DOT/FAA/AR-07/30

Air Traffic Organization
Operations Planning
Office of Aviation Research
and Development
Washington, DC 20591

Jet A Volatility Survey

Skip Byrnes

Federal Aviation Administration
William J. Hughes Technical Center
Airport and Aircraft Safety
Research and Development Division
Atlantic City International Airport, NJ 08405

July 2007

Final Report

U.S. Department of Transportation
Federal Aviation Administration

NOTICE

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
DOT/FAA/AR-07/30		

4. Title and Subtitle	5. Report Date
JET A VOLATILITY SURVEY	July 2007
	6. Performing Organization Code
7. Author(s) Skip Byrnes	8. Performing Organization Report No.
9. Performing Organization Name and Address Federal Aviation Administration William J. Hughes Technical Center Airport and Aircraft Safety R&D Division Propulsion and Fuel Systems Branch Atlantic City International Airport, NJ 08405	10. Work Unit No. (TRAIS)
	11. Contract or Grant No.
12. Sponsoring Agency Name and Address U.S. Department of Transportation Federal Aviation Administration Air Traffic Organization Operations Planning Office of Aviation Research and Development Washington, DC 20591	13. Type of Report and Period Covered Final Report
	14. Sponsoring Agency Code ANM-100

15. Supplementary Notes

16. Abstract

In response to the July 1996 TWA Flight 800 disaster, the Federal Aviation Administration (FAA) collected jet fuel samples from domestic and international flights to determine the actual flash point of jet fuel in service. This data was collected to help determine whether any change in the ASTM D1655 turbine fuel specification would help prevent any future such incident and to use in fuel tank flammability assessments. This report details the flash point results from 293 jet fuel samples collected from April 1998 through September 1999.

The results found no fuel samples to be out of specification. Samples were retrieved at the end of flights, before refueling, that ended in Philadelphia, PA; New York, NY (JFK); and Newark, NJ. These locations provided convenient locations for FAA technicians to be able to obtain samples from fuel from all over the US and abroad. The results helped determine that no change in the turbine fuel specification was required. The flashpoint distribution from the survey was also used in the harmonized FAA special conditions issued for the B-747 and B-737 fuel tank flammability reduction means and in the proposed Title 14 Code of Federal Regulations Part 25 Appendix L that was published in the Notice of Proposed Rulemaking titled, “Reduction of Fuel Tank Flammability in Transport Category Airplanes” (docket number FAA-2005-22997).

17. Key Words	18. Distribution Statement
Flash point, Jet fuel volatility, Jet fuel properties	This document is available to the U.S. public through the National Technical Information Service (NTIS), Springfield, Virginia 22161.

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	30	

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ACRONYMS

ARAC	Aviation Rulemaking Advisory Committee
ASTM	American Society for Testing and Materials
EWR	Newark International Airport
FAA	Federal Aviation Administration
FSDO	Flight Standards District Office
JFK	John F. Kennedy International Airport
NTSB	National Transportation Safety Board
PHL	Philadelphia International Airport
SFO	San Francisco International Airport

EXECUTIVE SUMMARY

In response to the July 1996 TWA Flight 800 disaster, the Federal Aviation Administration (FAA) collected jet fuel samples from domestic and international flights to determine the actual flash point of jet fuel in service. This data was collected to help determine whether any change in the American Society for Testing and Materials D 1655 turbine fuel specification would help prevent any future incident and to use in fuel tank flammability assessments. This report details the flash point results from 293 jet fuel samples collected from April 1998 through September 1999.

The results found no fuel samples to be out of specification. Samples were retrieved at the end of flights, before refueling, in Philadelphia, PA; New York, NY; and Newark, NJ. These locations provided convenient locations for FAA technicians to be able to obtain fuel samples from all over the United States and abroad. The results helped determine that no change in the turbine fuel specification was required. The flashpoint distribution from the survey was also used in the harmonized FAA special conditions issued for the B-747 and B-737 fuel tank flammability reduction means and in the proposed Title 14 Code of Federal Regulations Part 25 Appendix L that was published in the Notice of Proposed Rulemaking titled, "Reduction of Fuel Tank Flammability in Transport Category Airplanes" (docket number FAA-2005-22997).

1. INTRODUCTION.

1.1 BACKGROUND.

The tragic crash of TWA Flight 800 in July 1996 generated much investigation of its cause. One of the many questions considered was how the volatility of Jet A, the fuel used by commercial transport category aircraft, affected or contributed to the crash. An Aviation Rulemaking Advisory Committee (ARAC) was convened to evaluate methods that could eliminate or reduce the amount of time fuel tanks are flammable after the National Transportation Safety Board (NTSB) held the public hearings on the Flight 800 accident in December 1997. The ARAC was charged with, among many tasks, determining whether modifying the flash point specification, American Society for Testing and Materials D 56 (ASTM D 56), of Jet A could help prevent future disasters like flight 800. It became evident that actual Jet A flash point data obtained from service use was not readily available. In response to this need the Federal Aviation Administration (FAA) Transport Airplane Directorate (ANM-100) asked the FAA William J. Hughes Technical Center to collect Jet A fuel samples from a variety of sources and report on the volatility of Jet A by conducting flash point, distillation, and other tests on the samples obtained. This report contains the data generated from collecting and characterizing fuel samples and test data from various sources between April 20, 1998 and September 30, 1999.

1.2 TEST PLAN.

Discussions with ANM-100 focused on the desirability of obtaining and testing as many samples as possible from as wide a variety of sources as possible. It was decided to take advantage of the proximity of the FAA William J. Hughes Technical Center with the Philadelphia International Airport (PHL), John F. Kennedy International Airport (JFK), and Newark International Airport (EWR) by obtaining samples of fuel from incoming flights before the aircraft were refueled. This plan was designed to take advantage of the wide array of flights that arrive at these airports. Near the end of the sample collection period another airport were added to broaden the array of cities from which samples were obtained. The additional airport was San Francisco International Airport (SFO). Choosing this airport enabled Technical Center personnel to obtain samples from Asia that could not be obtained in the New York and Philadelphia airports because of the very limited number of nonstop flights into this area from the Pacific rim (with the exception of Japan). By choosing flights that arrived nonstop from the city of origin, fuel samples could reliably be considered as samples from the fuel distribution system at the origin of the flight. In addition, data were to be collected from fuel suppliers that were designed to satisfy two goals. The first was to try to track the seasonal variation, if any, in the flash point of Jet A, and the second was to see if it was possible to establish any connection between the fuel supplier flash point data and the in-service data generated from the incoming flights. Assistance from the Flight Standards District Office (FSDO) in Philadelphia, the FAA International Field Office at JFK, the FAA International Field Office at San Francisco International Airport (SFO), and the Port Authority of NY and NJ at EWR was requested by the Technical Center Propulsion and Fuel Systems Branch in arranging contacts with the airlines. This selection of airports enabled samples to be collected from nonstop flights that originated in 60 different cities across the globe. Arrangements were made to allow Technical Center personnel to have airport ramp access to facilitate the sampling process. With the help of these various offices, Technical

Center personnel secured the agreement of many airlines to participate in this fuel sampling project and sampling began on April 20, 1998. The only accomodation given to those who agreed to participate was that no entity would be identified as a source of the fuel samples. All data presented in this report are identified only as either from a flight that originated in a given city or from a fuel supplier. Samples were obtained from selected incoming flights and transported to a nearby commercial testing lab; the samples were then split into two parts, with one part transported back to the Technical Center fuels lab for analysis. In the case of samples obtained at PHL, JFK, and EWR, the samples were transported by pickup truck to the laboratory on the day they were obtained or the following day. Samples that were left overnight for pick up were kept in a sealed container at approximately room temperature. Sampling and testing continued over an 18-month period.

