How the Technology Works

1 Samples are taken of oil reservoir fluids.

2 Microbes within the oil reservoir are studied and analyzed.

3 Highly specialized medical-grade nutrients are formulated and lab tested on specific species of microbes.

4 These highly specialized medical-grade nutrients are then injected into the reservoir for particular classes and species of microbes, stimulating only certain colonies of microbes.

5 Trillions of subterranean colonies of microbes which inhabit the rock face of the pore spaces, feed on the nutrients. Microbes are so small that 5 million can occupy the head of a pin. The nutrients create a dramatic response in the microbe colony.

6 The nutrients make the population of microbes multiply by approximately tens of thousands of times. Each individual microbe first grows larger then shrinks dramatically. During this process a physiological change occurs created by the nutrients which change the skin characteristics of the microbes that causes them to seek and attach to oil droplets—a condition known as oleophilic [oil loving].

7 The microbe is now inclined to have its skin next to an oily surface and therefore is attracted to the oil droplets trapped inside the pore spaces of the reservoir.

8 Trillions of microbes now bathe in and attach to the trillions of oil droplets that were “trapped” inside pore spaces.

9 The microbe activity agitates, separates from the rock face, and uniquely breaks up oil droplets into smaller micro-droplets which can pass through pore throats and be released into the reservoir’s mobile fluid system.

10 This oil is now for the first time recoverable by conventional means.

11 Some released oil that is still attached to the microbes travels through the oil formation towards the production well. This “attached” combination of oil, microbes and water as it travels through high-permeability sections of the oil field is agitated and rapidly mixed and forms under this stress a natural mild emulsion that blocks off these highly permeable sections of the oil field that have created thief zones and channeling. Because of thief zones most of the water eventually is channeled through the path of least resistance (thief zones) and does not sweep into other areas of the reservoir to contact oil. With the emulsions blocking off these thief zones, it forces the injection water to now flow into untapped areas of the reservoir and contact oil and move it through to the production wells.

12 As a result of this process: 1) Large amounts of trapped, normally unrecoverable oil within the pore spaces is released by the creation of micro-droplets. 2) Thief zones are blocked allowing for new areas of the reservoir oil to now be contacted by injected water and pushed towards the production well.

13 Microorganisms have their own propulsion system so they can get to places in the pore spaces where no other secondary recovery substance (water, vapor or a chemical agent) which depends on injection pressure from the surface can penetrate.

An Industry Milestone

Below, Microscopic photos show for the first time an oil droplet deforming and breaking up by the activity of microbes under the influence of the Titan Process.

In the following series of nine microscopic photographs the Titan Process can be seen at work, surrounding an oil droplet, distorting and breaking off a smaller droplet of oil. These droplets will again be broken down into even smaller micro-droplets.

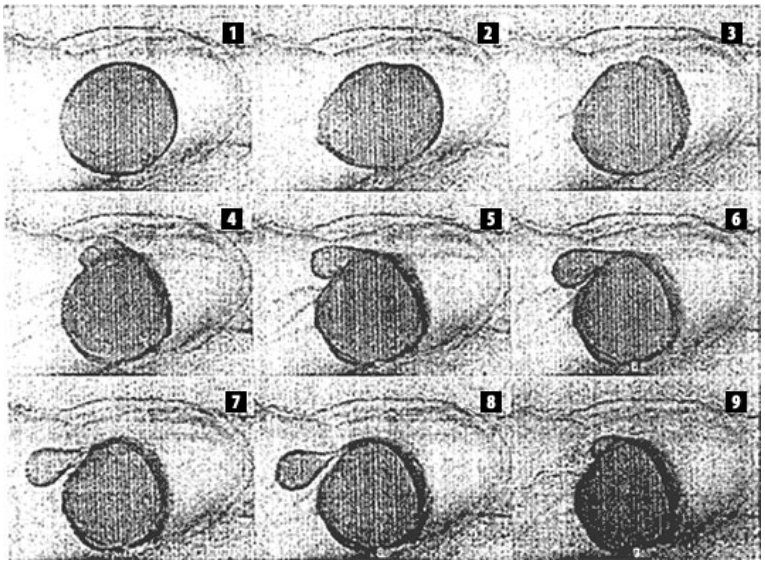

Photo 1: Titan Process microbes surround an oil droplet,

Photos 2 & 3: Oil droplet distorts due to microbial action.

