Rock Drill Oil Principles and Additive Packages

Functional Products Inc.

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Overview

- Rock Drill
  - Functional's position in the market
  - What is a rock drill?
  - What is rock drill oil?
  - Key additives and chemistry
  - Performance parameters
  - Formulation for petroleum and biobased

Functional Products

- Functional Products specializes in additive chemistry for lubricants that are tacky, high viscosity, corrosion-resistant, industrial, and optionally biobased

  - FPI can supply all of the additive chemistry required for rock drill

	Petroleum Rock Drill	Biobased Rock Drill
Base Oil	Paraffinic Gr. I/II	Canola Oil
Thickener	Bright Stock (150BS)	**Functional V-508F** **Functional V-515**
Additive Package	**Functional RD-540** **Functional RD-540CP**	
Pour Point Depressant	**Functional PD-610**	**Functional PD-590**
Tackifier	**Functional V-176**	**Functional V-584**

Rock Drill

- Percussive hammer drilling (rotary + shock) for digging, mining, tunneling
  - Wide range of scale in size and performance of drills
    - Handheld to mobile equipment

Atlas Copco, Surface Drill Rigs, ROC D5 D7 D9 D7LR Technical Specification

Wide Spectrum of RD

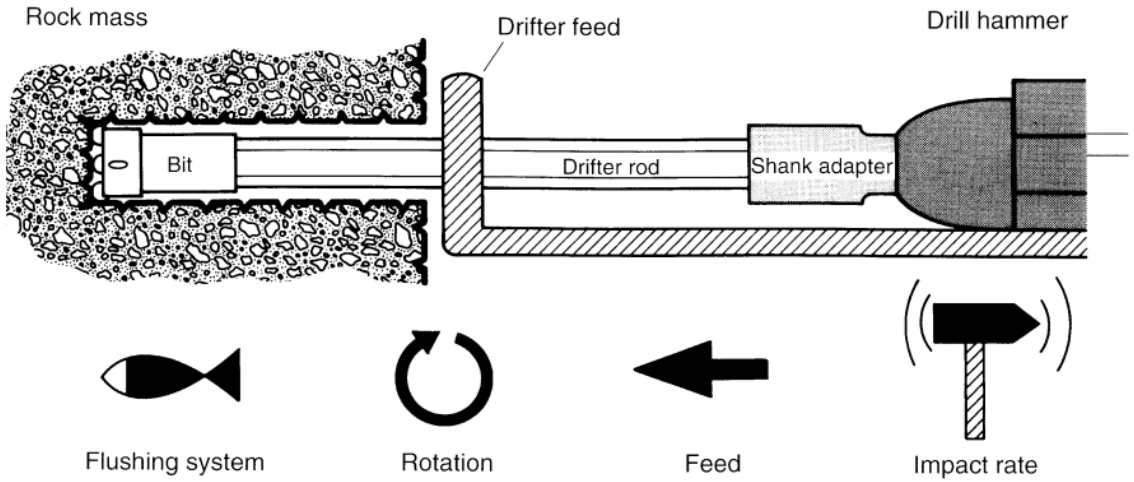
- Handheld operations to mobile drilling equipment
  - Mostly pneumatic with some hydraulic, diesel, or electric

	Handheld	Mobile
Mechanical Power, kW	1.2	20
Weight on Bit, lbs/in. dia.	250	4000
Bit Weight, lbs.	0.5	50
Bit Speed, RPM	100 – 300	20 – 40
Hammer Blows/Min	1500	2500
Air Flow, CFM	1000 - 2000	100 – 300
Air Pressure, PSI	90	20 – 50
Typical Rock Drill ISO VG	46 - 150	150 - 320

Service Offer for Pneumatic Rock Drills, Atlas Copco
Sullivan-Palatek SRD-70 Service Manual
SANDVIK HLX5 Rock Drill, Technical Specification

Rock Drill Operation

- Combination of rotary and hammering
  - Crush, fragment, and strip away rock / concrete / asphalt



