# Real Time Rock Destruction for Engineered Performance Improvement

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NYSE: **DVN**
devonenergy.com

# Rock Destruction Foundation

- Some Times You Have to Ask – "So What?"

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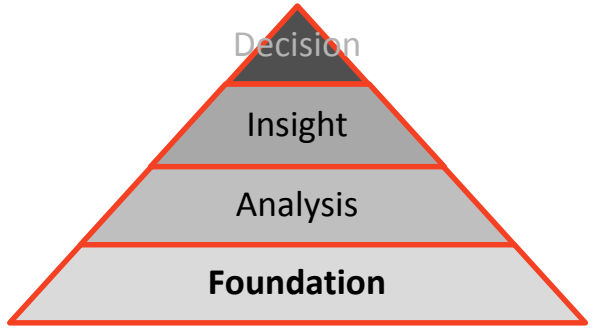
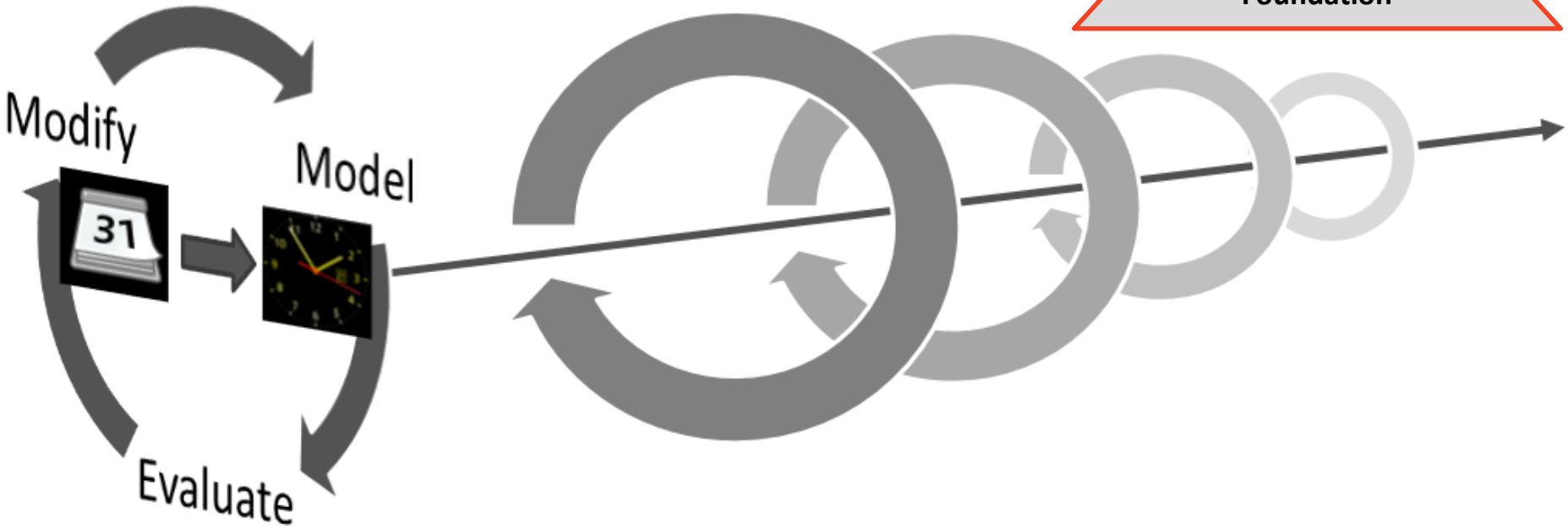
***"Mash on it!"***



