TERRATEC

Well Stimulation Technology T-SEISMO

TERRATEC
WELL STIMULATION TECHNOLOGIES

T-Seismo: optimizes waterflooding and solves injection problems.

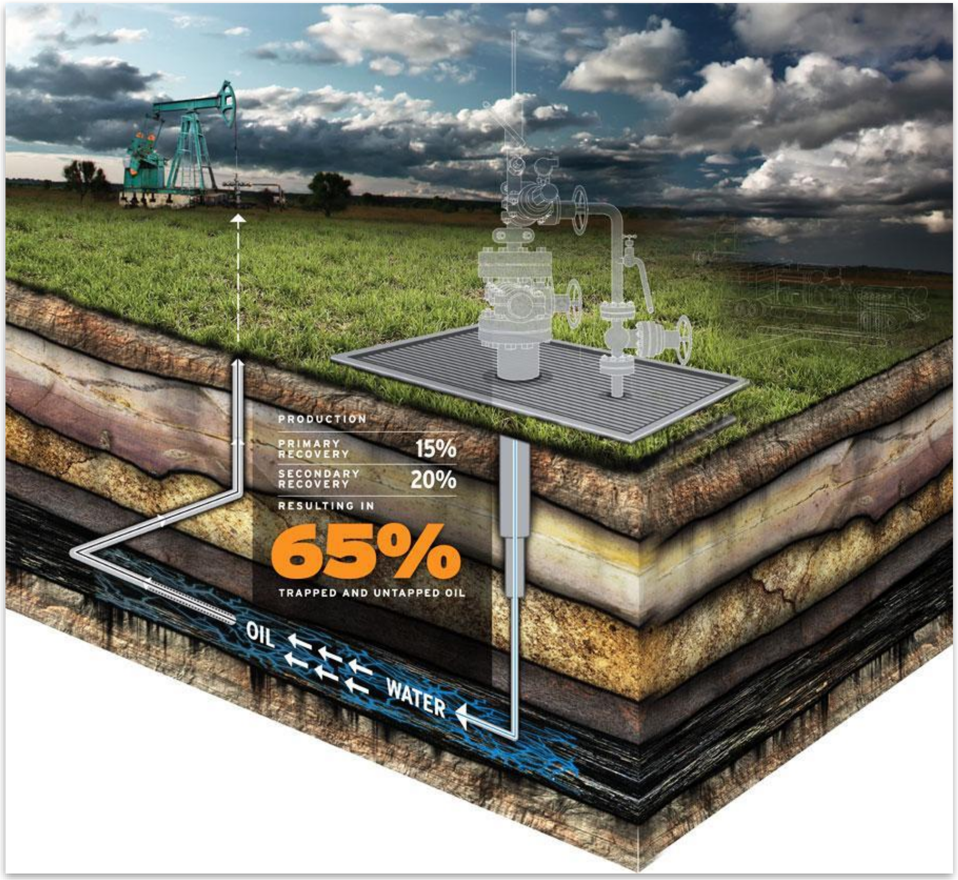
- Main technology of Terratec to optimize waterflood and improve oil recovery is T-Seismo, established method of injection wells treatment with 10 years history.
- It provides increasing well injectivity, water intake and oil production in given pattern.
- Terratec technologies have been successfully applied in many fields in Russia, Europe, Central Asia with very good results and HSE record.
- Our research team continues to innovate and improve current technologies through laboratory research and field pilots.

HQ, office, laboratory and field departments are in Moscow.

NEED TO OPTIMIZE WATER INJECTION

Up to 50% of the world's oil is produced by water flooding. However, performance of most waterfloods is suboptimal.

- 65% of oil is left in reservoir on average;
- tremendous potential for optimization;
- only streamlines, infill drilling or EOR?



On the mission to enhance injectivity

- reduced/low injectivity is among WF issues;
- scaling, sand-fill and other problems;
- only acid treatment or fracturing?

and productivity

- increase liquid (preferably oil) production rate;
- decrease/optimize water production.

T-SEISMO

Basic technology

Pneumo-pulse well stimulation

- We will clear the bottomhole zone of the well from the mudding, restore the permeability by pneumo-pulse and seismic effects from the wellhead in a few hours without running downhole equipment.
- Released clogging is removed from the formation into the well by a simultaneous swabbing effect.
- **For injectors**: The operation is performed without killing the well with a short-term stopping of water injection.
- **For producers**: We perform the impact during the next repair work on the well, with the pulled out pump and runned technological tubing with re-entry guide(a few hours). After that, workover crew will continue its normal work and start the well with increased productivity.

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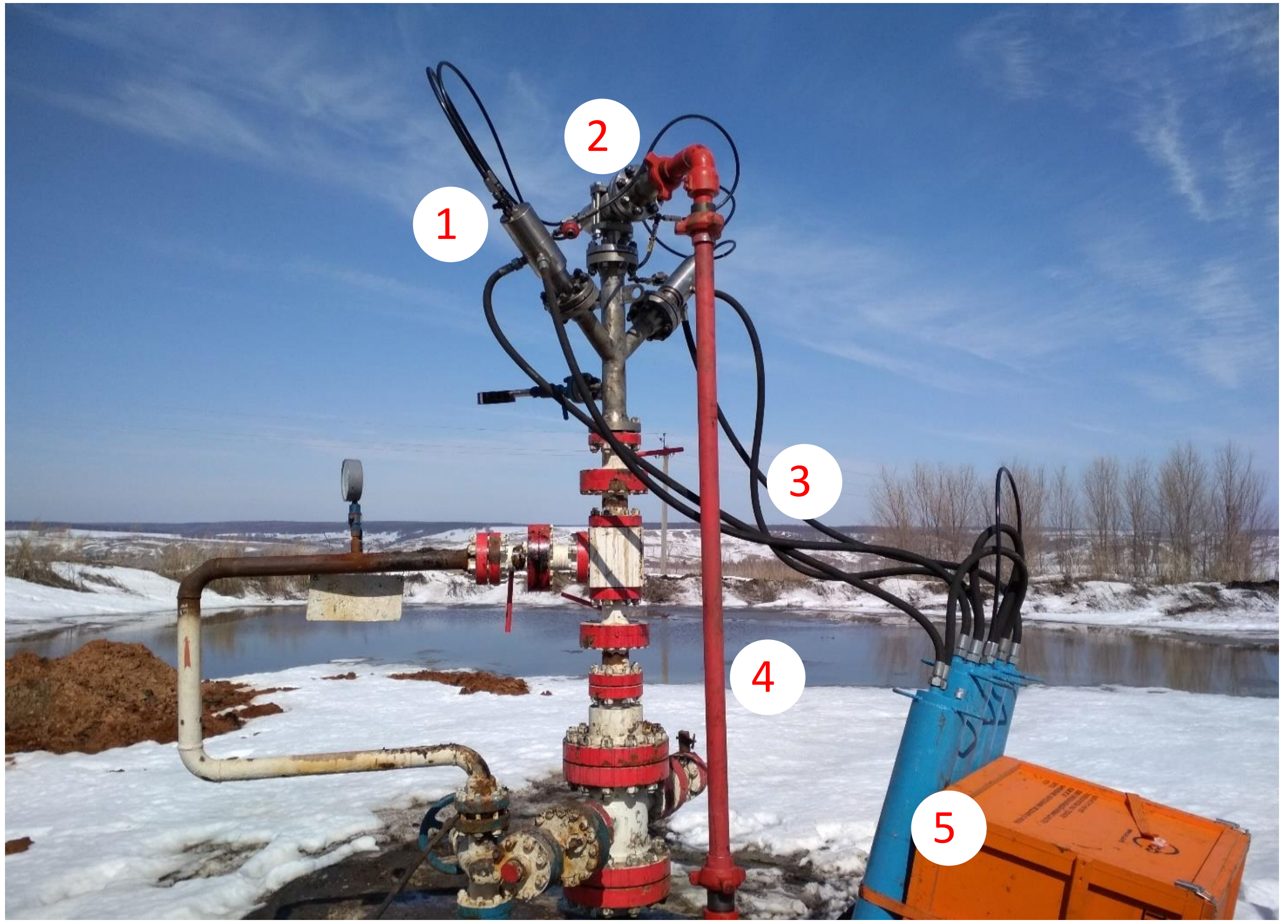
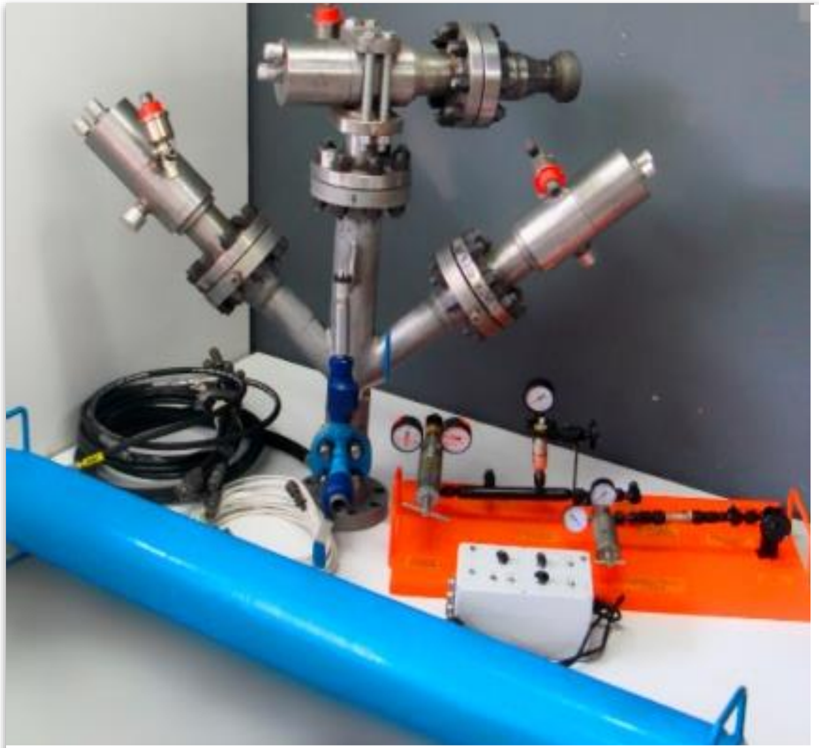


