Economic and Supply Impacts of a Reduced Cap on Gasoline Sulfur Content

Prepared for the

AMERICAN PETROLEUM INSTITUTE

by

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Abstract

Current federal regulations limit the annual average sulfur content of gasoline to 30 parts per million ("ppm") by weight and place a maximum (or "cap") of 80 ppm on each gallon. The U.S. Environmental Protection Agency ("EPA") is preparing a proposed rulemaking for Tier 3 gasoline expected to require an annual average of 10 ppm sulfur, but whether, and to what extent, this will be accompanied by a reduction in the per-gallon cap is currently unclear. The American Petroleum Institute ("API") engaged Turner, Mason & Company ("TM&C") to study and evaluate the economic, supply and overall gasoline pool quality implications for imposing more stringent per-gallon sulfur caps on U.S. gasoline in addition to the assumed reduction in the annual average sulfur limit to 10 ppm.

To quantify the economic and supply impacts of a reduction of the sulfur cap, TM&C conducted an industry survey and independent modeling of refining industry capabilities. We combined the results of these analyses with our own industry experience and knowledge and information gathered through a search of relevant related studies and other literature. From this, TM&C has concluded that reducing the sulfur cap from 80 ppm will unnecessarily impose significant additional costs, and result in substantial additional supply losses beyond those caused by the 80 ppm cap. Specific results from the study which led to these conclusions include:

1) Average pool sulfur level, not the sulfur cap, is the key factor in determining the level of automotive emissions;

2) Vehicle technology that requires very low sulfur gasoline to operate effectively, lean Gasoline Direct Injection (GDI) with a NOx trap, will not achieve any significant market penetration in the U.S.;

3) Fungible product-mixing will likely result in a gasoline sulfur content at the retail level very close to the 10 ppm average in the vast majority of locations;

4) An annual average sulfur limit of 10 ppm will effectively impose a de facto sulfur cap with the probability that less than 1% of gasoline will exceed 50 ppm;

5) The cost to manufacture gasoline will increase as the sulfur cap is reduced from the current 80 ppm standard; capital costs range from approximately $2 billion to over $6 billion and annual operating costs are estimated at $900 million for a 20 ppm cap. These costs are in addition to those required to meet a 10 ppm annual average limit;

6) Overall potential loss of gasoline supply will increase tenfold as the sulfur cap is reduced from the current 80 ppm standard, resulting in 130 MBPD of supply loss at a 20 ppm cap; and

7) Regions served by just a few refineries could experience shortages of 25% - 50% during outages of gasoline sulfur reduction units at a 20 ppm cap, while outages would be minimized at sulfur caps exceeding 50 ppm.

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I. Introduction

Current Federal regulations limit the sulfur in gasoline to a 30 ppm annual average with a maximum per-gallon cap of 80 ppm. EPA is preparing to issue a Notice of Proposed Rulemaking ("NPRM") for Tier 3 Motor Vehicle Emission and Fuel Standards. The issuance of this NPRM has been delayed several times and is now expected to be published in early 2013. It is expected to establish a new annual average gasoline sulfur limit of 10 ppm but it is unclear if this will be accompanied by a more stringent per-gallon cap.

The purpose of this study is to evaluate the manufacturing costs and supply implications of imposing a more stringent sulfur cap in addition to reducing gasoline sulfur to a maximum annual average of 10 ppm. To accomplish this, TM&C independently analyzed the impact that reducing the 80 ppm sulfur cap would have on the domestic refining industry's ability to produce gasoline, especially during upset conditions; studied how a more stringent sulfur cap would increase the cost of producing gasoline above the cost of meeting the 10 ppm annual average, and determined how refiners are likely to react to a more stringent sulfur cap.

To help assess costs and impacts, TM&C conducted a survey of the refining industry to determine the current capability of the industry and the approaches that refiners would likely pursue in meeting a 10 ppm average annual sulfur limit while also complying with more stringent sulfur caps. We also conducted targeted modeling of the industry to determine potential costs and supply impacts of meeting the average annual sulfur limit at different sulfur caps. Our work included an evaluation of the implications for the gasoline distribution system associated with a more stringent sulfur cap and the de facto standard a new regulation might create.

As part of this study, TM&C also reviewed all publicly available studies, research, reports and presentations that we could find that addressed the benefits and impacts of reducing sulfur levels in gasoline. We found very limited information on the costs specifically associated with per-gallon caps, as previous research focused almost exclusively on the impacts and cost of complying with annual average limits. Where relevant information was found, we incorporated this into our study design and results.

TM&C has conducted this study and prepared this report utilizing reasonable care in applying methodologies consistent with industry practice. No other representations or warranties, either expressed or implied, are made by TM&C. All results and estimates in this report are based on information available at the time of this study. To the extent that additional information becomes available or the factors upon which our analysis is based change, our opinions and estimates could be affected.

II. Executive Summary

The base case assumption for this study is that EPA imposes a 10 ppm annual average sulfur limit with a sulfur cap on Tier 3 Gasoline for each facility producing or importing gasoline into the U.S. regions and territories described in the Tier 2 Gasoline Sulfur Regulations. The study then examines the additional impact that the imposition of various per-gallon sulfur caps on gasoline would have on gasoline supply and manufacturing cost.

Conclusions

Based on our evaluation of individual and composite industry responses, TM&C concludes that reducing the sulfur cap from the current 80 ppm level will have significant negative impacts on the cost and supply of gasoline with negligible, if any, accompanying benefits. The costs and impacts increase progressively as the sulfur cap is lowered. The bases for these conclusions are summarized below:

- There are very limited, if any, emissions benefits derived from restrictive per-gallon sulfur caps in a 10 ppm annual average regulatory environment.
  - The vehicle technology (lean GDI with a NOx trap) that requires stringent per-gallon caps to operate effectively is not projected to achieve any significant U.S. market penetration[1].
  - A statistical analysis shows that the annual average sulfur limit of 10 ppm will effectively impose a de facto sulfur cap with over 95% of the gasoline produced being below 30 ppm and likely less than 1% in the 50-80 ppm range.
  - Fungible product mixing will result in gasoline sulfur content at the retail level very close to the 10 ppm average in the vast majority of locations.[2]

- Restrictive per-gallon sulfur caps will reduce refiners' flexibility resulting in both higher capital and operating costs and a loss of gasoline supply, especially during outages at key units, such as pre- and post-FCC hydrotreating units.
  - Even with a sulfur cap of 80 ppm, refiners are restricted in the amount of gasoline they can produce. We estimate that without a per-gallon sulfur cap, refiners could have produced an additional 12 MBPD of domestic gasoline.

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[1] Martec, *Technology Cost and Adoption Analysis: Impact of Ultra-Low Sulfur Gasoline Standards*, April, 9, 2010

[2] WSPA, *CARB Fuels Workshop*, Presentation by Albie Hochhauser, March 23, 2007

- A reduction in the sulfur cap from 80 ppm to 20 ppm at a 10 ppm annual average sulfur level would result in a ten-fold increase in gasoline supply loss to 130 MBPD.
- The cost to manufacture gasoline will increase as the sulfur cap is reduced from the current 80 ppm standard. Capital costs range from approximately $2 billion to over $6 billion; and annual operating costs are estimated at $900 million for a 20 ppm cap. These costs are in addition to those required to meet a 10 ppm annual average limit.
- Both gasoline supply losses and the required compliance capital are three times higher for a sulfur cap of 20 ppm compared to 60 ppm.

- Those regions in the U.S. that receive gasoline supplies from a limited number of refineries can expect to see severe supply disruptions when key gasoline units are down at the largest of the refineries under a 20 ppm sulfur cap regulation. Gasoline supply losses could range between 25% and 50% in isolated regions.

Study Design

TM&C used a three-part approach to understand the impacts of increasingly stringent sulfur caps on supply and manufacturing costs:

- Literature search;
- Industry survey; and
- Targeted modeling and analysis of the U.S. refining system.

Literature Search

Our literature search of public material provided relevant information regarding the following topics:

- The automotive emission reductions from reducing gasoline sulfur to as low as a 10 ppm annual average;
- The capabilities, projected implementation, and reaction to sulfur of different technologies for vehicle emissions control systems;
- The impact of how regulations are written and implemented on creating de facto sulfur limits; and
- The cost of reducing sulfur to an average sulfur level.

The literature survey did not provide the cost nor the supply impact of reducing the sulfur cap for a 10 ppm annual average sulfur maximum. To estimate this cost, TM&C conducted a survey of petroleum refiners and performed independent modeling calculations.

Industry Survey

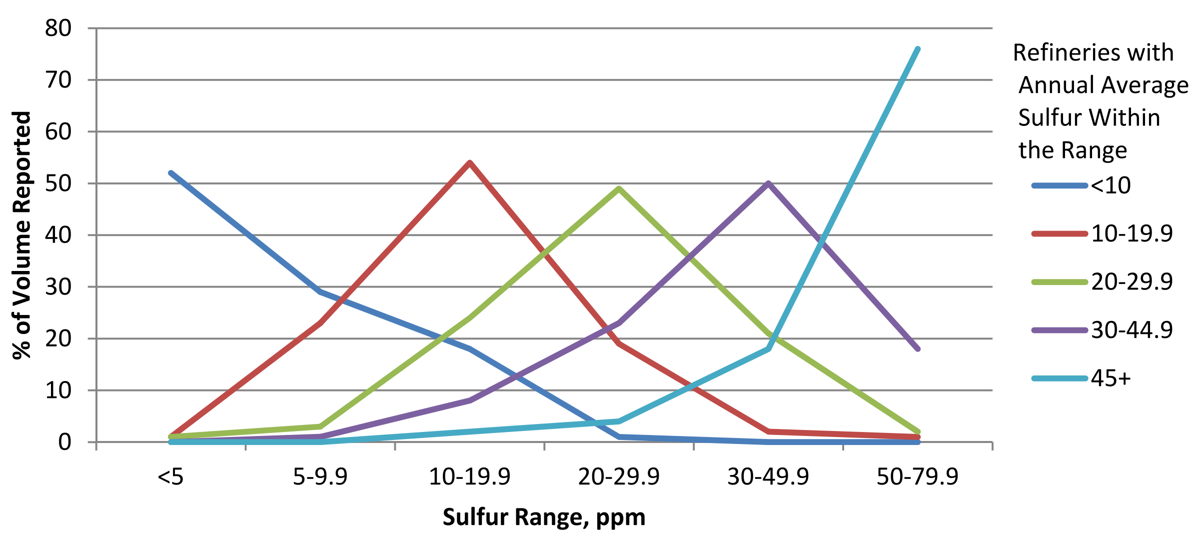
The questionnaire prepared by TM&C and sent to U.S. refiners is included in Appendix B. TM&C received responses from 30% of the operating refineries representing 44% of the gasoline produced in the U.S. The respondents covered a broad range of refineries, both from a geographic and configuration standpoint. Using our engineering experience and judgment, supplemented by modeling, we used the information from responding refineries to estimate impacts at similarly configured and situated non-responding refineries. This allowed us to extrapolate the survey data to the entire U.S. refining industry.

