Microwave System for Small-Scale Treatment of Rocket Propellant Laboratory Derived Waste

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Presented by

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Technology History

- Air Force Research Lab (1998-2002)
  - Destruction of Hydrazine Fuels in Aqueous Solution (SBIR Phase I)
  - Build and Demonstrate Pilot System for N_2O_4 and hydrazine Vapor Destruction
  - Demonstrated at the Hypergolic Fuel Storage Facility at Vandenberg AFB
    - Operational Support from United Paradyne Corp.
    - Performance Verification by Aerospace Corp.

Technology History (cont.)

- Vandenberg AFB (2003-2007)
  - Engineering Design for MW Fuel and Oxidizer Vapor Scrubbers
  - Construction and Installation of Microwave Scrubbers at the Vandenberg AFB Hypergolic Fuel Storage Facility
- AF Space Command, Space and Missile Command, and NASA (2008-2009)
  - Engineering Design For MW System to Treat Non-Spec Liquid Hydrazine Wastes
- The Boeing Company
  - Ongoing Maintenance and Support for MW Scrubber Operation at Vandenberg AFB

Hypergols

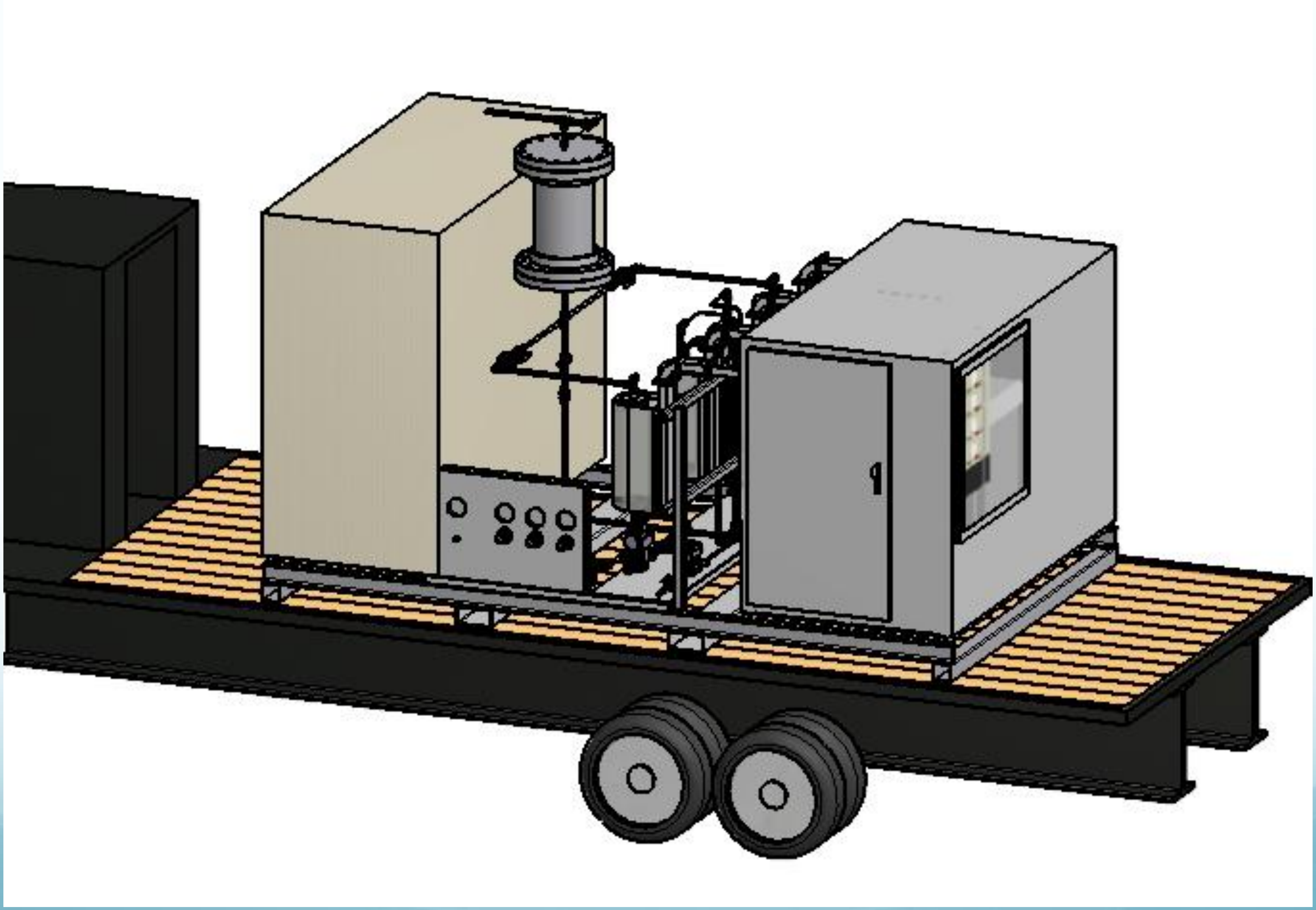
- Microwave Oxidizer Scrubber
  - Destroys dinitrogen tetroxide and mixed nitrogen oxide vapors
  - Installed at Vandenberg AFB in 2006
  - Currently operated by Boeing at Vandenberg with support from CHA Corporation
- Microwave Fuel Scrubber
  - Destroys hydrazine, monomethyl hydrazine, and dimethyl hydrazine vapors
  - Installed at Vandenberg AFB in 2007
  - Currently operated by Boeing at Vandenberg with support from CHA Corporation
- Hydrazine Liquid Disposal
  - Conceptual Design completed 2009
  - Mobile Unit with 30 lb/hr capacity