2. DISCUSSION.

2.1 SAMPLE COLLECTION.

The fuel samples for this effort were obtained from the sump of the aircraft as soon as the aircraft came to rest at its assigned arrival gate. It was necessary to coordinate with the maintenance personnel of the participating airlines to assure that samples were taken before the refueling process began. In all cases, the maintenance personnel were given the freedom to choose from which tank sump drain to draw the sample. Typically a center wing tank or inboard wing tank sump drain was used. This method of obtaining a sample was chosen because it is the quickest way to draw a fuel sample from underneath an aircraft. Samples were drawn from many aircraft including Boeing 737, 747, 767, MD-80, and Airbus A319 and A320. By taking the samples before refueling, it ensured the test results would reflect the volatility characteristics of the fuel loaded on the plane at the origin of the flight. It became evident that the refueling operation is started so quickly after aircraft arrival that occasionally samples were not obtained. When this occurred, it was usually possible to obtain a sample from the same flight number on a subsequent day. The flights were selected such that samples would be gathered from flights that originated in locations around the USA and from cities in Europe, South America, and Asia. Appendix A lists the airport code, sample number, and date from which the samples were obtained.

One gallon, cylindrical, epoxy-lined steel sample cans were obtained from a technical supplies vendor, and each can was used once to eliminate any possibility of sample mixing or contamination. The samples were drawn from the aircraft by airline maintenance personnel. On some occasions FAA personnel witnessed the sample collection, but as the maintenance personnel became familiar with obtaining the samples, it was decided that observation of the collection of each sample was unnecessary. Time and manpower limitations made the observation of the collection of each sample impractical. Each sample can was labeled with the date, a sample number, and a flight number. After the cans were filled, they were stored at room temperature by airline maintenance personnel until picked up for transport to laboratories for analysis. Since the first fuel samples obtained under this project wer obtained at PHL, it was convenient to engage the services of a commercial fuel testing laboratory close to the airport. The commercial laboratory selected was Intertek Testing Services-Caleb Brett U.S.A., Inc., a well-known petroleum testing organization. On some occasions, the samples were taken to the laboratory immediately after being drawn from the aircraft. On most occasions, the samples were drawn by airline maintenance personnel and stored at room temperature awaiting retrieval the following day by Technical Center personnel. Upon arrival at the commercial laboratory, the sample cans were opened to allow laboratory personnel to pour one half of the contents into an amber glass sample container. The screw-top lids were then put back on the cans and transported to the Technical Center for testing.

The process for handling the 32 fuel samples obtained at SFO differed from the handling described above since the airports in Philadelphia, Newark, and New York are within a reasonable driving distance from the Technical Center. A technician from the Technical Center spent 4 days with the assistance of a representative from the FAA field office at SFO and obtained samples from nonstop flights into SFO from such cities as Shanghai, Taipei, Hong Kong, and Manila. After collecting the samples, they were driven to another Intertek Testing Services-Caleb Brett laboratory located in Benecia, CA. After one-half of each sample was poured into containers for the commercial lab analysis, the remaining was tightly sealed in the epoxy-lined steel sample containers and boxed for overnight air shipment to the Technical Center. Upon receiving the samples at the Technical Center, they were tested in the same manner as all the samples obtained at PHL, EWR, and JFK.

2.2 LABORATORY TESTING.

After collection transport to the commercial and Technical Center laboratories, the fuel samples were subjected to the following tests:

- Flash Point—ASTM D 56
- Distillation—ASTM D 86
- Vapor Pressure—ASTM D 5191
- Kinematics Viscosity—ASTM D 445
- Freeze Point—ASTM D 2386
- Sulfur Content—ASTM D 4294

All six tests were performed at the commercial laboratory assisting on this project. Equipment for conducting three of the six (flash point, distillation, and vapor pressure) exists at the Technical Center laboratory and was used to perform those tests on all the samples. While all raw data from all the tests are included in appendix A, the analysis in this report is limited to the flash point results, since they were the prime concern of the sponsors.

2.2.1 Commercial Laboratory Testing.

The laboratory engaged by the Technical Center to conduct the volatility tests used the following test methods and instrumentation. All testing followed current American Society of Testing and Materials (ASTM) methodology.

- ASTM D 5191-96—Test Method for Vapor Pressure of Petroleum Products
  This method used a Grabner Vapor Pressure analyzer.

- ASTM D 56-96—Test Method for Flash Point by Tag Closed Tester
  This method used a Herzog Tag Closed Tester, Semi-Automatic

- ASTM D 86-96—Test Method for Distillation of Petroleum Products
  This method used an ISL Automatic Distillation Unit

2.2.2 Technical Center Laboratory Testing.

All fuel samples obtained in this project had been kept at moderate temperatures ranging from 65°F to approximately 80°F. The highest temperature environment the samples were exposed to would have been during the transportation either between PHL and the commercial laboratory or between the commercial laboratory and the Technical Center laboratory. The 1-gallon sample cans were transported in cardboard containers in the back of an open pickup truck. Once they were at either laboratory, they were kept in room temperature air conditioned spaces until they were opened for testing. The number of times the containers were opened was limited to the minimum necessary to obtain a sample for a given flash point, distillation, or vapor pressure test.

The flash point tests at the Technical Center were conducted on a Tag 2 Closed Cup Automatic Flash Point Tester, which is an approved flash point testing device as per ASTM D 56 test specifications. The instrument was manufactured by SUR of Berlin, Germany. This device minimizes operator-induced test variability and yields highly repeatable results. Experienced FAA engineering technicians conducted all the tests.

Distillation tests were conducted using a GT Instruments MINIDIST 86 JBUS. This automated instrument distills a 100-ml sample as per ASTM D 86 and records the distillation on a dedicated data acquisition system. Distillation tests were conducted by Technical Center project engineering personnel.

An automated Grabner Instruments MINIVAP VPS vapor pressure tester was used to conduct the ASTM D 5191. Although the vapor pressure of Jet A is so low that there is no actual value given in the ASTM D 1655 Jet A fuel specification, it was determined that testing the samples for vapor pressure could be used as an alert. If any samples exhibited a significant reading from this test, it would indicate possible fuel contamination. The vapor pressure tests were conducted by FAA engineering technicians.

3. RESULTS.

In the time period from April 20, 1999, through the end of August 1999, 293 fuel samples were collected and analyzed. Of the 293 samples, 175 were from foreign cities and 118 were from domestic U.S. cities (San Juan, Puerto Rico, is included in the domestic results). The foreign samples were obtained from 45 different locations around the world, and the domestic samples were obtained from 15 different locations in the U.S. The results of the flash point tests, in degrees Fahrenheit, from those samples are shown in table 1.

Table 1. Flash Point in Degrees Fahrenheit

	Average	Median	Mode	Standard Deviation	Maximum	Minimum
All fuels	120.0	120.2	127.2	8.1	139.3	84.2
Foreign	116.9	116.2	114.1	8.2	139.3	84.2
Domestic	124.6	124.6	127.2	5.2	137.5	110.3

All the compiled flash point results are presented in figures 1, 2, and 3 as plots of the flash point for all the samples together, one for the foreign samples, and one for the domestic samples.

