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Determination and Validation of Open Burn Emission Factors for JP-8 Aviation Fuel to Better Estimate Annual Emissions and to Learn the Role Pool Fire Size has in Production of Combustion Species

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Open Burning of JP-8 Aviation Fuel

- Research, Development, Testing, and Evaluation (RTD&E) of weapon systems for the Navy and other agencies:
 - Insensitive Munitions (IM) Program developed in the wake of catastrophic losses on USS Forrestal, USS Oriskany, USS Enterprise, and USS Nimitz
 - IM Program fast cook-off testing required by law to demonstrate fleet ordnance will resist detonation when subjected to liquid pool fire conditions



Courtesy of NAWCWD

Open Burning of JP-8 Aviation Fuel

- Army uses JP-8 open-burning for fire-fighting training and for permitted open-burning of some unserviceable munitions.



Courtesy of NAWCWD

Naval Air Warfare Center Weapons Division (NAWCWD)

- NAWCWD China Lake, CA, conducts open pool burning of JP-8 in support of the Department of Defense (DoD) RTD&E and fire training needs.
- Roughly 20,000 gallons of JP-8 is open-burned per year at NAWCWD China Lake.
- The amount of JP-8 burned in a year must reported to the local air pollution control districts and United States (U.S.) Environmental Protection Agency (EPA), along with an estimate of associated emissions.

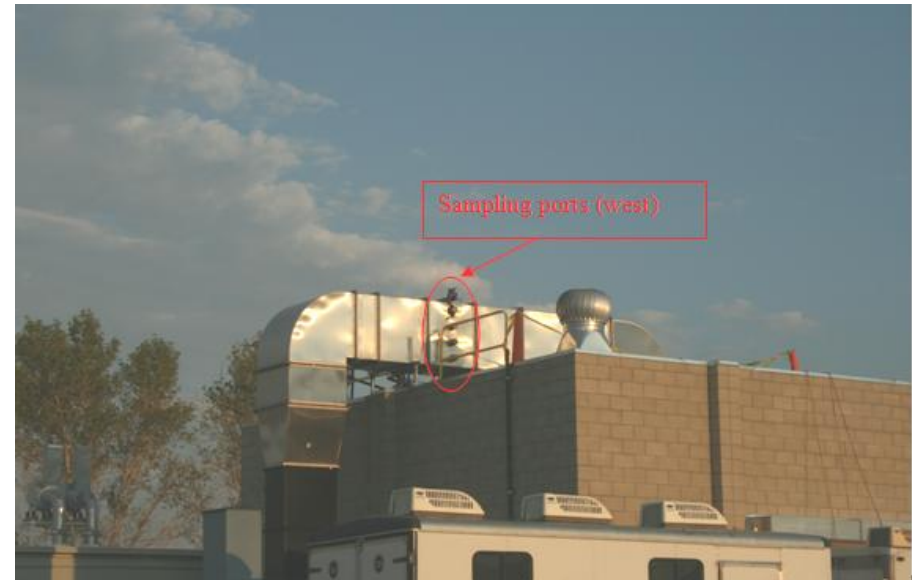
Quantifying JP-8 Emissions

- No suitable JP-8 emission factors exist; emissions must be estimated using methods developed for other types of sources such as boilers and orchard heaters (smudge pots).
- NAWCWD China Lake Environmental Office requested JP-8 emissions factors for controlled species.
- NAWCWD China Lake completed emission testing on a 5-ft² open pool fire of JP-8 using published U.S. EPA methods.

NAWCWD Testing at China Lake



Burn Room With Elevated
Burn Pan and Fuel Tank
Behind Radiant Barrier



Sampling Ports in Scrubber
Duct Atop the Burn Room

Objectives

- Validate NAWCWD China Lake data-
 - Validation is necessary because other defense agencies that open burn fuels for testing may depend on these results in the future.
- Determine what role (if any) pool fire size might play in the production of combustion species-
 - Provides a basis for future comparison of results and future prediction of emissions from larger fires
 - Potential to enhance the Army's ability to continue critical mission tasks by identifying environmental effects of the JP-8 burning in different configurations

