Operations planning for optimal hole cleaning

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Table of contents

Operations planning for optimal hole cleaning .......................................................... 1
   Table of contents ........................................................................................................ 2
1. Operations planning for optimal hole cleaning ......................................................... 3
   Introduction ............................................................................................................... 3
2. Hydraulics and wellbore cleaning problems .............................................................. 4
   2.1. Hole Cleaning/Cuttings Transport ...................................................................... 4
   2.2. Lost Circulation ................................................................................................. 6
   2.3. Well Control ...................................................................................................... 7
   2.4. Poor Cement Jobs ............................................................................................. 8
   2.5. Non-Optimum Operation of Downhole Tools and Bits ...................................... 9
3. Other Considerations ................................................................................................. 10
   3.1 Temperature/Pressure Effects on Mud Rheology .................................................. 10
   3.2 Effect of Polymer Additives on Mud Rheology ..................................................... 10
4. Hydraulics/Cleaning objectives to meet Well Design .............................................. 11
5. Operational guidelines .............................................................................................. 12
   5.1 Hole cleaning variables ...................................................................................... 12
   5.2 Further Well Planning considerations ................................................................. 13
   5.3 Equipment implementation and design considerations ....................................... 15
   5.4 Mud properties planning and management ...................................................... 16
   5.5 Drilling Practices & operating guidelines ......................................................... 18
   5.6 Rig Site Indicators ............................................................................................. 20
1. Operations planning for optimal hole cleaning

Introduction

Drilling fluid hydraulics and hole cleaning is an integral part of the practical processes required for planning and drilling a well. The use of hydraulics and hole cleaning therefore goes beyond calculating pump pressures and jet nozzle selection, although these functions are critical to optimum bit performance.

The primary use of drilling hydraulics and efficient, effective wellbore cleaning should be considered more as **Preventive Medicine** - to design, engineer and drill a well, with careful attention applied to hydraulics and hole cleaning aspects, to reduce or eliminate potential problems before they occur.
2. Hydraulics and wellbore cleaning problems

The hydraulics and hole cleaning related problems typically encountered in drilling and completing a well may be broken down into the following broad categories:

1. hole cleaning/cuttings transport
2. lost circulation
3. well control
4. poor cement jobs
5. non-optimum operation of down-hole tools and bits

2.1. Hole Cleaning/Cuttings Transport

Drilling problems

Poor hydraulics and wellbore cleaning may cause the following drilling problems.

- inadequate cuttings evacuation from bit
- lower than expected drilling performance
- grinding of cuttings into fines at bit
- mud and solid control maintenance difficulties
- increased ECD
- increased mechanical torque and drag - especially for deviated holes
- over pull in the wellbore due to ‘fines’ cuttings beds that often result in
- unnecessary backreaming
- stuck pipe
- fishing
- side-track of well.

Vertical wells

It is important to note that vertical wells are the easiest to clean where cutting beds will not form but where cuttings concentration and slip velocity considerations are perhaps the most important considerations when evaluating wellbore cuttings transport efficiencies.

Higher angle wells

In angles wells e.g. > 30degrees, hole cleaning and cuttings build up in the annulus is highly dependent upon hydraulic conditions. This is especially true in more deviated or horizontal wellbores.

Hole cleaning variables

Proper wellbore cleaning depends upon a combination of factors including mud properties, cuttings shape and size, cuttings concentration, annular flow regime (laminar or turbulent), annular geometry, formation erosion (washouts) due to annular turbulence and mud formation interaction.

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Operations planning for optimal hole cleaning

Flow loop, experimental and field validation tests indicate that, in general;

- Vertical wellbores are easiest cleaned with laminar flow and mud with higher yield values,
- Deviated wellbores are cleaned best with lower viscosity mud in turbulent flow. *Although often turbulence cannot be achieved due to wellbore size, length and pumping and/or flow equipment constraints.*

Since most deviated wells consist of vertical sections as well as deviated sections, the hydraulic and hole cleaning parameters must therefore be factored into the initial well design to enable proper selecting of casing sizes and casing points to optimize hydraulics and hole-cleaning throughout the well.