Microwave Fuel Scrubber at Vandenberg Air Force Base

MW Oxidizer Scrubber

MW Fuel Scrubber

Mobile Hydrazine Liquid Disposal System

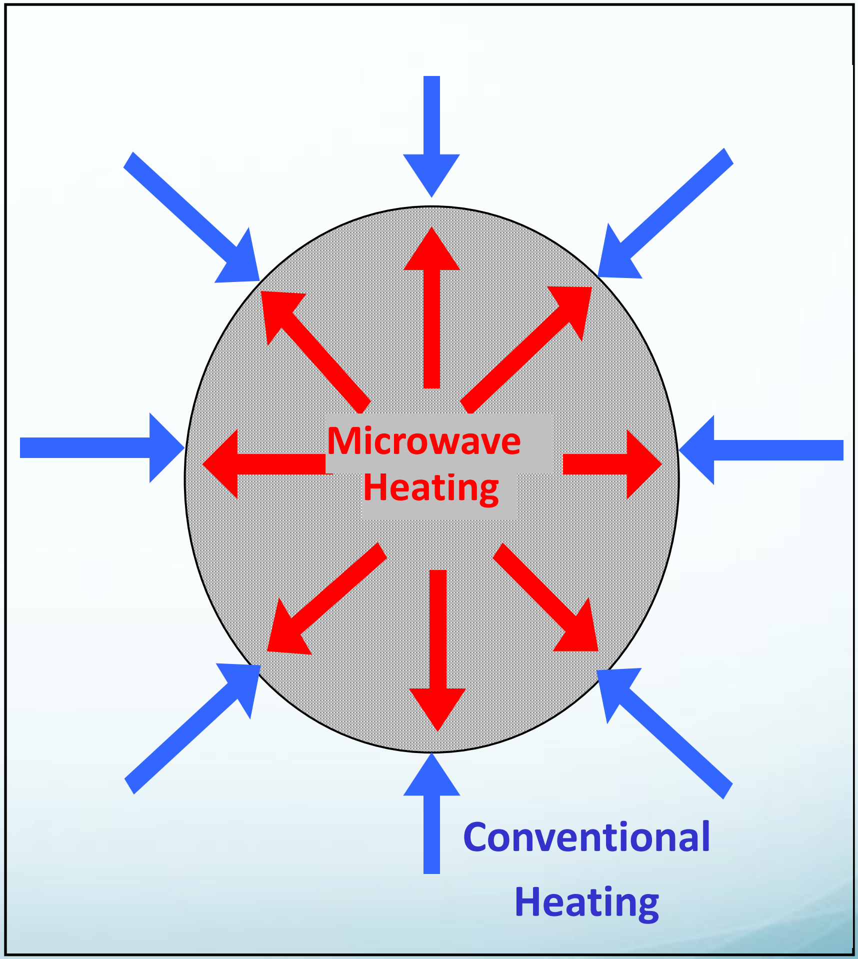


Problem/Challenge

- Air Force Research Lab at Edwards AFB
  - 15-30 lb/month of Propellant, Explosive or Pyrotechnic Waste
    - Propellant
    - Propellant Intermediates
    - Propellant Contaminated Material (Rags, Gloves, Paper Towels, Polyethylene Cups
  - Must be Disposed of Safely and in Accordance with RCRA
  - Currently Disposed of Using Open Burn/ Open Detonation

Why Microwaves?

- Volumetric Heating
- More Efficient than Conventional Heating
- Enhances Chemical Reactions
- Reactions Rates Can be Controlled by Varying Field Strength



