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AF WRIGHT AERONAUTICAL LABORATORIES

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PROPERTIES OF JP-8 JET FUEL

Charles R. Martel
Fuels Branch
Fuels and Lubrication Division

May 1988

Summary Report for Period August 1984 - April 1988

Approved for public release; distribution unlimited

AERO PROPULSION LABORATORY
AIR FORCE WRIGHT AERONAUTICAL LABORATORIES
AIR FORCE SYSTEMS COMMAND
WRIGHT-PATTERSON AIR FORCE BASE, OHIO 45433-6563

NOTICE

This technical report has been reviewed and is approved for publication.

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This report provides a summary of 80 JP-8 jet fuels produced over the time period of August 1984 to April 1988. The data were obtained from the test reports provided by the fuel supplier or receiving terminal. Averages, standard deviations, minimum and maximum values of the various data have been determined and are reported.

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FOREWORD

The work reported herein was performed under Program Element 62203F, Project No. 3048, Task No. 05, and Work Unit 91. The report was prepared during the March-June 1988 time period, but the data include fuels delivered to the Department of Defense over the period of August 1984 through April 1988. Mr Charles R. Martel (AFWAL/POSF), Aero Propulsion Laboratory, Air Force Wright Aeronautical Laboratories, Wright-Patterson Air Force Base, Ohio 45433-6563, was the author of the report.

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SECTION 1 - INTRODUCTION

The USAF is converting from JP-4 to JP-8 as its primary combat fuel. In 1979, USAF operations within the United Kingdom were converted from JP-4 (NATO designation F-40) to JP-8 (Nato F-34). NATO and USAF operations in Europe will be converted to JP-8 by the end of 1988. Plans are to convert USAF operations in the Pacific (Japan, Korea, and Okinawa) to JP-8 by 1991. The USAF is also considering switching continental US (CONUS) operations to JP-8.

JP-8 (F-34) is commercial Jet A-1 (NATO designation F-35) plus special additives, i.e., fuel system icing inhibitor, corrosion inhibitor/lubricity improver additive, and static dissipator additive. Although not widely used within the CONUS, Jet A-1 is the primary commercial jet fuel for the rest of the free world. In NATO, much of the JP-8 will be procured and shipped as Jet A-1, with the special additives, required to convert the Jet A-1 into JP-8, injected into the fuel prior to its delivery to air bases.

The primary commercial jet fuel within the CONUS is Jet A, a higher freeze point Jet A-1. Jet A, Jet A-1 and JP-8 are kerosene fuels with a minimum flash point of 100°F (38°C). JP-4, a mixture of naphtha (gasoline) and kerosene, is much more volatile with a flash point of about -10° to +10°F (-23 to -12°C). Combat and aircraft crash landing experiences have repeatedly demonstrated the significantly increased fire and explosion hazards of using JP-4, as compared to Jet A, Jet A-1 and JP-8.

The average properties of JP-8, as delivered to the USAF, have not been previously reported. These data are needed by engine and aircraft designers and operators to estimate aircraft and engine performance. This report documents the properties of 80 JP-8 and Jet A-1 fuels procured for use by the USAF in Europe over the time period of 1984 to April 1988. Fuel sources included Venezuela, Greece, Italy, Spain, the Netherlands Antilles (Aruba), the US, Singapore, France, and the Netherlands. This report also includes a comparison of JP-8 with commercial Jet A.

SECTION II - FUELS DATA

1. DATA SOURCE

Data were obtained from suppliers' test reports, required for each batch of fuel delivered to the USAF. Also, data were obtained from the Belvoir Fuels and Lubricants Research Facility (BELRF)[1] in the form of a letter report dated 22 January 1988. The BFLRF fuels data were incomplete, as the primary emphasis of the BFLRF report was the performance of JP-8 in diesel engines. Some of the test reports were also incomplete, with various fuel properties and test results either not measured or not reported.

The limited number of JP-8s included in this report are due to three factors: (1) USAF operations in Europe are a small fraction of those conducted within the CONUS, so far less fuel is required, (2) most of the fuel test reports represent large tanker shipments, and (3) only the United Kingdom received JP-8 during the 1984-86 time period.

2. DATA ANALYSIS

Table 1 is a compilation of all the JP-8 data, including source and date. Table 2 contains the statistical averages, standard deviations, and minimum and maximum values of the JP-8 date of Table 1. These statistical data were calculated or identified for each fuel property using the statistical functions incorporated into The Software Group's ENABLE, an integrated word processing, spreadsheet/graphics, data base, and telecommunications software program.

The heats of combustion reported in Table 1 include data measured directly using calorimeters and estimated values using the aniline-gravity correlations given in ASTM D 1405. To provide a standard method for comparison, heats of combustion were also calculated using ASTM D 3338. Also, the hydrogen mass percent was calculated for all fuels using ASTM D 3343.

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[1]Enclosure 2 to Belvoir Fuels and Lubricants Research Facility lett L.E. Pera, subject "Shipments of JP-5 and JP-8," dated 22 Jan 1988.

