Field Trial Results for Patent Pending Ninja for ESPs

EOG's low flow rate Bakken wells see producing gas/oil ratios (GORs) of 3,000-4,000 SCF/BBL. Despite installing industry leading gas handling pumps and VSD firmware, gas locking is still problematic at these high GORs. The effects of a gas locking event on ESP parameters are shown in **Figure 1**.

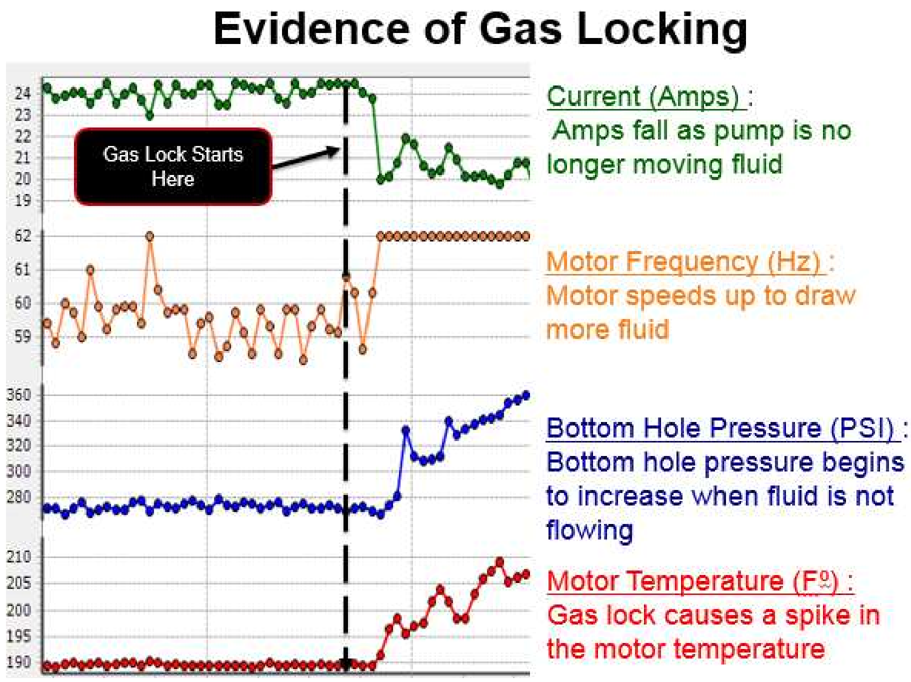

Figure 1-Effects of a typical gas locking event on ESP parameters.

ESP equipment designs typically assume all produced gas will move through the pump, but this should not be true if gas separators are functioning as intended. Gas separation efficiency can be quantified by measuring casing gas and total produced gas volumes. The difference between these volumes is gas produced through the ESP, because gas can only be produced up the annulus (casing gas) or through the pumps and up the tubing. Coriolis meters were installed on the casing of several wells, and total gas coming off the treater is metered for sale. Measurements were taken for analogous wells with and without the Ninja separator installed. **Figure 2** shows that around 65% of gas is produced through the ESP in a well with typical gas handling equipment. **Figure 3** shows that a comparable well with the Ninja installed in addition to typical gas handling equipment produces just 15% of its gas through the pump equipment. These promising results led to further prototype Ninja field tests.

