



Naval Fuels & Lubricants

Cross Functional Team

Test Report

Impact of 80% F-76/20% Hydrotreated Depolymerized Cellulosic Diesel (HDCD-76) on Coalescence

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LIST OF ACRONYMS/ABBREVIATIONS

ASTM	American Society for Testing and Materials
DLA	Defense Logistics Agency
DSH-76	Direct Sugar to Hydrocarbon F-76
F-76	USN F-76 Grade Diesel Fuel
FLC	Fleet Logistics Center
FT	Fischer Tropsch
HEFA	Hydroprocessed Esters and Fatty Acids
HDCD-76.....	Hydrotreated Depolymerized Cellulosic Diesel
IAW.....	in accordance with
NCT.....	Navy Coalescence Test
NSTM	Naval Ship's Technical Manual
PPM.....	parts per million

DEFINITIONS

Coalescence.....	the ability to shed water from fuel
Dissolved Water.....	water that is in solution with the fuel i.e. at or below the saturation point
Element	a separation device comprised of a filter coalescer and separator
Free Water	water in a multi-fluid stream which is above the fluid's saturation point (not dissolved water)
Saturation point.....	the total water concentration at which all water present in the fuel is dissolved in the fuel and the further addition of water will result in the presence of free water. The saturation point is heavily dependent on the chemical composition of the fuel and temperature.
Turnover	time required to flow the entire volume of fluid in a container, also known as residence time (volume of fuel ÷ volumetric flow rate)

EXECUTIVE SUMMARY

In October 2009, Secretary of the Navy Ray Mabus directed the Navy to decrease its reliance on fossil fuels. The Secretary set a goal of operating with at least 50% of energy consumption coming from alternative sources by 2020. He also set forth the goal of demonstrating a Great Green Fleet, operating on 50% alternative fuel, by 2012 and deploying by 2016. The use of alternative/petroleum sourced aviation fuel blends is a critical component to achieving these goals. The alternative sourced fuels will come from non-food sources and must be compatible with all existing hardware without compromising performance, handling or safety. The increased use of alternative sources to produce Naval tactical fuels will increase the Navy's energy independence while improving national security, decreasing environmental impact and strengthening the national economy. The objective of this test program is to ensure that all proposed alternative fuels perform equally or better than existing petroleum sourced fuels.

One such fuel that is undergoing qualification testing is an 80% petroleum F-76 and 20% Hydrotreated Depolymerized Cellulosic Diesel (HDCD-76), by volume, fuel blend. HDCD-76 is produced from cellulosic feedstocks such as wood chips, switch grass or corn stover. Unlike Hydroprocessed Esters and Fatty Acids (HEFA) or Fischer Tropsch (FT), neat HDCD-76 contains almost no normal or iso-paraffins. Instead, HDCD-76 is comprised of a mixture of dicyclic and tricyclic alkanes, and mono, di and tricyclic aromatics. HDCD is made up of a complex mixture of many different hydrocarbon compounds that are found in the boiling point range of typical F-76. Most of these compounds are found naturally in petroleum fuels.

The 80% F-76/20% HDCD-76 fuel blend's ability to coalesce free water was evaluated by performing a Navy Coalescence Test (NCT). The NCT is a level II fit-for-purpose test which uses a specially manufactured scaled down filter/coalescer and separator to simulate the performance of a full-scale filter separator system. This test is designed to predict the performance of new additives and fuels on filter separator systems currently in use by the fleet.

After 80 hours of testing 80% F-76/20% HDCD-76 met the acceptable performance criteria. Therefore it is recommended 80% F-76/20% HDCD-76 proceeds to full-scale single element testing. In the interim, 80% F-76/20% HDCD-76 qualification testing should continue.

