

Distributed Temperature Sensing (DTS) in a CO₂-EOR Complex

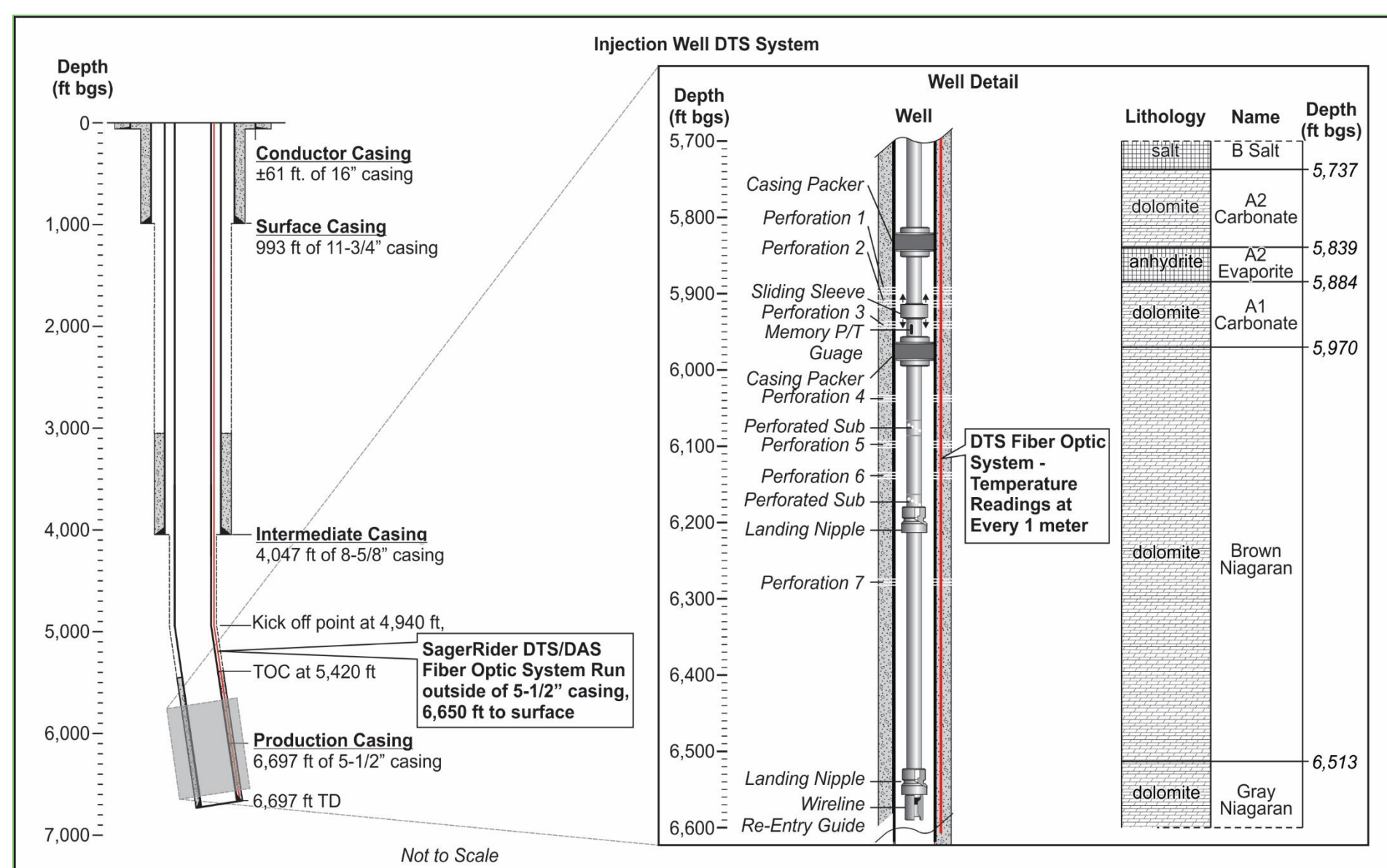
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ABSTRACT

MRCSP is monitoring CO₂ using Distributed Temperature Sensing (DTS) and Pressure during ~18 month period while CO₂ is being injected for EOR to raise reservoir pressure. The collection, processing, and interpretation of large amounts of streaming data from fiber-optic based DTS presents challenges for long-term geologic storage projects, while providing opportunity to obtain high-resolution information on CO₂ migration in the reservoir. A DTS system, along with a five-level, behind-casing pressure sensing array was installed as part of the MRCSP large-scale CO₂ storage test in a depleted pinnacle reef oil reservoir in Michigan. This poster discusses the value of having real-time DTS combined with multi-level pressure monitoring. DTS data is analyzed in Excel, with results from the initial injection of 26,000 metric tons of CO₂ presented here. Benefits of this new technology include:

- Monitoring the depth where CO₂ is entering the reservoir through various perforations in the injector well;
- Assessing potential vertical migration of fluids along the injection well borehole;
- Monitoring flow stratification in the reservoir and arrival of CO₂ at the monitoring well.

