Multi-Stage Hydraulic Fracturing in TNK-BP

Technologies: Advantages & Disadvantages

TNK-BP, Branch "Upstream Peer Review and Technical Development Center"

Oil Recovery Enhancement Design & Engineering Group

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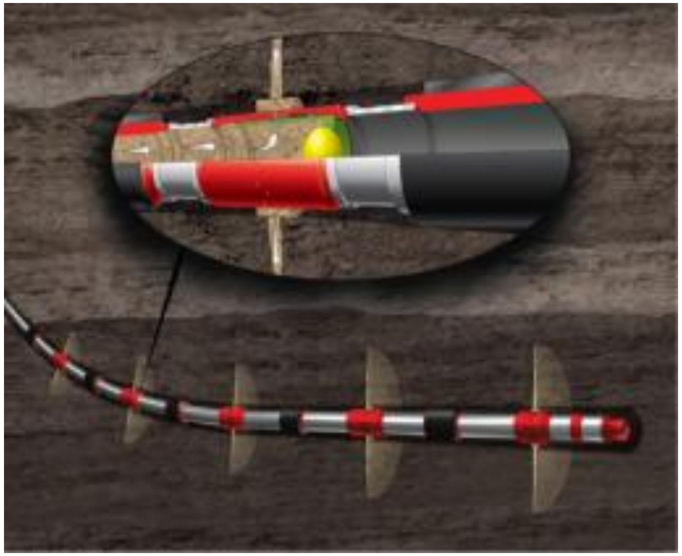
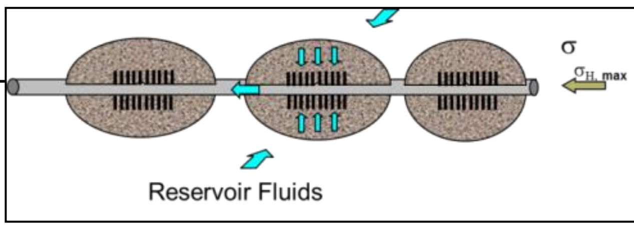
Multi-stage Frac

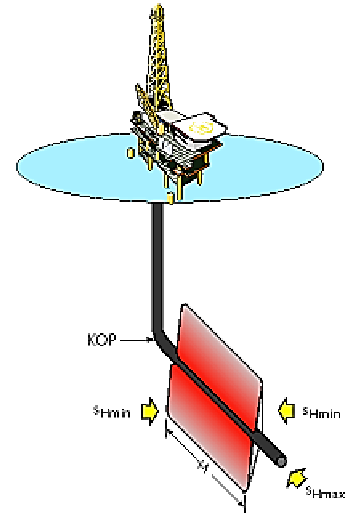
- Multi-stage frac is a serial frac jobs in the same well.
- Goal – well productivity improvement, drainage area increase, improvement of hydrocarbons recovery efficiency and field development economic efficiency



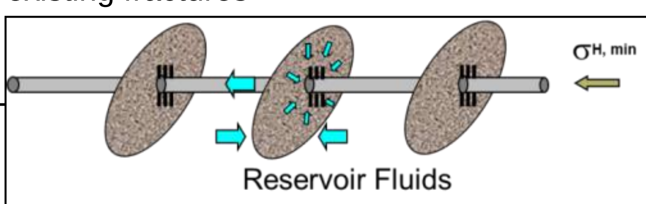
LONGITUDINAL FRACTURES

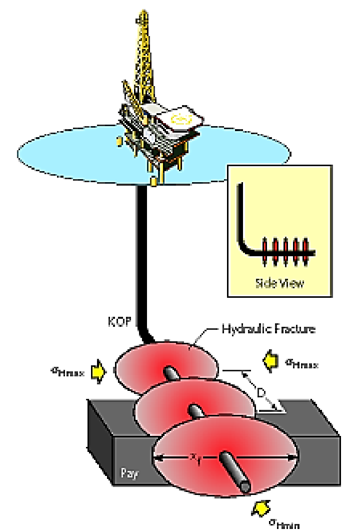
Advantages:	Disadvantages:
better cleaning from gel after frac; can propagate all along the wellbore length; similar to hydraulic fractures in vertical wells; Less pressures for hydraulic fracture initiation and propagation	Good-quality study of “stresses direction in the formation matrix” is necessary; Cover less reservoir space than transversal fractures; Less productivity of longitudinal fractures as compared to transversal fractures in low-permeable reservoirs.



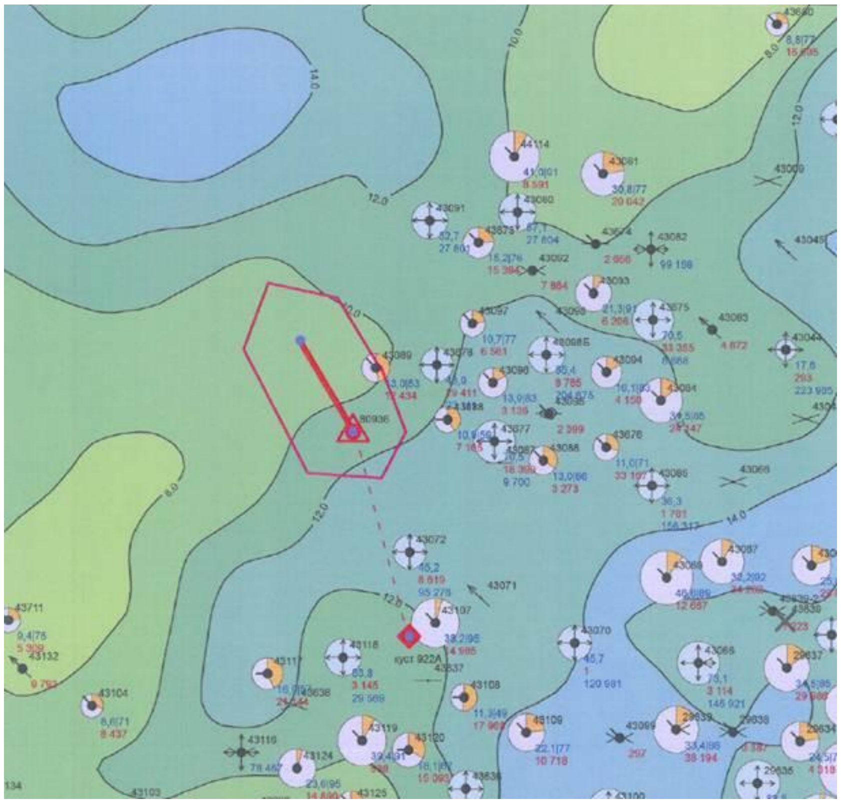


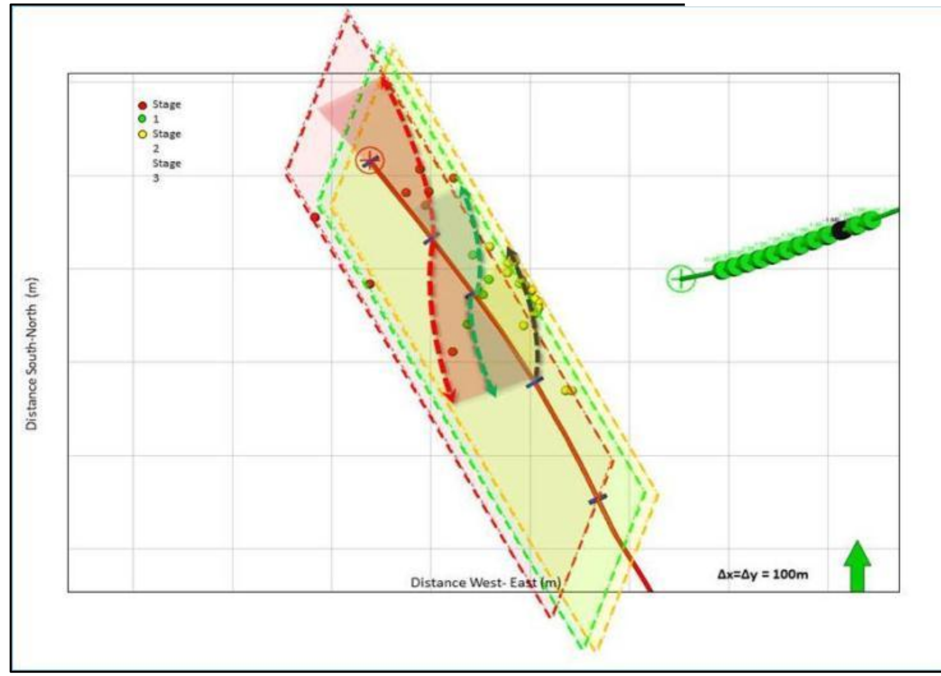
Advantages:	**Disadvantages:**
Cover more reservoir volume than longitudinal fractures; Preferable for low-permeable reservoirs; Small-sized fractures can be created, preventing breakthrough into the upper and lower intervals Additional fractures can be created between existing fractures	Transversal fractures are more “complex” in creation; Higher pressures of fracture initiation and propagation; Cleaning the fractures can be problematic; Influx choking («throating») along the fracture in the near-wellbore zone

