Conceptual Design of Modularized Field Wide Polymer Flood Application in South-Hospah Oil Field

Targets:

The Upper Hospah Sandstone contains some 30 Million barrel of oil in a stratified siltstone/ sandstone formation, from which 3.75 Million barrel have been recovered in the primary phase. From reservoir simulation of polymer flooding it can be expected that this figure can be extended by field wide polymer flooding to at least 2.25 Million barrel oil additional. The cumulative primary and secondary recovery results in a theoretical recovery factor of 20 % IOIP. This is far below the average recovery factor of worldwide oil production of 34 % IOIP and confirms the rather conservative EOR- concept.

Module Concept:

The suitability of polymer flooding in the Upper Hospah Sandstone must be tested in a small scale pilot test of about 30 acres per well pattern, before field wide application can be considered. From the simulation study we may conclude that approximately 50 to 100 acres of the reservoir extension can be influenced by one pattern. The additive installation of polymer flood patterns keeps the financial risks low and implements the "learning effects" into the technical "know how" basis. The relatively high investment for the hardware in polymer application and chemical cost requires a short term pay back and re-use of the technical equipment.

Therefore it is planned to start with 3 polymer flood patterns (A,B,C) simultaneously in the **Phase 1** of field wide application. The polymer injection is split up into- 2 years of a high polymer concentration Slug 1 (250 ppm) followed by 3 years down-graded polymer concentration of Slug 2. After 5 years the total amount of polymer should be in the reservoir. The chemicals injection must be continuous without interruption. Therefore at least 2 injectors per well pattern must be equipped to provide a backup in the case of any well problems in one of the injectors.

In **Phase 2** the flood equipment will be moved to another 3 well patterns (D,E,F), whereas the water injection into A,B,C is continued. The total field cycle of polymer injection will last 10 years. The pilot test patterns and time can be included in this scenario.

Polymer demand for Phase1 and 2 is quite high, with 175,000 pound active polymer each and must be continuously supplied by a reliable and experienced domestic manufacturer, e.g. Nalco or others. The choice of powder or liquid polymer will depend on local support and economics.

Therefore a central mixing plant has to be installed, where a stock solution of concentrated polymer (1500 ppm) is mixed and supplied to the individual well patterns by trucks or pipeline. Each injection well is equipped with a large volume polymer storage tank (stainless steel), a high pressure injection pump, feed water tank and blending/measurement devices.

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The quality of materials is most sensitive to avoid polymer contamination by iron, oxygen and bacteria. Quality control on the delivered polymer and the concentrated and diluted solutions is necessary to guarantee a sustainable polymer thickening effect for the make-up water and in the reservoir.

Source of Knowledge:

The coarse estimation of polymer specific expenditures in the field are based on German petroleum industry polymer application in the late seventies and eighties of the 20th century, local experience with PAR systems polymer injection for polymer/gel water control purposes in the Hospah field in 2011 and polymer flood simulation by CRE Littmann in 2013. All prices are estimated from relevant German manufacturer portfolios

Assumptions:

Chemical System: Cheapest polymer for fresh water is PH-PAA , stable at 94° F, but sensitive for bacteria and oxygen degradation. Biocides have to be added to the treated field water. The stock solution in the plant is made up with premium (iron free) surface water. Other chemicals are oxygen scavengers and retention reducers. The stock solution will contain about 1500 ppm of polymer and the injected solution will contain about 250 ppm in slug 1, which is then gradually diluted to zero concentration in slug 2.

Slug Volumes: The calculated volumes are valid for Phase 1 and have to be doubled for Phase 1 and 2.

Slug1: 6(wells) x 300 (bbl/d) x 600 (d) = 1,080,000 bbl

Slug 2: 6(wells) x 300 (bbl/d) x 900 (d) = 1,620,000 bbl

Total **2,700,000 bbl**

Polymer Amount: The calculated amounts are valid for Phase 1 and have to be doubled for Phase 1 and 2

Slug 1: Volume x Concentration = 1,080,000(bbl) x 0.00025 = 270 bbl

Slug 2: Volume x Concentration = 1,620,000 (bbl) x 0.00008 =130 bbl

Total **400 bbl**

Active polymer content 80 % (400/0.8) x 0.159 = 79,500kg =**175,267 lb**

Injection Well Capacities: Short term capacities of 500 bbl/d at maximum well head pressure of 300 psia have been measured during injection tests of highly concentrated PAA (5000 ppm) in the PAR water shut of gel treatments. A long term injection capacity of 300 bbl per day and well is assumed. For the injection of a 250 ppm solution, 50 bbl of concentrated (1500 ppm) stock solution for each injector are needed.