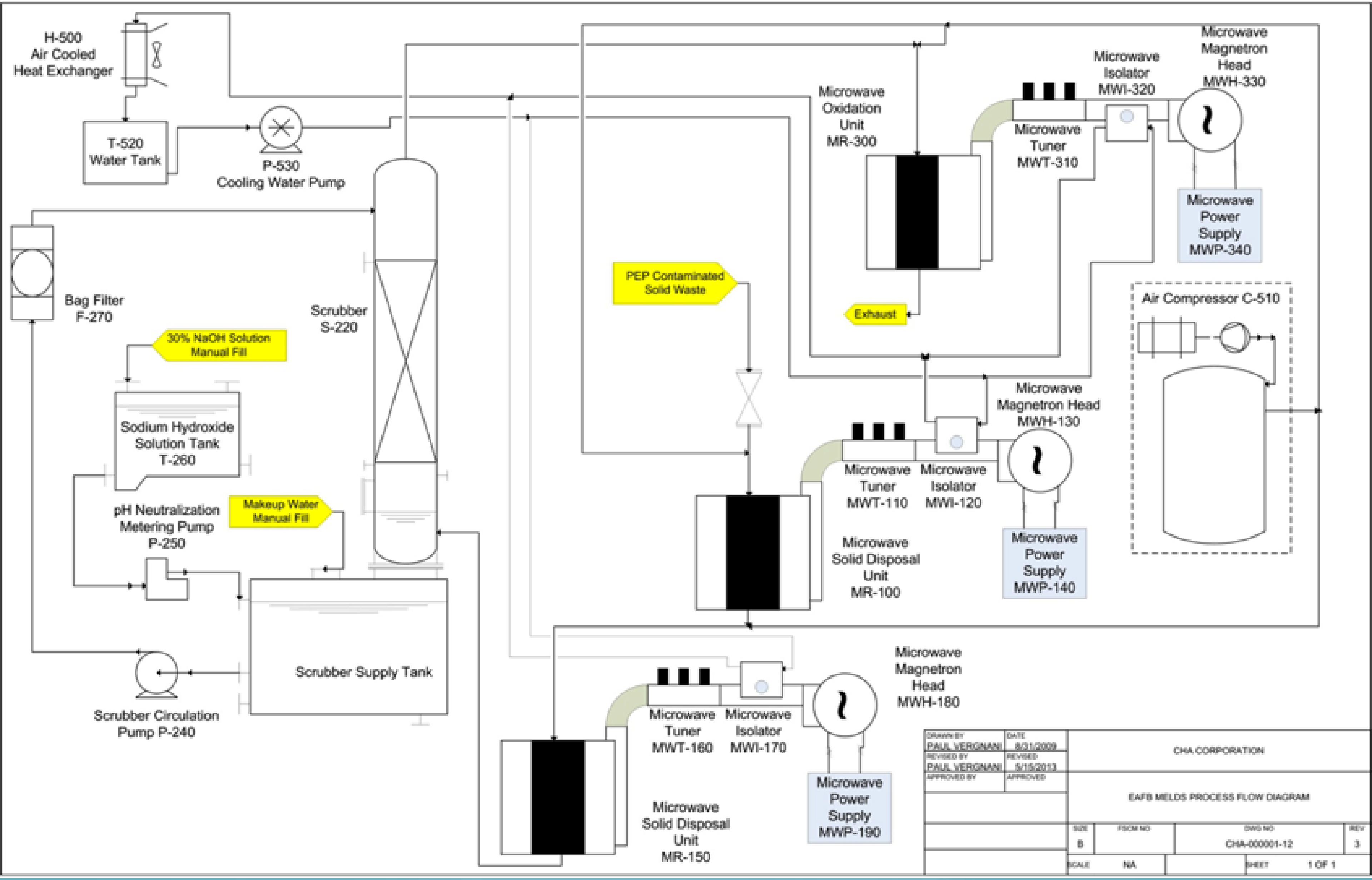
SBIR Phase I Program

- Demonstrated the Efficacy of the microwave disposal system to eliminate hazardous PEP wastes in solution to non-detectable levels
- PEP Chemicals Tested
  - 5% monomethylhydrazine (MMH)
  - 2% 2-hydroxylethylhydrazine (HEH)
  - 5% 2-nitrotoluene (NT)
  - 5% ammonium perchlorate

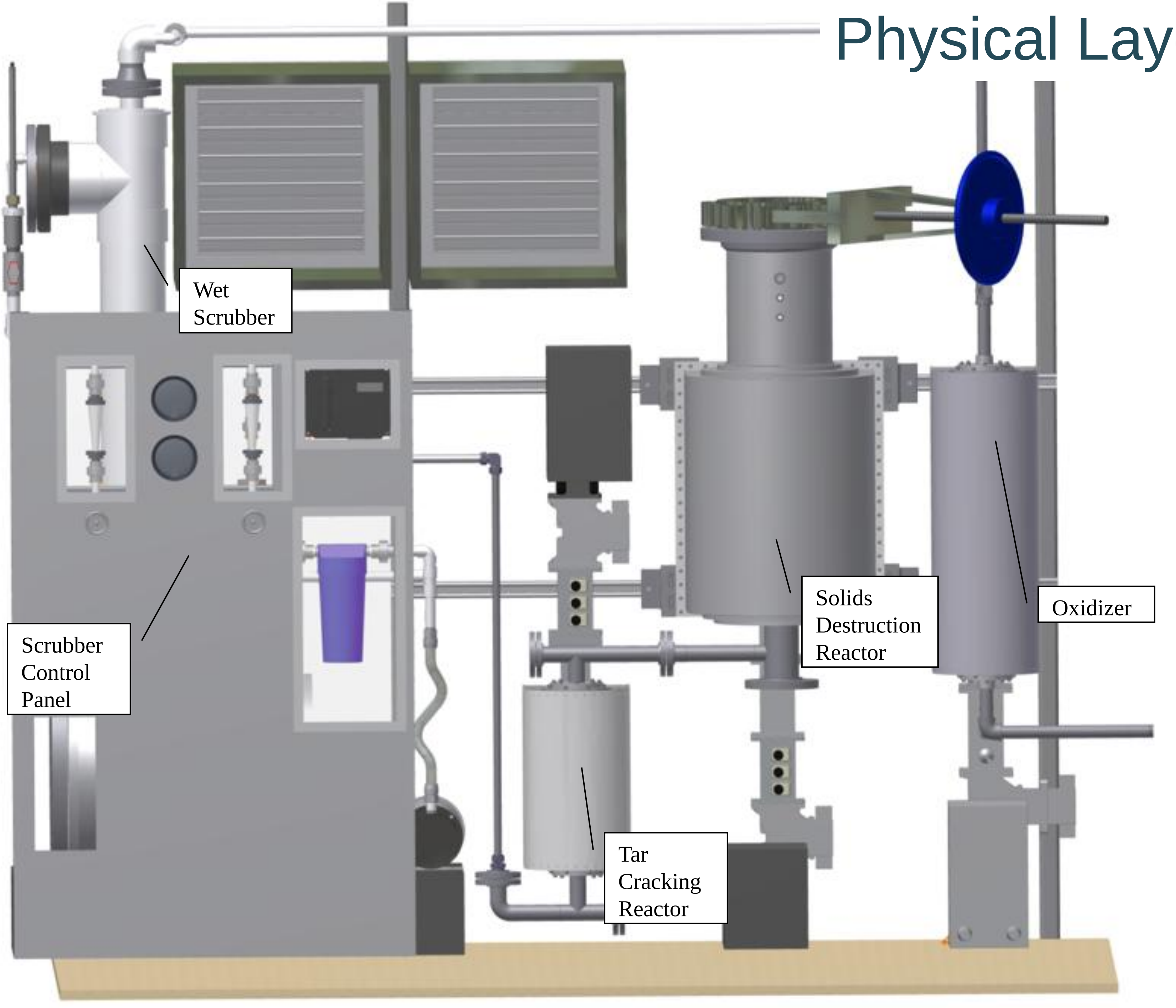
Phase II Program

- Construct and test a microwave prototype capable of destroying 15-30 pounds per month PEP wastes at the selected site
- After successful test, this system could be used at selected site to routinely destroy lab PEP wastes