TABLE 1 · JP-8 DATA SUMMARY

SOURCE	DATE YR-MO	ACID NO	AROM %	OLEFIN %	TOTAL SULFUR	MERCAP SULFUR	D86 DISTILLATION (C) TBP	%10	%20	%50	%90	EP	MEAN	FLASH PT	GRAV API	FRE POI
57 FRANCE PORT JEROME	8709		16.8	1.6	0.06		148	173		196	227	248	199	41	46.2	
61 FRANCE PORT JEROME	8710		17.5	0.5	0.04		151	170		193	225	248	196	36	47.4	
63 FRANCE PORT JEROME	8711		17.8	1.0	0.06		147	168		192	224	239	195	41	46.9	
65 FRANCE PORT JEROME	8712		17.3	1.7	0.07		144	173		195	223	235	197	39	47.6	
72 GERMANY, KARLSRUHE	8804	0.010	16.5	0.6	0.02	0.0002	152	173	181	197	220	240	197	44	46.2	-5
82 GERMANY, KARLSRUHE	8804	0.007	15.4	0.7	0.09	0.0008	152	173	180	196	226	244	198	44	46.9	-5
48 GREECE ST THEODORI	8704		16.5	1.0	0.01		164	181		208	243	271	211	49	43.6	
41 GREECE ST THEODORI	8704		14.0	0.1	0.12		153	173		198	236	259	202	42	45.9	
68 GREECE ST THEODORI	8704		12.6	0.1	0.20		149	169		198	239	259	202	42	46.0	
70 GREECE ST THEODORI	8705	0.004	13.5	0.1	0.08	0.0008	150	171	180	197	234	264	201	41	45.8	-4
69 GREECE ST THEODORI	8706	0.003	13.8	0.1	0.15	0.0009	153	171	180	199	235	252	202	43	45.6	-5
13 GREECE ST THEODORI	8708	0.003	15.5	0.1	0.17	0.0006	152	175	181	202	240	258	206	46	45.6	-4
14 GREECE ST THEODORI	8708	0.002	16.0	0.5	0.17	0.0008	152	176	181	202	238	257	205	47	44.8	-4
15 GREECE ST THEODORI	8708	0.003	16.0	0.3	0.17	0.0007	153	173	182	202	239	257	205	46	45.1	-4
52 GREECE ST THEODORI	8708		18.9	1.1	0.23		149	172		202	240	260	205	39	45.6	
55 GREECE ST THEODORI	8709		16.0	0.5	0.18		157	176		203	238	261	206	43	45.0	
54 GREECE ST THEODORI	8709		16.5	0.2	0.16		154	173		199	234	256	202	43	46.0	
62 GREECE ST THEODORI	8710		15.0	0.2	0.18		155	172		199	234	253	202	41	46.6	
24 GREECE ST THEODORI	8711	0.003	15.2	0.4	0.13	0.0008	146	170	178	193	230	250	198	43	47.2	-
37 GREECE ST THEODORI	8711	0.004	13.3	0.4	0.15	0.0008	148	171	178	193	227	250	197	41	47.2	-
23 GREECE ST THEODORI	8712	0.002	14.8	0.2	0.13	0.0009	149	172	178	195	233	249	200	42	46.4	-
27 GREECE ST THEODORI	8801	0.005	12.2	0.2	0.04	0.0008	147	170	178	193	226	253	196	43	46.3	-
36 GREECE ST THEODORI	8801	0.005	16.5	0.6	0.11	0.0008	152	171	179	198	232	250	200	45	45.2	-
26 GREECE ST THEODORI	8802	0.004	16.0	0.3	0.05	0.0009	150	171	179	194	228	253	198	43	46.4	-
25 GREECE ST THEODORI	8803	0.008	13.8	0.1	0.07	0.0008	154	172	179	190	213	245	192	47	47.4	-
32 ITALY, SILICY	8709	0.005	13.1	0.2	0.06	0.0010	147	172	178	192	226	252	197	42	48.3	-
33 ITALY, SILICY	8709	0.005	13.8	0.3	0.10	0.0008	152	176	181	196	227	252	200	42	47.9	-
22 ITALY, SILICY	8711	0.005	14.1	0.2	0.11	0.0008	152	169	176	192	225	244	195	47	46.5	-
64 ITALY, SILICY	8712		15.7	1.2	0.10		153	171		194	226	251	197	41	46.6	
21 ITALY, SILICY	8801	0.005	13.3	0.2	0.07	0.0010	144	164	170	185	219	240	189	41	49.2	-
28 ITALY, SILICY	8801	0.005	12.7	0.2	0.08	0.0007	143	164	170	185	222	244	190	42	49.3	-
3 NETH. ANTIL. ARUBA	8408	0.009	19.0		0.26	0.0019	152	172		214	258	280	215	43	40.3	-
73 NETH. ANTIL. ARUBA	8409	0.005	17.0		0.07	0.0003	150	173	183	213	255	276	214	44	40.8	-
2 NETHERLANDS R'DAM	8501	0.013	16.0		0.01	NEG		170		200	250	258	207	48	45.0	-
45 NETHERLANDS R'DAM	8706		16.5	1.0	0.01		166	180		202	237	260	206	51	46.5	
47 NETHERLANDS R'DAM	8707		16.0	1.0	0.01		165	179		204	240	264	208	48	45.8	
51 NETHERLANDS R'DAM	8707		15.9	1.0	0.01		166	181		212	241	266	211	51	45.3	
50 NETHERLANDS R'DAM	8707		15.1	1.0	0.01		164	180		206	242	264	209	49	45.5	
46 NETHERLANDS R'DAM	8707		17.0	1.0	0.01		163	181		207	243	267	210	49	43.9	
53 NETHERLANDS R'DAM	8708		16.5	1.0	0.01		167	182		204	237	261	208	51	45.5	
59 NETHERLANDS R'DAM	8710		16.5	1.0	0.01		163	180		202	237	258	206	51	45.8	
60 NETHERLANDS R'DAM	8710		16.0	1.0	0.01		158	176		199	236	260	204	48	46.2	
58 NETHERLANDS R'DAM	8710		16.0	1.0	0.01		161	179		202	235	263	205	51	46.2	
66 NETHERLANDS R'DAM	8712		18.9	1.7	0.01		163	178		203	242	263	208	51	45.1	
44 SINGAPORE	8706		19.0	1.0	0.08		149	166		202	253	281	207	42	44.8	
67 SPAIN DELLA PLANA	8712		14.7	1.7	0.15		154	173		206	246	261	208	46	42.7	
42 SPAIN HUELVA	8705		15.5	0.6	0.08		159	176		209	250	276	212	48	42.6	
49 SPAIN HUELVA	8707		16.0	2.0	0.13		172	188		210	239	262	212	54	45.1	
56 SPAIN HUELVA	8709		19.8	0.5	0.03		163	183		213	249	276	215	51	40.9	
71 SPAIN MADRID	8612	0.008	18.1	0.6		0.0009	145	173		215	262	279	217	42	41.5	-
4 SPAIN, CASTELLON	8411	0.002	18.4	1.9	0.21	0.0010	146	169		199	244	268	204	41	43.8	-
5 SPAIN, CASTELLON	8504		18.1				145	165		194	240	268	200	42	45.5	-
40 US SHELL NORCO LA	8702	0.005	12.0	1.2	0.01	NEG	157	182	189	211	247	259	213	51	41.3	-
39 US SHELL NORCO LA	8702	0.004	18.0	0.0	0.01	NEG	162	185	191	212	246	261	214	52	41.2	-
43 US SHELL NORCO LA	8705		18.0	1.5	0.03		161	179		209	246	266	211	48	41.5	-
34 US SHELL NORCO LA	8706	0.002	17.0	1.0	0.02	0.0010	158	184	192	212	246	259	214	49	41.9	-
35 US SHELL NORCO LA	8706	0.003	16.7	1.1	0.02	0.0010	157	182	189	208	243	258	211	48	41.9	-
12 VENEZUELA CORPOVEN	8512	0.015	12.4	3.3	0.11	NEG	146	166	172	191	227	252	195	40	46.7	-
38 VENEZUELA, LAGOVEN	8510	0.035	18.8		0.05	0.0003	166	177	179	188	217	254	194	46	46.1	
10 VENEZUELA, LAGOVEN	8511	0.022	18.8		0.04	0.0002	172	166	171	189	234	269	196	49	44.1	
11 VENEZUELA, LAGOVEN	8512	0.032	20.0		0.03	0.0003	157	167	171	182	221	262	190	46	45.2	
74 VENEZUELA, LAGOVEN	8512	0.004	18.8	2.9	0.03	0.0001	174	197	206	225	252	277	225	57	41.5	
9 VENEZUELA, LAGOVEN	8601	0.003	18.3	2.6	0.02	0.0001	177	199	206	224	249	277	224	57	41.5	
7 VENEZUELA, LAGOVEN	8601	0.038	18.6		0.06	0.0003	164	170	172	182	213	252	188	47	45.7	
75 VENEZUELA, LAGOVEN	8611	0.004	18.1	3.5	0.08	0.0003	169	182	188	206	243	262	210	52	42.0	
18 VENEZUELA, LAGOVEN	8708	0.006	18.8	3.0	0.10	0.0006	171	186	193	213	251	271	217	54	41.7	
31 VENEZUELA, LAGOVEN	8710	0.006	19.4	2.4	0.10	0.0005	168	182	188	204	242	263	209	54	41.9	
20 VENEZUELA, LAGOVEN	8711	0.010	18.3	2.9	0.08	0.0004	171	188	195	215	248	267	217	58	40.4	
29 VENEZUELA, LAGOVEN	8803	0.012	18.8	2.5	0.12	0.0005	163	179	188	204	242	263	208	51	41.9	
1 VENEZUELA, MARAVAN	8501	0.007	16.8		0.10	0.0004	148	162	168	184	225	249	190	41	46.8	
16 VENEZUELA, MARAVAN	8504	0.009	16.8		0.11	0.0004	146	163	173	199	242	264	201	41	44.5	
17 VENEZUELA, MARAVAN	8708	0.004	17.5	0.8	0.09	0.0005	147	167	174	198	244	272	203	43	45.2	
30 VENEZUELA, MARAVAN	8709	0.005	17.5	0.8	0.08	0.0006	141	165	173	198	248	273	204	40	45.5	
76 VENEZUELA, MARAVEN	8407	0.005	17.0		0.07	0.0006	146	166	175	197	245	267	203	43	44.1	
77 VENEZUELA, MARAVEN	8408	0.005	16.4		0.10	0.0005	148	165	174	198	243	266	202	41	45.3	
79 VENEZUELA, MARAVEN	8410	0.009	15.6		0.11	0.0003	146	165	174	195	242	268	201	42	45.8	
78 VENEZUELA, MARAVEN	8410	0.010	16.3		0.11	0.0003	150	169	176	188	240	266	199	41	46.1	
81 VENEZUELA, MARAVEN	8707	0.010	18.2	0.7	0.10	0.0003	145	164	172	196	240	266	200	41	45.3	
19 VENEZUELA, MARAVEN	8711	0.011	17.3	0.8	0.11	0.0008	140	167	176	202	246	272	205	42	45.0	
80 VENEZUELA, MARAVEN	8411	0.008	15.7		0.20	0.0003	149	167	175	197	245	269	203	41	46.4	

