

Making our world more productive



# RECHARGE HNP™

Introducing the new generation of well production enhancement solutions



# RECHARGE HNP™

## Energize, activate and enhance hydrocarbon recovery

RECHARGE HNP™ is a multi-spectrum treatment for vertical and horizontal wells experiencing a decline in production with restrictions to fluid flowing into the wellbore. This treatment enables the recovery of hydrocarbons to be accomplished faster, more completely, and with longer efficacy than existing options on the market today.

## A powerful combination

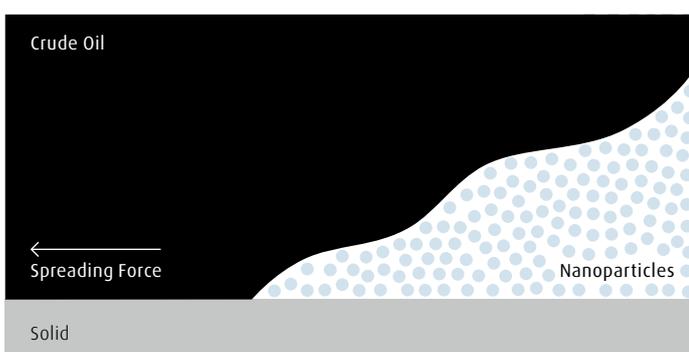
Combining the properties of gas and nanoparticles creates a unique, synergistic treatment that addresses several potential production issues simultaneously. The gas helps remove debris, fines and other matter and stimulates the well with pressure, while driving the effective distribution of the nanoparticles to deeper parts of the formation. In cases where the gas is miscible, it also helps to mobilize crude oil by causing it to swell and reducing its viscosity.

This treatment penetrates further and more thoroughly permeates the natural fracture network than traditional remediation or restimulation technologies. The nanoparticles produce a Brownian-motion, diffusion-driven mechanism, known as disjoining pressure, resulting in longer and more complete production efficacy. Field application data validates that particles pushed with Linde's gases produce significant and sustained improved hydrocarbon recovery.

## Application

Our solution is a prescribed well remediation treatment (Huff'n Puff) consisting of three phases: injection, soaking and production. Because of the synergies between gas and nanoparticles, the soak times can be dramatically reduced compared with traditional HnP treatments. Depending on the type of formation, well history and identified issues, a specific treatment plan is prescribed.

## Nanoparticles aligned at the three-phase contact angle to support hydrocarbon recovery (Wasan et al., 2003)



# Well Treatment Screening

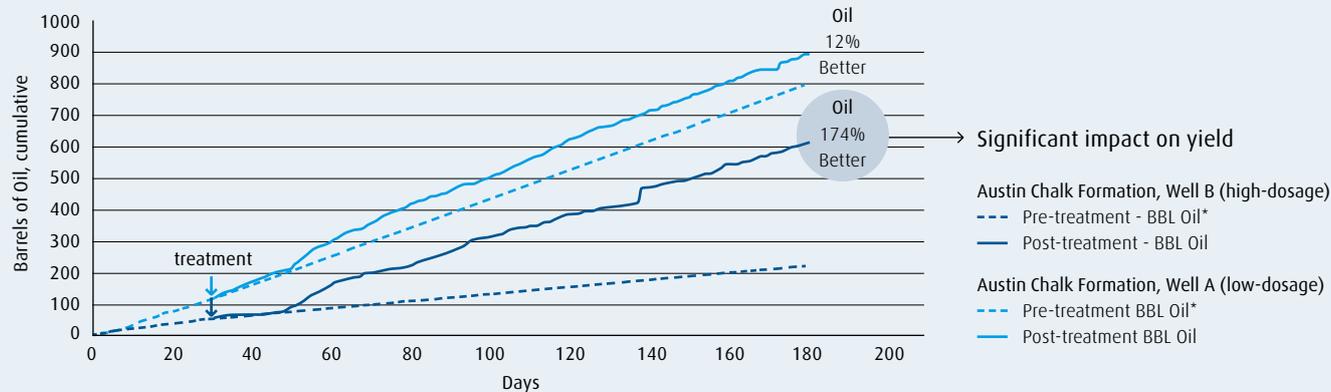
For a successful treatment, appropriate screening of candidate wells is the first step. Linde will work with operators on candidate identification before prescribing a recommended treatment plan.