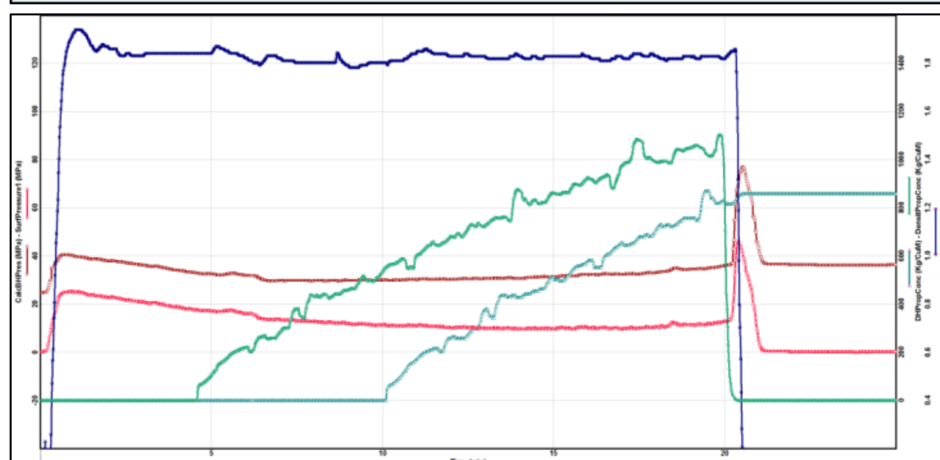




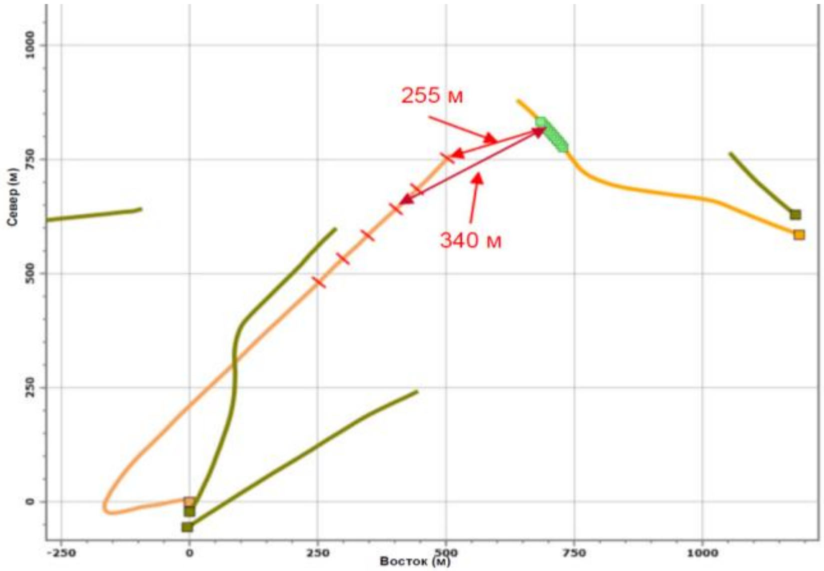
Microseismic:
Samotlor, well 80936/922, AV 1(1-2)

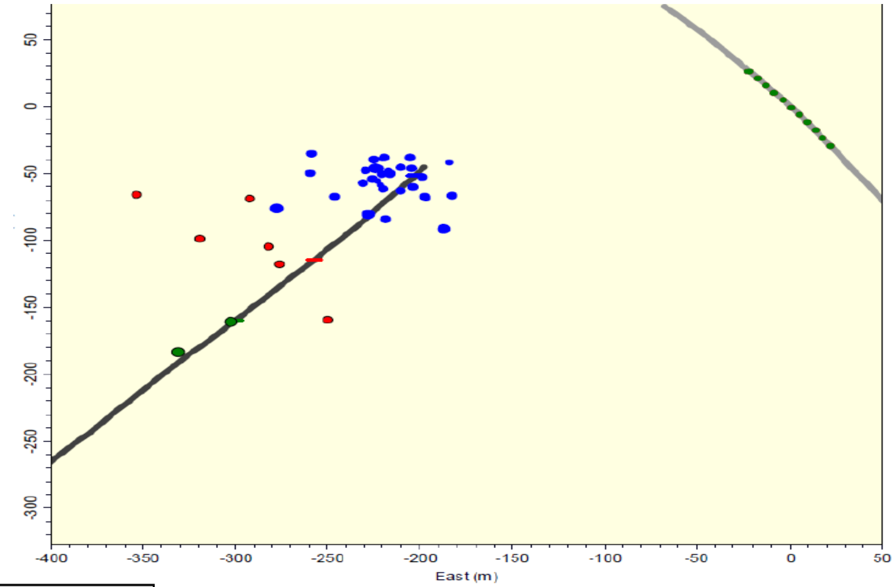


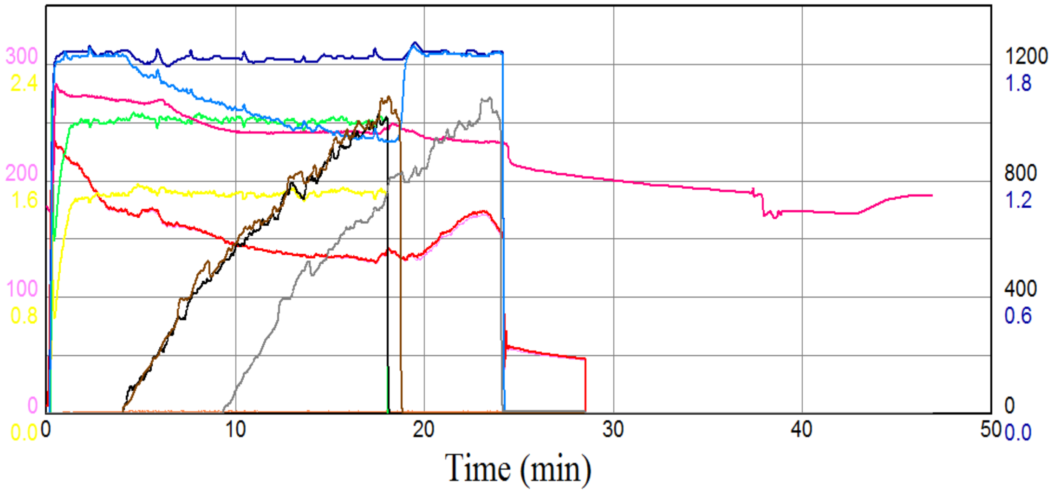


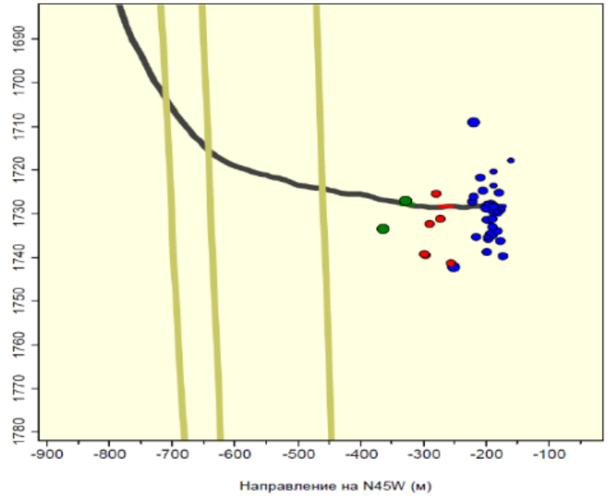


Microseismic
Samotlor, well 80983/1828, AV 1(1-2)



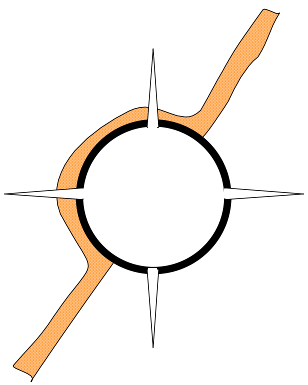


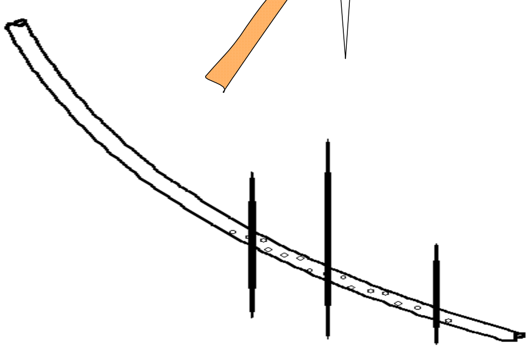


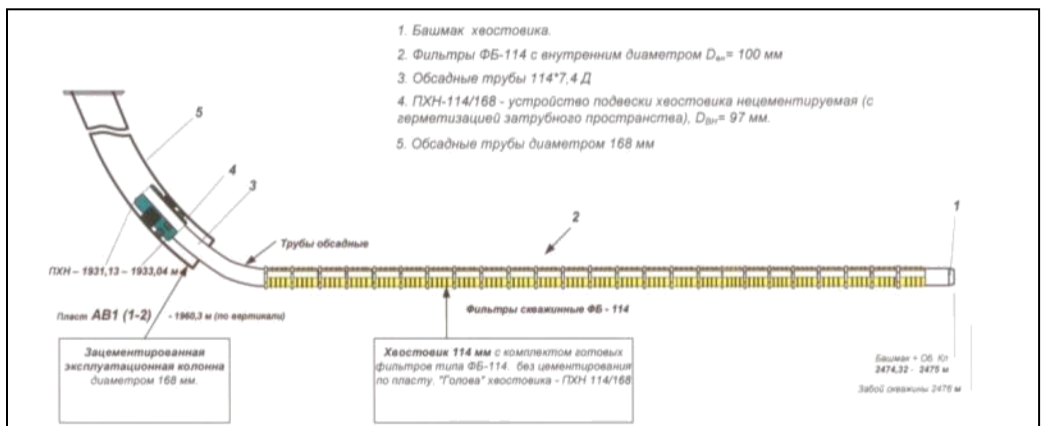


Slotted, screen, perforated uncemented liners / wellbores

Advantages:	Disadvantages:
Technological simplicity; Good communication with the formation ("well – formation"); Well completion cost	preparation for frac, issues related to the packer setting depth and tubing liner setting: Packer – in the production casing, tubing liner is higher / lower than the casing liner hanger? – the hanger washout risk… Packer –in the casing liner? – Is the packer for setting in the liner available? – Risk of complex workover and/or "well abandonment" after sand-off; The single frac stage: – Risk of proppant over-flush during multistage frac.