Proper hydraulics and hole cleaning criteria should thus be considered when selecting the minimum and maximum pump flow rates, wellbore size, cuttings generated, rates of penetration, required mud properties, casing size and casing point to obtain optimum drilling, flow and hole cleaning conditions in all annular sections, if possible.

This in turn requires knowledge of the laminar/turbulent transition for annular geometry (*eccentric or concentric*) and the effect of temperature and pressure on the local mud properties at the well depth of interest.

The most critical aspect for hole-cleaning is perhaps to understand the laminar, turbulent transition for annular geometries. The transition to turbulence in annuli is not as sharply defined as for pipes and depends upon the annulus diameter ratio and geometry *e.g. eccentric or concentric* as well as the mud properties.

Little information is available for annular transition for non-Newtonian fluids and even less for eccentric geometry.
Operations planning for optimal hole cleaning

2.2. Lost Circulation

Causes

Lost circulation may be caused by

- drilling into highly permeable formations
- excessive surge pressures during pipe trips
- formation fracture gradient exceeded e.g. due to excessive annular pressure friction loss
- increased ECD resulting from poor bit bottom hole cleaning and/or inadequate hole cleaning

Total losses

Loss of surface returns is in itself a serious drilling problem. Lost circulation may also result in other problems such as well control or inadequate hole-cleaning. At the least, the economic loss of costly drilling fluids may be significant.

Annular pressure and ECD management

Annular pressure losses (APL) are usually small, in conventional sized wells, and errors in calculating APL may be acceptable when calculating total pump pressures or selecting jet nozzles.

The APL is a significant factor when calculating equivalent circulating density (ECD) however, and the capability to calculate accurately the ECD at any well depth is an important factor in well design and analysis.

Current calculations for APL assume concentric geometry and smooth pipe, both of which are not valid, in general. The actual geometry is probably neither fully concentric nor eccentric, but a reason able approximation for conventional wells is to assume eccentric unless centralizers are present.

The wall roughness may be a significant factor in ECD calculations. Since roughness effects are felt only in turbulent flow, this is especially important for highly deviated or horizontal holes where turbulence is required for hole-cleaning.
2.3. Well Control

Well control is another serious drilling problem and is a prime example of the importance of the Preventive Medicine approach e.g. It is much preferable to prevent the occurrence of a kick than to control it after the fact.

If one drills into an unexpected, highly pressurized gas zone little can be done to prevent a kick. The driller then must rely on his kick detection equipment and standard kill procedures e.g., driller’s method, wait/weight to regain control of the well.

Standard kill procedures

In standard kill procedures, hydraulics calculations are not usually a significant factor in the kill procedure since the slow pump pressure (SPP) is recorded each tour at the pre-determined kill flow rate. Also, the annular pressures during the kill are primarily determined by the amount and distribution of gas in the wellbore and not friction pressures.

Non-standard kill procedures

Non-standard kill procedures e.g., relief well, reverse kill may be required in extreme cases and accurate hydraulics may be required. In a relief well, for example, the required pump pressure and kill flow rate must be calculated accurately to insure that the available pumps are sufficient to provide the kill flow rate without exceeding its maximum pressure limit. The SPP cannot be used because the geometry, and probably the kill mud also, is different.

Secondary effects

Kicks also may occur, however, as a secondary effect of other problems.

Lost circulation has been discussed above. If a total loss of returns occurs, the reduction in hydrostatic pressure in the annulus may be sufficient to permit a kick from a usually benign formation. Such kicks may be preventable if accurate annulus pressure loss calculations are available to permit better estimates of ECD while drilling.

Swabbed Gas, swabbed into the wellbore during pipe trips. Current swab, surge calculations do not account for annular roughness or downhole effects of mud properties and may under-predict the magnitude of the swab pressures.
2.4. Poor Cement Jobs

Causes

Poor cement jobs may be caused by
- highly eroded formation
- large formation washouts
- enlarged or oversized wellbore
- poorly cleaned formation wall prior to cement job

Cementing considerations

A successful cement job depends upon in-gauge clean, and relatively uniform borehole wall for optimum cement bonding.

