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SURVEY OF SULFUR LEVELS IN COMMERCIAL JET FUEL

prepared by
William F. Taylor

February 2009

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CRC Aviation Research Committee
of the
Coordinating Research Council

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1.0 Summary

A survey of the sulfur levels of commercial aviation turbine fuel has been completed by the Coordinating Research Council (CRC). Mandated sulfur level restrictions have been placed on ground transportation fuels in Europe, the United States and elsewhere which can also affect the sulfur level of jet fuel. The goal of the survey was to provide a data base of actual jet fuel sulfur levels to help the world wide aviation technical community reach informed conclusions and decisions.

The CRC survey obtained over 1,600 individual, monthly, confidential refinery reports from different parts of the world. Data were received covering the September 2005 to February 2008 period. Regional statistical data were reported using six CRC defined regions: US East Region, US Gulf Region, US West Region, European Region, Pacific Region and Other Region. The refineries also provided confidential jet fuel production rate data which were used to calculate volumetrically weighted mean sulfur levels for the regions. Because significant differences exist between refinery jet fuel production rates, volumetric averaging is important in measuring the true average fuel sulfur content of a given region.

Survey results did not show in any CRC region that jet fuel sulfur increased to a level near the specification limit (typically 3000 PPM S). Jet fuel monthly weighted mean sulfur reported to the survey for the Overall US Region ranged from 576 PPM S to 867 PPM S, for the European Region ranged from 176 PPM S to 293 PPM S, for the Pacific Region ranged from 223 PPM S to 449 PPM S and for the Other Region ranged from 350 PPM S to 958 PPM S. The maximum individual refinery monthly sulfur level reported by any US Region was 2250 PPM S, by the European Region was 1600 PPM S, by the Pacific region was 940 PPM S and by the Other Region was 1590 PPM S.

Results indicate that the production methodology for jet fuel is complex. Some refineries are producing jet fuel with mid-range sulfur levels while other refineries are producing jet fuel with sulfur levels less than 15 PPM S (termed for purposes of this report only as ultra low sulfur). Refineries producing ultra low sulfur (ULS) jet fuel tend to have lower jet fuel production rates than refineries producing higher sulfur levels. The survey reported volume of ULS jet fuel produced ranged from 3.4% to 5.4% in the Overall US Region, from 4.5% to 10 % in the European Region and from 8.4% to 16 % in the Pacific Region. The survey reported percent of refineries producing ULS jet fuel ranged in the Overall US Region from 9.4% to 21%, in the European Region from 21% to 23% and in the Pacific Region from 23% to 36%. The percent of refineries producing ultra low sulfur jet fuel rose over the length of the survey in the Pacific Region and in the US East Region, but exhibited a more complex pattern of change with time in the US West Region and in the US Overall Region.

2.0 Introduction and Background

The Coordinating Research Council has conducted a survey to determine the sulfur levels of commercial aviation turbine fuels. Mandated restrictions have taken place in the United States, Europe and elsewhere on the sulfur levels of ground transportation fuels. Because aviation fuels and ground transportation fuels are both manufactured together in integrated refineries, these restrictions have the potential to also result in changes in the sulfur levels of jet fuel. Because of the complexity of these refinery changes, it was not clear how the mandated ground fuel sulfur restrictions would affect jet fuel sulfur levels. Three general outcomes were possible (I) mean sulfur could remain essentially equal to current levels, (II) mean sulfur could increase since recent historic jet fuel sulfur levels (i.e. levels prior to mandated ground fuel restrictions) were well below commercial specification limits, and (III) mean sulfur could decrease as a result of greater refinery use of distillate hydro-desulfurization processes. In addition, the possibility existed that the effects on jet fuel sulfur levels could vary in different geographic regions and over time.

The CRC survey was a voluntary, confidential, informational directed program. The goal of the survey was to provide to the world wide aviation technical community a data based tool to help reach informed conclusions and decisions, rather than having conclusions and/or decisions proposed which are based on unfounded or speculative assertions.

3.0 Details of the Survey

3.1 Timing

Survey data collection covered a two and a half year period starting with the month of September 2005 and ending with the month of February 2008.

3.2 Confidentiality

The names of individual organizations and individual refineries which participated in the survey will be kept confidential. In addition, all individual refinery data and/or information including monthly jet fuel production rates (which are used for volumetrically averaging purposes) will be kept confidential. Only statistical sulfur level data are reported from CRC defined geographical regions.

3.3 Data Requested

Organizations were asked to provide the following for each refinery producing commercial aviation turbine fuel for each month of the survey data collection period.

1. The name or other identification of the refinery and location.

2. Grade of commercial turbine fuel produced e.g. Jet A, Jet A-1

3. The total sulfur content, in units of total mass % sulfur or equivalent, of one representative batch of jet fuel produced during the month, and its date of production. This sulfur value can be taken from a certificate of analysis and does not require a separate analysis for the survey.

4. An estimate of the refinery jet fuel production for that month to be used to volumetrically weight the individual total sulfur results for that region and month.

3.4 CRC Survey Geographical Regions

CRC geographical regions were defined to be used for averaging individual refinery jet fuel sulfur data. The CRC Jet Fuel Sulfur Survey regions are shown in Table 1. The CRC survey regions were defined to match up with the US Defense Energy Support Center's (DESC) Petroleum Quality Information System (PQIS) regions. In general, the CRC regions in the U.S. also match up with the US Department of Energy designated Petroleum Administration for Defense Districts (PADDs) which have been used in a number of studies of the U.S. refining industry since World War II. The six CRC Regions defined were US East, US Gulf, US West, European, Pacific and Other.

Table 1. CRC Jet Fuel Sulfur Survey Geographical Data Analysis Regions

CRC Region	PQIS Region	PADDs	Description
US East (a)	1 and 2	I and II	US East Coast and East Central
US Gulf (b)	3	III	US Gulf Coast
US West (c)	4 and 5	IV and V(ex HI & AK)	US West Coast and West Central
European	7	NA(d)	Europe
Pacific	8	NA(d)	Asia, Australia, HI and AK
Other	6 and 9 plus other areas	NA(d)	All areas not in another CRC Region

(a) US East: ME, VT, NH, MA, RI, CT, NY, PA, NJ, DE, MD, VA, WV, NC, SC, GA, FL, ND, SD, MN, IA, NE, WI, MI, OH, KY, TN, IN, IL, MO, KS, OK.
(b) US Gulf: AL, MS, AR, LA, TX, NM.
(c) US West: MT, ID, WY, UT, CO, WA, OR, CA, NV, AZ.
(d) Not Applicable

3.5 Estimation of the Regional Sample Sizes

An estimate was made of the magnitude of the regional sample sizes obtained by the survey. This estimate was made by comparing the volume of jet fuel production reported to the survey to the total jet fuel production for that region and survey length. Jet fuel production data reported by the U.S. Energy Information Agency (EIA) was used to calculate the total jet fuel production. EIA reports U.S. jet fuel production figures on an up to date basis, whereas world wide production values are reported for an earlier time period. These estimated survey regional sample sizes are shown in Table 2 below. Also shown are the average number of refineries which reported for each region.

Table 2. Estimate of Regional Sample Sizes

CRC Region	Estimated Survey Volume as % of Total Jet Fuel Production	Average Number of Refineries Reporting
Overall US	55 %(a)	36.8(a)
European	17 %(b)	10.7(b)
Pacific	20 %(c)	9.7(c)
Other	3 %(c)	4.8(c)

(a) For the thirty month period from September 2005 through February 2008.
(b) For the twelve month period from September 2005 through August 2006.
(c) For the twenty eight month period from September 2005 through December 2007.

