

Self-Sustaining Treatment for Active Remediation (STAR): Pilot Studies for the Treatment of Hydrocarbon-Impacted Soils



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UK Patent Office, GB 0525193.9, Filed 10/12/2005.

International PCT Filing, PCT/GB2006/004591, Filed 8/12/2006 (Priority Date 10/12/2005).

Overview

- Brief Overview of STAR Process
- Experiments Conducted to Date:
 - Column Experiments
 - Ex Situ Field Experiments
- Case Studies: In Situ and Ex Situ Pilot Tests
- Benefits and Limitations of STAR

What is STAR?

- STAR: Self-Sustaining Treatment for Active Remediation
- Patent-pending technique for destruction of NAPLs embedded in soil
- Reduced costs vs. other technologies
- Addresses recalcitrant contaminants
- Extensive laboratory research, ready for pilot trial

Smoldering Combustion

Combustion

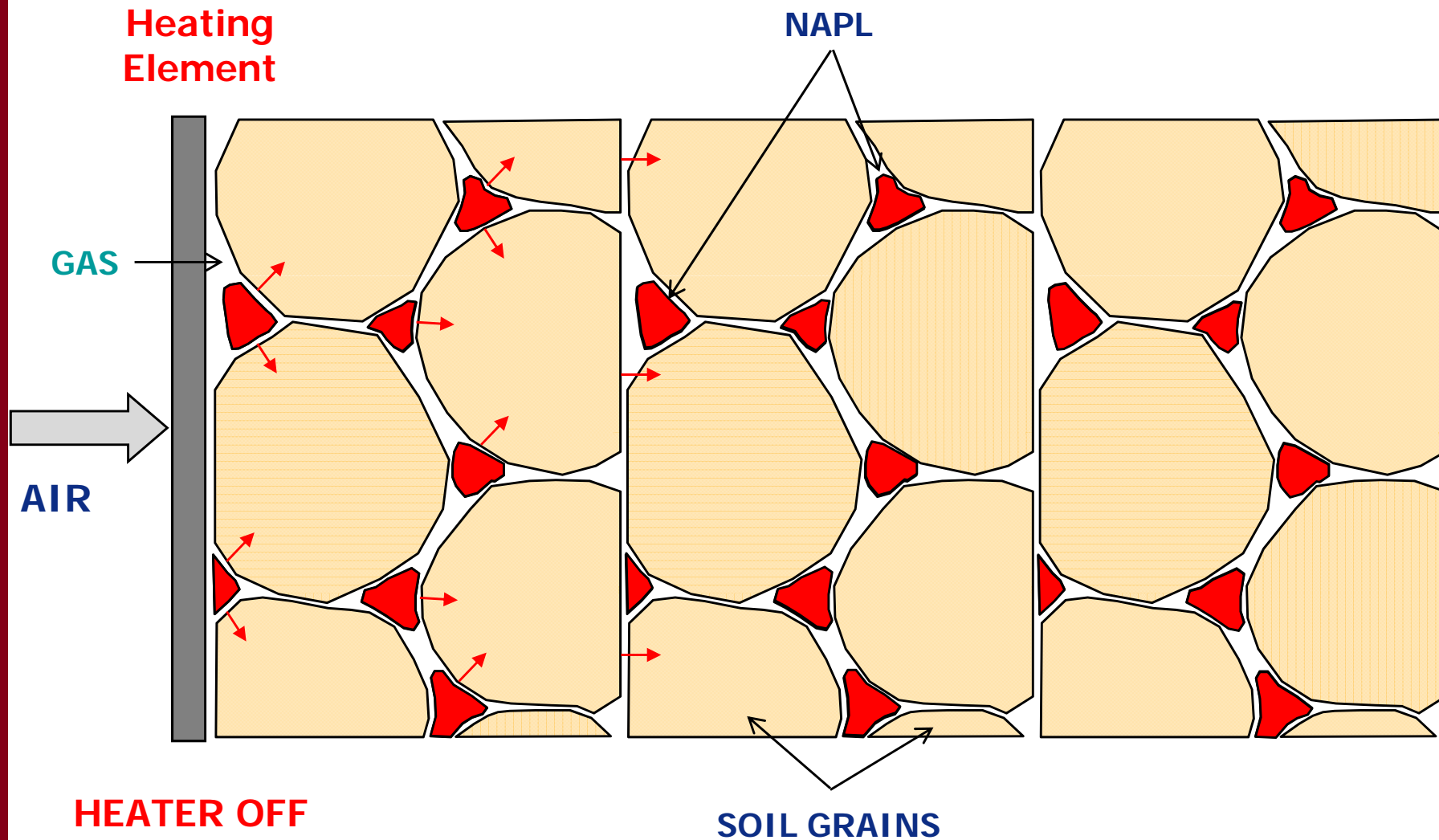
- exothermic reaction converting carbon compounds $\rightarrow \text{CO}_2 + \text{H}_2\text{O}$