Approach

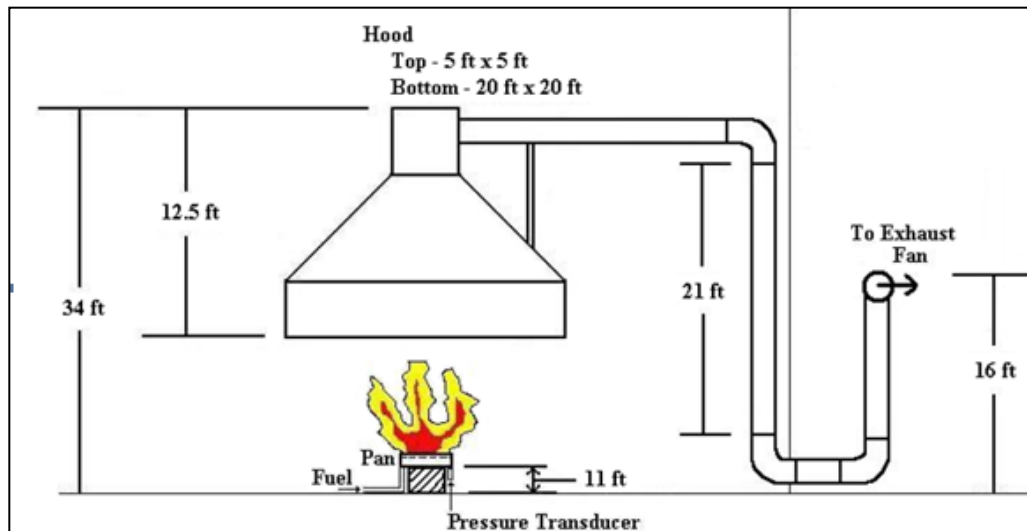
- Review NAWCWD China Lake data to determine the likelihood of reproducing data in a similarly instrumented fire
- Replicate the 5-ft² open pool fire previously accomplished at NAWCWD China Lake to verify data
- Conduct 7- and 10-ft² open pool fires to determine if pool fire size is significant in the production of combustion species

Review of NAWCWD China Lake Data

- Confirmed issues identified by NAWCWD China Lake in the data:
 - Unreasonably high results for Carbon Dioxide (CO₂) and Sulfur Dioxide (SO₂)
 - Presence of unexpected contaminants such as Dioxin
- Reviewed issues with the test set up that may have lead to the questionable data:
 - Inaccurate, inconsistent, and corrected fuel flow rates
 - Potential for the production of contaminants unrelated to JP-8 as a result of incomplete combustion
 - Overheated Continuous Emissions Monitoring Systems (CEMS)
- Utilize lessons learned from this testing event to eliminate the identified issues and produce results with a higher degree of accuracy and reliability

Design of Exhaust Collection System

- Determined that a 20-foot by 20-foot hood would be required to capture all emissions produced from the various size pool fires
- Designed and constructed an exhaust collection system



Exhaust Hood Design



Exhaust Hood as
Constructed

Design of Open Pool Fire System

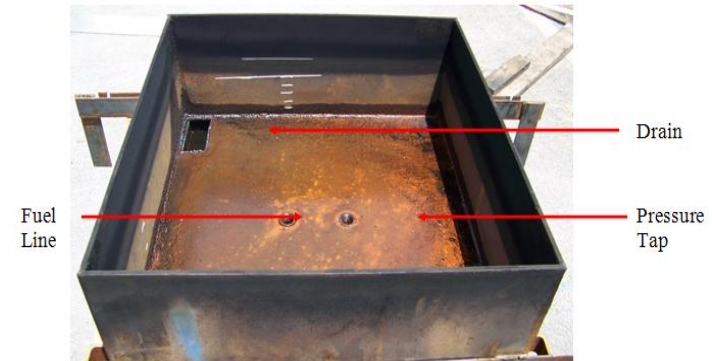
- Constructed open pool fire pans of 5, 7, and 10 ft² in size
- Designed a fuel delivery system to provide a consistent fuel supply as well as to track fuel consumption



