NAVAL SURFACE WARFARE CENTER · DAHLGREN DIVISION

Atmospheric Measurements in Propane and Liquid-Pool Fast Cook Off Fires

NAVSEA WARFARE CENTERS DAHLGREN

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NSWCDD-PN-16-00300; Distribution Statement A: Approved for Public Release; distribution is unlimited

Background

- Fast Cook-Off is a standard safety test required for all explosive ordnance
- Traditionally performed by immersing test item in a flame produced by a pool of burning liquid fuel

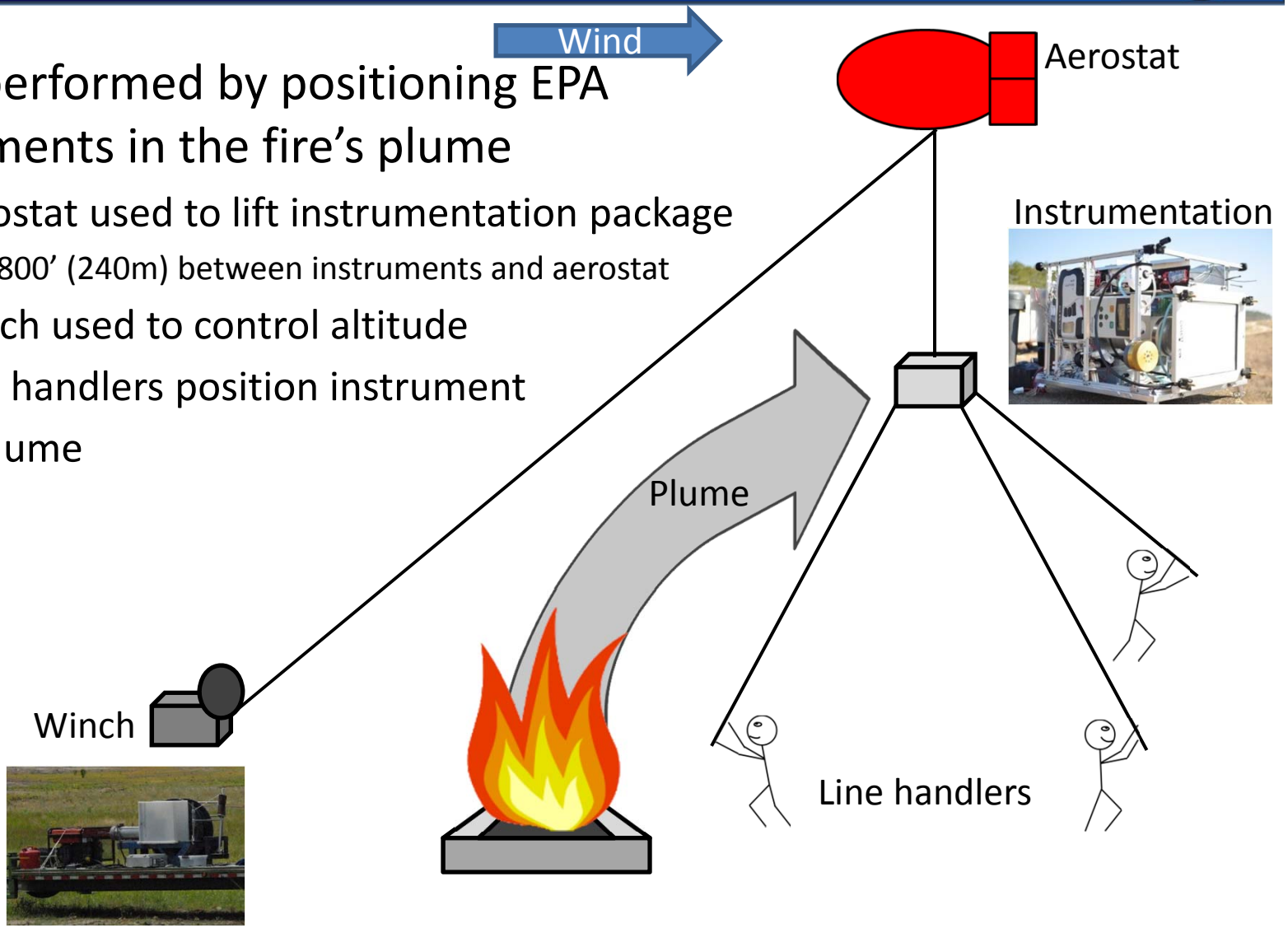
The Push for an Alternative Fuel

- One of the primary issues is the environmental impact of the test
  - Atmospheric emissions
  - Public relations
  - Soil contamination
- A propane burner has been developed to address these concerns
  - Obvious reduction in soot
  - Boiling point address soil contamination
  - Proving emissions reduction is more challenging

Testing was performed to quantify the emissions of equivalent propane and liquid-pool fires

