"ADP” LLC works in close cooperation with Dirill Pipes LTD

“ADP” LLC offers:

- Light-alloy aluminum drill pipes of improved dependability (LAIDP);
- Standard products development to the needs of the Customer;
- New products development;
- Engineering support (services in design of drill strings; practical recommendations for application of LAIDP while drilling deep, ultra-deep, vertical, directional and horizontal oil and gas wells).
Light alloys while drilling oil and gas wells

While drilling deep, ultra-deep and especially horizontal wells it is extremely important to ensure high operational reliability of drill string, to reduce its stress-strain state and to ensure trouble-free operation at extreme loads and high temperatures. Drill string assembly and its weight significantly affect the technical and economic parameters of well drilling process, the behavior of resisting forces and specify the level of load in the parts of a drilling rig.

Aluminum alloys possess several valuable physical and mechanical properties that favorably distinguish them from steels which are a traditional material in drill pipe production. The following should be referred to the basic properties of aluminium alloys:

- Low specific weight;
- Reduced modulus of longitudinal elasticity and shear;
- Workability in pipe production using extrusion process;
- Corrosion resistance in aggressive environment and, first of all, in $\text{H}_2\text{S}$ and $\text{CO}_2$;
- Non-magnetic and vibration resistance properties;
- High rate of weigh reduction in solutions of various density;
- Easy drill-out process (i.e. possibility to remove by drill bits and mills).

These properties of aluminium alloys specify the basic efficiency in LAIDP application in drill strings while constructing oil and gas wells.

**Low specific gravity** provides essential reduction in drill string weight, reduces the lateral loading, which, in turn, results in decrease of friction forces. It is well-known, that the basic limitations in reaching maximum length of ultra long wells are the high values of axial loads during drill string POOH and sticking elimination by power methods, high torque during drill string rotation and complexity in providing designed WOB while drilling, due to high friction forces. Taking into account the weight of the steel tool joint, LAIDP in air is almost 2.5 times lighter than a steel pipe of similar type and size. In a drill mud due to the effect of weight reduction factor, this difference is even bigger. At the same time LAIDP’s strength properties are only 1.5 times lower than the properties of similar steel pipes. This difference in weight parameters, in friction forces and in strength also defines the basic efficiency of LAIDP application. So, e.g., while drilling a deep deviated well at the design depth of 8000 m the designed POOH force with steel pipes is equal to 2605 kN (585627 lbf), while with the combined string containing LAIDP its only 1104 kN (248189 lbf). The torque to rotate the steel string at 80 RPM is equal to 23.2 $\text{kNm}$ (17111 lbf-ft), but equals to 12.2 $\text{kNm}$ (8998 lbf-ft) with LAIDP.

Very often the drillers share the erroneous opinion, that higher strength properties of steel pipes compared to the same with aluminium ones provide an opportunity to apply higher axial loads and torque to the stuck-in well section. This statement is fair, but only with depths of up to 3000 – 3500 m (9840 – 11480 ft). With higher depths the capacity of steel pipes strength is spent to overcome the forces related to its own weight and friction. In ultra long wells only the use of LAIDP enables to apply higher load and torque to the stuck-in section.

**Modules of longitudinal elasticity and shear** for aluminium alloys, which characterize material plasticity, level of applied stresses and its resistance against alternating bending loads, is almost three times less than with steel. This gives possibility, while using LAIDP, to reduce the general level of stresses in drill string, increase the level of pipe fatigue resistance and to ensure the possibility of drilling wells with small borehole radius.
The significant advantage of LAIDP application is the corrosion resistance of aluminium alloys in aggressive environments and, first of all, the ones containing H₂S and CO₂.

Taking into account the fact that LAIDP has a steel joint and the fact that steel is known as a subject to corrosion in H₂S environment, there is a question on stability of LAIDP in these conditions.

No doubt, LAIDP steel joints are also subject to corrosion, but LAIDP application practice while drilling in high H₂S environment has shown, that in these conditions the steel joints are corroded at a significantly lesser rate, than with steel pipe. It is rather difficult to explain this phenomenon, but there is an assumption that aluminium pipe carries out a role of anode protector for the pipe steel tool joint, which reduces the level of its corrosion damage.

**Non-magnetic and vibration resistance properties** of aluminium alloys allow to apply Light Alloy Integral Joint Drill Pipe (LAIJP) in the lower section of a drill string to perform magnetic geophysical studies without drill string POOH. The application of thick-walled LAIDP in BHA together with steel pipes reduces general level of BHA vibrations. Besides, heavy-wall integral joint drill pipes of aluminium alloys are used as non-magnetic housings for telemetry systems and as non-magnetic drill collars.

During drilling operations it becomes necessary to set cement bridges and to install casing liners with drill pipes. While performing these operations the cement slurry in many cases comes above the drill string shoe and sticks it in the well. The operation to pull out the stuck-in drill string is a long one and is referred to as a well problem. Usually this problem is eliminated by drilling-out (milling) of the stuck pipe section by specific mills. In case LAIJP's were used for cementing the lower section of drill string, this problem becomes significantly simpler, since aluminium pipes may be easily drilled out by an ordinary roller cone bit at ROP 15-20 m/hr.