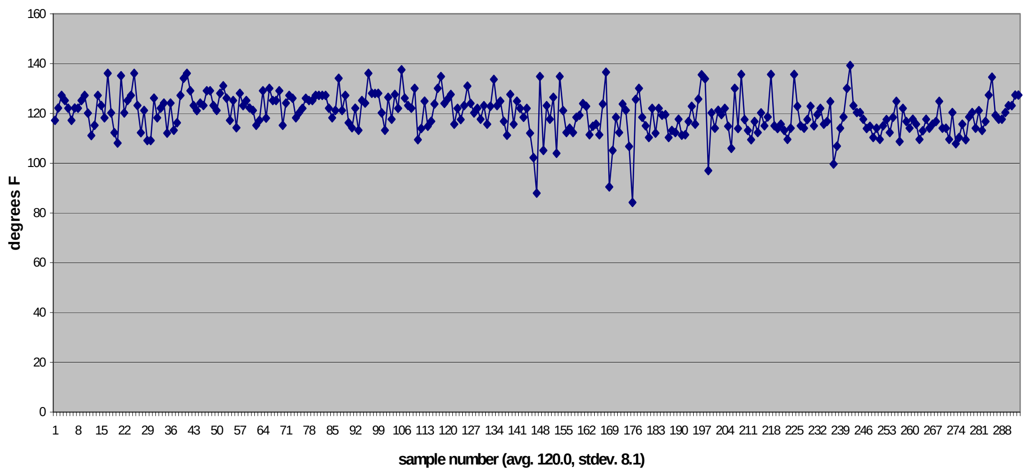

Figure 1. Flash Point—All Samples

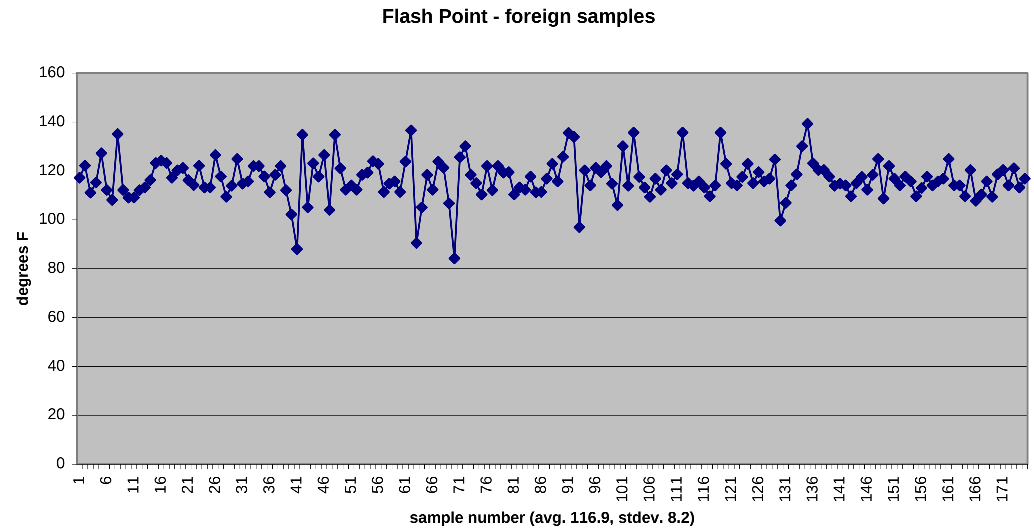

Figure 2. Flash Point—Foreign Samples

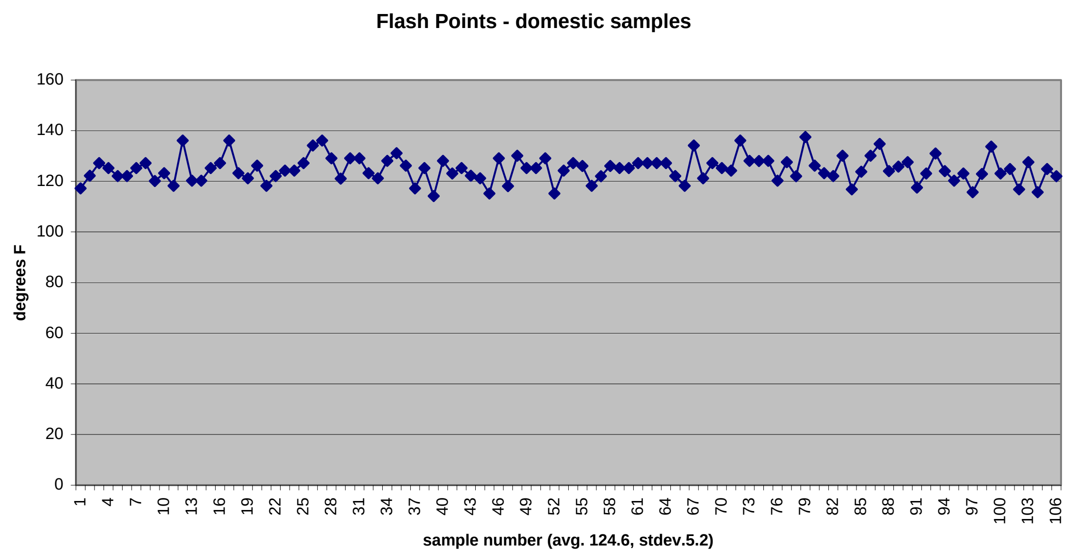

Figure 3. Flash Point—Domestic Samples

All the flash point results met the appropriate specification under which the fuel was processed. Those familiar with ASTM D 1655, Standard Specification for Aviation Turbine Fuels know that the specification for flash point is a minimum of 100°F. There are some flash point results in the foreign data that appear to violate this specification. However, the lowest results in the data are fuels that were obtained from flights that originated in Russia. The Russian fuel specification has a minimum accetable flash point of 80°F; and therefore, it can be stated that all fuels tested were within the allowable flash point range as it applied to that fuel. There were 12 samples obtained from flights that originated in Russia. The average for these samples was 99.6°F. The maximun result from these 12 samples, 106.9°F, was in fact less than the lowest reading from the entire 281 remaining samples, which was 107.8°F (Sydney, Australia). Considering the 281 samples without the Russian samples moves the overall average from 120.0° to 120.8°F and the foreign average from 116.9° to 118.1°F.

A frequency distribution from the data in figures 1, 2, and 3 are shown in figures 4, 5, and 6, respectively, for all samples together and then for foreign samples and finally domestic samples.

