Charge testing for frac operations optimisation

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Restricted

Content

- Case for charge testing
- DoP / EH framing
- Test set-up / test conditions
- Charge test results
- Impact test results on operational decisions

Case for charge testing for fraccing operations

- Re-vitalised MHF (massive hydraulic fracturing) in NL/Southern UK sector, no operations since end ‘90’s/early 20’s.
- No of jobs offshore, rig- & stimulation vessel assisted, high cost environment. Typical (indicative) cost levels:
  - rig rate (spread):
  - Stimulation vessel:
  - Single frac operation, typ
  - Multiple frac operation ➔

High cost / exposure environmnent

With logistical issues

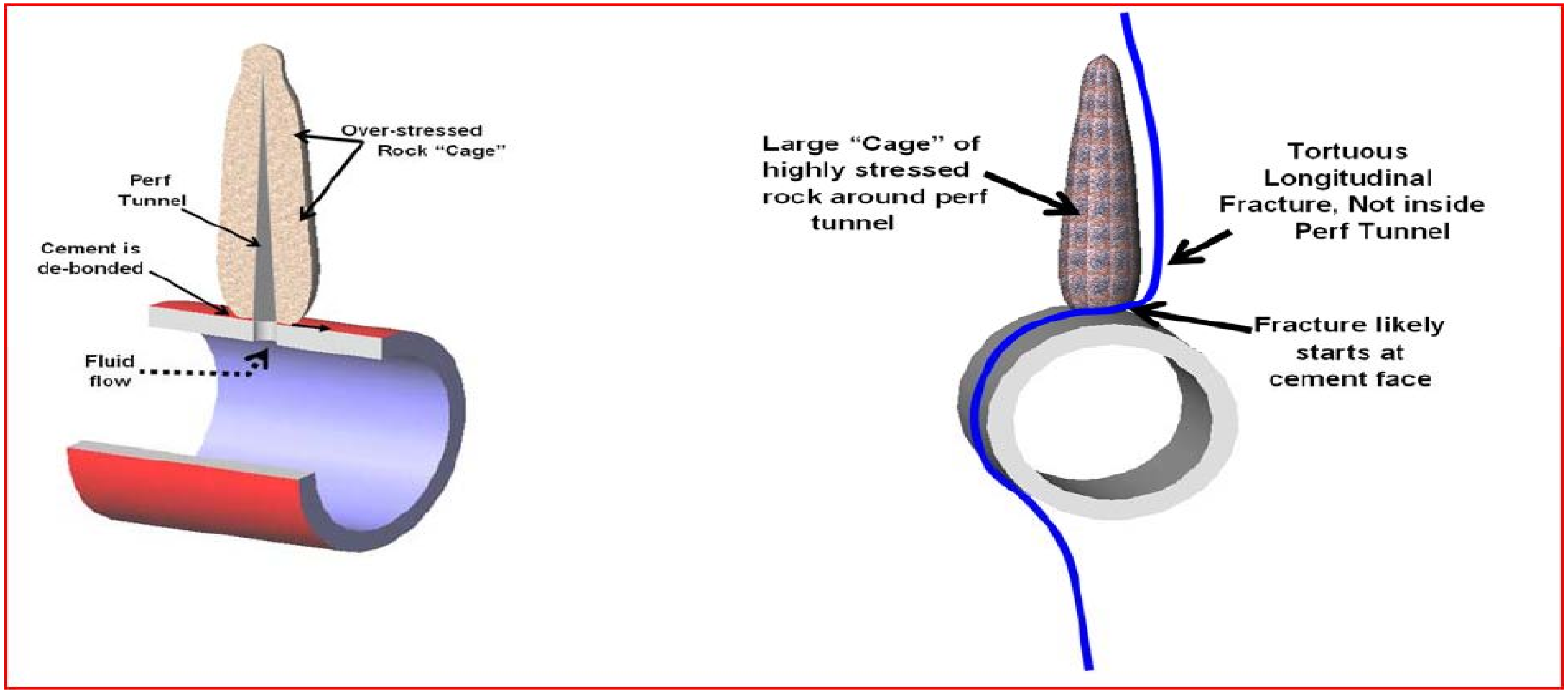
- New wells to be fracced
  - 3 ½” cemented completions
  - E-line perforating vs CT jetting
- Additional operational “boundary conditions”
  - Rig logistics

➔ Optimise operations wherever possible !!

