The Smith Bits definitions and guidelines shown within are NOT IADC standards. They were created solely for internal purposes to reduce ambiguities and to improve our consistency in grading dull bits within the current IADC structure.
System Structure

<table>
<thead>
<tr>
<th>Inner Rows (I)</th>
<th>Outer_rows (O)</th>
<th>Dull Char. (D)</th>
<th>Location (L)</th>
<th>Brng. Seal (B)</th>
<th>Gauge 1/16 (G)</th>
<th>Other Dull (O)</th>
<th>Pull (R)</th>
</tr>
</thead>
</table>

1. **(I) = Inner Rows**
   - Used to report the condition of the cutting elements not touching the wall of the hole.
   - Linear scale from 0 - 8 measuring the combined cutting structure reduction due to lost, worn and/or broken cutting elements.

2. **(O) = Outer Rows**
   - Used to report the condition of the cutting elements that touch the wall of the hole.
   - Linear scale from 0 - 8 measuring the combined cutting structure reduction due to lost, worn and/or broken cutting elements.
   - Smith Bits guideline - Do not include heel elements.

**TOOTH HEIGHT MEASUREMENT**

- T0 - NEW
- T1
- T2
- T3
- T4
- T5
- T6
- T7
- T8
Identifying TCI and Milled Tooth Bit Rows

Conventional Cutting Structure

Inner Row
Gauge Row
Heel Row

Trucut™ Cutting Structure

Inner Row
Gauge Row
Heel Row
(offers-gauge)
Roller Cone Dull Grading Manual

3: (D) = Dull Characteristics

Uses a two letter code to indicate the major dull characteristic of the cutting structure.

**DULL CHARACTERISTICS**

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>BC</td>
<td>Broken Cone</td>
</tr>
<tr>
<td>BF</td>
<td>Bond Failure</td>
</tr>
<tr>
<td>BT</td>
<td>Broken Teeth / Cutters</td>
</tr>
<tr>
<td>BU</td>
<td>Balled Up Bit</td>
</tr>
<tr>
<td>CC</td>
<td>Cracked Cone</td>
</tr>
<tr>
<td>CD</td>
<td>Cone Dragged</td>
</tr>
<tr>
<td>CI</td>
<td>Cone Interference</td>
</tr>
<tr>
<td>CR</td>
<td>Cored</td>
</tr>
<tr>
<td>CT</td>
<td>Chipped Teeth / Cutters</td>
</tr>
<tr>
<td>ER</td>
<td>Erosion</td>
</tr>
<tr>
<td>FC</td>
<td>Flat Crested Wear</td>
</tr>
<tr>
<td>HC</td>
<td>Heat Checking</td>
</tr>
<tr>
<td>JD</td>
<td>Junk Damage</td>
</tr>
<tr>
<td>LC</td>
<td>Lost Cone</td>
</tr>
<tr>
<td>LN</td>
<td>Lost Nozzle</td>
</tr>
<tr>
<td>LT</td>
<td>Lost Teeth / Cutters</td>
</tr>
<tr>
<td>NO</td>
<td>No Dull</td>
</tr>
<tr>
<td>OC</td>
<td>Off Center Wear</td>
</tr>
<tr>
<td>PB</td>
<td>Pinched Bit</td>
</tr>
<tr>
<td>PC</td>
<td>Plugged Nozzle / Flow Passage</td>
</tr>
<tr>
<td>PG</td>
<td>品种。</td>
</tr>
<tr>
<td>PT</td>
<td>Flat Crested Wear</td>
</tr>
<tr>
<td>RG</td>
<td>Rounded Gauge</td>
</tr>
<tr>
<td>RO</td>
<td>Ring Out</td>
</tr>
<tr>
<td>SD</td>
<td>Shirttail Damage</td>
</tr>
<tr>
<td>SS</td>
<td>Self-Sharpening Wear</td>
</tr>
<tr>
<td>TR</td>
<td>Tracking</td>
</tr>
<tr>
<td>WD</td>
<td>Washed Out Bit</td>
</tr>
<tr>
<td>WT</td>
<td>Worn Teeth / Cutters</td>
</tr>
</tbody>
</table>

* Show cone # or #'s under location 4. # Not used for roller cone bits.

- Smith Bits guideline - input only one dull characteristic code.
- Smith Bits definition - The cutting structure dull characteristic is that observed cutting structure dull characteristic that would most likely limit further usage of the bit for that application.
- This column is only for codes that apply to cutting structures.

4: (L) = Location

Uses a letter or number code to indicate the location on the face of the bit where the cutting structure dull characteristic occurs.

**LOCATION - ROLLER CONE BITS**

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
<th>Cone #</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>Nose Row</td>
<td>1</td>
</tr>
<tr>
<td>M</td>
<td>Middle Row</td>
<td>2</td>
</tr>
<tr>
<td>G</td>
<td>Gauge Row</td>
<td>3</td>
</tr>
<tr>
<td>A</td>
<td>All Rows</td>
<td></td>
</tr>
</tbody>
</table>

- Generally, the #1 cone contains the centermost cutting element. The #2 and #3 cones follow in a clockwise rotation. However, accurate determination of the #1 cone, on any roller cone bit by visual examination alone, is not always possible.
- G = Gauge - those cutting elements which touch the hole wall.
- N = Nose - the center most cutting elements of the bit.
- M = Middle - the cutting elements between the nose and the gauge.
• A = All rows
• Cone numbers
• Smith Bits guidelines - a maximum of two characters to be input.

5: (B) = Bearings / Seals

Non-Sealed Bearings
Linear scale from 0 - 8 estimating bearing life used.

Sealed Bearings
E - Seals effective
F - Seals failed
N - Not able to grade

Smith Bits guidelines
• This column is used to indicate condition of the bearing and seal assembly. If either component in the assembly has failed, then the code is F.
• If any portion of the bearing is exposed or missing, it is considered an ineffective (F) assembly.
• Use N if unable to determine the condition of both components.
• Smith Bits grades each assembly separately.
• If grading all assemblies as one, list the worst case.

Sealed Bearing Checklist

Items To Check When Determining Seal / Bearing Effectiveness

- Ability to rotate cone
- Cone springback
- Seal squeak
- Internal sounds
- Weeping grease
- Shale burn
- Shale packing
- Gaps - backface or throat
- Bearing letdown - inner or outer

6: (G) = Gauge

Used to report the undergauge condition of the cutting elements that touch the wall of the hole.

- Use only a nominal ring gauge to gauge a dull bit.
- New bits are built to API specifications. Ring gauges built for new bits have the tolerances listed in the table below and should not be used for gauging dull bits.

API Tolerance For New Bits

<table>
<thead>
<tr>
<th>Bit Size</th>
<th>API Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 5/8 - 13 3/4</td>
<td>+ 1/32 : -0</td>
</tr>
<tr>
<td>14 - 17 1/2</td>
<td>+ 1/16 : -0</td>
</tr>
<tr>
<td>17 5/8 &amp; larger</td>
<td>+ 3/32 : -0</td>
</tr>
</tbody>
</table>
Smith Bits guidelines

• Round to nearest 1/16”.

• Bits with bearing/seal failures: can measure amount out of gauge as long as cones do not have any axial or radial movement.

• Measurement to be made on either gauge or heel elements which ever is closer to gauge.

• Applies to cutting structure elements only.

• Ensure that a nominal ring gauge is used. If nominal ring gauges are not available, true gauge condition can not be determined.

**DULL CHARACTERISTICS**

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>BC</td>
<td>Broken Cone</td>
</tr>
<tr>
<td># BF</td>
<td>Bond Failure</td>
</tr>
<tr>
<td>BT</td>
<td>Broken Teeth / Cutters</td>
</tr>
<tr>
<td>BU</td>
<td>Balled Up Bit</td>
</tr>
<tr>
<td>CC</td>
<td>Cracked Cone</td>
</tr>
<tr>
<td>CD</td>
<td>Cone Dragged</td>
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<tr>
<td>CI</td>
<td>Cone Interference</td>
</tr>
<tr>
<td>CR</td>
<td>Cored</td>
</tr>
<tr>
<td>CT</td>
<td>Chipped Teeth / Cutters</td>
</tr>
<tr>
<td>ER</td>
<td>Erosion</td>
</tr>
<tr>
<td>FC</td>
<td>Flat Crested Wear</td>
</tr>
<tr>
<td>HC</td>
<td>Heat Checking</td>
</tr>
<tr>
<td>JD</td>
<td>Junk Damage</td>
</tr>
<tr>
<td>LC</td>
<td>Lost Cone</td>
</tr>
<tr>
<td>* LN</td>
<td>Lost Nozzle</td>
</tr>
<tr>
<td>LT</td>
<td>Lost Teeth / Cutters</td>
</tr>
<tr>
<td>NO</td>
<td>No Dull Characteristics</td>
</tr>
<tr>
<td>OC</td>
<td>Off Center Wear</td>
</tr>
<tr>
<td>* PB</td>
<td>Pinched Bit</td>
</tr>
<tr>
<td>* PN</td>
<td>Plugged Nozzle / Flow Passage</td>
</tr>
<tr>
<td>RG</td>
<td>Rounded Gauge</td>
</tr>
<tr>
<td># RO</td>
<td>Ring Out</td>
</tr>
<tr>
<td>* SD</td>
<td>Shirrtail Damage</td>
</tr>
<tr>
<td>SS</td>
<td>Self-Sharpening Wear</td>
</tr>
<tr>
<td>TR</td>
<td>Tracking</td>
</tr>
<tr>
<td>* WO</td>
<td>Washed Out Bit</td>
</tr>
<tr>
<td>WT</td>
<td>Worn Teeth / Cutters</td>
</tr>
</tbody>
</table>

* Used only in the ‘Other Dull Characteristics’ column.
# Not used for roller cone bits.
8: (R) = Reason Pulled

Used to report the reason pulled.

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>BHA</td>
<td>Change Bottom Hole Assembly</td>
</tr>
<tr>
<td>CM</td>
<td>Condition Mud</td>
</tr>
<tr>
<td>CP</td>
<td>Core Point</td>
</tr>
<tr>
<td>DMF</td>
<td>Downhole Motor Failure</td>
</tr>
<tr>
<td>DP</td>
<td>Drill Plug</td>
</tr>
<tr>
<td>DSF</td>
<td>Drill String Failure</td>
</tr>
<tr>
<td>DST</td>
<td>Drill Stern Testing</td>
</tr>
<tr>
<td>DTF</td>
<td>Downhole Tool Failure</td>
</tr>
<tr>
<td>FM</td>
<td>Formation Change</td>
</tr>
<tr>
<td>HP</td>
<td>Hole Problems</td>
</tr>
<tr>
<td>HR</td>
<td>Hours on Bit</td>
</tr>
<tr>
<td>LIH</td>
<td>Left in Hole</td>
</tr>
<tr>
<td>LOG</td>
<td>Run Logs</td>
</tr>
<tr>
<td>PP</td>
<td>Pump Pressure</td>
</tr>
<tr>
<td>PR</td>
<td>Penetration Rate</td>
</tr>
<tr>
<td>RIG</td>
<td>Rig Repair</td>
</tr>
<tr>
<td>RS</td>
<td>Retrieve Survey</td>
</tr>
<tr>
<td>TD</td>
<td>Total Depth / Casing Depth</td>
</tr>
<tr>
<td>TQ</td>
<td>Torque</td>
</tr>
<tr>
<td>TW</td>
<td>Twist Off</td>
</tr>
<tr>
<td>WC</td>
<td>Weather Conditions</td>
</tr>
<tr>
<td>WO</td>
<td>Washout in Drill String</td>
</tr>
</tbody>
</table>
BC - Broken Cone
This describes a bit with one or more cones that have been broken into two or more pieces, but with most of the cone still attached to the bit. Cone shell peeling is considered to be a broken cone.

POTENTIAL CAUSES

Cracked cone
- Progression from a cracked cone. See respective section.

Excessive impact load / improper drilling practices
- Dropping of the drill string.
- Tagging bottom too hard or intentional spudding.
- Hitting a ledge while tripping or making a connection.
- Running on junk.