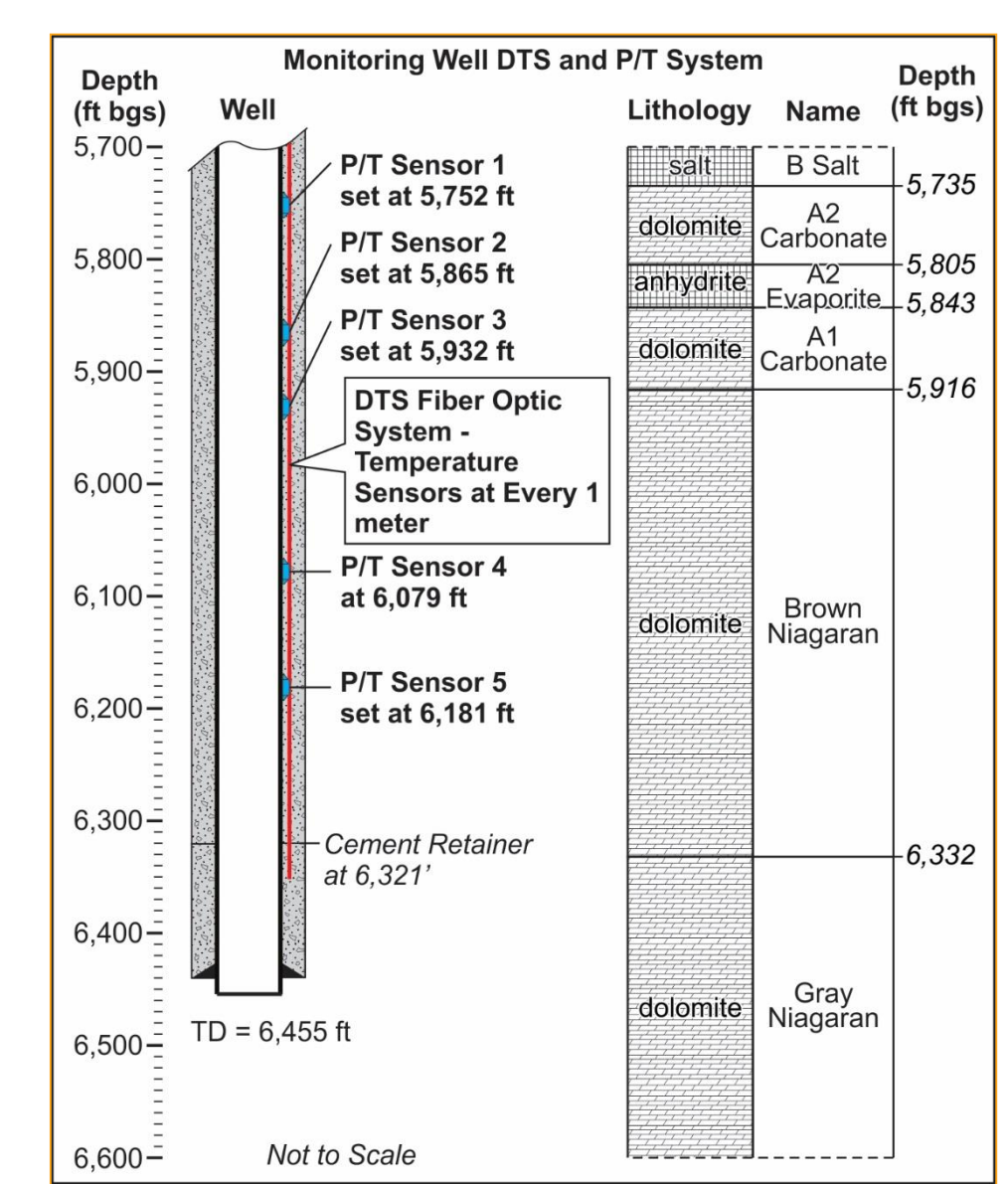
REEF DETAILS AND WELL CONFIGURATIONS



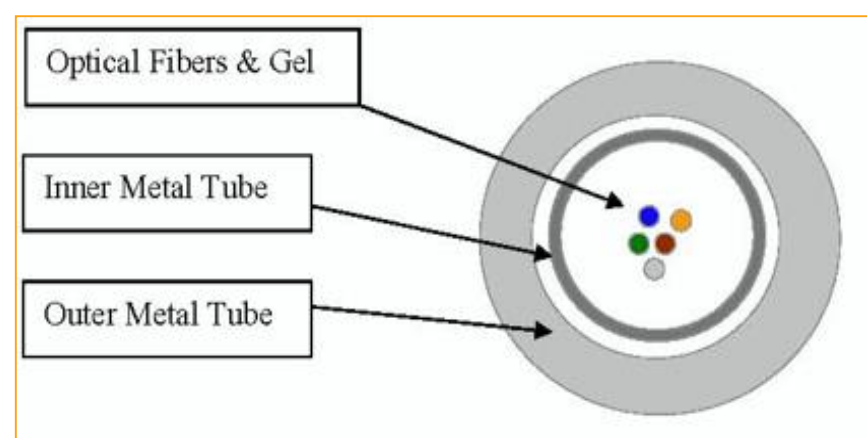
- ### Reef Details
- New EOR reef, part of 10 existing Niagaran reefs at various stages of EOR (CO₂ Flood, Active EOR, Late Stage).
 - As of June 2017, **26,000 MT** of CO₂ has been injected.

