



A Noble Drilling  
Corporation Subsidiary

# **Deep Drilling Problems**

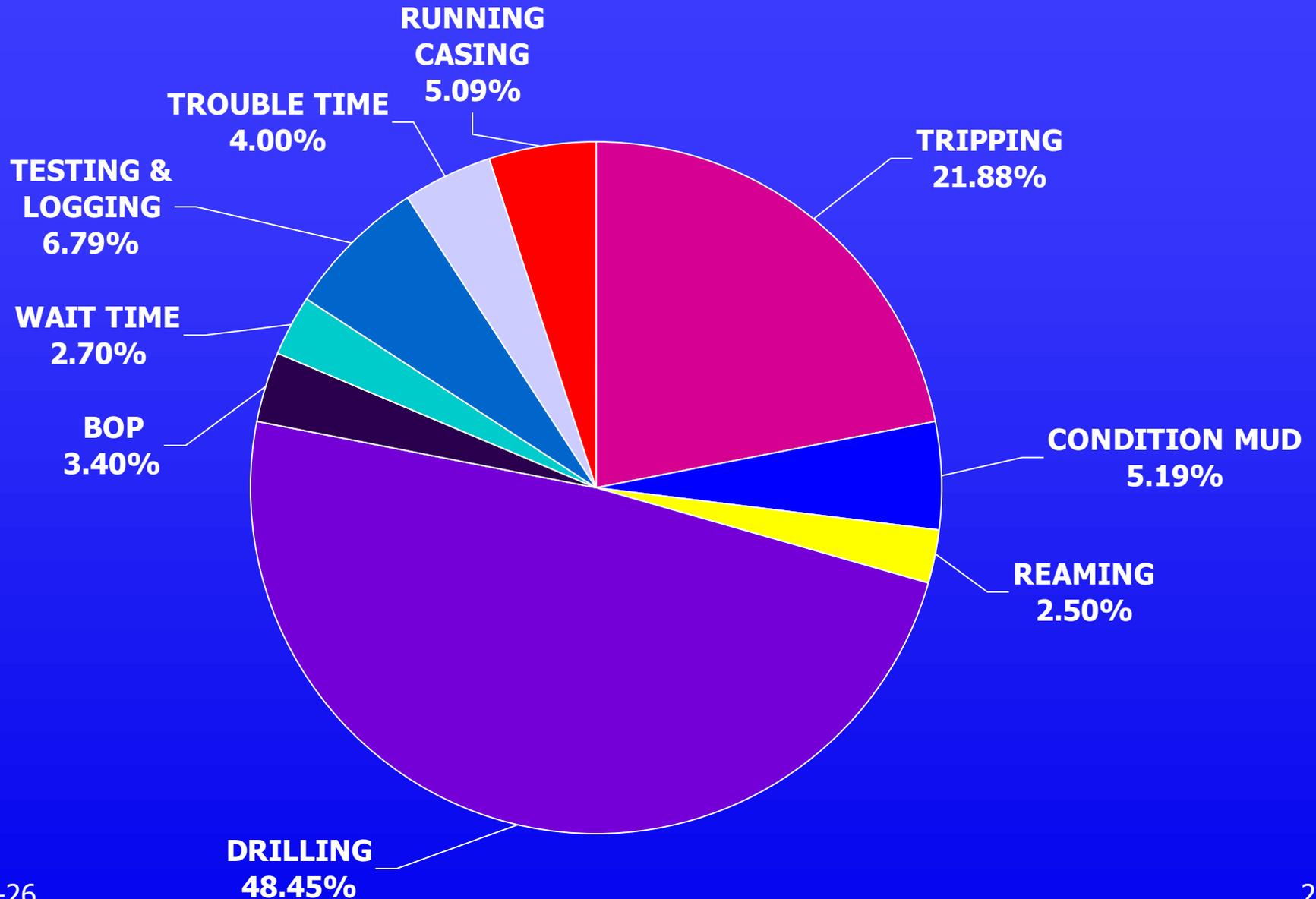
**Dr. William C. Maurer**

**DOE Deep Trek Workshop**

**Houston, TX**

**March 20, 2001**

# Deep Well Drilling Time Breakdown (GRI Report, 1990)



# Deep Drilling Concept Rankings

(GRI Report, 1990)

Drilling Concept	Ranking
PDC/TSD Bits	31.10
Slim Holes	30.98
Roller Cone Bits	29.58
Down Hole Motors	28.20
Top Drives	28.13
Coiled Tubing	27.70
Optimized Drilling	26.45
MWD Equipment	25.48
Automated Rig	23.70
High Pressure Jets	21.03
Casing While Drilling	18.30
Explosive Drills	13.70
Thermal Drills	11.53

# **Deep Well Drilling/Completion Problems**

## Problem

Low drilling rates

Short bit life

Slow trips

High casing costs

Motor failures

MWD failures

High drilling cost

Casing wear

## Cause

Hard rock, chip hold-down

Abrasive rock, impact loading

Deep wells

Multiple strings, deep wells

High temperature

Vibrations, high temp

Large rig, low ROP, casing

Long drilling time

# Deep Well Drilling/Completion Problems (Cont.)

## Problem

## Cause

Mud thermal degradation

>350°F

High mud ECDs

Small holes, long intervals

Poor cement bond

Poor mud displacement

Lost circulation

High cement density

Cementing liners

Sealing lap joints

Packer failures

Small diameter, high temp

Corrosion

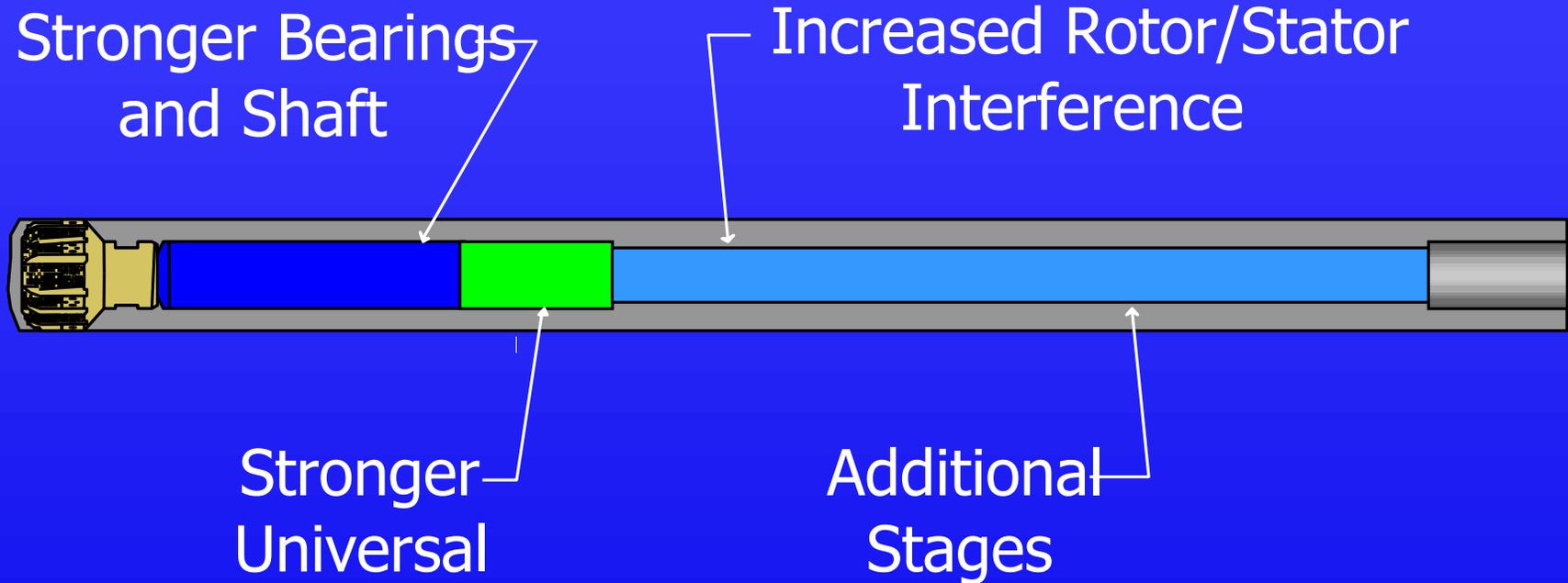
High Temp, CO<sub>2</sub>, H<sub>2</sub>S

