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safe, and
better for the
environment

STARx Treatment Plants: Smoldering Hydrocarbons, Waste Products, Contaminated Soils, and Recalcitrant Compounds at Scale

Presented by: D.Liefl, P.Eng

Company Profile

Savron is a multi-national provider of sustainable applied smoldering solutions (STAR/STARx)



- **Smoldering Combustion Introduction**
- **STAR/STARx Application Methods**
- **STARx Full Scale Treatment**
 - STARx HP250 Plant – Bahamas
 - STARx HP250 Plant – Kuwait
 - STARx HP10 Mobile System – Brazil
- **Summary**

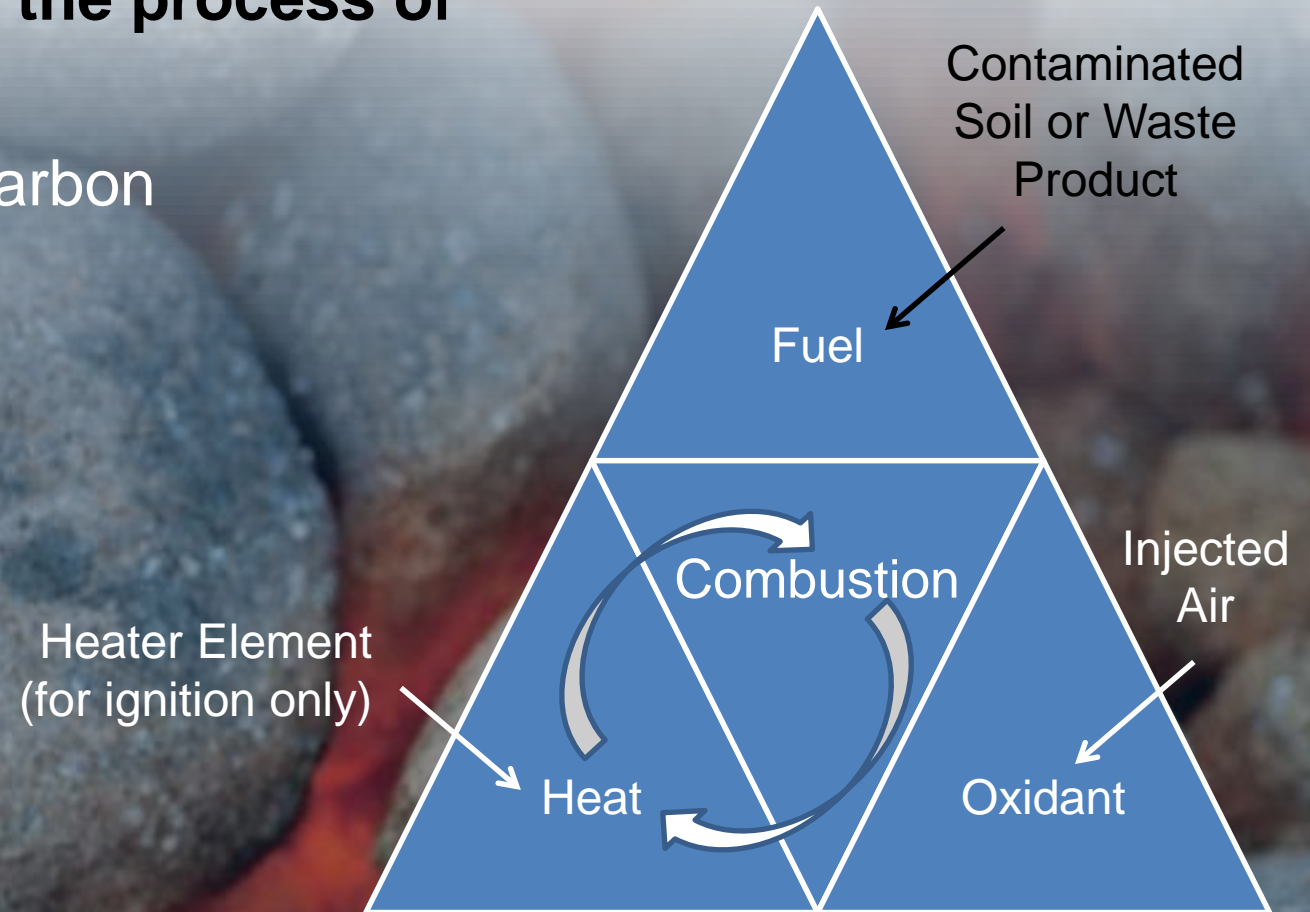


Smoldering Combustion

Smoldering Combustion

STAR and STARx are based on the process of smoldering combustion:

Exothermic reaction converting carbon compounds to $\text{CO}_2 + \text{H}_2\text{O}$



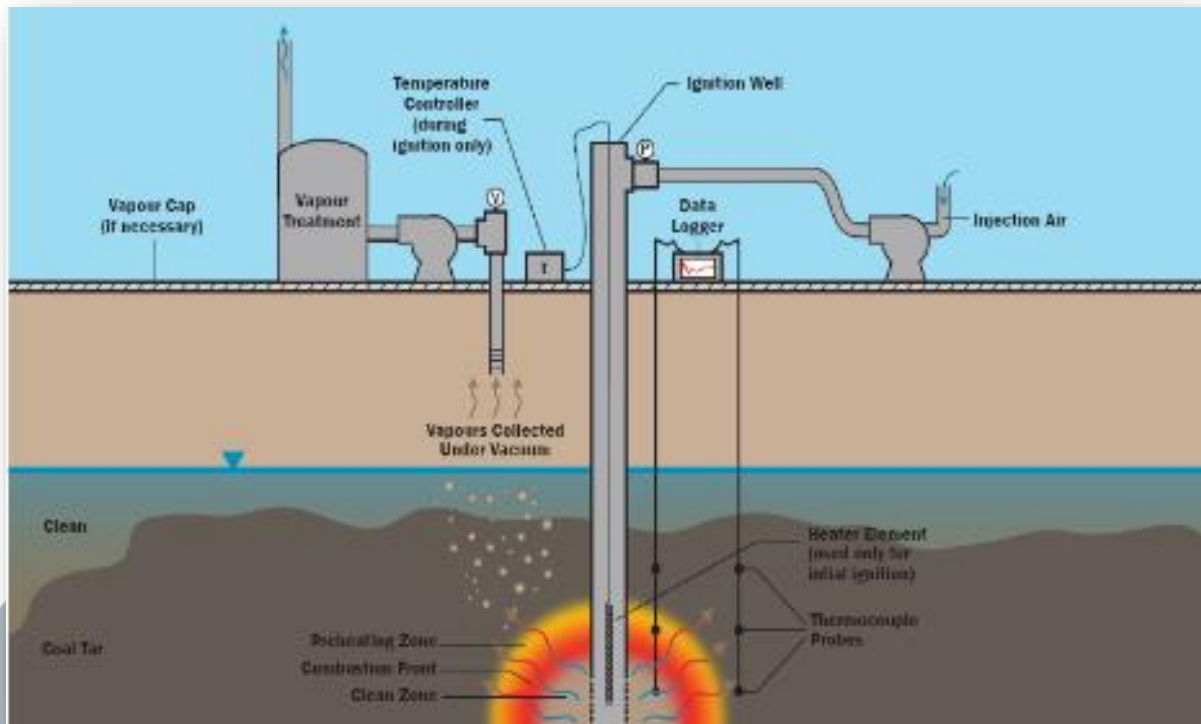
STAR / STARx is a flameless combustion process: only smoldering is possible within a porous matrix (i.e., soil)



