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ARTICLE

Overcome casing integrity issues in your plug-and-perf operations

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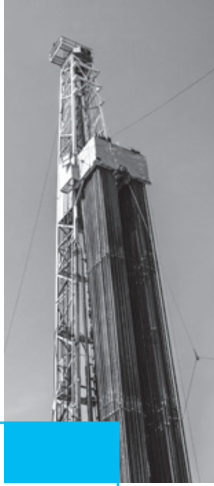
SECTION 1

A challenge to plug-and-perf success

A CHALLENGE TO PLUG-AND-PERF SUCCESS

Approximately 90% of hydraulically fractured wells in North America employ plug-and-perf completions—because of the favorable deployment economics and because the technique enables greater flexibility in designing and pumping stimulation jobs.

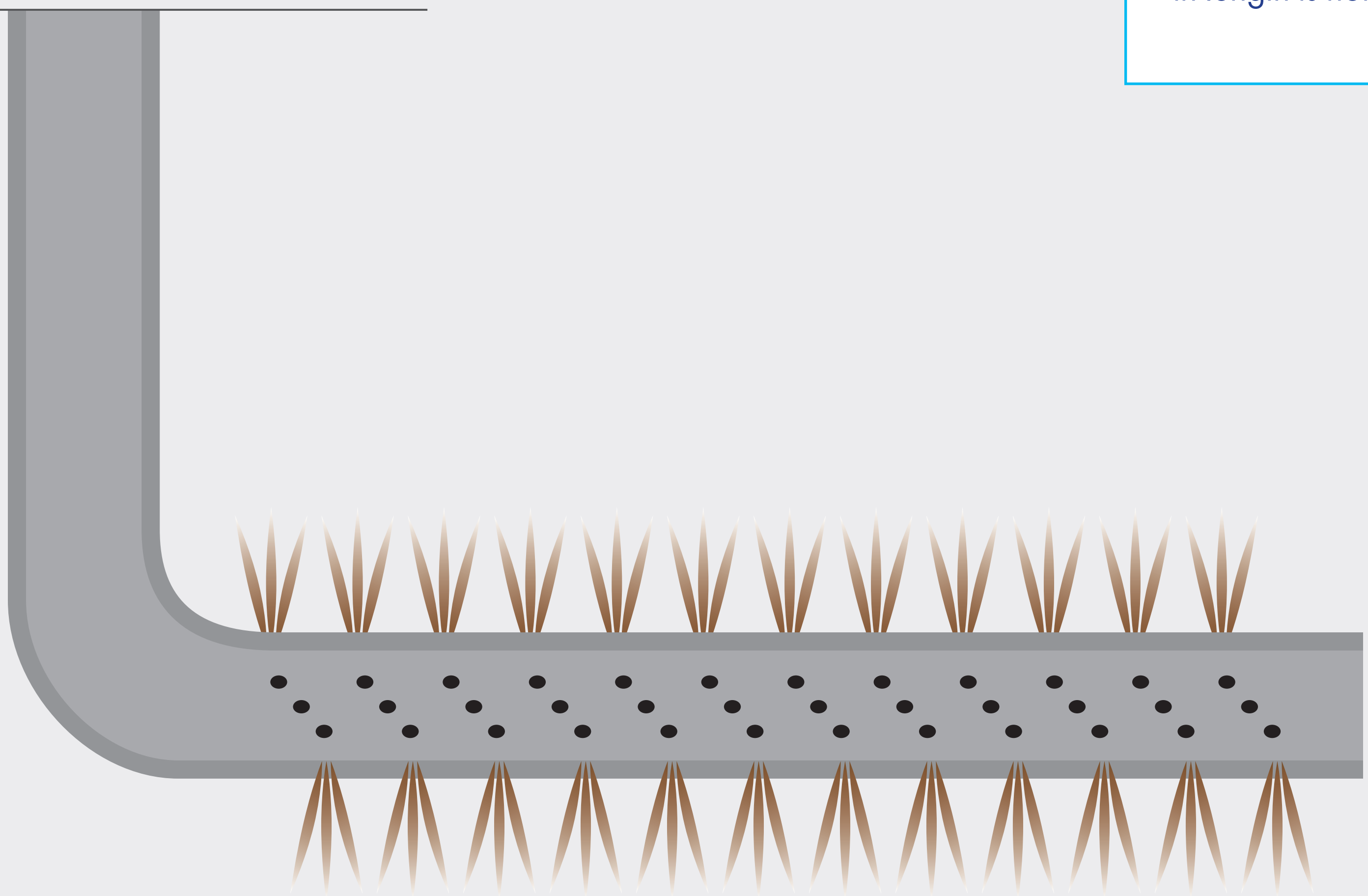
Whether fracturing or refracturing, modern plug-and-perf operations incorporate dozens of stages, and hence dozens of frac plugs, per well.