A larger sample size (as shown both by a greater sample volume and a greater number of refineries participating) increases the probability that the survey weighted mean sulfur value will be closer to the actual weighted mean sulfur. Clearly, the sample size of the US Overall Region is the largest while the European and Pacific Regions sample sizes are smaller, and thus more limited in their ability to predict the actual regional mean sulfur levels. The Other Region sample size is quite small and appears severely limited.

3.6 Data Reporting

The CRC survey received over 1,600 individual monthly refinery reports. Regional statistical data calculated for each month included both mean sulfur values and weighted mean sulfur values. Mean values (Mean) are the sum of all individual refinery jet fuel sulfur values divided by the total number of refineries reporting for that region and month. Weighted means (Wt Mean) are the sum of individual refinery jet fuel sulfur values times the average monthly production rate for that individual refinery divided by the total jet fuel production rate for that region and month. Also reported are the minimum (Min) and Maximum (Max) sulfur values for the various regions for each month as well as the number of refineries which reported data. The mean sulfur values, weighted mean sulfur values, minimum and maximum sulfur values and number of refineries reporting for each month are shown in Table 6 in the Appendix.

4.0 Survey Results

4.1 Weighted Mean and Mean Regional Survey Results

A comparison of regional mean sulfur against the corresponding weighted mean indicates in many cases that the values differ significantly. The weighted mean sulfur is intrinsically more accurate in measuring the total sulfur content of all the jet fuel manufactured in a particular region, since it accounts for the differences between production rates among the various refineries. Because of the frequent differences seen in the survey between mean and weighted mean values, it is important that weighted mean results be used in determining the true average sulfur content of the total fuel produced by a region.

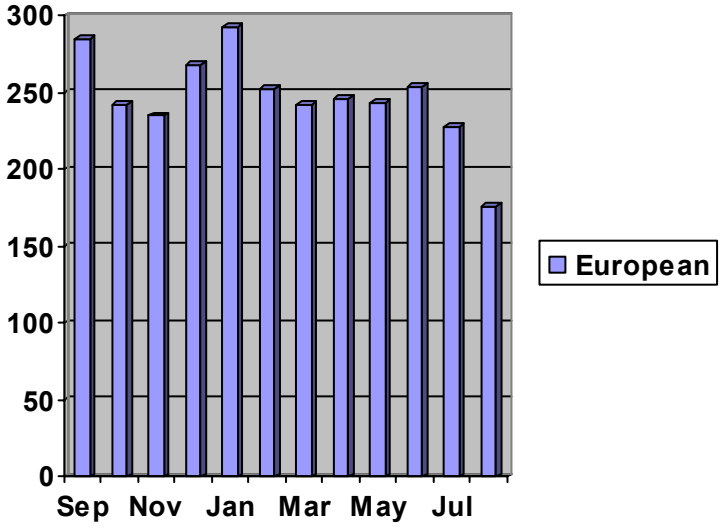
Where differences exist between the weighted mean and mean, the weighted mean values are generally higher; indicating that, on average, refineries producing lower sulfur levels are producing lower volumes of jet fuel than refineries producing higher sulfur levels.

4.2 Regional Weighted Mean Sulfur Data

4.2.1 European Regional Data

CRC European regional data was obtained over the one year time period of September 2005 through August 2006. Detailed data are shown in the Appendix. In Figure 1 the weighted mean sulfur values for the CRC European Region are plotted versus time.

Figure 1. European Region Weighted Mean Sulfur, PPM S
September 2005 through August 2006



The European regional monthly survey reported weighted mean sulfur ranged from 176 PPM S to 293 PPM S. The data does not show a strong changing trend with time over most of the survey period. Table 3 lists weighted mean sulfur values that are time averaged for the last four months and for the full year (with the exception of the European Region where the data for the first eight months of 2006 rather than the full year is shown). For the European Region the average of the monthly weighted mean sulfur for the last four months of 2005 was 258 PPM S and for the first eight months of 2006 was 242 PPM S.

Table 3. Survey Time Averaged Weighted Mean Sulfur – PPM S

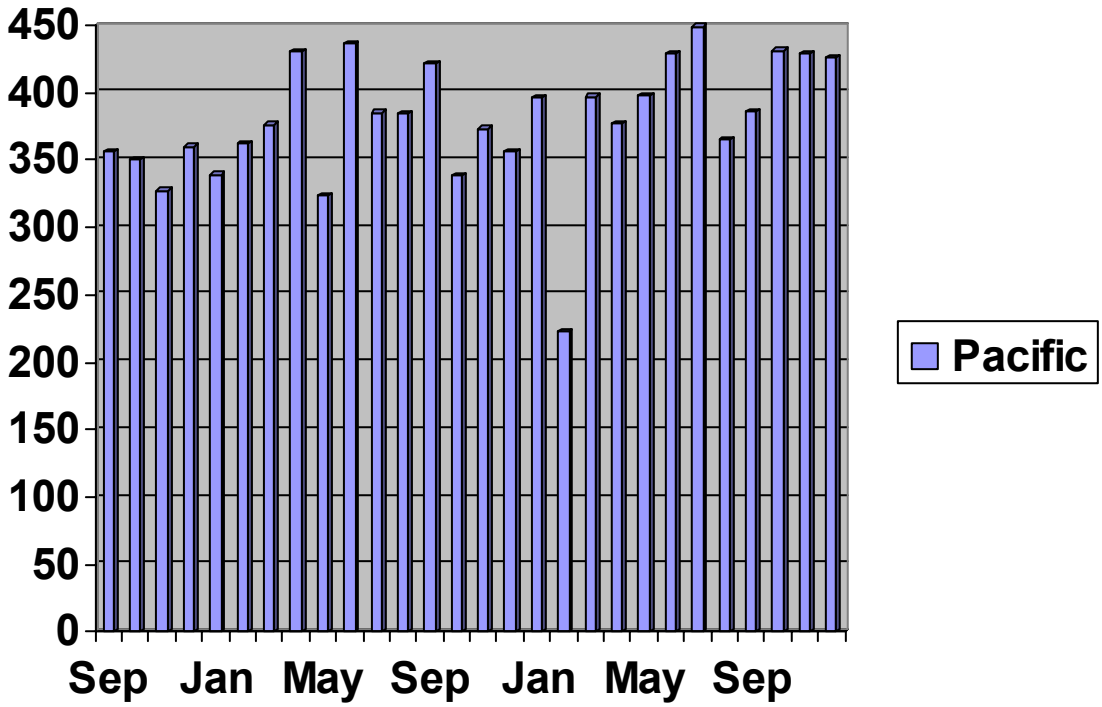
	2005 Last Four Months(a)	2006 Full Year(b)	2006 Last Four Months(a)	2007 Full Year(b)	2007 Last Four Months(a)
US East	684	446	309	321	260
US Gulf	791	858	763	800	851
US West	318	240	260	395	410
Overall US	704	709	614	677	706
European	258	242(c)	NA	NA	NA
Pacific	348	377	372	392	418
Other	734	656	661	720	853

(a) September to December 2005, 2006 or 2007.
(b) January to December 2006 or 2007.
(c) January to August 2006 only.