Microwave Prototype PFD



Physical Layout



Reactor System

Solid Disposal Reactor

- Batch Reactor-Loaded Through Top
- Welded Aluminum Cavity
- 12” ID Quartz Tube Window
- Stainless Steel Inlet and Outlet Piping
- 3-kW 2450 MHz Microwave Source

Tar Cracker

- Welded Aluminum Cavity
- 4” ID Quartz Tube Packed with Granular Silicon Carbide
- Stainless Steel Inlet and Outlet Piping
- 3-kW 2450 MHz Microwave Source

Wet Scrubber

- 6” Diameter PVC Tower
  - 48” Random Packing
  - Plastic Pall Rings
- PVC Reservoir
  - 30 Gallon Capacity
- Circulation Pump
  - Polypropylene Turbine Pump
  - Magnetic Drive

Microwave Oxidizer

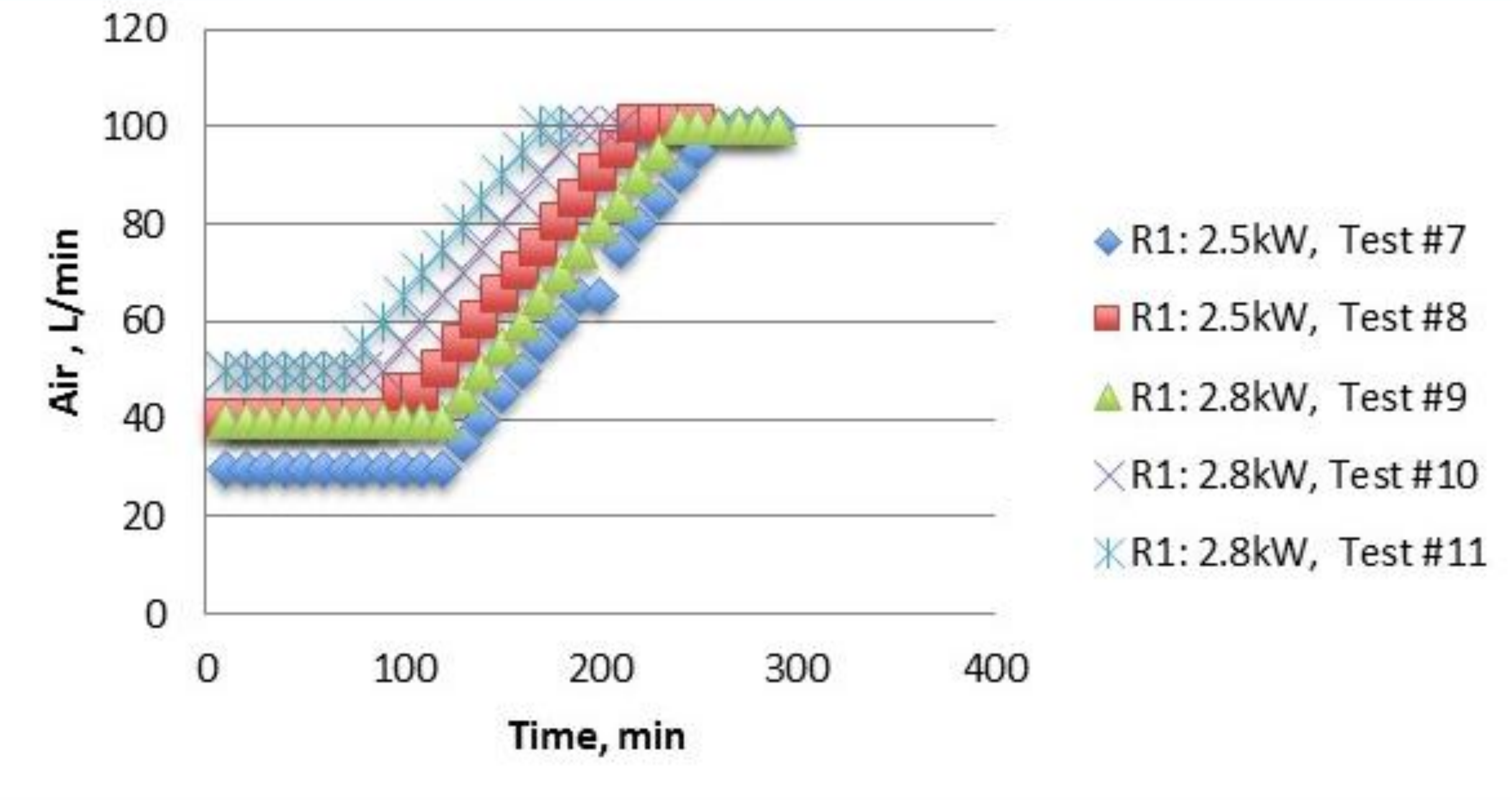
- Aluminum Cavity
- 3.5" ID Quartz Tube packed with mixture of granular Silicon Carbide and Alumina Supported Oxidation Catalyst
- Stainless Steel Inlet and Outlet Piping
- 6-kW 2450 MHz Microwave Source

