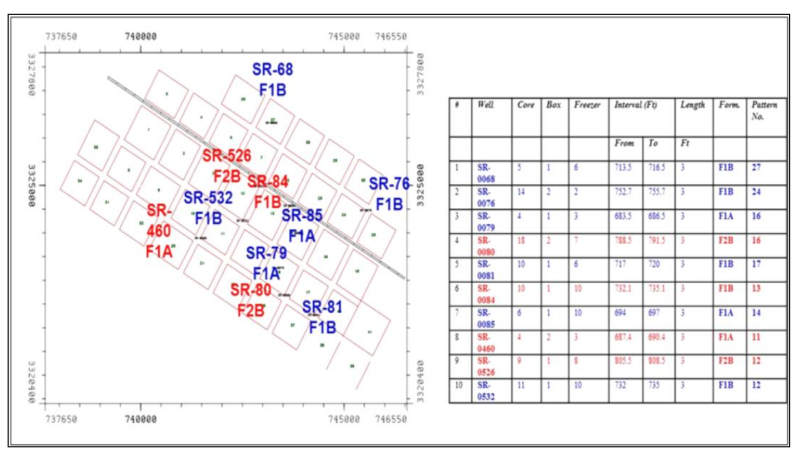
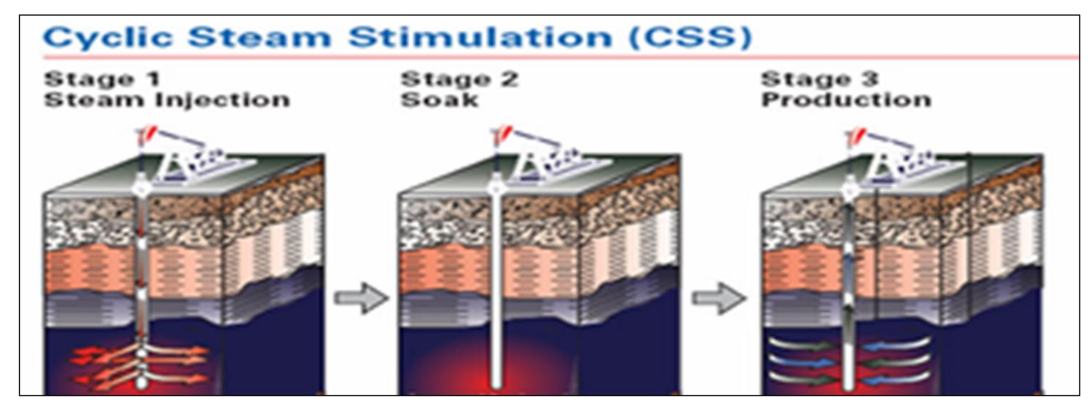
# Testing to Optimize Perforating Strategy in Shallow, High-Viscosity Oil Wells—Through Enhanced API RP 19B Section IV Data and Results

IPS-16-50-MS

Kevin Harive, Dennis Haggerty, Jacob McGregor, Halliburton






**The purpose of this undertaking was to formulate a perforating strategy for shallow, viscous oil wells to be steam flooded**.

