EPA420-R-93-017
December 1993

Final Regulatory Impact Analysis for Reformulated Gasoline

Office of Mobile Sources
U.S. Environmental Protection Agency

TABLE OF CONTENTS

. Treatment of Ethanol

One of the most controversial issues in the reformulated gasoline rulemaking has been the treatment of ethanol blends. In the April, 16, 1992 proposal, EPA treated all fuels equally by requiring them to meet the same emission performance standards. The February 26, 1993 proposal, however, proposed an incentive program for the use of renewable oxygenates such as ethanol which would allow them to meet a less stringent performance standard. Numerous comments were received on a number of topics related to whether EPA should or should not provide special treatment for ethanol blends. The following discussion presents EPA's summary and analysis of those comments received which EPA believed were relevant to the reformulated gasoline rulemaking. Some other comments were received which did not have any relevance to the rule (e.g., relating to ethanol's use as a neat or near-neat alternative fuel in alternative fueled vehicles), and as a result did not influence the decision making process. A large number of comments were also received which made unsubstantiated statements regarding the reformulated gasoline proposal. To the extent these statements had any bearing to the final rule they are also addressed in the summary and analysis of comments below.

A. Exclusion from Market

A number of comments were received from ethanol and grain producing industries that the April 16, 1992 proposal effectively excluded ethanol blends from participating in the reformulated gasoline market. Ethanol is typically splash blended into finished gasoline obtained at the gasoline terminal, increasing the volatility of the resulting blend. According to the commenters the simple model's reliance on a straight RVP standard, with no volatility waiver for ethanol blends, would require ethanol blenders to use sub-RVP gasoline blendstocks to enable the resulting blend to meet the simple model RVP standard. This would be a clear departure from past practice, where ethanol could lawfully be splash blended into almost any finished gasoline (as long as it did not already contain an oxygenate). Commenters claimed that refiners would be unwilling to provide sub-RVP clear gasoline blendstocks for blending with ethanol given the refiners competitive interest in minimizing ethanol's market share. In addition, commenters claimed that limitations in terminal storage capacity would also preclude the use of unique blendstocks such as a sub-RVP clear gasoline. Commenters also noted that the proposal's provisions on presumptive liability and contract requirements between refiners and blenders would make provision of the sub-RVP blendstock too risky. Finally, even though volatility was only an issue during the high ozone season, commenters claimed ethanol would as a practical matter be excluded year round as refiners would likely establish long term contracts for oxygenates that would make it unlikely for them to switch oxygenates during the course of the year. In addition, it would be hard for marketers to switch from an ethanol based ether (ETBE) for summer use and an alcohol (ethanol) for winter use. Exclusion from the summer market would therefore lead to exclusion year round and would jeopardize the ethanol industry's ability to maintain a market even in the wintertime oxygenate program in CO nonattainment areas. While the reformulated gasoline standards appeared to be fuel neutral on their face, commenters believed that in practice they would lead to exclusion of ethanol from the reformulated gasoline program.

As discussed below in subsection E. the commenters also claimed that this exclusion of ethanol would reduce competition in the oxygenate market and thereby cause higher prices for reformulated gasoline, reduce investment in rural and farm communities, increase federal grain subsidies, reduce domestic jobs, and otherwise have serious adverse effects on the ethanol and grain producing industries.

Other commenters disputed these various assertions. For example, various refiners claimed that there was no foundation for the assertion that ethanol would be excluded. Certain refiners noted that they have used ethanol in the past and intended to continue to do so in the reformulated gasoline program. Some commenters claimed ethanol use would in fact expand, based on the need for oxygenates year round in the reformulated gasoline program and in wintertime program in many CO nonattainment areas. The Department of Energy commented that the reformulated gasoline and wintertime CO programs were expected to cause a substantial increase in the demand for all oxygenates, including ethanol.

In general the comments which argued ethanol would be excluded from the market focussed on the possible reduction in ethanol market growth in the future under the reformulated gasoline program, not a reduction in the current size of the ethanol market. As shown in Appendix I.A., a minority of the areas currently covered by the reformulated gasoline program (including areas opted in as of November, 1993) had any gasohol market share in 1990. Of those that did, only a few had gasohol market shares above the national average of approximately 8%. As a result, only about 20% of the ethanol demand in 1990 was used in reformulated gasoline areas, and only about 10% was used in those areas during the summer VOC control period. Even if ethanol achieves only a small market share under the reformulated gasoline program, it is likely to be greater than the 4.5% average market share of gasohol in those areas prior to the reformulated gasoline requirements, and no economic hardship to the industry should result. Furthermore, demand for ethanol has already risen dramatically as a result of the wintertime oxygenated fuels program required under section 211(m) of the CAA.[1] As a result, it is very difficult to believe any case where ethanol demand would decrease below the level that existed prior to the CAA amendments of 1990. That being said, EPA has always maintained that ethanol blends would not be excluded from the RFG market by the April 16, 1992 proposal and that demand for ethanol would grow considerably as a result of the program.

The largest part of the cost associated with Phase I reformulated gasoline is the oxygen content required to be added by the Act. The RVP control cost is small in comparison to the oxygen cost. Since ethanol costs less than MTBE per gallon and contains almost twice as much oxygen per gallon, it has a considerable economic advantage (as shown in Appendix I.B), particularly given various state subsidies, and thus should be able to expand its market. This is particularly true during the 6.5 to 7.5 months of the year when no VOC control is necessary. But even during the 4.5 to 5.5 summer months the only significant economic issue is the incremental costs for distribution and segregation of ethanol blends which are no different from those in the winter. Even the additional RVP control costs for ethanol are reduced by the oxygen averaging provisions of the reformulated gasoline program which allow ethanol to be blended at 3.5 wt% oxygen instead of 2.0 wt% and receive economic compensation for the additional oxygen. Thus, EPA believes that the economic advantage of ethanol over other oxygenates will translate into refiners supplying sub-RVP gasoline for blending with ethanol out of economic necessity. If they choose not to, at least in the areas where the incremental distribution costs are small or where state subsidies for ethanol exist, they will place themselves at a considerable disadvantage relative to their competitors. The economic advantage of ethanol relative to

---

[1] Memorandum from Paul Argyropoulos, Acting Chief, Regional/State/Local Coordination Section, to Paul Machiele, "Estimates of Volume of Ethanol Use in Oxy Fuel Program Areas During the 1992/1993 Control Season," August 24, 1993.

MTBE was supported by a recent analysis for the National Corn Growers Association[2] even with the higher cost of a sub-RVP blendstock.

The economic advantage of ethanol was very evident during the 1992-3 oxygenated fuels program where ethanol made large market gains, even in areas which had traditionally used little or no ethanol, and ethanol producers earned record profits. While some ethanol producers may find it necessary to reduce their profit margin somewhat to remain competitive under the reformulated gasoline program, this neither excludes ethanol from the marketplace nor treats it unfairly relative to any of the other oxygenates.

Some commenters claimed that regardless of ethanol's economic advantage refiners would somehow band together to cut ethanol out of the reformulated gasoline market. EPA believes such an action by the refiners to be highly unlikely. Not only have refiners not taken such an action in the past under either the conventional gasoline market or under the oxygenated fuels program, but comments have also been received from various refiners stating their intent to blend ethanol into reformulated gasoline. Furthermore, the competitive economic risk is simply too great if even one refiner decided to break ranks and blend ethanol. If, however, refiners were to decide as a group not to blend ethanol, nothing short of a legal mandate for the use of ethanol in reformulated gasoline could prevent such action. EPA has no legal authority under the CAA to provide such a mandate for the use of ethanol.

Regardless of whether refiners intended to exclude ethanol from the reformulated gasoline market or not, some commenters believed this would occur automatically due to the risk to the refiner and necessary contract requirements which would result to ensure that the final gasoline blend met the requirements for reformulated gasoline. While EPA believes that there may be some additional risk to the refiners to rely on downstream blenders for the final quality of their reformulated gasoline, EPA has provided mechanisms whereby refiners can minimize or even eliminate such additional risk (refer to §80.69 of the regulations). As such, EPA does not believe it to be a significant enough risk such that they would avoid entering into contractual agreements with downstream blenders.

In addition to being economically competitive as a pure additive, ethanol may also be economically competitive as an ether feedstock. Due to their low blending vapor pressure, ETBE (ethyl tertiary butyl ether) and TAEE (tertiary amyl ethyl ether), ethers made from ethanol, may become competitive with other oxygenates during the summer months under the reformulated gasoline program, especially in the future when the more stringent Phase II performance standards take effect. In fact, some commenters stated that ETBE was already cost competitive with MTBE. Contrary to comments received, the current lack of ETBE or ETAE production is not solely a result of their relative cost. Such oxygenates and their production on a large scale are very recent technological developments. As such there has been no reliable cost information for them until recently. Furthermore, their cost effectiveness in reformulated gasoline is expected to exceed that in conventional gasoline due to their low blending vapor pressure, high octane value per unit oxygen, and various other factors which are of value to refiners in meeting the reformulated gasoline requirements, but are not of value otherwise. As shown in Appendix I.B., when these factors are taken into account ETBE nears the point of being cost competitive with MTBE even at today's ethanol costs.

---

[2] "Evaluation of the USDA Alternative Renewable Oxygenate Proposal," Final Report, Jack Faucett Associates for the National Corn Growers Association, October 30, 1993.

Some commenters claimed that if ethanol was unable to maintain a large market share during the summer months, that it would become uneconomical to use during the winter months as well. They believed refiners would be unwilling to switch off between various oxygenates. This belief, however, appears to be unfounded. First of all, it is based on the invalid assumption that ethanol will have no market either in the RFG program or in conventional fuel areas during the summer months. Secondly, contrary to the intent of various refiners to blend ethanol as stated in their comments, it assumes no refiners would enter into long term contracts to blend ethanol, and third, it ignores the fact that refiners have been willing to switch off between oxygenates in the past. During the 1992-3 oxygenated fuels program refiners blended ethanol during the winter and then switched back to conventional gasoline during the summer. Furthermore, many refiners switched between oxygenates during the winter period as well based on the local economic conditions. Ethanol and MTBE producers alike were able to produce and store adequate oxygenate to meet the peak demand during the winter months. In addition, contrary to the commenter's belief, it could be argued that it is easier for ethanol blends to tolerate an interrupted market than MTBE blends. The nature of ethanol production is that it could be reduced during the summer by optimizing on plant production of corn sweeteners which are in high demand during the summer. As a result, while ethanol production may be reduced in lieu of reducing its price to maintain market share, the ethanol production plant may be able to maintain full operating capacity. Methanol used to produce MTBE has no other compensating market during the winter and is forced to either reduce its price to maintain market share, rely on storage, or shut down production. Since the winter period when ethanol is at an economic advantage is longer than the summer period when MTBE may be at an economic advantage, ethanol should have less of a burden. In fact, some of the statements made supporting the claim that ethanol would be excluded from the RFG market: inadequate tankage for multi-grades of fuel, inability of refiners to switch off between oxygenates, etc., are equally applicable if not more so to MTBE. Furthermore, using ethanol to produce ETBE during the summer when ETBE's other advantages have value could be a viable means of maintaining ethanol production year-round.

None of the comments received provided any data, information, or analyses to support the statements being made. As a result, EPA stands behind its analysis and belief that ethanol is fully capable of competing in the reformulated gasoline market either as gasohol or as an ether feedstock. This is particularly the case during the initial years of the reformulated gasoline program when ethanol will have to play a strong role due to the demand for oxygenates under the program which cannot be met through the use of MTBE alone. This belief was echoed by a variety of other commenters.

A. Congressional Intent

A number of comments were received stating that it was the intent of Congress in the Clean Air Act (CAA) that ethanol be included in the reformulated gasoline program and that the April 16, 1992 proposal by EPA violated that intent by discriminating against ethanol.

Congressional intent in establishing the reformulated gasoline program can best be learned from the text of the statute and the legislative history. A review of the terms of section 211(k) makes clear that the central, overriding purpose of this provision was the achievement of significant reductions in ozone forming VOCs and toxic air pollutants in the major metropolitan areas confronted with the most severe air pollution problems. Section 211(k)(1) establishes this as the central focus of this program, mandating that EPA require the greatest achievable reductions in these pollutants, considering various factors such as cost, air quality and other impacts. In addition to this broad expression of intent, Congress specified certain minimum elements of the reformulated gasoline program. Section

211(k)(1) established various restrictions on gasoline qualities such as oxygen and benzene content, and a cap on NOx emission increases, and section 211(k)(3) established minimum standard levels of performance for VOC and toxics emission reductions. Congress also addressed a variety of other important elements of the reformulated gasoline program, from credit programs to certification and opt-in by states.

All of the minimum requirements in section 211(k) are set in a fuel neutral manner, using performance criteria that are independent of the type of gasoline subject to the criteria. There is no indication from the text of the statute that Congress intended that ethanol blends not be subject to the same minimum standards applicable to all reformulated gasoline. This is in marked contrast to section 211(h), where Congress quite clearly established one RVP standard for gasolines in general, and a separate, less stringent RVP standard for ethanol blends under specified circumstances.