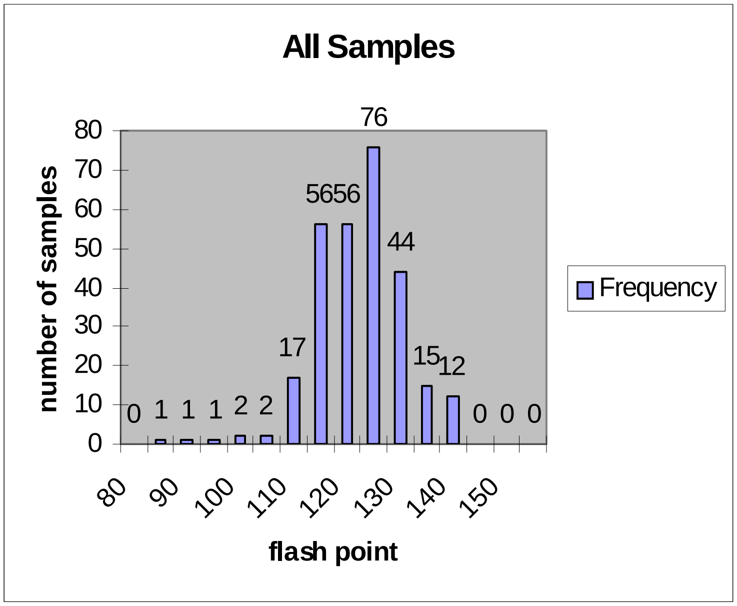

Figure 4. Flash Point Distribution—All Samples

The data from figure 4 show that a large majority of the results, 241 of the total 293 samples, or 82.3%, are greater than or equal to 110°F but less than 135°F. Only 24 of the 293 samples, or 8.2 %, were less than 110°F. At the high end of the flash point data, 28 of the 293 samples, or 9.6%, were greater than or equal to 135°F.

When the foreign samples are considered alone as in figure 5, a similar frequency distribution analysis shows that 24 of 175 samples, or 13.7%, are less than 110°F; 138 of 175 samples, or 78.9%, are in the 110° to 135°F range; and 13 of 175 samples, or 7.4%, are greater than or equal to 135°F.

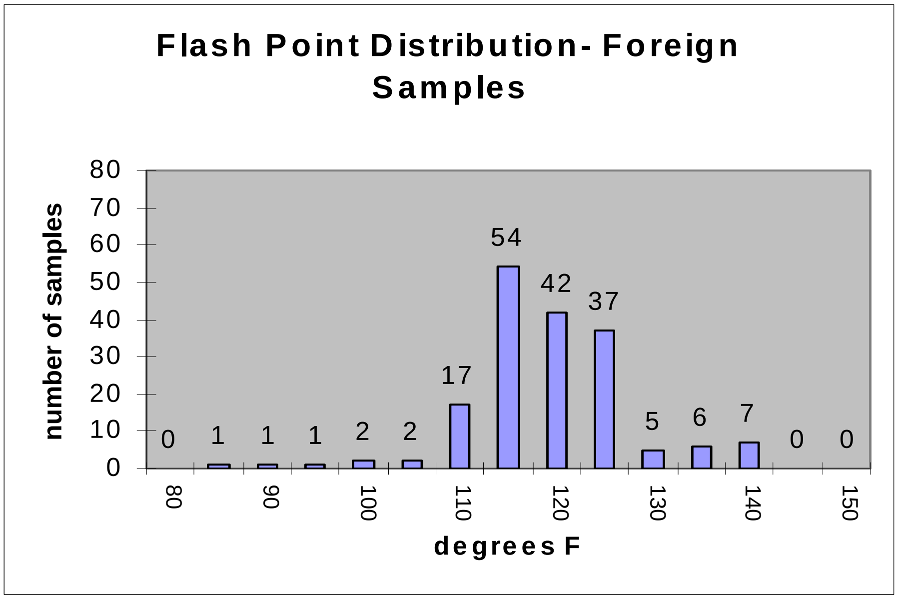

Figure 5. Flash Point Distribution—Foreign Samples

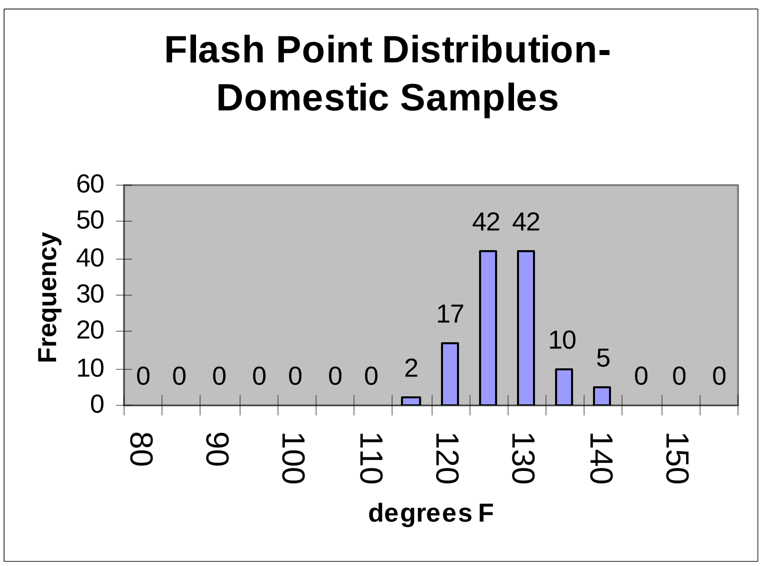

Figure 6. Flash Point Distribution—Domestic Samples

The domestic results, figure 6, show that none of the samples tested less than 110°F; 103 of 118 samples, or 87.3%, fall in the 110° to 135°F range; and 15 of 118 samples, or 12.7%, were greater than or equal to 135°F. These data suggest that the flash point of a fuel sample can be expected to be between 110° and 135°F at least 78% of the time.

A trend that is evident in the data is that, in general, foreign samples have a somewhat lower flash point than samples obtained from domestic locations. Figures 7 and 8 demonstrate this observation in bar graph and line graph format, respectively.