4.2.2 Pacific Regional and Other Regional Data

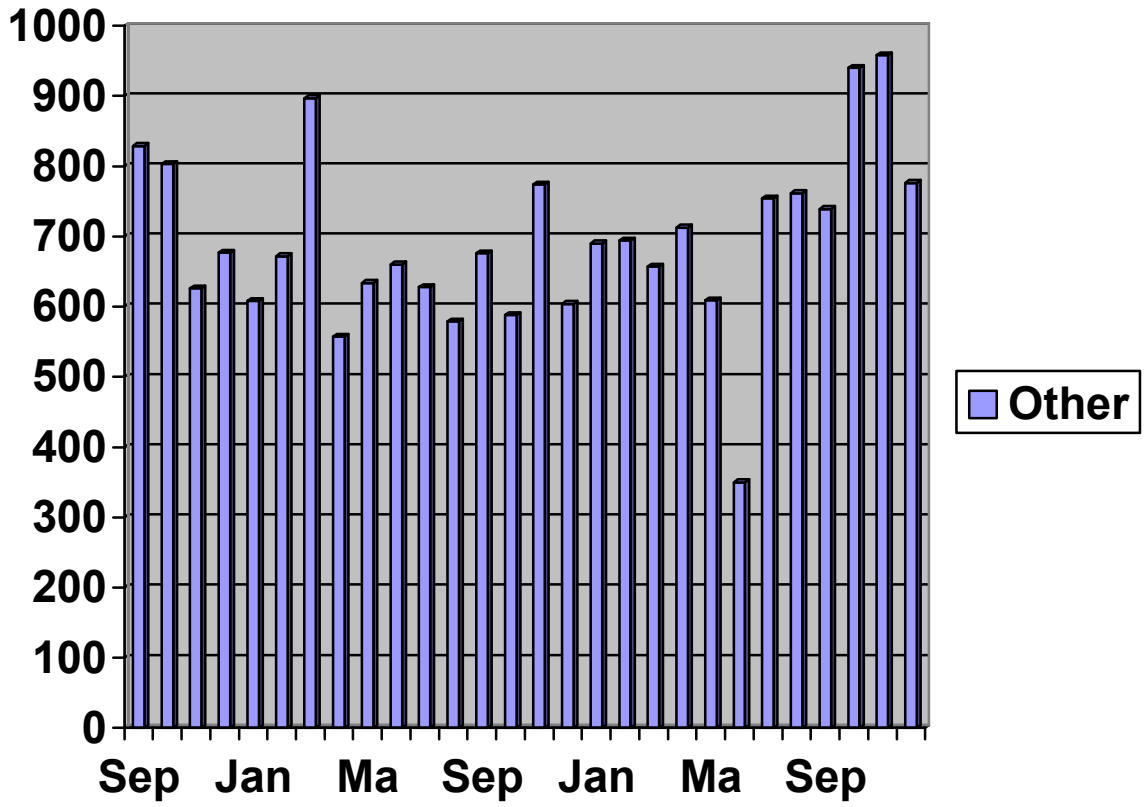
Data for the Pacific Region and the Other Region were obtained over the twenty eight month time period from September 2005 through December 2007. Detailed data are shown in the Appendix. In Figure 2 survey reported weighted mean sulfur values are shown for the Pacific Region, and in Figure 3 survey reported weighted mean sulfur values are shown for the Other Region; both plots starting with September 2005 and ending with December 2007.

Figure 2. Pacific Region Weighted Mean Sulfur, PPM S
September 2005 through December 2007



As shown in Table 3, for the Pacific Region the average of the monthly weighted mean sulfur values for the 2006 year (12 months) was 377 PPM S and for the 2007 year (12 months) was 392 PPM S. The weighted mean sulfur values for the last four month time periods over the three years covered by the survey was 348 PPM S in 2005, 372 PPM S for 2006 and 418 PPM S for 2007. Weighted mean sulfur values in the Pacific Region, thus, appear to be showing a small upward trend over time.

Figure 3. Other Region Weighted Mean Sulfur, PPM S
September 2005 through December 2007

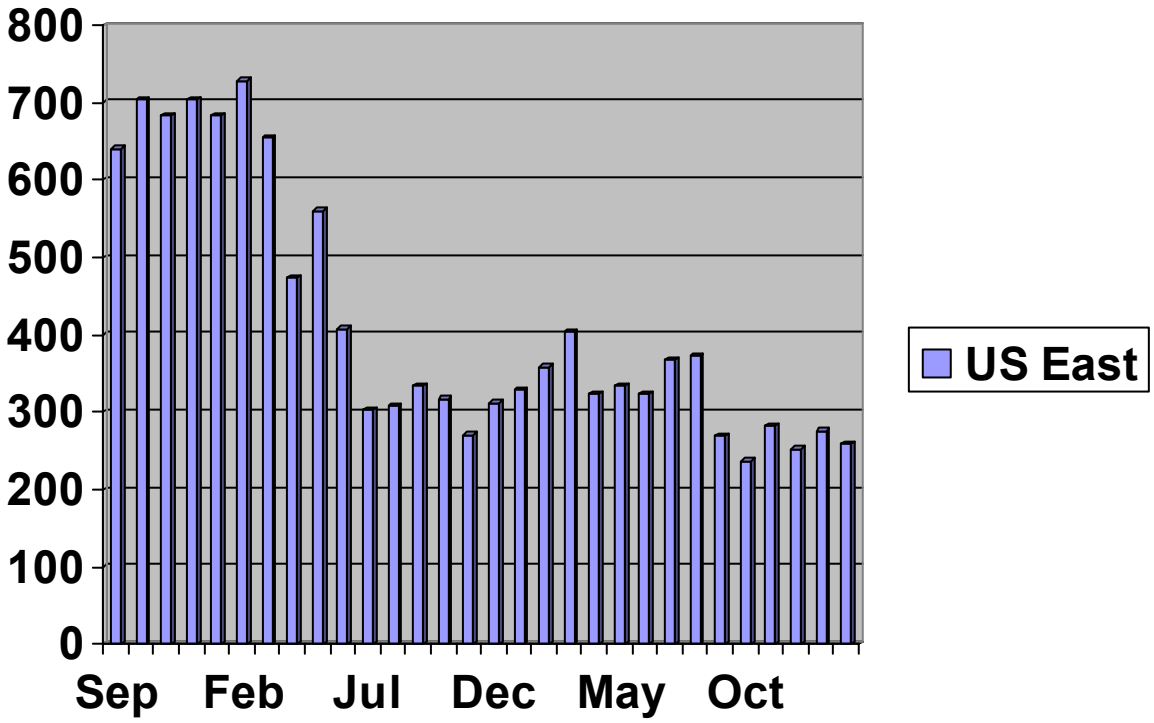


For the Other Region, as shown in Table 3, the average of the survey reported monthly weighted mean sulfur values for the 2006 year (12 months) was 656 PPM S and for the 2007 year (12 months) was 720 PPM S. Comparing the last four month time periods, the average weighted mean sulfur value for 2005 was 734 PPM S, for 2006 was 661 PPM S and for 2007 was 853 PPM S.

