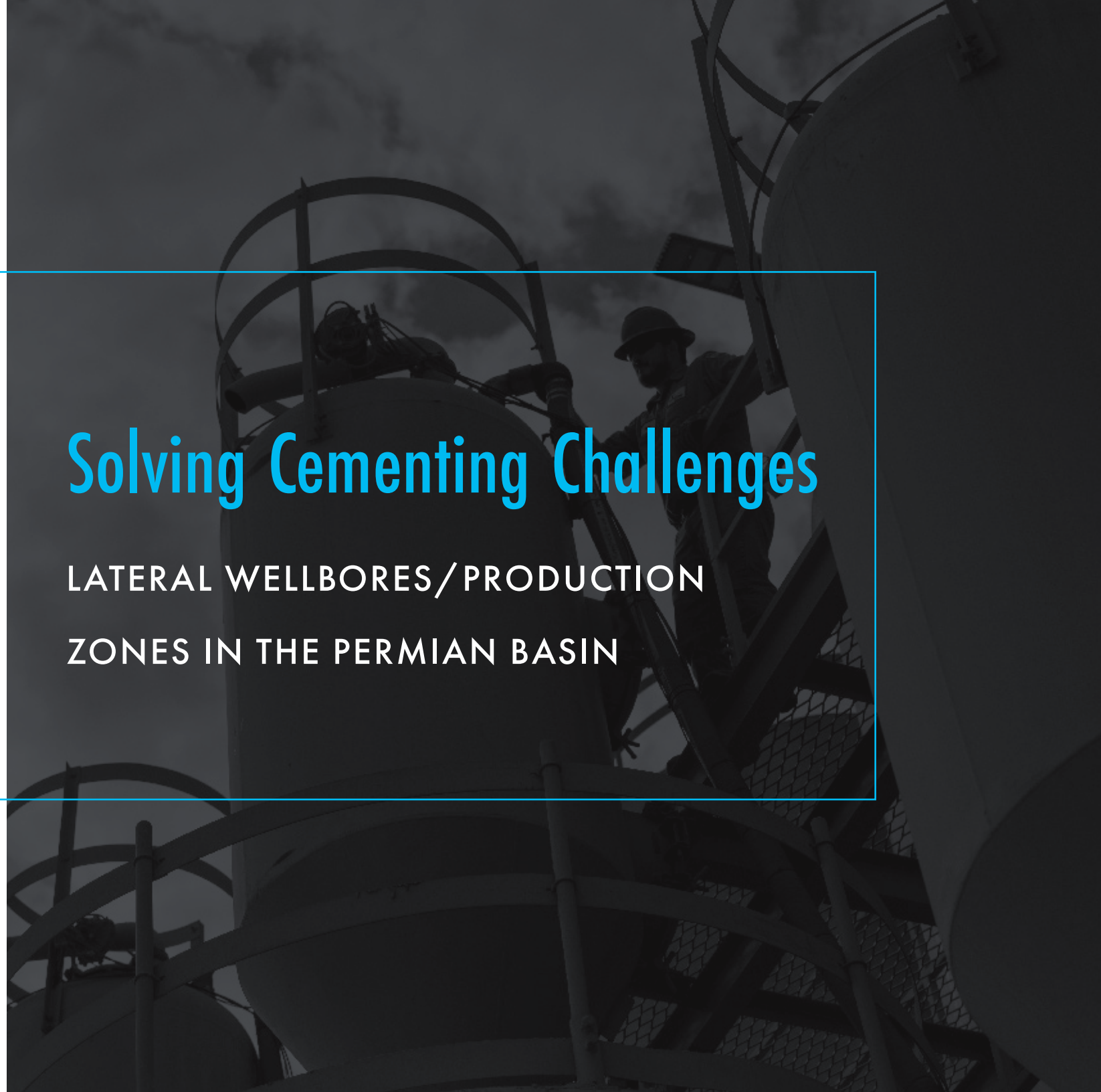
Nine



Solving Cementing Challenges

LATERAL WELLBORES/PRODUCTION ZONES IN THE PERMIAN BASIN

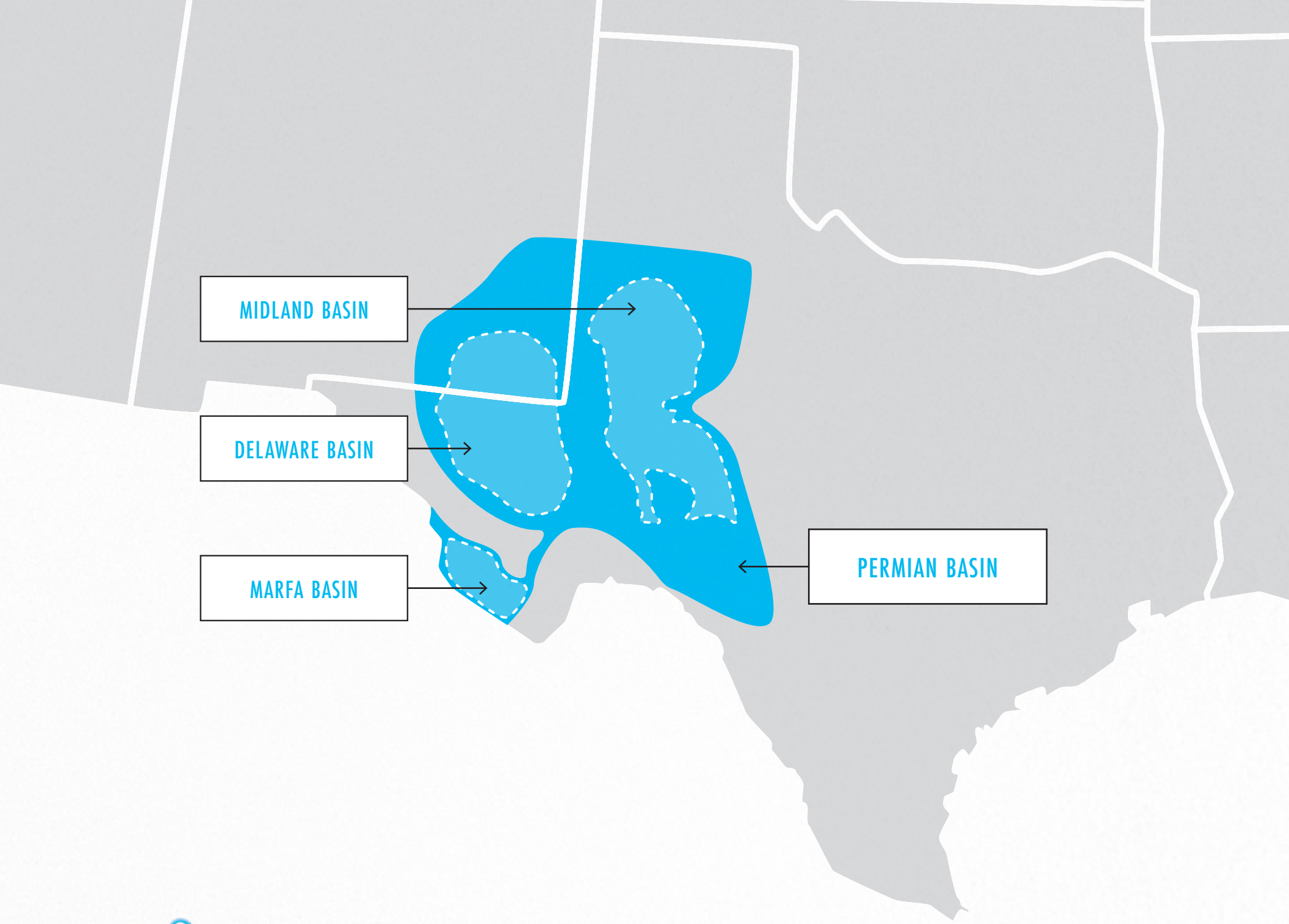
CONTENT

SECTION 1

A FRAGILE RESERVE

THE PERMIAN BASIN

The Permian Basin, which sprawls across West Texas and into New Mexico, encompasses the Midland, Delaware, and Marfa Basins. Although it produces more oil than any other field in the United States, it is considered a highly complex, fragile formation due to tight windows between pore pressure and fracture gradients. Static and circulating temperatures are relatively low and rarely reach up to 200°F.