Reduction in cone shell thickness
- Cone Interference - see respective section.
- Erosion - see respective section.
- Tracking - see respective section.
- Off Center Wear - see respective section.

Drilling environment
- Hydrogen sulfide embrittlement.
- Corrosion.
APPLICATION RECOMMENDATIONS

Excessive impact load / improper drilling practices
• Follow proper drilling practices.

Drilling environment
• Follow recommended drilling fluid guidelines.
BT - Broken Teeth
A cutting element is considered broken if over 1/3 of the cutting element is missing regardless of the cause. In some formations, broken teeth can be a typical dull characteristic for tungsten carbide insert bits if performance meets established standards. However, BT may be a potential indicator of problems in bit selection or operating practices if performance falls significantly short of expectations. Broken teeth is not a typical dull characteristic for steel tooth bits and may indicate an improper application or improper operating practices.

POTENTIAL CAUSES

Formation / improper bit selection
- No specific breakage pattern. Typically an overload. Occurs when the compressive strength of the formation exceeds design criteria.

Excessive WOB for application and specific bit type
- Indicated by broken teeth predominantly in the middle rows, but can also occur in the nose rows.

Excessive RPM for application and specific bit type
- Indicated by broken teeth predominantly in the gauge row due to high relative velocities and impact force generated.

Broken formations (includes boulders)
- Broken formations are those that have alternating hard and soft interbedded laminated sections with distinct well defined boundaries laid down at an angle. As drilling progresses through the bedding planes, pieces break at the bedding planes causing uneven loading on the cutting structure as the broken portions of formation move or roll under the bit.

Improper bottom hole pattern break-in
- Excessive WOB and RPM and the previous bits’ bottom hole pattern can create high cutting structure loading causing broken teeth unless the bit can create its own bottom hole pattern.

Excessive impact load / improper drilling practices
- Dropping of the drill string.
- Tagging bottom too hard or intentional spudding.
- Hitting a ledge while tripping or making a connection.
- Running on junk.

Cone interference
- See respective section.

Heat checking
- Heat checking generates stress risers allowing breakage at lower energy levels. See respective section.
Rounded gauge
• The cross-section is worn to the extent it is insufficient to with-stand applied drilling loads. See respective section.

Erosion
• Cutting elements effectively become longer due to cone shell ero-sion. By increasing the effective extension, the cutting element becomes easier to break. See respective section.

APPLICATION RECOMMENDATIONS
Formation / improper bit selection
• Select a bit with less offset, and/or less tooth extension, and/or greater tooth count, and/or tougher tooth shape.

Excessive WOB for application and specific bit type
• Use proper WOB for formation.
• Use a shock sub when anticipating numerous formation changes. See broken formations.
• For hard formations, select a bit with less offset, and/or less tooth extension, and/or greater tooth count, and/or tougher tooth shape.

Excessive RPM for application and specific bit type
• Use proper RPM for formation.
• For hard formations, select a bit with less offset, and/or less tooth extension, and/or greater tooth count, and/or tougher tooth shape.
• Can also be caused by heat checking or gauge rounding. See respective sections.

Broken formations (includes boulders)
• Broken teeth due to drilling broken formations can occur in any row. This can be excessive WOB or RPM related. An indicator of broken formations is when the torque becomes extremely erratic when drilling through the boundaries, then smooths out. Use a shock sub.

Improper bottom hole pattern break-in
• Bottom hole pattern break-in is considered to be when a new bit achieves uniform cutting structure loading. This is done with light weights and slow RPM and is normally achieved within 3 to 6 inches. At that point WOB and RPM can be gradually increased to typical operating levels.

Excessive impact load / improper drilling practices
• Follow proper drilling practices.
**BU - Balled Up**

Bit balling is a condition where formation becomes packed between the cones and bit body or between the cutting elements such that the ROP suffers. There may or may not be any evidence of skidding or physical damage to the bit. The cutting elements are packed off to the extent that they are not penetrating into the formation effectively. Rotary torque will typically decrease as the bit balls up.

**POTENTIAL CAUSES**

**Formation**
- Drilling a sticky formation (e.g., gumbo, hydratable shales).

**Inadequate hydraulics**
- Poor hole cleaning and/or bit cleaning for penetration rate achieved with the WOB and RPM combination used.

**Poor fluid distribution**
- Improper nozzle configuration or nozzle type selection.

**Improper drilling practices**
- Forcing the bit into formation cuttings with the pump not running.
- Inadequate cleaning of the hole while making a connection.

**Improper bit selection**
- Harder bit types have less optimal cleaning attributes. These bits generally have greater tooth count and/or shorter teeth which are easier to pack off. They also provide less flow area on the hole bottom.

**Drilling environment**
- Poorly maintained or not optimized drilling fluid.
- Improper drilling fluid.
APPLICATION RECOMMENDATIONS

Formation
- See all the following.

Inadequate hydraulics
- Ensure that the hydraulics have been optimized for the parameters available.
- Increased hydraulic energy is needed to address this condition.

Poor fluid distribution
- For all bit balling problems, center jets are recommended to enhance cone cleaning.
- Full-extended nozzles enhance hole bottom cleaning but can slightly reduce cone cleaning since the fluid from the nozzle exit, is so close to the hole bottom, that it may create less turbulence and fluid entrainment around the cones.
- Mini-extended nozzles can slightly reduce cone cleaning due to less fluid diffusion from this nozzle type. Also, extending the nozzle exit closer to the hole bottom can slightly reduce the turbulence and fluid entrainment around the cones.
- Crossflow and asymmetrical nozzle configurations typically provide better bottom hole cleaning and can influence cone cleaning as well.

Improper drilling practices
- Follow proper drilling practices.

Improper bit selection
- Select bits with less flow restrictive cutting structures. These will typically be more aggressive types and for milled tooth bits, may have a combination of the following:
  - Narrow crest widths on gauge, specifically no T or L shaped gauge teeth or web gauge structures.
  - Gauge and adjacent rows with tooth deletions and interruptions.
  - Teeth as long as possible.

Drilling environment
- Follow recommended drilling fluid guidelines.
- Consider alternative mud systems.
CC - Cracked Cone
This characteristic describes a bit with one or more cones that have a crack or cracks, but the cones are still wholly intact and not separated. If any portion of the cone is missing, it is a broken cone.

**POTENTIAL CAUSES**

**Excessive WOB for particular type**
- Cyclic fatigue of a cone due to excessive loading.

**Excessive hours for application and specific bit type**
- Cyclic fatigue of a cone when the bit is run past typical expectation.

**Overbalanced drilling condition**
- Cyclic fatigue usually seen on aggressive bit types.

**Excessive impact load / improper drilling practices**
- Dropping of the drill string.
- Tagging bottom too hard or intentional spudding.
- Hitting a ledge while tripping or making a connection.
- Running on junk.

**Heat checking**
- See respective section.

**Broken teeth / worn teeth / lost teeth**
- Drilling after the cutting elements have broken, worn or lost to the extent that the cone shell is contacting the hole bottom can cause a cracked cone. See respective section.

**Reduction in cone shell thickness**
- Cone Interference - see respective section.
- Erosion - see respective section.
- Tracking - see respective section.
- Off center wear - see respective section.

**Drilling environment**
- Hydrogen sulfide embrittlement.
- Corrosion.
Overheating
• Inadequate hydraulics.
• Drilling without fluid circulation.
• Cone Drag - see respective section.

APPLICATION RECOMMENDATIONS
Excessive WOB for particular type
• Run proper WOB for specific bit type to achieve typical expectation.

Excessive hours for application and specific bit type
• Select a more durable bit type or reduce operating hours.

Overbalanced drilling condition
• Reduced hydrostatic pressure is needed to address this condition.

Excessive impact load / improper drilling practices
• Follow proper drilling practices.

Drilling environment
• Follow recommended drilling fluid guidelines.

Overheating
• A higher flow rate is needed to address this condition.
• Follow proper drilling practices.
CD - Cone Dragged
This dull characteristic indicates that one or more of the cones did not rotate during part of the bit run, shown by one or more flat wear spots.

POTENTIAL CAUSES

Bearing / seal failure
- Seizure of the bearing prevents cone rotation.

Bit balling
- See respective section.

Improper drilling practices
- When drilling cementing equipment, rubber or metal becomes wedged between the cones preventing cone rotation.

Junk damage
- See respective section.

Cone interference
- See respective section.

Pinched bit
- See respective section.

Insufficient WOB
- To initiate cone rotation, a sufficient WOB must be applied to prevent cone slippage (drag).

Packed open bearing bits
- Bearings in new open bearing bits, with tight clearances, can pack off with fine solids. The fine solids pack into the roller bearing assemblies, eventually preventing rotation. This condition is not as prevalent in rerun bits due to increased bearing clearances caused by bearing wear.

Improper bottom hole pattern break-in
- The previous bits’ bottom hole pattern can load the inner portions of the cones preventing cone rotation.
APPLICATION RECOMMENDATIONS

Bearing / seal failure

- In some applications a bearing / seal failure may not indicate a bit related problem if performance meets established standards. However, bearing / seal failures may be a potential indicator of problems in bit selection or operating practices if performance falls significantly short of expectations.
- Select bits and/or features with a capacity for greater total revolutions.

Improper drilling practices

- Follow recommended procedures for drilling out cementing equipment. Technical papers available from Smith Bits.

Insufficient WOB

- Based on field experience, a minimum of 500 lb./in. of bit diameter is sufficient to ensure cone rotation in most applications.

Packed open bearing bits

- Adequate hydraulics are necessary to help prevent fines from entering bearing assemblies.
- Clean and regrease bit between runs.
- Follow recommended drilling fluid guidelines to reduce fines.

Improper bottom hole pattern break-in

- Proper bottom hole pattern break-in is considered to be when a new bit achieves uniform cutting structure loading. This is done with light weights and slow RPM and is normally achieved within 3 to 6 inches. At that point, WOB and RPM can be **gradually** increased to typical operating levels.
CI - Cone Interference
A condition where the cutting structure of at least one cone has impacted upon at least one of the adjacent cones. This contact can range from a singular cutting element indentation to a groove. A bearing /seal failure may or may not have occurred.

POTENTIAL CAUSES
Bearing / seal failure
- Enough bearing wear to allow the cones to contact one another.

Pinched bit
- See respective section.

Improper drilling practices
- Forcing into an undergauge hole.
  - Improper reaming.
  - Bit being forced into a less than nominal size hole.
  - Roller cone bit being forced into a section of hole drilled by fixed cutter bits, due to different API O.D. tolerances.
- Bit being pinched in the bit breaker.
- Bit being forced into an undersized blowout preventer stack.
- Forcing a bit through casing that does not drift to the bit size used.
APPLICATION RECOMMENDATIONS

Bearing / seal failure

• In some applications a bearing / seal failure may not indicate a bit related problem if performance meets established standards. However, bearing / seal failures may be a potential indicator of problems in bit selection or operating practices if performance falls significantly short of expectations.

• Select bits and/or features with a capacity for greater total revolutions.

Improper drilling practices

• Forcing into an undergauge hole.
  • Ream undergauge holes using very light WOB and low RPM. A hole in a slightly undergauge condition requires a lesser amount of WOB than a hole in a greater undergauge condition. For example, a hole 1/16” undergauge requires less WOB in order not to damage the bit than a hole 1/2” undergauge.

• Bit being pinched in the bit breaker.
  • Caused by the bit rotating beyond the make-up lugs in the breaker indicated by damage seen on the legs. Ensure the use of a proper bit breaker in good condition and use proper make-up technique to prevent bending of the legs.
CR - Cored

A bit is cored / coring when its centermost cutting elements are broken, worn and/or lost to the extent that the nose area of a cone shell or cone shells is showing significant wear from the formation. If any evidence of a fracture surface is seen, then broken cone (BC) is the cutting structure dull characteristic.

**POTENTIAL CAUSES**

**Improper bottom hole pattern break-in**
- Excessive WOB and RPM and the previous bits’ bottom hole pattern can create high cutting structure loading causing broken teeth unless the bit can create its own bottom hole pattern. Mill tooth bits may experience spearpoint breakage.

