Operator Uses Advanced Perforation Flow Laboratory to Support HMX Perforating by Coiled Tubing in HP/HT Field

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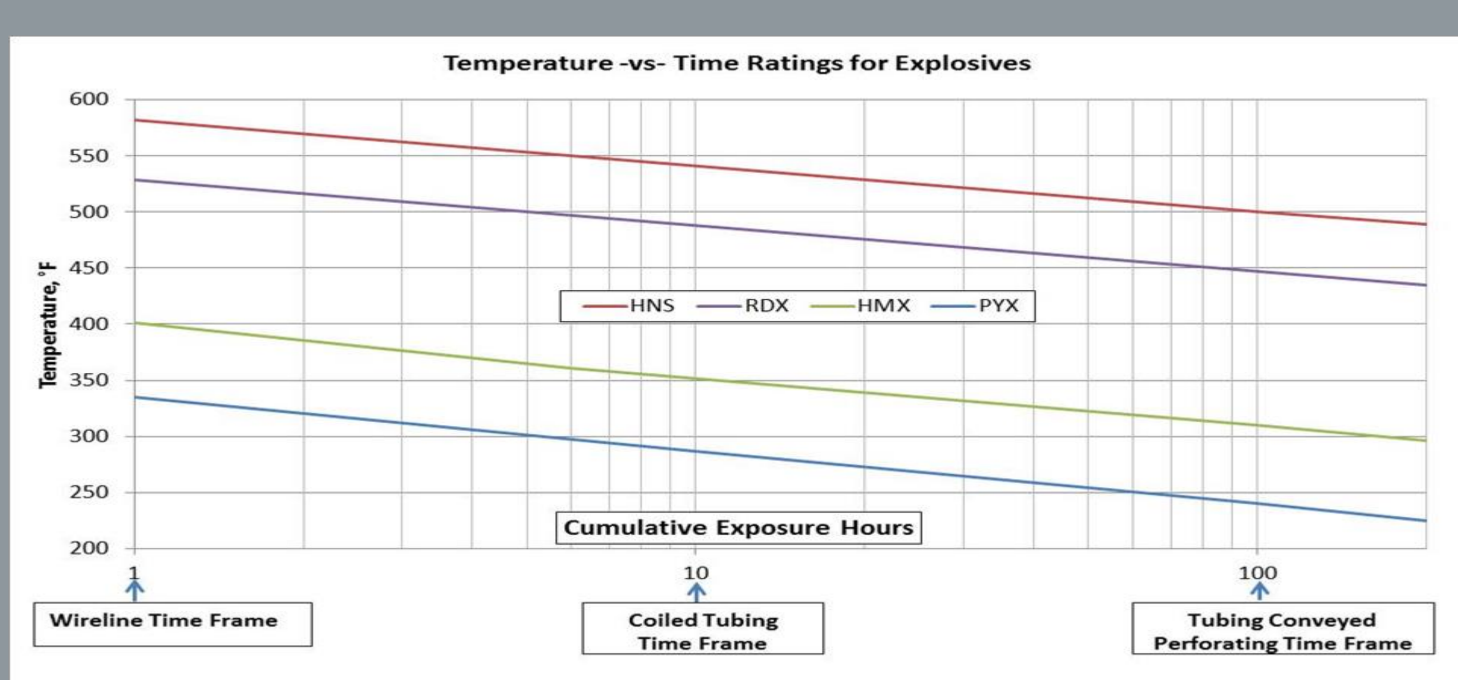
Abstract

The advanced perforation flow laboratory (APFL) can measure the depth of penetration performance of shaped charges at downhole conditions to confirm whether or not the formation penetration will exceed the depth of formation damage attributable to drilling. In tubing-conveyed perforating, hexanitrostilbene (HNS) explosive shaped charges have historically been used in elevated temperature environments. The option of using the deeper penetrating but less heat-resistant high melting explosive (HMX) shaped charge is possible in the North Sea Hejre field wells. This is because the depth to the reservoir interval to be perforated is within the reach of the coiled tubing. This process exposes the perforating guns to elevated temperatures for less time. In addition, coiled tubing provides a means of circulating cooling fluid, further increasing the charge lifespan. Based on conservative run times for deploying guns on coiled tubing (an estimated 4 to 6 hours from surface), there will be sufficient time to position the guns at depth before detonation. There will also be sufficient time to retrieve the gun string from the wellbore in the event of a misfire.

