IADC DULL GRADING SYSTEM FOR FIXED CUTTER BITS

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INTRODUCTION

Information provided by dull grading bits can be very significant. This value was recognized by the IADC some 25 years ago when a worldwide dull grading system for roller cone bits was established.

For fixed cutter bits - that is, all non-roller cone bits - this dull grading system could not be applied, and a new system had to be established. The fixed cutter dull grading system was developed by the IADC Drill Bits Sub-Committee in 1987 and revised in 1991.

The fixed cutter dull grading system can be used for all non-roller cone bits, including natural diamond, polycrystalline diamond compacts (PDC), thermally stable polycrystalline (TSP) diamonds, impregnated bits, core bits and non-roller cone bits which do not employ diamond material as a cutting element.

The system does not distinguish between drilling and coring bits. This guide will only show examples of PDC, TSP, natural diamond and impregnated or sintered drill bits.

SYSTEM STRUCTURE

The Dull Grading System Chart adopted by IADC includes all codes necessary to dull grade roller cone bits and fixed cutter bits.

The chart describes eight factors on drill bits. The first four spaces describe the *"Cutting Structure"*. The fifth space *("B")* refers to "Bearing Seals" and does not apply to fixed cutter bits. This space is always marked with an "X" when fixed cutter bits are graded. The sixth space *("G")* refers to "Gauge Measurement" while the last two *"Remarks"* spaces indicate "Other Dull Characteristics" (or secondary dull characteristics) and "Reason Pulled".

Inner/Outer Rows

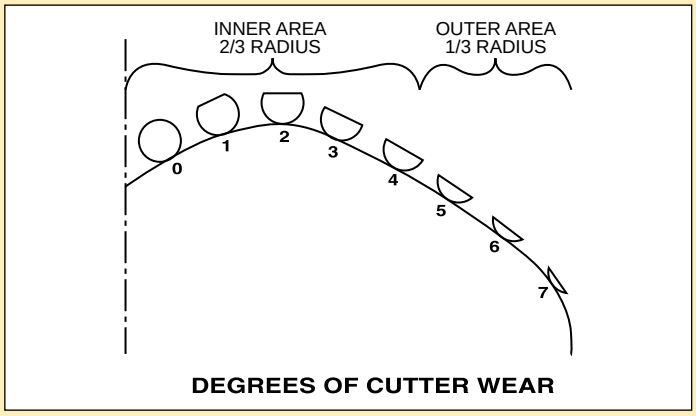
Using a linear scale from zero to eight, a value is given to cutters in the inner and outer rows of surface-set bits to indicate the amount of wear. Grading numbers increase with amount of wear, with "zero" representing no wear and "eight" meaning no usable cutter left. Accordingly, "four" indicates 50% wear.

PDC cutter wear is measured in a linear scale from one to eight across the diamond table, regardless of the cutter shape, size, type or exposure. Figure 1 illustrates the cutter wear grading system schematically.

IADC DULL GRADING SYSTEM CHART

Cutting Structure				B	G	Remarks	
Inner Rows	Outer Rows	Dull Charact-eristics	Location	Bearing Seals	Gauge 1/16"	Other Charact-eristics	Reason Pulled
2	6			X			

FIGURE 1



When grading a dull bit, the average amount of wear for each area should be recorded. As shown above, 2/3 of the radius represents the "inner rows". The five cutters in this area would be graded "two". This is calculated by averaging the individual grades for each cutter in the area:

$$\frac{(4 + 3 + 2 + 1 + 0)}{5} = 2$$

The average wear for the "outer" area is calculated in the same manner:

$$\frac{(5 + 6 + 7)}{3} = 6$$

"Six" would be the average wear gradient for the outer area. This information can now be transferred to the IADC Dull Grading System Chart above.

NOTE: For a core bit, the centerline in Figure 1 would be the inside of the core bit ID.

Dull Characteristics / Other Characteristics

The third and seventh spaces are for use in noting dull characteristics of the bit, i.e., the most prominent physical changes from its new condition. Codes for these characteristics are listed below in Table 1. In general, four different wear characteristics can be distinguished for fixed cutter bits, as shown in Figures 2A and 2B.