**Junk damage**
- Breakage of cutting structure due to running on junk whether external or from the bit itself. *See respective section.*

**Erosion**
- Erosion causing loss of cutting structure. *See respective section.*

**Formation / improper bit selection**
- Abrasiveness of formation exceeds the wear resistance of the nose cutting elements.
- Formation too hard for bit type selected resulting in breakage of the nose cutting elements.

**Excessive WOB for application and specific bit type**
- Indicated by broken teeth predominantly in middle rows but can also occur in the nose rows.

**Excessive hours for application and specific bit type**
- Indicated by broken, worn and/or lost cutting elements when exceeding typical expectations.

**Off center wear**
- Reduces cone support of the nose cutting elements leading to loss of these cutting elements. *See respective section.*
Improper drilling practices
• Improperly drilled back flow valves in casing shoes can create high inner cutting structure loading.

APPLICATION RECOMMENDATIONS
Improper bottom hole pattern break-in
• Proper bottom hole pattern break-in is considered to be when a new bit achieves uniform cutting structure loading. This is done with light weights and slow rpm and is normally achieved with in 3 to 6 inches. At that point WOB and RPM can be gradually increased to typical operating levels.

Formation / improper bit selection
• For hard formations, then select a bit with less offset, and/or less tooth extension, and/or greater tooth count, and/or tougher tooth shape.

Excessive WOB for application and specific bit type
• Use proper WOB for formation.
• Use a shock sub.
• For hard formations, then select a bit with less offset, and/or less tooth extension, and/or greater tooth count, and/or tougher tooth shape.

Excessive hours for application and specific bit type
• Select more durable bit type or reduce operating hours.

Improper drilling practices
• Follow recommended procedures for drilling out cementing equipment. Technical papers available from Smith Bits.
CT - Chipped Teeth
A cutting element is considered chipped if less than 1/3 of the cutting element is gone regardless of the cause. Chipped hardfacing on mill tooth bits is considered to be chipped teeth.

POTENTIAL CAUSES

Rough running in air drilling application
- Using air as a circulation medium eliminates the damping effect normally seen in other drilling fluids.

Formation / improper bit selection
- Formation too hard for bit type selected. No specific chippage pattern.
- Specific bit types may not provide smooth drilling characteristics.
- Bit bouncing due to formation changes can cause chipping. No specific chippage pattern. See “Broken Formations” below.

Excessive WOB for application and specific bit type
- Indicated by chipped teeth predominantly in the middle rows, but can also occur in the nose rows.

Excessive RPM for application and specific bit type
- Indicated by chipped teeth predominantly in the gauge row.

Broken formations (includes boulders)
- Broken formations are those that have alternating hard and soft interbedded laminated sections with distinct well defined boundaries laid down at an angle. As drilling progresses through the bedding planes, pieces break at the bedding planes causing uneven loading on the cutting structure as the broken portions of formation move or roll under the bit.

Improper bottom hole pattern break-in
- Excessive WOB and RPM and the previous bits’ bottom hole pattern can create high cutting structure loading causing chipped teeth unless the bit can create its own bottom hole pattern.

Excessive impact load / improper drilling practices
- Dropping of the drill string.
- Tagging bottom too hard or intentional spudding.
- Hitting a ledge while tripping or making a connection.
- Running on junk.
- Improper casing clearances.

Cone interference
- See respective section.

Heat checking
- See respective section.
APPLICATION RECOMMENDATIONS

Rough running in air drilling application
- Elimination of rough running is primarily achieved by changing RPM.

Formation / improper bit selection
- Formation too hard for bit type selected.
- Select a bit with less offset, and/or less tooth extension, and/or greater tooth count, and/or tougher tooth shape.
- Bits with multiple cutting elements which share the gauge cutting function should run smoother due to kerf reduction.

Excessive WOB for application and specific bit type
- Use proper WOB for formation.
- Use a shock sub.
- For hard formation, select a bit with less offset, and/or less tooth extension, and/or greater tooth count, and/or tougher tooth shape.

Excessive RPM for application and specific bit type
- Use proper RPM for formation.
- For hard formations, select a bit with less offset, and/or less tooth extension, and/or greater tooth count, and/or tougher tooth shape.
- Can also be caused by heat checking, gauge rounding. See respective sections.

Broken formations (includes boulders)
- Chipped teeth due to drilling broken formations can occur in any row. This can be excessive WOB or RPM related. An indicator of broken formations is when the torque becomes extremely erratic when drilling through the boundaries, then smooths out. Use shock sub. Reduction of rough running is primarily achieved by optimizing RPM.

Improper bottom hole pattern break-in
- Bottom hole pattern break-in is considered to be when a new bit achieves uniform cutting structure loading. This is done with light weights and slow rpm and is normally achieved with in 3 to 6 inches. At that point WOB and RPM can be gradually increased to typical operating levels.

Excessive impact load / improper drilling practices
- Follow proper drilling practices.
ER - Erosion
Erosion is used to describe the loss of material on the cutting structure due to the impact of the drilling fluid, the solids and the cuttings against the cutting structure. Erosion can reduce the size of the cutting element, alter its shape and cause loss of cone shell material thus decreasing the cutting element support.

POTENTIAL CAUSES

Inadequate and/or poor hydraulics
• Cuttings accumulate underneath and around the bit due to the lack of hydraulic energy.

Excessive hydraulics
• High velocity fluid creates turbulence and impingement on the cones and cutting elements.
• High air or gas volumes creates turbulence and impingement on the cones and cutting elements.

Abrasive formations
• Cuttings from abrasive formations can cause erosive wear even with minimum hydraulics.

Drilling environment
• Abrasive drilling fluids.
• Poor solids control.
• Corrosive drilling environments enhance rate of erosion.
APPLICATION RECOMMENDATIONS

Inadequate and/or poor hydraulics

- Increased hydraulic energy is needed.
- Mini-extended nozzles can improve bottom hole cleaning by extending the nozzle exit closer to the hole bottom improving impinging jet velocity and pressure profile.
- Crossflow and asymmetrical nozzle configurations can provide better bottom hole cleaning.
- Select bits with shirttail protection features.
- Select a bit with an erosion wear reduction feature.

Excessive hydraulics

- Reduce the hydraulic energy level (jet velocity).
- Diffuser type center jets will provide reduced impact force on the cone and the cutting elements due to diffusion characteristics.
- Reduced air or gas volumes are needed to reduce erosion.
- Select a bit with an erosion wear reduction feature.

Abrasive formations

- Select a bit with an erosive wear reduction feature.

Drilling environment

- Follow recommended drilling fluid guidelines to reduce solids.
- Select a bit with an erosive wear reduction feature.
- Follow recommended drilling fluid guidelines to reduce corrosion.
FC - Flat Crested Wear
Flat crested wear is an even reduction in height on a cutting element. The worn surfaces will be ‘flat’ and have little or no radii at the tooth flanks. Flat crested wear does not have to occur on the entire cutting structure. Wear modes will vary from row to row and from cone to cone. By design, scraping can be a desirable cutting action, with the result being flat crested wear. This may be the desirable or typical dull characteristic. It is not a concern unless performance falls short of expectations. If so, select a more aggressive bit type and/or one with a self sharpening feature.

POTENTIAL CAUSES
Tracking
• Tracking of the “drive rows” will cause the inner rows to skid.

Not enough WOB
• In harder formations, the bit is not able to effectively drill the rock. The bit therefore tries to ‘abrade’ away the formation.
• Light WOB and high RPM is one drilling practice used to control deviation.
APPLICATION RECOMMENDATIONS

Tracking

• See respective section.

Not enough WOB

• It may not be desirable, practical or possible to increase the WOB. In this case, a harder bit type will last longer with typically only a small reduction in ROP (for that specific formation). The limiting factor / cost effectiveness is the interval length before softer formations are encountered.

• Alternatively, going to a more aggressive bit type with more wear resistance should improve the ROP especially if softer sections are to be encountered.

• Determining which bit to run is based upon each respective design, dull condition, drilled intervals and comparison between drill-off tests.

• Increased WOB may be possible with a change in BHA stabilization. Refer to manufacturer’s of stabilization equipment for proper practices.
HC - Heat Checking
A biaxial or cross hatched pattern of surface cracks intersecting at approximately right angles. The number of cracks on a cutting element can vary significantly. These cracks initiate on the surface due to thermal shock and fatigue and propagate due to stress relief. Increasing the wear / contact area on the cutting element can amplify heat input aggravating the thermal shock and fatigue, increasing crack propagation. Heat checking is not limited to any particular row.

POTENTIAL CAUSES

**Insufficient WOB to prevent HC on inner rows**
- To initiate and maintain cone rotation, a sufficient WOB must be applied to prevent cone drag.

**Reaming a slightly undergauge hole at high RPM**
- Heat checking on the gauge and heel rows due to cyclic thermal stress generated with high RPM and high reaming rates.

**Drilling at high RPM**
- High RPM generates higher cyclic thermal stresses.

**Formation**
- This may be a typical dull characteristic in some formations, especially carbonates. It can appear in middle, gauge or heel rows.
APPLICATION RECOMMENDATIONS

**Insufficient WOB to prevent HC on inner rows**
- Based on field experience a minimum of 500 lb./in. of bit diameter is sufficient to ensure cone rotation in most applications.

**Reaming a slightly undergauge hole at high RPM**
- Ream using very light WOB and low RPM. A hole in a slightly undergauge condition requires a lesser amount of WOB than a hole in a greater undergauge condition. For example, a hole 1/16” undergauge requires less WOB in order to not damage the bit than a hole 1/2” undergauge.

**Drilling at high RPM**
- Gauge and heel structures with diamond enhanced cutting elements can prevent heat checking and resultant breakage / chip-page in many applications.

**Formation**
- Gauge and heel structures with diamond enhanced cutting elements can prevent heat checking and resultant breakage / chip-page in many applications.
JD - Junk Damage
A condition where the bit has indentations or cutting structure damage caused by contact with objects other than formation. It is to be used in the “Cutting Structure Dull Characteristics” column when describing damage to a bit knowingly caused by external sources of junk. The use of ‘JD’ in the “Remarks Other Dull Characteristic” column implies damage caused by junk from the bit itself.

POTENTIAL CAUSES
Run on junk
- Junk dropped in the hole from the surface (tong dies, tools, etc.).
- Junk from the drill string (reamer pins, stabilizer blades, etc.).
- Junk from a previous bit run (tungsten carbide inserts, ball bearings, etc.).
- Junk from the bit itself.
- Damage due to contact with casing.
APPLICATION RECOMMENDATIONS

Run on junk

- May not know if junk has been dropped in the hole from the surface.
- Run junk basket. Follow manufacturer’s recommended procedure.
- For small quantities of parts, ¾” diameter or less, consider running a boot basket or magnet. Follow manufacturer’s recommended procedure.
LC - Lost Cone
A bit condition when one or more cones are missing from the leg assembly(s). Also, since there is no existing IADC code for a broken leg, use LC to indicate the loss of a cutter / leg assembly.

POTENTIAL CAUSES
All conditions that lead to broken cone (BC) and cracked cone (CC) can result in lost cone
• See respective sections.

Excessive hours after a bearing / seal failure
• Running a bit too long after a bearing / seal failure results in enough cone movement to allow the cone to separate from the journal.
APPLICATION RECOMMENDATIONS

Excessive hours after a bearing / seal failure

- Follow proper drilling practices of monitoring torque on bit. Bearing / seal failures are typically indicated by erratic torque and/or bouncing after a connection when drilling resumes. Torque values that indicate a bearing / seal failure are application dependent. Local experience dictates when to pull the bit based on torque. There is no consistent and common value or threshold indicating a failure. A steady increase of torque, two or three times the normal values, may indicate a bearing / seal failure.
LN - Lost Nozzle
This characteristic describes a bit that is missing one or more jet nozzles. It is not a “Cutting Structure Dull Characteristic” and should only be used in the “Remarks Other Dull Characteristic” column.

POTENTIAL CAUSES

Improper nozzle installation
- Washouts and loss of nozzles can occur due to improper installation procedures.