All perforation flow lab tests in the APFL were conducted at Hejre well pressures with overburden stress at 17,500 psi and pore pressure at 14,600 psi. Several tests were conducted at the reservoir temperature of 160˚C (320˚F). Aligned with API RP 19B Section 4 (2006), the APFL tests were conducted to closely match the expected conditions in the Hejre field, requiring minimal scaling of the results.

Tests conducted at the APFL compared the different explosive powder charges and showed a nearly 50% increase in formation-analog target penetration using the HMX charge vs. the HNS charge. This depth of penetration increase helps improve the prospect of penetrating the estimated drilling damage zone to vastly improve production and the effectiveness of further stimulation. This work discusses the methodology, obstacles encountered and means of addressing them, and the test program results.

Before the construction and development of testing equipment to shoot a shaped charge at elevated temperatures and high pressures, extrapolations had to be used to predict perforator performance with a higher level of uncertainty.

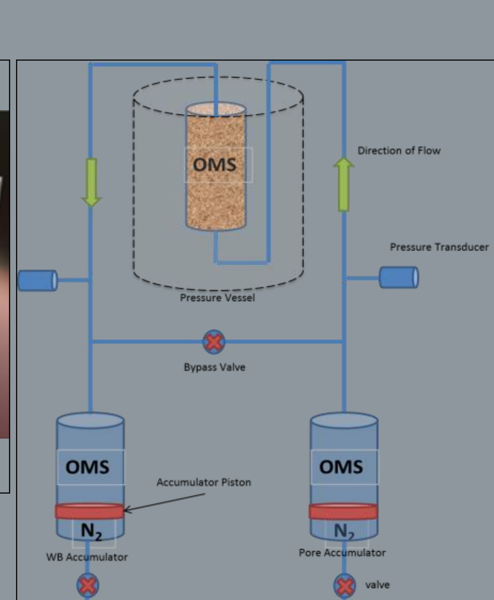


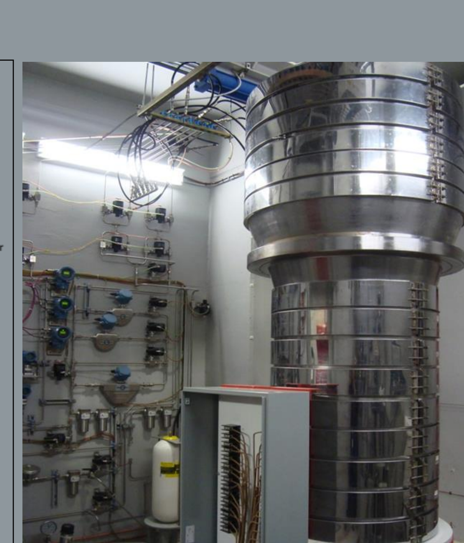
