

**CRC Project AV-1-10**

**UPDATE OF THE  
SURVEY OF SULFUR LEVELS IN  
COMMERCIAL JET FUEL**

**Final Report**

**November 2012**



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(CRC Project AV-1-10)

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prepared by

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CRC Aviation Committee  
of the  
Coordinating Research Council

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## 1.0 Summary

An update of the CRC (Coordinating Research Council) survey of the sulfur levels in commercial Jet fuel has been completed. Refinery reports were obtained for the four (4) month period September to December 2010 for the same six CRC Regions covered in the original survey. Data from the US East, US Gulf, US West, Pacific and Other Regions were obtained by the Aviation Research Committee of the CRC. Data for the European Region was obtained by the Aviation Fuel Ad Hoc Group of CONCAWE (the oil companies' European Organization for Environment, Health and Safety).

Weighted mean sulfur levels measured in 2010 for the East, Gulf, West and Overall US Regions, the European Region and the Pacific Region are well below the typical 3,000 PPM sulfur (S) maximum specification limit. The four month averaged weighted mean sulfur level in the Overall US Region was 544 PPM S, in the European Region was 500 PPM S and in the Pacific Region was 830 PPM S. The 2010 weighted mean sulfur level for the Overall US Region dropped 23% from the three year earlier 2007 level.

Statistical data were also reported for the ultra-low sulfur (<15 PPM S) jet fuel production in the US East, Gulf, West and Overall Regions, the European Region and the Pacific Region.

The updated survey has brought the European Region data forward in time five (5) years, and the data in the other Regions forward in time three (3) years. Also the estimated sample size for the European Region was increased from 17% to 67.2 %, and the sample size for the Overall US Region increased from 55% to 62%. A larger survey sample size increases the statistical significance of the measured weighted mean sulfur levels and other reported values.

## **2.0 Introduction**

The Aviation Research Committee of the Coordinating Research Council (CRC) in conjunction with the Aviation Fuel Ad Hoc Group of CONCAWE has conducted a survey of the total sulfur levels of commercial aviation turbine fuel over the four (4) month period of September through December 2010. The primary purpose was to update the CRC jet fuel sulfur survey which covered the thirty (30) month period of September 2005 through February 2008 (1).

The survey is a voluntary, confidential, informational directed program. It reports data on jet fuel sulfur levels in CRC geographically defined regions over the six (6) year span from 2005 through 2010. The goal of the survey is to provide a data based tool to help the world- wide aviation fuel technical community reach informed conclusions and make appropriate decisions relative to this subject.

## **3.0 Details of the Update Survey**

### **3.1 Timing**

The update survey data collection covered the four (4) month period from September to December 2010. The original survey data collection covered the two and one half year (30 month) period from September 2005 through February 2008. Thus, the data from the September to December four month period in 2010 can be directly compared to data obtained in the same four month period in 2005, 2006 and 2007. The overall CRC survey spans the six (6) years from 2005 through 2010 inclusive.

### **3.2 Confidentiality**

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

### **3.3 Data Requested**

Participation in the initial survey was not a requirement for participation in the update survey. Organizations were requested to provide the following information about commercial aviation turbine fuel produced by each refinery for the four months of the update survey.

1. The name, or other identification, and location of each refinery.
2. The grade of the commercial jet fuel produced.
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. The 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 in the update survey are the same as defined in the initial survey (1). The CRC regions are used in reporting averaged data obtained from individual refineries. The CRC Jet Fuel Sulfur Survey regions are shown in Table 1. The CRC regions were defined to match up with the Petroleum Quality Information System (PQIS) regions. 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**

<b>CRC Region</b>	<b>PQIS Regions (e)</b>	<b>PADDS (f)</b>	<b>Description</b>
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 and 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

(e) US Defense Logistics Agency, Energy – Petroleum Quality Information System

(f) US Department of Energy- Petroleum Administration for Defense Districts

### 3.5 Data Reporting

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 number of refineries reporting for that region and month. Weighted mean values (Wt Mean) are the sum of individual jet fuel sulfur values times the average monthly production rate for that individual refinery divided by the total reported jet fuel production rate for that region and month. The minimum (Min) and maximum (Max) sulfur values for each region are also included, as well as the number of refineries which reported data.