Photos 4 through 8: A smaller droplet is formed by the microbes and released.

Photo 9: Another smaller droplet starts to form and break away by the action of the microbes. These newly formed smaller oil droplets have less resistance to capillary pressure within the pore spaces of the reservoir and thereby are more mobile and can more easily move through the pore throats and the pore matrix.

Technology Overview

- Biodegradable nutrients
- Relatively fast response time
- Requires no capital expense
- The Process works deep within the reservoir not just near the wellbore
- Micro-droplets are created
- Flow improvement
- Oil permeability increases
- Water permeability decreases
- Wettability changes
- Interfacial tension between the water and oil changes
- Apparent Viscosity Decreases
- Oil production increases

Titan Technology Description

The Titan Process is Organic Oil Recovery (OOR) and is a sub-set of the more general category of Enhanced Oil Recovery (EOR) techniques designed to mobilize oil in mature wells that is un-producible by conventional pumping. Other EOR methods include CO2 and steam-flooding as well as chemical treatments such as surfactant-polymer flooding.

Titan's OOR represents an advance on previous microbial approaches: first, for its un-matched and thoroughly documented success in increasing rates of production in suitable wells and, second, because it operates using microbes that are already present in (not artificially introduced to) the subject oil reservoirs.

Applied through existing water-flood operations, Titan's new process works entirely within the natural ecology of the oil reservoir by selectively stimulating particular species of the formation's resident microbes with custom formulated, biodegradable and organic nutrients. The targeted microbes proliferate as a result of these specialized nutrients and interact with immobile, trapped oil, affecting the surface tension and reducing the globules to microscopic droplets (micro-droplets) and altering the interfacial tension between oil and water to allow oil to flow more freely through the reservoir to the producing wells.

Titan's OOR has generated significant increases in the rate of production in 98% of injector applications on fields. Further, Titan's OOR has never reduced production or in any way damaged a reservoir or a well.

Flow Improvement

Fluid flow within oil reservoirs under reservoir conditions is generally governed by Darcy's Law of radial flow in porous media. Any improvement in flow characteristics must positively impact at least some of the components of this flow equation. The Titan Process releases oil and changes the relative concentration of oil and water within the pore space of the rock formation. In turn, the new fluid saturations—both oil and water—affect the ability of the fluids to flow as a result of changes in relative permeability (flow capacity of the rock), wettability (the attraction of the fluids to the rock surface), and the interfacial tension between oil and water (fluid-to-fluid interaction forces) and capillarity (a fluid force resisting flow).

The "oil-release" mechanism results from biological changes in the naturally occurring microbes as a result of increased availability of Titan nutrient materials. Nutrient availability acts like a biological "catalyst" that causes the microbial population to grow rapidly and proceed through its natural life cycle in an accelerated way. As the life cycle proceeds, there are more changes to the microbial species and this allows the microbes and by-products of the life cycle to interact with the trapped oil.

This interaction creates something akin to a physical (rather than chemical) "lubrication" allowing the oil to flow more freely. All of this interaction occurs at the micro-level within the oil reservoir. The process does not introduce microbes cultured and grown at the surface. The oil reservoir becomes a natural bio-reactor to create the quantity of organisms necessary to cause the oil to be released.

The process is biologically complex but elegantly simple in application. There is no attempt to genetically modify the natural microbes. The process is an acceleration and concentration of natural processes already occurring within the oil reservoir.

From the application of the Titan Process on 48 oil fields on 4 continents and after over 300 well applications, production at the targeted project wells have increases by 92%. These increases have lasted from 30 days to three years from a single Titan Process application. Increases in ultimate recovery of the original-oil-in-place by 10-20% is possible over longer periods of time.

A New Direction in Microbial Enhanced Oil Recovery

The Titan Process® injects nutrients into a reservoir and induces certain targeted microbes to become oleophilic [oil loving] and attach themselves to oil droplets. The microbes then dislodge and uniquely break down the trapped oil within the pore spaces into smaller droplets which can be recovered more efficiently. This oleophilic activity is an entirely new direction in the field of microbial enhanced oil recovery (MEOR). This process is simple, efficient, inexpensive and 100% environmentally friendly.

The Titan Process uses indigenous microbes that have already adapted to their environment over millions of years. The Titan Process does not inject microbes into oil fields and only uses resident microbes. Problems and complex solutions to aid in the survival of injected microbes to deal with reservoir pressure, saline content and temperature are therefore not encountered.