IADC DULL GRADING SYSTEM CHART

Cutting Structure				B	G	Remarks	
Inner Rows	Outer Rows	Dull Charact-eristics	Location	Bearing Seals	Gauge 1/16"	Other Charact-eristics	Reason Pulled
		WT		X		RO	

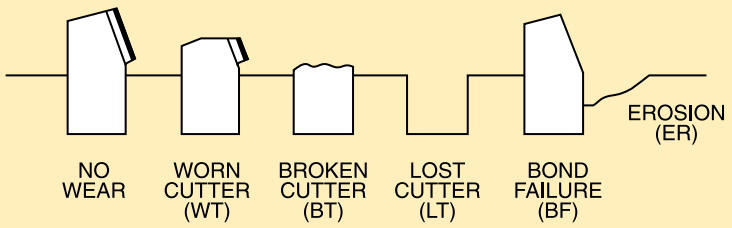
TABLE 1. DULL/OTHER CHARACTERISTICS

- *BC - Broken Cone
- BF - Bond Failure
- BT - Broken Teeth / Cutters
- BU - Balled Up
- *CC - Cracked Cone
- *CD - Cone Dragged
- CI - Cone Interference
- CR - Cored
- CT - Chipped Teeth / Cutters
- ER - Erosion
- FC - Flat Crested Wear
- HC - Heat Checking
- JD - Junk Damage
- *LC - Lost Cone
- LN - Lost Nozzle
- LT - Lost Teeth / Cutters
- NO - No Major / Other Dull Characteristics
- NR - Not Rerunnable
- OC - Off-Center Wear
- PB - Pinched Bit
- PN - Plugged Nozzle / Flow Passage
- RG - Rounded Gauge
- RO - Ring Out
- RR - Rerunnable
- SD - Shirttail Damage
- SS - Self Sharpening Wear
- TR - Tracking
- WO - Washed Out Bit
- WT - Worn Teeth / Cutters

**Show cone number(s) under "Location".*

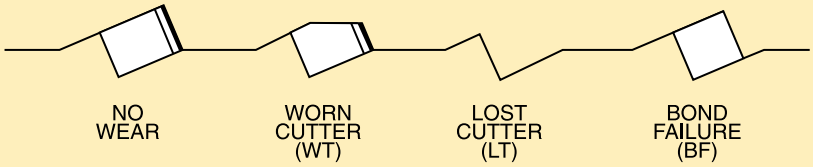
NOTE: If no "Dull Characteristic" is visible, mark this space "No". If no "Other Characteristic" is visible, mark this space "No".

FIGURE 2A. STUD CUTTERS



WEAR CHARACTERISTICS: POST OR STUD CUTTERS

FIGURE 2B. CYLINDER CUTTERS



WEAR CHARACTERISTICS: CYLINDER CUTTERS

Dull grading characteristics are based on PDC or stud wear, but also apply for TSP or Natural Diamond material. See photographs on the following pages.

IADC DULL GRADING SYSTEM CHART							
Cutting Structure				B	G	Remarks	
Inner Rows	Outer Rows	Dull Charact-eristics	Location	Bearing Seals	Gauge 1/16"	Other Charact-eristics	Reason Pulled
		BT		X		WT	

Worn Cutter (WT), Round TSP

Worn Cutter (WT), Mosaic

Worn Cutter (WT), Round TSP
Broken Cutter (BT), Round TSP

Broken Cutter (BT),
Natural Diamond

Worn Cutter (WT), Triangular TSP
Broken Cutter (BT), Triangular TSP

Broken Cutter (BT), Triangular TSP

IADC DULL GRADING SYSTEM CHART							
Cutting Structure				B	G	Remarks	
Inner Rows	Outer Rows	Dull Charact-eristics	Location	Bearing Seals	Gauge 1/16"	Other Charact-eristics	Reason Pulled
		CR		X		ER	

Cored PDC Bit (CR)