Mechanical damage to nozzle and/or nozzle retaining system
- Enough movement within a worn or incorrect bit breaker can result in damaging contact between the nozzle or retention system and the bit breaker.
- Improper bit make-up procedure.
- Junk in the hole can damage nozzle retention system resulting in nozzle loss.

Wrong nozzle type for application
- Using one manufacturer’s bit and another manufacturer’s nozzles will result in a washout due to slight dimensional differences.

Erosion damage to nozzle and/or nozzle retaining system
- High solid muds or abrasive muds (e.g., hematite) can cause severe internal erosion leading to nozzle loss.

Bit balling
- Fluid entrainment and turbulence around the nozzle retention system when severe bit balling occurs.
  - See respective section.
APPLICATION RECOMMENDATIONS

Improper nozzle installation
- Follow manufacturer’s recommended procedures.

Mechanical damage to nozzle and/or nozzle retaining system
- Use appropriate bit breaker in good condition for bit type selected.
- Proper make-up for small diameter bits is to make-up by hand for several turns, then place in the bit breaker and make-up to the recommended torque. Care should be taken when making up bits with extended nozzles, or bits with carbide mini-nozzles to prevent damaging contact.
- May not know if junk has been dropped in the hole from the surface.
- Run junk basket. Follow manufacturer’s recommended procedure.
- For small quantities of parts, ¾” diameter or less, consider running a boot basket or magnet. Follow manufacturer’s recommended procedure.

Wrong nozzle type for application
- Ensure use of proper nozzle.

Erosion damage to nozzle and/or nozzle retaining system
- Solids reduction is needed to address this condition.
**LT - Lost Teeth**

This characteristic describes a cutting structure that is missing one or more cutting elements. Lost teeth can be very damaging to the remainder of the cutting structure. Typically a lost cutting element creates a ‘flat spot’ that increases adjacent cutting element or row loading, leading to further cutting structure damage under high energy levels. The loss of one cutting element in a row can reduce retention forces for the remaining cutting elements in cutting structures with extremely high density.

**POTENTIAL CAUSES**

**Excessive WOB for particular type**
- Loss of cutting element retention due to cyclic fatigue of cone the steel.
- Overload condition, exceeding the yield point of cone steel to the extent that loss of cutting element retention occurs.

**Excessive hours for particular type**
- Loss of cutting element retention due to cyclic fatigue of cone the steel when the bit is run past typical expectations.

**Erosion**
- See respective section.

**Cone cracking**
- See respective section.

**Broken cone**
- See respective section.

**Drilling environment**
- Hydrogen sulfide embrittlement cracks.
- Corrosion.

**Overbalanced drilling condition**
- Cyclic fatigue usually seen on aggressive bit types.
APPLICATION RECOMMENDATIONS

**Excessive WOB for particular type**
- Run proper WOB for specific bit type to achieve average run hours.

**Excessive hours for particular type**
- Reduce operating hours or select a more durable bit type.

**Drilling environment**
- Follow recommended drilling fluid guidelines to address these conditions.

**Overbalanced drilling condition**
- Reduced hydrostatic pressure is needed to address this condition.
OC - Off Center Wear
This dulling characteristic occurs when the geometric center of the bit and the geometric center of the hole do not coincide. Orbiting about different centers creates rings of uncut formation on the hole bottom. Drilling in this mode results in an oversized hole. Symptom is typically a reduced penetration rate. Off center wear can be recognized on the dull bit by wear on the cone shells between the rows of cutting elements, potentially more wear on one or more cone, gauge row, leg or nozzle boss. The wear on the cone shell may have a “scalloping” pattern or may be symmetrical. Wear may or may not occur on the cutting elements themselves, but if it occurs, it will typically be on the inner and/or outer flanks.

POTENTIAL CAUSES

Slow ROP
• Some formations are considered “plastic”. The bit cannot effectively drill the hole bottom. The slow ROP in combination with the formation yielding on the hole bottom allows lateral bit movement and enlarges the hole diameter due to the inherent drilling action in a roller cone bit.

Inadequate WOB for formation and bit type
• Related to slow ROP above, this is typically seen in horizontal applications. Insufficient WOB will change the bit dynamics.

Bent collar
• A bit can be forced to drill off center when the collar directly above the bit is not straight (angular misalignment). A bearing failure can also result due to one cone being overloaded.

Inadequate stabilization
• Rock bits drill most effectively when stabilized. Lack of or inadequate stabilization can create angular or parallel misalignment resulting in off center wear.

Steerable systems or downhole motors
• A downhole motor or steerable system forces the bit to drill an oversized hole creating the off center wear pattern.
**Overbalanced drilling condition**

- Some brittle formations (e.g., shales, depleted sands) can become “plastic” in overbalanced situations.

**APPLICATION RECOMMENDATIONS**

**Slow ROP**

- Increasing the ROP does not allow the bit as much time to enlarge the hole diameter reducing tendency to run off center. Selecting a more aggressive bit type and/or changing operating parameters may increase ROP thereby reducing off center wear.

**Bent collar**

- Ensure BHA meets manufacturer’s specifications.

**Inadequate stabilization**

- Angular and parallel misalignment is typically due to using drill collars too small in relation to the hole size. Refer to manufacturer’s of stabilization equipment for proper practices.

**Steerable systems or downhole motors**

- Specific bit features may enhance bit stabilization reducing the tendency to run off center that is inherent in a steerable system. Applications that force the bit to rotate off center can significantly reduce performance and do not indicate a bit deficiency.

**Overbalanced drilling condition**

- Reduced hydrostatic pressure is needed to address this condition.
- This can sometimes be addressed by changing bit types and thus changing the bottom hole pattern. Generally a more aggressive bit type will fatigue the formation faster.
Roller Cone Dull Grading Manual

PB - Pinched Bit
A condition in which a cone or cones on the bit have been mechanically forced together to a less than original gauge condition at some point during its run. Evidence of cutting element to cone shell contact between opposing cones may or may not be seen. The bit may or may not be less than nominal gauge when measured. The bearings / seals may or may not be effective when the dull is seen, but they were intact when the pinching occurred. If cone shell contact did not occur and one or more bearing / seal failures has occurred, there is no conclusive external evidence of pinching. Pinched bits can lead to bearing / seal failures, broken teeth, chipped teeth, cone interference, cone drag and many other cutting structure dull characteristics. Pinched Bit (PB) is not used in the “Cutting Structure Dull Characteristic” column.

POTENTIAL CAUSES
Improper drilling practices
- Forcing into an undergauge hole.
  - Improper reaming.
  - Bit being forced into a less than nominal size hole.
  - Roller cone bit being forced into a section of hole drilled by fixed cutter bits, due to different API O.D. tolerances.
- Bit being pinched in the bit breaker.
- Bit being forced into an undersized blowout preventer stack.
- Forcing a bit through casing that does not drift to the bit size used.
APPLICATION RECOMMENDATIONS

Improper drilling practices

- Forcing into an undergauge hole.
  - Ream undergauge holes using very light WOB and low RPM. A hole in a slightly undergauge condition requires a lesser amount of WOB than a hole in a greater undergauge condition. For example, a hole 1/16” undergauge requires less WOB in order not to damage the bit than a hole 1/2” undergauge.

- Bit being pinched in the bit breaker.
  - Caused by the bit rotating beyond the make-up lugs in the breaker indicated by damage seen on the legs. Ensure the use of a proper bit breaker in good condition and use proper make-up technique to prevent bending of the legs.
PN - Plugged Nozzle
A characteristic where one or more of the nozzles are obstructed. This characteristic is used only in the “Remarks Other Dull Characteristic” column.

**POTENTIAL CAUSES**

**Improper drilling practices**
• Jamming the bit into fill with the pump off.

**Pumped foreign material**
• Solid material pumped down the drill string and becoming lodged in a nozzle. The foreign material can also come from a drill string component.
• Lost circulation material lodging in the nozzle.

**Formation plugging**
• During a connection, reverse circulation can occur allowing formation chips to pass through the nozzles up into the bore of the drill string. When circulation is resumed, these formation chips can then become lodged in the nozzle(s).
APPLICATION RECOMMENDATIONS

Improper drilling practices
- Use nozzle strainers when tripping in.
- Follow proper drilling practices.

Pumped foreign material
- If known conditions exist, use pipe screens.
- For lost circulation material, an increase in the nozzle size or a change in the nozzle arrangement is needed to address this condition.

Formation plugging
- Run float to prevent reverse circulation during connections.
- Small nozzles are more susceptible to plugging. An increase in the nozzle size or a change in the nozzle arrangement is needed to address this condition.
- Asymmetrical nozzle arrangements may be more susceptible to plugging than standard two or three nozzle arrangements.
RG - Rounded Gauge
Rounded gauge is a condition where the outermost tip of the gauge cutting element has rounded over such that it is not cutting nominal gauge. Rounded gauge can occur regardless if the bit is in nominal gauge. A typical gauge cutting element not only drills the hole bottom, but drills (scrapes) the hole wall. The hole wall scraping creates a larger wear flat than does the hole bottom drilling. Rounded gauge will decrease the ROP and can increase torque.

POTENTIAL CAUSES
Reaming an undergauge hole in an abrasive formation
- More gauge wear / rounding will occur in a reaming mode than in a drilling mode for exactly the same interval. Reaming creates a severe in-thrust loading condition that is normally counteracted by an out-thrust loading condition seen in the drilling mode. This force imbalance causes more cone slippage on the hole wall, thus more wear / rounding.

Formation / improper bit selection
- Gauge rounding can be a typical dull characteristic in abrasive formations.
- Formation too abrasive for bit selected.
- See “Excessive hours for bit type selected” under Application Recommendations.

Excessive RPM for application and specific bit type
- Excessive RPM accelerates the mechanism of gauge rounding due to increases in relative surface velocities.

Off center wear
- See respective section.
- See “Excessive hours for bit type selected” under Application Recommendations.
APPLICATION RECOMMENDATIONS

Reaming an undergauge hole in an abrasive formation

- Ream using very light WOB and low RPM. A hole in a slightly undergauge condition requires a lesser amount of WOB than a hole in a greater undergauge condition. For example, a hole 1/16” undergauge requires less WOB in order to not damage the bit than a hole 1/2” undergauge.

Formation / improper bit selection

- Gauge and heel structures with diamond enhanced cutting elements can eliminate gauge rounding in many applications.
- For abrasive formations, select bits with less offset, and/or greater gauge tooth count, and/or a more wear resistant gauge / heel structure.
- Bits with multiple cutting elements which share the gauge cutting function should round less due to kerf reduction.

Excessive RPM for application and specific bit type

- Use proper RPM for formation.
- For abrasive formations, select bits with less offset, and/or greater gauge tooth count, and/or a more wear resistant gauge / heel structure.
- Gauge and heel structures with diamond enhanced cutting elements can eliminate gauge rounding in many applications.

Excessive hours for bit type selected

- Reduce operating hours or select bits with less offset, and/or greater gauge tooth count, and/or a more wear resistant gauge / heel structure.
- Gauge and heel structures with diamond enhanced cutting elements can eliminate gauge rounding in many applications.
**SD - Shirrtail Damage**
A condition where damage due to wear, erosion or junk occurs in the shirttail area. Shirrtail damage can lead to seal failures. Shirrtail Damage (SD) is not used in the “Cutting Structure Dull Characteristic” column.

**POTENTIAL CAUSES**

**Run on junk**
- Junk dropped in the hole from the surface (tong dies, tools, etc.).
- Junk from the drill string (reamer pins, stabilizer blades, etc.).
- Junk from a previous bit run (tungsten carbide inserts, ball bearings, etc.).
- Junk from the bit itself.

**Reaming undergauge hole**
- Reaming can pinch the bit enough to allow hole wall contact with the shirttails and/or legs.
- A roller cone bit following a fixed cutter bit can be pinched due to the differences in API O.D. specifications.

**Deviated holes**
- Gravity causes the bit to lay on the low side of the hole. This allows the shirttails to contact the hole wall and/or drilled cuttings.

**Off center wear**
- See respective section.

**Inadequate and/or poor hydraulics**
- Can occur in straight or deviated holes. Cuttings accumulate around the bit causing shirttail wear.