### 3.6 Estimation of the Regional Sample Sizes

An estimate was made of the magnitude of the regional sample sizes obtained by the update survey. The estimates were made by comparing the volume of jet fuel produced by refineries participating in the survey to the total jet fuel production for that region. The estimated regional sample sizes and number of refineries who participated are shown in Table 2. The Overall US is the combination of the East, Gulf and West US Regions. Corresponding values from the initial survey are also shown (1).

**Table 2. Estimates of Regional Sample Sizes**

<b>CRC Region</b>	<b>Initial Survey Est. Volume %</b>	<b>Initial Survey Ave. Number Refineries (e)</b>	<b>Update Survey Est. Volume %</b>	<b>Update Survey Ave. Number Refineries (e)</b>
Overall US	55% (a)	36.8 (a)	62% (d)	31.5 (d)
European	17% (b)	10.7 (b)	67.2% (d)	41 (d)
Pacific	20% (c)	9.7 (c)	16% (d)	9.5 (d)
Other	3% (c)	4.8 (c)	2 % (d)	5 (d)

(a) September 2005 through February 2008. (b) September 2005 to August 2006.

(c) September 2005 through December 2007. (d) September 2010 to December 2010.

(e) Average number of monthly refinery reports received over the indicated periods.

## **4.0 Survey Results**

### **4.1 CRC: US East, Gulf and West Regions, Pacific Region and Other Region**

Detailed results obtained by CRC for the September through December 2010 Update Survey data collection period are shown in Table 3. A comparison of the time averaged weighted mean sulfur values for the four month September through December periods obtained in the Initial Survey for 2005, 2006 and 2007 and obtained in the Update Survey for 2010 is shown in Table 4 and Figure 1. A similar comparison of ultra-low sulfur jet fuel production is shown in Table 5.

The data shows that in the Overall US Region the weighted mean sulfur level in 2010 compared to the same period in 2007 decreased 23%, dropping from 706 PPM S to 544 PPM S. US Regional results comparing 2010 weighted mean sulfur levels to the 2007 levels showed that East Region level remained essentially the same at approximately 260 PPM S, the Gulf Region level dropped 223 PPM S from 851 to 628 PPM S, and West Region level rose 118 PPM S from 410 to 528 PPM S.

In the Pacific Region the weighted mean sulfur of 418 PPM S in 2007 rose to 830 PPM S in 2010, continuing to exhibit the same rising trend observed in the 2005 through the 2007 results. In the Other Region weighted mean sulfur levels are lower in the Update Survey than obtained in the Initial Survey.

In the Overall US Region, ultra-low sulfur jet fuel production volume % increased from 4.4% to 8.0%, and refinery % increased from 16% to 25% in 2010 versus 2007. This suggests that increased ultra-low sulfur jet fuel production is one of the factors responsible for the decrease in weighted mean sulfur level.

**Table 3. Jet Fuel Sulfur Survey 2010 Update Results for the US, Pacific & Other Regions**

CRC Region		September	October	November	December
US East	Mean S, PPM	323	354	227	249
	Wt Mean S, PPM	290	290	220	240
	S Min, PPM	3	3	5	7
	S Max, PPM	802	808	800	921
	No. Refineries	9	7	8	8
US Gulf	Mean S, PPM	559	661	661	656
	Wt Mean S, PPM	581	640	652	638
	S Min, PPM	1	3	2	2
	S Max, PPM	1982	1470	1303	1355
	No. Refineries	13	14	14	14
US West	Mean S, PPM	383	470	284	318
	Wt Mean S, PPM	633	565	438	476
	S Min, PPM	1	1	1	1
	S Max, PPM	1300	2400	1165	1150
	No. Refineries	9	10	10	10
Overall US	Mean S, PPM	439	530	434	449
	Wt Mean S, PPM	532	570	534	541
	No. Refineries	31	31	32	32
Pacific	Mean S, PPM	302	324	308	308
	Wt Mean S, PPM	774	840	815	889
	S Min, PPM	3	3	3	3
	S Max, PPM	1500	1500	1400	1500
	No. Refineries	10	9	9	10
Other Region	Mean S, PPM	243	298	263	297
	Wt Mean S, PPM	194	179	192	205
	S Min, PPM	28	27	27	25
	S Max, PPM	503	550	587	638
	No. Refineries	5	5	5	5