Fifty-five or more frac plugs set in a lateral that extends one mile or more in length is not unusual.

FIGURE 1

Pay zone and a plug getting hung up on a kink



THE REALITY

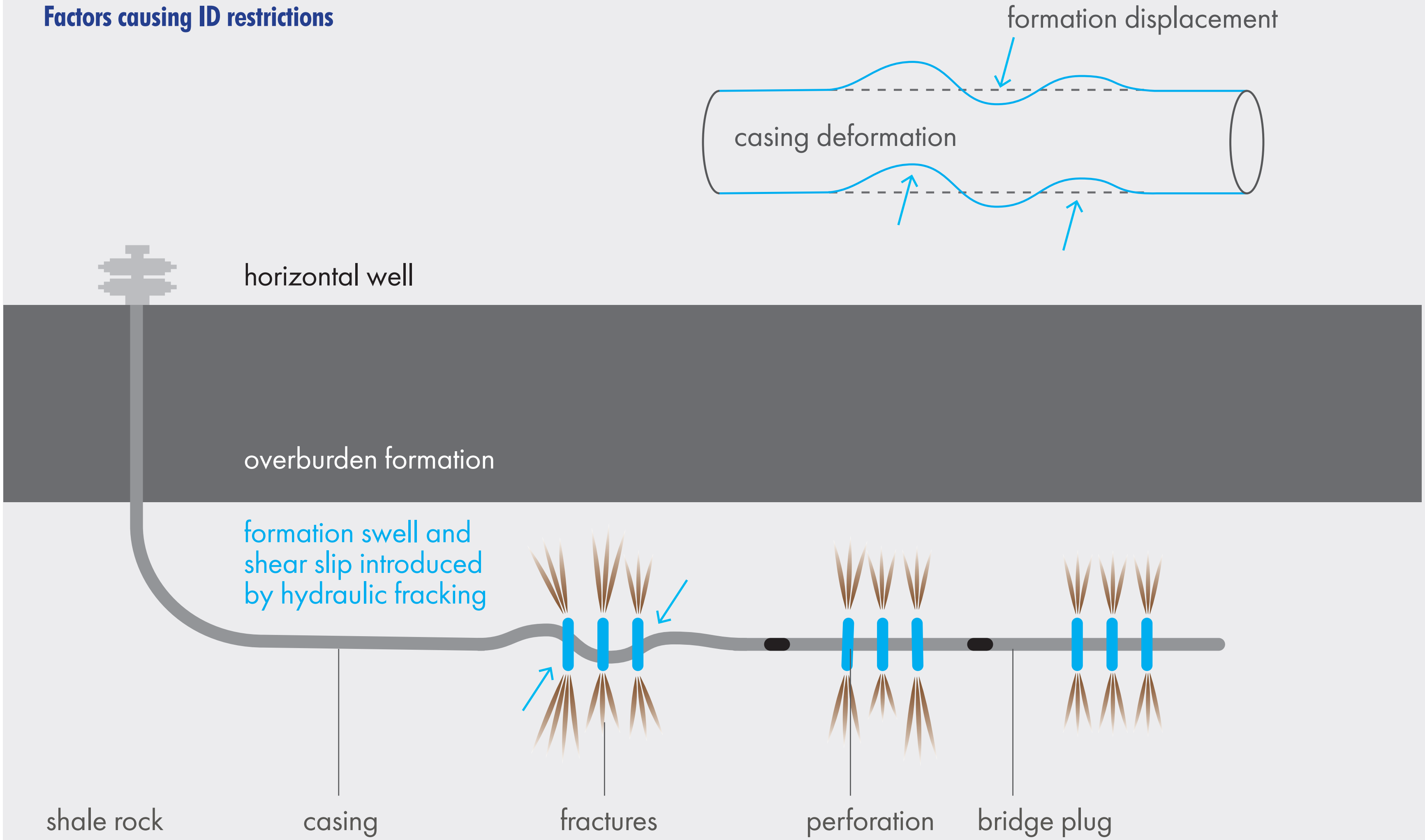
Fifty-five or more frac plugs set in a lateral that extends one mile or more in length is not unusual.