- ### Injection Well Configuration
- DTS installed from surface to 6697' MD (6345' TVD) bottomhole, outside the 5.5" production casing.
 - Injection well perforated at 7 depths, between 5892' and 6284' MD, each perforated interval is ~10 feet.
 - Memory pressure and temperature (P/T) gauges for monitoring bottomhole conditions.
 - Combination of tubing packers and sliding sleeve allows injection into the A1 Carbonate or the Brown Niagaran formations.

- ### Monitoring Well Configuration
- DTS installed from surface to 6352' MD (6253' TVD) bottomhole, outside 4.5" production casing.
 - Monitoring well also has five casing mounted *real time* P/T sensors in the A2 Carbonate, A1 Carbonate and Brown Niagaran formations.

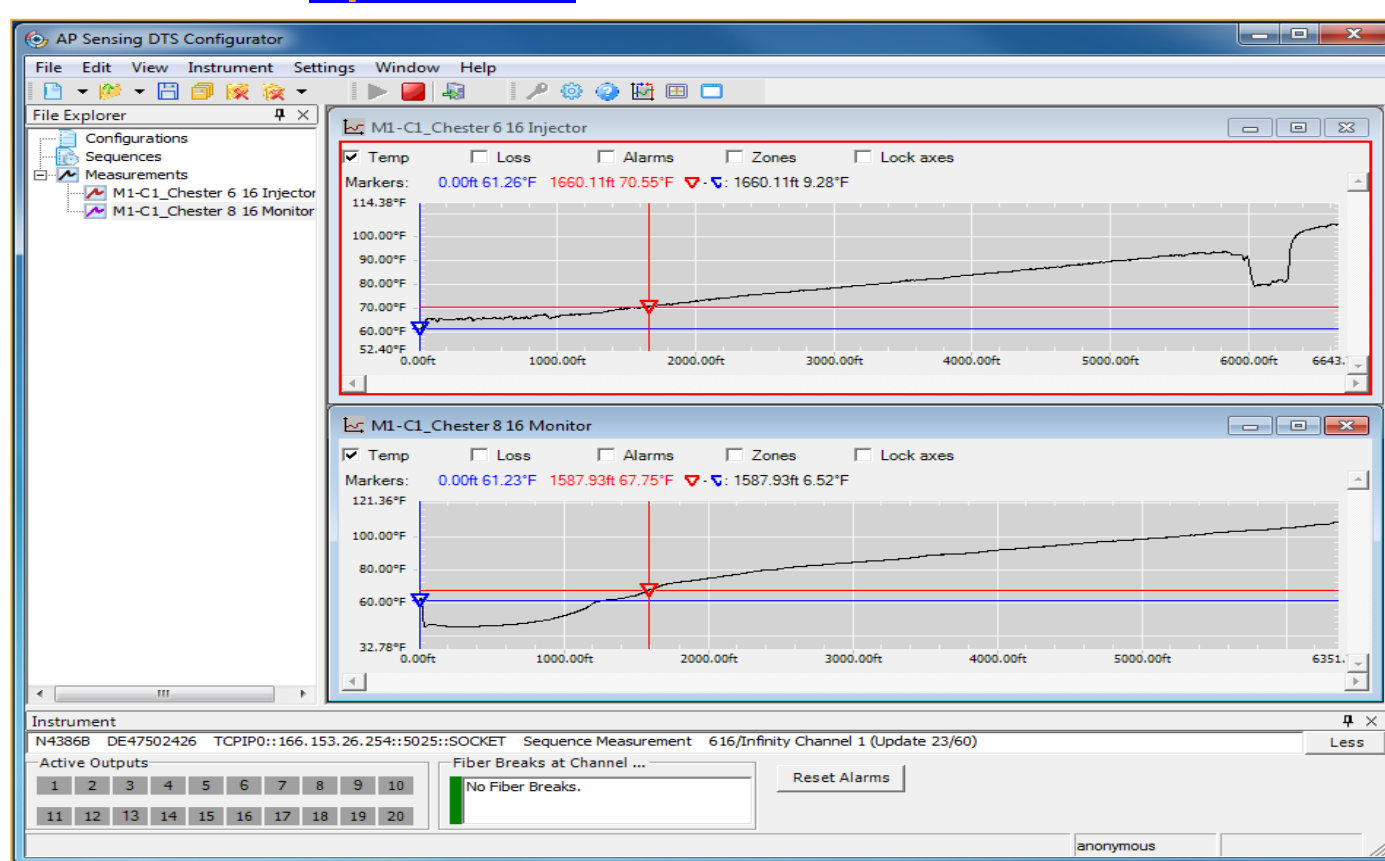


DISTRIBUTED TEMPERATURE SENSING (DTS)