1 – Generator (fast operated electropneumatic valves)
2 – Central valve(for swabbing effect)
3 – High pressure line;
4 – Discharge line;
5 – High pressure receivers.



PRINCIPAL SCHEME OF T-SEISMO

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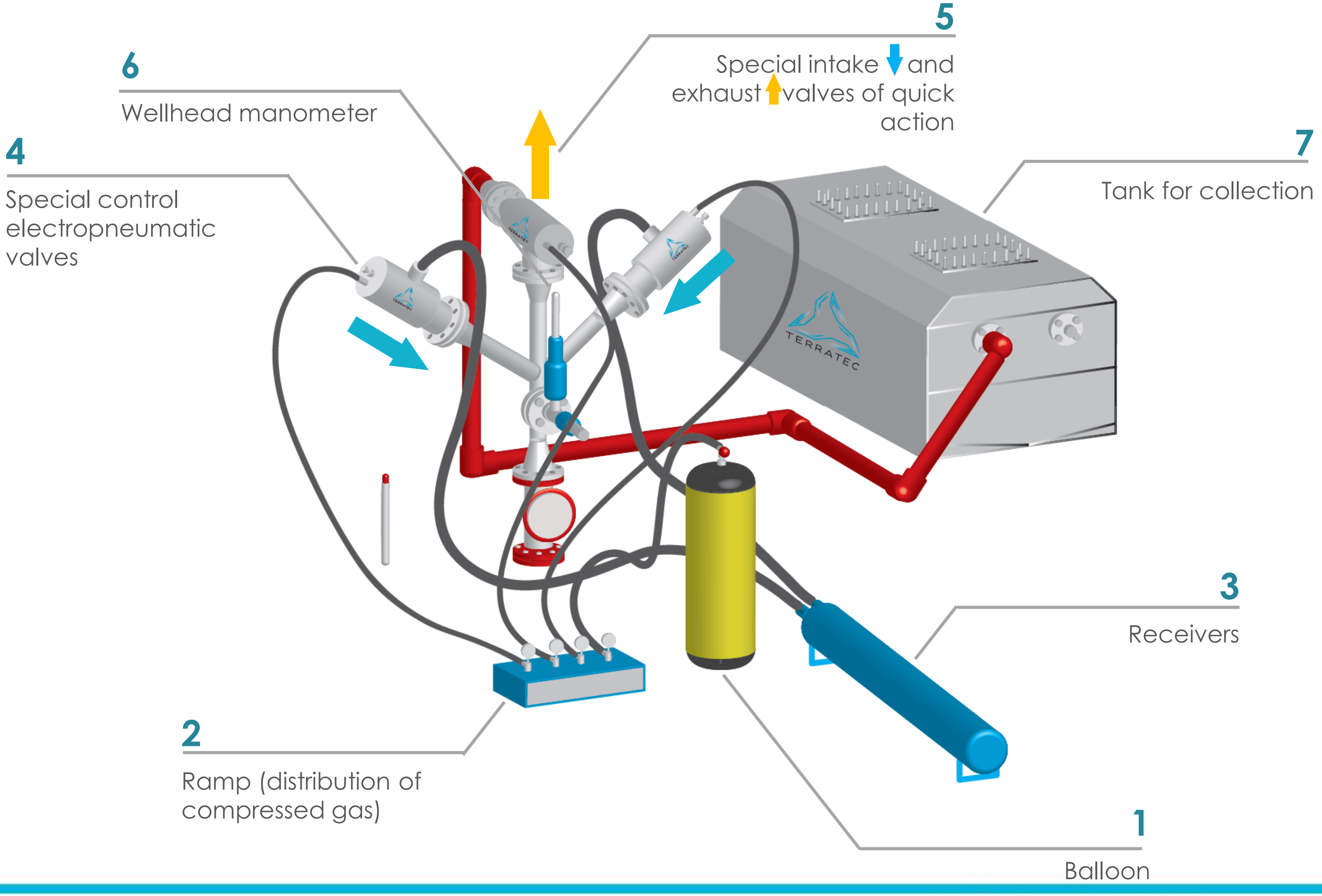

HOW IT WORKS

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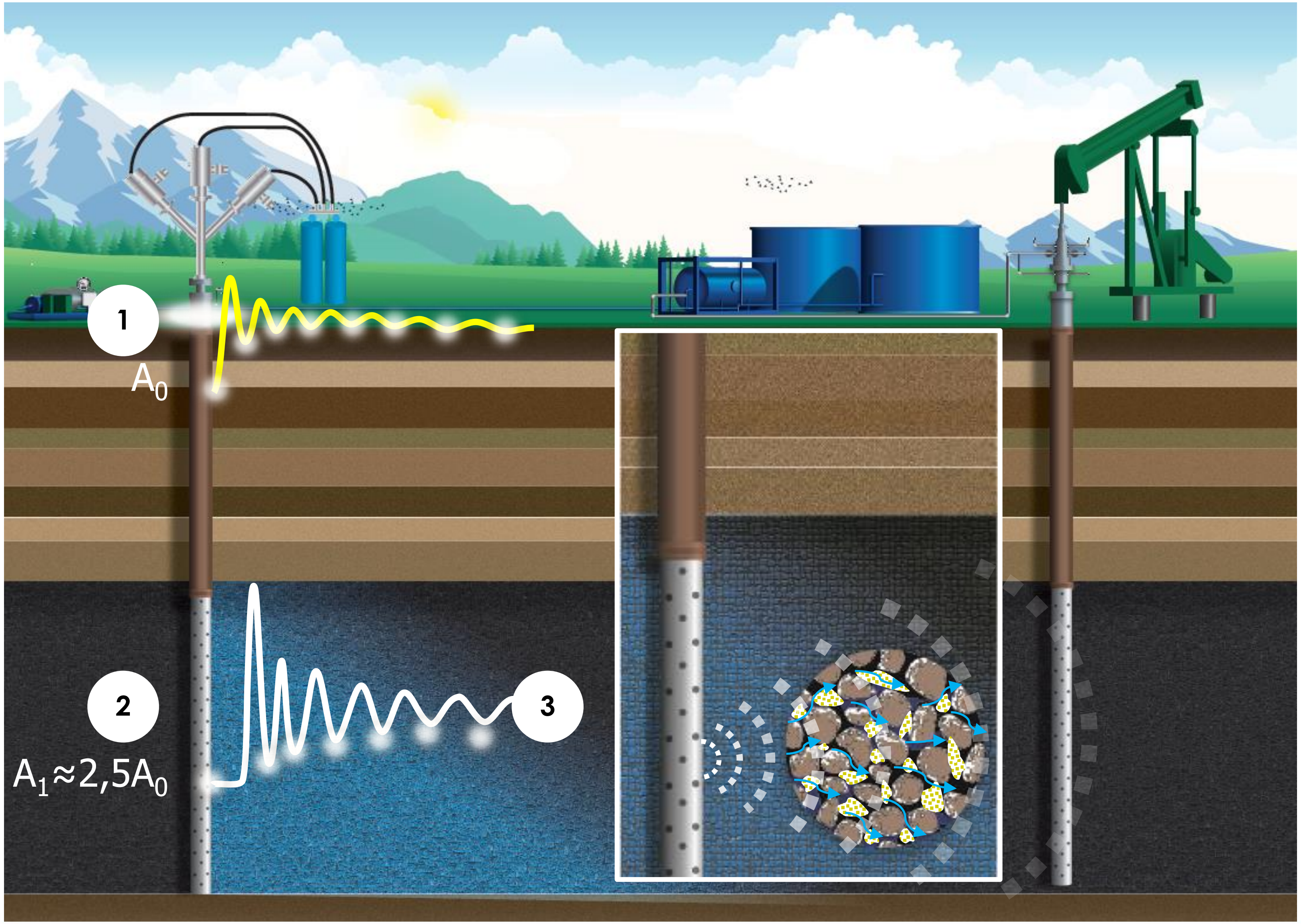