**Inadequate stabilization**
- Rock bits drill most effectively when stabilized. When the drill collar centerline and hole centerline do not coincide but are parallel (parallel misalignment), shirttail damage can result.

**Pinched bit**
- See respective section.

**Rounded gauge**
- See respective section.
APPLICATION RECOMMENDATIONS

Run on junk

- May not know if junk has been dropped in the hole from the surface.
- Run junk basket. Follow manufacturer’s recommended procedure.
- For small quantities of parts, ¾” diameter or less, consider running a boot basket or magnet. Follow manufacturer’s recommended procedure.

Reaming undergauge hole

- Ream using very light WOB and low RPM. A hole in a slightly undergauge condition requires a lesser amount of WOB than a hole in a greater undergauge condition. For example, a hole 1/16” undergauge requires less WOB in order to not damage the bit than a hole 1/2” undergauge.
- If the life of a roller cone bit is limited due to immediate gauge wear when following a fixed cutter bit, select a bit with a more robust gauge structure and/or with less offset.

Deviated holes

- Select bits with shirrtail protection features and/or with stabilization features.

Inadequate and/or poor hydraulics

- Increased hydraulic energy is needed to address this condition.
- Mini-extended nozzles can improve bottom hole cleaning by extending the nozzle exit closer to the hole bottom improving impinging jet velocity and pressure profile.
- Crossflow and asymmetrical nozzle configurations can provide better bottom hole cleaning.
- Select bits with shirrtail protection features.

Inadequate stabilization

- Select bits with stabilization features.
- Parallel misalignment is typically due to using drill collars too small in relation to the hole size. Refer to manufacturers of stabilization equipment for proper practices.
SS - Self Sharpening Wear
This dull characteristic is reserved for milled tooth bits. It is a condition that occurs when the milled teeth wear in a manner such that they retain a sharp crest shape. This characteristic is considered an indication of proper bit selection on bits with a self-sharpening feature at normal operating parameters. The self sharpening hardfacing scheme is when more hardfacing is applied on the trailing tooth flank than on the leading tooth flank. The leading flank hardfacing wears off faster than the trailing flank resulting in and maintaining a sharp cutting edge. This is a desirable wear characteristic. Bits with full tooth hardfacing will prevent premature tooth wear in intervals with abrasive properties.
TR - Tracking
A condition where the cutting elements on a given row impact on the same bottom hole location with each successive cone revolution. The action of the cutting element sliding into the previously formed pattern typically produces an asymmetrical wear pattern, which can be individualistic and distinctive between the rows on different cones. The wear is not limited to a particular area on the cutting element, nor does wear on the cone shell have to occur. If cone shell wear occurs it is a result of cone contact with the hole bottom or contact/erosion with cuttings.

POTENTIAL CAUSES

Formation
- Occasionally some bit types cannot effectively drill the hole bottom in some formations resulting in less than expected ROP.
- Some formations are considered “plastic”. The bit cannot effectively drill the hole bottom allowing tracking to occur.
- Tracking can be influenced by the cutting element shape and unit loading which varies as the bit dulls. Therefore, tracking may occur at some point in the run, but may not be seen in the dull condition.

Overbalanced drilling condition
- Some brittle formations (e.g., shales, depleted sands) can become “plastic” in overbalanced situations.
APPLICATION RECOMMENDATIONS

Formation

- Selecting a different bit type and/or changing operating parameters may reduce tracking thereby increasing ROP.

Overbalanced drilling condition

- Reduced hydrostatic pressure is needed to address this condition.
- This can sometimes be addressed by changing bit types (generally more aggressive) and thus changing the bottom hole pattern.
WO - Washed Out Bit
A washout is where drilling fluid has eroded a passage from an internal flow area to the exterior of the bit. It is not limited to welds. This characteristic is used only in the “Remarks Dull Characteristic” column.

POTENTIAL CAUSES

Excessive impact load / improper drilling practices
• Welds may crack during the bit run due to excessive impact. When a crack occurs and circulation starts through the crack, the washout is established very quickly. Causes of excessive impact are:
  • Dropping of the drill string.
  • Tagging bottom too hard or intentional spudding.
  • Hitting a ledge while tripping or making a connection.
  • Running on junk.

Improper nozzle installation
• Washouts can occur due to improper installation procedures.

Mechanical damage to nozzle and/or nozzle retaining system
• Enough movement within a worn or incorrect bit breaker can result in damaging contact between the nozzle or retention system and the bit breaker.
• Improper bit make-up procedure.
• Junk in the hole can damage nozzle retention system resulting in washout.

Wrong nozzle type for application
• Using one manufacturer’s bit and another manufacturer’s nozzles will result in a washout due to slight dimensional differences.

Erosion damage to nozzle and/or nozzle retaining system
• High solid muds or abrasive muds (e.g., hematite) can cause severe internal erosion leading to a washout or nozzle loss.

Bit balling
• Fluid entrainment and turbulence around retention system when severe bit balling occurs.
• See respective section.
APPLICATION RECOMMENDATIONS

Excessive impact load / improper drilling practices

• Follow proper drilling practices.

Improper nozzle installation

• Follow manufacturers’ recommended procedures.

Mechanical damage to nozzle and/or nozzle retaining system

• Use appropriate bit breaker in good condition for bit type selected.
• Proper make-up for small diameter bits is to make-up by hand for several turns, then place in bit breaker and make-up to recommended torque. Care should be taken when making up bits with some type of extended nozzles, or bits with carbide mini-nozzles to prevent damaging contact.
• May not know if junk has been dropped in the hole from the surface.
• Run junk basket. Follow manufacturer’s recommended procedure.
• For small quantities of junk, ¾” diameter or less, consider running a boot basket or magnet. Follow manufacturer’s recommended procedure.

Wrong nozzle type for application

• Ensure use of proper nozzle.

Erosion damage to nozzle and/or nozzle retaining system

• A reduction in solids or a less abrasive mud type is needed to reduce the internal erosion leading to a washout or a nozzle loss.
WT - Worn Teeth
Worn teeth is a condition that describes the reduction in the height of the cutting elements due to the drilling action. This is a normal and expected wear mode. When worn teeth is observed on milled tooth bits, it is preferred to further define the wear type by denoting self sharpening (SS) or flat crested (FC).

POTENTIAL CAUSES
Flat crested wear
- See respective section.

Self-sharpening wear
- See respective section.

Tracking
- Tracking of the “drive rows” will cause the inner rows to skid more than designed. See respective section.

Not enough WOB
- In harder formations, the bit is not able to effectively drill the rock. The bit therefore tries to ‘abrade’ away the formation.

Formation / improper bit selection
- Formation too abrasive for bit selected.

Excessive RPM for application and specific bit type
- Excessive RPM accelerates the mechanism of wear due to increases in relative surface velocities.

Excessive hours for application and specific bit type
- Wear due to rotating hours greater than typical expectations.

Inadequate hydraulics
- Inadequate cuttings removal accelerating cutting structure wear.
APPLICATION RECOMMENDATIONS

Not enough WOB

- It may not be desirable, practical or possible to increase the WOB. In this case, a harder bit type will last longer with typically only a small reduction in ROP (for that specific formation). The limiting factor / cost effectiveness is interval length before softer formations are encountered.
- Alternatively, going to a more aggressive bit type with more wear resistance should improve the ROP especially if softer sections are to be encountered.
- Determining which bit to run is based upon each respective dull condition, drilled intervals and comparison between drill-off tests.
- Increased WOB may be possible with a change in BHA stabilization. Refer to manufacturer’s of stabilization equipment for proper practices.

Formation / improper bit selection

- For abrasive formations, select bits with less offset, and/or greater tooth count, and/or a more wear resistant cutting structure.
- Bits with multiple cutting elements which share the gauge cutting function should wear less due to kerf reduction.
- Cutting structures with diamond enhanced cutting elements can eliminate wear in many applications.

Excessive RPM for application and specific bit type

- Use proper RPM for formation.
- For abrasive formations, select bits with less offset, and/or greater gauge tooth count, and/or a more wear resistant cutting structure.

Excessive hours for application and specific bit type

- Reduce rotating hours or select a more durable cutting structure.

Inadequate hydraulics

- Increased hydraulic energy is needed to address this condition.
FIXED CUTTER
DULL GRADING
MANUAL
The Smith Bits definitions and guidelines shown within are NOT IADC standards. They were created solely for internal purposes to reduce ambiguities and to improve our consistency in grading dull bits within the current IADC structure.
System Structure

The first four spaces describe the extent of wear, type and location on the cutting structure. The fifth space is reserved for grading bearing wear of roller cone bits. The sixth space indicates out of gauge measurement. The last two spaces provide additional information concerning the dull bit such as secondary dull characteristics and reason pulled.

<table>
<thead>
<tr>
<th></th>
<th>T</th>
<th>B</th>
<th>G</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Inner Rows</td>
<td>Outer Rows</td>
<td>Dull Char.</td>
<td>Location</td>
</tr>
<tr>
<td>2</td>
<td>(I)</td>
<td>(O)</td>
<td>(D)</td>
<td>(L)</td>
</tr>
</tbody>
</table>

1: (I) = Inner Rows — used to record the average wear on the inner two-thirds of the bit radius.

- **PDC** - cutter wear should be measured across the diamond table regardless of the cutter shape, size, type or exposure. Cutter wear is recorded using a liner scale from 0 to 8, with 0 representing no wear and 8 meaning no diamond remaining.

### Degrees of Cutter Wear

![Degrees of Cutter Wear](image)

- **Inner 2/3 Radius**
- **Outer 1/3 Radius**

### Inner / Outer Body Designation

- **PDC Bits / Impregnated Bits**
• **Bi-center** – the inner section is considered the entire pilot section. Degrees of cutter wear on bi-centers are the same as for PDC bits.

![Diagram of Bi-Center Bits](image)

• **Impregnated Bits (K Series)** - use Grit Hot-Pressed Inserts (GHI), which protrude out of the ribs on a new bit. At the point where the GHI wear is flush with the ribs, the bit should be graded a “1”. Wear after that point is measured using a ratio of remaining -rib-height to original -rib-height. If the original-rib-height was 0.5 inches and the remaining-rib-height is 0.25 inches, the grading would be a “4” (50% wear).

**APPROXIMATE RIB HEIGHT FOR VARIOUS IMPREGNATED BITS**

<table>
<thead>
<tr>
<th>K403</th>
<th>K405</th>
<th>K503</th>
<th>K505</th>
<th>K507</th>
<th>K703</th>
<th>K705</th>
<th>K707</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.8”</td>
<td>1.1”</td>
<td>0.8”</td>
<td>1.1”</td>
<td>0.8”</td>
<td>1.1”</td>
<td>0.8”</td>
<td>1.1”</td>
</tr>
</tbody>
</table>
2: **(O) = Outer Rows** — used to record the average wear on the outer one-third of the bit radius, except for bi-center bits.

- **PDC** - cutter wear measurement is identical to the “Inner Rows” section.
- **Bi-center** – the outer radius is considered the reamer section. The amount of cutter wear is determined by the same method as for PDC bits.
- **Impregnated bits** – identical procedure to the “Inner Rows” section.