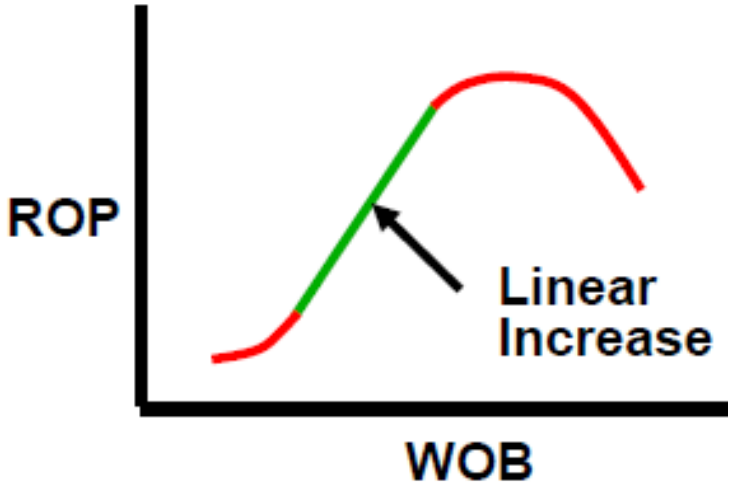



**"For drilling data to be meaningful it must be interpreted to show the physics of how the rock is being destroyed."**

# Rock Destruction Basics

*Bit / Rock Interaction*

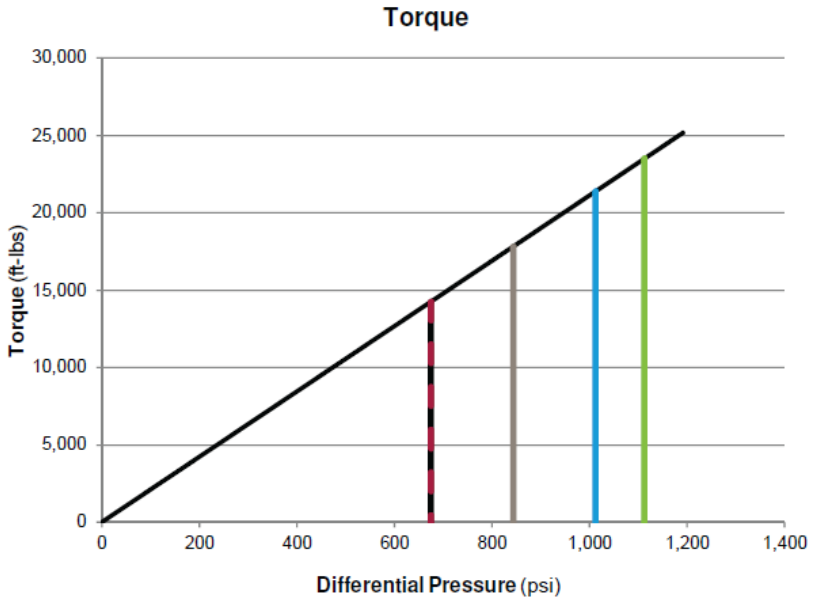
- The weight on bit (WOB) determines depth of cut (DOC).
- The DOC determines the amount of rock removed per rotation.
- The RPM determines the amount of rock removed per minute.
- The Torque is determined by DOC and the rock compressive strength.
  - Force to fail the rock
- There are linear increases in ROP for increases in WOB and RPM.
- Understanding the Rock Destruction Basics is required to understand Mechanical Specific Energy (MSE) which helps determine the efficiency for the rock destruction and removal.



# Mud Motor Basics

## *Mud Motor Differential Pressure and Torque at the Bit*

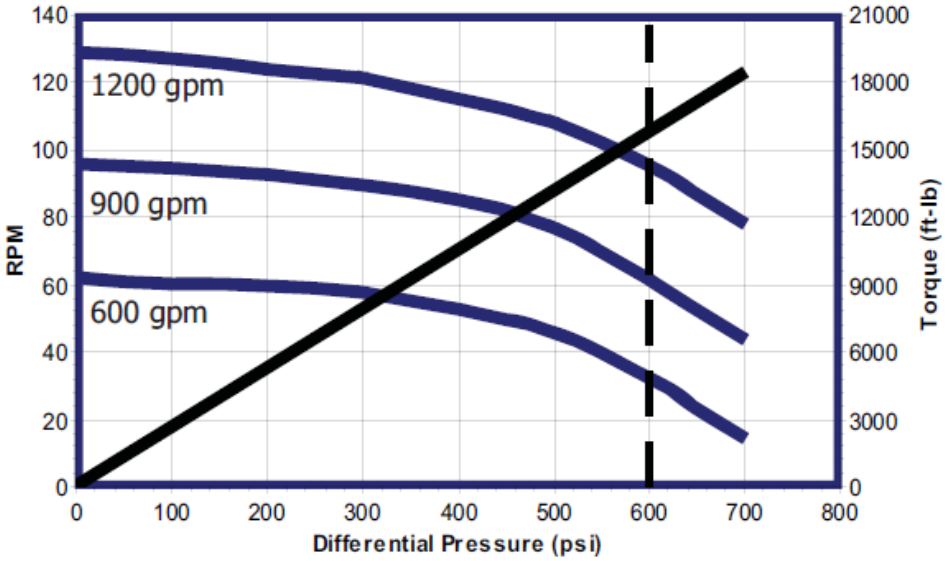
- Motor operation is typically described in terms of differential pressure.
- Differential pressure does not accurately depict the energy being exerted upon the formation thus destroying the rock.
- Differential pressure is an indication of the torque demand/output of the motor.
  - Torque output is linear and can be determined by utilizing the performance graph on the motor specification sheet.



