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Best Practices for Fuel Quality Inspection Programs

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1. Introduction

Controlling the composition of vehicle fuel can reduce pollutant emissions from combustion and, more importantly, enable the use of advanced emission control technologies. Achieving best-practice vehicle emission performance therefore depends on having standards for fuels in place that complement standards for vehicular emissions. But fuel standards alone are insufficient. A compliance program is important to ensure that fuels sold at retail stations meet all the mandated specifications.

Establishing an effective fuel compliance program is challenging because fuel is handled by many parties along the distribution chain: refiners, blenders, pipeline companies, fuel truck operators, and retail stations. Intentional addition of off-specification (off-spec) fuel or contaminants can occur during distribution and is difficult to identify unless the fuel is analyzed or the fuel quality is carefully monitored. The challenges are particularly daunting for countries with less mature programs where regulatory authority is unclear and enforcement resources and capacity are limited.

This memo reviews the experiences of the US, Japan and UK in enforcing motor fuel quality requirements. Lessons learned from these three countries are discussed to inform recommendations for the establishment of an effective fuel quality enforcement program.

These three countries were selected because they all demonstrate a high degree of conformity with their respective fuel standards. The US example illustrates a comprehensive program for ensuring quality of fuel sold in an expansive territory through a distribution system that involves a large number of fuel distributors and retailers. The Japan and UK programs represent two successful models for countries with smaller geographical areas: the Japan program relies more on government-funded testing and monitoring, and the UK program depends more on industry self-policing.

Section 2 below summarizes key elements of the fuel quality assurance programs in these three countries, section 3 discusses the common elements of these programs, and section 4 outlines key steps for establishing an effective fuel quality inspection program.

2. Overview of the fuel quality assurance programs in the US, Japan and the UK

2.1 Key elements of the US program

The U.S. Environmental Protection Agency (EPA) manages a comprehensive fuel compliance program that combines fuel registration, extensive fuel inspections, fuel quality testing and reporting system, as well as stiff noncompliance penalties. Most of the fuel inspection programs are funded by EPA; industry is required to fund one program that assures the reformulated gasoline (RFG) sold in each RFG[1] control area conforms with the annual average standards for RFG. Another voluntary quality assurance survey program for diesel fuel sulfur compliance is also funded by an industry consortium as an alternative defense that will be discussed in more detail later in this section. Section 211 of the U.S. Clean Air Act (CAA) gives EPA the authority to prohibit the manufacture or sales of fuel and fuel additives if they may reasonably be anticipated to endanger the public health or welfare, or impair emission control devices or systems. The 1990 CAA amendments added provisions to mandate that fuel combustion result in fewer emissions than a 1990 baseline vehicle using 1990 fuel, and expanded EPA's authority to include fuels used in non-road engines.

EPA's fuel compliance program targets all parties in the distribution system, including refiners, importers, distributors, carriers, oxygenate blenders, retailers, and wholesale-purchaser-consumers (fleet operators with their own dispensing pumps). The compliance program places the onus of proof largely on refiners, importers and other fuel handlers to demonstrate compliance through registration, fuel analysis and reporting. EPA assures the authenticity and probity of industry's proof of compliance by mandating independent lab sampling and testing, third party auditing of industry reports, and by conducting targeted and random audits at refineries, import facilities, truck loading terminals and retail stations.

These measures are to ensure that fuel leaving the refinery gate or import facility meets all requirements or prohibitions on a per-gallon and annual average basis, and that quality of fuel is maintained downstream of the refinery on a per-gallon basis. Table A.1 in the Appendix shows the per-gallon and average fuel requirements for gasoline and diesel fuel. Each of

[1] RFG is a cleaner burning gasoline blend required in certain regions that do not meet air quality standards for ozone.

the enforcement measures is discussed in more detail in the following sections.

2.1.1 Registration and certification of fuel and fuel additives

Refiners and importers are required to register any motor vehicle fuel or fuel additive with EPA prior to marketing it in the US. Registration requires submission of the chemical description of the fuel or fuel additive as well as technical, marketing and health-related information, such as the in-use purpose of their product. EPA might also require testing for possible health effects for a product to maintain its registration or for a new product to be registered.

Since 1998, domestic and international refineries, as well as refined product importers, must use the complex model[2] to certify that combustion and evaporative emissions generated by their fuel comply with the RFG requirements or the anti-dumping requirements. The anti-dumping requirements are set to ensure that conventional gasoline sold in non-RFG regions is not more polluting than it was in 1990 (EIA, 1998). EPA uses the registration information to assess the likely combustion and evaporative emissions from gasoline and to identify products whose emissions might pose unreasonable risks to public health (EPA, 2011). EPA can deny new registration or repeal existing registration of any fuel or fuel additive that may endanger public health or impair emission control devices.

