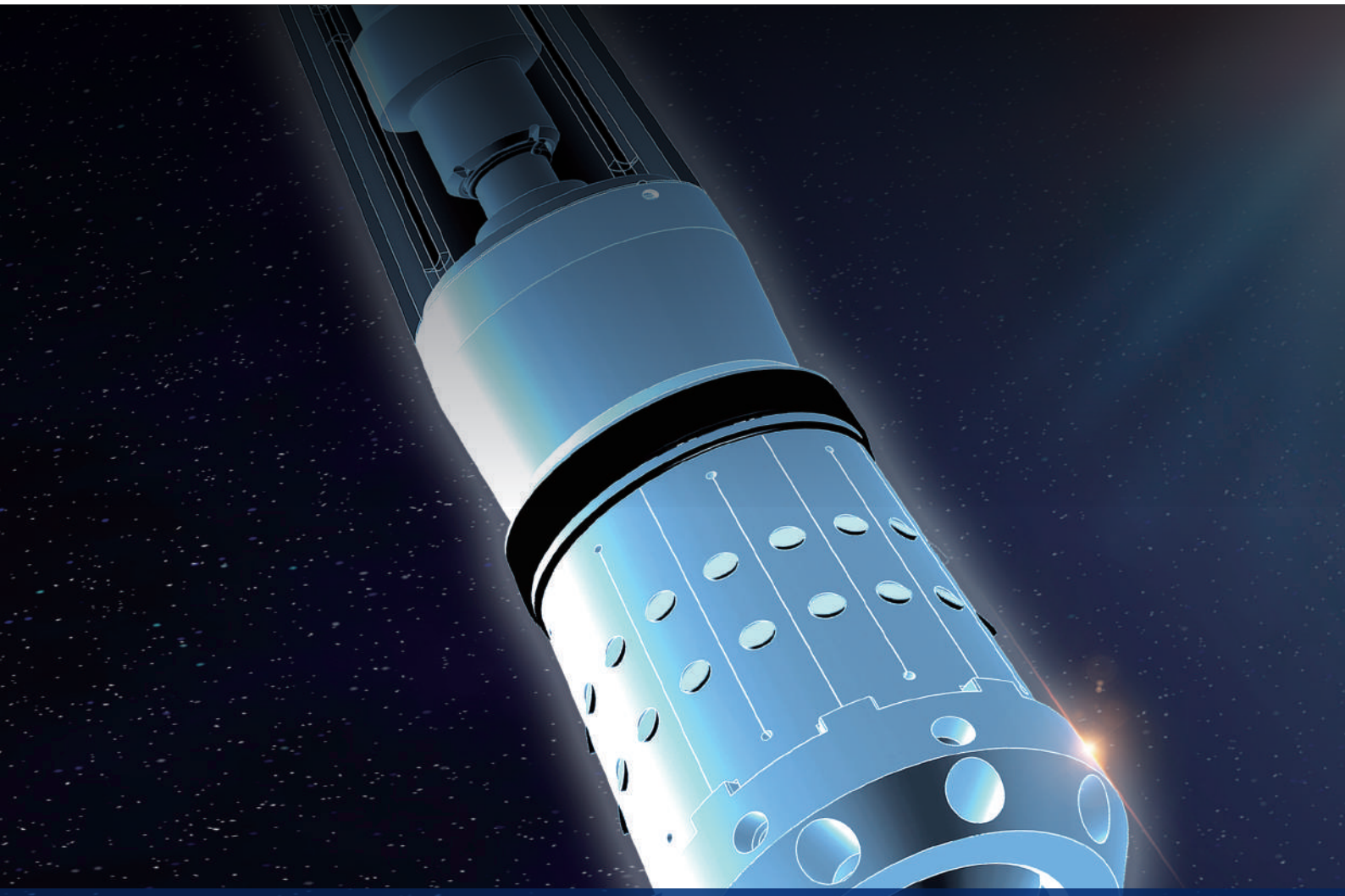
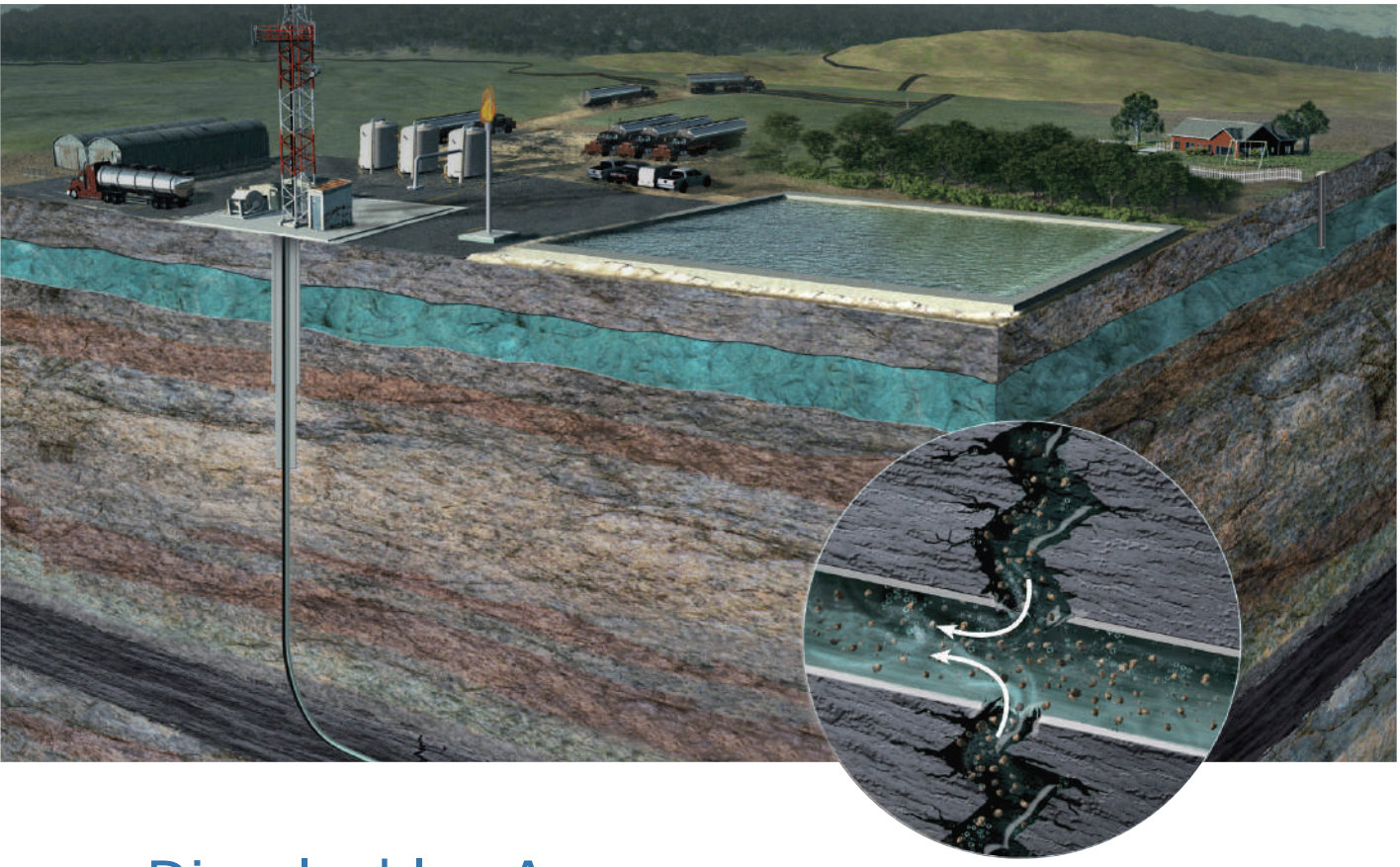