Inability to run one or more of these plugs to depth because of a casing ID restriction leads to an unsuccessful or partially successful job, resulting in lost reserves and a negative impact on well economics. If the restriction is shallow enough, the entire operation may have to be abandoned.

North American shale operators have—unfortunately—become all too familiar with this contingency.

FIGURE 2

Factors causing ID restrictions



SECTION 2

Causes of casing restrictions

CAUSES OF CASING RESTRICTIONS

A range of factors can restrict casing ID and prevent a successful completion. Advances in unconventional reservoir understanding and drilling technology are driving increasingly complex drilling patterns and individual well designs.

Higher build rates, complex trajectories, and longer horizontal sections pose considerable challenges to casing integrity.

COMMON FACTORS

Common factors that lead to casing damage or restricted ID include the following.

1

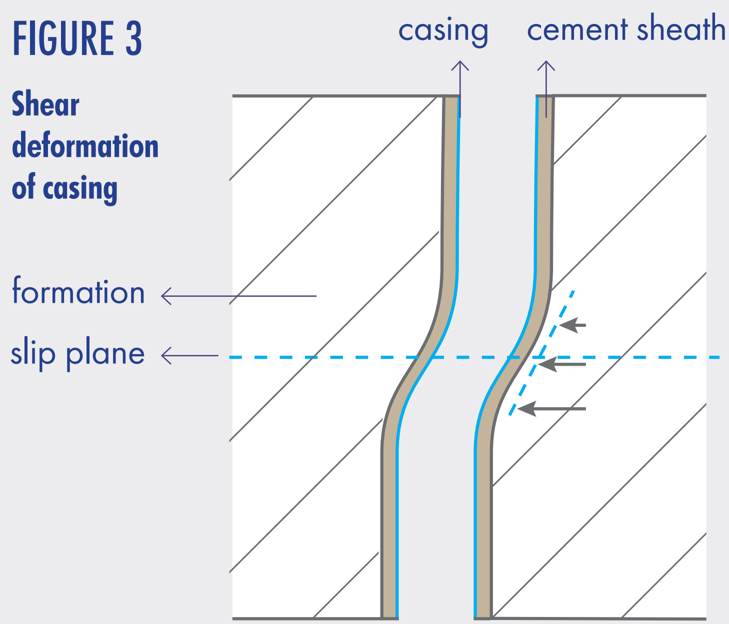
Long horizontal sections and severe doglegs can necessitate repeated reciprocation and rotation of the casing string, increasing the likelihood of mechanical damage.