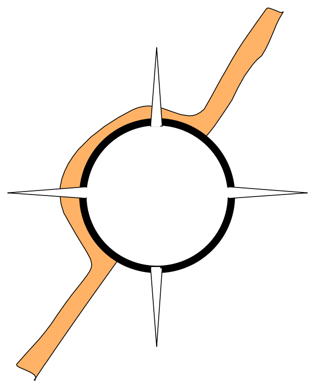


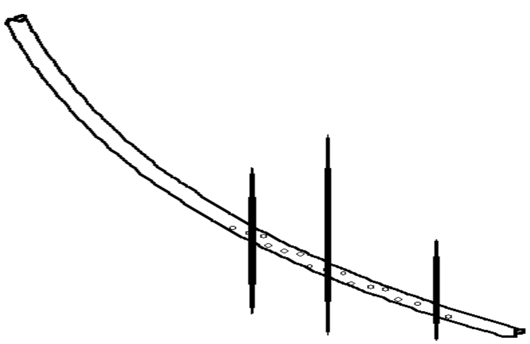




Slotted, screen, perforated uncemented liners / wellbores

Advantages:	Disadvantages:
Technological simplicity; Good communication with the formation (“well – formation”); Well completion cost	Uncontrollable “**blind**” frac: – impossibility to define the fracture initiation point; – necessity of re-perforation (on the tubing); – fissuring + uncontrollable frac fluid losses; – “obscure” mini-frac; – design oriented on “safe frac performance”; – high risks of “sand-off”, in spite of quality control and best practices of modeling and mini-frac results interpretation; – squeeze down to upper perfs (as an exception: fiber + maximum concentration of proppant on linear gel – initiation of “sand-off” at the tail-in stage of frac job); Bottomhole clean-out: –flowback of considerable amount of proppant; –high risks of intensive fluid loss and complications; Impossibility of fractures isolation after breaking into water zones.

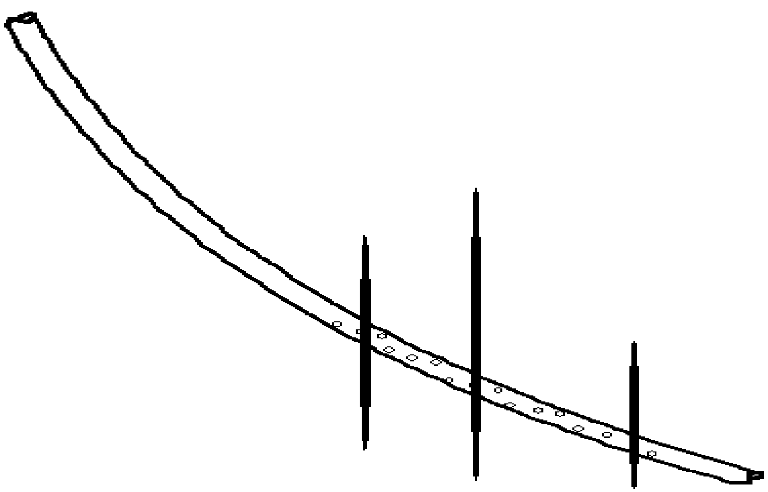


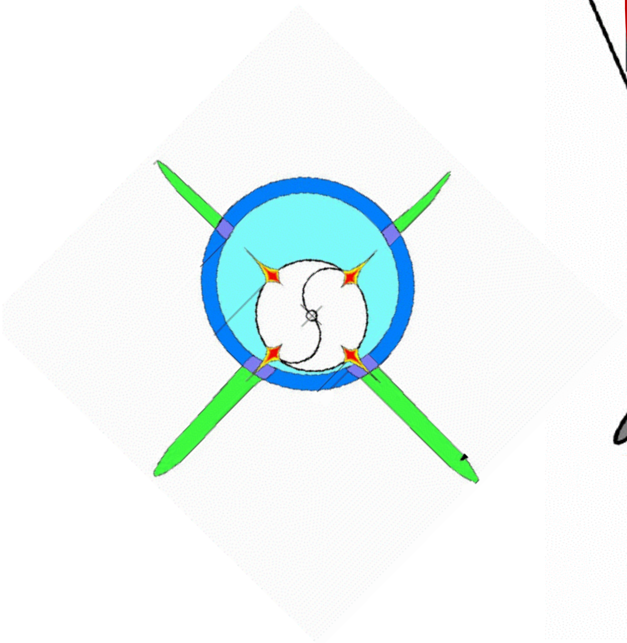


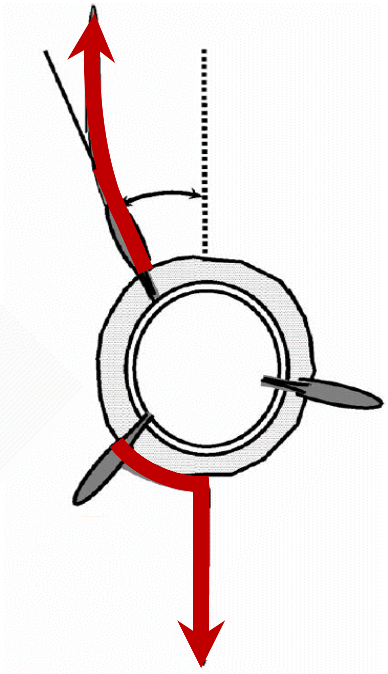
Cemented perforated horizontal sections / liners

As compared to slotted, screen, perforated uncemented liners

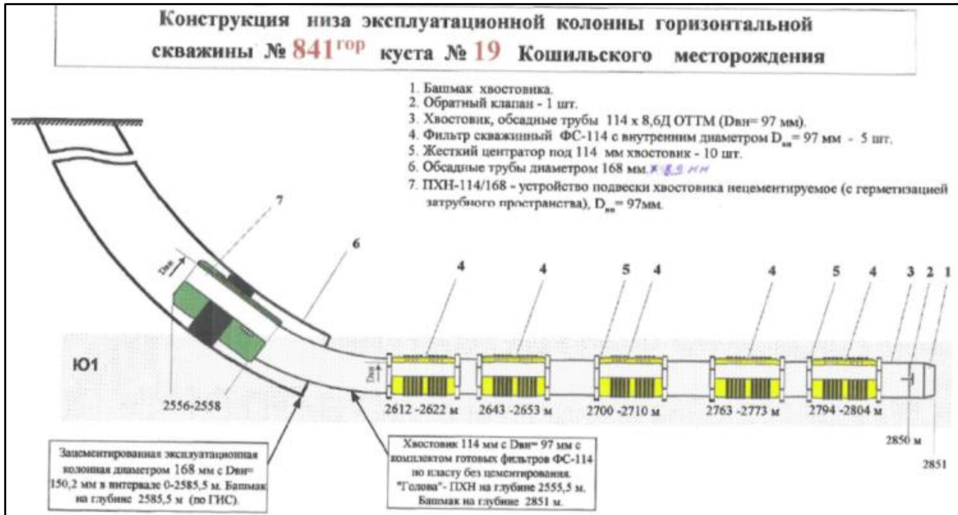
Advantages:	Disadvantages:
Relatively lower risk of uncontrollable frac fluid losses into the formation (depends on the perforated interval length)	Relatively lower quality of communication with the formation (“well – formation”) – less contact area; Risks of high friction pressure losses while the fluid is pumped through the perfs.