The legislative history of this provision does contain many discussions pertaining to ethanol and other oxygenates. Since many of the detailed provisions of section 211(k) were first adopted in floor amendments to the House and Senate Bills, much of that legislative history is found in the floor debate in the House and Senate on their bills and on the conference committee bill. A large part of the discussion there on ethanol shows the belief of many congressmen that ethanol would play a major role in supplying the oxygen content required for this program, and would help to clean up gasoline by reducing toxic air pollution.[3] There were no indications, however, that ethanol blends of reformulated gasoline were not subject to the minimum requirements established for all reformulated gasolines. There are in fact indications that Congress saw these as fuel neutral standards that all blends would have to face.[4]

In sum, EPA believes Congressional intent was to achieve significant reductions in important air pollutants in areas of the Country with some of the worst air pollution problems, and intended to accomplish this in part by establishing minimum standards of performance that were fuel neutral and that all reformulated gasolines would have to meet. EPA believes its final rule faithfully implements this intent by setting identical emission performance standards for all reformulated gasolines, regardless of the oxygenate used.

It is also true that many congressmen expected that ethanol blends would be able to meet these standards, and would thereby play a major role in the program. EPA believes this was a well founded expectation, and as noted above, believes that ethanol blends will in fact play an important role in this program. However, there is no indication that Congress intended or authorized EPA to dilute the minimum requirements of the section 211(k) described above to ensure an important role for ethanol. Congress did envision that ethanol would play a large role in the reformulated gasoline program, but only if it could meet the minimum requirements applicable to all reformulated gasoline.

As stated above, EPA believes that the demand for ethanol will grow as a result of the reformulated gasoline program as it has under the oxygenated

---

[3] See e.g., 136 Congressional Record S3510,11 (March 29, 1990) (Statement by Senator Daschle); 136 Congressional Record H2852 (May 23, 1990) (Statement by Representative Richardson).

[4] See e.g., 136 Congressional Record S3513 (March 29, 1990)(Statement by Senator Daschle); 136 Congressional Record S16922 (October 27, 1990) (Statement by Senator Durenberger).

fuels program. While it is true that the demand for ethanol could increase even more if special provisions or incentives are provided for its use such as proposed in the February 1993 proposal, EPA does not now believe that such provisions are consistent with the minimum requirements that Congress intended for all reformulated gasoline. While EPA is not opposed to further expanding demand for ethanol, the authority granted to EPA under Section 211(k) of the CAA is limited in this respect. It would be much more appropriate to provide such incentives for ethanol outside of the reformulated gasoline rulemaking as is currently done with the federal tax incentives for ethanol.

A. Waiver

A large number of commenters stated that EPA should grant a 1.0 psi RVP waiver to ethanol blended reformulated gasolines. They argued that it was the intent of Congress that the RVP waiver granted to ethanol blended with conventional gasoline under Section 211(h) of the CAA also apply to ethanol blended in reformulated gasolines under Section 211(k). They further argued that the rationale used by Congress and EPA in granting the waiver under Section 211(h) was equally applicable to reformulated gasoline and that the ozone reactivity and other benefits were sufficient to offset any emission increase which might result. Granting a waiver, it was stated, would allow ethanol to effectively compete in the reformulated gasoline market. Finally, some commenters explained that during the regulatory negotiations on this rulemaking they had assumed that a one psi RVP waiver would be applied to ethanol blends of reformulated gasoline.

There were also many comments disputing the above assertions. These commenters claimed that a one psi waiver for ethanol blends was unlawful and that granting such a waiver would violate the intent of Congress. They claimed that a waiver would have serious adverse environmental impacts. They argued that such a waiver would be discriminatory and unfair, and would be counter to free market principles. Finally, they argued that such a waiver was discussed during the regulatory negotiations, at least informally, and that granting an RVP waiver for ethanol blends would violate the consensus agreement reached during these negotiations.

1. Intent of Congress

EPA has closely considered the arguments that the 1.0 psi waiver for ethanol blends provided under section 211(h) applies to the RFG program. For the reasons set forth in a legal opinion issued by EPA's legal council,[5] EPA believes that the 1.0 psi waiver under section 211(h) does not apply to section 211(k).

2. Environmental Impact

EPA believes that granting a 1 psi RVP waiver for ethanol blends would have significant adverse environmental impacts. As shown in a memorandum and

---

[5] Memorandum from Acting General Councel to the Administrator, dated November 17, 1992, "Applicability of One-psi Ethanol Waiver Under Section 211(k) of the Clean Air Act to Reformulated Gasoline."

subsequent letter from EPA staff in the docket,[6] [7] an ethanol blend that meets all of the requirements for reformulated gasoline except that it has an RVP 1.0 psi higher than that required of non-ethanol blends would cause roughly a 20% increase in VOC emissions relative to the baseline gasoline (including estimates for the effect of commingling and distillation). This represents a 31% increase in VOC emissions compared to a fuel which meets the minimum requirements for reformulated gasoline. Based on the relative costs of the various oxygenates as shown in Appendix I.B., ethanol blends with a 1.0 psi RVP waiver would have a significant competitive advantage over other reformulated gasoline blends and could be expected to dominate the RFG market in some areas, particularly mid-western RFG cities such as Chicago and Milwaukee where ethanol distribution costs are relatively small. With a 1.0 psi waiver EPA expects there would be a significant shift to ethanol blends and a resulting significant increase in VOC emissions over what would occur without a waiver. Many areas would achieve significantly smaller reductions in VOC emissions than the minimum 15% required under the Act, and in areas with a large market share for ethanol blends, the reformulated gasoline program would actually increase summertime VOC emissions and not decrease them. For example, as shown in Table I.1., even at the pre-program ethanol market share of approximately 8% an ethanol waiver would eliminate nearly 28% of the VOC control otherwise achieved by the program. If the ethanol market share increases to 24% as under 1992-3 the winter oxygenated fuels program (on average), roughly 74% of the VOC control otherwise achieved by the program is eliminated. At an ethanol market share above just 35%, as would be expected in many areas where a waiver granted (particularly the Midwest as occurred under the oxygenated fuels program), all of the VOC control of the program is eliminated and VOC emission increases would actually occur relative to the pre-program baseline.

---

[6] Memorandum from Paul A. Machiele, Fuel Studies and Standards Branch, to Richard D. Wilson, Director, Office of Mobile Sources, "Update of the Relative Ozone Reactivity of Reformulated Gasoline Blends," June 11, 1993.

[7] Letter from Chester J. France, Director, RDSD to Dr. Gary Whitten, Chief Scientist, Systems Applications International, September 24, 1993.

Table I.1. Loss in In-Use VOC Emission Control as a Result of Ethanol Waiver Under RFG[*]

	Ethanol Market Share				
	0%	8%	24%	30%	35%
% VOC Reduction Due to MTBE Share	11	10.1	8.4	7.7	7.2
% VOC Reduction Due to Ethanol Share (with distillation)	0	-1.0	-3.1	-3.9	-4.6
% VOC Reduction Due to Commingling	0	-1.2[**]	-2.4	-2.4	-2.4
Total % VOC Reduction	11	7.9	2.9	1.4	0.2
Percentage Change from 100% MTBE Baseline	NA	28	74	87	98

[*] Emission percentage change input values for the table are based on those calculated in the letter from Chester France to Dr. Gary Whitten described in footnote 6.

[**] Commingling assumed half of that at higher market shares based on analysis in Appendix I.D.

A 1.0 psi waiver would therefore have a large impact on the VOC emission inventory. EPA believes this would have a significant adverse impact on ozone levels in the areas of the country already facing the worst ozone problems. EPA does not agree with the arguments made by several commenters that for reactivity and other reasons this increase in VOC emissions would not increase ozone (see subsection D). This increase in VOC emissions would also place a serious obstacle in the way of the states in their planning to meet the Act's reasonable further progress requirements.

EPA would appear to have the flexibility, under certain circumstances, to establish a different VOC or toxics emission reduction standard for ethanol blends. Under section 211(k)(1), EPA is to consider "cost..., any nonair-quality and other air-quality impacts" in establishing requirements that obtain the greatest achievable emission reductions from gasoline reformulation. This mandate, in conjunction with the minimum requirements of section 211(k)(2) and (3), arguably would authorize EPA to establish a less stringent RVP or VOC performance standard for ethanol blends if the circumstances warranted and the ethanol blends still met all the minimum requirements of section 211(k), including the minimum VOC and toxics reductions required under section 211(k)(3). The Renewable Oxygenates Program proposed by EPA in February 1993 was based in part on this approach. However, for all of the reasons described above and elsewhere, EPA does not believe that it could take this approach in the context of a 1.0 psi waiver for ethanol blends. EPA believes that ethanol can and will play an important role in reformulated gasoline without a 1.0 psi waiver, and that granting such a waiver would therefore be unreasonable.

With a 1.0 psi waiver, the RVP standard for reformulated gasoline under the first phase of the program would have to be roughly 7.1 psi in both northern and southern areas if the ethanol blends were to still achieve the minimum VOC and toxics reductions required under section 211(k). This would not be a reasonable exercise of EPA's discretion given the cost, energy, and other impacts described elsewhere. Even in the southern portions of the country, where EPA does believe a 7.1 RVP standard is currently feasible, a

1.0 psi waiver for ethanol is not appropriate. In the context of a 1.0 psi waiver, the RVP standard under Phase I in southern areas would have to be 6.2 psi if comparable emission reductions are to be achieved under the reformulated gasoline program in the South as in the North; otherwise little or no environmental benefit would be achieved in southern areas under the reformulated gasoline program. Furthermore, since the majority of the southern reformulated gasoline required under the Act is sold in California which has its own strict requirements for reformulated gasoline, a waiver for ethanol in southern areas would be of little or no benefit to the ethanol blending industry.

3. Gasoline Volatility Rulemaking Decision

Several commenters argued that EPA should allow a 1.0 psi waiver for ethanol blends in the reformulated gasoline program for the same reasons EPA allowed such a waiver in its national regulations of gasoline RVP. EPA disagrees with these commenters for a number of reasons.

EPA established limits on the summertime volatility of gasoline in two Phases, pursuant to its broad regulatory authority under section 211(c) of the Act.[8] These limits applied nationwide. For both Phase I and Phase II RVP regulations EPA set a 1.0 psi waiver for ethanol blends that met certain alcohol content requirements. The primary reason EPA adopted such a waiver was to avoid the near catastrophic economic impact on that industry if no such waiver was allowed. EPA was convinced of the reality of this jeopardy, and the inability of the industry to survive it. At that time there was no significant alternate market for ethanol such as widespread use of the ether ETBE or a large-scale program to require the use of oxygenates in various cities. In that context, EPA believed it would require strong evidence of severe environmental consequences before it would impose a policy which might eliminate that industry. There was no evidence of such severe environmental consequences, and instead EPA's concerns over the negative air quality impact of 1.0 psi RVP waiver had been moderated during the rulemaking process (See 55 FR 23665, 23666). At the same time, EPA announced that it would continue to explore the economic and air quality issues involved with a 1 psi RVP waiver, and reserved the right to propose changes in the RVP regulations if appropriate (See 55 FR 23666).

EPA's concern over the environmental impact of a 1 psi RVP waiver stemmed from the evidence showing that substantial VOC emission increases were known to occur with ethanol blends relative to conventional gasoline. This RVP and resulting VOC emission increase, however, existed with ethanol blends prior to the volatility control rule. Thus, providing a waiver under the volatility control rule required only the same RVP control from ethanol blends as from non-ethanol containing gasoline. Since the rule was not expected to increase the use of gasohol with its higher emission potential (the market share of gasohol had been approximately 8% nationwide), EPA believed that providing a waiver would not significantly compromise the environmental benefits of the program nationwide. To illustrate this point, the volatility control rulemaking reduced the volatility of all gasoline by approximately 2.7 psi RVP. The 1 psi RVP waiver for the 8% of the gasoline market represented

---

[8] Phase I regulations applied to the 1989 through 1991 summertime control period (52 FR 31274, August 19, 1987), while Phase II regulations applied thereafter (5 FR 23658, June 11, 1990). EPA recently revised the Phase II regulations to conform with the requirements of § 211(h), added in the Clean Air Act Amendments of 1990 (56 FR 64704 (December 12, 1991).

by ethanol blends, thus, represented a loss of only 0.08 psi across all in-use gasoline, or less than 3% of the volatility control that would otherwise have been achieved by the rulemaking. To the extent that ethanol blends achieved lower exhaust VOC and CO emissions, these only served to offset what was already considered to be a small loss in emission control relative to the control achieved. As a result, providing the waiver did not result in any environmental detriment, but just slightly diminished the potential environmental benefits that could otherwise have been achieved by the regulations.

In balancing the severe economic impact of not allowing a RVP waiver with the generally modest concerns about the VOC and ozone impacts of such a waiver, EPA reasonably exercised its broad discretion under section 211(c)(1) of the Act and provided a 1.0 psi RVP waiver in the national RVP regulations.

The situation confronted in this rulemaking is significantly different. First, the existence of a 1.0 psi waiver in the reformulated gasoline program does not raise the same kind of life or death situation confronting the ethanol industry in EPA's RVP rulemakings. The requirements for reformulated gasoline do not apply nationwide, thereby maintaining markets for ethanol in conventional gasoline during the summertime. In addition, refiners have no choice on whether or not their reformulated gasoline will be oxygenated. Based on the year-round oxygen content requirement for reformulated gasoline, and the wintertime oxygen requirement for gasoline marketed in numerous CO nonattainment areas, EPA believes that the demand for ethanol will increase significantly without an RVP waiver, either as an oxygenate or as a blendstock to produce ETBE. This is in marked contrast to the situation confronting EPA and the ethanol producing industry in the national RVP rulemaking.

Furthermore, the environmental impact of an RVP waiver under the reformulated gasoline rulemaking would be significantly more severe than it was under the volatility control rulemaking. As discussed above in subsection C.2, a 1.0 RVP waiver coupled with the reformulated gasoline program's oxygen requirement could result in a significant increase in the use of ethanol during the summer months, leading to significant emission increases and the elimination of a large percentage of the ozone-related benefits of the program. This stands in stark contrast to the less than 3% loss of the emission reductions from the gasoline volatility control program as a result of the waiver.