Underbalanced Drilling

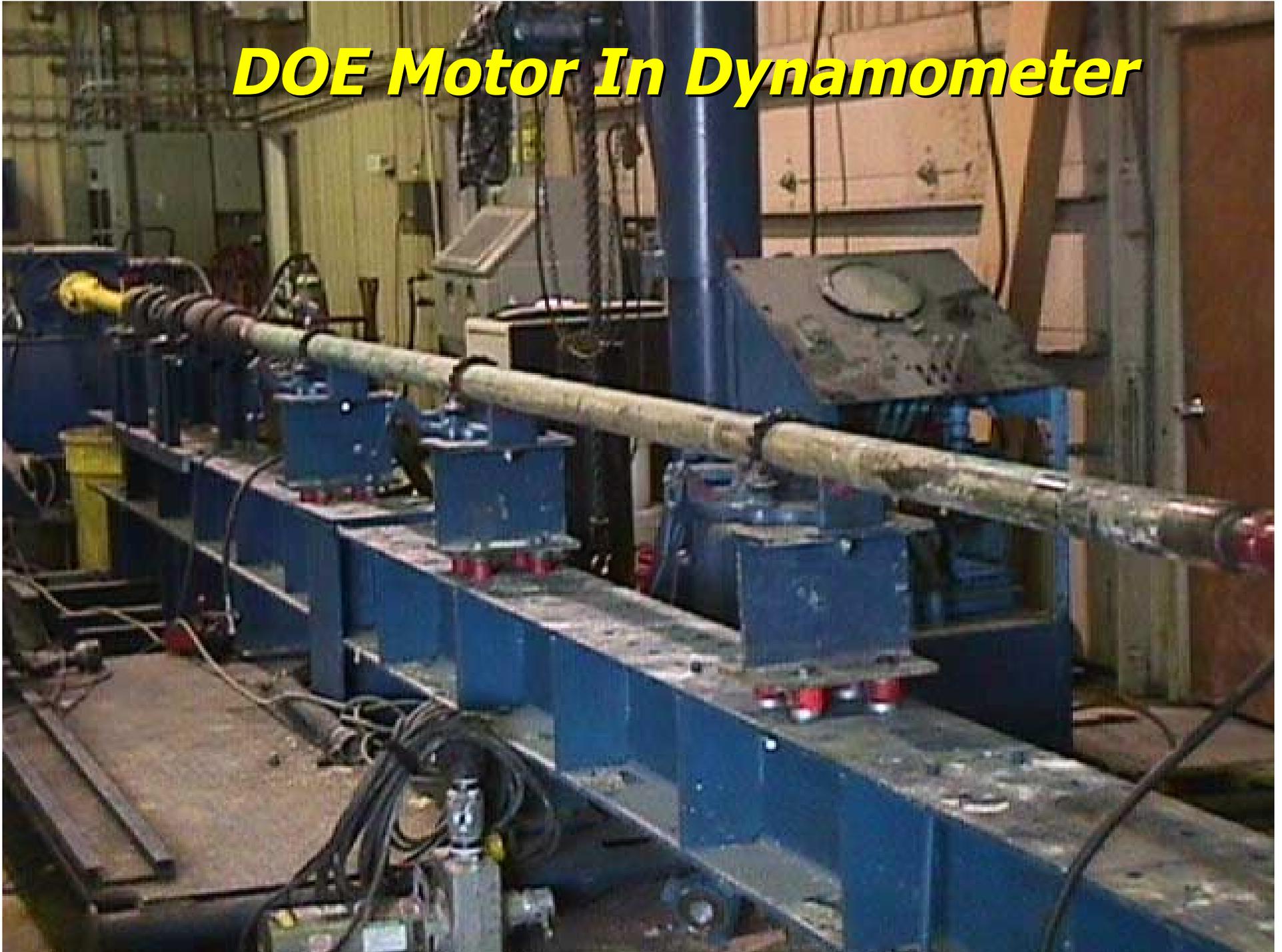
Gas compressibility

# ***High-Power Motor***

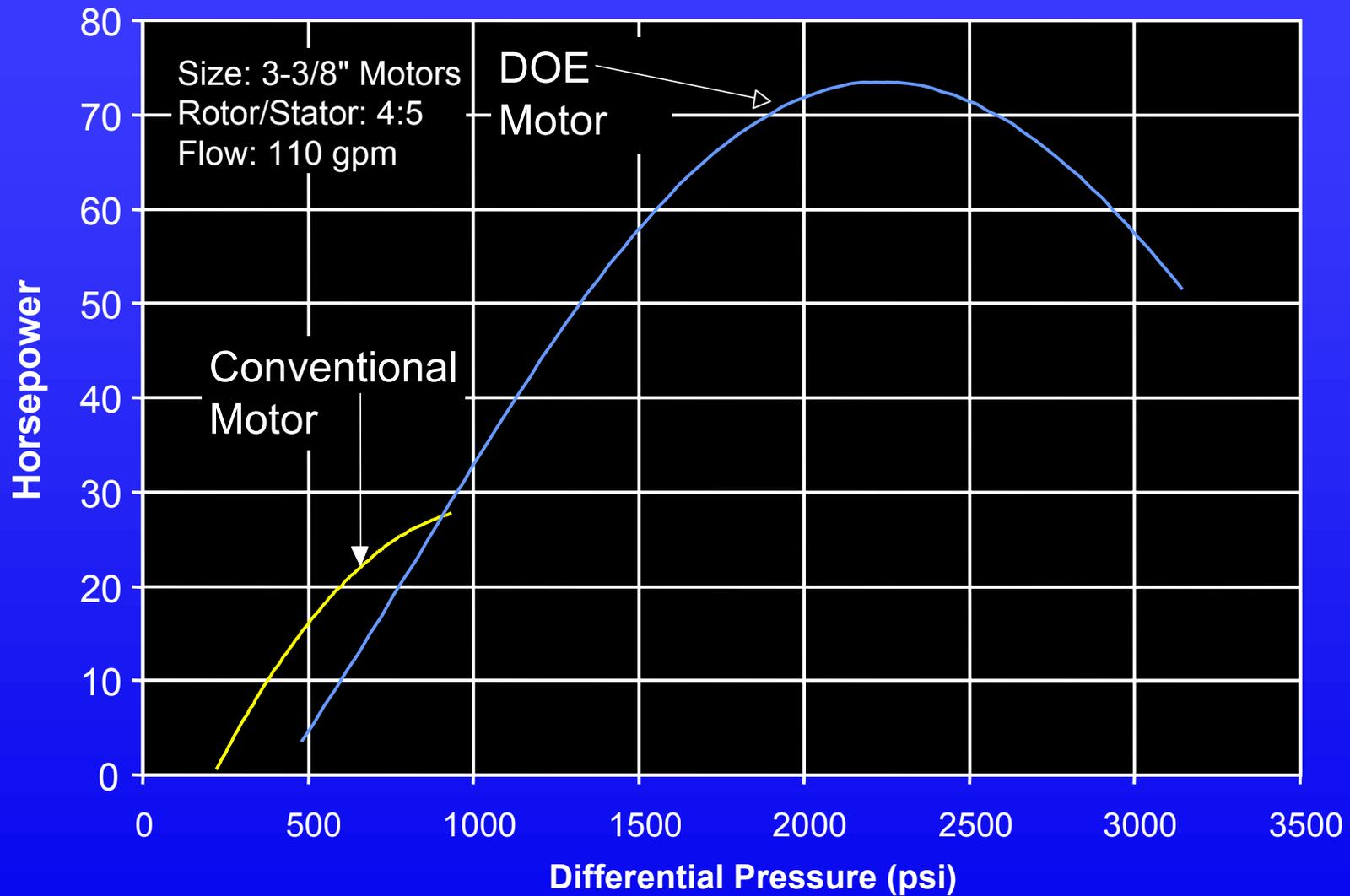
# **DOE High-Power Motor Design**



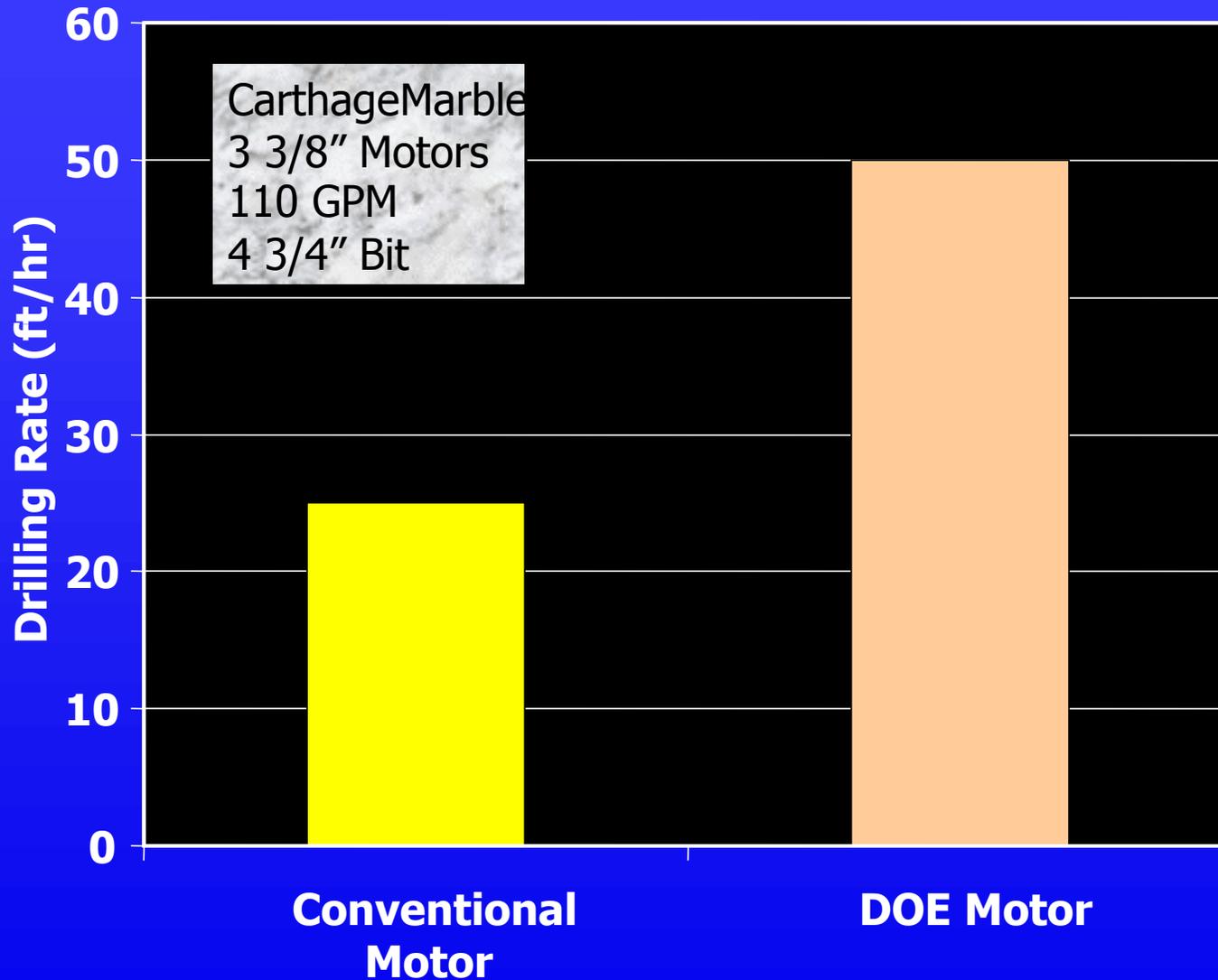
# ***DOE Motor In Dynamometer***



# Motor Performance Comparison



# Laboratory Drilling Rates DOE Slim Hole System

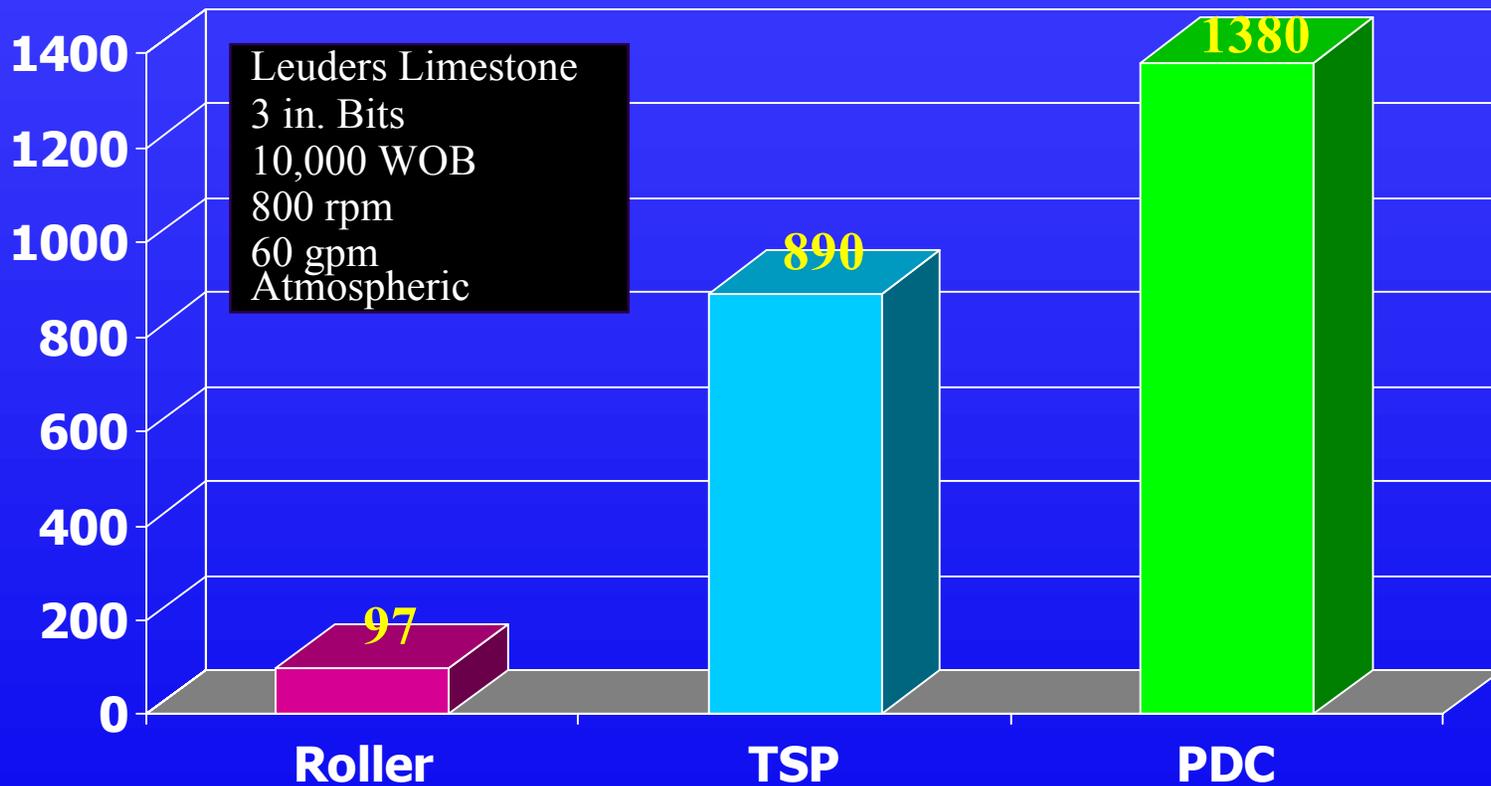


# ***Hybrid PDC/TSP Bits***

***DOE Hybrid TSP/PDC Bit***

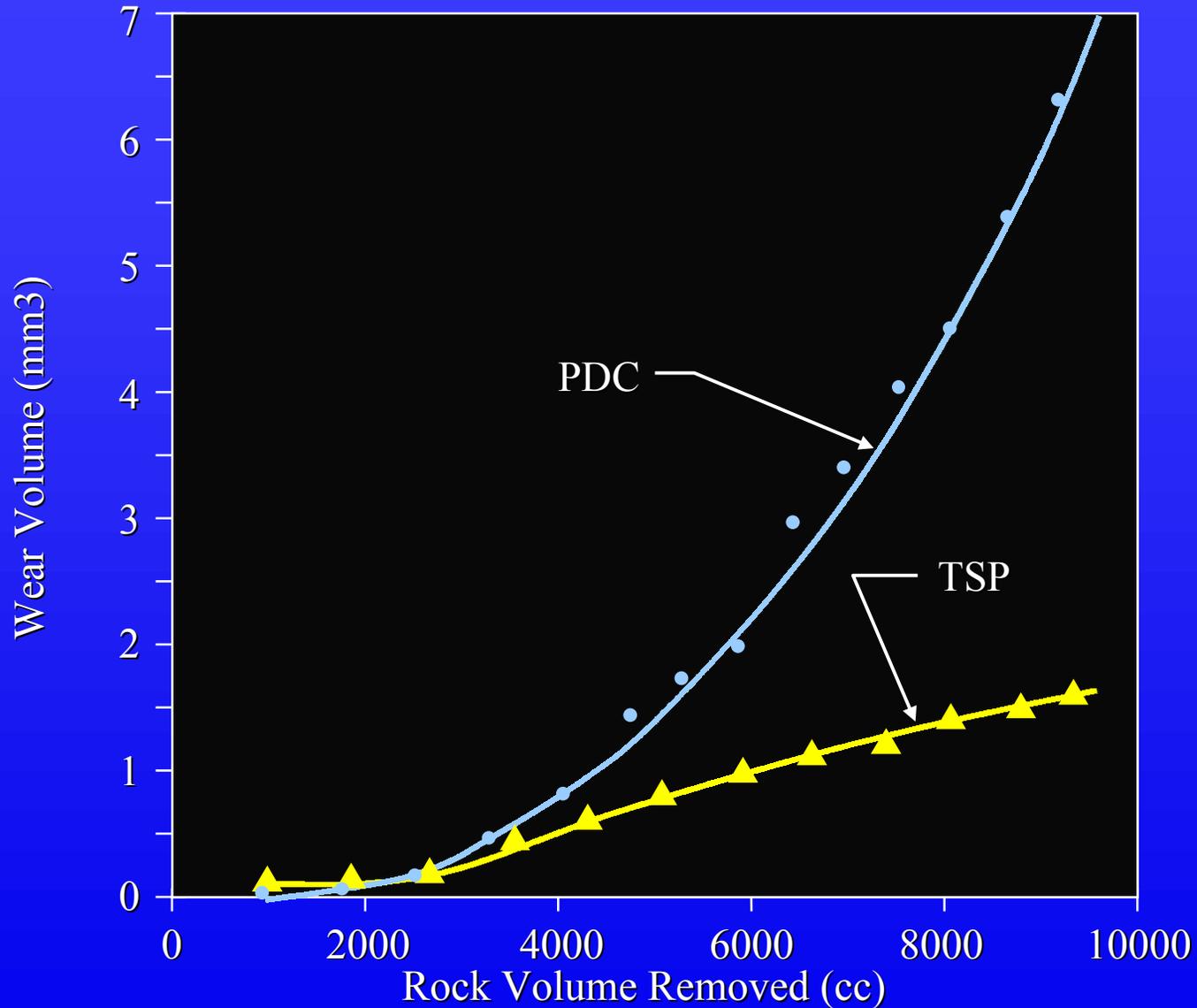


# Drilling Rates



# Cutter Wear Volume vs. Rock Volume Removed

20 rpm, water cooled, Sierra White Granite,  
0.06 in. DOC, 0.08 in/rev feed rate