ThunderCloud™ Dissolvable Frac Plugs
The Interventionless Solution

Increased Efficiency, Controlled Dissolution, Faster time to Production

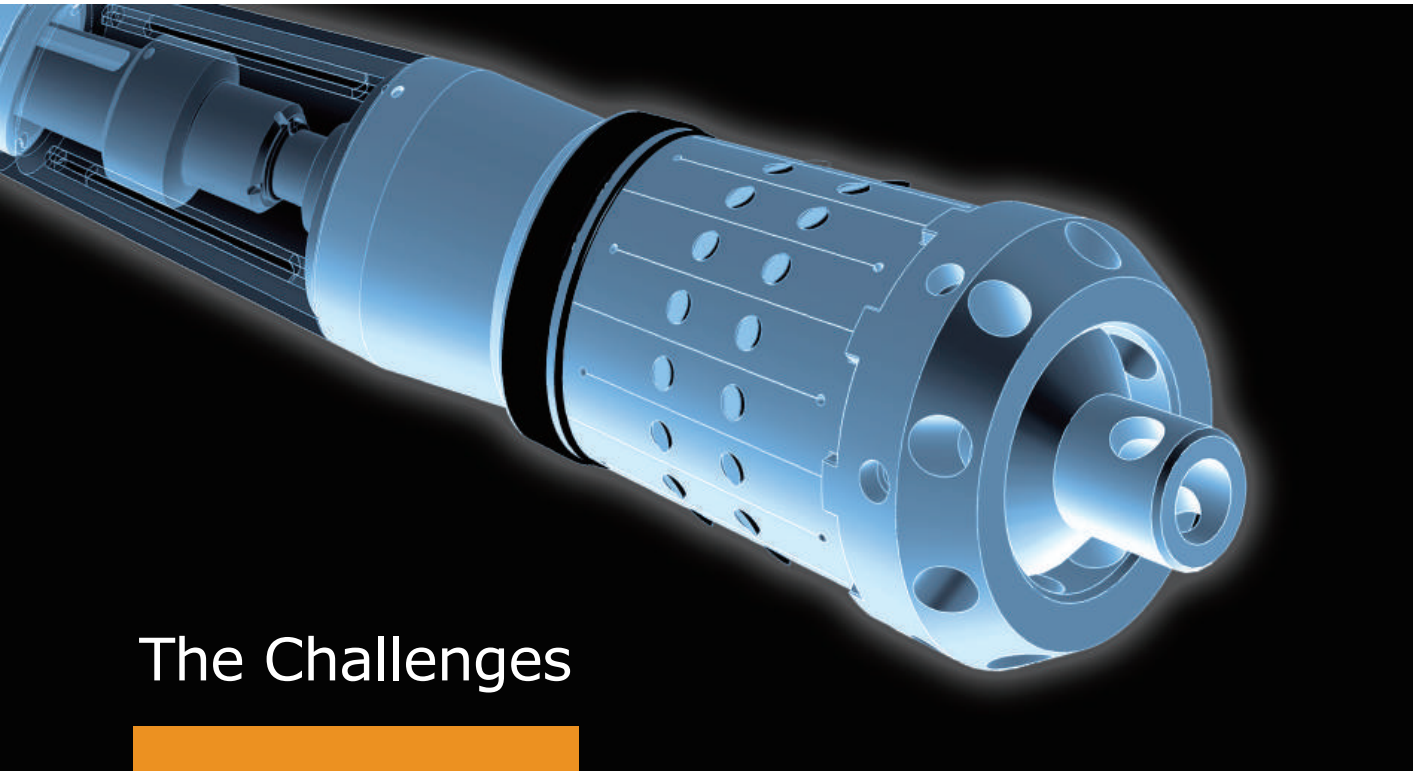
Petrostar | Completion Tools



Dissolvables Age – Extended Technology, Reach, and Beyond

After the first decade of the 21st century, the composite age of frac plugs began growing exponentially. As with many modern technological improvements, the technological improvements for hydraulic fracturing build upon themselves. Unlike previous evolutions in frac plug technology and horizontal drilling which took multiple decades to materialize, the evolution to the dissolvable age happened within a decade. The step change for frac plug technology during this time was the challenge of eliminating or simplifying the coiled tubing mill-out or drill-out operations that had previously been integral to plug-and-perf fracturing. Dissolvable materials were used to create dissolvable frac plugs that greatly reduced the need for milling with coiled tubing. The reduced need for coiled tubing after a successful completion provided a quicker return on investment and lowered overall risk and cost. Extended-reach wells allow more reservoir contact area for a given wellbore without having to drill a new well, however, the need to mill out frac plugs at these extended reaches proved difficult. These two advances together, dissolvable materials and extended reach fracturing, would usher in the start of the dissolvable age of frac plug technology.

—— *(Walton et al. 2019)*



The Challenges

With the designs rapidly changing and dissolving material readily available in the industry, it was now time for the operational processes to catch up with the design, which was a complete reversal when compared to the cast iron-to-composite switch. This led to the current climate for frac plug technology where rapid development is followed by rapid field trialing with the goal of each subsequent step moving the industry one step closer to no longer requiring a milling operation. The current phase in the operational process catchup is one where the use of dissolvables is economically viable in extended-reach applications and often a very minimal clean-out run is required.

The evolution of frac plug technology started slowly but has rapidly expanding over the last decade. The industrial trends point to the continued technological development of hydraulic fracturing to further increase total energy recovery.

- Ensuring zonal isolation requires a frac plug that can pass through the restricted section yet still be set in the nominal casing ID
- Mechanical strength and integrity to isolate effectively, and dissolve fully and efficiently, no matter the wellbore conditions
- BHT, Salinity, PSI rating and Holding Time, Total Dissolving Time and Flow-back plan keys to a successful Dissolvable Frac Plugs plug-and-perf job

WHY ThunderCloud™?

Experience

Established in 2002, listed in HKEX in 2013, Petrostar a Petro-king company, has been a pioneer in the plug and perforate completion technique for decades, gaining great field experience from booming China shale plug-and-perf operations in challenging China shale plays leads the industry with the most reliable completion systems available.

Technology

Our First Generation Dissolvable Plug was introduced to the market in 2017. Through continuous innovation, rigorous in-house testing, and large scale field application and testing Petrostar now offers the Next Generation ThunderCloud™ Large Bore ID, Fully Dissolvable Plugs to reduce or even eliminate the need for Coiled Tubing mill-outs. This reduces or eliminates the costs, risks, and extended reach limitations associated with Coiled Tubing mill-outs.