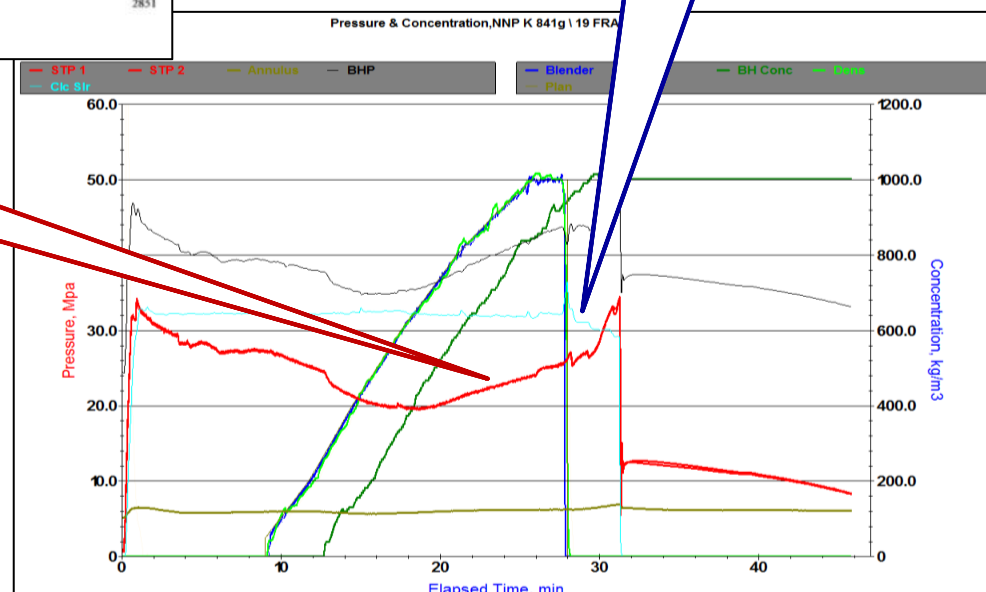


Performing the “blind” frac job: examples

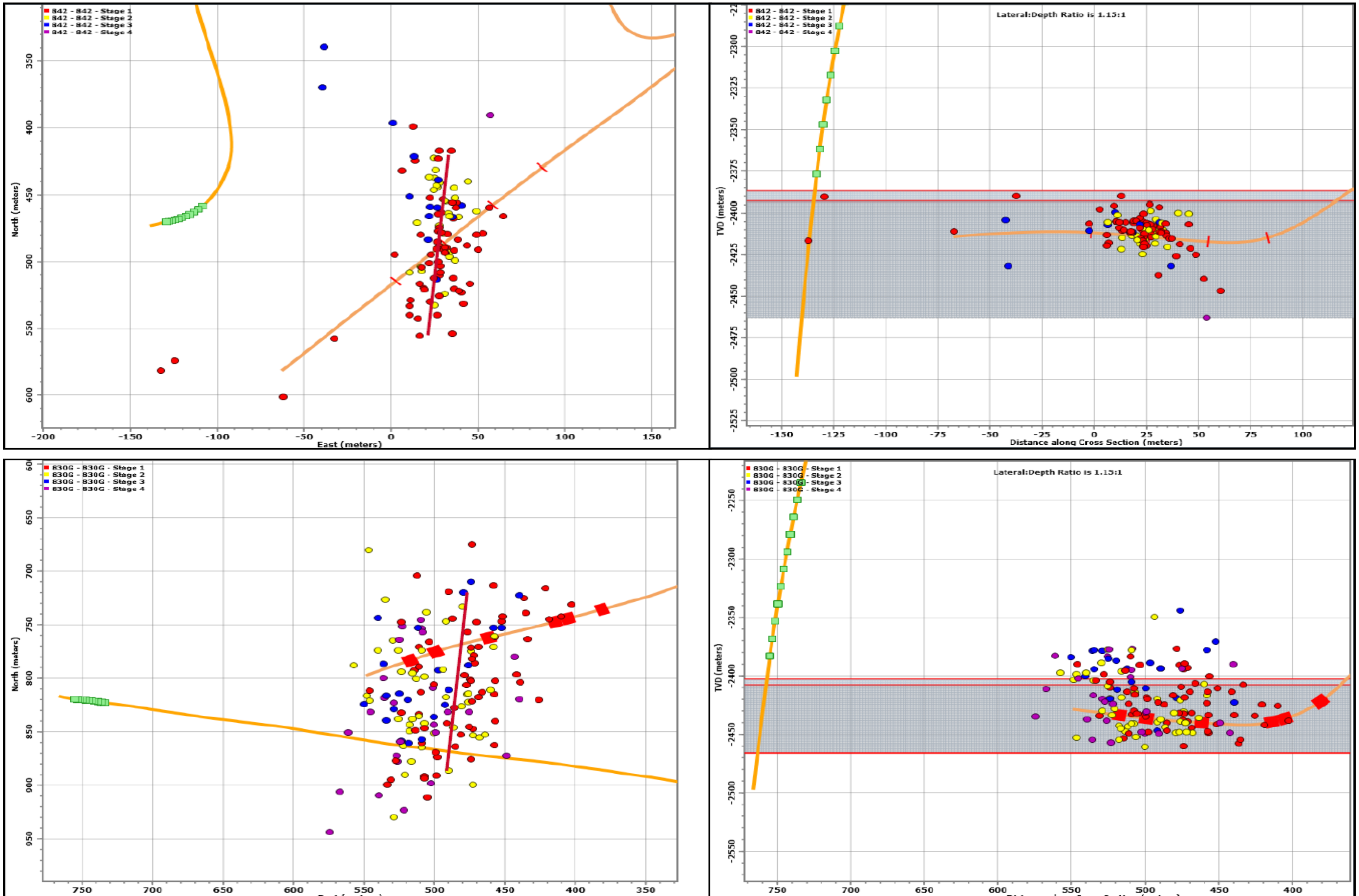


Rate decrease at the flush stage because of pressure rise

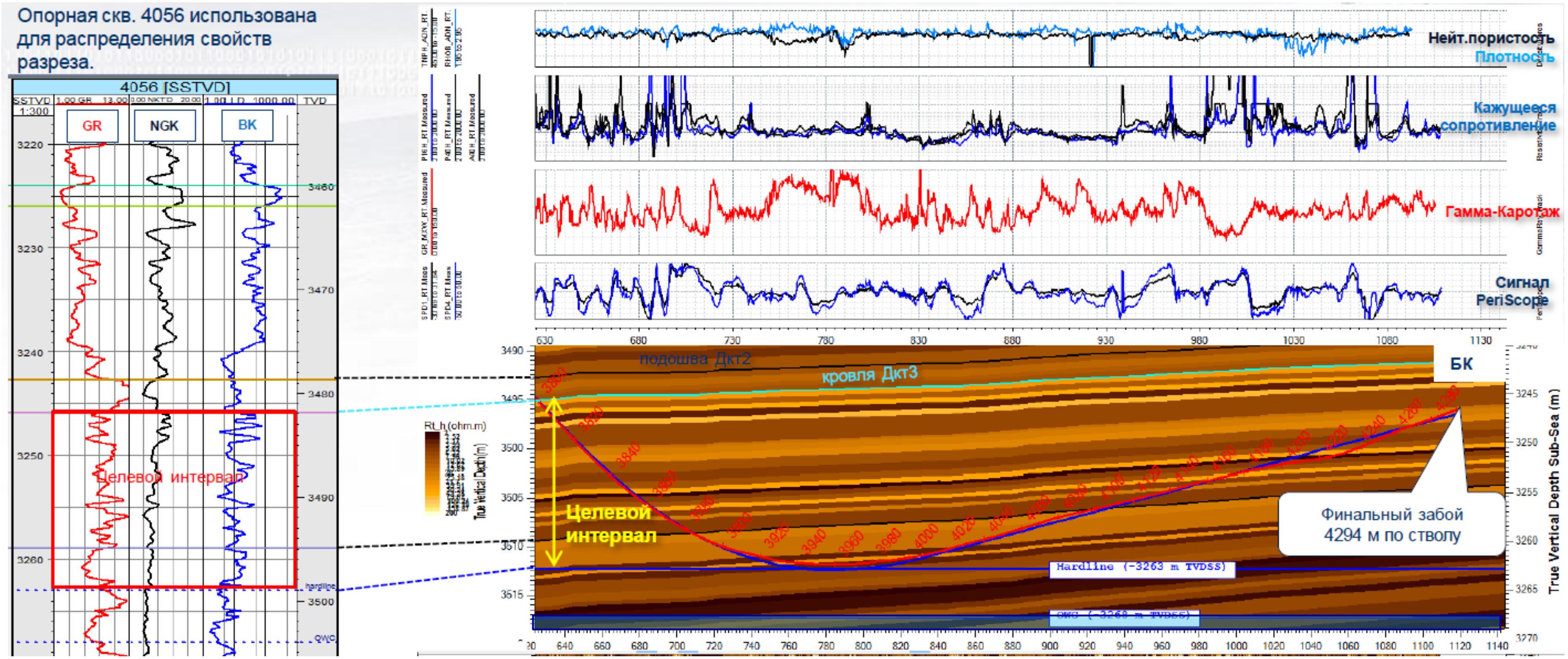
Early fracture packing



"Blind" multi-stage frac operation: Koshilskoe field, well 842G & 830G



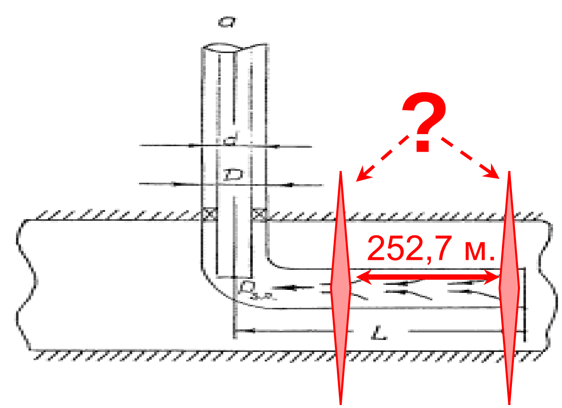
Donetsko-Syrtovskoe field:
Well 4079, Layer DKT-3



Length of casing slot liner – 252.7m;

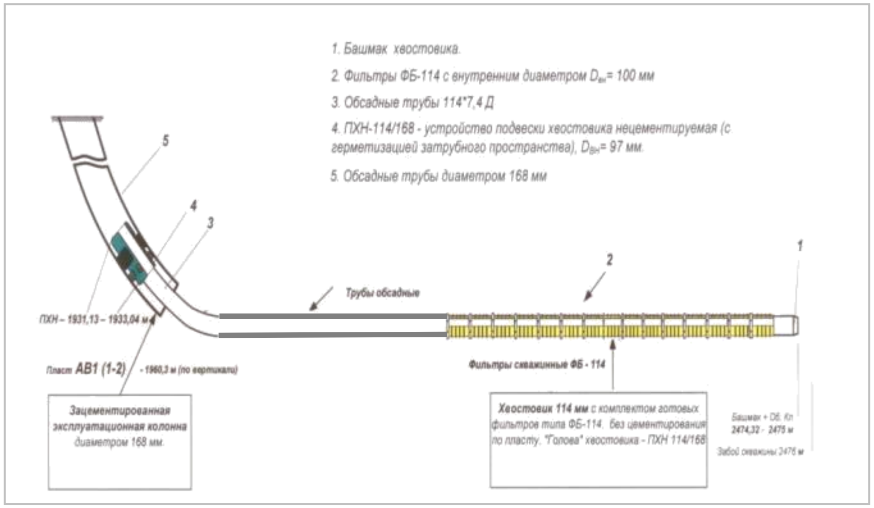
Distance from the bottom point of the liner to OWC ≈ 5m;

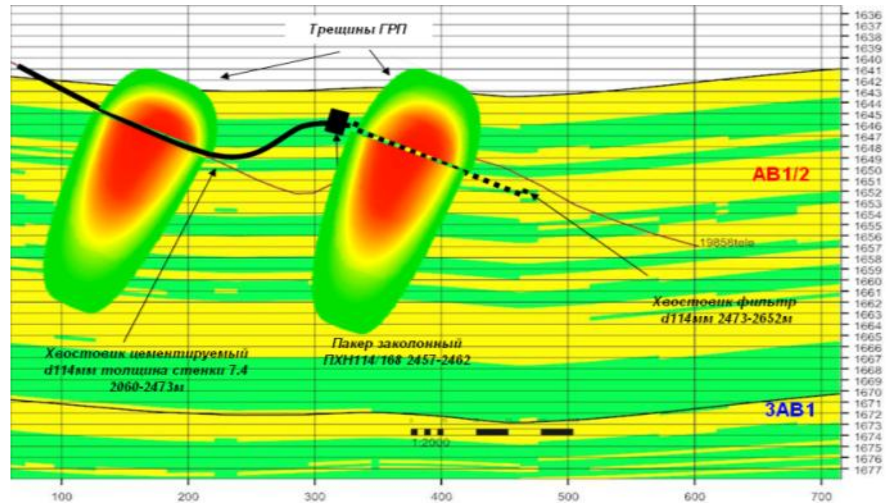
Frac job was cancelled

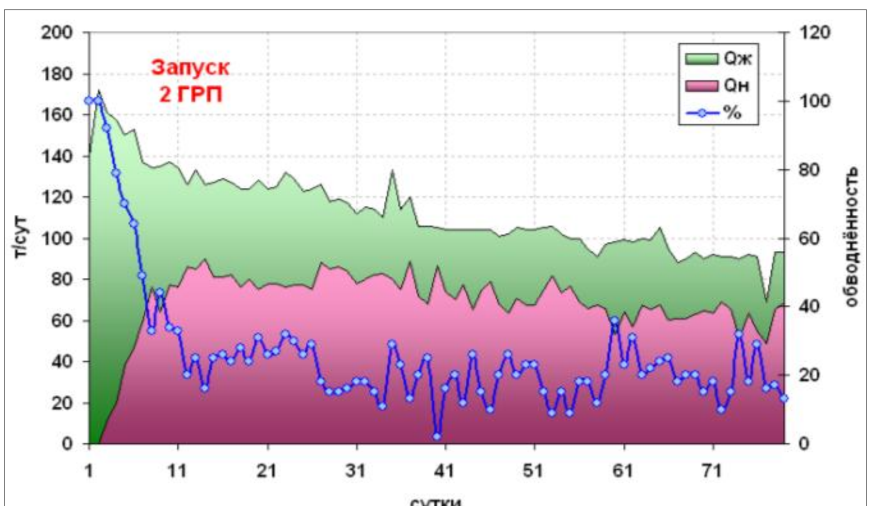


2-stage frac:
slot liner + perforation

Samotlorskoe field: Layer AV 1(1-2), Pad № 2041







Flow rates:

without frac: 24 T/day;