JP-8 Fuel Reservoir on
Load Cell



Foxboro Digital
Coriolis Mass Flowmeter



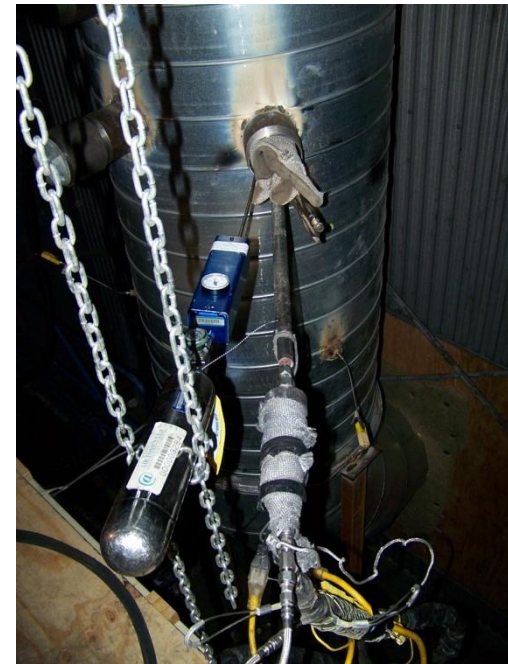
Pan Constructed for
Pool Fire Testing

Open Pool Fire Emissions Testing

- Completed four individual runs for each pool fire size and collected emissions according to established U.S. EPA methods



Conducting Open Pool
Fire Testing



Sampling Probes in
Exhaust Duct

Validation of NAWCWD Data for CO₂

- Completed three independent testing methods to obtain CO₂ results:
 - U.S. EPA Method 3A “Determination of Oxygen and CO₂ Concentrations in Emissions from Stationary Sources (Instrument Analyzer Procedure)”
 - U.S. EPA Method 3 “Gas Analysis for the Determination of Dry Molecular Weight (Fyrite Procedure)”
 - U.S. EPA Compendium Method TO-15 “Determination Of Volatile Organic Compounds (VOCs) In Air Collected In Specially-Prepared Canisters And Analyzed By Gas Chromatography/ Mass Spectrometry (GC/MS)”



Fyrite



TO-15 Canister

Validation of NAWCWD Data for CO₂ (Cont'd)

- Determined that the NAWCWD China Lake emission factor for CO₂ (4.09 lbs/lb of fuel) was statistically higher than what was generated in this study (3.38 lbs/lb of fuel)
- Discovered that this result of 3.38 lbs/lb of fuel was still higher than the calculated maximum CO₂ emission factor of 3.12 lbs/lb fuel, based on composition of the fuel
- Determined that U.S. EPA Method 3A (instrumental) may be contributing to the unexplainably high CO₂ emission factors; it produced higher average results when compared to Method 3 (Fyrite) and TO-15 (GC)

	Run 1	Run 2	Run 3	Run 4	Avg
Method 3A (instrumental)	3.55	3.08	3.61	3.27	3.38
Method 3 (Fyrite)	2.77	ND*	3.61	ND*	3.19
TO-15 (GC)	3.05	2.65	2.65	2.83	2.79

ND – No Data

* - Analysis was not performed on this run.

Validation of NAWCWD Data

- Generated emission factors that were not statistically different (95% CI) from the NAWCWD China Lake emissions factors for:
 - Carbon Monoxide (CO)
 - Total Gaseous Nonmethane Organics (TGNMO)
 - VOCs (except Methylene Chloride and Benzene)
- Generated emission factors that were statistically lower than reported by the NAWCWD China Lake:
 - SO₂
 - Polycyclic Aromatic Hydrocarbons (PAHs)
 - Total Dioxin/Furans
- Generated emission factors that were statistically higher than reported by the NAWS China Lake for:
 - Nitrogen Oxide (NO_x)
 - Particulate Matter