Another significant difference between this rulemaking and the previous national RVP rulemaking is the difference in statutory authority. The nationwide RVP regulations were based on EPA's broad discretionary authority under section 211(c) of the Act. An RVP or VOC performance waiver could be established for ethanol blends in the reformulated gasoline program only if it was authorized and justified under section 211(k). That provision, however, places many more constraints on EPA's discretion than section 211(c), including, for example, the minimum mandatory reductions in emissions of ozone forming VOCs and toxics. This and the other statutory provisions in section 211(k) limit EPA's discretion to allow a 1.0 psi waiver for ethanol blends. For all the reasons described above and elsewhere, EPA does not believe that a 1.0 psi waiver for ethanol blends would be proper under section 211(k) of the Act.

4. RVP Increase From Ethanol Blending

Some comments suggested that ethanol blends may not actually cause an increase in the volatility of in-use gasoline. Other comments suggested that the volatility increase disappears at ethanol concentrations of 20%. A great deal of data and information collected by both EPA and outside parties on a wide variety of gasolines demonstrates that ethanol does in fact increase the vapor pressure of in-use gasolines when blended in at low concentrations.

Some of this data is discussed in section G. There is less data available as to what the vapor pressure increase is at ethanol concentrations above 10 volume percent, but the available information suggests that blending as much as roughly 50% ethanol into gasoline still increases the vapor pressure of the blend.[9] Since blends of 10 volume percent ethanol or less are all that could lawfully be used in the reformulated gasoline program at the present time, the fact that the volatility increase disappears with blends with greater than 50% ethanol is not relevant to this rulemaking. Despite the available data, if ethanol were to be determined not to cause an increase in the volatility of the blend, then there would be no need for a waiver since ethanol could easily comply with the RVP requirements.

Some comments were also received suggesting that the volatility increase for ethanol blends was due to the butane in the gasoline, and not the ethanol being added to the gasoline. While butane is a hydrocarbon found in gasoline with a high vapor pressure, and as such represents the largest fraction of evaporative emissions from today's gasolines, the RVP increase which occurs when ethanol is added to gasoline is not due to butane. Ethanol, being an alcohol, is a polar molecule that has a low vapor pressure when relatively pure due to a strong tendency to self-associate through hydrogen bonding. When mixed with gasoline the hydrogen bonding is greatly reduced causing a large increase in the vapor pressure of the mixture. The increased vapor pressure increases the tendency of all of the hydrocarbons in the mixture to evaporate, not just butane. The vapor pressure increase would occur even if all butane were removed from the gasoline prior to blending with ethanol. In fact, as the vapor pressure of the base gasoline decreases (and butane content decreases) the RVP increase resulting from adding ethanol to the gasoline increases rather than decreases. In any case, the source of the volatility increase in ethanol blends is not important--no matter the source, blending ethanol into gasoline at the levels expected in the reformulated gasoline program leads to significant increases in volatility.

5. Mandate for Blendstock and Ethanol Market Share

In the context of the waiver discussion a number of commenters also suggested that if a waiver were not granted that EPA should promulgate provisions to mandate that refiners either produce a blendstock capable of being blended with ethanol downstream and still meet the criteria for reformulated gasoline certification, or use ethanol as the oxygenate in a certain fraction of the RFG they produce. In the alternative, one commenter suggested providing a 1.0 psi waiver for ethanol blends if refiners did not provide an adequate supply of sub-RVP blendstock. While these approaches would ensure the use of ethanol in the reformulated gasoline program during the summer months, EPA does not believe that it has authority under either §211(c) or 211(k) to impose the suggested provisions under the present circumstances. Furthermore, as discussed in section G., these approaches would not necessarily be environmentally neutral even though no increase in RVP would result.

---

[9] "Volatility Characteristics of Gasoline-Alcohol and Gasoline-Ether Fuel Blends," Robert L. Furey, General Motors Research Laboratories, SAE Paper No. 852116, October 1995.

A. Reactivity

A number of comments were received which attempted to find methods by which the evaporative VOC emission increases associated with splash blending ethanol into gasoline could be offset. These comments stated that while the RVP increase resulting from blending ethanol into gasoline may cause an increase in evaporative VOC emissions, the additional exhaust VOC and CO reductions resulting from the additional oxygen in a 10 volume percent ethanol blend and the lower relative reactivity of emissions from ethanol blends offset any increase in ozone that might occur. As a result, they stated that this justified either the RVP waiver discussed above, or the inclusion of relative ozone reactivity in the determination of the VOC performance standards for reformulated gasoline. As discussed in the April 16, 1992 proposal, one method suggested for incorporating the ozone reactivity benefits of ethanol blends was to include carbon monoxide (CO) in the definition of what comprises a reactive VOC and adjust its mass to take into account its relative ozone reactivity. This method was referred to as the "carbon mass equivalent" method.

6. Statutory Authority for Reactivity Based Adjustment

The text of section 211(k) does provide EPA with certain discretion to consider the relative reactivity of different volatile organic compounds; however, it is clear from this section that EPA may not consider reactivity for purposes of compliance with the minimum emissions reductions required by section 211(k)(3). Section 211(k)(1) requires that EPA establish requirements for reformulated gasoline that obtain the greatest achievable reductions in emissions of "ozone forming volatile organic compounds... and toxic air pollutants" and the provision for certification of reformulated gasoline again refers to ozone forming volatile organic compounds (see section 211(k)(4)(B)). While the statute defines toxic air pollutants (see section 211(k)(10)(C)), it defines neither ozone forming volatile organic compounds nor volatile organic compounds. The use of the undefined phrase ozone forming volatile organic compound would, therefore, appear to provide EPA with certain discretion to consider ozone forming potential or reactivity of different VOCs.

At the same time, Congress clearly limited this discretion by explicitly stating that the minimum reductions in emissions of ozone forming VOCs and toxic air pollutants required under section 211(k)(3) "shall be on a mass basis."[10] Since both of these provisions must be given meaning, there would appear to be only one reasonable interpretation. EPA would have discretion to consider reactivity in deciding what volatile organic compounds should be considered ozone forming, but compliance with section 211(k)(3)(B)'s minimum percentage reduction in ozone forming VOCs would be based on mass reductions, without further adjustment for ozone forming potential. In effect, EPA would establish what VOCs are ozone forming VOCs and reformulated gasoline would then have to meet at least a minimum percentage reduction, on a mass basis, of these VOCs. Since the limitation to reductions on a mass basis refers to requirements under section 211(k)(3)(B), if EPA required greater than these minimum emissions reductions, then its authority under section 211(k)(1) would appear to give EPA the discretion to consider reactivity in requiring these

---

[10] In a similar fashion Congress, in the separate provision addressing anti-dumping, established limits on the average per gallon emissions of volatile organic compounds, without reference to ozone forming potential, and again specified that compliance with the anti-dumping requirements was to be measured "on a mass basis." See §211(k)(8)(A) and (C).

further reductions, as long as the minimum required reductions were obtained on a mass basis.

The legislative history for this provision supports EPA's interpretation. The bills passed by the House and Senate both contained provisions for reformulation of gasoline, requiring reductions in "ozone-forming volatile organic compounds" and "ozone-forming potential of volatile organic compounds,"[11] respectively. Both provisions required 15% reductions in these volatile organic compounds, but neither provision referred to mass emissions. In fact, the House bill specifically required that the Administrator consider "reactivity and relative toxicity" in establishing the reformulated gasoline requirements. In conference, Congress removed the reference to reactivity and relative toxicity found in the House bill, and added the provision calling for measurement of emissions on a mass basis. The House bill's anti-dumping provision was generally adopted by the conference committee, but again a provision for determining compliance on a mass basis was added. Although there is no indication in the conference committee report on why these changes were made, the clear import of these changes is that Congress intended to restrict the Administrator's ability to consider reactivity, at least in the context of the minimum reductions required in Phase I and II of the reformulated gasoline program. The statements of various congressmen during debate of this provision support this view, indicating the conscious choice of a mass basis standard.[12]

EPA's interpretation is also reasonable when considered in relation to another important ozone control provision in the Act. Section 182 requires that various ozone nonattainment areas submit SIP revisions providing for a schedule of percentage VOC reductions from a 1990 baseline of actual VOC emissions. Compliance with this requirement is based on reductions in the mass of the VOCs, without adjustment for reactivity. Interpreting section 211(k) to allow for significant increases in VOC emissions would present a major impediment for state compliance with the section 182 requirements. Commenters failed to provide a resolution to this problem other than suggest that states be provided with a credit for the VOC increases caused by ethanol blends. EPA does not have authority to grant such a credit.

Several commenters also suggested that EPA define CO as an ozone forming VOC. While the technical and policy reasons for rejecting this approach are discussed later, it is also important to note that EPA recently conducted a rulemaking to define volatile organic compounds for a wide variety of CAA purposes. In that final rule EPA followed its prior regulatory approach and excluded CO from the definition, as well as several other chemical compounds

---

[11] Section 217, S. 1630 as passed by the Senate on January 23, 1990.

[12] See, e.g. 136 Cong. Rec. S16922 (daily ed. October 27, 1990) (statement of Senator Durenberger) ("The VOC reduction requirement is 15 percent in the year 1995. The reduction is measured in the mass of emissions comparing emissions from [baseline vehicles burning baseline gasoline] and the same vehicles burning any proposed reformulated gasoline...."); and 136 Cong. Rec. H12900 (daily ed. October 26, 1990) (statement of Representative Hall) ("... the use of a mass basis test... compares the percentage difference between emissions from baseline gas and from the proposed reformulated gas" (discussing the need to control the vehicle variable in evaluating a reformulated gasoline performance)).

that include carbon. The agency clearly stated that CO and certain other compounds were well understood by the scientific community not to be considered as organic and, therefore, could not be considered as a VOC (see 57 FR 3944, February 3, 1992). Furthermore, as discussed below the relative reactivity of CO is very low such that even if it were considered to be organic, it would be excluded from the definition of VOC on this basis as well under the established EPA regulations. The comments do not present material to change this view, and it would be arbitrary for EPA to do so now, given the significant, adverse impact this would have on EPA's and the states' overall ozone control strategy.

7. Technical Validity

a. CO as an Ozone Forming VOC

As noted above, EPA has discretion to determine what VOCs are "ozone forming" for purposes of section 211(k). The low relative reactivity of methane and more recently ethane was the basis for their exclusion from the Agency's definition of VOC in the rulemaking discussed in the previous paragraph, and ozone forming VOC in the most recent proposal for this rulemaking. According to the California Air Resources Board's (CARB) relative reactivity scales, methane is more than one order of magnitude less reactive than the next least reactive hydrocarbon, ethane, and more than two orders of magnitude less reactive than the average hydrocarbons contained in gasoline vehicle emissions. Since there are a number of compounds in the emissions from gasoline vehicles that are just slightly more reactive than ethane, there is no justification at this time for excluding any additional compounds from the current definition. Ethanol's relative reactivity is more than five times that of ethane, while methyl tertiary butyl ether's (MTBE) is 2-1/2 times that of ethane and half that of ethanol. In fact, 50 of the 168 hydrocarbons in CARB's scale have ozone reactivities less than that of ethanol. Furthermore, since the emissions from ethanol blends are comprised of essentially the same compounds as the emissions from MTBE and pure gasoline blends (with the exception of the oxygenates themselves), just in different amounts, excluding any of the compounds with the next lower relative ozone reactivity would effect the performance of ethanol blends little relative to other fuels.

Just as there is no justification for excluding any additional compounds from the definition of what comprises reactive VOCs, there is also no justification for including any additional compounds at the present time. A number of comments were received suggesting EPA should include CO in the definition of ozone forming VOC. CO, however has a relative ozone reactivity of roughly one-fifth that of ethane and nearly one-fiftieth that of average gasoline hydrocarbon emissions. Given its low reactivity relative to the majority of hydrocarbons, it would be inappropriate to include it in the definition of ozone forming VOC. This is particularly true given the relative magnitude of CO emissions to hydrocarbon emissions in the exhaust of gasoline vehicles. If the Agency included CO in the definition of VOC the relative ease of reducing CO emissions to hydrocarbon emissions through fuel modification would turn the reformulated gasoline program into a CO control program and virtually eliminate all ozone benefits.

b. Reactivity Adjustment

Even if the Clean Air Act provisions allowed the minimum VOC performance standard to be met on an ozone reactivity weighted basis, the science is far from adequate to support a move away from mass based standards. All reactive VOCs eventually react to form ozone. Their relative reactivity is merely a measure of how quickly they react compared to other VOCs. Depending on the ambient conditions, some VOCs may not react before being blown out of the non-attainment area by the prevailing winds. However, they will then react downwind to form ozone. Thus, even the less reactive VOCs can represent a significant concern, particularly in areas such as the northeast corridor, where there are many ozone non-attainment areas at some distance downwind of each other. Furthermore, the determination of the relative reactivity of the various VOCs is a function of the ambient conditions. As a result, the relative reactivity of various VOCs may be very different from day to day and from city to city making it difficult to apply one set of relative reactivity assumptions nationwide. A compound which demonstrates a low tendency to form ozone in one city may demonstrate a higher tendency in another city, or even the same city on a different day.

Even if we were to consider reactivity in the context of the reformulated gasoline rulemaking despite the legal constraints and scientific uncertainties, it would not be beneficial to ethanol. An analysis using the CARB relative reactivities in a letter from Chester France to Dr. Gary Whitten[13] indicates that an ethanol blend with 1 psi higher RVP would, after adjustments for ozone reactivity, increase VOC emissions from a typical 1990 model car by approximately 19% relative to other reformulated gasolines (if the commingling effect of ethanol blends with other gasolines is incorporated into the analysis).

