuously to the injection water work synergistically to further enhance water penetration into the tightest oil bearing rock. TIORCO[®] 535 reduces the contact angle of injection water to the reservoir rock, thus permitting water to enter pore throats that are normally restricted to water intrusion. Thus, even more oil bearing rock is swept for improved recovery of incremental oil.

Case history data from treated and untreated injection wells in the same field attest to the exponential affect of increased water injection rates produced by the TIOR-KOH[®] process -



faster reservoir fill-up, re-establishment of reservoir pressure, and increased fluid production (Figure 3). The technical paper below further describes the TIOR-KOH[®] technology and process.

- SPE 12927 - *How To Stabilize Clays and Improve Injectivity*

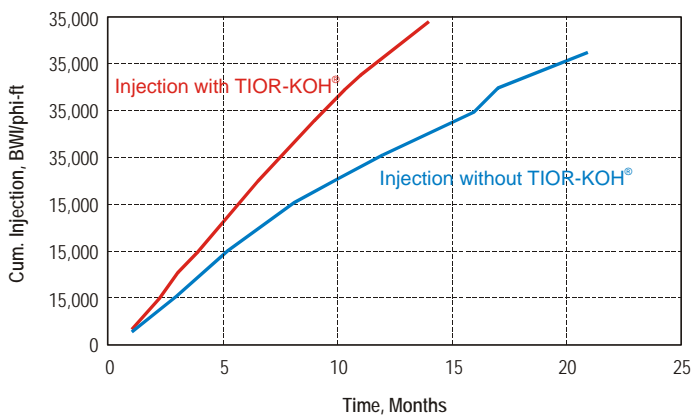


FIGURE 3. Effect of TIOR-KOH[®] on injectivity.

Mobility Control to Improve Waterflood Performance - HI-VIS[®]

While a uniform reservoir is expected to bank oil evenly over the pay zone, a poor mobility ratio between the drive fluid and the crude oil may create 'water fingering' and premature water breakthrough at the offset producers. If the crude oil shows a mobility ratio greater than 2, the injection water viscosity and flow characteristics should be modified to become more like the oil. TIORCO HI-VIS[®] technology utilizes high grade polyacrylamide at low concentrations under continuous injection to produce a bank of drive fluid that will stay 'behind' the oil. The volume of HI-VIS[®] is designed to produce a frontal drive zone to maximize recovery efficiency, while minimizing the chance of polymer breakthrough.

To determine applicability for the HI-VIS[®] technology, TIORCO engineers study the reservoir data provided by the customer and perform a laboratory crude oil analysis. Then, commercial and proprietary reservoir simulation models are run to determine projected recovery improvement and economic viability.

Alkaline-Surfactant-Polymer Residual Oil Recovery Technology - TIOR-CO₃[®]

Properly implemented and monitored, secondary recovery processes greatly improve oil recovery efficiencies, thus reducing the overall cost of produced reserves. However, in some oil bearing rock, even the best engineered oil recovery method will not mobilize all recoverable oil that is contacted by the drive fluid. The TIOR-CO₃[®] chemical augmented waterflood process releases residual oil saturated within the reservoir rock and allows it to be produced.

Many crude oils are reactive to alkaline and surfactant agents; that is, drive fluids augmented with either an alkaline or surfactant chemical, or both, will scour residual oil from the rock. If crude oil screenings indicate that the interfacial tension between the crude and reservoir rock can be reduced at least 100 times with an economical alkaline and/or surfactant drive fluid, then one may expect to increase ultimate recoveries 3 to 15 percent. The laboratory crude oil screening represents the first engineering step in determining ASP flood performance. If the crude is reactive, then the operator may continue the study with laboratory core flooding to help quantify the amount of residual oil liberated. A case history describing all facets of a typical ASP project is shown in the paper below.