Ring Out (RO) on a PDC Bit

Junk Damage (JD), PDC Bit

Balled Up (BU), Impregnated Bit

Ring Out (RO) on a TSP Bit

Erosion (ER) on a PDC Bit

IADC DULL GRADING SYSTEM CHART							
Cutting Structure				B	G	Remarks	
Inner Rows	Outer Rows	Dull Charact-eristics	Location	Bearing Seals	Gauge 1/16"	Other Charact-eristics	Reason Pulled
		CT		X		LT	

Worn Cutter (WT), PDC

Chipped Cutter (CT), PDC

Lost Cutter (LT), PDC

Chipped Cutter (CT), PDC

Worn Cutter (WT), PDC
Heat Checking (HC), PDC

Erosion (ER), PDC

Location

The "Location" space is used to indicate the location of the primary "Dull Characteristics" noted in the third space. Four possible fixed cutter bit profiles are shown in Figure 3, along with the codes used to identify commonly referred to locations on the bit. One or more of these codes are used to indicate the location of the dull characteristic(s) noted.

Bearing Seals

This space is used only for roller cone bits. Therefore, it will always be marked "X" when grading fixed cutter bits.

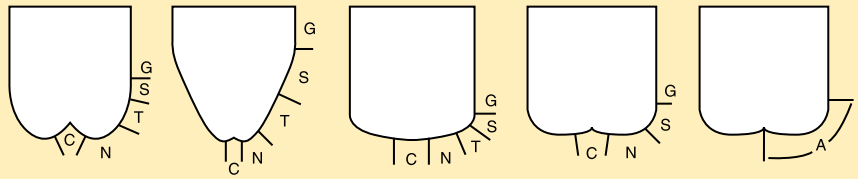
Gauge

The "Gauge (G)" space is used to record the condition of the bit gauge. Record an "I" here if the bit is still in gauge. Otherwise, the amount the bit is undergauge is recorded to the nearest $^1/_{16}$". For specific undergauge markings, see Figure 4.

IADC DULL GRADING SYSTEM CHART

Cutting Structure				B	G	Remarks	
Inner Rows	Outer Rows	Dull Charact-eristics	Location	Bearing Seals	Gauge $^1/_{16}$"	Other Charact-eristics	Reason Pulled
			N	X	I		

FIGURE 3. FIXED CUTTER BIT PROFILES



C — CONE N — NOSE T — TAPER S — SHOULDER G — GAUGE A — ALL AREAS

FIGURE 4. GAUGE CONDITION

Code	Explanation
I	In Gauge
1/16	Undergauge up to $^1/_{16}$"
2/16	Undergauge $^1/_{16}$" to $^1/_8$"
3/16	Undergauge $^1/_8$" to $^3/_{16}$"
4/16	Undergauge $^3/_{16}$" to $^1/_4$"

Reasons Pulled

The last space on the IADC Dull Grading System Chart is used to record the reason the bit was pulled. A list of codes is shown below in Table 2.

TABLE 2. REASONS FOR PULLING BIT

- BHA - Change Bottomhole Assembly
- DMF - Downhole Motor Failure
- DSF - Drillstring Failure
- DST - Drill Stem Test
- DTF - Downhole Tool Failure
- LOG - Run Logs
- RIG - Rig Repair
- CM - Condition Mud
- CP - Core Point
- DP - Drill Plug
- FM - Formation Change
- HP - Hole Problems
- HR - Hours
- PP - Pump Pressure
- PR - Penetration Rate
- TD - Total Depth / CSG Depth
- TQ - Torque
- TW - Twist Off
- WC - Weather Conditions
- WO - Washout Drillstring

IADC DULL GRADING SYSTEM CHART

Cutting Structure				B	G	Remarks	
Inner Rows	Outer Rows	Dull Charact-eristics	Location	Bearing Seals	Gauge 1/16"	Other Charact-eristics	Reason Pulled
				X			BHA

DULL GRADING WORN BITS

The following examples show how to apply the IADC Fixed Cutter Dull Grading System to worn bits.