Several commenters submitted modeling analyses prepared by Systems Applications International (SAI) as justification for much larger ozone reactivity benefits for ethanol blends than estimated by EPA. EPA has carefully reviewed SAI's analyses and rejects their conclusions because the analyses are fraught with invalid assumptions and inconsistencies which make it impossible to use the studies to appropriately quantify the effect on ozone resulting from the use of a reformulated gasoline containing ethanol with a 1.0 psi RVP waiver relative to a reformulated gasoline containing MTBE. EPA's comments and criticisms of these studies are contained in various letters and memorandums located in the Docket and in Appendix I.C.[14] [15] [16] [17] [18] In the most recent study for the Council of Great Lakes Governors, SAI attempted to correct many of the problems which they recognized existed with the earlier

---

[13] See Footnote 6

[14] Letter from Chester J. France, Director, RDSD to Dr. Gary Whitten, Chief Scientist, Systems Applications International, September 24, 1993.

[15] Letter from Paul A. Machiele, Fuel Studies and Standards Branch, to Dr. Gary Whitten, Chief Scientist, Systems Applications International, September 8, 1992.

[16] Letter from Paul A. Machiele, Fuel Studies and Standards Branch, to Eric Vaughn, President, Renewable Fuels Association, August 6, 1992.

[17] Letter from Charles L. Gray Jr., Director, Regulatory Programs and Technology, to Timothy McNulty, Executive Director, Council of Great Lakes Governors, June 4, 1993.

[18] Evaluation of the Ethanol Air Quality Study by the Council of Great Lakes Governors," Memorandum from Paul A. Machiele to Richard A. Rykowski, Chief, Fuel Studies and Standards Branch, and Chester J. France, Director, Regulation Development and Support Division, August 5, 1993.

studies. However, a number of serious errors were made in the protocol causing the study's results to be of little scientific value. One of the most serious of these errors being the exhaust VOC and CO emission credit assigned to the ethanol by comparing an ethanol blend with 3.5 weight percent (wt%) oxygen to an MTBE blend with 2.0 wt% oxygen. This comparison, assumed in all three of these SAI studies, is invalid for analyzing the air quality impacts of fuels under the reformulated gasoline program due to the oxygen averaging provisions of the Act. Furthermore, the magnitude of the credit given for the additional oxygen is significantly larger than that now predicted by EPA's Complex Model. Due to this and other erroneous assumptions, the study drastically underpredicted the evaporative emission increases and overpredicted the exhaust emission benefits with ethanol blends relative to MTBE blends (not only in highway vehicles, but even more so in non-road engines which are not even considered under section 211(k) of the Act) for a reformulated gasoline scenario. Since the study assumed only a small contribution of gasoline vehicles to the total VOC inventory, the result of the combined set of assumptions was very little increase in VOC emissions for the ethanol blend. The study also assumed large NOx emission increases for both on-road and non-road engines with ethanol blends which, combined with the very low VOC/NOx ratio assumptions caused the urban ozone decreases shown with the ethanol blend despite a small increase in overall VOC. Such an assumption with respect to NOx is in violation of the requirements for reformulated gasoline under section 211(k), and is also inconsistent with the currently available information on the effect of fuels on NOx.

Even if the studies performed of Chicago and New York by SAI were valid studies, it would be difficult for EPA to justify using their results to reactivity weight VOC emissions in the reformulated gasoline rulemaking. Reformulated gasoline will be sold in many different areas of the country, representing a wide variety of ambient conditions. Given our current understanding of air chemistry, widely different results would be expected for different cities, episodes, and timeframes. Thus, it would be difficult to draw conclusions that are applicable nationwide from urban airshed modeling of just one or two ozone episodes in one or two cities. This is especially the case when the model is used to focus on the ozone effects of one specific change, such as the use of ethanol, in motor vehicle fuel. The model considers the entire emissions inventory (mobile, point, area and biogenic sources) for the area, as well as a large number of other variables for which input assumptions must be made. All of these factors can influence the results and mask the impact of fuel changes on overall VOC mass emissions and ozone. The influence of these factors is one of the primary reasons for the widely different results of studies conducted by SAI for the Illinois Corn Growers Association, National Corn Growers Association, and Council of Great Lakes Governors and studies conducted by SAI for the Auto/Oil Air Quality Improvement Research Program and in the past for EPA.

8. Carbon Mass Equivalent

In the April 16, 1992 proposal, EPA asked for comments on a concept referred to as the carbon mass equivalent (CME) method, a modified approach for treating CO as a VOC. Rather than merely counting the mass of CO emissions as VOC as discussed above, this approach would exclude the mass of oxygen from CO and apply certain other adjustments to its mass before counting it as VOC. EPA received a number of comments supporting such an approach, as well as a number of comments rejecting such an approach.

EPA does not believe the CME approach represents a valid approach in the context of our reformulated gasoline rulemaking. Excluding only the oxygen mass from carbon monoxide would still greatly overemphasize the ozone forming potential of carbon monoxide relative to other gasoline vehicle emissions by roughly a factor of 20. As discussed above, this would quickly turn the reformulated gasoline program into a CO control program and virtually eliminate all ozone benefits. The only rationale for making additional adjustments to the mass of CO would be its relative ozone reactivity. This would improperly incorporate ozone reactivity into the rulemaking, contrary to EPA's authority under section 211(k). Furthermore, there is no justification for giving credit for only the CO emission reductions resulting from one type of oxygenate as was suggested by some of the comments, or even just oxygenates as a group. The effects on CO of all fuel modifications would have to be determined and appropriate credit given. If the proper adjustment were made to the carbon mass to reflect the relative reactivity of CO and other oxygenates and fuel parameters that affected CO emissions were also provided this carbon mass equivalent, then ethanol blends would receive little additional credit relative to other reformulated gasolines.

A. <u>Benefits of Ethanol to the Nation</u>

A number of comments were received supporting a strong role for ethanol blends in reformulated gasoline through either an RVP waiver, former President Bush's ethanol announcement or some other means on the basis of the benefits of ethanol to our Nation relative to a situation where ethanol is excluded from participation in the reformulated gasoline market. Such stated benefits included: improved energy security, increased rural development, reduced foreign trade deficit, reduced U.S. unemployment, reduced federal agricultural subsidies, and many others.

EPA believes that the ethanol industry is important to the nation, and provides many valuable benefits. As stated before, EPA does not believe that ethanol will be locked out of the reformulated gasoline program, or that the demand for ethanol will shrink. Instead, EPA believes that ethanol will play a large role in providing oxygenate to meet the increased demand for oxygen from the year-round reformulated gasoline program and from the wintertime CO programs. In that context, the issue before the Agency is to identify and quantify the benefits to the nation from any additional increase in demand over and above that anticipated from these programs that might result from either a one psi waiver under reformulated gasoline or from an incentive program such as the program proposed by EPA in the February 26, 1993 proposal. EPA, of course, would also need to look at any adverse impacts from such an increase in demand, as well as its authority to allow a one psi waiver or an ethanol incentive plan like that proposed in February, 1993. Viewed in that light, many of the comments submitted in support of the ethanol industry position provide little help in resolving these issues. Few of the comments contained any analysis supporting how the claimed benefits would be achieved, and when analysis was provided, it focused on comparing the benefits of a large increase in the demand for ethanol with a large decrease in demand. None of the comments showed why EPA's April 1992 proposal would fail to achieve the claimed benefits. In addition, none of the comments provided a direct link between such benefits and special provisions for ethanol. Finally, none of the comments provided an analysis showing that the claimed increase in benefits was justified in light of the cost and environmental impacts from such a program.

As discussed in Section A., EPA believes ethanol is not excluded from the reformulated gasoline market. Rather, EPA believes that the reformulated gasoline program will increase the market share of ethanol over and above the increase already achieved under the wintertime oxygenated fuels program. As a result, EPA believes that if the benefits to the nation discussed in the comments will occur as a result of increased ethanol demand, then the incremental increase in ethanol demand resulting from the reformulated gasoline program will result in a corresponding incremental increase in such benefits to the nation. As discussed in section C., however, further encouraging the use of ethanol through an RVP waiver could easily eliminate all of the VOC emission reductions of the reformulated gasoline program. As such, there would not appear to be any rationale for attempting to increase the ethanol market in this manner.

Similarly, the loss in environmental control discussed in Section G. resulting from the renewable oxygenate provisions of the February 26, 1993 proposal strongly argue against its use to expand the market share of ethanol despite the potential incremental benefits to the nation that might otherwise accrue. Increasing the ethanol market to just 30% under the proposed program is estimated to eliminate roughly 40-50% of the VOC emission reductions of the reformulated gasoline program (as discussed below in Section G.). This is a large environmental cost, particularly since it is possible that ethanol market shares of 30% may occur without such provisions. Furthermore, comments submitted by the Department of Energy indicate that there in fact would be no energy or crude oil benefits under an ethanol incentive program as proposed by EPA.[19] The marginal net energy benefit of producing ethanol from corn using the current processes is offset by the increased energy consumption at the refinery to offset the RVP increase resulting from the use of ethanol. This belief that there are no energy benefits was echoed by various other commenters based on their own refinery modeling. Given the potential lack of energy benefits, and the dramatic environmental impacts of either a waiver as discussed above, or the special incentives in the February 26, 1993 proposal as discussed below, EPA does not believe that the reformulated gasoline rulemaking is the appropriate program by which benefits to the country such as those described in the comments should be obtained.

A. Feasibility of Renewable Oxygenate Proposal

In the February 26, 1993 proposal, EPA proposed an incentive program to encourage the use of renewable oxygenates in reformulated gasoline. This program, in keeping with the October 1, 1992 announcement by former President Bush, essentially provided an RVP incentive of 0.3 psi RVP in a refiner's performance standard for the use of 30% renewable oxygenates in his RFG. The VOC emission increase resulting from the ethanol and other renewable oxygenate blends would be offset by a reduction in the emissions from non-ethanol blends. In order to provide additional incentive for a refiner to actually use the renewable oxygenate, however, EPA proposed that refiners would forfeit the ability to obtain the RVP incentive to their competitors if they did not commit to use the renewable oxygenate. Without such an added incentive EPA feared some refiners might decline to use the renewable oxygenate and instead opt for the performance standard 0.3 psi more stringent. EPA also proposed various tracking and recordkeeping provisions to ensure that the program resulted in the required RVP control (and VOC control under the complex model) in all areas covered by the reformulated gasoline program.

A large majority of comments from parties on both sides of the ethanol issue claimed that EPA's proposal was unworkable and too intrusive to permit efficient market operation. Ethanol producers and blenders and agriculture interests argued that the program was so burdensome and complex and the limitation on the ethanol market share which received the incentive so restrictive that any incentive the program was designed to create was

---

[19] As discussed previously, neither the 1.0 psi waiver under section 211(h), adjustments to reactivity, nor adjustments based on CO emission reductions can be used to offset the RVP and resulting VOC increase in ethanol blends. An energy analysis based on such assumptions would therefore not be relevant.

effectively eliminated. Instead they argued for an outright waiver from the RVP requirement as discussed above.

Similarly, the oil industry argued that the fuel tracking and recordkeeping requirements on each batch of fuel were not feasible, especially given the short lead time between now and the programs initiation in 1995 to satisfy the proposals new tankage and distribution requirements. The increased complexity in production, transportation, distribution, and enforcement of the program would dramatically increase the cost of the reformulated gasoline program to the consumer. Such a cost increase was not justified given the small, or even negative energy benefits of the program (as discussed above), and the negative environmental impact of the program (as discussed below). Both the oil and non-ethanol oxygenate industries argued that ethanol and its derivative ethers would already represent a considerable portion of the RFG market and did not need any additional subsidies. Providing incentives for ethanol and its derivative ethers would place other competing oxygenates at a considerable economic disadvantage with a resulting economic impact on the industries which currently produce these oxygenates. They argued that any additional incentives or federal subsidies for ethanol should be considered in forums other than the RFG rulemaking, as section 211(k) did not authorize EPA to provide such a incentive for ethanol use.

EPA acknowledges the burden caused by the additional fuel tracking, recordkeeping, and enforcement provisions of the February 26, 1993 proposal. While EPA believes that the program's design provides a large economic incentive for the use of renewable oxygenates such as ethanol in reformulated gasoline relative to other oxygenates (refer to Section VIII. of the Draft Regulatory Impact Analysis), EPA also acknowledges the considerable increase in cost for fuel production, transportation, distribution, and enforcement which resulted from such an intrusion into the marketplace which may offset much or all of this incentive. Given the significant increase in the cost and burden to the regulated industry, the various questions raised in regard to its workability and impact, the lack of any energy benefits (as discussed in section E.), and the significant environmental loss (as discussed in section G.), EPA does not believe it to be appropriate, in light of the provisions of section 211(k), to adopt the renewable oxygenate program proposed in February, 1993. The lack of support from the ethanol industry for this proposal further indicates that adoption of this proposal would not be appropriate.

In response to the criticisms of the proposal, EPA investigated a number of options aimed at making the program more workable by reducing the fuel tracking, recordkeeping, and enforcement burden associated with the proposal. While such options tended to make the program more workable from the standpoint of the refining and fuel distribution processes, they also tended to either reduce the assurance that the environmental benefits of the program would be achieved in all areas covered by the RFG program, or to place additional restrictions on the RVP and emission performance of the ethanol blends (thereby reducing the certainty that ethanol would actually be used). Furthermore, they did little to address the environmental concerns discussed in Section G. Given this and the other concerns with the proposal (cost, lack of energy benefits, significant environmental loss, etc.), EPA did not believe these options to be appropriate for promulgation either.

