Abstract
A Sakhalin major operator is developing the Piltun-Astokhskoye oil and Lunskoye gas fields off the northeastern coast of Sakhalin Island, Russia. The Lunskoye-Alpha (LUN-A) platform is known as the first Russian offshore gas production platform since 2006.

Plans were made to extend the operating envelope of the Lunskoye field by exploring extended reach drilling (ERD) practices through a first campaign with two critical wells: LA-528 and LA-529. Critical intervals on those wells were 12.25 in. near horizontal sections 4013 and 4266 m, respectively, with an angle drop at the last few hundred meters to 45°.

ERD has been around for many years, but the tempo of technical developments is quickening in response to the ever-growing challenges the industry faces. As drilling conditions continue to become more challenging, the need for performance becomes imminent to developing a drilling solution.

Uncontrolled equivalent circulating density (ECD) can increase the possibility of drilling-induced fractures, nonproductive time (NPT), and costs associated with fluid loss. ERD well profile design is not a simple geometric curve, particularly if the well interval departure is beyond the 24,000-ft (7-km) depth. It is an integrated process that requires an optimal well path profile with respect to its detailed design of service.

Introduction
For the previously mentioned challenges, a high-performance nonaqueous fluid system was customized and fit-for-purpose, with its unique organophilic clay-free (OCF) nature and rheological profile designed to provide low, controlled ECD in wells with narrow pore pressure/fracture pressure gradients. This fluid reduced the potential risk of drilling-induced fractures and enhanced the likelihood of a successful drilling campaign.

The fluid maintains excellent wellbore stability with its fragile gel strength and exceptional suspension properties to effectively clean the wellbore and resist barite sag. At the same time, the fluid reduces the potential risk of stuck pipe and packoff. These are some of the most frequent challenges operators face while drilling complex wells, such as deep water, extended reach, or narrow pressure margin wells.

The case histories described in this paper illustrate that challenges were met through detailed fluid designs that extended the drilling ability on Sakhalin Island, proving to be an effective operational driver to success.

Project Objectives
The objective was to successfully drill and complete wells that could not be reached with conventional systems because of its pressure regimes. Later to target is providing sand control capabilities and enabling longer well life and higher ultimate recovery by using annular isolation to isolate future water production. There was a target depth of 8320-m MD and 2069-m TVD for Well LA-528 and 8395-m MD and 2082-m TVD for Well LA-529. Figure 1 shows the well schematic, and Figures 2 and 3 show the proposed trajectories for the wells.

Offset Evaluation
Previous offset wells had no direct experience with sections of 4 km, 12.25 in. on this project, which was the first of its kind. However, the following challenges were raised while preparing for the execution of the ERD project based on previous experience with conventional invert emulsion fluid (IEF) on the same intervals, which were half as long.

- Keeping the mud-circulating temperature less than 80°C (blowout preventer rating)
- Losses while drilling through the faults
- Losses while running the liner for a long time without circulating well volume
- Friction factor (FF) limitation with the bottomhole assembly (BHA) previously used
- Sag was not a challenge on shorter intervals; however, this concern was raised with increasing static time for fluid in the well for the period required to back ream out of hole (BROOH) and run in hole (RIH) with the liner

Solution Provided
The OCF-IEF was selected because offset field experience from the North Sea and Gulf of Mexico indicated excellent low ECD characteristics, reduction in pump on/off pressure, fragile gel structure, and an improved sag resistance ability. A
combination of these properties was expected to help the operator deliver the well objectives and minimize the potential risk of NPT within the estimated cost and schedule. To control circulating temperature, a fit-to-purpose mud cooling system was installed. For the FF expected based on the conventional IEF, the change from the standard drillpipe to aluminum pipe was initially planned, reducing weight of the drillstring at the bottom of the lateral, thereby lowering the torque on the drive motor. Furthermore, using lighter-weight aluminum drillpipe in lateral sections of drill strings can lower the overall stress on conventional steel drill strings, thus reducing fatigue and extending the life of the steel pipe.

OCF-IEF systems have been in use since the early 2000s (Burrows et al. 2004). The nonorgano-clay viscosifiers used in the formulation provide a lower high-end rheology profile at a comparable carrying/cleaning capacity of the fluid and a fragile thixotropic nature to the emulsion gel structure when fluid flow begins. These fluid features begin as the foundation for a formulation with enhanced sag resistance and improved carrying capacity, allowing further reductions in rheology and resulting in the low ECD characteristics. The system provided a superior rheological profile and robust, yet fragile, gels with which were customized for the application in different narrow margin formations, delivering engineered ECD control and best performance.

Modelling

Proprietary software was used to accurately model expected ECD and to customize the lost-circulation material (LCM) decision tree based on previous lost-circulation incidents experienced. This software helped demonstrate the difference in ECD for OCF-IEF and conventional IEF (Figures 4 and 5). Table 2 and Graph 1 show findings of the model.

