# Water control in basement reservoir: a case study from high water cut wells of Borholla, Assam Asset.

**Sudipta Biswas, Saroj Choudhary, Om Prakash**

Institute of Oil & Gas Production Technology
Oil & Natural Gas Corporation Ltd, Panvel, Navi Mumbai, India-410221
Email:biswas1967@yahoo.com
Mb: 9969228769, 022-27486213(O)

## Intoduction

Borholla field is located about 35 kms SSE of Jorhat town in the north eastern margin of Dhansiri valley along the Naga foothill. Structurally, Borholla field is on intensely faulted anticline. Oil is being produced from Sylhet, Kopili, basement and basal sandstone reservoirs. The field has two other reservoirs i.e. Tipam and Girujan, which are gas bearing. The first commercial discovery of hydrocarbons in the igneous / metamorphic rocks of India was made in this field

The production from this reservoir peaked in 1988-89 at the rate of 159TPD (water cut 3.34%) with 04 producers. Subsequently rising trend of water cut in producing wells and transfer of wells to the other layers resulted in gradual decline of production. Rapid increase in water cut in the wells of Basement reservoir may be mainly due to non-existent of transition zone in the fracture systems. Further preferential movement of water in the fractured networks due to relatively low water viscosity compared to oil viscosity at reservoir condition may also contribute to increased water cuts. The reservoir has the aquifer support which is evident from the slow rate of pressure decline and high water cut. The water cut problem is severe in the wells which are structurally down and have large penetration in basement.

## Challenges of WSO in Basement reservoir of Borholla

To control excess water in these wells was more challenging in terms of fracture system know-how, oil-water contact, source of water. Moreover; isolation of zone was not possible due to barefoot/ uncemented slotted casing. Nonetheless; conventional water shut off like cement squeeze/sealant gel methods was another hurdle as it may cause blocking on all the fractures including oil producing ones.

WSO jobs done earlier showed encouraging results but did not sustain for a considerable period. It is suspected that sand plug placement was not proper as it was designed to block only 5 ½’’casing liner with no sand placement behind casing liner. This had resulted in partial success of earlier jobs.

The reservoir has aquifer support which is evident from the slow rate of pressure decline and high water cut. The aquifer is an infinite acting, steady state aquifer providing pressure support. It is also responsible for the encroachment of water towards the well bore through the fractures bypassing the oil in the matrix blocks. This is observed in the well performances with rapid increase in produced water cuts.

The reservoir has different pressure –production decline behavior due to complex fracture system. The problem of high water cut has been critical in the structurally down and deeper wells in basement (more than 50mt). Water entries most likely come from the bottom intervals due to reservoir structure and presence of bottom water. There are no available data for fracture systems and fractures contributing water. Placement of sand plug can help in selective bottom water isolation. Table I below shows the slow rate of pressure decline.

**Table-1**

| **PARAMETERS** | **Well A** | **Well B** | **Well C** | **Well D** |
|---|---|---|---|---|
| Initial Res Pressure | 284Ksc | 247ksc | 268.2ksc | 267.8ksc |
| Current Res Pressure | 263.8ksc | 259.87ksc | 268.2ksc | 267.8ksc |

All these wells are showing water cut in the range of 80-95%. The well wise analysis for cause of excess water production is done by using the water control diagnostic plots, liquid, oil and water production history. Accordingly water control diagnostic plots were drawn for above wells. It was inferred that increase water production is from bottom water coning. .

## Laboratory studies

Lab Studies were carried out to design the required formulation for effective water shut off treatment in the basement wells of Borholla. All the experiments were done at 70$^{o}$C with varying concentrations of polymer and cross linker. It was observed that Alco flood -935 at 70$^{o}$C forms a good RPM (flowing) type gel (does not form gel at room temperature for 2 to 3 days) as shown in Fig-1 .