FLASH PT	GRAV API	FREEZ POINT	CST AT -20	SMOKE PT	H2 WT %	COMB (BTU/LB) REPORT	COMB (BTU/LB) D3338	EXIST GUM	WSIM	FSII %	ANTIOXIDANT CONC	ANTIOXIDANT TYPE	COR INHIBIT MG/L	COR INHIBIT TYPE	MDA MG/L	FILTER TIME	SOLIDS MG/L
41	46.2		3.9		13.90	18393	18622										
36	47.4		3.6		13.95	18486	18637										
41	46.9		3.5		13.89	18502	18621										
39	47.6		3.5		13.98	18489	18645										
44	46.2	-54	3.9	24	14.00	18628	18652	1.00	98	0.13	22.4		20.2			7	0.38
44	46.9	-53	3.9	25	14.04	18637	18660	1.00	97	0.15	22.4		20.2			6	0.10
49	43.6		4.8		13.79	18463	18593										
42	45.9		4.2		14.00	18507	18643										
42	46.0		4.1		14.05	18413	18655										
41	45.8	-48	3.2	27	13.70	18636	18644	3.00	84		17.2	AO-35	8.9	DCI-4A		11	0.70
43	45.6	-51	4.0	26	13.98	18606	18637	2.00	86		17.4	H 4733	8.6	N 5403		11	0.65
46	45.6	-49	3.7	26	13.98	18644	18633	2.00	90							8	0.85
47	44.8	-48	3.9	26	13.86	18603	18612	3.00	78							7	0.68
46	45.1	-49	3.8	26	13.93	18625	18617	2.50			17.2	H 4733	8.6	N 5403		8	0.83
39	45.6		3.8		13.78	18430	18607										
43	45.0		3.8		13.88	18403	18617										
43	46.0		3.8		13.92	18454	18627										
41	46.6		3.9		13.94	18444	18650										
43	47.2	-53	3.8	26	13.86	18646	18653	2.00	94		17.2	H 4733	8.9	HIT 580	5.7	5	0.35
41	47.2	-53	3.5	26	14.09	18642	18666	2.50	85		17.0	H 4733	8.6	HIT 580	7.2	5	0.60
42	46.4	-50	3.2	26	13.93	18625	18644	2.00	92		17.2	H 4733	8.9	HIT 580	5.7	8	0.41
43	46.3	-53	3.6	26	14.13	18660	18653	2.00	82		17.2	H 4733	8.6	HIT 580	5.7	6	0.26
45	45.2	-50	3.2	26	13.84	18611	18606	3.00	92		17.2	H 4733	8.9	HIT 580	5.7	6	0.42
43	46.4	-52	3.6	26	13.94	18631	18630	2.00	78		17.2	H 4733	8.9	HIT 580	5.7	8	0.45
47	47.4	-58	2.7	27	14.05	18650	18655	2.00	78		17.2	H 4733	8.9	HIT 580	5.7	6	0.45
42	48.3	-52	3.0	29	14.18		18690	2.00	94	0.11	18.0	BHT	10.5	N 5403	5.8	9	0.55
42	47.9	-50	3.3	28	14.03		18683	3.00	86	0.13	20.0		15.0		5	9	0.43
47	46.5	-56	3.3	29	14.00		18641	1.00	80	0.12	18.0	A	13.0	N 5403	5.7	8	0.26
41	46.6		4.6		13.93	18516	18635										
41	49.2	-53	3.3	28	14.20		18692	0.00	75	0.12	20.0	A	12.0	N 5403	5.8	7	1.10
42	49.3	-49	3.3	28	14.13		18702	0.00	78	0.12	20.0	A	12.0	N 5403	5.8	9	0.98
43	40.3	-52	5.5	20	13.88	18463	18513	2.00	96		6.1	E 733				7	0.70
44	40.8	-52	5.2	21	13.90	18505	18530	1.80	97		17.5	E 733				3	0.30
48	45.0	-48	4.0	22	13.82	18602	18605	1.00	86		20.0	J65				10	0.20
51	46.5		3.7		13.85	18534	18647										
48	45.8		4.3		13.53	18559	18638										
51	45.3		4.6		13.59	18562	18636										
49	45.5		4.4		13.94	18519	18641										
49	43.9		4.4		13.79	18516	18596										
51	45.5		4.1		13.99	18537	18628										
51	45.8		4.0		13.91	18534	18632										
48	46.2		4.3		13.96	18488	18638										
51	46.2		4.3		13.93	18536	18642										
51	45.1		3.4		13.82	18537	18603										
42	44.8		4.0		13.83	18417	18595										
46	42.7		4.6		14.01	18454	18580										
48	42.6		5.0		13.75	18480	18579										
54	45.1		6.5		13.60	18483	18633										
51	40.9		6.0		13.83	18443	18522										
42	41.5	-51	5.5	22	13.92	18530	18520	1.20	90		20.0	E 733	15.7	N 5403	5.8	13	0.60
41	43.8	-49	4.0	20	13.91		18571	1.20	98								
42	45.5	-49	4.2	22	13.59		18600	0.60	97							7	0.32
51	41.3	-59		21	13.77	18491	18576	2.00	96							7	0.30
52	41.2	-48		22	13.85	18549	18538	0.70	85							8	0.30
48	41.5		4.2		13.58	18405	18539										
49	41.9	-48	5.6	22	13.63	18550	18559	1.00	98		20.0		14.3		2.9	15	0.20
48	41.9	-49	5.3	21	13.80	18552	18555	1.00	92		20.0		14.3		2.9	10	0.20
40	46.7	-58	3.5	27	14.07	18623	18657	3.20	90						5.7	7	0.12
46	46.1	-53	3.1	22	13.42	18583	18595	1.00	90		19.4	AO-30			5.6	6	0.20
49	44.1	-56	4.0	22	13.45	18570	18558	1.00	98		18.8				5.7	6	0.27
46	45.2	-30	3.4	22	13.40	18600	18558	1.00	89		18.8				5.5	5	0.25
57	41.5	-48	5.9	21	13.83	18557	18525	0.80	99		18.8	AO-30			5.3	.7	0.15
57	41.5	-49	6.1	21	13.69	18565	18562	1.10	96		18.8	TOPANOL			5.2	11	0.35
47	45.7	-56	3.4		13.99	18570	18575	1.00	97		19.4				5.7	5	0.31
52	42.0	-54	5.3	21	13.58	18542	18539	1.00	48		20.0	AO-30	11.8	HIT 480	5.8	7	0.45
54	41.7	-48	5.7	21	13.95	18529	18549	1.20	90		20.0	AO-30	12.0	HIT 580		6	0.29
54	41.9	-54	4.5	21	13.72	18529	18534	1.10	90		20.0	AO-30	10.9	HIT 580		6	0.13
58	40.4	-54	6.3		13.61	18529	18524	1.10	92		20.0	AO-30	12.6	HIT 580		7	0.40
51	41.9	-55	3.6		13.82	18516	18536	1.10	91		20.0	AO-30	13.7	HIT 580		7	0.27
41	46.8	-55	3.2		13.48	18604	18617	0.50			6.9	TOPANOL				10	0.29
41	44.5	-51	4.0		13.79	18581	18591	0.40	98		20.5	TOPANOL				9	0.16
43	45.2	-48	4.0	22	13.56	18590	18605	0.60	97		18.6	AO-30	11.7	N 5403		8	0.26
40	45.5	-49	4.0	21	13.58	18603	18613	0.50	94	0.16	22.6	AO-30	14.4	N 5403		8	0.26
43	44.1	-49	4.1		13.81	18570	18600	0.40	74		18.1	TOPANOL				14	0.40
41	45.3	-53	3.9		13.90	18609	18625	0.40	98		21.6	TOPANOL				15	0.40
42	45.8	-52	4.0		13.96	18626	18651	0.40	95		19.4	TOPANOL				7	0.21
41	46.1	-54	3.9		13.97		18649	0.40	95		19.7	TOPANOL				11	0.24
41	45.3	-50	3.9	22	13.95	18587	18620	0.40	89		17.9	AO-30	10.8	HIT 580	4	13	0.90
42	45.0	-47	3.1	22	13.83	18592	18606	0.50	85		22.3	AO-30	14.5	HIT 580		10	0.23
41	46.4	-51	4.6	23	13.92	18629	18657	0.50	96		20.2	TOPANOL				12	0.60