Detergent additives, which are required under the Clean Air Act (CAA) to be added to all gasoline to reduce accumulation of deposits in engines and fuel supply systems, have to be certified with EPA. The certification process includes:

[2] The complex model estimates NOx, toxics and VOC emission performance of fuels based on the following parameters: olefin, aromatics, sulfur, benzene, oxygen, distillations (E200 and E300) and RVP.

1) Registration with EPA like other additives, and the registration should include the additive's composition and the minimum recommended additive concentration. The recommended concentration cannot be lowered without first notifying EPA.
2) Submission of a sample of the detergent additive to EPA.
3) Submission of a certification letter for the detergent additive package. The letter must be signed by a person legally authorized to represent the certifying party.

After receiving the certification letter, EPA may review the certification data, analyze the submitted detergent additive sample, or subject the additive package to confirmatory testing, and may disqualify a certification where appropriate.

In addition, the detergent additive manufacturers are required to accurately communicate the minimum recommended concentration to each fuel manufacturer who purchases the detergents for compliance with EPA's requirement (40 CFR 86.161-00).

2.1.2 Fuel quality testing

Fuel quality testing and reporting by oil companies at the refinery gate or import facilities

EPA requires refiners and importers to analyze the properties of every batch[3] of fuel produced or imported for fuel properties associated with that kind of fuel.[4] Refiners and importers have to maintain all testing records and retain test samples. Fuel properties are reported to EPA on a quarterly or annual basis depending on the design of the particular compliance program[5]. In addition, annual reports are filed with EPA summarizing test results of every batch and the associated properties to show compliance with the per-gallon and average standards. EPA selectively audits the

[3] In the diesel fuel program, by definition (40 CFR 80.502(d)), a batch is a volume of fuel whose custody has been transferred to another party. A batch of gasoline is defined as a homogeneous mixture. Section 80.2 (gg).
[4] Sulfur content, aromatics and cetane number for diesel; sulfur, aromatics, benzene, lead, summer RVP distillation, olefin for gasoline, and other fuel properties that demonstrate compliance with the reformulated gasoline or conventional gasoline anti-dumping requirements.
[5] For instance, refiners and importers are required to submit fuel quality report for every batch of fuel produced or imported to show that all per-gallon requirements are met. To demonstrate compliance with the RFG and anti-dumping requirements, refiners or importers are required to submit reports every quarter and annually. Annual reports are required for demonstrating compliance with the benzene, VOCs and air toxics requirements, and the average and per-gallon maximum gasoline sulfur limits.

annual and quarterly reports, as well as the lab records, to check if they are internally consistent. EPA also audits the laboratories and the laboratory methods, quality assurance procedures, etc.

Industry-paid third party testing and auditing

In addition to conducting self-testing of every batch of fuel, EPA requires refiners and importers to hire independent labs to sample and test reformulated gasoline and certain imported gasoline. Independent lab test reports are submitted to EPA for comparison with the reports submitted by the regulated parties. All laboratory reports have to be signed by the lab's senior management, and EPA can file criminal charges against the signatory if a laboratory is found to have filed falsified reports.

Refiners and importers are required to hire independent certified public accounting firms or certified internal auditors to audit all fuel test results, volume reports and other information.

Fuel sampling and testing conducted by EPA and other government agencies

Besides auditing industry self-reports and requiring industry to arrange for independent lab testing and auditing to verify the authenticity and probity of test results, EPA conducts both random and targeted inspections of refineries. In the case of targeted inspections, EPA investigates any refineries that are suspected of producing non-conforming fuels. It also audits a small number of independent labs every year to ensure that testing results are correctly reported and that relationships between the testing labs and the industry do not affect the independence of the laboratories.

Motor vehicle fuels are subject to fuel tax in the US, but non-road fuels are exempted. For tax purposes, Internal Revenue Service (IRS) and some state governments established their own enforcement programs to ensure non-road fuels are not intentionally used for onroad purposes.

Testing conducted by consortium prompted by presumptive liability

EPA rules place liability on refiners, importers, distributors, carriers, resellers, retail and wholesale purchase-consumers if they sell or use motor

vehicle diesel fuel that does not meet the sulfur standards or that does not comply with the benzene, sulfur, volatility, toxics and lead contamination regulations. This means that when a violation is found, the party in possession of the non-conforming fuel, as well as all parties upstream in the fuel distribution system, are presumed liable unless they establish an affirmative defense. Refiners and importers whose brands appear at retail outlets may implement downstream quality assurance programs to monitor and assess fuel quality compliance and to establish one element of defense against presumptive liability (40 C.F.R. 80.613 (d), 2005). Other elements of an affirmative defense, such a documented lack of causation, must also be established.

