Monitoring of Radioactive scaling and effect on well performance in well of Mumbai High field

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Summary

Occurrence of strontium sulphate scales have been seen in number of tubing retrieved during work over. The strontium sulphate (SrSO₄) precipitates in the formation due to reaction of injection water (treated sea water) with formation water, which is rich in strontium. The SrSO₄ is a radioactive salt and may crystallise on the wall of casing and tubing. The increase of Gamma Ray radioactivity over base value recorded in the cased hole logs is used as indicator of RA scale growth. Present case history well is the first example of physical measurement of scaling and correlation between scale thickness and performance. It was general understanding that scaling chokes the perforations and reduces the production from the layer.

In one of Mumbai High wells, during production logging, radioactive scale of over one inch thickness was found along more than 25m of 7” casing length. This thick scale has formed in 7 years since last work over. In this well, 8 sub layers of LIII reservoir are open. At the time of production logging, well was flowing oil at the rate of 148 BOPD with 87% water cut. Full Bore Spinner Flow meter with spring cage, though could pass through scale section, but spinner blades collapsed when it entered this section. Turbine Flow meter of smaller diameter was run and flow meter data against scaling could be recorded. Bottom most five layers were found to be in-active. Against these layers, no scaling was observed. One of the layers which is known to be most susceptible for water break through was, however, inactive. At the same time, against even 1” thick scaling, three upper layers were active.

Activity of layers behind thick scale and passivity of layers against which there is no scaling contradicts the general understanding. This has significance in deciding the strategy for productivity improvement. Scale removal by blasting/mechanical removal may not improve well performance. Chemical stimulant may be more beneficial.

Thickness of the scales was not uniform but varying along casing length. Recorded Gamma Ray radioactivity against scales was up to 18,000 API. A relationship has been established between scale thickness and radioactivity. Exponential Transform is found to fit better with regression coefficient of 0.86. This relationship can be used to convert radioactivity measurement to scale thickness in other wells having 7” casing, where direct measurement (calliper log) is not available.

Introduction

Mumbai High, located about 165 km WNW of Mumbai city is the largest and most prolific oil field in India. The field has been divided into two blocks- North and South based on a relatively low permeability zone. Based on this barrier, these two blocks (Mumbai High North and South) have been independently developed. Both north and south fields are anticlines with eastern boundary fault. Structure is gently dipping towards west with dip of 1.5 to 2.0°. L-III is main reservoir and accounts 95% of reserves. The L-III pay is of Miocene age, at 1250-1400m depth and overlain by Miocene, Pleistocene to recent clay/clay stone sediments. L-III is divided into A1, A2- I, A2-II, A2-III, A2-IV, A2-V, A2-VI, A2-VII, N, B, C, D, E sub layers separated by 1-3m shale bands. Pay lithology is micritic and fossiliferous limestone with shale partings. L-III reservoir has Gas Oil Contact and Oil Water Contact for various layers. Field has partial aquifer support.

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Field has production history of more than 35 years. The field is on water injection since March’84, Water cut started soon after water injection and gradually increases to 70% at present.

Scaling observations in Mumbai Field

During work overs in wells since nineties, retrieved production tubing in some of the wells are found to have crystalline thick scales in the tubing (Figure-1). Upon analysis these scale were found to be of strontium sulphate.

Figure 1 Strontium sulphate Scale deposition in 3 ½” tubing

Strontium sulphate scale is formed when injected treated sea water reacts with formation water, which is rich in strontium ions. The break through water brings the strontium sulphate to the borehole and crystallizes at the wall of casing or tubing. Strontium sulphate is radioactive element. Radioactivity level against tubing and casing in wall of casing or tubing. Strontium sulphate scale is formed when injected treated sea water reacts with formation water, which is rich in strontium ions. The break through water brings the strontium sulphate to the borehole and crystallizes at the wall of casing or tubing. Strontium sulphate is radioactive element. Radioactivity level against tubing and casing in wall of casing or tubing.

The scales formed at mandrels and affected port of gas lift valves making gas lift de-optimized. This can happen as short as in few months. Thick scale deposited on the wall of the tubing can reduce cross section available for flow substantially. Whereas, direct physical observation of scales is possible in retrieved tubing, it is not possible in production casing as it could not be retrieved.

Calliper log in production logging was introduced recently only few years back in Mumbai High, making it possible to correlate scale thickness with Gamma Ray activity. Case history presented in the paper is first observation in Mumbai high, where scales of 1” thickness having Gamma ray radioactivity of up to 18,000 API was recorded during production logging.

Case History Well MHA

Well MHS-A, was drilled in Nov’88 and completed in L-III reservoir in 7” liner as conventional deviated well with maximum deviation of 520. Well was initially completed in A1(1810-1814.5m), A2(1820.5-1824m), I(1825.5-1828.5m), II(1831-1835m), IV(1836-1841m), V(1846.5-1848m), VI(1857.5-1863m).