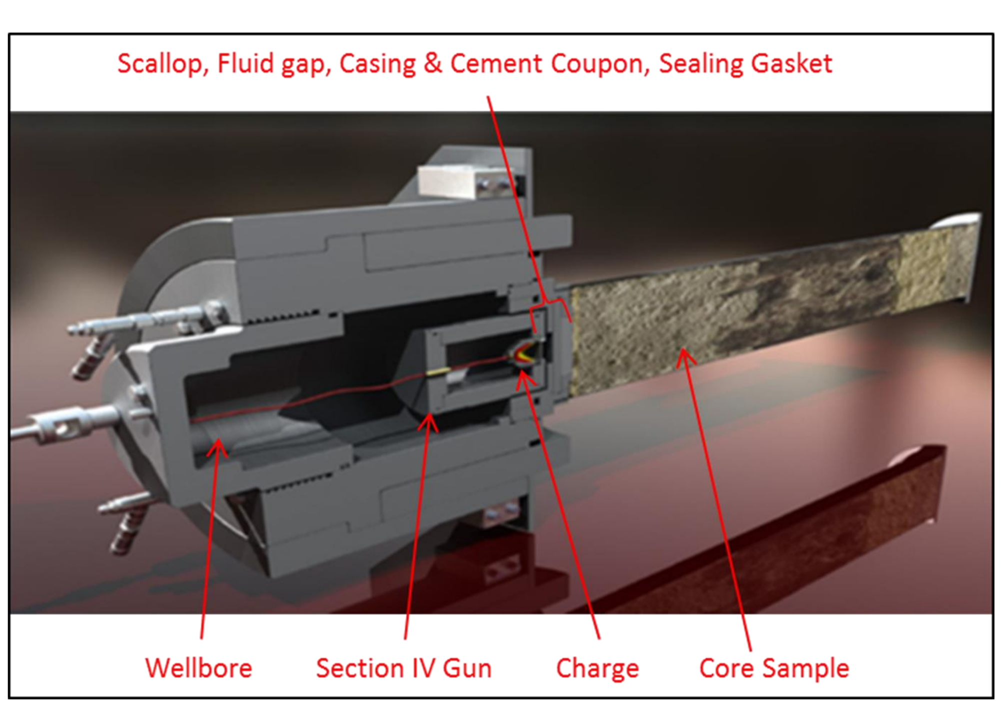
- 2020 Kuwait production goal of 4 million b/d (bopd), which will necessitate overcoming the challenges of extracting heavy crude, including:
  - Replacing the aging fields
  - Increasing reserves to sustain production growth through the exploration of new fields
  - Improving the recovery rate from the actual fields through enhanced oil recovery (EOR) technologies
- The first use of EOR techniques in a commercial project in the country, as distinguished from experimental projects.
  - EOR approaches will be deployed on a pilot basis, with experimentation intended to maximize output and eventually extend the field's production life cycle.

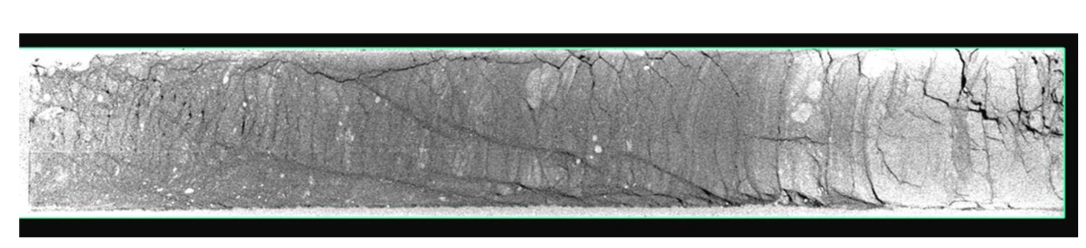
**The perforations must be balanced for both efficient steam injection into the well and oil flow out of the well.**

- First operation in Kuwait to employ the EOR method of cyclic steam stimulation.
- The cyclic steam stimulation (CSS) "huff 'n' puff" approach is currently widely practiced in heavy oil production globally as a result of its highly efficient initial production rates.
  - The drawback is that the overall recovery factors are comparatively low at 10 to 40% of oil in place.
  - This technique involves three stages: steam injection, a soaking period, and production.
- First stage, steam is directly pumped into a well at a temperature range of 300 to 340°C for a sustained period of weeks to months.
- Second stage, the well is left alone to settle for days to weeks to allow the heat to deeply permeate into the formation.
- Third stage, the hot oil is drawn out of the well through pumping operations that go on for a period of weeks or months.
- Upon visible indications that the production is beginning to taper off, the well is then subjected to a brand new cycle of injection, soaking, and production.
  - Perforations must be balanced for both efficient steam injection into the well and oil flow out of the well

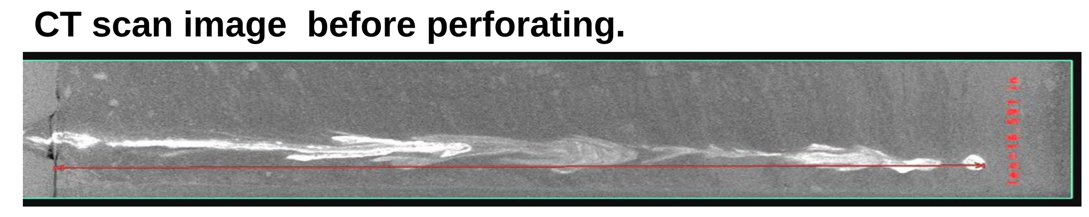
**An effective method to prepare the unconsolidated core from the target sands**

- The core inside was held together by viscous crude.
  - A technique had to be developed to remove the core from the aluminum tube to allow a stress to be applied while flowing without bypass concerns and perforating at reservoir conditions.
- The cores consist of 4-in. diameter field core representative of the target formation and were potted to approximately 28 in. in length using industry-recommended techniques.
- A new potting procedure to confine and preserve the cores in low-strength cement was used to create a 7-in. diameter core target.