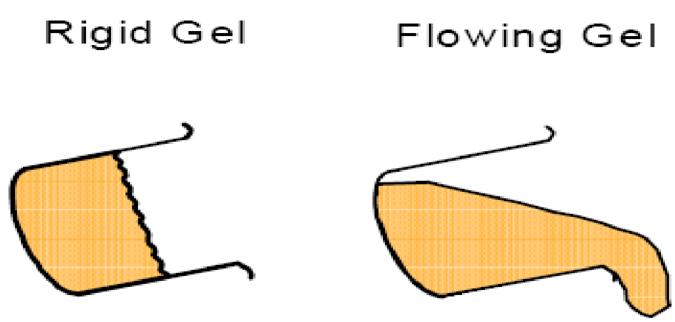


**Fig-1 Showing flowing type of Gel**

**Ingredients of the gel Alco flood -935**

1. Alcoflood-935
2. Chromium Acetate (III)
3. Sodium Chloride
4. Sodium Thiosulphate.

Chromium Acetate (III) used in the gel is eco friendly because of its low toxicity. Hydrogen Peroxide acts as gel breaker.

## Sand Plug Technology

Earlier 20/40 mesh sand has been used which has got very high permeability and the job did not sustain for an appreciable period. In order to reduce the permeability of the sand plug, intermix of 20/40 mesh sand and 100 mesh silica flour (coarse) in a proportion of

60:40 has been experimented in the lab and has given excellent results. Different stages of gelation are described below:

**Pre Gelation**

The sand plug as mentioned above was prepared in the sand pack holder. A 5%KCl brine solution was passed at 5CC/M rate under a back pressure of 600 psi in order to reduce channeling. Stabilized pressure readings and flow rates were recorded and average permeability as per measurements were calculated.

**Gel Flow**

Gel formulation was prepared and flown through sand pack at 5CC/M rate. The composition of gel is given below:

Alcoflood-935 - 5000 ppm
Chromium Acetate (III) - 500 ppm
Sodium Chloride - 5000 ppm
Sodium Thiosulphate - 2000 ppm
Calcium Chloride - 1000 ppm

The above gel passed through the sand pack holder is kept at 650C in a hot air oven for four days.

**Post Gelation**

Then again 5% KCl brine solution was passed at 5CC/M rate. Stabilized pressure readings and flow rates were recorded and average permeability as per measurements were calculated. The diesel was passed through sand pack at 5CC/M rate. The stabilized pressure readings and flow rates were recorded. The experiment showed that water was blocked by gel and diesel passed easily proving the nature of RPM type gels.

The curve of brine flow (pre gelation) in Fig I1 shows a free flow of brine with a good permeability and there is hardly any change in pressure. Gel also flows freely. The effective reduction of water permeability is evident from the curve of brine flow (post gelation) because delta P increases which means that the flow of water is restricted as it is facing resistance to flow because of reduced permeability and hence the increase in delta P. Oil permeability is not reduced as evident from the graph. The initial rise of pressure is due to some amount of brine left in the pack.