Reliability

ThunderCloud™ series of Dissolvable Plugs has a standardized line of frac plugs that meet most well conditions and we can also customize our plugs to meet special conditions. Our Dissolvable Plugs have been deployed successfully in thousands of plug and perf operations, successfully holding pressure during fracking, dissolving at predictable rates, and eliminating the cost, time, risks, and limitations of milling out composite plugs.

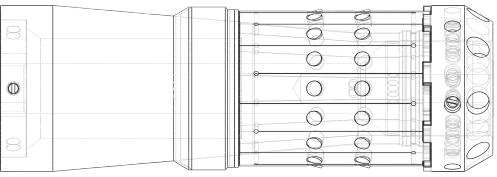
GETTING YOUR DUCs IN A ROW

ThunderCloud™ Dissolvable Frac Plugs The Interventionless Solution

Increased Efficiency, Controlled Dissolution, Faster time to Production

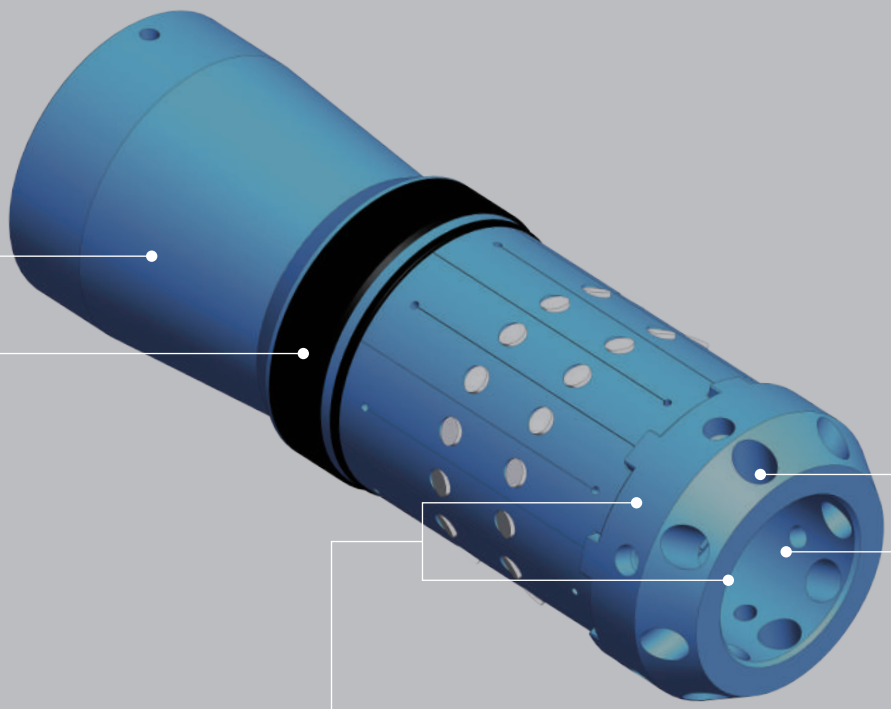
ThunderCloud™ demonstrates our investment in R&D and our commitment to provide customers with the most technologically advanced, innovative, and cost-saving tools on the market. It is a comprehensive upgrade from our previous dissolvable frac plugs that was independently developed and produced by Petrostar. ThunderCloud™ was developed through additional R&D investment, technology, optimization and improvement, rigorous in-house testing, and large-scale field application and testing. ThunderCloud™ is manufactured by utilizing a sophisticated manufacturing and Quality Assurance system. ThunderCloud™ is available through our standardized product line, or can be customized to meet specifications.

ThunderCloud™, a Large Bore, Fully Dissolvable Isolation System adds value to multistage stimulation completions by reducing risks, decreasing costs and increasing production by providing faster production.



Dissolvable Rubber

Dissolvable Metal



Material

Advanced Dissolving Alloy and Rubber materials allows for simpler compact design, design simplifications lowered the overall cost and risk for operation

Reacting Area

Larger external and internal contact areas to reacting fluids for consistent and faster dissolution

Engineering Design

Large Bore ID and By-pass ports for immediate flow-back and higher production prior to full dissolution