MIDLAND BASIN
DELAWARE BASIN
MARFA BASIN
PERMIAN BASIN

SECTION 2

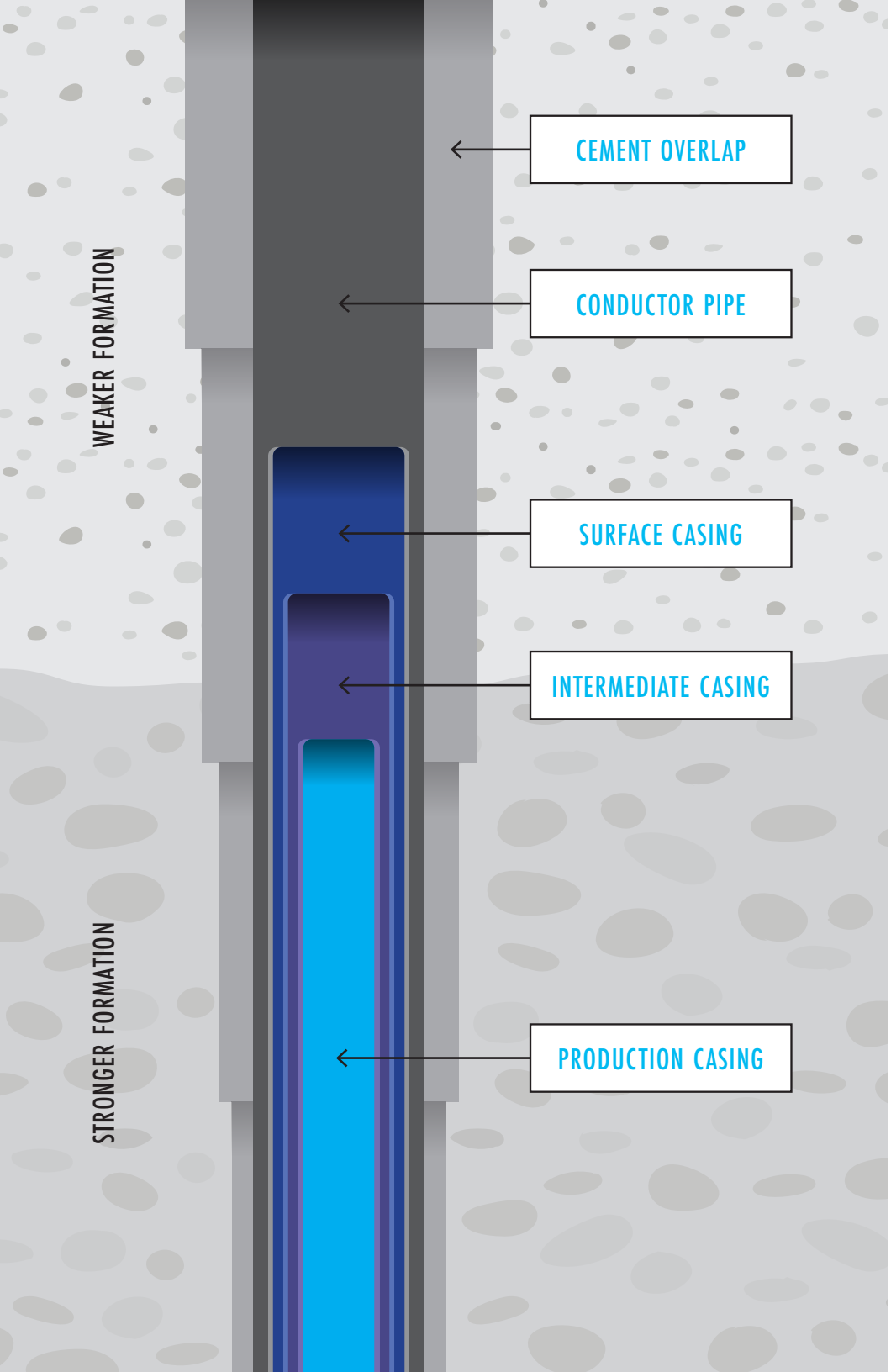
CHALLENGES FOR HORIZONTAL CEMENTING OPERATIONS IN THE PERMIAN

PRESSURE TO MAXIMIZE

For operators in the Permian, there is strong pressure to maximize economic efficiency in wells with laterals that keep getting longer. Operators routinely drill laterals that reach 3 miles or longer. Economic success depends largely on optimizing zonal isolation by creating a cement sheath that protects the casing and prevents fluid migration. In the Permian Basin, cementing objectives are often complicated by features of the formation, particularly depleted weak zones and salt zones.

WEAK ZONES

The formations in the Permian at or near 6,000 ft are weak, especially in the Delaware Basin. Achieving top of cement to the desired depth is a challenge because friction pressure or hydrostatic pressure can cause formation rock to crack. Operators often use multistage tools to divide the cement columns into shorter, more manageable heights, which lowers the hydrostatic pressure against the wellbore wall on weak strata. Multistage tools do increase the cementing operation time, which also increases operator costs.



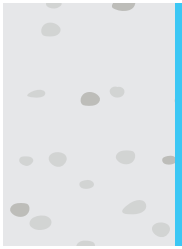
CASING STRINGS

Weaker formations require more multistage tools because they fracture more easily.

In the Permian Basin, it is common to have three or more casing strings if the formation requires.

SALT ZONES

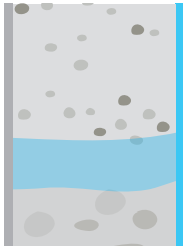
There are many salt zones in the Permian Basin, and these are especially notable in the Delaware Basin. Salt is water-soluble, so it dissolves when it encounters water-based drilling fluids, creating large, irregular voids in the wellbore. In the Permian Basin, salt zones may lead to excessive washout.