Poor hydraulics and hole-cleaning during drilling of a well may prevent ideal wellbore condition from resulting. *E.g. Formation erosion due to excessive turbulence will produce larger wellbore diameters and may produce wellbore enlargements and/or washouts*. Drilled, regrout, fines, resulting filter cakes and gelled mud build-up on the wall is also harder to remove in larger holes, because of lower turbulence, and may prevent good cement bonding. The pre-flush may not have the velocity and turbulence required and may result in poor wellbore cleaning and wellbore wall filter cake cleaning.

Spacer design

While cementing the casing, spacer fluids are designed to be circulated in turbulent flow to remove any material missed by the pre-flush. These fluids usually have properties, both rheology and density, between the mud and cement. The ability to determine the L/T transition is critical to determine the proper pump rate to ensure fully developed turbulence.

Cement job simulations

The cement job is continually monitored via a computer program. The observed surface pressures are compared with those predicted simulations performed to ensure that the job is proceeding as designed.

The ability to accurately calculate pipe and annular friction losses is critical for the application of any cement programs.
2.5. Non-Optimum Operation of Downhole Tools and Bits

Optimum operation of downhole tools requires that the pressure drop across the tool be within the range of operation specified by the manufacturer. To select the pump flow rate while insuring that the required pressure is available at the tool requires accurate calculation of the parasitic losses in the drillstring and annulus.

The hydraulic requirements for optimum performance from a drill bit are not well defined. Laboratory research, backed by preliminary field tests, has shown that increases in the turbulence generated by the bit nozzles beneath tri-cone bits improve penetration rates.

The cooling efficiency and cuttings removal efficiency of PDC bit nozzles are important criteria to be considered when designing bit nozzle placement and orientation geometries. Tests have shown that under certain conditions, jets flowing from nozzles in PDC bits are sometimes directed away from the cutters they were intended to cool and clean.
3. Other Considerations

3.1 Temperature/Pressure Effects on Mud Rheology

Current hydraulic calculations assume that the mud rheology remains constant at the surface measured values. Both the mud rheology and density vary with depth, in some cases significantly.

The most significant effect is generally seen near the bit where the temperature is greater. This is also the location where most of the swab/surge pressure is developed, and swab/surge calculations may be affected significantly. Since a large fraction of the annular pressure loss also occurs around the drill collars. ECD may be significantly affected.

Perhaps more significant than effects on pressure loss is the effect on the true yield value (not necessarily the same as the YV calculated from the 600 and 300 RPM Farm data) for the mud. Significant reduction in the yield value downhole, although the surface value is satisfactory for cuttings removal, could create hole cleaning problems. Significant increases in mud rheology could create high APL and lost circulation problems.

3.2 Effect of Polymer Additives on Mud Rheology

High molecular weight polymers are known to be drag reducing agents that reduce the turbulent friction loss below that of the fluid to which they are added. There are many unanswered questions about polymer mud’s that must be resolved if their effect is to be accounted for.

Does the shearing action of the mud pump and bit nozzles affect the drag reducing action of a polymer? If so, how much? How long must the mud be sheared to effectively eliminate any drag reduction effect?

Since drag reduction is theorized to be a result of the length and flexibility of the long-chained polymers, how do mud solids interact with the polymer? Do they bind to the polymer, reducing the flexibility and energy range capacity? If so, do all solids interact the same way and to the same degree?
4. Hydraulics/Cleaning objectives to meet Well Design

The objectives for hydraulic wellbore cleaning design of a well can be summarized in a few rules.

1. Maintain vertical sections in laminar flow for hole cleaning and minimum wellbore enlargement e.g. flow rate should be maximum possible without transition to turbulence for best cuttings transport,
2. Maintain highly deviated or horizontal sections in turbulent flow for maximum hole cleaning (if possible.) The flow rate should also be the minimum required for ROP's anticipated, turbulent flow to minimize hole erosion, washouts and ECD,
3. Select jet nozzles to optimize bit/bottom hole cleaning performance e.g. often a 3-4% reduction in flow rate can add several times this amount of energy to a bits drilling capability,
4. Do not allow a hole to be cleaned faster than it can be drilled. E.g. Instantaneous rates of penetration through highly drillable sequences often will need to be controlled to ensure adequate hole cleaning results,
5. Do not drill a hole that cannot be readily tripped out of. E.g. Data shows that prioritizing ROP and failing to clean holes is often a false economy that results in hole tripping, casing, and cementing loss that far outweighs what was gained while drilling.
6. Optimize mud properties for all sections drilled.