1. Pneumatic shock at the wellhead.

2.Propagation of the shock wave along the column of liquid in the tubing to the bottom-hole.

3. When the wave reaches the bottom-hole a **hydropulse impact** on the formation occurs and subsequent multiple reflections from the bottom-hole to the wellhead.

T-SEISMO: TECHNOLOGICAL SEQUENCE AT THE INJECTOR

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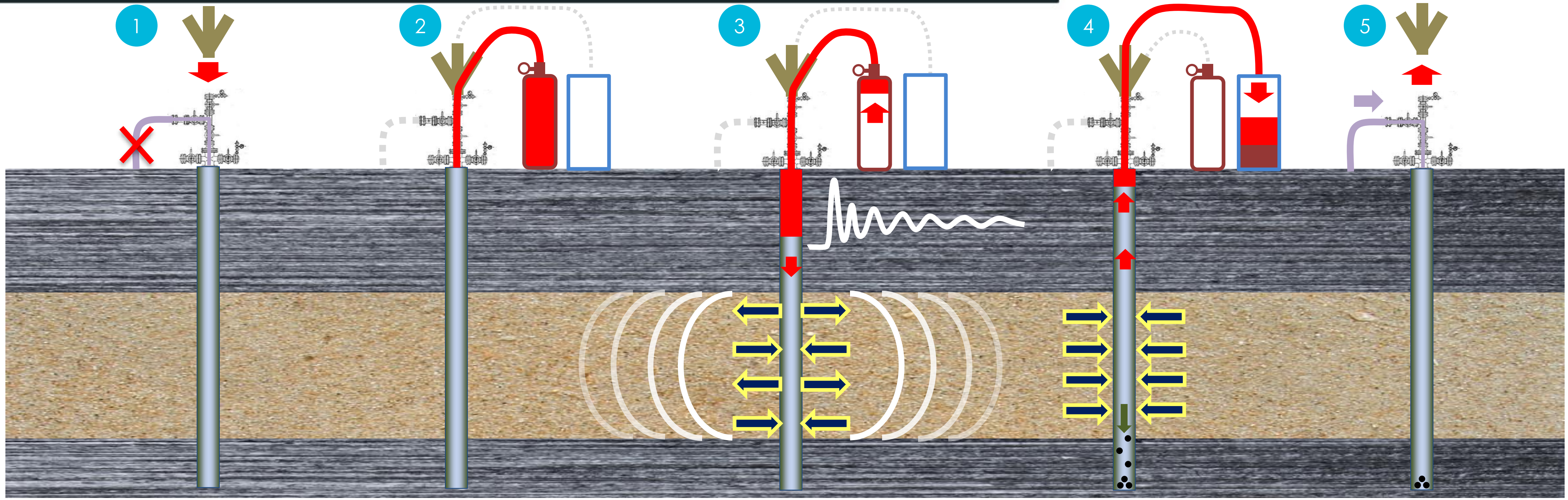

1. Stopping the well, rig-up of the shock module on the christmas tree.
2. The impact on the water column in the tubing by a sharp injection of high-pressure gas (P = 100-150 bar).
3. Hydro pulse and seismic vibrations in the near-wellbore zone (lasts 10-12 seconds). The shock wave travels from the wellhead to the bottom and back several times and fades out.
4. Sharp release of the gas cap from the top of tubing into the receiving tank. The swabbing effect. Particles in free state are removed from the reservoir, fall down in the diphole or carried to the surface by a brief upward flow of fluid.
5. Rig-down of the equipment and start-up the well.

T-SEISMO: TECHNOLOGICAL SEQUENCE AT THE PRODUCER

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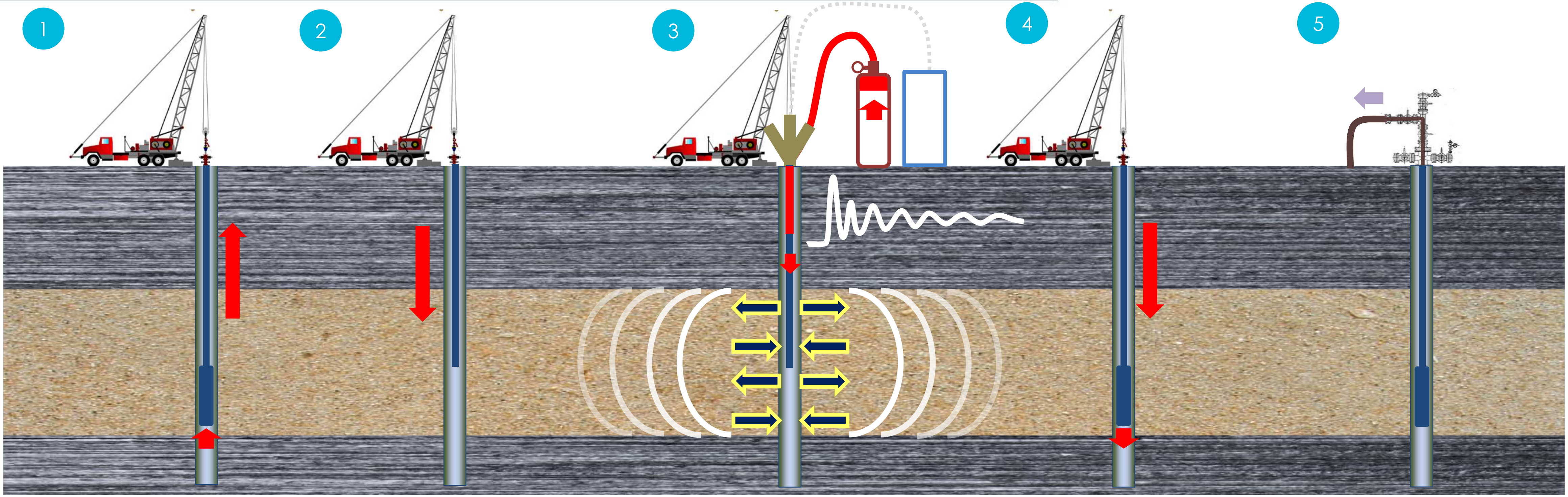
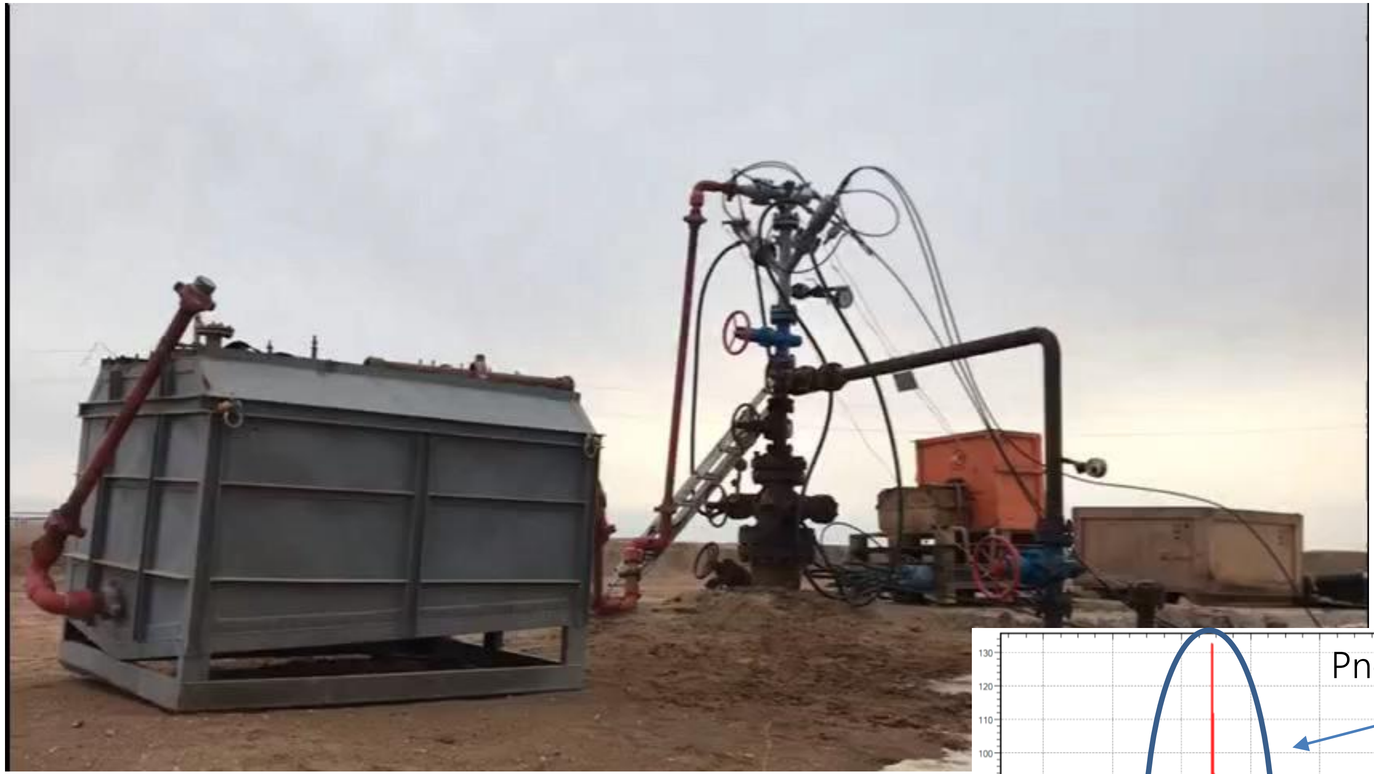