3: **(D) = Dull Characteristics - Cutting Structure**

- Uses a two letter code to indicate the **major** dull characteristic of the cutting structure.
- Input only one dull characteristic code.
### DULL CHARACTERISTICS

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>BF</td>
<td>Bond Failure</td>
</tr>
<tr>
<td>BT</td>
<td>Broken Teeth / Cutters</td>
</tr>
<tr>
<td>BU</td>
<td>Balled Up Bit</td>
</tr>
<tr>
<td>CR</td>
<td>Cored</td>
</tr>
<tr>
<td>CT</td>
<td>Chipped Teeth / Cutters</td>
</tr>
<tr>
<td>DL</td>
<td>Cutter Delamination</td>
</tr>
<tr>
<td>ER</td>
<td>Erosion</td>
</tr>
<tr>
<td>HC</td>
<td>Heat Checking</td>
</tr>
<tr>
<td>JD</td>
<td>Junk Damage</td>
</tr>
<tr>
<td>LM</td>
<td>Lost Matrix</td>
</tr>
<tr>
<td>LN</td>
<td>Lost Nozzle</td>
</tr>
<tr>
<td>LT</td>
<td>Lost Teeth / Cutters</td>
</tr>
<tr>
<td>NR</td>
<td>Not Rerunable</td>
</tr>
<tr>
<td>OC</td>
<td>Off Center Wear</td>
</tr>
<tr>
<td>PN</td>
<td>Plugged Nozzle / Flow Passage</td>
</tr>
<tr>
<td>RO</td>
<td>Ring Out</td>
</tr>
<tr>
<td>RR</td>
<td>Rerunable</td>
</tr>
<tr>
<td>SP</td>
<td>Spalled Cutters</td>
</tr>
<tr>
<td>WO</td>
<td>Washed Out Bit</td>
</tr>
<tr>
<td>WT</td>
<td>Worn Teeth / Cutters</td>
</tr>
<tr>
<td>NO</td>
<td>No Dull</td>
</tr>
</tbody>
</table>

### Location Designation

- **C** = Cone
- **N** = Nose
- **T** = Taper
- **S** = Shoulder
- **G** = Gauge
- **A** = All Areas

4: **(L)** = Location

- Use a letter code to indicate the location on the bit face where the major dull characteristic occurred.
5: (B) = Bearings / Seals
This space is used only for roller cone bits. It will always be marked “X” for fixed cutter bits.

6: (G) = Amount Undergauge
• Used to record the condition of the bit gauge. It is based upon nominal ring gauge (ensure that a PDC and not roller cone ring gauge is used as tolerances between the two are different).
  – “IN” is used if the bit is still in gauge.
  – Otherwise, the amount the bit is undergauge is recorded to the nearest 1/16th of an inch.
  – For bi-centers, use the special bi-center gauge measurement procedure below.

API tolerances for fixed cutter and roller cone bits

<table>
<thead>
<tr>
<th>Nominal Bit Size (in.)</th>
<th>Fixed Cutter</th>
<th>Roller Cone</th>
</tr>
</thead>
<tbody>
<tr>
<td>6 ¾ and smaller</td>
<td>-0.015 to +0.00</td>
<td>-0.0 to +1/32</td>
</tr>
<tr>
<td>6 25/32 including 9</td>
<td>-0.020 to +0.00</td>
<td>-0.0 to +1/32</td>
</tr>
<tr>
<td>9 1/32 including 13 ¾</td>
<td>-0.030 to +0.00</td>
<td>-0.0 to +1/32</td>
</tr>
<tr>
<td>13 25/32 including 17 ½</td>
<td>-0.045 to +0.00</td>
<td>-0.0 to +1/16</td>
</tr>
<tr>
<td>17 17/32 and larger</td>
<td>-0.063 to +0.00</td>
<td>-0.0 to +3/32</td>
</tr>
</tbody>
</table>

Bi-Center Gauge Measurement Procedure
• Measure the shank diameter with a caliper, making sure that the full shank is measured. Do not measure inside the breaker slots. This is illustrated in Figure 1 below.

Figure 1 - Measuring the Shank Diameter
• Next, measure the height of the longest reamer blade from the outer surface of the shank. This can be accomplished by using a straight edge and a ruler. This step is illustrated in Figure 2.
• For accuracy, the straight edge must be placed parallel to the shank. Also, the closer the ruler is placed to the reamer-blade, the more accurate the reading.
• The bit’s diameter is then calculated by taking the diameter of the shank and 2 times the height of the longest reamer blade.

\[
\text{Gauge Diameter} = \frac{\text{Shank Diameter}}{2} + 2 \times \text{Reamer Height}
\]

\[
= \text{_________ inches}
\]

7: (O) = Other Dull Characteristics
• Used to record other dull characteristics such as secondary evidence of bit wear. The secondary evidence may identify the cause of the primary dull characteristic in the third space.

8: (R) = Reason Pulled
• Used to record the reason the bit was pulled.
Cutter Types and Nomenclature

This shows the PDC cutter in various configurations such as single-substrate (fig. 1), two-piece (fig. 2) and stud cutters (fig. 3). The important terms to remember are:

- **PCD layer** – also known as the diamond table.
- **Carbide substrate** – acts as the support for the diamond table, and provides toughness. It also helps bond the cutter into the bit body.
- **LS bond line** – is a cemented boundary between two carbide substrates that may have different characteristics.
BF - Bond Failure
Bond failure results in the cutter failing along the bond between two carbide substrates. The failure is seen as a smooth surface on the remaining substrate.

POTENTIAL CAUSES

Improper bit selection
- Formation too hard for bit type selected.
- Specific bit types may not provide smooth drilling characteristics.

Excessive WOB for application and specific bit type
- Indicated by chipped cutters predominantly in the middle but can also occur in the nose area.

Broken formations (includes boulders)
- Broken formations are those that have alternating hard and soft interbedded laminated sections with distinct well defined boundaries laid down at an angle. As drilling progresses through the bedding planes, pieces break at the bedding planes causing uneven loading on the cutting structure as the broken portions of formation move or roll under the bit.

Improper bottom hole pattern break-in
- Excessive WOB and RPM and the previous bit’s bottom hole pattern can create high cutting structure loading.

Excessive impact load / improper drilling practices
- Dropping of the drill string.
- Tagging bottom too hard / intentional spudding.
- Hitting a ledge while tripping or making a connection.
- Running on junk.
- Improper casing clearances.

Drilling environment
- Follow recommended drilling fluid guidelines.

Bit vibration
- Bit bouncing due to formation changes.
APPLICATION RECOMMENDATIONS

Improper bit selection
- Formation too hard for bit type selected.

Excessive WOB for application and specific bit type
- Optimize WOB for formation.
- Consider using a shock sub or thruster.

Excessive hours for application and specific bit type
- Failure can be reduced by reducing RPM or selecting a more heavy-set cutting structure.

Broken formations (includes boulders)
- Bond failures due to drilling broken formations can occur in any row. This can be related to excessive WOB. An indicator of broken formations is when the TQ becomes extremely erratic when drilling through the boundaries, then smooths out. Consider using a thruster or shock sub.

Improper bottom hole pattern break-in
- Bottom hole pattern break-in is considered to be when a new bit achieves uniform cutting structure loading. This is done with light weights and slow rpm and is normally achieved with in 3 to 6 inches. At that point WOB and RPM can be gradually increased to typical operating levels.

Excessive impact load / improper drilling practices
- Follow proper drilling practices.

Bit vibration
- Change operating parameters.
BT - Broken Cutters

A cutting element is considered broken if over 1/3 of the cutting element is broken to the substrate. BT may be a potential indicator of problems in bit selection or operating practices if performance falls significantly short of expectations.

**POTENTIAL CAUSES**

**Formation / improper bit selection**
- Bit selection too aggressive. High point loading on cutters. Lack of bit stability.

**Excessive WOB for application and specific bit type**
- Depth of cut too deep.

**Excessive RPM for application and specific bit type**
- Indicated by broken cutters predominantly on the ODR and gauge due to high relative velocities and impact force generated.

**Broken formations (includes boulders)**
- Broken formations are those that have alternating hard and soft interbedded laminated sections with distinct well defined boundaries laid down at an angle. As drilling progresses through the bedding planes, pieces break at the bedding planes causing uneven loading on the cutting structure as the broken portions of formation move or roll under the bit.

**Improper bottom hole pattern break-in**
- Excessive WOB and RPM and the previous bit’s bottom hole pattern can create high cutting structure loading causing broken cutters unless the bit can create its own bottom hole pattern.

**Excessive impact load / improper drilling practices**
- Dropping of the drill string.
- Tagging bottom too hard / intentional spudding.
- Hitting a ledge while tripping or making a connection.
- Running on junk.
- Drill-out with hi-bend motors.

**Bit vibration**
- Improper bit selection / BHA / operating parameters.
APPLICATION RECOMMENDATIONS

Formation / improper bit selection
- Consider a more stable design.
- Use more impact resistant cutters.
- Reduce bit aggressiveness.
- Reduce cutter loading.

Excessive WOB for application and specific bit type
- Optimize WOB for formation.
- Consider using a shock sub when anticipating numerous formation changes. See broken formations.

Excessive RPM for application and specific bit type
- Optimize RPM for formation.

Broken formations (includes boulders)
- Broken cutters due to drilling broken formations can occur in any location. An indicator of broken formations is when the TQ becomes extremely erratic when drilling through the boundaries, then smooths out. Consider using a thruster or shock sub.

Improper bottom hole pattern break-in
- Bottom hole pattern break-in is considered to be when a new bit achieves uniform cutting structure loading. This is done with light weights and slow rpm and is normally achieved within 6 to 12 inches. At that point WOB and RPM can be gradually increased to typical operating levels.

Excessive impact load / improper drilling practices
- Follow proper drilling practices.

Bit vibration
- Change operating parameters.
BU - Balled Up
Bit balling is a condition whereby formation becomes attached to the bit blades and bit body or on the face of the cutters such that the ROP suffers. There may or may not be any evidence of physical damage to the bit. The cutting elements are packed off to the extent that they are not penetrating into the formation effectively. Rotary torque (TQ) typically will decrease as the bit balls up and pump pressure will increase.

POTENTIAL CAUSES

Formation
- Drilling a sticky formation (i.e., gumbo - hydratable clay).

Inadequate hydraulics
- Poor hole cleaning and/or bit cleaning for penetration rate achieved with the WOB and RPM combination in use.

Poor fluid distribution
- Improper nozzle selection or hydraulic calculations.

Drilling practices
- Forcing the bit into formation cuttings with the pump not running.
- Inadequate cleaning of the hole before making a connection.
- High WOB.

Improper bit selection
- Harder bit types have less optimal cleaning attributes. These bits generally have greater cutter count and/or less junk slot area which are easier to pack off. They also provide less flow area on the hole bottom.

Drilling fluid (with regards to bit balling only)
- Poorly maintained drilling fluid.
- Improper drilling fluid.
APPLICATION RECOMMENDATIONS

Formation
• See all the following.

Inadequate hydraulics
• Ensure that the hydraulics have been optimized for the parameters available.
• Optimize HSI or flow to address application.

Poor fluid distribution
• For all bit balling problems, higher HSI is recommended for better blade cleaning.

Drilling practices
• Follow proper drilling practices.

Improper bit selection
• Select bits with less flow restrictive cutting structures. These will typically be more aggressive types such as steel bits which possess:
  • Taller blade height / larger cutters.
  • More nozzles.

Drilling fluid (with regards to bit balling only)
• Follow recommended drilling fluid guidelines.
• Consider alternative mud systems. (inhibitive)
CR - Cored
A bit is cored when its centermost cutting elements are worn, broken and/or lost to the extent that the cone area of the bit is showing significant wear from the formation.

POTENTIAL CAUSES

Improper bottom hole pattern break-in
- Excessive WOB and RPM and the previous bit’s bottom hole pattern can create high cutting structure loading causing broken cutters unless the bit can create its own bottom hole pattern, especially after coring operations.

Junk damage
- Breakage of cutting structure due to running on junk whether external or from the bit itself. See respective section.

Erosion
- Erosion causing loss of cutting structure. See respective section.

Formation / improper bit selection
- Abrasiveness of formation exceeds the wear resistance of the cutting elements.
- Formation too hard for bit type selected resulting in breakage of the cutting elements.

Excessive WOB for application and specific bit type
- Indicated by broken cutters predominantly in nose area but can also propagate to the cone area.

Excessive hours for application and specific bit type
- Indicated by broken / worn / lost cutters when exceeding typical expectations.

Improper drilling practices
- Improperly drilled back flow valves in casing shoes can create high inner cutting structure loading.
- Improper type of float.

Bit vibration
- Could cause a loss or breakage of cutters, resulting in a core out.
APPLICATION RECOMMENDATIONS

Improper bottom hole pattern break-in
• Proper bottom hole pattern break-in is considered to be when a new bit achieves uniform cutting structure loading. This is done with light weights and slow rpm and is normally achieved with in 6 to 12 inches. At that point WOB and RPM can be gradually increased to typical operating levels.

Formation / improper bit selection
• For hard formations, then select a bit with higher abrasion resistance and/or impact resistance.