Hydraulic simulation for ECD shows that in the same conditions for the same interval proposed, the new fluid solution demonstrates a lower ECD, which can help minimize potential risks of downhole losses and NPT.

Barite Sag

To address the concern for barite sag, several laboratory tests were performed while formulating the fluid, including VSST (AADE-10-DF-HO-25/SPE-147005) and a SAG factor test following static aging at 181°F for 120 hours (AADE-13-FTCE-16).

Fluid Stability

Several laboratory tests determined that the fluid had ample stability to contaminants such as water, solids, and base oil, with the key properties exhibiting good stability.

Application

System Performance

The proposed fluid for ERD performed as planned and demonstrated a stable lower ECD than conventional IEF used previously on a shorter section, maintaining wellbore stability and the required hole cleaning ability with no sag issues. The FF on OCF-IEF was lower than on conventional IEF, which helped save approximately seven days for the operation during the changing of the drillpipe (POOH//RIH/single in/single out). Initially, the objective of the aluminum drillpipe (ADP) trial on LUNA was to develop nonupgraded rig capability solutions for ERD opportunities LA-528 and LA-529 in line with the current drilling sequence timing. Rig upgrades were required for the original LA-528 and LA-529 development plan and were not feasible in the acceleration scenario for LA-528 and LA-529; hence, ALDP technology was proposed as an enabler for the same development plan (Table 5).

Drilling of LA-528 and LA-529 using ADP without a top drive upgrade was confirmed as technically feasible at DG2, whilst meeting drilling sequence plans.

On Well LA-529, LCM strategy worked well, and the pill cured the losses, with the first attempt showing correct modelling using propriety software. The losses themselves were induced because the predicted fracture gradient (FG) was higher than actual; therefore, the FG was exceeded. The mud cooling unit (MCU) confirmed effectiveness by maintaining the flowline temperature at a maximum of 62°C.

Offset Comparisons

Graph 2 shows actual ECD data from the pressure-while-drilling (PWD) tool compared to conventional IEF (was recalculated to match TVD and MW for OCF-IEF) vs. OCF-IEF. The fragile thixotropic character of the emulsion gel structure can be observed on Graph 3 (time period is the same) by:

- Breaking gels after a long static period with fewer potential risks of losses
  - At 8000-m MD, breaking gels with OCF-IEF occurs at 200 lpm at 550 psi
  - At 6000-m MD, breaking gels with conventional oil-based mud (OBM) occurs at 450 lpm at 650 psi
  - Stabilize circulating pressure/get well to the desired regime requires less time with OCF-IEF
    - At 8000-m MD, pressure stabilized with OCF-IEF in 10 minutes on desired flow rate
    - At 6000-m MD, pressure stabilized with conventional OBM 60 minutes on desired flow rate
- Less circulating pressure before the cement operation with higher flow rate
  - At 8000-m MD, flow rate is 1,000 lpm with OCF-IEF at 550 psi
  - At 6,000-m, flow rate is 750 lpm with conventional OBM at 600 psi

Table 4 shows the actual FF measured at the same depth with the same BHA and on the same well for conventional IEF and OCF-IEF and shows much less FF on OCF-IEF. Graphs 4 and 5 show less dilution rate and less product requirements for OCF-IEF vs. conventional IEF.

Nevertheless, Sakhalin operation is well known for...
encountering numerous challenges in regards to logistics, schedule, location because of a harsh environment, limited weather window, environmental sensitivities, and stringent regulations. In addition, supplying the necessary additives to a drilling operation in a remote location can be a major logistical burden, leading to a compromise in the fluid formulation.

Laboratory work during the design phase required to optimize the fluids for this project had to account for not only the requirements for the best fluid performance technically but also the effect of the limitations created by working in a remote location. Considerations included minimum loading for fluid maintenance and system reconditioning. The results were significantly acknowledged with savings compared to conventional systems because of the low consumption rates of additives and dilution rates.

Conclusions

- The OCF-IEF performed per the plan on the two wells mentioned in this paper led to no NPT on the fluids side, minimizing the time for overall well construction. Running the liner and circulation with the OCF-IEF secured the most critical interval for this first ERD campaign for Sakhalin Energy by lowering “pumps on” pressure, minimizing time for breaking the gel structure of the drilling fluid, and achieving higher flow rates on the pre-cement operation circulation.

- Results achieved on the first ERD campaign, including the longest single run 12.25 for the company, has validated the fluid formulation methodology and selection of OCF-IEF for the next ERD campaign with wells totaling lengths of 10 and 12 km.
Figure 1 – Well schematic.