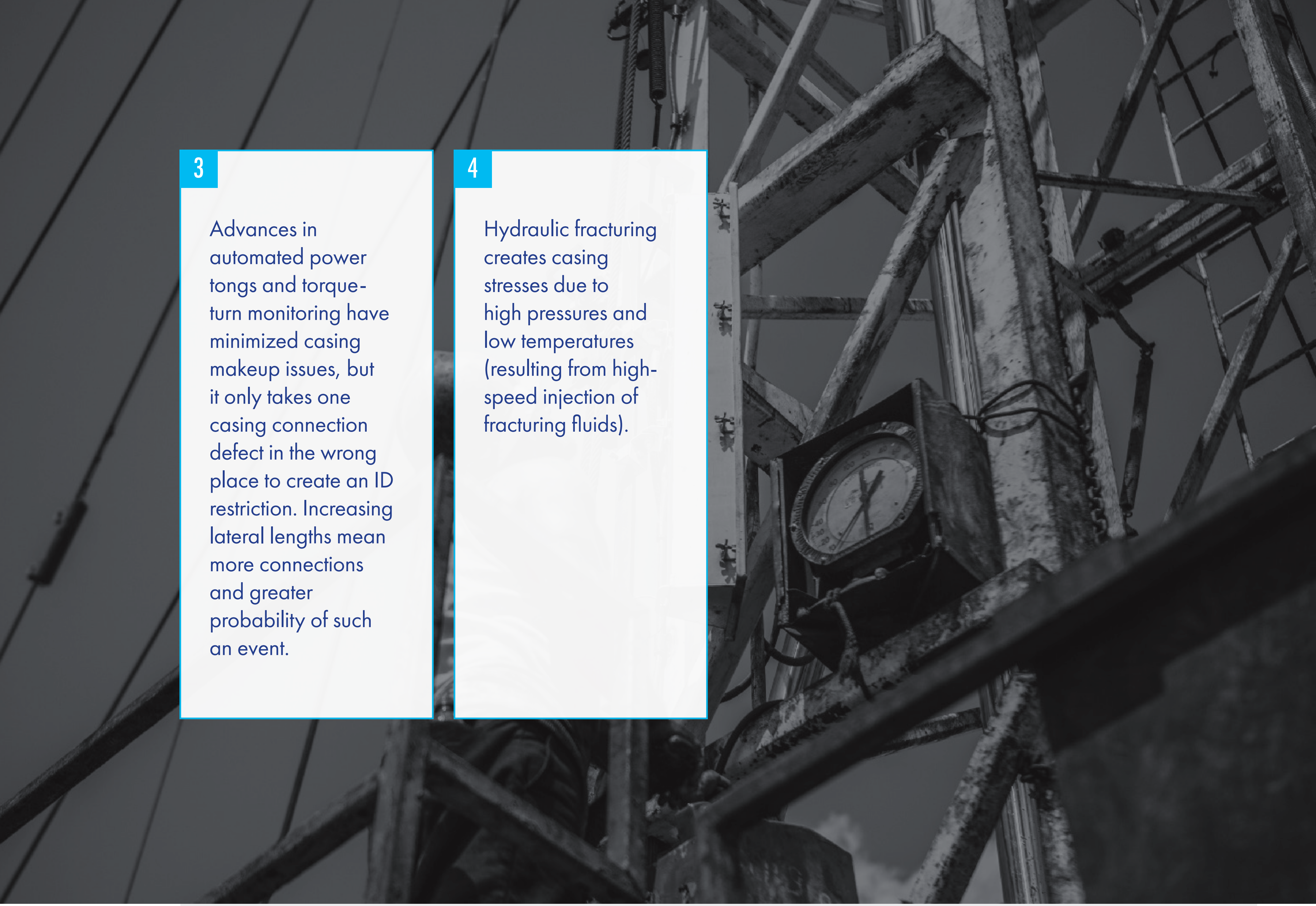
2

Studies have shown that borehole curvature and dogleg severity also have a detrimental effect on casing pressure rating, increasing the potential for casing damage.