4.2.3. US Regional Data

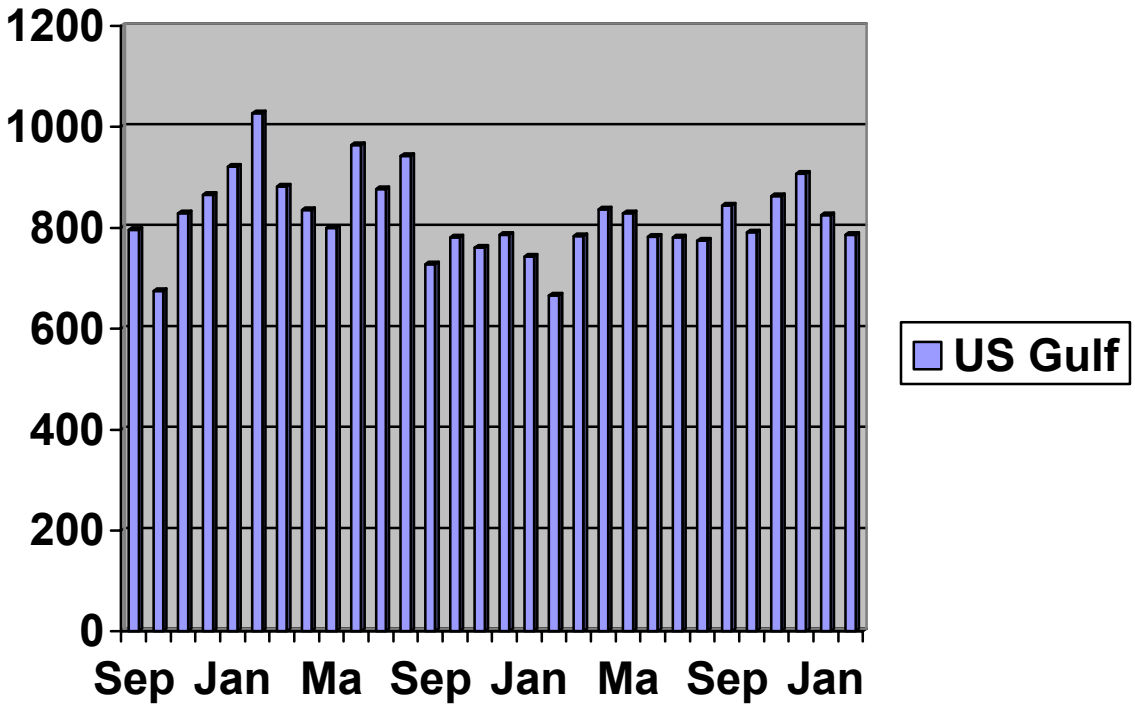
Survey data were obtained for all three regions, i.e. US East, US Gulf and US West, over the thirty month time period from September 2005 through February 2008. The weighted mean sulfur values for the three regions were also combined to obtain a volumetrically averaged US Overall Region weighted mean sulfur level for each month. The US mandated change to ultra low sulfur content Diesel fuel occurred in mid-2006, so that the CRC survey includes data both before and after this transition period. Detailed data are shown in the Appendix. In Figures 4, 5, 6 and 7 the US regional weighted mean survey sulfur values are plotted starting with September 2005 and ending with February 2008.

Figure 4. US East Region Weighted Mean Sulfur, PPM S
September 2005 through February 2008



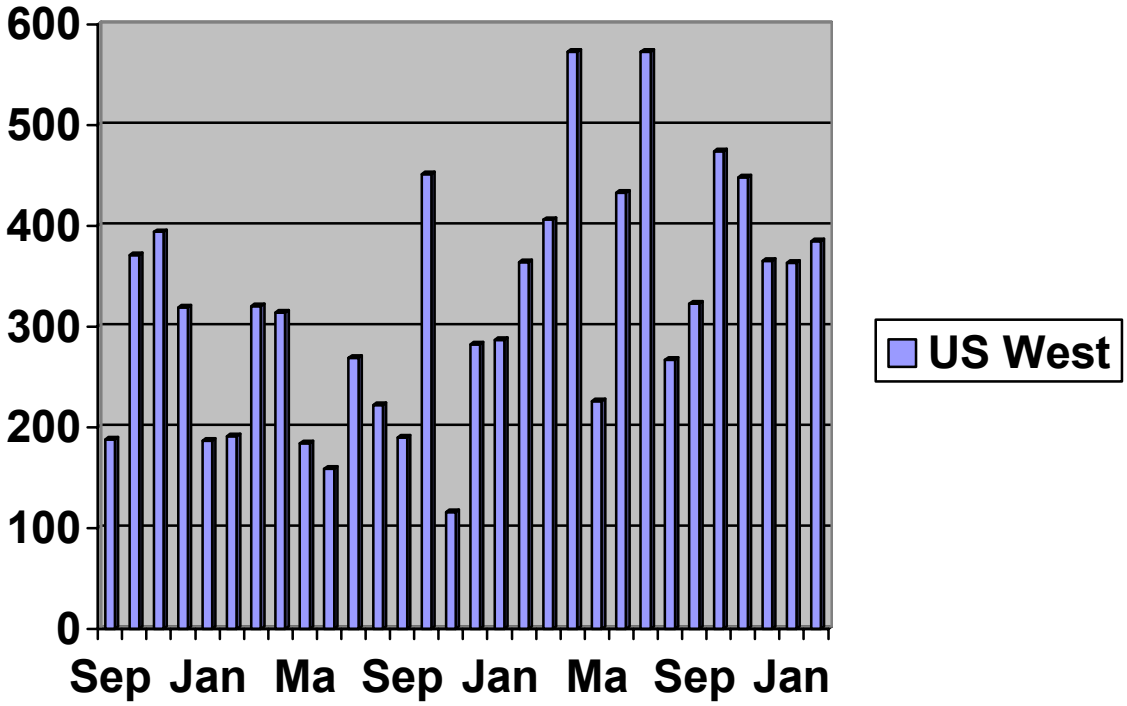
For the US East Region the average of the monthly weighted mean sulfur values for the 2006 year(12 months) was 446 PPM S and for the 2007 year (12 months) was 321 PPM S. The weighted mean sulfur values for the last four months time periods over the three years covered by the survey was 684 PPM S in 2005, 309 PPM S in 2006 and 260 PPM S in 2007. The weighted mean sulfur values in the US East Region dropped sharply over the April to July 2006 period, and do not show a clear indication at the end of the survey that they have completely leveled out.

Figure 5. US Gulf Region Weighted Mean Sulfur, PPM S
September 2005 through February 2008



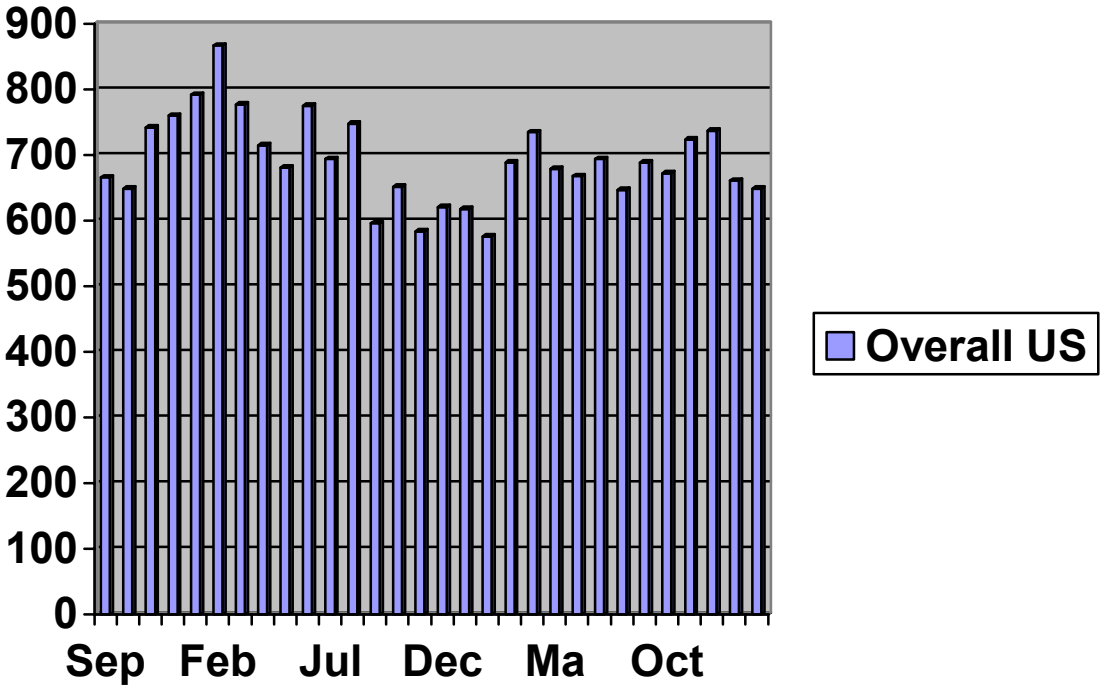
The average survey reported weighted mean sulfur values for the US Gulf Region, as shown in table 3, was 858 PPM S for the year 2006 (12 months) and 800 PPM S for the year 2007 (12 months). The weighted mean sulfur values for the last four month time periods over the three years covered by the survey was 791 PPM S for 2005, was 763 PPM S for 2006 and was 851 PPM S for 2007. Thus, although the US Gulf monthly weighted mean sulfur values varied somewhat over the 30 month survey period, the data does not exhibit a strong trend with time.