- SPE 17801 - *Performance Data Through 1987 of the Isenhour Unit, Sublette County, Wyoming, Polymer-Augmented Alkaline Flood*

TIORCO SERVICE

Design of an IOR project starts with data collection. Laboratory analysis is used to determine the impact of the injection water chemistry and the best combination of chemicals. Designs are optimized using computer projections of waterflood performance and chemical flood performance (Figure 4 & 5).

Improved Oil Recovery



Once the EOR project is underway, ongoing surveillance and monitoring ensures the best and most cost effective use of improved oil recovery technologies. TIORCO works with field operators to monitor and perform feed system calibration, water sample collection, reservoir performance reviews, and problem solving.

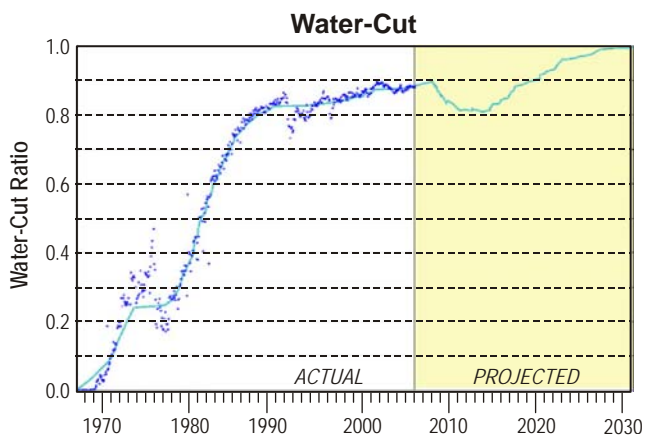


FIGURE 4. Poly-Sim™ projection of water-cut.

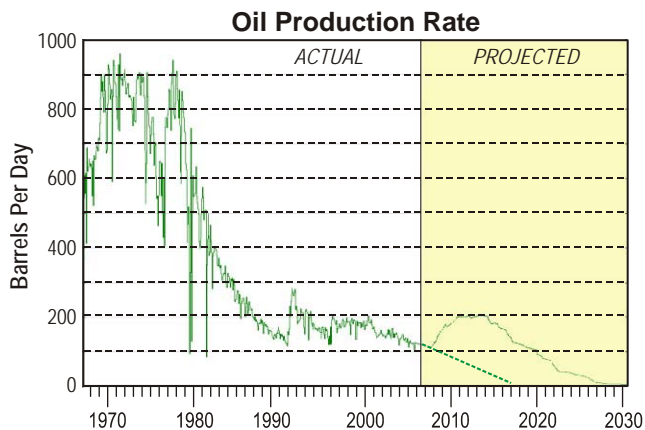


FIGURE 5. Poly-Sim™ projection of oil production rate.

TIORCO EQUIPMENT

To meet the rigorous demands of remote oil field installations, TIORCO designed and developed POL-E-DUC® process and metering systems. The rugged design, ease-of-use, and precise controls of the chemical feed systems are well suited to operating in demanding oil field conditions from the Siberian winter to the deserts of China's Heilongjiang Province.

On-site and portable units offer microprocessor-based control and electrical panels to provide complete integration and automatic control of all systems and plant functions. All process systems are integrated through design and electronic control to easily operate with minimal field staff. Manual override and operation of each process system are also provided.