The layer L-III B (1872-1875m) was added in May’99. Last work over job was carried out in Dec’2004 for servicing. During service the well was scraped and cleared up to 1905m by 6” bit and scraped up to 1904m. This depth was 29m below the bottom most perforation. Though calliper was not recorded during work over, the 6” bit and 7” scraper ensured absence of any appreciable scale throughout 7” liner. After work over well flowed around 1000 BLPD with more than 60% water cut. Production of liquid level remained at the same level but water cut increased gradually with time.

Production Logging

In April ’11, the well was flowing at the rate of 1140 BLPD, 148 BOPD with 87% water cut, Production logging was carried out with the objective to find source of water. The production logging strings comprised Full bore flow meter with 3 1/2” spinner blade having spring cage & Calliper, Temperature, gradio-manometer, pressure gauge, Natural Gamma Ray and Casing Collar Locator. The descent to the bottom bit spinner blade was collapasing in the interval 1792-1825m in all the 10 up & down passes.

Above and below this interval the spinner blades were open and flow meter was working normal (Figure 2) . The spinner blades were found to be collapsing in internal casing diameter below 5”, which is normal. Against this interval abnormal high Gamma Ray above 10,000 API was recorded.
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Figure 2 Production Log Well Mhs-A
To record complete production profile, turbine flow meter of size 1.38” was run. There is no collapsible part in the tool and it measures fluid velocity even in diameter lesser than 2”. The fluid velocity from Turbine Flow Meter and cross section area from X-Y calliper of Full Bore Flow Meter were used to calculate production profile accurately. The processed results of production logging are summarised below:

<table>
<thead>
<tr>
<th>Layer</th>
<th>Perforated Interval (m)</th>
<th>Calliper (inch)</th>
<th>Contribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
<td>1810-1814.5</td>
<td>4.0-4.3</td>
<td>112 BOPD+603 BWPD+12500 SCMD</td>
</tr>
<tr>
<td>A2-I</td>
<td>1820.5-1824</td>
<td>4.0-4.1</td>
<td>46 BOPD+369 BWPD+1000 SCMD</td>
</tr>
<tr>
<td>A2-II</td>
<td>1825.5-1828.5</td>
<td>6.2- 6.6</td>
<td>17 BOPD+683 BWPD+ negligible SCMD</td>
</tr>
<tr>
<td>A2-III</td>
<td>1831-1835</td>
<td>6.3</td>
<td>Negligible</td>
</tr>
<tr>
<td>A2-IV</td>
<td>1836-1841</td>
<td>6.3</td>
<td>Traces of oil</td>
</tr>
<tr>
<td>A2-V</td>
<td>1846.5-1848</td>
<td>6.3</td>
<td>Negligible</td>
</tr>
<tr>
<td>A2-VII</td>
<td>1857.5-1863</td>
<td>6.4</td>
<td>Negligible</td>
</tr>
<tr>
<td>B</td>
<td>1872-1875</td>
<td>6.3</td>
<td>Negligible</td>
</tr>
<tr>
<td>Total Production</td>
<td></td>
<td>165 BOPD +1655 BWPD + 13,500 SCMD</td>
<td></td>
</tr>
</tbody>
</table>

Table 1 Results of production Logging

The result shows that layers against which, no appreciable scale was observed is inactive and layers against which appreciable scale thickness (1” or more) was observed is contributing the oil, water and gas. The layer A2-IV (1836-1841m) needs special mention as this layer is most likely candidate for injection water break through due its high porosity and permeability (Figure 3). Gamma Ray activity level against A2-III and other lower layers in year 2011 is same as seen in year 1988, when well was drilled.

The above observation is against general notion that strontium sulphate scaling blocks the flow from formation to hole and removal of scale may improve the production performance. In fact, near well bore chemical stimulant, which act on formation matrix may be more beneficial.

**Relationship between scale thickness and GR activity**

X-Y calliper readings are showing almost similar reading indication absence of any ovality in the casing. One of the callipers is taken as internal diameter of casing. Casing pipes used in the well are 7” 29ppf having nominal diameter of 6.3”. Thickness of scales is calculated from recorded calliper values. Thickness of the scales was found to be varying from 0 to 1.1” along casing length. Recorded Gamma Ray radioactivity against scales was up to 18,000 API. A relationship [thickness (inch) = 0.2441 * exp (0.00008* GR)] has been established between scale thickness and radioactivity.
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Figure 3: Base GR, Neutron Density Log

Figure 4: Correlation between GR activity and scale thickness
Exponential Transform is found to fit better with regression coefficient of 0.86. This relationship can be used to convert radioactivity measurement to scale thickness in other wells having 7” casing, where direct measurement (calliper log) is not available.

Conclusions

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