**Competing Science and Competing Interests:**
**Making Sense of the MMT Debate**

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*Abstract*

The octane-enhancing fuel additive known as MMT® has long been the subject of considerable debate.[2] Much of the debate has centered around the effects of MMT on the operation of vehicle emission control systems.[3] The producer and users who support MMT and the automakers who oppose MMT have each conducted or sponsored a substantial number of scientific studies and each camp claims the results of their studies support their respective positions. As the competing claims are so different (i.e., "MMT causes failure of emission system components" versus "MMT can improve the performance of emission system components"), separating fact from fiction is not a simple endeavor in the case of MMT. Fortunately, government and independent reviewers who lack the divergent economic incentives that motivate the opposing camps in the on-going MMT debate have been tasked from time to time to determine the facts and decide whether to allow the use of MMT in gasoline. This paper describes the many government and independent reviews of MMT that have occurred over the past three decades in North America and the results of those reviews.

*Introduction*

Vehicles and the fuels they consume have long been treated as a unified "system" for the purpose of controlling emissions that contribute to air pollution. As early as the 1970s, government regulators understood that the emission reductions made possible by the development of catalytic converter technology could not be achieved without a parallel change in gasoline quality. Recognizing that gasoline containing lead fuel additives renders catalytic converters ineffective, regulators directed gasoline refiners to produce for the first time "unleaded gasoline" for use in cars and trucks equipped with the first generation of emission control systems. Regulators also provisionally restricted the use of any fuels or fuel additives that were not "substantially similar" to the fuels and fuel additives used to demonstrate the effectiveness of the new emission control technology.[4] In this way, automakers and fuel producers shared from the start the costs and engineering burdens created by the need to reduce air pollution from cars and trucks.

The shared burdens inherent to the "system" approach to vehicle and fuel regulation has spawned competition between the automakers and fuel producers as each interest seeks to shift to the other a larger relative share of the costs of more stringent emission standards. As one automaker recently explained in support of tighter fuel controls, "*variability of in-use fuel quality causes an increase in our development burden* . . . We must spend additional development and testing resources to assure acceptable idle quality and drivability *over a wide range of fuels*. . . ."[5] By contrast, more robust (and costly) emission control systems (i.e., those that include larger or more numerous catalytic converters or multiple emission reduction systems, including EGR or variable valve timing controls) can accommodate a broader range of fuel characteristics thereby increasing fuel production flexibility and lowering costs to fuel refiners and consumers. Because more

stringent fuel controls impose increased costs on fuel producers and more robust hardware imposes increased costs on automakers, each stakeholder has economic incentives that unavoidably pit one against the other.

Nowhere has this competition been more intense or more long lasting than in the case of the octane-enhancing fuel additive known as methylcyclopentadienyl manganese tricarbonyl (MMT). MMT is one of a handful of metallic-based fuel additives (other than lead) available to gasoline refiners. As far back as 1987, one major automaker openly expressed concern that the presence of MMT in gasoline complicated the testing necessary to validate vehicle design:

> With regard to use of MMT-free fuel in emissions testing, *this becomes an issue of economic practicality*. . . GM alone conducts literally hundreds of emissions and fuel economy tests each year in the validation of the new fleet. To repeat all of these tests on a second fleet of cars would be very costly, in the order of hundreds of thousands of dollars, and time consuming, [] with no benefit as the engine systems would be identical. . . *Duplicate testing on two mileage accumulation fuels [one with and one without MMT] would add a significant expense with no resulting benefit*.[6]

Whether motivated by "economic practicality" or otherwise, automakers have long claimed that MMT increases emissions, reduces fuel economy, and causes failure of critical emission control devices, including plugging of catalytic converters, failure of oxygen sensors, spark plug fouling that leads to misfire, and failure of fuel injectors. To support these claims, automakers have conducted a range of in-house tests and published the results in the peer-reviewed scientific literature and elsewhere.[7]

By contrast, the producer of MMT has long claimed that MMT is fully compatible with the effective operation of emission control technology and highly beneficial to gasoline refiners (because it lowers energy consumption and increases flexibility in the refining process). Like automakers, an equally impressive list of studies has been published in the peer-reviewed scientific literature supporting the claim that MMT is a beneficial fuel additive.[8]

Mediating this clear disagreement have been government regulators or other independent reviewers who have been tasked from time to time to determine what the science regarding MMT means for vehicle emission control system performance. The most active regulator has been the U.S. Environmental Protection Agency ("EPA") which has formally reviewed MMT on at least five different occasions (1978, 1981, 1990, 1991, and 1994). (EPA has also opted not to act on a formal petition to ban MMT in U.S. gasoline submitted by automakers in 2002.) Another country with multiple MMT reviews is Canada (1986, 1997-1998 and 2003-2005).[9]

Since automakers and the producer and users of MMT have clear financial incentives either to support or to oppose use of MMT, the conclusions of government and independent technical reviews of MMT provide a more neutral and less self-interested assessment of the substantial body of scientific data for MMT that has been developed over time. The purpose of this paper is to describe the independent technical reviews of MMT and to present the results of those reviews.

*Government and Independent Reviews*

Table 1 shows the time course of the various government and independent reviews that have occurred in North America from the 1970s to the present compared to the various studies of MMT completed either by automakers or MMT proponents and published in the peer-reviewed

scientific literature. Table 1 shows that MMT has been the subject of numerous reviews. Table 1 also shows that these reviews have resulted in authorization for use of MMT throughout North America.

*United States*

Shortly after the introduction of catalytic converter technology on vehicles operating in the U.S., the automobile industry expressed concerns that use of gasoline different from the gasoline used to demonstrate compliance with emission standards might cause the failure of new emission control system technology. The U.S. Congress responded to these concerns in 1977 by enacting § 211(f) of the U.S. Clean Air Act ("Act"). That provision of the Act limits the use of any fuel or fuel additives that are not "substantially similar" to the fuels or fuel additives used to obtain vehicle "certification" under the Act, commencing with the 1975 model year. The limitation is not absolute, however, as EPA was authorized to "waive" the limitation under § 211(f)(4) of the Act. To obtain a waiver, the manufacturer of the non-substantially similar fuel or fuel additive must establish that:

> such fuel or fuel additive or a specified concentration thereof, will not cause or contribute to a failure of any emission control device or system (over the useful life of any vehicle in which such device or system is used) to achieve compliance by the vehicle with the emission standards with respect to which it has been certified pursuant to [§ 206 of the Act].[10]

The new provision provisionally prohibited use of a wide range of fuel additives, including oxygenates, such as ethanol and methyl tertiary butyl ether ("MTBE"), and metals, such as MMT.