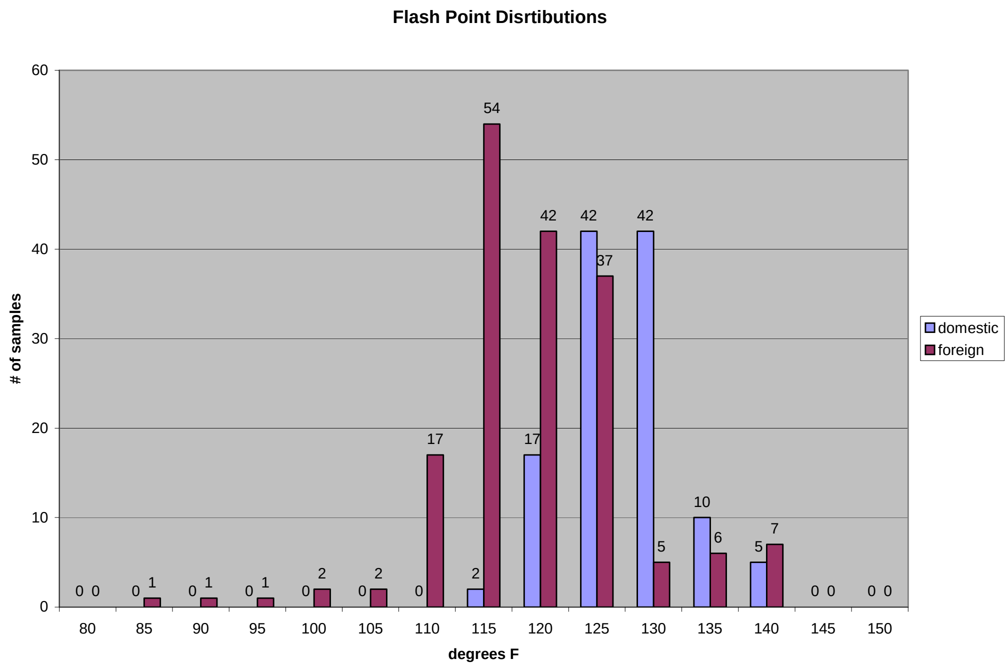

Figure 7. Flash Point Distribution, Bar Graph Format

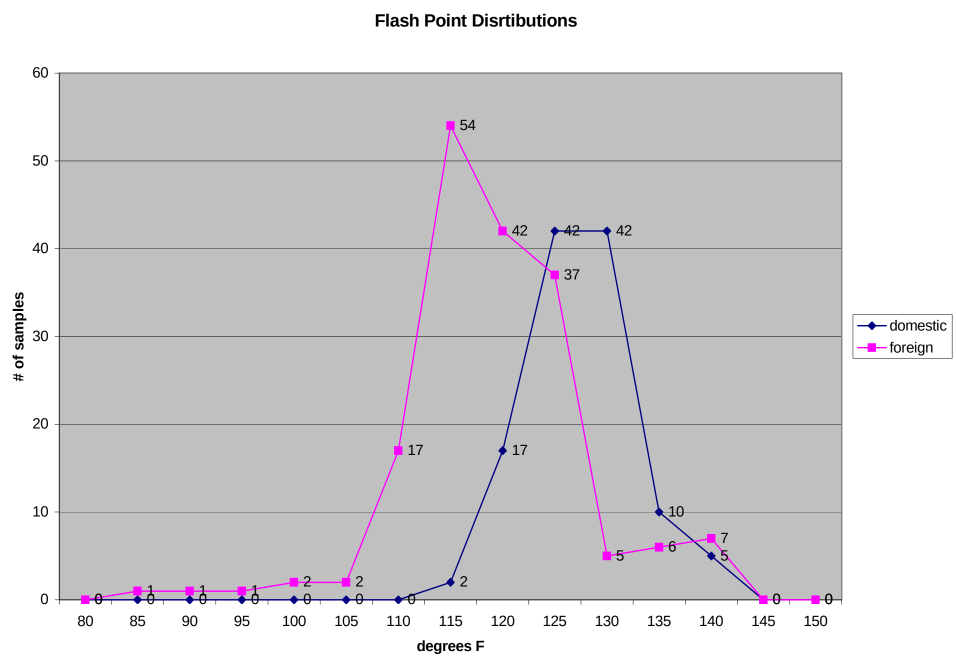

Figure 8. Flash Point Distribution, Line Graph Format

In addition, the average of the foreign samples is lower, as reflected in table 1. While it is difficult to conclude that any given foreign sample will be lower than a given domestic sample, the data show that foreign samples on the whole tend to be approximately 5°F lower. Another way of describing the tendency for foreign samples to have a lower flash point than domestic

Jet A is to draw a line at 120°F. Of the 80 samples with flash point results less than 120°F, 78 of the 80 are foreign samples. A less dramatic difference is evident when the samples that are less than 125°F are totaled. That produces the fact that of 139 samples that were less than 125°F, 120 of those, or 86.3%, were foreign.

3.1 AVERAGE FLASH POINT BY CITY.

As mentioned earlier in this report, the 293 in-service samples were obtained from 60 different cities around the world. A complete list of the cities, their airport code, and the number of samples obtained from each is in appendix A. Table 2 shows the average of the results obtained from each city.

Table 2. Average Flash Point by Origin of Flight

Average	City	Number
122.1	BOG	3
120.6	CUN	3
113.2	FRA	3
119.9	HNL	3
114.3	JNB	3
133.2	MEX	3
120.0	MNL	3
112.3	SEL	3
111.6	SID	3
117.0	WAW	3
114.8	ATH	4
123.6	ATL	5
117.8	GRU	5
122.8	PHX	5
118.8	FCO	6
123.3	IST	6
114.8	LGW	6
114.6	LIM	6
112.8	CDG	7
116.6	AMS	8
135.3	BUD	8
127.0	DEN	8
112.0	HKG	8
122.3	MAD	9
124.1	TPA	9
116.4	TPE	9
121.5	CCS	10
122.3	MIA	10

Table 2. Average Flash Point by Origin of Flight (Continued)

Average	City	Number
99.8	SVO-DEL	11
123.3	LAX	13
131.6	SJU	13
121.7	SFO	14
123.6	DFW	15
114.1	NRT	16
125.3	ORD	19

Twenty-nine of the data points, or 83%, are between the 110° and 135°F range. The most notable data point in this section is the 99.8°F result from SVO, which came from Moscow. Jet fuel loaded into a plane in Russia is processed in Russian refineries and must meet a specification known as TS-1. The flash point specification according to TS-1 is a minimum of 80°F. This is markedly different from the ASTM specification followed in most of the rest of the world where the flash point specification minimum is 100°F.

3.2 AIRPORT FUEL SUPPLIER RESULTS.

Flash point data were obtained from an airport fuel supplier to compare with the in-service data and also to see if any noticeable seasonal trend exists in the flash point of Jet A. A total of 1710 flash point test results were obtained and compiled. These tests were done between January 1998 and September 1999. Table 3 summarizes the airport fuel supplier data.

Table 3. Flash Point Results From Airport Fuel Supplier

Month	Count	Average	Median	Mode	Maximum	Minimum	Standard Deviation
Jan 1998	31	117.4	118	116	124	112	3.0
Feb 1998	53	118.4	118	116	127	108	4.1
Mar 1998	82	119.4	120	120	132	109	4.5
Apr 1998	83	119.7	120	118	130	110	4.6
May 1998	82	120.0	120	118	138	107	5.6
Jun 1998	80	120.9	120	120	136	110	5.2
Jul 1998	95	120.9	120	120	142	110	6.0
Aug 1998	97	120.4	118	118	140	110	6.2
Sept 1998	88	120.8	120	122	136	114	4.1
Oct 1998	93	119.8	120	118	136	114	3.6
Nov 1998	87	118.7	118	118	128	114	3.6
Dec 1998	76	116.5	116	116	136	108	3.8
Jan 1999	89	115.6	116	114	122	110	2.8
Feb 1999	80	118.7	118	118	128	114	2.7

Table 3. Flash Point Results from Airport Fuel Supplier (Continued)

Month	Count	Average	Median	Mode	Maximum	Minimum	Standard Deviation
Mar 1999	90	117.8	118	118	126	114	2.9
Apr 1999	88	118.9	118	118	126	112	2.5
May 1999	84	118.5	118	118	136	112	4.0
Jun 1999	100	117.7	118	118	134	107	4.6
Jul 1999	103	118.0	118	118	126	108	3.6
Aug 1999	105	119.3	118	118	134	110	4.6
Sept 1999	25	122.0	121	121	143	117	6.5

From this table and figure 9, which shows the average flash point as well as the minimum and maximum value obtained for each month, it is evident that there is no detectable seasonal trend with respect to flash point tests.

