Upgrade to Intelligent TCP Firing System Service Life Increases Safety and Flexibility in Complex Permanent Completions.

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Presentation Overview

Background

- Completion Overview

New Challenges

- Increasing complexity in the completion string precludes the use of traditional hydraulic firing heads
- Due to possible weather/mechanical delays, a 14 week window was specified for the intelligent firing heads
- Firing head must fit in current dimensional envelope.

Solution

- Develop a new battery pack and electronics package for the intelligent firing head
- Develop a test protocol to certify the firing head at well conditions for the specified 14 week time period.

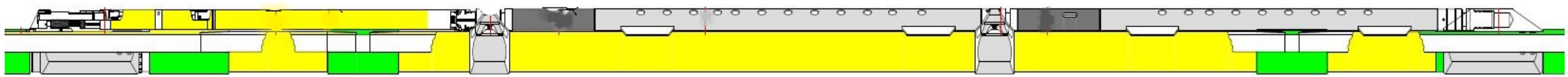
Case History

- 24 successful deployments of the new system

Completion Overview

Standard Completion

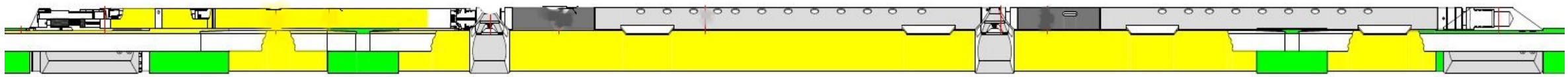
- 2-2⅞” 6 spf Side Mounted Guns per Module
- Two Hydraulic Time Delay Firing Heads Per Module
- Two to Four Modules per Completion
- Modules Mounted to 5 ½” 13 Chrome Tubing inside 9⅝” Casing
- Modules Isolated by hydraulic set packers
- Each zone controlled by “smart” Sliding Side Doors
- Rupture discs in the firing heads are set above setting pressures of the packers.
- Sliding Slide Doors are opened, pressure applied, guns fire.



New Challenges

New Completion

- The customer required design changes to the existing completion that added another level of complexity.
- Additional control lines with rupture discs closed up pressure windows between tools and packers
- The increased number of pressure operated devices incorporated into the completion precluded the use of hydraulically actuated firing heads.
- The electronic firing head could not exceed the dimensions of the existing hydraulically actuated system.
- It must remain fully operation at least 14 weeks after deployment.



Electronic Firing Head

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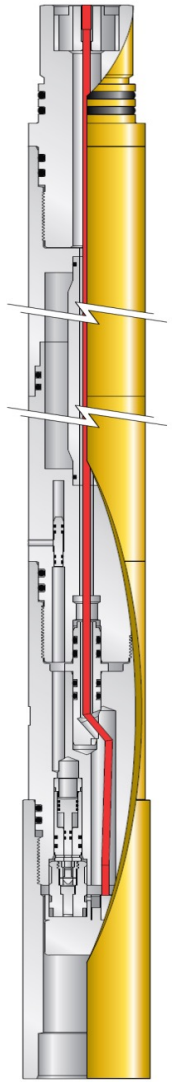
Existing Architecture

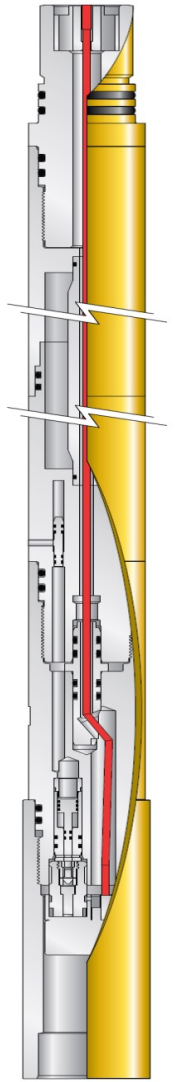
- Signature pressure pulse reduces firing pressure requirements, critical for high pressure wells
- Does not use electric detonators, minimizing battery requirements and extending battery life downhole
- Compact 3.125” OD and 28.00” Length
- Rated to 20,000 psi and up to 392° F
- Programmable delay option to facilitate underbalanced operations
- Onboard pressure/temp/time recorder for diagnostics