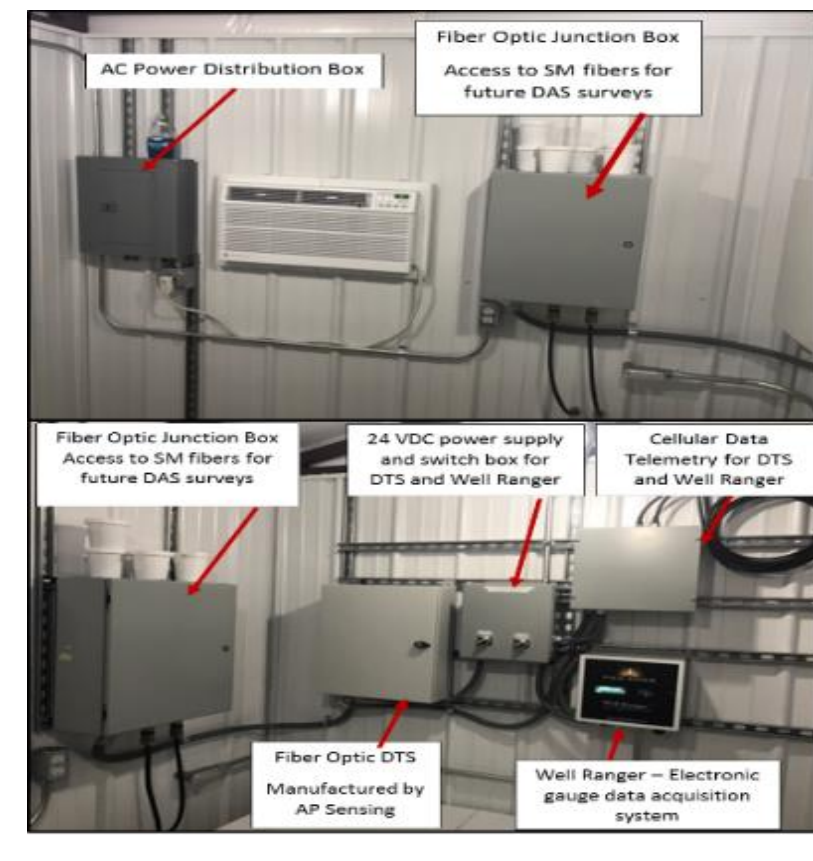


Cross Section of Downhole Fiber Optic Cable

- ### DTS Fiber Optic Technology
- Two multi-mode (MM) DTS fiber optic cable and three single mode (SM) cables for DAS. Cables contained in two concentric metal tubes, attached to 5.5" (Injection well) and 4.5" (Monitoring well) production casing from surface to bottom.
 - **DTS Configurator & Download** software for monitoring *real-time* temperature vs. depth readings in both wells (once every hour at every 1 m depth intervals).