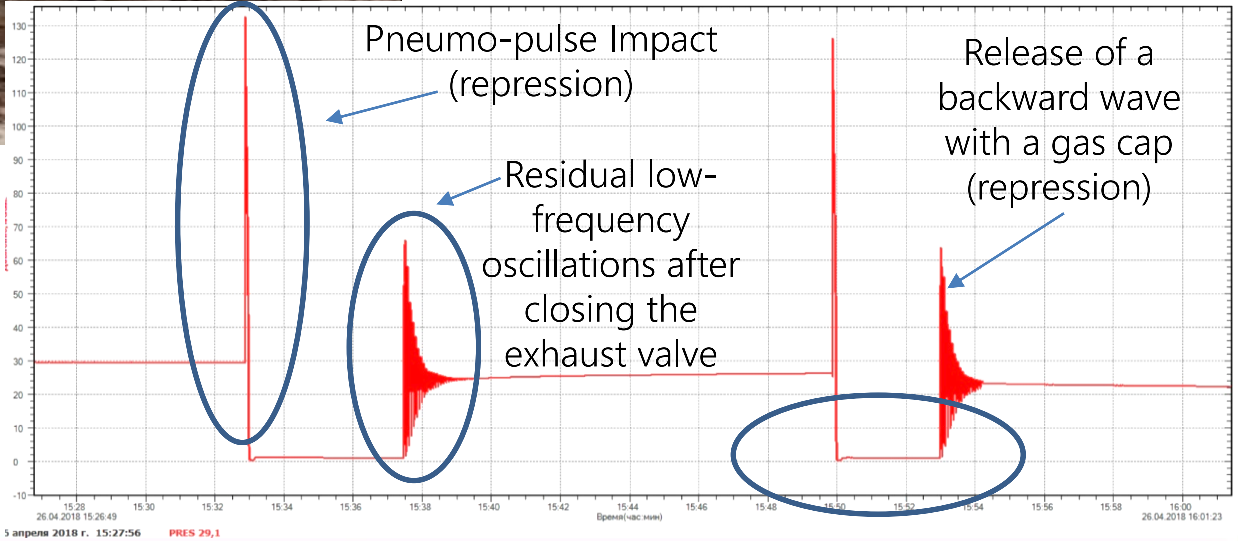
T-SEISMO can be performed during regular workover operations. Treatment time is not more than 12 hours.

1. During regular workover operation crew pulls out downhole equipment (pump).
2. Technological tubing runs for cleanout.
3. T-Seismo equipment is mounted at the wellhead. Impact to the formation via tubing (not more than 6 hours).
4. Workover crew is cleaning the well and downhole equipment (pump) runs.
5. Start-up the well.

EQUIPMENT OPERATION AT THE INJECTOR



Record wellhead pressure
during work (2 cycles of impact)



FIELD CASE 1: STANDART INJECTOR

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Sandstone onshore field

- depth 3500 m;
- net reservoir 17 m;
- porosity (average) 17%;
- permeability (average) 232 mD;
- acid treatment has been applied many times before T-Seismo with limited success.

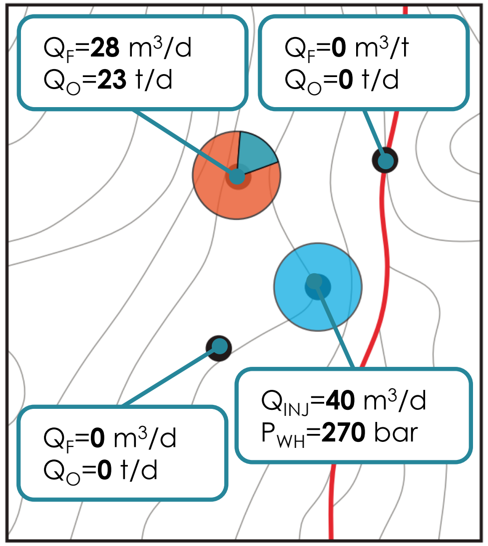
Standard T-Seismo treatment

- has been applied for 7 days.

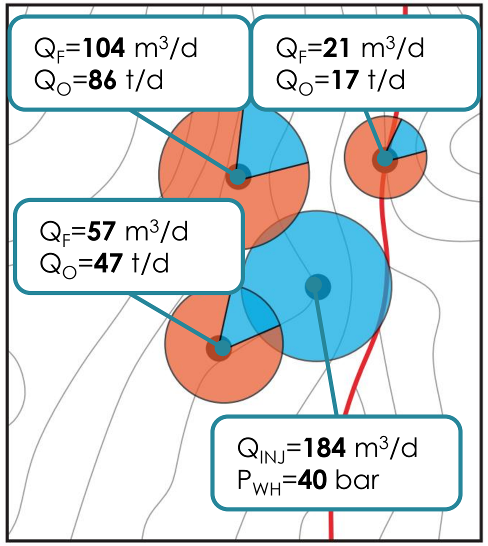
Results of T-Seismo application

- Well injection rate was 35 m^3/d at WHP of 250 bar before treatment;
- Injection rate peaked at 205 m^3/d at WHP of 45 bar after treatment;
- Increased injectivity and productivity were observed for at least 500 days;
- Total incremental oil production: 276,500 bbl;
- Two wells almost no producing prior also responded strongly.