Limited deck space / small footprint with difficult logistical issues

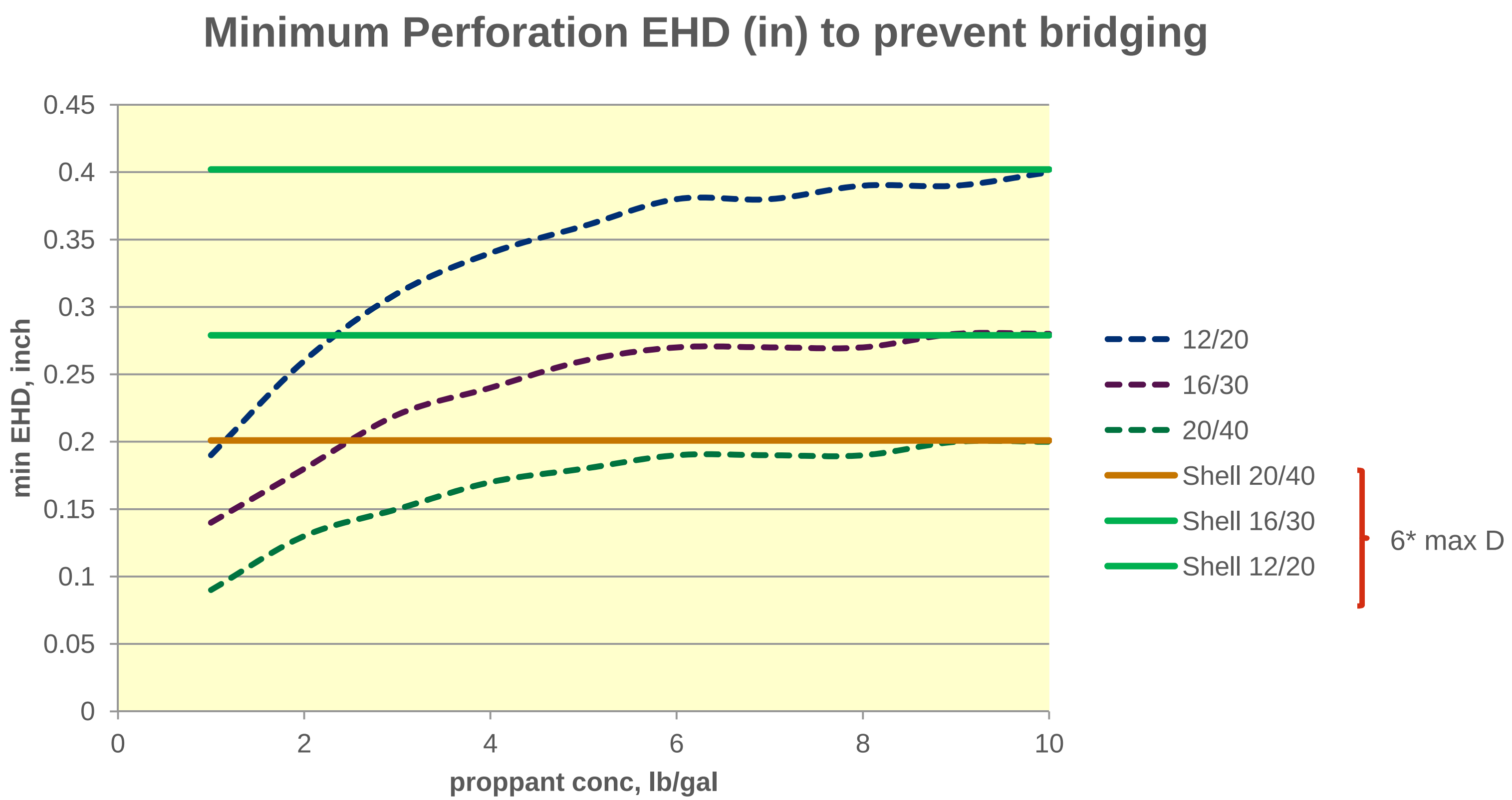
DoP / EH framing : perforating criteria / limitations