In the survey, TM&C asked refineries to provide information about sulfur in the gasoline produced in 2011 by gasoline batch reported to the EPA. For 2011, the required annual average maximum gasoline sulfur allowed was 30 ppm with a per-gallon cap of 80 ppm. Participating refiners provided a breakdown of their individual batch sulfur in the six pre-defined categories denoted in Table II-1, ranging from <5 ppm to 50-80 ppm. As shown in Table II-1 and Figure II-1, the sulfur distributions fit a classic bell curve – the category representing the refinery's average sulfur level contained about 50-55% of the gasoline produced with about 20-25 % on either side.

Refiners indicated that to achieve the 10 ppm sulfur annual average, as expected, they would have to further reduce sulfur in their FCC gasoline. However, they also identified other streams, both purchased and produced, that would require sulfur reduction. As the sulfur cap is reduced, the ability to blend these other streams will be reduced and as a result they may require alternate dispositions.

Table II-1 Batch Sulfur Distribution for 2011 Gasoline Batches by Sulfur Category					
	Refineries with Annual Average Sulfur Within the Range ppm				
	<10	10-19.9	20-29.9	30-44.9	≥45
% of Gasoline Produced	6	19	34	30	11
Average Sulfur, ppm	5.6	14.4	24.6	37.0	57.6
Volume Weighted Sulfur Distribution of Gasoline Batches, % of Volume Reported					
<5 ppm	52	1	1		
5-9.9 ppm	29	23	3	1	
10-19.9 ppm	18	54	24	8	2
20-29.9 ppm	1	19	49	23	4
30-49.9 ppm	<1	2	21	50	18
50-79.9 ppm		<1	2	18	76

Figure II-1
Batch Sulfur Distribution for 2011 Batches by Sulfur Category



Based on survey responses and our modeling work, TM&C has determined that as the sulfur cap is reduced, refiners will face increased difficulty maintaining the gasoline supply during turnarounds on sulfur reducing units. Even at the current 80 ppm sulfur cap, refiners responded that without the cap they could have produced an estimated additional 12 MBPD of gasoline for the domestic market. As shown in Table II-2, calculated probable annual average gasoline supply losses increase as the sulfur cap tightens. At a sulfur cap of 20 ppm, the loss of gasoline production increases more than ten-fold to almost 130 MBPD.

Table II-2 Impacts of Different Sulfur Caps on Gasoline Supply and Refining Compliance Costs					
	Sulfur Cap, ppm				
	80	60	40	30	20
Extrapolated Estimated Annual Average Gasoline Supply Loss					
Supply Loss, MBPD	12	43	63	108	129
Extrapolated Total U.S. Compliance Capital Cost					
Additional Capital Cost, $ billion		1.8	3.4	5.5	6.1
Note: For each row, cells are color coded in increasing color gradients to show the progression of change.					

Based on the survey, TM&C calculated the additional cost for the U.S. refining industry to comply with the Tier 3 Gasoline Sulfur Regulations at the five different sulfur caps presented. These costs, which are shown in Table II-2, are in addition to those for reducing the annual average sulfur in gasoline from 30 ppm to 10 ppm. As shown in Table II-2, the additional cost ranged from $1.8 billion for a 60 ppm cap to $6.1 billion if a 20 ppm cap is imposed.

Modeling and Analysis

An annual average sulfur specification imposes limits on the volume of higher sulfur gasoline which can be produced. TM&C performed a two-step statistical analysis to determine one "de facto" cap this represents. First we analyzed how much higher sulfur gasoline could be produced at different averages and still comply with the 10 ppm average, assuming the majority of the gasoline is produced at 8 ppm (typical compliance margin allowance). As shown in Figure II-2, if 5% of the gasoline pool were higher sulfur, that volume would have to average less than 50 ppm for the overall pool to comply with the 10 ppm average. If 10% of the gasoline pool is higher sulfur, it would have to average less than 30 ppm to comply with the overall 10 ppm average. Based on survey results and our discussions with refiners on how they would handle turnarounds and other deviations from steady-state operations, we anticipate that the average sulfur of the high sulfur gasoline would be about 40 ppm for 6% of the gasoline pool.

Using gasoline batch sulfur distribution patterns from the survey TM&C conducted, we calculated a distribution pattern for the gasoline pool at three different levels of average high sulfur gasoline combined with the 8 ppm base. Based on our discussion above, we anticipate that the gasoline pool sulfur distribution for the 37 ppm high sulfur gasoline case shown in Table II-3 would be the most likely distribution at an 80 ppm sulfur cap.

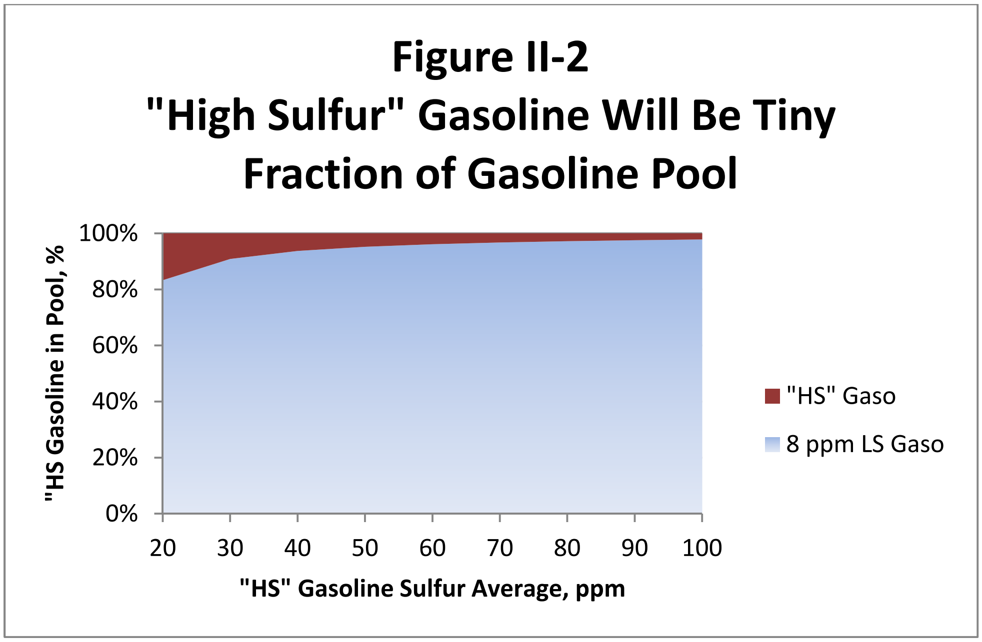


Table II-3 Gasoline Pool Sulfur Distribution for Different High Sulfur Average Gasoline Combined with 8 ppm Sulfur Gasoline Base			
Sulfur Range	If the High Sulfur Gasoline Averages		
	25 ppm	37 ppm	58 ppm
<5 ppm	25%	26%	27%
5-9.9 ppm	32%	34%	35%
10-19.9 ppm	32%	31%	32%
20-29.9 ppm	8%	3%	2%
30-49.9 ppm	3%	4%	2%
50-80 ppm	0%	1%	3%
Note: Due to rounding, columns may not add to exactly 100%.			

As shown in Table II-3, regardless of the average sulfur level of the high sulfur gasoline, with an 80 ppm cap and a 10 ppm annual average sulfur requirement, no more than about 10% of the gasoline batches at the refinery level would exceed 20 ppm; and only about 5% of the gasoline batches would exceed 30 ppm. Considering the fact that the gasoline distribution system provides for significant mixing of fungible product, TM&C would expect very few gasoline batches above 20 ppm at the retail level in almost all regions of the country.

In an average-and-cap regulatory environment, refiners with multiple refineries might be able to optimize investment by reducing sulfur below the average at its larger refineries and minimizing capital investment at its smaller ones. In this manner, a company could employ the economics of size. TM&C studied a series of refinery size and location combinations to determine a sulfur range that the smaller/higher sulfur refinery of a multiple plant system might average. We found that range to be 25 – 45 ppm.

In modeling the most likely approach refiners would take to meet a sulfur cap, TM&C found that refiners would spend capital to build additional storage and incur temporary increases in operating costs to handle turnarounds instead of building redundant systems. However, the approach could result in significant loss of supply, exceeding 5% in some regions. At a 40 ppm cap, the loss of supply would only be about 2 – 3%, and at 60 ppm the loss of supply would be negligible.

III. Study Design and Assumptions

Regulatory Assumptions

The study is premised on Tier 3 gasoline sulfur regulations being similar in structure to the current Tier 2 regulations. It further assumes that the EPA will establish a 10 ppm annual average with per gallon cap requirement for each facility that produces gasoline or each importing region for importers.

A sulfur credit program, identical to the one under the Tier 2 gasoline sulfur regulations, is also assumed to be in place. Facilities with an annual average level of less than 10 ppm will generate credits equal to the volume of gasoline produced or imported multiplied by the difference between 10 ppm and their annual sulfur level. Facilities with an annual average sulfur level greater than 10 ppm would create a deficit equal to the gasoline volume produced multiplied by the difference between their annual average sulfur level and 10 ppm. These latter facilities could comply with the required 10 ppm annual average by acquiring sufficient sulfur credits to reduce their annual average sulfur level to 10 ppm. Sulfur credits would have the units of ppm-gallons.

For this study, TM&C has assumed different per-gallon sulfur caps that no facility can exceed for any batch of gasoline produced or imported ranging from the current 80 ppm cap down to a minimum cap of 20 ppm.

Infrastructure Assessment

The downstream cap on gasoline sulfur will affect how high sulfur materials can be handled in the distribution system. As pipelines transport fuels from the refiner or importer to market, they generate an interface mixture called transmix at the boundary layer between two different fuels. Because the sulfur level of jet fuel and heating oil can still be as high as 3,000 – 5,000 ppm, high sulfur transmix is usually produced. TM&C has noted that the sulfur level of transmix is typically in the range of 200 ppm – 800 ppm. A pipeline blending transmix using procedures currently approved by the EPA could raise the sulfur level of compliant gasoline by 4 ppm. A pipeline that is unable to blend off transmix into gasoline will sell the material to a transmix processor. With a very tight sulfur cap, the transmix processor could find that it would not be possible to produce a transmix gasoline product compliant with the regulations. How the EPA establishes downstream sulfur caps will significantly impact the compliance margin that the distribution system establishes to comply with the Tier 3 gasoline sulfur regulations. A very tight downstream sulfur cap could set a de facto sulfur cap at the refinery gate that is stricter than the regulatory cap. TM&C analyzed the potential for a de facto more strict sulfur standard based on different applications of sulfur caps downstream of the refiner or importer.