Application Methods

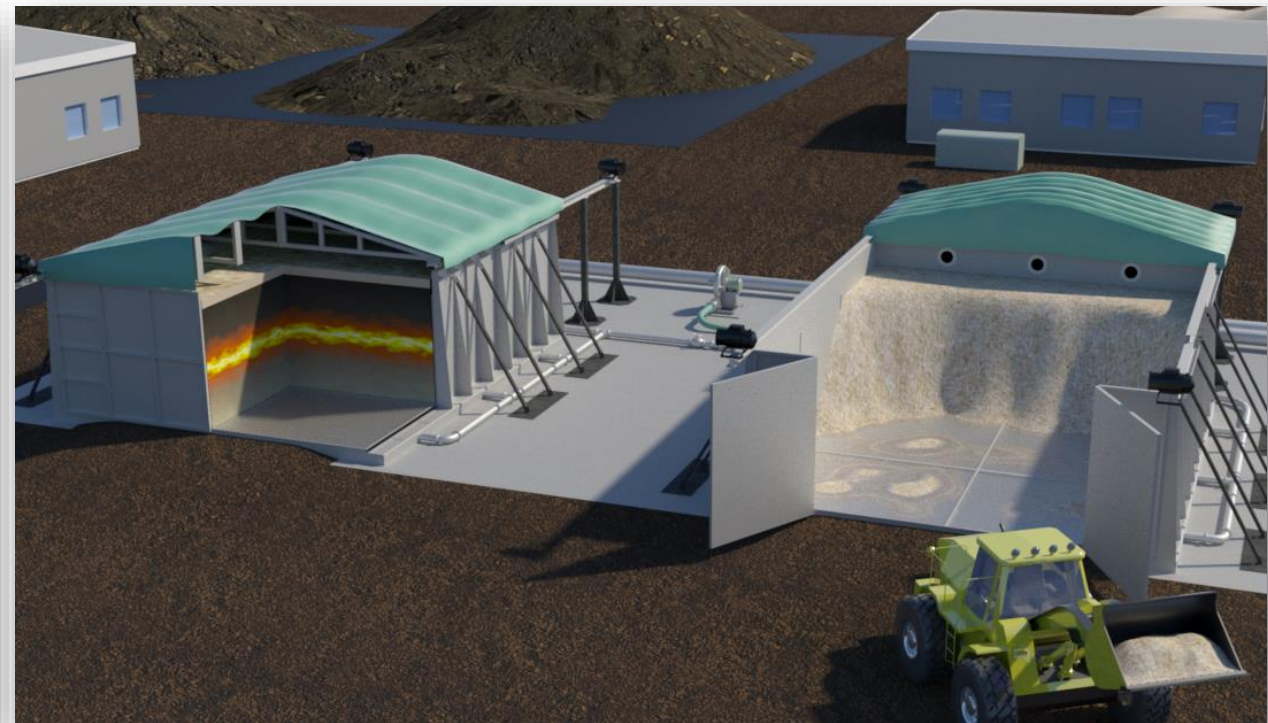
STAR

- **In situ (vadose zone & below water table)**
 - Applied via ignition points & portable heaters



STAR_x

- **Ex situ (above ground)**
 - Soil piles placed on Hottpad™ system



- **Silty sands and coarser**
- **Coal tar, creosote, hydrocarbons**
- **TPH > 3,000 mg/kg**
- **Example projects:**
 - Coal tar MGP – NJ, IL, MI, Belgium
 - Navy Special Fuel Oil (NSFO) - VA
 - Petroleum Hydrocarbons – Canada, Taiwan
 - Gasoline / Diesel (with fuel surrogate) - MI
 - Creosote - WA



- **Silty sands and coarser**
- **Co-treatment of impacted soils and liquid organic wastes = significant cost savings**
- **TPH > 3,000 mg/kg**
- **Example Projects:**
 - Hydrocarbon-impacted soil, Canada, Africa Taiwan & SE Asia
 - Oily sludge, USA & China
 - Chloronitrobenzene soil, Brazil
 - Tank bottom residuals, Australia
 - Oily sludge, Middle East & Caribbean