One frac: 50 T/day

Two fracs: 65-70 T/day

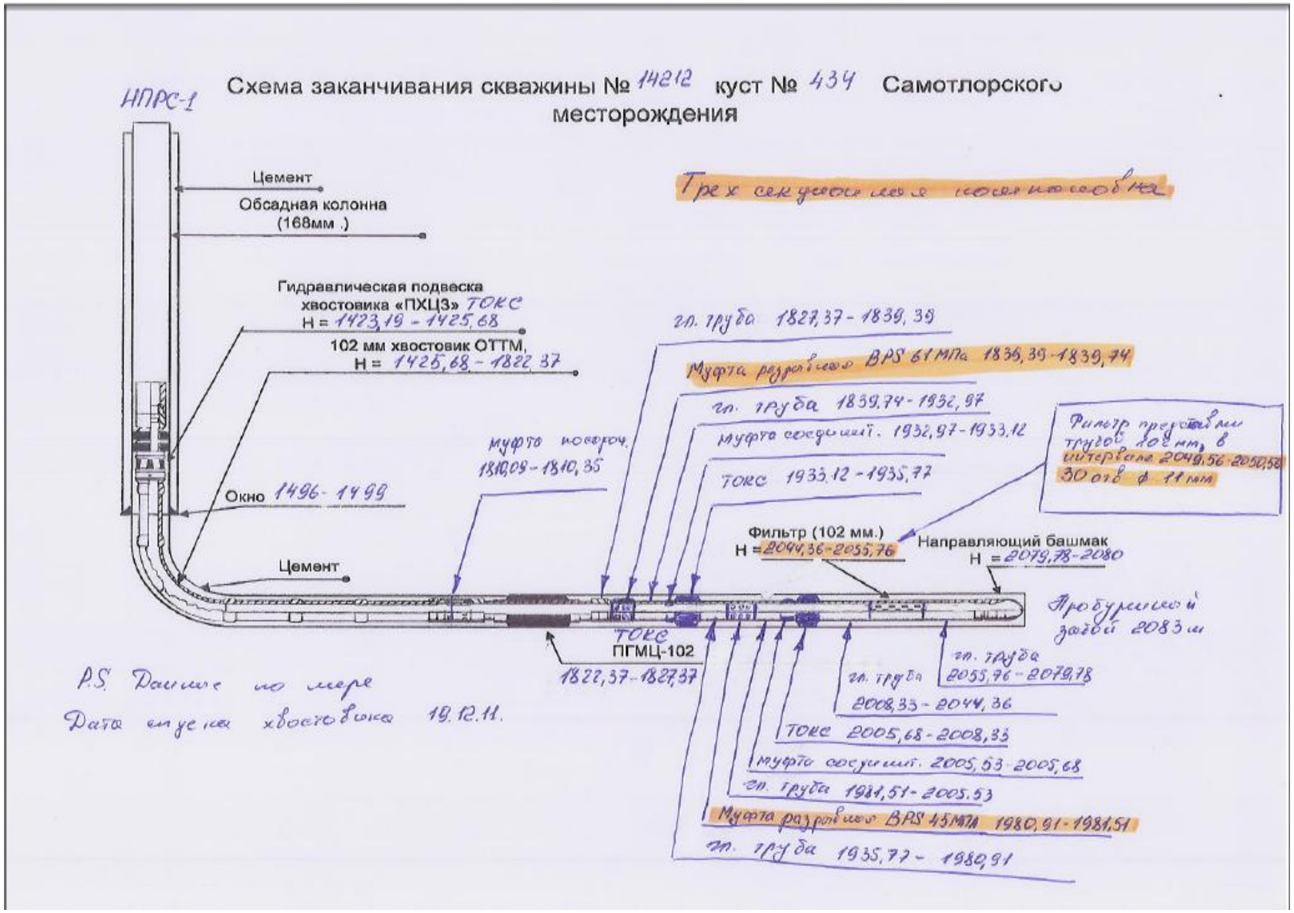
The same risks as in case of fracturing though screen, slotted, perforated liners.

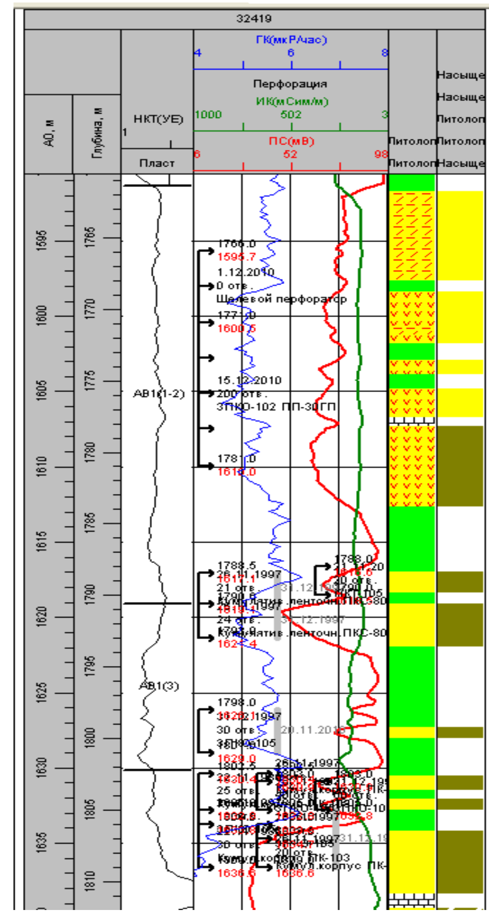
Completion assembly: screen liner + 2 burst collars

- Activation pressure for the 1st burst collar is less than for the 2nd burst collar. The 1st burst collar is activated by means of "screen-out" initiation on the first frac job (pumped through the screen liner).

Advantages:	Disadvantages:
Mechanical simplicity; a part of casing – therefore, simplified RIH operations and completion procedure; Possibility to perform multi-staged fracs in Ø = 102mm.	Risk of insufficient set packers; Risk of multiple fissures development; Risk of fractures breakthrough between the sections and activation of burst collars or warping of the liner; Risk that the burst collars wouldn't activate; Risk of simultaneous activation of the both burst collars ; Risk of increased friction pressure losses on burst collars ; Complexity of isolating the water-cut intervals of the formation; Risk of proppant over-flush (no mechanical means to prevent overdisplacement).

Samotlorskoe field, Well 14212, BV 20-21: uncemented liner

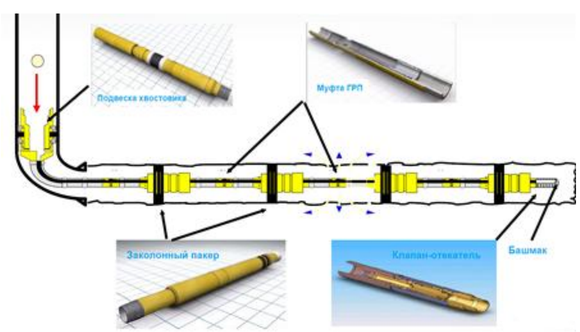


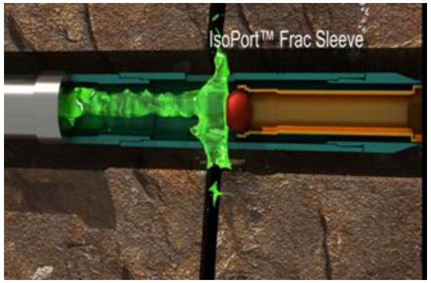


- Pressure of the 1st burst collar activation: 450 atm;
- Pressure of the 2nd burst collar activation: 610 atm;
- Isolation of previous frac interval:
  - high proppant concentration & “Bio-Balls”.

Frac sleevs

Advantages:	Disadvantages:
Control over the fracture development (fracture initiation point, flush volume); Isolation of previously stimulated zones; Mechanical reliability in case of best engineering practices applying; Potential possibility of high water-cut intervals isolation by means of closing the ports.	Complexity of well completion; Risk of insufficient pressure integrity of the external casing packers (crossflows between zones); Number of ports is limited by the casing liner ID, sizes of ball seats and sequence of balls with increasing sizes; Risk of multiple fissures development; Risk of breakthrough between the sections (*); Complexity of bottomhole cleanout; Human factor, engineering mistakes (selection of equipment, dropping the balls); High cost of equipment.