Before T-Seismo



After T-Seismo

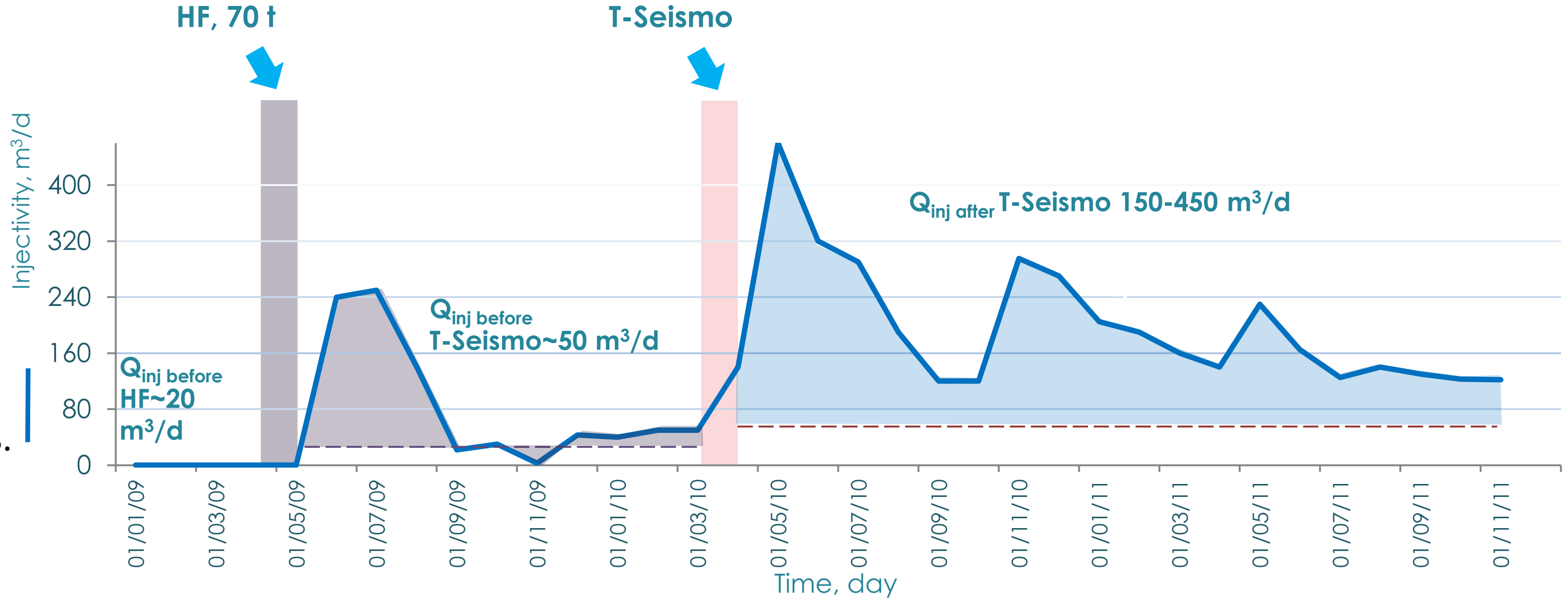


FIELD CASE 2, 3: INJECTORS WITH LOW PERMEABILITY

Treatment of injector (Western Siberia)

Reservoir characteristics:

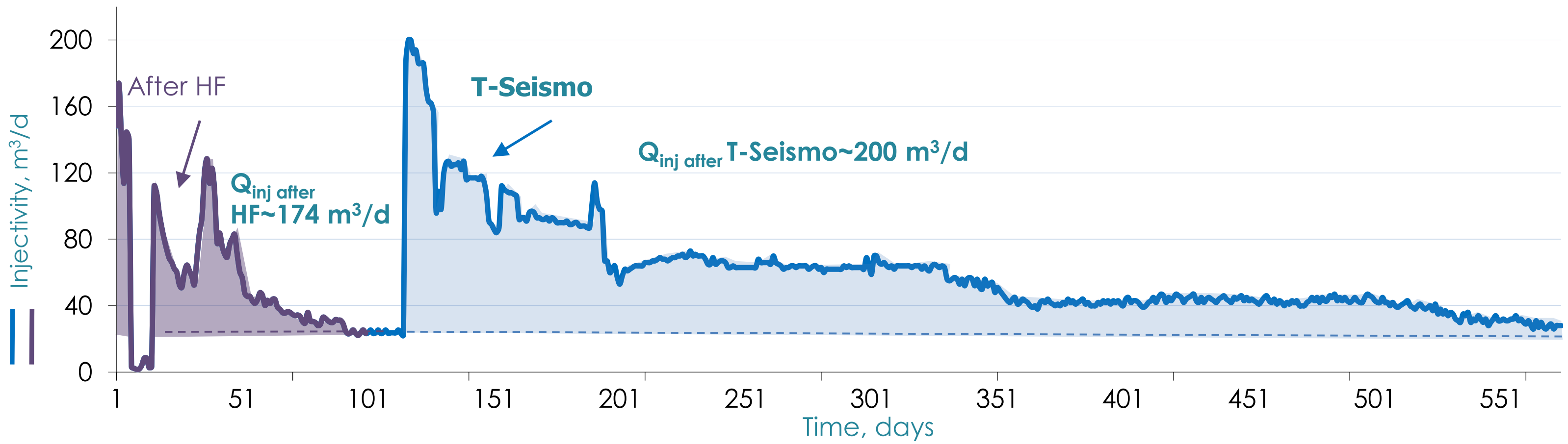
- sandstone;
- permeability 0.8–11.7 mD;
- porosity 14.7–18.3%;
- depth 2416 до 2926 m;
- net reservoir 15.6–41.4 m;
- high clayiness;
- high watercut of reaction wells ~80%.



Reservoir characteristics:

- sandstone;
- average depth: 2400 m;
- net reservoir 12,8 m;
- porosity 18%;
- permeability 2–9 mD.

Treatment of injector (Western Siberia)



COMPARISON WITH COMPETITORS

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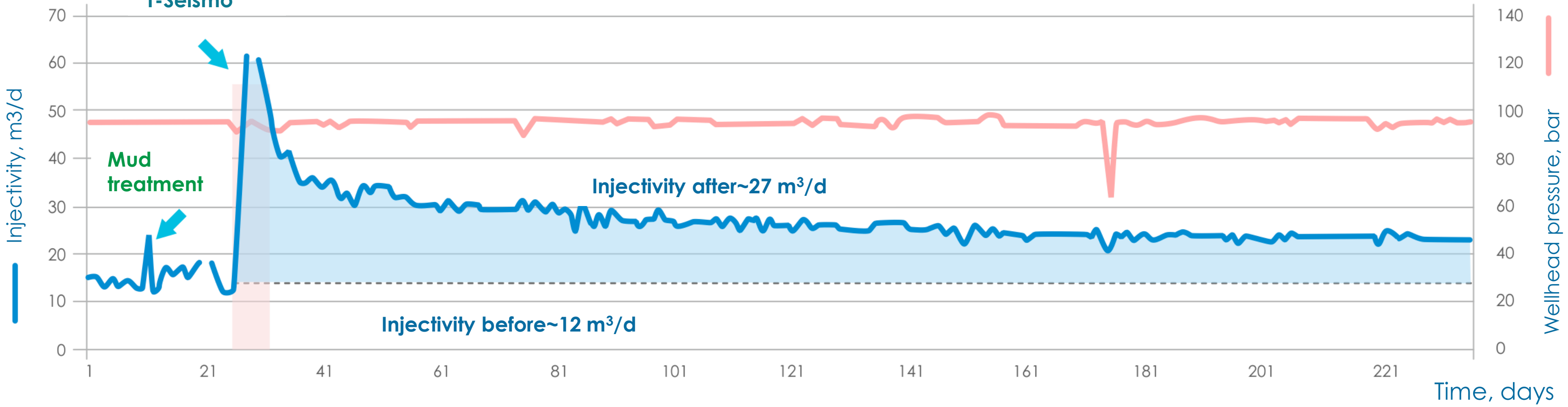
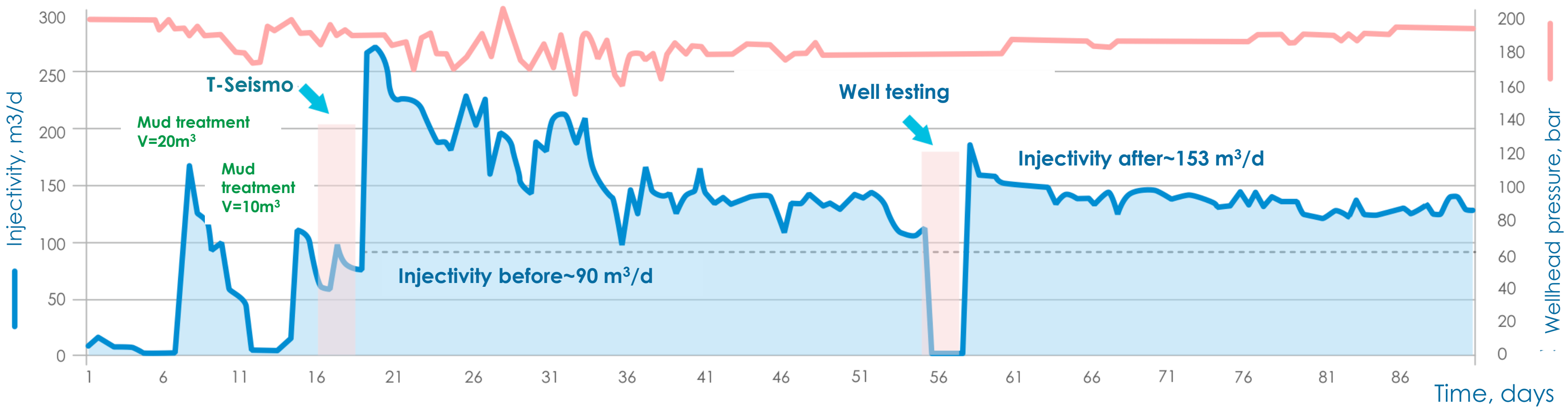
Treatment of injector in East Europe

Old sandstone field. Acid treatments aren't effective.
High water cut of neighboring producers. High risk of hydraulic fracturing.



