



RAM BIOCHEMICALS, INCORPORATED

Enhanced Oil Recovery Technology and Methods

Enhanced Oil Recovery processes (EOR) use chemical or thermal energy to recover additional oil from petroleum reservoirs beyond what is economically recoverable by conventional primary and secondary recovery methods.

1.0 EOR Methods: Chemical Flooding, Miscible Flooding, Thermal Recovery

Primary and secondary production recovery methods combined can produce only about 40% of the original in-place oil. Consequently, the importance of tertiary recovery technology and methods can not be over emphasized. For this reason there is renewed worldwide interest in the use of microorganisms and their metabolic products to increase oil production. These recovery processes, known originally as MEOR (Microbial Enhanced Oil Recovery) have more recently been termed Microbial Increased Oil Recovery (MIOR).

2.0 MEOR / MIOR Methods

MEOR / MIOR technology and processes are not new! Both microorganisms and microbially derived products (bioproducts such as surfactants, polymers, and acids) have been used for over 40 years in a variety of approaches to recover oil from individual wells or entire reservoirs.

Injection of microorganisms, nutrient, or microbial bioproducts can take place one well at a time – the *cyclic injection method* (also called the “bio-huff and puff” method), or it can take place in conjunction with a water flood project – the *field flood method*. Wel-Prep 5™ treatments are adaptable to either cyclic injection (bio-huff & puff) or field flooding.

These two approaches are implemented by various methods which include:

- 1) production of various bioproducts in large-scale fermenters and injection of these products into individual wells or entire fields;
- 2) continuous injections of selected bacterial cultures into single wells or entire fields;
- 3) continuous injection of selected bacterial cultures and nutrient into single wells or entire fields;
- 4) one-time inoculation with selected bacterial cultures followed by injection of nutrients;
- 5) one-time inoculation followed by repeated cycles of nutrient injection with an incubation (shut-in) period, and;
- 6) *in situ* stimulation of indigenous microorganisms beneficial to oil recovery by injection of biocatalytic agents and micronutrients.

Wel-Prep 5™ treatments utilize the method described in item #6 above for both cyclic injection and field flood applications.

There are constraints associated with MEOR / MIOR just as with EOR, but a unique feature of MEOR is the use of living, self-replicating organisms to produce a variety of products beneficial to increased oil production. MEOR/MIOR holds the promise of a superior and more cost effective process for recovery of heretofore unrecoverable residual reservoir oil.

3.0 WEL-PREP 5™

Wel-Prep 5™ Oil Recovery Fluid is a proprietary formulation of micro-nutrients and naturally derived biocatalysts suspended in a water-soluble protein digest extract broth. It is designed to promote and stimulate the growth beneficial indigenous micro-organisms and thereby increase their production of biosurfactants and gases. These bioproducts, in turn, release oil from the oil-bearing formation without causing production problems such as plugging, sour gas, and corrosion.

As a result of treatments with Wel Prep 5™, the indigenous microorganisms are enzymatically stimulated to produce biosurfactants, emulsifiers, and gasses at the oil/water and carbon to rock interfaces. These bio-products are produced continuously, sometimes in excess of 30 days, by the activity Wel-Prep 5™ elicits from the beneficial down-hole microbial populations.

Wel-Prep 5™ treatments do not require the injection of large volumes of additional nutrients as do the more conventional MEOR treatments which often utilize CO₂ producing bacteria. Wel-Prep 5™ should always be used at controlled levels and should ONLY be mixed with COMPATIBLE chemicals. Our treatment fluids are not compatible with strong acidizing or caustic chemicals and should not be used with them in a multi-chemical treatment. However, a Wel-Prep 5™ treatment regimen can follow acidizing or caustic treatments when functionality testing determines that proper down hole conditions exist.

Wel-Prep 5™ treatments are compatible with granite, chalk and sandstone oil bearing strata at temperatures to 180° F. Field trials have demonstrated; improvements in oil viscosity, partial repressurization at the well head, reduction in paraffin accumulation on rods, reduction in carbon and iron sulfide plugging in lead lines. Increases in oil production of 30 percent and more are documented. By oil industry estimates, many oil fields still contain up to 70% of their original oil. Wel-Prep 5™ was formulated to maximize production of these untapped reservoirs in a cost effective and environmentally safe manner. Wel-Prep 5™ may prove useful in shale oil and tar sand oil recovery. Research in these areas is on going.

3.1 MODE OF ACTION – Cyclic Injection or Field Flooding

Wel-Prep 5™ is introduced into the well bore and flushed as far back into the oil producing formation as possible. This treatment is intended to cause a long-lasting reduction of interfacial surface tension at the carbon and liquid to rock interfaces. Wel-Prep 5™ treatments can help establish a down-hole microbial condition advantageous for oil production.