Literature Search

TM&C conducted a literature search to identify any previous studies that quantified (at varying levels of per-gallon sulfur caps) the cost to manufacture gasoline and any impacts on the volume of gasoline that could be produced. We were unable to find any studies which specifically did this.

Industry Survey

The U.S. refining system is quite complex and each refinery is unique in both its capabilities and operating situation. Because of this uniqueness, each refinery will be impacted in different ways and have a variety of responses to proposed fuels regulations. The inherent nature of a per-gallon sulfur cap makes it very difficult to model refinery impacts and responses compared to annual average specifications and, as a result, we decided that a formal industry survey was required to perform this study.

TM&C split the survey into three parts (see questionnaire in Appendix B.)

- What was each participating refinery's actual performance in 2011, the last year with full data?
- What was the source of gasoline sulfur, and what processes were used to reduce sulfur?
- At different sulfur caps, how would the refinery achieve 10 ppm annual average sulfur; how would the refinery handle unit outages; and how much does the refinery anticipate investing to achieve 10 ppm annual average sulfur?

To answer the question of a refinery's actual performance, TM&C asked the refinery to provide us with the average sulfur level achieved in 2011 and to provide the percentage of gasoline produced within certain defined sulfur ranges. We used the sulfur distribution data to help us estimate how much gasoline production would be lost to the U.S. market at different sulfur caps.

Modeling and Analysis

TM&C maintains working models of most of the fuels refineries in the U.S. Utilizing this modeling platform, we investigated the investment and operating costs for refineries in all geographical and supply regions for the various sulfur cap cases. Our modeling work also allowed us to determine the following:

- Potential to utilize caps above 20 ppm by refiners with multiple refineries;
- Capital costs for storing high sulfur FCC gasoline during low-sulfur blendstock outages or FCC gasoline treater outages;
- The difference in operating costs and loss of production for FCC gasoline treater turnarounds at different sulfur caps; and
- The cost difference between U.S. markets and export markets if high sulfur gasoline is exported due to a low sulfur cap.

A very low sulfur cap could lead to supply problems in areas with limited supply options. Should a refinery suffer an outage of its FCC gasoline desulfurization unit, a very low sulfur cap would severely limit the amount of high sulfur FCC gasoline the refinery could blend during the outage. If the refinery is located in a region with limited optional supply, a supply disruption could result. TM&C has reviewed supply patterns to locate areas that could be affected.

A question that regulators face is whether a relaxed cap could be detrimental to emissions reductions, even at the ultra-low annual average sulfur level of 10 ppm. To evaluate the potential for damage to emissions control systems, TM&C performed a statistical analysis to determine the amount of gasoline that could be produced at different sulfur levels above 10 ppm if the majority of the gasoline produced averaged slightly less than 10 ppm, as would be expected.

IV. Literature Review

TM&C conducted a literature search of publicly available studies and industry analyses which address the impacts and benefits of reducing sulfur in gasoline (see Appendix A for a complete list). This search found several studies that analyze the impacts of either proposed or considered regulations, but none that attempted to specifically quantify the costs and/or benefits of imposing per gallon sulfur caps in conjunction with an annual average sulfur limit. We did discover some information that was relevant to this study:

- The apparent perceived rationale behind reducing sulfur in gasoline and how the application and market acceptance of different engine technologies determines the sulfur impact on emissions; and

- How constraints written into the regulations or applied by the regulatory bodies can create de facto operational sulfur caps and allowable refinery sulfur averages that are significantly lower than the regulatory standard.

The literature sources reviewed indicated that three-way catalyst technology currently being used becomes more efficient at reducing emissions as the <u>average</u> sulfur level in gasoline is reduced.[3] [4] [5] There were no studies or research which tested reductions based on per-gallon sulfur caps. The literature also reported that catalyst systems have been developed that will recover from sulfur spikes.[6] [7] Those analyses were performed by testing emissions at a base sulfur level, then testing the emissions at a significantly higher sulfur level, and then again testing the emissions at the base level. The recovery studies that TM&C found were old and performed at sulfur levels ten times greater than we would expect catalyst systems to encounter in a 10 ppm average environment. In those old studies, some catalyst systems were easily reversible, others were not. The reversibility was dependent on the catalytic system design.

There are certain engine-emission systems that require essentially no sulfur in gasoline to be effective. These include lean-burn engines with NOx traps and fuel cell vehicles, which both require sulfur levels below 10 ppm to be effective. These systems would be subject to efficiency loss or failure in a 10 ppm sulfur <u>average</u> environment even with

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[3] NESCAUM, Arthur Marin, *Benefits and Costs of Tier 3 Low Sulfur Gasoline Program*, January 2012
[4] NACAA, Nancy Kruger, *Cleaner Cars, Cleaner Fuel,, Cleaner Air: The Need for and Benefits of Tier 3 Vehicle and Fuel Regulations*, December 2011
[5] The International Council on Clean Transportation, Katherine O. Blumburg, Michael P. Walsh, Charlotte Pera , *Low Sulfur Gasoline and Diesel: The Key to Lower Vehicle Emissions*, May 2003
[6] IBID
[7] U.S. Environmental Protection Agency, EPA *Staff Paper on Gasoline Sulfur Issues* EPA 420-R-98-005), May 1, 1998

very strict sulfur caps. Our literature review included studies[8] which determined that these systems are highly unlikely to be employed in any meaningful way in the foreseeable future, if ever. Lean-burn engines in North America would be limited to stranded V-8 engine capital. Under new CAFÉ standards, manufacturers are highly unlikely to keep inefficient legacy technology. For fuel cell technology, gasoline in its current form would not be a preferred fuel.

The fungible gasoline distribution system will moderate any temporary sulfur spike in gasoline produced by a single refinery. In testimony before the California Air Resources Board, industry representatives described how the fungible California system maintained a relatively steady sulfur environment.[9] A similar fungible gasoline distribution system exists for most of the rest of the U.S.

[8] Martec, *Technology Cost and Adoption Analysis: Impact of Ultra Low Sulfur Gasoline Standards*, April 9, 2010

[9] WSPA, Albie Hochhauser, *CARB Fuels Workshop Presentation*, March 23, 2007

V. Survey Results

Section A – 2011 Gasoline Batch Data

The survey requested information for conventional gasoline/CBOB without ethanol, RBOB with ethanol and CARB gasoline with ethanol in the same manner as the properties are reported to the regulatory agencies. Responses to the survey were provided by 41 refineries producing 3,446 MBPD, or 44% of the 7,842 MBPD[10] refiner production of RFG and CARB with ethanol and conventional gasoline without ethanol. TM&C excludes the ethanol in conventional gasoline because sulfur in conventional gasoline is reported exclusive of ethanol, whereas sulfur in RBOB and CARB gasoline is reported including ethanol.

The average sulfur level for the combined CG/CBOB and RBOB was 30.7 ppm, slightly more than the 30 ppm annual average Federal regulatory limit, and TM&C noted that refiners were optimizing their operations by consuming sulfur credits. The average sulfur of conventional gasoline was slightly lower than the sulfur of reformulated gasoline, but this difference is not statistically significant. Survey responses for CARB gasoline averaged 6.8 ppm for 2011, much lower than the apparent regulatory limit. Refiners producing CARB gasoline informed TM&C that the California regulatory limits for CARB3 gasoline - 15 ppm average with a 20 ppm cap - are not the de facto limits. The calculations in the predictive model (used for ethanol blended gasoline) for NOx emissions limit the average sulfur in CARB 3 gasoline to essentially 10 ppm. Exported gasoline averaged 36.8 ppm sulfur with a range of 3 ppm – 137 ppm.

TM&C grouped refineries into different sulfur ranges based on their annual average sulfur and performed a distribution analysis. As shown in Table V-1, we found that the sulfur distribution followed a standard bell curve. Ninety to ninety-five percent of the gasoline was produced within three adjacent sulfur categories. The category representing the annual sulfur average contained 50% or more of the total volume with about 20% - 25% on either side of the central category. At the fringes of the range for allowed sulfur, the bell curve was truncated and the representative category represented 75% to 80% of the total. We find this distribution analysis important in predicting how refineries will produce gasoline under a 10 ppm annual average requirement.

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[10] The value of 7,842 MBPD for refinery production of RFG & CARB (with ethanol) and conventional gasoline(without ethanol is calculated from 2011 EIA data as follows:

Finished motor gasoline supplied	8,753 MBPD
Net gasoline imports	(286) MBPD
Ethanol in conventional gasoline	(533) MBPD
Adjustments/stock changes	(92) MBPD
Net refinery production	7,842 MBPD

Table V-1 Batch Sulfur Distribution for 2011 Gasoline Batches					
	Refineries with Annual Average Sulfur Range, ppm				
	<10	10-19.9	20-29.9	30-44.9	≥45
Volume, MBPD	214	645	1,130	1,006	364
Volume, %	6	19	34	30	11
Average sulfur, ppm	5.6	14.4	24.6	37.0	57.6
Volume Weighted Sulfur Distribution of Gasoline Batches, % of Volume Reported					
<5 ppm	52	1	1		
5-9.9 ppm	29	23	3	1	
10-19.9 ppm	18	54	24	8	2
20-29.9 ppm	1	19	49	23	4
30-49.9 ppm	<1	2	21	50	18
50-79.9 ppm		<1	2	18	76

PADD V refineries producing both Federal and CARB 3 gasoline could be split into two separate categories: producers of CARB3 gasoline with a 10 ppm limit, and producers of conventional gasoline with a 30 ppm annual average limit. TM&C split the refineries in this manner for the analysis of distribution by sulfur category. CARB3 gasoline produced in PADD V is included in the <10 ppm category.

Section B – Typical Process Operation for 2011

The average sulfur content of the FCC gasoline among our survey participants was 61 ppm with a range of 4-139 ppm. Sulfur by type of processing is presented in Table V-2. Refineries with both an FCC feed pre-treater and an FCC gasoline post treater had the lowest average sulfur level at 35 ppm.

Table V-2 FCC Gasoline Treatment by Process			
Process	Number	Average Sulfur ppm	Sulfur Range ppm
Pre-treater without Post Treater	13	58	6-134
Pre-treater with Post Treater	9	35	4-139
Post Treater without Pre-treater	12	70	27-121
No Treatment	3	109	100-112
No FCC Gasoline	4		

The U.S. average distribution of the FCC gasoline sulfur is presented in Table V-3. This distribution shows that 61% of the FCC gasoline used for blending had a sulfur level of 50 ppm or higher.

Table V-3 FCC Gasoline Sulfur Distribution	
Sulfur Range, ppm	Percent of FCC Gasoline
<20	15
20-49.9	24
50-69.9	28
70-89.9	14
90-109.9	5
≥110	14

Thirty of the 41 survey refineries reported storage capacity for unhydrotreated FCC gasoline with a shell capacity equal to 4.6 days of production. Twenty-two refineries reported storage capacity for hydrotreated FCC gasoline with a shell capacity equal to 5.5 days of production. Of the refineries reported above, 16 had capacity for both unhydrotreated and hydrotreated gasoline.