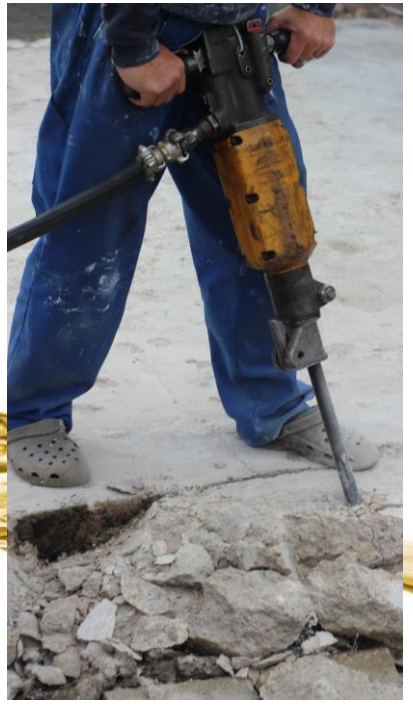
YouTube, 4mile engines

Thuro, K. (1997). *Drillability prediction: geological influences in hard rock drill and blast tunnelling. Geologische Rundschau, 86(2), 426.* doi:10.1007/s005310050151

Other Uses for RD

- Rock drill oil typically used in a range of “lower” intensity applications:
  - Pneumatic hand tools
    - Hammer drill, masonry, impact driver, scaler

  - Construction equipment
    - Jack hammers, rock and pavement breakers
    - Riveters and railroad spike drivers



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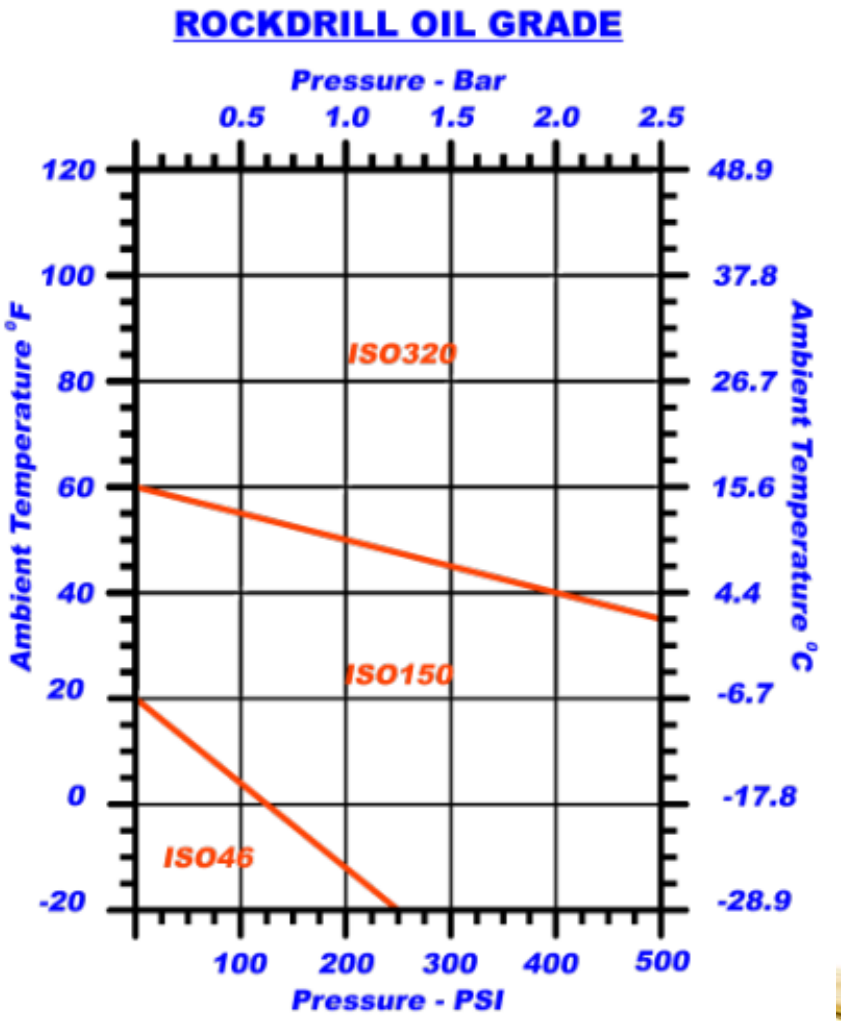
Lubrication