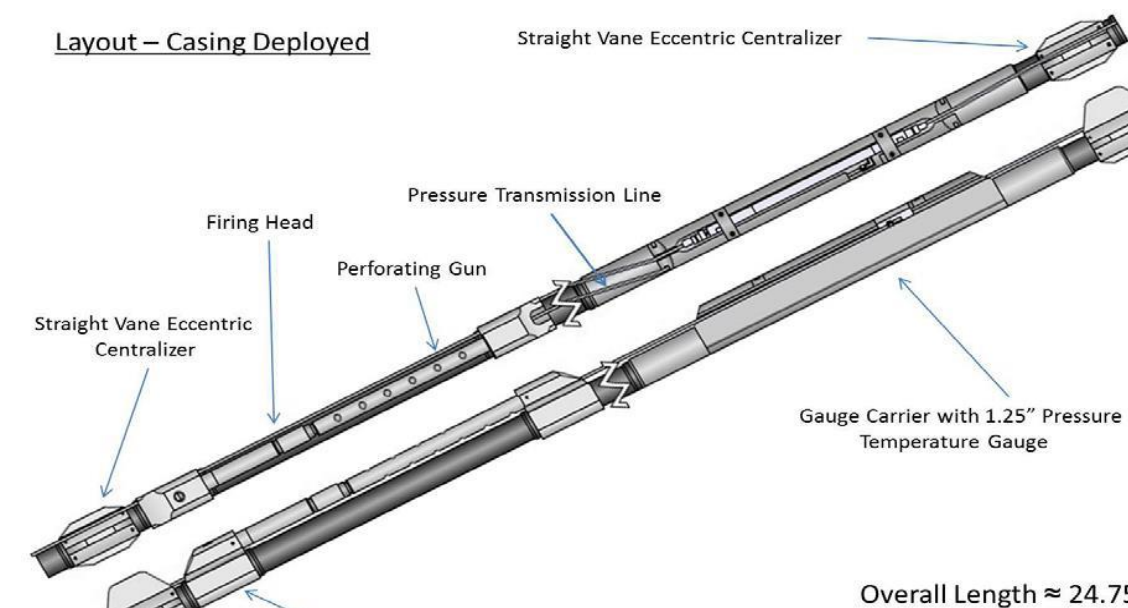


DTS Configurator Real-time Software Utility

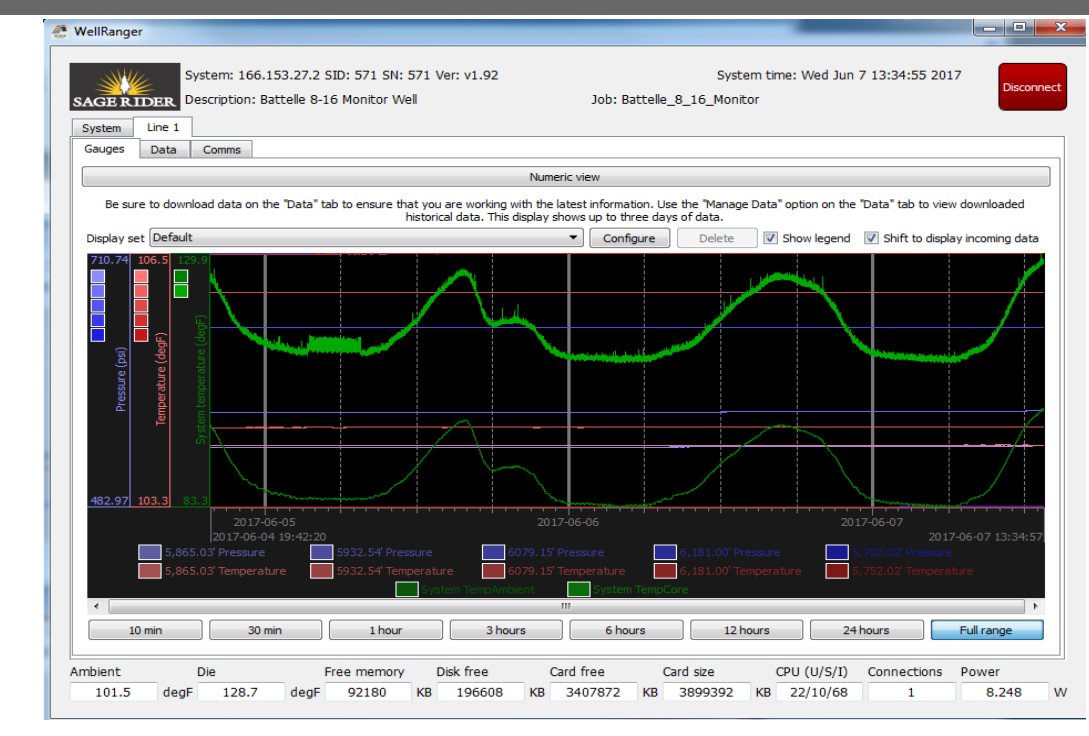


DTS Junction Box

MULTI-LEVEL PRESSURE MONITORING SYSTEM



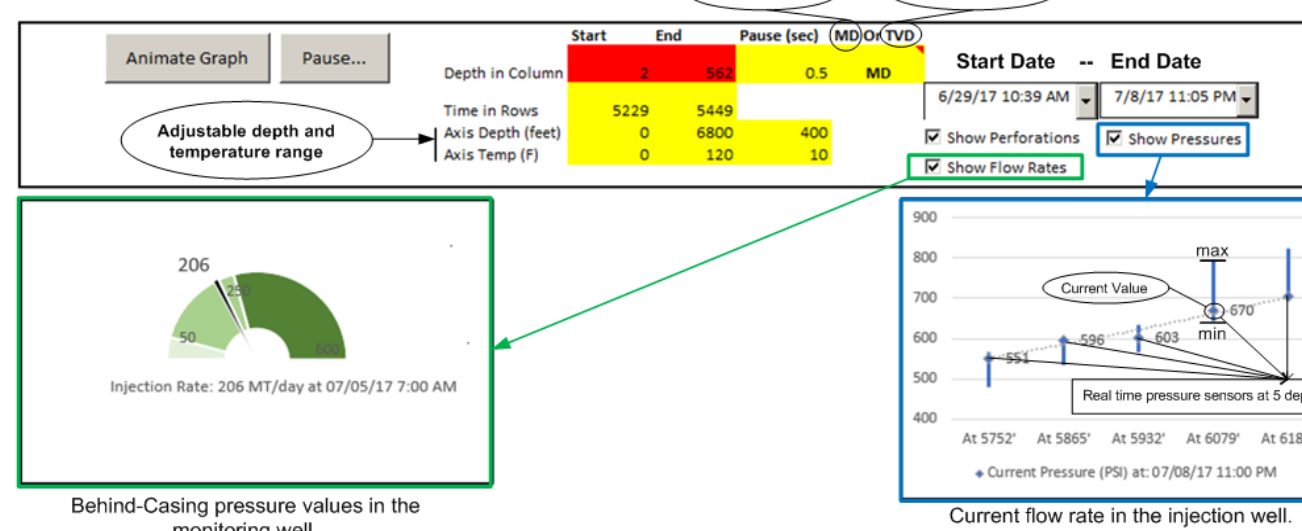
External Casing Deployed SageWatch™ Station