# Mud Motor Basics

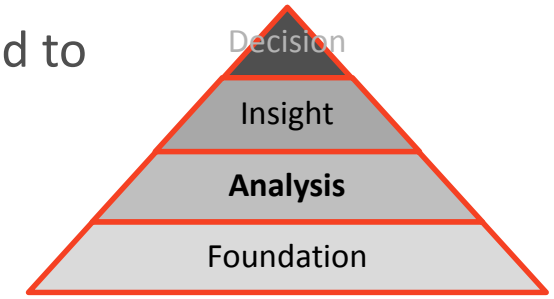
## *Mud Motor Revs Per Gallon and Total Bit Speed*

- Flow can be utilized to determine the RPM (Bit Speed) of the motor.
  - The theoretical motor rev/gal (RPG) listed on the motor spec sheet can be utilized to calculate no load RPM.
  - The RPM / differential pressure chart for the motor spec sheet should be utilized for detailed drilling performance analysis.
    - The RPG is not linear. The bit speed will be reduced as the differential pressure is increased. This RPM reduction is caused by fluid leakage through the motor power section.



# Horsepower at the Bit

*Analysis for Power Exerted in Destroying the Rock*



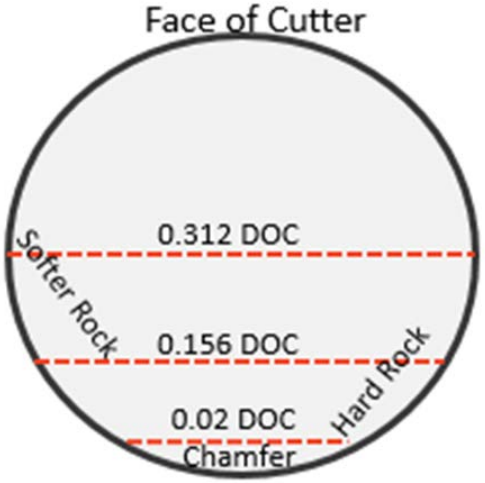

- Together the values for torque and RPM can be utilized to calculate the horsepower (HP) at the bit.
  - HP = (RPM x torque)/5252
  - Sliding HP from motor RPM and torque
  - Rotating HP from string RPM and motor RPM and torque
- Drilling parameter changes will affect the HP at the bit.
- HP can be utilized to:
  - Compare different mud motors for power output capability
  - Compare mud motor output in different drilling environments

| Motor | Bit Speed | Bit Torque | Horse Power |
|---|---|---|---|
| PDM | 100 | 10,500 | 200 |
| Turbine | 1,000 | 1,050 | 200 |

# Depth of Cut

*Analysis for Cutter / Rock Engagement*

- Depth of cut (DOC) can be calculated from the drilling data.
  - DOC = (12*ROP)/(60*RPM)
  - DOC sliding from motor RPM
  - DOC rotating from string RPM and motor RPM
- The minimum DOC should greater than the chamfer dimension of the cutters.
- The maximum DOC should be equal to the dimension of the cutter standoff from the blade.