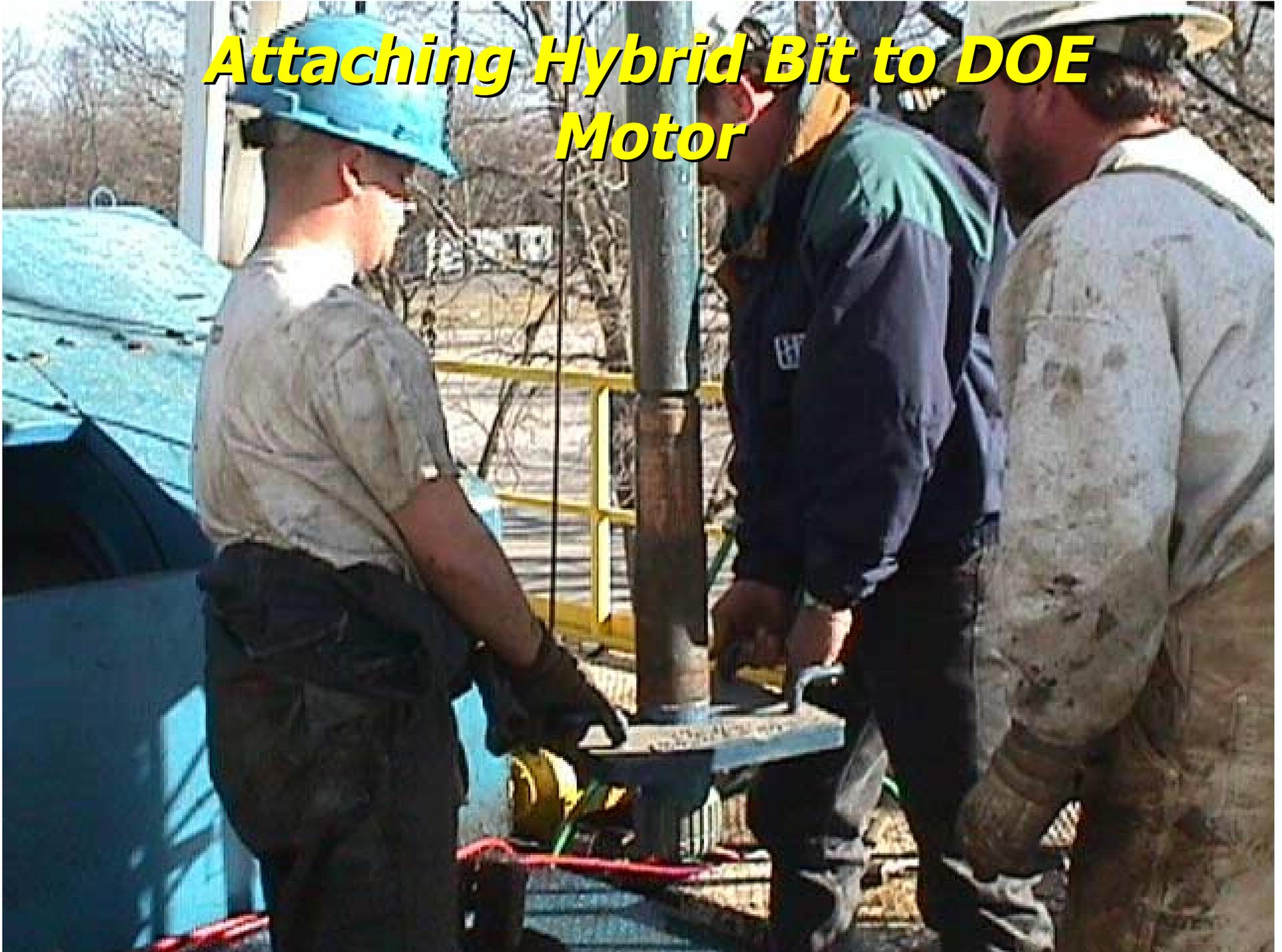


## ***Catoosa Test Site***

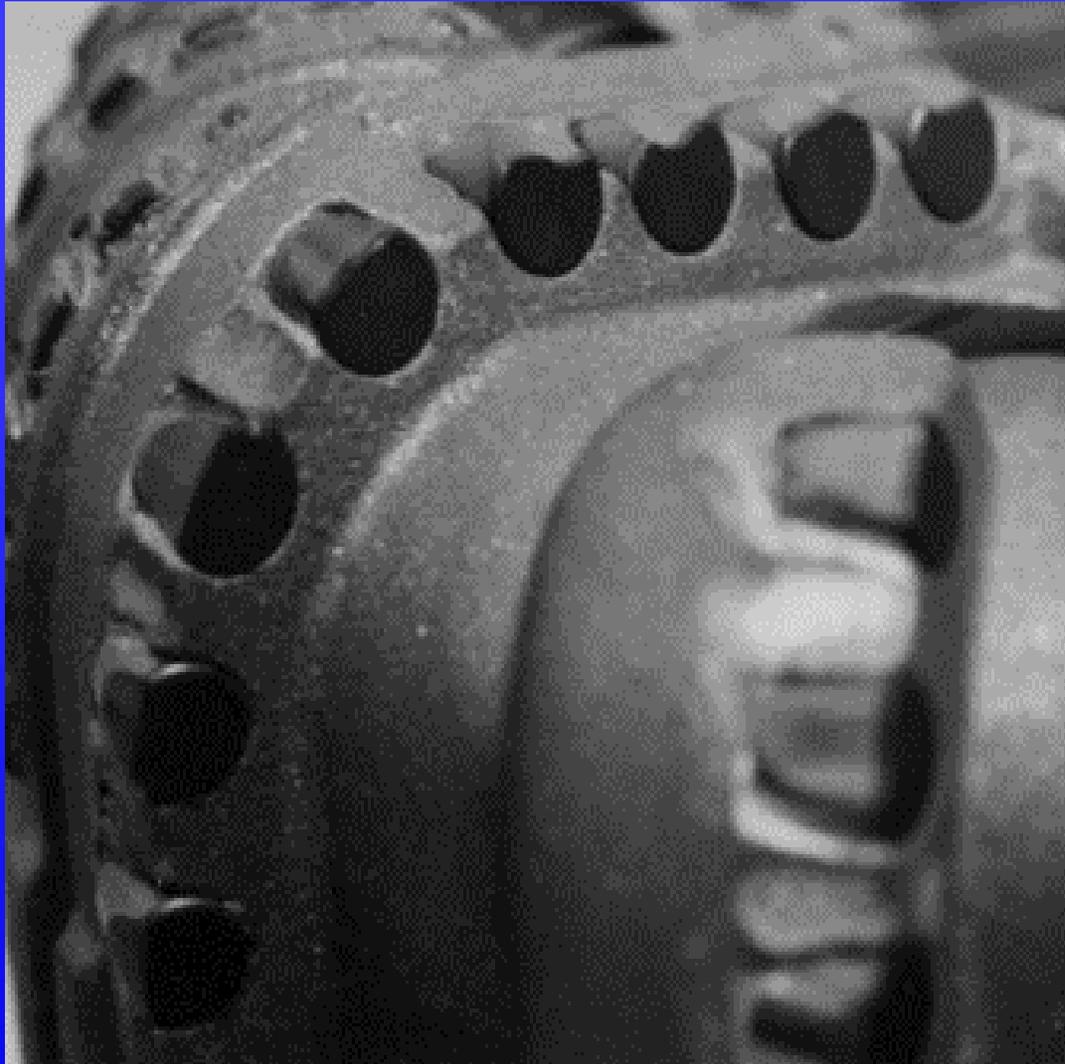
***DOE Motor In Derrick***



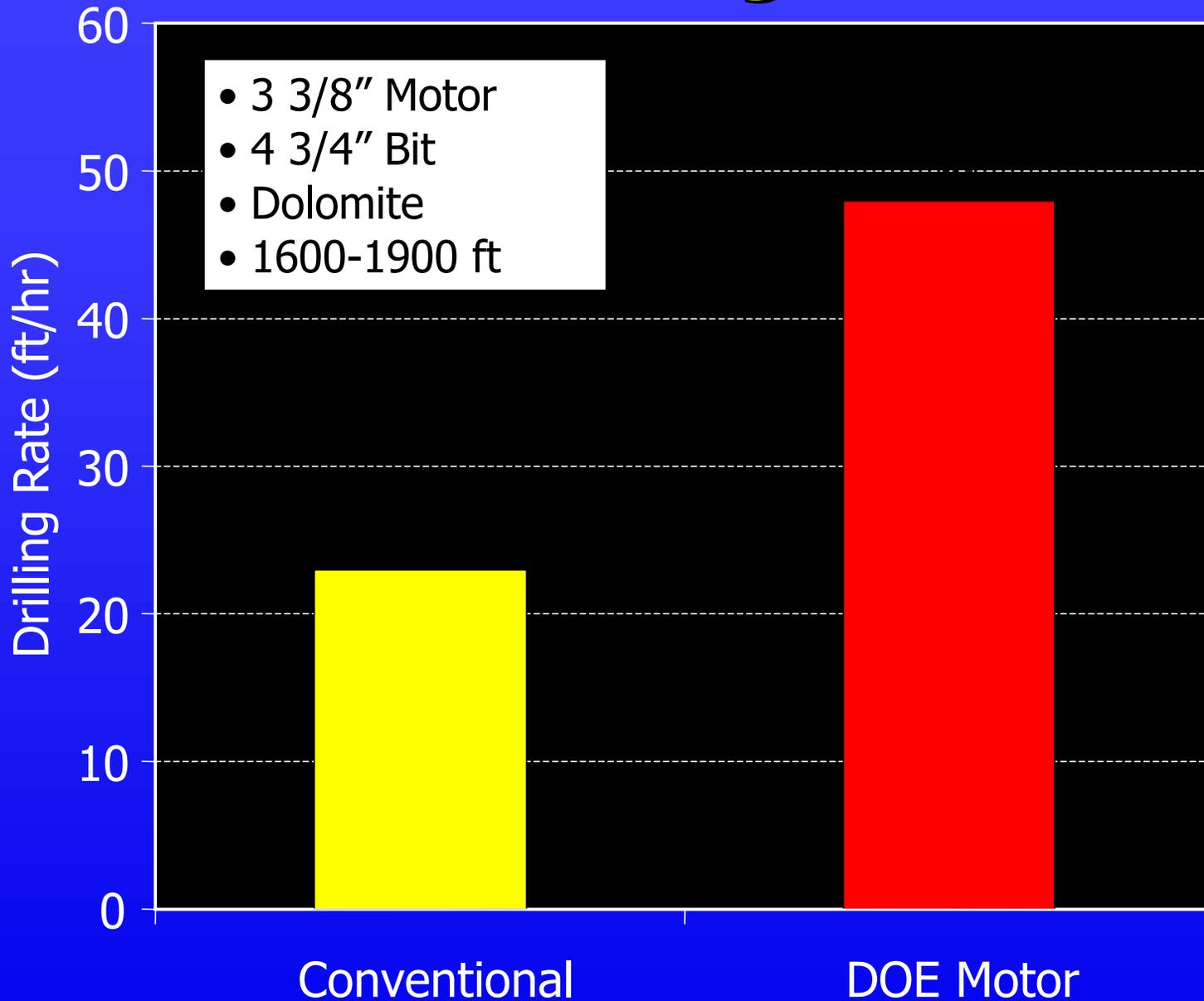
***Attaching Hybrid Bit to DOE  
Motor***



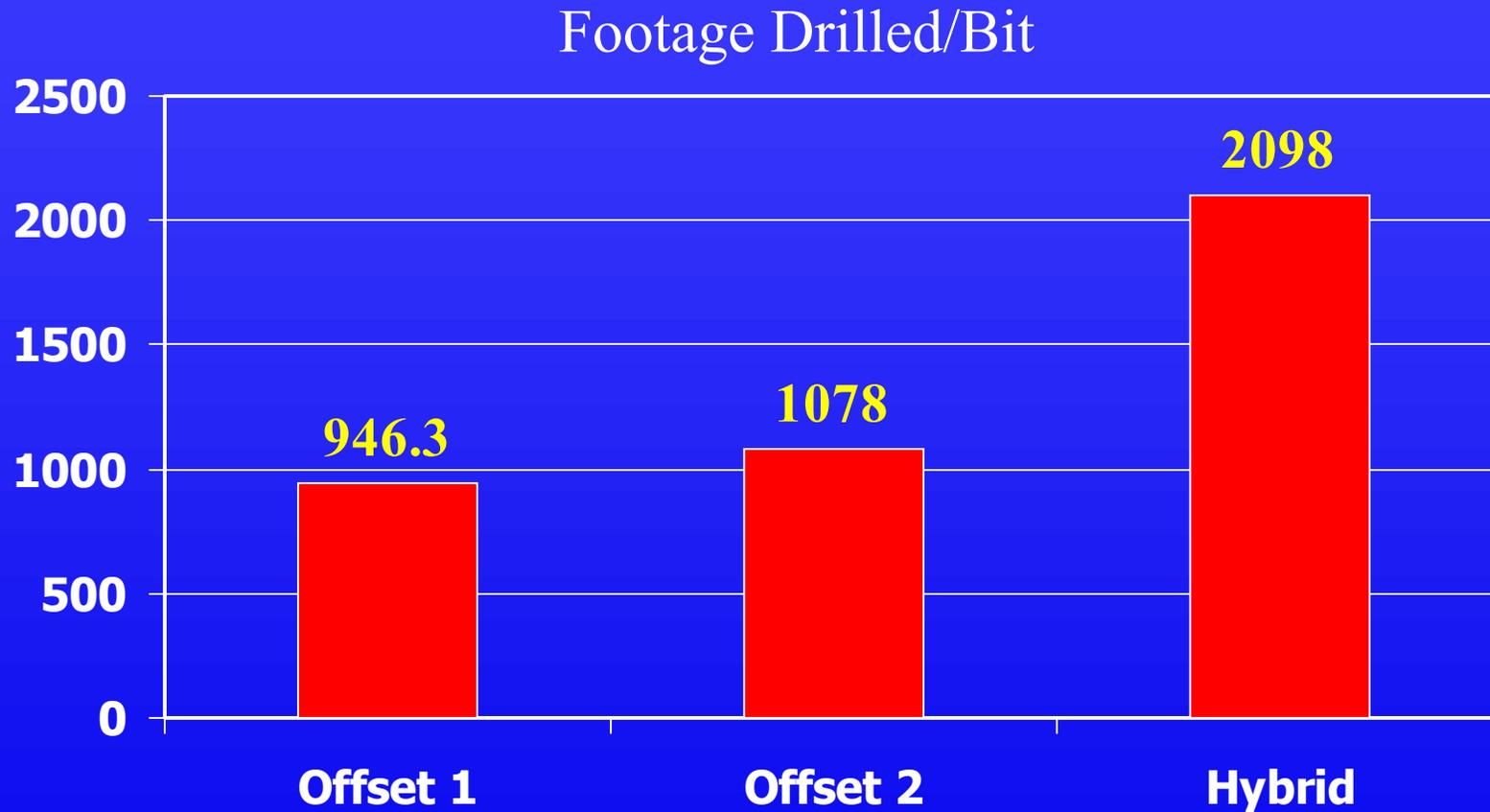
# **Hybrid Bit After Drilling "The Wall"**