IST GUM	WSIM	FSII %	ANTIOXIDANT CONC	ANTIOXIDANT TYPE	COR INHIBIT MG/L	COR INHIBIT TYPE	MDA MG/L	FILTER TIME	SOLIDS MG/L	JFTOT MM HG	JFTOT CODE
0	98	0.13	22.4		20.2			7	0.38	0	1
0	97	0.15	22.4		20.2			6	0.10	0	0
	84		17.2	AO-35	8.9	DCI-4A		11	0.70	0	0.5
	86		17.4	N 4733	8.6	N 5403		11	0.65	0	0.5
	90							8	0.85	0	0.5
	78							7	0.68	0	0.5
			17.2	N 4733	8.6	N 5403		8	0.83	0	0.5
	94		17.2	N 4733	8.9	HIT 580	5.7	5	0.35	0	0.5
	85		17.0	N 4733	8.6	HIT 580	7.2	5	0.60	0	0.5
	92		17.2	N 4733	8.9	HIT 580	5.7	8	0.41	0	0.5
	82		17.2	N 4733	8.6	HIT 580	5.7	6	0.26	0	0.5
	92		17.2	N 4733	8.9	HIT 580	5.7	6	0.42	0	0.5
	78		17.2	N 4733	8.9	HIT 580	5.7	8	0.45	0	0.5
	78		17.2	N 4733	8.9	HIT 580	5.7	6	0.45	0	0.5
	94	0.11	18.0	BHT	10.5	N 5403	5.8	9	0.55	2	1
	86	0.13	20.0		15.0		5	9	0.43	2	1
	80	0.12	18.0	A	13.0	N 5403	5.7	8	0.26	2	1.0
	75	0.12	20.0	A	12.0	N 5403	5.8	7	1.10	2	1.0
	78	0.12	20.0	A	12.0	N 5403	5.8	9	0.98	2	1.0
	96		6.1	E 733				7	0.70	3	1.0
	97		17.5	E 733				3	0.30	2	1
	86		20.0	J65				10	0.70	0	1.5
	90		20.0	E 733	15.7	N 5403	5.8	13	0.60	1	0.5
	98									13	0
	97							7	0.32	1	0.0
	96							7	0.30	1	1
	85							8	0.30	1	1
	98		20.0		14.3		2.9	15	0.20	1	1
	92		20.0		14.3		2.9	10	0.20	1	1.0
	90						5.7	7	0.12	8	1.0
	90		19.4	AO-30			5.6	6	0.20	0	1.0
	98		18.8				5.7	6	0.27	0	0.0
	9		18.8				5.5	5	0.25	0	0.0
	9		18.8	AO-30			5.3	7	0.15	0	1
	6		18.8	TOPANOL			5.2	11	0.35	0	0.0
	7		19.4				5.7	5	0.31	0	1.0
	8		20.0	AO-30	11.8	HIT 450	5.8	7	0.45	0	1
	0		20.0	AO-30	12.0	HIT 580		6	0.29	0	1.0
	3		20.0	AO-30	10.9	HIT 580		6	0.13	0	1
	2		20.0	AO-30	12.6	HIT 580		7	0.40	0	1.0
	1		20.0	AO-30	13.7	HIT 580		7	0.27	0	1.0
			6.9	TOPANOL				10	0.29	0	1.0
	9		20.5	TOPANOL				9	0.16	0	1.0
	7		18.6	AO-30	11.7	N 5403		8	0.26	0	1.0
		0.16	22.6	AO-30	14.4	N 5403		8	0.26	0	1
			18.1	TOPANOL				14	0.40	0	1
			21.6	TOPANOL				15	0.40	0	1
			19.4	TOPANOL				7	0.21	0	1
			19.7	TOPANOL				11	0.24	0	1
			17.9	AO-30	10.8	HIT 580	4	13	0.90	0	1
			22.3	AO-30	14.5	HIT 580		10	0.23	0	1.0
			20.2	TOPANOL				12	0.60	0	1