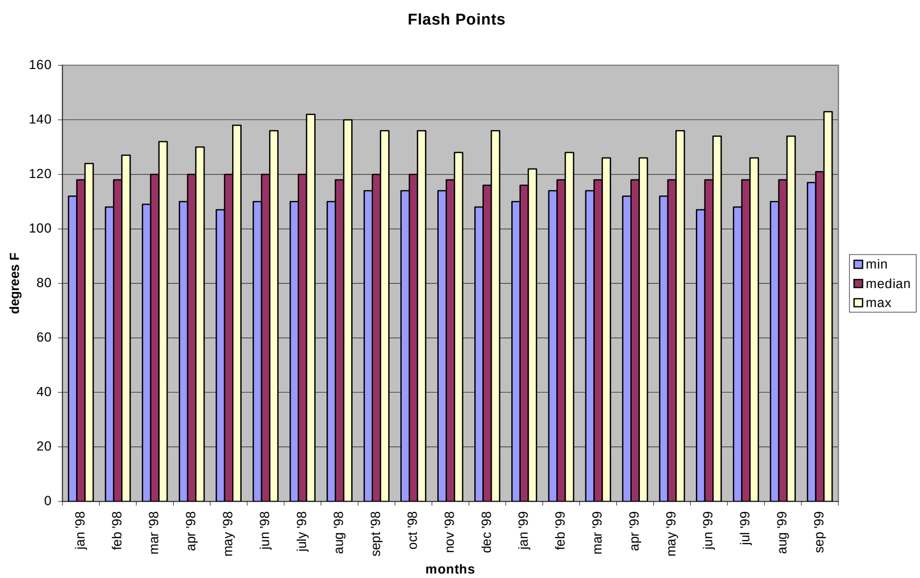

Figure 9. Flash Point Values From the Airport Fuel Supplier

The standard deviation for each month shows only mild monthly variation. The month with the highest standard deviation is August 1998 (ignoring September 1999 because of an incomplete data set for the month). During that month, 97 flash point tests were conducted by a large aviation fuel supplier on 31 different batchs of fuel. The complete data set from that month is shown in figure 10.

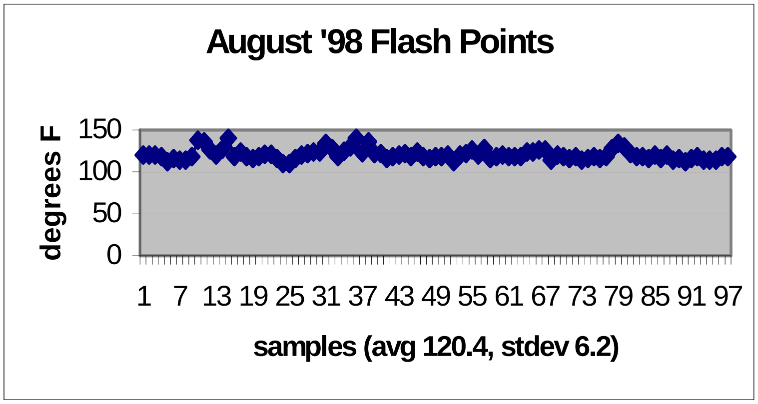

Figure 10. August 1998 Flash Point Results

Two other months are worth examining closer as examples of the degree of variation in flash point shown on a large number of different fuel batches and flash point tests. In April 1999, 88 flash point tests were conducted yielding an average of 119.7 with a standard deviation of 2.5. This month showed the least data scatter. The flash point results are shown in figure 11.

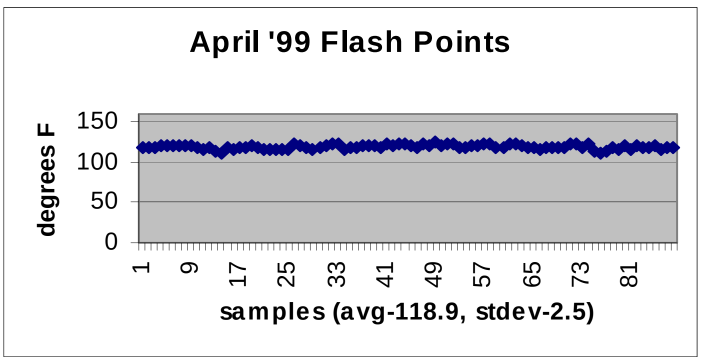

Figure 11. April 1999 Flash Point Results

While the two previous months' data illustrate the extremes of the flash point data variation, it is perhaps best illustrated by looking at the results from September 1998, as shown in figure 12.

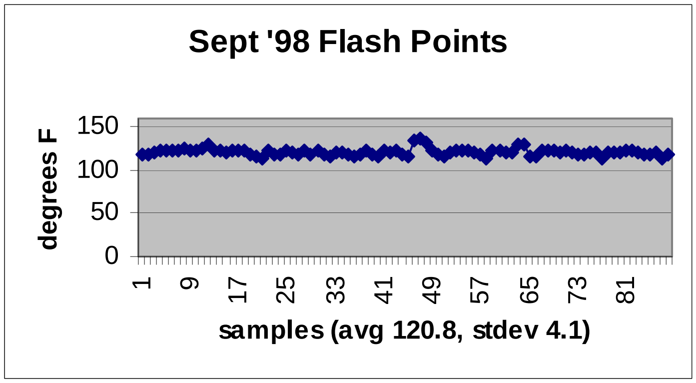

Figure 12. September 1998 Flash Point Results

The September 1998 data's standard deviation of 4.1 is representative of the average deviation about the mean shown by all the airport fuel supplier data covering the time from January 1998 to September 1999. Perhaps the most significant information derived from the airport fuel supplier flash point data is shown in figure 13.

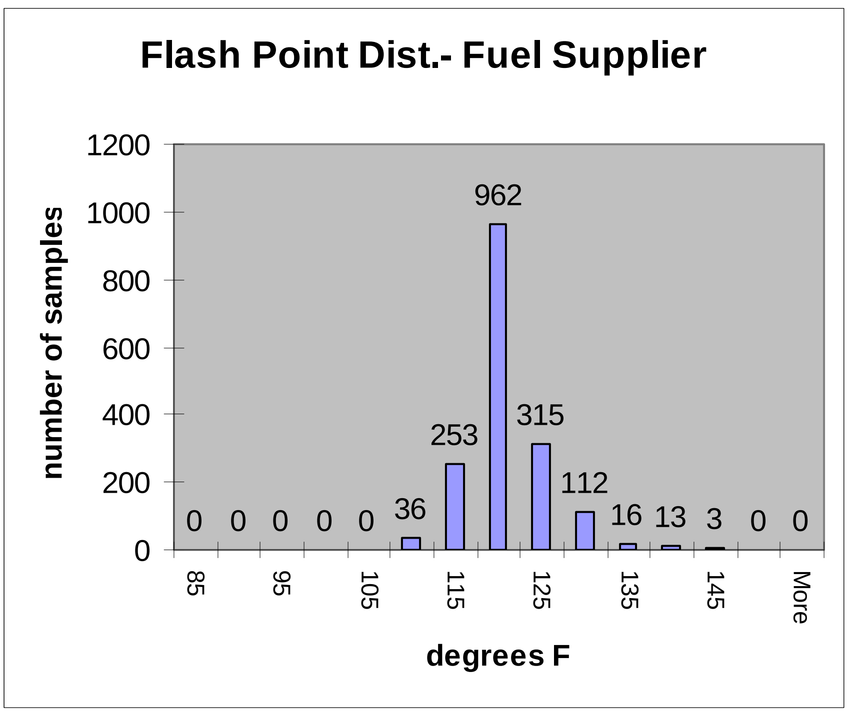

Figure 13. Flash Point Distribution—Airport Fuel Supplier

Figure 13 illustrates that of the 1710 flash point test results depicted in this frequency distribution, 1642 of them, or 96%, were greater than or equal to 110°F and less than 135°F.