Figure 6. US West Region Weighted Mean Sulfur, PPM S
September 2005 through February 2008



The US West survey reported weighted mean sulfur values showed considerable month to month variation. The average weighted mean sulfur value, from Table 3, for the year 2006 (12 months) was 240 PPM S and for the year 2007 (12 months) was 395 PPM S. The weighted mean sulfur values for the last four month periods over the three years covered by the survey was 318 PPM S for 2005, was 260 PPM S for 2006 and was 410 PPM S for 2007. Results thus suggest that the US West Regions weighted mean sulfur levels varied with time in a complex manner, falling during the early part of the survey and then rising toward the end of the survey period. The later survey period data does not show clear evidence that the weighted mean sulfur level of the US West Region has leveled out.

Figure 7. Overall US Region Weighted Mean Sulfur, PPM S
September 2005 through February 2008



The survey reported average weighted mean sulfur value for the Overall US Region, from Table 3, for the year 2006 (12 months) was 709 PPM S and for the year 2007 (12 months) was 677 PPM S. The average weighted mean sulfur values for the last four month periods over the three years covered by the survey was 704 PPM S for 2005, was 614 PPM S for 2006 and was 706 PPM for 2007.

In general, the US East, US Gulf and US West Regions show differences in weighted mean sulfur levels; and also in the case of the US East and US West Regions different variations with time. However, in spite of these complexities, the weighted mean sulfur level of the Overall US Region was essentially the same when comparing the four month period at the end of 2005 (before the mandated change to ultra low sulfur Diesel fuel in mid 2006) to the same four month period at the end of 2007.

4.2.4 Comparison of Commercial and US Military Procured Jet Fuel

The geographical regions used in the CRC survey were defined to match up with the PQIS regions, as described in Section 3.4. In Table 4, the sulfur levels of commercial jet fuels seen in the CRC survey are compared with the sulfur levels of US military jet fuels procured by DESC, as reported in the PQIS annual reports (1, 2, 3). Relative to this comparison, a number of points should be noted. The quantity of commercial jet fuel which is produced is much larger than military jet fuel (4).The CRC survey reports weighted mean sulfur values based on the production of commercial jet fuel by individual refineries whereas the PQIS reports weighted mean sulfur values based on the volume of military fuel which was procured by DESC. In the US the composition of military JP-8 could differ somewhat from commercial Jet A whereas outside the US, such as in Europe, commercial Jet A-1 should have essentially the same composition as military JP-8.

Although the CRC individual US regions show somewhat different levels than the PQIS levels; the level seen in the CRC Overall US region compares well with the PQIS level. However, the European and Pacific levels are markedly lower.

Table 4. Comparison of CRC Survey Commercial Jet Fuel versus DESC Procured JP-8 Average Weighted Mean Sulfur Levels

CRC Region	Commercial Year 2006(a) PPM	DESC JP-8 Year 2006(a) PPM	Commercial Year 2007(b) PPM	DESC JP-8 Year 2007(b) PPM
US East	446	670	321	693
US Gulf	858	600	800	610
US West	240	564	395	544
US Overall	709	599	677	599
European	242 (c)	600	NA	1070
Pacific	377	1400	392	1330

(a) January to December 2006
(b) January to December 2007
(c) January to August 2006 (8 months)

4.3 Ultra Low Sulfur Jet Fuel Production

4.3.1 Trends in Volume Percent and Percent of Refineries

Survey results indicate that some refineries are producing very low sulfur levels and others are producing mid-range sulfur levels. Tables 5A and 5B summarize the survey reported occurrence of jet fuel with sulfur levels below 15 PPM S (which for purposes of this report only has been termed ultra low sulfur). Both the volume percent of ultra low sulfur (ULS) jet fuel (Volume %) and the percent of refineries who are producing ULS jet fuel (Refinery %) are shown. This data is reported in four month time periods from the beginning of the survey in September 2005 through December 2007. Results available for two month time period of January and February 2008 are also shown in Table 5B.

Table 5A. Survey Occurrence of Ultra Low Sulfur Jet Fuel (a) September 2005 to December 2006

Region		September to Decem 2005	January to April 2006	May to August 2006	September to Decem 2006
US East	Volume %	0.03	0.7	2.9	6.7
	Refinery %	2.1	7.8	14	17
US Gulf	Volume %	0	0.6	1.0	1.1
	Refinery %	0	2.8	7.0	5.8
US West	Volume %	27	27	26	28
	Refinery %	33	46	53	53
US Overall	Volume %	3.4	3.6	4.0	5.4
	Refinery %	9.4	16	20	21
European	Volume %	5.2	4.5	10	
	Refinery %	23	23	21	
Pacific	Volume %	8.4	8.9	16	14
	Refinery %	23	25	26	28

(a) Total sulfur content < 15 PPM S.

Table 5B. Survey Occurrence of Ultra Low Sulfur Jet Fuel (a)
January 2007 to February 2008

Region		January to April 2007	May to August 2007	September to December 2007	January and February 2008
US East	Volume %	12	10	13	9.4
	Refinery %	26	19	25	25
US Gulf	Volume %	1.2	0.8	1.3	1.1
	Refinery %	5.8	5.6	5.4	5.6
US West	Volume %	16	29	18	7.8
	Refinery %	39	45	30	24
US Overall	Volume %	4.6	5.1	4.4	3.4
	Refinery %	19	19	16	15
European	Volume %				
	Refinery %				
Pacific	Volume %	13	16	13	
	Refinery %	30	31	36	

(a) Total sulfur content < 15 PPM S.

The survey reported volume of ULS jet fuel produced in the Overall US Region ranged from 3.4% to 5.4% of the total jet fuel produced. Higher percentages were seen in the Pacific Region which ranged from 8.4% to 16%, and in the European Region which ranged from 4.5% to 10%.

In general, the survey reported percent of refineries producing ULS jet fuel was higher than the survey reported volume percent of ULS fuel again indicating that refineries producing lower sulfur content jet fuel, on average, are producing lower volumes of jet fuel. The survey reported percent of refineries producing ULS jet fuel for the four month survey periods from September 2005 to December 2007 are plotted for the European and Pacific Regions in Figure 8 and for the various US Regions in Figure 9.

Figure 8. Percent of Refineries Producing Ultra Low Sulfur Jet Fuel In the European and Pacific Regions. Four Month Periods: Sep 2005 To Dec 2007.