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Units</th>
<th>Parameters</th>
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<tr>
<td>System and type of alloy</td>
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<td>Al-Cu-Mg</td>
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<tr>
<td></td>
<td></td>
<td>D16T</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Al-Zn-Mg</td>
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<td></td>
<td></td>
<td>1953T1</td>
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<td>MPa (Psi)</td>
<td>460 (65 300)</td>
</tr>
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<td></td>
<td></td>
<td>530 (75 300)</td>
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<tr>
<td>Yield strength, min (0.2 % shear method)</td>
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<td></td>
<td></td>
<td>480 (68 200)</td>
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<td></td>
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<td>2820 (176)</td>
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<tr>
<td>Relative elongation, min</td>
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<td></td>
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<td>Relative reduction of area, min</td>
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Serial LAIDP manufacturing

Light Alloy Drill Pipe of Improved Dependability (LAIDP) are used for drilling oil and gas vertical, directional and horizontal wells using mud motors, rotary and combined drilling procedures.

The growth in well depth during the drilling phase reduces the time share for deepening the bottom-hole and increases the timing for trip operations for replacement of rock-destructing tools. This also complicates the control of well problems and makes the emergency fishing jobs more complicated. In these conditions the application of LAIDP gives the greatest effect.

Application of LAIDP with improved resistance to alternating loads and high corrosion resistance considerably simplifies the objective to drill deep and ultra long wells and increases the efficiency of drilling process.

At present more than 500,000 meters (1,430,000 ft) of LAIDP are successfully operated in Western Siberia in drilling inclined and horizontal wells.

“ADP” LLC has developed the production of the complete range of drill pipes according to ISO 15546.

The following is used in manufacturing of LAIDP:
• Aluminium blank pipes of alloys D16T or 1953T1
• Pipe tool joints of steel 40XMFA or 40XN2MA with threads corresponding to API standard

Base pipe length is equal to 12200 mm (40 ft); upon the Customer’s demand it can be reduced down to 8300-9600 mm (27.2-31.2 ft).

LAIDP are produced with internal and external upset ends as well as protective thickening in the middle of the pipe body in order to reduce the intensive pipe wear. Spiral Ribbed LAIDP provide improvement in the removal of cuttings from flat and horizontal borehole sections, the drill string longitudinal stability and delivering designed weight on bit, reduction of the possible differential pressure sticking of pipes.
The connection features trapezoidal taper thread TT with relieving stabilizing shoulder and stop face. The assured shrink fit by thread, stabilizing shoulder and stop face in «pipe – tool joint» connection is accomplished with «hot assembly» method. The stabilizing shoulder partially relieves the thread and improves the connection fatigue strength by 60–80% compared to the standard triangular thread connection.

LAIDP connection

<table>
<thead>
<tr>
<th>Pipe size</th>
<th>Pipe length, mm</th>
<th>Wall thickness, mm</th>
<th>Nominal diameters, mm</th>
<th>Tool-joint dimension, mm</th>
<th>Type of tool-joint thread</th>
<th>Weight of pipe with tool-joint in air, kg</th>
<th>LAIDP with protective thickening</th>
<th>Protector dimension, mm</th>
<th>Weight of pipe with tool-joint in air, kg</th>
<th>Tensile ultimate load, kN</th>
<th>Ultimate Torque, kN*m</th>
<th>Max. internal pressure, MPa</th>
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<td>178</td>
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<td>147</td>
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<td>147</td>
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<td>168х11</td>
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<td>168</td>
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<td>68/100</td>
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</table>
New products development

Flush-joint, light-alloy, hydrogen sulfide corrosion-resistant casing LOT 178 x 14 and tubing LNKT – 90 x 10.5 were developed by Akvatik-DP specially for Bayandyskoye oilfield. The major problem of this field is high level of H₂S and CO₂ presence in formation fluids. Prevalence of such aggressive conditions set special requirements for well construction, casing, completion type, wellhead, BOP and drilling equipment, as well as for locations of drilling equipment.

The assessment of stress and strain state of the threaded connections under different load conditions involved analytical calculations with finite elements analysis. Based on calculations, the recommended makeup torque was determined, and stress-strain state was evaluated for cases of application of sole strain, internal pressure, or their combination. The make-up torque assessment was performed by modeling geometrical radial standoff at the connection. The calculations determined an optimal make-up torque of 8000 Nm for LOT 178х14 and 3800 Nm for LNKT 90х14.

To verify the calculated values and evaluate operational reliability of the designed casing pipes, a number of bench tests for full-sized samples was carried out. The tests were run on tailored stands at Krylov Research Institute in St. Petersburg and included the following:
- Durability test at internal pressure;
- Endurance test using 1.5x operational tensile load, with concurrent internal pressure;
- Critical tensile fracture load test;
- Pressure test at internal fracture limit;
- Pipe collapse test check at critical external pressure;
- Thread joint collapse test at critical external pressure.