Discussion of Validation Results

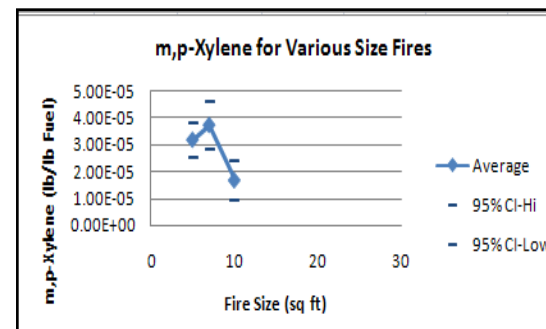
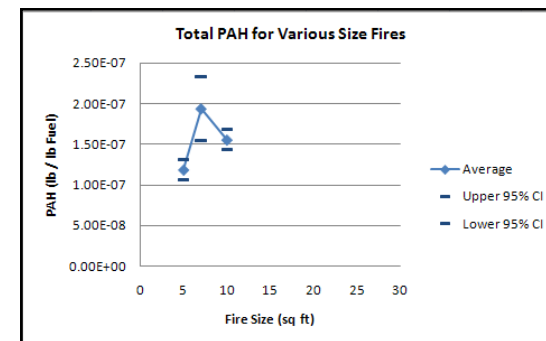
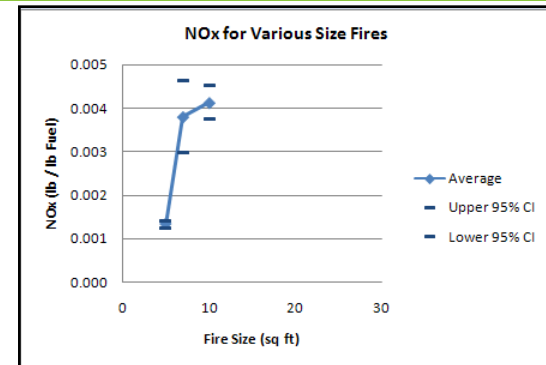
- Observed decrease in SO₂.
 - Expected to be lower based on issues with the CEMS overheating during the NAWCWD testing
 - Results questionable based on sulfur content of the fuel
- Decrease in total PAHs.
 - Higher flow rates used during the NAWCWD testing (~16,000 Actual Cubic Feet Per Minute [ACFM]) as compared to what was used in this testing (~ 6,000 ACFM) may have resulted in capturing PAHs from the fuel
- Decrease in Total Dioxin/Furans.
 - Expected to be lower because detection in NAWCWD testing was unexplainable
- Increase in NO_x.
 - Potentially due to differences in fuel composition
- Increase in Particulate Matter.
 - Higher flow rates used during the NAWCWD testing may have provided for more efficient combustion, resulting in less soot production

Evaluation of Pool Fire Size

- Determined that there was not a statistically significant difference between the results obtained from the different size pool fires for the following combustion species:
 - Particulate Matter
 - CO₂
 - CO
 - SO_x
 - TGNMO
 - VOCs (Acetone, Methylene Chloride, Benzene, Toluene, Ethyl Benzene, O-Xylene, Styrene, 4-Ethyl Toluene)
 - Dioxin/Furan
- Determined that there was a statistically significant difference between the results obtained from the different size pool fires for the following combustion species:
 - NO_x
 - m,p-xylene
 - Total PAHs

Discussion of Results from the Evaluation of Pool Fire Size

- Discovered that the flow rate was not consistent for each fire size.
 - ~6,000 ACFM used for the 5 ft²
 - ~12,000 ACFM used for the 7 ft²
 - ~14,000 ACFM used for the 10 ft²
- NO_x and PAH results for the 5-ft² testing were found to be statistically different from the 7 and 10-ft² testing.
- m,p-Xylene result for the 10 ft² was found to be statistically different from the 5 and 7-ft² testing.



Conclusions

- Validated NAWCWD concerns that their results for CO₂ and SO₂ were unreasonably high
- Validated NAWCWD data for CO, TGNMO, and VOCs (except methylene chloride and benzene)
- Identified issues with accurately quantifying CO₂ and SO₂ emissions from open burning of JP-8
- Determined that the majority of the combustion species of concern (14 of 17 or ~83%) were not significantly affected by changing pool fire size
- Determined that the flow rate used to capture emissions has the potential to have a significant affect on the results
- Determined that ongoing efforts within the U.S. EPA and the DoD will have a significant impact on the submission of emission factor information to the U.S. EPA



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