TABLE 2. JP-8 DATA STATISTICS

	ACID NO.	AROM. VOL %	OLEF. VOL %	TOTAL SULFUR	MERCAP. SULFUR	D86 DISTILLATIONN IBP	%10	%20	%50	%90	EP	FLASH PT (C)	GRAV API	FREEZE PT (C)	VISC CST*
AVERAGE	0.008	16.4	1	0.084	0.0006	155	174	180	200	237	260	45.5	45	-52	4.2
STD DEV	0.0077	1.9	0.86	0.06	0.00036	8.8	7.4	8.5	8.8	10.4	10.2	4.8	2.1	3.2	0.84
MAX VALUE	0.038	20	3.5	0.26	0.0019	177	199	206	225	262	281	58	49.3	-47	6.5
MIN VALUE	0.002	12	0	0.01	0	140	162	168	182	213	235	36	40.3	-60	2.7
NO. POINTS	51	80	65	78	51	79	80	47	80	80	80	80	80	52	78

*AT -20C

	SMOKE PT	H2 WT %	COMB (BTU/LB) RPT.	D3338	EXIST GUM	WSIM	FSII %	A-OCOR MG/L	INH MG/L	MDA MG/L	FILT TIME	SOLIDS MG/L	JFTOT MM HG	CODE
AVERAGE	23.8	13.85	18546	18610	1.3	89	0.13	18.5	11.8	5.5	8	0.42	1	0.7
STD DEV	2.7	0.18	70	45	0.84	9	0.02	2.6	3.4	0.9	2	0.24	2.4	0.4
MAX VALUE	29	14.20	18660	18702	3.2	99	0.16	22.4	20.2	7.2	15	1.10	13	1.5
MIN VALUE	20	13.40	18393	18513	0	48	0.11	6.1	8.6	2.9	3	0.1	0	0
NO. POINTS	43	80	72	80	52	50	8	33	24	23	39	51	40	40