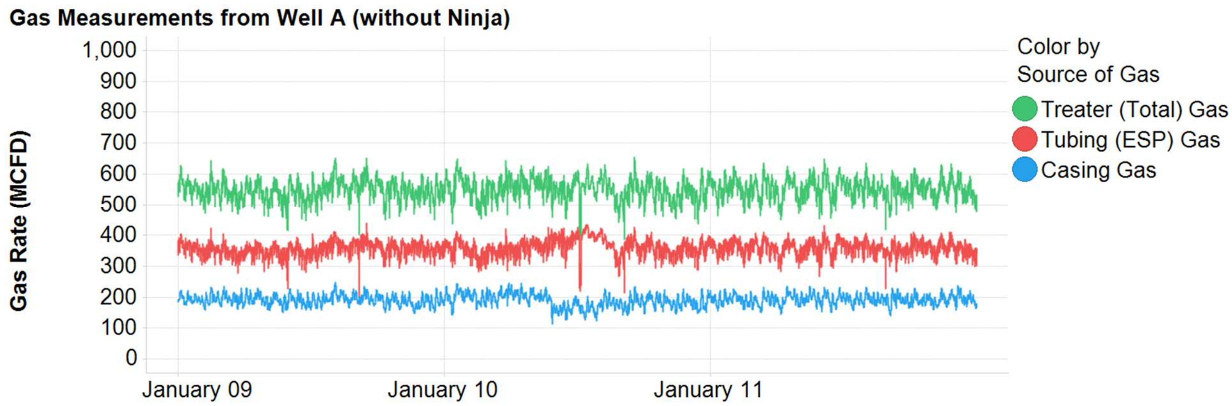

Figure 2-Gas measurements from well with typical gas handling equipment (without Ninja intake). Gas is produced via two pathways: through the tubing by way of the ESP and up the backside of the casing. Casing gas is measured with a Coriolis meter and total gas is measured coming off the treater. The difference between those values is the gas produced through the ESP. Without a Ninja intake installed, around 65% of gas is produced through the ESP.

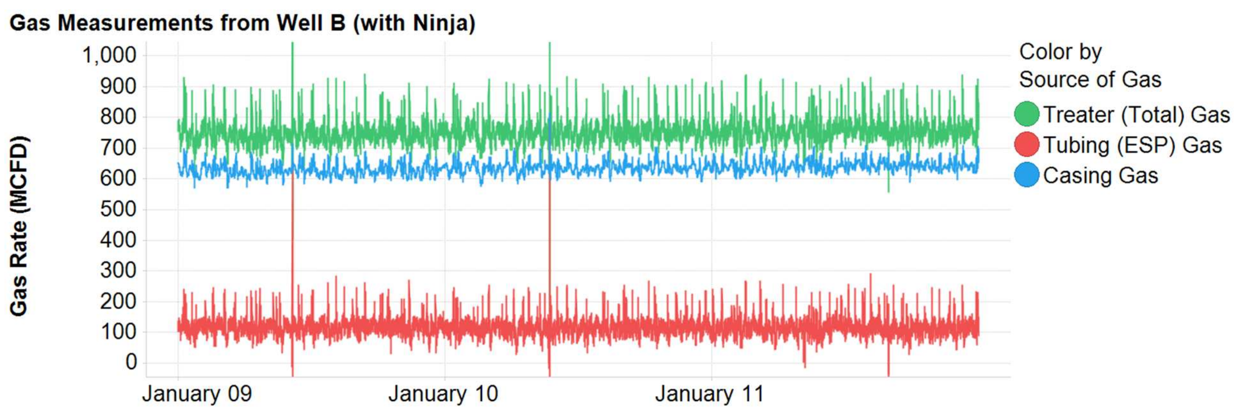

Figure 3-Gas measurements from well with Ninja intake (in addition to typical gas handling equipment). Just 15% of gas is produced through the ESP.

The initial targets of the following case studies are smaller volume pumps, which are commonly installed later in the well's life. GORs are typically higher and flow rates are lower, which leads to more gas locking and accelerated ESP failure. Poor ESP run times are often a driver to convert to rod pump, with a goal of minimizing workovers and lease operating expenses associated with ESP replacements. If the Ninja can prevent or delay gas-related damage to these smaller ESPs, the performance and reliability improvements could justify keeping wells on ESP later in the well's life before swapping to rod pump.