Impact of 80% F-76/20% Hydrotreated Depolymerized Cellulosic Diesel (HDCD-76) on Coalescence

1.0 BACKGROUND

In October 2009, Secretary of the Navy Ray Mabus directed the Navy to decrease its reliance on fossil fuels. The Secretary set a goal of operating with at least 50% of energy consumption coming from alternative sources by 2020. He also set forth the goal of demonstrating a Great Green Fleet, operating on 50% alternative fuel, by 2012 and deploying by 2016. The use of alternative/petroleum sourced aviation fuel blends is a critical component to achieving these goals. The alternative sourced fuels will come from non-food sources and must be compatible with all existing hardware without compromising performance, handling or safety. The increased use of alternative sources to produce Naval tactical fuels will increase the Navy's energy independence while improving national security, decreasing environmental impact and strengthening the national economy. The objective of this test program is to ensure that all proposed alternative fuels perform equally or better than existing petroleum sourced fuels.

One such fuel that is undergoing qualification testing is an 80% petroleum F-76 and 20% Hydrotreated Depolymerized Cellulosic Diesel (HDCD-76), by volume, fuel blend.

HDCD-76 is produced from cellulosic feedstocks such as wood chips, switch grass or corn stover. Unlike Hydroprocessed Esters and Fatty Acids (HEFA) or Fischer Tropsch (FT), neat HDCD-76 contains almost no normal or iso-paraffins. Instead, HDCD-76 is comprised of a mixture of dicyclic and tricyclic alkanes, and mono, di and tricyclic aromatics. HDCD is made up of a complex mixture of many different hydrocarbon compounds that are found in the boiling point range of typical F-76. Most of these compounds are found naturally in petroleum fuels.

Chapter 541 of the Naval Ship's Technical Manual (NSTM) specifies a free water limit of 40 ppm in F-76 grade diesel fuel. Excessive free water in fuel systems will facilitate the growth of microbial organisms and negatively impact engine performance. Therefore filter coalescers are commonly used at shore stations and onboard sea vessels to remove free water to acceptable limits. The Navy Coalescence Test (NCT) is a level II fit-for-purpose test in the Navy's qualification protocol designed to simulate a full-scale filter separator system so that a fuel's ability to coalesce water can be evaluated on a small-scale.

2.0 OBJECTIVE

The objective of this test was to determine the effects of 20% HDCD-76 (by vol.) on the coalescence properties of F-76 by comparing free water levels upstream and downstream of a scaled down filter coalescer and separator filtration system.

3.0 APPROACH

3.1 Test Overview

Testing was conducted in accordance with (IAW) NCT Standard Work Package SWP44FL-003. The test is comprised of saturating dry fuel with water (via wet N₂ sparging), injecting 250 ± 50 ppm of free water upstream of a filter coalescer and separator element, and removing the water via the element. The total water concentration in the fuel is measured at each of these three locations per American Society for Testing and Materials (ASTM) procedure ASTM D6304. Three samples from the inlet and outlet of the filter separator capsule and one sample of water saturated fuel are measured each hour. By measuring and graphing the water levels at these three locations, the effects on coalescence can be determined. When coalescence is unaffected, the water levels in the saturated fuel and at the outlet of the element are close in value and give consistent results. When coalescence is compromised, the water levels at the inlet and outlet of the element are closer. Differential pressure across the coalescer is also recorded to ensure the differential pressure does not exceed 15 psi at which point filter coalescer and separator performance is compromised. The standard test duration is 80 hours. A flow schematic for the NCT rig is shown in Figure 1.