A number of comments were received concerning the justification and rationale for various detailed provisions of the renewable oxygenate incentive proposal (e.g., the percent of ethanol in the fuel needed to receive the RVP incentive). Given the fact that we are not promulgating the proposal, EPA does not believe there to be any reason to evaluate the relative merits of these provisions.

A. Emission Impacts of the Renewable Oxygenate Proposal

As discussed above, granting ethanol a 1.0 psi waiver from the reformulated gasoline requirements would result in a significant loss (if not a total loss) in the environmental control of the reformulated gasoline program. EPA also received a number of comments that there are significant negative environmental impacts from providing incentives for ethanol use as under the February 26, 1993 proposal. Despite EPA's best efforts to propose an environmentally neutral incentive program for renewable oxygenates, VOC emissions would be expected to rise under the program for four main reasons; fuel commingling, distillation effects, unrestricted early use of the complex model, and greater permeation of oxygenates through non-metal fuel lines and hoses. Appendix I.D. contains EPA's analysis of the ethanol commingling effect. References located in the docket[20] discuss its impact on VOC emissions. EPA's analysis of the distillation effects are discussed in detail in a recent paper published in the technical literature[21], and again, the references cited above discuss its impact on VOC emissions. The emission impact of unrestricted early use of the complex model is discussed below. EPA has not had an opportunity to evaluate the effects of oxygenates on fuel line and fuel tank permeation, but the reader is referred to SAE paper number 920163 suggesting dramatic increases in permeation emissions with oxygenates, particularly alcohols.[22]

9. VOC Emission Increase Estimate

Assuming a 30% market share for ethanol in reformulated gasoline during the summer months, the commingling effect is estimated to result in roughly a 2-2.5% increase in fleetwide (6-8% if applied to ethanol market share only) gasoline vehicle VOC emissions (for an assumed 0.15-0.20 psi increase in in-use RVP), the distillation effect a 3% increase in gasoline vehicle emissions (relative to CAA baseline gasoline), and unrestricted early use of the complex model a 1-2% increase, for a total increase of 6-7.5% relative to a scenario with no gasoline reformulated with ethanol. This represents a loss of 40-50% of the VOC emission control required under section 211(k). EPA is in the process of collecting additional data and information which will enable a better analysis of the distillation effect, but does not expect the current emission effect estimate to change appreciably once the new data is incorporated due to the scientific theory which supports the effect. Inclusion of fuel tank and fuel line permeation, however, would be expected to further increase the estimate.

Comments were received suggesting EPA take into consideration additional effects on emissions when analyzing the in-use impact of ethanol blends such as fuel weathering and enrichment of the air fuel ratio when vehicles accelerate above and beyond that which occurs during EPA's certification test

---

[20] Refer to footnotes 5 and 6

[21] "Running Loss Emissions From Gasoline Fueled Motor Vehicles," C.E. Lindhjem and D. Korotney, U.S. EPA, SAE Paper No. 931991, October, 1993.

[22] "Fuel-Alcohol Permeation Rates of Flouroelastomers, Fluoroplastics, and other Fuel Resistant Materials," W.M. Stahl and R.D. Stevens, E.I. du Pont de Nemours and Co., Inc., SAE Paper No. 920163, February, 1992.

procedure. Fuel weathering is already contained in the MOBILE model and as such already reflected in EPA's evaporative emission estimates, including the estimates of emission increases resulting from commingling. The emission differences between EPA's certification test procedure and those which occur during in-use driving, often referred to as off-cycle emissions, is currently the focus of a great deal of study. However, there is not adequate data and information available at the present time to approximate with any confidence the magnitude of such emission effects.[23] In addition, enrichment of exhaust emissions during acceleration is only one of the off-cycle emission impacts currently being evaluated. It is possible that off-cycle vehicle driving patterns will have just as large of an effect on non-exhaust emissions as exhaust emissions. Due to the lack of data, however, EPA is not able at this time to determine whether such off-cycle emissions improve or exacerbate the emission impacts of ethanol blends described above.

10.   Unrestricted Early Use of CM

EPA proposed three different options for early use of the complex model, that is, optional use of the complex model before its use became mandatory. The first option would require that the reformulated gasoline achieve VOC, toxics, and NOx performance that was no worse than the complex model would achieve for a simple model fuel using that refiner's 1990 baseline for sulfur, T-90 (E300), and olefins. This was designed to ensure that early use of the complex model would not upset the expected emissions benefits in the early years of the reformulated gasoline program. For example, if a refiner could optionally use the complex model and measure performance against the CAA baseline, then those refiners with individual baselines that were more stringent than the CAA baseline (for example, lower sulfur levels) could be expected to use the complex model early and take credit for their lower sulfur levels. However, those refiners who had baselines that were less than the CAA baseline, for example with sulfur levels higher than the CAA baseline, would be expected to use the simple model as use of the complex model would require that they offset the emissions impact of higher sulfur levels. Unrestricted early use of the complex model might in effect unbalance the emissions balance imposed under the simple model which established refiner-specific caps on sulfur, T-90, and olefins. EPA discussed the pros and cons of this option in the April 1992 proposal.

EPA also proposed a second option in the April 1992 proposal, where refiners could use the complex model early for fuel distributed to VOC control region 1 (southern areas of the Country), and measure performance against the CAA baseline and not their individual baselines. To limit interference with the enforcement scenario proposed by EPA, a cap would be placed on maximum RVP levels.

A third option for early use of complex model was proposed in February 1993 as part of the incentive program for ethanol blends. Under this option, performance under the complex model would be measured using either the CAA baseline or the refiners' 1990 baseline, at their option. This was described as providing the maximum flexibility for refiners, and, therefore, the maximum incentive for ethanol use. However, EPA was still concerned this would lead to a reduction in the emissions benefits expected from the simple model.

Unfortunately, it is difficult to assess with any precision the environmental impact that would result from unrestricted early use of the complex model. EPA does not have any information at the present time to estimate the number of refiners that would opt for early use of the complex model, nor does EPA have any information on the number of refiners with 1990 baseline levels of sulfur, T90, and/or olefins below the CAA baseline levels,

---

[23] Refer to footnotes 5 and 6

or what the levels of these parameters are for these refiners. As shown in Table I-2, if refiners had low levels of sulfur, T90 (high E300), and/or olefins, they would achieve substantially lower emissions reductions than required by the simple model. Assuming a normal distribution about the CAA baseline 7/8 of all refiners would have a low baseline of one or more of sulfur, T90, and olefins. Given these estimates, and the incentive for low baseline refiners to opt for early use of the complex model relative to the CAA baseline gasoline, it would not seem unreasonable to conclude that the proposal to allow such an option would sacrifice 1-2 percentage points of the VOC emission reductions expected under the simple model.

Table I-2 Emission Impacts of Unrestricted Complex Model Use

Fuel Parameter	CAA Baseline Level	Refiner A	Refiner B	Refiner C	Refiner D
Sulfur (ppm)	339	150	339	339	150
E300 (%)	83	83	92	83	92
Olefins (vol%)	9.2	9.2	9.2	3.0	3.0
VOC %Change From Baseline*	N/A	-1.6	-1.4	-0.7	-2.3
NOx Change From Baseline*	N/A	-5.4	+0.8	-0.5	-5.2

* Based on the Phase I Complex Model

A. Reg Neg

A number of comments were received suggesting that the renewable oxygenate provisions of the February 26, 1993 proposal violated the agreement reached through regulatory negotiation. As a result, these comments suggested that if EPA were to promulgate the provisions, EPA would face numerous lawsuits. While EPA shares the desire of the commenters to maintain the provisions reached through negotiation, it must be made clear that the negotiated agreement is not in and of itself legally binding. EPA's final rule must be based on the authority provided by the Act. The regulatory negotiation process is intended to develop a consensus among the affected parties on how the Act should be interpreted and implemented. To EPA's knowledge, there was no consensus reached during the negotiation on any special provisions or waivers for ethanol blends. Only if a deviation from the negotiated agreement, such as the renewable oxygenate provisions, also resulted in a deviation from EPA's legal authority under the Act, however, would EPA be at risk in any ensuing litigation.

A. Appendices

Appendix I.A. Ethanol Sales in 1990

The following table shows and analysis of the ethanol sales in 1990 in those areas currently covered by the reformulated gasoline program. The gasohol sales data on a state by state basis were obtained from the 1992 National Petroleum News Factbook. Sales data for each covered area was obtained by ratioing the gasohol sales in the state by the proportion of the state population represented by the covered area based upon 1990 census data. This same population weighting is what EPA used to obtain the percent of national gasoline consumption in each covered area.

Insert ethanol sales table here

Appendix I.B. Relative Economics of Oxygenates in RFG

Historically, oxygenates (primarily ethanol) have been used as fuel extenders or more recently as octane enhancers. With the advent of the oxygenated fuels program to control wintertime carbon monoxide emissions and the reformulated gasoline program to control summer ozone, oxygenates now have value for other purposes, as well.

First, the addition of an oxygenate to gasoline impacts the Reid vapor pressure (RVP) of the blend. Since Phase I reformulated gasoline (RFG) has restrictions on RVP, and Phase II RFG requires significant reductions in VOC emissions that will likely require further reductions in RVP, the impact of oxygenates on the RVP of the blend is an important factor to consider.

Second, oxygenates are high in octane, and thus enhance the octane of the finished gasoline. Since other means of providing octane, such as the addition of aromatics, are costly and often have negative consequences for emissions, oxygenates are valuable for their role as octane enhancers.

Finally, in the context of an oxygen content requirement such as exists in the RFG requirement for 2.1 wt% oxygen (on average), oxygenates are valued for their oxygen content.

The relative costs of three major oxygenates, ethanol, MTBE, and ETBE, have been compared based on their purchase prices and their values as fuel extenders, RVP modifiers, octane enhancers, and oxygen sources. Since MTBE is believed to be the oxygenate likely to be used in reformulated gasoline in the largest volumes (given the current market conditions), the costs of ETBE and ethanol have been compared relative to the cost of MTBE.[24]

The purchase price of the oxygenates was determined from the spot market prices or reasonable assumptions about their costs. The price of MTBE was estimated to be $0.70 per gallon, based on the recent (1993) spot prices reported in trade press publications such as *Octane Week* and *Oxy-Fuel News*. The price of ethanol was assumed to be $1.20 per gallon, the typical price over much of 1993. (See below for further discussion of the price of ethanol.) The purchase price of ETBE ($1.01/gallon) was estimated from the price of MTBE, assuming ethanol is purchased at $1.20 per gallon and the capital and operating costs for ETBE production are slightly higher (5% and 10%, respectively) than for MTBE since somewhat large equipment is necessary to process the same volume of isobutylene into ETBE. The cost per gallon of isobutylene was assumed to be equivalent for both ethers.

The value of the oxygenates as a fuel extender was based on the recent spot market price of unleaded regular gasoline at the U.S. gulf coast (around $0.50/gallon). Since the analysis was performed on the basis of the relative cost per gallon of each oxygenate, the oxygenates have equivalent values as fuel extenders and thus the magnitude of the value assumed for the gasoline displaced is unimportant.

The values of the oxygenates as octane enhancers, oxygen additives, and RVP modifiers were estimated based on market trends and on the results of the refinery modelling used to develop costs for Phase II RFG. It was assumed

---

[24] ETBE like MTBE can be added at the refinery. While it shows promise for the future, ETBE has not been widely used in the market to date. Ethanol blends cannot travel through petroleum pipelines and thus ethanol is blended at the distribution terminal.

that the oxygenates were worth $0.006 per octane number added per gallon of blend produced. All of the oxygenates have octane ratings higher than the base gasoline, so all have a value as octane enhancers. The value of the oxygen provided was assumed to be $0.003 per weight percent oxygen added per gallon of blend produced. Since ethanol has the highest oxygen content per gallon, it has the highest value as a source of oxygen. The cost of reducing the RVP of the blendstock (to maintain a constant RVP in the final blend) was estimated for this analysis to be $0.005 per psi per gallon of blend produced. (Recent refinery modeling, however, suggests that in some cases the cost of RVP control could be considerably less expensive.) Ethanol has a higher RVP than gasoline, so ethanol incurs a cost because the RVP of the blendstock must be lowered. The ethers have lower RVPs than gasoline and thus are valuable because the RVP of the blendstock does not have to be reduced to accommodate these oxygenates.

Ethanol is eligible for a $0.54/gallon tax credit which adds to its value. In this analysis, it was assumed that ethanol used in ETBE was similarly eligible for this tax credit. Ethanol is also eligible for additional tax credits and other forms of economic support as high as $0.50/gallon of ethanol in a number of States. These credits have not been factored into this analysis.

Table 1 presents the comparison of the oxygenates. As the table shows, ethanol costs less and ETBE costs more than MTBE for use as a gasoline oxygenate. When expressed on a cost per gallon of finished gasoline basis, the ethanol has a small advantage over MTBE of around 0.4 cents per gallon gasoline. ETBE, however, is slightly more costly than MTBE, adding an additional 0.8 cents per gallon gasoline. Distribution costs have not been included in this analysis. Since ethanol cannot be shipped through pipelines, it tends to incur greater distribution costs if shipped over long distances. Distribution costs will vary significantly depending on the locations involved, but for many of the RFG areas the incremental cost for distribution of ethanol should be less than 5 cents/gallon of ethanol. ETBE, however, is likely to be produced in the Gulf, while the ethanol is largely produced in the Midwest. Therefore, ETBE will also incur an additional cost for the distribution of the ethanol to the Gulf, which could reach about $0.01 per gallon of ETBE produced.