Project Details

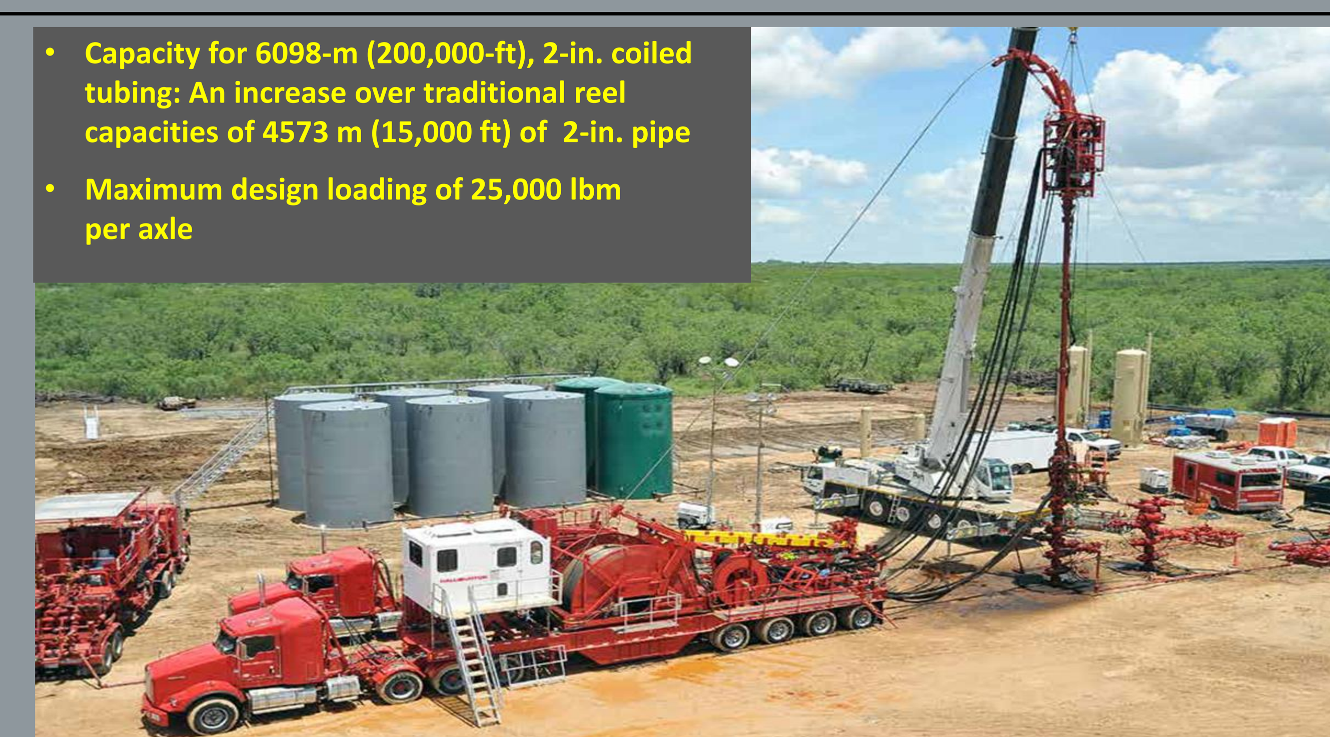
- Optimize the perforation job for maximum production
  - Focus on achieving sufficiently deep and clean perforation tunnels to obtain a low skin number
  - Use independent tests on the formation core to select optimal oil-based mud (OBM)
- Compare specific-sized charges to determine and select the best performer
  - 3 1/8-in. HMX DP-oriented in 5 1/2-in., 26.8-lb Cr13S casing
  - 3 1/8-in. HNS DP-oriented in 5 1/2-in., 26.8-lb Cr13S casing
  - 2 7/8-in. HMX DP-oriented in 5-in., 23.2-lb Cr13S casing
  - 2 7/8-in. HNS DP-oriented in 5-in., 23.2-lb Cr13S casing
- Utilize the APFL, which is capable of shooting these shaped charges under Hejre field downhole pressure and temperature conditions into a detailed, field-matching target.
- Conduct a sufficient number of tests: 11 ambient and five reservoir temperature tests (16 total)—all at reservoir pressure

Parameter	Value
Depth to Formation	18,000 Ft (5.5 Km)
Reservoir Temperature	320°F (160°C)
Overburden Stress	17,500 psi (121 MPa)
Reservoir Pressure	14,600 psi (101 MPa)
Effective Stress	*2,900 psi*
Initial Wellbore Pressure	12,100 psi
Underbalance Perforating Pressure	*2,500 psi*

