Statoil Hard Rock Drilling Experience

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Limited experience

- Most operations in sedimentary formations
  - Relatively soft
  - Hard stringers
  - Section in one run with good progress
- Drilled basalt outside Faroe Islands
- Drilled calcareous sand in Algeria
- Drilled silica cemented sand at Morvin
- Test drilling of basalt on Iceland

Brugdan I 17 ½" basalt drilling data

Run	Type	IADC	Motor	RPM	WOB (tonns)	ROP (m/hr)
1	MX-ST31	115	12 ¾" X-treem	120	30	1,6
2	M57ODCPS	635	Rotary	105	27	1,4

- 1.15 sg KCL mud
- 135 bar hydrostatic pressure at 1200 m TVD.

Algeria

- Erratic performance
- Short runs
- Bit selection based on limited experience

Morvin

- Experienced rapid bit wear and frequent tool failure
- Improvment seen over 4 well campaign
- Not good enough as roundtrip take 2 days

	B-3 H	A-1 H	A-4 H	A-2 H
Number of trips/bit runs*	17	8	12	7
Average run length	76 m	142 m	112 m	178 m
Average ROP**	3,9 m/hr	3,4 m/hr	3,0 m/hr	3,7 m/hr

Bit testing Iceland

17 ½” Drilling Tests Iceland

- 17 ½” HP633 Kymera S/N 7026018:

Depth in	Depth out	Distance	Hrs	ROP
97	270.1	173.1	16	10.82

- Dull grading:
  - PDC 1-0-BT-C-X-0-NO-TD (1 broken cutter in very centre)
  - TCI 0-0-NO-A-E-0-NO-TD

- Almost tripling the ROP compared to offset wells despite controlling ROP to max 15 m/hr due to hole problems.

12 ¼” Drilling Test Iceland

12 ¼” KG533FX Kymera S/N 7027524:

Depth in	Depth out	Distance	Hrs	ROP
270	397	127	5.4	23.5
416	776	360	17.5	20.5

Dull grading:

- PDC 1-3-BT-G-X-I-NO-TD (Chipped PDC cutters on the gauge)
- TCI 1-1-WT-A-E-I-NO-TD

Drilled twice as fast with substantial lower WOB compared to offset wells and observed excellent steerability.

Conclusions, Kamyra Iceland tests

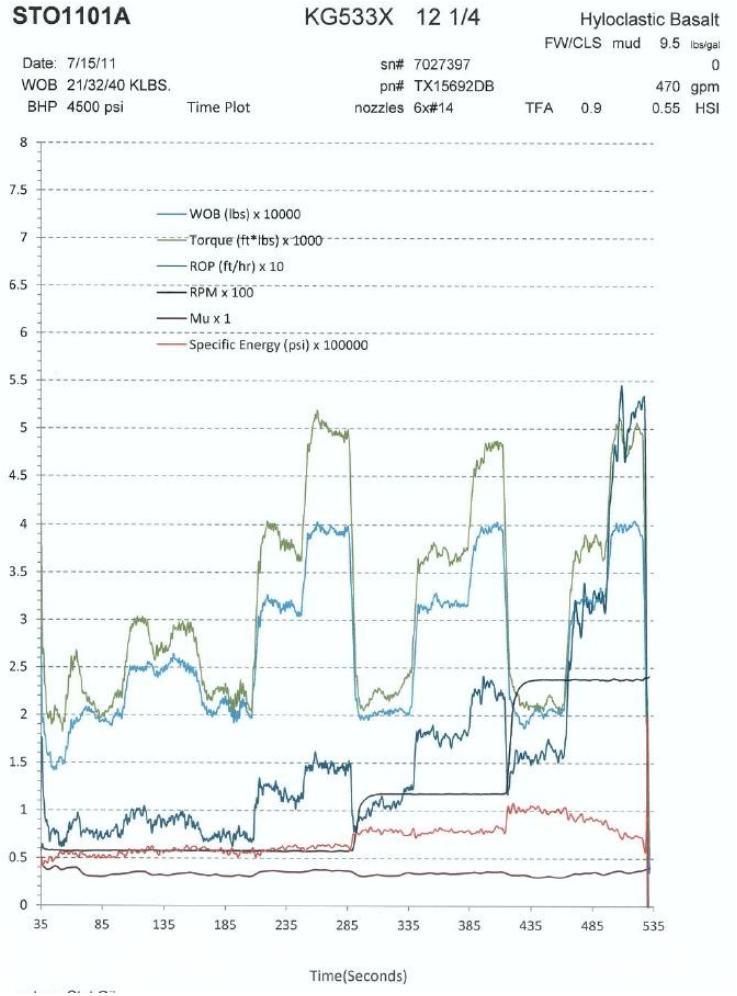
- 100% - 200% improvement in ROP.
  - ROP controlled to max 15 m/hr because of temperature problems.
- Rock types drilled: basaltic Tuff, glassy Basalt, fine medium grained Basalt, medium coarse grained Basalt, basaltic Breccia.
- Icelandic basalt are on the low side in strength.
- No signs of detrimental drilling dynamics.
- Minor wear observed.