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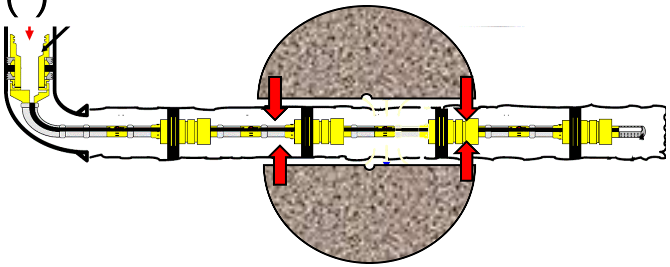
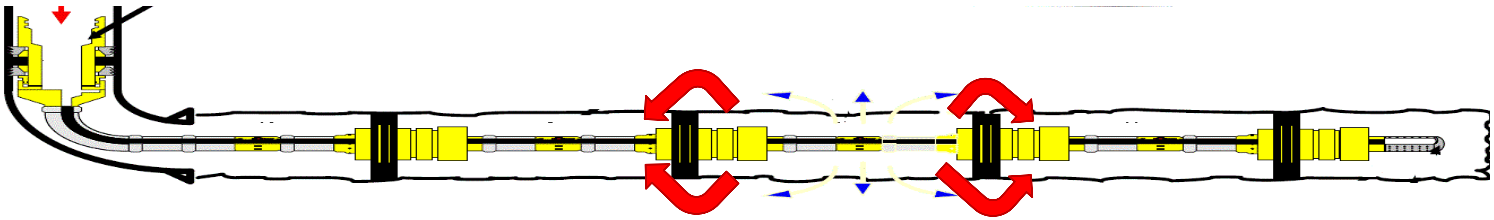


Frac sleevs: risks of application

- Risks related to the use of swelling / hydraulic packers
  - Example: VCNG, 2011: insufficient packers swelling;
  - Risks of frac fluid crossflows between sections, uncontrolled leak-off and screen-outs;



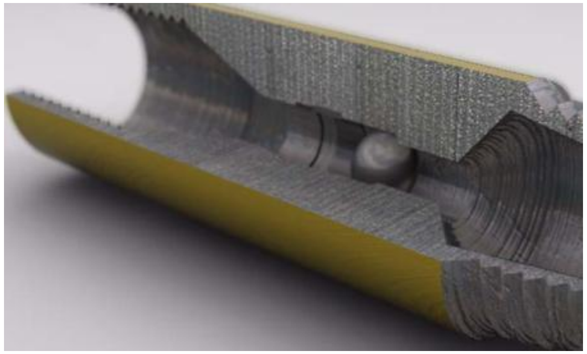
- Conformity between balls and seats Ø (human factor)
  - Example: VCNG, 21/03/2012,

    Well 1431/29: Mistake in ball seat (Ø = 60.3 mm)

    It was planned to run a ball (Ø = 54.0 mm);

  - Risk: proppant overflush &

    decrease of fracture conductivity;

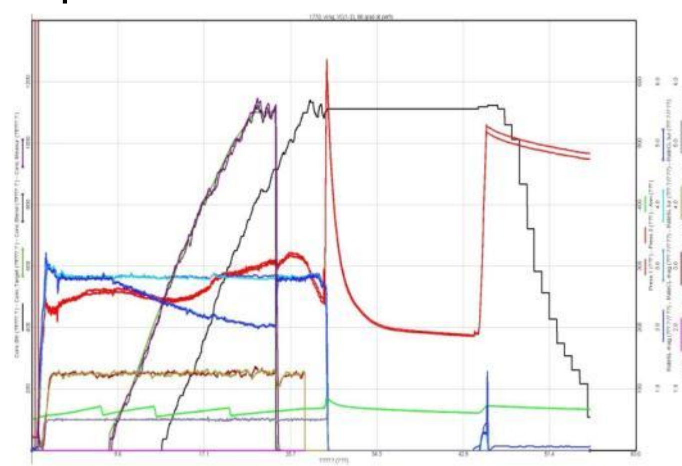


Frac sleevs: risks of application

- Correct sequence of balls (human factor in performing frac jobs)
  - Potential risk:

    constant control is required;

- Timely ball dropping (short time interval for the operation, human factor in performing frac jobs)
  - Example: Well 1770/30 VCNGKM: the ball got into “tail” of proppant during the flush stage). Pressure spike during the displacement stage.
  - Risks of frac to occur in the next collar.



Frac sleevs: risks of application

- Fracture initiation through the circulation ports, which are not designed for frac
  - As a <u>possible </u>example (<u>burst </u>collars – BPS): Well 81056/4303 Samotlor.

    Frac job with mark-proppant through the circulation port which is not designed for frac;
  - Risks:
  - Excessive pressure losses → “SAND-OFF”

    decrease in fracture conductivity (“choking” the flow by means of the circulation port)

- Closing the ports in case of water-cut increase (water breakthrough)
  - Risks:

    Currently applied equipment is not designed for closing the ports in case of production water-cut increase;

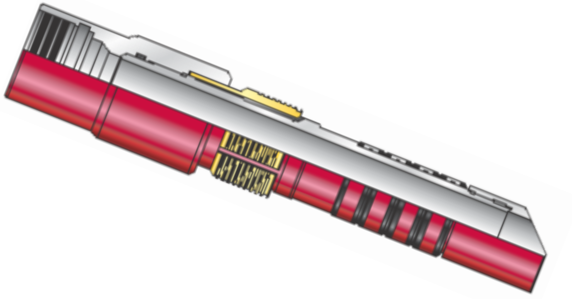
    lack of experience in performing the operations where closing of the ports is required,

    Expected high cost of work without a guaranteed result.

Frac sleevs: risks of application

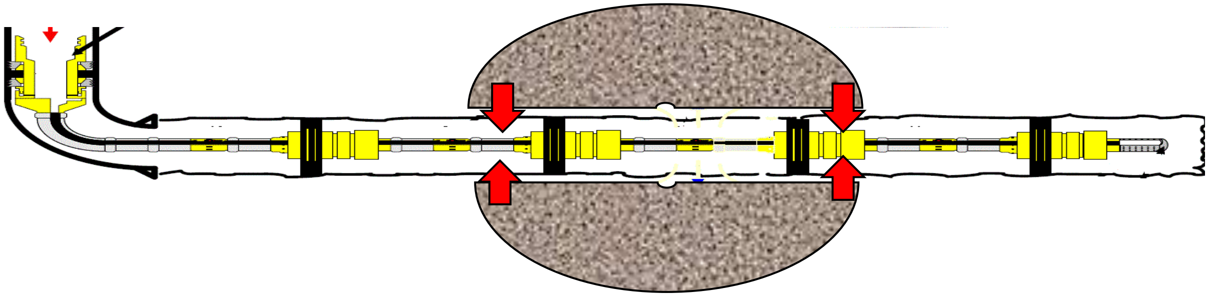
- Drilling balls & seats with coil tubing
  - Example: VCNGKM, Frac Project 2012:
    insufficient loading weight-on-bit in downhole
    conditions + other problems;
  - Risks:
    extension of well-starting time period
    lower fracture conductivity.
    decrease in expected oil production rates,
    Probable problems during workover operations, well logging etc.

- Problems with stinger release after frac
  - Example: Wells 1769 and 3200 in VCNGKM,
    Frac Project 2012;
  - Risks of equipment sticking in hole



Frac sleevs: risks of application

- Liner deformation (completion BHA)
  - <u>Probable</u> risk of equipment deformation in case of longitudinal fracture propagation and "fracture breakthrough beyond the packer" into near section intervals.

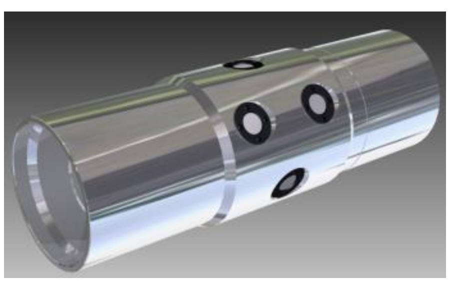


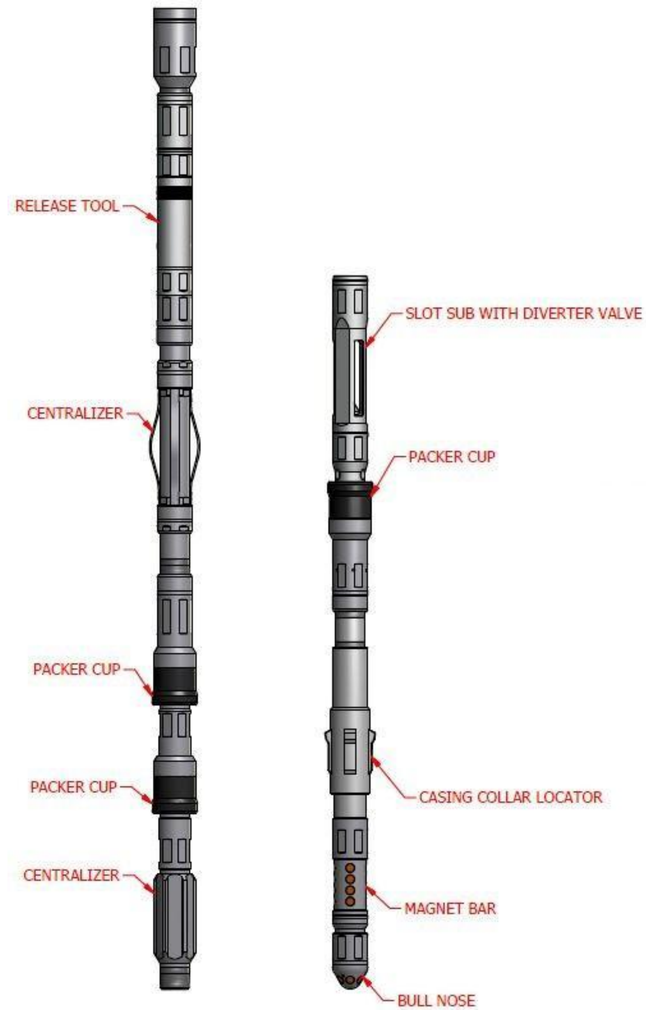
- Using composite and/or aluminum balls
  - Possible solution of 'drilling-out' problem;
  - Successful field testing
  - Risks:

    Acids affecting the completion BHA, proppant and formation matrix;