As a means of meeting the sampling and testing defense element for ULSD, industry funds a fuel survey program. Under this program, industry-paid surveyors take statistically representative samples regularly from retail stations and test them against the diesel fuel sulfur requirements.

2.1.3 Prohibitive non-compliance penalty

The CAA sets a maximum civil penalty of USD 37,500[6] per day per occurrence plus the amount of economic benefit or savings resulted from such violation. The actual penalties are determined by EPA based on various considerations including economic benefits, business size, and the gravity of violation (whether it results in significant increases in emissions). While the maximum fines are seldom assessed, EPA has levied heavy fines for severe violations. For instance, in 1985, EPA imposed fines of USD 266,000 (1.8 million RMB) against Decker Coal Co. for using leaded gasoline in 37 vehicles marked for unleaded fuel only (AP, 1985). In 2008, EPA assessed a penalty of USD 1.25 million (8.75 million RMB) against Biofriendly Corporation for failing to register an additive (EPA 2008). In addition, EPA can file criminal charges against refiners, importers and independent labs should they be found to have falsified or assisted in falsifying test results. As an example, in 1998, Saybolt Inc., which performed testing and inspection services for refiners and importers, was fined a total of USD 4.9 million (33 million RMB) for submitting false statements to EPA about results of lab testing performed for refiners and importers.

[6] Per 40 CFR Part 19, the civil penalties are adjusted for inflation from the $25,000 cap on civil penalties when the CAA was enacted.

2.1.4 Compliance flexibility

In order for the industry to meet the standards in the most cost-effective way, EPA has introduced a number of flexibility measures. The two major flexibility measures are discussed below.

Averaging, banking and trading systems

Averaging, Banking and Trading (ABT) systems allow flexibility in meeting the standard over a specific compliance period without hurting the environment. For example, in EPA's gasoline sulfur reduction programs, suppose a refinery over-complies with the standard for a period of time; that refinery can bank credits for use at a later time of the year, when refinery units are being upgraded or are down for repairs, or at a different refinery, to make motor fuel with slightly higher levels of sulfur so that the refinery can meet the standard over the entire compliance period, typically a year. Nevertheless, the per-gallon caps cannot be exceeded. Credits can only be applied to meet the average requirement, not the cap (i.e., the per-gallon requirements). Table A1 in the appendix lists the per gallon and average limits for gasoline and diesel sold in the U.S.

EPA allows regulated parties to meet some requirements on an annual average basis. Table A.1 summarizes the US fuel property and performance requirements that can be met on a per-gallon and on an average basis.

Designate and track

EPA allows onroad and non-road diesels that are subject to different sulfur content requirements before 2010, to be distributed and transported through the same system, as long as all handlers file quarterly electronic reports listing the type of diesel fuel they received (non-road or onroad), and the person to whom it was delivered. The Designate and Track program hence enables refiners and importers to maximize utilization of the existing fuel distribution system while allowing EPA to track fuel distribution to ensure that no party illegally represents off-road diesel as on-road. To facilitate enforcement, all non-road diesels have to be dyed red at the terminal so enforcement staff can easily determine compliance by placing fuel in a white bucket and observing the color (known as a "white bucket test"). Also, retail stations are required to put labels on the fuel

pumps to identify the fuel sulfur level and the intended use of the fuel. Since December 1, 2010, when almost all highway and non-road fuels became subject to the ULSD 15-ppm sulfur standard, the process of distinguishing highway and non-road fuel using designate and track has become less important to EPA.

2.1.5 Results and costs of the US fuel quality enforcement program

EPA's enforcement program has been successful: Less than 1% of facilities audited are found in violation with fuel quality requirements every year (EPA Enforcement staff, personal communication, February 2010). Below are the major factors attributing to the success of the program:

Non-compliance penalty: As mentioned previously, the fuel compliance program has aggressively pursued violators, including refineries, importers and testing laboratories. Substantial fines (millions of dollars) were imposed on big companies when severe violations were found, and criminal charges have been filed against laboratories found to have falsified test results. Therefore, even though the maximum civil penalty of USD 37,500 per day per occurrence is seldom assessed, the possibility of being subjected to a hefty fine creates a deterrent effect forcing fuel producers, importers and handlers to more diligently monitor fuel quality to ensure compliance.

Presumptive liability: The presumptive liability provisions encourage all parties along the distribution chain to undertake efforts to assure the quality of fuel received, and deter the dropping of illegal fuel during fuel distribution. The industry-paid surveys for verifying retail fuel quality help to ensure compliance along the chain and lessen the regulatory burden on EPA.

Independent testing and auditing: The EPA requirements of independent lab testing for every batch of fuels and independent auditing of in-house and lab test results add an extra verification step to the testing conducted by oil industry and independent laboratories. Such requirements make it more difficult for refineries, importers and independent laboratories to cheat by submitting falsified data to EPA.