Drillabillity

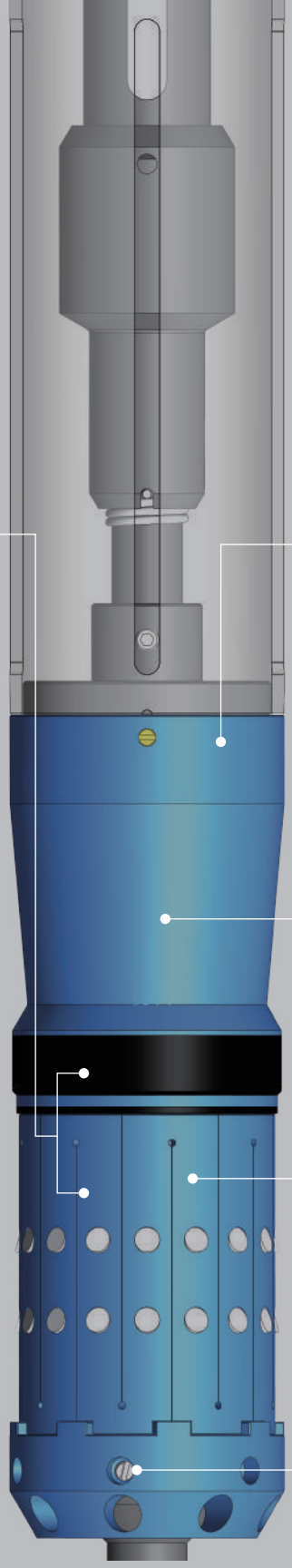
Drillable design enabling fast mill-out if needed

10,000 psi

10,000 psi pressure rating tested and field proven for reliable performance and demanding frac stimulation

Length

Reduced length by 45% increases efficiency in both placement and production, less materials for faster dissolution, enabling the plug dissolvable away downhole over time returning the wellbore back to full bore casing I.D.



Compact

Smaller plug size allowing significantly smaller wellbore foortprint than standard frac plugs. The reduced plug size allows quicker dissolution, more effective plug placement without the need for ID profiling

Anti-Preset

Integrated Anti-Preset features helps ensure that plugs reliably get to depth in even the most demanding environments