Example 1

This S279 was used to drill a very hard and abrasive sandstone formation in the Rotliegendes in Northern Germany. The special feature on this bit is its Core Ejector (CE).

It drilled 100 meters in 51 hours on a 4 3/4" Mach 2 downhole motor at an average ROP of 2.0 m/hr, and was pulled at 4750 meters to change the BHA.

After pulling the bit, a uniform wear pattern was observed with the exception of the beginning of a ring out on the bit shoulder. Eight waterways were plugged with formation, which did not slow down the penetration rate. The bit was still in gauge.

IADC DULL GRADING SYSTEM CHART

Cutting Structure				B	G	Remarks	
Inner Rows	Outer Rows	Dull Charact-eristics	Location	Bearing Seals	Gauge 1/16"	Other Charact-eristics	Reason Pulled
3	4	WT	A	X	I	BU	BHA

BIT INFORMATION
Style: S279CE
Size: 5.875"
TFA: 0.5

BIT INFORMATION
Pulled Bit

Example 2

This R437GN was run in a horizontal drilling operation. The first run was in shale on a 6 3/4" Mach 1 fixed angle-build motor.

The bit drilled 118 meters in 8.5 hours and was pulled at 1433 meters. The ROP was 13.9 m / hr.

After the bit was pulled, no obvious wear could be seen, resulting in the IADC grading shown above.

The bit was re-run on another well in the same field in the same formation, drilling 218 meters in 13.5 hours for an average ROP of 16.2 m / hrs.

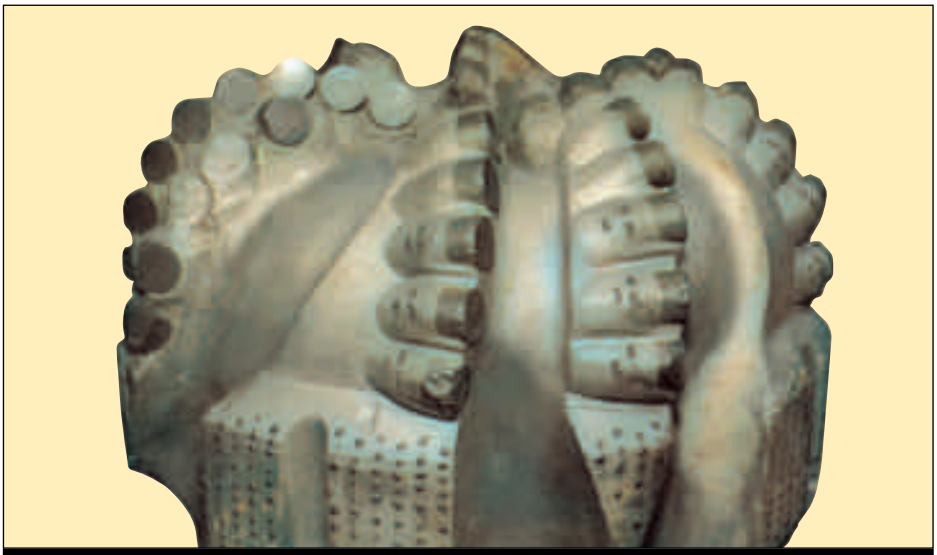
The bit was pulled when the bottomhole assembly had to be changed.

When dull grading the bit, little wear on the cutting structure was seen, resulting in a dull grading of 1 for "inner / outer rows". Three cutters were lost due to matrix erosion from a high flow rate, as shown in the "Dull" and "Other Characteristics" columns. The bit was still in gauge, as indicated by "I" in the "Gauge" column.

IADC DULL GRADING SYSTEM CHART							
Cutting Structure				B	G	Remarks	
Inner Rows	Outer Rows	Dull Charact-eristics	Location	Bearing Seals	Gauge 1/16"	Other Charact-eristics	Reason Pulled
0	0	NO	A	X	I	NO	TD

Dull grading for the rerun bit.