# Field Drilling Rates



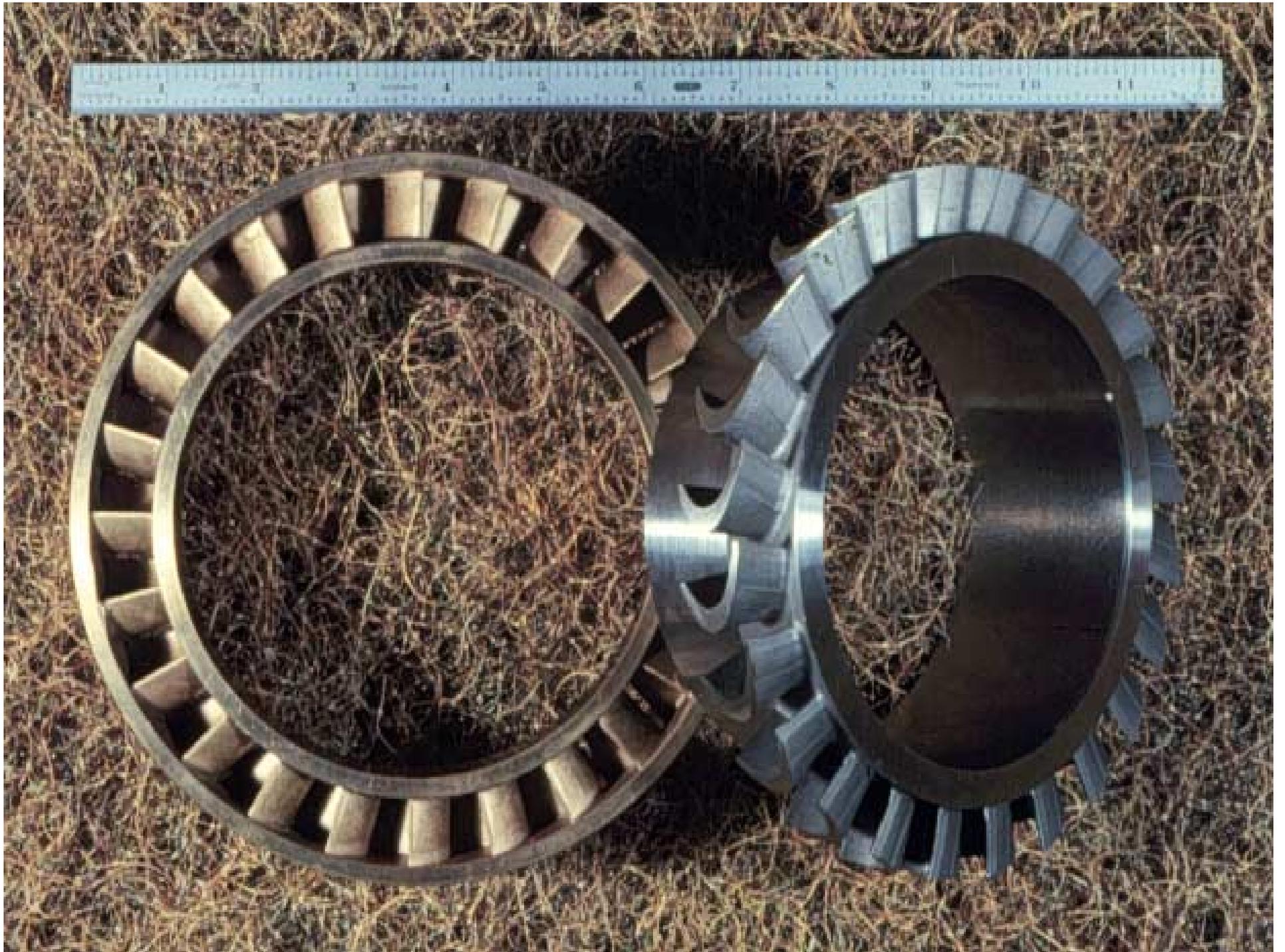
# Comparison to Offset Wells



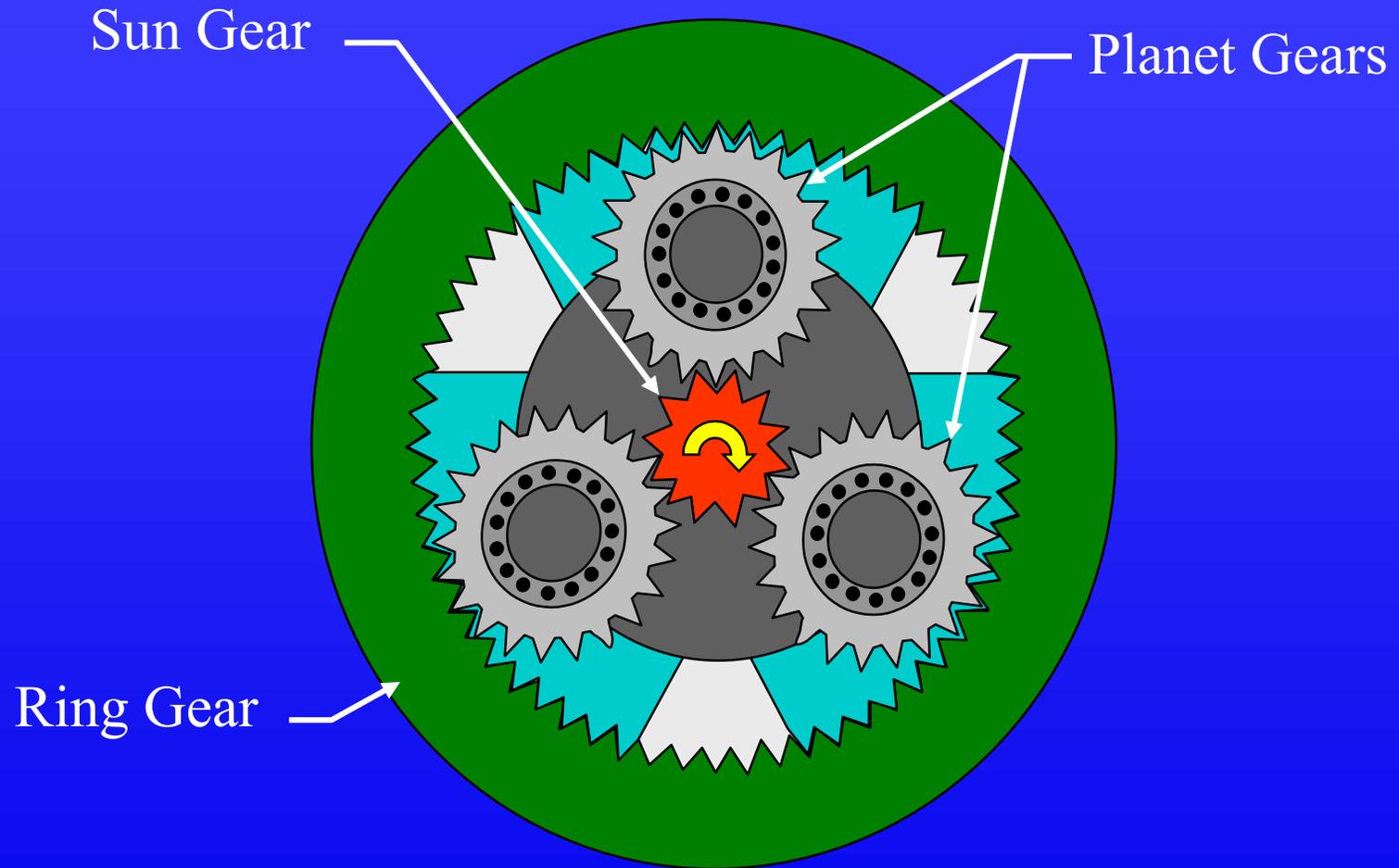
# ***High Power Geared Turbodrill***

## ***Advanced Geothermal Turbodrill (AGT)***



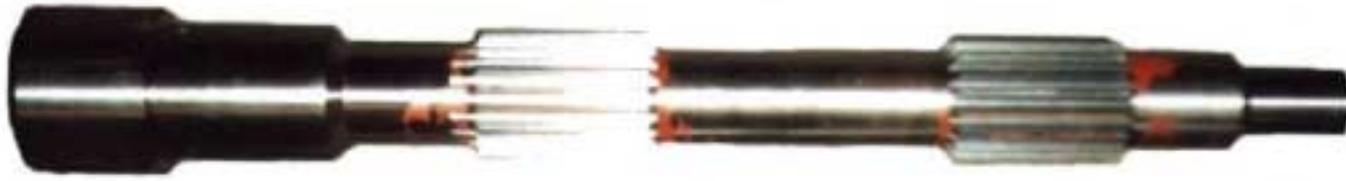


# Planetary Gears



# **VECTOR OIL TOOL**

## **Speed Reducer Shafts and Gears**



Lower Sun Gear

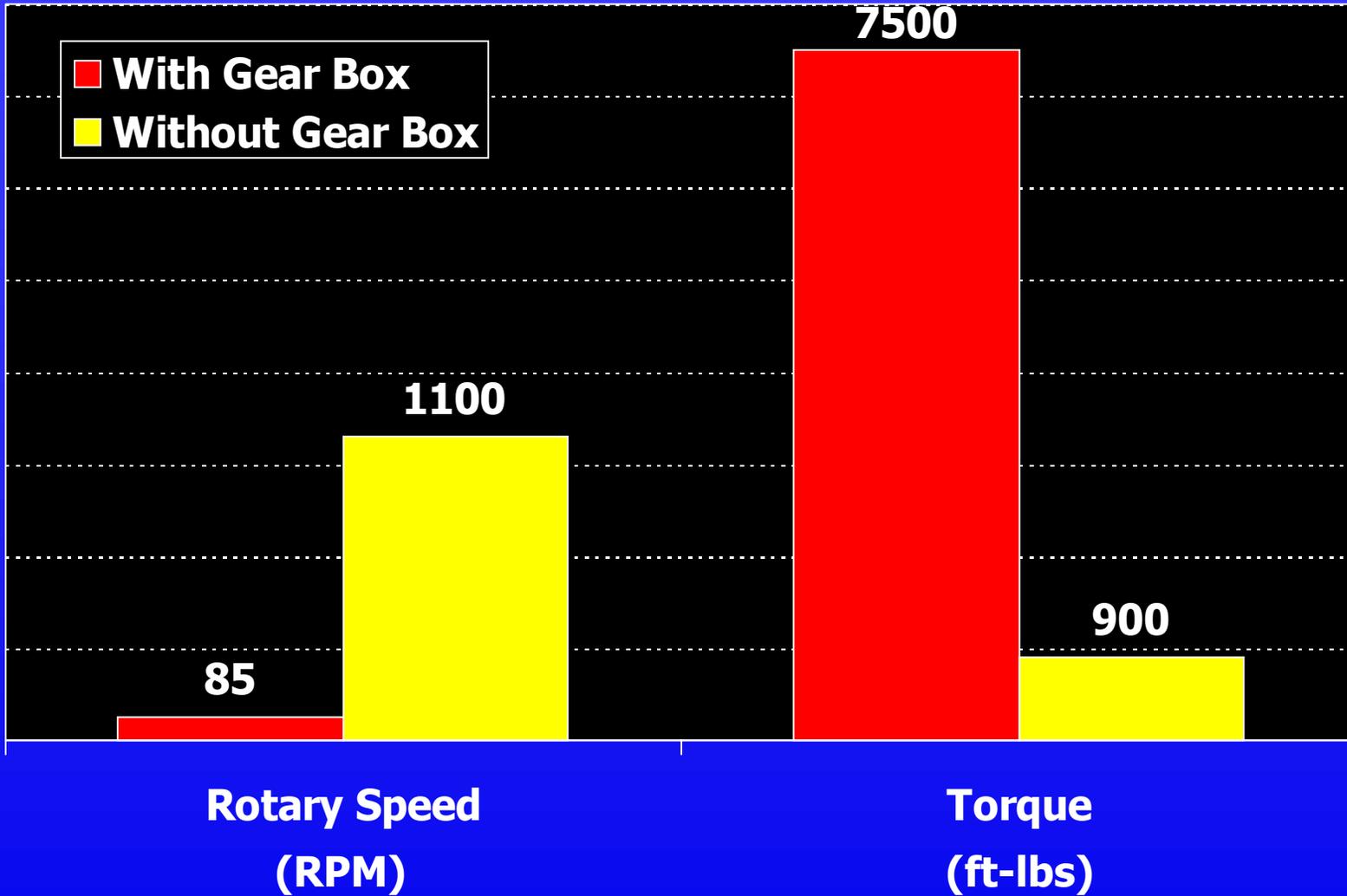


Upper Sun Gear