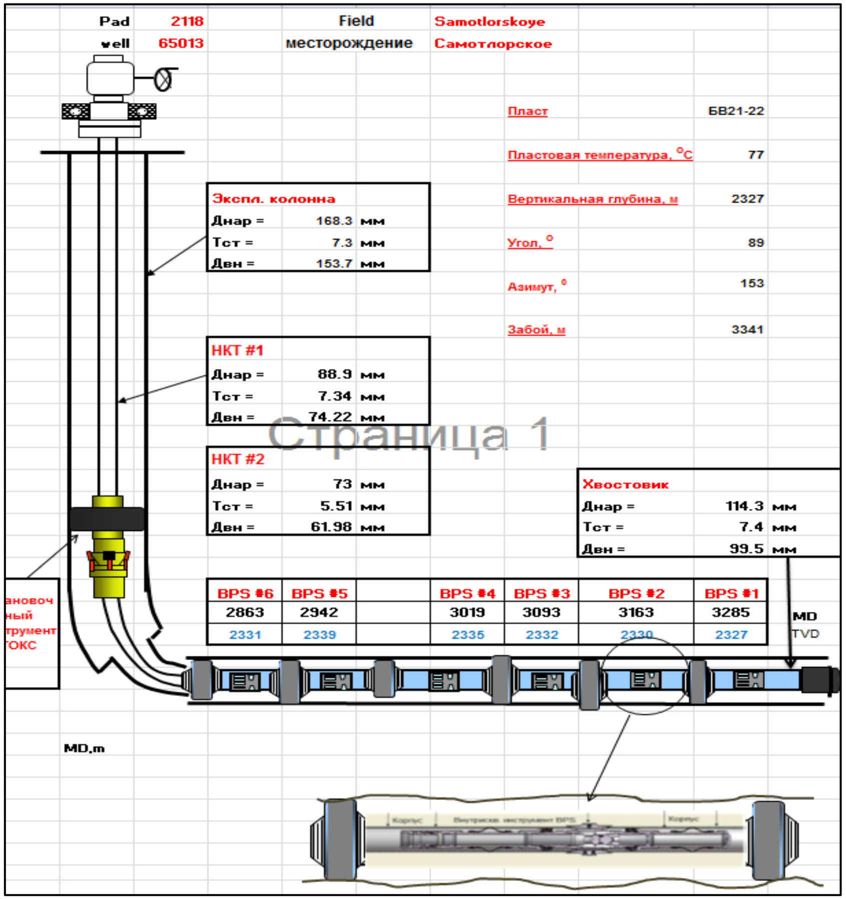
    Incomplete decomposition / solution of ball materials.

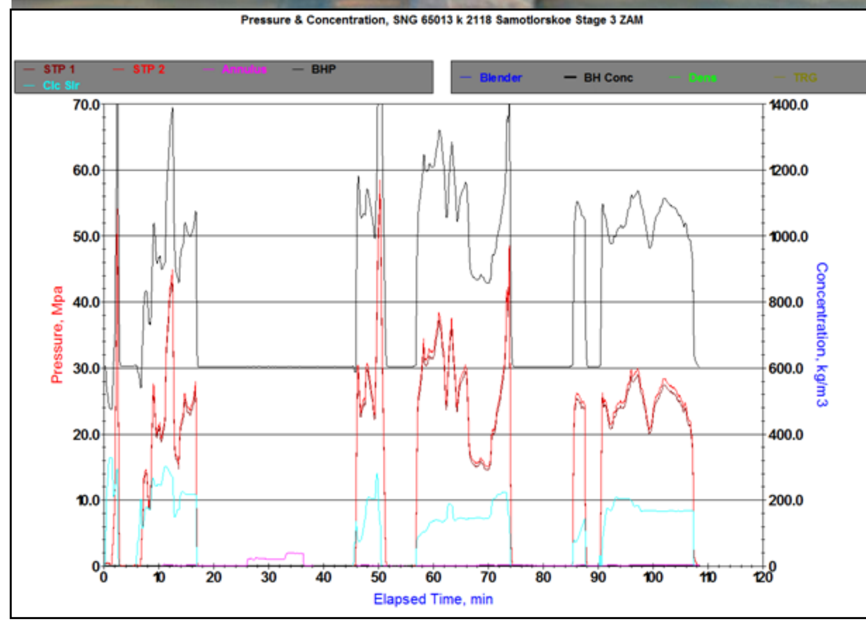
Cup packer + burst collars

Advantages:	Disadvantages:
Mechanical simplicity; a part of casing – simplified RIH operations and well completion procedure; can be used both in cemented and uncemented casing; no necessity of post-frac well clean-out; quick bottom hole treatment after screen-out without coil tubing 	Risk of insufficient pressure integrity of packers; Risk of multiple fissures; Risk of fractures breakthrough between sections and the liner deformation (if the liner is uncemented); Risk of cement-filled cavities / holes occurrence against the burst collars setting interval; Risk of collars activation at the moment of packer release (down hole incident) during frac; Risk of non-activation of collars; Risk of increased pressure losses for friction on the collars; Necessity of frequent replacement of cup packers; Complexity of water-cut intervals insulation; High cost of equipment



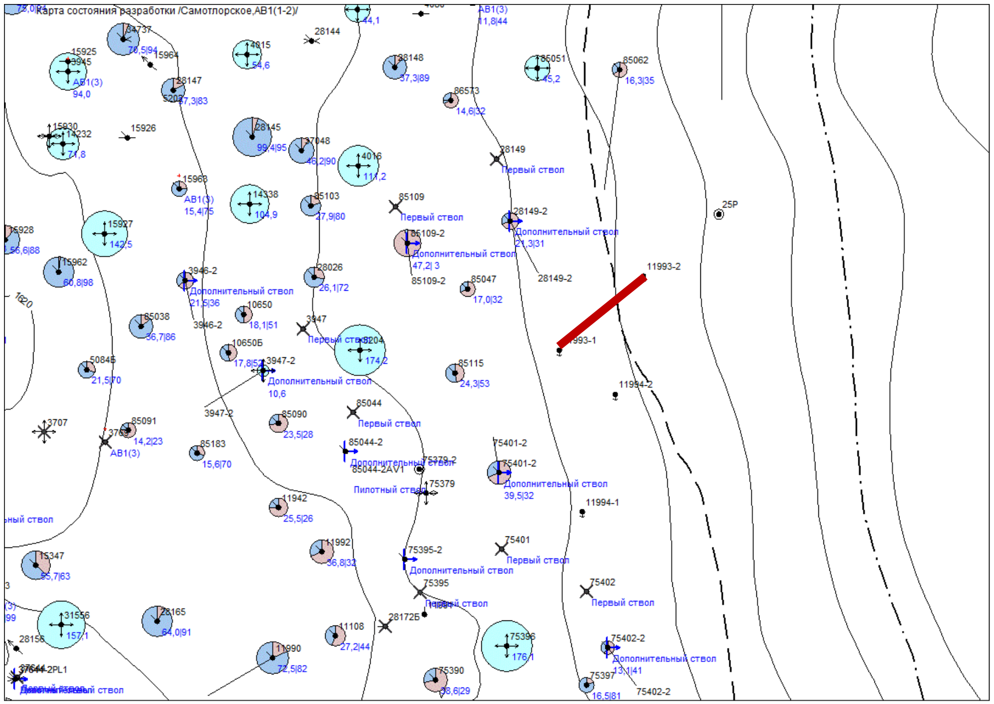
Samotlorskoe field, Well 65013, BV 20-21: uncemented liner

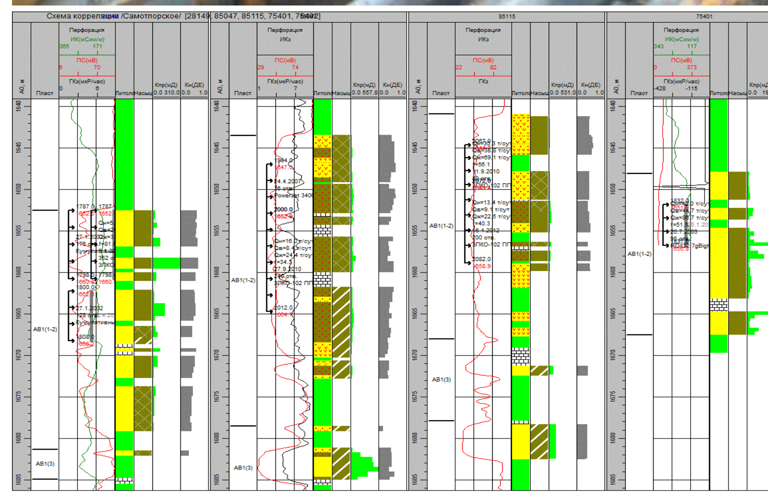




- Problems related to activation of the 3rd burst collar;
- Frequent tripping operations to replace the cup packers sealing elements;
- At the 5th stage of frac (the 6th burst collar) the centralizer was lost in hole.

Samotlorskoe field, Well 11993, AV 1(1-2): cemented liner





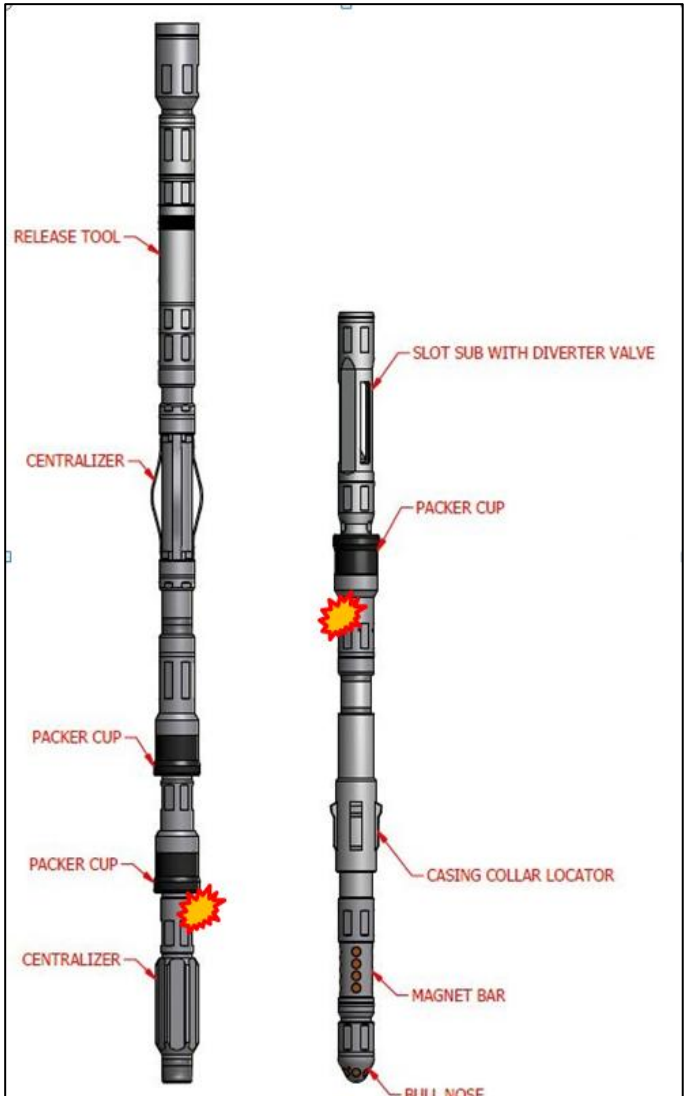
- Problems related to activation of the 3rd burst collar;
- Frequent tripping operations to replace the cup packers sealing elements;
- The 3rd frac (the 4th burst collar) resulted in premature screen-out, 3.5 tons of proppant were washed out quickly