In the case of MMT, EPA construed this provision to require a clear demonstration that the emission by-products of MMT -- mostly inorganic manganese in various forms -- will not cause or contribute to the failure of any emission control devices or system. As EPA explained,

> [u]nlike materials traditionally allowed in unleaded gasoline, metallics, such as MMT, produce non-gaseous combustion products, some of which may be deposited on parts of the vehicle that come into contact with the combustion products of the burned fuel. These areas of the vehicle include the combustion chamber, the catalyst, the oxygen sensor, and all parts of the exhaust system.[11]

The fundamental question for resolution in the waiver proceeding, in other words, was whether coating of internal engine and emission control system components by manganese from the combustion of MMT would cause or contribute to emission system failure.

1978

In 1978, Afton Chemical Corporation ("Afton Chemical" then known as Ethyl Corporation) submitted a request to EPA for a waiver to allow use of MMT at concentrations resulting in 1/16 and 1/32 gram per gallon (gpg) manganese in U.S. unleaded gasoline. Included in the data considered by EPA were preliminary results from a 63 vehicle fleet test sponsored by automakers and the oil industry. After careful review, EPA denied the waiver request based on concerns that use of MMT might increase exhaust hydrocarbon emissions.[12]

1981

In 1981, Afton Chemical once again sought a waiver from EPA, but this time at a concentration of MMT resulting in 1/64 gpg manganese in unleaded gasoline. Afton Chemical did not provide any new data in support of the request, opting instead to model potential impacts based on the data underlying the 1978 waiver request. Once again, EPA denied the request, this time concluding that Afton Chemical had not presented sufficient data to show that use of MMT at the lower concentration would not cause or contribute to emission control component failure.[13]

1990-1995

In 1990, Afton Chemical submitted a third request for a waiver to allow use of MMT at a concentration resulting in 1/32 gpg manganese in U.S. unleaded gasoline.[14] In support of the waiver request, Afton Chemical conducted a wide range of tests to assess the automobile industry's concerns (and, by extension, EPA's concerns) for all emission system components, including catalytic converters, oxygen sensors, fuel injectors, the combustion chamber, spark plugs, exhaust gas recirculation ("EGR") systems, and on-board diagnostic systems ("OBD-II"). The foundation for these tests was vehicle fleet testing. Afton Chemical commissioned extensive vehicle fleet tests involving nearly 100 test vehicles with forward-looking emission systems to age emission system components on gasoline with and without MMT. Separately, automakers conducted their own testing on a more limited set of vehicles. All of the test vehicles were equipped with the same basic emission control system that is still used today: three-way catalytic converters (many closely-coupled to the engine), computer driven, closed-loop air/fuel control systems, oxygen sensors and fuel injection, among other similar components. Following mileage accumulation for as many as 100,000 miles, major emission system components underwent comprehensive examination to determine if the characteristic manganese deposits associated with use of MMT adversely impacted component operation.

In addition, automakers presented data they claimed demonstrated that use of MMT in Canada had caused catalyst plugging, spark plug misfire, and other adverse impacts for vehicles in–use. Included among the data were pictures of what automaker claimed to be failed emission control system components from Canadian vehicles.[15]

After more than four years of detailed assessment, EPA concluded that the extensive testing conducted by Afton Chemical and others to evaluate the impact of manganese deposition on emission control system components from MMT combustion showed that MMT does not "cause or contribute" to the failure of vehicles to meet applicable emission standards.[16] As part of its analysis, EPA "chose to examine the additive's performance against the most stringent of the possible criteria – a requirement that the additive cause no statistically significant increase in emissions."[17] EPA concluded that applying this stringent criteria "to the full mileage range of HC emissions data from Ethyl's tests of 1992 and 1993 vehicles results in a failure to discern any 'real' emission increase at all – that is, no increase that we may not reasonably attribute to sampling error rather than to an additive effect on HC in the sampled vehicle population."[18] On this basis, among others, EPA concluded that:

> Based on all of the information [] available concerning the potential effect of use of MMT in unleaded gasoline on regulated emissions, as submitted by Ethyl and others, the Administrator of EPA determined . . . that, "Ethyl has satisfied its burden under Clean Air Act 211(f)(4) to establish that use of [MMT] at the specified concentration will not cause or contribute to a failure of any emission control device or system (over the useful life of any vehicle in which such device

or system is used) to achieve compliance by the vehicle with the emission standards with respect to which it has been certified."[19]

Ultimately, EPA determined that the presence of manganese in gasoline does not cause emission system component failure or degradation:

- Catalytic converters do not plug, degrade, or otherwise fail;
- Oxygen sensors do not malfunction;
- Spark plugs do not misfire;
- Fuel injectors are not fouled; and
- Small changes (whether up or down) in vehicle emissions do not impact compliance with applicable emission standards.

EPA also acknowledged several benefits associated with MMT. First, EPA acknowledged "the obvious economic benefits associated with reductions in petroleum use and fuel prices" that MMT provides.[20] Second, EPA acknowledged that "there might also be some favorable health and environmental effects" linked to use of MMT:

- "Regarding CO emission decreases, EPA's analysis indicates that examination of all of the available test data on the CO effects of MMT shows a small (0.07 gpm or 2% of applicable standards) decrease attributable to the additive."[21]
- "EPA also examined $NO_x$ emissions changes demonstrated by the data which had been submitted by both Ethyl and Ford. The test data for $NO_x$ show a more substantial and more consistent decrease of this pollutant than was the case for CO. The average across models was 0.08 gpm or 8% of the standard."[22]
- "EPA has therefore concluded that it is likely that in certain $NO_x$-limited areas, ambient levels of ozone would decrease based on the expected $NO_x$ reductions resulting from MMT use."[23]