Treatment of injector in West Siberia



DESCRIPTION OF THE EFFECT FROM IMPLEMENTATION OF TECHNOLOGY

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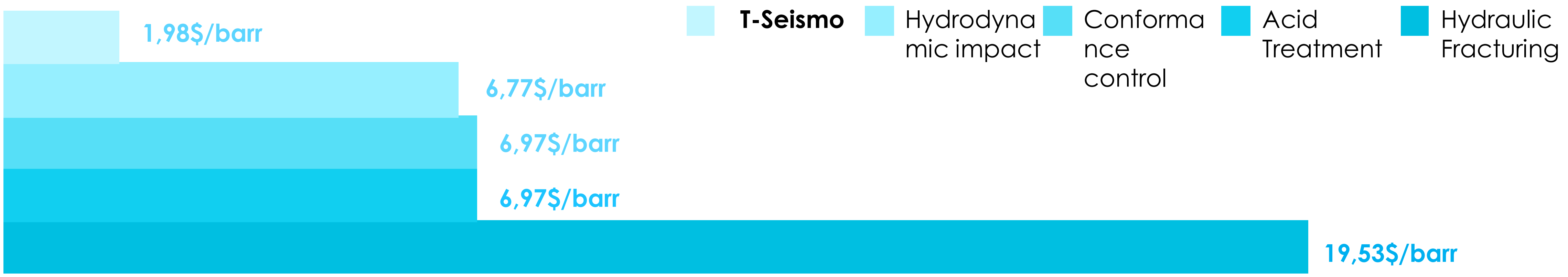
- Success rate: 85-90%.
- Increase of injectivity: range 90-220%.
- Increase in oil production rate on 30% of the base.
- The integrity of the reservoir is maintained.
- No repair crew, no coil.
- Duration of the effect: more than 18 months.

Comparison of cost of additional production
The 1st barrel of Brent oil for various technologies (less-better)



SUMMARY STATISTICS

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Region	Field	Object	Type of reservoir	Type of well	Depth, M	Thickness, m	Porosity, %	Permeability, mD	Clay content, %	Increasing of Injectivity, times	Addit. Oil Prod., ton	Duration, month
	Kharyaginskoe	D2st.		Injector	3700	15	12	206-230	0,58	1-5,5	0-37 039	0-34
	Kharyaginskoe	P2-III,P2-IV; P2-V		Injector	1608 -1640	4,8	22-25	295-984; 1131	0,31-0,54	0,8-2,4	0-4 978	0-25
	Usinskoe	D2st.		Injector	3300	22	13,3	100-145	0,57	1-4	0-14 114	0-32
	Vozeyskoe	D2st.; interlayers I+II+III; P2-III+IV+V		Injector	1428-3270	2,3-8,5	13,3-22	149-168	0,57-0,73	1-10	0-13 535	0-29
	Taylakovskoe	Yu2, Yu3		Injector	2630	4,3	16,6	18	48-83	0,7-6	0-10 049	0-20
	Mamontovskoe	BS10, 11		Injector	2598	6,7	18,3	12,5	35-65	1-2,6	726-3 736	8-18
	Malobalykskoe	Ach1-3		Injector	2610-2727	10,2-29,6	14,4-18,3	1-16,7	30-63	0,7-5	661-6 737	0-30
	Teplovskoe	BS6, YuS2-3		Injector	2211-2996	4,9-6,7	15,5-23	3-328	6-81	1,3-2,5	1 609	3-42
	Priobskoe	AS10-12		Injector	2416-2926	15,6-41,4	14,7-18,3	0,8-11,7	37-96	1,2-6,7	780-22 938	6-24
	Prirazlomnoe	BS4		Producer	2606-2948	9,8-21,5	15,3-17,3	1,84-12,7	11-26	-	156-4 696	3-9
	Katylginskoe	Yu10		Injector	2520	4,7	17,6	12,2	n/d	1-7	156-4 697	3-27
	Vakhskoe	Yu1-1		Injector	2520	2,1-4,7	16,4-17,6	11-18	20-80	1-5	0-12 105	0-36
	Sovetskoe	AV1		Injector	2520	4,7	17,6	12,2	30-50	1	0-376	0-22
	Maloreche	Yu1-2, Yu1-3		Injector	2630	4,3	16,6	18	14-50	1,4	-67	6
Western Siberia	Lomovoe	Yu1-1, Yu1-2		Injector	250	4,7	17,6	12,2	n/d	8	7 146	17
	Karayskoe	Yu1-2		Injector	2550	2,1	16,4	11	18	2,4	5 056	24
	Igolskoe	Yu1-2	Sandstone	Injector	2520	4,7	17,6	12,2	n/d	1	3 126	5
	Sovetskoe	AB1		Producer	2539	2,1	16,9	1,1	30-50	2	0-3 910	0-36
	Osaninskoe	Yu1-1, Yu1-3		Producer	2630	4,3	16,6	18	n/d	-	11 139	29
	Osaninskoe	Yu1-1, Yu1-4		Producer	2630	4,3	16,6	19	n/d	-	11 140	30
	Poludennoe	AB1-3, A2		Producer	2539	2,1	16,9	1,1	n/d	-	72	12
	Karayskoe	Yu1-2		Producer	2550	2,1	16,4	11	n/d	-	1 103	23
	Katylginskoe	Yu1-0, Yu1-1+2		Producer	2520	4,7	17,6	12,2	n/d	-	0-40	0-4
	Luginetskoe	Yu1-2, Yu1-3		Producer	2630-2643	4,3-8,4	16,6-17,8	12,9-18	n/d	-	209-1 791	16-36
	Malorechenskoe	Yu1-0, Yu1-1+4		Producer	2520	4,7	17,6	12,2	n/d	-	571	36
	Niznevartovskoe	BV10-1		Producer	2520	4,7	17,6	12,2	n/d	-	0	0
	Olenye	Yu1(0+1+2)		Producer	2520	4,7	17,6	12,2	n/d	-	1 617	34-36
	Vakhskoe	Yu1-1		Producer	2520	4,7	17,6	12,2	n/d	-	0-6 347	0-36
	Yuzno-Priobskoe	AS10-0-1, AS10-0-3, AS10-4		Injector	2400	11,8-17,6	17,2-18,2	4,9-9,2	50-73	2,3	250-1 400	4-15
Turkmenia	Barca-Gelmes	B4		Injector, Prod.	1895	20	23	28,5	n/d	2	1 609	3-6
Romania	Bordei-Verde, Tasbuga, Geamana, Zemez, Toporu, Recea	Meotian VII+Meotian VIII, Oligocen I Kliwa		Injector	1410-2205	30-148	14-28,3	4-520	n/d	2-6,7	n/d	3-9

CLIENTS

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ГАЗПРОМ НЕФТЬ

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TURKMENNEBIT
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More than **230** treated wells In Russia and abroad.