The focus of the first case study, Well X, had seen eight ESPs fail in two years, with an average run time of 68 days per pump. Gas issues were the predominant cause of failure. This well has a producing GOR of 4,000 SCF/BBL, GLR of 3,800 SCF/BBL, total fluid production of 200 BFPD, and a very low water cut. Surging pump intake pressures (PIP) suggest slugging within the wellbore, making this well a prime candidate for the new intake.

As soon as the Ninja was installed with a new Summit SF320 pump, improvements in pump operation and well production were observed. Without the Ninja intake, the pump could not achieve a constant PIP drawdown and leveled out at 600-700 psi (**Figure 4**). Surging was also observed. With the Ninja intake preventing gas from entering the pump, drawdown reached 510-550 psi. This 200 psi of additional drawdown increased oil production (**Figure 5**).

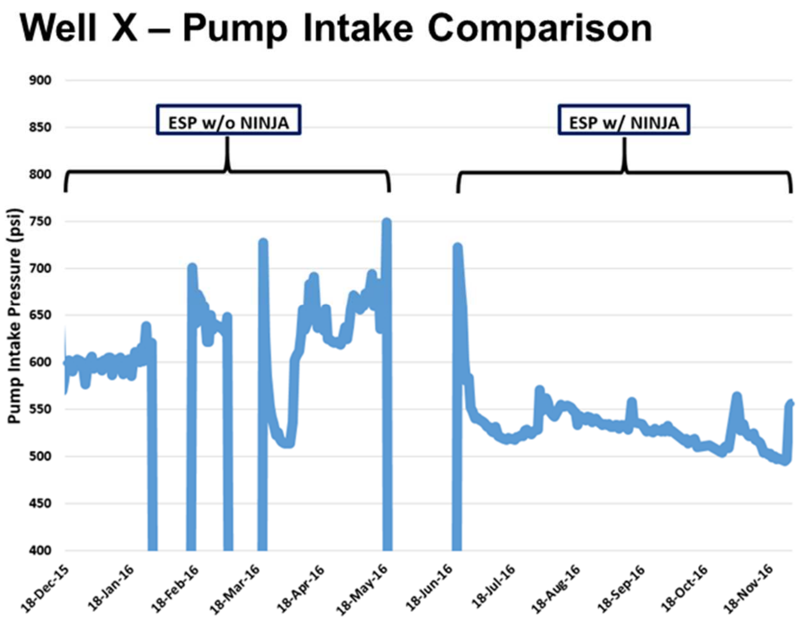

Figure 4-Ninja intake installation results in PIP surging reduction and additional drawdown.

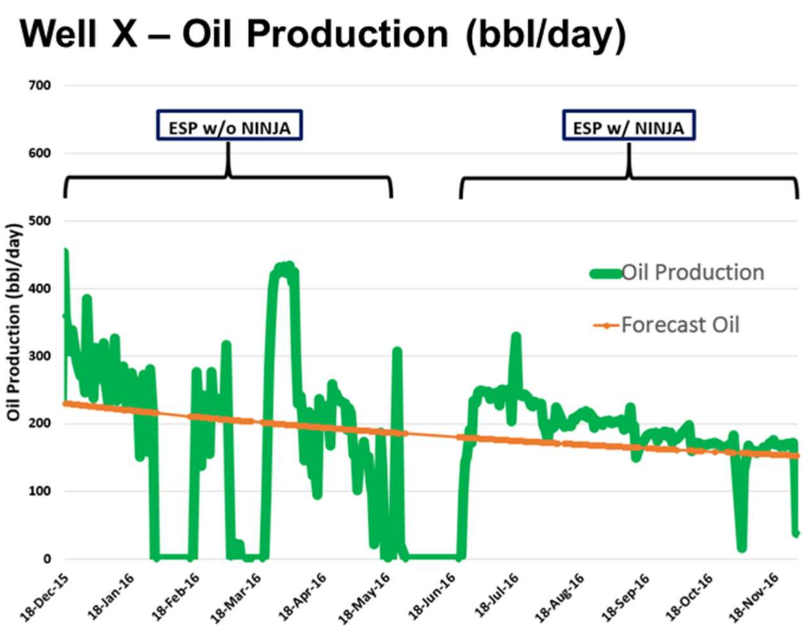

Figure 5-Additional PIP drawdown achieved through Ninja installation leads to increased oil production.