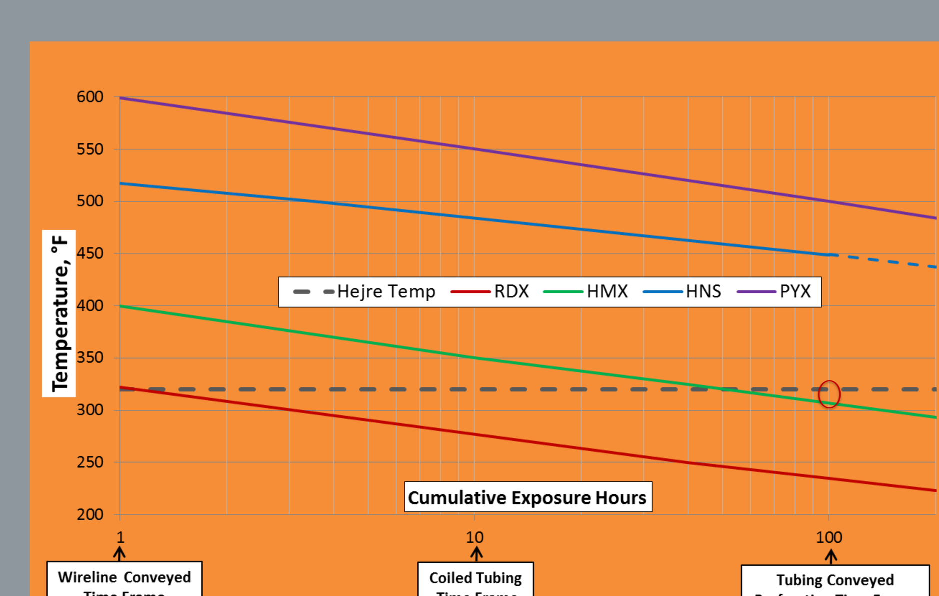
- Open hole (drill bit): 8 1/2 in.
- Centralized production liner: 5-in., 23.2-lb/ft ID, 4.04-in. 110Cr13S for 2 7/8-in. guns or
- Centralized production liner: 5 1/2-in., 26.8-lb/ft ID, 4.50-in. 110Cr13S for 3 3/8-in. guns
- Production liner cement: More than eight additives (unconfined compressive strength approximately 2,900 psi)