Salt zones could also accelerate cement, so it is important for operators to select cement slurries that contain salt.

FORMATION FLUIDS

The Permian Basin is rich in hydrocarbon resources, and the presence of oil and natural gas in the formation fluids can affect cementing jobs. Operators sometimes encounter hydrocarbon intervals in laterals where oil-based mud (OBM) or synthetic-based mud (SBM) channels form. If hydrocarbons fill these voids, this can interfere with cement bonding, cause poor zonal isolation, and detract from overall stimulation.



Formation water, formation gases, salt water, and drilling fluid residues can also create problems for cementing jobs.

SECTION 3

IMPORTANT SUCCESS FACTORS

AVOIDING COSTLY MISTAKES

In a fragile formation such as the Permian, operators must consider many factors to avoid costly mistakes when cementing:

1. The Right Slurry: Relevant and Protective
2. The Right Spacer Fluid: Flexible Optimization
3. The Right Pump Rate
4. Simulation: A Precursor to Success

THE RIGHT SLURRY: RELEVANT AND PROTECTIVE

The success of a cementing operation hinges upon slurry selection. When selecting a slurry for a cementing operation, Permian Operators need to identify slurries that are both relevant for the conditions and protective against harmful formation fluids.

RELEVANT

Slurries must align with the specific conditions of the well, including temperatures, pressures, and formation complexities. In the Permian, it is best to find a slurry that can be adjusted for a range of temperatures and has thixotropic and low fluid loss properties. Low-density, high-strength formulations help prevent circulation loss by decreasing the hydrostatic pressure of the column.