Refiners reported purchased blendstocks as shown in Table V-4. Much of the material reported as "other" was butane. Refiners noted that they would have to treat purchased streams to remove sulfur, especially natural gasoline. Opportunistic purchases would have to be treated at the low sulfur caps.

Table V-4 Purchased Blendstocks		
Blendstock	Volume MBPD	Average Sulfur ppm
Natural gasoline	86.8	62
Reformate	7.7	0
Alkylate	9.0	11
Raffinate	20.6	22
Other	25.5	9

Four refineries reported that they were limited by the 80 ppm sulfur cap and could have produced an additional 5 MBPD of domestic gasoline without the sulfur cap.

Section C – Future Operations with Gasoline Sulfur Average of 10 ppm with Alternative Caps

Some U.S. refiners have already included design features in their FCC gasoline treaters in anticipation of a lower average sulfur environment. Although, the operating severity which will be required is unproven, these modifications could allow this small group of refiners to meet the 10 ppm average sulfur specification through more moderate upgrades such as catalyst changes, or more severe operation with more frequent turnarounds. Refiners that have not pre-invested in anticipation of lower sulfur in gasoline specifications will have to change their approach to reducing the sulfur in the FCC gasoline, if the sulfur cap in addition to the sulfur average is lowered.

Table V-5 outlines the range of options we have identified for U.S. refiners seeking to comply with more restrictive gasoline sulfur caps. As the sulfur cap becomes more restrictive, many refiners with only pre-treating will have to add post treating, refiners with partial post-treating will move toward 100% post treating, refiners will reduce the endpoint of FCC gasoline and increase the treatment of other sulfur bearing blendstocks.

Table V-5
Probable Activities for Making 10 ppm Sulfur Gasoline

	Sulfur Cap, ppm				
	80	60	40	30	20
Pre-treating of FCC feed only	++	+	+	-	-
Combined pre and 100% post treating	-	-	+	++	++
100% post-treating	-	++	++	++	++
Reduce end point of FCC gasoline	-	-	+	++	++
Treat other blendstocks	-	-	+	++	++

Note: For each row, cells are color-coded in increasing color gradients to show the progression of change.

When refiners experience an unplanned reduction in low sulfur blendstocks, they will have to adjust their operation to balance the loss of the sulfur sink without preplanning. At all sulfur caps, the refiner's first choice is to store high sulfur components and increase the severity of the FCC gasoline hydrotreater. Refiners will progressively move from the easiest option to the most difficult as the sulfur cap is reduced. As shown in Table V-6, as the sulfur cap is tightened, refiners would lose the ability to easily manage the sulfur balance by temporarily storing some high sulfur components, purchasing low sulfur blendstocks, or adjusting the sulfur of feedstocks, if possible. Instead, refiners would have to respond to the unplanned loss of low sulfur blendstocks by: getting rid of high sulfur components and idling or significantly reducing the feed rate of the FCC.

The ability of refiners to plan eases the impact of the loss of low sulfur blendstocks as refiners continue to produce gasoline under different sulfur caps. This difference is shown in a comparison between Table V-6 and V-7. With an unplanned loss of low sulfur blendstocks (Table V-6), refiners' most available actions are to store high sulfur components and increase the severity of the FCC pre- and post-treaters. Balancing inventory through the purchase and sale of low and high sulfur blending components is more difficult because reaction time to an outage is much shorter. For a planned loss of low sulfur blendstocks, refiners are able to balance their options, and Table V-7 shows a more uniform approach of using the options available. Purchasing low sulfur components can be an expensive option, especially if it is done in the form of changing the crude slate to use lower sulfur crudes. Tables V-6 and V-7 do show that as the sulfur cap becomes more stringent, more options, especially the more expensive options such as cutting feed rate, must be employed; this raises the cost of compliance with the sulfur regulations and limits gasoline supply.

Table V-6 Making 10 ppm Sulfur Gasoline with an Unplanned Loss of Low Sulfur Blendstocks					
	Sulfur Cap, ppm				
	80	60	40	30	20
Increase severity of FCC pre-treater or post treater	++	++	++	++	++
Idle or significantly reduce feed rate to FCC	+	++	++	+++	+++
Reduce end-point of FCC gasoline	+	+	+	+	+
Sell high-sulfur components and/or export high-sulfur gasoline	-	+	+	+	+
Purchase low sulfur components	+	+	-	-	-
Store high sulfur components	+++	+++	++++	+++	+++
Other (primarily crude rate reduction)	+	+	+	+	+
Note: Cells are color-coded to show intensity level of the activity.					

Table V-7 Making 10 ppm Sulfur Gasoline with a Planned Loss of Low Sulfur Blendstocks					
	Sulfur Cap, ppm				
	80	60	40	30	20
Increase severity of FCC pre-treater or post treater	+	+	++	++	++
Idle or significantly reduce feed rate to FCC	+	++	+++	+++	+++
Reduce end-point of FCC gasoline	+	+	+	+	+
Sell high-sulfur components and/or export high-sulfur gasoline	+	++	++	++	++
Purchase low sulfur components	+	+	+	+	+
Store high sulfur components	+	+	++	++	++
Other (primarily crude rate reduction)	-	+	+	+	+
Note: Cells are color-coded to show intensity level of the activity.					

As shown in Table V-8, if refiners were to experience an outage in the unit or units that reduce the sulfur in FCC gasoline, they would have to idle or significantly reduce the feed rate to the FCC (the primary option), store high sulfur FCC gasoline or sell it either as a blendstock or high sulfur gasoline. As the sulfur cap becomes more stringent, the actions mentioned above become more necessary, decreasing domestic supply. Increasing the severity of the unaffected FCC pre or post treater is a limited option because many refiners have only one treater; thus, this option is shown not being heavily used in the overall analysis.

Table V-8 Making 10 ppm Sulfur Gasoline with a Planned or Unplanned Outage of the FCC Pre-treater or Post Treater					
	Sulfur Cap, ppm				
	80	60	40	30	20
Increase severity of the unaffected FCC pre-treater or post treater, if applicable (limited option)	-	+	+	+	+
Idle or significantly reduce feed rate to FCC	+++	++++	++++	++++	++++
Reduce end-point of FCC gasoline	+	+	+	++	++
Sell high-sulfur components and/or export high-sulfur gasoline	+	+	+	++	++
Purchase low sulfur components	-	-	-	+	+
Store high sulfur components	+	++	++	+++	+++
Other (primarily crude rate reduction)	-	+	+	+	+
Note: Cells are color-coded to show intensity level of the activity.					

Based on our analysis, we believe that refiners would need a sulfur cap of at least 40 – 50 ppm to be able to optimize their gasoline production during periods of higher sulfur in their gasoline pool resulting from loss of low sulfur blendstocks or loss of FCC gasoline desulfurization. Our analysis also finds that refiners would change their crude slates, manage intermediate products, and exchange or sell high sulfur gasoline blendstocks to respond to those situations.

Table V-9 Additional Storage Capacity Required at Different Sulfur Caps					
	Sulfur Cap, ppm				
	80	60	40	30	20
Change in Storage Requirement					
Alkylate	-	-	++	++	++
Light St Run Naphtha	-	+	+	+	+
Light Coker Naphtha	-	-	+	+	+
Unhydrotreated FCC Gasoline	-	++	++	+++	+++
Hydrotreated FCC Gasoline	-	++	++++	++++	++++
Investment					
Calculated Investment, $billion		$0.5	$1.1	$1.2	$1.2
Note: Cells are color-coded to show intensity level of the activity.					

As shown in Table V-9, as the sulfur cap is lowered, refiners would have to add additional storage capacity for gasoline blendstocks. The largest increase takes place at a sulfur cap of 40 ppm reflecting increases in storage of alkylate, light coker naphtha and hydrotreated FCC gasoline. At a sulfur cap of 30 ppm, refiners would increase the storage capacity of unhydrotreated FCC gasoline. The calculated investment for the storage capacity doubled, from $0.5 billion at 60 ppm to $1.1 billion at 40 ppm.

As the sulfur cap is reduced, refiners will experience difficulty maintaining their gasoline production during turnarounds of units for reducing sulfur in gasoline. Based on six pre-determined survey responses ranging from "no loss of production" to "loss of production exceeding 50%," we calculated an annual average gasoline supply loss for the survey respondents and extrapolated it to cover the entire U.S. refining industry. This calculated annual average supply loss, by sulfur cap, is shown in Table V-10: the volume increases ten-fold to approximately 130 MBPD as sulfur cap is reduced from 80 to 20 ppm.

Table V-10
Estimated U.S. Gasoline Supply Loss at Different Sulfur Caps

	Sulfur Cap, ppm				
	80	60	40	30	20
Supply Loss, MBPD	12	43	63	108	129

Note: Cells are color-coded to show intensity level of the activity.

A low sulfur cap could be particularly impactful on gasoline supplies in some isolated geographic regions during downtimes of key refinery equipment units. These regions are dependent on supply from just two or three refineries and have limited ability to import additional product by pipeline. We have determined that, under a 20 ppm sulfur cap regulation, when key gasoline units are down at the largest of the refineries serving these areas, gasoline supplies could be severely impacted. Under these circumstances, these regions could lose between 25% and 50% of their gasoline supplies. To maintain supply would require the industry to utilize temporary, non-traditional means of gasoline procurement.

Refiners will have to spend additional capital to meet the 10 ppm annual average as the sulfur cap is reduced. Based on six pre-determined survey responses ranging from "no additional cost" to "greater than $250 million," we have calculated the additional capital costs for the entire U.S. refining industry to meet the different sulfur caps in a 10 ppm average environment, and have presented these additional costs in Table V-11.

Table V-11 Estimated Additional Compliance Capital Costs for the Different Sulfur Caps					
	Sulfur Cap, ppm				
	80	60	40	30	20
Additional Capital Cost, $ million		1,768	3,390	5,533	6,090
Note: Cells are color-coded to show intensity level of the activity.					

Summary

During 2011, refiners meeting the Tier 2 gasoline sulfur standard averaged slightly above 30 ppm because they were using sulfur credits before they expired. Additionally, we found no statistically significant difference in the sulfur content of reformulated and conventional gasoline. Because of the design of the predictive model, the de facto standard for CARB gasoline is already 10 ppm.

At each of the different sulfur ranges TM&C surveyed, the sulfur distribution followed a standard bell curve. Ninety to ninety-five percent of the gasoline was produced within three adjacent sulfur categories. The category encompassing the refinery's annual sulfur average contained 50% or more of the total volume with about 20% - 25% on either side of the central category.

As expected, to average 10 ppm sulfur in finished gasoline, refiners will have to reduce the sulfur of their FCC gasoline, which averaged 61 ppm in 2011. They must also reduce the sulfur of other blendstocks, including light straight run gasoline, natural gasoline, and some butane streams.