# Rock Destruction Calculator

*Analysis for Specific Mud Motor Output*

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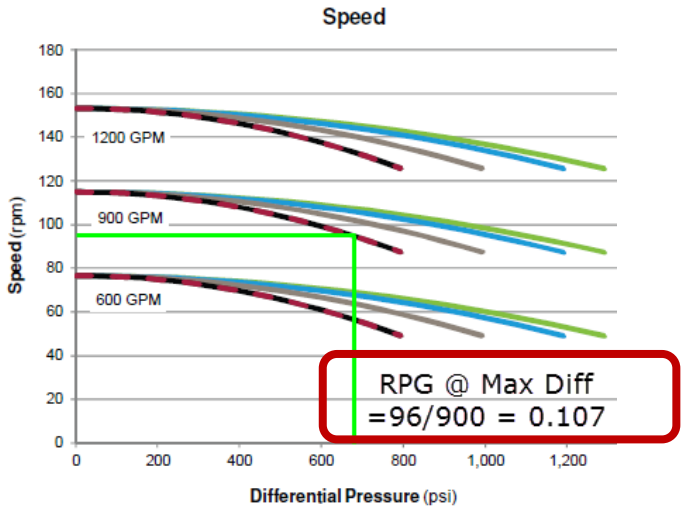
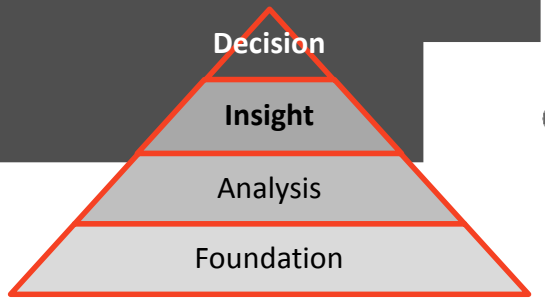
| Performance Specifications | | | | |
|---|---|---|---|---|
| Flow Range | | | 600-1200 | |
| Rev per Unit Volume | | | 0.13 | |
| Speed Range | | | 76-153 | |
| No Load Pressure Loss | | | 160 | |
| | RR-UF100D-UF180 | | UF114 | |
| Max Δ Pressure | 675 | psi | 844 | psi |
| Max Torque | 14,251 | ft-lbs | 17,814 | ft-lbs |
| Stall Δ Pressure | 1,080 | psi | 1,350 | psi |
| Stall Torque | 22,802 | ft-lbs | 28,503 | ft-lbs |




| | | |
|---|---|---|
| Maximum Differential Pressure | 675 | From the motor specification sheet performance graph enter the maximum differential pressure |
| Maxium Torque | 14251 | From the motor specification sheet performance graph enter the maximum torque |
| Surface RPM | 50 | Enter the surface RPM being utilized |
| Motor Rev/Gal - Theoretical | 0.13 | From the motor specification sheet enter the no load RPG |
| Motor Rev/Gal - At Max Diff | 0.11 | From the motor specification sheet enter the RPG at a given flow and maximum Diff Press |
| GPM | 800 | Enter the flow rate being utilized |
| Total Bit RPM - Slide | 100 | This is a calculated number for slide drilling from the RPG @ Diff Press x flow rate |
| Total Bit RPM - Rotate | 143 | This is a calculated number for rotate drilling from the RPG @ Diff Press x flow rate + surface RPM |
| Differential Pressure Sliding | 200 | Enter the differential pressure being utilized while sliding |
| Torque From Motor Specs Graph Sliding | 4223 | This is a calculated number for slide drilling motor torque |
| Differential Pressure Rotating | 600 | Enter the differential pressure being utilized while rotating |
| Torque From Motor Specs Graph Rotating | 12668 | This is a calculated number for rotate drilling motor torque |
| Bit Horsepower Sliding (RPM x Torque)/5252 | 81 | This is a calculated horsepower number for slide drilling from the motor RPM and torque |
| Bit Horsepower Rotating (RPM x Torque)/5252 | 346 | This is a calculated horsepower number for rotate drilling from the total RPM and torque |
| Slide ROP | 100 | Enter the sliding ROP |
| Depth of Cut / Revolution (Inches) | 0.199 | This is a calculated number for slide drilling depth of cut |
| Rotate ROP | 100 | Enter the rotating ROP |
| Depth of Cut / Revolution (Inches) | 0.140 | This is a calculated number for rotate drilling depth of cut |

