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Evaluation of the fire protection effectiveness of firefighting foams

Appendix: Comparative Characterization of Gasoline Samples

FINAL REPORT BY:

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FOREWORD

This report is an Appendix of the research report titled “Evaluation of the fire protection effectiveness of firefighting foams”. Appendix includes summary of comparative characterization of gasoline samples used for experiments the effectiveness of fluorine free firefighting foams.

Fire Protection Research Foundation (FPRF) facilitated this program to evaluate the fire protection performance and effectiveness of fluorine free, Class B firefighting foams on fires involving hydrocarbon and alcohol fuels. The deliverables from this project are intended to provide guidance for foam system application standards (e.g., NFPA 11: Standard for Low−, Medium−, and High− Expansion Foam) and to identify any additional research needed to better understand the capabilities and limitations of Fluorine Free Foams (FFFs).

The objectives of this study were to determine the firefighting capabilities (i.e., control, extinguishment and burnback times) for four FFFs and one C6 AFFF formulation (for baseline) as a function of application rate (gpm/ft^2) and discharge density (gal/ft^2) for a range of test parameters including fuel type, water type and fuel temperature.

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About the Fire Protection Research Foundation

The Fire Protection Research Foundation plans, manages, and communicates research on a broad range of fire safety issues in collaboration with scientists and laboratories around the world. The Foundation is an affiliate of NFPA.

About the National Fire Protection Association (NFPA)

Founded in 1896, NFPA is a global, nonprofit organization devoted to eliminating death, injury, property and economic loss due to fire, electrical and related hazards. The association delivers information and knowledge through more than 300 consensus codes and standards, research, training, education, outreach and advocacy; and by partnering with others who share an interest in furthering the NFPA mission.

All NFPA codes and standards can be viewed online for free.

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Keywords: foams, fluorine free foams, extinguishment, control, burnback, discharge density, AFFF, foam quality, NFPA 11.

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Advancing the Science of Safety

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RESULTS SUMMARY: COMPARATIVE CHARACTERIZATION OF GASOLINE SAMPLES

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Samples

On March 16, 2020, Jensen Hughes (Seattle Laboratory) received two-sealed, 40-ml vials of gasoline. One sample was labeled “Sample A, E-10” (Ethanol Gasoline) and the other was labeled “Sample B, EF” (Ethanol Free – MILSPEC Gasoline). Information that accompanied the samples indicated that the gasoline samples, which were locally sourced, were samples of gasolines used for testing the effectiveness of fluorine free firefighting foams. Pursuant to your request, each sample was subjected to a comparative compositional characterization. Our analytical technique and findings are presented below and in Table 1.

Analysis

The analyses of the fuels were conducted using the prescribed methods for fuel standardization outlined in ASTM E1618-14 (*Standard Test Method for Ignitable Liquid Residues in Extracts from Fire Debris Samples by Gas Chromatography-Mass Spectrometry*). The samples were analyzed using a Hewlett Packard 5890 Plus Gas Chromatograph equipped with a Hewlett Packard 5972 Mass Ion Spectrometer (GC/MS). Duplicate samples of each fuel were analyzed using headspace and solvent dilution techniques.

Jensen Hughes Comment: the GC/MS possesses the ability separate to respective components of the fuel sample that is injected onto the instrument. As each separated component of the fuel eludes through the spectrometric detector a peak with a marked retention time is produced and the resulting mass spectrum of each peak is automatically compared to spectral library. The height and area of each peak is used to quantitate the identified compound as relative percent of all the detected peaks. The volatility of each compound decreases with increasing retention times.

Findings

Based upon a review of the analytical data, each gasoline sample yielded an identical peak-to-peak match with exception of the expected ethanol peak in Sample A (E10 gasoline). It was noted, however, that some comparative variations in the peak sizes (quantity) of some of the fuel’s primary compounds were observed. Results of the analysis revealed some variation the primary and volatility of the gasoline fraction in each sample such that Sample A has a higher concentration of volatile compounds. The results of the analyses are presented in Table 1.

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Table 1 - Comparative GC/MS Characterization of Fuel Samples

Rows containing the Primary Compounds Highlighted in Green. Percent Values highlighted in Red represent comparatively high values as compared to Sample A. Percent values highlighted in blue are comparatively low values as compared to Sample A. Compound designated as unknown or marked with an asterisk were poor library matches.