As the sulfur cap becomes more restrictive from the current 80 ppm, refiners will have to increase the amount of combined pre and post treating, reduce the endpoint of FCC gasoline, and increase the treatment of other sulfur bearing blendstocks. To cope with the loss of low sulfur blendstocks, whether planned or unplanned, as the sulfur cap is tightened, refiners will have to consider an increased number of responses. Among these, they will probably increasingly idle or significantly reduce the feed rate of the FCC, reducing gasoline production.

During an outage of the FCC pre-treater or post-treater, refiners would primarily idle or significantly reduce the feed rate to the FCCU and store high sulfur components. As the sulfur cap is reduced, refiners would progressively need higher storage capacity; capital costs for storage double from $0.5 to $1.1 billion as the sulfur cap decreases from 60 ppm to 40 ppm.

During turnarounds of key units, estimated supply loss will increase as the sulfur cap is decreased; the increase is ten-fold (almost 130 MBD) as the cap is reduced from 80 ppm to 20 ppm. Based on survey responses we have estimated the annual average supply loss for the U.S. at the different sulfur caps:

Sulfur Cap ppm	Incremental Supply loss MBPD	Total Supply Loss MBPD
80		12
60	31	43
40	20	63
30	45	108
20	21	129

Finally, from survey responses, TM&C has calculated the additional cost for the U.S. industry to comply with a 10 ppm annual average sulfur limit based on the sulfur cap as follows:

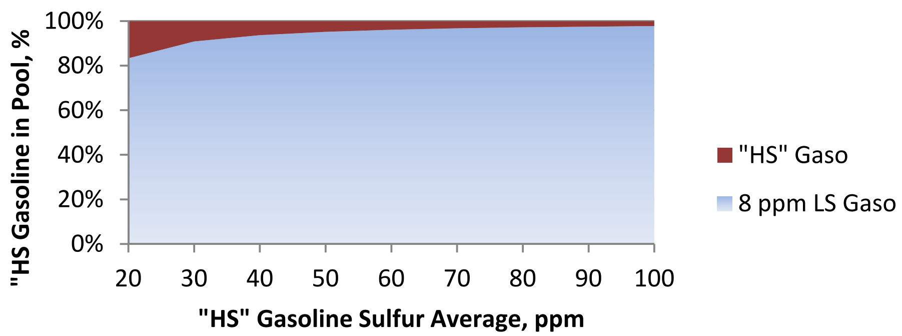
Sulfur Cap Ppm	Incremental Capital Cost $ million	Cumulative Capital Cost $ million
80		0
60	1,768	1,768
40	1,622	3,390
30	2,143	5,533
20	557	6,090

VI. Modeling and Analysis

Statistical Analysis

TM&C finds that at an annual average sulfur maximum of 10 ppm for the U.S. gasoline pool, very few gasoline batches with a sulfur level exceeding 30 ppm would be produced. As shown in Figure VI-1, if most of the gasoline produced averages 8 ppm, only a small fraction of the gasoline pool can average a higher sulfur level. For example, if all of the remaining gasoline were to average 30 ppm, it could comprise only 9% of the gasoline pool; whereas, if the remaining high sulfur gasoline were to average 60 ppm, it could comprise only 4% of the gasoline pool.

Figure VI-1
"High Sulfur" Gasoline Will Be Tiny Fraction of Gasoline Pool



Performing a statistical analysis of the gasoline batches from the survey, we determined that a general distribution of sulfur in gasoline batches averaging 8 ppm sulfur would have the general composition shown in Table VI-1.

Table VI-1
Sulfur Distribution for 8 ppm Average Base

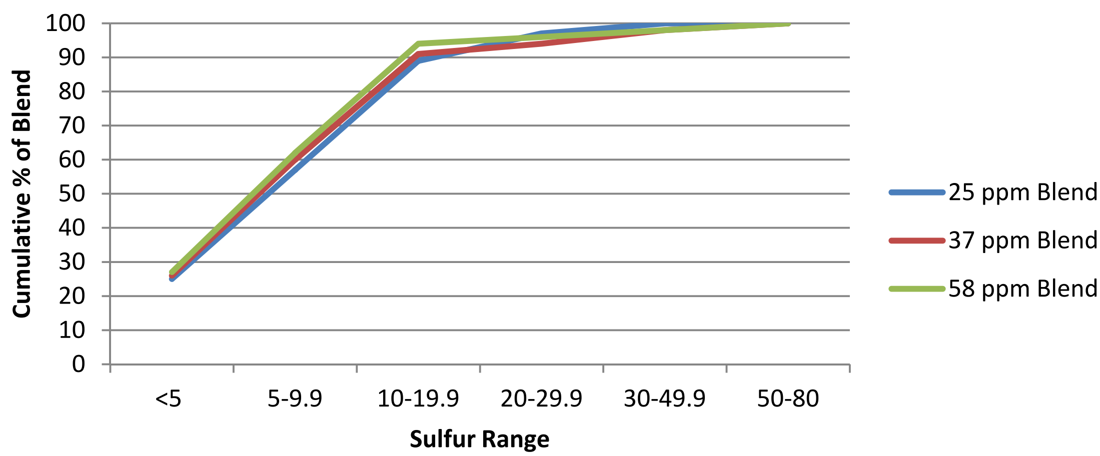
Sulfur Range	Percent of Batches
<5 ppm	28
5 – 9.9 ppm	36
10 – 19.9 ppm	33
20 – 29.9 ppm	2
30 – 49.9 ppm	1
50 – 80 ppm	0

Referring back to Table V-1, TM&C obtained, from the refinery survey, typical sulfur distributions for the refineries whose gasoline averaged about: 25 ppm, 37 ppm, and 58 ppm. Blending the sulfur distribution of each of the higher sulfur gasoline averages with the sulfur distribution of the 8 ppm sulfur average shown in Table VI-1, we determined the potential sulfur distributions shown in Table VI-2. In Table VI-2, we proportionally blended the 8 ppm sulfur base gasoline with the higher sulfur gasoline at the percentage the higher sulfur could be produced in a 10 ppm annual average sulfur environment. In Figure VI-2, we visually demonstrate the sulfur distribution probability for these three blend combinations.

Table VI-2
Sulfur Distributions for Different High Sulfur Combinations

	8 ppm Base Distribution	25 ppm Blend Distributions		37 ppm Blend Distributions		58 ppm Blend Distributions	
		25 ppm	Total Pool	37 ppm	Total Pool	58 ppm	Total Pool
Fraction		0.118		0.069		0.040	
Sulfur Range							
<5 ppm	28%	1%	25%		26%		27%
5-9.9 ppm	36%	3%	32%	1%	34%		35%
10-19.9 ppm	33%	24%	32%	8%	31%	2%	32%
20-29.9 ppm	2%	49%	8%	23%	3%	4%	2%
30-49.9 ppm	1%	21%	3%	50%	4%	18%	2%
50-80 ppm		2%	0%	18%	1%	76%	3%
Note: Due to rounding, columns may not total to exactly 100%.							

Figure VI-2
Cumulative Sulfur Distribution for Different High Sulfur Combinations



Based on the distributions shown in Table VI-2 and Figure VI-2, TM&C would expect that there would be almost no batches produced above 50 ppm with an annual sulfur average limit of 10 ppm. The probability of the “high sulfur” gasoline averaging above 30-40 ppm is quite low. We place the probability of the amount of gasoline exceeding 50 ppm at no more than 2%, and would expect a distribution closer to no more than 1%.

Thus, we find that a regulation requiring the annual average of the U.S. gasoline pool to not exceed 10 ppm will establish a practical operating per-gallon cap for refiners of 30 - 50 ppm.

Investment Optimization

One might postulate that the large refining companies might choose to optimize their investments in sulfur reduction by investing in their larger refineries and allowing smaller refineries to produce gasoline at higher sulfur levels. If too many small refineries producing gasoline at the higher sulfur levels were in the same area, a region might see elevated sulfur levels. TM&C evaluated this possibility and concluded that this scenario is not likely for the following reasons:

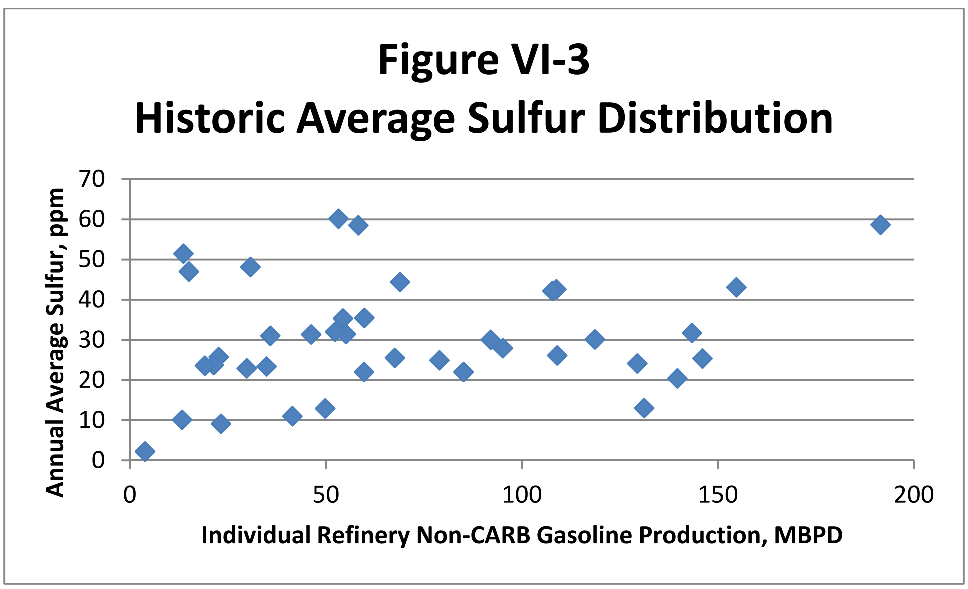
- As shown in Table VI-3, at a 10 ppm annual average, gasoline production averaging above 50 ppm, even by a large refiner optimizing its investment, is not likely; and

- As shown in Figure VI-2, we have not seen this type of concentrated strategic optimization under the current 30 ppm regulations.

As shown in Table VI-3, it is possible for a large refiner producing 750 MBPD of gasoline, almost 10% of the gasoline pool, to concentrate sulfur in the gasoline produced at one small refinery to a level approaching 60 ppm by producing 8 ppm sulfur gasoline at all the rest of its refineries. However, that capability quickly drops to no more than 45 ppm as the refinery size grows slightly. Thus, TM&C concludes that it is improbable for a large refiner optimizing its investment to have any refinery with an annual average sulfur level exceeding the 25 – 45 ppm range.