STARx HP250 Plant - Bahamas

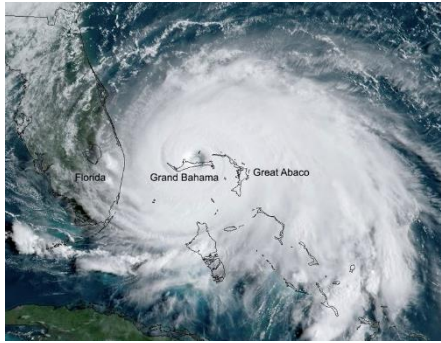
Project Background

- **Former oil terminal**
- **Sustained damaged during Hurricane Dorian**
- **11,250 m³ of consolidated oily sludge**
 - Tank bottom materials
 - Industrial hydrocarbon products
- **Generated during clean up activities**
- **Stored in onsite holding pond**





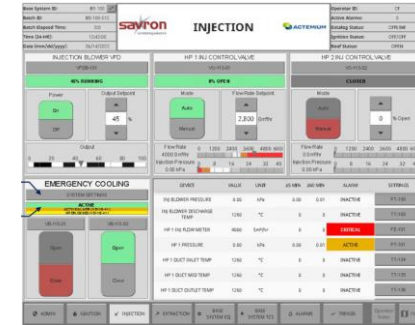
Project Timeline



Hurricane Dorian



Engineering Design and Procurement



Commissioning

2019

2020

2021

2022

2023

Contract Award



Start of Construction



Start of Operations



Engineering Design

- **(2) HP250 Base Systems**

- 250 m³ batch volume per Base System
- 4 to 7-day cycle time, dependent on feedstock

- **Project specific considerations;**

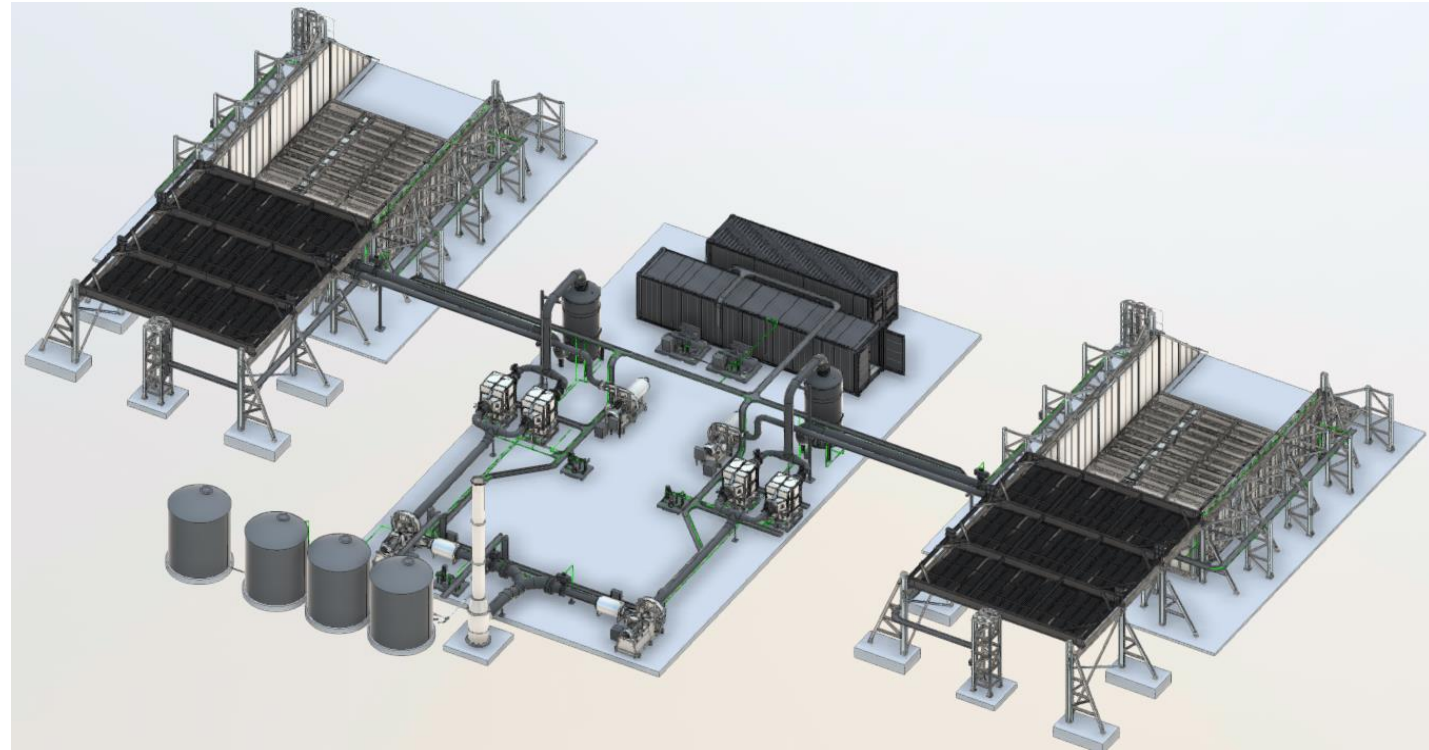
- Sludge viscosity
- Oil mist emissions treatment