Assembled Prototype

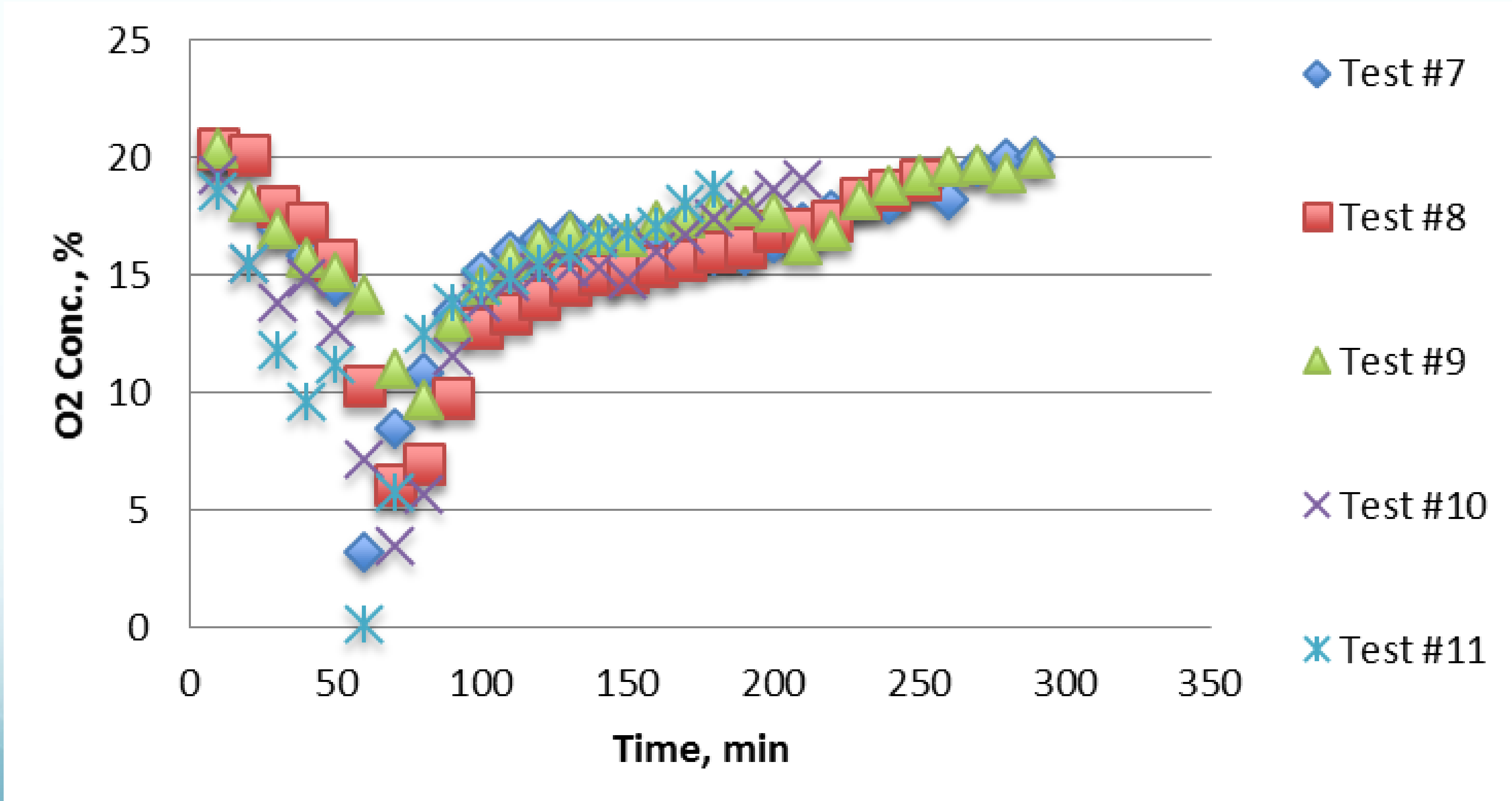
Prototype Optimization Test

- Test Charge: 600 g Paper Towel + 600 g Rubber Gloves Packed in Velostat Bags
- Increased airflow to disposal reactor (R1) and decreased airflow to tar cracker (R2) by 5 L/min after predetermined time
- Measured concentrations of O_2, CO_2, CO and Total Hydrocarbons of the outlet gas