Smoldering:

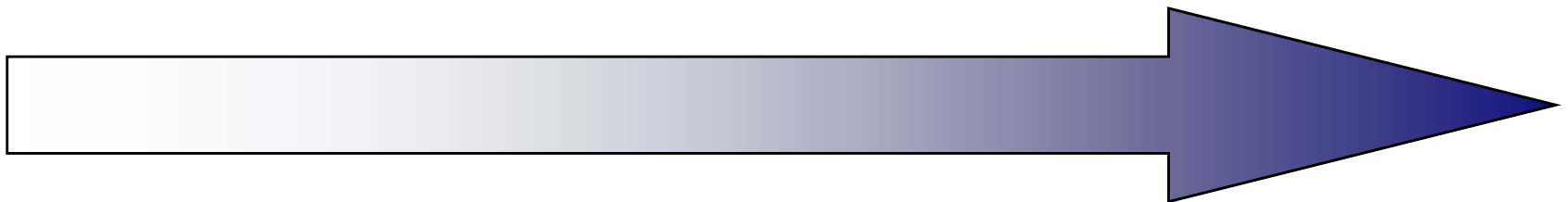
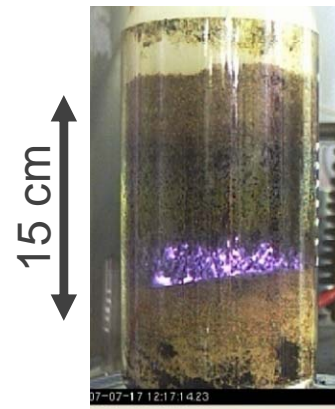
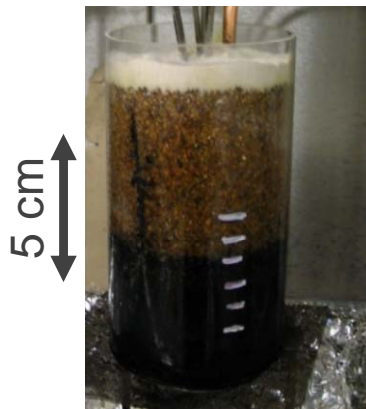
- Flameless
- Occurs in porous materials
- Temperatures typically between 400 – 800 °C
- Propagation typically 0.1 to 1.0 cm/min
- Oxygen-limited, thus controlled