These objectives may not be attainable simultaneously unless the hydraulic design is considered during initial well planning, applied while drilling and reviewed post well.

In some cases, such as two vertical sections separated by a deviated section, complete optimization may not be possible. In that situation, the potentially most troublesome section should be given the highest priority. E.g. suppose for the deviated wellbore section selected that desired mud properties to clean the deviated section have been determined. The optimum casing size required to maintain laminar flow just below the turbulent threshold can then be determined for the vertical section.

If the mud viscosity is low, for turbulence in the deviated hole, a larger casing diameter may be required in the vertical section for laminar flow.

The additional well cost incurred for a change in well design to optimize the hydraulics must be compared to anticipated drilling problems and potential well savings resulting from reduced drilling problems.
Operations planning for optimal hole cleaning

5. Operational guidelines

5.1 Hole cleaning variables

Mud flow rate and Mud Properties are perhaps considered the two major variables to ensure effective and efficient wellbore solids removal, i.e. wellbore or hole cleaning.

They are however only part of a much more needed integrated planning, implementation and control processes to achieve the end result, i.e. a clean, smooth in gauge trouble free wellbore.

Other variables therefore if not fully examined and duly considered can result in a damaging operational effect, e.g. stuck pipe and hole problem prevention.

Hole cleaning variables to consider have been tabulated and qualified in the table 1. All these factors should be duly considered in the pre planning, well engineering drilling and post review of well operations.

Table 1 : Hole cleaning variables

<table>
<thead>
<tr>
<th>Hole cleaning (transport) variables</th>
<th>Major</th>
<th>Moderate</th>
<th>Minor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annular velocity*</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mud rheology</td>
<td>✓</td>
<td>✓ (high angle)</td>
<td></td>
</tr>
<tr>
<td>Bit &amp; bottom hole cleaning</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cuttings-size, shape, density</td>
<td></td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Mud weight</td>
<td>✓</td>
<td>✓ (water based)</td>
<td>✓ (OBM&amp;synthetic)</td>
</tr>
<tr>
<td>Pipe reciprocation</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Pipe rotation-mode, speed, effect</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Drillstring &amp; hole size</td>
<td>✓ (&lt;17 ½&quot; hole)</td>
<td>✓ (&gt;17 ½&quot; hole)</td>
<td></td>
</tr>
<tr>
<td>Hole and pipe eccentricity</td>
<td></td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Drilling rate</td>
<td></td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Drilling operation</td>
<td>✓ (Rotary)</td>
<td>✓ (Sliding)</td>
<td></td>
</tr>
</tbody>
</table>

* Annular velocity is determined by (flowrate, wellbore and drillstring geometry.)

In reality a compromise of all hole-cleaning variables, in the well planning, engineering and operational circumstances must be investigated and accounted for. Engineers must use well engineering design and planning tools, offset information, and consider specific rig and down
Operations planning for optimal hole cleaning

hole operational equipment aspects to be able to best develop the most suited drillstring / bottom-hole assembly design configurations to be run.

Wellbore sizes, angle, casing setting depths, downhole conditions and formation characteristics must also be suitably planned, engineered and accounted for. The following guidelines have therefore been compiled to support the cleaning of the wellbore in the well planning and operational phases of drilling operations.

5.2 Further Well Planning considerations

- **Trajectory** - The choice of well trajectory is often limited by other wells in the area, the choice of target and economics. Plan and consider the implications of choosing certain trajectories. *e.g. 17.5” holes at inclinations >55° are best avoided if possible.*

- **Hole angle** - Deviated wells will require higher annular velocities than Vertical wells

- **Hole size** - Minimise hole size where possible to maximise hole cleaning *e.g. 16” instead of 17 ½” increases annular velocity by approximately 20%, Plan large diameter hole sections closer to vertical.

- **Wellbore Stability** – Engineer and ensure best practices are utilised to maintain a gauged and consolidated wellbore.