4. CONCLUSIONS.

The flash point data collected for this report consisted of 293 Jet A fuel samples taken from aircraft immediately following their arrival after nonstop flights from a given location. As noted earlier, those locations consisted of 60 different cities around the world. In addition, 1710 flash point test results were tallied from airport fuel suppliers' data that covered January 1998 through September 1999. From all those samples and pieces of data, it is noteworthy that not one piece of flash point data was out of specification. Although the TS-1 obtained from Moscow does not always meet the ASTM flash point specification, there is no requirement that it must.

The flashpoint of fuel manufactured in the United States can be expected, on average, to have a flash point 5 to 7 degrees higher than fuel that was manufactured anywhere else in the world. In spite of that, the data show that regardless of where the fuel samples where obtained or the data was gathered for this project, when it was examined on a frequency distribution basis, at least 78% of the fuels examined yielded flash point results in the range covered by the range where 110°F is less than or equal the flash point result, which is less than 135°F.

APPENDIX A—FLASH POINT DATA

Counter	Sample	Date	Origin	SUR
1	101	4/20/1998	MIA	117.2
2	102	4/20/1998	PHX	122.2
3	103	4/20/1998	LAX	127.2
4	104	4/20/1998	DEN	125.2
5	105	4/20/1998	ATL	122.1
6	106	4/20/1998	FRA	117.2
7	108	4/20/1998	FCO	122.2
8	109	4/27/1998	MIA	122.1
9	110	4/27/1998	PHX	125.2
10	112	4/27/1998	DEN	127.2
11	113	4/27/1998	ATL	120.1
12	114	4/27/1998	FRA	111.1
13	115	4/27/1998	LGW	115.2
14	116	4/27/1998	FCO	127.2
15	117	4/29/1998	ORD	123.2
16	118	4/29/1998	DFW	118.2
17	119	4/29/1998	SJU	136.1
18	120	4/29/1998	MIA	120.2
19	121	5/6/1998	LGW	112.2
20	122	5/6/1998	CDG	108.1
21	123	5/6/1998	MAD	135.1
22	124	5/6/1998	LAX	120.2
23	125	5/6/1998	ORD	125.2
24	126	5/6/1998	DFW	127.2
25	127	5/6/1998	SJU	136.1
26	128	5/6/1998	MIA	123.2
27	129	5/11/1998	LGW	112.2
28	130	5/11/1998	PHX	121.2
29	131	5/11/1998	CDG	109.1
30	132	5/11/1998	MAD	109.1
31	133	5/11/1998	ORD	126.2
32	134	5/11/1998	DFW	118.2
33	135	5/11/1998	SJU	122.1
34	136	5/11/1998	MIA	124.2
35	137	5/13/1998	LGW	112.1
36	138	5/13/1998	PHX	124.2
37	139	5/13/1998	CDG	113.2
38	140	5/13/1998	MAD	116.2
39	141	5/13/1998	ORD	127.2
40	142	5/13/1998	DFW	134.1
41	143	5/13/1998	SJU	136.1

Counter	Sample	Date	Origin	SUR
42	144	5/13/1998	MIA	129.1
43	145	5/20/1998	LGW	123.2
44	146	5/20/1998	PHX	121.1
45	147	5/20/1998	CDG	124.2
46	148	5/20/1998	MAD	123.2
47	149	5/20/1998	ORD	129.1
48	150	5/20/1998	DFW	129.1
49	151	5/20/1998	SJU	123.2
50	152	5/20/1998	MIA	121.2
51	153	5/20/1998	ORD	128.1
52	154	5/20/1998	DEN	131.1
53	155	5/20/1998	LAX	126.2
54	156	5/20/1998	SFO	117.2
55	157	5/27/1998	ORD	125.2
56	158	5/27/1998	SFO	114.2
57	159	5/27/1998	DEN	128.1
58	160	5/27/1998	LAX	123.1
59	161	6/8/1998	ORD	125.2
60	162	6/8/1998	DEN	122.2
61	163	6/8/1998	LAX	121.2
62	164	6/8/1998	SFO	115.2
63	165	6/8/1998	AMS	117.2
64	166	6/8/1998	SJU	129.1
65	167	6/8/1998	SFO	118.1
66	168	6/8/1998	TPA	130.1
67	169	6/8/1998	ORD	125.2
68	170	6/8/1998	DFW	125.2
69	171	6/8/1998	SJU	129.1
70	172	6/8/1998	MIA	115.2
71	173	6/15/1998	ORD	124.2
72	174	6/15/1998	DEN	127.2
73	175	6/15/1998	LAX	126.1
74	176	6/15/1998	SFO	118.2
75	177	6/15/1998	AMS	120.2
76	179	6/15/1998	SFO	122
77	180	6/15/1998	TPA	126.1
78	181	6/15/1998	ORD	125.2
79	182	6/15/1998	DFW	125.2
80	183	6/15/1998	SJU	127.2
81	184	6/15/1998	MIA	127.2
82	185	6/23/1998	ORD	127.2
83	186	6/23/1998	DEN	127.2
84	187	6/23/1998	LAX	122.1

Counter	Sample	Date	Origin	SUR
85	188	6/23/1998	SFO	118.2
86	189	6/23/1998	AMS	121.2
87	190	6/23/1998	SJU	134.1
88	191	6/23/1998	SFO	121.2
89	192	6/23/1998	TPA	127.2
90	193	8/6/1998	CDG	116.2
91	194	8/6/1998	AMS	114.2
92	195	8/6/1998	MAD	122.1
93	196	8/6/1998	FCO	113.2
94	197	8/6/1998	ATL	125.2
95	199	8/6/1998	TPA	124.2
96	200	8/6/1998	SJU	136.1
97	201	8/6/1998	SFO	128.1
98	202	8/6/1998	ORD	128
99	203	8/6/1998	DFW	128.1
100	204	8/6/1998	LAX	120.2
101	206	8/29/1998	AMS	113.2
102	207	8/29/1998	MAD	126.5
103	208	8/29/1998	FCO	117.7
104	210	8/29/1998	DFW	127.6
105	211	8/29/1998	TPA	122
106	212	8/29/1998	SJU	137.5
107	213	8/29/1998	SFO	126.2
108	214	8/29/1998	ORD	123.2
109	215	8/29/1998	DFW	122.1
110	216	8/29/1998	LAX	130.1
111	217	8/31/1998	CDG	109.4
112	218	8/31/1998	AMS	113.9
113	219	8/31/1998	MAD	124.9
114	220	8/31/1998	FCO	114.8
115	222	8/31/1998	DFW	116.8
116	223	8/31/1998	TPA	123.8
117	224	8/31/1998	SJU	130.1
118	225	8/31/1998	SFO	134.8
119	226	8/31/1998	ORD	124
120	227	8/31/1998	DFW	125.8
121	228	8/31/1998	LAX	127.6
122	230	9/14/1998	AMS	115.7
123	231	9/14/1998	MAD	122
124	234	9/14/1998	DFW	117.5
125	235	9/14/1998	TPA	123.1
126	237	9/14/1998	SFO	131
127	238	9/14/1998	ORD	124