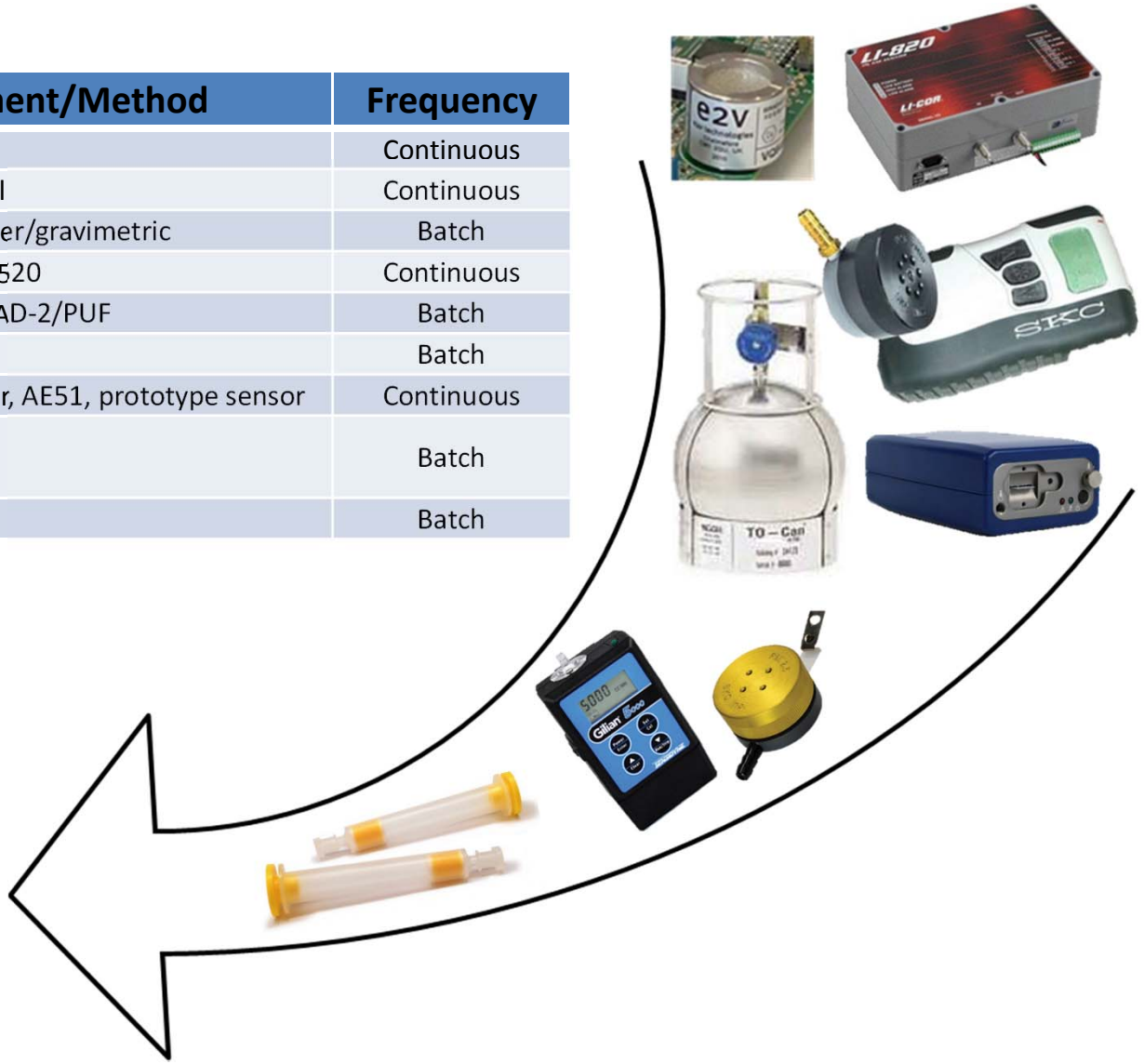
Test Overview

- Tests performed by positioning EPA instruments in the fire's plume
  - Aerostat used to lift instrumentation package
    - 800' (240m) between instruments and aerostat
  - Winch used to control altitude
  - Line handlers position instrument in plume



Instrumentation

Analyte	Instrument/Method	Frequency
CO_2	NDIR	Continuous
CO	Electrochemical cell	Continuous
$PM_{2.5}$	Impactor/Teflon filter/gravimetric	Batch
PM by size	TSI DustTrak DRX/8520	Continuous
PAHs	Quartz filter PUF/XAD-2/PUF	Batch
VOCs	SUMMA canister	Batch
Black carbon	Micro Aethalometer, AE51, prototype sensor	Continuous
Elemental carbon/ Organic carbon/Total Carbon	Quartz filter	Batch
Carbonyls	DNPH cartridge	Batch



Test Fire - Propane

- 12’ Propane burner
- Liquid propane vaporized within burner tubes
- Injected as gas
  - 676 gas jets
  - consumes 13.5 gallons (51 L) of liquid propane per minute
- Burner has previously been calibrated and shown to meet heat flux and temperature requirements for testing*

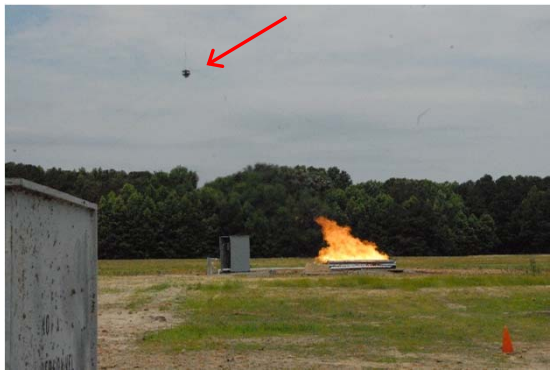
*Hubble et. al. “Development and Calibration of a Propane Fueled Fast Cook-off Burner,” IMEMTS Rome, Italy, 2015

Test Fire – Liquid Pool Fire

- 12’ (3.7m) square liquid pan
  - Same physical size as propane burner
- JP5 floated on water
  - Standard practice for FCO testing at NSWCDD
- 500 gallons (1900 L) used to give approximately 30 minute burn time
- Ignited using 10 gallons (40 L) of gasoline and two thermite grenades
  - Sampling was delayed 5 minutes after ignition which allowed all gasoline and thermite emissions to dissipate

Test Details

- 6 total tests performed: 3 liquid pool fires, 3 propane fires
- Liquid pool fires
  - 500 gallons of JP5 each test
  - For tests 1 and 2, wind was 3-7 mph (1.5-3 m/s) and burns lasted approximately 26 minutes
    - Instruments were intermittently visible within the plume
  - Calm conditions for test 3, burn lasted 38 minutes
    - Easy to maintain instruments in plume
- Propane fires
  - Each fire burned for 25 minutes
  - Plume is transparent, depend on on transmitted CO_2 data to determine proper sensor positioning