Test Protocol

Statement of Requirements

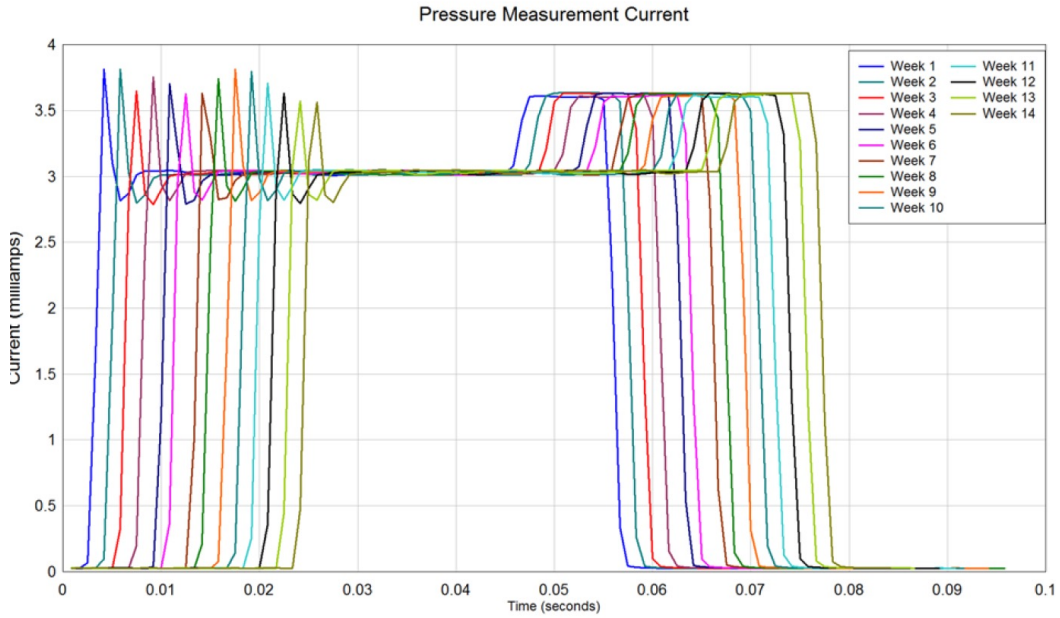
- Battery pack must deliver sufficient voltage for firing head activation after 14 weeks at an anticipated bottom hole temperature of 147º degrees C(300º degrees F)and 6,450 psi bottom hole pressure
- This is to ensure that in the event the rig must “hanger off” the subsea completion in the winter due to storms, the system will still be functional
- Maximum time a rig has been off location on Troll is 10 weeks
- The extended life capability was achieved by using a new Lithium Sulfuryl Chloride battery pack for temperatures below 150º degrees C
- For applications up to 200º C a Lithium Thionyl Chloride Battery would be used



Electronic Firing Head Modifications

Procedure

- The Pulsar Firing Head has pressure and temperature “gates” as part of the integral safety system, the firing head can be configured to sample these gates at specific times
- The processor battery life test uses the new, low-power design processor running a special version of test code that exactly mimics the tool load. Simulated temperature and pressure are measured on a periodic basis, at the same intervals as a downhole tool.
- Once per week, the tool current was measured, and the pressure and temperature measurements were recorded
- The chart shows a comparison of the pressure measurement current signal at one-week intervals, starting after one week and continuing throughout the test.
- There is no perceptible difference between the first week and the completion of the test.