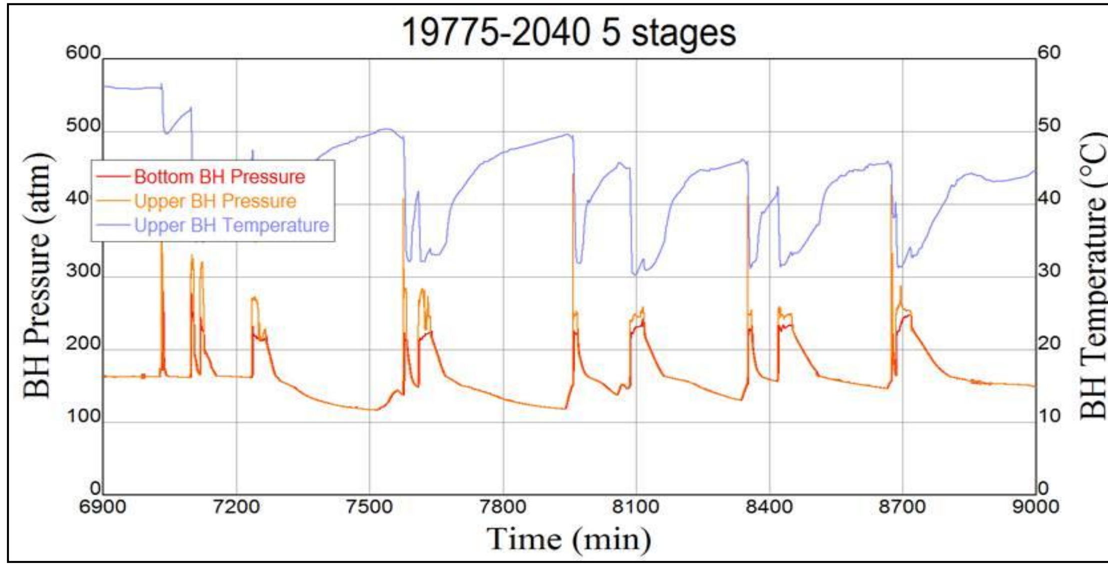
Samotlor, well 11994, AV 1(1-2): cemented liner + burst collars

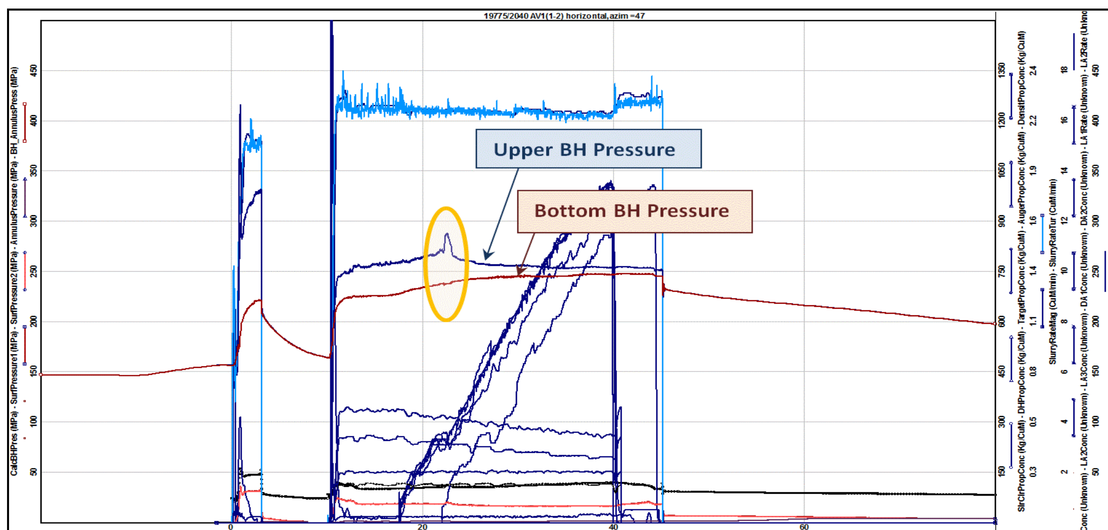
Multi-frac job stages:
1st – 15.08.2012г.;
2nd – 18.08.2012г.;
3rd – 20.08.2012г.;
4th-6th – 22-23.08.2012г.

Cement in the liner – cause of multiple workover round-trips and long time period for frac job execution

Samotlor, well 19775, AV 1(1-2): hydraulic casing packers + burst collars







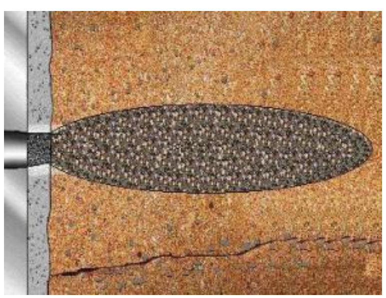
Burst collars activated with balls

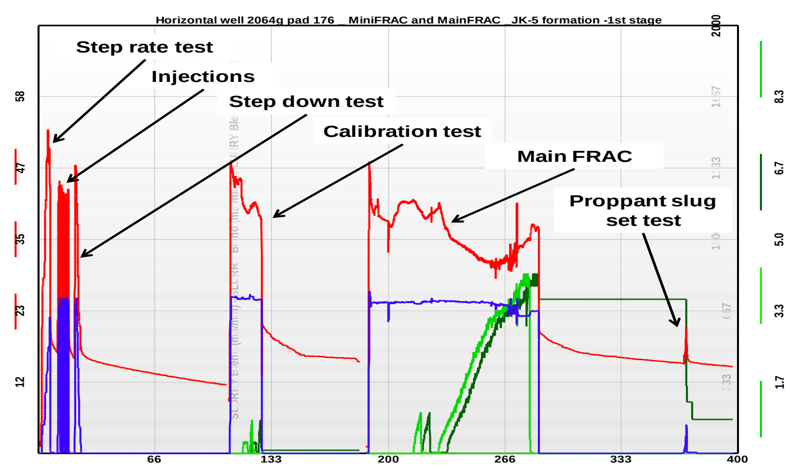
Advantages	Disadvantages:
Combined merits of the two previously reviewed technologies Lack of mechanically shifted completion BHA elements (in process of frac)	Combined risks of the two previously reviewed technologies

- In TNK-BP these completion BHA's are not used because they don't have any considerable advantages as compared to BHA with burst collars (when using the cup packers) and BHA's activated by means of balls.

Multi-staged frac using CT (coiled tubing)

- Application of CT:
  - Jet perforation between the frac stages;
  - Well commissioning and flow rate stabilization after the last stage of frac.
- After perforating with abrasive solution, CT with BHA is pulled out to the surface;
- Frac job via the tubing, previously run in hole;
- After the frac stage in the perforated interval – proppant pack which isolates the formation ("plug-back" prior to the next frac stage);
- No technical limitations for the amount of proppant being pumped.





Thanks for your attention!

Questions?

Comments?

SPE 137328. Oil wells: Criteria for Decision

For horizontal wells in oil formations, transverse fractures are very attractive for low permeability formations and for higher permeability formations up around 10 md. Above this permeability, vertical fractured wells or horizontal wells with longitudinal fractures should be considered. The choice between these two options should be based on the relative economics of the two types of completion.

Permeability Range, mD	Best Technical Solution	Comments
> 10	Horizontal Wellbore, Longitudinal Fractures OR Vertical Well with Fracture	Dependent upon project economics and the relative costs of vertical and horizontal wellbores and zonal isolation techniques
< 10	Horizontal Wellbore, Transverse Fractures	Dependent upon project economics and the relative costs of vertical and horizontal wellbores and zonal isolation techniques

SPE 137328. Gas wells: Criteria for Decision

For horizontal wells in gas formations, transverse fractures are preferred when the formation permeability is lower than +/- 0.5 md. Below approximately 0.1 md, multiple vertical wellbores with fractures may be preferred, depending upon the relative economics of vertical and horizontal wellbores.

In gas formations above 0.5 md, horizontal wells with longitudinal fractures become more attractive than similar wells with transverse fractures, due to the mitigation of the choking effect at the contact between the fracture and the wellbore. However, in the range of 0.5 to 5 md, multiple vertical fractured wells may be more attractive than a horizontal well with multiple longitudinal fractures, depending upon the relative economics of vertical and horizontal wellbores.

In gas formation above 5 md, horizontal wellbores with multiple longitudinal fractures are the most attractive option in all cases.

Permeability Range, mD	Best Technical Solution	Comments
> 5	Horizontal Wellbore, Longitudinal Fractures	In all cases
0.5 to 5	Horizontal Wellbore, Longitudinal Fractures OR Vertical Well with Fracture	Dependent upon project economics and the relative costs of vertical and horizontal wellbores and zonal isolation techniques
0.1 to 0.5	Horizontal Wellbore, Transverse Fractures	Above 0.5 md, the “choked” connection between the fracture and the wellbore makes transverse fractures relatively inefficient
< 0.1 md	Horizontal Wellbore, Transverse Fractures OR Vertical Well with Fracture	Dependent upon project economics and the relative costs of vertical and horizontal wellbores and zonal isolation techniques