Counter	Sample	Date	Origin	SUR
128	240	9/14/1998	LAX	120.2
129	243	9/23/1998	MAD	122
130	244	9/23/1998	FCO	117.7
131	245	9/23/1998	ATL	123.1
132	246	9/23/1998	DFW	115.7
133	247	9/23/1998	TPA	122.9
134	248	9/23/1998	SJU	133.7
135	249	9/23/1998	SFO	123.1
136	250	9/23/1998	ORD	124.9
137	252	9/23/1998	LAX	116.8
138	255	9/30/1998	FRA	111.2
139	256	9/30/1998	DEN	127.6
140	259	9/30/1998	SFO	115.7
141	260	9/30/1998	ORD	124.9
142	262	9/30/1998	LAX	122
143	263	2/8/1999	YVR	118.4
144	265	3/2/1999	CCS	122
145	266	3/2/1999	NRT	112.1
146	267	3/2/1999	SVO	102.2
147	268	3/2/1999	SVO	88.0
148	269	3/2/1999	BUD	134.8
149	270	3/3/1999	SVO	105.1
150	271	3/3/1999	STB	123.1
151	272	3/3/1999	LIS	117.7
152	273	3/3/1999	BUH	126.5
153	274	3/3/1999	SVO	104.0
154	275	3/3/1999	BUD	134.8
155	276	3/3/1999	TSR	121.1
156	277	3/3/1999	SID	112.3
157	278	3/3/1999	LIM	114.1
158	279		SID	112.3
159	280	3/18/1999	GHANA	118.4
160	281	3/3/1999	CCS	119.3
161	282	3/3/1999	CUN	124.0
162	283	3/3/1999	BOG	122.9
163	284	3/3/1999	NRT	111.4
164	285		WAW	114.8
165	286		LIM	115.7
166	288		NRT	111.4
167	289	3/29/1999	BUH	123.8
168	290		BUD	136.6
169	291		SVO-AER	90.5
170	292		SVO-DEL	105.1

Counter	Sample	Date	Origin	SUR
171	293		CUN	118.4
172	294		NRT	112.3
173	295		CCS	123.8
174	296		BOG	121.3
175	297	4/8/1999	SVO-DEL	106.7
176	298	4/8/1999	SVO-AER	84.2
177	299	4/8/1999	IST	125.6
178	300	4/8/1999	BUD	130.1
179	301	4/8/1999	WAW	118.4
180	302	4/9/1999	SCL	115.0
181	303	4/9/1999	SID	110.3
182	304	4/7/1999	CCS	122.0
183	305	4/8/1999	NRT	112.1
184	306	4/8/1999	BOG	122.0
185	307	4/8/1999	CCS	119.3
186	308	4/8/1999	CUN	119.5
187	309	4/8/1999	NRT	110.3
188	310	4/29/1999	JNB	113.2
189	311	4/29/1999	LIM	112.3
190	312	4/29/1999	WAW	117.7
191	313	4/29/1999	NRT	111.2
192	314	4/29/1999	SEL	111.4
193	315	4/29/1999	GRU	116.8
194	316	4/29/1999	CCS	122.9
195	317	4/29/1999	NRT	115.7
196	318	4/29/1999	IST	125.8
197	319	4/29/1999	BUD	135.5
198	320	4/29/1999	MEX	133.9
199	321	4/29/1999	LEN	97.0
200	322	5/10/1999	GRU	120.2
201	323	5/10/1999	SCL	114.1
202	324	5/10/1999	UIO	121.3
203	326	5/10/1999	GRU	119.5
204	327	5/10/1999	CCS	122.0
205	328	5/10/2000	NRT	114.8
206	329	5/10/1999	SVO-DEL	106.0
207	330	5/10/1999	IST	130.1
208	331	5/10/1999	ATH	113.9
209	332	5/10/1999	BUD	135.7
210	333	5/10/1999	NRT	117.5
211	334	5/10/1999	NRT	113.2
212	336	5/10/1999	CDG	109.4
213	337	5/10/1999	BRU	116.8

Counter	Sample	Date	Origin	SUR
214	339	5/24/1999	LIM	112.3
215	340	5/24/1999	CCS	120.2
216	341	5/24/1999	NRT	115.0
217	342	5/24/1999	GRU	118.6
218	343	5/24/1999	BUD	135.7
219	344	5/24/1999	IST	115.0
220	345	5/24/1999	ATH	113.9
221	346	5/24/1999	SNN	115.7
222	347	5/24/1999	BHX	113.2
223	348	5/24/1999	DUB	109.6
224	349	5/24/1999	LGW	114.1
225	350	06/07/99	MEX	135.7
226	351	06/07/99	IST	122.9
227	352	06/07/99	ATH	115.0
228	353	06/21/99	GRU	114.1
229	354	06/07/99	NRT	117.5
230	355	06/07/99	CCS	122.9
231	356	06/07/99	JNB	115.0
232	357	06/07/99	LIM	119.5
233	358	06/07/99	HNL	122.0
234	359	06/07/99	ZRH	115.7
235	360	06/07/99	NRT	116.8
236	361	6/7/1999	UIO	124.7
237	362	6/21/1999	SVO-AER	99.7
238	363	6/21/1999	SVO-DEL	106.9
239	364	6/21/1999	ATH	114.1
240	365	6/21/1999	BCN	118.6
241	366	6/21/1999	MEX	130.1
242	367	6/21/1999	BUD	139.3
243	368	6/21/1999	LIS	123.1
244	369	6/21/1999	IST	120.4
245	370	6/21/1999	CCS	120.4
246	371	6/21/1999	NRT	117.7
247	372	6/21/1999	LIM	113.9
248	373	6/21/1999	JNB	114.8
249	374	6/21/1999	HON	110.3
250	375	6/21/1999	ZRH	114.1
251	377	6/21/1999	BHX	109.6
252	378	7/19/1999	YTO	115.0
253	379	7/19/1999	AMS	117.5
254	380	7/19/1999	SEL	112.3
255	381	7/20/1999	SHA	118.4

Counter	Sample	Date	Origin	SUR
256	382	7/19/1999	TPE	124.9
257	383	7/19/1999	HKG	108.7
258	384	7/19/1999	MNL	122.0
259	385	7/19/1999	TPE	116.8
260	386	7/20/1999	TPE	114.1
261	387	7/20/1999	MNL	117.7
262	388	7/20/1999	TPE	115.7
263	389	7/20/1999	HKG	109.6
264	390	7/20/1999	HKG	113.0
265	391	7/20/1999	YVR	117.7
266	392	7/21/1999	HKG	114.1
267	393	7/21/1999	TPE	115.7
268	394	7/21/1999	NRT	116.8
269	395	7/21/1999	MXP	124.9
270	396	7/21/1999	PEK	114.1
271	397	7/21/1999	TPE	114.1
272	398	7/21/1999	HKG	109.6
273	399	7/21/1999	MNL	120.4
274	400	7/22/1999	SYD	107.8
275	401	7/22/1999	HKG	110.3
276	402	7/22/1999	TPE	115.7
277	403	7/22/1999	HKG	109.4
278	404	7/22/1999	KIX	118.6
279	405	7/22/1999	SHA	120.4
280	406	7/22/1999	TPE	114.1
281	407	7/22/1999	HKG	121.1
282	408	7/22/1999	SEL	113.2
283	409	7/22/1999	TPE	116.8
284	410	8/23/1999	PHL	127.4
285	411	8/23/1999	CLT	134.6
286	412	8/23/1999	RIC	119.3
287	413	8/23/1999	TPA	117.7
288	414	8/23/1999	PIT	117.7
289	415	8/23/1999	CHI	120.4
290	416	9/13/1999	DFW	123.1
291	417	9/13/1999	MIA	123.1
292	418	9/13/1999	HNL	127.4
293	419	9/13/1999	ATL	127.4