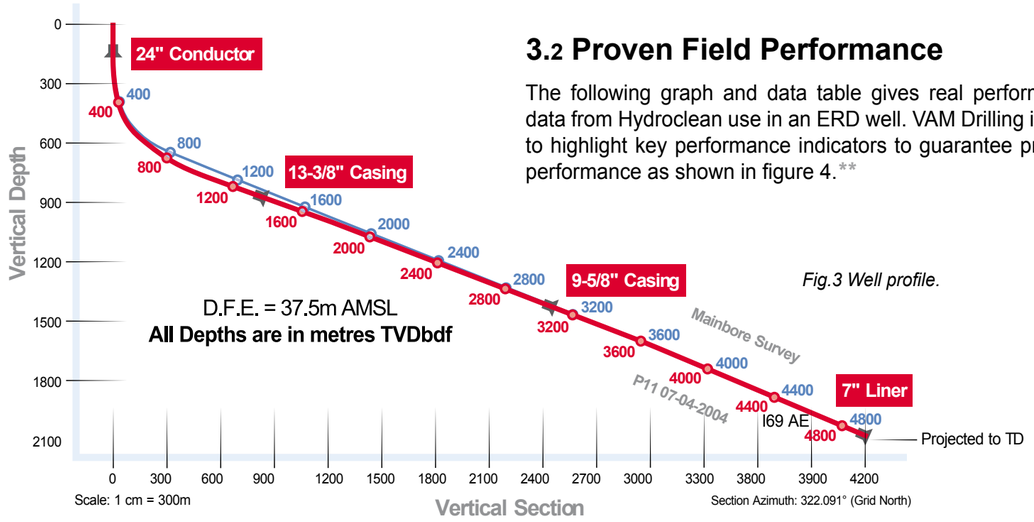

Fig.3 Well profile.

3.2 Proven Field Performance

The following graph and data table gives real performance data from Hydroclean use in an ERD well. VAM Drilling is able to highlight key performance indicators to guarantee product performance as shown in figure 4.**

1st Performance Class **Cleaning Efficiency KPI i's:**	
Increase cutting size indicator	+14%
Decrease circulating time indicator	-52%
2nd Performance Class **Time saving KPI i's:**	
Decrease in tripping time indicator	-49%
3rd Performance Class **Operational Safety KPI i's:**	
Decrease in TD friction factor	-60%
4th Performance Class **Well Bore Quality & Stability KPI i's:**	
Decrease in backreaming time indicator	-75%

Fig.4: Achieved results obtained with Hydroclean systems.

4. Conclusion

Hydroclean is the best available drill string system for improving both hole-cleaning and induced frictional loads caused by cuttings generated though drilling and tripping.
More than just trouble shooting devices, Hydroclean systems must be considered as performance drilling systems designed for optimizing drilling parameters.

The combination of Hydroclean functional properties is unique:
- Scooping and eroding cutting beds,
- Recirculation of all solid particles in high velocity zone of hole section,
- Hydrobearing (fluid bearing) effects at all dual OD bearing points between bore-wall and drillstring.

With Hydroclean there are three powerful operating parameters providing significant increases in efficiency and helping to achieve all fundamental drilling performance, safety and wellbore quality requirements:
- The flow rate value,
- The rotational speed,
- The axial displacement speed.

Marked improvements linked to Hydroclean use can be measured in these 4 key performance areas:
- Cleaning efficiency,
- Time saving,
- Operational safety,
- Wellbore quality.

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Maximizing Drilling Efficiency in High-Angle Wells with New Hole Cleaning - Torque & Drag Reduction Systems
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Understanding how innovative hole-cleaning solutions can improve your performance at every turn

Efficient cuttings transport is important when drilling highly deviated and horizontal wells. In directional wells, drilled cuttings tend to accumulate on the lower side of the annulus and form a thick bed of cuttings when the flow velocity becomes insufficient to suspend particles. In high-angle and horizontal boreholes particularly, the formation of a thick cutting bed can give rise to numerous difficulties such as lost circulation, differential sticking, high torque and drag.
Thus, **hole-cleaning becomes an important factor in Extended Reach Drilling (ERD) wells**.

Flow rate is considered to be the main component of hole-cleaning as it provides the only physical means of achieving a decrease in and the transportation of solid particles. Achieving the proper flow rate is made difficult because of two factors:
- Improper flow rates can degrade the hole, cause hole enlargement or caving, produce equipment wear or create high standpipe pressure,
- In many instances, the required levels of flow rate values will not be achievable because of rig capability or maximum equivalent circulating density (ECD) values afforded by the formation.

Thus increasing the flow rate, necessary on ERD wells, can improve hole-cleaning within certain limitations but care must be taken to avoid worsening the well situation.

Rotational speed (RPM) is the second most well-known, and sometimes misunderstood, hole-cleaning component.
Although increasing pipe rotation improves cuttings agitation, rotational speed of the string has a limited effect on cuttings recirculation and cannot achieve a completely clean hole. However, increasing rotational speed increases the risk of drill string fatigue and dynamic vibration. It also increases the risk of wellbore damage and caving. Additionally, high RPMs can negatively impact ECD values.

Finally, **mud rheology** plays a significant role in hole-cleaning as it impacts cuttings suspension in the flow. Mud rheology is not an optimization parameter because the mud properties are adapted to the formation and well profile.