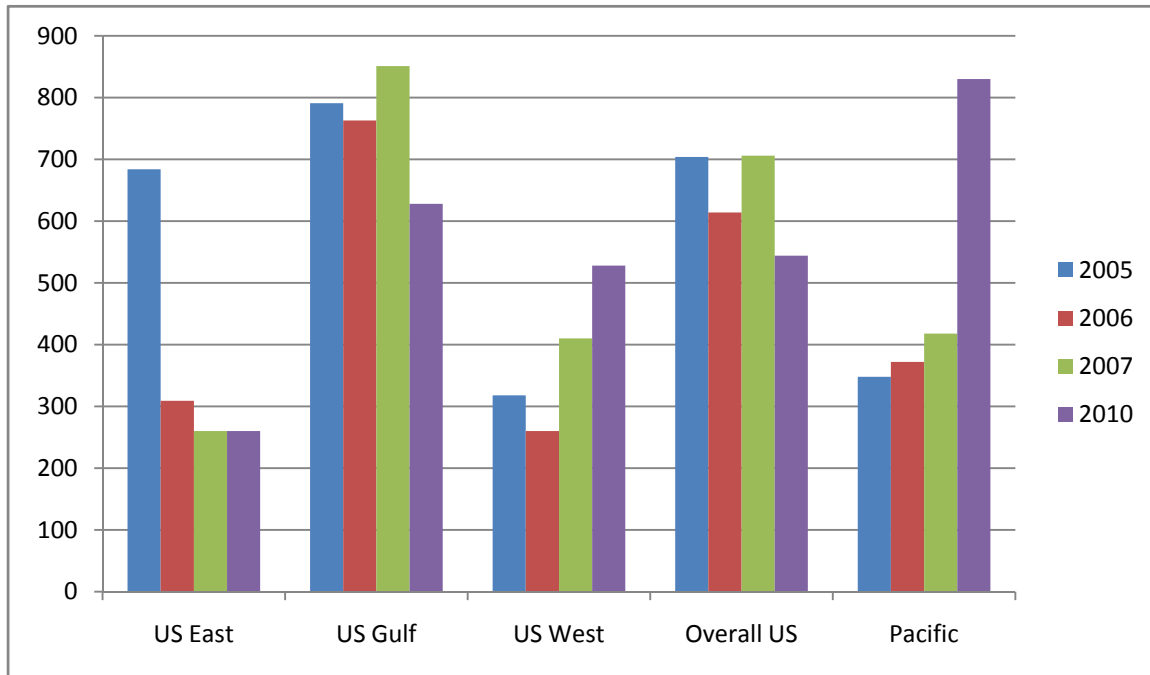
**Table 4. Time Averaged September to December Period Weighted Mean Sulfur, PPM S**

CRC Region	Initial Survey 2005	Initial Survey 2006	Initial Survey 2007	Update Survey 2010
US East	684	309	260	260
US Gulf	791	763	851	628
US West	318	260	410	528
Overall US	704	614	706	544
Pacific	348	372	418	830
Other	734	661	853	193

**Table 5. Ultra-low Sulfur (< 15 PPM S) Jet Fuel Production for September To December Periods**

CRC Region		Initial Survey 2005	Initial Survey 2006	Initial Survey 2007		Update Survey 2010
US East	Volume %	0.03	6.7	13		13
	Refinery %	2.1	17	25		25
US Gulf	Volume %	0	1.1	1.3		1.5
	Refinery %	0	5.8	5.4		7.3
US West	Volume %	27	28	18		20
	Refinery %	33	53	30		49
Overall US	Volume %	3.4	5.4	4.4		8.0
	Refinery %	9.4	21	16		25
Pacific	Volume %	8.4	14	13		12
	Refinery %	23	28	36		29

**Figure 1. Time Averaged September to December Period Weighted Mean Sulfur, PPM S**



## 4.2 CONCAWE: European Region

European regional data were obtained by the Aviation Fuel Ad Hoc Group of CONCAWE (the oil companies' European Organization for Environment, Health and Safety). Statistical data obtained by CONCAWE for the four month data collection period September through December 2010 including mean sulfur, weighted mean sulfur, and minimum and maximum sulfur are shown in Table 6. The number of refineries reporting individual data to the survey is also shown. In Table 7 the European Region ultra-low sulfur (< 15 PPM total sulfur) jet fuel production statistical data are shown. Both the percent of the number of refineries producing ultra-low sulfur jet fuel and the percent of the total jet fuel volume which was ultra-low sulfur jet fuel are reported. Time averaged values for the four month data reporting period were calculated by arithmetically averaging the individual monthly results. A comparison is shown in Table 8 of the 2010 versus the 2005 four month time averaged results for the European Region.