Table 1: Costs of Oxygenates at 2.1 wt% Oxygen ($/gal oxygenate)
Ethanol Price: $1.20/gallon

	Ethanol	ETBE	MTBE
Purchase Price	1.20	1.01	0.70
Fuel Extender Value	-0.50	-0.50	-0.50
RVP Modifier Value	0.050	-0.020	0.001
Octane Enhancer Value	-0.160	-0.148	-0.141
Oxygen Value	-0.108	-0.049	-0.056
Blender's Tax Credit*	-0.54	-0.23	0.00
Total Cost ($/gal oxygenate)	-0.06	0.06	0.00
Total Cost ($/gal RFG)	-0.004	0.008	0.000

* Federal credit only, individual state credits have not been included in this analysis

Recently, the price of ethanol has decreased as the oxy-fuels season started and refiners found that there was sufficient oxygenate supply. The price reported for the October-November timeframe has been around $1.05 per gallon. If this price is assumed for ethanol, the relative values ethanol and ETBE as oxygenates compared to MTBE change somewhat, as shown in Table 2. At the lower purchase price, combined with the tax credit, ethanol costs $0.01 less per gallon of gasoline than MTBE. ETBE costs the same as MTBE on this basis.

Table 2: Costs of Oxygenates at 2.1 wt% Oxygen ($/gal oxygenate)
Ethanol Price: $1.05/gallon

	Ethanol	ETBE	MTBE
Purchase Price	1.05	0.94	0.70
Fuel Extender Value	-0.50	-0.50	-0.50
RVP Modifier Value	0.050	-0.020	0.001
Octane Enhancer Value	-0.160	-0.148	-0.141
Oxygen Value	-0.108	-0.049	-0.056
Blender's Tax Credit*	-0.54	-0.23	0.00
Total Cost ($/gal oxygenate)	-0.21	0.00	0.00
Total Cost ($/gal RFG)	-0.013	0.000	0.000

* Federal credit only, individual state credits have not been included in this analysis

Appendix I.C. Critique of the Draft Final Report: "Comparison of the Air Quality Effects of Ethanol and MTBE in Reformulated Gasoline in the New York Region in 1995," for National Corn Growers Association, by Gary Z. Whitten, Systems Applications International, August 18, 1992.

General Overview of Comments:

As discussed in the August 6, 1992 letter to Eric Vaughn shown in Appendix I.C., EPA has serious reservations with respect to the ability of the UAM to adequately evaluate the relative ozone impacts of oxygenated blends in the New York airshed. Past experience with New York indicate that transport of pollutants into the airshed dominates the result and makes establishment of appropriate initial and boundary conditions extremely difficult. As a result, we recommended that some other city be modeled instead where transport was not such an overwhelming issue. Instead, SAI proposed a new approach of adjusting the initial and boundary conditions based on the results from the first day. It was agreed, however, that external peer review of this method would be obtained by a panel of recognized experts in the field. It was also agreed that a number of sensitivity analyses would be performed to allow evaluation of the study's results. These agreements were not fulfilled. The results cited in the introduction and conclusion sections of the final draft report contained in the docket to this rulemaking are not based upon any runs for which the transport issue was addressed. Furthermore, while a sensitivity analysis was performed using an approach for dealing with transport, peer review of the method was not obtained, nor was enough information provided in the draft final report by which EPA could evaluate the approach. As a result, EPA has no choice other than to maintain our position expressed in the August 6, 1992 letter to Eric Vaughn that the results from the modeling of New York are not valid.

Furthermore, our preliminary review of the report provided suggests that even if the transport issue were adequately addressed, the inappropriate assumptions made in the protocol would invalidate the results. Other than using UAM-IV instead of UAM-V and including the specific air chemistry for ethanol and MTBE, the protocol for New York is virtually identical to the protocol used in the Chicago study. As a result, most of the comments and criticisms of that study contained in Appendix I.B also apply to this study. Comments specific to the New York study are discussed below. As with the previous Chicago study, however, the documentation which was provided for both the protocol and the final results does not allow for a thorough evaluation of the appropriateness of the study or usefulness of its results.

The EKMA modeling which was performed for 14 cities also appears to be of limited usefulness as discussed in the comments below.

Detailed Comments on the New York UAM:

1) Model Validation

- It is necessary to show that the model is adequately predicting historical ambient ozone (and other pollutant) levels for the ozone episode being modeled. There was no discussion of this. Presumably since the same model and episode were used by AQIRP, it has been validated, but it is not known if the same initial and background assumptions were used.

- The modeling, with the exception of some sensitivity runs (which were downplayed and ignored in the final conclusions) apparently did not address the impact of transport on the initial and boundary conditions.

- In the sensitivity runs that were performed, the method of adjusting the boundary conditions for transport was not adequately explained. While it may be directionally better than making no adjustment, based on the limited explanation in the final report, the method used appeared to be of little merit. It used the effects of ethanol on the inventory 55 km downwind from New York to adjust the boundary conditions since New York is 55 km downwind from Philadelphia. As a result, it appears to ignore the impacts of Newark, Jersey City, Baltimore, Washington D.C., Trenton, etc. It is also unclear how well it represents the upwind effects of Philadelphia since no explanation was given as to what the time period was over which the emission effects of ethanol were evaluated in order to adjust the initial and boundary conditions. The difference would be dramatic between evening, early morning, or afternoon emission effects. Furthermore, as in the Chicago study, the primary compounds of interest in this study (ethanol and MTBE) were substituted with similar CBM-IV species in the air chemistry for the boundary conditions.

2) Episode Selected

- The maximum temperature, diurnal temperature swing, and any other relevant episode information were not provided. Without such information it is difficult to evaluate the results.

- There was no explanation provided for the assumptions made for the initial and boundary conditions (other than the adjustments made for the sensitivity runs).

3) Selection of 1995 as the Future Study Year

- The ozone impact of ethanol and MTBE blends in the year 1995 was evaluated. The ozone impact of ethanol in particular, is the sum of a number of impacts, some positive and some negative. One of the positive impacts is the likelihood that ethanol provides additional exhaust VOC and CO emissions beyond that provided by 11 volume percent MTBE. However, these benefits are greater for older vehicles than for recent model year vehicles. Likewise, the evaporative emission detriments of ethanol are greater for vehicles not designed to meet EPA's upcoming enhanced evaporative and running loss emission control.

  The choice of 1995 as the focus of the study (the earliest possible year to evaluate reformulated gasoline) maximizes the exhaust emission benefits of ethanol. However, assuming the same assumptions were made for New York as for Chicago, unrealistic and insupportable assumptions were made concerning the implementation of new vehicle evaporative emission controls in 1995.

  Since the decision to grant or not to grant ethanol a 1.0 psi waiver will affect reformulated gasoline well into the next century, evaluating the impact only in 1995 is unacceptable. At minimum, evaluations should be performed in 2000 and 2005, as well.

4) Inventory

- The final report gives no detail of the control assumptions for area and point sources assumed for 1995. If as in the Chicago study, no controls were assumed for these sources despite the application of stringent mobile source controls, and rapid growth was instead assumed, the relative importance to ozone levels of the increases in mobile source emissions resulting from the use of ethanol blends is underestimated.

- As confirmed in subsequent conversations and discussions since the time of the previous Chicago study's release, the MOBILE model used in SAI's work was not EPA's MOBILE4.1 model, but a version of MOBILE4.0 modified by SAI and/or DOE. The impact of this on the results of the UAM, however, may be small based on the analysis performed by SAI in a September 10 memorandum from JGH to Dr. Whitten. The original MOBILE model used by SAI with assumptions of enhanced I/M and a new evaporative test procedure and Tier I controls gave similar results as using the actual MOBILE4.1 model with corrected I/M assumptions, no new evaporative test procedure assumptions, and Tier I controls. The MOBILE4.1 results, however, do not appear to be consistent with the actual inventories used. Apparently there are other assumptions made in developing the inventories from the MOBILE model outputs that change the relative contribution of the various pollutants and emission types. Until EPA is provided with such information we cannot ascertain the validity of the mobile source inventory.

- Use of the same evaporative test procedure assumption as in the Chicago study is just as inappropriate in the New York study (if in fact the same assumption was made). Either 1998 or a later year should have been modeled (decreasing the exhaust emission benefit of the ethanol blend), or no evaporative emission reduction should have been claimed for 1995 due to the new test procedure.

- If the same assumption was made here as in the Chicago study, the inspection and maintenance program assumptions are unrealistic. Not only are these assumptions inconsistent with the proposed I/M rule, but they also provide an effectiveness which can not be achieved in-use. Full effectiveness is not likely for a few years after the start of the program which is currently scheduled for the beginning of 1995. Once again, either 1998 or a later year should be modeled, or reduced benefits claimed in 1995.

- Presumably, the same assumptions were used for the exhaust VOC emission benefits for the oxygenated blends as in the Chicago study. As discussed in the comments on the Chicago study, the assumption for ethanol is too high relative to that for MTBE, especially considering the I/M scenario assumed in the study. At a meeting in Ann Arbor on 9/11/92, apparently Dr. Whitten agreed with EPA's assessment of the oxygenate effects as he raised no objection to EPA's assumptions. As a result, SAI overstates the exhaust VOC benefit of ethanol blends in the inventory. This is particularly important since much of the air quality benefit given to ethanol to offset the evaporative and running loss emission increases was in the form of exhaust VOC emissions.

- The fuel assumption of ethanol at 3.5 wt% oxygen and MTBE at 2.0 wt% oxygen is not valid for a reformulated gasoline scenario. The oxygen averaging provisions under the reformulated gasoline program will limit the maximum average oxygen content in the fuel to 2.1 wt% oxygen. When combined with the minimum oxygen content requirement for 1.5 wt% oxygen, if ethanol is used at 3.5 wt% oxygen, it will only be used in 30% of the fuel, with the remainder of the fuel containing ethanol or some other oxygenate at 1.5 wt% oxygen. If the study is to have any relevance to the reformulated gasoline rulemaking as it purports, then both the ethanol and MTBE scenarios should have the same overall oxygen content. This will essentially eliminate the exhaust VOC and CO emission credits applied to ethanol in the study, and greatly increase the ozone estimates for the ethanol scenario relative to the MTBE scenario.

- Presumably the non-road inventory was based upon EPA's non-road study. However, there is no explanation of this. Furthermore, there is no explanation made for the temporal, spacial, and growth assumptions made for non-road emissions.

- Presumably the non-road inventory in Table 1 is only the gasoline portion of the non-road inventory. However, it is not possible to know this from the information provided. Neither the non-road or the diesel related inventory is broken down into its constituent pieces allowing for any clarification.

- One glaring error in the New York study which benefits ethanol tremendously is that it was assumed that there were no evaporative or running loss emissions from non-road vehicles. Since non-road vehicles and engines do not have any evaporative emission control systems, the non-road evaporative VOC inventory should be significant. As a result, SAI provides a very large exhaust VOC credit to ethanol relative to MTBE (roughly half that of the exhaust credit from on-road vehicles) and ignores completely the evaporative emission increases with ethanol relative to MTBE. EPA acknowledges that there is a general lack of information on the evaporative VOC emissions from non-road sources, and we will be working to improve our understanding of their magnitude. However, to ignore them completely while including the exhaust inventory when the fuel effect being evaluated has dramatically different effects on exhaust and evaporative emissions is unconscionable. Either non-road emissions should have been assumed constant for both scenarios, or some sensitivity runs performed with reasonable assumptions made as to their magnitude.

- For the effect of oxygenates on non-road exhaust emissions, SAI used data from Southwest Research Institute on one 4-stroke engine and one 2-stroke engine. This test data may be of some use for demonstrating certain trends, but is hardly adequate to quantify the effect of oxygenates on exhaust emissions from non-road vehicles. The fuels used in the testing are not representative of in-use fuels, and the two engines are not representative of the wide variety of non-road emission sources. As a result, there should be no distinction made between the MTBE and ethanol fuels for the effect of oxygenates on non-road emission sources in this study. The results of the study may be too sensitive to any assumptions made for non-road, which cannot be substantiated.

- Why is there only a 9.8% increase in refueling emissions for LDVs with ethanol, and why is it different for MDVs and HDVs? Based on the vapor pressures of the fuels in question, there should be roughly a 12-13% increase.

- If the same assumption was made here as in the Chicago study, Stage II refueling controls were assumed by SAI to reach full benefit by 1993, but probably will not be in effect until 1995 and will not reach full effectiveness for several years. Once again, either 1998 or a later year should have been modeled, or reduced benefits claimed in 1995.

- Based on the protocol, the same data, information, and assumptions were supposedly made in the New York study as in the Chicago study regarding the impact of ethanol and MTBE on VOC, CO, and NOx emissions. This held true in the New York inventory for CO emissions. The percent changes in CO emissions from MTBE to ethanol in the inventory were exactly the same as in the Chicago study. However, the percent changes for VOC and NOx were different. Exhaust VOC emissions decreased with ethanol by smaller percentages, NOx emissions increased by smaller percentages (except for HDVs which now showed a decrease in NOx instead of an increase), running loss emissions increased by smaller percentages, and evaporative emissions increased by slightly larger percentages. What is the justification and rationale for these changes? Temperature conditions were likely different prompting different evaporative and running loss emission changes, but the changes should have been in the same direction. Furthermore, given that the changes in CO were the same, they should have been for exhaust VOC and NOx as well. There especially does not appear to be any justification for why NOx was now assumed to decrease with ethanol for heavy-duty vehicles.