- **Wellbore enlargement** - Every effort should be made in well planning to avoid enlargement of the open hole. *Mud weights, formation characteristics, fluid and drillstring dynamics are critical considerations to be accounted for in the planning process.* Study offset well data for signs of over gauge hole, which may need to be included in minimum flow rate calculations.

- **Pump rates** - Use hydraulic programmes to determine minimum flowrates to clean each section *(based on ROP, cuttings size & weight, wellbore angle, mud properties, BHA/Drillstring design etc.)* and maximum mud flow rates *(Equipment & pressure ratings available)*

  - **Minimum annular velocities** required to clean the open hole/ drillpipe sections. *This process is especially important in hole angles of over 30° when cuttings beds start to form.*

  - **Maximum annular velocities attainable** E.g. calculated from No. of mud pumps, liners required, surface equipment, large diameter dp (in open hole), restrictions in mwd / motor / collars etc.

  - As a rule of thumb guide, the annular velocity necessary to get cuttings moving in a well inclined at 30° is about 20% higher than in a vertical well.

  - Between 50° and 60°, the annular velocity needs to be about twice that in vertical holes.

- **Mud properties and flow rates** - should be planned to ensure the hole is cleaned as fast as it is drilled. This is a primary criterion (total pump capacity) to consider when selecting the rig.

- **Bit Hydraulics** - Select nozzles to balance ROP optimisation, bit / bottom hole cleaning and annular velocity available to remove solids from the hole.
Operations planning for optimal hole cleaning

- **Slide / Oriented drilling** – Plan to optimise use of rotary drilling. *Note; Type of bit and BHA selected for directional work can affect this significantly.*

- **Casing Programme** - Plan minimum rat-holes consistent with safe running of casing

- **Floating Vessels** - The use of a booster line is recommended when high solids’ loading in the riser and BOP’s is expected i.e. where annular velocities may be significantly less than optimum.

- **Planning Tools** - Use PC applications / Hole Cleaning Charts / Guidelines / Stuck pipe handbooks that are available.

- **Plan for typical operating conditions** - It is recommended that hydraulic and hole-cleaning simulations are run for each well. This enables mud properties and flow rates to be optimised to provide adequate wellbore cleaning in all sections of the well.

- **ECD’s in Higher angle and horizontal sections** – ECD increase over section length must be taken into account e.g. formation breakdown gradients will reaming the same in horizontal section. Critical circulating pressures, swab/surge must be accounted for in well planning considerations.

- **Hole-cleaning problems** do not necessarily result near total depth, but will often occur further up in the hole where enlargement or increase in casing diameters, reduce mud velocities. Simulation of cleaning efficiency at several points in the annulus can thus determine areas of inadequate cleaning.

### Table 2 : Typical flow rates

<table>
<thead>
<tr>
<th>Hole Size</th>
<th>Typical Flow Rates</th>
</tr>
</thead>
<tbody>
<tr>
<td>17 ½”</td>
<td>Aim for 1100 gpm +</td>
</tr>
<tr>
<td>12 ¼”</td>
<td>Typically 750 - 1150 gpm.</td>
</tr>
<tr>
<td>8 ½”</td>
<td>Aim for 500 gpm.</td>
</tr>
</tbody>
</table>

*Note:* It is important to calculate minimum flow rates required for hole and wellbore conditions, i.e. hole angle, casing setting depth, mud properties, anticipated ROP’s etc. If not achievable, then ensure that drillstring engineering, BHA design, drilling & tripping procedures are in place to best manage cuttings beds that may form.
5.3 Equipment implementation and design considerations

- **Surface equipment** - This covers rig pumps, flow lines and shakers. The surface equipment is essential for obtaining good hole cleaning.
- **Drillstring & Bottom hole assembly (BHA) design**
- **Time allocations** *(especially 'circulating hole clean' times)*
- **Correct mud gradient selection**
- **Casing setting depths**
- **Mud Pumps** - Determine flow rate and horsepower requirements for all critical sections.
- **Surface pressure losses**
- **Surface equipment** - 5000 or 7500psi rated
- **Drillstring components, BHA and drillstring design**
- **BHA** - Select simple BHA with high bypass area to assist tripping in & out of hole