<b>Production</b>	Good initial production (IP) with a decline curve that indicates wettability issues. Current production <20% of IP and >5-10 BOPD or 20 mscf.
<b>Field data</b>	Overall well performance should be on par with other wells in the field.
<b>Treatments</b>	Acid and other chemical treatments may negatively impact properties of the nanoparticles.
<b>Well equipment</b>	To be in good mechanical condition. Pumps, linings, gaskets.
<b>Water</b>	Too high content of salts (e.g. KCl) and TDS may negatively impact the nanoparticles.
<b>Water cut</b>	<80% (N <sub>2</sub> ), <90% (CO <sub>2</sub> )
<b>Net pay zone</b>	<100 ft (30 m) to optimize for 60-90 -day payback.
<b>Porosity</b>	Conventional >8%, unconventional >4%.
<b>Oil</b>	Oil gravity <30 API it's recommended to use CO <sub>2</sub> . Asphaltene precipitation may be caused by gas injection.

# Oil production

## Austin Chalk Wells A&B – FRIO County

RECHARGE HNP (nanoparticles and Nitrogen) pre- and post-treatment comparison after 180 days of cumulative production.



\*Post-treatment projection based upon the trajectory from the 30-day pre-treatment actuals.

### Austin Chalk Formation, Well A (low dosage)

RECHARGE HNP pre- and post-treatment comparison after 180 days of cumulative production. Cumulative oil production increased 12%.

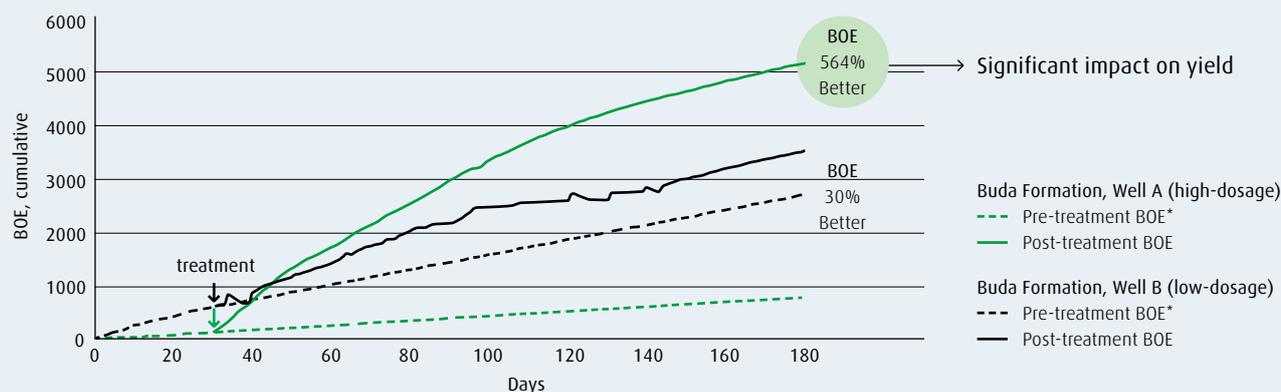
### Austin Chalk Formation, Well B (high dosage)

RECHARGE HNP pre- and post-treatment comparison after 180 days of cumulative production. Cumulative oil production increased 174%.

# Gas production

## Buda Well A&B – FRIO County

RECHARGE HNP (nanoparticles and Nitrogen) pre- and post-treatment comparison after 180 days of cumulative production.



\*Post-treatment projection based upon the trajectory from the 30-day pre-treatment actuals.

### Buda Formation, Well A (high dosage)

RECHARGE HNP pre- and post-treatment comparison after 180 days of cumulative production. Cumulative gas production increased 564%.

### Buda Formation, Well B (low dosage)

RECHARGE HNP pre- and post-treatment comparison after 180 days of cumulative production. Cumulative gas production increased 30%.

Numerous factors affect the performance of an oil well — the geology, the number and size of treatment stages, the choice of additives, etc. Wells treated with RECHARGE HNP have shown meaningful performance improvement versus comparative wells from the same operators. While no single technology or treatment can account for the entire performance of an oil well, the effects of RECHARGE HNP are significant and compelling.

# Getting ahead through innovation

With its innovative concepts, Linde is playing a pioneering role in the global market. As a technology leader, it is our task to constantly raise the bar. Traditionally driven by entrepreneurship, we are working steadily on new high-quality products and innovative processes.

Linde offers more. We create added value, clearly discernible competitive advantages, and greater profitability. Each concept is tailored specifically to meet our customers' requirements – offering standardized as well as customized solutions. This applies to all industries and all companies regardless of their size.

If you want to keep pace with tomorrow's competition, you need a partner by your side for whom top quality, process optimization, and enhanced productivity are part of daily business. However, we define partnership not merely as being there for you but being with you. After all, joint activities form the core of commercial success.

Linde – ideas become solutions.

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