Table VI-3 Potential Maximum Average Sulfur at One Refinery for Large Refiner Optimizing Investment					
Company Non-CARB Gasoline Production		Individual Refinery Producing Higher Sulfur Gasoline			
Total MBPD	Averaging 8 ppm MBPD	Location	Crude Capacity MBPD	Gasoline Make MBPD	Potential Avg. Sulfur, ppm
750	721	PADD 4	60	29	61
750	710	PADD 2	80	40	45
750	708	PADD 3	100	42	44
500	471	PADD 4	60	29	43
500	460	PADD 2	80	40	33
500	458	PADD 3	100	42	32
250	221	PADD 4	60	29	26
250	210	PADD 2	80	40	20
250	208	PADD 3	100	42	20

TM&C's review of the sulfur level by refinery size shown in Figure VI-3 confirmed our conclusion. When we reviewed the distribution of the annual average sulfur by refinery reported in the survey, we could not find a pattern for the average sulfur in non-CARB gasoline based on refinery size. Figure VI-3 shows this random distribution for the 2011 average sulfur reported by the refineries in the survey.



Supply and Economic Ramifications for Turnarounds

Refiners indicated in response to our survey that during a turnaround of FCC gasoline hydrotreating units, they will adjust crude slates as possible to reduce sulfur in crude and balance their operations by storing or selling high sulfur blendstocks and/or purchasing low sulfur blendstocks. We have attempted to model this strategy of replacing higher sulfur crudes with low sulfur crudes and storing any high sulfur gasoline that could not be blended for future blending once the hydrotreater was returned to service.

TM&C ran cases with sulfur caps of 20 ppm, 40 ppm, and 60 ppm. Our modeling resulted in three cost allocations: (1) the change in gross margin for processing different, non-optimum crude oils, (2) the annualized cost for gasoline storage, and (3) the working capital required to maintain inventory for the period of time necessary to blend off the high sulfur gasoline blendstock.

As shown in Table VI-4, we found that the lower the sulfur cap, the higher the cost. Based on the way the study was designed, the resulting cost curve was fairly linear. The gross margin reduction due to changing the crude slate was a major component of the cost.

Table VI-4
Costs to Reduce Gasoline Sulfur at Different Sulfur Caps
During FCC Gasoline Treater Turnaround,
Non-CARB Gasoline

	Sulfur Cap, ppm		
	60	40	20
Gasoline storage construction cost, $ million	720	1,490	2,130
Annualized cost during turnaround, $ million	480	660	880
Breakdown of Annualized Cost			
Gasoline storage	27%	39%	41%
Working capital	1%	2%	10%
Gross margin reduction	72%	59%	49%

TM&C's modeling, which allowed an optimum response to a planned turnaround, did show that in some regions, with few refineries serving a particular area, that the short-term loss of gasoline supply could well exceed 5% for a refinery turnaround at a sulfur cap of 20 ppm. In TM&C's modeling, the supply loss at 40 ppm was about 2 – 3%, while at 60 ppm; the supply loss was generally less than 1%. We find a 5% supply loss significant. We would not expect to see any major supply disruption in the large refining centers or areas well supplied by outside sources unless several large refineries went into turnaround at the same time.

How Regulations Are Implemented

Where and how the EPA sets the standard for a 10 ppm average gasoline sulfur will set the de facto standard for refiners. When the EPA established the Tier 2 Gasoline Sulfur Standards, the EPA set the standard at the refinery with a 30 ppm annual average and an 80 ppm per-gallon cap. The EPA set the downstream standard as 95 ppm, using the refinery per-gallon cap and test reproducibility. Because of the way the Tier 2 regulations were written, the downstream distribution industry has been able to set its specified maximum for receipt of gasoline from refineries at the 80 ppm per-cap maximum.

The California Air Resources Board regulations for CARB3 gasoline allow an annual average of 15 ppm with a cap of 20 ppm or a flat limit of 20 ppm; however, refiners are not able to use these CARB3 limits. The representation of NOx reduction based on sulfur levels in the CARB3 predictive model for CARBOB limits sulfur to a de facto standard of about 10 ppm. Thus, survey responses from refineries producing CARB3 gasoline indicated that the average sulfur level for CARB3 gasoline was about 7 ppm.

When the EPA established the sulfur limit for motor vehicle, non-road, locomotive and marine (MVNRLM) diesel, the EPA set the limit as a 15 ppm cap at the point of delivery to the ultimate consumer with a testing allowance of only 2 ppm. Based on this restriction, pipelines set the maximum for delivery at or below 10 ppm. In actual operation, refineries have been averaging in the 5 – 8 ppm range.

Pipelines and transmix processors fear that they will not have a sulfur window sufficiently wide to allow them to blend or process transmix into gasoline. Blending transmix at 0.25%, the rate previously allowed in the regulations, could raise the sulfur in gasoline by 4 ppm. Transmix processors could also expect to see the sulfur level of their transmix gasoline product exceeding 20-30 ppm.

The proposed Tier 3 regulations should provide similar flexibility as the Tier 2 gasoline sulfur standards, including a separate downstream standard. EPA should also not impose a stringent cap that would effectively force an average sulfur limit below the proposed standard.

Summary

Based on our statistical analysis, TM&C has determined that at a 10 ppm annual sulfur average for the U.S. gasoline supply, very little high sulfur gasoline would reach the consumer. We would not expect refiners to produce more than 1% of the gasoline pool exceeding 50 ppm sulfur, nor more than 3 – 4% of the gasoline pool exceeding 30 ppm.

Large refiners optimizing their systems by allowing one refinery to produce higher sulfur gasoline still do not have the capability of producing super high sulfur gasoline at that one refinery. Based on the size of refineries the large refiners might own, we expect the range of sulfur at a refinery averaging above the 10 ppm standard to be in the range of no more than 25 – 45 ppm sulfur. Our statistical analysis predicted these results and the 2011 survey results confirmed them.

In modeling the most likely approach refiners would take to meet a sulfur cap, we found two key implications: capital cost required to build storage and temporary operating cost to handle turnarounds instead of building redundant systems. Furthermore, this could result in significant loss of supply, exceeding 5% in some regions if the sulfur cap is 20 ppm. At a 40 ppm cap, the supply loss would decrease to 2 – 3%, and at 60 ppm the loss of supply would be less than 1%.

How the Tier 3 gasoline regulations are implemented will set the operational limit on gasoline sulfur. The proposed Tier 3 regulations should provide similar flexibility as the Tier 2 gasoline sulfur standards, including a separate downstream standard. EPA should also not impose a stringent cap that would effectively force an average sulfur limit below the proposed standard.

VII. Conclusions

Limited to No Benefits for Restrictive Sulfur Caps in a 10 ppm Annual Average Environment. Vehicle technologies (e.g., lean Gasoline Direct Injection with a NOx trap) that require stringent per-gallon gasoline sulfur caps to operate effectively are not projected to achieve any significant U.S. market penetration. As a result, there are very limited, if any, emissions benefits derived from restrictive per-gallon sulfur caps in a 10 ppm annual average regulatory environment.

Refiners Will Not Be Able to Produce Significant Volumes of High Sulfur Gasoline in a 10 ppm Annual Average Environment.

TM&C performed a statistical analysis of the amount of gasoline that could be produced at different sulfur averages above 10 ppm if the rest of the gasoline pool was being produced at an 8 ppm average. At an average of 25 ppm, the higher sulfur gasoline could only be 12% of the gasoline pool, and the amount of gasoline averaging above 30 ppm would only be about 3%. At an average of 37 ppm, the higher sulfur gasoline could only be 7% of the gasoline pool, and the amount of gasoline exceeding 30 ppm would only be about 5% of the pool. At an average of 58 ppm, the higher sulfur gasoline would only be 4% of the pool, and the amount of gasoline averaging above 30 ppm would still only be about 5% of the pool. We conclude that the probable level of gasoline exceeding 50 ppm in the pool is no greater than 1%.

Performing a statistical analysis at a 10 ppm sulfur annual average, it was also determined that it would be difficult for a company with multiple refineries to produce very high sulfur gasoline at its smallest refinery. When studying the potential for a refiner with non-CARB gasoline production ranging from 250 MBPD to 750 MBPD from a multiple refinery system, it was found that the probable average sulfur range would be 25 – 45 ppm for the highest sulfur small refinery in that refiner's system.

Loss of Gasoline Production (up to 10X) during Turnarounds Increases with the Tightening of the Sulfur Cap.

TM&C has determined that refiners would experience greater degrees of difficulty to produce on spec gasoline during turnarounds at sulfur cap levels below the current 80 ppm. We also calculated potential loss of gasoline supply at different sulfur caps. As shown in Table VII-1, we note that supply loss will increase ten-fold to approximately 130 MBD as the cap is reduced from 80 ppm to 20 ppm.

Table VII-1 Loss of Production During Turnarounds at Different Sulfur Caps	
Sulfur Cap ppm	Lost Production MBPD
80	12
60	43
40	63
30	108
20	129

TM&C's modeling indicated that, during FCC gasoline treater turnarounds, short-term gasoline supply in regions with limited supply options could be hampered. We optimized our models to maximize gasoline production during the FCC gasoline treater turnarounds by changing crude slates to minimize sulfur and allowing high sulfur FCC gasoline to be stored for blending later. On average, in some regions, at a 20 ppm sulfur cap, the loss of gasoline supply could well exceed 5%; at a 40 ppm sulfur cap, the loss of supply was reduced to 2 – 3%; while at a 60 ppm sulfur cap, the supply loss was generally less than 1%. We find a 5% supply loss significant.

Our analysis concludes that refiners would need a sulfur cap of at least 40 – 50 ppm to keep from losing significant gasoline production during periods of higher sulfur in their gasoline pool resulting from loss of low sulfur blendstocks or loss of FCC gasoline desulfurization.

Those regions in the U.S. that receive gasoline supplies from a limited number of refineries can expect to see severe supply disruptions when key gasoline units are down at the largest of refineries under a 20 ppm sulfur cap regulation. Gasoline supply losses could range between 25% and 50% in isolated regions.

Refiners' Capital and Operating Costs Will Increase as the Sulfur Cap is Reduced.

TM&C has calculated that the cost of reducing sulfur to meet the Tier 3 Gasoline Sulfur Standards will increase as the sulfur cap is reduced. An optimized study, based on minimizing initial capital costs, accepting higher operating costs at optimized operating conditions, and ultimately blending all high sulfur blendstocks generated, resulted in capital cost estimates ranging from approximately $2 billion to over $6 billion and annual operating costs estimated at $900 million for a 20 ppm cap. These costs are in addition to those required to meet a 10 ppm annual average limit.

How Regulations Are Drafted Can Set More-Stringent De Facto Standards.

How the Tier 3 gasoline regulations are implemented will set the operational limit on gasoline sulfur. The proposed Tier 3 regulations should provide similar flexibility as the Tier 2 gasoline sulfur standards, including a separate downstream standard. EPA should also not impose a stringent cap that would effectively force an average sulfur limit below the proposed standard.