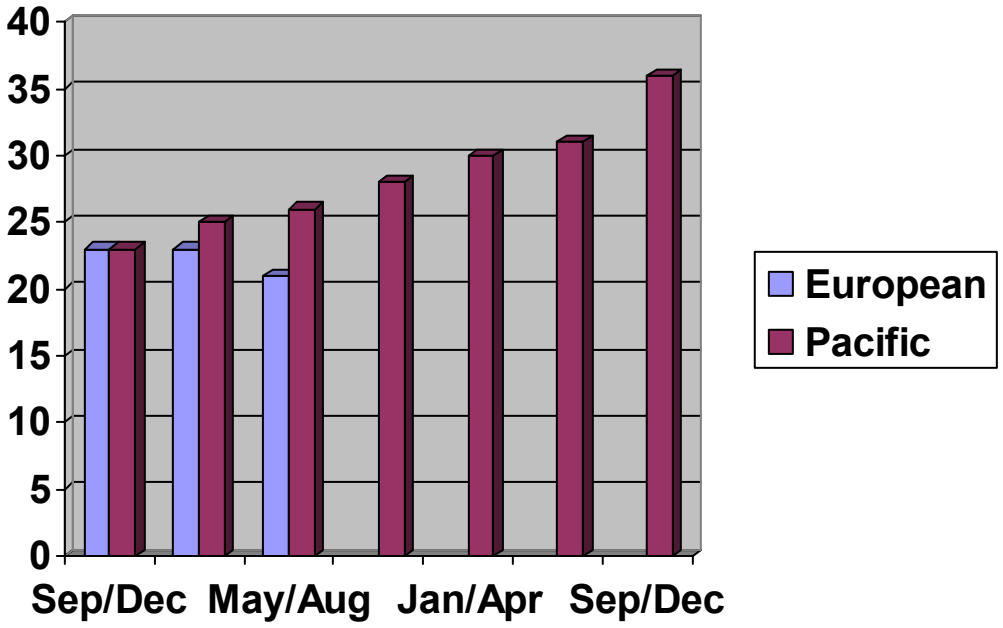
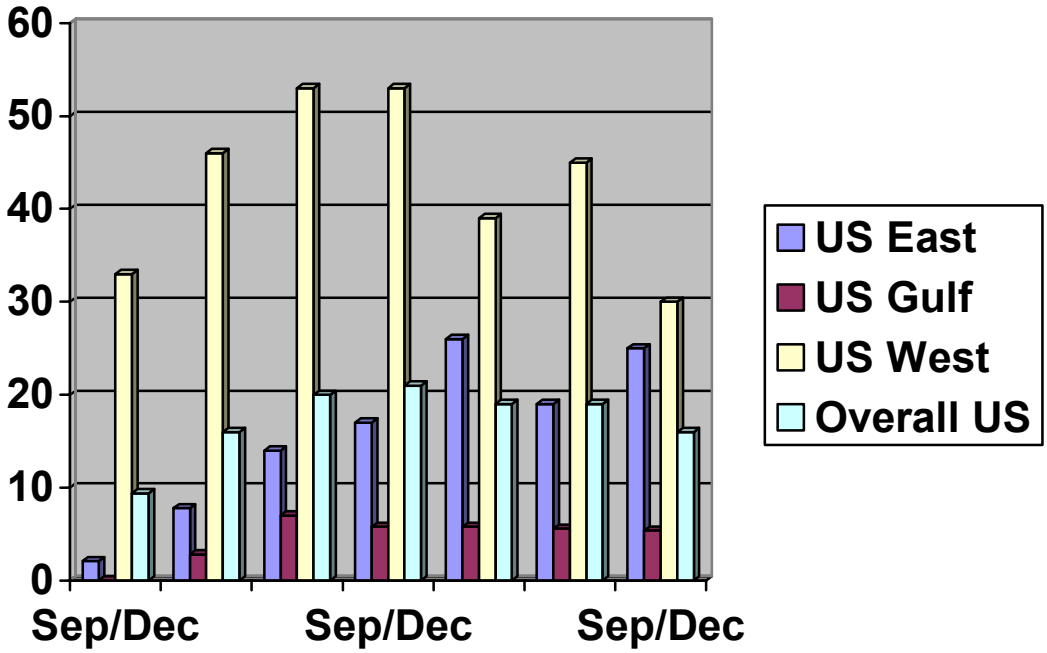


Figure 9. Percentage of Refineries Producing Ultra Low Sulfur Jet Fuel in the US Regions. Four Month Periods: September 2005 To December 2007.



The percentage of survey reported refineries producing ULS jet fuel during the first four months of the survey was 23% in both the European and Pacific Regions. The European Region level remained essentially the same over their one year survey participation period. In the Pacific Region the percent of refineries producing ULS jet fuel rose over the twenty eight month period of their survey participation to 36 %.The US survey results over the thirty month period of their participation are complex. In the US East Region the percent of refineries producing ULS jet fuel rose from 2% to 26%. In the US Gulf Region no refineries were producing ULS jet fuel at the start of the survey, and participation remained low throughout the survey period. In the US West Region at the beginning of the survey 33% of refineries were producing ULS jet fuel, which rose to over 50% in late 2006 and then declined over the rest of the survey period. The Overall US Region survey results show a rise and fall in the percent of refineries producing ULS jet fuel; starting with 9.1%, rising to 21% and then falling back to a lower range.

4.3.2 Potential Effects of Processing to Ultra Low Sulfur Levels

The severe hydro-desulfurization processing used to achieve ultra low sulfur levels in distillates can affect other jet fuel properties by removing various compounds normally present. For example, drastically lower sulfur levels could signal possible lubricity problems in jet fuel (5). Severe hydrotreating could also reduce the electrical conductivity of jet fuel, to which no conductivity improver additive has been added, relative to that of a typical mid-range sulfur level fuel (6). Severe hydrotreating can also remove naturally occurring antioxidants, which could result in hydroperoxide formation during storage in the absence of an added antioxidant additive (7).

5.0 Conclusions

A survey of the sulfur levels of commercial jet fuel was completed covering the two and one half year period from September 2005 to February 2008. The CRC survey received over 1,600 individual, confidential, monthly refinery reports from different parts of the world. Statistical data were reported using CRC defined regions as follows: US East Region, US Gulf Region, US West Region, Overall US Region (combining the US East, Gulf and West regions), European Region, Pacific Region and the Other Region. The refineries also provided confidential monthly jet fuel production rates which were used to calculate volumetrically averaged sulfur values (which were termed weighted mean sulfur) for each month and region.

Results did not show in any region surveyed that jet fuel sulfur increased to a level near the maximum specification limit (typically 3000 PPM S). The Overall US Region survey results indicated that the average weighted mean sulfur level for the last four months of 2005 was 704 PPM S, for the full year 2006 was 709 PPM S and for the full year 2007 was 677 PPM S. The European Region survey results indicated that the average weighted mean sulfur for the last four months of 2005 was 258 PPM S and for the first eight months of 2006 was 242 PPM S. The Pacific Region survey results indicated that the average weighted mean sulfur for the last four months of 2005 was 348 PPM S, for the full year 2006 was 377 PPM S and for the full year 2007 was 392 PPM S. The Other Region survey results indicated that the average weighted mean sulfur for the last four months of 2005 was 734 PPM S, for the full year 2006 was 656 PPM S and for the full year 2007 was 720 PPM S. The maximum individual refinery monthly sulfur level reported by any US Region was 2250 PPM S, by the European Region was 1600 PPM S, by the Pacific Region was 940 PPM S and by the Other Region was 1590 PPM S.

Results indicate that the production methodology for jet fuel is complex, varies significantly from region to region, has changed and may be still changing with time at the end of the survey. Significant differences exist in the level of jet fuel sulfur being produced by individual refineries, with many refineries producing mid-range sulfur levels while other refineries are producing jet fuel with less than 15 PPM S (termed for purposes of this report only as ultra low sulfur).

By the end of the survey most regions were producing ultra low sulfur (ULS) jet fuel to varying extents. In general, the percentage of refineries producing ULS jet fuel was greater than the volume percent of fuel produced, indicating that refineries producing ULS jet fuel, on average, were producing smaller volumes of jet fuel than refineries producing higher sulfur levels. The reported volume of ULS jet fuel produced over the survey period ranged from 3.4% to 5.4% in the Overall US Region, from 4.5% to 10% in the European Region and from 8.4% to 16% in the Pacific Region.

The percentage of refineries producing ULS jet fuel reported to the survey in Europe ranged from 21% to 23%; while in the Pacific Region the percent rose from 23% to 36%. The Pacific Region data did not show evidence of having reached a stable level by the

end of the survey period. The US data on percent of refineries producing ULS jet fuel showed a complex pattern. In the US East Region over the survey period the reported percent of refineries producing ULS jet fuel rose from 2.1% to 26%, and did not show clear evidence that it had reached a stable level by the end of the survey. At the start of the survey period there were no reported refineries in the US Gulf Region producing ULS jet fuel; and during later periods of the survey they remained at a very low level. In the US West Region the percent of reported refineries producing ULS jet fuel rose initially from 33% to over 50% in late 2006, and then fell back substantially. The percent of refineries producing ULS jet fuel in the US West Region also did not show clear evidence of having stabilized by the end of survey. The Overall US Region percent of reported refineries producing ULS jet fuel rose initially from 9.1% to 21% in late 2006, and then declined somewhat over the rest of the survey period.