Disputing EPA's determination that MMT does not cause or contribute to emission control component failure, an association of U.S. automakers (AAMA) challenged the decision in a federal appeals court, seeking to have it overturned as "arbitrary and capricious" and contrary to law. EPA vigorously defended its decision, arguing in its brief to the court that "AAMA fails to acknowledge that, in addition to applying the traditional statistical tests, EPA also concluded that the Ethyl test data for 1992 and 1993 vehicles (with new technologies) *did not show any statistically significant increase in hydrocarbon emissions*."[24] Following extensive proceedings, the court upheld EPA's 1994 "cause or contribute" determination, noting that "[t]he Administrator's analysis of the data submitted by Ethyl was careful and searching; AAMA did not come close to proving that the Administrator's analysis of the data was arbitrary and capricious."[25]

On July 11, 1995, EPA formally granted the waiver for MMT.[26] Later, in December of 1995, EPA formally registered MMT for use in unleaded gasoline, thereby making it legal for use in conventional U.S. gasoline.[27]

2002-2003

Following the unsuccessful legal effort to overturn EPA's 1994 determination that MMT does not cause or contribute to emission control component failures, automakers commenced during 1996 what they described to be the most comprehensive study of MMT ever undertaken. Conducted over a span of nearly six years and at a cost of more than eight million dollars, the sponsors of the study released the study results in July of 2002[28] and immediately petitioned EPA to "use its authority to prevent the expanded use of MMT in the country's gasoline supply."[29] The petitioners (the Alliance of Automobile Manufacturers (AAM)) claimed that "the study conclusively establishes that MMT":

- "increases hydrocarbon emissions and causes vehicles with today's advanced emissions control systems to fail certification standards;
- increases emissions of carbon monoxide and oxides of nitrogen;
- impairs the performance of catalysts and emission control systems; and
- increases fuel consumption and $CO_2$ emissions."[30]

One year later, the producer of MMT responded to the AAM study with its own critical assessment of the AAM study results and reported very different conclusions to EPA, including an alternative statistical analysis of the data conducted by a different group of independent statisticians.[31] This competing assessment concluded that:

- All of the test vehicles in the AAM study easily met applicable in-use emission standards;

- Emission control system components exposed to MMT performed as well as, and in some cases better than, base fuel components in the AAM study; and

- None of the very small differences in fuel economy and $CO_2$ reported in the AAM study are statistically significant on a model by model basis, notwithstanding an initial bias in $CO_2$ and fuel economy against the fleet of MMT-fueled LEV vehicles at the zero mile interval.

On this basis, the producer of MMT concluded that the AAM study reaffirmed what EPA had determined in 1994 – namely, that manganese from the combustion of MMT does not harm vehicle emission control systems.

Presented with these new data and competing claims, EPA has chosen not to act on the AAM petition to restrict use of MMT or to alter its determination that manganese deposition on vehicle emission system components does not harm advanced emission control systems. In December, 2007, moreover, EPA restated its determination that "MMT, added at 1/32 gpg Mn, will not cause or contribute to regulated emissions failures in vehicles."[32] As a result, MMT remains a legal fuel additive for use in conventional gasoline in the U.S.

*Canada*

Although § 211(f) of the Clean Air Act provisionally restricted use of MMT (and other non-substantially similar fuel additives) in U.S. unleaded gasoline commencing in the late 1970s, no similar restriction existed in Canada. For that reason, MMT was available for use by refiners for use in both unleaded and leaded gasoline during the period of Canada's lead phase down and was used in both grades of gasoline during that time.

1986

In 1986, as the lead phase-out accelerated, Canada's Minister of Environment directed the Royal Society of Canada to assess alternatives to lead in gasoline, including MMT. With respect to MMT, the Royal Society of Canada concluded that "the current-technology catalysts are unlikely to be damaged or rendered inoperative by the use of [MMT] at the present federal standard concentration (0.018 grams of manganese per liter)."[33] The Royal Society's technical appraisal of MMT also included these additional conclusions about the impact of MMT on vehicle operation:

- "[I]n eight years of use of MMT in unleaded gasoline in Canada there does not appear to have been a higher incidence of catalytic converter failure than in the United States;"[34]

- "MMT does not appear to cause failure of oxygen sensor or deactivate the catalyst;"[35]

- "The effects of MMT on automotive emissions are very small. They appear to range from slightly improved to slightly worse than for clear unleaded fuel, but it is unlikely that even a fleet test of unprecedented magnitude and scope would be large enough to show any statistically significant differences."[36]

Also in 1986, Environment Canada requested that the Canadian General Standards Board ("CGSB") Petroleum Committee "assess the potential effects of manganese compounds on vehicle emissions and on emission system durability in Canada."[37] The CGSB Gasoline and Alternative Fuels Committee subsequently appointed a working group to carry out the review. The working group included members from the petroleum industry, vehicle manufacturers and the federal government.[38] As part of the review, the working group reviewed relevant technical reports on MMT, including new in-use surveillance test data generated by Environment Canada, and requested information "from both the Motor Vehicle Manufacturers Association (MVMA) and the Automobile Importers of Canada (AIC) member companies . . . as to how current emission-control systems were behaving in Canada and how future emission-control systems would behave if MMT were retained in gasoline at the current CGSB limits."[39]

The working group first concluded that "[t]here are sound economic reasons for the retention of MMT in Canadian unleaded gasolines."[40] As explained by the working group, "[t]his useful antiknock agent saves energy and money in meeting the octane requirements of the Canadian automobile population."[41] Having established MMT's value as a fuel component, the working group recommended that "MMT be retained at current levels as an octane enhancer in unleaded gasoline."[42] The working group based its recommendation on the following technical findings:

- Use of MMT results in a small "average increase in tailpipe HC emissions over clear fuel," but "the effect[] of MMT is considered miniscule" as it relates to any corresponding change in air quality.[43]

- "The use of MMT at current CGSB levels does not significantly compromise emission control system operation or component durability."[44]

- "[T]here is no evidence to suggest that emission control systems that have been developed for today's market would experience adverse effects with regard to function or performance from the use of MMT in gasoline. Current systems do not indicate that durability is lower in Canada, where MMT is used, then in the United States where MMT

has been disallowed in unleaded gasoline. Members of MVMA and AIC indicate that manufacturers' Canadian warranty claims on emission components are comparable to the U.S."[45]

1990

In 1990, Environment Canada submitted comments to EPA on Afton Chemicals' application for permission to market MMT in U.S. unleaded gasoline. Environment Canada reported at that time that, although the incidence of catalyst plugging "is difficult to enumerate", an "examination of the manufacturer's claims did not reveal any abnormal incidence of plugging."[46]

1997-1998

After EPA rebuffed automaker concerns about the impact of manganese deposition on emission control system component operation in 1995, automakers reiterated their concerns about MMT in Canada as Canada moved toward adoption of "Tier 1" emission standards, commencing with the 1998 model year. Asserting that the deposition of manganese on emission system components altered component operation sufficiently to foreclose the proper operation of the second generation of on-board diagnostic systems ("OBD-II"), the automobile industry successfully persuaded the Canadian government to restrict the importation and inter-provincial trade of MMT in Canada.