In smaller hole consider running two jet bits vs. three to improve bottom hole cleaning and ROP. *(Two jets being less likely to plug than three smaller ones for same total flow area (TFA).*

- **On-line drillstring simulator** using data from drilling mechanics sub is capable of calculating the variations in friction factors and can provide early indications of wellbore cleaning problems.
- **Downhole torque and downhole WOB monitoring** has proved to be an important tool in qualitatively assessing hole cleaning efficiency. Trend analysis can indicate the condition of the hole while drilling, as well as the effectiveness of any remedial action such as reaming, circulating and wiper tripping.
- **Solids control equipment** – Ensure shakers are fitted with correct screens for section. Run centrifuges only as required.
- **Floaters.** The use of a booster line is recommended when high solids loading in the riser and BOP's is expected.
Operations planning for optimal hole cleaning

5.4 Mud properties planning and management

- **Oil-based and synthetic-based fluids** - mud-rheology used in the modelling process should be based on downhole conditions, not surface conditions.
- **Mud Chemistry** - Ensure chemical compatibility to prevent cuttings swelling.
- **Mud weight** - Increased mud weight provides buoyancy, reduces the effective weight of cuttings with effective transport occurring at lower annular velocities. Mud weight is governed by other drilling considerations (e.g. well control, wellbore stability and losses).
- **Mud gel** - Elevated low end rheology (i.e. high gels) assists in Hole Cleaning. It does this by preventing cuttings from settling into a cuttings bed.
- **Flow Regimes** - Generally use thick mud’s in laminar flow (unless ECD is critical)
- **Typical ranges of fluid properties for a selection of hole sizes** - are specified by either the Yield Point (based on Bingham Model) or the Power Law Index (n) as illustrated below.

**Table 3 : Typical range of fluid properties**

<table>
<thead>
<tr>
<th>Hole Size</th>
<th>Recommended YP Limits (lb/100 ft²)</th>
<th>Recommended “n” Range</th>
<th>Flow Regime</th>
</tr>
</thead>
<tbody>
<tr>
<td>17½”</td>
<td>28 Min</td>
<td>0.5 - 0.7</td>
<td>Laminar</td>
</tr>
<tr>
<td>12 ¼”</td>
<td>21 Min</td>
<td>0.5 - 0.75</td>
<td>Laminar</td>
</tr>
<tr>
<td>12 ¼”</td>
<td>5 - 10 Max</td>
<td>0.5 - 0.95</td>
<td>Turbulent*</td>
</tr>
<tr>
<td>8 ½”</td>
<td>22 Min</td>
<td>0.5 - 0.7</td>
<td>Laminar</td>
</tr>
<tr>
<td>8 ½”</td>
<td>5 - 12 Max</td>
<td>0.5 - 0.9</td>
<td>Turbulent*</td>
</tr>
</tbody>
</table>

**Note**: In general higher viscosity muds pumped in laminar flow are preferred. * May result in hole washout/enlargement especially around BHA components.

- **Mud Rheology** - Select mud’s with high YP/PV ratios and enhanced low shear viscosity.
- **Pump Rate** - Use hydraulics programmes to determine minimum mud flow rate
- **Drill pipe rotation** - is more pronounced in viscous muds and in smaller hole,
- **Hole cleaning pills** - Circulating mud properties must be optimised to provide adequate wellbore cleaning. Under certain conditions, it may be necessary to supplement wellbore cleaning with “viscous” pills. *Excessive use of pills should be avoided since they can contaminate the mud system.*

- Generally a high viscosity (and preferably high weight) pill is effective at removing accumulated cuttings.
- Low viscosity pills can also be effective in smaller hole sizes (12-1/4 inch and below).
- Low and high viscosity pills can also be pumped in tandem. The maximum volume of the pills should be based on hole size and changes in hydrostatic.
Similar improvements in hole cleaning have been achieved using lost circulation material (LCM) pills.

- **Viscous Pills** - Use only when essential. Take special care with low viscosity pills to maintain high flow rate.
- **Dense Pills** - Use only when essential. Limit volume to avoid fracturing formation.