Test Results - Carbon

- Both fires produced approximately the same amount of CO_2 per mass of fuel consumed
  - Expected due to similar carbon fractions, 82% in propane, 85% in JP5
- Carbon monoxide emissions reduced by 88%
  - 20 g/kg reduced to 2.4 g/kg
  - Propane burns more efficiently than JP5
  - Gaseous injection results in better mixing, more complete combustion

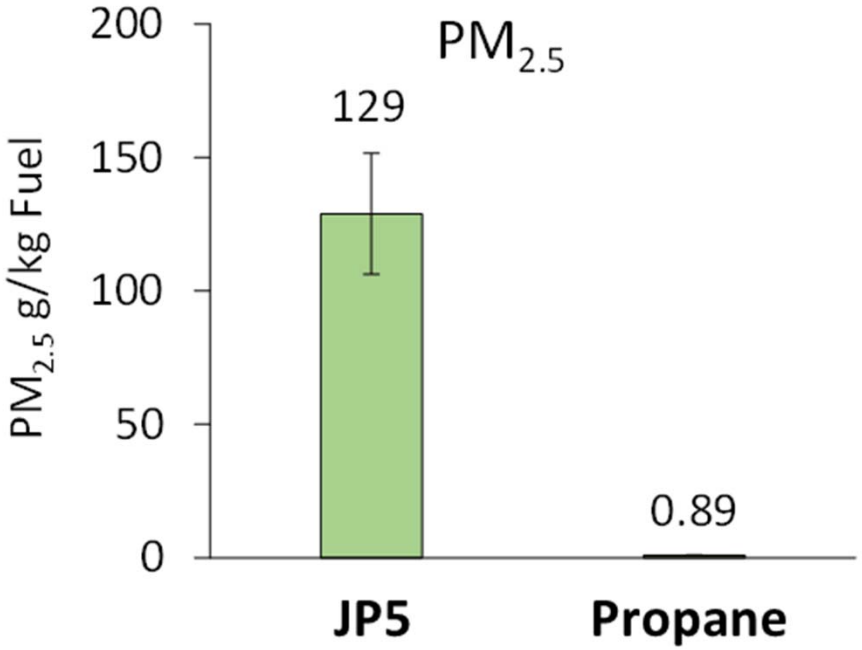
Pollutant	JP5	Propane
CO_2 (g/kg Fuel consumed)	3,085 ± 7.0	3,003 ± 0.34
CO (g/kg Fuel consumed)	20 ± 4.4	2.4 ± 0.22
MCE (ratio)	0.990 ± 0.002	0.999 ± 0.0001

Test Results – Particulate Matter

- $PM_{2.5}$ represents all suspended matter smaller than 2.5 microns
  - Primarily composed of unburned carbon (soot)
  - PMs represent the most visible form of pollution
  - These very small (<2.5 µm) particles can get deep into the lungs
  - Contribute to a number of health problems including asthma, lung cancer and cardiovascular disease