Costs for running EPA's enforcement program

The EPA contractor for conducting field sampling and testing costs over one million US dollars per year. In addition, there are over 20 full time EPA staff members in the fuel compliance program, including lawyers, engineers and inspectors. This figure does not take into account the cost to the industry of the two field survey consortiums that ensure compliance with RFG and ULSD requirements. Financing for the fuel compliance program comes from EPA's budget, which is appropriated by the Congress. EPA does not profit from the penalties assessed; all fines go directly to the US treasury.

2.2 Key elements of the Japan program (see Hirota, 2008; NPA, 2006)

Japan dropped the ban on petroleum product imports in April 1996, allowing imported refined petroleum products to be sold in the country. With fuels offered by more companies and coming from different regions, there was a need to impose stricter fuel quality controls to ensure that the quality of fuel imported or refined domestically met all necessary requirements, while assuring a stable supply of petroleum products. This led to the promulgation of the Law on the Quality Control of Gasoline and Other Fuels (Fuel Quality Control Law), which put the Ministry of Economy, Trade and Industry (METI) in charge of enforcing quality of gasoline, diesel and kerosene sold on the market.

Based on environmental and safety considerations, the Fuel Quality Control Law established mandatory specification for ten gasoline properties and three diesel properties (see properties in bold in Table A.2 in the Appendix). The Fuel Quality Control Law also specified a set of Standard Specifications that included all mandatory requirements and additional recommended requirements for gasoline and diesel fuels (see Table A.2).

2.2.1 Quality assurance obligations of fuel importers and refiners

The Fuel Quality Control Law requires refineries and importers to test the quality of fuel prior to distribution and sale to ensure that the petroleum products they offer meet all the mandatory requirements. Refiners and importers share the responsibility should non-conforming fuel be found at

any retail station they supply fuel to. This prompts the industry to regularly test fuel along the distribution chain.

2.2.2 Registration of retail stations and strict testing requirements for retail stations

All retail stations selling gasoline must register with the METI. The Fuel Quality Control Law also stipulates that retail stations test the fuels they sell against the compulsory requirements listed in Table A.2 once every ten days. Retail stations may commission any one of the four laboratories accredited by the METI for fuel testing.

If a retail station can show that it has 1) a clear distribution channel and 2) a distributor who is jointly responsible for ensuring product quality, it can apply to METI to be exempted from the frequent testing requirement (which mandates fuel testing once every 10 days), and permitted to test fuel only once per year.

2.2.3 Extensive government-funded fuel testing (METI) to monitor fuel quality sold on the market

METI conducts massive fuel sampling and testing every year. It contracts the National Petroleum Association (NPA), an independent public corporation, to collect and test fuel samples at least once a year from each of the more than 45,000 retail stations in the country (see Quality Control, 2011).

NPA owns nine testing labs around the country, and each lab is responsible for fuel testing in its region. Once or twice a year, NPA purchases one liter of premium gasoline, regular gasoline, diesel and kerosene from each of the 4,500+ retail stations without giving them advance notice. Fuels purchased are analyzed against the mandatory and standard specifications. Non-conforming samples are then sent to the Quality Testing Laboratories, which provide technical support to NPA's nine testing labs, for further analysis. Results are sent immediately to METI and the Economic and Industry Bureau (EIB). The METI and EIB, in collaboration with the Police and Fire Department, then conduct surprise inspections at retail stations suspected of selling off-spec fuels. If the METI and EIB confirm the

suspected violations, they may suspend operations, order improvements, or impose other regulatory action.

2.2.4 Government fuel quality certification – SQ fuel quality logo

To enable and encourage consumers to choose high-quality fuels, any retail station selling fuels that meet all the Standard Specifications (including all the mandatory and recommended specifications) can display a Standard Quality (SQ) logo issued by the EIB.

2.2.5 Heavy non-compliance penalty, including fines, criminal penalty (jail time) and shut down of businesses

Refineries, importers and retailers found guilty of selling fuels that fail to meet all the mandatory specifications are subject to a fine of up to ¥1,000,000 and/or up to 1 year of imprisonment. METI also has the authority to suspend any business for up to 6 months for distributing/selling non-conforming fuels, and then publicize the name of the non-compliant business to the public. METI will revoke the SQ logo if a retail station that displays it is found selling fuel that does not meet the Standard Specifications.

2.2.6 Regulatory actions against illegal mix of diesel fuel with heavy oil

Tax authorities and several local governments in Japan, including Tokyo, have taken aggressive action against illegal use of mixed diesel and heavy oil for environmental and tax purposes. According to a 2000 study by Tokyo Research Institute for Environmental Protection, using illegal diesel fuel with 50% heavy oil content results in 15% higher PM and 7% higher NOx emissions, and higher toxic emissions (such as benzene and toluene).