Thus, TM&C concludes that there are very limited to no benefits for more restrictive sulfur caps in gasoline. Reducing the sulfur cap from the current 80 ppm level will increase gasoline cost, potentially increase loss in gasoline production ten-fold to 130 MBPD, and will have negligible, if any, accompanying emissions benefits.

VIII. Appendix A - Literature Reviewed

Emissions Control Technology Association
Economic Analysis of the Implications of Implementing EPA's Tier 3 Rules
June 14, 2012

Baker & O'Brien
REFINING ECONOMICS OF A NATIONAL LOW SULFUR, LOW RVP GASOLINE STANDARD
Original Report: July 2011; Addendum: March 2012

JATOP Website
Contains information and several presentations regarding the impacts of cleaner fuels in Japan
March 2012

NESCAUM
Benefits and Costs of Tier 3 Low Sulfur Gasoline Program
January 2012

NACAA
Cleaner Cars, Cleaner Fuel, Cleaner Air: The Need for and Benefits of Tier 3 Vehicle and Fuel Regulations
December 2011

API Letter to EPA
November 11, 2011

MathPro, Inc.
REFINING ECONOMICS OF A NATIONAL LOW SULFUR, LOW RVP GASOLINE STANDARD
October 25, 2011

California Environmental Protection Agency: Air Resources Board
Proposed 2011 Amendments to Phase 3 California Reformulated Gasoline Regulations
August 21, 2011

MECA
Sulfur Impacts on Advanced Emission Control Technologies for Gasoline Engines
May 2011

Martec
Technology Cost and Adoption Analysis: Impact of Ultra-Low Sulfur Gasoline Standards
April 9, 2010

American Automobile Manufacturers

National Clean Gasoline: An Investigation of Costs and Benefits
June 2009

Asian Development Bank Consulting
A Road Map for Cleaner Fuels and Vehicles in Asia
November 2008

WSPA
CARB Fuels Workshop, Presentation by Albie Hochhauser
March 23, 2007

WSPA
CARB Fuels Workshop, Presentation by James P. Uihlein
January 26, 2007

CONCAWE
The impact of reducing sulfur to 10 ppm max in European automotive fuels: an update
August 2005

JCAP Website
Contains information and several presentations regarding the impacts of cleaner fuels in Japan
2005

The International Council on Clean Transportation
LOW-SULFUR GASOLINE & DIESEL: THE KEY TO LOWER VEHICLE EMISSIONS
May 2003

Purvin & Gertz
ULS GASOLINE AND DIESEL REFINING STUDY
November 17, 2000

CONCAWE
Impact of a 10 ppm sulfur specification for transport fuels on the EU refining industry
October 2000

CONCAWE
Consultation on the need to reduce the sulfur content of petrol and diesel fuels below 50 parts per million
July 2000

Mustang Engineers
IMPACT ON FUTURE REFINERY OF PRODUCING ULTRA LOW SULFUR GASOLINE
2000

CONCAWE
EU oil refining industry costs of changing gasoline and diesel fuel characteristics
April 1999

EPA
Staff Paper on Gasoline Sulfur Issues
May 1, 1998

IX. Appendix B – Survey Questionnaire

AMERICAN PETROLEUM INSTITUTE
REDUCED SULFUR CAP QUESTIONNAIRE
INDIVIDUAL REFINERY SURVEY

INSTRUCTIONS

The questionnaire, which should be completed for each refinery location, is comprised of three sections. Section A covers EPA Batch Gasoline and Export Gasoline information. We would like you to send us your complete 2011 EPA Batch Report (RFG0301) as well as provide summarized data from the report in questions A-1 through A-5. If any gasoline was exported in 2011, please supply export data in questions A-1 and A-6.

For Sections A and B, we seek your typical 2011 process or product data as an average. However, if there were any unusual events during 2011 that would distort your full year average data, you may annualize a meaningful period as a substitute, including a period prior to 2011. If you annualize an alternate period, please strive to answer questions in Section A & B based on a consistent time period. Please note that California refiners have three slightly different questions at the bottom of Section B.

Section C asks for your most likely approach or plan to meet a possible future gasoline sulfur average of 10 ppm with four alternative caps. If you don't have a plan yet, please provide your best thinking on a likely approach.

Individual survey responses will be held in strict confidence and the results will be reported in aggregate only. Upon completion or termination of this project, TM&C will destroy or return to the provider any Confidential Information submitted, whether in paper or electronic format. The preferred approach is for you to send your completed questionnaire to TM&C and a Confidentiality Agreement is included in this package if you elect to do this. However, if you prefer, you may alternatively send your questionnaire to API or AFPM, who will blind the identity of the submitter and forward the survey responses to TM&C.

The standard questionnaire is a Microsoft Excel spreadsheet. Most answers can be made by simply placing a value in the designated cell (light green color). Where written answers are required ("Other, please describe"), space is provided. Completed electronic questionnaires should be returned by e-mail to (depending on your preference) either Paul Smith at pbs@turnermason.com, Bryan Just at justb@api.org, or Tim Hogan at thogan@afpm.org. For questions, please contact Paul Smith by e-mail or phone at 214-754-0898.

Please provide the following information:

Company Name:

Refinery Location:

Contact information, if we have any questions.

Name:

Phone:

Fax:

E-mail:

SECTION A: 2011 GASOLINE BATCH DATA

Please give us your complete EPA Batch Report (RFG0301) for 2011 in Excel (our strong preference). If this is not possible, you can alternatively provide the summarized data from the report in A-1 through A-4 below. In either case, please fill out A-5 and A-6, if you produced any CARB or export gasoline and also report those volumes in A-1. Please let us know if any batches produced in 2011 were distorted by unusual events so that we can consider the possibility of excluding any non-representative batches. If you annualize an alternate period, please strive to answer questions in Section A & B based on a consistent time period.

	Question	Answer	
A-1	What were your 2011 gasoline batch volumes by type and average sulfur level?	**M Bbl**	**Sulfur, ppmw**
	Conventional/CBOB (without ethanol)		
	RBOB (with ethanol)		
	RFG produced without oxygenate, if any		
	CARB (with ethanol)		
	Export		
	Total (Thousands of Barrels)	**0**	

	Question	Answer	
A-2	For Conventional/CBOB volume shown in A-1, report the volume and sulfur level for each group	**M Bbl**	**Sulfur, ppmw**
	Less than 5 ppmw		
	Sulfur Level: 5-9.9 ppmw		
	Sulfur Level: 10-19.9 ppmw		
	Sulfur Level: 20-29.9 ppmw		
	Sulfur Level: 30-49.9 ppmw		
	Sulfur Level: 50-79.9 ppmw		
	Sulfur Level: 80 ppmw or greater		
	Total (Thousands of Barrels)	**0**	

	Question	Answer	
A-3	For RBOB volume shown in A-1, report the volume and sulfur level for each group	**M Bbl**	**Sulfur, ppmw**
	Less than 5 ppmw		
	Sulfur Level: 5-9.9 ppmw		
	Sulfur Level: 10-19.9 ppmw		
	Sulfur Level: 20-29.9 ppmw		
	Sulfur Level: 30-49.9 ppmw		
	Sulfur Level: 50-79.9 ppmw		
	Sulfur Level: 80 ppmw or greater		
	Total (Thousands of Barrels)	**0**	

	Question	Answer	
A-4	For RFG volume shown in A-1, report the volume and sulfur level for each group	**M Bbl**	**Sulfur, ppmw**
	Less than 5 ppmw		
	Sulfur Level: 5-9.9 ppmw		
	Sulfur Level: 10-19.9 ppmw		
	Sulfur Level: 20-29.9 ppmw		
	Sulfur Level: 30-49.9 ppmw		
	Sulfur Level: 50-79.9 ppmw		
	Sulfur Level: 80 ppmw or greater		
	Total (Thousands of Barrels)	**0**	

	Question	Answer	
A-5	For CARB volume shown in A-1, report the volume and sulfur level for each group	**M Bbl**	**Sulfur, ppmw**

SECTION A: 2011 GASOLINE BATCH DATA

Please give us your complete EPA Batch Report (RFG0301) for 2011 in Excel (our strong preference). If this is not possible, you can alternatively provide the summarized data from the report in A-1 through A-4 below. In either case, please fill out A-5 and A-6, if you produced any CARB or export gasoline and also report those volumes in A-1. Please let us know if any batches produced in 2011 were distorted by unusual events so that we can consider the possibility of excluding any non-representative batches. If you annualize an alternate period, please strive to answer questions in Section A & B based on a consistent time period.

	Question	Answer	
	Less than 5 ppmw		
	Sulfur Level: 5-9.9 ppmw		
	Sulfur Level: 10-19.9 ppmw		
	Sulfur Level: 20-29.9 ppmw		
	Sulfur Level: 30-49.9 ppmw		
	Sulfur Level: 50-79.9 ppmw		
	Sulfur Level: 80 ppmw or greater		
	Total (Thousands of Barrels)	**0**	
A-6	For Export volume shown in A-1, report the volume and sulfur level for each group	**M Bbl**	**Sulfur, ppmw**
	Less than 5 ppmw		
	Sulfur Level: 5-9.9 ppmw		
	Sulfur Level: 10-19.9 ppmw		
	Sulfur Level: 20-29.9 ppmw		
	Sulfur Level: 30-49.9 ppmw		
	Sulfur Level: 50-79.9 ppmw		
	Sulfur Level: 80 ppmw or greater		
	Total (Thousands of Barrels)	**0**	

SECTION B - TYPICAL PROCESS OPERATION FOR 2011

For Section B, please provide your typical 2011 process or product data as an average. However, if there were any unusual events during 2011 that would distort your full year average data, then you may annualize a meaninful period as a substitute, including a period prior to 2011. If you annualize an alternate period, please strive to answer questions in Section A & B based on a consistent time period. Please note that California refineries have 3 slightly different questions to answer, B-11 through B-13, instead of B-9 and B-10 (which should be completed by all other refineries.