WellRanger Software Utility

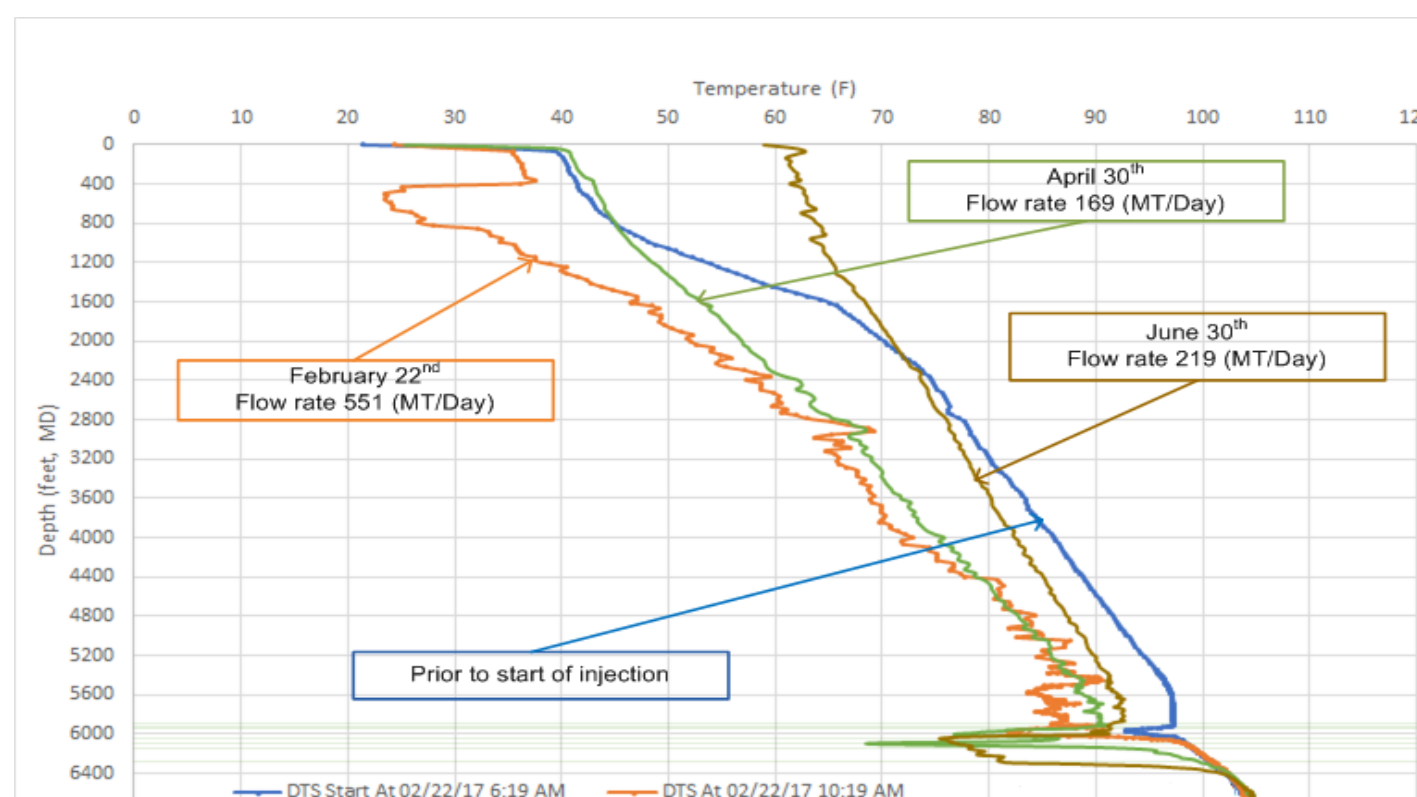
- **SageWatch™** installed in the monitoring well (at five depths) for monitoring *real-time* pressure and temperature in the A2 Carbonate, A1 Carbonate and Brown Niagaran formations.
- WellRanger software for monitoring *real-time* pressure and temperature (once every minute).