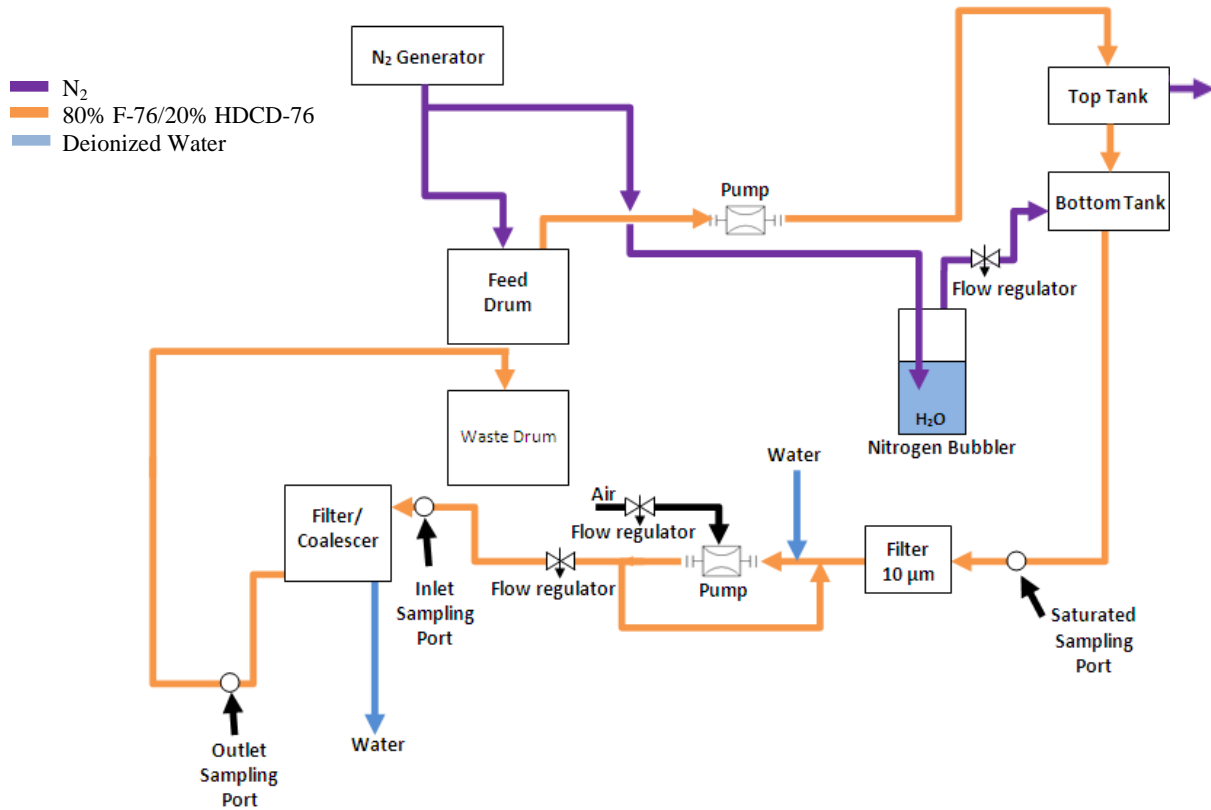


Figure 1: NCT Flow Schematic

3.2 Test Fuel

The F-76 was acquired from Fleet Logistics Center (FLC) Craney Island. The HDCD-76 was acquired directly from the manufacturer, Kior. Prior to blending the two components, specification tests were completed at NAS Patuxent River's Naval Fuels Laboratory to ensure the F-76 met all chemical and physical properties specified in MIL-DTL-16884M. The two components were then blended at an 80% F-76/20% HDCD-76 by volume ratio and tested to ensure conformance to MIL-DTL-16884M chemical and physical property limits. To prevent sediment from clogging the lines of the NCT rig, the blended fuel was recirculated through a series of 0.5 micron (nominal) filters and coalescers until the particulate content of the test fuel was 2.0 mg/L.

3.3 Acceptance Criteria

In order to successfully pass the NCT, the difference between the total water concentration of the saturated fuel and the fuel leaving the test element (i.e. free water) must be less than 100 ppm. If this criterion is exceeded for four consecutive hours, the test will be reported as a failure. The 100 ppm limit has been chosen because it allows for variations in the fuel sample, as well as system disturbances such as excess water injection and incomplete saturation. The differential pressure across the capsule which houses the filter and separator shall not exceed 15 psi at any point during the test. If the differential pressure exceeds 15 psi the fuel fails the NCT.