- In moderate hard or hard formations, shape charges create a radial, high-stress zone of damage (the “stress-cage”) around the perforation tunnel . Less penetration (BH charges) will result in a large stress-cage diameter. DP charges also create a stress-cage. However, as the gun energy is divided over a longer tunnel, the resulting diameter of the stress cage is much smaller zone. Local de-bonding of cement around perforation could also result that hydraulic fracture will form. Optimal connection to reservoir will reduce/eliminate



Some criteria for optimum reservoir connection

- Minimum EHD criteria: fixed 6 * max D / 7 * avg D (used in Shell / Industry) or variable pending proppant concentration

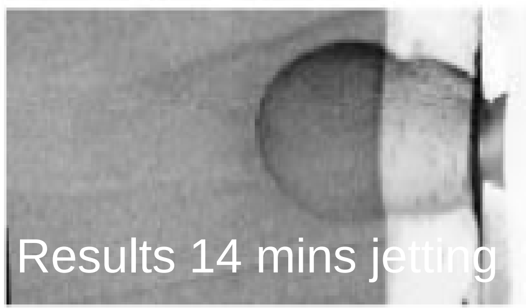


- No fixed / established criteria for DoP
  - Reduce or preferably eliminate crushed zone

Jetting

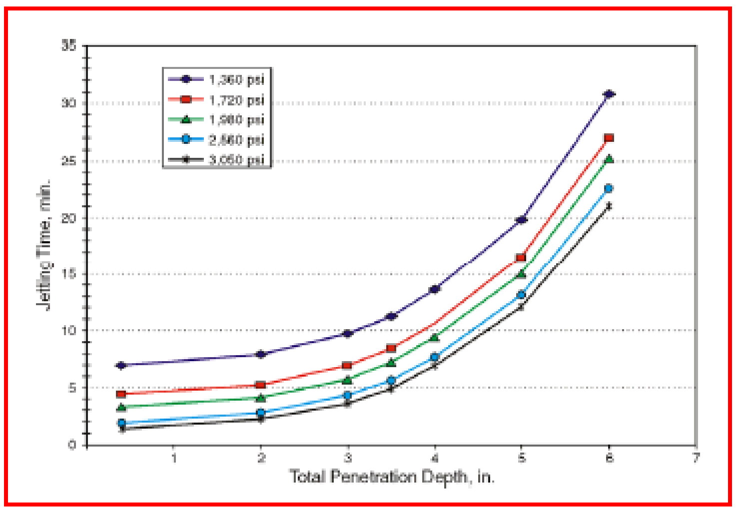
- Primary feature: undamaged, non-stressed perf tunnel

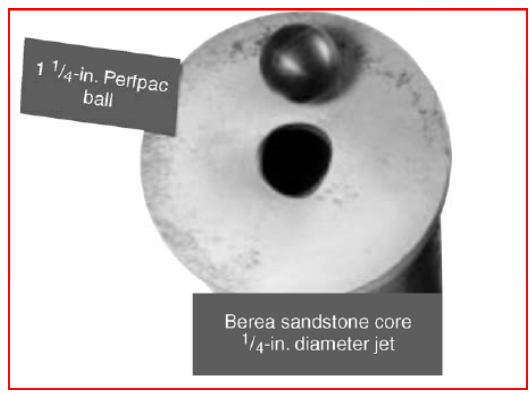
Hydra-Jet perforation with no crushed zone around tunnel



Typical jetting design parameters

- fluid with 100 mesh sand pumped down 2 3/8"CT, 3 nozzles, 120 deg phasing, pumprate 300ltr/min, abrasive slurry contains 1 ppa sand in 20cp gel.





Courtesy

Halliburton,

SPE105064

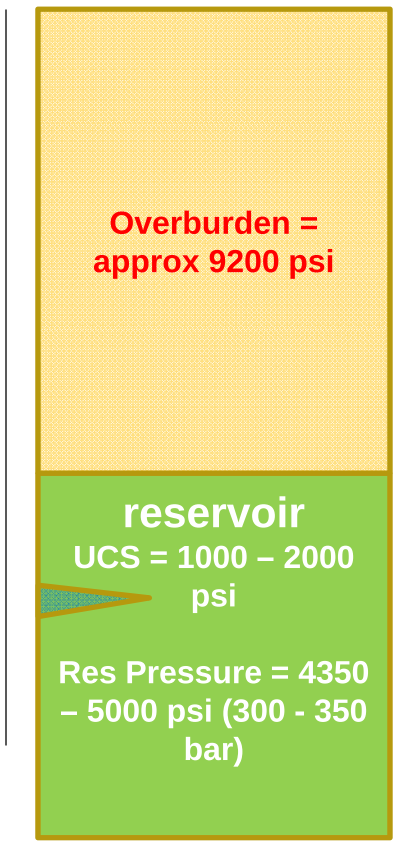
Some criteria for optimum reservoir connection (literature etc)