The severe hydrodesulfurization processing used to achieve ultra low sulfur levels in distillates can remove various compounds normally present in jet fuel, and could affect jet fuel product quality in areas such as lubricity, electrical conductivity and hydroperoxide formation.

Estimates indicated that the percent of the CRC reported survey volume compared to the total jet fuel production volume was 55% for the Overall US Region, 17% for the European Region, 20% for the Pacific Region and 3% for the Other Region. The larger the survey sample size the greater the probability that the measured weighted mean sulfur value will be closer to the actual total jet fuel sulfur. A comparison of weighted mean sulfur levels from the CRC survey of commercial jet fuel to DESC procured military JP-8 data showed that the Overall US region data compared well but that the survey results for European Region and Pacific Region were lower.

6.0 References

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Acknowledgements

The CRC survey of the sulfur levels of commercial jet fuel received over 1,600 individual, confidential refinery reports from all over the world during a two and one half year data collection period. The successful completion of a survey of this magnitude and length was the result of the highly dedicated commitment and very hard work by a large number of organizations and individuals. Unfortunately, because of the confidential nature of the survey these organizations and individuals cannot be acknowledged by name. However, the world wide aviation fuel technical community owes them a great debt of gratitude for the success of the survey.

Appendix

Appendix Descriptors

(1) JP-8 data for the years 2005, 2006 and 2007 was obtained from the US Defense Logistics Agency, Defense Energy Support Center (DESC), Petroleum Quality Information System (PQIS) reports of DESC procured fuels for these years. The PQIS reports also included data on Jet A-1 refined or imported into the UK (provided by QinetiQ Ltd on behalf of the UK MOD) which showed weighted mean total sulfur values of 560 for 2005, 550 PPM for 2006 and 480 PPM for 2007.

(2) The total number of refineries from all companies reporting for a given region and month.

(3) CRC Regions US East, US Gulf and US West combined.

Table 6A
Jet Fuel Sulfur Survey 2005 Data

CRC Region		September	October	November	December	JP-8 2005 (1)
US East	Mean S, PPM	571	677	551	623	
	Wt Mean S, PPM	640	709	683	704	755
	S Min, PPM	60	60	10	90	
	S Max, PPM	1481	1575	1350	1320	
	No. Refiners.(2)	12	11	12	11	
US Gulf	Mean S, PPM	771	652	732	760	
	Wt Mean S, PPM	795	675	829	865	500
	S Min, PPM	130	46	15	25	
	S Max, PPM	1700	2200	2080	1700	
	No. Refiners (2)	16	16	20	18	
US West	Mean S, PPM	144	193	249	175	
	Wt Mean S, PPM	188	371	394	319	445
	S Min, PPM	2	1	2	1	
	S Max, PPM	772	1459	1887	1200	
	No. Refiners (2)	10	11	11	11	
Overall US(3)	Mean S, PPM	543	526	558	561	
	Wt Mean S, PPM	666	649	742	760	516
	No. Refiners (2)	38	38	43	40	
European	Mean S, PPM	279	249	213	217	
	Wt Mean S, PPM	285	242	235	268	1000
	S Min, PPM	4	5	2	5	
	S Max, PPM	1600	1400	1200	1200	
	No. Refiners (2)	11	11	11	11	
Pacific	Mean S, PPM	330	339	341	335	
	Wt Mean S, PPM	356	350	327	360	1100
	S Min, PPM	6	5	4	6	
	S Max, PPM	860	850	830	850	
	No. Refiners (2)	11	11	11	11	
Other	Mean S, PPM	564	648	479	616	
	Wt Mean S, PPM	829	803	626	677	NA
	S Min, PPM	43	100	100	100	
	S Max, PPM	1330	1440	1250	1280	
	No. Refiners (2)	6	5	6	5	

Table 6B
Jet Fuel Sulfur Survey 2006 Data

CRC Region		January	February	March	April	JP-8 2006 (1)
US East	Mean S, PPM S Wt Mean S, PPM S Min, PPM S Max, PPM No. Refiners(2)	569 682 20 1451 11	462 728 10 1723 10	489 654 60 1263 10	444 474 10 1100 9	670
US Gulf	Mean S, PPM Wt Mean S, PPM S Min, PPM S Max, PPM No. Refiners(2)	742 921 19 2000 19	740 1026 10 1936 18	642 881 7 1600 18	708 835 17 1800 19	600
US West	Mean S, PPM Wt Mean S, PPM S Min, PPM S Max, PPM No. Refiners(2)	133 187 1 574 11	150 191 1 600 11	242 320 2 1255 9	200 314 1 1014 10	564
Overall US(3)	Mean S, PPM Wt Mean S, PPM No. Refiners(2)	532 792 41	499 867 39	504 777 37	515 715 38	599
European	Mean S, PPM Wt Mean S, PPM S Min, PPM S Max, PPM No. Refiners(2)	231 293 5 1200 11	209 253 5 1000 10	223 242 5 1200 11	220 246 5 1000 11	600
Pacific	Mean S, PPM Wt Mean S, PPM S Min, PPM S Max, PPM No. Refiners(2)	326 339 4 810 11	333 362 5 880 11	340 376 5 850 11	391 430 4 856 11	1400
Other	Mean S, PPM Wt Mean S, PPM S Min, PPM S Max, PPM No. Refiners(2)	562 608 100 1344 6	641 672 100 1529 6	619 897 100 1470 6	495 557 22 1068 6	NA

Table 6C
Jet Fuel Sulfur Survey 2006 Data

CRC Region		May	June	July	August	JP-8 2006(1)
US East	Mean S, PPM S	524	432	318	342	
	Wt Mean S, PPM	560	408	304	308	670
	S Min, PPM	10	3	5	5	
	S Max, PPM	1165	1350	1230	1190	
	No. Refiners(2)	10	11	11	10	
US Gulf	Mean S, PPM	711	809	748	779	
	Wt Mean S, PPM	800	964	876	942	600
	S Min, PPM	1	1	1	1	
	S Max, PPM	2060	2000	2000	2000	
	No. Refiners(2)	20	18	19	19	
US West	Mean S, PPM	123	97	143	124	
	Wt Mean S, PPM	184	159	269	222	564
	S Min, PPM	1	1	2	1	
	S Max, PPM	473	505	805	626	
	No. Refiners(2)	10	10	11	11	
Overall US(3)	Mean S, PPM	517	520	467	483	
	Wt Mean S, PPM	681	775	694	748	599
	No. Refiners(2)	40	39	41	40	
European	Mean S, PPM	222	242	278	297	
	Wt Mean S, PPM	244	254	228	176	600
	S Min, PPM	5	2	3	1	
	S Max, PPM	1100	1200	1400	1400	
	No. Refiners(2)	11	11	11	9	
Pacific	Mean S, PPM	346	379	375	375	
	Wt Mean S, PPM	324	436	385	384	1400
	S Min, PPM	5	6	6	6	
	S Max, PPM	856	896	910	940	
	No. Refiners(2)	10	9	9	9	
Other	Mean S, PPM	516	601	528	418	NA
	Wt Mean S, PPM	634	660	628	579	
	S Min, PPM	14	16	19	13	
	S Max, PPM	1153	1288	1260	1430	
	No. Refiners(2)	6	6	6	6	