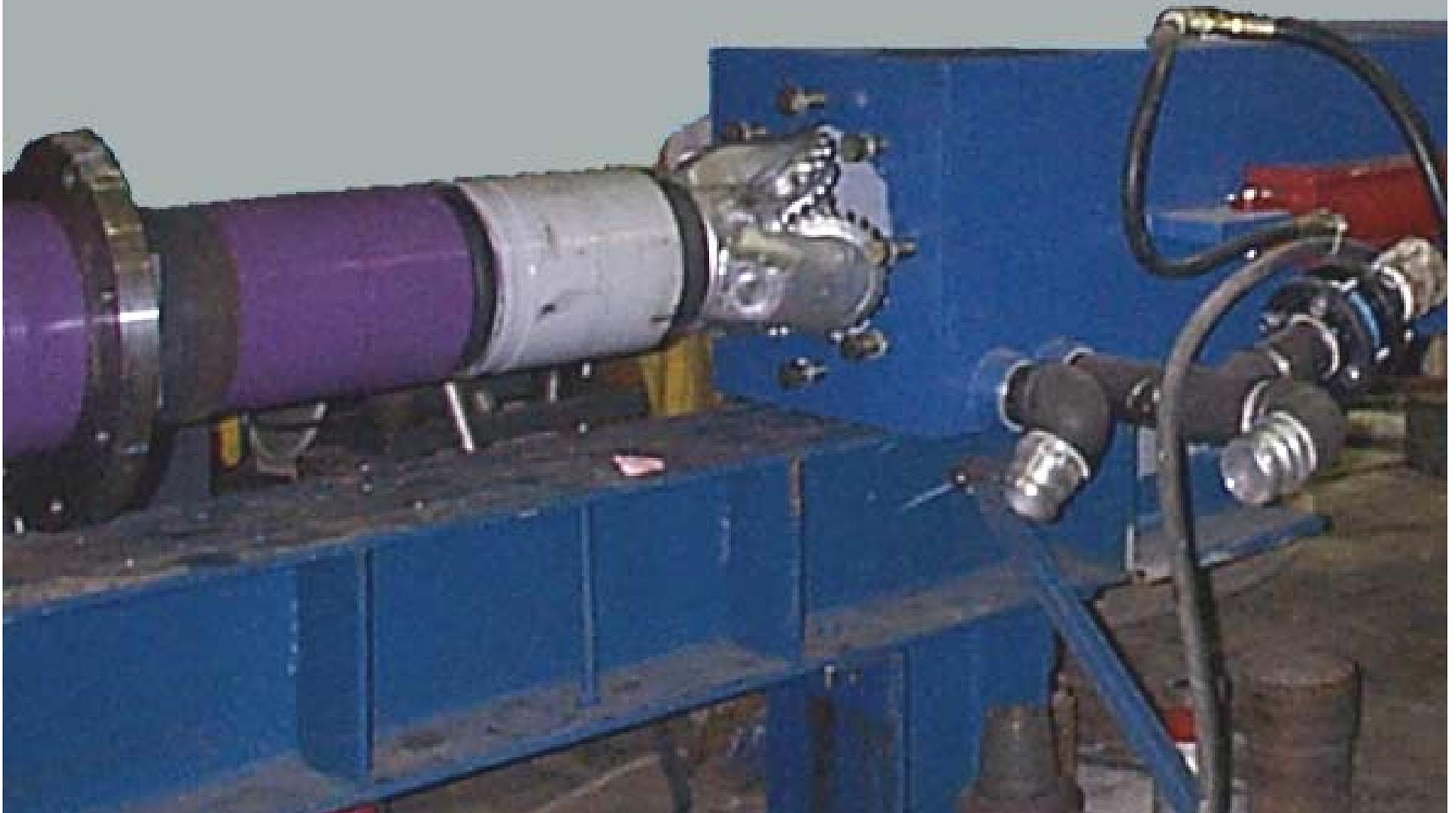


Planet Gear

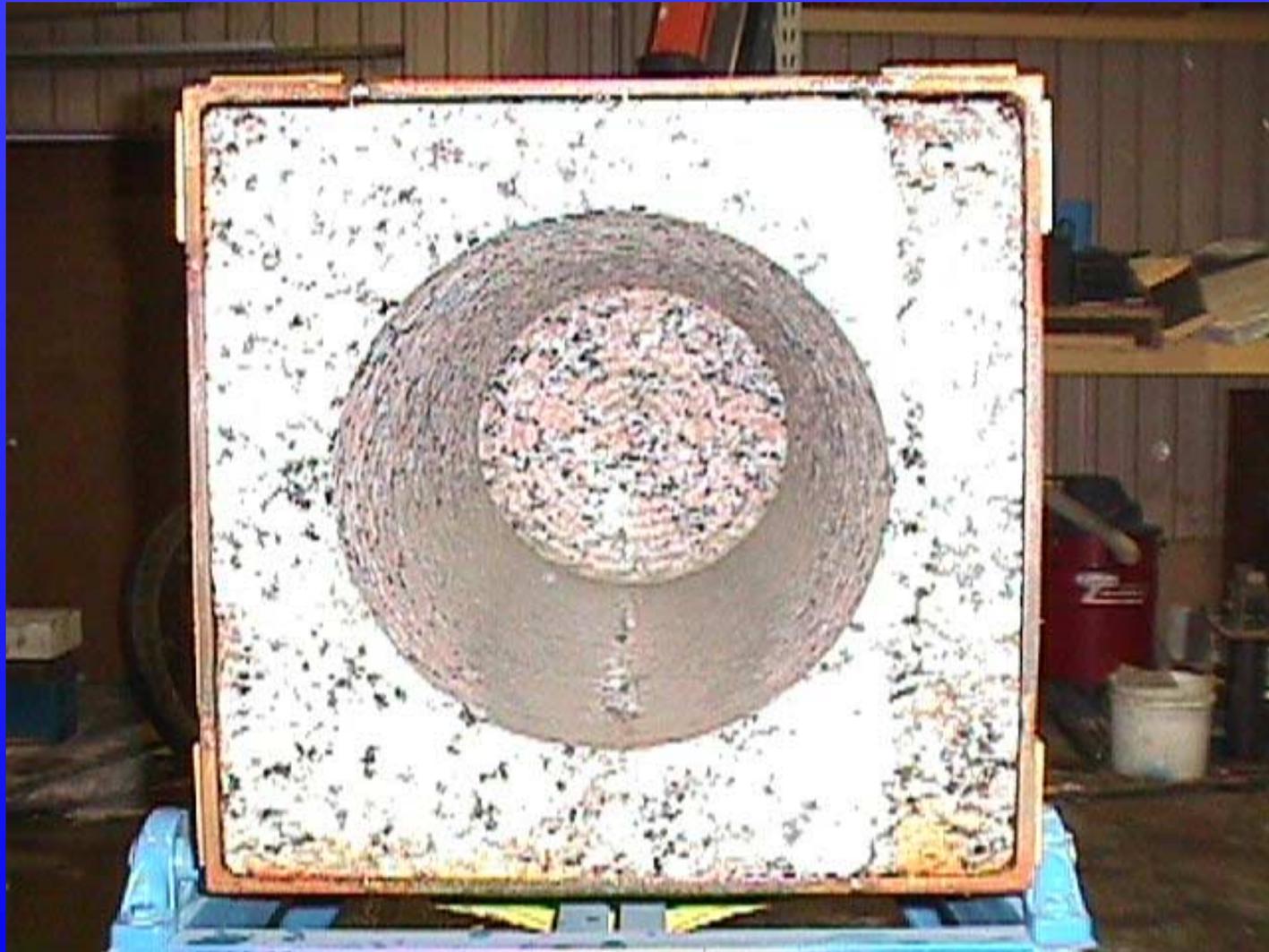
# ***Turbodrill Performance***



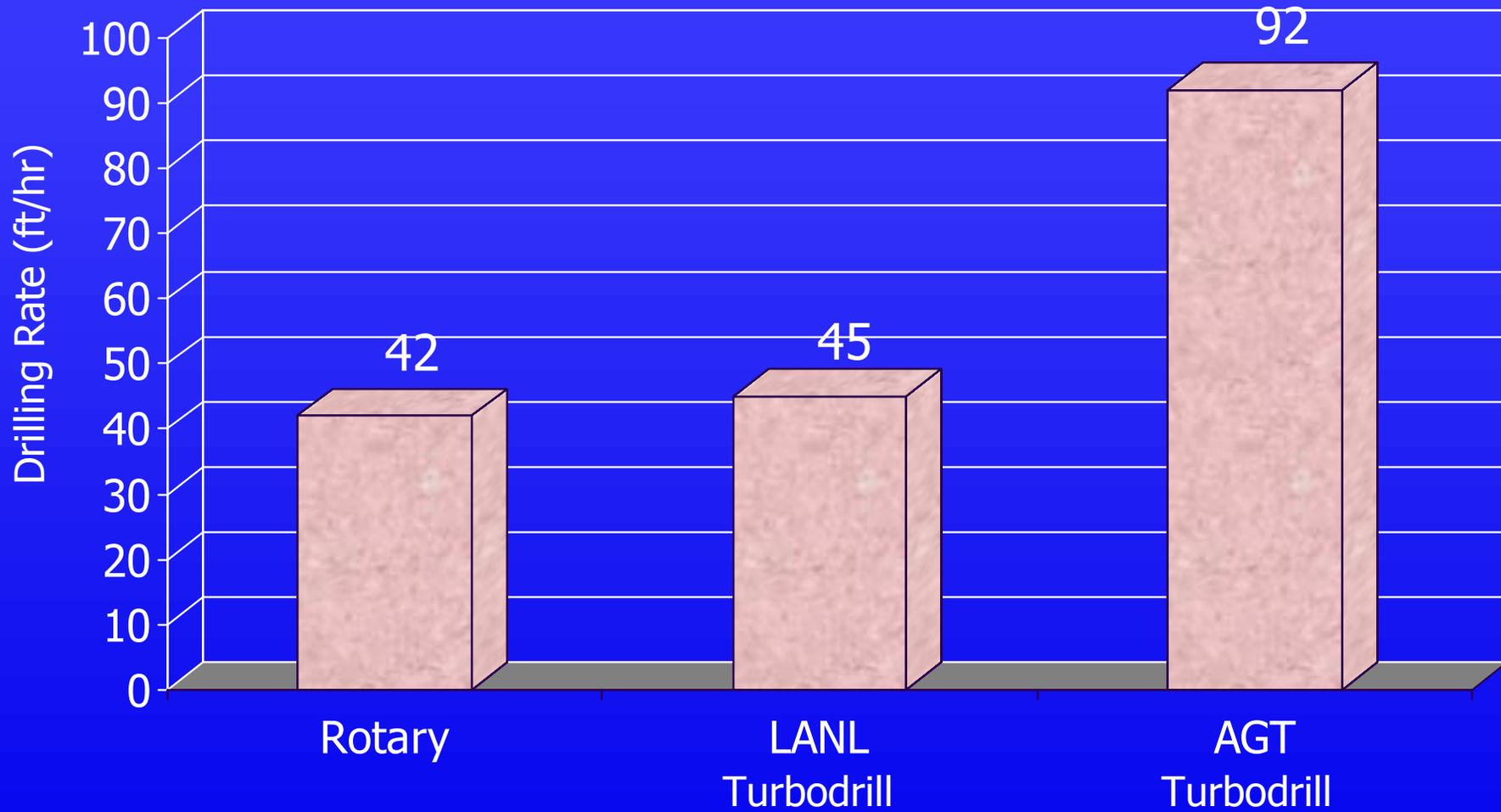
# ***Turbodrill Drill Stand***



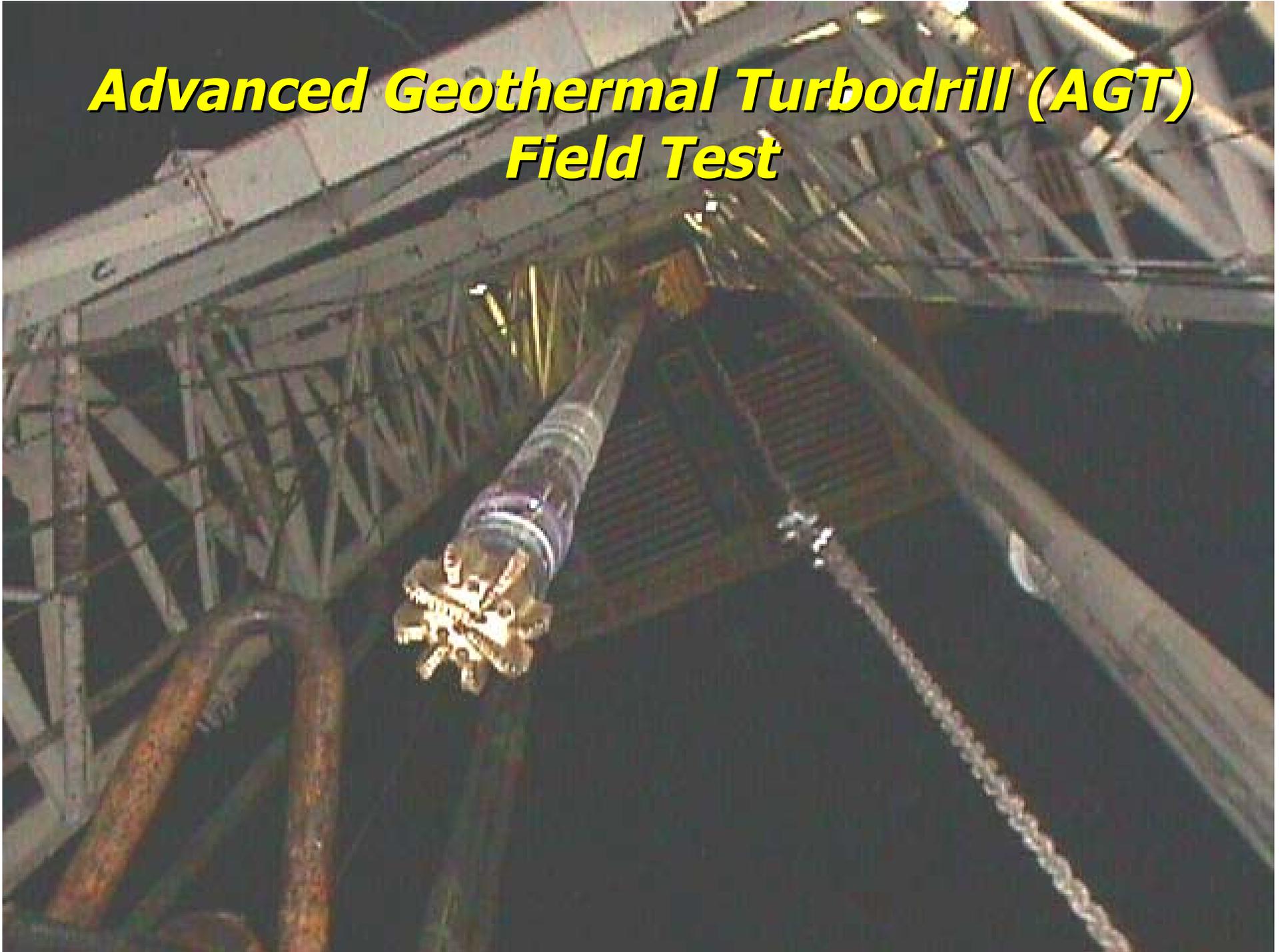
# ***Drilled Rock Sample***



# 12 1/4" Carbide Roller Bit Texas Pink Granite



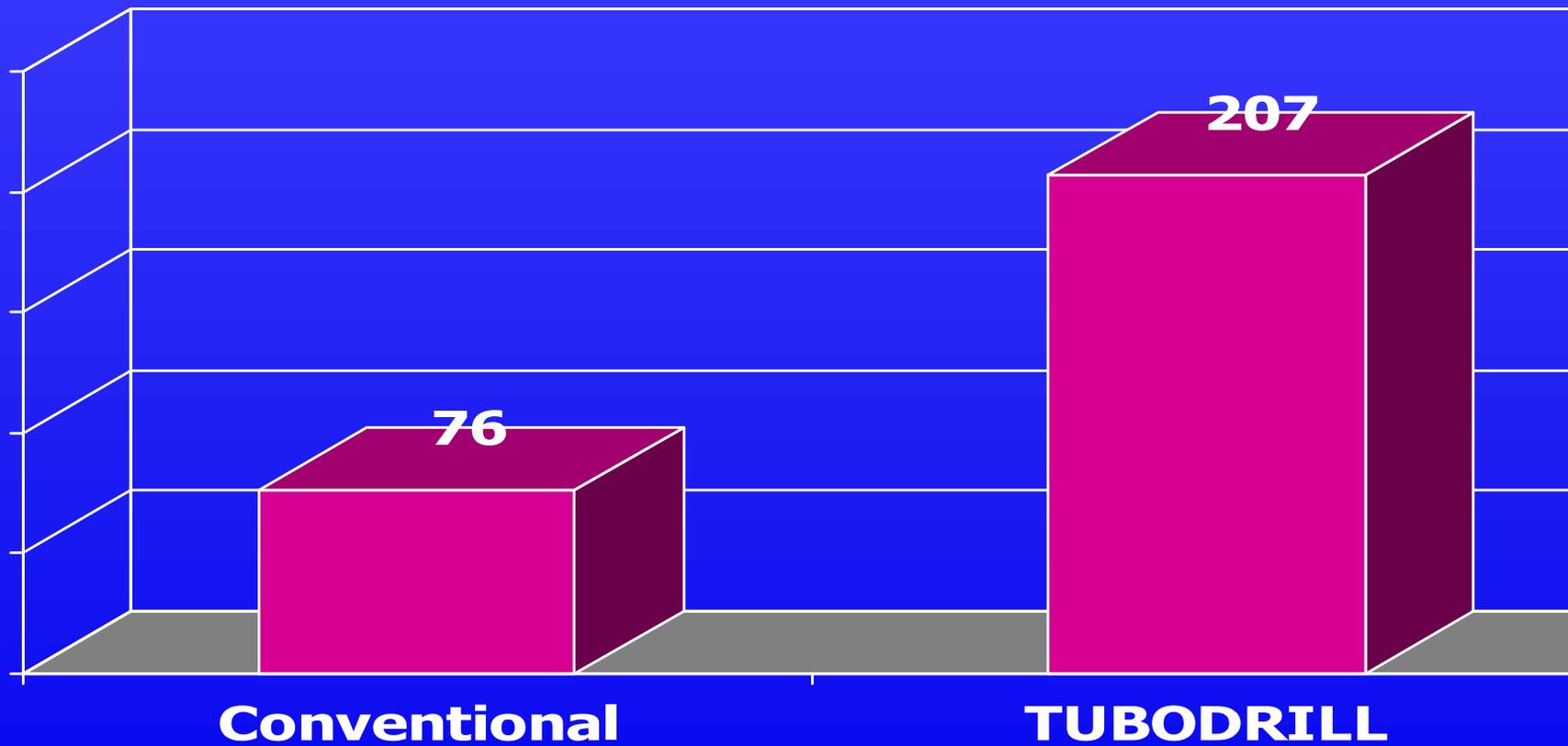
***Advanced Geothermal Turbodrill (AGT)  
Field Test***