Certifications

API Q1

API 14A

API 11D1

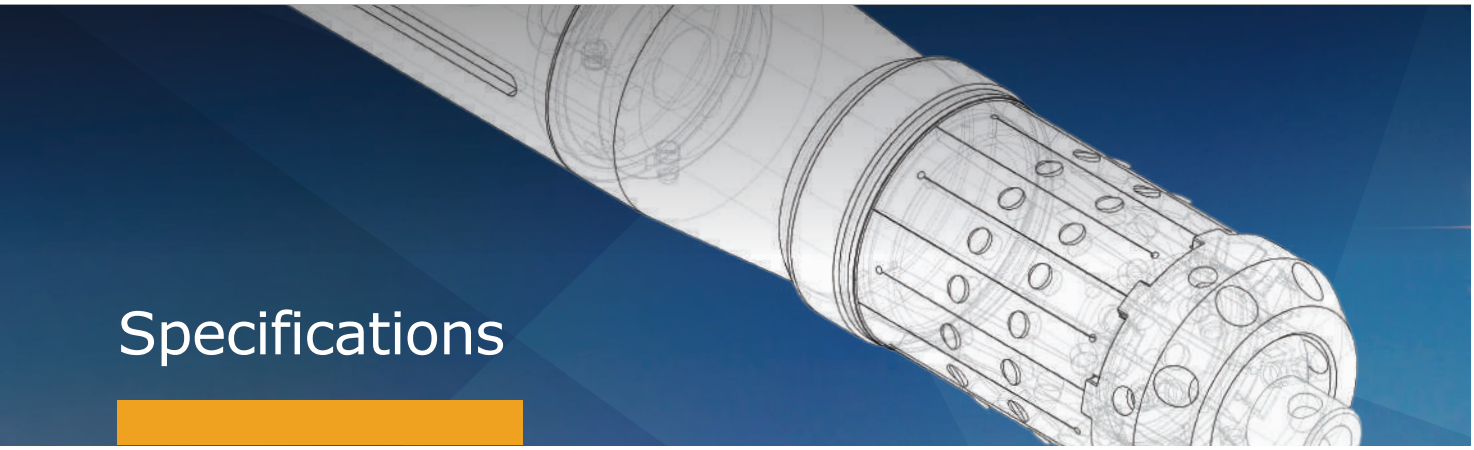
API 6A

API 19G1

ISO 9001: 2015

API 14L

API 19AC

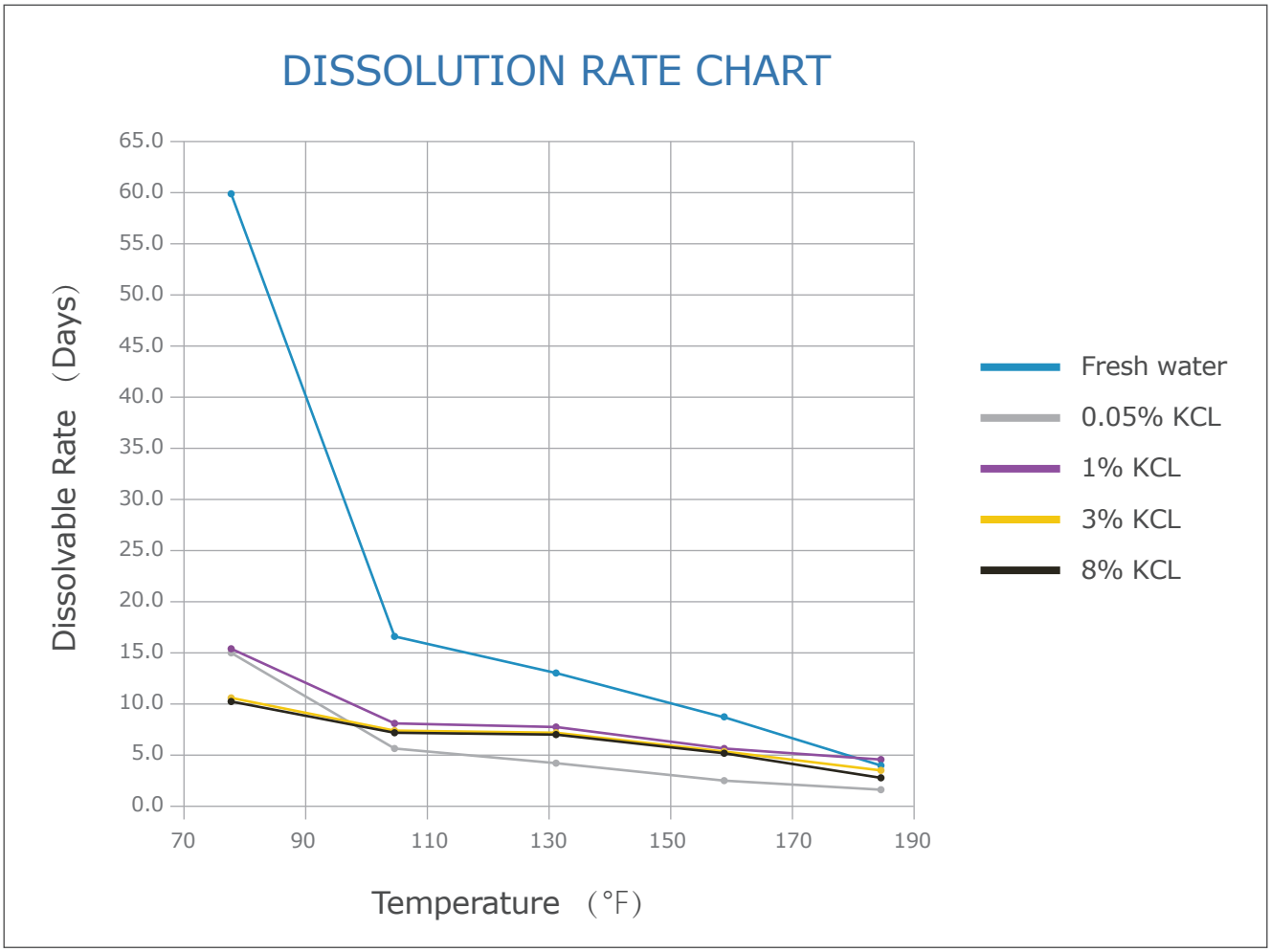


Specifications

ThunderCloud™ - Standard							
Casing (in)	Weight Range (ppf)		Max OD (in)	Min ID (in)	Pressure Rating (psi)	Temperature Rating (°F)	Length (in)
	Min	Max					
5.5	17	20	4.4	2.48	10,000	104 ~ 248	12.99
	20	23	4.33	2.48	10,000	104 ~ 248	12.99
	23	26.8	4.13	1.81	10,000	104 ~ 248	12.99
5	21.4		3.75	1.81	10,000	104 ~ 248	12.36
4.5	11.6		3.75	1.81	10,000	104 ~ 248	12.36
	13.5		3.66	1.81	10,000	104 ~ 248	12.24
	15.1		3.58	1.81	10,000	104 ~ 248	12.24
3.5	9.2	10.2	2.75	0.94	10,000	104 ~ 248	12.04

ThunderCloud™ - Low Temperature & Water							
Casing (in)	Weight Range (ppf)		Max OD (in)	Min ID (in)	Pressure Rating (psi)	Temperature Rating (°F)	Length (in)
	Min	Max					
5.5	17	20	4.33	1.968	10,000	68 ~ 122	20.07
	23	26.8	4.05	1.772	10,000	68 ~ 122	20.07
			3.9	1.654	10,000	68 ~ 122	17.2
5	18	21.4	3.66	1.575	10,000	68 ~ 122	16.53
4.5	11.6	13.5	3.66	1.575	10,000	68 ~ 122	13.93
3.5	9.2		2.6	0.866	10,000	68 ~ 122	10.82