Since 2000, the Tokyo Metropolitan Government, together with other local governments, launched an Illicit Diesel Fuel Eradication Campaign, which cracked down on illegal diesel manufacturing bases, launched education campaigns, and conducted roadside inspections (Gilhooly, 2000). A chemical marker, coumarin, is added to diesel and heavy oil sold in Japan. Tax authorities and local government can easily determine if heavy oil is illegally added by testing the concentration of coumarin in the fuel samples collected during roadside inspections.

2.2.7 Results and Cost of Japan's enforcement program

In the first quarter of 2010, NPA has collected and tested over 11,000 samples of premium gasoline, over 12,000 samples of regular gasoline and about 12,000 samples of diesel fuel. Less than 1% of the samples tested exceeded the mandatory specifications (see Results/Analysis, 2011). Fuel quality monitoring data from the auto industry also suggest that diesel and gasoline sold in Japan has met the 10-ppm sulfur limit since 2007.

METI pays NPA USD 15.7 million every year for fuel quality testing (Nakayama, 2006). This does not include the expenses for METI's staff time and other resources for managing the fuel quality enforcement program and conducting surprise inspections at retail stations.

2.3 Key elements of the UK program

Directive 98/70/EC and the subsequent amendment, Directive 2003/17/EC, require all EU member states to introduce 10-ppm sulfur motor fuel into the market starting on January 1, 2005, and the directives prohibit sales of motor fuel with over 10-ppm sulfur from January 1, 2009 onward. Member states must ensure that non-road fuel does not contain more than 1000-ppm sulfur by January 1, 2008. In addition to sulfur, the Directives specify limits for other fuel properties to be compatible with the current and forthcoming vehicle standards (see Table A.3 in the Appendix). The Directives also require each member state to introduce a Fuel Quality Monitoring (FQM) System to monitor fuel quality and report to European Commission a summary of the quality of fuel sold in each of the member states (Directive 2003/17/EC, 2003). Member states must introduce penalties for non-compliance with fuel specifications.

In the United Kingdom (UK), the Department of Energy and Climate Change is responsible for the annual reporting to the European Commission. Enforcement of the fuel composition and content regulation falls on the local authorities' Trading Standards Office. Below is a summary of the key elements of the UK fuel quality monitoring program.

2.3.1 Testing every batch of fuel out of the refineries before releasing into the distribution system

As in the US and Japan, refineries and import terminals in the UK are required to test and analyze every batch of fuel produced or imported for compliance with fuel specifications before it can be released into the distribution system. The fuel quality parameters analyzed for compliance include:

Gasoline: Octane number (Research Octane Number (RON), Motor Octane Number (MON)), summer vapor pressure, olefins, distillation, aromatics, benzene, oxygenates, sulfur, and lead

Diesel: Cetane number, density, distillation (95% point), polycyclic hydrocarbons, sulfur (Brannigan, Glenn, Griffin, Hill, & Twisse, 2009).

Fuel analysis data from the refineries and importing facilities are submitted to the Department of Energy and Climate Change for reporting to the European Commission.

2.3.2 Fuel quality check at retail stations by local Trading Standards Officers and fuel suppliers

The Trading Standards Office of local authorities has the statutory duty to enforce the UK motor fuel composition and content regulation. The enforcement priorities are set by the local governments. Fuel samples are collected at the distribution terminals and at retail stations for monitoring fuel quality. Oil companies also analyze fuel purchased from their own and their competitors' retail stations. The summary reports to European Commission include fuel quality data from both the local authorities and the industry.

Considering the large number of fuel samples tested at the refineries and import terminals as well as the high compliance rate from upstream testing, limited samples (about 5% of all fuel samples tested and reported in 2007) are collected and tested at the service stations each year.

2.3.3 Non-compliance penalty

Section 32 of the 1994 UK Clean Air Act states that any party that fails to comply with the fuel standards "shall be guilty of offence and liable on a) conviction on indictment, to a fine; and b) on summary conviction, to a fine not exceeding the statutory maximum" (U.K. Clean Air Act, Section 32, 1993). The level of fine is determined by a judge in a court of summary jurisdiction. The penalty to be paid depends on the severity of the breach of the Act and the previous history of convictions of the accused. For a very severe breach, there is no limit to the maximum level of fine.

2.3.4 Results and Cost of UK's enforcement program

According to the report to the European Commission, a total of 4,217 samples (2046 samples of gasoline and 2171 samples of diesel) from the refineries, import terminals, distribution terminals and retail stations in the UK were analyzed and tested in 2007. About five percent of the samples for which results have been reported (3,942 samples) are collected from retail stations.

Analysis of the gasoline samples suggest that gasoline sold in the UK in 2007 is in compliance with the fuel specifications with 95% confidence, except for the summer vapor pressure and olefins. In both cases, only one sample tested exceeded the summer vapor pressure limits and one sample exceeded the limit values for olefins by a statistically significant margin.