NAPL Smoldering

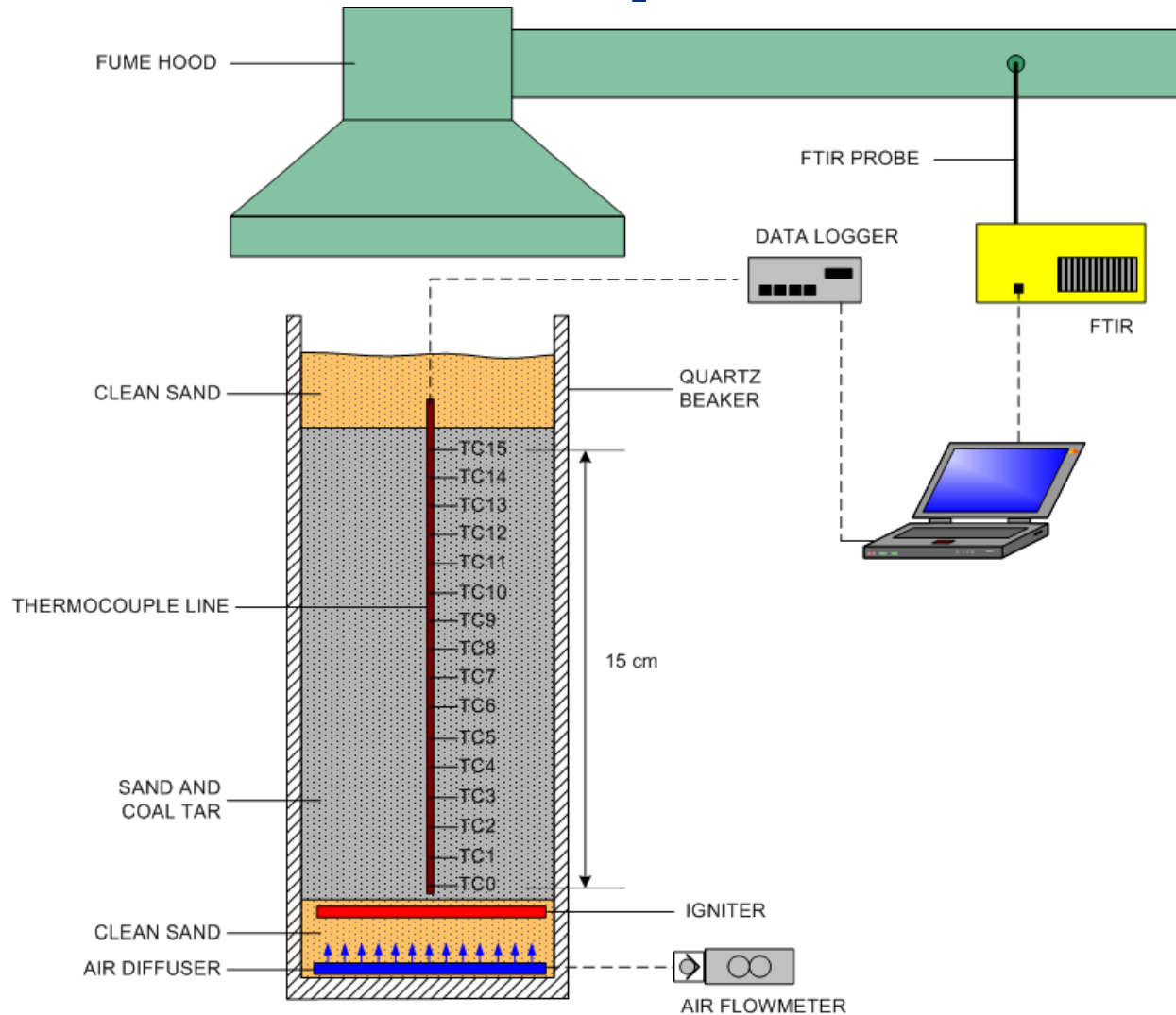


STAR Experimental Scales



laboratory experiment (0.003m^3) to field experiment (2.5m^3)