Retention Time (Minutes)	Compound (Best Spectral Match)	SAMPLE A E-10 Relative %	SAMPLE B MILSPEC Relative %
1.52	Butane	1.101	**1.814**
1.56	Ethanol	9.862	**Not Detected**
1.60	2-methyl butane	10.951	**7.042**
1.64	Pentane	**Not Detected**	**1.632**
1.72	2,2-dimethyl butane	0.642	0.863
1.82	2-methyl pentane	5.378	**3.739**
1.89	3-methyl pentane	2.227	**1.479**
1.96	Hexane	2.265	**1.357**
2.14	Methyl cyclopentane	2.594	**1.863**
2.24	**Unknown**	0.021	0.014
2.30	**Unknown**	0.368	0.292
2.39	2,4-dimethyl pentane *	3.302	3.399
2.45	3-methyl hexane	1.915	1.888
2.56	2,2,4-trimethyl pentane	7.018	**5.765**
2.67	Heptane	1.153	1.328
2.73	3-methyl-2-hexene	0.398	0.295
2.79	3-methyl-2-hexene	0.097	0.075
2.85	3,5-dimethylcyclopentene	0.114	0.082
2.89	2,2-dimethyl hexane	0.077	0.132

2.96	Methyl cyclohexane	1.175	1.219
3.03	2,4 dimethyl hexane	2.200	2.156
3.13	1,2,4 Trimethyl cyclopentane	0.286	0.323
3.26	2,3,4-trimethy pentane	2.226	2.171
3.32	2,3,3-trimethyl pentane	2.571	2.231
3.38	2,3-dimethyl hexane	0.754	0.882
3.45	2-methyl heptane	1.292	1.637
3.53	Toluene	2.937	**4.589**
3.67	2,2,4-trimethyl hexane	1.766	1.705
3.80	1-ethyl-3-methyl cyclopentane	0.241	0.245
3.84	1-ethyl-2-methyl cyclopentane	0.257	0.259
3.95	Octane	1.093	**1.456**
4.06	1,3-trimethyl cyclohexane	0.301	0.286
4.12	1,2,3-trimethylcycopentene	0.160	0.152
4.18	2,3,5 trimethyl hexane	0.327	0.348
4.28	2,4-dimethyl heptane	0.156	0.173
4.33	1-ethyl-2-methyl cyclopentane	0.070	0.071
4.38	2,6-dimethyl heptane	0.276	0.303
4.51	Unknown dimethyl alkane/alkene	0.735	0.743
4.57	1,1,3 trimethyl cyclohexane	0.157	0.199
4.61	1,2,3 trimethyl cyclohexene	0.070	0.063
4.64	1,3-dimethyl cyclohexane	0.122	0.107
4.71	3-ethyl hexane	**Not Detected**	0.078
4.74	2-Nonene	**Not Detected**	0.099

4.76	6-methyl-1-octene	0.175	**Not Detected**
4.80	1,2,4-trimethyl cyclohexane	0.126	0.119
4.86	5,6-dimethyl decane	0.242	0.259
4.91	4-ethyl heptane	0.173	0.190
4.98	Ethyl benzene	1.716	**2.459**
5.12	1,3-dimethyl benzene	4.052	**6.866**
5.21	2,2-dimethyl octane	0.356	0.351
5.27	1,2,3-trimethyl cyclohexane	0.066	0.065
5.32	2,2-dimethyl octane	0.227	0.231
5.37	1,ethyl-3-methyl cyclopentane	0.143	0.139
5.41	1-ethyl-3-methyl cyclohexane	0.210	0.202
5.54	(1,2) or 1,3-dimethyl benzene	1.791	**3.162**
5.58	Nonane	0.649	0.735
5.72	3,5-dimethyl hexene	0.064	0.070
5.75	1-ehtyl-4-methyl cyclohexane	0.104	0.098
5.80	Unknown compound	0.093	0.087
5.89	2,4,6-trimethyl heptane	0.220	0.208
6.01	4-methyl nonane	0.263	0.229
6.07	1-methylethyl benzene	0.331	0.404
6.17	3-methyl nonane	0.369	0.354
6.28	Trans-4-decene	0.106	0.086
6.30	3-ethyl-2-methyl heptane	0.081	0.078
6.35	Ethyl cyclopentane	0.043	**Not Detected**
6.39	5-Decene	0.064	0.055

6.46	**Unknown**	0.077	0.067
6.57	Propyl benzene	0.665	0.872
6.64	6-methyl tridecane	0.814	0.790
6.71	1,3,5 trimethyl benzene	2.715	3.740
6.83	1,2,3 trimethyl benzene	1.528	1.867
7.04	1-ehtyl-2-methyl benzene	0.884	**1.143**
7.10	1,1,3 trimethyl cyclopentane	0.083	0.069
7.18	2,6-dimethyl heptane decane	0.205	0.194
7.27	1,2,3 trimethyl benzene	3.610	**5.086**
7.36	3-ethyl 2,5-dimethyl-3 hexene*	0.085	0.075
7.44	Unknown	0.056	0.041
7.50	2-methylpropyl benzene	0.149	0.143
7.55	1-methylpropyl benzene	0.184	0.169
7.63	Nonane or Other Alkane	0.119	0.086
7.70	2,2,5 trimethyl decane	0.528	0.442
7.77	1,2,4-trimethyl benzene	0.947	1.276
7.83	pentamethyl heptane	0.152	0.121
7.91	2,3,4-trimethyl hexane	0.498	0.366
8.01	indane	0.531	0.575
8.06	3-ethyl hexane	0.059	0.045
8.12	Butyl cyclopentane	0.048	0.034
8.22	1-methyl-3-propyl benzene	1.310	1.195
8.30	Butyl benzene	**Not Detected**	0.542
8.34	1-ethyl-2,3-dimethyl benzene	1.737	**1.036**