TABLE 3 - COMPARISON OF JP-8 AND JET A

FUEL PROPERTY	SPEC. REQUIREMENTS		DELIVERED JP-8 FUELS			JET A*
	MINIMUM	MAXIMUM	AVERAGE	MINIMUM	MAXIMUM	AVERAGE
TOTAL ACID NO., MG KOH/GM		0.015	0.008	0.002	0.038	0.008
AROMATICS, VOLUME PERCENT		25	16.4	12	20	17.8
OLEFINS, VOLUME PERCENT		5	1	0	3.5	1.2
SULFUR, TOTAL, WT PERCENT		0.3	0.08	0.01	0.26	0.05
MERCAPTAN SULFUR, WT PERCENT		0.002	0.0006	0.0000	0.0019	0.001
DISTILLATION TEMP., C (D86)						
INITIAL BOILING POINT		REPORT	155	140	177	
10 PERCENT RECOVERED		205	174	162	199	189
20 PERCENT RECOVERED		REPORT	180	168	206	
50 PERCENT RECOVERED		REPORT	200	182	225	213
90 PERCENT RECOVERED		REPORT	237	213	262	245
END POINT		300	260	235	281	
FLASH POINT, DEG C	38		46	36	58	54
GRAVITY, API	37	51	45	40.3	49.3	42.4
FREEZING POINT, DEG C		-47	-52	-60	-47	-45
VISCOSITY, CST AT -20C		8	4.2	2.7	6.5	5.1
SMOKE POINT, MM	19		24	20	29	23
HYDROGEN, MASS PERCENT	13.4		13.85	13.40	14.20	
HEAT OF COMB, BTU/LB	18,400		18,610	18,513	18,702	18,572
THERMAL STABILITY						
PRES. DROP, IN HG		25	1	0	13	2.3
HEATER TUBE RATING		L.T. 3	0.7	0	1.5	L.T. 1
EXISTENT GUM, MG/100 ML		7	1.3	0	3.2	1.1
PARTICULATE MATTER, MG/L		1	0.4	0.1	1.1	
FILTRATION TIME, MINUTES		15	8	3	15	
WATER SEPARATION INDEX	85		89	48	99	95

NOTES:

SMOKE POINT MINIMUM IS 25 UNLESS LESS THAN 3% NAPHTHALENES PRESENT

WATER SEPARATION INDEX MINIMUM IS 70 WITH ALL ADDITIVES PRESENT EXCEPT STATIC DISSIPATOR ADDITIVE, 85 MINIMUM WITH ALL ADDITIVES EXCEPT STATIC DISSIPATOR AND CORROSION INHIBITOR PRESENT.

* "AVIATION FUELS, 1983", NIPER-134-PPS, APRIL 1984

SECTION III - DISCUSSION

1. FUEL PROPERTIES

Table 3 compares the specification limits for JP-8 with the average, maximum and minimum values of Table 2. For comparison, Table 3 also includes the average properties of Jet A fuels[1]. Each of these properties or measurements are discussed below:

a. Acid Number - The acid number controls the amount of acidic components in the fuel, carried over from the crude oil, formed or added in refinery processes, or added after processing. The specification level is 0.015 mg KOH/gm fuel. Four JP-8 fuels exceeded the specification limit. All four of these fuels were supplied by the Lagoven refinery in Venezuela.

b. Aromatics Content - Aromatics are unsaturated, cyclic hydrocarbons that are excellent solvents, have a strong odor (hence the name aromatics), and have poor combustion performance. As the solvency of aromatics causes some elastomers to swell excessively, specifications typically limit aromatics content to 20 to 25 percent by volume. The poor combustion performance of aromatics is another reason for limiting aromatics content of jet fuels. None of the JP-8 fuels exceeded or even closely approached the specification limit of 25 percent aromatics. The average aromatics content of JP-8 was slightly less than that for Jet A (16.4 vs. 17.8 percent.)

c. Olefins Content - Olefins are chain and branched chain paraffins that have double carbon bonds. As the double carbon bonds cause olefins to be less stable, olefins are limited to 5 percent by volume. Average olefins content of JP-8 and Jet A was 1.0 and 1.2 percent, respectively. However, the accuracy of the test method used to measure olefins content is poor, so the differences in the average values is meaningless. As the most likely source of olefins is cracked stocks, the specification limit on olefins effectively limits the use of thermally and catalytically cracked stocks.

d. Sulfur Content - Sulfur is limited in jet fuels because of its corrosivity and the noxious nature of its combustion products. The specification limit for JP-8 and Jet A is 0.3 percent by mass. Both JP-8 and Jet A had average sulfur contents well below specification limits, but JP-8 averaged 0.08 wt percent vs. 0.05 wt percent for Jet A. Referring to Table 1, the fuels obtained

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[1] Shelton, E. M. and Dickson, C. L., "Aviation Fuels, 198J," NIPER-1 April 1984.

from Greece, Italy, Spain, and Aruba were notably higher in sulfur content than fuels obtained from Venezuela and in the US. These differences reflect either different crude oils or refining techniques.

e. Mercaptan Sulfur Content - Mercaptan sulfur is one of the most noxious forms of sulfur, both in odor and in corrosiveness. None of the JP-8 fuels exceeded the specification limit of 0.002 wt percent, and the average mercaptan sulfur content of JP-8 was only slightly less than that for Jet A, which has a specification limit of 0.003 wt percent.

f. Distillation Range - The distillation range for JP-8 and Jet A are identical (see Table 3). None of the JP-8 fuels approached either the maximum allowable 10 percent recovered temperature or the end point temperature. The Jet A fuels had slightly higher distillation temperatures than JP-8, reflecting the higher allowable freeze point of Jet A.

g. Flash Point - All but one JP-8 met or exceeded the minimum allowable flash point. The average flash point for Jet A was significantly higher than for JP-8. This correlates with the higher average distillation temperatures of Jet A.