# Christensen Bit

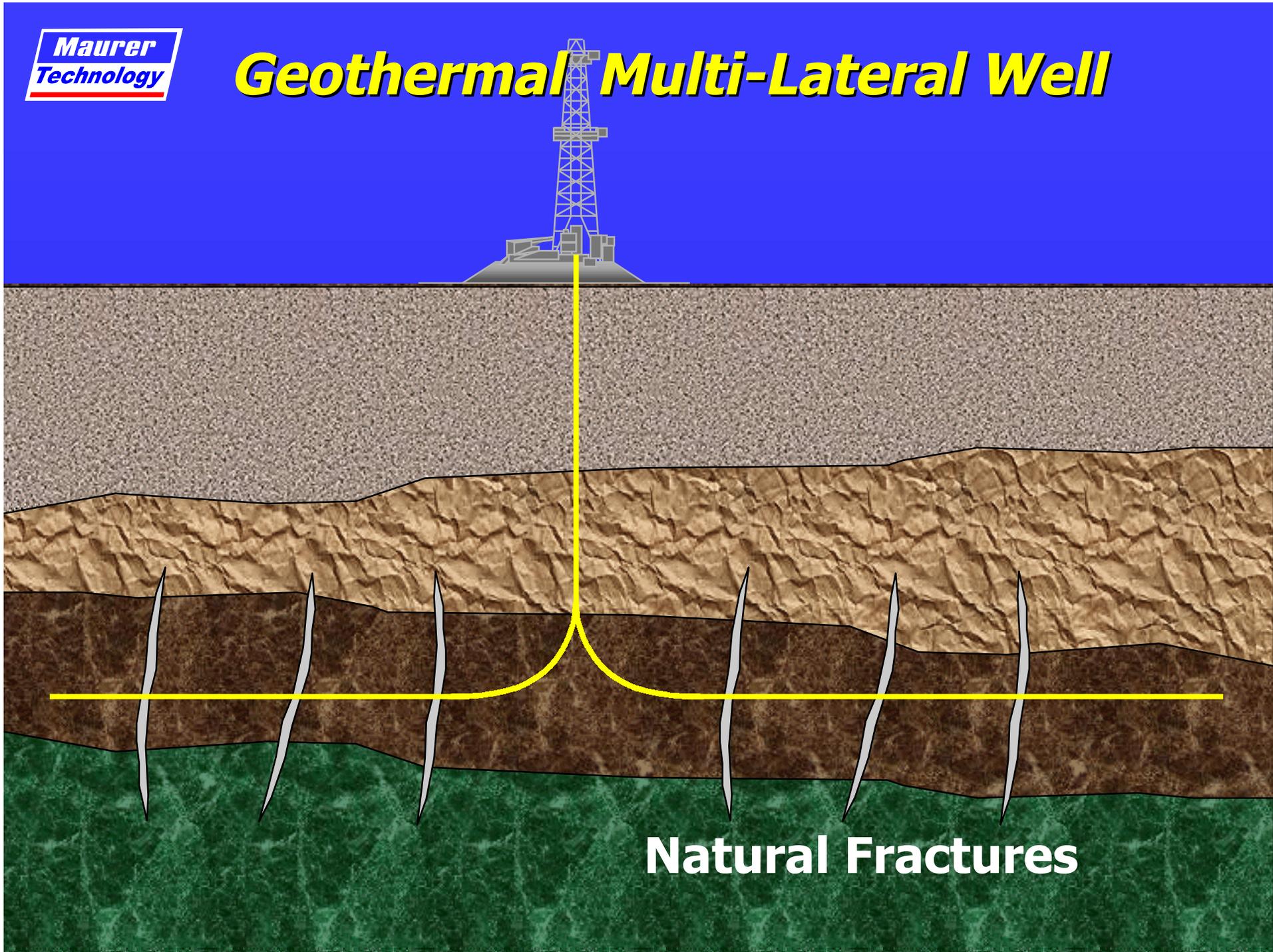


# Peak Drilling Rates





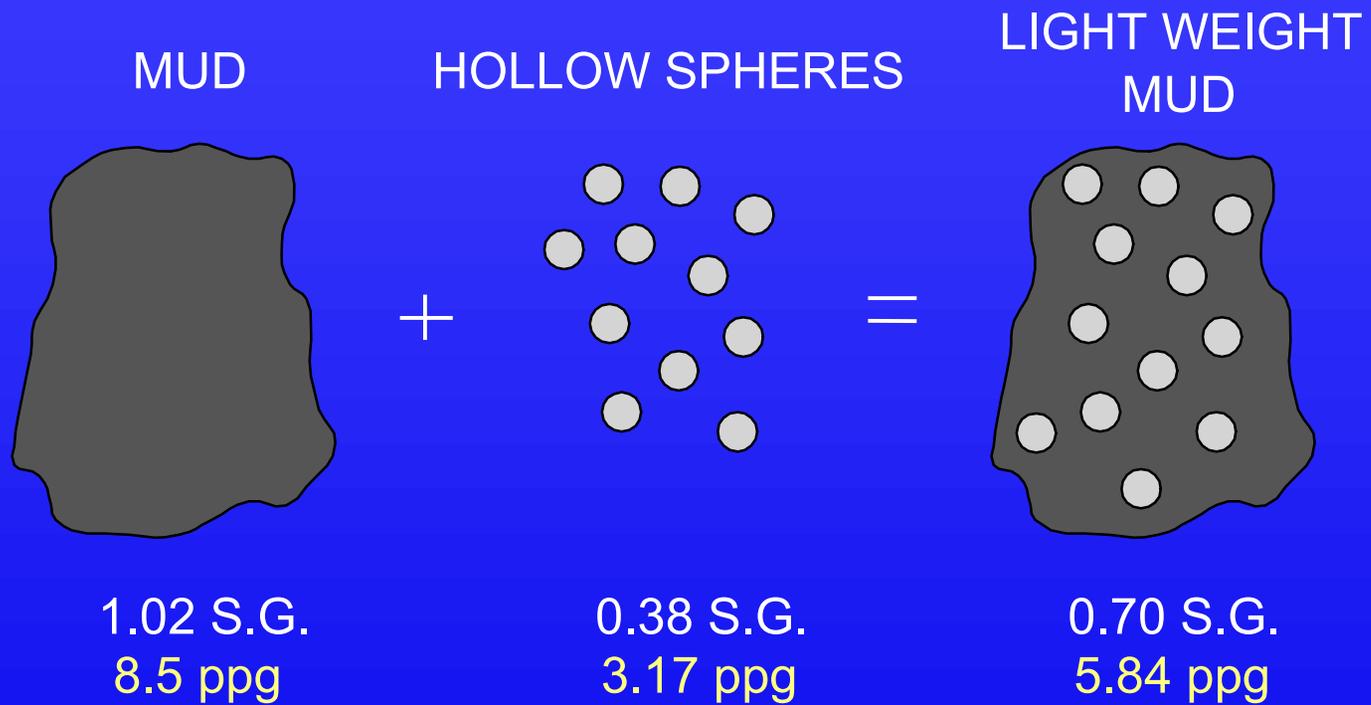
# Geothermal Multi-Lateral Well

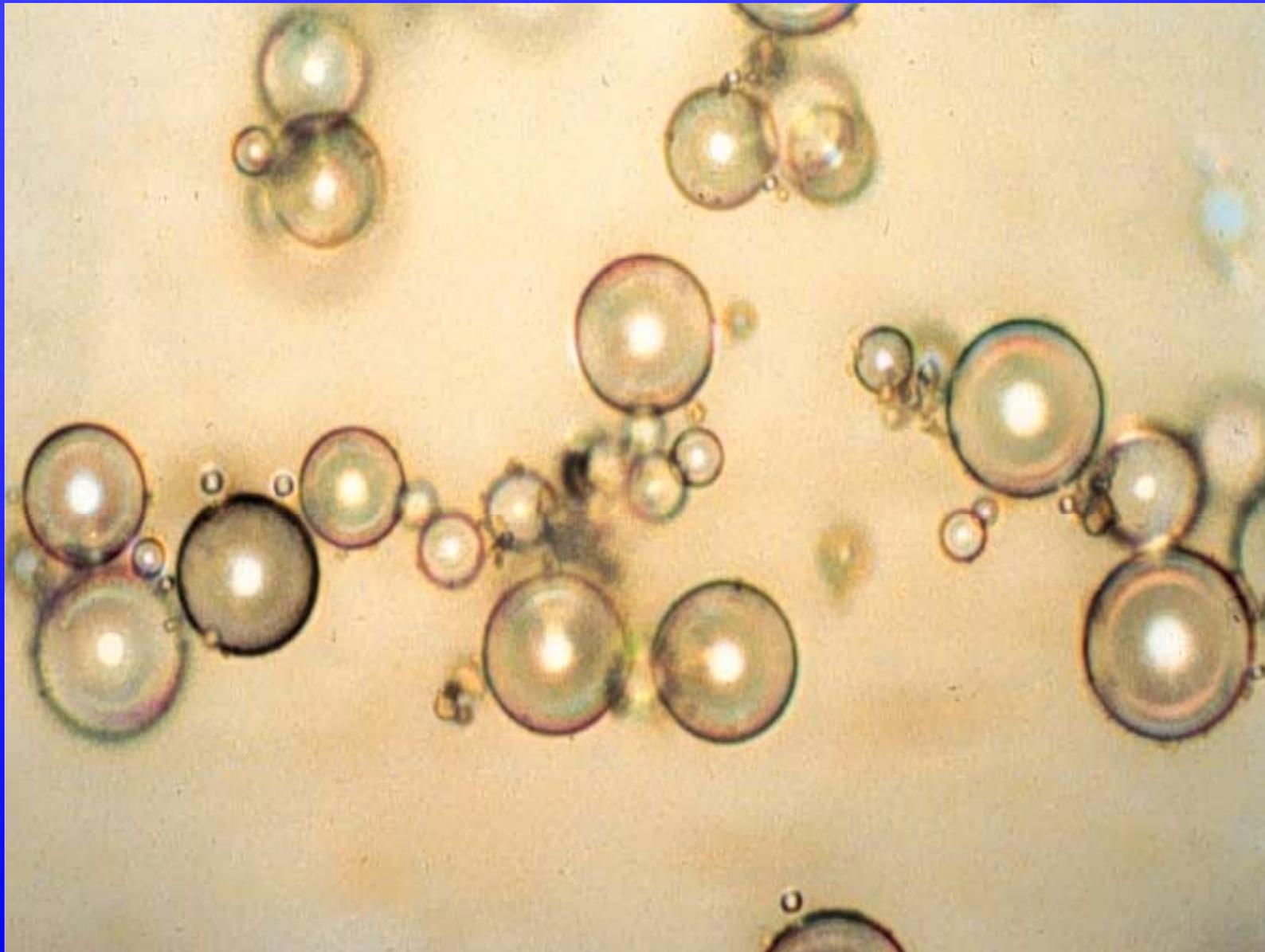


Natural Fractures

# ***Deep Well Lightweight Mud***

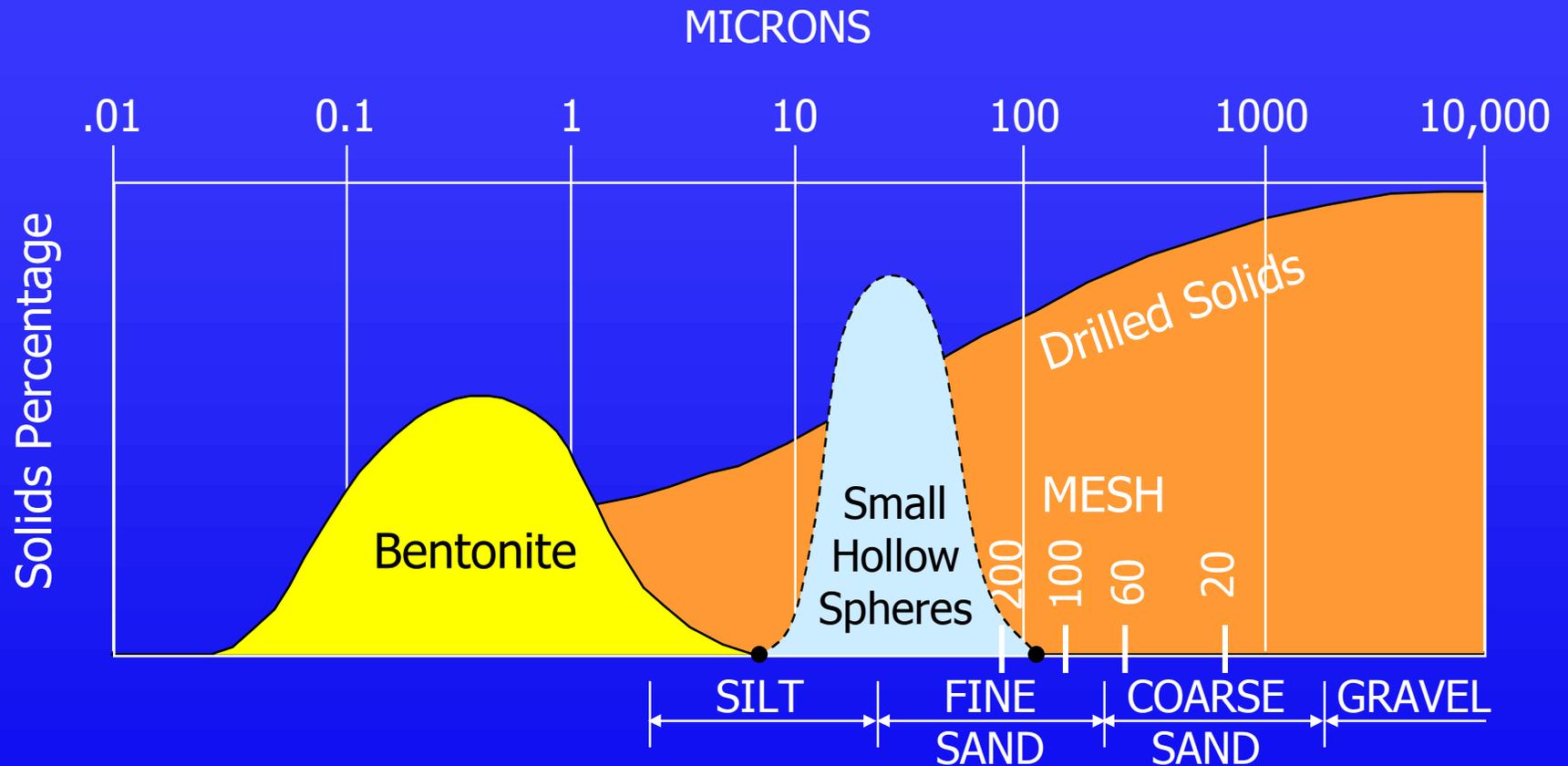
# Lightweight Mud





# Particle Sizes in Unweighted, Water-Based Mud

(After Bourgoyne Jr. et al, 1986)