In support of their concerns, automobile representatives presented to the Canadian parliament photographs of emission system components obtained from Canada, where MMT was then in widespread use, and from the U.S., where MMT use was non-existent.[47] Representatives from major automobile companies also relied on alleged differences in warranty failure rates for components from U.S. and Canadian vehicles. [48] Industry representatives also maintained that additional field data, separate from the photographs, also supported their concerns about MMT, but they refused to share the other data with the Canadian parliament arguing that the data was "confidential" in nature.[49]

Relying upon visual evidence and alleged differences in warranty rates in the U.S. and Canada, the automobile industry collectively maintained that OBD-II systems mandated by new Canadian regulations "are not compatible with Canadian gasoline containing MMT" because manganese deposits from the combustion of MMT accumulated on emission system components.[50]

Members of parliament determined that the photographic and other visual evidence provided by the automobile industry representatives in their testimony, together with the alleged differences in warranty experience, provided a sufficient basis to determine that MMT was not compatible with OBD-II systems. On that basis, the Canadian parliament enacted the MMT trade restriction known as the *Manganese-Based Fuel Additives Act*.[51]

Afton Chemical challenged the restrictions in court seeking a means to force the automobile industry to substantiate its claim of incompatibility with more than the photographic evidence displayed in hearings before parliament.[52] In connection with litigation challenging the constitutionality of the MMT trade restriction, Afton Chemical succeeded in prompting representatives from several major automakers (General Motors, Ford, and Honda) to submit under oath the evidence they had developed purporting to demonstrate why the visual appearance of the components shown to the Canadian parliament was linked to component failure, as had been alleged in testimony. Once submitted, the parties proceeded to debate the technical merit of the vehicle manufacturers' data in an exchange of affidavits by technical experts. Among other

things, Afton Chemical submitted the results of a substantial body of new fleet test data (supplementing the comprehensive data previously supplied to the U.S. EPA) showing that MMT is fully compatible with the effective operation of advanced vehicle emission control systems, including the new OBD-II systems.

This exchange of technical information ultimately prompted the Canadian government to reverse course by lifting the trade restrictions on MMT, and to declare separately that "[c]urrent scientific information fails to demonstrate that MMT impairs the proper functioning of automotive on-board diagnostic systems."[53] Government documents declassified and released to the public record by Environment Canada (EPA's Canadian counterpart) several years later in response to an Access to Information request explain the basis for the government's decision:

- "[I]n preparing [the government's] defense of the numerous challenges to the legislation, new evidence has surfaced. Specifically, the government has learned that the automobile manufacturers have *not* been able to demonstrate that MMT impairs the functioning of OBDs or jeopardized the ability to meet current emission standards."[54]

- "In March [1998], representatives of domestic and foreign automakers told us that preliminary results of their latest studies could *not* confirm that MMT impairs the proper functioning of on-board diagnostic systems nor that MMT jeopardizes their ability to comply with current vehicle emission standards. These were key elements in our original decision to pass the legislation."[55]

- "No convincing evidence relating to widespread in-use failures was contained in the affidavits filed by the automobile industry in the matter of the enjoining motion sought by Ethyl Canada to the *Manganese-based Fuel Additives Act*."[56]

- "To date, there has been no reported widespread impact on catalysts, OBDs or any other emissions control related component or any warranty related problems in Canada due to the use of MMT."[57]

- "[T]he automotive industry has not been able to make a case to support their claims regarding the warranty issue even though MMT has continued to be present in Canadian retail gasoline. The government is not aware of any widespread warranty claims that are attributable to the continued use of MMT in Canadian fuels over the many years of its use."[58]

- "The scientific basis provided for manufacturer's concerns would suggest that the reported phenomena should manifest themselves across a large segment of the in-use vehicle population on a persistent basis which has not been the case to date."[59]

As part of its decision to rescind the prohibition on the importation and inter-provincial trade of MMT, the Government of Canada also agreed to pay $13 million (U.S.) in damages to Afton Chemical.

2005

In July of 2002, automakers presented to the Minister of the Environment (among other Canadian ministries) the results of the comprehensive MMT vehicle fleet test that provided the basis for the AAM Petition to EPA to restrict use of MMT in the U.S. The automakers requested that Environment Canada convene an independent third party panel to review the data. In April of

2003, Environment Canada indicated that it planned to conduct a third-party review of the new automaker data.[60] At about the same time, reports surfaced that some vehicles in consumer use in Canada were experiencing catastrophic failures due to the plugging of new close-coupled, high cell density catalytic converters. These reports attributed the plugging to use of MMT in Canadian gasoline.[61] The reports of component failure prompted Environment Canada to propose for public comment in December of 2003 terms of reference for a review of MMT that covered both the new data from the automaker sponsored MMT study released in mid-2002 and the claims of catalyst failure in Canada.[62] Environment Canada requested that the EPA jointly sponsor the proposed review, but EPA declined, apparently having told Canadian government officials that EPA had "reviewed" the automaker's latest MMT study report and determined "that the evidence is inconclusive."[63]

Nonetheless, Environment Canada completed its own investigation of the claims of catalyst plugging attributable to MMT in January of 2005. Section 157 of the *Canadian Environmental Protection Act, 1999* (CEPA) imposes a regulatory reporting requirement that provided Environment Canada a direct way to evaluate the automaker claims. The CEPA reporting requirement specifies that:

