DOWNHOLE TECHNOLOGY

WORKS TO MAXIMIZE RESERVOIR RECOVERY FACTOR

by Maurice Dusseault

Energy diversity is a worthy goal, but viable alternatives to fossil fuels are not yet available on a large, commercial scale. Also, a serious dilemma looms: world production is approaching a critical juncture where many once-prolific oil fields are reaching maturity; production rates from these fields are in steady decline. Large new field discoveries are now rare, or they are found in difficult conditions (Arctic, deep offshore), so maximizing oil recovery is paramount.

Surprisingly, even after many stages of production, up to 60 percent of all oil remains stranded in depleted reservoirs, locked in the porous rock that contains it. Producing this oil seems straightforward, but producers actually face numerous technical and economic challenges in mobilizing the stranded oil. Thus, technologies that can easily mobilize stranded oil in depleted reservoirs and increase the overall recovery factor (enhanced oil recovery methods, or EOR) are widely sought.

Wavefront Energy and Environmental Services Inc. of Edmonton, Alberta, believes it holds a significant key to the global challenge of maximizing recovery factors. More efficient than traditional flooding methods, Wavefront's Powerwave-driven flooding process unlocks stranded oil from the porous rock that holds it, and has the potential to increase recovery factors by 10 percent or more. The fluid pressure pulse created by Powerwave breathes new life into existing, shut-in, or abandoned fields, and may eventually add billions of barrels of oil to the world's recoverable reserves.

How does Powerwave work to gain such large returns with a fluid pressure pulse?

Perhaps the best natural example of the Powerwave process is your heart. Your heartbeat generates

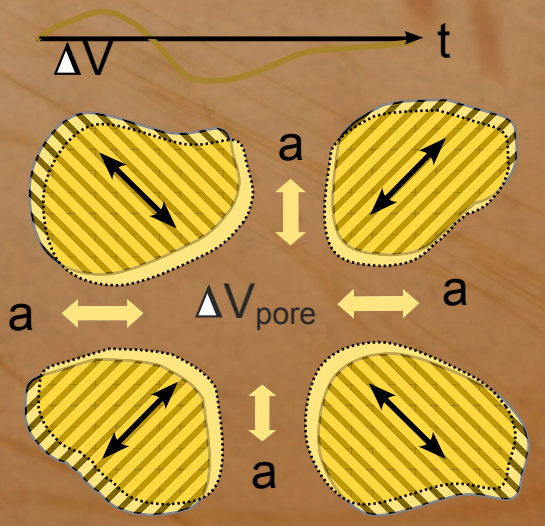

FIGURE 1 – MECHANISMS OF POWERWAVE

Pores are physically linked and in liquid communication. A sudden fluid pressure pulse leads to high liquid acceleration resulting in small expansion and contraction of the pores and a more uniform distribution of the injected fluid

fluid pressure pulses in your blood vessels. This causes expansion and contraction of the small capillaries throughout your body, allowing the red blood cells to move through them, even though the diameter of the red blood cells is about the same as the capillary! If your heart was a continuous pump, like a centrifugal pump, the red blood cells would pile up in the constricted passages and you would suffocate from lack of oxygen. A heartbeat contains just the right excitation impulse to generate this pressure pulse; if the impulse were too slow or too rapid, expansion and contraction of the small capillaries could not take place.

To apply this to oil production, a downhole positive displacement device is used to generate a sharp impulse that creates a pressure pulse in the pore liquids. This pulse propagates out from the source, causing small expansion and contraction of the pores (Figure 1), which leads to accelerations of the liquids into and out of the pores as the pressure wave passes. These small accelerations dramatically help fluid flow and fluid distribution. Furthermore, the sudden surge of the pressure pulse provides the right impact momentum to break down pore throat blockages.

Suppose that a pore throat is blocked by clay particles or asphaltenes; under a constant pressure gradient, the blockage remains stable. However, with pulsing, the liquid in the pore throat is suddenly moved back and forth; these accelerations break up the particle blockage, allowing the particles to be flushed through the pore throat, opening it to allow flow. The same principle is used by a farmer to free a blocked grain hopper: repeated impacts with a rubber mallet break the blockage, and the grain can flow again. If the impact momentum is too low nothing happens; if the impact momentum is too high there is also no effect. A rubber mallet creates the right impact momentum to destabilize the blockage.

In the case of residual oil trapped in a porous rock, flow blockages exist because the oil phase is no longer continuous: surface tension between the water and the oil maintains a capillary blockage at pore throats. Pulsing can overcome these barriers if the additional force caused by acceleration of the liquids in the pore throat is larger than the capillary force. When this happens, the oil phase moves through the pore throat and continues to flow down the pressure gradient. Apparently, aggressive pulsing can help increase the recovery factor and reduce – although not fully eliminate – channelling and fingering.

How can Powerwave be exploited? Continuous downhole pulsing must be maintained by repeated sharp impulses so that the pores in the rock expand by a small amount and then contract as each pulse passes. During expansion, liquid from the high-pressure side of the pore is taken in; during contraction it is expelled out the low-pressure side, which helps the flow rates, even in the case of a single-phase liquid. There are some limitations. Perhaps the most important one is a high gas content in the producing zone: gas is highly compressible so it merely compresses and decompresses, giving no significant benefits. This means that Powerwave is most effective in liquid-saturated reservoirs.

Powerwave can be used in all types of wells to optimize waterfloods, miscible CO_2 floods or chemically aided floods. The injected liquids are more uniformly dispersed in the reservoir because of the pulsing, improving displacement efficiency and oil recovery. Similarly, during placement of chemicals such as solvents and surfactants, it is best to inject them with aggressive pulsing so that less fingering and channelling takes place. Pulsing increases the contacted volume in the reservoir through dispersion, reducing the amount of chemicals that simply flow back undiluted.

Is there a track record of Powerwave in practice? It has been successfully used in several hundred injection points to place remedial liquids used to help bring shallow contaminated aquifers back to mandated standards. In the oil sector, commercial waterflood applications show improved oil rates, and over 200 successful single-well stimulations in Canada and the United States have been performed. In Canada, in Cold Heavy Oil Production (CHOPS) cases, Powerwave helps rehabilitate wells that have become poor producers. The aggressive stimulation that Powerwave provides dislodges pore blockages in a large zone around the wellbore, remobilizing the sand flux which then improves oil flow rates and recovery factors.

Powerwave is a fluid injection concept with many practical applications. Because existing wells can be used and the cost is low compared to the returns, it should be considered in all flooding approaches in conventional oil production as well as in CHOPS. Wavefront anticipates Powerwave will bring a new reality to 'recovery factor' expectations. AO

Maurice B. Dusseault, BSc, PhD, PEng is a Professor of Geological Engineering, Earth and Environmental Sciences, University of Waterloo.