Central Polymer Mixing Plant: The total capacity of the plant should exceed the required 300 bbl/d on the long term basis up to 500 bbl/d of concentrated polymer solution (1500 ppm) with a stable and relatively small mole mass distribution characteristics and a low filtration loss in the quality assessments.

Field distribution: The polymer stock solution demand per well and day of approximately 50 bbl have been assumed to be organized by liquid transport trucks from the mixing plant to the storage tanks at the injection wells.

Injector: each injector is equipped with a stainless steel, 100 bbl polymer storage tank, a stainless steel plunger pump, field water tank (300 bbl) with inhibitor and biocide dosage systems, blending and metering devices.

Hardware Cost Estimations: In US Dollar

Plunger Pump: 150,000 $, Transport Truck: 200,000 $, Polymer Mixing Plant (semi-automatic): 1,000,000 $, Polymer Storage Tank (100 bbl): 150,000 $, Water Tank with Chemicals Dosage System: 100,000 $, Blending and Metering Device: 75,000$, New Wells (1500 ft): 250,000 $

Chemical Cost Estimates: in US Dollar

Chemistry Mix: 5 $ / bbl solution
Blending Water: 1 $ / bbl solution

Project Maturity Level:

Savings of equipment and chemicals are expected by starting on the know how basis of the previous pilot stage

Polymer Specific Expenditures:

Investments for Well Patterns (A,B,C)

Pumps[1]	**(6+1) x 150,000**	**1,050,000 US $**
Water Tanks[1]	**(6+1) x 100,000**	**700.000 US $**
Polymer Storage Tanks[1]	**(6+1) x 150,000**	**1,050,000 US $**
Blending /Metering Device[1]	**(6+1) x 75,000**	**525,000 US $**
Polymer Mixing Plant	**1x 1,000,000**	**1,000,000 US $**
Transport Trucks	**3 x 200,000**	**600,000 US $**
Additional Wells	**6 x 250,000**	**1,500,000 US $**
Total		**6,425,000 US $**

[1] one extra item is considered as spear part

Investments for Well Patterns (D,E,F)

Pumps	**(6+1) x 150,000**	**1,050,000 US $**
Water Tanks	**(6+1) x 100,000**	**700,000 US $**
Polymer Storage Tanks	**Re-used**	**Up-grade and Maintenance 800,000 US $**
Blending /Metering Device	**Re-used**	
Polymer Mixing Plant	**Re-used**	
Trucks	**Re-used**	
Additional Wells	**6 x 250,000**	**1,500,000 US $**
Total		**4,050,000 US $**

Chemicals Cost Pattern (A,B,C)

Slug 1: 1,080,000 bbl x 5 $ **5,400.000 US $**

Slug 2: 1,620,000 bbl x 1.5 $ (average concentration 1/3) **2,430,000 US $**

Total Chemical Cost A,B,C **6,830,000 US $**

Chemicals Cost Pattern (D,E,F)

Slug 1: 1,080,000 bbl x 5 $ **5,400.000 US $**

Slug 2: 1,620,000 bbl x 1.5 $ (average concentration 1/3) **2,430,000 US $**

Total Chemical Cost D,E,F **6,830,000 US $**

Large saving potentials exist by leasing of equipment and by involvement of external services for transport, make-up and control

Upside Potential of Oil Recovery by Polymer Flood

Recovery expectations by polymer flooding range from 10 percent IOIP additional oil production up to 15 percent. The quick-look estimate from the Hospah pilot flood simulation study targets a value of 2.25 Million barrel extra oil as the lower recovery level and the experience from similar reservoirs aims at 3 Million barrel extra oil as the mode level.

Considering a net revenue of 40 $ per barrel presents a fair market value of 120 Million US Dollar compared to a total investment for hardware of 10.5 Million US Dollar and cost for chemicals of 14 Million US Dollar.

For the Hospah Sand Unit, that is the northern unit of the Hospah field, the recovery situation in the Upper Hospah Sandstone is similar to the South Hospah Field. The upside potential for polymer flooding is of the same magnitude as in the southern unit, but has not been reviewed in detail.

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