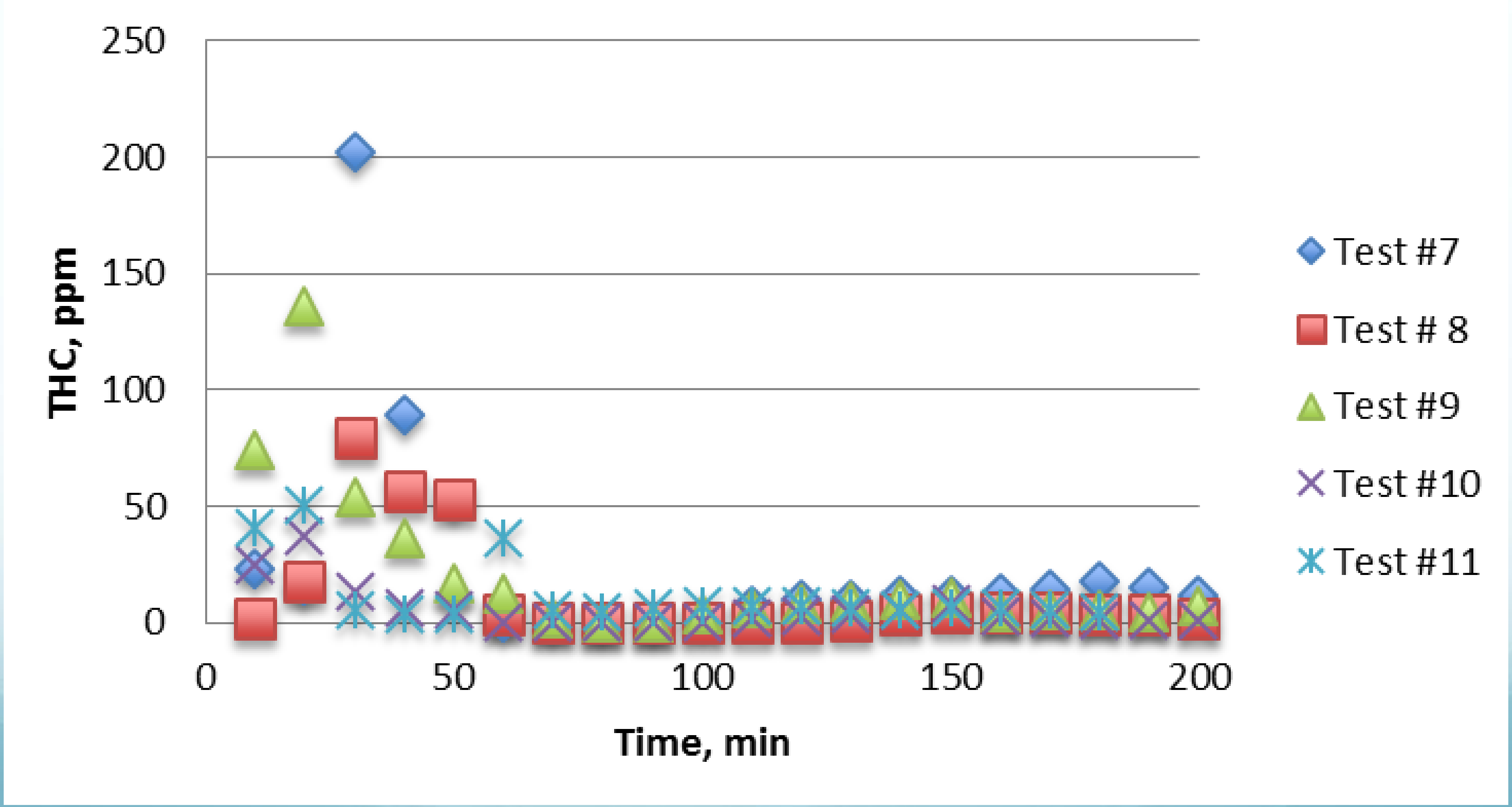
Solid Disposal Reactor- Air Flow Rate vs. Time