- **Modular air plenums and wall panels**

- **Retractable roof system**

- **Equipment pad**

- Air handling equipment
- Emissions treatment equipment



Challenge – Feedstock Variability

- **Feedstock Characteristics**

- Sludge vs. pumpable oil
- Viscosity and volatility

- **Sludge access difficult due to overlying pumpable oil**

- **Caused product mobilization during treatment**

- Downwards into modules
- Upwards into cap material

- **Increases risk of unintended flaming combustion**

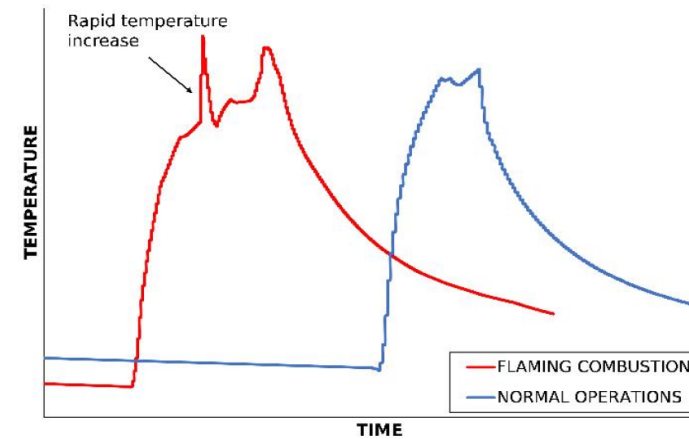


FIGURE 1: Example c-channel temperature data for comparison of plenum flaming combustion vs. normal operating conditions

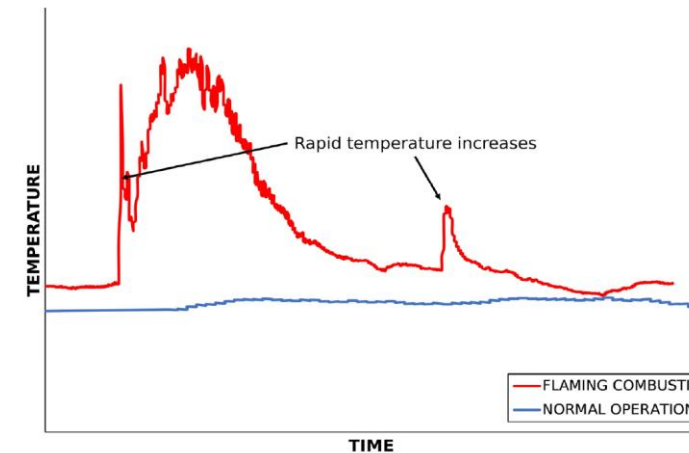


FIGURE 1: Example of hood space temperature data for comparison of hood space flaming combustion vs. normal operating conditions