	Question	Unit A	Unit B	Unit C	Unit A	Unit B	Unit C
		M Bbl	**M Bbl**	**M Bbl**			
B-1	**How much FCC naphtha was produced prior to any HDS in Thousands of Barrels in 2011?**						
B-2	**What was the annual average FCC naphtha sulfur level (ppmw) PRIOR to any HDS during 2011?**						
B-3	**What was the annual average FCC naphtha sulfur level (ppmw) AFTER any HDS during 2011?**						
B-4	**For FCC naphtha volume reported above, estimate the hydrotreated volume by analyzed sulfur level during 2011. If possible, also include the estimated average sulfur for the volume falling within each of the defined categories.**	**M Bbl**	**M Bbl**	**M Bbl**	**Sulfur, ppmw**	**Sulfur, ppmw**	**Sulfur, ppmw**
	Sulfur Level: Less than 20 ppmw						
	Sulfur Level: 20-49.9 ppmw						
	Sulfur Level: 50-69.9 ppmw						
	Sulfur Level: 70-89.9 ppmw						
	Sulfur Level: 90-109.9 ppmw						
	Sulfur Level: 110 ppmw or Greater						
	Total (Thousands of Barrels)	**0**	**0**	**0**			
B-5	**For FCC total fresh feed, report the annual average sulfur levels during 2011**						
	Before HDS, Sulfur, wt %						
	After HDS, Sulfur, wt %						
		M Bbl	**M Bbl**	**M Bbl**			
B-6	**For unhydrotreated FCC naphtha, how much storage capacity do you have?**						
		M Bbl	**M Bbl**	**M Bbl**			
B-7	**For hydrotreated FCC naphtha, how much storage capacity do you have?**						
B-8	**Please report your typical purchased gasoline blendstocks, if any, during 2011 by volume and sulfur level**						
		M Bbl	**Sulfur, ppmw**				
	a) Natural gasoline						
	b) Reformate						
	c) Alkylate						
	d) Raffinate						
	e) Other, please describe						
		0					

If you are a California refinery, please skip over Questions B-9 and B-10, and answer Questions B-11 thru B-13.
Otherwise, a non-California refinery should answer Questions B-9 and B-10 to complete Section B.

SECTION B - TYPICAL PROCESS OPERATION FOR 2011

For Section B, please provide your typical 2011 process or product data as an average. However, if there were any unusual events during 2011 that would distort your full year average data, then you may annualize a meaninful period as a substitute, including a period prior to 2011. If you annualize an alternate period, please strive to answer questions in Section A & B based on a consistent time period. Please note that California refineries have 3 slightly different questions to answer, B-11 through B-13, instead of B-9 and B-10 (which should be completed by all other refineries.

	Question	Unit A	Unit B	Unit C	Unit A	Unit B	Unit C
B-9	During 2011, did the gasoline per gallon sulfur cap of 80 ppmw ever limit the volume of finished gasoline Yes = 1, No = 0						
		M Bbl					
B-10	If you answered Yes for B-9, how much additional overall finished gasoline volume could you have produced during 2011 if there were no 80 ppmw sulfur cap?						
B-11	For 2011, which finished gasoline sulfur compliance option did you choose? Place a "1" in appropriate cell.						
	Finished Gasoline sulfur flat limit of 20 ppmw						
	Finished Gasoline sulfur average of 15 ppmw with a cap of 30 ppmw						
B-12	During 2011, did your compliance option limit (Flat or Average) in B-11 ever limit the volume of finished gasoline produced? Yes = 1, No = 0						
		M Bbl					
B-13	If you answered Yes for B-12, how much additional overall finished gasoline volume could you have produced during 2011 if you had met a 15 ppmw average without a sulfur cap?						

SECTION C - FUTURE OPERATIONS WITH GASOLINE SULFUR AVERAGE OF 10 ppmw WITH ALTERNATIVE CAPS

Section C asks for your most likely approach or plan to meet a possible future gasoline sulfur average of 10 ppmw with four alternative caps. If you don't have a plan yet, please provide your best thinking for a likely approach. Please provide an answer for each of the four alternative caps, even if your response is the same for each cap. Place a "1" in each box for which your reply is "Yes".

	Question	Sulfur Cap 20 ppmw	Sulfur Cap 30 ppmw	Sulfur Cap 40 ppmw	Sulfur Cap 60 ppmw
C-1	**What is your planned approach or enhancement to making 10 ppmw sulfur gasoline?**				
	a) Pre-treating of FCC feed (FCC feed HDS) only				
	b) 100% post-treating (FCC naphtha HDS) only				
	c) Combined pre and 100% post treating				
	d) Combined pre and partial post treating				
	e) Reducing end-point of FCC naphtha				
	f) Other, please describe				
C-2	**Under your planned approach to making 10 ppmw sulfur gasoline, what would be your most likely responses to a significant unplanned reduction of low sulfur blendstocks, such as reformate, alkylate, raffinate, etc lost suddenly? Place a 1 for your most likely response. Place a 2 for your next most likely response.**				
	a) Increase severity of FCC pre-treater and/or post-treater				
	b) Store high sulfur components				
	c) Sell high-sulfur components and/or export high-sulfur gasoline				
	d) Idle or significantly reduce feed rate to FCC				
	e) Purchase low sulfur components				
	f) Reduce end-point of FCC naphtha				
	g) Other, please describe				
C-3	**Under your planned approach to making 10 ppmw sulfur gasoline, what would be your most likely responses to a significant planned reduction of low sulfur blendstocks, such as reformate, alkylate, raffinate, etc lost during a turnaround? Place a 1 for your most likely response. Place a 2 for your next most likely response.**				
	a) Increase severity of FCC pre-treater and/or post-treater				
	b) Store high sulfur components				
	c) Sell high-sulfur components and/or export high-sulfur gasoline				
	d) Idle or significantly reduce feed rate to FCC				
	e) Purchase low sulfur components				

SECTION C - FUTURE OPERATIONS WITH GASOLINE SULFUR AVERAGE OF 10 ppmw WITH ALTERNATIVE CAPS

Section C asks for your most likely approach or plan to meet a possible future gasoline sulfur average of 10 ppmw with four alternative caps. If you don't have a plan yet, please provide your best thinking for a likely approach. Please provide an answer for each of the four alternative caps, even if your response is the same for each cap. Place a "1" in each box for which your reply is "Yes".

Question	Sulfur Cap 20 ppmw	Sulfur Cap 30 ppmw	Sulfur Cap 40 ppmw	Sulfur Cap 60 ppmw
f) Reduce end-point of FCC naphtha				
g) Other, please describe				

C-4 **Under your planned approach to making 10 ppmw sulfur gasoline, what would be your most likely responses to a significant (planned or unplanned) elevation of sulfur in catalytic cracked gasoline product due to an outage of a catalytic cracking pre-treater or post-treater? Place a 1 for your most likely response. Place a 2 for your next most likely response.**

	Sulfur Cap 20 ppmw	Sulfur Cap 30 ppmw	Sulfur Cap 40 ppmw	Sulfur Cap 60 ppmw
a) Increase severity at the unaffected unit (FCC pre-treater or post-treater), if applicable				
b) Store high sulfur components				
c) Sell high-sulfur components and/or export high-sulfur gasoline				
d) Idle or significantly reduce feed rate to FCC				
e) Purchase low sulfur components				
f) Reduce end-point of FCC naphtha				
g) Other, please describe				

C-5 **Under your planned approach to making 10 ppmw sulfur gasoline, do you anticipate building or allocating more storage capacity for any gasoline blending components? Place a 1 for all that apply.**

	Sulfur Cap 20 ppmw	Sulfur Cap 30 ppmw	Sulfur Cap 40 ppmw	Sulfur Cap 60 ppmw
a) Natural gasoline				
b) Reformate				
c) Alkylate				
d) Raffinate				
e) Light SR naphtha				
f) Light coker naphtha				
g) Unhydrotreated FCC naphtha				
h) Hydrotreated FCC naphtha				
i) Other, please describe				

SECTION C - FUTURE OPERATIONS WITH GASOLINE SULFUR AVERAGE OF 10 ppmw WITH ALTERNATIVE CAPS

Section C asks for your most likely approach or plan to meet a possible future gasoline sulfur average of 10 ppmw with four alternative caps. If you don't have a plan yet, please provide your best thinking for a likely approach. Please provide an answer for each of the four alternative caps, even if your response is the same for each cap. Place a "1" in each box for which your reply is "Yes".

	Question	Sulfur Cap 20 ppmw	Sulfur Cap 30 ppmw	Sulfur Cap 40 ppmw	Sulfur Cap 60 ppmw
C-6	**Under your planned approach to making 10 ppmw sulfur gasoline, which gasoline blendstocks (other than FCC naphtha) will contain more than 10 ppmw sulfur? Place a 1 for all that apply.**				
	a) Natural gasoline				
	b) Reformate				
	c) Alkylate				
	d) Raffinate				
	e) Light SR naphtha				
	f) Light coker naphtha				
	i) Other, please describe				
C-7	**Under your planned approach to making 10 ppmw sulfur gasoline, how many treated FCC naphtha streams will you have available for blending?**				
	a) One				
	b) Two or more (including streams from multiple treaters)				
	c) Other, please describe				
C-8	**Under your planned approach to making 10 ppmw sulfur gasoline, which configuration do you plan to have?**				
	a) Multiple FCC post treaters (parallel units only)				
	b) Multiple FCC pre treaters				
	c) Single train only				
	d) Other, please describe				
C-9	**Under your planned approach to making 10 ppmw sulfur gasoline, will you hydrotreat LSR naphtha?**				
	a) No				
	b) Yes, in a single full range naphtha HDS				
	c) Yes, commingled with feed to a FCC naphtha HDS				
	c) Yes, in a single LSR naphtha HDS				
	d) Yes, in multiple LSR naphtha HDS units				
	e) Yes, in multiple full range naphtha HDS units				

SECTION C - FUTURE OPERATIONS WITH GASOLINE SULFUR AVERAGE OF 10 ppmw WITH ALTERNATIVE CAPS

Section C asks for your most likely approach or plan to meet a possible future gasoline sulfur average of 10 ppmw with four alternative caps. If you don't have a plan yet, please provide your best thinking for a likely approach. Please provide an answer for each of the four alternative caps, even if your response is the same for each cap. Place a "1" in each box for which your reply is "Yes".

	Question	Sulfur Cap 20 ppmw	Sulfur Cap 30 ppmw	Sulfur Cap 40 ppmw	Sulfur Cap 60 ppmw
	f) Yes, commingled with feed to multiple FCC naphtha HDS units				
	f) Other, please describe				
C-10	**Under your planned approach to making 10 ppmw sulfur gasoline, will you have the ability to sell significant volumes of high sulfur gasoline components in order to stay below the cap?**				
	a) Sell components				
	b) Export gasoline				
	c) Both sell components and export gasoline				
	d) Neither				
C-11	**Under your planned approach to making 10 ppmw sulfur gasoline, rate the difficulty of complying with the per gallon sulfur cap during turnarounds, shutdowns and upsets. Place a "1" in the best answer for each cap.**				
	a) No difficulty				
	b) Some difficulty (small economic loss)				
	c) Moderate difficulty (reduced gasoline production as much as 10%)				
	d) Great difficulty (reduced gasoline production 11-30%)				
	e) Severe difficulty (reduced gasoline production 31-50%)				
	f) Nearly impossible (>50% reduction of gasoline production)				
C-12	**What is your estimated capital spending required ABOVE that needed to meet a 10 ppmw average sulfur level in order to comply with the sulfur CAPS as shown? Place a "1" in the best answer for each cap.**				
	a) Less than $10 million				
	b) $10-50 million				
	c) $50-100 million				
	d) $100-250 million				
	e) Greater than $250 million				