O_2 Concentration vs. Time



Total Hydrocarbon Concentration vs Time



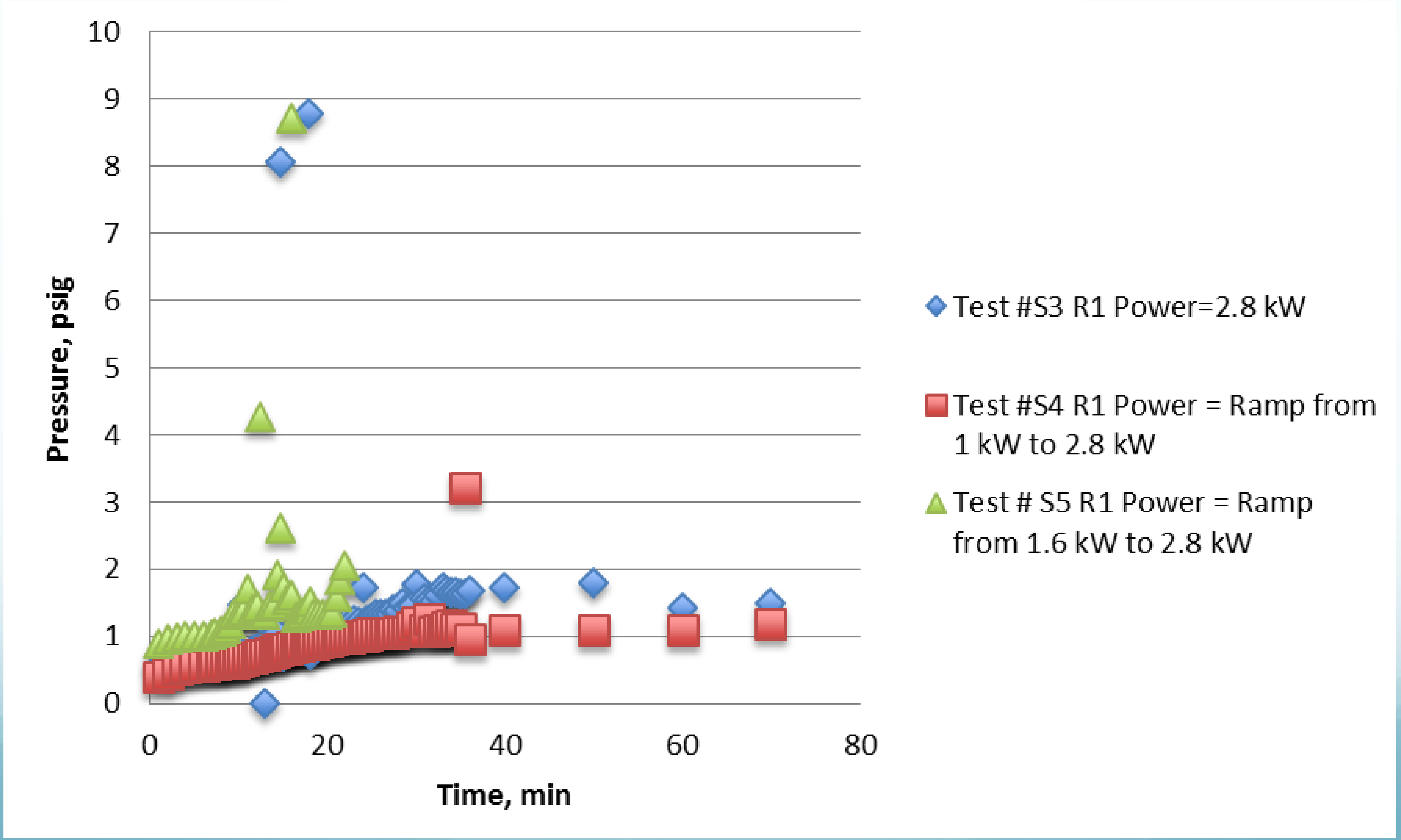
Optimum Conditions

- Microwave power
  - Destruction Reactor- 2.5kW
  - Tar Cracker- 2kW
  - Oxidizer- 2.5kW
- Initial Air Flow Rate
  - Destruction Reactor- 50 L/min
  - Tar Cracker- 80 L/min
  - Oxidizer- 80 L/min
- Begin Increasing Air Flow to the Destruction Reactor and Decreasing Air Flow to the Tar Cracker after 80 minutes
- Operating Time
  - Destruction Reactor- 150 min
  - Tar Cracker- 170 min
  - Oxidizer- 180 min

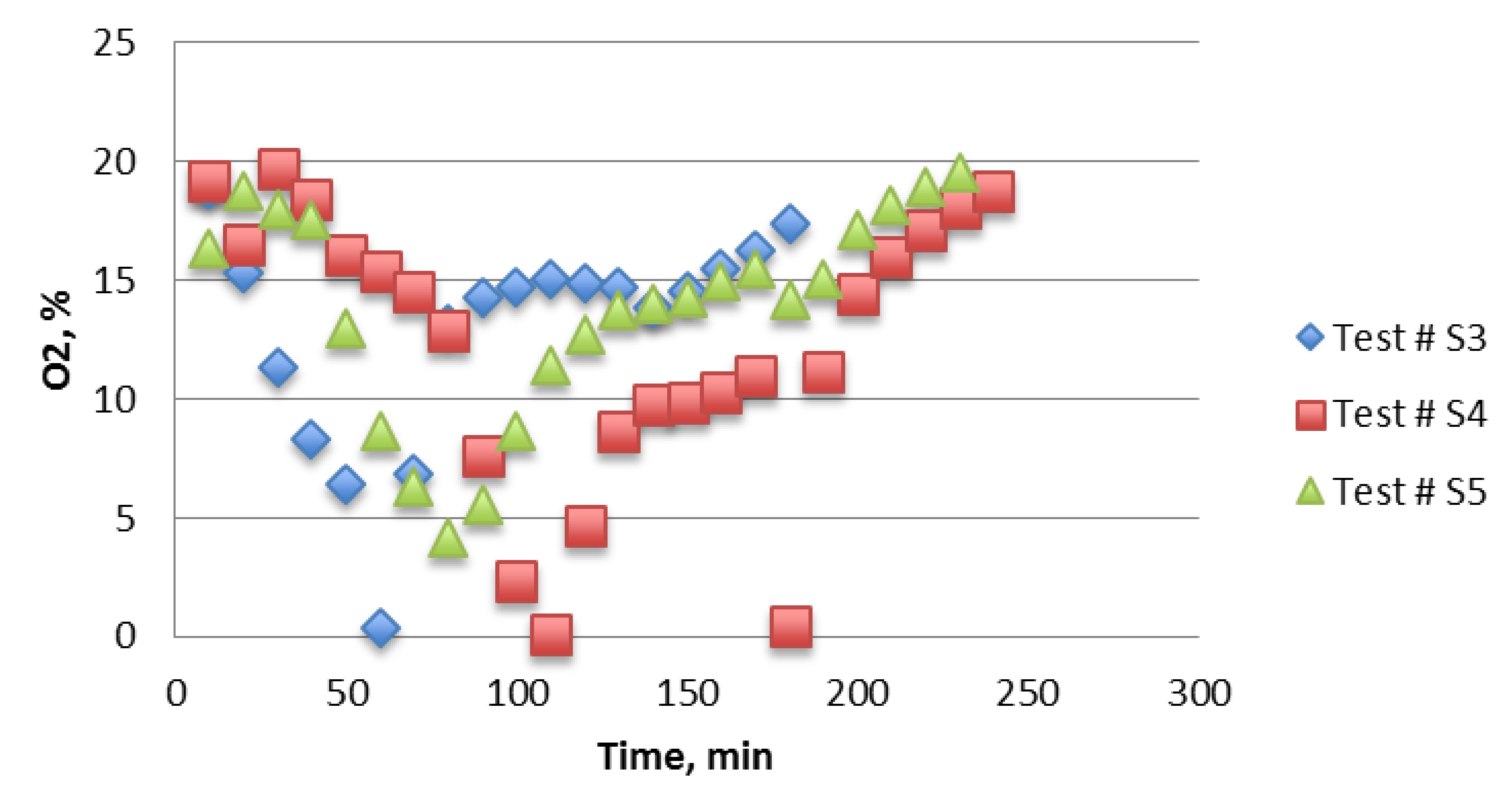
Prototype Surrogate Test

- Test Charge: 600 g Paper Towel + 600 g Rubber Gloves+Variable Amount of Smokeless Powder and Calcium Hypochlorite Packed in Velostat Bags
- Increased the Quantity of Smokeless Powder and Calcium Hypochlorite
- Measured Destruction Reactor Pressure
- Measured concentrations of O_2, CO_2, CO and Total Hydrocarbons of the outlet gas.