Solutions – Feedstock Variability

Procedural:

- Extended bake out procedure
- Updated injection air protocol
- Improved material handling operator training
- Feedstock Enrichment Plan

Engineering Design:

- Supplemental air duct covers
- Side wall flow diverters
- Improved rate of change alarm functionality

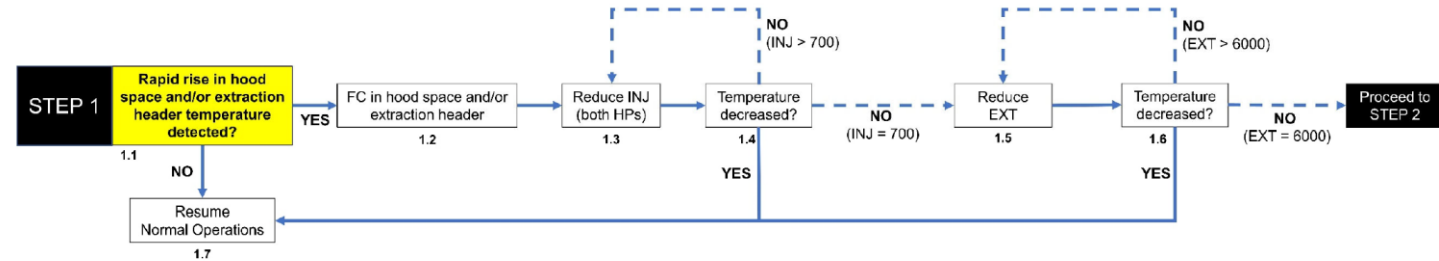


FIGURE 2: Airflow reduction decision tree for STARx Operator guidance

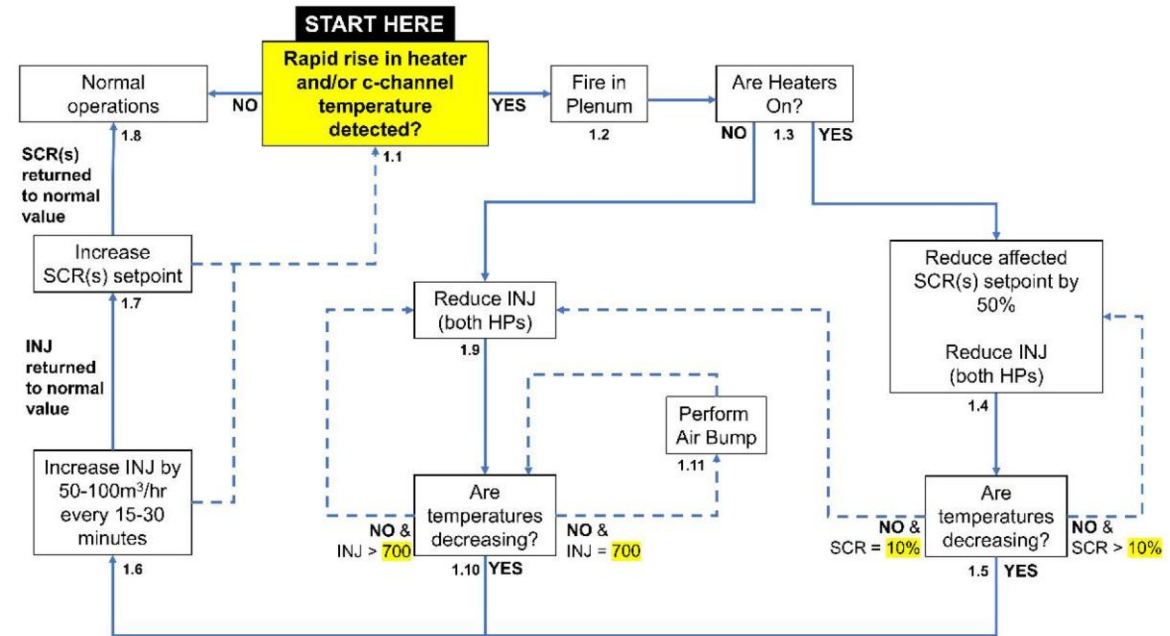


FIGURE 2: Plenum FC decision tree for STARx Operator guidance

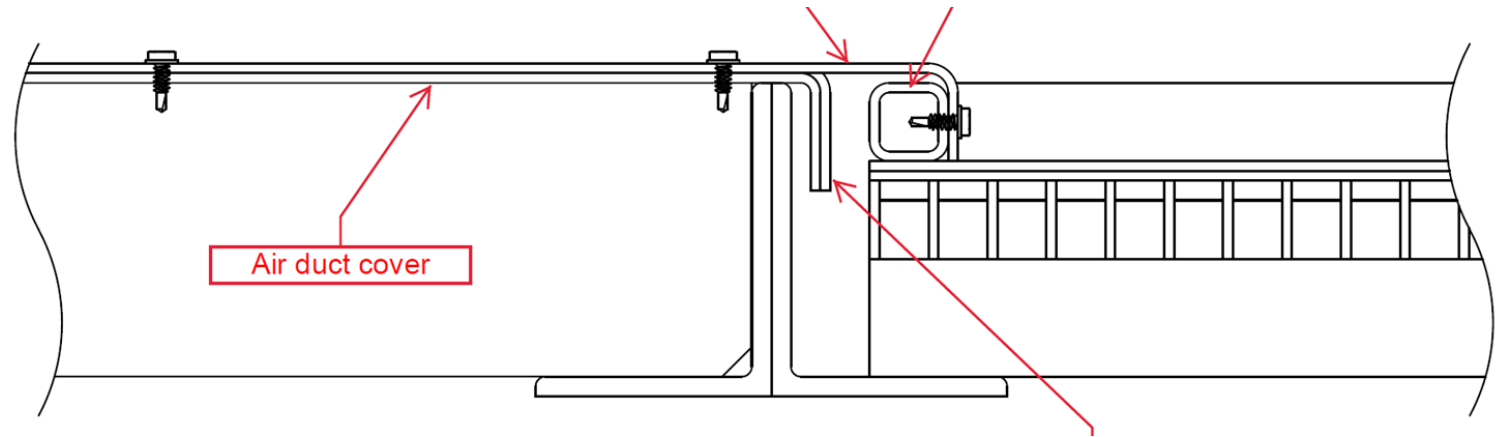
Solutions – Feedstock Variability

- **Procedural:**

- Extended bake out procedure
- Updated injection air protocol
- Improved material handling operator training
- Feedstock Enrichment Plan

- **Engineering Design:**

- Supplemental air duct covers
- Side wall flow diverters
- Improved rate of change alarm functionality



- **35 batches completed**
- **650 m³ sludge destroyed**
- **Operational Delays:**
 - Hurricane shutdowns
 - Feedstock inconsistency
- **Enrichment plan started March 2023**
 - Sludge content increased by 3X per batch
- **Full processing capacity by July 2023**





STARx HP250 Plant – Kuwait

Project Background

- **Operating oil field**
- **300,000 m³ of consolidated oily sludge**
 - Generated during processing activities
 - Co-treatment with low impact site soils (30,000 - 35,000 mg/kg TPH)
- **STARx selected over six remedial alternatives via pilot scale studies**
- **Supply turnkey STARx, commission, train local operators**
- **Multi-year contract**



