

Meeting Sulfur Specifications for 2000 and Beyond

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Trends in diesel fuel sulfur regulations

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1.0 Summary

During the next 5-10 years a bimodal diesel sulfur pool is expected to emerge: sub-50ppm in the United States , Canada and the European Union, and approximately 500ppm in the rest of the world.

2.0 Introduction

Diesel engines emit particulate matter (PM) in the sub-micron range, which has been shown to cause respiratory ailments with potentially cancer-causing consequences. Principal elements of PM include carbon (soot), soluble organic fraction (SOF), and sulfates. SOF consists of condensed aromatic compounds resulting from the incomplete combustion of diesel fuel. The oxidizing environment of the combustion process converts most of the indigenous sulfur into a mixture of sulfur dioxide and sulfur trioxide (SO_x). Some of the diesel sulfur, however, will form hydrated sulfates which become part of the total PM. The extent of sulfate-PM is directly related to the sulfur content of diesel fuel, therefore, there is an incentive to reduce fuel sulfur as part of the overall strategy to reduce total PM emissions. For example, reducing sulfur from 500ppm to 30ppm has been predicted to reduce PM emissions by 9-12% for heavy-duty engines (1). Oxidation catalysts have been

shown to be effective to reduce the SOF fraction of PM but countering this beneficial effect, oxidation can also increase sulfate formation.

Efforts to reduce diesel sulfur in the different regions of the world vary depending existing refinery technologies, availability of low sulfur crude, tax incentives, and regulatory pressure.

3.0 Diesel Sulfur Standards in the USA

Effective 1993, EPA mandated maximum 500ppm sulfur level and maximum 35% aromatics in diesel fuel used in on-road engines. Concurrently, introduced in 1988 and effective 1993, California required 500ppm sulfur and 10% aromatics in diesel fuel for on-road engines and for non-road engines. EPA's recently proposed Tier 2 emission program (2), effective 2004, predicted that in 5 years up to 50% of light trucks and sport utility vehicles will be equipped with diesel engines. While this prediction can be challenged, there is little doubt that the final Tier 2 program will require drastic reductions of diesel fuel sulfur to 50ppm or even lower levels. The Tier 2 program is also expected to require significant reductions, down from the current 3,300ppm to 500ppm, in the sulfur content of diesel fuel used in non-road engines.

4.0 Diesel Sulfur Standards in Canada

The *Low Sulfur Diesel Fuel Regulation* under the *Canadian Environmental Protection Act* mandated as of January 1, 1998, maximum 500ppm sulfur in diesel fuel for on-road light and heavy-duty vehicles (3). As a consequence of the ongoing national diesel fuel program, the average sulfur level of the total diesel pool decreased from 1,530ppm in 1994 to 1,154ppm in 1995, a 25% decline (4).

Future scenarios under consideration include 50-300ppm sulfur for on-road and 400ppm

sulfur for non-road diesel fuel.

5.0 Diesel Sulfur Standards in the European Union

The Council of Ministers of the European Union (EU) established 3000ppm sulfur in diesel fuel by 1989. In areas of significant air pollution the limit was set at 2000ppm. In 1991 the Council of Ministers of the EU required member countries to reduce sulfur to 2000ppm by 1994 and 500ppm by 1996. Subsequently, the Council of Ministers of the EU proposed 350ppm sulfur in diesel fuel effective 2000. The existing (pre-2000) diesel fuel specifications did not address aromatics content. The year-2000 specifications set this limit at 11wt%. By 2005 the EU proposed the same 50ppm sulfur for both gasoline and diesel fuel.

Germany opted for an accelerated schedule by planning to introduce diesel fuel and gasoline containing a uniform 50 ppm sulfur by the year of 2001, four years before the EU deadline (5). Sweden, Finland and Denmark introduced extensive tax incentives to encourage the production of ultra-low sulfur diesel (5ppm) for urban use (6).

The European Petroleum Industries' Association (Europia) and the Association des Constructeurs Europeens d'Automobiles (ACEA) jointly proposed 5 diesel fuels as candidates for future use having sulfur contents between 300-50ppm (7)

6.0 Diesel Sulfur Standards in the Asia-Pacific Region (8)

Countries in the Asia-Pacific region have no joint effort regarding diesel fuel specifications comparable to those of the European Union.

In Thailand provisions for improving air quality are priority issues in the *Seventh Plan* program. Diesel sulfur was reduced from 5000ppm to 3000ppm by 1996 and to 500ppm by

1999.

In Singapore diesel sulfur was reduced to 3000ppm by 1996. Further reduction to 500ppm is under consideration.

Hong Kong-China required maximum 500ppm sulfur in diesel fuel as of April 1997.

In South Korea the *Air Quality Control Law* gradually tightened diesel sulfur levels during the past 10 years. Sulfur levels were reduced to 4000ppm by 1992, 2000ppm by 1995, and to 500ppm by 1998.

In Taiwan , the Taiwan Environmental Protection Agency (TEPA) required to reduce the existing 3000ppm diesel sulfur to 500ppm by 1999. Japan introduced diesel fuel with 500ppm sulfur in 1997.

7.0 Diesel Sulfur Standards in Central and South America

Brazil is in the process of spending over \$1billion on hydrotreating at refineries to produce diesel fuel with less than 10,000ppm sulfur (9). Mexico introduced diesel fuel with 500ppm sulfur and maximum 30% aromatics in several urban areas effective 1995.

Venezuela has a single grade diesel fuel with 10,000ppm sulfur content. Ecuador and Colombia allow 500ppm and 4000ppm sulfur in diesel fuel, respectively. Puerto Rico set 500 ppm sulfur content for diesel fuel (10).

8.0 The World-Wide Fuel Charter

The American Automobile Manufacturers Association (AAMA), ACEA, and the Japan Automobile Manufacturers Association (JAMA) issued jointly the World-Wide Fuel Charter in 1998. The objective was to harmonize gasoline and diesel fuel standards world wide to reduce vehicular pollution. The World-Wide Fuel Charter recommended 3

categories for both gasoline and diesel fuel qualities (Table 1).

- Category 1 for markets with no or minimal emission controls
- Category 2 for markets with stringent emission control requirements (EU stage 2, US Tier 0 and 1)
- Category 3 for markets with advanced emission control requirements (EU Stage 4/5, California LEV/ULEV)

Table 1.

World-Wide Fuel Charter-Proposed Diesel Fuel Types

	Category 1	Category 2	Category 3	Category 4
Cetane number,min	48	53	55	55
Density, kg/m ³ ,min/max	820/860	820/850	820/840	N/A
Sulfur, ppm	5000	300	30	<10
Total aromatics, wt%	N/A	25	15	15
PAH, wt%	N/A	5.0	2.0	2.0
T95, C, max	370	355	340	340

Interestingly, Category 2 diesel would allow a maximum of 5wt% bio-diesel in the diesel fuel. No such allowance has been proposed for the Category 3 diesel.

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