- Lubricant dispersed as oil mist carried by pressurized air via venturi
  - Total loss lubricant
  - 3 pints/hr per 1000 CFM

- ISO VG depends on air psi, temp.
  - ISO 32 to ISO 680
  - Set by equipment maker



Key Features

- Four key features in rock drill oil:
  - Extreme Pressure Protection
  - Tack and Adherence
  - Emulsifier or Demulsifier
  - Ashless Additive Package

Extreme Pressure

- Extreme pressure (EP) or “anti-scuff” protection is key
  - Specifically, shock loading from rotary and percussive loads
    - Sudden and non-constant loads provide a different challenge than heavily loaded but steady moving gear oils
    - EP agent leaves soft, ablative layer to prevent metal-metal contact

- Three test methods
  - 4-ball EP (D2783)
  - Timken OK load (D2782)
  - Falex EP (D3233)

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Adherence

- Tackifier provides stay-in-place behavior
  - Prevents fling-off on high RPM equipment or drippage on low RPM

- Biobased formulations can also gain tack from using moderate amounts of polymeric thickener (Functional V-515 and V-508F)

Misting with Tack?

- Rock drill oils must be tacky but also mist
  - Tackifiers are known to provide an anti-mist effect

- Tackifiers reduce but do not eliminate misting by 50 – 70%
  - Increases droplet size and reduces oil consumption
  - Oil mist and fog control in the drill is important
    - Mist + low flashpoint + heat can ignite oil inside the drill (“dieseling”)

Emulsifying or Not

- Two major options in Functional rock drill package
  - Functional RD-540 – emulsifying rock drill package (2.2wt%)
  - Functional RD-540CP – demulsifying rock drill package (2.4wt%)

- Of 13 major brands, six advertise emulsifying rock drill
  - Mobil Almo
  - Shell Torcula
  - Petrocanada Ardee
  - Valvoline Rock Drill
  - Royal Rock Drill
  - D-A Rock Drill

Note: *"CP" is an old designator, doesn't mean chlorinated paraffin*

Ashless?

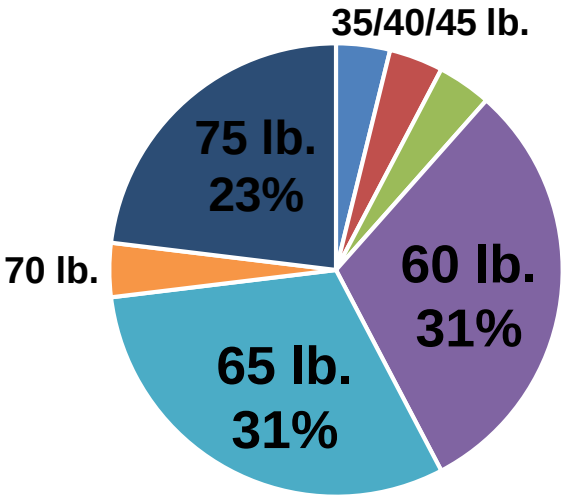
- Functional RD-540/540CP products are metal-free and **ashless**
  - No zinc (Zn), tin (Sn), molybdenum (Mb), or antimony (Sb)
    - Instead use sulfur-phosphorus chemistry
  - Called “ashless” at < 0.01wt% residual ash from Ca/Si/Na

- Advantages:
  - Greatly improved personal and environmental safety
    - No heavy metal contamination
  - Greater stability in humid environments
    - Metal complexes form insoluble deposits when exposed to water, air
      - $M^+ R_2^- + 2H_2O \rightarrow M(OH)_2 + 2RH$

Performance Metrics (1/2)

81 oils – 26% report 4-Ball EP, 47% report Timken, 30% report Falex

- 4-Ball Extreme Pressure (D2783) – 200-250 kg weld load typical
- Timken OK Load (D2782) – 60-65 lbs. typical



- Falex Failure Load (D3233) – 2200-7500 lb.
  - Highly varied in commercial examples

Performance Metrics (2/2)

- Water separability (D1401)
  - Ideally, close to 40/40/0 for demulsifying and 0/0/80 for emulsifying