Excessive WOB for application and specific bit type
• Optimize WOB for formation.
• Consider using a shock sub or thruster.
• For hard formations, then select a bit with smaller cutters and/or higher blade count.

Improper drilling practices
• Follow recommended procedures for drilling out cementing equipment. Floats must be PDC drillable. Technical papers available from Smith Bits.

Bit vibration
• Change operating parameters.
CT - Chipped Cutter

A cutting element is considered chipped if less than 1/3 of the cutting element is gone regardless of the cause. Chipping of diamond tables generally occurs on the outer most edge of a cutter.

**POTENTIAL CAUSES**

**Formation / improper bit selection**
- Improper cutter selection.
- Formation too hard for bit type selected. No specific chippage pattern.
- Specific bit types may not provide smooth drilling characteristics.
- Bit bouncing can cause chippage. No specific chippage pattern. See “Broken Formations” below.
- Cutters were subjected to numerous heat cycles (rebuild).

**Excessive WOB for application and specific bit type**
- Indicated by chipped cutters predominantly on the nose, but can also occur on the gauge area.

**Excessive RPM for application and specific bit type**
- Indicated by chipped cutters predominantly in the gauge area.

**Broken formations (includes boulders)**
- Broken formations are those that have alternating hard and soft interbedded laminated sections with distinct well defined boundaries laid down at a angle. As drilling progresses through the bedding planes, pieces break at the bedding planes causing uneven loading on the cutting structure as the broken portions of formation move or roll under the bit.

**Improper bottom hole pattern break-in**
- Excessive WOB and RPM and the previous bits’ bottom hole pattern can create high cutting structure loading causing chipped cutters unless the bit can create its own bottom hole pattern.

**Excessive impact load / improper drilling practices**
- Dropping of the drill string.
- Tagging bottom too hard / intentional spudding.
- Hitting a ledge while tripping or making a connection.
- Running on junk / float not PDC drillable.
- Improper casing clearances.

**Heat checking**
- See respective section.

**Bit vibration**
- Improper bit selection / BHA / operating parameters.
APPLICATION RECOMMENDATIONS

Formation / improper bit selection
- Formation too hard for bit type selected.
- Select a bit with smaller cutters and/or higher blade count.

Excessive WOB for application and specific bit type
- Optimize WOB for formation.
- Consider using a shock sub or thruster.
- For hard formation, select a bit with higher impact resistance.

Excessive RPM for application and specific bit type
- Optimize RPM for formation.
- For hard formations, select a bit with higher impact resistant cutters.
- Can also be caused by heat checking. See respective sections.

Broken formations (includes boulders)
- Chipped cutters due to drilling broken formations can occur in any location. This can be excessive WOB or RPM related. An indicator of broken formations is when the TQ becomes extremely erratic when drilling through the boundaries, then smooths out. Use shock sub. Reduction of rough running is primarily achieved by optimizing RPM.

Improper bottom hole pattern break-in
- Bottom hole pattern break-in is considered to be when a new bit achieves uniform cutting structure loading. This is done with light weights and slow rpm and is normally achieved with in 6 to 12 inches. At that point WOB and RPM can be gradually increased to typical operating levels.

Excessive impact load
- Follow proper drilling practices.

Bit vibration
- Change operating parameters.
- Select a bit with higher vibration control.
DL - Delaminated Cutters
Cutter delamination is caused by a separation of the diamond table from the carbide substrate. A smooth carbide surface of the geometric, non-planar interface can be seen.

**POTENTIAL CAUSES**

*Formation / improper bit selection*
- Formation too hard for bit type selected. No specific chippage pattern.
- Specific bit types may not provide smooth drilling characteristics.

*Excessive WOB for application and specific bit type*
- Indicated by delaminated cutters predominantly on the nose area, but can also occur in the center.

*Broken formations (includes boulders)*
- Broken formations are those that have alternating hard and soft interbedded laminated sections with distinct well defined boundaries laid down at an angle. As drilling progresses through the bedding planes, pieces break at the bedding planes causing uneven loading on the cutting structure as the broken portions of formation move or roll under the bit.

*Improper bottom hole pattern break-in*
- Excessive WOB and RPM and the previous bits’ bottom hole pattern can create high cutting structure loading causing chipped cutters unless the bit can create its own bottom hole pattern.

*Excessive impact load / improper drilling practices*
- Dropping of the drill string.
- Tagging bottom too hard / intentional spudding.
- Hitting a ledge while tripping or making a connection.
- Running on junk.
- Improper casing clearances.

*Heat checking*
- See respective section.

*Bit vibration*
- Bit bouncing can cause delamination due to high axial loading.
APPLICATION RECOMMENDATIONS

Formation / improper bit selection
• Formation too hard for bit type selected.
• Select higher impact resistant cutters.
• Select a bit with higher impact resistance and vibration control.

Excessive WOB for application and specific bit type
• Optimize WOB for formation.
• Consider using a shock sub or thruster.
• For hard formation, select a bit with smaller cutters and/or higher blade count.

Broken formations (includes boulders)
• Delaminated cutters due to drilling broken formations can occur in any location. This can be excessive WOB or RPM related. An indicator of broken formations is when the TQ becomes extremely erratic when drilling through the boundaries, then smooths out. Use shock sub. Reduction of rough running is primarily achieved by optimizing RPM.

Improper bottom hole pattern break-in
• Bottom hole pattern break-in is considered to be when a new bit achieves uniform cutting structure loading. This is done with light weights and slow rpm and is normally achieved with in 6 to 12 inches. At that point WOB and RPM can be gradually increased to typical operating levels.

Excessive impact load / improper drilling practices
• Follow proper drilling practices.

Bit vibration
• Change operating parameters.
ER - Erosion
Erosion is used to describe the loss of material on the cutting structure due to the impact of the drilling fluid, solids and the cuttings against the drill bit. Erosion can undermine the cutters, resulting in a lost cutter. In addition, erosion can wear away blade and body material.

Potential Causes

Inadequate hydraulics
- Cuttings accumulate underneath the bit due to the lack of hydraulic energy. These cuttings are re-cut again and again.

Excessive hydraulics
- High velocity fluid creates turbulence and impingement on the blades and cutting elements.
- Improper nozzle size combinations.

Abrasive formations
- Cuttings from abrasive formations can cause erosion even with minimum hydraulics.

Drilling environment
- Abrasive drilling fluids. (hematite)
- Poor solids control.
- Corrosive drilling environments enhance rate of erosion.
APPLICATION RECOMMENDATIONS

Excessive hydraulics
- Reduce the hydraulic energy level (jet velocity / HSI).
- Increase nozzle count and improve hydraulic distribution.
- Select a bit with an erosion protection feature. Matrix bits provide better erosion resistance than steel bits.
- Optimize TFA with erosion reduction in mind.

Abrasive formations
- Select a bit with an erosive wear reduction feature.

Drilling environment
- Follow recommended drilling fluid guidelines to reduce solids.
- Select a bit with an erosive wear reduction feature.
- Follow recommended drilling fluid guidelines to reduce corrosion.
Heat checking is seen as biaxial or cross-hatched pattern of surface cracks intersecting at approximately right angles. The number of cracks on a cutting element can vary significantly. These cracks initiate on the surface due to thermal shock / fatigue and propagate due to stress relief. Increasing the wear / contact area on the cutting element can amplify heat generation and aggravate thermal shock / fatigue, increasing crack propagation. Not limited to any particular location, it is most prevalent on the nose, shoulder and gauge areas; on cutter substrates, and gauge pads.

**POTENTIAL CAUSES**

**Insufficient fluid flow**
- Insufficient flow will allow heat build up.

**Reaming a slightly under gauge hole at high RPM**
- Heat checking on the gauge due to cyclic thermal stress generated with high reaming rates.

**Drilling at high RPM**
- High RPM generates higher cyclic thermal stresses.

**Formation**
- This may be a typical dull characteristic in some formations, especially carbonates or abrasive formations.
APPLICATION RECOMMENDATIONS

Insufficient fluid flow
- Refer to minimum GPM for size bit.
- Consider bit design with improved hydraulic distribution.
- Consider running higher nozzle count.

Reaming a slightly underguage hole at high RPM
- Ream using very light WOB and low RPM. A hole in a slightly underguage condition requires a lesser amount of WOB than a hole in a greater under gauge condition. For example, a hole 1/16” underguage requires less WOB in order to not damage the bit than a hole 1/2” underguage.

Drilling at high RPM
- Investigate use of bit with more abrasion resistant design.
- Consider use of Quick cutters.
- Select more abrasion resistant cutters.
- Reduce RPM while drilling abrasive formations.
JD - Junk Damage
A condition where the bit has indentations or cutter damage caused by contact with objects other than formation. It is to be used in the “Remarks Other Dull Characteristics” column when describing damage to a bit knowingly caused by external sources or junk.

POTENTIAL CAUSES
Run on junk
• Junk dropped in the hole from the surface (tong dies, tools, etc.).
• Junk from the drill string (reamer pins, stabilizer blades, etc.)
• Junk from a previous bit run (tungsten carbide inserts, ball bearings, cutters, etc.).
• Junk from the bit itself.
• Damage due to contact with casing.
• Junk from casing float equipment.
• Damage caused by whipstock, casing windows, etc.
APPLICATION RECOMMENDATIONS

Run on junk

- Junk may have been dropped in the hole from the surface.
- Run junk basket. Follow manufacturer’s recommended procedure.
- For small quantities of parts, ¾” diameter or less, consider running a boot basket or magnet if made of iron. Follow manufacturer’s recommended procedure.
LM - Lost Matrix
This characteristic describes a bit with one or more blades that have lost an outer piece of matrix. This should not be confused with worn blade tops, but can include broken blades.

**POTENTIAL CAUSES**

**Excessive WOB for particular type**
- Fracture caused by excessive WOB.

**Excessive impact load / improper drilling practices**
- Dropping of the drill string.
- Tagging bottom too hard / intentional spudding.
- Hitting a ledge while tripping or making a connection.
- Running on junk.
- RPM too high.
- Interbedded / inconsistent formation compressive strength.

**Heat checking**
- See respective section.

**Broken cutters / worn cutters / lost cutters**
- Drilling after the cutting elements have broken, or worn or lost to the extent that the blade is contacting the hole bottom can cause a lost matrix. See respective section.

**Drilling environment**
- Hydrogen Sulfide embrittlement.
- Corrosion.
- Formation stringers, resulting in high torque.

**Overheating**
- Inadequate hydraulics.
- Drilling without fluid circulation.

**Bit vibration**
- Improper bit selection / BHA / operating parameters.
APPLICATION RECOMMENDATIONS

Excessive WOB for particular type
• Run proper WOB for specific bit type to achieve typical expectation.

Excessive impact load
• Follow proper drilling practices.
• Reduce RPM.

Drilling environment
• Follow recommended drilling fluid guidelines.

Overheating
• A higher flow rate is needed to address this condition.
• Follow proper drilling practices.

Bit vibration
• Change operating parameters.
LN - Lost Nozzle
This characteristic describes a bit that is missing one or more jet nozzles. It is not a “Cutting Structure Dull Characteristic” and should only be used in the “Remarks Other Dull Characteristic” column. A lost nozzle is identified by a loss of pump pressure and reduced ROP.

**POTENTIAL CAUSES**

**Improper nozzle installation**
- Washouts and loss of nozzles can occur due to improper installation procedures.

**Wrong nozzle type for application**
- Using one manufacturer’s bit and another manufacturer’s nozzles will result in a washout due to slight dimensional differences.

**Erosion damage to nozzle and/or nozzle bore**
- High-solid muds or abrasive muds (ex. hematite) can cause severe internal erosion leading to nozzle loss.
- Excessive hours on bit.