> [a] company that manufactures, sells, or imports any vehicle, engine or equipment of a class for which standards are prescribed shall, on becoming aware of a defect in the design, construction *or functioning of the vehicle, engine or equipment* that affects or is likely to affect its compliance with a prescribed standard, *cause notice of the defect to be given in the prescribed manner*….[64]

The specified notice must be given both to the Minister of Environment and to the owners of the affected vehicles.[65] The reporting requirement is mandatory so that the Minister of Environment can issue orders in appropriate cases compelling the recall and repair of any non-compliant vehicles.[66]

Environment Canada's Transportation Systems Branch completed the investigation. The objective of the investigation was "to identify defects that *might* have been caused by the presence of MMT in fuel."[67] To meet this objective, personnel from the Transportation Systems Branch evaluated defect notices submitted by automakers in both the U.S. and Canada as required by law. The key conclusion of Environment Canada's analysis was that during 2000 to 2004 "no Notice of Defect was found to be potentially caused by MMT."[68]

To date, Environment Canada has not convened the technical review that was proposed in late 2003 and it remains unclear if such a review will ever occur now that refiners in Canada have opted to voluntarily suspend use of MMT pending the review.[69] Nevertheless, the performance of vehicles in Canada using gasoline containing MMT remains a hot topic. In August of 2008, a private automobile industry consultant, Sierra Research, released a study claiming that vehicle performance problems were widespread for the 1999 to 2003 model years. The report, which does not appear to have been subjected to any form of peer-review, attributes the problems to the presence of MMT in Canadian gasoline.[70]

Among other things, the Sierra Research paper reports the results of a "confidential survey" involving 18 automakers who were asked to provide data showing that MMT caused in-use vehicle performance problems in Canada involving plugging of high cell density catalytic converters. Fifteen automakers reported that they introduced into Canada vehicles with the most

advanced emission control systems sometime during the period 1999 to 2004. Eight of these automakers reported that they were not aware of any warranty cases that appeared to involve catalyst plugging with MMT use.[71] Two automakers alleged an unspecified number of problems with in-use experience but chose not to present any data to support the allegations.[72] The remaining five automakers either reported having no problems with most models equipped with advanced emission control systems and an unspecified number of problems with one or two models or, in one case, reported having an unspecified number of problems in each of three models equipped with the most advanced emission control systems.[73] Because the survey was "confidential" in nature, the report does not disclose by name any of the automakers who were surveyed, nor does it identify by name any of the specific models that reportedly experienced functional problems in the Canadian market or the magnitude of the alleged problems.

Clearly, Environment Canada's conclusion that "no Notice of Defect was found to be potentially caused by MMT" during 2000 to 2004 and the more recent claim by Sierra Research that defects in vehicle performance for various unidentified automakers and unidentified Canadian vehicles were widespread for the 1999 through 2003 model years *cannot both be true*. The Sierra Research paper makes no attempt to explain the apparent inconsistency and does not discuss the reporting of vehicle defects in Canada. How, if at all, Environment Canada will deal with this apparent inconsistency is as yet unknown, but Canadian regulators have not been persuaded to date to impose any further restrictions on use of MMT. MMT therefore remains available to gasoline refiners in Canada as a blending option at concentrations up to 18 milligram manganese per liter.

## Conclusion

The divergent economic incentives that motivate the opposing camps in the on-going MMT debate have prompted considerable study of MMT over the past three decades. These same divergent economic interests have also prompted strikingly different interpretations of the data generated in those studies. Because government and independent reviewers lack similar economic motivations, the results of government and independent reviews of MMT provide one way to make sense of the competing technical claims of the different stakeholders. In North America, where numerous government and independent reviews of MMT have occurred, MMT remains at present a legal fuel additive for use by fuel producers. Recent efforts by automakers to persuade U.S. and Canadian regulators to restrict use of MMT have not been successful, but their parallel efforts in North America to persuade refiners voluntarily not to use MMT have met with greater success, particularly as North America shifts increasingly towards use of biofuels, such as ethanol. That said, the debate about MMT is likely to continue. Ultimately, market forces may prove to be the most effective means to resolve the MMT debate as fuel producers and automakers struggle to serve a common customer (the consumer) in different parts of the world.

## Endnotes

[1] Kevin L. Fast is an attorney with more than two decades of experience, much of which has focused on the regulation of vehicles and fuels under Title II of the U.S. Clean Air Act. Prior to commencing an independent practice in the summer of 2005, the author was a partner for more than ten years on the environmental and natural resources team in the Washington, D.C., office of Hunton & Williams. Additional information about the author is available at http://www.kevinfast.com. Anyone interested in obtaining source documents cited in this paper is invited to contact the author directly.

[2] MMT® is a registered trademark owned by Afton Chemical Corporation.

[3] The potential health impacts of manganese emissions resulting from use of MMT have also been the subject of considerable debate, but those potential impacts are beyond the scope of this paper.

[4] *See, e.g.*, 45 Fed. Reg. 67,443 (October 10, 1980).

[5] Comments of Nissan Technical Center (May 30, 2006), p. 4 available at www.regulation.gov at docket EPA-HQ-OAR-2005-0036 (emphasis added). This "development burden" has prompted automakers to adopt and promote a "Worldwide Fuel Charter" (WWFC) that seeks to harmonize fuel quality worldwide. The WWFC treats vehicles meeting North American Tier 2 and European Euro IV or Euro V emission standards as functionally equivalent under the "Category 4" fuel specification.

[6] Letter from R.W. Baker, General Motors of Canada Limited, to B.B. Smith, Canadian Renewable Fuels Association (April 14, 1987), p. 2 (emphasis added).

[7] *See* Table 1 (Auto Industry Sponsored Studies).

[8] *Id.*, (MMT Producer Sponsored Studies).

[9] Other countries that have reviewed MMT are China, South Africa, Mexico and Peru. Several countries or groups of countries, including New Zealand, Vietnam, and the European Union have either banned or restricted the use of MMT, but they have done so based on political rather than scientific considerations as none of these countries has undertaken any sort of scientifically sound review of MMT. Many other countries have not expressed a formal position with respect to use of MMT.

[10] 42 U.S.C. § 7545(f)(4).

[11] 59 Fed. Reg. 42233 (August 17, 1994).