SLURRY & ADDITIVE SAMPLES

FLOWLOK

A specialized combination of additives

CRACK ATTACK

Multi-particle size lost circulation material

FLEX 50H

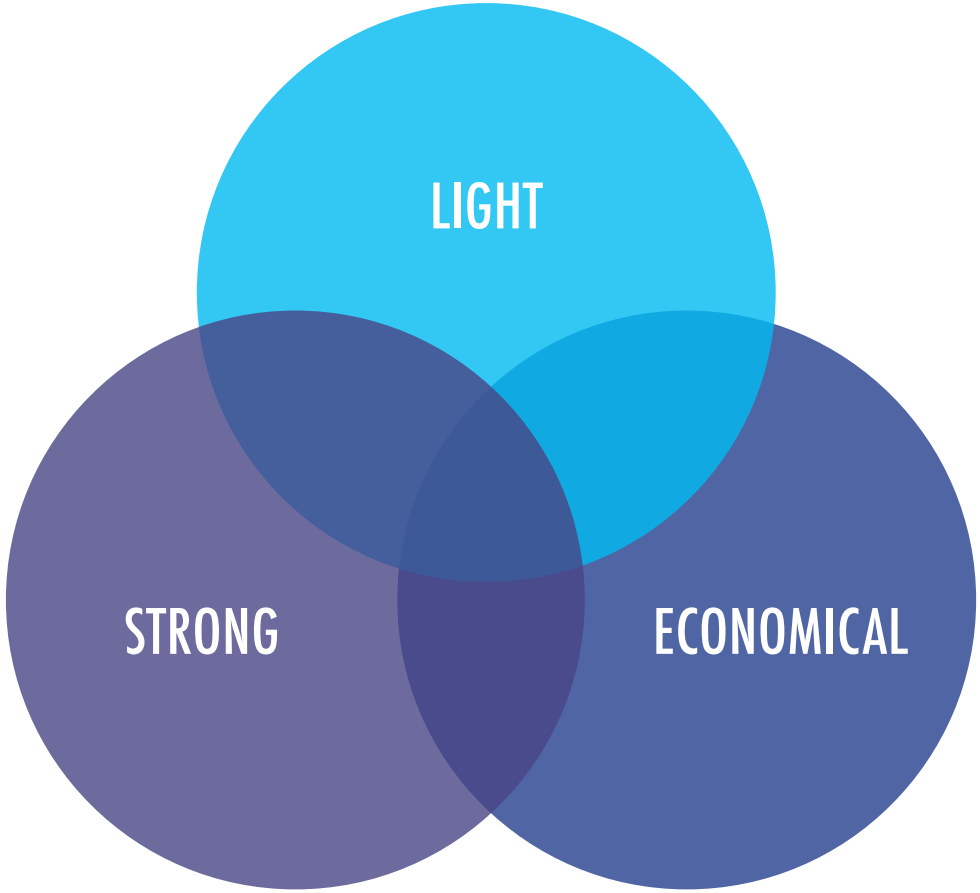
A versatile, advanced polymer additive

Low-density cements include lightweight additives that minimize lost circulation. Water extended cement, foam cement and beaded cement slurries are all low-density slurry options available to operators. Beaded cements are especially suited to the Permian. The best beaded slurries use engineered hollow glass spheres (not cenosphere beads, which are energy byproducts). Specific gravity is important for bead selection because the heavier the beads are, the more beads must be run to get the same properties out of the slurry. Beaded slurries can be as lightweight as 8.7 lb/gallon of slurry and achieve 500+ psi in 72 hours. They are both high performing and costly.

ESG WIN:

Lightweight technologies reduce reliance on fly ash, a coal byproduct, in cement jobs.

The ideal cement slurry for the Permian is light, strong, and economical. In reality, operators can generally **choose two** of these three options.