Wel-Prep 5TM treatments can also cause an increase in hydrocarbon gas production, which provides a drive mechanism for oil recovery. Well head oil saturates with hydrocarbon gas and is both lowered in viscosity and more easily separated from the co-produced brine.

3.2 WEL-PREP 5TM vs. OTHER EOR & MEOR PRODUCTS

A major advantage Wel-Prep 5TM treatments have over conventional EOR and MEOR treatments is the volume (level) of treating fluid needed. Wel-Prep 5TM treatment levels are measured in gallons not barrels. This is possible because of the apparent bio-catalytic effect Wel-Prep has on the natural metabolic processes of beneficial microbial populations which are stimulated to produce biochemicals which, in turn, enhances oil recovery. The need for injecting large volumes of nutrient medium is eliminated. Wel-Prep 5TM has a significant advantage over microbial systems that utilize CO₂ producing organisms exclusively, because these systems require continual injections of large amounts of sugar or other carbohydrates. Additionally, carbon dioxide lowers the sales value of any co-produced hydrocarbon gas and must often be removed from saturated oil by a gas/liquid separator.

Field trials have demonstrated that approximately 70% of selected candidate wells respond to the initial treatment of Wel-Prep 5TM. However, the response time and retreatment intervals vary from well to well and from field to field. Down-hole differences in porosity, permeability, fluid properties of the reservoir, interfacial tension, and make-up of the indigenous microbial population would account for these differences. The oil producer is in the best position to monitor Wel-Prep 5TM treatments and match treatment levels and retreatment intervals to individual well and/or field conditions. RAM Biochemicals, Inc. provides testing and technical support for application of its products and will work with producers to design field flood programs.

In general, a single Wel-Prep 5TM treatment will last 20 to 30 days or longer. Incremental oil and/or gas increases are typically noted within five to ten days after turning the well back into production and following the recovery of flush production. A second treatment may be required to stimulate down-hole microbial activity when the well fails to respond to its initial treatment. RAM Biochemicals utilized a 'shot gun' approach to treating individual candidate wells, and recommends suspending wells from the treatment program if they are non-responsive after two consecutive treatments.

4.0 DOWN-HOLE TEMPERATURE & SHUT-IN TIMES

Indigenous down-hole microorganisms are a mixture of mesophilic and facultative thermophilic bacteria. This means they are capable of surviving in a temperature range from 10° to 85° C (50° to 185° F). However, there is a big difference between "survival" and optimum growth rate. Many bacteria are known to survive at temperatures to 100° C and higher, but at these temperatures their life functions take place in a diminished capacity. Optimum growth generally takes place between 25° and 50° C (80 to 120° F). It is extremely important to know the down-hole temperature of a potential candidate well because temperature is the single most important factor in a successful MEOR treatment with Wel-Prep.

Down-hole temperatures also help determine shut-in times following initial treatment. The lower the temperature the longer the shut-in time required, the higher the temperature the shorter the shut-in. Because formation temperature is in direct proportion to depth, the effective cut off or the depth below which treatments will likely be ineffective is approximately 9,000 feet.

5.0 THE ECONOMICS OF EOR & MEOR

Traditional EOR and most MEOR treatment processes are costly in relation to the additional barrels of oil they recover. They range from \$10 to \$46 per barrel of oil produced with injection costs accounting for \$3 to \$35 of per barrel costs.⁶ Please notice we are not speaking about incremental oil, the amount of oil produced which falls above a calculated decline curve, but real or actual production over and above the average for the previous 12 month period.

These cost figures hold true for all EOR and MEOR processes except those MEOR processes using in situ methods without large amounts of injected nutrients. Wel-Prep 5TM treatments do not require continuous or periodic injection of large amounts of carbohydrate nutrients. Instead, Wel-Prep 5TM treatments utilize and stimulate microorganisms that can assimilate hydrocarbon nutrients in situ - in the reservoir. This eliminates the need for injecting molasses or other carbohydrate nutrients, the most commonly used MEOR approach.

Wel-Prep 5TM stripper well treatments by cyclic injection range in cost from \$0.90 to approximately \$10.00 per additional barrel of oil produced.⁷

6.0 TAX CONSIDERATIONS

Qualified tertiary oil recovery projects receive special tax considerations at the County, State and Federal level. These include; 1) County Ad Valorem Taxes, 2) State Severance Taxes (BOD allowable per well), 3) Federal Excise Taxes, and 4) Federal Itemized Deductions for Tertiary Injectant Expenses.

These tax savings should not be overlooked as a means of cutting expenses. They offer the operator significant advantages and in Kansas, for example, can amount to a \$1,500 to \$1,700 yearly savings per well on the State Severance Tax alone.