Column experiments



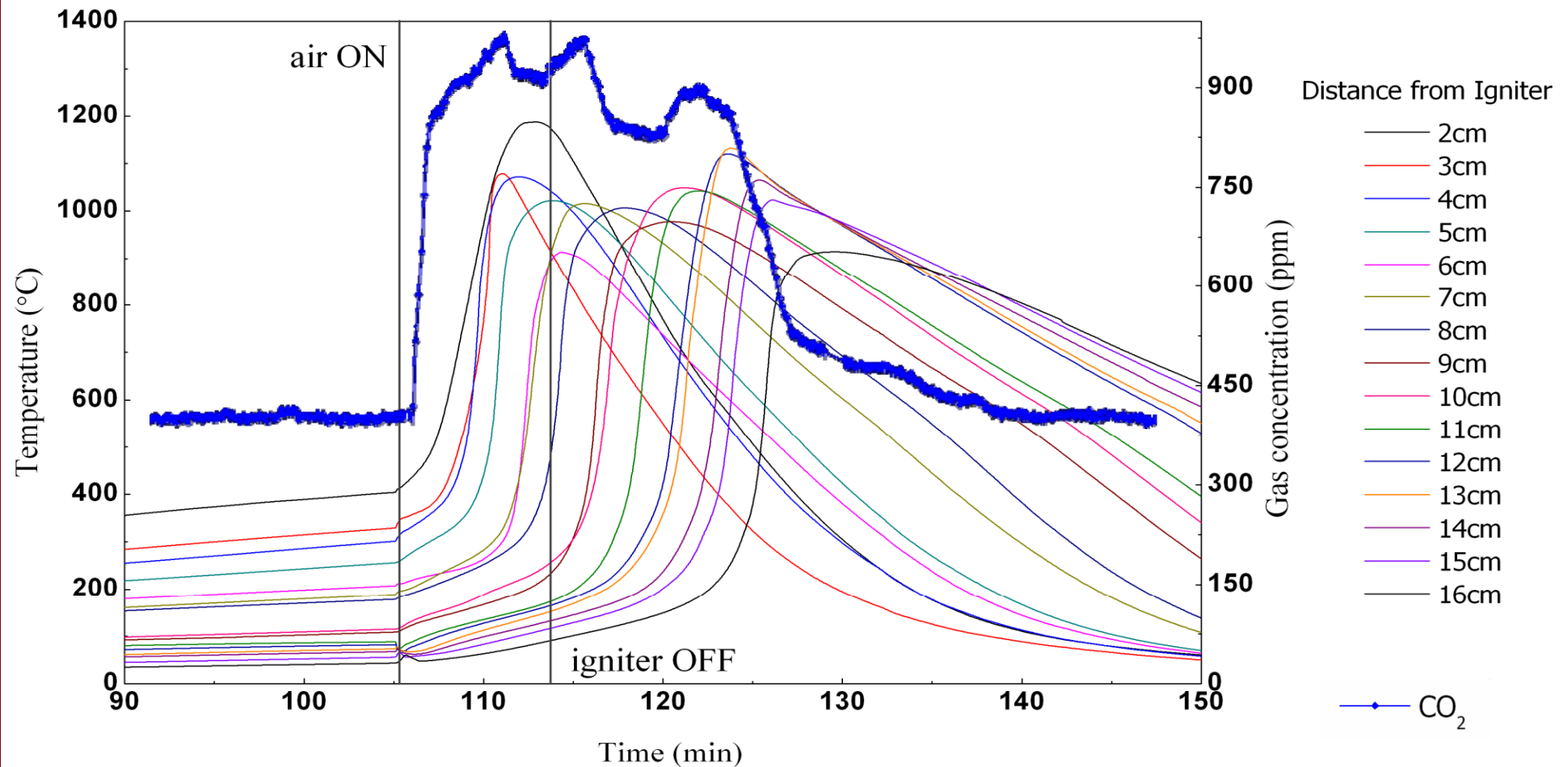
Scenarios Examined at the Column Scale

- Variable Porous Media Types (fine sand to gravel)
- Variable air flow rates
- Variable NAPL / water saturations
- Variable NAPL types (coal tar, hydrocarbons, crude oil etc.)

Results showed process to be generally self-sustaining and to result in >99% reduction in contaminant concentrations