- 30" Conductor Shoe
- 24" Liner Shoe
- 18-5/8" Casing Shoe
- 13 3/8" casing shoe
- OCF-IEF interval
- 9-5/8" Liner shoe
- Gravel pack screens
- TD

Figure 2 – Deviation schematic for Well LA-528.
Figure 3 – Deviation schematic for Well LA-529.

Figure 4 – Modelled drill-ahead hydraulics OCF-IEF.
Figure 5 – Modelled drill-ahead hydraulics with conventional-IEF.
Graph 1 – Modelled fracture length based on offset wells experience.

Graph 2 – ECD data for conventional IEF and OCF-IEF.
Graph 3 – Data comparison for circulation with the liner on target depth for conventional IEF and OCF-IEF.

Graph 4 – Data for dilution used on wells with conventional IEF and OCF-IEF.
**Graph 5** – Weight of products comparison used offshore on wells with conventional IEF and OCF-IEF.

**Table 1 – Chosen target fluid properties**

<table>
<thead>
<tr>
<th></th>
<th>WM (SG)</th>
<th>PV (cP)</th>
<th>YP (lbf/100 ft²)</th>
<th>6 rev/min</th>
<th>HP/HT (ml)</th>
<th>OWR (%)</th>
<th>ES (volts)</th>
<th>WPS (mg/L)</th>
<th>LGS (%)</th>
<th>Tau 0 (lbf/100 ft²)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1.35</td>
<td>20-30</td>
<td>20-30</td>
<td>12-14</td>
<td>&lt;4</td>
<td>70-80</td>
<td>&gt;400</td>
<td>190-235</td>
<td>&lt;5</td>
<td>9-12</td>
</tr>
</tbody>
</table>

**Table 2 – Modelled the formation properties based on offset experience**

<table>
<thead>
<tr>
<th>Minimum Horizontal Stress</th>
<th>Poisson’s Ratio</th>
<th>Static Young’s Modulus</th>
</tr>
</thead>
<tbody>
<tr>
<td>920,000 psi</td>
<td>0.34</td>
<td>3,920 psi</td>
</tr>
</tbody>
</table>

**Table 3 – Fluid properties used for modelling**

<table>
<thead>
<tr>
<th>Fluid Type</th>
<th>600</th>
<th>300</th>
<th>200</th>
<th>100</th>
<th>6</th>
<th>3</th>
<th>PV</th>
<th>YP</th>
<th>ECD Shoe with Cuttings</th>
<th>ECD Shoe Without Cuttings</th>
<th>ECD TD with Cuttings</th>
<th>ECD TD Without Cuttings</th>
</tr>
</thead>
<tbody>
<tr>
<td>OCF-IEF</td>
<td>57</td>
<td>38</td>
<td>29</td>
<td>22</td>
<td>12</td>
<td>10</td>
<td>19</td>
<td>19</td>
<td>1.483</td>
<td>1.448</td>
<td>1.526</td>
<td>1.489</td>
</tr>
<tr>
<td>Conv IEF</td>
<td>79</td>
<td>49</td>
<td>38</td>
<td>26</td>
<td>13</td>
<td>12</td>
<td>30</td>
<td>19</td>
<td>1.526</td>
<td>1.492</td>
<td>1.559</td>
<td>1.523</td>
</tr>
</tbody>
</table>

**Table 4 – Actual data for friction factor comparison on wells with conventional IEF and OCF-IEF**

<table>
<thead>
<tr>
<th>Dry weights at 3735 m</th>
<th>PUW (klbs)</th>
<th>SOW (klbs)</th>
<th>FRW (klbs at 30 rev/min)</th>
<th>TQ (klb*ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional IEF</td>
<td>225</td>
<td>133</td>
<td>170</td>
<td>19 to 20</td>
</tr>
<tr>
<td>OCF-IEF</td>
<td>210</td>
<td>132</td>
<td>167</td>
<td>11 to 14</td>
</tr>
</tbody>
</table>

**Table 5 – Modelling torque using historical conventional IEF friction factor (with and without aluminum drillpipe)**

| Drilling surface TRQ at TD without 2000 m AIDP | 45,000 ftlbs |
| Drilling surface TRQ at TD with 2000 m AIDP   | 39,500 ftlbs |
| BROOH surface TRQ at TD without 2000 m AIDP   | 54,000 ftlbs |
| BROOH surface TRQ at TD with 2000 m AIDP      | 48,000 ftlbs |
| TDS-8 TRQ-Rating                              | 52 ftkip @ 120 rev/min |
| TDS-8 TRQ-Rating                              | 37 ftkip @ 160 rev/min |
| TDS-8 TRQ rating                              | 63 ftkips continues drilling TRQ |
| TDS-8 TRQ rating                              | 95 ftkips intermittent TRQ |