8.49	1-methylpropyl benzene	0.439	0.377
8.58	2,4-dimethyl heptane	0.319	0.220
8.65	2-ethyl-1,4-dimethyl benzene	0.769	0.418
8.68	1-methyl-2(1-methylethyl) benzene	**Not Detected**	0.390
8.79	4-ethyl-2,3-dimethyl benzene	0.874	0.860
8.85	1-methyl indane	0.275	0.200
8.93	Undecane	0.462	0.323
8.98	Octahydro 4.7,methanol-1 indene	0.129	0.217
9.03	**Unknown**	0.083	**Not Detected**
9.08	2-ethyl-1,4-dimethyl benzene	0.093	0.065
9.13	4-ethyl-1,2-dimethyl benzene	0.235	0.214
9.20	Undecane	0.137	0.072
9.28	1,2,4,5-tetramethyl benzene	0.561	0.539
9.36	1,2,4,5-tetramethyl benzene	0.659	0.689
9.47	Normal Alkane	0.147	0.081
9.55	1-(ethenyloxy)-octadecane	0.047	**Not Detected**
9.60	1-methyl-4-(1-methylpropyl) benzene	0.156	0.128
9.68	2-ethenyl-1,4-dimethyl benzene	0.647	0.470
9.80	2,6-dimethyl decane	0.145	**Not Detected**
9.86	2,4-dimethylstyrene benzene	0773	0.706
9.92	**Unknown**	0.226	0.127
9.97	1-methyl-4-(1-methylpropyl) benzene	0.188	0.121
10.04	1,2,3,4-terahydro naphthalene	0.502	0.339
10.18	1-methyl-4-(1-methylpropyl) benzene	0.171	0.114

10.33	2,3-dihydro-1,3-dimethyl Indene	0.136	0.071
10.41	Naphthalene	0.572	0.438
10.47	Dodecane	0.292	0.154
10.54	Pentamethyl benzene	0.220	0.145
10.58	2,3,-dihydro-1,2-dimethyl indene	0.219	0.157
10.63	Nonane / Normal Alkane*	0.039	**Not Detected**
10.67	2,6-dimethyl undecane	0.096	0.038
10.72	Pentyl methyl benzene	0.109	0.071
10.79	Undesignated alkane	0.081	0.037
10.86	Indol-4-ol	0.068	0.038
10.90	**Unknown**	0.045	**Not Detected**
10.94	1-ethyl-1-methyl propyl benzene	0.112	0.046
11.11	2-Pentene-3-phenyl	0.133	0.118
11.13	2-ethyl-2,3-dihydro Indene	0.111	**Not Detected**
11.22	**Unknown**	0.096	0.038
11.26	Dimethyl undecane*	0.073	0.028
11.35	2,3,dihydro-4,7-dimethyl indene	0.215	0.128
11.38	Eicosane*	0.073	**Not Detected**
11.44	**Unknown**	0.056	0.024
11.48	3-methyl dodecane	0.103	0.039
11.55	2,3,dihydro-1,2-dimethyl indene	0.085	0.043
11.60	**Unknown**	0.091	0.024
11.69	**Unknown**	0.063	0.026
11.78	Pentamethyl benzene	0.098	0.061

11.82	2,3,dihydro-4,7-dimethyl indene	0.063	0.031
11.90	Tridecane	0.148	0.054
11.98	4-(2-butenyl) 1,2,-dimethyl benzene	0.063	0.029
12.04	2-methy naphthalene	0.293	0.193
12.21	**Unknown**	0.028	**Not Detected**
12.27	2-methyl naphthalene	0.146	0.108
12.39	**Unknown**	0.025	**Not Detected**
12.46	Trimethyl dodecane	0.057	0.035
12.58	**Unknown**	0.066	0.035
12.70	Normal Alkane *	0.023	**Not Detected**
12.77	Normal Alkane *	0.039	**Not Detected**
12.88	**Unknown**	0.026	**Not Detected**
12.94	**Unknown**	0.014	**Not Detected**
12.99	Normal Alkane*	0.016	**Not Detected**
13.25	Undecane*	0.047	0.023
13.35	**Unknown**	0.013	**Not Detected**
13.75	**Unknown**	0.030	0.039
14.04	Normal Alkane*	0.023	**Not Detected**
14.52	Heptadecane	0.028	0.014
15.71	Heptadecane	0.033	**Not Detected**
16.85	**Unknown**	0.019	**Not Detected**
16.89	**Unknown**	0.017	No Peak
17.93	**Unknown**	0.006	No Peak