FIGURE 3

Shear deformation of casing





3

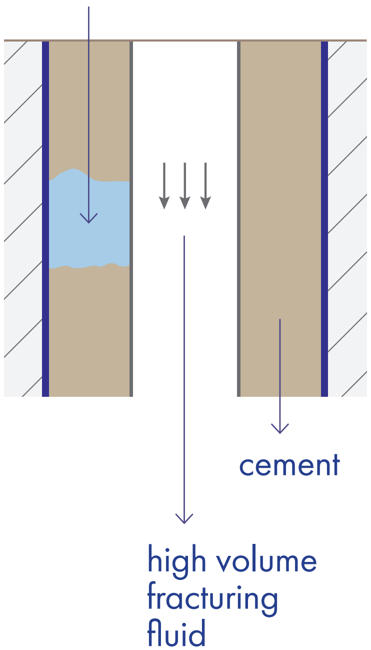
Advances in automated power tongs and torque-turn monitoring have minimized casing makeup issues, but it only takes one casing connection defect in the wrong place to create an ID restriction. Increasing lateral lengths mean more connections and greater probability of such an event.

4

Hydraulic fracturing creates casing stresses due to high pressures and low temperatures (resulting from high-speed injection of fracturing fluids).

FIGURE 4

Annular vacant spaces of a cemenented horizontal shale gas well

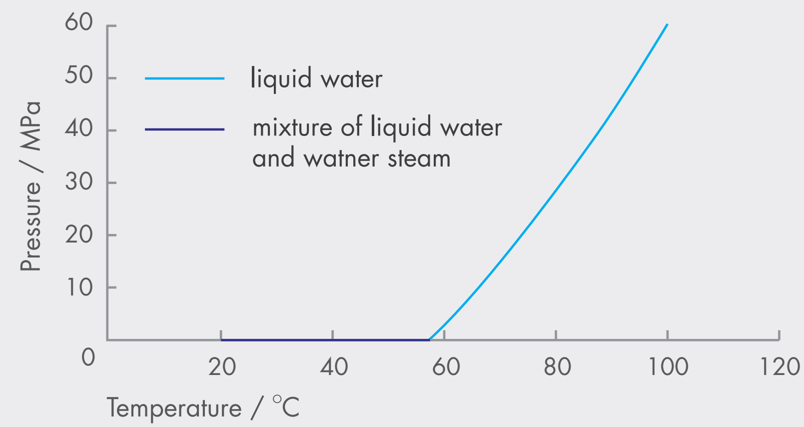


5

Poor-quality cement may contain liquid-filled channels. High-speed injection of fracturing fluids can reduce the temperature of the casing, causing it to shrink, as well as the temperature of the liquids. Because the liquids in the spaces are incompressible and the low-permeability shale formations cannot quickly supplement them with formation water, the result is a rapid drop of pressures in these spaces, increasing the pressure differential across the casing and consequently, the likelihood of damage.

FIGURE 5

Dynamic changes of pressures of fluids contained in vacant spaces of cement at horizontal shale gas well



6

Heterogeneities in set cement are known to produce casing deformation. An abrupt change in set cement quality that provides a good "edge of set cement" combined with pressure from the surrounding formation has been seen to cause severe deformation.

7

Shale slip (shear dislocation) during fracturing operations, earthquakes, and movement of geological faults can damage casing significantly.

8

Expandable casing patches used to repair casing can restrict ID.

9

Pad drilling results in well paths in close proximity to each other. Frac hits—caused by hydraulic fracturing treatments pumped in offset wells—can be violent enough to damage casing. Interwell spacing for shale wells has reduced from a minimum of 1,000 ft to just 250 ft at times, increasing the probability of these events.

NOTE

Careful casing and borehole trajectory design and appropriate drilling and completion techniques can reduce the risks, but cannot eliminate them.

In addition, the constant pressure to lower well costs has resulted in abandoning practices such as drift runs and the use of premium connections, which could mitigate operational risk.