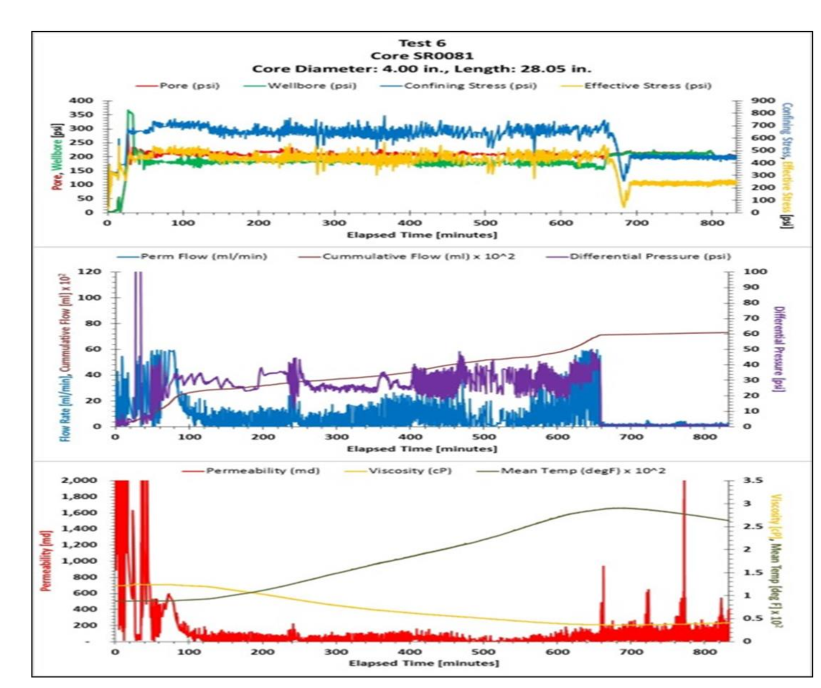


**CT scan image before perforating.**



**CT scan image after perforating. Notice no cavity was formed near the perforation entrance on the left and even after the hot water displaced the majority of the crude oil coating the sand grains.**




**Stress and pore pressure applied to match bottom hole conditions:**

  - Depth of penetration
  - Casing and cement hole size
- Each test target consisted of:
  - Scallop plate, fluid gap, casing plate, cement, and field core
  - A sealing gasket was placed between the face of the core and the cement coupon to ensure all fluid movement was through the perforation.
- The overburden stress, wellbore, and pore pressures were tuned to match field conditions.

**This work is intended to support perforating decisions for two types of steam injection operations**:

cyclical steam stimulation (CSS) and steam flood (SF).

**Tests 1–3**

- A drawdown pressure across the core of 50 psi was applied to displace the crude oil, and OMS flow was continued until a stable flow rate to drawdown pressure condition was achieved to determine if sand remained in place. Drawdown was increased until sand began to flow.

**Tests 4–5**

- To determine if a smaller hole in the casing by a small DP charge would resist sand movement leading to failure better than a larger casing hole mimicking a perforation by a BH shaped charge.

**Tests 6–7**

- Used heat with water as the displacing fluid to more closely match the planned steam-cycling stimulation by increasing the temperature of the core. This was to gain a truer assessment of the cohesive strength of the stressed, oil-saturated sand and determine if the heated crude could be displaced out the perforation without destructive sand movement.
- These tests were conducted to gain an understanding of the non-solvent displacement of the heated crude oil through the viscous crude oil-saturated sand.

**Results, Conclusions, and Recommendations**

- For Injection:
  - Gun type: HSC
  - Centralized
  - Charge type: DP
  - Shot density and gun phasing: 4 SPF at 60° Phasing
  - Optimal injection pressure:350-450 psi (35 to 20-ft zone, respectively)
  - Minimum overbalance with water: 200 psi
- For Production (on CSS):
  - Same gun and charge as injection above for CSS stage
  - Minimum overbalance with water: 200 psi
  - Initial production drawdown: 50 psi
  - Maximum production drawdown: 180 psi
- For SF:
  - Re-perforation run for each well with the same or new gun may be recommended based on the production data from the CSS operations.

**Recommendations**

Perforate at a downward angle. Use gravity for keeping loose rock out of the casing hole window. In addition, this would enhance steam contact with less disturbed formation and also create flow channels for turnaround production flow reducing the risk of sand movement. Mitigate DUB. This would greatly reduce the sand produced in the wellbore during the perforation event.