Rate of propagation a function of NAPL type and air flow rate

Column Experiment: Base case



Experimental results: Base case



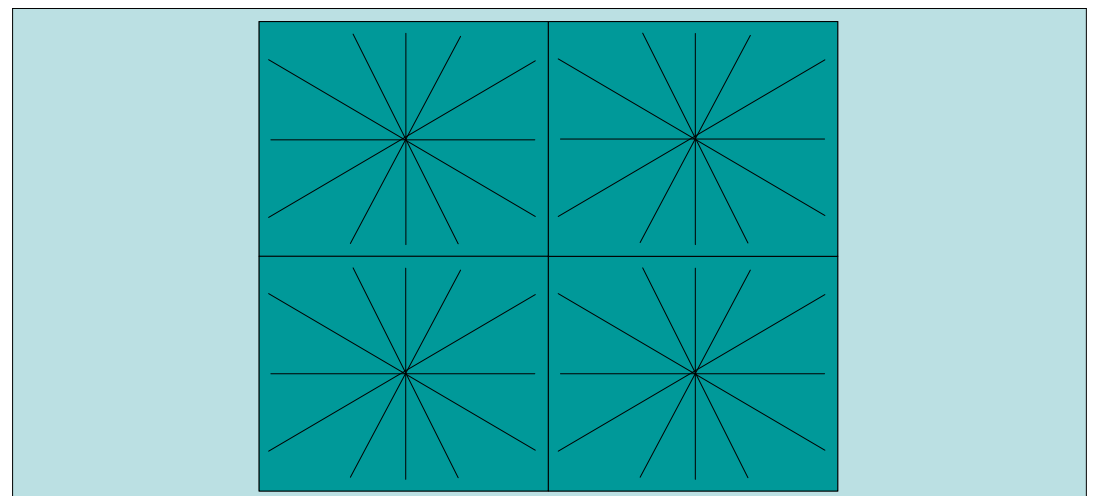
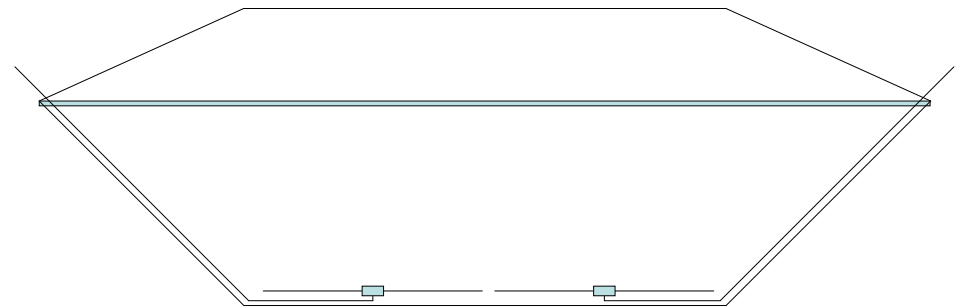
0-1 1-2 2-3 3-4 4-5 5-6 6-7 7-8



8-9 9-10 10-11 11-12 12-13 13-14 14-15 15-16

Distance from igniter (cm)	TPH (mg/kg)	PAH (mg/kg)
0-1	<0.1	<0.1
1-2	<0.1	<0.1
2-3	<0.1	<0.1
3-4	<0.1	<0.1
4-5	0.3	0.3
5-6	<0.1	<0.1
6-7	<0.1	<0.1
7-8	<0.1	<0.1
8-9	<0.1	<0.1
9-10	<0.1	<0.1
10-11	<0.1	<0.1
11-12	<0.1	<0.1
12-13	1.2	1.2
13-14	<0.1	<0.1
14-15	<0.1	<0.1
15-16	<0.1	<0.1
Initial concentration	38000	9500

Ex-Situ Field Experiments



Field Trial 1: Excavation



Before

Conc (TPH) = 31,000 mg/kg
± 14,000 mg/kg



After

Conc (TPH) = 10 mg/kg
± 4 mg/kg

Total Gaseous Emissions (Approximate)

	Total mass recorded (kg)	Projected total mass (kg)*
Water vapor H ₂ O	33	65
Carbon dioxide CO ₂	73	146
Carbon monoxide CO	31	63
Nitrogen monoxide NO	0.1	0.2
Methane CH ₄	0.2	0.4
Benzene C ₆ H ₆	0.1	0.2
Toluene C ₇ H ₈	0.1	0.2
Naphtalene C ₁₀ H ₈	1.4	2.8
Xylenes C ₈ H ₁₀	0.2	0.4