With the Titan Process microbes are able to multiply by thousands of times on specialized nutrients, and their small size helps them penetrate deep into the formation where they act to break up and mobilize previously trapped oil droplets, which have been left behind by both Secondary and Tertiary recovery methods because the oil droplets were 1) too large to pass through the pore throats (tiny openings in the sand/rock formation) of the reservoir, or 2) never contacted by the recovery method in the first place.

Ultimate Reservoir Performance

The Titan Process stimulates naturally occurring microbes within the oil reservoir in two ways, both of which increase oil production. First they dislodge and then uniquely break up droplets from the pore spaces within the rock matrix, which then become recoverable. Second, they also create a unique natural emulsion within high permeability thief zones (channels that divert water from pushing oil toward a production well). The mild emulsion blocks thief zones and allows for a more efficient waterflood.

The process is all natural, no harsh chemicals are used and there are no adverse effects in the reservoir. A single well test can be easily implemented to gain important performance predictability for an entire field.

The Titan Process® causes specific effects in a reservoir to increase the efficiency and performance of the waterflood to move oil towards the producing wells. It is a dynamic technology that solves many reservoir management problems.

- Poor injection efficiency
- Trapped oil
- Premature breakthrough
- Poor injection profiles (channels, fractures and thief zones)
- Poor sweep efficiency
- Poor pattern recovery

Waterflood recovery performance depends on many technical factors. The Titan Process has a positive effect on some of the more important elements that aid in well and reservoir performance. Important elements to a successful waterflood, such as areal (outward) sweep efficiency, vertical sweep efficiency and displacement sweep efficiency all can be improved by the application of the Titan Process.

The Titan Process supplies nutrients to specific colonies of microbes within the biomass of the reservoir. The microbes' skin surface characteristics are changed by the nutrient protocol of the Titan Process. This process, when applied through an existing waterflood project, will re-profile the reservoir. Three distinct changes take place that enhance areal and vertical sweep efficiency and displacement efficiency:

- Oil droplets are dislodged from pore spaces;
- Oil droplets uniquely become smaller;
- A natural emulsion blocks thief zones.

The Titan Process mobilizes incremental and “un-recoverable” oil. The purpose is not to just increase short term production rates but to greatly increase the long term efficiency of the field. The Titan Process helps eliminate high water production ratios, lowering both lifting and water disposal costs, but the ultimate advantage is an increase in oil production.

Waterflood Improvements

Areal Sweep Efficiency
The area that the water will contact in the reservoir and the flow properties of the oil and water as well as pattern and pressure distribution are aided by the Titan Process. This is due to the dislodging of trapped oil droplets from within the pore spaces that in combination with some of the microbes and water creates a natural emulsion that blocks thief zones, and aids in the redistribution of the water flow and hence the flood efficiency.

Displacement Efficiency
This relates to the amount of oil which water will displace in the invaded zone. By dislodging oil droplets from the rock face within pore spaces and the subsequent distortion of the oil droplets by the microbes into smaller droplets, the tendency is for the smaller droplets to more easily overcome the capillary pressure that is trapping the oil. Also because of the energy being released by microbes and their activity, fluid motion is created within the pore matrix. The oil droplet is now surrounded by microbes. The microbes’ skin, because of the Titan Process, becomes oleophilic (oil-loving) and shrinks and is now wrinkled and unsmooth, creating a dramatically increased surface area allowing for improved interfacial contact. This much larger wrinkled surface allows for less fluid force or pressure to be needed to move the oil droplet. An example would be a very smooth-surfaced round rock on the bottom of a stream. It would be slowly pushed downstream, but a similar rock with a very rough surface would be pushed more easily by the increased friction of the water flow against its surface. Smaller oil droplets surrounded by microbes can now flow more easily through the pore spaces and pore throats of the strata towards the well bore, thus the displacement sweep efficiency is increased.

Vertical Sweep Efficiency
The percent of a formation on a vertical plane that water will contact depends primarily on the degree of reservoir stratification. Composition, porosity and permeability of the strata will all effect vertical sweep efficiency. The important factor is that major problems can be caused by the injection water seeking zones of higher permeability.