SECTION 3

How extended-range frac plugs keep operations moving

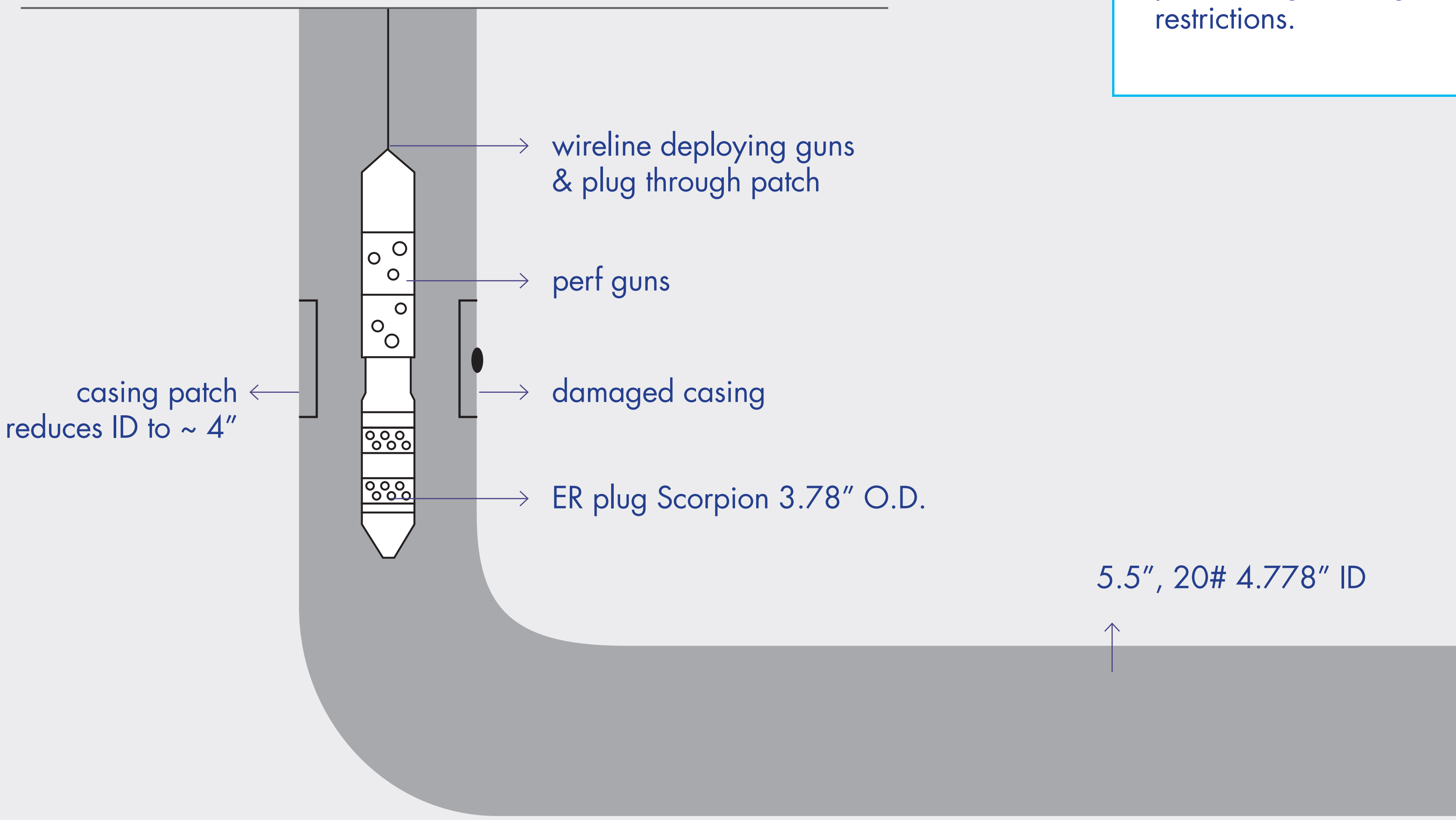
EXTENDED-RANGE FRAC PLUGS

The oil and gas industry has a long tradition of using engineering ingenuity to solve the never-ending challenges to finding and producing oil. Enter the innovative extended-range frac plug!

These plugs have a small OD that enables them to pass through casing ID restrictions; subsequently they expand to the standard casing ID. As a result, they keep operations moving in damaged and repaired wells and eliminate the worst-case scenario of having to abandon the well because of a restricted ID.

FIGURE 6

Extended-range frac plugs pass through restrictions



INNOVATIVE DESIGN

The extended-range frac plugs have a small OD that enables them to pass through casing ID restrictions.