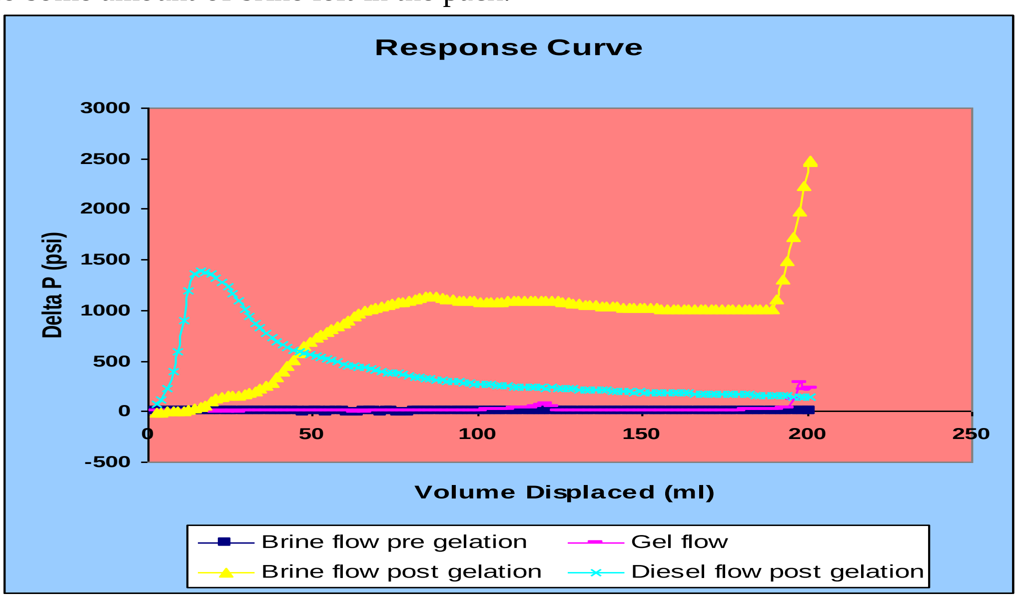

**Fig-II**

## Water shut off plan for well #A

Well #A was intended to be barefoot. Slotted casing was lowered. During cementation, due to failure of protecting petals cement went below the petal and damaged the formation. Later on casing was perforated in the interval 2780-2800m.

### Work Over History of well #A

1. Installation of GLVs (13.10.1996)
2. Installation of re-designed GLVs (Dec, 1999)
3. Sand plug job for water shut off ((July, 2001
4. Well was unloaded with gas injection and activated. (August, 2002)

### Present Well Completion

| Well No. | A |
|---:|:---:|
| Well Profile | Vertical |
| Perforation Interval | 2800-2780 m |
| Well depth | 2802 m (D), 2803 m (L) |
| Tubing Size | 2 7/8" 6.5 ppf |
| Tubing shoe | 2750 m |
| Casing Size | 5 1/2" (Slotted) |
| 5 1/2" Casing shoe | 2800.15 m |
| Top of slotted CSG pipe | 2776 m |
| Packer Depth | 2742.15 M |

## Tentative water shut off plan for Well A

1. Kill the well with brine and install BOP. Tag the sand plug with tubing.
2. Pull out the completion.
3. Run in tubing with jet, clear up to 2882m with viscous brine.
4. Run in open end 2 7/8''tubing with tubing shoe at 2880 m.
5. Check the injectivity of the well with plain water. If injectivity is more than 200LPM we can go ahead with sand plug placement.
6. Prepare 150 m3 of Alcoflood 935 polymer solution.
7. Pump 60 m3of crosslinked Alcoflood 935 polymer solution along with 0.25ppg (= 29.95661 kg/ m3) of 100 mesh silica flour fine in suspended form.
8. Lift tubing upto 2820m.
9. Pump remaining 90 m3Alcoflood 935 polymer solutions with 1055 kgs of sand of 20/40 mesh sand along with 500kgs of 100 mesh silica flour.
10. Close the well for 72 hrs for settlement
11. Tag the sand top.
12. Activate and monitor the well for oil/water/gas and carry out reservoir studies.

**Requirement of gel and sand quantity for Well A**

| Gel Penetration radius, m | wellbore rad, m | Area, m2 | Bulk Volume, m3 | Pore volume, m3 | Gel volume, m3 |
|---|---|---|---|---|---|
| 3 | 0.0635 | 28.24734 | 282.4734 | 70.61835 | 69.21 |

**Volume required for Sand plug of 15 meter**

| | | |
|---|---|---|
| Well radius | 6.35 | cm |
| Area | 126.613 | sq cm |
| Volume | 189919 | cc |
| | 189.919 | Litres |
| Total volume of 15 m 5" hole | 189.92 | Litres |
| Volume of Sand | 113.95 | Litres |
| Volume of Silica | 75.97 | Litres |
| Weight of Sand | 182.55 = 185 | Kgs |
| Weight of silica flour | 85.16 = 85 | Kgs |

## Conclusions:

- Water shut off in basement wells is a real challenge as no case histories are available.
- Diagnosis of candidate wells A, B.C.D based on production history, reservoir data and well diagnostic plots indicated water coning as a reason of high water cut.
- Laboratory studies show that Alcoflood -935 at reservoir temperature conditions works as relative permeability modifier.
- The Alcoflood -935 gel system with sand plug (20/40 mesh sand with 100 mesh silica flour the ratio of 60:40 found effective for water control.

## Recommendations:

1. Alcoflood 935 gel system followed by selective isolation by sand plug mixture of 20/40 mesh sand and 100 mesh silica flour in the ratio of 60:40 is recommended.
2. The source of water identified by PLT studies is a necessity for selective plugging of fracture zones.

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