- The study assumes 100% replacement of gasoline with gasohol under the ethanol scenario. This is unrealistically high and results in the commingling effects of ethanol on in-use RVP being ignored.

- Presumably SAI made the same faulty VMT and ambient temperature adjustments to the running loss emissions that were made in the Chicago study. The VMT adjustment shifts more emissions to the morning hours than is appropriate based upon EPA information. The temperature adjustment then zeros out most of these inflated morning running loss emissions and forces the remaining running loss inventory to the end of the day when there is not adequate time for it to react and contribute to peak ozone. Emissions do not vary linearly with temperature so a linear weighting of running loss emissions with ambient temperature does not reflect the diurnal variability of running loss emissions. For example, the methodology used assumes running loss emissions are zero at the morning low temperature, eliminating virtually all running loss emissions from the morning commute. While running loss emissions are temperature dependent, all currently available data suggests that significant running loss emissions occur even at morning low ambient temperatures down to about 40°F. The effect of these VMT and temperature assumptions together is to drastically reduce the impact of running loss emissions on ozone formation. As a result, the largest source of emission increases (running losses) in the inventory with ethanol blends is virtually eliminated.

  SAI could have very easily adjusted the running loss emission profile for temperature in an appropriate manner by running the MOBILE model for each hour of the ozone episode. In addition to being erroneous, however, the adjustment made to running loss emissions based upon the time of day is in and of itself biased in favor of ethanol. To make adjustments only for running loss emissions without also making adjustments for all other portions of the inventory is inappropriate.

- Another serious oversight in the study is that while fuel effects on refueling emissions were taken into account, for some reason the fuel effects on storage emissions which represent a three times larger portion of the inventory were ignored. The effect of this is to ignore some of the adverse effects of volatility increases with the ethanol blend.

- The methodology used to develop the emission inventories (and speciation profiles) for medium and heavy-duty vehicles was not explained in the protocol. Based on follow up discussions, these inventories were based on crude extrapolations of light-duty vehicle data which are not supportable. The overall effect on the results of these assumptions is unknown, but it does raise additional uncertainty as to the validity of the study's results.

5) Speciation

- Refer to comments in Appendix I.B. on the Chicago study. Apparently the same speciation profiles were assumed for both studies. As for that study, EPA cannot agree with the profiles developed and recommends the use of our own speciation profiles.

- Formaldehyde and acetaldehyde emission increases with ethanol are ignored, while the formaldehyde and isobutylene increases with MTBE are not. This is inappropriate.

- Using EPA default species for non-road is inappropriate since they are based on light-duty vehicle data. The SwRI report from which the oxygenate effects data was taken suggests that 2-stroke exhaust is predominantly unburned fuel, and that 4-stroke exhaust resembles that of conventional gasoline engines. If your assumption is true that 70% of non-road exhaust is 2-stroke, then the speciation profiles should approximate those of the raw fuel.

- The CO reactivity in a 1988 SAI study was assumed to be 71% greater than that of ethane. The Carter reactivity for CO is 1/5th that of ethane. What was used in these studies? It could have a significant impact on the results.

6) Results

- Results discussion ignores first day results. New York gets blown through in a day. As a result first day results are just as valid as second day. Much higher - why?

- The results are difficult to interpret since isoline results for the ethanol blend scenario and no gasoline mobile source scenario were not provided separately.

- The adjustment for transport in the sensitivity runs resulted in ozone increases. These were ignored and downplayed in the discussion of the results.

- As in the Chicago study, the results discussion still focussed only on the peak ozone and not the larger and geographically dispersed ozone increases.

- The sensitivity of ozone to VOC emission increases from ethanol were more appropriate than in the Chicago study, but still lower than for other studies - including the SAI/AQIRP study of New York. Since New York was the least sensitive city in the AQIRP work, larger increases in ozone would be expected in other cities.

Detailed Comments on the EKMA Modeling of 14 cities

- Mobile emission inventories for the cities were based on the New York UAM inventory and were not specific to the different cities. Not specific for temperatures or RVPs, etc. As a result, they were not appropriate.

- As discussed above and in the comments on the Chicago UAM study, the New York inventory has numerous inaccuracies and is based on many unrealistic assumptions. As a result, the inventories used for the EKMA modeling are also invalid.

- The baseline gasoline inventory was arbitrarily assumed to be MTBE blended gasoline.

- Again, default chemistry is used for the many different VOC compounds, and not the specific chemistry for the compounds being evaluated in the study.

- No explanation is given why for Philadelphia and San Diego the EPA inputs could not be used, and instead why the precursor ratios had to be raised and the default chemistry replaced with an "updated version".

Given the results for these two cities showed that removing all mobile source emission increased ozone, something appears to have gone awry.

- No explanation given for the city selection and its representativeness to the nation or the RFG program.
- It is not possible from the results to say that in 4 cities "ethanol reduces ozone compared to the MTBE base." The results for three of those cities should have been thrown out since eliminating all mobile source emissions increased ozone.
- The results showed a -0.7 to 4.1% increase in the mobile source contribution to ozone with the use of ethanol (average of 1.75%). While much smaller than predicted by other studies, this is nevertheless a very significant increase, representing a large fraction of the ozone benefits achieved by RFG.
- How can the 23.2% motor vehicle contribution to the VOC inventory in Chicago be reconciled with the 5.1% assumed in the Chicago UAM study?

Appendix I.D. Commingling Effect of Ethanol

I. INTRODUCTION

Ethanol has a Reid Vapor Pressure (RVP) of 2.4 psi, and most gasolines will have an RVP of 6.5 to 9.0 during the summer months. When ethanol is mixed with the gasoline a non-linear increase in the RVP is observed. For example, if gasoline with an original RVP of 8.0 is mixed with ethanol (10% by volume) the resultant RVP is approximately 9.1. This RVP increase can be offset at the refinery by using a lower RVP gasoline so when the two substances are mixed together the desired final RVP can be achieved. However, due to the non-linear nature of ethanol's blending RVP, the mixing of ethanol blends with other non-ethanol containing gasolines downstream of the refinery in vehicle fuel tanks can result in an additional vapor pressure increase across the in-use pool of gasoline. This RVP increase caused by fuel mixing is what is known as the commingling effect. This study will only address the commingling effect in vehicle fuel tanks. Other effects outside of the vehicle fuel tanks are assumed to be small due to fuel segregation through the fuel distribution system.

The commingling effect is not a simple matter to model for any geographical area. Many factors must be taken into account in order to accurately describe the overall consumer refueling behavior which is so critical in establishing a viable commingling model. Such factors are the refueling patterns of the consumers using the various gasoline blends, their loyalties to various brands, the base RVP of the fuels used, the market share of gasolines using ethanol as an additive, and whether the geographical area in question is utilizing reformulated gasoline or not (due to the cosolvent effects of other oxygenates). Such complexities and variables are extremely difficult to account for using simple hand or spreadsheet calculations, thus a computer program was developed to attempt to include as many of these variables as possible in order to develop a more accurate estimate of the commingling effects that ethanol as a gasoline additive has on in-use RVP.

II. THE COMMINGLING MODEL

A. General Overview

The commingling model developed here simulates real world conditions by performing 100 refueling events for each of 1000 vehicle owners, for a total of 100,000 refueling events. The model utilizes brand loyalty curves and refueling pattern curves in order to determine the quantity and type of fuel for each refueling event.

The model is flexible enough to be used for a number of different in-use assumptions (a listing of the computer program is contained in the appendix). One of these is whether it is a reformulated gasoline scenario where the ethanol blend is assumed to be mixed with a MTBE blend, or a conventional gasoline scenario where the ethanol blend is mixed with pure gasoline. The model, however, is not flexible enough to model a scenario where the ethanol blend is mixed with both MTBE blended gasoline and conventional gasoline. Another in-use assumption of the model is that the base RVP is the same for all blends. This means that the RVP of the gasoline that is initially mixed with the pure ethanol is lower such that all gasoline blends have the same RVP. Thus, the results from this commingling analysis are incremental to any RVP increase that might result from RVP waivers for ethanol blends. A third in-use assumption is that of the ethanol market share in the particular region being modeled.

Two other important variables in the model are the brand loyalty and the consumer refueling pattern. Due to a degree of uncertainty in the available for brand loyalty and consumer refueling data, the model was designed to allow for a number of different assumptions. This was done in order to bracket the range of possible in-use conditions.

B. Brand Loyalty

Figures #1 - #3 represent the various forms of owner brand loyalty curves that were derived for use in this computer model. Figure #1 defines the customer loyalty to a particular brand of fuel based on data collected by Arco. This data, submitted to EPA in 1981 as part of ARCO's oxinol waiver request, only has a few points and indicated a great propensity towards extremely high owner loyalty[25]. Of particular importance with this data is the seemingly large percentage of customers that have 100% brand loyalty. The Arco data appeared to be unrealistic because of this fact. Much of the reasoning behind the apparent skewing of this graph towards high loyalty may be in the manner that the data was collected. The questionnaire only made an inquiry as to how many customers purchase the same brand of gasoline 75% to 100% of the time. Thus it is the sensitivity of the data collection procedure that produced this high loyalty skew. One would expect there to be actually very few customers who are 100% loyal to one brand (never use a different brand of gasoline, even on long trips), however, this data serves well as an upper bound for consumer brand loyalty. Two other curves were developed in an attempt to exhibit consumer brand loyalty in a less dramatic measure.

Figure #2 shows these two other curves. The curve labeled "Curve #2" is an attempt to retain the general trend of the Arco data yet adjust for the concept that there would be a decrease in the percentage of owners with high loyalties (80% to 100%) to a particular brand. Curve #3 shows an assumed normal distribution of loyalty that assumes that most people in major urban

---

[25] U.S. Environmental Protection Agency, Arco Oxinol Waiver Request, 1981.

areas purchase fuel from a number (e.g. 2-6) different brands. As such, the maximum percentage of the time that they purchase the brand they use most often tends to be rather low. A fourth brand loyalty not shown in Figure #2 but permitted in the model assumes that the consumers all have zero loyalty[26]. This assumption is on the opposite end of the spectrum as the Arco data and serves as the lower end of the loyalty bracket.

Figure #3 shows each of these brand loyalty assumptions as a cumulative percentage of the total. The Arco data (at the far right in Figure #3) shows the greatest trend toward high levels of consumer loyalty, while the other three curves show lesser degrees of loyalty.

EPA has recently obtained some additional brand loyalty data through contract with the NPD Group that serves to support the assumptions of curve #2[27]. These results are shown in Table #1

---

[26] Zero loyalty assumes that customers have no preference at all to the brand of fuel they purchase. Thus in these cases there is a completely random determination of the fuel brand being used with each fill-up of fuel.

[27] NPD Group Inc., "Special Gasoline Analysis, Annual 1992 Data Prepared for: U.S. Environmental Protection Agency". 1993.

Table #1 Brand Loyalty Data, Total U.S. Industry - NPD Group

Brand Grouping	Percent Loyalty
Always use One Brand	37.8%
Use 2 or 3 Brands	51.2%
Use Many Different Brands	11.0%

By assuming that the heading "Always use one brand" indicates an actual consumer loyalty of 90% - 100%, the "Use 2 or 3 brands" indicates a loyalty of 40% - 60%, and the "Use many different brands" corresponds to an actual loyalty of 20% to 40%, then an average consumer loyalty of this data can be compared to that for the other brand loyalty curves.[28] Using these assumptions consumer loyalty for the NPD data is calculated to range from 57% to 73% (ave is 65%). The average brand loyalties for each of the curve of Figure #3 are: 75% for the Arco data, 64.5% for the adjusted Arco data (Curve 2) and 50% for the even distribution (Curve 3). Thus Curve #2 appears to closely match the interpretation of the NPD data, and may be the best representation of consumer brand loyalty available for this model.

There is, however, no one loyalty curve that will fit all geographical areas. One may expect large cities to have a lower overall owner loyalty because of the large number of different brands available in close proximity to one another. Conversely, rural areas should have a higher degree of consumer loyalty, particularly if there is only one or two gasoline stations available and thus only one or two brands.

There are two assumptions made in this model that are concerned with consumer loyalty. The first assumption is that the loyalty curves the model uses are applicable only to a fuel brand and nota particular oxygenate. There was no data available on oxygenate loyalty of which EPA was aware. Another assumption of the model is that it does not allow for individual loyalties for various grades of gasoline. Ethanol tends to be used more in mid and premium grades of gasoline than in the regular grade. At this time EPA can not speculate on what effect, if any, these assumptions may have on the model results. As more information becomes available that sheds light on these two points EPA may consider their applicability to this model.

C. Refueling Patterns

---

[28] The 95% to 100% loyalty indicates that even though consumers may report 100% loyalty only one purchase of a different brand per year is enough to drop that loyalty to about 97% to 99%. Therefore, consumer response to "always use one brand" may not indicate their actual buying patterns. The other loyalties, 45% to 50%, and 25% to 30% represent an assumed distribution among multiple brand purchases. These ranges were purposely made slightly higher than a strict division of 100% by the number of brands involved to account for the likely preferential use of one brand out of the total number of brands purchased. Without any further information on the loyalty to one particular brand, when more than one brand is purchased, it is difficult to establish unequivocally what the actual brand loyalty should be in the multiple brand purchase scenarios.