[12] 43 Fed. Reg. 41,424 (September 18, 1978).

[13] 46 Fed. Reg. 58,630 (December 1, 1981).

[14] *See generally* EPA Public Air Dockets A-90-16, A-91-46 and A-93-26. The waiver sought permission for use of MMT in conventional gasoline only. Neither the producer of MMT nor refiners in the U.S. have pursued a separate waiver that would allow use of MMT in reformulated gasoline (RFG) intended for use in areas of the U.S. with degraded air quality. Unlike the § 211(f)(4) waiver, the RFG waiver addresses how use of the additive impacts emission of five key air toxic emissions (benzene, 1,3 butadiene, polycyclic organic matter, formaldehyde and acetaldehyde). Approximately 30 percent of the gasoline in the U.S. is reformulated.

[15] *See, e.g.*, 59 Fed. Reg. 42,227, 42,237 (August 17, 1994).

[16] EPA's detailed assessment of MMT proved contentious at times. In December of 1991, for example, EPA denied the waiver request based on a concern that the effect of MMT on vehicle performance might change depending upon the severity of vehicle operation. 57 Fed. Reg. 2,535 (January 22, 1992). EPA later reversed course and sought to reconsider its decision after reviewing new data which specifically disproved EPA's "driving cycle" concern. *See Ethyl Corp. v. Browner*, 989 F.2d 522 (D.C. Cir. 1993).

[17] 59 Fed. Reg. at 42,238.

[18] *Id.*

[19] *Id.* Although EPA expressed concern that MMT might conceiveably have an adverse impact on the first generation of more sophisticated on-board diagnostic systems, EPA concluded that there was insufficient evidence to demonstrate the existence of any such adverse impact. *Id.* at 42,239. EPA indicated that it would continue to investigate the impact of MMT on OBD-II systems and would "initiate an appropriate rulemaking under section 211(c)" to regulate MMT if warranted. To date, EPA has not initiated any such rulemaking.

[20] *Id.* at 42,260.

[21] *Id.* at 42,258 (footnotes omitted).

[22] *Id.*

[23] *Id.*

[24] Reply Brief for Respondents, p. 4, n. 2 in *Ethyl Corp. v. Browner*, No. 94-1505, United States Court of Appeals for the District of Columbia Circuit (November 29, 1994) (emphasis added).

[25] *See Ethyl Corp. v. EPA*, 51 F.3d 1053 (D.C. Cir. 1995).

[26] 60 Fed. Reg. 36,414 (July 17, 1995).

[27] In 1994, EPA refused to "register" MMT for use in unleaded gasoline under § 211(a) of the Act as part of the decision on the § 211(f) waiver request. *See* 59 Fed. Reg. 42,255-42,257. This decision allowed EPA to demand completion of additional studies concerning potential public health risks of manganese emissions from use of MMT before issuance of a waiver for MMT. A court later overturned EPA's registration decision, effectively ordering EPA to treat MMT like any other existing fuel or fuel additive for the purpose of health effects testing. *See Ethyl Corp. v. Browner*, 67 F.3d 941 (D.C. Cir. 1995). MMT, like all other existing fuels and fuel additives in the U.S., is currently subject to health effects testing mandated by EPA.

[28] The study as reported by the automobile industry sponsors is available at www.autoalliance.org. The study sponsors included the Alliance of Automobile Manufacturers, the Association of International Automobile Manufacturers, and the Canadian Vehicle Manufacturers Association.

[29] Letter to Christine Todd Whitman, Administrator of the U.S. EPA from Josephine S. Cooper, President & CEO of the AAM dated July 30, 2002 (hereafter "AAM Petition").

[30] AAM Petition, p. 1.

[31] A Critical Analysis of the Alliance of Automobile Manuafacturers' MMT Study: Separating Fact from Friction, Ethyl Corporation (July 2003) available at www.aftonchemicalcorp.com.

[32] See www.epa.gov/otaq/regs/fuels/additive/mmt_cmts.htm.

[33] Lead in Gasoline Alternatives to Lead in Gasoline, *Supplementary Report,* Royal Society of Canada, February 1986, p. v.

[34] *Id.*, p. 6.

[35] *Id.*

[36] *Id.*

[37] An Assessment of the Effect of MMT on Light-Duty Vehicle Exhaust Emissions in the Canadian Environment, The CGSB Gasoline and Alternative Automotive Fuels Committee, April 4, 1986, p. 1.

[38] *Id.*

[39] *Id.*, p. 2.

[40] *Id.*, p. 1.

[41] *Id.*

[42] *Id.*, p. 10.

[43] *Id.*

[44] *Id.*

[45] *Id.*, p. 6. The working group noted, however, "that the effect of MMT on emission-control system components may be subtle and may never result in a falure that would be apparent through analysis of warranty claims." *Id.* For this reason, the working group also recommended that "the issue be reexamined in the event that future emission-control technology or the generation of additional data, should show adverse effect due to the use of MMT beyond those recognized in this report." *Id.*, p. 10.

[46] *See* Letter from Environment Canada, to the U.S. Environmental Protection Agency Regarding Ethyl Corporation's Fuel Additive Waiver Application for MMT (July 20, 1990), EPA Air Docket A-90-16, No. IV-D-181.

[47] Proceedings of the Standing Senate Committee on Energy, the Environment and Natural Resources, Issue 6 (February 4, 1997), p. 9 ("If you turn to the section on catalysts, we have here a series of photographs illustrating the problem experienced by all vehicle manufacturers. Specifically, the cross-section view of these catalysts clearly show a high level of manganese oxide deposition on the catalyst surface causing measurable impairment of its operation.") (Statement of Mark Nantais, President of the Canadian Motor Vehicle Manufacturers Association).

[48] *See, e.g., id.*, p. 6 ("General Motors data, some of which we have shared with representatives of all major Canadian petroleum companies, indicate that our customers are already experiencing power-train and emission control-systems failures at a rate many times greater than in the United States where MMT is not in use. This warranty data is in direct contradiction of Ethyl's data from their test programs which claimed real world problems would not occur. We also have conclusive test and laboratory data showing that MMT is the sole factor contributing to rapid spark plug deterioration.") (Statement of Maureen K, Darkis, President, General Motors of Canada Limited).