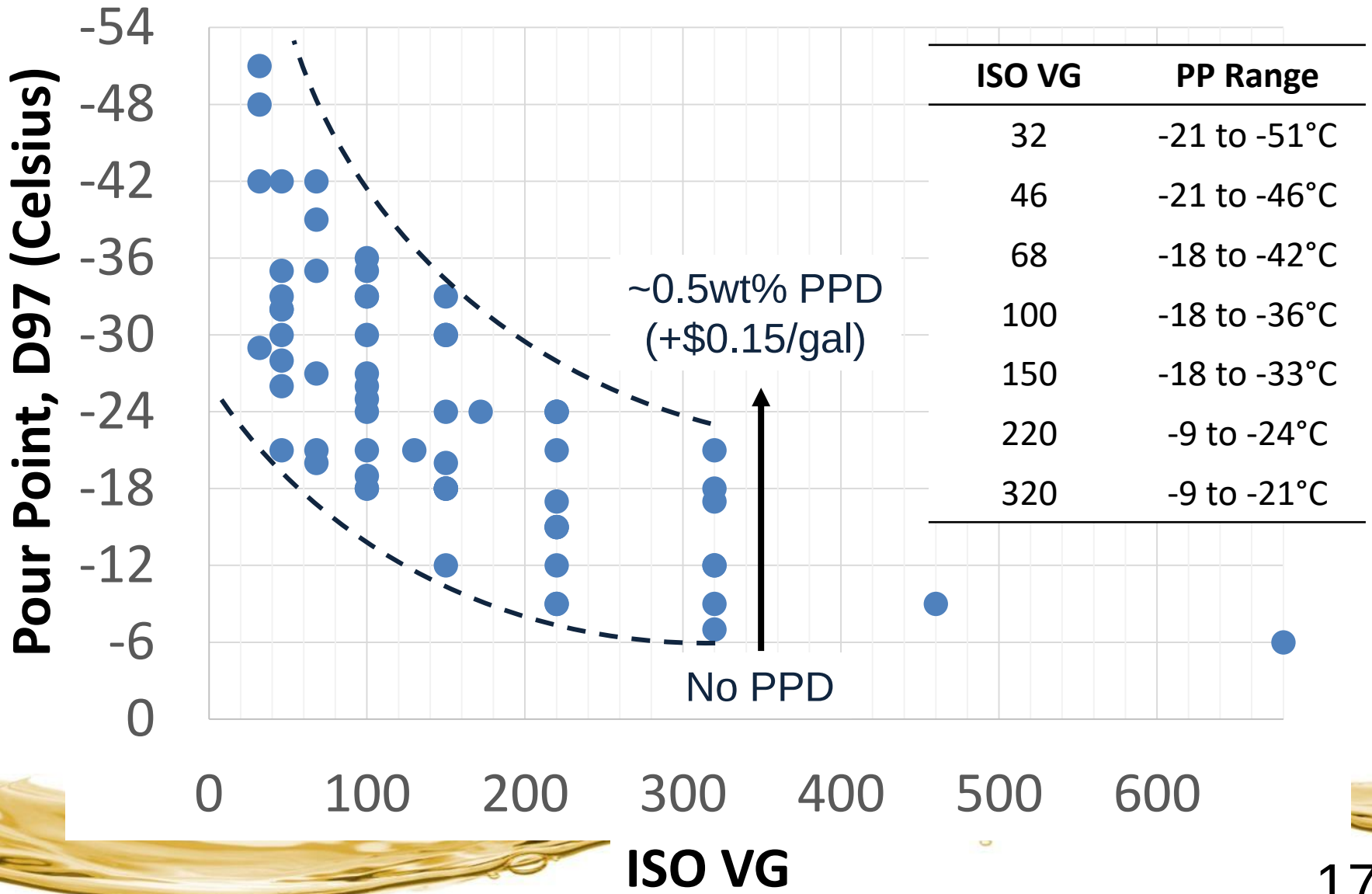
- Corrosion
  - Ferrous/rust (D665A, distilled water) – Pass

  - Copper corrosion (D130) – Pass
    - Some copper bushings in the equipment construction

- Pour point
  - Big question for formulators
  - Service temperature of monogrades is narrowly defined by ISO VG