BATTELLE DTS & PRESSURE VISUALIZATION SOFTWARE



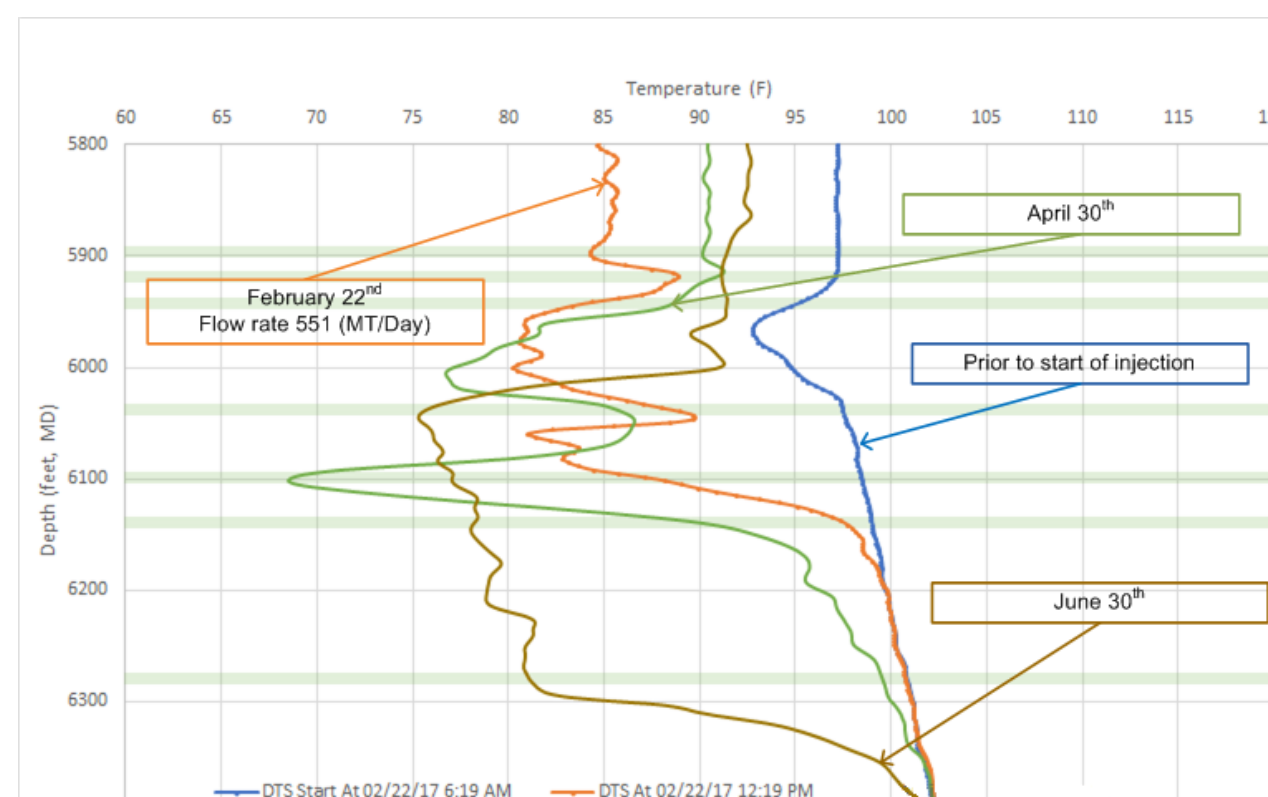
- Choose Start/Stop time, adjust depths and temperature axis, TVD/MD basis;
- Display Perforated Zones, Flow Rates in the Injection Well, and Pressure at Monitoring Well