Electronic Firing Head Modifications

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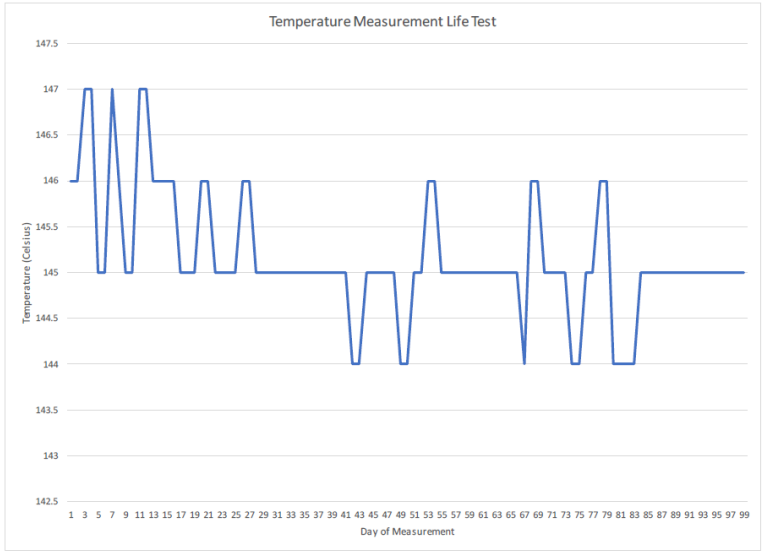
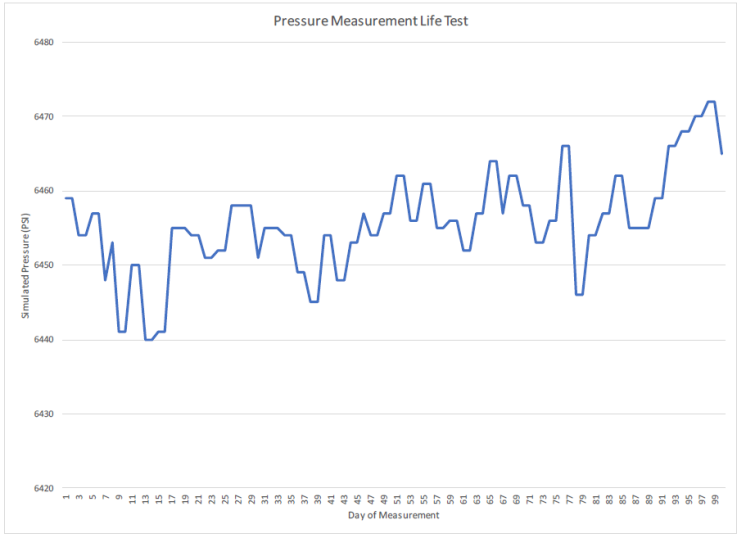
Test Conclusion

- The processor battery performed well throughout the 14-week life test. The total life of the battery is unknown, but the present design is adequate for the 14-week target.
- Extrapolating the current test data shows that the firing head could remain fully operational for up to 42 week at reservoir conditions.



Daily Temperature Measurements



Daily Pressure Measurements

Case Histories

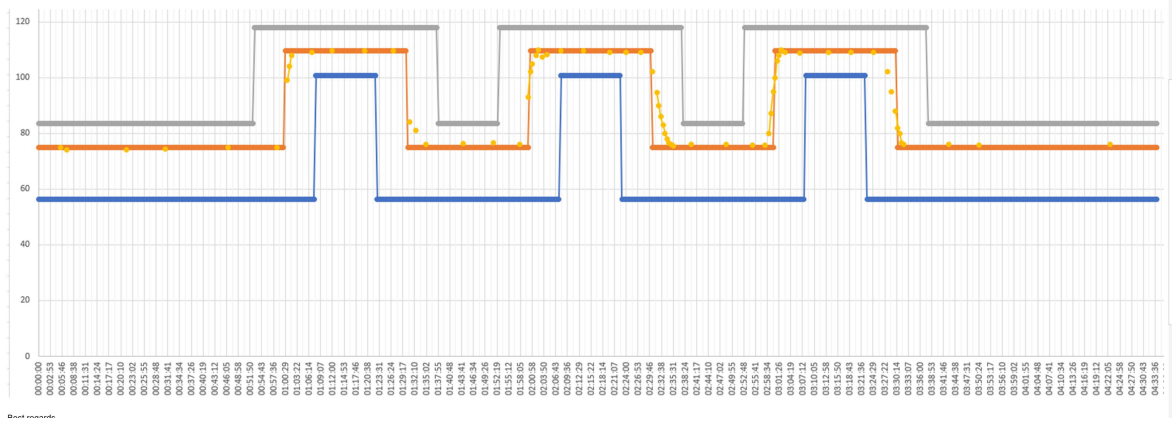
Case Histories

- The customer accepted the test protocols and results
- Dimensionally the new firing heads were unchanged from the original design
- 28 tools were built and delivered to Norway
- The new firing head was incorporated without issue into the side mounted gun system
- To date, 24 firing heads in 12 gun modules have been successfully deployed and actuated
- Maximum activating pressure per module dose not exceed 500 psi surface pressure

Latest Case History

June-July 2022

- Completion with 2 side mounted gun systems deployed
- Sub Sea completion, 5 control lines, 2 hydraulic set packers, intelligent valves and glass disc sub
- Deployed on the drilling rig and well was suspended
- IMR vessel arrived one week later to finish the completion.
- Numerous attempts to cycle the glass disc sub without success
- IMR vessel left location, returned 1 week later, it was decided to perforate without opening the glass disc.
- Long cycles had been programmed into the electronic firing heads due to the low capacity pump available on the IMR.
- 3-30 minute cycles followed by a 7 minute delay were used
- Guns fired 3 hours and 11 minutes after pressure sequencing began
- On bottom at reservoir conditions for 22 days
- Glass plug opened when guns fired.



Q&A

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