While there were some diesel samples that exceeded the minimum limit for cetane number, and some that exceeded the maximum limit values for distillation, the exceedances were deemed not statistically significantly. Therefore all the diesel samples were considered in compliance with the specifications in 2007 (U.K. Clean Air Act, Section 32, 1993).

The general view is that market forces (i.e., the potential risk of damaged reputation) are the main motivation for oil companies to monitor and ensure fuel sold in the UK conforms to the standards, and the potential financial penalties play a less important role. Off-spec fuel used in vehicles could result in damage to vehicles and/or their emission control systems, and vehicle owners would lose confidence in companies that sold non-conforming fuels. It is in the oil companies' interest to maintain a good

reputation by making sure their fuel meets all the specifications. The high compliance rate therefore reflects the industries' efforts to protect their reputations in a competitive market.

3. Common themes of the fuel compliance programs

The successful U.S., U.K., and Japanese fuel quality programs exhibit some common elements. These elements, discussed in more detail below, include both upstream (refineries/import terminals) and downstream fuel testing, presumptive liability that holds all upstream fuel suppliers liable to non-conforming fuel found at retail stations, and severe non-compliance penalties.

3.1 Upstream testing (at the refineries or import facilities) and downstream quality check

The only way to ensure that fuel complies with the specifications is to test and verify it. Because of the fungibility of fuels, all three countries require refineries and importers to test every batch of fuels to demonstrate compliance before the fuel is released into the distribution system and blended with fuel products from other manufacturers.

Fuel testing at the retail stations is equally important to deter contamination or mixing of off-spec fuel along the distribution chain. Downstream quality check is extensive in Japan (which mandates at least one sample be taken from each of the 45,000 retail station every year) and the US (where about 9,000 samples are taken and analyzed for diesel content and over 10,000 samples are assessed for RFG compliance each year) (see EPA: Information, 2011; Nakayama, 2006). In the UK, far fewer samples (~200 per year) are collected and tested at the retail stations due to market pressure; it seems that the industry demonstrates a high level of self-policing for fear of reputational damage. For countries that are at the infant stage of establishing a fuel quality enforcement program, it would be advisable to set aside resources for fuel sampling and testing, at both the upstream and the retail stage. Only by doing so could the government establish enforcement presence (meaning that quality of fuel will be checked) so that illegal blending can be deterred. Also, fuel testing would make the government confident that fuels sold in the market actually

conform to specifications and will not cause any damage to vehicle emissions control devices.

3.2 Presumptive liability puts the onus on fuel suppliers to deter fuel contamination and the mixing of low quality fuel along the distribution chain

A lack of fuel quality monitoring along the distribution chain makes it hard to isolate and identify the source of problems (such as dumping illegal fuel during fuel distribution) when non-conforming fuels are found at retail stations. In the US, making all parties along the supply chain presumptively liable forces all parties, including refineries and importers, fuel handlers and distributors, and retail stations to dedicate resources to assure adherence to fuel requirements at every stage, from production to distribution to final sale. Similar requirements are in place in Japan, where refiners and importers are liable for any violation found at the downstream retail stations, leading refiners and importers to check fuel quality during distribution.

3.3 Prohibitive non-compliance penalty

Fuel sampling and monitoring serves an important role in identifying incidences of non-compliance, but whether non-compliance will recur depends on the level of penalty. The penalty imposed on fuel suppliers selling off-spec fuel can be in the form of fines, criminal charges or reputational damage. In any case, the penalty needs to be severe to avert illegal mixing of low-quality fuel and to coerce the industry to do more to ensure quality of fuel.

3.3.1 Financial and criminal penalty

In all three countries reviewed in the memo, fuel retailers and/or oil companies can be subject to substantial penalties (fines or shut down of business) and even criminal charges (in Japan) if found selling off-spec fuels. The substantial fines that can potentially be levied on the oil industry and retailers are considered an important deterrent for infringement on the fuel standards in the US and Japan.

3.3.2 Reputational damage

Studies of both the UK and Japanese programs suggest that the risk of reputational damage is a powerful driver for ensuring compliance. Hence a "name and shame" program could potentially be a persuasive tool to induce companies to monitor the quality of fuel sold by their own suppliers and their competitors. This tactic is likely more useful in countries where competition is strong and the value of a company's brand is high.

4. Key Steps: Establishing a fuel quality assurance program

Based on the experiences of the US, Japan and the UK, below are five steps that countries with less mature fuel quality assurance program could consider to establish better control of motor vehicle fuel quality:

- *Establish in-house capacity to enforce fuel standards*

As reviewed earlier, the US fuel quality program involves audits of industry reports and operation, and provides oversight to fuel quality sampling and testing conducted by the industry and EPA contractors. Similarly, oversight of fuel sampling and testing conducted by the industry and METI contractors are key elements of Japan's fuel quality assurance program.