# ***Golden State Drilling Rig Mud System***

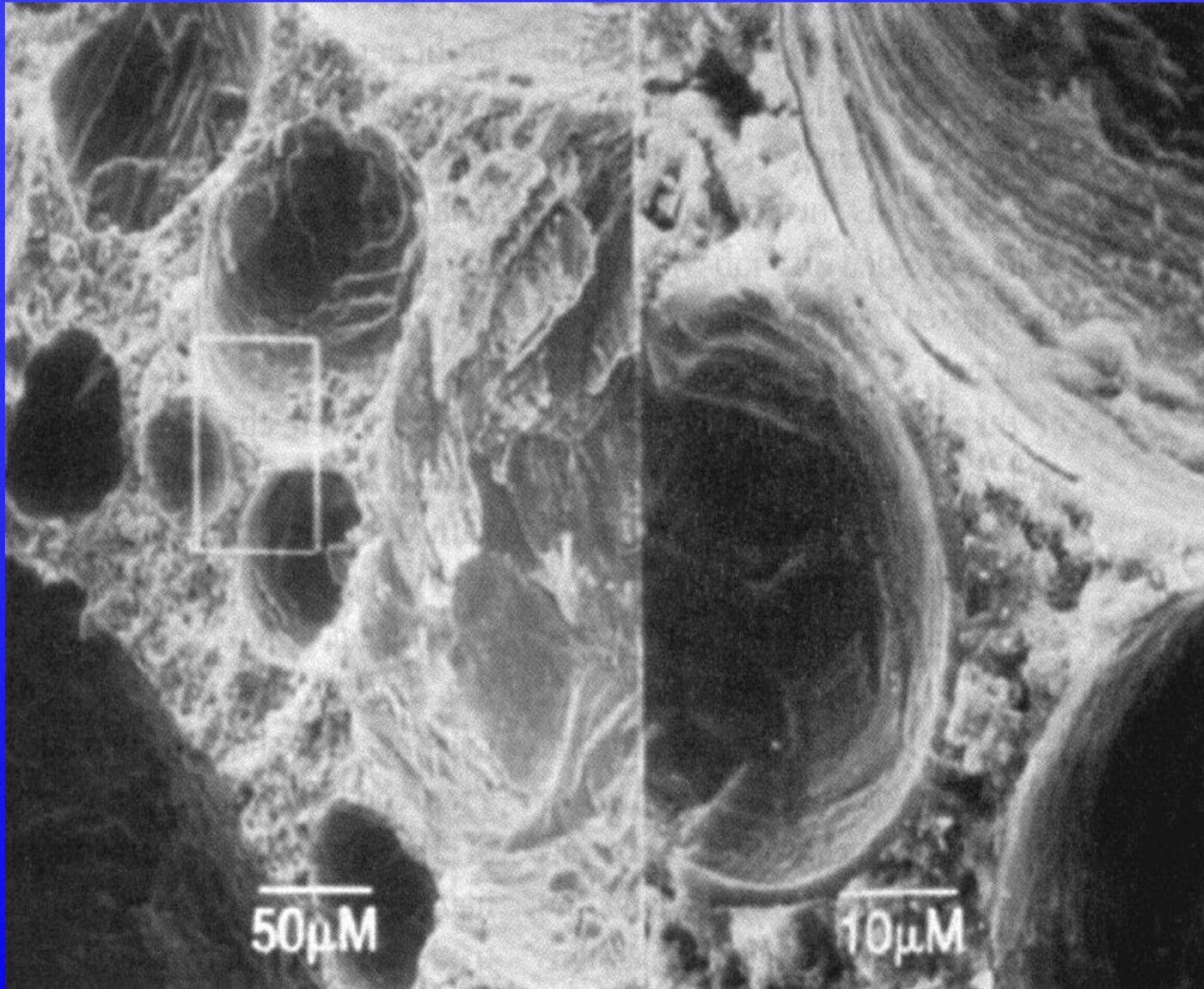


# Mud Returns

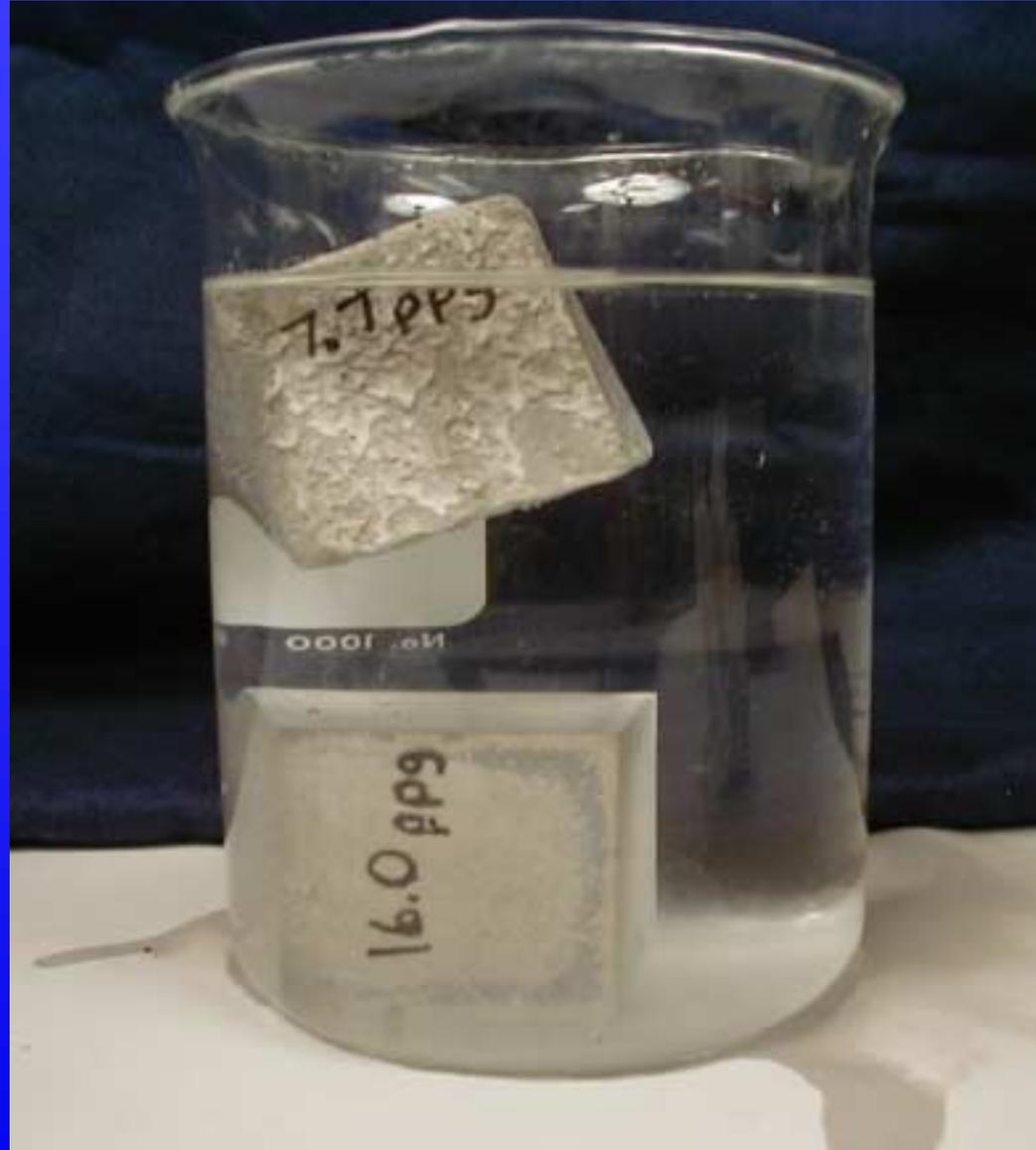


# ***Lightweight Cement***

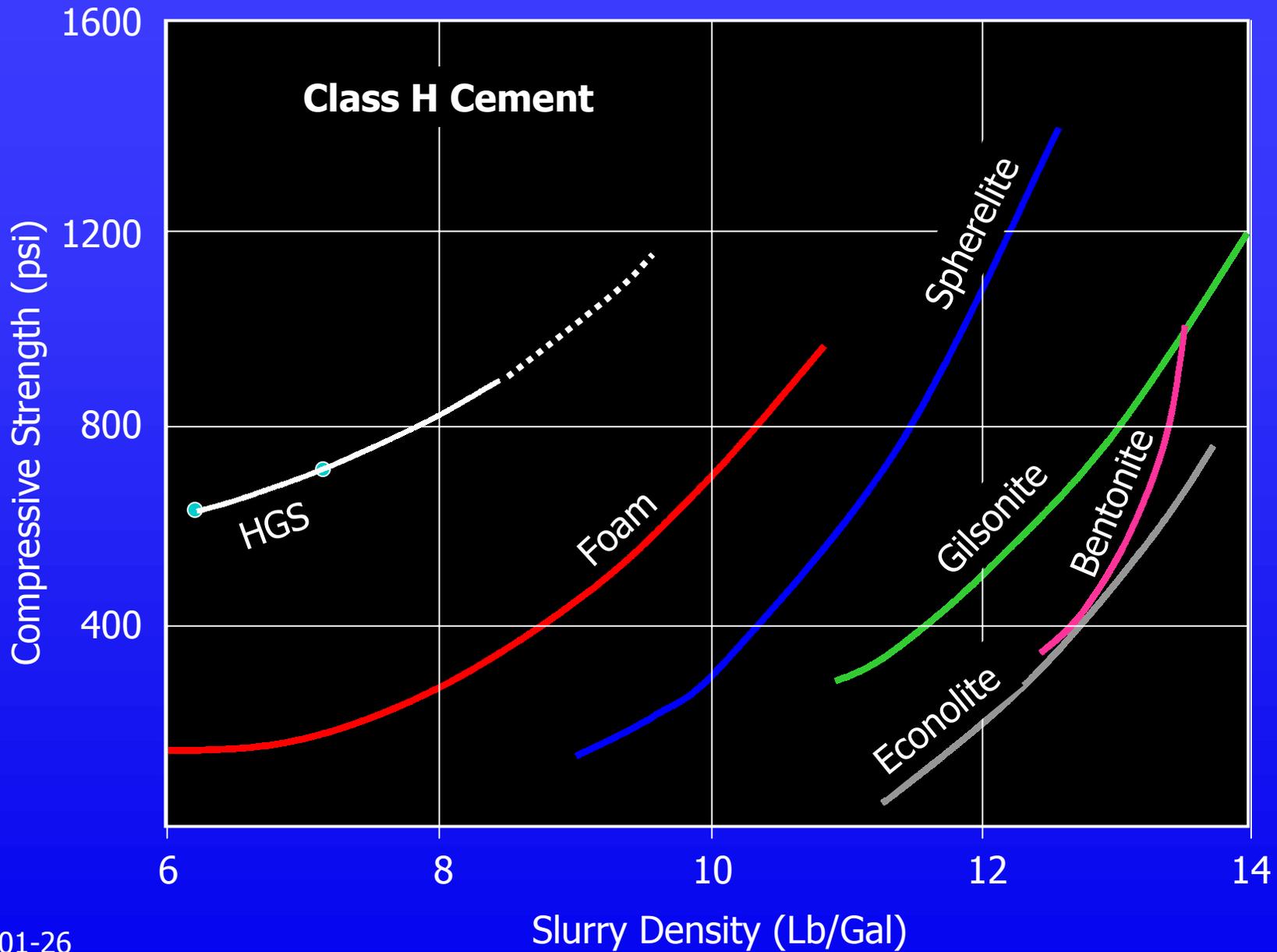
# ***Foam Cement Photomicrograph***



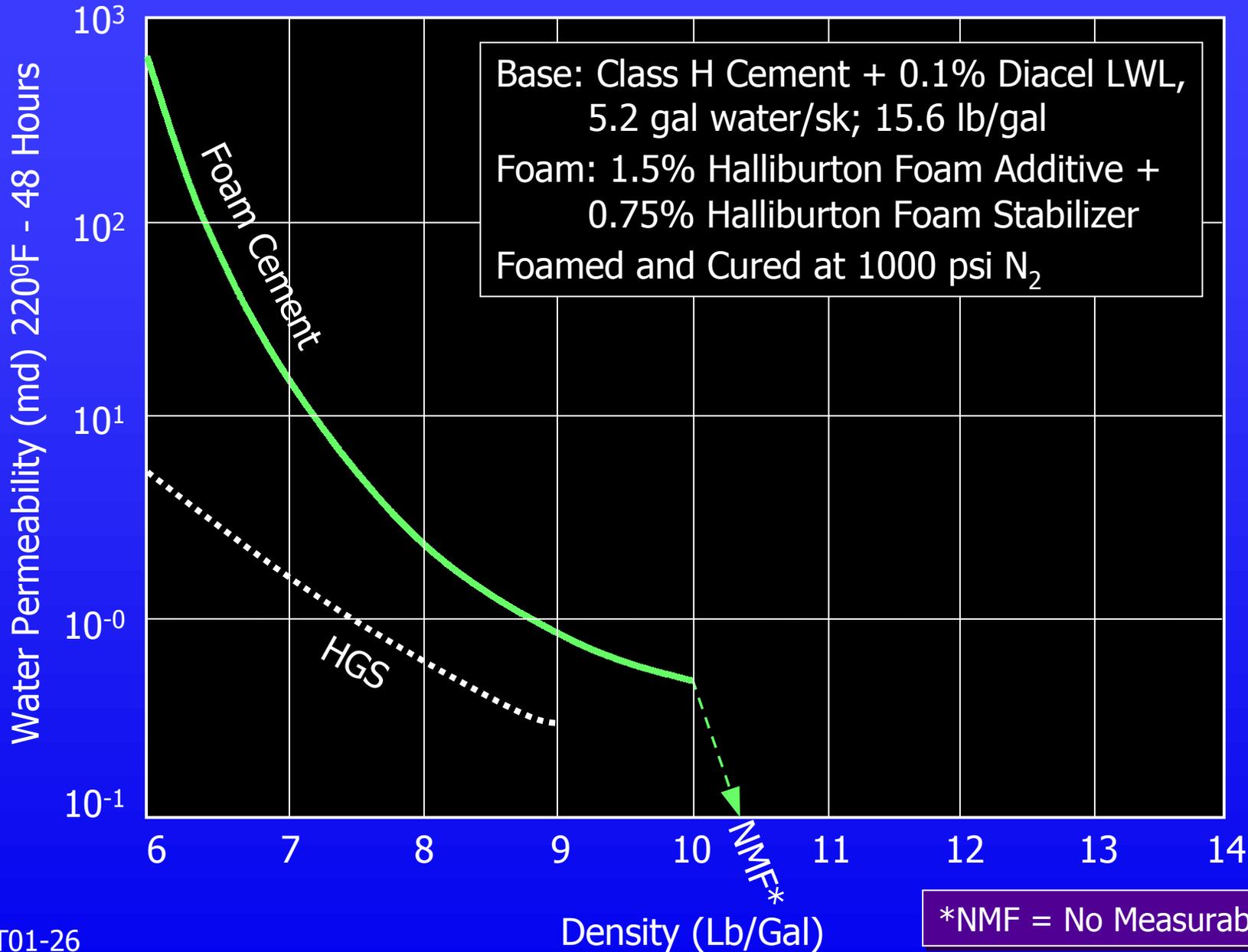
# ***Lightweight Cement***



# Lightweight Cement Compressive Strengths

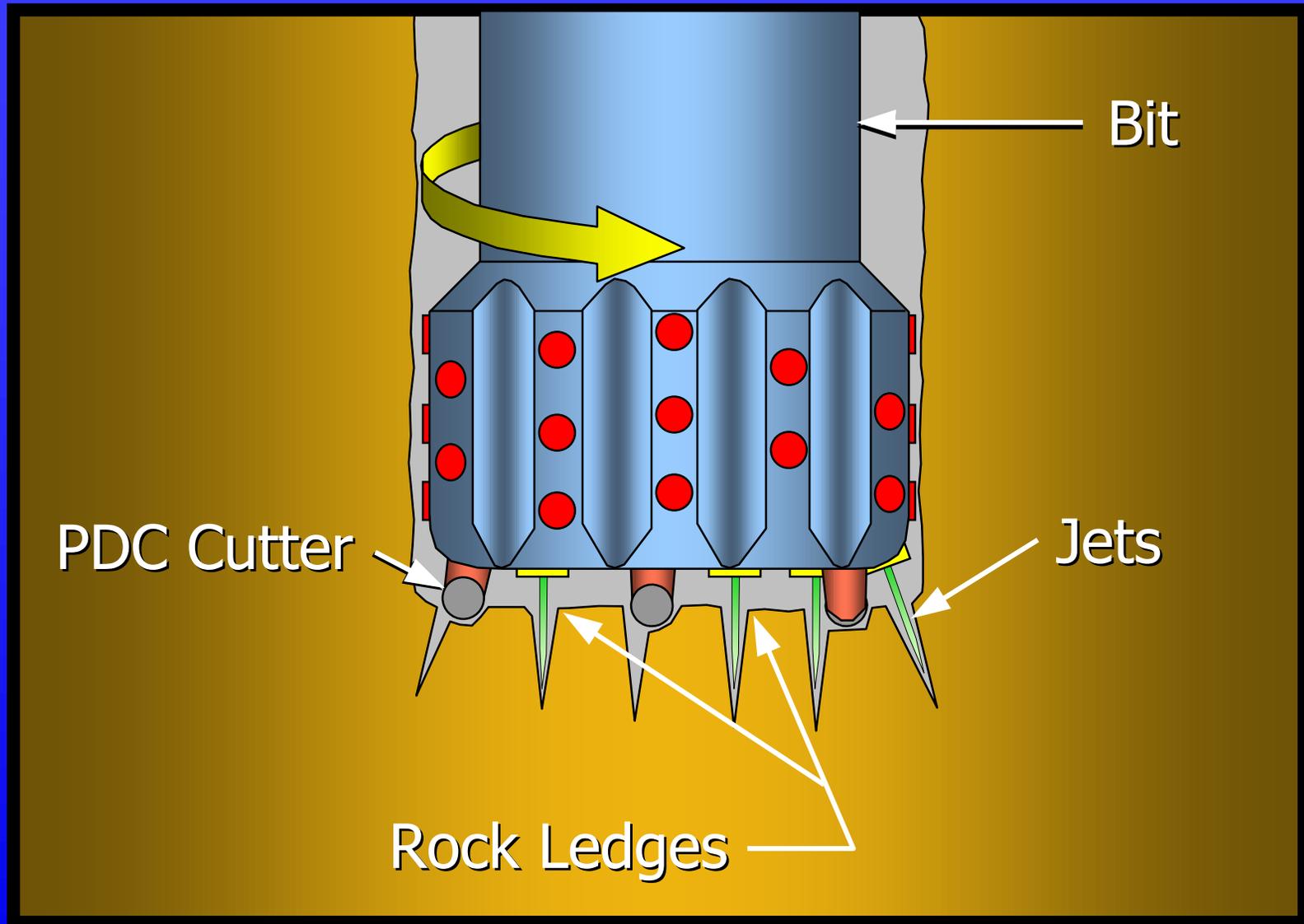


# Lightweight Cement Water Permeabilities



# ***High Pressure CT Jet Drill***

# High Pressure Drilling Mechanism



**Maurer  
Engineering**

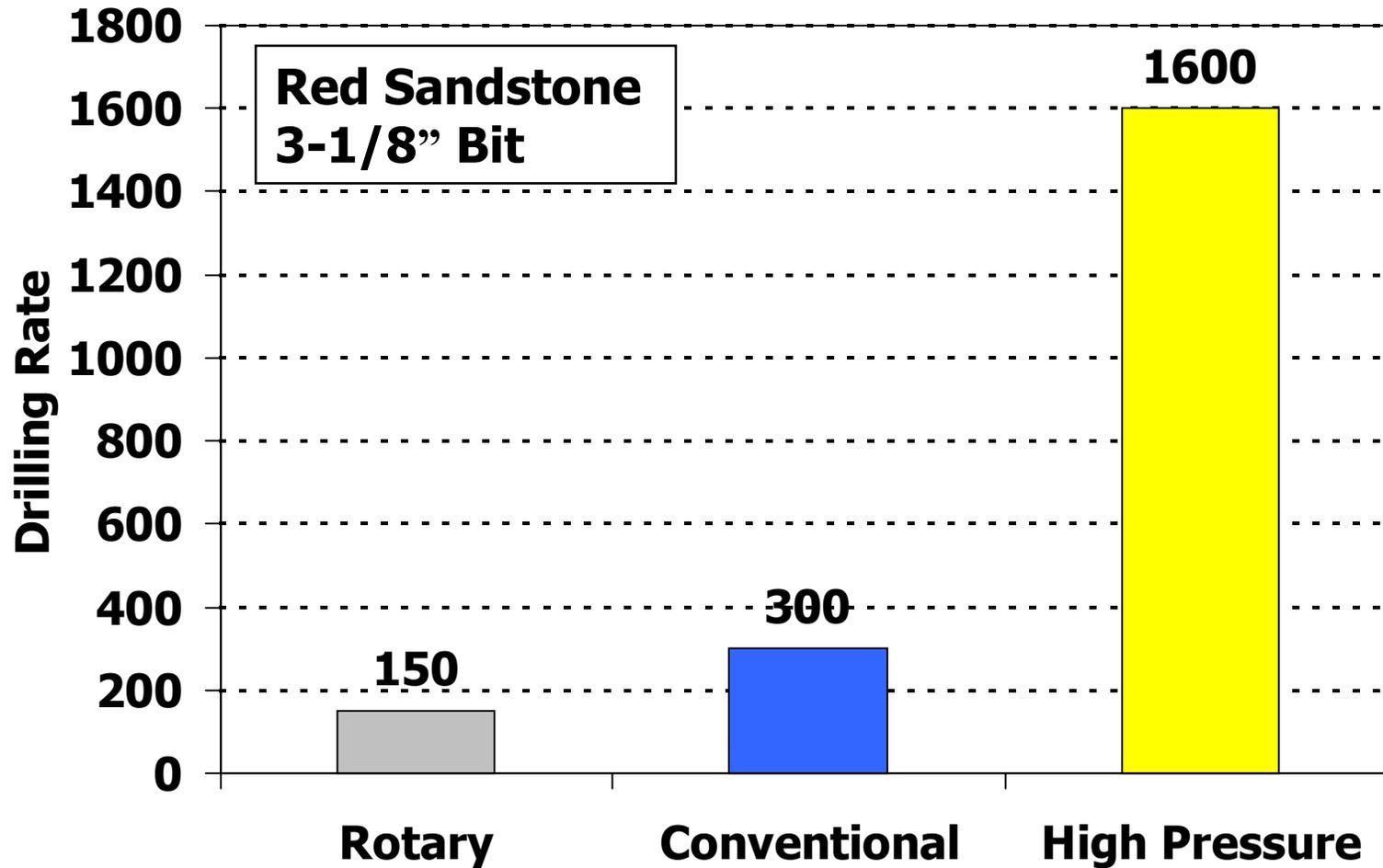
# ***High Pressure Motor***

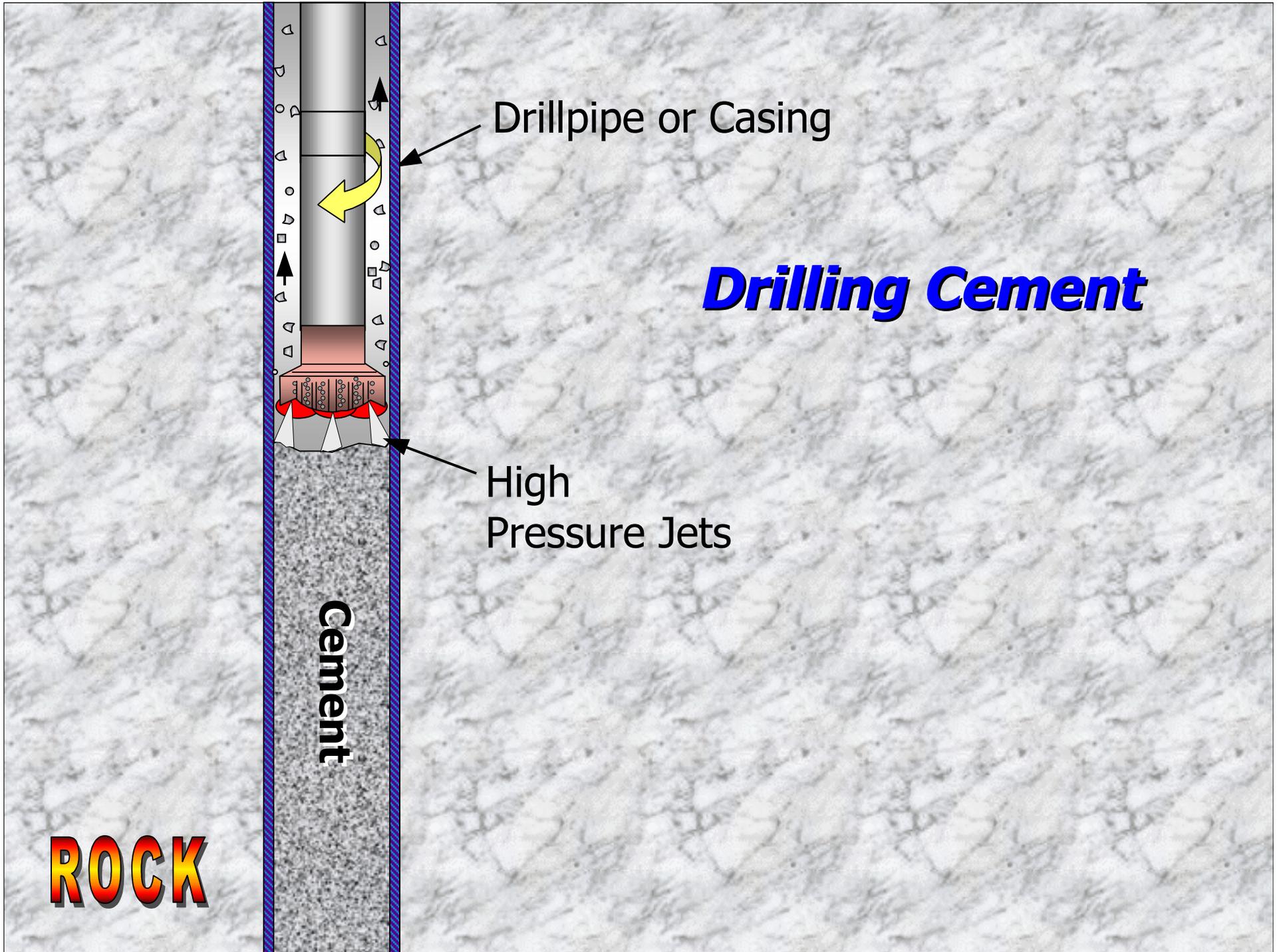