CONTACT INFORMATION

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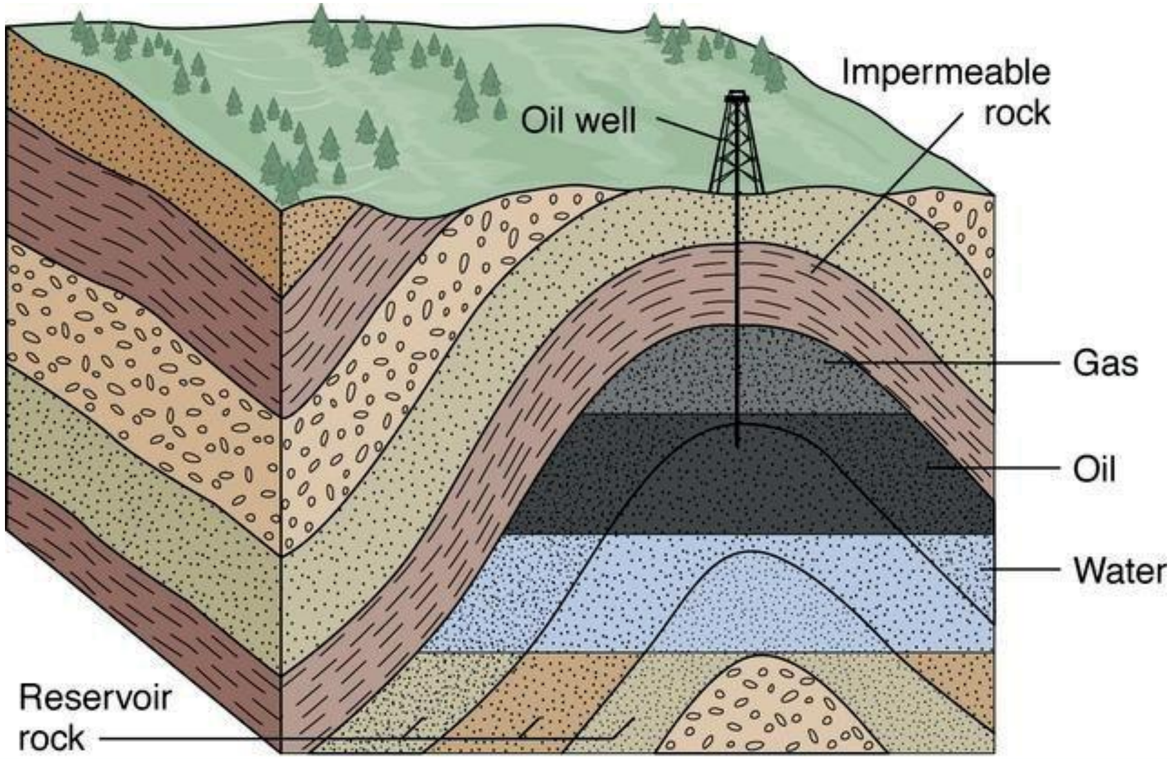
ANNEX

Optimal field criteria

- sandstone (main focus)/carbonate reservoirs*,
  - including sandstone formations with carbonate inclusions or high clay content;
- wide range of oil viscosity: from light to medium-heavy oils
  - technology has been normally applied to fields with oil viscosity <15 cp
- reservoir/layer thickness > 1m;
- average porosity above 12%;
- permeability starting from 1 mD;
- temperature
- depth: confirmed up to 3600 m;
- Stable hydrostatic level at the wellhead
  (leak off rate – not more than 200 mm/min in tubing)

*for carbonate reservoirs and often for producers:

- T-Seismo.
- Acid treatment + T-Seismo.



TERRATEC LABORATORY

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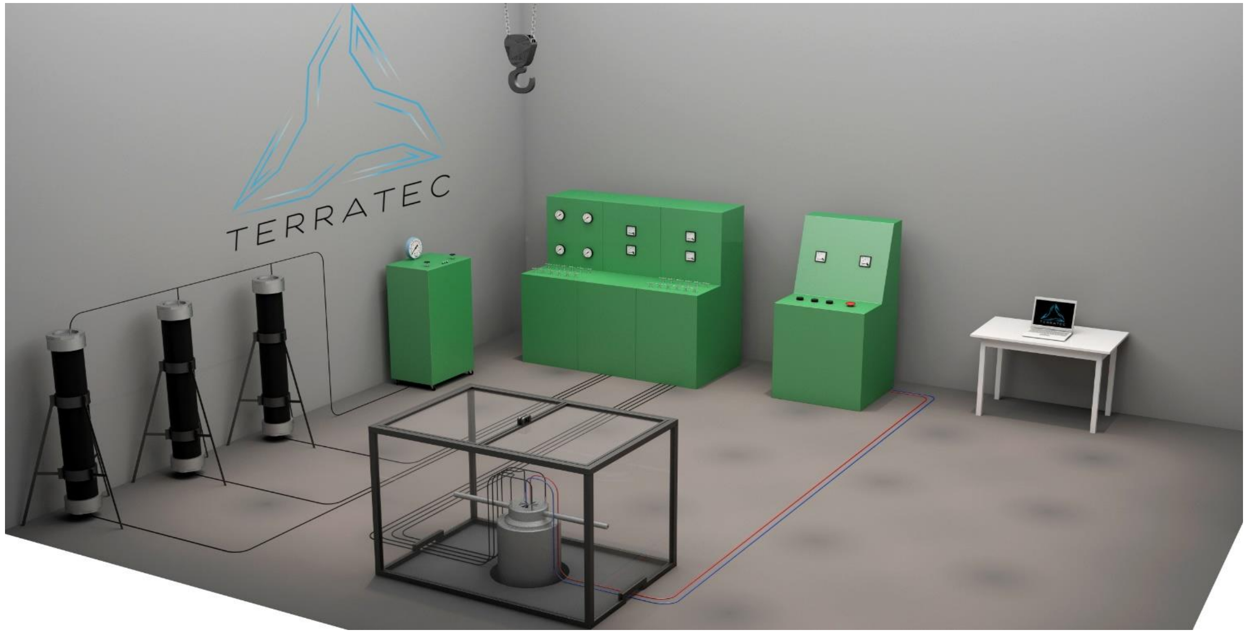
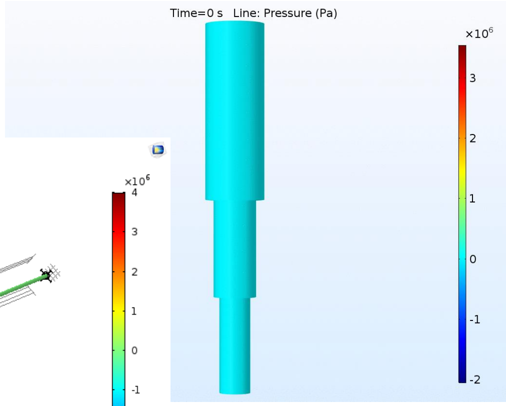
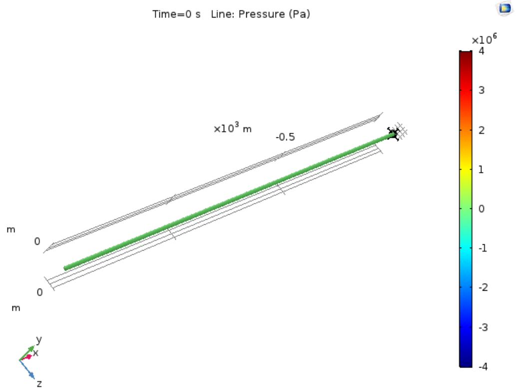
- **Terratec laboratory :** unique equipment for full-scale simulation and calibration of impulse impact on full-size core samples.





- **Modeling** the propagation of wave impact in modern mathematical packages.



- **Customized approach** is the key to effective application of T-Seismo technology: optimization and targeted impact.
    - Test on the customer cores.
    - Mathematic modelling.