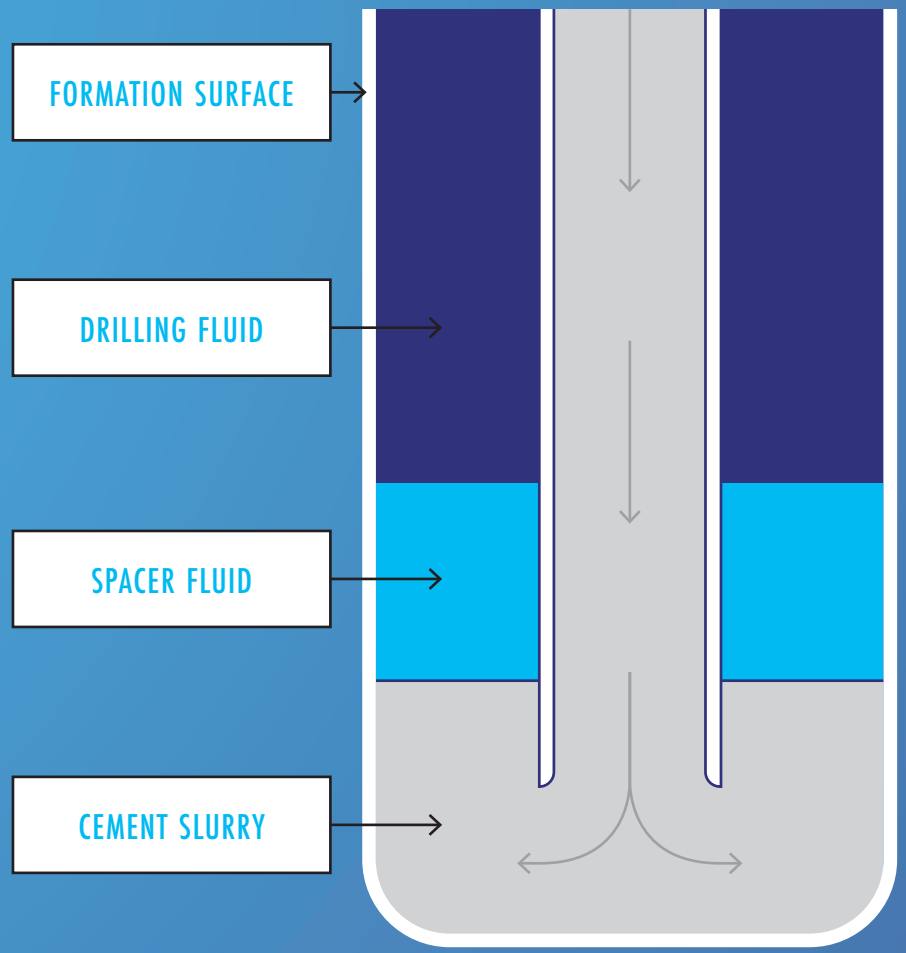
PROTECTIVE

Hydrocarbons and other formation fluids can be damaging to a cement sheath, deteriorating it over time and compromising its sealing properties. As a protective measure, Permian operators need to ensure that their slurries are compatible with the formation fluids at play.

Cement options include reactive additives that swell to seal off cracks when they contact hydrocarbons. To provide adequate contact area, operators should use a minimum additive concentration of 10 to 15 lb./bbl. Maximize the concentration of additives, keeping slurry mixability and stability in mind.

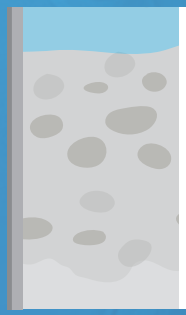
THE RIGHT SPACER FLUID

Spacer fluids help the mud displacement process and optimize zone isolation in horizontal wells. Spacer fluids must be compatible with the drilling fluid and the cement slurry and, in the Permian, must remain stable at temperatures of up to 200°F. Permian spacer fluid should also allow for casing rotation throughout the entire production, which will help overcome torque limitations, dramatically improving the quality of the cement job.



SPACER FLUID SHOULD ALSO INCLUDE THE FOLLOWING FEATURES:

+ Flexible design rheology with density
+ Sealing properties
+ Wettability of pipe for bonding
+ Reduced fluid loss in cement
+ Loss control
+ Excellent mud removal



Reactive spacers may also be helpful in preventing lost circulation in the Permian. Reactive spacers with the addition of lost circulation materials (LCMs) can help to heal seepage.

