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Extreme Overbalance Perforating Maximizes Water Injectivity for Pilot Well in Middle East

PowerJet Omega charges in fit-for-purpose gun string used to boost injection rate from 20 to 500 m^3/d, exceeding expectations

CHALLENGE

Increase injectivity rate in pilot water injection well by perforating in extreme overbalance.

SOLUTION

Use PowerJet Omega* deep-penetrating shaped charges to penetrate past formation damage and increase well injectivity as well as improve reservoir connection.

RESULTS

Increased injection rate from 20 m^3/d to 500 m^3/d in less time and at less cost than previously applied techniques.

Optimal perforation system required for pilot injection well

An operator in the Middle East drilled a pilot water injection well using underbalanced perforating techniques, which resulted in a marginal injection rate of 20 m^3/d. After a month of water injection, the well stopped accepting water. The operator then sought an infill water-injection strategy that could improve oil production from the well.

Extreme overbalance perforating was selected as the solution. This technique involves perforating or surging existing perforations at pressures above the fracture gradient of the reservoir rock. Commonly, a compressed gas such as nitrogen is used in conjunction with a small volume of liquid in the wellbore to enhance the perforation tunnel depths, enabling improved communication with the virgin reservoir fluid. The operator consulted with Schlumberger to define the specifications and scope of the perforating project, and a fit-for-purpose perforating gun string was designed for the operation.

Deep-penetrating charges qualified to meet objectives

The gun system was designed with perforation tunnels that would exceed the wellbore region that was damaged by postdrilling operations, approximated at 8 in [20.3 cm]. Because three zones were expected to take water, perforation intervals were split into three. Schlumberger and the operator decided that 4.5-in high-shot density, 5-spf Power Jet Omega 4505 deep-penetrating perforating shaped charges were optimal.

A tubing-conveyed perforating string was also designed to maximize—and accommodate—the extreme bottomhole pressure. Prior to perforating, an extremely high pressure was applied to the wellbore, resulting in downhole pressure higher than the fracture gradient of the reservoir rock to induce fractures. A total of 4,000 psi [27.6 MPa] would be applied on the nitrogen at the surface, which was acting on the reservoir rock through the liquid column covering the perforation intervals. At the time of detonation the expansion of the gas acted immediately as an extreme force to the reservoir rock.

Injectivity Test				
Reservoir	**Length, m**	**Pressure, MPa**	**Rate, L/min**	**Rate, m^3/d**
A	8	5	28	40
		11	62	89
B	13	3	212	305
		5	365	526
	3	7	500	720
C	13	3	208	300
		5	281	405
		8	495	713

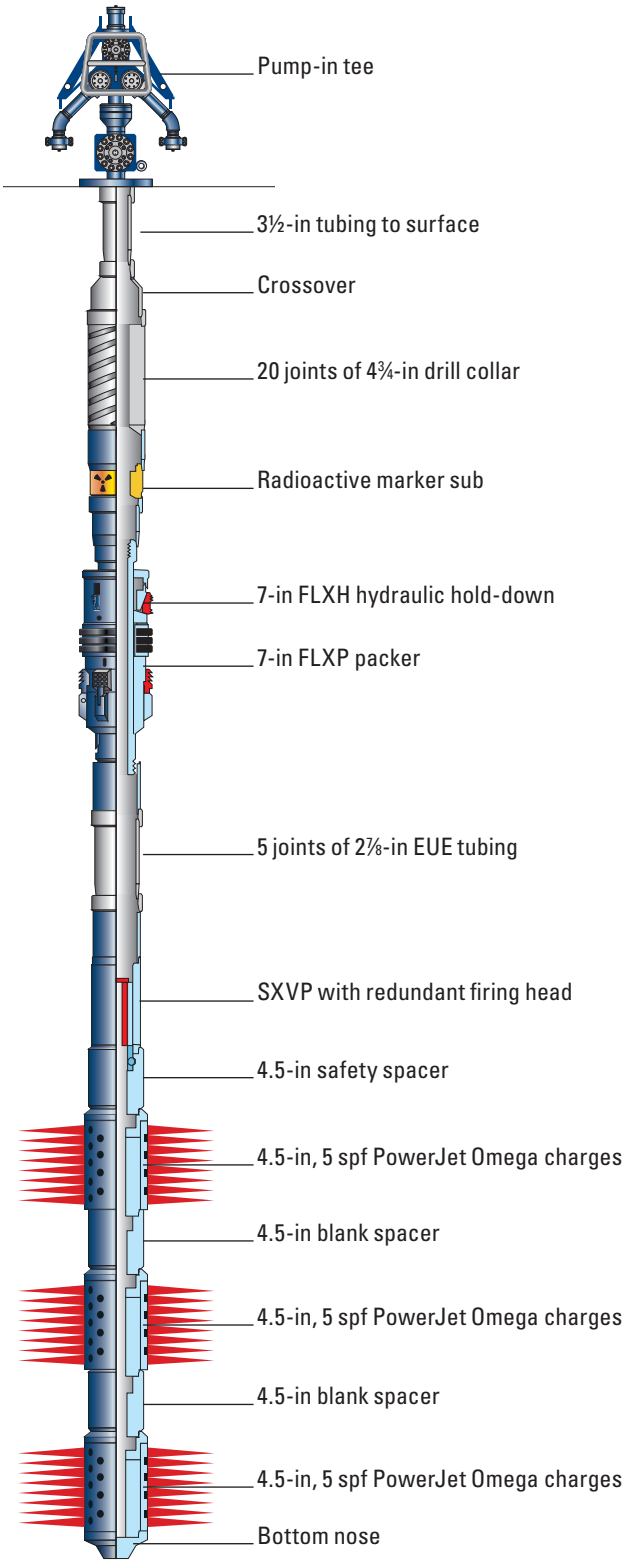
Injectivity results from postperforation tests show increases from 20 m^3/d to rates greater than 500 m^3/d, validating the choice in perforating systems.

Simultaneously, the extreme overbalance displaced large amounts of fluids into the perforation tunnels. This fluid displacement can easily saturate the tunnels and quickly pressurize the reservoir rock to the fracture gradient level. Once fractures are created, fluid displacement continues by introducing more fluids from surface to sustain and stimulate the formation by cracking down further into the formation.

A special solvent used within the brine column also helped to wash and dissolve the reservoir rock across the perforations while changing the wettability of the formation favorably for water injection. The height of the brine–solvent mixture column was approximately 984 ft [300 m], ensuring that the perforation intervals were fully covered with the brine and solvent.

Enhanced injection rate exceeded client expectations

The methodology applied for this EOP and completion enabled the operator to achieve injection rates not normally attainable from the surface. After perforation was complete, a selective injection test was performed. Results included surface water-injection rates that ascended from 20 m^3/d to 500 m^3/d at relatively low surface pressures. Further, inducing microfractures and expanding them into the reservoir greatly improved the well-to-reservoir communication; a cement bond log showed 100% cement bonding 9.8 ft [3 m] behind the casing. Because the injection operation was quicker than previously applied techniques, the operator saved time and money throughout the operation.



Tubing-conveyed perforating string configuration with PowerJet Omega charges.

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