[49] *See, e.g.*, Proceedings of the Standing Senate Committee on Energy, the Environment and Natural Resources (February 4, 1997), p. 36 ("We have more data, *which are confidential and I do not share them with anyone*, but they clearly indicate to us that we have problems with certain components of OBD-II in Canada. That is clearly due to MMT additives.")(Statement of Mr. Ernest Lieb, President, Mercedes Benz Canada) (Emphasis added.)

[50] *Id.*, p. 8.

[51] S.C. 1997, c. 11.

[52] *Ethyl Canada, Inc. v. Minister of Environment*, Ontario Court (General Division), Case No. 97-CV-126708.

[53] Government of Canada Statement on MMT (July 20, 1998). A press release issued the same date by the Canadian government makes a similar statement (i.e., "The current scientific information fails to demonstrate that MMT impairs the proper functioning of OBDs.").

[54] Draft Communications Approach – MMT (June 16, 1998), Document #9657 (emphasis added).

[55] Federal Government Action on the Manganese-Based Fuel Additives Act – Talking Points (July 13, 1998), Document #9269 (emphasis added).

[56] Draft Point-by-Point Review of Items Raised in Caccia/Lincoln Letter (August 14, 1998), Document #8866.

[57] *Id.*

[58] *Id.* (Document #8871).

[59] *Id.* (Document #8866) (emphasis added).

[60] Letter from Minister of Industry Allan Rock to Mark Nantais, President, Canadian Vehicle Manufacturers Association (April 7, 2003).

[61] *See, e.g.*, Inside Fuels and Vehicles (June 19, 2003) ("An official with an automaker using the new catalysts on vehicles sold in Canada has reported a 50 percent reduction in catalytic function after 30,000 miles. After 45,000 miles the catalyst is completely plugged, leading to a 15 percent reduction in fuel economy and the 'check engine light' coming on, the company official added, and the company is having to meet an increasing number of warranty claims as a result of the clogged catalysts." )

[62] *See* "Environment Canada's Proposed Framework for an Independent Third-Party Review of New Information on the Effects of MMT on Vehicle Emissions," Environment Canada (December 9, 2003).

[63] Refiners in Canada voluntarily suspended use of MMT pending the outcome of the independent third party review. Whether Canadian refiners might opt to return to use of MMT without a review is unclear. However, at about the same time that the suspension went into effect, Canada adopted a national program to promote greater use of biofuels, including ethanol, in Canadian gasoline. The shift to biofuels lessens the need for competing octane-enhancers, such as MMT.

[64] *CEPA, 1999* s. 157(1) (emphasis added).

[65] *Id.*, s. 157(1)(a)-(c).

[66] Environment Canada, *Compliance and Enforcement Policy for the Canadian Environmental Protection Act, 1999 (CEPA, 1999)* (March 2001), p. 5 and pp. 25-26.

[67] Access to Information Request A-2006-00320, Document No. 013157 (emphasis added).

[68] *Id.*, Document No. 013159.

[69] New Fuels & Vehicles Online Daily Updates (March 17, 2004) ("The suspension of MMT use by the oil companies will last at least until an expert panel issues a report on the effects of MMT on vehicle emissions control systems.").

[70] James Lyon, "Impacts of MMT Use in Unleaded Gasoline on Engines, Emission Control Systems, and Emissions," Sierra Research Report No. SR-2008-08-01 (August 29, 2008) (hereafter "Sierra Research paper").

[71] Sierra Research paper, p. D-3 ("Manufacturer A did not know of any plugging with its MY2002 HDCC application."); p. 103 (Manufacturer B is "not aware of any warranty cases that appeared to involve catalyst plugging associated with MMT® use."); p. 103 (Manufacturer G is "not aware of any warranty cases that appeared to involve catalyst plugging associated with MMT® use."); p. D-60 (Manufacturer I reported that "[g]iven it was a 2002 model year vehicle, very few of them would have been expected to have accumulated significant mileage before MMT was removed from the Canadian fuel."); p. D-122 ("Manufacturer L did not observe any plugged catalysts identified by customer warranty cases."); p. D-231 ("Through 2005, no field experience has been identified with HDCC catalysts that indicate an MMT plugging problem. Examination of the warranty data base did not show any catalyst replacement cases where the failure codes would indicate a symptom of MMT plugging."); p. 103 (Manufacturer Q is "not aware of any warranty cases that appeared to involve catalyst plugging associated with MMT® use."); p. 103 (Manufacturer R is "not aware of any warranty cases that appeared to involve catalyst plugging associated with MMT® use.").

[72] *Id.*, p. 103 (Manufacturers F and P).

[73] *Id.*, pp. 103-125 (Manufacturer C (3 of 3), Manufacturer D (1of 7), Manufacturer J (2 of 5+), Manufacturer K (1of 8), Manufacturer M (2 of 8+)) and Appendix D, pp. D-8 to D-55, D-67 to D-118, and D-131 to D-229).