ThunderCloud™ - Conventional							
Casing (in)	Weight Range (ppf)		Max OD (in)	Min ID (in)	Pressure Rating (psi)	Temperature Rating (°F)	Length (in)
	Min	Max					
5.5	17	20	4.44	1.378	10,000	158 ~ 248	23.62
	20	23	4.33	1.378	10,000	158 ~ 248	23.62
	26.8	29.7	4.055	1.378	10,000	158 ~ 248	22.32
			3.897	1.378	10,000	158 ~ 248	22.32
			3.74	1.181	10,000	158 ~ 248	22.32
5	21.4		3.675	1.181	10,000	158 ~ 248	21.96
4.5	11.6	13.5	3.675	1.181	10,000	158 ~ 248	21.96
	13.5	15.1	3.6	1.181	10,000	158 ~ 248	21.96
3.5	9.2	10.2	2.66	0.954	10,000	158 ~ 248	17.2



CASE STUDY

ThunderCloud™ Frac Plugs 18 Stages Fully Dissolved at Low Salinity

ThunderCloud™ ELIMINATED TIME AND MONEY CONSUMING MILLING REMOVAL AT LOW SALINITY DH CONDITIONS

JILING, NORTHEAST, CHINA

WELL PROFILE

- Oil well
- MD 12,169 Ft TVD 7,425 Ft
- 3,871 Ft Hor. Interval
- 4-1/2" 13.5-15.1# Csg.
- DHT 194 F
- CL- 3,000mg/l
- 9,863 psi pressure rated

CHALLENGES

- Low Salinity
- Area Record Plugs to be set
- No CT unit available on-site for
- Contingency mill-out

SOLUTIONS

- Pre-job fluids analysis to select correct grade of dissolving materials needed for the application
- Lab Tested

RESULTS

- Packer Set and Ball Seated with no issues
- Pressure held up when fracturing
- Fully reliable dissolution confirmed by wiper trip conducted 20 days later

OVERVIEW

In an effort to eliminate time and money consuming milling removal of composite plugs, CNPC challenged Petrostar for an interventionless plug-and-perf frac completion by setting 18 dissolvable frac plugs, a record number of plugs to be set at low salinity environment in the 3,871 length horizontal interval in Qian block, Northeast China. A pre-job fluid analysis and rate of dissolving test were conducted to select the correct grade of dissolving materials needed for the application.

OPERATIONS

18 ThunderCloud™ frac plugs were set while the 7th plug set was rerun due to wireline tools malfunction. Fracturing went smoothly with max. pressure recorded at 9,863 psi and pressure held up without any issues. Wiper trip conducted 20 days later, no restriction encountered and fine debris returned verifying the reliable fully dissolution of all 18 plugs.

ThunderCloud™ Frac Plugs Success In Pre-Acid Treatment Application

ThunderCloud™ PROVIDES ZONAL ISOLATION IN PRE-ACID TREATMENT APPLICATION AT CONTROLLED DISSOLUTION RATE

INNER MONGOLIA, NORTH, CHINA

WELL PROFILE

- Gas well
- MD 12,169 Ft
- 2,631 Ft Hor. Interval
- 4-1/2" 11.6-13.5# Csg.
- DHT 200.3 F
- Frac Fluid CL- 3,000mg/l, Formation Fluid CL- 60,000mg/l
- 8,702 psi pressure rated

CHALLENGES

- Pre-acid application
- 20 hours interval from setting to frac

SOLUTIONS

- Lab test for the selection of correct grade of dissolving materials in acidic conditions

RESULTS

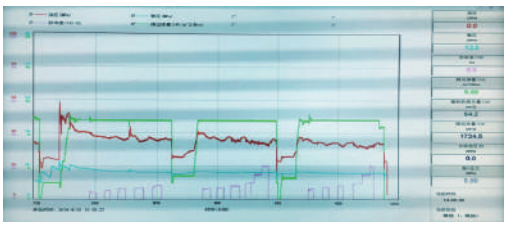
- Packer Set and Ball Seated with no issues
- Pressure held up when fracturing
- All 4 ThunderCloud™ dissolvable frac plugs fully dissolved and CT wipe thru at no time vs. 1.2 days milling out 4 composite plugs at toe section

OVERVIEW

SinoPec one of the largest Chinese operators wanted to test dissolvable frac plugs with direct comparison of composite plugs in a pre-acid treatment application. Total 8 plugs which consists of 4 composite plugs in the toe section and 4 ThunderCloud™ dissolvable frac plugs were pumped down with 8x30m3 HF Acid+12% sulfuric acid completion fluids due to anticipating high formation fracture breaking point. Application with pre-acid treatment is known to decrease the integrity of dissolving materials, which sometimes results in failed zonal isolation. Petrostar conducted lab test for the selection of correct grade of dissolving materials in acidic conditions ensuring reliable integrity of the plugs at controlled dissolution rate.