# Rock Destruction

*Case Study: Rig Roll Out with MSE*

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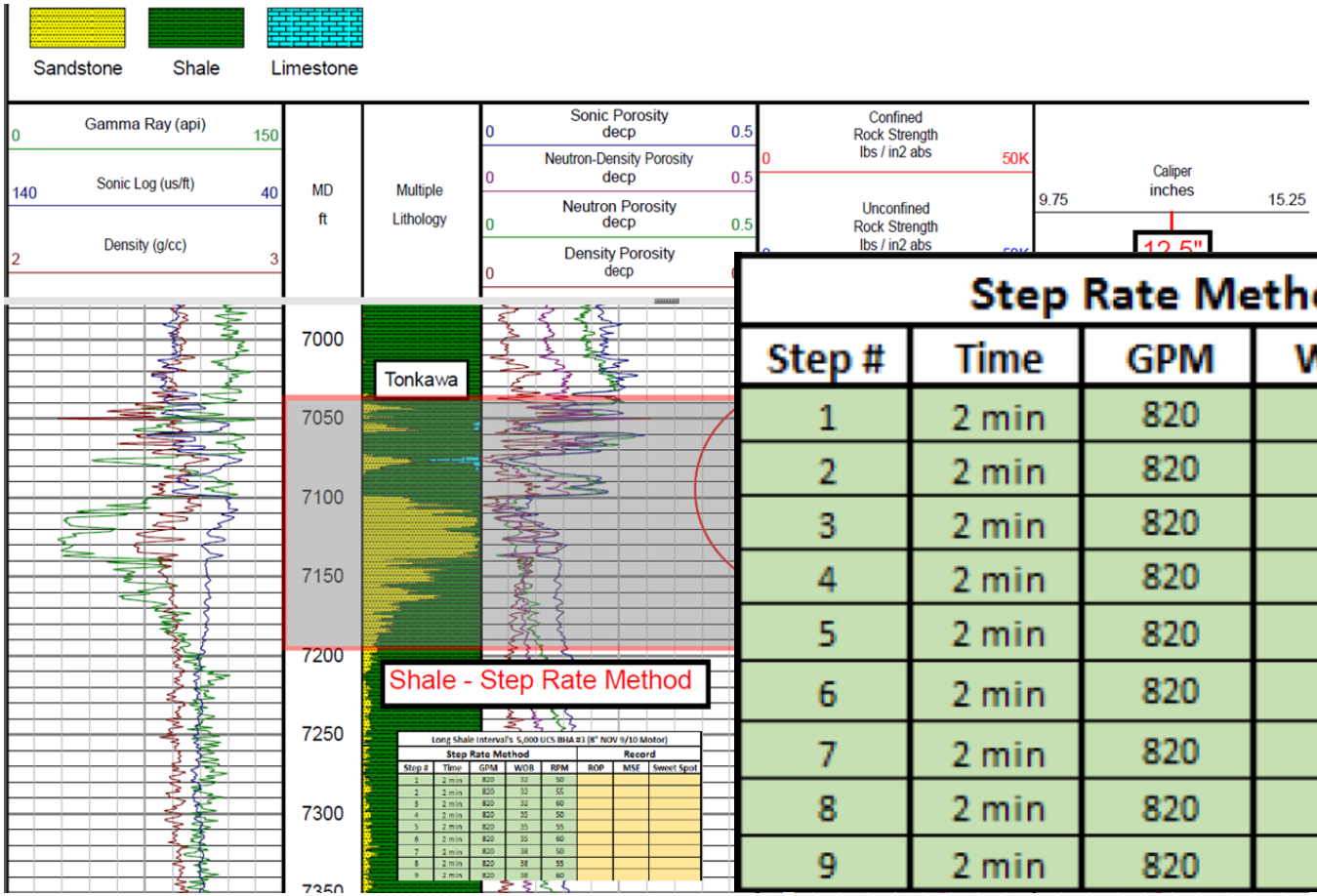
- Dialog in terms of rock destruction physics.
- Road mapping overburden characterization.
- Roll out MSE to the drilling team with understanding.