Table 4: Recommended sweep size

<table>
<thead>
<tr>
<th>26&quot; &amp; 36&quot; Intervals</th>
<th>17½&quot;, 16&quot; Intervals</th>
<th>12¾&quot; Intervals</th>
<th>8½&quot; Intervals</th>
</tr>
</thead>
<tbody>
<tr>
<td>80 + bbl</td>
<td>60 + bbl</td>
<td>30 - 50 bbl</td>
<td>20 bbl</td>
</tr>
</tbody>
</table>

![Graph showing the effect of yield point on critical flow rate](image-url)

**Figure 1**: Effect of yield point on critical flow rate
5.5 Drilling Practices & operating guidelines

- **Vertical holes** - reciprocate rather than rotate the pipe during circulation prior to tripping - this helps remove cuttings from stagnant zones near the wellbore wall.
- **Vertical holes** - Poor wellbore cleaning is generally indicated by cuttings fill at the bottom of the hole.
  - **ROP** - Higher penetration require higher flow rates to clean the hole. Instantaneous ROP must be pre-determined and maintained to avoid overloading annulus with cuttings. Mud properties and flow rates should be adjusted to ensure the hole is cleaned as fast as it is drilled.
- **Pump Failure** - Stop drilling and circulate until full pump capacity is restored
- **Slide Drilling** – Orientate directional BHA to high side when wiping string and circulating. Consider rotary wiper trip after prolonged periods of sliding as hole cleaning conditions dictate.
- **Tripping** - Circulate the hole clean prior to tripping. a single bottoms up is not sufficient
- **Drags** – Abnormal drags should be attempted to be wiped out mechanically. If they persist on subsequent trips, a increase in mud weight may assist. Note: It is not advised to systematically ream, backream or circulate through trouble spots as this can result in deteriorating hole condition (instability, washout, enlargement that should be avoided if possible.)
- **Allowable drag** - Agree to a maximum allowable drags in advance with the Company Man. Do not go immediately to the maximum allowable drag, but work to this value progressively ensuring that the pipe is free in the opposite direction on every occasion.
- **Backream** - Avoid precautionary backreaming. Understand the nature and causes of any problems encountered on tripping and aim to prevent rather than cure e.g. by having to backream out of the wellbore. Even then; **Only backream when absolutely essential**
- **Pipe movement** - Avoid sudden mechanical or hydraulic shocks (swab and surge) which may cause cuttings to avalanche.
- **Control tripping rates** - to avoid pulling rapidly into a cuttings beds or causing excess swab/surge pressure.
- **Stop and circulate** - the hole clean if drags continually increase and cuttings beds are suspected.
- **Drill pipe rotation/reciprocation** - Will mechanically disturb cutting beds and assist hole cleaning. **Downward and stationary rotation is most effective rotating modes** helping to equalise fluid velocities on the low and high side of the hole. **Backreaming does not achieve this !**

The influence of drill pipe rotation is more pronounced in viscous muds and in smaller holes < 17 ½”. In cases of slide drilling, cuttings beds may form are more difficult to remove.
Operations planning for optimal hole cleaning

- Under these special circumstances, increased flow rate or changes in operation practices, wiping every stand to achieve normal drag may be necessary to improve cuttings bed management and overall hole cleaning and ease of tripping.

- **Drill pipe reciprocation** helps wellbore cleaning by causing surges in the AV.

- **Record pickup, slack off and off-bottom rotating torque regularly** - at connections to establish actual trends for comparison to predicted trends. Always wipe stand prior to connection and if necessary ream stand down. *(Avoid upward rotation.)*

- **Horizontal hole** – As circulating ECD increase with section length, control pipe movement to minimise swab and surge and resultant ECD’s.
  - Minimization of the damage consists of keeping the invasive fluids and solids within a tight radius of the borehole axis, either by tight time constraints or **careful drilling practices**.
  - Avoid circulating for extended periods with the same stand, as a rule of thumb, keep pipe moving and lay out a stand every half hr to prevent wellbore enlargement.

- **Data Acquisition** - Trend sheets should be used to log all wellbore cleaning parameters for future use, *i.e.* flow rate, rpm, mud rheology Vs depth and evidence of dirty hole on trips etc.

- **Trip procedures** - should be prepared in advance with guidance on tripping intervals, such procedures can be modified over the well as necessary.