OPERATIONS

4 composite plugs were first set in toe section, and then 4 ThunderCloud™ dissolvable frac plugs were pumped down with HF Acid+12% sulfuric acid. There was an operational interruption from setting the #3 and #5 ThunderCloud™ plugs and plugs were soaked for 20.5 hours. Fracturing went smoothly with max. pressure recorded at 8,702 psi and pressure held up without any issues. A CT clean up and mill-out operation was performed 8 days later, the first 4 ThunderCloud™ dissolvable frac plugs wipe thru with no restriction encountered, and the following mill-out of composite plugs took 1.2 days.



ThunderCloud™ Frac Plugs Success In Low BHT No Chlorine Content Application

ThunderCloud™ FULLY DISSOLVES AT LOW BHT NO CHLORINE APPLICATION

TUHA, NORTHWEST, CHINA

WELL PROFILE

- Oil well
- 5-1/2" 20-23# Csg. T50
- DHT 104 F
- NO Chlorine Content
- 8,402 psi pressure rated

CHALLENGES

- Low BHT
- No Chlorine Content

SOLUTIONS

- Special Dissolving materials with self-heating features
- Lab tested
- 8 ThunderCloud™ Low Temperature Dissolvable Frac Plugs

RESULTS

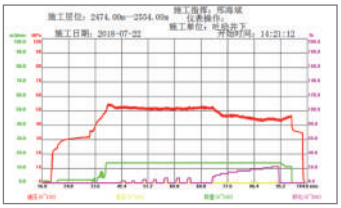
- Packer Set and Ball Seated with no issues
- Pressure held up when fracturing
- Immediate flowback after frac.
- Fully Dissolution confirmed by fine returns in a fullly flowback 20 days later

OVERVIEW

SinoPec one of the largest Chinese operators performing plug-and-perf completion in Northwest China wanted to lower operation cost by eliminating CT mill-out post-frac treatment and extensive debris removal by using ThunderCloud™dissolvable frac plugs in a well with low bottomhole temperature (BHT) of 104 F and at nearly zero chlorine content. Petrostar recommended an new series of ThunderCloud™ Low Temperature Dissolvable Frac Plugs with correct grade of dissolving materials in this challenging application ensuring fully dissolution and reliable integrity.

OPERATIONS

8 ThunderCloud™ Low Temperature dissolvable frac plugs were set. Packer set and balled seated without any issues. Fracturing went smoothly with max. pressure recorded at 8,402 psi and pressure held up without any issues. The customer was able to successfully flow back the wellbore and start production without issues. The fully flow back 20 days later with fine returns confirming all 8 plugs were fully dissolved.



ThunderCloud™ Frac Plugs Fully Dissolved In Low Salinity Application

ThunderCloud™ MITIGATED CONCERNS OF FULLY DISSOLVING IN A LOW SALINITY DH CONDITION

JILING, NORTHEAST, CHINA

WELL PROFILE

- Oil well
- 2,720 Ft Hor. Interval
- 5-1/2" 20-23# Csg.
- DHT 206.6 F
- CL- 3,000mg/l
- 9,427 psi pressure rated

CHALLENGES

- Low Salinity
- No CT unit available for
- contingency mill-out

SOLUTIONS

- Customized design
- Lab Tested
- 7 ThunderCloud™ Dissolvable
- Frac Plugs

RESULTS

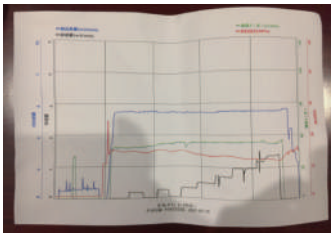
- Packer Set
- Ball Seated
- Pressure held up when fracturing
- Fully reliable dissolution confirmed by wiper trip conducted 7 days later

OVERVIEW

To reduce cost and completion time, CNPC one of the largest NOC China opted to use dissolvable technology to omit CT mill out intervention. But there were concerns about the capability to fully dissolved in the low salinity completion fluids. Petrostar tested and introduced an new series of ball and plugs with customized recipe. 7 ThunderCloud™ frac plugs were installed and well was isolated for fracturing without any issues, wiper trip conducted 7 days later confirming all plugs, balls were fully dissolved with fine debris returns.

OPERATIONS

7 ThunderCloud™ frac plugs were installed. Packer set, Balled seated and confirmed by pressure rating, Fracturing went well with max. pressure recorded at 9,427 psi and pressure held up without issues during fracturing. Wiper trip conducted 7 days later, no restriction encountered and fine debris returned verifying the reliable full dissolution.



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