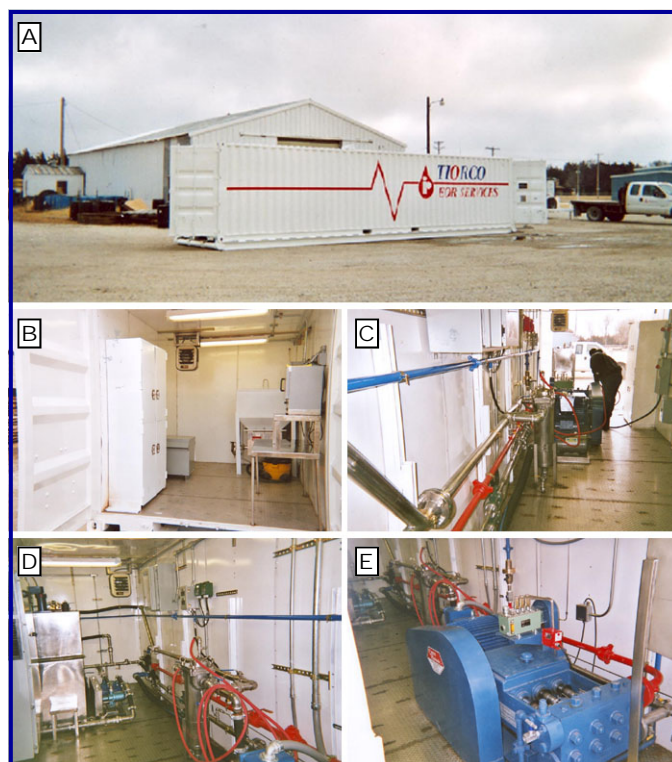


FIGURE 6. A) Portable chemical injection plant in a shipping container. B) Dry room storage and test oven. C) High pressure piping. D) Chemical feed system. E) Triplex pump.

Improved Oil Recovery



TIORCO's in-depth polymer processes rely on specially formulated, high quality, polyacrylamide chemicals to assure continuous movement into the reservoir matrix. Polymers manufactured and transported to the oil field in the dry form assure engineers of the necessary purity and also ease field handling, while reducing transportation cost and risk of shelf-life loss.

In order to process the dry polyacrylamide into a pure solution of the required concentration, automatic chemical process equipment is required at the waterflood plant location. The POL-E-DUC[®] polymer process and metering system was developed by TIORCO application engineers to perform reliably and to optimize chemical activation under the rigorous demands of remote oil field installations. These systems utilize the POL-E-DUC[®] Dispersion Device technology for instantaneous wetting of the dry polymer particle and accelerated dissolution. Furthermore, these automatic systems are physically designed to require minimum installation space, and are controlled by the most reliable microprocessor science available. POL-E-DUC[®] systems installed worldwide are operated continuously at unmanned locations with documented operating efficiencies nearing a 100 percent factor.

POL-E-DUC[®] process and feed systems are operated worldwide in many different polymer applications. These catalog sheets further describe the venerable POL-E-DUC[®] oil field polymer feed system and chemical process technology.

- POL-E-DUC[®] SERIES A: Dry Polymer and Chemical Dispersion Systems
- POL-E-DUC[®] SERIES AF: Automatic Polymer Preparation Systems
- THE POL-E-DUC[®] DISPERSION DEVICE: Development and Performance
- POL-E-DUC[®] TECHNOLOGY DESCRIPTION: Design Features and Benefits

THE TIORCO COMMITMENT

TIORCO is committed to continual improvement of our processes, products and people, and to the success of our clients. Behind that mission are six values we believe are critical to the success of our work and the achievement of the TIORCO mission:

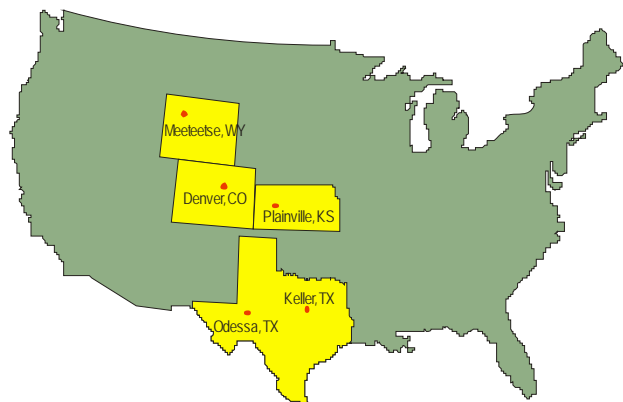
- Service to customers that exceeds expectations
- Productivity through clear vision, focused planning and peak performance
- Profitability enabling us to retain the highest quality people and deliver exceptional value
- Team relationships that ensure individual contribution
- Leadership in applied "IOR" technology
- Growth and Innovation to answer industry challenges

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Improved Oil Recovery



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