- **Cuttings returns log** - can provide valuable information on trends in cuttings returns versus ROP by measuring the amount of cuttings over the shakers at regular intervals

<table>
<thead>
<tr>
<th>Well inclination</th>
<th>Section length factor*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Range</td>
<td>17 ½” hole</td>
</tr>
<tr>
<td>0° - 10°</td>
<td>1.5</td>
</tr>
<tr>
<td>10° - 30°</td>
<td>1.7</td>
</tr>
<tr>
<td>30° - 60°</td>
<td>2.5</td>
</tr>
<tr>
<td>60° +</td>
<td>3.0</td>
</tr>
</tbody>
</table>

* Factor = Bottoms up factor

- **Avoid hole enlargement and/or washouts** – Prevention rather than cure is paramount in this case *e.g.* If hole washout increases from 17 ½” to 20”, the volume of rock *increases by 166%* over that area. The pump rate at this stage *drops by 281%*. **Hole cleaning is now a problem.**
Operations planning for optimal hole cleaning

5.6 Rig Site Indicators

- **Cutting size & shape** - Rounded cuttings indicate poor carrying capacity
- The volume of cuttings generated - is a function of hole size and ROP. The table below illustrates the amount of cuttings generated for given hole sizes and ROP

Table 6: Approximate cuttings volume generated

<table>
<thead>
<tr>
<th>Hole size</th>
<th>Average ROP’s</th>
<th>Tonnes / hour</th>
</tr>
</thead>
<tbody>
<tr>
<td>17 ¼”</td>
<td>30 m/hr (100 ft/hr)</td>
<td>12 tonnes/hour</td>
</tr>
<tr>
<td></td>
<td>60 m/hr (200 ft/hr)</td>
<td>24 tonnes/hour</td>
</tr>
<tr>
<td></td>
<td>90 m/hr (300 ft/hr)</td>
<td>36 tonnes/hour</td>
</tr>
<tr>
<td>12 ¾”</td>
<td>30 m/hr (100 ft/hr)</td>
<td>5 tonnes/hour</td>
</tr>
<tr>
<td></td>
<td>60 m/hr (200 ft/hr)</td>
<td>10 tonnes/hour</td>
</tr>
<tr>
<td></td>
<td>90 m/hr (300 ft/hr)</td>
<td>15 tonnes/hour</td>
</tr>
<tr>
<td>8 ½”</td>
<td>15 m/hr (100 ft/hr)</td>
<td>0.5 tonnes/hour</td>
</tr>
<tr>
<td></td>
<td>30 m/hr (200 ft/hr)</td>
<td>1.0 tonnes/hour</td>
</tr>
<tr>
<td></td>
<td>45 m/hr (300 ft/hr)</td>
<td>1.5 tonnes/hour</td>
</tr>
</tbody>
</table>

- **Cuttings Return** - Use average ROP’s to estimate anticipated cuttings rate at shakers for hole size being drilled
- **Torque & Drag** - Use to predict torque and drag. Look for deviations from trend
- **Erratic Torque / SPP** – Formation related or Indicator of cuttings beds & hole packing-off
- **Tripping Analysis** - Compare drag trends with subsequent trips to indicated possible presence of cuttings beds
- **Hole drag & fill** - Monitor string weights for indications of drag and fill on bottom before and after each connection and while tripping in/out of the hole. Ensure trouble spots trends are recorded, handed over and monitored.
- **Formations being drilled** – will result in variable drilling indicators and changing hole cleaning efficiencies. *E.g.* while drilling mudstones inefficient hole cleaning is indicated by an increasing drag trend with very little increase in drilling torque. However, both torque and drag may increase with poor wellbore cleaning while drilling some sandstone reservoir sections. A straightforward analysis is therefore not always possible, *e.g.* a decrease in wellbore lubricity with increasing sandstone cuttings may play a vital role in the drilling mechanics response required.
- **Shale Shaker monitoring** - The shakers will indicate the effectiveness of the wellbore cleaning and provide and early warning sign to a wellbore cleaning problem. Are volumes of cuttings right for the ROP? Do slugs of cuttings appear followed by very few cuttings? Etc.