While fuel sampling and testing can be outsourced to contractors, it is important for the environmental agency to build up its own in-house capacity for developing and managing the program. It is critical for the environmental agency to design and execute the reporting and testing part of the program; this ensures that the regulatory agency and the industry are not over-burdened with paperwork and fuel testing needs.

- *Secure funding for conducting fuel testing and managing the program*

Studies of the US and Japanese programs point to the need for substantial resources for conducting comprehensive fuel quality inspections and for verifying and auditing industry-submitted testing data. Even when the industry is required to test fuel periodically and report results to the regulatory agency, inspections conducted by the environmental agencies

or contractors are still needed to verify industry test results. If substantial funding cannot be secured initially, the regulatory agency may prioritize resources by conducting a small number of targeted tests at retail stations that are suspected of selling off-spec fuel.

Regulatory agencies can look for potential funding sources to finance fuel testing from fuel taxes, vehicle taxes, fuel registration fees, retail station registration fees, vehicle registration fees and/or inspection and maintenance (I/M) fees.

- *Seek authority to impose non-compliance fines*

The US and Japanese fuel quality programs have demonstrated that fuel testing and monitoring, comprehensive industry-sponsored fuel quality monitoring programs, and punitive non-compliance fines provide considerable incentives for fuel providers to comply with regulations. The environmental agency should seek the authority to impose non-compliance fines on the oil industry and retailers.

- *Secure industry cooperation (mandatory/voluntary self testing, and mandatory reporting)*

As mentioned earlier, fuel testing is the only way to ensure that fuel sold on the market actually meets the standards. However, funding for fuel testing programs is limited for many countries, so it would be best to spend the limited resources on conducting targeted testing or limited randomized testing. Additionally, the government should leverage industry resources by demanding industry-funded self-testing and monitoring. The US, Japanese and UK programs all require that fuel refineries/importers test fuels and demonstrate compliance before the fuels are released to the market. It is important for the industry to self-test fuels that they produce and to submit test results to the environmental agency in order to verify the probity of results.

5. Conclusions

Fuel evaporative emissions and by-products from vehicle fuel combustion produce harmful compounds that lead to air pollution. Fuel specifications are developed to minimize these emissions to protect air quality and

human health. The effect of fuel regulation can only be realized with an effective fuel quality management program. With the adoption of advanced vehicle emissions standards, advanced emission control devices, which are susceptible to damage by high sulfur fuels, could be more often deployed. As such, an effective fuel quality control program is an increasingly critical element of vehicle emission control efforts.

Evaluation of the successful fuel quality management programs in the US, Japan and the UK suggest that an effective program should include three key elements: 1) fuel sampling and testing upstream at the refineries/import facilities and retail stations, 2) a presumptive liability policy that places the onus of testing on industry to assure fuel quality along the distribution chain, and 3) heavy non-compliance penalties. For countries that have not yet established a mature fuel quality assurance program and whose authority to regulate fuel is not clear, the environmental agency should take the first step of securing the authority and resources for enforcing emissions-related fuel requirements and establishing in-house enforcement capacity. With the authority to regulate emissions-related fuel characteristics, plus increased enforcement staff capacity, the agencies could then gradually build up an effective fuel monitoring program that keeps off-spec fuel off the market, and ensures that vehicle standards and their accompanying fuel standards deliver the promised environmental and health benefits.

APPENDIX: Fuel specification / standards of the US, Japan and EU

Table A.1: US per gallon and average standards and performance requirements for gasoline and diesel

Gasoline

PROPERTY OR PERFORMANCE REQUIREMENT	REFORMULATED GASOLINE (RFG)		OTHER GASOLINE	
	PER GALLON	AVERAGE	PER GALLON	AVERAGE
Lead	Non-detectable	-	Non-detectable	-
Sulfur, ppm, max	80	30	80	30
Volatility (summer RVP)	Approximately 7.0 psi (48 kPa)	-	7.8-9 psi (54-62 kPa)	-
Aromatics	25%	-	25%	-
Benzene	1.3 vol.%	0.95 vol.%	-	-
Other heavy metals (e.g., manganese)	Non-detectable	-	-	-
RFG and anti-dumping[7]	Reduce VOCs and air toxics by 25-30% (compared with 1990 gasoline quality)	Reduce VOCs and air toxics by 25-30% (compared with 1990 gasoline quality)		Fuel not dirtier than 1990 gasoline quality
Mobile Source Air Toxics (MSAT 1)		Further reduces average toxics		Further reduces average toxics
MSAT 2	Benzene: 1.3 vol%	0.62 vol.% on average	No cap but refinery/importer annual average cannot exceed 1.3 vol.% before use of credits	0.62 vol.% average