Table 6D
Jet Fuel Sulfur Survey 2006 Data

CRC Region		Septem	October	Novem	Decem	JP-8 2006 (1)
US East	Mean S, PPM S Wt Mean S, PPM S Min, PPM S Max, PPM No. Refiners(2)	422 334 5 1430 9	376 317 6 1340 9	352 271 5 1030 9	397 312 5 1360 9	670
US Gulf	Mean S, PPM Wt Mean S, PPM S Min, PPM S Max, PPM No. Refiners(2)	628 727 1 1510 19	744 781 1 2004 16	773 760 1 1880 17	714 785 1 1800 17	600
US West	Mean S, PPM Wt Mean S, PPM S Min, PPM S Max, PPM No. Refiners(2)	136 190 2 692 11	215 451 1 1449 10	72 116 2 384 9	143 282 1 1042 10	564
Overall US(3)	Mean S, PPM Wt Mean S, PPM No. Refiners(2)	438 596 39	492 652 35	483 584 35	472 621 36	599
European	Mean S, PPM Wt Mean S, PPM S Min, PPM S Max, PPM No. Refiners(2)					600
Pacific	Mean S, PPM Wt Mean S, PPM S Min, PPM S Max, PPM No. Refiners(2)	394 421 4 918 9	365 338 4 875 9	407 373 3 855 9	395 356 6 880 9	1400
Other	Mean S, PPM Wt Mean S, PPM S Min, PPM S Max, PPM No. Refiners(2)	569 676 12 1440 6	398 588 18 1330 5	484 774 85 1350 4	407 604 68 930 4	NA

Table 6E
Jet Fuel Sulfur Survey 2007 Data

CRC Region		January	February	March	April	JP-8 2007(1)
US East	Mean S, PPM S	412	441	410	420	
	Wt Mean S, PPM	329	359	403	323	693
	S Min, PPM	6	6	4	4	
	S Max, PPM	1380	1430	1350	1400	
	No. Refiners(2)	9	8	9	8	
US Gulf	Mean S, PPM	690	649	733	734	
	Wt Mean S, PPM	743	666	783	836	610
	S Min, PPM	1	1	1	1	
	S Max, PPM	1800	1950	1770	2250	
	No. Refiners(2)	18	16	17	18	
US West	Mean S, PPM	201	223	211	330	
	Wt Mean S, PPM	287	364	406	573	544
	S Min, PPM	2	2	2	4	
	S Max, PPM	1056	1260	1029	1430	
	No. Refiners(2)	9	9	8	7	
Overall US(3)	Mean S, PPM	492	476	519	562	
	Wt Mean S, PPM	618	576	689	735	599
	No. Refiners(2)	36	33	34	33	
European	Mean S, PPM					
	Wt Mean S, PPM					1070
	S Min, PPM					
	S Max, PPM					
	No. Refiners(2)					
Pacific	Mean S, PPM	381	323	374	336	
	Wt Mean S, PPM	396	223	397	377	1330
	S Min, PPM	6	5	4	5	
	S Max, PPM	801	879	876	872	
	No. Refiners(2)	10	9	10	11	
Other	Mean S, PPM	423	445	440	485	NA
	Wt Mean S, PPM	690	694	657	713	
	S Min, PPM	73	49	68	61	
	S Max, PPM	1120	1260	1000	1200	
	No. Refiners(2)	4	4	4	4	

Table 6F
Jet Fuel Sulfur Survey 2007 Data

CRC Region		May	June	July	August	JP-8 2007(1)
US East	Mean S, PPM S	404	350	336	381	
	Wt Mean S, PPM	335	324	368	372	693
	S Min, PPM	5	5	3	4	
	S Max, PPM	1300	1070	1090	1090	
	No. Refiners(2)	8	8	9	9	
US Gulf	Mean S, PPM	703	694	755	704	
	Wt Mean S, PPM	828	782	780	774	610
	S Min, PPM	1	2	2	3	
	S Max, PPM	1750	2000	2010	1700	
	No. Refiners(2)	18	18	18	18	
US West	Mean S, PPM	153	306	252	154	
	Wt Mean S, PPM	226	433	573	267	544
	S Min, PPM	2	2	9	1	
	S Max, PPM	767	1383	1538	859	
	No. Refiners(2)	8	8	8	9	
Overall US(3)	Mean S, PPM	494	505	532	486	
	Wt Mean S, PPM	679	668	694	647	599
	No. Refiners(2)	34	34	35	36	
European	Mean S, PPM					
	Wt Mean S, PPM					1070
	S Min, PPM					
	S Max, PPM					
	No. Refiners(2)					
Pacific	Mean S, PPM	330	352	335	330	
	Wt Mean S, PPM	398	429	449	365	1330
	S Min, PPM	5	6	6	5	
	S Max, PPM	870	910	930	940	
	No. Refiners(2)	9	10	10	10	
Other	Mean S, PPM	449	289	505	532	NA
	Wt Mean S, PPM	609	350	754	762	
	S Min, PPM	64	67	80	99	
	S Max, PPM	1000	500	1290	1430	
	No. Refiners(2)	4	4	4	4	

Table 6G
Jet Fuel Sulfur Survey 2007 Data

CRC Region		September	October	November	December	JP-8 2007 (1)
US East	Mean S, PPM S Wt Mean S, PPM S Min, PPM S Max, PPM No. Refiners(2)	332 269 5 1090 8	287 237 4 930 8	366 283 6 970 8	295 253 6 1000 8	693
US Gulf	Mean S, PPM Wt Mean S, PPM S Min, PPM S Max, PPM No. Refiners(2)	775 843 4 1700 18	680 791 4 1600 18	776 863 3 1900 19	785 907 3 2000 19	610
US West	Mean S, PPM Wt Mean S, PPM S Min, PPM S Max, PPM No. Refiners(2)	167 323 2 1031 9	228 474 2 1340 8	244 448 2 1508 8	253 365 6 1452 8	544
Overall US(3)	Mean S, PPM Wt Mean S, PPM No. Refiners(2)	502 689 35	485 672 34	560 724 35	551 737 35	599
European	Mean S, PPM Wt Mean S, PPM S Min, PPM S Max, PPM No. Refiners(2)					1070
Pacific	Mean S, PPM Wt Mean S, PPM S Min, PPM S Max, PPM No. Refiners(2)	331 386 5 890 10	257 431 5 790 8	221 429 5 810 8	230 426 5 800 8	1330
Other	Mean S, PPM Wt Mean S, PPM S Min, PPM S Max, PPM No. Refiners(2)	541 739 75 1590 4	545 940 99 1400 4	670 958 91 1430 4	500 776 79 1130 4	NA

Table 6H
Jet Fuel Sulfur Survey 2008 Data

CRC Region		January	February
US East	Mean S, PPM S	351	326
	Wt Mean S, PPM	276	259
	S Min, PPM	5	5
	S Max, PPM	1030	1050
	No. Refiners(2)	8	8
US Gulf	Mean S, PPM	743	693
	Wt Mean S, PPM	824	785
	S Min, PPM	3	4
	S Max, PPM	2000	1800
	No. Refiners(2)	18	18
US West	Mean S, PPM	238	215
	Wt Mean S, PPM	363	385
	S Min, PPM	2	2
	S Max, PPM	1347	1481
	No. Refiners(2)	8	9
Overall US(3)	Mean S, PPM	532	486
	Wt Mean S, PPM	661	649
	No. Refiners(2)	34	35
European	Mean S, PPM		
	Wt Mean S, PPM		
	S Min, PPM		
	S Max, PPM		
	No. Refiners(2)		
Pacific	Mean S, PPM		
	Wt Mean S, PPM		
	S Min, PPM		
	S Max, PPM		
	No. Refiners(2)		
Other	Mean S, PPM		
	Wt Mean S, PPM		
	S Min, PPM		
	S Max, PPM		
	No. Refiners(2)		