SALTY SOLUTIONS: GETTING AHEAD OF EXCESSIVE WASHOUT

Washouts do occur during drilling in the Permian, but best practices can prevent the situation from becoming worse. To limit further washout, a general best practice is to run a spacer with LCM followed by a slurry with salt. These slurries are designed with thixotropic properties and lost circulation properties to correct washouts. The slurry should gel up or stack upon itself when it reaches the opening into the formation instead of rushing through.

RECOMMENDATION:

Use a slurry that contains salt at around 5% by weight of water (BWOW). For salt domes, use salt saturate slurries.

THE RIGHT PUMP RATE

A consistent but maximized pump rate is vital to creating a strong cement sheath. The goal is to maximize the pump rate without fracturing the formation.

OPTIONS TO IMPROVE A PUMP RATE INCLUDE:

1

PUMP TRUCKS

2

BLENDERS

3

BLENDERS + FRAC PUMP

SIMULATION: A PRECURSOR TO SUCCESS

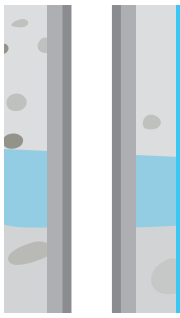
Simulations can be an immense boost to the success of a cementing operation. Job simulations take into account the geology of the location, well geometry, the physical properties of fluids and friction pressure from the pumping operations to determine the rates, volumes, and tops that can be achieved to balance pore pressure and fracture gradients. Cement simulation allows operators to fine tune pump schedules and overall cement job design. They can also calculate how much time the cement requires to be workable and involve safety factors.

SECTION 4

CASE STUDIES

FLUID FLOW CONTROL CEMENT

A study published by the American Association of Drilling Engineers (AADE-23-NTCE-038) demonstrates how the composition of cement can eliminate water flows on intermediate strings in the Permian. Focusing on the Midland and Delaware Basins, the case study shows the efficacy of fluid flow control (FFC) cement slurries through a review of 75 applications in both primary cementing and remedial cementing.
For well construction operations, in 42 well intermediate cement jobs, fluid flow was reduced from 50% to 9%.



MULTIFUNCTIONAL CEMENT SPACER SYSTEM

A study of 60 jobs using a spacer system with LCM and thixotropic cement in the Midland Basin (AADE-22-FTCE-009) showed that the operator was able to move from a two-stage to a single-stage process with a higher success rate and lower cement volumes. The study concluded that cementing treatment in the Midland Basin shale wells should include a multifunctional cement spacer system to control losses and help with sealing the formation. Such an approach has significant cost benefits for the operator as well.

IN SUMMARY

The fragility of the Permian Basin presents unique cementing challenges, especially for lateral wells. Successful cementing in the Permian requires a careful selection of slurries, spacer fluids, pump rates, as well as simulations. By considering the temperatures, pressures, and complexities of the formation (such as the presence of salt zones and formation fluids) operators can avoid problems such as lost circulation, worsened excessive washout, and weakened cement. Specialized design criteria, technology and expertise are essential to operate in the area.

REFERENCES

Multifunctional Cement Spacer Fluid Improves Cement Seal Integrity, Minimizes Formation Damage, and Controls Lost Circulation, Fred Sabins, John Ward, Larry Watters, Russel Roberts | AADE 2022

Novel Cement Composition Eliminates Water Flows on Intermediate Strings in Midland and Delaware Basins, Russel Roberts, Lynelle Martinez, Casey Bristow, Fred Sabins, Larry Watters | AADE 2023

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Nine Energy Service is an oilfield services company that offers completion and production solutions throughout North America. The Company brings years of experience with a deep commitment to serving clients with smarter, customized solutions and world-class resources that drive efficiencies. Strategically located throughout the U.S. and Canada, Nine continues to differentiate itself through superior service quality, wellsite execution and cutting-edge technology. Nine is headquartered in Houston, Texas with operating facilities in the Permian, Eagle Ford, SCOOP/STACK, Niobrara, Barnett, Bakken, Marcellus, Utica and throughout Canada. For more information, visit nineenergyservice.com.