Diesel (Motor vehicle, non-road)

PROPERTY REQUIREMENT	PER GALLON
Sulfur	15 ppm
Cetane index, min	40
Or Aromatics, max	35%

[7] Sec. 211 of the Clean Air Act specifies a backstop limit on NOx, requiring that NOx emissions from a baseline vehicle using non-RFG shall not exceed the level from the baseline vehicle using the baseline gasoline in 1990. EPA no longer enforces the NOx standard, since compliance with the low sulfur levels in gasoline (30 ppm average and 80 ppm per-gallon cap) assures compliance with the old NOx standards. Starting 2011, EPA will begin to phase out the toxics standards as well. These will be replaced by a standard on benzene (annual average of 0.62 volume percent).

Table A.2: The Japan Fuel Quality Control Law – mandatory and standard specifications

		GASOLINE		DIESEL		
		PROPERTY	STANDARD	PROPERTY	STANDARD	
Standard specifications	Mandatory Specifications	**Lead**	Non-detectable	Cetane Index	45 min.	Mandatory
		Sulfur content	10 ppm	Sulfur	10 ppm	
		MTBE	7% vol. max.	Distillation, T90%	360°C max.	
		Benzene	1% vol. max.	FAME *	0.1 mass% max.	
		Kerosene	4% vol. max.	Triglyceride *	0.01 mass% max.	
		Methanol	Non-detectable	Flash point	45°C min.	
		Washed gum	5 mg/100 ml. max.	Pour point	Depends on regions and month	
		Color	Orange	Cold Filter Plugging Point (CFPP)	Depends on regions and month	
		Oxygen content	1.3% mass% max.	Carbon residue **	0.1 mass% max.	
		Ethanol	3% vol% max.	Kinematic viscosity @30 °C	1.7 mm^2/s min.	
		Octane	Regular: 89 min. Premium: 96 min.			
		Density	0.783 g/cm^3 max.			
		Distill	T10/T50/T90			
		Copper corrosion @50 °C	1 max.			
		RVP	44-78kPa (kgf/cm^2)			
		Oxidation stability	240min min.			

Source: Petroleum Association of Japan. 2009. Petroleum Industry in Japan 2009.

Note: All properties listed above are included in the Standard Specifications; items in bold are mandatory specifications.

* This specification is applicable to diesel fuels without international blending of FAME (Fatty Acid Methyl Ester). Mandatory standards allow FAME upper blending limit of 0.5 max%. In such as case, additional standards include:

Triglyceride: 0.01 mass% max.; Methanol: 0.01 mass% max.; Acid Value: 0.13 mgKOH/g max.; Formic Acid+Acetic Acid+Propionic Acid: 0.003 mass% max.; Acid Stability: 0.12 mgKOH/g max.

** CCR, from 10% distillation residue.

Table A.3: Fuel requirements for gasoline and diesel in the EU

Gasoline

PARAMETER UNIT		98/70/EC LIMIT VALUES MIN.	98/70/EC LIMIT VALUES MAX.
Research Octane Number (RON)	--	95	
(RON 91 fuel only)	--	91	
Motor Octane Number (MON)	--	85	
(RON 91 fuel only)	--	81	
Vapor Pressure, DVPE			
--summer period (normal)	kPa		60
--summer period (arctic or severe	kPa		70
Distillation *			
-- evaporated at 100 deg C	% (v/v)	46	
-- evaporated at 150 deg C	% (v/v)	75	
Hydrocarbon analysis			
-- Olefins	% (v/v)		18.0
-- Olefins (RON 91 fuel only)	% (v/v)		21.0
-- Aromatics	% (v/v)		35.0
-- Benzene	% (v/v)		1.0
Oxygen content	% (m/m)		2.7
Oxygenates			
-- Methanol	% (v/v)		3.0
-- Ethanol	% (v/v)		5.0
-- Iso-propyl alcohol	% (v/v)		10.0
-- Tert-butyl alcohol	% (v/v)		7.0
-- Iso-butyl alcohol	% (v/v)		10.0
-- Ethers with 5 or more carbon	% (v/v)		15.0
-- other oxygenates	% (v/v)		10.0
MMT	mg/l		6 (Jan 1, 2011) 2 (Jan 1, 2014) Limit review by end of 2012
Sulfur content	mg/kg		10
Lead content	mg/l		5

Diesel

PARAMETER	UNIT	98/70/EC LIMIT VALUES MIN.	98/70/EC LIMIT VALUES MAX.
Cetane number	--	51.0	--
Density at 15 deg C	kg/m3		845
Distillation – 95% Point	Deg C		360
Polycyclic aromatic hydrocarbon	% (m/m)		8
Sulfur content	mg/kg		10

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