INITIAL RESULTS: DEPTH VS. TEMPERATURE AND PRESSURE MONITORING



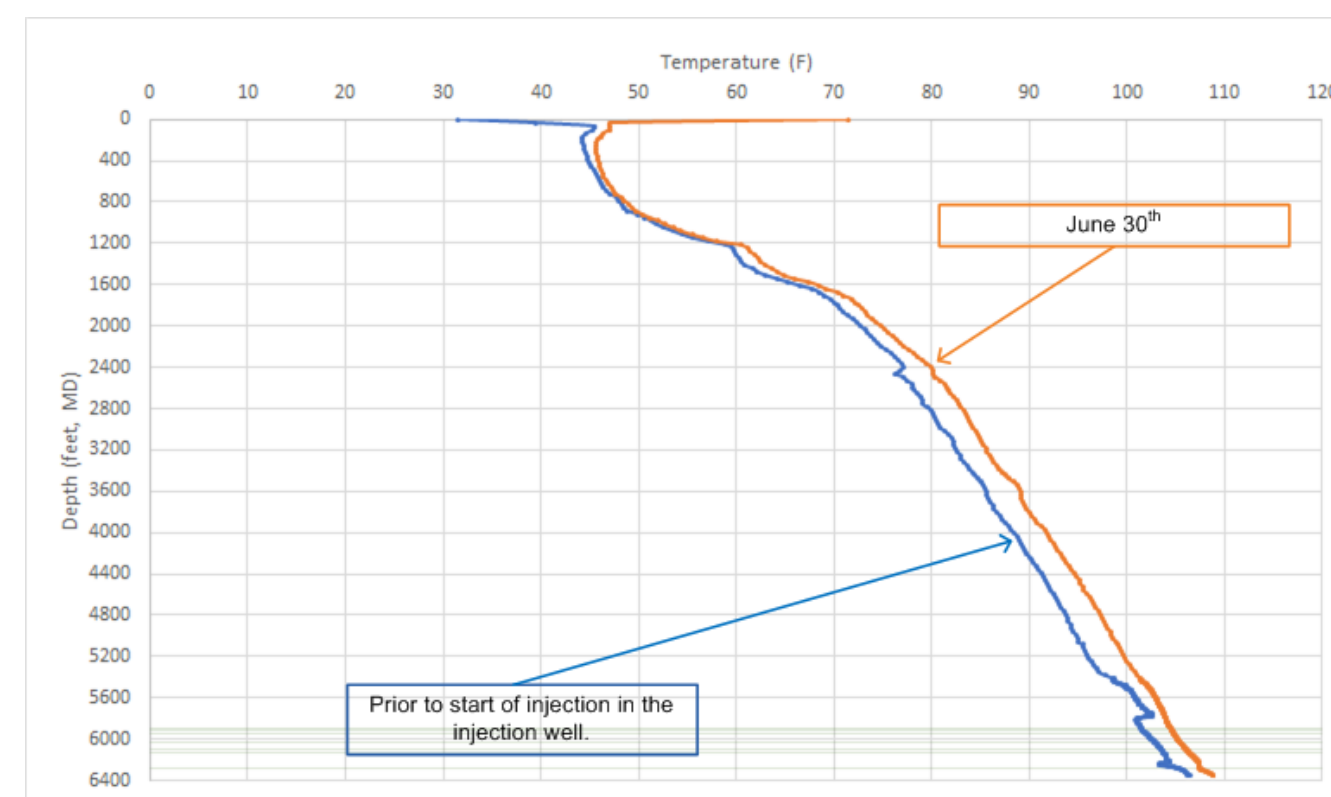
Injector Well Temperature profile

- Plot shows profile of Temperature at various times after start of injection on February 22nd,
- Cooling observed in perforated zones where CO₂ is being injected.



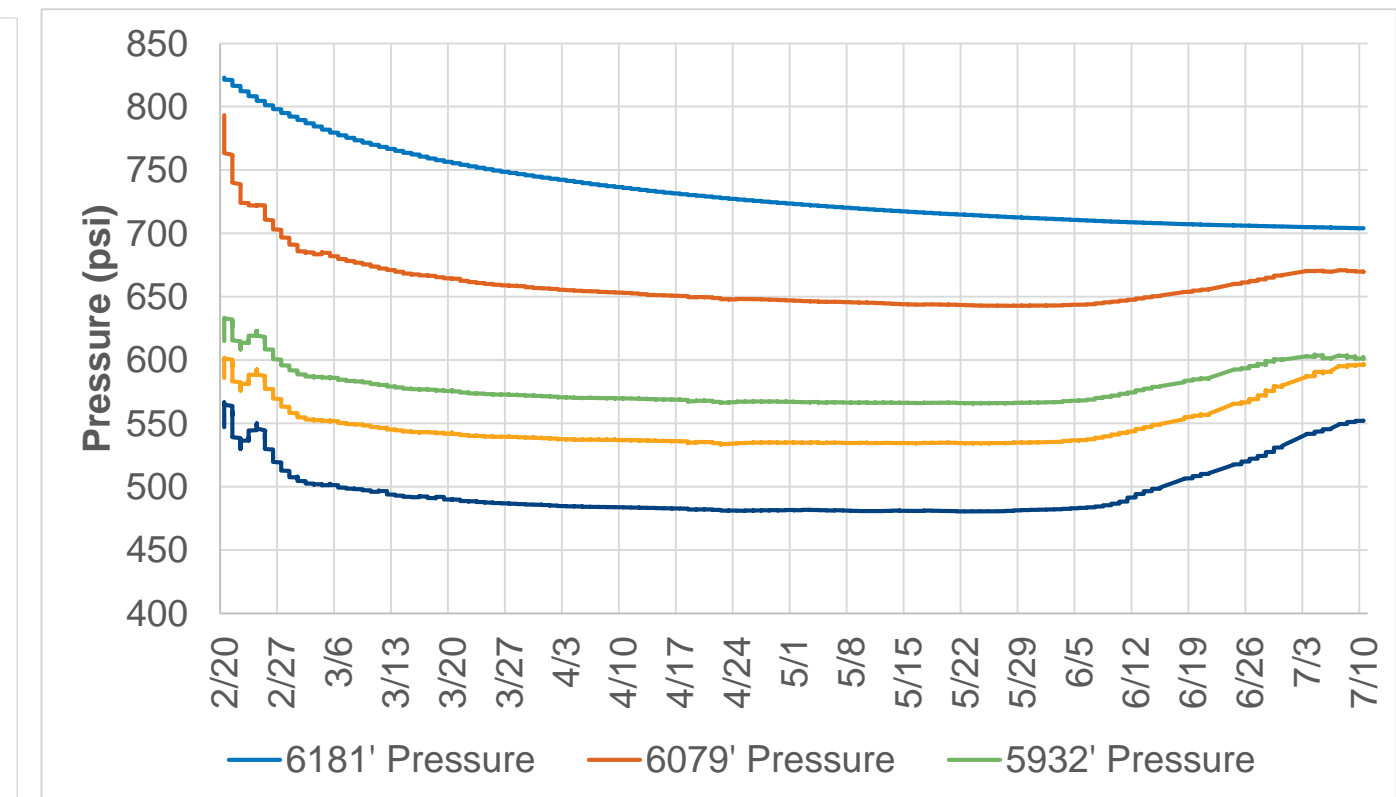
Injector Well Temperature Profile, Perforated Zones

- Green bars indicate 7 Perforated Zones
- Adjusting the Sliding Sleeve (open/close), switches flow into either the A1 Carbonate or Brown Niagaran formations.



Monitoring Well Temperature Profile

- Plot shows profile of Temperature at prior to start of injection on February 22nd and on June 30th,
- No significant cooling observed.



Monitoring Well Outside Casing Pressure Profile

- Slight increase in pressure observed in A2 Carbonate, A1 Carbonate and upper Brown Niagaran formations.

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