## Table 1

## Overview of Peer-reviewed MMT Studies and North American Independent Reviews of MMT®

## (Shaded Rows Denote Government or Independent Reviews)

| Auto Industry Sponsored Studies | MMT Producer Sponsored Studies |
|---|---|
| 1977: Manganese Fuel Additive (MMT) Can Cause Vehicle Problems, SAE 770655 | 1975: An Evaluation of Manganese as an Antiknock in Unleaded Gasoline, SAE 750925 |
| 1978: A Study of the Effects of Manganese Fuel Additive on Automotive Emissions, SAE 780002 | 1977: MMT-A Further Evaluation, SAE 770656 |
| 1978: How MMT Causes Plugging of Monolith Converters, SAE 780004 | 1978: Effect of MMT on Emissions from Production Cars, SAE 780003 |
| 1978: **U.S. EPA** Waiver Denial (1/16$^{th}$ and 1/32$^{nd}$ gram Mn per gallon) | |
| 1979: Results of Coordinating Research Council MMT Field Test Program, SAE 790706 | 1980: A Statistical Analysis of the Effect of MMT Concentration on Hydrocarbon Emissions, SAE 800393 |
| 1981: **U.S. EPA** Waiver Denial (1/64$^{th}$ gram Mn per gallon) | |
| 1982: Effects of Fuel Additive MMT on Contaminant Retention and Catalyst Performance, SAE 821193 | |
| 1984: Combuster Study of the Deactivation of a Three-Way Catalyst by Lead and Manganese, SAE 841408 | |
| 1986: **Royal Society of Canada** ("[C]urrent-technology catalysts are unlikely to be damaged or rendered inoperative by the use of [MMT] at the present federal standard concentration (0.018 grams of manganese per liter.") | |
| 1986: **Canadian General Standards Board** ("[T]here is no evidence to suggest that emission control systems that have been developed for today's market would experience adverse effects with regard to function or performance from the use of MMT in gasoline.") | |
| 1989: Characterization of Automotive Catalysts Exposed to the Fuel Additive MMT, SAE 890582 | 1990: Effect of a Fuel Additive on Emission Control Systems, SAE 902097 |
| 1991: Particulate Emissions from Current Model Vehicles Using Gasoline with MMT, SAE 912436 | |
| 1991: The Effect on Emissions and Emission Component Durability by the Fuel Additive MMT, SAE 912437 | |
| 1992: **U.S. EPA** Waiver Denial (1/32$^{nd}$ gram Mn per gallon) ("The Agency is today denying Ethyl's request for a waiver for [MMT] based on new data which indicate that factors other than those taken into account in Ethyl's test program may significantly and adversely influence the magnitude of the emissions increase caused by addition of [MMT] to unleaded gasoline.") | |
| 1992: The Effect of Mileage on Emissions and | |

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|---|---|
| Component Durability by the Fuel Additive MMT, SAE 920730 | |
| 1992: Effect of Mileage Accumulation on Particulate Emissions from Vehicles Using Gasoline with MMT, SAE 920731 | |
| 1993: The Effect of MMT on the OBD-II Catalyst Monitor, SAE 932855 | |
| | 1994: The Effects of Manganese Oxides on OBD-II Catalytic Converter Monitoring, SAE 942056 |
| | 1994: The Physical and Chemical Effect of Manganese Oxides on Automobile Catalytic Converters, SAE 940747 |
| 1995: **U.S. EPA** Waiver Granted (1/32nd gram Mn per gallon) ("Ethyl has satisfied its burden under Clean Air Act 211(f)(4) to establish that use of HiTEC 3000 at the specified concentration will not cause or contribute to a failure of any emission control device or system (over the useful life of any vehicle in which such device or system is used) to achieve compliance by the vehicle with the emission standards with respect to which it has been certified.") | |
| | 1997: Evaluation of On-Board Diagnostic Systems and Impact of Gasoline Containing MMT, SAE 972849. |
| 1997: **Government of Canada** prohibits the importation or inter-provincial trade of MMT in Canada because of concerns that MMT may harm vehicle on-board diagnostic systems. | |
| 1998: **Environment Canada** (18 milligrams Mn per liter) ("Current scientific information fails to demonstrate that MMT impairs the proper functioning of automotive on-board diagnostic systems.") | |
| | 2000: A Systems Approach to Improved Exhaust Catalyst Durability: The Role of the MMT Fuel Additive, SAE 2000-01-1880 |
| | 2000: Analysis of Nitrous Oxide Emissions from Light Duty Passenger Cars, SAE 2000-01-1952 |
| 2002: The Impact of MMT Gasoline Additive on Exhaust Emissions and Fuel Economy of Low Emission Vehicles, SAE 2002-01-2894 | 2002: A Peer-Reviewed Critical Analysis of SAE Paper 2002-01-2894 "The Impact of MMT Gasoline Additive on Exhaust Emissions and Fuel Economy of Low Emission Vehicles," SAE 2002-01-2903 |
| | 2002: Reformulating Gasoline for Lower Emissions Using the Fuel Additive MMT, SAE 2002-01-2893 |
| 2002: **U.S. EPA** takes no action in response to automaker petition to restrict use of MMT in U.S. gasoline. | |
| | 2003: AAM/AIAM Fleet Test Program: Analysis and Comments, SAE 2003-01-3297 |
| 2003: **U.S. EPA** takes no action in response to automaker petition to restrict use of MMT in U.S. gasoline. | |
| 2004: Effect of MMT Fuel Additive on Emission System Components: Detailed Parts Analysis from Clear- and MMT-Fueled Escort Vehicles from the Alliance Study, SAE 2004-01-1084 | |
| 2004: **U.S. EPA** takes no action in response to automaker petition to restrict use of MMT in U.S. gasoline. | |
| 2005: Effect of MMT Fuel Additive on Emission | 2005: Assessing High-Cell Density Catalyst |

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|---|---|
| System Components: Detailed Parts Analysis from Clear- and MMT-Fueled Escort Vehicles from the Alliance Study, SAE 2005-01-1108 | Durability with MMT Fuel Additive in Severe Driving Conditions, SAE 2005-01-3840 |
| 2005: **U.S. EPA** takes no action in response to automaker petition to restrict use of MMT in U.S. gasoline. | |
| 2005: **Environment Canada** completes an evaluation of emission system component defect reports prompted by claims that MMT caused failure of components on 2001 and later model year vehicles in Canada and concludes that no defect reports linked to MMT were submitted by automakers from 2000-2004 in Canada. | |
| | 2006: A Survey of American and Canadian Consumer Experience – The Performance of Late Model Year Vehicles Operating on Gasoline With and Without the Gasoline Fuel Additive MMT®, SAE 2006-01-3405 |
| | 2006: Evaluation of Factors Affecting Vehicle Emission Compliance Using Regional Inspection and Maintenance Program Data, SAE 2006-01-3406 |
| 2006: **U.S. EPA** takes no action in response to automaker petition to restrict use of MMT in U.S. gasoline. | |
| 2007: Parametric Analysis of Catalytic Converter Plugging Caused by Manganese-based Gasoline Additives, SAE 2007-01-1070 | 2007: Interaction of MMT Combustion Products with the Exhaust Catalyst Face, SAE 2007-01-1078 |
| 2007: **U.S. EPA** Updates Its "Comments on the Gasoline Additive MMT," restating its prior determination that "MMT, added at 1/32 gpg Mn, will not cause or contribute to regulated emissions failures of vehicles." (Available at www.epa.gov/otaq/regs/fuels/additive/mmt_cmts.htm) | |