h. Gravity - All JP-8 fuels met the gravity limits. As API gravity is inversely related to specific gravity, the higher average API gravity for JP-8, as compared to Jet A, means that JP-8 is less dense than Jet A. The higher density of Jet A correlates with the higher distillation range and aromatics content of Jet A.

i. Freezing Point - Aside from additives, the major difference between JP-8/Jet A-1 and Jet A is the freezing point requirement. All JP-8 fuels had freezing points of -47 ^{o}C or below. With a maximum allowable freezing point of -40 ^{o} C, the average Jet A freezing point was -45 ^{o}C.

j. Viscosity - Engine starting and altitude relight performance requires excellent fuel atomization, and atomization is a function of viscosity. Although the viscosity limit for JP-8, Jet A-1 and Jet A is the same, viscosity tends to correlate with freezing point, density, and distillation range. As seen in Table 3, the average viscosity of JP-8 is less than for Jet A.

k. Smoke Point - The smoke point is the maximum flame height (in millimeters) that can be obtained without smoking, using a standard wick lamp. Smoke point correlates with fuel combustion performance in gas turbine engines. A high smoke point insures that the fuel will burn with a minimum of exhaust smoke and minimum heat transferred to the combustor liner via radiation. All JP-8 fuels exceeded the specification limit of 19 mm. The slightly higher average smoke point of JP-8, as compared to Jet A, is due to the higher aromatics content of the Jet A fuels.

l. Hydrogen Content - The hydrogen content of jet fuels also correlates with fuel combustion performance. For the JP-8 fuels listed in Table 1, the mass percent hydrogen was calculated using ASTM D 3343. All JP-8 fuels met or exceeded the minimum allowable hydrogen content of 13.4 percent of specification MIL-T-83133B.

m. Heat of Combustion - The calorific value of a fuel can be measured directly in a calorimeter or estimated using correlations based on other fuel measurements. All but one JP-8 met or exceeded the minimum specification limit of 18,400 Btu/lb. However, a significant bias was noticed in the data supplied by BFLRF (fuels number 40-67). Therefore, the heats of combustion of all fuels were calculated using ASTM D 3338. The average heats of combustion are:

	Average Heat of Combustion (Btu/lb)	
	Reported	Calculated
Fuels # 1 - 80	18,541	18,610
Fuels 42 - 69 (BFLRF)	18,500	18,614

It is obvious that the BFLRF reported heats of combustion are significantly lower than those reported by the fuel suppliers and as calculated using ASTM D 3338. Using the D 3338 values, all of the JP-8 fuels easily exceeded the specification limit of 18,400 Btu/lb. The reason for the apparent bias of the BFLRF data is unknown. Because of this apparent bias, the ASTM D 3338 data are shown in Table 3, where the JP-8 fuels have a slightly higher heat of combustion than Jet A fuels.

n. Thermal Oxidative Stability - Jet fuel is becoming the primary coolant for airframe and engine components and engine lubricant. As aircraft become more complex and engine fuel flow rates decrease with increasing engine efficiencies, fuel temperatures increase. Fuel must withstand these higher temperatures without forming deposits within the fuel system. A Jet Fuel Thermal Oxidative Tester (JFTOT) test apparatus is used to insure that each batch of fuel has acceptable stability. The JFTOT monitors the formation of deposits on a heated, polished aluminum tube and plugging of a filter downstream of the heated tube. The tube deposit must be less than a Code 3 (a dark tan) and the pressure drop across the filter must not exceed 25 mm of mercury. All JP-8 fuels easily passed the JFTOT. (Note that the Tube Deposit Codes are normally listed as zero, less than one,

one, less than two, two, less than three, etc. For statistical purposes, a less than a Code one was assumed to be 0.5, etc.)

o. Existent Gum - Jet fuels are good solvents and may contain quantities of dissolved gums and resins, which can form deposits within the fuel system and combustor. To analyze for existent gum, a sample of the fuel is evaporated and the residue remaining is weighted. All JP-8 fuels passed the existent gum test, and JP-8 and Jet A fuels had similar quantities of gum.

p. Particulate Matter - This test measures the quantity of solid particulates (contaminants) by filtering a gallon of fuel through a 0.8-micron pore size filter membrane, which is weighted before and after the filtration. Only one of the JP-8 fuels exceeded the specification particulate matter limit. The commercial specification for Jet A and A-1 (ASTM D 1655) does not include a particulate matter test.

q. Filtration Time - DoD jet fuel specifications limit the time required to filter one gallon of jet fuel through a 0.8-micron filter. (This test is run in conjunction with the Particulate Matter test, above.) The purpose of this test is to insure that the fuel does not contain contaminants that will rapidly plug the filters and filter-water separators in the bulk fuel storage and servicing systems at Air Force bases. Compliance with the Filtration Time test has greatly reduced filter replacement requirements at AF bases. The contaminants that can plug filters include solid particulates (sand, rust, fibers, etc.), precipitates from refinery treating solutions left in fuels, and reaction products of fuel corrosion inhibitors (fatty acids that have reacted with water and metals to form gelatinous soap-like materials). The effects of corrosion inhibitors (CI) on filtration time are given below:

JP-8	Ave. Filt. Time (Minutes)	Std Dev. (Min)	Max Filt. Time (Min)
Without CI	7.6	1.8	11
With CI	7.9	2.2	15

However, the effects of corrosion inhibitors on filtration time is most pronounced if the fuel has been contacted with water, such as during barge or ship transport.

r. Water Separation Index - The most common and potentially serious contaminant in jet fuel is water. Filter-water coalescer/separator devices are used in the base fuel servicing systems to remove particulates and undissolved water. The water is removed by coalescence; i.e., small water droplets coalesce to form large droplets that are then separated by gravity and hydrophobic filter media. However, coalescence of water can be degraded or prevented by trace quantities of surface active (surfactants) materials in the fuel. The Water Separation Index (Modified) apparatus consists of a miniature coalescer device through which a sample of the fuel, emulsified with water, is passed. The ability of the coalescer to remove the water is then determined. A Water Separation Index Modified (WSIM) rating of 100 is excellent; a rating of less than 70 is cause for concern. As fuel additives affect the WSIM, different limits are placed on the fuel, depending on which additives are present. With corrosion inhibitor (CI) but not the static dissipator additive present, a minimum WSIM of 70 is allowed. As seen below, the presence of the corrosion inhibitor does significantly lower the WSIM.