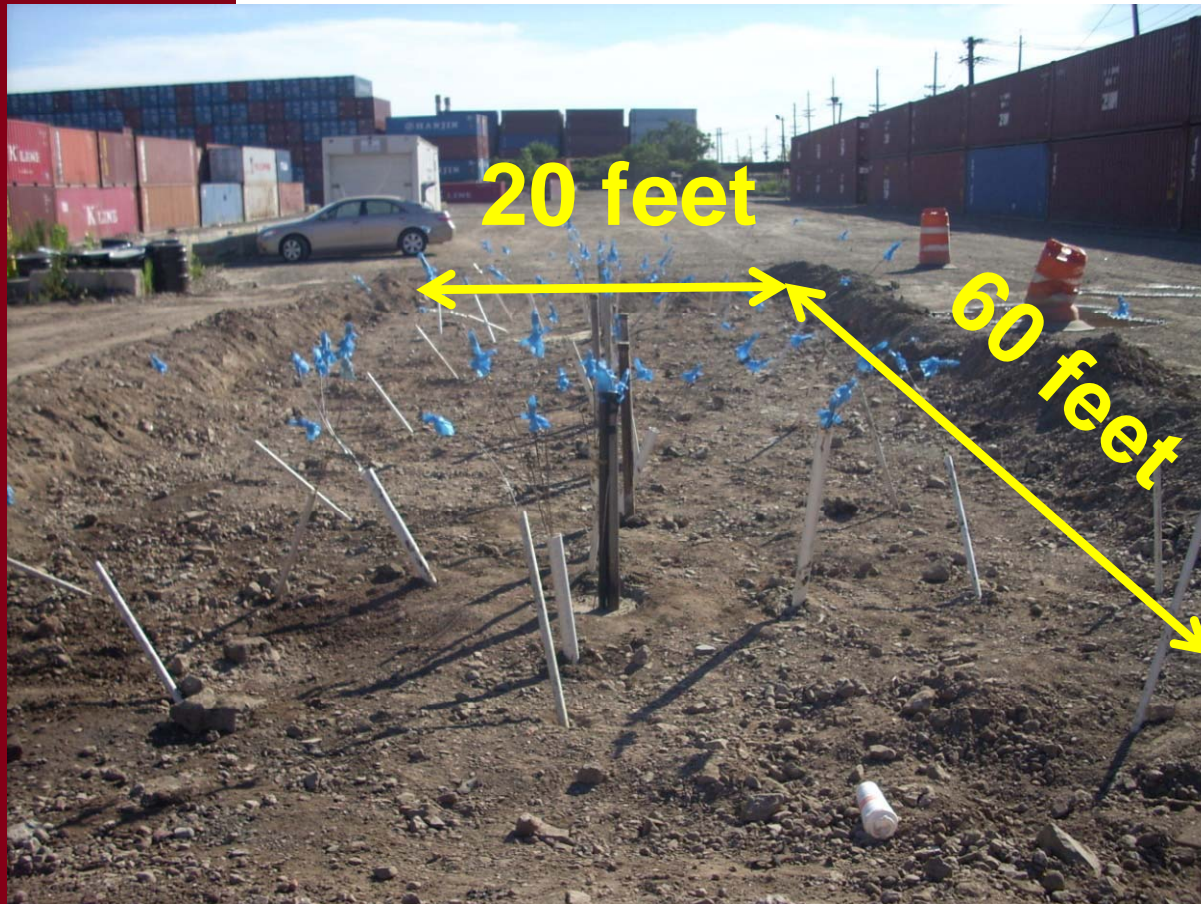
* FTIR analysis continued only for first half of experiment



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Case Study: In Situ STAR Pilot Test at a Former Industrial Facility in New Jersey

In Situ Pilot Test



- Pilot test designed to test STAR:
 - Focus on the scale of a single point application in the field
 - Under saturated conditions (i.e., Below ground surface and below the water table)