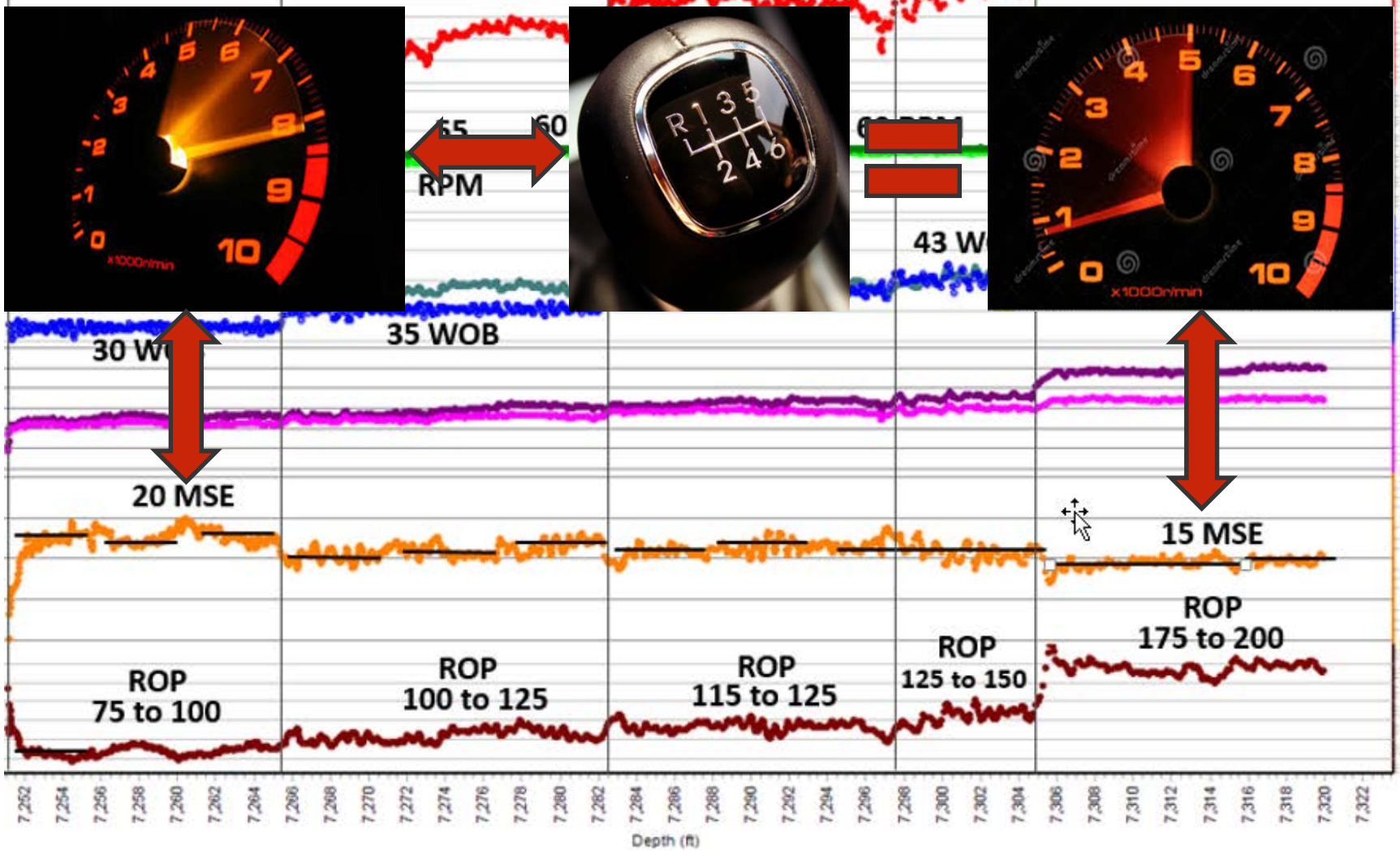



**Step Rate Method**

| Step # | Time | GPM | WOB | RPM |
|---|---|---|---|---|
| 1 | 2 min | 820 | 32 | 50 |
| 2 | 2 min | 820 | 32 | 55 |
| 3 | 2 min | 820 | 32 | 60 |
| 4 | 2 min | 820 | 35 | 50 |
| 5 | 2 min | 820 | 35 | 55 |
| 6 | 2 min | 820 | 35 | 60 |
| 7 | 2 min | 820 | 38 | 50 |
| 8 | 2 min | 820 | 38 | 55 |
| 9 | 2 min | 820 | 38 | 60 |