The tests have also been used to study corrosion properties of the alloy in such operations as well cementing and bottomhole acid treatment.

In January 2011 the casing string was successfully run in a hole to target depth and cemented. A tentative cumulative perforation was made on 1 meter of pipe, and a seisviewer analysis showed that such method of perforation was suitable for the purpose. After this, perforation was done on the whole oil-bearing stratum and the bottom-hole area was treated with sulfamic acid.
The existing methods of drill string assembly design, especially the design of drill strings containing LAIDP, do not take fully into account the specific conditions of the pipe function in a borehole. Among the factors which are not properly considered are: actual values and the distribution along the drill string of longitudinal drag forces while the drill string is rotated and tripped in the borehole, values of maximum compression forces causing the loss of longitudinal stability in some sections of the drill string as well as loss of strength characteristics of aluminum alloy and working parameters of LAIDP during high temperature applications.

LAIDP possess a specific range of mechanical properties and physical characteristics, and their application technology is quite different, when compared to steel drill pipe (SDP). That is why the design and analysis of drill string containing ADP differs from the commonly used methodology of drill string design using SDP.

The design and analysis of drill string are divided into the following stages:

- Selecting BHA components;
- Deciding the size of drill pipe required for the drill string;
- Selecting appropriate drill pipe material for each section of the drill string;
- Determining required mechanical properties and physical characteristics of drill pipe materials;
- Performing static calculation of the drill string assembly;
- Calculating fatigue resistance and operational life of drill pipe and tool joints;
- Service calculations which include estimation of:
  - Allowable loading parameters while drilling and tripping;
  - Ultimate loading parameters while eliminating emergency situations;
  - Hydraulic pressure losses in well circulation system;
  - Elastic elongation of drill string, taking into account all loading factors and well temperature distribution along the length of borehole;
  - Allowable hook loads while pulling out the drill string.

For the purpose of optimizing drill string assembly design and ability to perform analysis when in stress-strain state, Akvatik – DP uses a proprietary software program 3-DDT, which provides design and verification calculations of drill string containing ADP.
As a sample, we show comparative 3-DDT calculations for selecting drill string assembly for drilling the ERD well in Yuzhno-Astrakhanovskoe field (Sakhalin) to the total depth of 8300 m. Two versions were evaluated, one with the use of steel drill pipe only, the other containing mostly ADP with some SDP.

## Comparable calculated loading parameters of drill string in Yuzhno-Astrakhanovskoe field

<table>
<thead>
<tr>
<th>Drill string assembly version</th>
<th>Steel drill string</th>
<th>Drill string with LAIDP</th>
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</thead>
<tbody>
<tr>
<td>Weight of drill string in the air, kN</td>
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<td>2121</td>
</tr>
<tr>
<td>Estimated weight of drill string in mud, kN</td>
<td>2620</td>
<td>1377</td>
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### Rotary drilling

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Steel drill string</th>
<th>Drill string with LAIDP</th>
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</thead>
<tbody>
<tr>
<td>Hook load, kN</td>
<td>475</td>
<td>306</td>
</tr>
<tr>
<td>Torque on kelly bushing, kN*m</td>
<td>49</td>
<td>27.8</td>
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<tr>
<td>Minimum safety margin while drilling</td>
<td>2.09</td>
<td>2.61</td>
</tr>
<tr>
<td>Buckling safety margin</td>
<td>1.73</td>
<td>1.25</td>
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<tr>
<td>Hydraulic losses, MPa</td>
<td>14.5</td>
<td>13.7</td>
</tr>
</tbody>
</table>

### Running in with rotation 40 RPM

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Steel drill string</th>
<th>Drill string with LAIDP</th>
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<tbody>
<tr>
<td>Hook load, kN</td>
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<tr>
<td>Torque on kelly bushing, kN*m</td>
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### Running out without rotation

<table>
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<th>Drill string with LAIDP</th>
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<td>Hook load, kN</td>
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<tr>
<td>Minimum safety margin</td>
<td>2.03</td>
<td>3.22</td>
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</table>
Advantages of LAIDP

Generalization and analysis of extensive LAIDP practical application have allowed to reveal essential technical and economic advantages of their use in comparison with steel pipes:

- Increase in rilling depths from drill rigs of identical load capacity;
- Reduction in stress-strain state of drill string;
- Reduction of tripping time;
- Reduction of power consumption to drill a well caused not only by significant drop in weight of a drill string, but also by improved (if compared to steel drill pipes) LAIDP hydraulic characteristics, as well as by reduction in operating costs due to the decrease of the expense of fuel and lube consumption, ropes, braking pads, time reduction required to repair drilling rig equipment;
- Reduction in transportation costs especially while transporting the pipes to remote locations;
- Improvement of drill crew working conditions.

“ADP” LLC together with Dirill pipes LTD carries out industrial manufacturing and commercial supply of LAIDP to Russian drilling companies since 2004. Along with the distribution of pipes “ADP” LLC provides the following extra services: choice of rational pipe size-type as per the Client’s needs; calculation and recommendations for drill string assembly, development of practical recommendations for drill pipes operation.

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