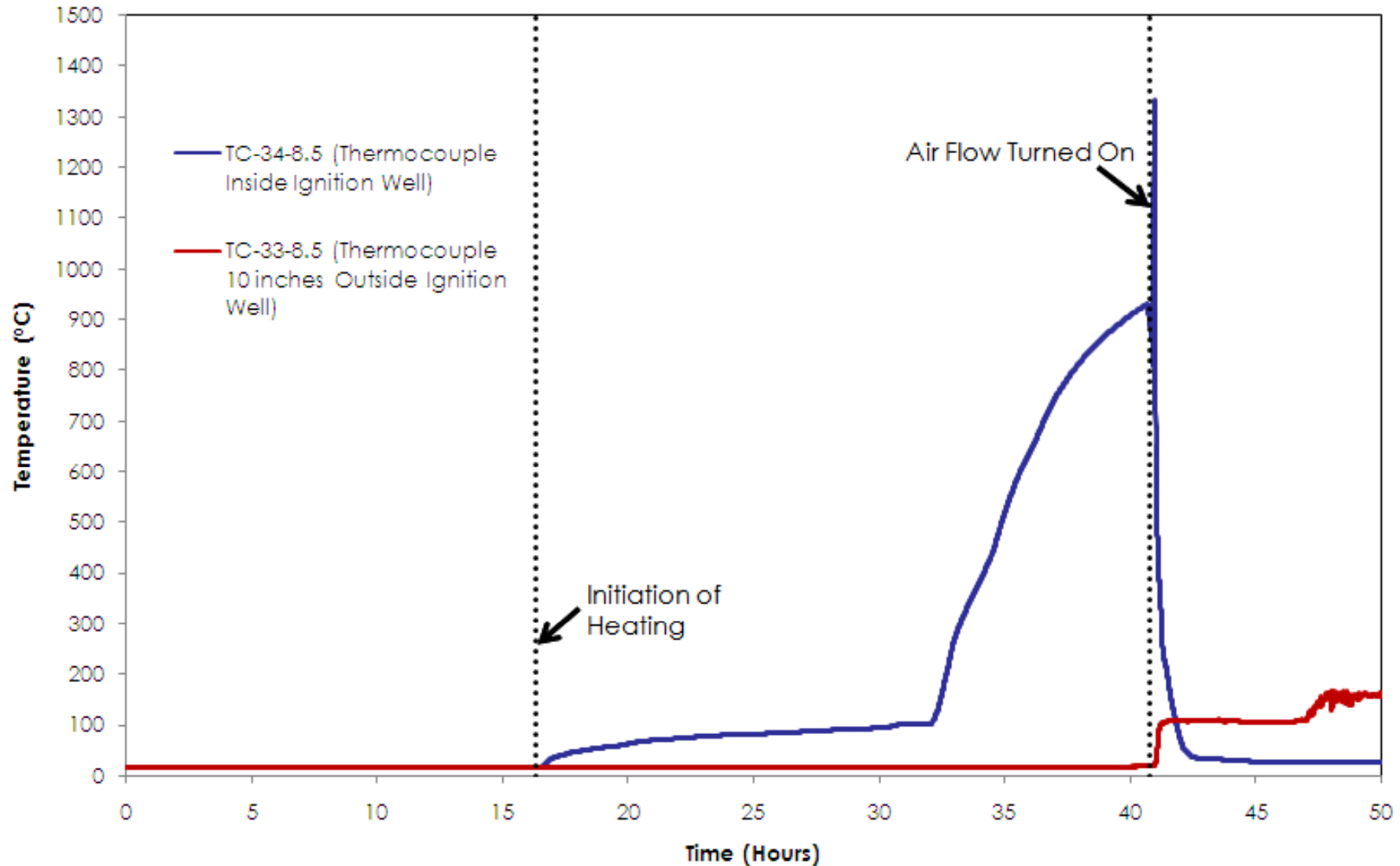
Pre-Pilot Characterization



Pilot Test Instrumentation



Initial Results - Ignition



Pilot Test Summary

- **Successfully achieved self-sustaining smoldering combustion below ground surface and below the water table**
- **Smoldering occurred for 9 days**
- **370 kg coal tar destroyed (> 800 lbs)**
- **NAPL migration fed relatively stationary reaction front due to high NAPL saturations / mobility**