**10,000 psi**





# ***CT High Pressure Jet Drilling Rate***





Drillpipe or Casing

**Drilling Cement**

High Pressure Jets

Cement

**ROCK**

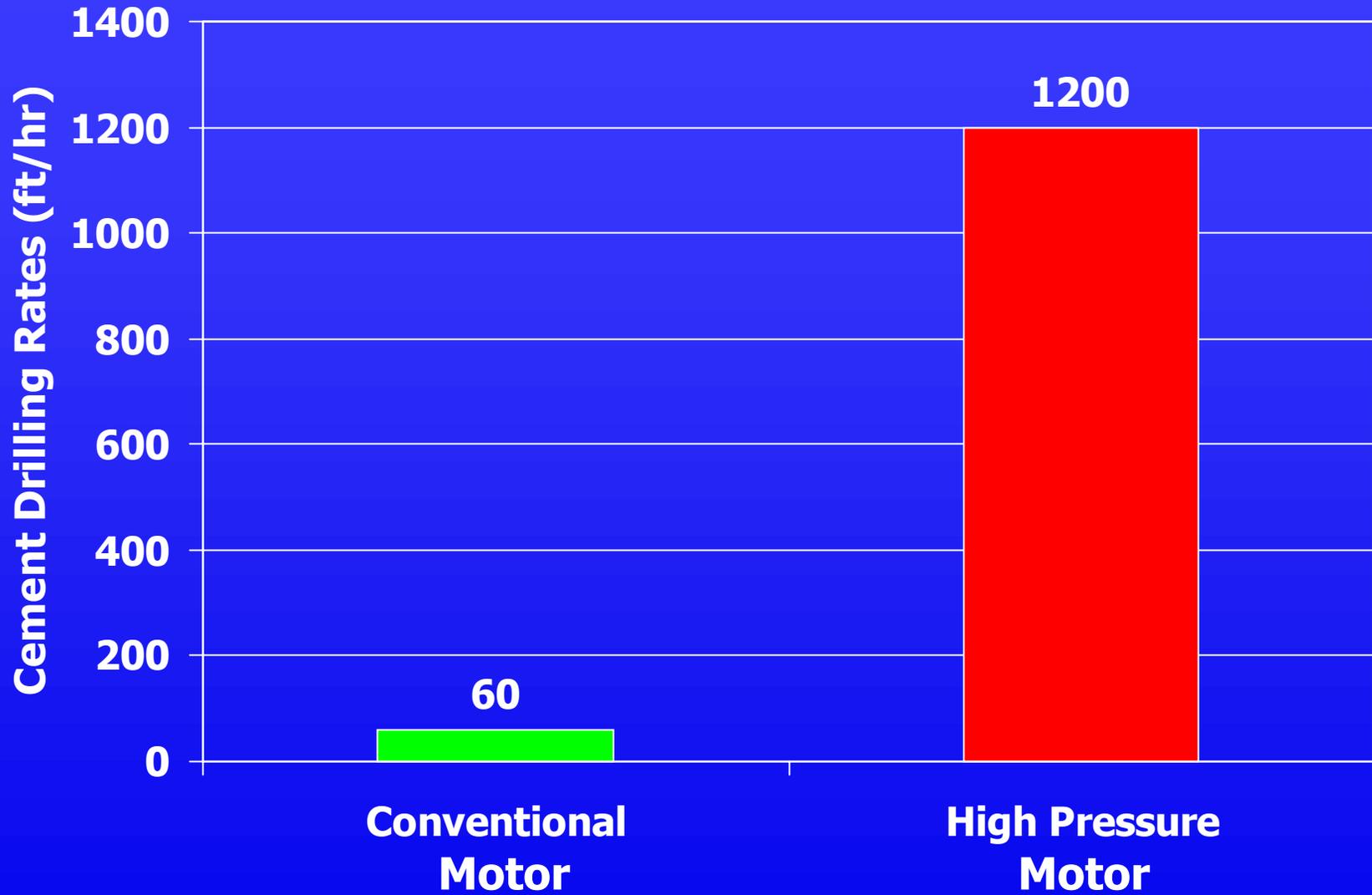
***Tubing Filled With Cement***



# ***Tubing After Drilling Cement***



# ***Cement Drilling Rates***



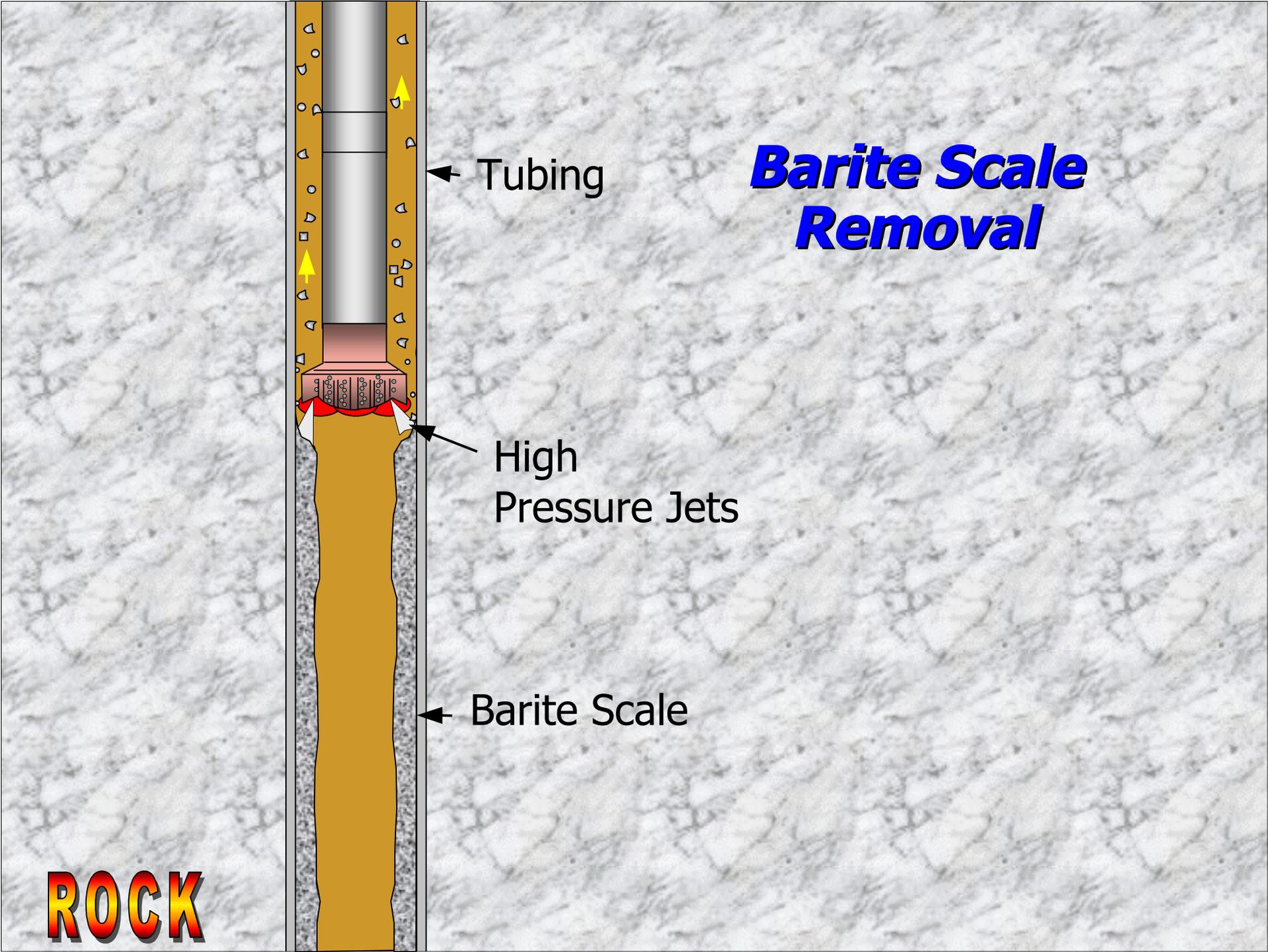
# ***Barite Scale Removal***

← Tubing

High Pressure Jets

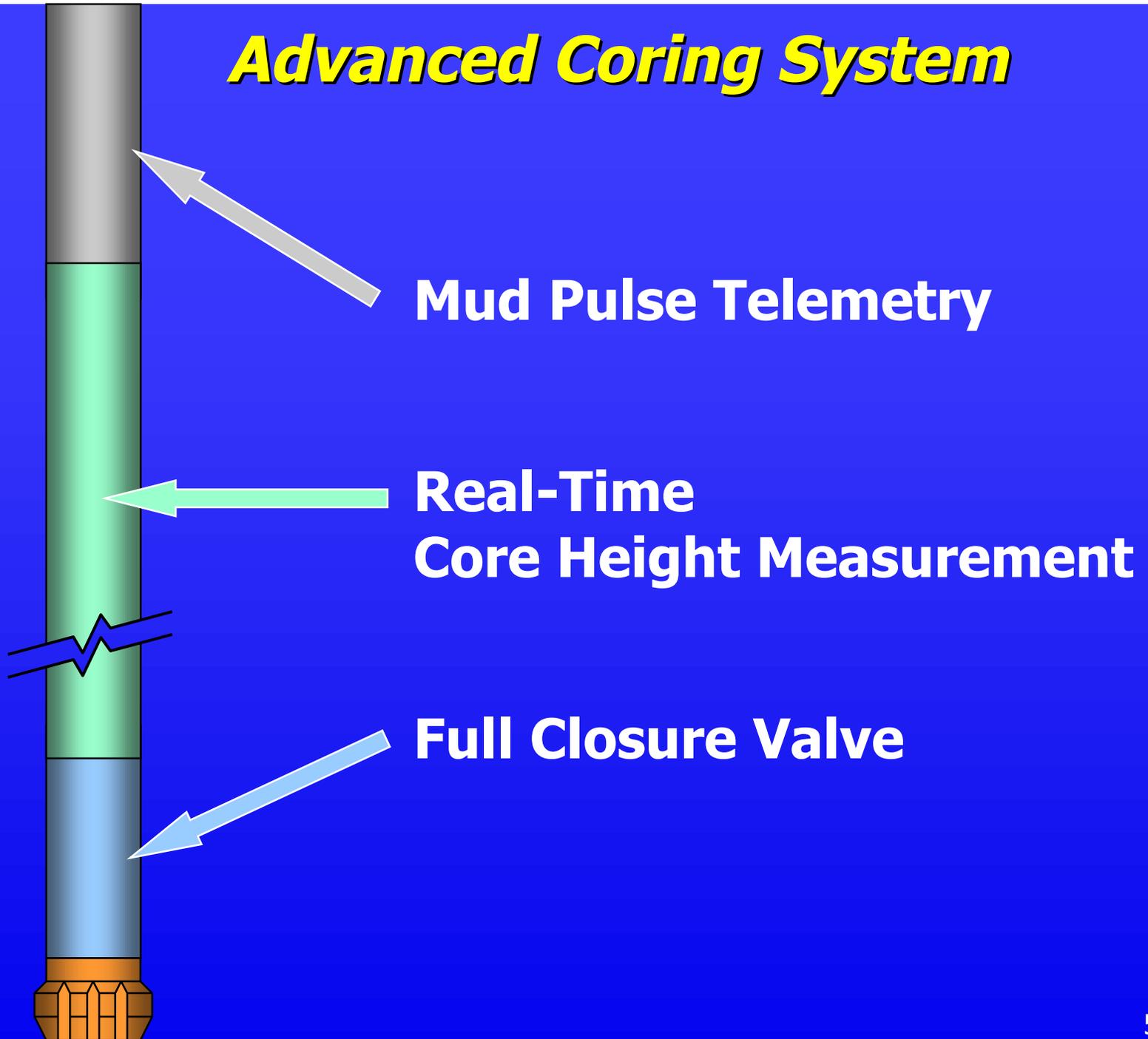
← Barite Scale

**ROCK**

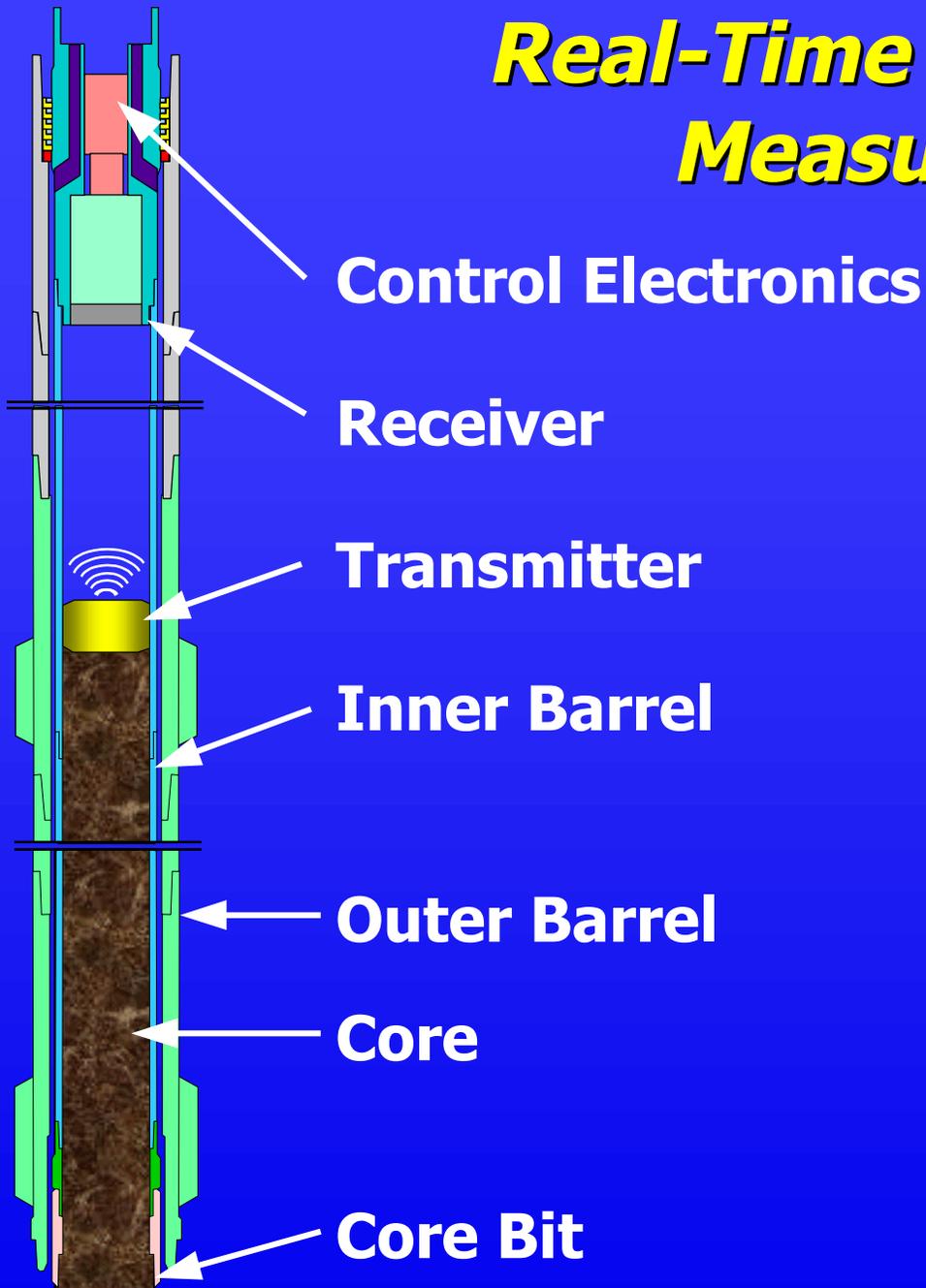


# ***Advanced Coring System***

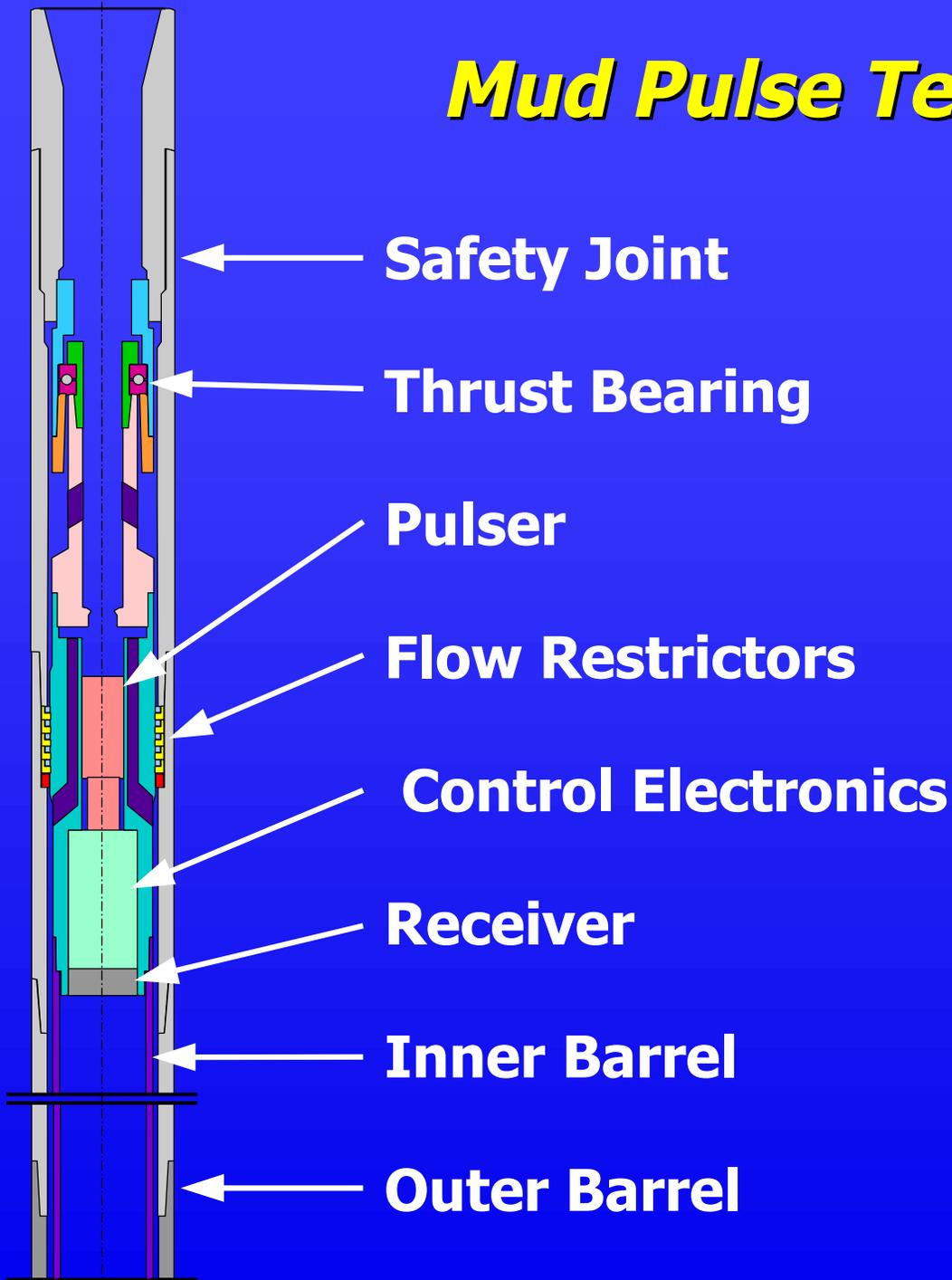
# ***Advanced Coring System***



# ***Real-Time Core Height Measurement***



# ***Mud Pulse Telemetry***



*The End*