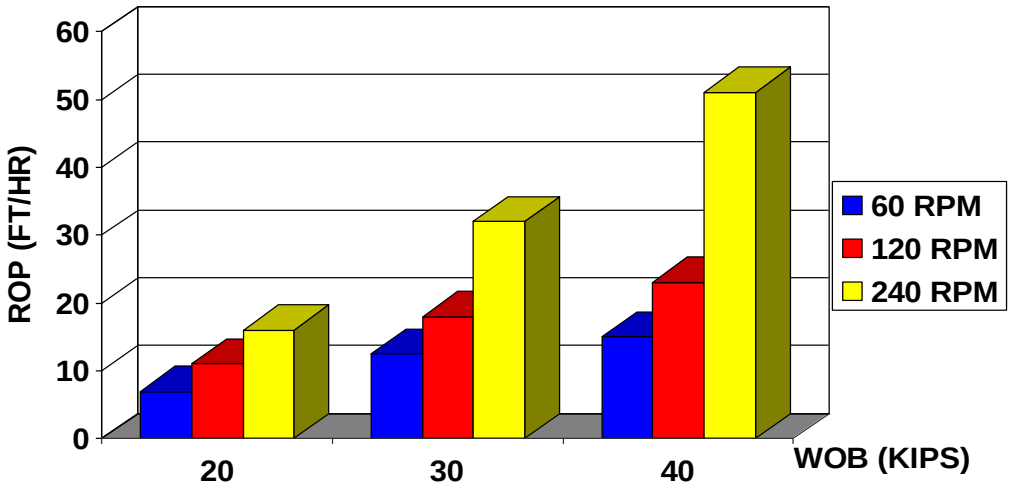
17 ½” SDH616S – Best Estimate

- ROP
  - Brugdan I: 17 ½” TCI, 25m @ 1.6 m/hr
  - PDL test, S / H type: 580 / 780% increase
    - ROP differentiation holds true for pressurized conditions and bit size-up
    - Brugdan I: 17 ½” TCI less aggressive compared to 8 ½” TCI benchmark in PDL testing

→ Brugdan II: 9.3 m/hr in S type basalt

12 ¼” Drilling Test Houston, Results

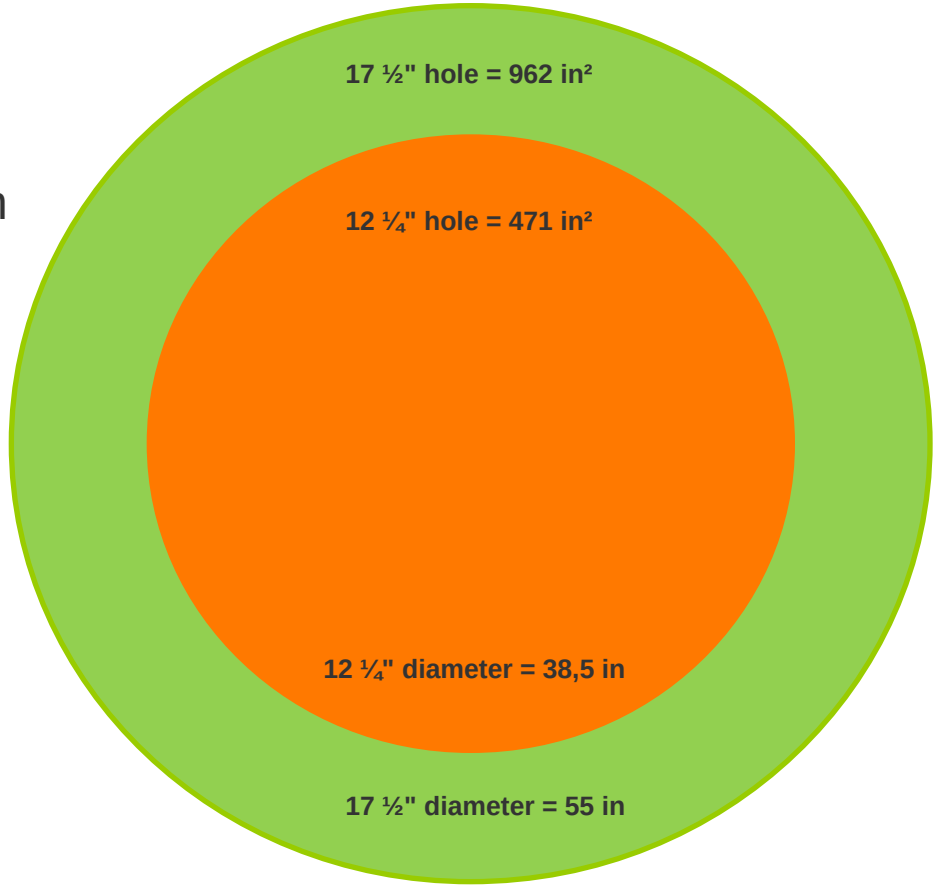




12 ¼" vs. 17 ½” hole

- 17 ½" hole has 100% larger area than 12 ¼" hole.
- 17 ½" bit needs 100% more WOB than 12 ¼" bit to get the same WOB / area.

- 17 ½” hole has 43% larger circumference than 12 ¼” hole.
- 17 ½” radial speed are 43% higher than 12 ¼” at same RPM.



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Conclusions and Need

- We can increase penetration rate by several 100 % using latest bit technology
  - From 2 m/hr to 10 m/hr ?
- Need to look at well design to reduce hole sizes through hard formation
- Drilling practice and parameters important to improve progress and run length

- Still exposed to short runs and limited ROP
- **Not sufficient with operational rates of 800.000 dollar per day**

- Improvement to existing technology is only giving marginal improvement.
- **Need new technology**

There's never been a better time for good ideas

- Electropulse drilling
- Jet assisted drilling
- Particle impact drilling
- Hammer drilling
- Heat spallation
- Laser drilling

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