The 2010 CONCAWE updated European survey brings the European Region data forward in time five (5) years. Thus, the 2010 updated survey data are more representative of today's fuel. Also the CONCAWE updated survey increased the European sample size from 17 % in 2005 to 67.2 % by volume in 2010, and the number of participating refineries from 11 to 41. As a result of the increased quantities considered in the 2010 survey, the statistical accuracy of the jet fuel sulfur content measured in the European Region has increased significantly.

The time averaged European Region weighted mean sulfur level of 500 PPM S is much lower than the 3,000 PPM S maximum which is typical of many jet fuel specifications; and is slightly lower than the 544 PPM S weighted mean sulfur level in the Overall US Region. The 28 % of refineries producing ultra-low sulfur jet fuel in the European Region is similar to the 25% ultra-low sulfur refineries in the Overall US Region. The 15.5 % of ultra-low sulfur jet fuel produced in the European Region is higher than the 8.0 % by volume produced in the Overall US Region.

**Table 6**

**CONCAWE's Jet Fuel Sulfur Survey:  
Results for Jet A-1 Production Reported by European Refineries  
September to December 2010**

	September 2010	October 2010	November 2010	December 2010
Mean S, PPM	519	495	534	437
Wt. Mean S PPM	543	502	501	453
Minimum S PPM	1	1	1	1
Maximum S PPM	2600	2900	2900	2600
Number of Refineries Reporting	42	41	41	40

**Table 7**

**CONCAWE Jet Fuel Sulfur Survey  
Ultra-low Sulfur (< 15 PPM S) Jet A-1 Production from European Refineries  
September to December 2010**

	September 2010	October 2010	November 2010	December 2010
% of reported volume as ULS Jet A-1	12	16	18	16
% of reporting refineries producing ULS Jet A-1	29	29	29	25



**Table 8**

**European Region Time Averaged Four Month Statistical Data:  
September to December 2005 Versus 2010**

	2005(a)	2010(b)
Mean S PPM	240	496
Wt. Mean S PPM	258	500
Minimum S PPM	4	1
Maximum S PPM	1350	2750
Number of Refineries	11	41
Ultra-low S Volume %	5.2	15.5
Ultra-low S Refinery %	23	28

(a)Time averaged four month September to December 2005 from CRC Report AV-1-04.

(b)Time averaged four month September to December 2010 from CONCAWE survey.

## 5.0 Conclusions

Weighted mean sulfur levels measured in the 2010 survey for the US East, Gulf, West and Overall Regions, the European Region and the Pacific Region are well below the typical 3,000 PPM S maximum specification limit. The four month averaged weighted mean sulfur level in the Overall US Region was 544 PPM S, in the European Region was 500 PPM S, and in the Pacific Region was 830 PPM S.

In the Overall US Region, the 2010 weighted mean sulfur level dropped 23% from the three year earlier 2007 level (from 706 PPM S to 544 PPM S). Comparing US regional levels over the three year 2007 to 2010 period shows the US East remaining essentially the same at approximately 260 PPM S, the US Gulf Region level dropping 223 PPM S from 851 to 628 PPM S and the US West Region rising 118 PPM S from 410 to 528 PPM S. In the Pacific Region the weighted mean sulfur level of 418 PPM S in 2007 rose to 830 PPM S in 2010; continuing to exhibit the rising trend seen in the 2005 through 2007 levels.

The minimum sulfur values for the US East, US Gulf, US West, European and Pacific Regions were generally in the 1 to 3 PPM S range. The maximum sulfur values varied between the regions: US East from 800 to 921 PPM S, US Gulf from 1303 to 1982 PPM S, US West from 1150 to 2400 PPM S, European from 2600 to 2900 PPM S and Pacific from 1400 to 1500 PPM S. Thus, the data from the European and US West regions are more scattered than the data from the other regions.

In the Overall US Region, the volume % ultra-low sulfur (< 15 PPM S) jet fuel production rate increased from 4.4% in 2007 to 8.0% in 2010, and the refinery percent rate increased from 16% to 25%. The 2010 European Region ultra-low sulfur 28% percent refinery production rate is similar to the 25% refinery production rate seen in the Overall US Region; while the European Region 15.5% volume production rate is higher than the 8.0% volume production rate in the Overall US Region.

## 6.0 References

(1) CRC Survey of Sulfur Levels in Commercial Jet Fuel, Final Report Project AV-1-04, W. F. Taylor, February 2009.

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