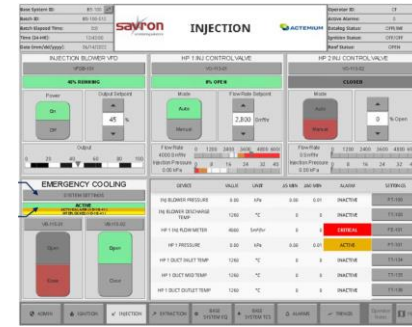
Project Timeline



STARx Selected as Remediation Technology



Plant Lease Executed



Commissioning



Field Contractor Selected by Client

Start of Construction

Start of Operations



- **(4) HP250 Base Systems**
 - 250 m³ batch volume per Base System
 - 5-6 day cycle time, dependent on material handling rates
- **Project specific considerations;**
 - Rich feedstock blend
 - Emissions scrubber
 - Ambient particulate loading
- **COVID travel restrictions and delays**
- **International operator group**



Challenge – Waste Minimization

- **Client's sustainability goals focused on waste minimization and water recovery/reuse**
 - Knock out tank (moisture)
 - Oil mist filters (entrained hydrocarbons)
- **Water scarcity high priority**
 - Desert environment
- **Condensate requires pH neutralization**





Solution – Oil Water Separation

- **2 Stage Oil Water Separation System**
 - Light fractions skimmed off
 - Heavy sludge sent for STARx treatment
 - Water sent to pH neutralization
- **Water reused in STARx utility water system & revegetation pilot project**
- **210 bbl of recovered oil returned to Client for processing**



- **Plant operations fully transitioned to sub-contractor**
 - Savron maintaining contracted technical support
- **52 batches completed**
- **2000 m³ sludge destroyed**
- **3-year lease ends 2025**
 - Additional plant
 - Lease extension





STARx HP10 Mobile System – Brazil

Project Background

- **Former chemical manufacturing facility**
- **Chloronitrobenzene-impacted soils**
- **Project specific considerations:**
 - Complex semi volatile COCs
 - Acidic off-gases
- **(9) 10 m³ batch test program to evaluate:**
 - On-site crushed concrete bulking ratio
 - Locally sourced waste biomass fuel amendments



- **(2) 10 m³ Hottpads**
 - Air injection system
 - Ignition system
- **Emissions Treatment**
 - Moisture knock out tank
 - (2) vapour-phase GAC (VOCs)
 - Caustic impregnated GAC (acidic off gases)
- **Controls & Instruments**
 - Central PLC
 - CEMs (CO, CO₂)
 - Lower Flammability Limit Analyzer



Corrosion Study

- **Employed sacrificial coupons:**

- Vapor: Install in Hottpad hood space, inlet and outlet of the knockout tank
- Liquid: Immersed in the liquid collection section of the knockout tank

- **Results:**

- “Severe”: Carbon steel (A36) and structural steel (A36W)
- “Minimal”: Stainless steel (316L & 316W)
- “NA”: Epoxy coated carbon steel (E-A36)

- **Wetted process locations to be epoxy coated**



Project Conclusion

- **STARx removed COCs below soil management goals (SMG) in all 9 tests**
 - Eucalyptus bark and coconut husks are viable sustainable surrogate fuels
 - Co-treatment of GAC from thermal desorption system
 - Vapor treatment system effectively reduced PM, VOCs, SVOCs, HCl, NOx and SOx in emissions
 - No dioxins and furans generated (emissions), post treatment soil concentrations were below SMG
- **STARx selected for full scale remediation**
 - Contracting underway
 - Engineering design scheduled for Summer 2023





Summary

- **Effective and Robust**
 - Rapid on-site treatment, complete destruction of contaminants
- **Reduced cost versus other technologies**
- **Safe and Sustainable**
 - Self-sustaining process = less energy use
- **Flexible**
 - Modular STARx systems fully expandable to meet target throughput
 - Deployable at source areas and remote locations all over the world
- **Recalcitrant compound treatment proven with sustainable fuel amendments**



Questions?
savronsolutions.com
DLiefl@savronsolutions.com