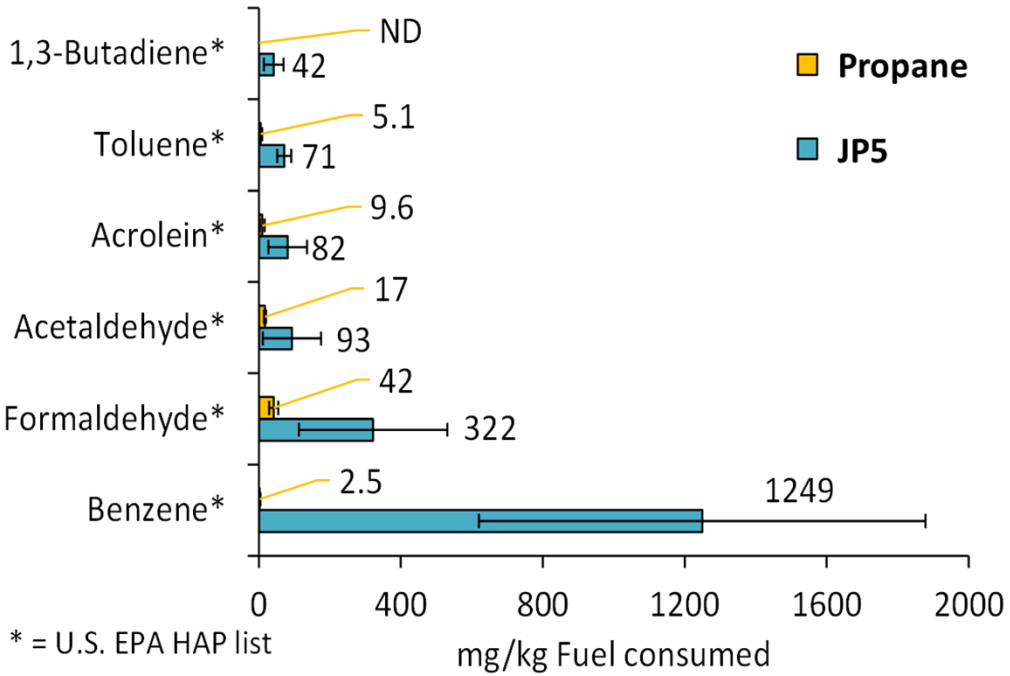
Test Results – Particulate Matter

- The propane burner produced 150 times less $PM_{2.5}$
  - 129 g/kg reduced to 0.89 g/kg
- Indication of burning efficiency, propane more completely combusts the carbon to CO_2



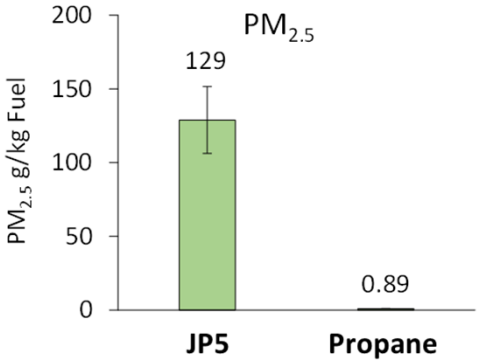
Test Results – Volatile Organic Compounds

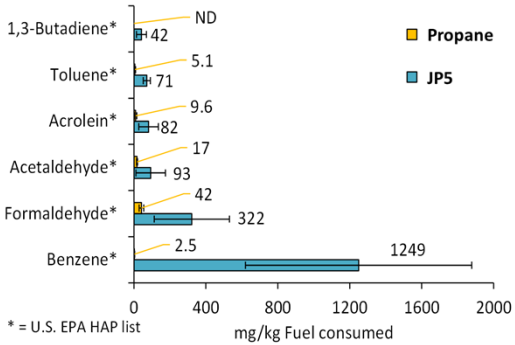
- VOCs represent some of the most dangerous chemicals that result from burning fossil fuels
- These six VOCs are all on the EPA's Hazardous Air Pollutants (HAP) list
- These chemicals are all toxic or carcinogenic
- Reduction in emissions were drastic for all
  - 500x less Benzene
  - All reduced by at least 81%



Conclusions

- Tests were performed to measure the emissions from liquid pool and propane fueled fast cook-off fires
- The results show large reductions in:
  - Carbon monoxide
  - Particulate matter ($PM_{2.5}$, soot)
  - Volatile Organic Compounds (VOCs)
- These results prove that the propane burner offers significant environmental advantages over liquid pool fires
- The Propane burner should be utilized for fast cook-off testing whenever possible





Acknowledgements

Funding provided by:

- The Environmental Security Technology Certification Program (ESTCP)
- The Insensitive Munitions Advanced Development (IMAD) Program

Special thanks to the Environmental Protection Agency for their assistance

Extra Material