IADC DULL GRADING SYSTEM CHART							
Cutting Structure				B	G	Remarks	
Inner Rows	Outer Rows	Dull Charact-eristics	Location	Bearing Seals	Gauge 1/16"	Other Charact-eristics	Reason Pulled
1	1	LT	A	X	I	ER	BHA



BIT INFORMATION
Style: R437GN
Size: 8.5"
TFA: 0.6

Example 3

This R437GN was run in a horizontal well to drill brittle to plastic shale and sandstone. It drilled 387 meters in 29.5 hours with an average ROP of 13.1 m / hr on a Mach 1 Adjustable Kick Off Motor. The bit was pulled at 1820 meters because of slow penetration rates.

IADC DULL GRADING SYSTEM CHART							
Cutting Structure				B	G	Remarks	
Inner Rows	Outer Rows	Dull Charact-eristics	Location	Bearing Seals	Gauge 1/16"	Other Charact-eristics	Reason Pulled
6	2	CR	C	X	I	LN	PR

Upon pulling the bit, it became obvious why the bit had ceased drilling — it was cored out and had lost all four nozzles. The remaining cutters did not show any significant wear.

NOTE: Although the bit lost all four nozzles, the primary "Dull Characteristic" is "cored" because this is the main reason the nozzles were lost. Lost nozzles are recorded under "Other Characteristics".

BIT INFORMATION
Style: R437GN
Size: 8.5"
TFA: 0.6

Example 4

This S725 BallaSet bit with cylindrical TSPs was used to drill claystone and sand in the medium hard and dense Rotliegendes formation in Holland. It drilled 154 meters in 57 hours, achieving an ROP of 2.7 m/hr on a Mach 2 downhole motor in a directional well. The bit was pulled due to a slow rate of penetration. Dull grading indicated the cutters were worn 75% and 100% on the inner and outer rows, respectively. In addition, a ring out can be seen in the taper area. The bit was also 1/16" undergauge due to abrasive sands in the formation.

IADC DULL GRADING SYSTEM CHART

Cutting Structure				B	G	Remarks	
Inner Rows	Outer Rows	Dull Characteristics	Location	Bearing Seals	Gauge 1/16"	Other Characteristics	Reason Pulled
6	8	RO	T	X	1/16	WT	PR

BIT INFORMATION
Style: S725GN
Size: 8.38"
TFA: 0.10

Example 5

This R435SG was run four times in the North Sea area. The bit drilled a total of 977 meters in 166.3 hours, mainly in salt / anhydrite formations of the Zechstein. Three of the four runs were on a Mach 1 DTU motor with RPMs of 210 to 320.

Dull grading of the first two runs shows no visible cutting structure failure. The "Reason Pulled" was Downhole Tool Failure (DTF) in both cases. After the third run (389 meters in 89.5 hours), the bit was pulled due to BHA prob-lems, and showed a uniform wear pattern of ±20% wear for the inner and outer rows. When pulled after run four, the cutting structure wear was 50% and 60% for the inner and outer rows, respectively. After four runs, the bit also showed some severe erosion and lost cutters in the taper area. *(See photo taken after run 4)*

Practical Applications.

The IADC Dull Grading System can be used for multiple purposes. Manufacturers evaluate bit design and bit application. Operators evaluate and improve their drilling programs. The system can be computerized to build up a worldwide database in order to coordinate bit applications.

The main objective of the dull grading system is to draw a "*standardization picture*" of a bit, regardless of where, or under what circumstances the bit may have been used. This standardization is expected to lead to better bit application and design throughout the industry.

IADC DULL GRADING SYSTEM CHART

Cutting Structure				B	G	Remarks	
Inner Rows	Outer Rows	Dull Charact-eristics	Location	Bearing Seals	Gauge 1/16"	Other Charact-eristics	Reason Pulled
0	0	NO	A	X	I	NO	DTF
Run 2							
0	0	NO	A	X	I	NO	DTF
Run 3							
2	2	NO	A	X	I	NO	BHA
Run 4							
5	4	BT	A	X	I	ER	DTF

BIT INFORMATION

Style: R435SG
Size: 12.25"
TFA: 0.65 - 1.60

References:
SPE/IADC Papers 16142, 16145 and 23939.

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