Vallourec Group

1. HOLE-CLEANING CHALLENGES

When considering the cleaning modes for drilling and tripping, there are three distinct stages that characterize the hole-cleaning process:

- Scooping stage: Solid particles on the low side of the hole must be mechanically lifted in order to decay the cuttings bed and decrease its overall height,
- Recirculation stage: The lifting effect at the scooping stage is not sufficient to ensure cuttings bed erosion. Once lifted, solid particles must be driven all the way up to the high side of the hole, where fluid velocities are at a maximum,
- Transportation stage: Regardless of the energy input exerted on the solid particles during the recirculation stage, after certain distance, cuttings will eventually resettle to the low side of the hole. This phenomenon is exacerbated in ERD wells. The transportation stage is designed to establish a "conveyor belt" that will continuously transport cuttings from downhole to the surface.

Therefore, an efficient hole-cleaning process is the combination of a complete bed erosion action with a "cuttings conveyor belt" mechanism that will transport the maximum amount of solid particles to the surface. In order to optimize hole-cleaning, a complete hole-cleaning system must be in place.

However, even with a fully optimized system, it may still be impossible to clean the hole sufficiently to achieve the desired drilling performance. A "mechanical" boost of the system is required.

2. HYDROCLEAN: YOUR SOLUTION TO HOLE-CLEANING CHALLENGES

2.1 Hydroclean Design

Hydroclean drill pipe and heavy-weight drill pipe is a new-generation hole-cleaning and torque management tool that provides that "mechanical" boost. Integrally machined on full-length joints, Hydroclean upsets have specially designed grooves or blades. In these bladed sections, the combination of rotational speed, flow rate and the specially designed angles produce a number of hydro-mechanical effects that significantly improve hole-cleaning.

The Hydroclean upset is composed of two distinct sections:

- The hydro-cleaning zone: provides optimum scooping effect while the variable helix angle accelerates the lifted particles and re-circulates them in the upper zone of the hole where fluid velocity is at a maximum,
- The hydro-bearing zone: Protects the wellbore from the blades and provides optimized sliding properties.

Particle transportation is ensured by creating a "cuttings conveyor belt effect".

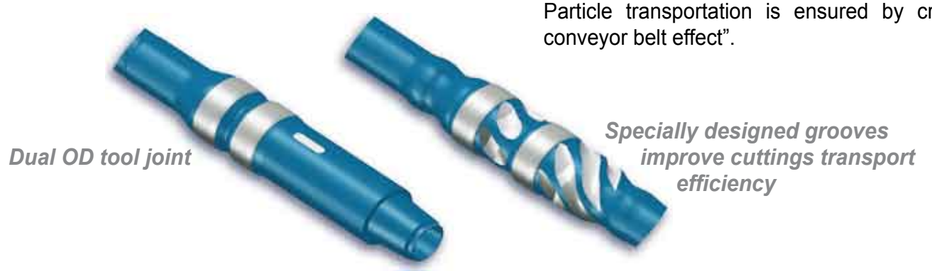

Fig.1 Patented features.

2.2 Hydroclean Qualification

Two testing programs were carried out in order to qualify the hole-cleaning efficiency of Hydroclean. The results presented below were obtained in specific drilling conditions and allowed for the development of analytical models which help us to estimate the benefits of Hydroclean for other wells characteristics and drilling parameters.

Fig 2: Tulsa University flow loop used for qualification test.

2.3 Results

Based on the test results the following conclusions can be drawn:

1. Using Hydroclean reduces significantly the time to clean the hole and final weight of cuttings in the testing section.
2. Hydroclean enhances and improves hole-cleaning in horizontal wells. The improvement is more significant with a limited RPM (typically around 80 RPM).
3. Bed erosion test: Depending upon operating parameters, Hydroclean tools may be used at a flow rate 30 to 50% less than that used for standard equipment and still achieve a similar cutting bed height or weight. This represents a potential decrease of pressure losses (ΔP) from 60 to 75%, assuming the pressure loss formula: $\Delta P = kp \times Q\ 1{,}85$
4. Equilibrium bed height test: As for bed erosion tests, depending on operating parameters, flow rate (Q) may be reduced by 20 to 30%, from that used on standard equipment, which represents a potential decrease of pressure loss from 40 to 60%.*

2.4 Placing Hydroclean

Placement of Hydroclean in the drill string follows simple and straightforward rules based on diversified field experiences. The key principle is that there must be Hydroclean joints located from the top of the BHA up to the 30 / 40° inclination zone of the well profile spaced at regular intervals known as Hydroclean placement spacing. Such assemblies will produce a Hydroclean cuttings transportation conveyor belt effect from top of BHA up to the non-sedimentation zones.

The conveyor belt effect is the same whether in an open or cased hole. Other benefits of this pipe profile include torque and drag reduction, improved sliding behavior of the drill string, better weight on bit transmission, wellbore protection, stuck pipe prevention and casing and equipment wear prevention. Field experience has proven that the most common spacing will be two or three standard drill pipe stands between two Hydroclean joints.

3. HYDROCLEAN FIELD PROVEN & ASSOCIATED SERVICES

3.1 Field Experience

More than 500 Hydroclean operations have been carried out worldwide, confirming the superior performance of this technology in highly deviated wells. Our clients include some of the world's largest international oil companies, drilling contractors and rentals:

- **StatoilHydro,**
- **Total,**
- **ExxonMobil,**
- **Chevron,**
- **KCA Deutag,**
- **COR,**
- **Weatherford,**
- **TNK-BP.**

* **Experimental Studies on the Effect of Mechanical Cleaning Devices on Annular Cuttings Concentration and Applications for Optimizing ERD Systems**
Co-Authors: Ramadan Ahmed, Munawar Sagheer, Nicholas Takach, Reza Majidi, Mengjiao Tu, and Stefan Miska, University of Tulsa, and Christophe Rohart and Jean Boulet, VAM Drilling