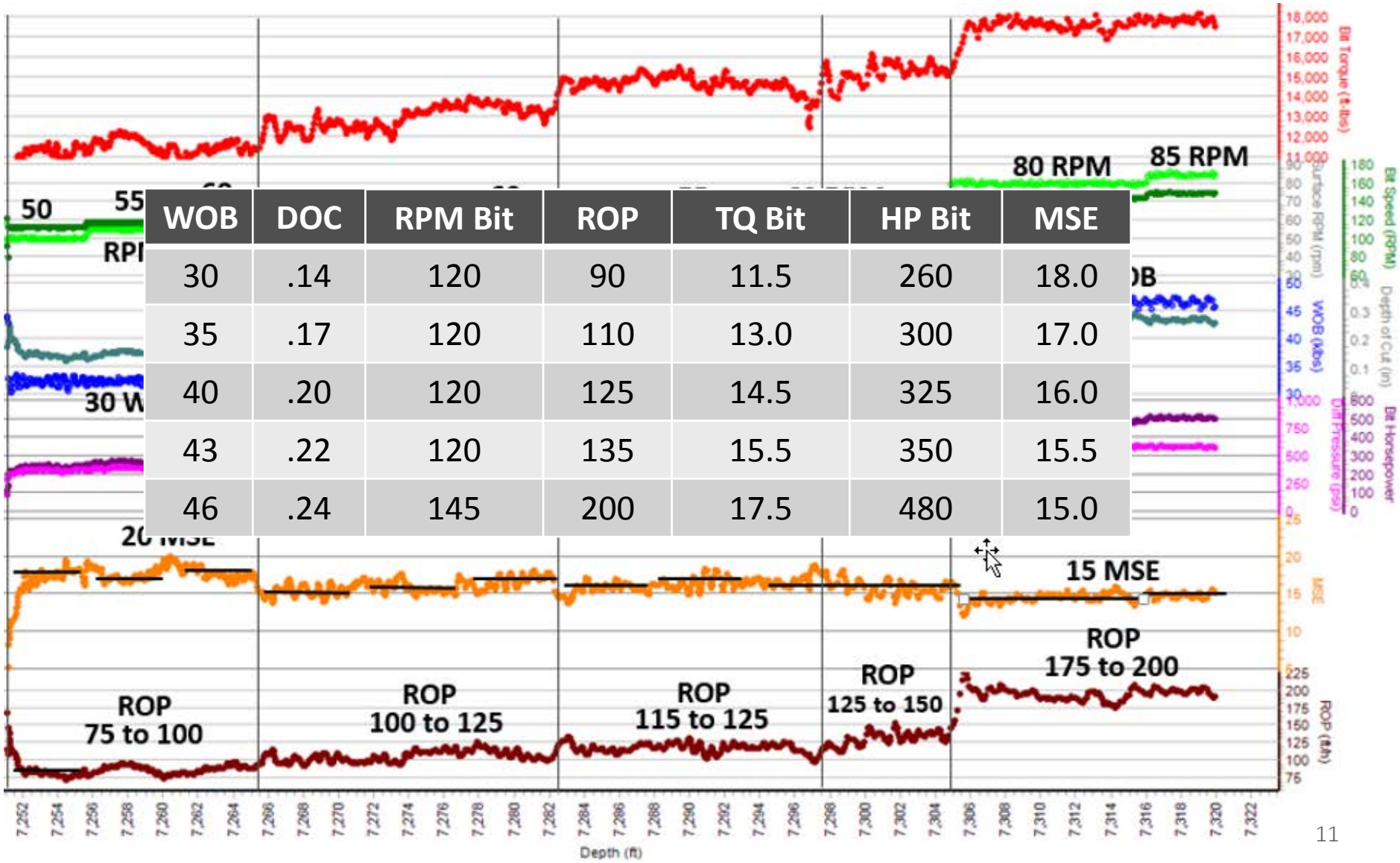
# Rock Destruction

*Case Study: Rig Roll Out with MSE*



# Rock Destruction

*Case Study: Linear Relationships*




| WOB | DOC | RPM Bit | ROP | TQ Bit | HP Bit | MSE |
|---|---|---|---|---|---|---|
| 30 | .14 | 120 | 90 | 11.5 | 260 | 18.0 |
| 35 | .17 | 120 | 110 | 13.0 | 300 | 17.0 |
| 40 | .20 | 120 | 125 | 14.5 | 325 | 16.0 |
| 43 | .22 | 120 | 135 | 15.5 | 350 | 15.5 |
| 46 | .24 | 145 | 200 | 17.5 | 480 | 15.0 |