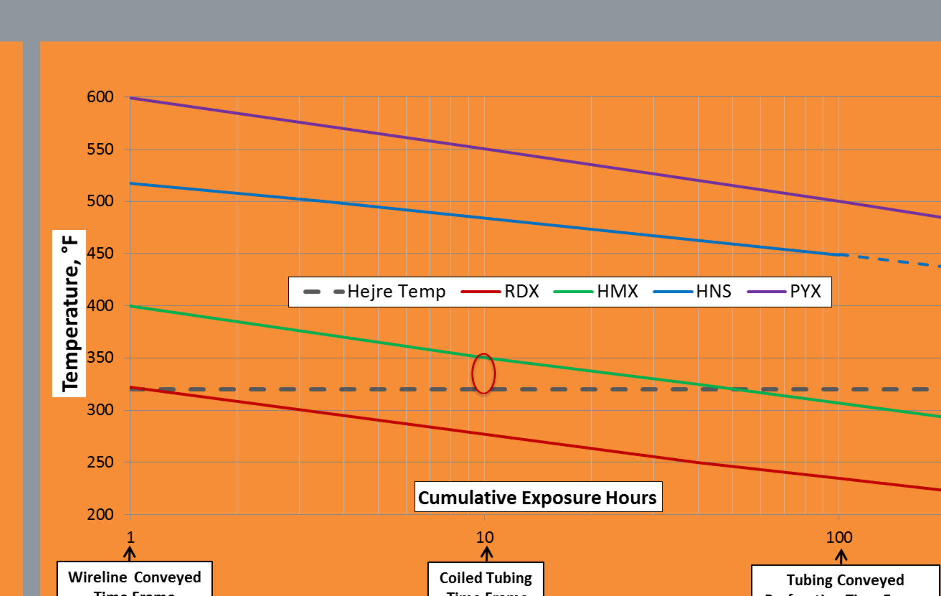




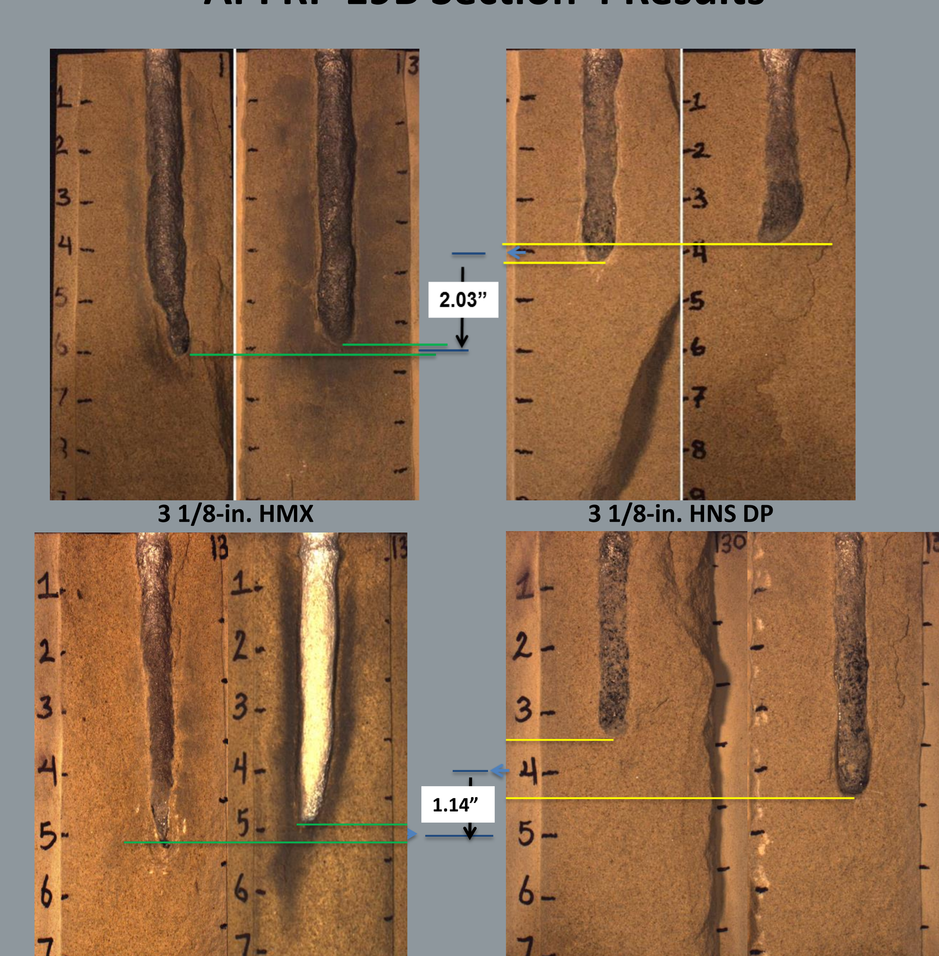


- HMX
  - One of the most powerful high explosives: A good measure of its power is its detonation pressure of 316 kbar (~4.6 million psi at density of 1.75 g/cm^3).
- HNS
  - High-thermal stability: Its detonation pressure is 241 kbar (~3.4 million psi at a density of 1.74 g/cm^3), 75% that of HMX. This means HNS perforating charges have almost 25% lower performance compared to HMX charges.
  - HNS has thermal stability over HMX but at the expense of power.





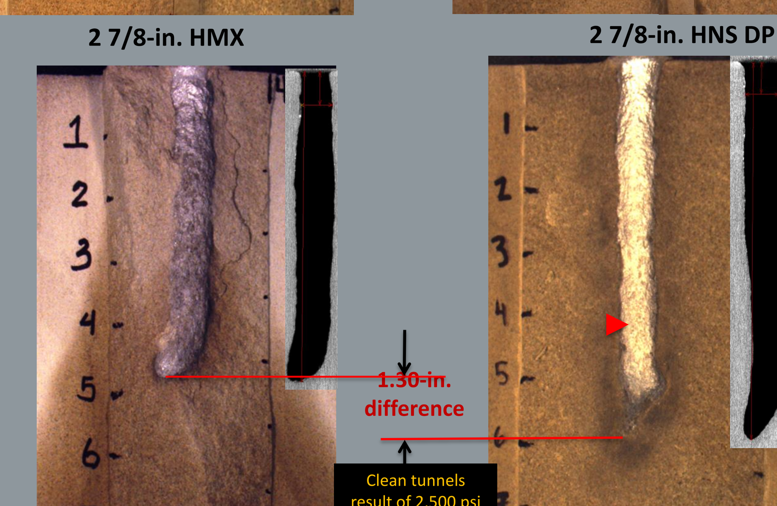
API RP 19B Section 4 Results



3 1/8-in. HMX | 3 1/8-in. HNS DP

2 7/8-in. HMX | 2 7/8-in. HNS DP

Perforation tunnel at high pressure/high temperature (HP/HT) made by the 2 7/8-in. HMX DP charge in 5-in. casing.



Perforation tunnel at HP/HT made by the 3 1/8-in. HMX DP charge in 5.5-in. casing.