4.0 DISCUSSION

The average total water concentration of the saturated fuel stream and the filter separator inlet and outlet fuel streams can be found in Figures 2 and 3. Figure 3 excludes the inlet total water concentrations to better illustrate the differences between the saturated and outlet water concentrations. Total water concentration measurements are omitted for test hour 39 due to a titrator issue which prevented any samples from being analyzed. Times when the outlet water concentrations are below the saturation concentration are indicative of periods of excessive water saturation since filter coalescers are only able to remove free water. For the 23 test hours excessive water saturation occurred, the water saturation point is estimated as the average of the 56 test hours oversaturation did not occur. This was calculated to be 65 ppm total water. Since the fuel temperature varied between 60°F and 70°F (average = 68°F) throughout the evaluation period, 65 ppm is a reasonable estimate of the actual water saturation concentration.

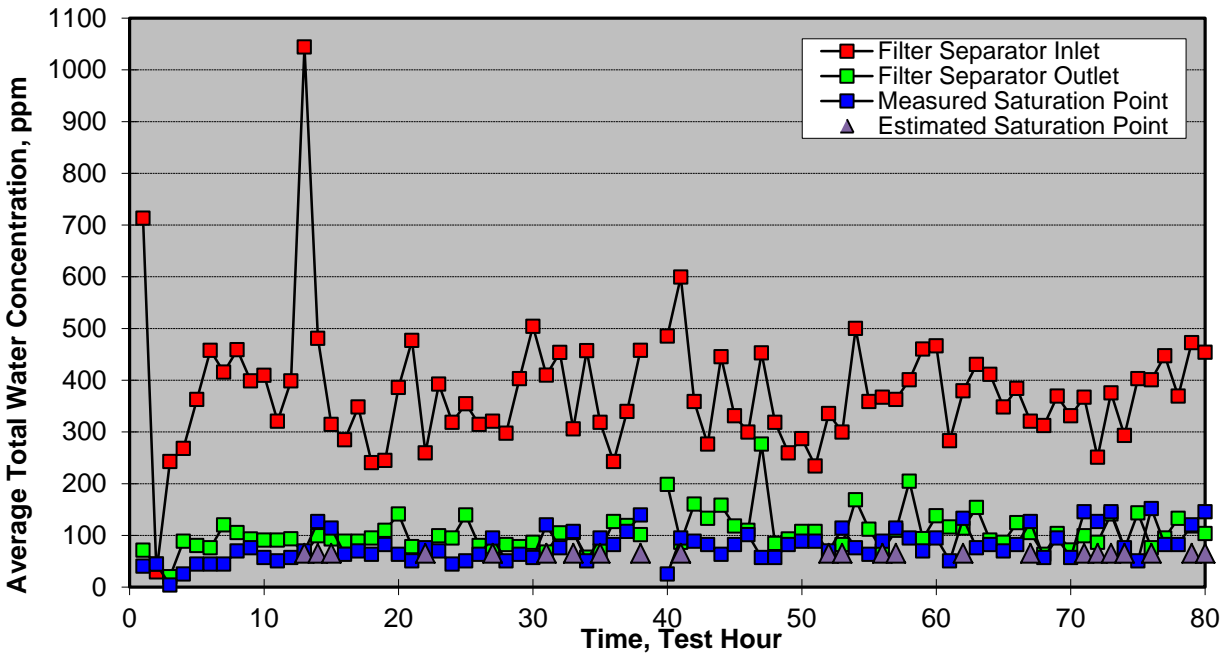


Figure 2: Average Total Water Concentration: Saturated Fuel Stream, Filter Separator Influent and Effluent