# Rock Destruction

*Case Study: Depth of Cut Limiters*

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- Lateral BHA and bit with depth of cut limiter features.
- DOC limiters had to wear to desired ROP DOC.
- Opportunity for improved DOC design based on rock destruction data and increase ROP 18 ft/hr for a 15% improvement.

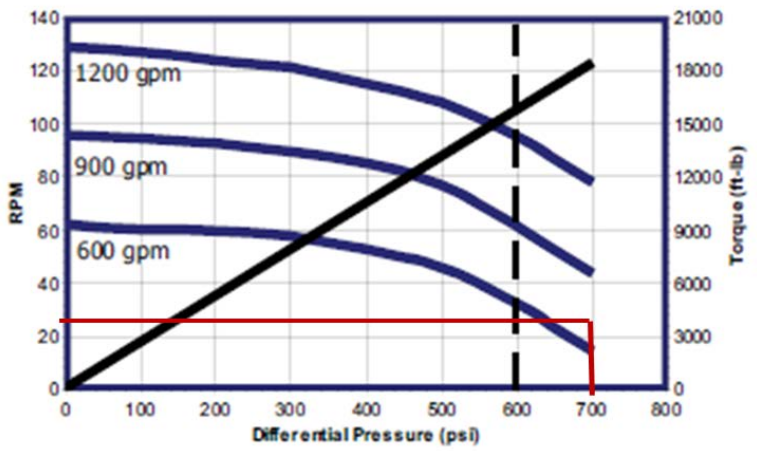
| Comment | ROP | WOB | Bit Torque | Bit RPM | DOC | HP |
|---|---|---|---|---|---|---|
| Whole run | 124 | 32 | 5353 | 191 | 0.13 | 194 |
| First 1,000 feet | 99 | 30 | 4580 | 183 | **0.11** | 160 |
| After 1,000 feet | **142** | 34 | 5894 | 196 | 0.14 | 219 |

# Rock Destruction

*Case Study: Motor Selection and Operation*

- Two motors with identical RPG but different maximum torque.
- Similar GPM, surface RPM, and WOB but different results!

| | Motor #1 | Motor #2 |
|---|---|---|
| Maximum Differential Pressure | 1090 | 600 |
| Maxium Torque | 26160 | 15850 |
| Differential Pressure Rotating | 800 | 700 |
| Torque From Motor Specs Graph Rotating | 19200 | 18492 |
| Motor Rev/Gal - Theoretical | 0.11 | 0.11 |
| Motor Rev/Gal - At Max Diff | 0.08 | 0.05 |
| Total Bit RPM Rotate (Theoretical) | 128 | 128 |
| Total Bit RPM Rotate (Load Corrected) | 111 | 75 |
| Bit Horsepower Rotating (Theoretical) | 468 | 451 |
| Bit Horsepower Rota | | 263 |
| Percent of Reductio | | -41.56% |
| Percent of Horsepov | | -35.25% |
| Rotate ROP | | 200 |
| Percent ROP Delta B | | -33.33% |



# So What?

*From "mash on it" to " the physics of how rock is being destroyed."*

- Engineer drilling based on how the rock is being destroyed.
- Characterize the rock with respect to drilling.
- Add MSE as another tool on the Drillers dashboard.
- Calculate the real output of the motor.
  - What is the differential pressure and torque at the bit?
  - With the motor producing torque what is the reduced speed at the bit?
- Calculate the real rock destruction output of the drilling system (surface and motor).
  - What is the horse power at the bit?
  - What is the depth of cut?
- Provide this information to the drilling team in an interpreted fashion.

**"For drilling data to be meaningful it must be interpreted to show the physics of how the rock is being destroyed."**


Thank you.