- Requirements for fraccing – length / type of perforations or entrance holes
- Rules of thumb prevail – “to be placed where they are needed most”
  - Vertical wells
    - < 15 degrees → perforate 15 – 25 m
    - > 15 degrees → 1 – 3 m
    - perforate short interval at the top of the zone only in order to minimise chance of fraccing into the water leg (worse for depleted wells)
    - Some extremes : 70 – 100 shots / interval (no interval thickness specified – SPE 38630) versus 1 shot every 6 feet
    - Phasing 60 deg
  - Horizontal wells
    - Transverse fracs → 0.5 m
    - Longitudinal frac → 1 – 3 m
    - No of perforations to be limited to reduce multiple fractures, 12 – 15 would suffice (2spf)?.
    - Phasing 60 – 120 deg

Test set-up / test conditions

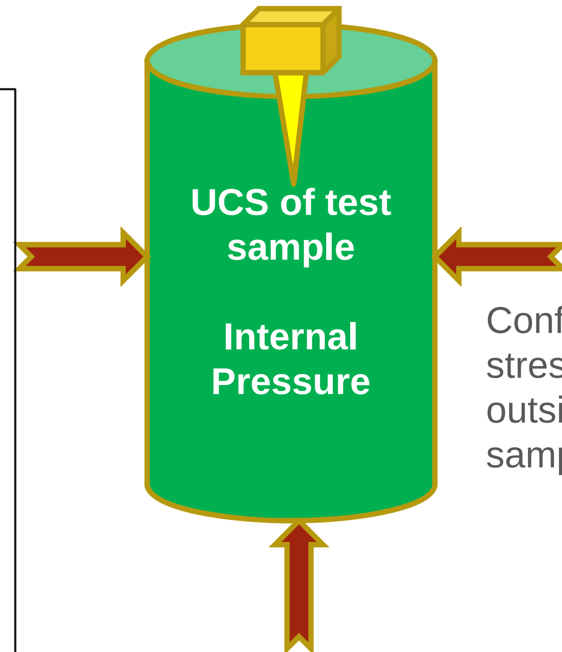
Field conditions

Charge testing conditions in lab

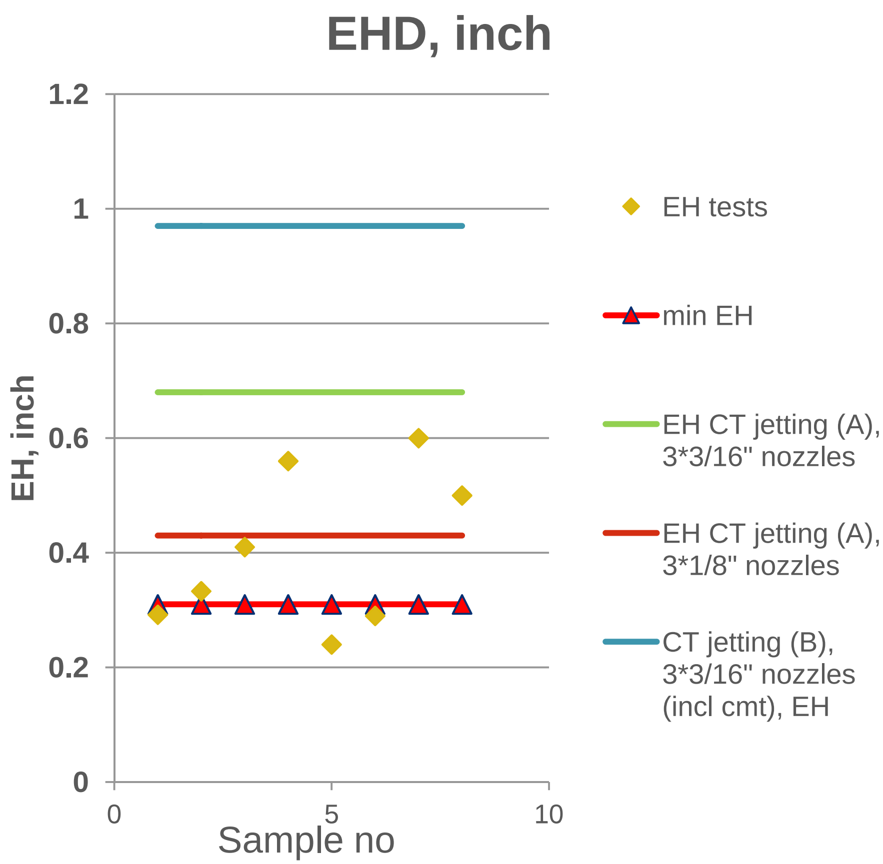


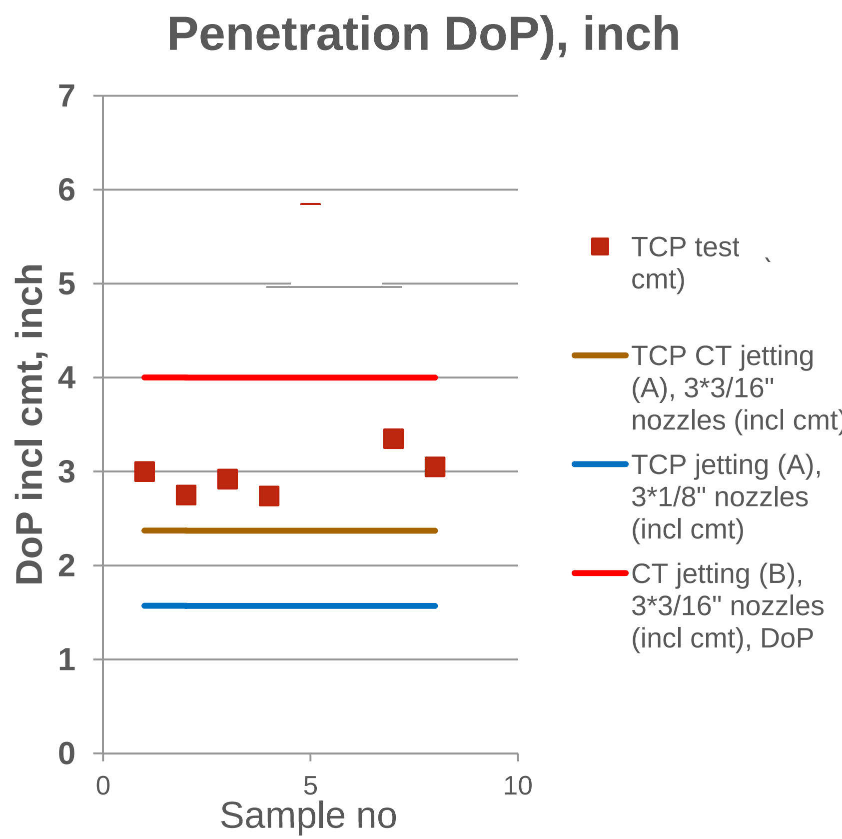
In order to mimic field conditions as good as possible selected the following parameters:

- Carbon Tan material (sandstone)
- internal / confining stress
- Section 2 only, no flow conditions
- Representative tbg (3 ½”) and 6” OH = “worst” condition



Results charge testing





- Carried out some 8 tests (3 labs, test data randomly plotted !!)
- Tests in 7” and 4” Carbon Tan cores, both centralised / excentralised.

Impact test results on operational decisions

- Test results
  - Pre-frac options: no showstoppers for either jetting or perforating
  - Other factors drive operational decisions
    - Jetting: clearance 1 ¾” CT in 3 ½” tubing.
    - Other operations prior to fraccing:
      - logging, bridge plug setting, sand clean-out to required depth for next frac etc etc.
  - Current proposal
    - E-line perforating of bottom zones / set plugs
    - After 1st frac: CT clean-up / jetting subsequent zones
    - ➔ testing potentially saved significamt $$’s by optimising rig ups/downs