THE TYPE OF DESIGN ENHANCES RESULTS

A number of design considerations enhance the applicability of these plugs and must be taken into account for optimal results.

1

The plugs must, of course, be rated high enough to withstand expected bottomhole temperatures and high-pressure hydraulic fracturing operations.

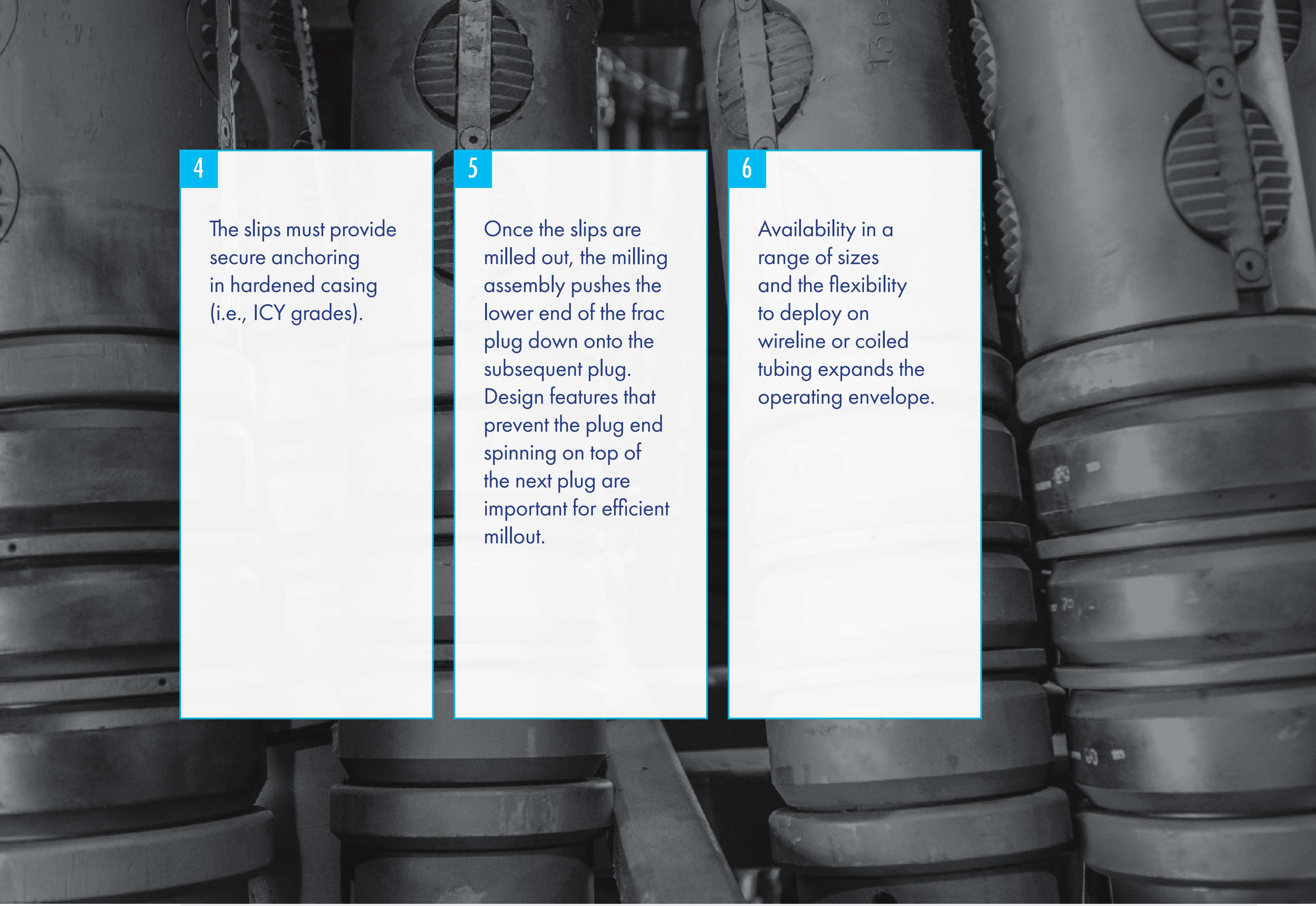
2

A molded element system with a smooth surface devoid of rough edges or protrusions lowers the risk of the plug presetting or getting stuck while running into the hole, enabling faster run-in speeds. Design features that reduce the risk of element flaring during deployment also expedite run in.