Figure 6 shows how ESP running parameters were also simplified. Without the Ninja intake, the motor was run in PID control mode with a frequency range of 43-65 Hz and subsequent 35-55 amp range. With the Ninja installed, the motor ran at a fixed frequency of 63 Hz and only saw 50-57 amps. This first Ninja installation successfully simplified operations, minimized pump stress in a slugging well, and provided additional oil production.

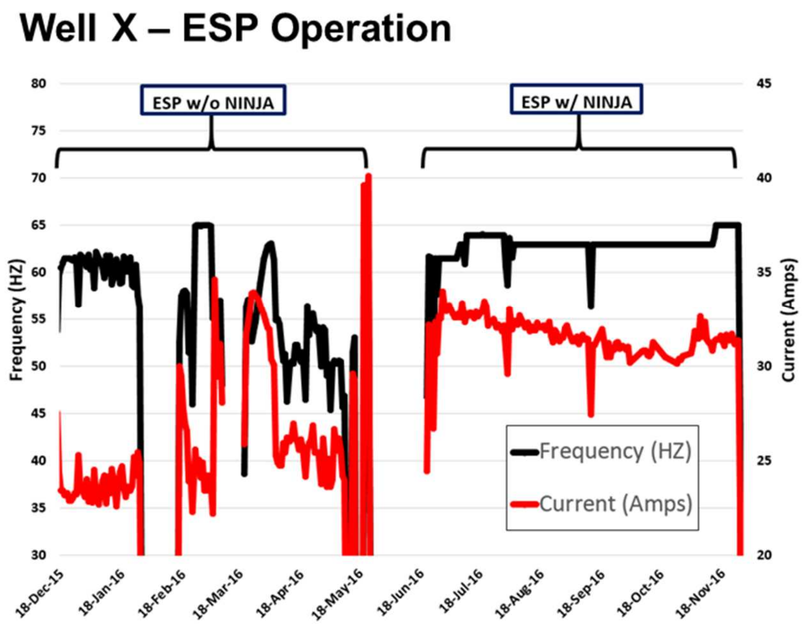

Figure 6-Ninja installation enabled the ESP to run in fixed frequency mode, resulting in more consistent amperage.

The next study target was Well Y, which has a producing GOR of 2,000 SCF/BBL and almost no water production. This well had previously switched from ESP to rod pump, leading to a 50% drop in oil and gas production. This drop was attributed to extreme gas interference. That lost production was recovered by switching the artificial lift method back to ESP. Unfortunately, the new ESP failed after 143 days due to gas locking. Earlier ESPs had run lives of 439 days and 261 days, but lower flow rates were now gas locking the pump. Following this failure, a new SF320 pump was installed with a Ninja prototype. The combination has already run longer than its predecessor. It is currently operating in fixed frequency mode with minimal amperage swings (**Figure 7**). Production is steady with a flatter decline curve (**Figure 8** and **Figure 9**).