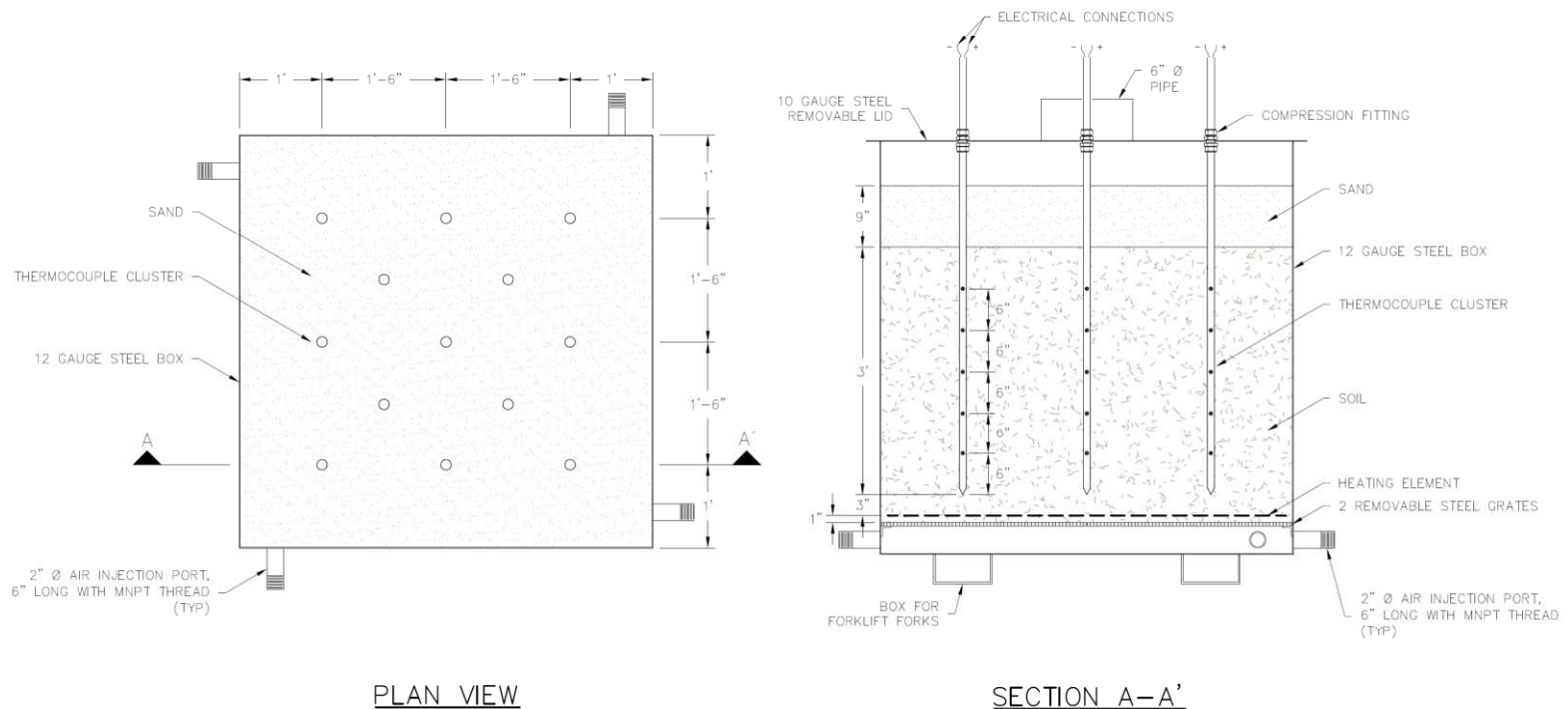


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Case Study 2: Ex Situ Pilot Test for Oil and Gas Industry 'Upstream' Sites

Ex Situ Pilot Test Design

- ‘Upstream Sites’ – flare pits and other hydrocarbon-impacted sites associated with the recovery of petroleum hydrocarbons
- Current remedial options include excavation and disposal (expensive) and excavation and biopiling (ineffective)



References and Further Reading

- UK Patent Office, GB 0525193.9, Filed 10/12/2005; International PCT Filing, PCT/GB2006/004591, Filed 8/12/2006 (Priority Date 10/12/2005).
- Switzer *et al.*, 2009. Smoldering combustion: A novel remediation process for non-aqueous phase liquids in porous media. *Environmental Science and Technology*, 43, pp. 5871–5877.
- Pironi *et al.*, 2009. Small-Scale Forward Smoldering Experiments for Remediation of Coal Tar in Inert Media, *Proceedings of the Combustion Institute* 32 (2), pp. 1957-1964, doi:10.1016/j.proci.2008.06.184.
- Switzer *et al.* 2008. Experimental Studies of Self-Sustaining Thermal Aquifer Remediation (STAR) for Non-Aqueous Phase Liquid (NAPL) Sources. In *Proceedings from ConSoil 2008*, Milano, Italy, 3-6 June.

Coming Soon: www.starsiteremeddy.com