Thin, high permeability channels in stratified reservoirs can prevent efficient flooding of other zones. This results in lower oil production and increased water production. The natural emulsions produced by the Titan Process reduce high water injection concentrations within these small zones or intervals (thief zones). This is caused by the combination of the energized microbes, oil and water joining to form a viscous emulsion, allowing for new flood direction and sweep efficiency.

Summary
Besides the creation of micro droplets that can escape the pore spaces in the reservoir, the Titan Process can significantly improve the management of waterflood operations by allowing for increased multi-well pattern communication from injection to producing wells. Injection efficiency is greatly enhanced by the microbial actions. Thin, high permeability channels in stratified reservoirs also are less likely to affect flooding efficiencies as they will be subject to the natural emulsion tendencies created by the Titan Process.

By increasing the fluid penetration and vertical and areal sweep efficiency, the Titan Process allows greater access to the remaining oil-in-place. An important action of the microbes is that by surrounding the oil droplet they reduce the tension (interfacial tension) of oil droplets to the rock face, thereby allowing for the oil droplet to be easily dislodged allowing for increased recovery.

Water being pushed through the reservoir relies on its force of movement from afar (the injection well pressure). Microbes in contact with this water volume have their own propulsion system (a small flagella) that can allow them to also move into adjacent areas where immobile water is present. Thus they can migrate where water "flow" is not present.

As injection water is eventually diverted into these "no flow" or unswept areas of the reservoir due to the blocking of thief zones, water flow into these new areas will increase. This enables the recovery of newly contacted oil as well as newly dislodged oil droplets from these pore spaces, since the microbes to some extent will have already been active in this area through their migration under their own power.

The gentle emulsions blocking the thief zones are not permanent and cannot damage the reservoir because the microbes are smaller in size than normal, and the new nature of their skin (oily) keeps them apart. Also, if the nutrient source is stopped, the reservoir will return to its original state.

The Titan Process is environmentally friendly as there is no change in the chemical or physical properties of the reservoir fluids. The Titan nutrients are biodegradable. No harsh chemicals are used in the Titan Process, and H2S levels usually decrease as the friendly Titan microbe's crowd out the sulfate reducing bacteria. Microbes stimulated by the Titan Process reduce the activity of sulfate reducing bacteria.

Controllable and Consistent:

- Preferentially targets mature water floods
- Uses specific microbes that are resident in the reservoir
- Batch treats with specifically selected nutrients
- Manages microbial ecology of the reservoir
- Promotes oil interactive microbes
- Impacts at the oil-water interface
- Not just accelerated production rate, true additional reserves and new value creation

Reservoir Characteristics and Microbes

According to the "Handbook of Physical Quantities" by Grigoriev & Meilikous, there are 10 billion grains of fine sand in a cubic foot. In between all these grains are spaces (pore spaces). In sandstones, a cubic foot of fine sand contains over 10 billion pore spaces. In an oil reservoir there are oil and water molecules occupying and trapped in these pore spaces.

Relating this to the Titan Process, the microbes that will be used in the reservoirs are about 1800 times as small as a fine sand grain. That's the same ratio of a golf ball to an office building 190 feet tall. Because of their size and propulsion system, the microbes can penetrate the pore spaces and smaller pore throats of the oil-bearing rock and attach to the oil trapped within the pore spaces.

Efficient, Low Cost Recovery

It is now possible that an oil field that has produced 40% of its known resource over a period of time (and is now considered almost depleted) could, with the Titan Process, continue for many years and economically extract significant amounts of the original oil in place.

The eventual failure of secondary oil production procedures to release trapped residual oil results from capillary forces in the oil/water/rock system and the failure of injected fluids to penetrate parts of the reservoir formation. **The Titan Process changes this equation.**

The Titan Process versus Other Enhanced Recovery Methods

The Titan Process is superior to the use of surfactants. Surfactants are used to lower the interfacial tension between reservoir fluids and residual oil so that some oil which was not able to be removed by the injected fluids can now be displaced. Surfactants used in chemical EOR (enhanced oil recovery) show optimal activity over a narrow range of temperature, salinities and rock types. Therefore they are limited in application and are significantly more expensive and complex than the Titan Process.

CO_2 flooding has had success as a tertiary recovery method. Its drawbacks are that it is capital intensive and a CO_2 source and pipeline is required with extensive surface equipment. CO_2 floods are more expensive to operate than the Titan Process.

Polymers have had some success in enhanced recovery but are acknowledged as a high-cost solution. Polymers can also cause reservoir damage.