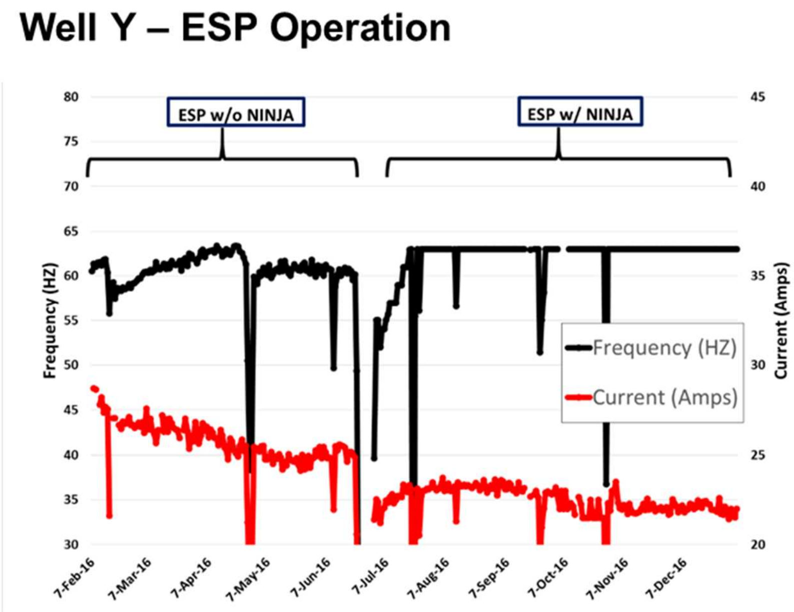

Figure 7-Improved ESP operating conditions with addition of Ninja intake.

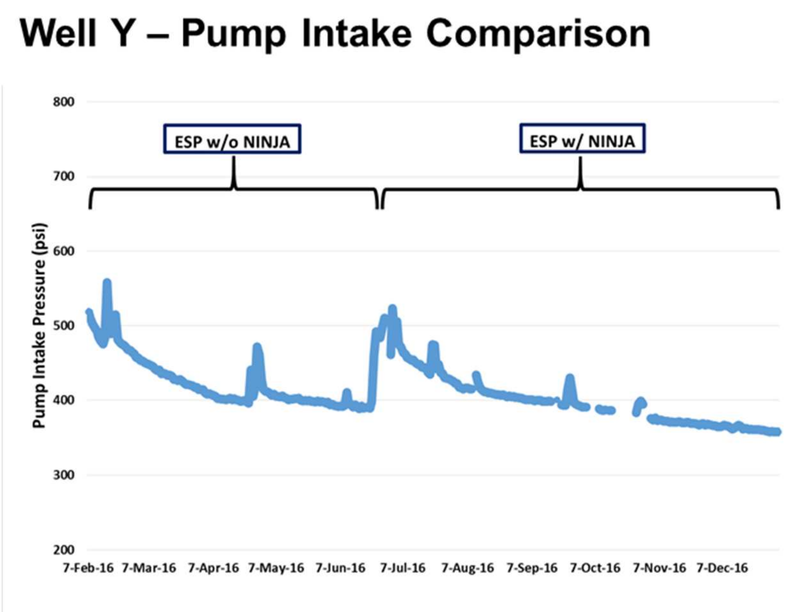

Figure 8-Increased drawdown with addition of Ninja intake.

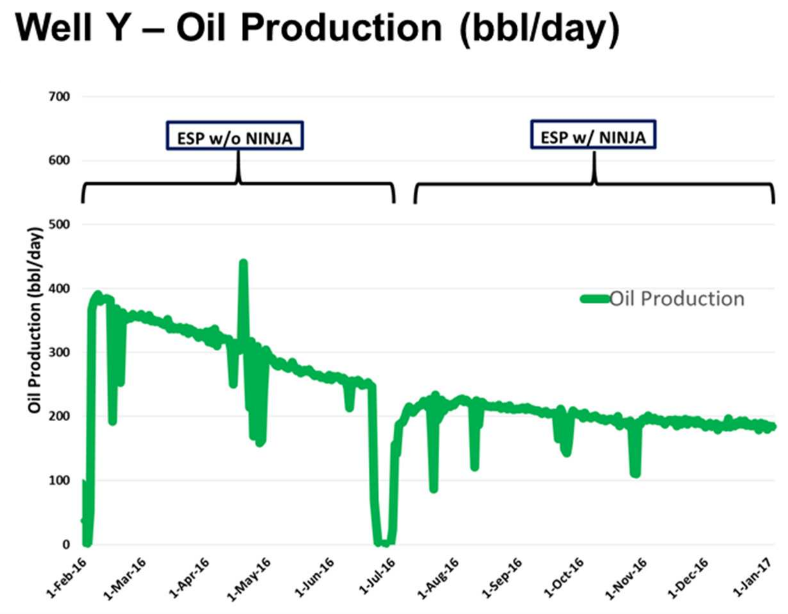

Figure 9-Production shifted to a flatter decline curve with addition of Ninja intake.