FIELD EXPERIMENT CONFIRMS THE RESULTS OF MODELING

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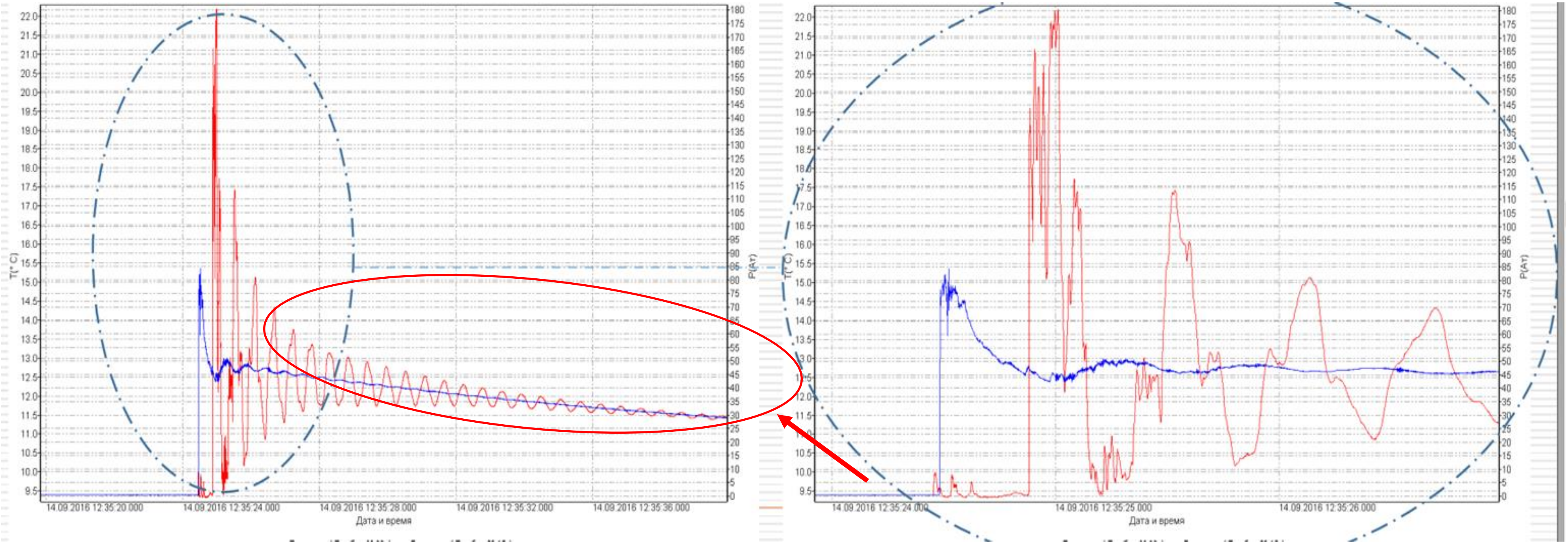

Pressure pulsations at the bottom cause seismic effects on the formation at a frequency of 2-8 Hz

Measurement of pressure pulsations at the wellhead

Measurement of pressure pulsations at the bottom, initiated by pulsations of pressure from the wellhead

STUDIES ON THE PROPAGATION OF A SHOCK WAVE FROM THE WELLHEAD TO THE BOTTOM

SCALE OF MODELING - WELL. NUMERICAL SIMULATION OF THE SHOCK WAVE DISTRIBUTION

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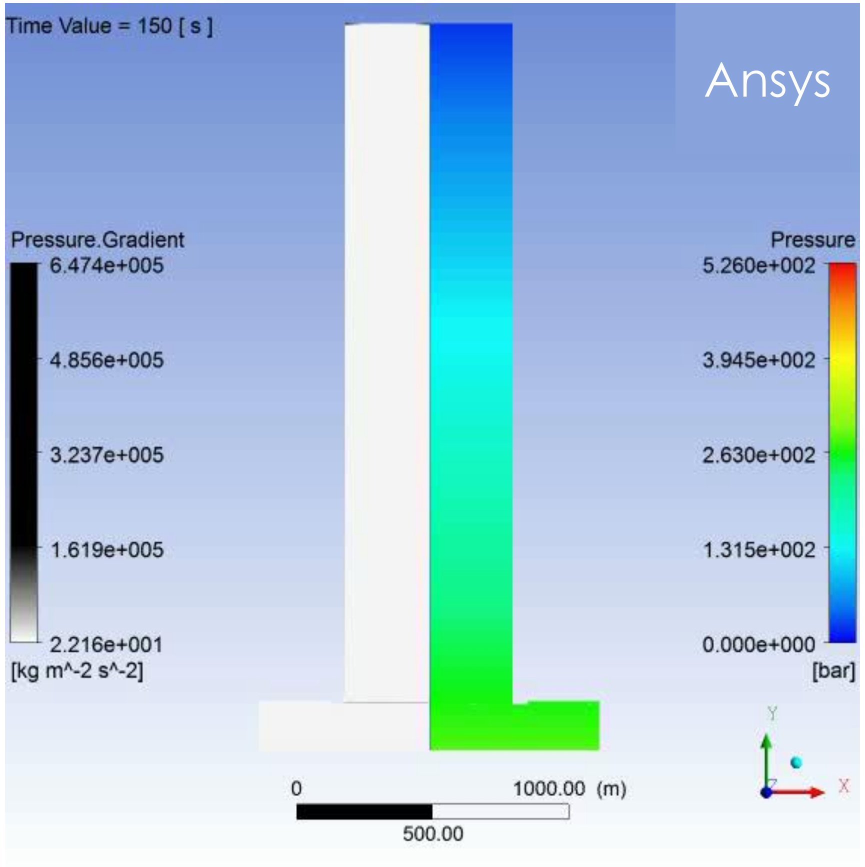
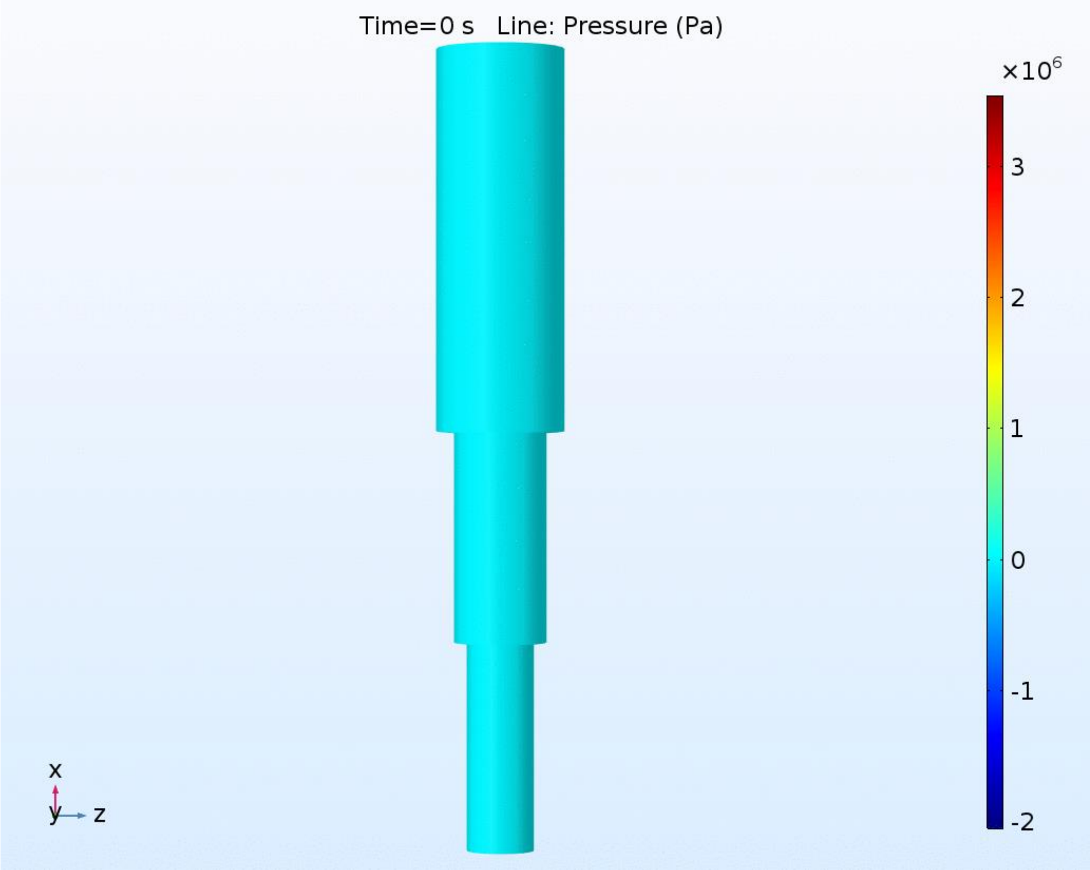
Modeling in Ansys
Typical example. Single impact.

Well depth – 2 500 m



Modeling in COMSOL Multiphysics.
Simulation of Impact for one of the clients in Southeast Asia.
Picture of the pressure field after a single impact.

Well depth – 2 449 m



Numerical simulation of shock wave propagation from the wellhead to the bottom independently by two teams on various specialized software packages showed exceedance of pulsation pressure amplitudes at the bottom in comparison with the initial amplitude of the impact by more than 2 times.