JP-8	Avg. WSIM	Std. Dev.	Min. Value
Without CI	94	4.8	86
With CI	88	6.8	75

The average WSIM value of 95 for the Jet A fuels (which normally do not contain corrosion inhibitor additives) is essentially the same as for the JP-8 fuels that do not contain a corrosion inhibitor additive.

s. Fuel Additives - JP-8 requires, as mandatory additives, fuel system icing inhibitor, corrosion inhibitor/lubricity improver, and static dissipator additives. Antioxidants are optional unless the fuel has been hydrogen treated, in which case the antioxidant is also mandatory. The metal deactivator additive is optional.

Tables 1 and 2 show that 8 of the 80 fuels contained fuel system icing inhibitor, 33 contained antioxidant, 24 contained corrosion inhibitor, and 23 contained metal deactivator. These numbers reflect three facts: (1) metal deactivator additives are optional, (2) antioxidants are optional unless the fuel has been hydrogen treated, and (3) fuel system icing inhibitor and corrosion inhibitor additives, while mandatory, may not be added until the fuel has been transported to terminals near the using bases. For example, in the United Kingdom (and proposed for part of NATO), JP-8 will be procured without fuel system icing inhibitor and corrosion inhibitor additives. These additives will be added at terminals that support military bases. Thus, the fuel procured will be Jet A-1 (NATO F-35) and will be converted to JP-8 (NATO F-34) prior to delivery to air bases. (This survey did not include the static dissipator additives.)

2. INTERPRETATION OF RESULTS

a. Low Temperature Performance. Of primary concern to the Air Force is the performance of its aircraft with JP-8, as existing aircraft were designed to use the lower viscosity and more volatile JP-4. Most aviation turbine engines are supposed to start and operate satisfactorily with fuels that have a viscosity of 12 centistokes or less. Table 4, below, lists the viscosity of the average JP-8, the maximum viscosity JP-8, the average JP-8 plus one, two, and three standard deviations, and the average and maximum viscosity Jet A fuels from 1983. Also listed are the fuel temperatures at which the fuel viscosity is 12 centistokes.

TABLE 4. VISCOSITIES OF JP-8 AND JET A FUELS

JP-8 Fuel	Visc at -20C	Temp at 12 cSt
Average	4.2	-47°C
Maximum	6.5	-35°C
Ave + 1 Std Dev	5.0	-40°C
Ave + 2 Std Dev	5.9	-37°C
Ave + 3 Std Dev	6.7	-34°C
Specification Limit	8.0	-29°C
JET A	**Viscosity**	**Temp. at 12 cSt**
Average	8.86 @ -34.4°C	-43°C
Maximum	14.9 @ -34.4°C	-29°C

A review of Table 4 indicates that engine starting (i.e., 12 centistokes) should not be a problem with the average JP-8 down to -47°C, its maximum allowable freezing point. About one third of the JP-8 fuels (i.e., the average JP-8 plus one standard deviation) may not start at temperatures below -40°C, 5 percent (average plus two standard deviations) may not start below -37°C, and 1 percent (average plus three standard deviations) may not start below -34°C. Jet A fuels are slightly more viscous than JP-8 fuels and may give starting problems at -29°C and below.

For long duration, high-altitude flights in cold climates, the freezing point of fuel must be sufficiently low so as to prevent fuel from freezing and preventing fuel flow to the engine. The freezing point of JP-8 fuel has been selected to insure that USAF flight operations will not be compromised by the freezing point of the fuel. Commercial airlines typically use Jet A for transcontinental flights across the US, but use Jet A-1 fuel (with its lower freezing point) for transoceanic flights.

Most USAF flight operations within the CONUS could safely use Jet A. However, some CONUS originated USAF flights stay aloft for many more hours than required for commercial transcontinental operations or may terminate overseas or in Alaska, using flight routes that include very cold air mass temperatures. Thus, the use of a Jet A based fuel for all USAF aircraft in the CONUS would not be possible, if potential fuel freezing problems are to be avoided. The logistics of stocking and servicing two grades of JP-8 fuel, differing only in freezing point, would not be acceptable at many bases. Thus, the choice of a kerosene-based military jet fuel for CONUS bases is not a simple, straightforward problem.

b. Fuel Energy Content - Aircraft may be either weight limited or volume limited; i.e., the fuel load and cargo or bomb load may be constrained by the maximum allowable gross weight at take-off or by the available space for cargo or weapons. Weight limited aircraft have increased range when using a fuel with increased energy content per unit mass. Conversely, volume limited aircraft have increased range using a fuel with increased energy content per unit volume. Compared to JP-4, JP-8 has an increased volumetric energy content with a slight mass energy content penalty.

TABLE 5. ENERGY CONTENT OF FUELS

Fuel	Btu/Lb	Btu/Gallon
Ave. JP-4[1]	18,702	118,645
Ave. JP-8	18,610	124,221

Table 5 shows that JP-8 has about 0.5 percent less energy content per unit mass and about 4.7 percent more energy content per unit volume. Thus, there will be an insignificant range penalty for weight-limited aircraft and a slight increase in range for volume limited aircraft.

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[1]Harrison, W. E. III, "The Chemical and Physical Properties of JP-4 1980-1981," AFWAL-TR-82-2052, June 1982.

SECTION IV - CONCLUSIONS

1. The average properties of the JP-8 fuels supplied to the Air Force for European operations have been determined. JP-8 fuels are slightly less dense, have slightly lower viscosities, lower freezing points, and are slightly more volatile than commercial Jet A fuels.

2. Most of the JP-8 fuels met all specification limits. One notable exception was that several of the fuels from Venezuela had high acid numbers.

3. About a 3- to 4-percent range increase can be expected for volume limited aircraft (such as fighters) when using JP-8, as compared to JP-4.

SECTION V - RECOMMENDATION

This survey of JP-8 fuel properties should be periodically updated, especially once the conversion to JP-8 within NATO has been completed and the conversion to JP-8 in the Pacific has been initiated.