Pour Point

- Mostly paraffinic monogrades (86% of products report PP)



ISO VG	PP Range
32	-21 to -51°C
46	-21 to -46°C
68	-18 to -42°C
100	-18 to -36°C
150	-18 to -33°C
220	-9 to -24°C
320	-9 to -21°C

Operating T vs. VG

- How low of a PP do you need?
  - Look at typical operating temperature ranges for the ISO VG

ISO VG	Typical Operating Temperature
32	-33 to -12°C
46	-29 to 4°C
68	-21 to -1°C
100	4 to 27°C
150	>24°C
220 - 1000	> 27°C

Typical Treat of PPD

- Functional PD-610 for Group I/II + BS blends
  - *Do you really need a PP lower than your operating temperature?*

wt% PD-610	PP in ISO 32	PP in ISO 150
0.0%	-18°C	-18°C
0.05%	-33°C	--
0.1%	-39°C	-21°C
0.2%	-42°C	-24°C
0.3%	-48°C	-30°C
0.5%	--	-33°C

- For biobased:

wt% PD-585	Pour Point, D97 Canola	Soybean
0.0%	-24C	-12C
0.5%	-33C	-21C
1.0%	-36C	-24C

Rock Drill Formulating

- ISO 32 – 680 grades, very diverse
  - Lube companies generally making paraffinic monograde (VI 90 – 110)
    - Equipment makers offering private labeled biobased

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ISO 6743 Standard

- Quality levels scaling based on use of additives
  - Low to high/extended loads and service life
  - RD-540 and RD-540CP suitable for PAC/PAD and PBC/PBD lubes

Application	Class	Requirement	Functional Additive
Percussive Pneumatic Tools	**PAA**	Straight Oil	--
	PAB	+ Anti-Corrosion + Anti-Wear	CI-426, CI-426EP, SGP-563
	PAC	+ Emulsifiers + Foam Inhibitors	**RD-540, RD-540CP**
	PAD	+ Synthetic Base Fluid	--
Rotary Pneumatic and Air Tools	**PBA**	Straight Oil	--
	PBB	+ Anti-Corrosion	CI-426
	PBC	+ Anti-Wear + Emulsifiers + Defoamer	**RD-540, RD-540CP**
	PBD	+ Synthetic Base Fluid	--

Petroleum Rock Drill

	ISO 150 Emulsifying	ISO 150 Demulsifying
ISO 32 Gr. I/II	55.3%	55.2%
150 Bright Stock	40.5%	40.4%
Functional RD-540	2.2%	
Functional RD-540CP		2.4%
Functional V-178	2.0%	2.0%
Pour Point (D97)	-18°C	-18°C
4-Ball EP Weld Load (D2783)	315	250

Optional ways to differentiate:

- 0.1% to 0.5% Functional PD-610 will reduce pour point (slide 17)
- 1wt% Functional GA-614 industrial gear top treat for 400 kg weld load

Biobased Rock Drill

- Simple, high performance formulations using V-515 as thickener/tackifier

	ISO 100 Bio Emulsifying	ISO 150 Bio Emulsifying	ISO 220 Bio Emulsifying
Canola Oil	86.9%	82.4%	78.1%
Functional V-515	10.9%	15.4%	19.7%
Functional RD-540	2.2%	2.2%	2.2%
Viscosity Index	248	251	261
Pour Point (D97)	-24°C	-24°C	-24°C
Water Separability (D1401)	5/25/50	6/25/49	3/26/51
Flash Point (D92, COC)	240°C	245°C	248°C
Load Wear Index (D2783)	53	54	51
4-Ball EP Weld Load (D2783)	315	315	315
Falex EP Load (D3223)	4502	4534	4549
Timken OK Load (D2782)	70	70	70
FZG Load Stage	>12	>12	>12

Biobased Advantages

- High flashpoints and less opportunity for “dieseling” or combustion of mist
  - Heavy Gr. II paraffinic f.p. is 260-300°C
  - Veg oil f.p. is 320-350°C

- Good inherent lubricity and emulsibility
  - May increase EP by one level (200 → 250 → 315 → 400) vs. petroleum