**Bit balling**
- Fluid entrainment & turbulence around the nozzle retention system when severe bit balling occurs.
  - See respective section.
APPLICATION RECOMMENDATIONS

**Improper nozzle installation**
- Follow manufacturer’s recommended procedures.

**Wrong nozzle type for application**
- Ensure use of proper nozzle.

**Erosion damage to nozzle and/or nozzle bore**
- Solids reduction is needed to address this condition.
LT - Lost Cutter
This characteristic describes a cutting structure that is missing one or more cutting elements. The loss of the entire cutting element from the pocket assumes a brazing related failure. Lost cutters can be very damaging to the remainder of the cutting structure. Typically a lost cutting element creates a ‘flat spot’ that increases to adjacent cutting elements, leading to further cutting structure damage under high energy levels. The loss of one cutting element can increase the workload for the remaining cutting elements. This could lead to a ring-out or core-out.

POTENTIAL CAUSES

**Excessive WOB for particular type**
- Overload condition, exceeding the yield point of the cutter braze and mechanical lock to the extent that loss of cutting element retention occurs.

**Erosion**
- See respective section.

**Lost matrix**
- See respective section.

**Drilling environment**
- Hydrogen sulfide embrittlement cracks.
- Corrosion.

**Bit vibration**
- Improper bit / operating parameters / BHA selection.

**Manufacturing defects**
- Loss of cutting element retention due to poor braze.

**Excessive hours for particular type**
- Loss of cutting element retention due to the bit being run past typical expectations.
APPLICATION RECOMMENDATIONS

Excessive WOB for particular type
• Run proper WOB for specific bit type to achieve average run hours.

Drilling environment
• Follow recommended drilling fluid guidelines to address these conditions.

Bit vibration
• Change operating parameters.

Excessive hours for particular type
• Reduce operating hours or select a more durable bit type.
OC - Off Center Wear
This dulling characteristic occurs when the geometric center of the bit and the geometric center of the hole do not coincide and the center of the bit moves in the opposite direction to drill string rotation. Better known as backward whirl, or back whirl, this type of bit dynamic is more damaging than forward whirl. Most notable by wear of the matrix behind the cutters on the blade tops without substantial wear to the cutters themselves. Often included along with the matrix wear is heat checking of the cutters substrate. The diamond table itself may or may not show wear. Typically the wear pattern on the matrix is not in the same radial pattern as the cutters travel when rotation about the bits axis. All evidence of backwards whirl coincides with backwards rotation of the bit allowing the back of the blades to contact the formation prior to the cutters. Not a “Cutting Structure Dull Characteristic” and should only be used in the “Remarks Other Dull Characteristic” column.

POTENTIAL CAUSES

Oversize hole
• Bit is unconstrained allowing for lateral movement.
• Results of directional tools (bent housing motor, push-the-bit rotary steerable systems)
• Excessive flow causing washout.

Stabilization
• Inadequate stabilization
• Under gauge stabilizers.

Improper bit selection
• Too aggressive side cutters cause bit to grab the hole wall, forcing the bit to rotate about an axis other than it’s center
• Light-set bits allow for a deeper side cutting action.
APPLICATION RECOMMENDATIONS

Oversize hole
- Use rotary drilling methods if possible. Match bit to BHA type.
- Avoid excessive flow in unconsolidated or soft formations.

Stabilization
- Optimize BHA for stabilization by adding more stabilizers or near bit stabilizers.
- Select full-gauge stabilizers.

Improper bit selection
- Select bit with less aggressive side cutters.
- Select a heavier-set bit.
PN - Plugged Nozzle / Waterway
A characteristic where one or more of the nozzles are obstructed. This characteristic is used only in the “Remarks Other Dull Characteristic” column. Pump pressure will generally increase when nozzles / waterways become plugged.

POTENTIAL CAUSES

Improper drilling practices
• Jamming the bit into fill or soft formation with the pump off.

Pumped foreign material
• Solid material pumped down the drill string and becoming lodged in a nozzle. The foreign material can also come from a drill string component.
• Lost circulation material lodging in the nozzle. (Never use material that exceeds \( \frac{1}{3} \) diameter of smallest nozzle / port)

Formation plugging
• Chips of formation going up the drill string through the bit on a connection and becoming lodged in a nozzle when circulation is resumed. (u-tubing)

Drill pipe scale
• Deposits can build up on the inside of drill pipe, becoming dislodged and plugging nozzles when flow is passed through.

Hydraulics
• Consider bit with better cleaning capabilities.
APPLICATION RECOMMENDATIONS

Improper drilling practices
- Use nozzle strainers when tripping in.
- Follow proper drilling practices.

Pumped foreign material
- If known conditions exist, use pipe screens / junk baskets.
- For lost circulation material, an increase in the nozzle size is needed to address this condition.

Formation plugging
- Run float to prevent reverse circulation during connections.
- Small nozzles are more susceptible to plugging. An increase in the nozzle size or nozzle arrangement is needed to address this condition.

Drill pipe scale
- Have drill pipe cleaned.
RO - Ring Out
A bit is considered to have a ring out when a circular band of cutting elements are worn, broken and/or lost to the extent that blade is showing significant wear from the formation. A ring out generally is associated with an increase in pump pressure and a decrease in ROP.

POTENTIAL CAUSES
Improper bottom hole pattern break-in
- Excessive WOB and RPM and the previous bits’ bottom hole pattern can create high cutting structure loading causing broken cutters unless the bit can create its own bottom hole pattern.

Junk damage
- Breakage of cutting structure due to running on junk whether external or from the bit itself. See respective section.

Erosion
- Erosion causing loss of cutting structure. See respective section.

Formation / improper bit selection
- Abrasiveness of formation exceeds the wear resistance of the cutting elements.
- Formation too hard for bit type selected resulting in breakage of the cutting elements.

Excessive WOB for application and specific bit type
- Indicated by broken cutters predominantly in middle rows but can also occur in the nose rows.

Excessive hours for application and specific bit type
- Indicated by broken / worn / lost inserts when exceeding typical expectations.

Bit vibration
- Improper bit / operating parameters / BHA selection.

Improper drilling practices
- Improperly drilled back flow valves / casing shoes can create high inner cutting structure loading.
APPLICATION RECOMMENDATIONS

Improper bottom hole pattern break-in
- Proper bottom hole pattern break-in is considered to be when a new bit achieves uniform cutting structure loading. This is done with light weights and slow rpm and is normally achieved with in 6 to 12 inches. At that point WOB and RPM can be gradually increased to typical operating levels.

Formation / improper bit selection
- Consider more abrasion resistant cutters.
- Consider more abrasion resistant cutting structure.
- Consider more impact resistant cutting structure.

Excessive WOB for application and specific bit type
- Optimize WOB for formation.
- Consider using a shock sub or thruster.
- For hard formations, then select a bit with more blades and/or smaller cutters.

Excessive hours for application and specific bit type
- Select more durable bit type or reduce operating hours.
- Broken and/or worn cutting elements can be reduced by decreasing operating hours or by selecting a more robust cutting structure.

Bit vibration
- Change operating parameters.

Improper drilling practices
- Refer to Recommend Drilling and Drillout Procedures.
**SP - Spalled Cutters**
A partial fracture of the diamond table, similar to cutter delamination, but where the non-planar interface is not completely exposed and some diamond remains bonded to the carbide substrate.

**POTENTIAL CAUSES**

**Formation / improper bit selection**
- Bit selection too aggressive. High point loading on cutters. Lack of bit stability.

**Excessive WOB for application and specific bit type**
- Depth of cut too deep.

**Excessive RPM for application and specific bit type**
- Indicated by broken cutters predominantly on the ODR and gauge due to high relative velocities and impact force generated.

**Broken formations (includes boulders)**
- Broken formations are those that have alternating hard and soft interbedded laminated sections with distinct well defined boundaries laid down at a angle. As drilling progresses through the bedding planes, pieces break at the bedding planes causing uneven loading on the cutting structure as the broken portions of formation move or roll under the bit.

**Improper bottom hole pattern break-in**
- Excessive WOB and RPM and the previous bit’s bottom hole pattern can create high cutting structure loading causing broken cutters unless the bit can create its own bottom hole pattern.

**Excessive impact load / improper drilling practices**
- Dropping of the drill string.
- Tagging bottom too hard / intentional spudding.
- Hitting a ledge while tripping or making a connection.
- Running on junk.
- Drill-out with hi-bend motors.

**Bit vibration**
- Improper bit selection / BHA / operating parameters.
APPLICATION RECOMMENDATIONS

Formation / improper bit selection
- Consider a more stable design.
- Use more impact resistant cutters.
- Reduce bit aggressiveness.
- Reduce cutter loading.

Excessive WOB for application and specific bit type
- Optimize WOB for formation.
- Consider using a shock sub when anticipating numerous formation changes. See broken formations.

Excessive RPM for application and specific bit type
- Optimize RPM for formation.

Broken formations (includes boulders)
- Broken cutters due to drilling broken formations can occur in any location. An indicator of broken formations is when the TQ becomes extremely erratic when drilling through the boundaries, then smooths out. Consider using a thruster or shock sub.

Improper bottom hole pattern break-in
- Bottom hole pattern break-in is considered to be when a new bit achieves uniform cutting structure loading. This is done with light weights and slow rpm and is normally achieved within 6 to 12 inches. At that point WOB and RPM can be gradually increased to typical operating levels.

Excessive impact load / improper drilling practices
- Follow proper drilling practices.

Bit vibration
- Change operating parameters.
WO - Washed Out Bit
A washout is where drilling fluid has eroded a passage from an internal flow area to the exterior of the bit. This characteristic is used only in the “Remarks Other Dull Characteristic” column. If allowed to continue, a washout may result in a twist off. A washout causes a decrease in pump pressure and ROP. Bit balling may also occur.

POTENTIAL CAUSES
Excessive impact load
- A crack occurs during the bit run due to excessive impact or fatigue. When a crack occurs and circulation starts through the crack, the washout is established very quickly. Causes of excessive impact are:
  - Dropping of the drill string.
  - Tagging bottom too hard / intentional spudding.
  - Hitting a ledge while tripping or making a connection.
  - Running on junk.
  - Cyclic fatigue loading.

Improper bit / nozzle installation
- Washouts can occur due to improper installation procedures.
- Damaged threads, improper make-up torque
- Pinched o-ring seal.

Wrong nozzle type for application
- Using one manufacturer’s bit and another manufacturer’s nozzles will result in a washout due to slight dimensional differences.

Erosion damage to nozzle and/or nozzle retaining system
- High solid muds or abrasive muds (ex. hematite) can cause severe internal erosion leading to nozzle loss.
- Fluid entrainment and turbulence around retention system when severe bit balling occurs.

Bit balling
- Fluid entrainment and turbulence around the retention system when severe bit balling occurs.
  - See respective section.

Bit vibration
- Bit vibration can cause fatigue in tool joints of the BHA.
APPLICATION RECOMMENDATIONS

Excessive impact load
• Follow proper drilling practices.

Improper bit / nozzle installation
• Follow manufacturer’s recommended procedures.

Wrong nozzle type for application
• Ensure use of proper nozzle.

Erosion damage to nozzle and/or nozzle retaining system
• It may not be desirable, practical or possible to reduce solids or mud type.
• See respective dull characteristic, “Balled-Up”.

Bit vibration
• Change operating parameters.
WT - Worn Cutter
Worn cutter is a condition that describes the reduction in the cutter height due to the drilling action. This is a normal and expected wear mode. Worn cutters on a PDC is described by a value 0 to 8, 0 being no wear and 8 being no cutter remaining.

**POTENTIAL CAUSES**

**Formation / improper bit selection**
- Formation too hard / abrasive for bit selected.

**Excessive RPM for application and specific bit type**
- Excessive RPM accelerates the mechanism of wear due to increases in relative surface velocities.

**Excessive hours for application and specific bit type**
- Wear due to rotating hours greater than typical expectations.

**Inadequate hydraulics**
- Inadequate cuttings removal, accelerating cutting structure wear.
APPLICATION RECOMMENDATIONS

Formation / improper bit selection
- Formation too abrasive for bit type selected.
- For abrasive formations, select bits with smaller cutters and/or greater blade count.
- Use premium PDC cutters.

Excessive RPM for application and specific bit type
- Optimize RPM for formation.
- For abrasive formations, select bits with smaller cutters and/or greater blade count.

Excessive hours for application and specific bit type
- Reduce rotating hours or select a more durable cutting structure.

Inadequate hydraulics
- Increased hydraulic energy is needed to address this condition.