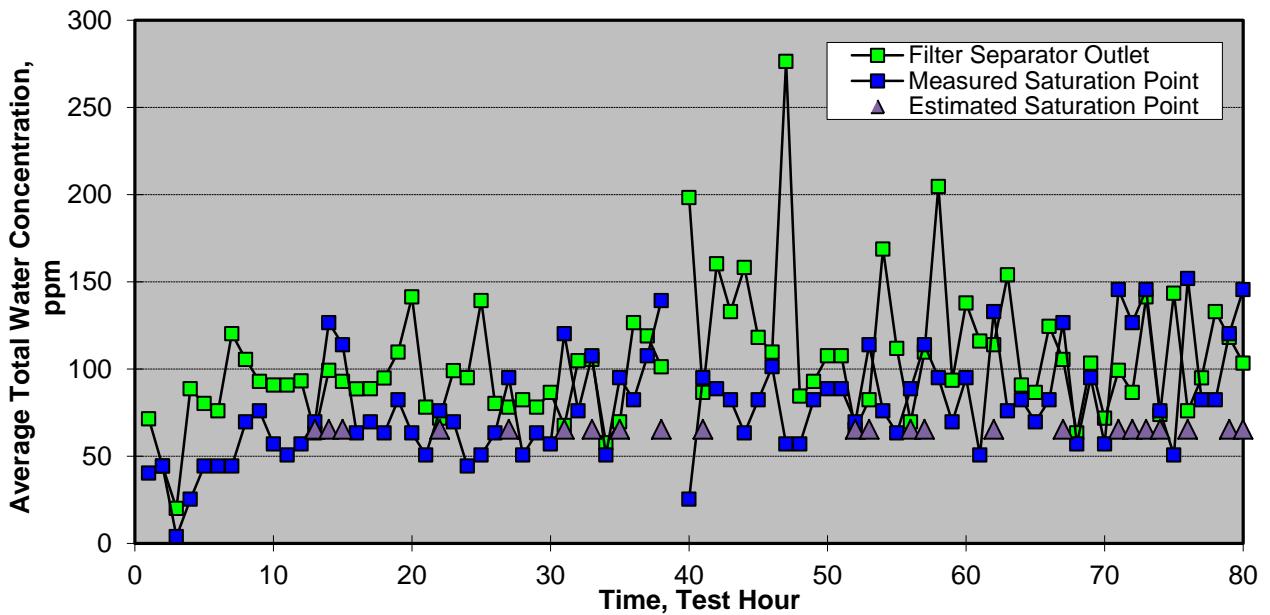


Figure 3: Average Total Water Concentration: Filter Separator Effluent and Saturated Fuel Stream

The average amount of free water injected in the saturated fuel stream and coalesced by the filter separator at each test hour can be seen in Figure 4. For the 23 test hours that over saturation of the test fuel occurred, the estimated saturation point, 65 ppm, was used to calculate the amount of free water injected into the fuel stream (indicated by a purple marker). Since the

amount of free water coalesced is the difference between the inlet and outlet measurements, oversaturation of the test fuel does not directly affect the amount of free water coalesced. On average, 311 ppm free water was injected.