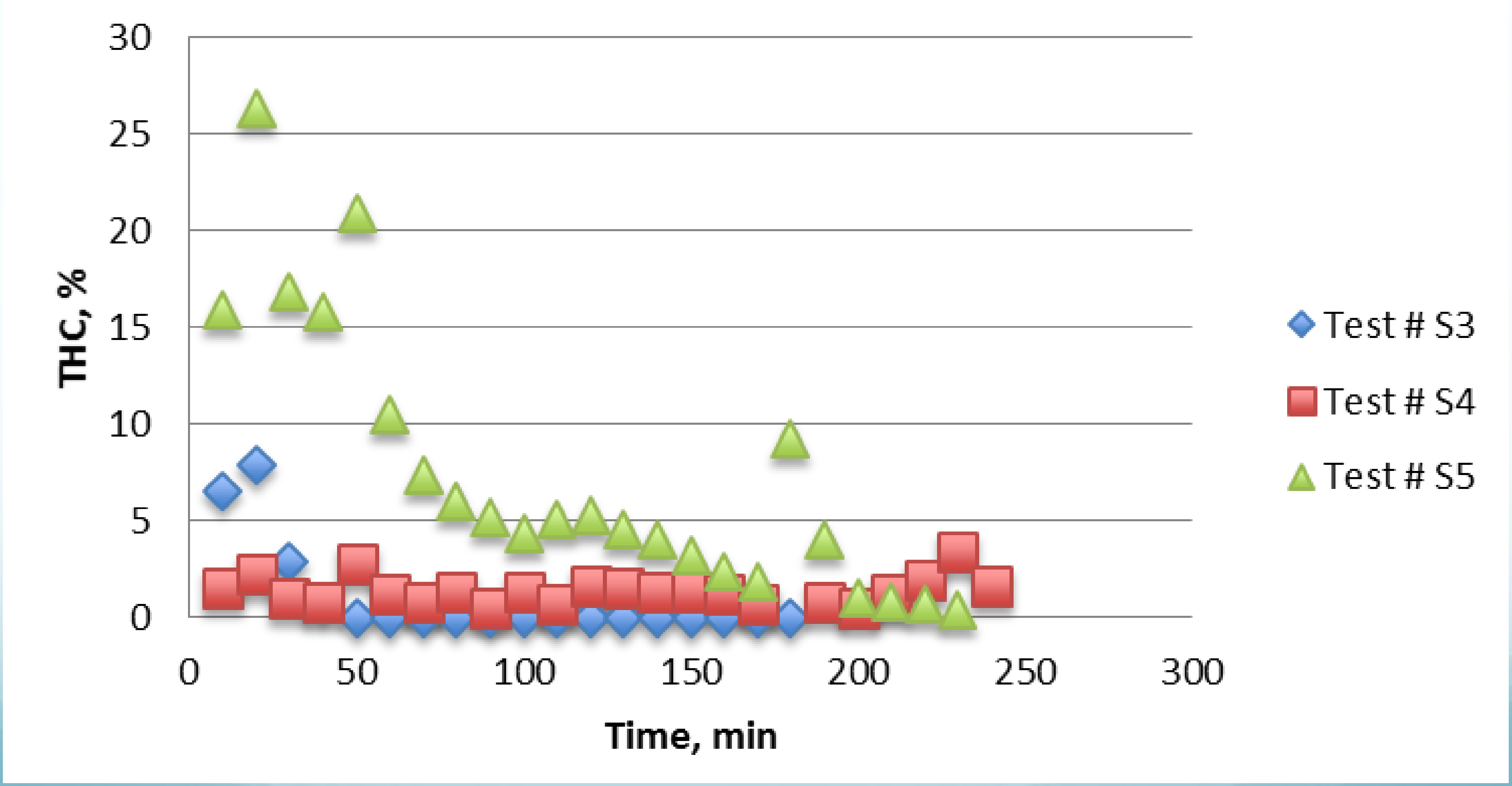
Solid Disposal Reactor Pressure



O_2 Concentration vs. Time



Total Hydrocarbon Concentration vs Time



Surrogate Test Summary

Test Number	3	4	5
Destruction Reactor Starting MW Power (kW)	2.8	1.0	1.6
Total Hydrocarbon Oxidized (g)	1,012	1,272	1,046
Total Hydrocarbon Exhausted (g)	0.008	0.054	0.010
% THC Emitted	0.008	0.004	0.010

Conclusions

- Microwave Disposal of is a Safe and Viable Alternative to Open Burn Methods.
- Is Well Suited to Disposal at the Point of Generation
  - Limits Accumulation
  - Available to Handle Waste from Unplanned Events
  - Reduces Issues with Transportation
- Process can be Modified to Handle Different Quantitites
- Technology Can be Extended to Other Hazardous Waste Streams