- Readily biodegradable, low toxicity, no oil sheen

- High VI (200+) for wider operating temp. range
  - Low starting PP: -27°C for canola w/o PPD
  - Customer can consolidate several grades into one

Biobased Options

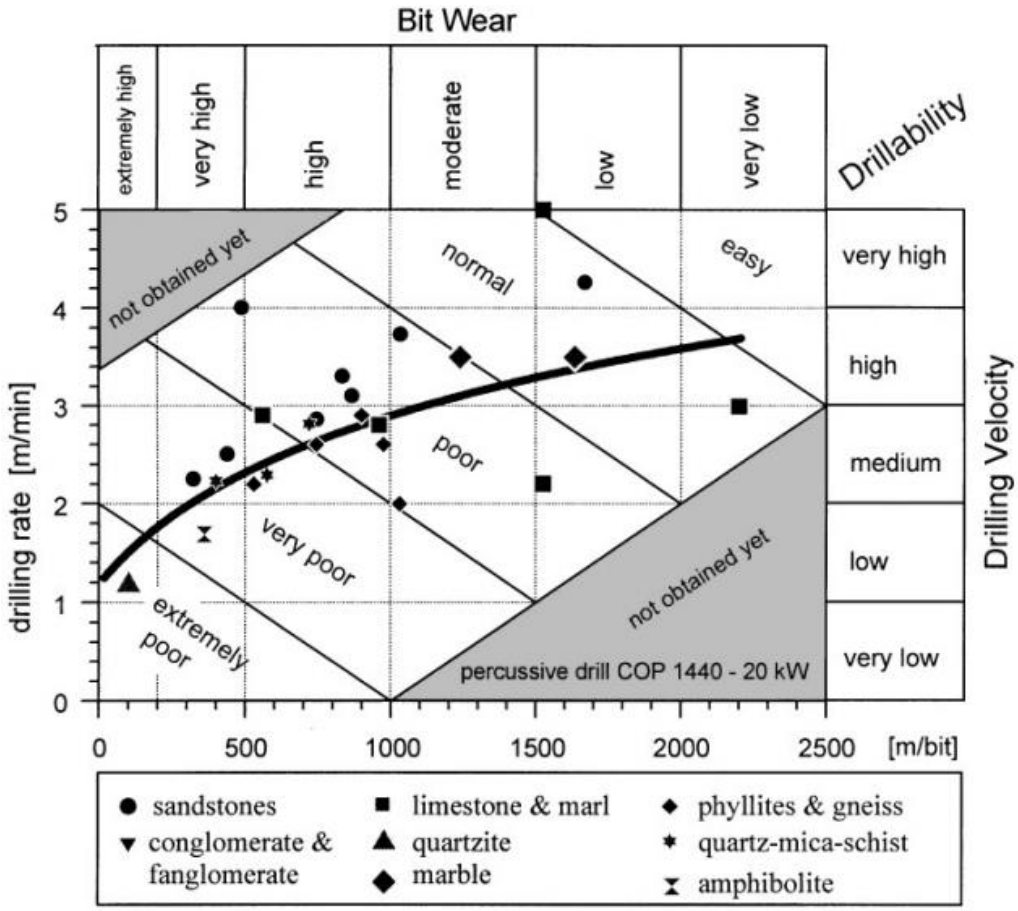
- Which biobased VM? V-515 vs. V-508F?
  - V-515 will offer better tack and low temperature fluidity
  - V-508F is more efficient thickener but will need V-584 tackifier
- Different ester fluids may yield different performance, demulsibility, etc.
  - Able to customize package to optimize for different esters
- Any interest in Ecolabel / EAL rock drill?

Summary

- Functional Products additives for petroleum and biobased rock drill oil
  - RD-540 and RD-540CP emulsifying and demulsifying packages
  - Tackifiers for adherence and mist control
  - Pour point depressants for petroleum and biobased
  - Unique polymeric thickeners and tackifiers for biobased

RD Needs by Rock Type

- Easiest rock to drill
  - Marble and limestone
  - Faster, higher CFM of air
    - Less wear
    - More lubricant used
  - Water or aquifer present
- Hardest rock to drill
  - Quartzite and mica-schist
  - Slower, less CFM of air
    - Less lubricant, more wear
  - More EP and additives



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