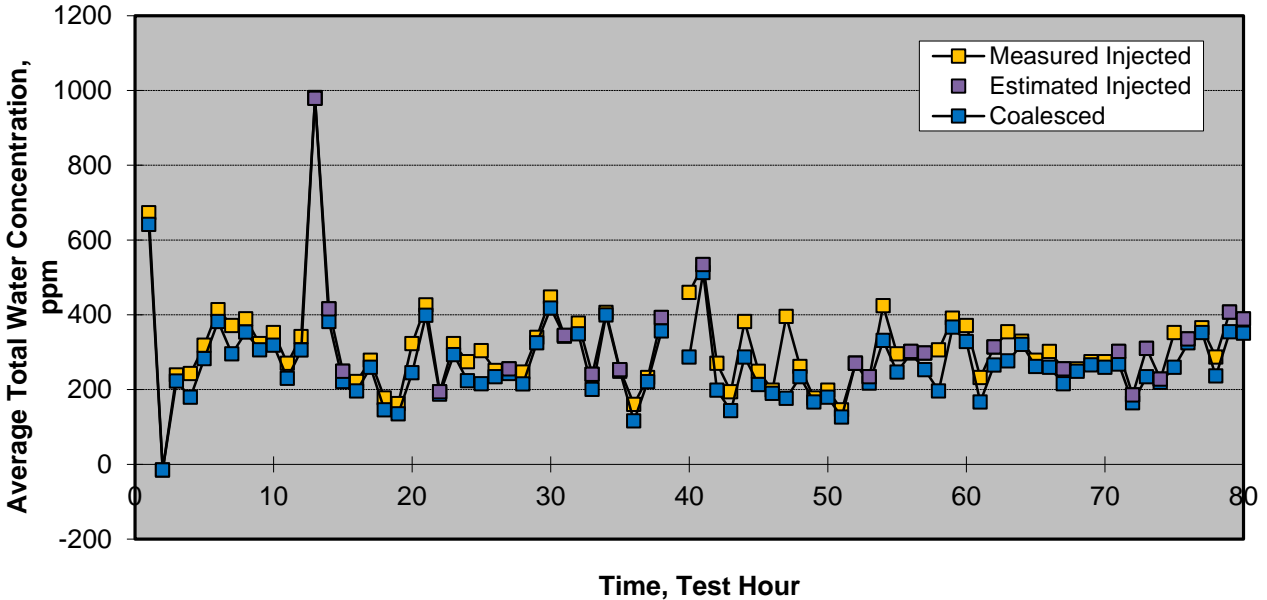


Figure 4: Injected and Coalesced Water

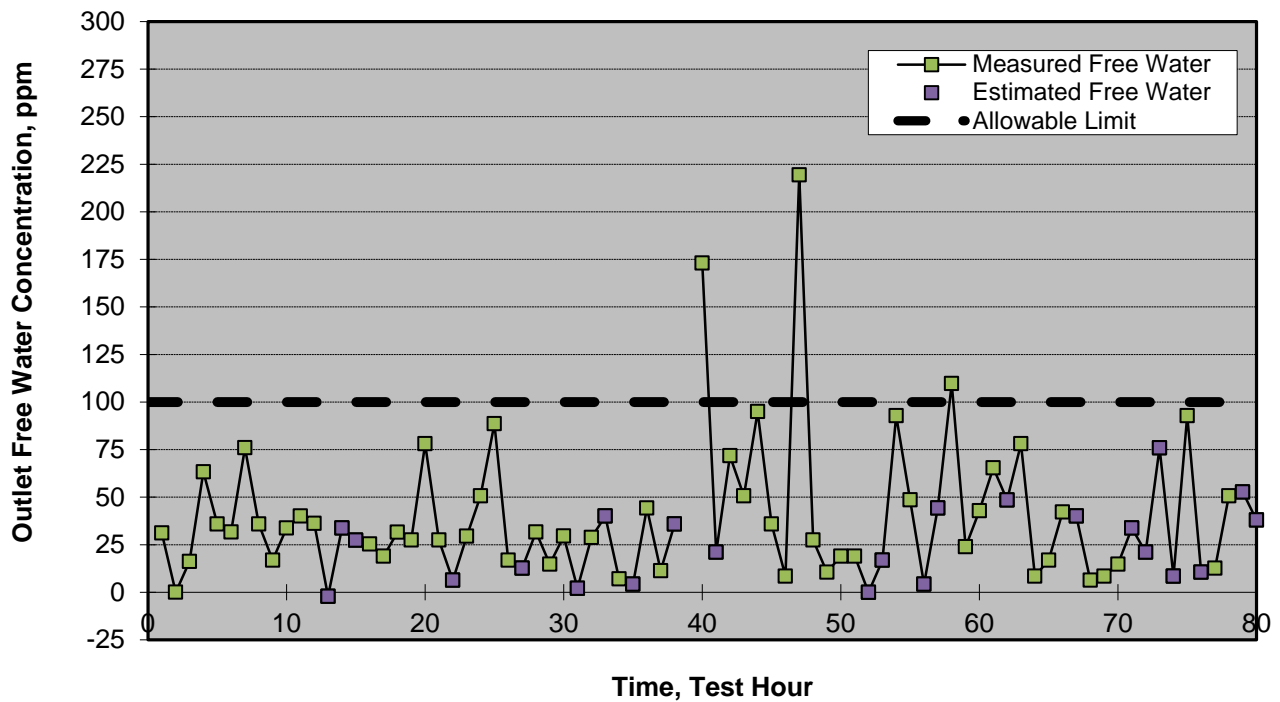


Figure 5: Free Water Concentration at Outlet of Test Element

As can be seen in Figure 5, free water concentrations >100 ppm were measured at only three test hours (40, 47, and 58). The average free water concentration measured at the outlet of the filter separator was 38 ppm (std dev= 36 ppm). At no point during the test did the differential pressure across the filter separator capsule exceed 1 psi. Therefore the 80% F-76/20% HDCD-76 fuel blend satisfactorily met the NCT acceptance criteria.