3

The plugs should be easy to mill out once the fracturing operation is complete because casing ID restrictions necessitate use of a smaller mill and motor. Compact composite plugs with ceramic button slips reduce millout time to just a few minutes per plug.

These materials also reduce debris size, so that cuttings are easily circulated out of the well, facilitating cleanup.



4

The slips must provide secure anchoring in hardened casing (i.e., ICY grades).

5

Once the slips are milled out, the milling assembly pushes the lower end of the frac plug down onto the subsequent plug. Design features that prevent the plug end spinning on top of the next plug are important for efficient millout.

6

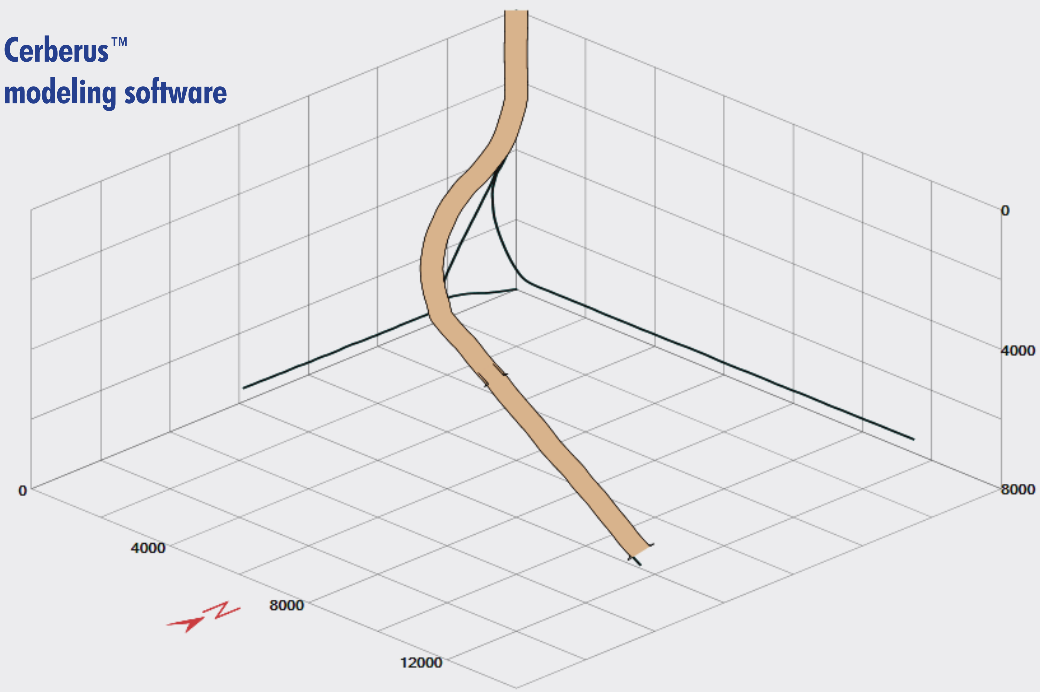
Availability in a range of sizes and the flexibility to deploy on wireline or coiled tubing expands the operating envelope.

7

Use of modeling software that provides details of the wellbore and restriction before plugs are run in helps optimize run-in speeds and pump down rates. In regions where tortuous wells are common, this modeling can make the difference in achieving a positive outcome.

FIGURE 7

Cerberus™ modeling software



IN SUMMARY

All frac plugs are not created equal.

A small investment in time spent selecting the right product and modeling the completion will bring disproportionately enormous returns by enabling a successful fracturing operation and reducing time to first oil.

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