Well Z, the third case study well, was also swapped from ESP to rod pump and then back to ESP as part of a study to demonstrate achievable flowing bottomhole pressures with different artificial lift methods. During the swap back to ESP, the Ninja intake was run on an SF500 pump. Well Z had a producing GOR of 1,500 SCF/BBL on rod pump, but jumped to 3,500 SCF/BBL on ESP with the resulting oil and gas production gain. The Ninja has proven capable of handling this additional gas, as the pump system is now running smoothly in fixed frequency mode and maintaining a steady PIP drawdown (**Figure 10**).

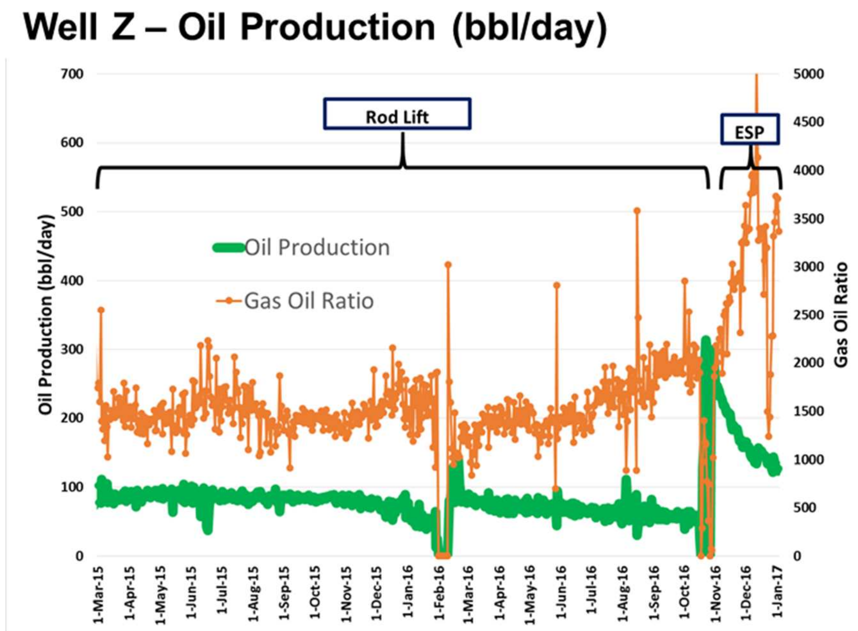

Figure 10-Increased production accompanied by spike in GOR upon installation of Ninja intake.

These case studies in gassy low volume wells have illustrated the Ninja's potential for improving ESP performance and increasing production volumes, primarily through the elimination of gas locking. Ninja intakes have also been installed on several larger volume pumps, with the goal of extending pump run life by improved flow conditioning. Two adjacent wells are of interest. A Ninja intake was installed with an SF2250 pump upon initial completion of one well. The neighboring well had an SF2250 installed with no Ninja. The goal of this trial was to see if the Ninja would choke production at high volumes and if it would extend ESP run life as production declines and GOR increases. No reduction in produced flow was observed in the well with the Ninja, eliminating any concerns of a system choke. The well without the Ninja failed after 136 days, while the well with the Ninja continues to run smoothly. While these higher volume trials continue, performance data suggest that the Ninja successfully conditions flow at higher flow rates and lowers the GLR of fluid entering the ESP by the liquid concentrating mechanism.