5.0 CONCLUSIONS

The 80% F-76/20% HDCD-76 fuel blend met the acceptable performance criteria stated in section 3.3. Based on this analysis, HDCD-76 does not adversely affect F-76 water coalescence when blended at a ratio of 80% F-76 and 20% DSH-76 by volume.

6.0 RECOMMENDATIONS

It is recommended that 80% petroleum F-76/20% HDCD-76 blends continue qualification testing. Additionally, it is recommended that an 80% F-76/20% HDCD-76 blend be tested on a full-scale single filter element system to ensure compatibility with current filtration infrastructure.

7.0 REFERENCES

SWP44FL-003 Navy Fuels and Lubricants CFT Navy Coalescence Tester (NCT)

APPENDIX A

Table 1. Test Data

Run Time (test hour)	avg. inlet (ppm)	avg. outlet (ppm)	avg. tank (ppm)	ΔP (psi)	Temperature (°F)
1	713	71	40	1	60
2	29	44	44	1	61
3	243	20	4	1	62
4	268	89	25	1	63
5	363	80	44	1	64
6	458	76	44	1	64
7	416	120	44	1	64
8	459	105	70	1	64
9	399	93	76	0	69
10	409	91	57	0	69
11	321	91	51	1	69
12	399	93	57	1	69
13	1044	63	70	1	69
14	481	99	127	1	69
15	314	93	114	1	70
16	285	89	63	1	69
17	348	89	70	1	65
18	240	95	63	1	65
19	245	110	82	1	65
20	386	141	63	1	65
21	477	78	51	1	65
22	259	72	76	1	66
23	392	99	70	1	66
24	319	95	44	1	65
25	354	139	51	1	65
26	314	80	63	1	66
27	321	78	95	1	66
28	297	82	51	1	65
29	403	78	63	1	65
30	504	87	57	1	65
31	410	68	120	1	65
32	454	105	76	1	69
33	306	105	108	1	69
34	457	58	51	1	69
35	319	70	95	1	69
36	243	127	82	1	69
37	340	119	108	1	69
38	458	101	139	1	69
39	-	-	-	1	69
40	485	198	25	1	69

Table 1. Test Data (Continued)

Run Time (test hour)	avg. inlet (ppm)	avg. outlet (ppm)	avg. tank (ppm)	dP (psi)	Temperature (°F)
41	599	87	95	1	69
42	359	160	89	1	69
43	276	133	82	1	69
44	445	158	63	1	69
45	331	118	82	1	69
46	300	110	101	1	70
47	453	276	57	1	69
48	319	84	57	1	69
49	259	93	82	1	69
50	287	108	89	1	69
51	234	108	89	1	69
52	335	65	70	1	69
53	300	82	114	1	69
54	500	169	76	1	69
55	359	112	63	1	69
56	367	70	89	1	69
57	363	110	114	1	69
58	401	205	95	1	69
59	460	93	70	1	69
60	466	138	95	1	69
61	283	116	51	1	69
62	379	114	133	1	69
63	430	154	76	1	69
64	411	91	82	1	69
65	348	86	70	1	69
66	384	124	82	1	69
67	321	105	127	1	69
68	312	63	57	1	69
69	369	103	95	1	69
70	331	72	57	1	69
71	367	99	146	1	69
72	251	86	127	1	69
73	376	141	146	1	69
74	293	74	76	1	69
75	403	143	51	1	69
76	401	76	152	1	67
77	447	95	82	1	68
78	369	133	82	1	68
79	473	118	120	1	69
80	454	103	146	1	69

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