Two curves can be chosen in the model in order to describe the fuel fill patterns of each customer for each individual fill-up as a percentage of the total tank capacity. The data of Figure #4 indicates the fuel fill level prior to a fill-up. The bars labeled "Case 1 (Actual Data)" are taken from a General Motors refueling survey of over 1100 refueling events[29]. This data shows a relatively uneven distribution in some areas. The bars labeled "Case 2 (Assumed Fit)" are a smoothing of the GM data. This is an attempt to eliminate some of the unevenness in the data that may have been caused by anomalies in the method of reporting the fuel tank fill levels, particularly at the 0.2 gallons in/tank capacity level on the graph. It is also important to note that whatever the fuel fill scenario that is used for any particular run the model will always assume an existing "heel" in the tank of 10 percent of capacity. Thus, any numbers derived from this graph are assuming that the tank capacity does not include the "heel".

Figure #5 describes the possible levels of the tank after fill-up. This particular graph is for the case where the initial amount in the tank before refill was equal to zero (except for the "heel"). There are other fill scenarios based on each possible pre-fill level of the tank (i.e. 0.1, 0.2, etc.). All scenarios are based on the same basic information. In Figure #5 the bars labeled "Case #1 (Actual Data)" are again from the GM refueling survey, while the bars labeled "Case #2 (Assumed Fit)" are a smoothing of portions of this GM data (particularly at the 0.8, 0.9, and 1.0 fill levels).

The reasoning behind this smoothing is that the original GM data had an inordinate amount of data points representing a complete fill-up. EPA believes that the incidences of actual total fill-up are less than this due to the manner in which the data was collected. The general inaccuracy of most gasoline fill level gauges, many of which read full even though the tank is much less than full causes an over estimation of "full" reportings. EPA hopes to obtain more substantive information to either support the present data or provide for a more accurate representation of typical consumer fill up patterns in the future.

D. Vapor Pressure Curves

In order to assess the RVP boost that will be experienced with the mixing of an ethanol fuel with either a non-reformulated or a reformulated[30] gasoline a series of tests were performed to measure the resultant RVP boost at various levels of ethanol/gasoline in the case of non-reformulated gasoline and ethanol/MTBE/gasoline in the case of reformulated gasoline. Tables #2 and #3 show the percentage of concentration of the various constituents in the tests for non-reformulated and reformulated gasoline, respectively. The tests in Table #3 adjusted the ethanol and MTBE concentrations to simulate the mixing that would be experienced in an actual reformulated gasoline scenario. The results of these tests were used to produce the vapor pressure curves for use in the commingling model. Smoothed graphs of the resultant curves are shown in Figure #6.

---

[29] U.S. Environmental Protection Agency, "Draft Regulatory Impact Analysis, Control of Gasoline Volatility and Evaporative Hydrocarbon Emissions from New Motor Vehicles", July, 1987.

[30] In this computer program reformulated gasoline is assumed to be oxygenated with MTBE. All properties of the reformulated gasoline and the non-reformulated gasoline were assumed to be identical except for the difference in RVP boost responses when mixed with another fuel containing ethanol.

The RVP boost represented in Figure #6 is only applicable at the base RVP that these particular tests were performed[31]. In order to determine the RVP boost at different base RVPs a RVP adjustment factor was determined. This factor is applied to the RVP boost in order to arrive at the final adjusted RVP boost of the mixture.

The RVP adjustment factor was determined based on experiments performed at General Motors in which ethanol was added to gasolines of varying RVP[32]. It was determined upon examination of the trends in this data that the RVP boost changed roughly 0.05 psi for every 1.0 RVP increase or decrease in the base RVP. The resultant straight line curve that was used in the commingling model is shown in Figure #7.

Although, in actuality this 0.05 psi RVP adjustment factor is at best an estimate based on available information, its influence is actually quite small for the ranges of RVP that are generally being considered (RVP 7.0 - 9.0). Table #4 provides some of the numerical data provided by GM upon which this 0.05 psi RVP adjustment was based.

Table #2 - Non-reformulated Gasoline Testing Chart

Run Number	Percent of 10% Ethanol Blend in Total Mixture	Percent of Base Gasoline in Total Mixture	Total Percent of Ethanol* in Mixture
1A	0.0	100.0	0.0
2A	2.5	97.5	0.25
3A	5.0	95.0	0.5
4A	7.5	92.5	0.75
5A	10.0	90.0	1.0
6A	15.0	85.0	1.5
7A	20.0	80.0	2.0
8A	25.0	75.0	2.5
9A	30.0	70.0	3.0
10A	40.0	60.0	4.0
11A	50.0	50.0	5.0
12A	60.0	40.0	6.0
13A	80.0	20.0	8.0
14A	100.0	0.0	10.0

* Denatured without methanol

---

[31] These particular tests were done using a base RVP of 8.4. It has been found that as the base RVPs become greater there is a decrease in the RVP boost for the same percentage of added ethanol and conversely at increasingly lower RVPs there is an increase in the RVP boost greater than that observed in Figure #6.

[32] General Motors Corp., Letter to U.S. Environmental Protection Agency, May 21, 1993.

Table #3 - Reformulated Gasoline Testing Chart

Run Number	Percent of 10% Ethanol Blend in Total Mixture	Percent of 11% MTBE Blend in Total Mixture	Total Percent of Ethanol* in Mixture	Total Percent of MTBE in Mixture
1B	0.0	100.0	0.0	11.0
2B	2.5	97.5	0.25	10.725
3B	5.0	95.0	0.5	10.45
4B	7.5	92.5	0.75	10.175
5B	10.0	90.0	1.0	9.9
6B	15.0	85.0	1.5	9.35
7B	20.0	80.0	2.0	8.8
8B	25.0	75.0	2.5	8.25
9B	30.0	70.0	3.0	7.7
10B	40.0	60.0	4.0	6.6
11B	50.0	50.0	5.0	5.5
12B	60.0	40.0	6.0	4.4
13B	80.0	20.0	8.0	2.2
14B	100.0	0.0	10.0	0.0

* Denatured without methanol

TABLE #4 GENERAL MOTORS RVP TEST DATA

	BASE RVP	ΔRVP
STUDY 1	9.4	1.1
	12.7	0.9
STUDY 2	7.0	1.1
	9.0	1.0
	14.0	0.7

III. RESULTS AND CONCLUSIONS

Figures #8 and #9 show the results of the commingling model for a base RVP of 8 psi. Figure #8 shows the RVP boost due to the commingling effect that can be expected across all the gasoline in the fleet based on ethanol market shares of 10%, 30%, or 50%. For each market share a number of runs were performed to incorporate results from the various loyalty and fill curves that are available. Figure #9 provides what is called the "Effective Commingling Boost", which is defined as the fleetwide RVP boost due to commingling divided by the fraction of the fuel represented by the ethanol blend.

The results for an individual ethanol market share appear to be most dependent upon the type of loyalty curve chosen. For each ethanol market share the lowest commingling effect is calculated using the Arco brand loyalty data which is considered to be the high end of the loyalty curves used. The highest commingling effect is found when no brand loyalty is assumed. The other two brand loyalty curves provide similar results that are in the middle of these two extremes. It is believed that the these curves successful bracket the "actual" loyalty curve and thus these results should bracket the "actual" commingling effect[33].

The results appear to be fairly insensitive to the type of fill curve used. In some instances there is little or no difference in the commingling effect between the use of the actual General Motors fuel refill data or the smoothed version of that data. Thus this variable appears to be not as critical a factor as does the owner loyalty to a fuel brand.

The results do show, however, that commingling can be a significant effect. The effect appears to be greater as the ethanol market share becomes large (Figure #8), however, the increase in the commingling effect appears to level off at a maximum as the ethanol market share becomes 30% or greater. The effective commingling boost per gallon of ethanol blend, however, is the greatest at low gasohol market shares.

One of the most dramatic points in these results is the fact that the non-reformulated gasoline scenario results in a much greater commingling boost than that of the reformulated gasoline case). This is due to the fact that the presence of MTBE mitigates the RVP boost somewhat at low concentrations of ethanol as is evident from Figure #6.

---

[33] The term "actual" in this case does not imply that there is one loyalty curve that is applicable. As was discussed earlier the loyalty curve should vary from one geographical area to the next depending on availability of gasoline stations and other variables.

Insert page of graphs here

Insert page of graphs here

Insert page of graphs here

II. Simple Model

A. Simple Model Equations and Referenced Work

1. Baseline Determination

The Act requires EPA to promulgate standards for the performance of reformulated gasoline that are relative to emission levels from baseline vehicles using baseline fuel. In order to determine whether fuels are meeting the performance requirements of reformulated gasoline under the simple model, EPA must, therefore, establish the baseline to which fuels are to be compared. The following discussion describes how EPA derived the emission baselines.

a. Control Periods

Before the emission baselines can be determined, the time frame to which a fuel's performance will be compared must first be identified. Section 211(k) of the Act requires control of VOC emissions during the "high ozone season." For the purposes of this rulemaking, the high ozone season is defined to be June 1 through September 15. This period covers the vast majority of days during which the national ambient air quality standard for ozone is exceeded nationwide and is consistent with the period covered by EPA's gasoline volatility control requirements. Fuel will be required to meet the VOC control requirements at the retail outlet from June 1 through September 15 and at the refinery from May 1 through September 15. Additional VOC controlled fuel is likely to be produced by the refiner prior to May 1 to ensure compliance on that date.

b. Baseline Gasoline

The Act specified the baseline fuel to be used in determining compliance with the reformulated gasoline performance requirements during the summer months (high ozone season). That specification is shown below. The Act did not specify the requirements for the winter baseline (non-high ozone season) gasoline, but requires that EPA establish the winter baseline specifications to reflect gasoline qualities in 1990. The July 9, 1991 **(1)** proposal contained a description of the data and methodology EPA used in determining the winter baseline fuel. That methodology was revised somewhat by the April 16, 1992 **(2)** proposal. The final winter baseline fuel specification is shown below, consistent with the non-high ozone period described above. Beyond the requirements of the Act, and in keeping with EPA's July 9, 1991 and April 16, 1992 proposals for reformulated gasoline, the summer baseline fuel is also assumed to be free of oxygen and lead, and contain deposit control additives sufficient to meet the requirements of Section 211(l) of the Act.

Table II-1: Baseline Fuel Compositions

	Summer	Winter
Sulfur, ppm	339	338
Benzene, volume percent	1.53	1.64
RVP, psi	8.7	11.5
Octane, R+M/2	87.3	88.2
T10, degrees F	128	112
T50, degrees F	218	200
T90, degrees F	330	333
Aromatics, volume percent	32.0	26.4
Olefins, volume percent	9.2	11.9
Saturates, volume percent	58.8	61.7

c. Baseline Vehicles

Under Section 211(k) of the Act, reformulated gasoline must result in reduced emissions relative to emissions from baseline or representative model year 1990 vehicles when using baseline gasoline. For the purposes of this rulemaking, EPA has based its emission modeling on vehicles having technology representative of that used in 1990. As a result, 1990 technology vehicles could be as early as 1986 model year vehicles, or as late as current model year vehicles. The data used to develop the simple model relationships being promulgated today are based on this. For more information regarding 1990 baseline vehicles, the reader is referred to the Docket.[34]

2. In-Use Basis

a. MOBILE4.1 and Enhanced I/M

The goal of EPA in developing the procedures for certifying fuel as meeting the reformulated gasoline requirements is to assure that a certified fuel will achieve the required emission reductions in-use. This goal necessitates the use of a fuel effects model which predicts in-use emissions. For the simple model, EPA proposed to use the MOBILE4.1 emissions model to determine the baseline emission levels for 1990 technology vehicles over their full useful life. Since the existence of an enhanced inspection and maintenance (I/M) program will significantly effect the in-use emission performance of 1990

---

[34] Memorandum from Dave Korotney to Air Docket A-92-12 entitled "1990 Baseline Vehicles", November 30, 1993.

technology vehicles during the period when the reformulated gasoline program is in place, EPA also proposed to assume an enhanced I/M program was in place before determining baseline emissions. As discussed at length in the February 26, 1993 proposal, a more recent MOBILE model now exists, and EPA has now promulgated the requirements for enhanced I/M programs. The latest MOBILE model and actual I/M program requirements differ significantly from those assumed for the proposal. However, given the impact of changes to these assumptions on the relative benefits of exhaust and evaporative controls and the short lead time available for refiners to respond to any such changes, the simple model as promulgated here remains based upon the July 29, 1991 version of MOBILE4.1 and an enhanced I/M scenario consisting of a gas cap check and a 2500 rpm idle test. EPA believes this is appropriate for the same reasons relied on to delay mandatory use of the complex model until January 1, 1998.

b. Temperature Conditions

MOBILE4.1 was developed to predict motor vehicle emissions on an area-specific basis. In order to use MOBILE4.1, it is necessary to specify a temperature range for the areas in which motor vehicle emissions are being evaluated. For purposes of reformulated gasoline, emissions are modelled during the summer assuming temperatures ranging from 71.6 to 91.6 degrees Fahrenheit in VOC control region 2 (northern areas) and ranging from 69.4 to 94.0 degrees F in VOC control region 1 (southern areas). These temperatures represent the population-weighted average of minimum and maximum temperatures measured in each of 25 serious and worse ozone nonattainment areas during their ten worst ozone days in each of the months of July and August for the years 1986 to 1989 (in ten of the cities) and 1985 to 1987 (in the other fifteen cities).[35] **(3)**

Refueling emissions were derived assuming an ambient temperature of 90°F for both VOC control regions 1 and 2. Distinguishing between the different areas did not appear justified given the similarity of Class B and Class C area temperatures, the relatively low magnitude of refueling emissions, and the wide range of times and temperatures at which refueling occurs during a day. 90°F was considered to represent a severe case in order to account for average in-use refueling emissions on high ozone days.

For determination of winter baseline emissions, an average low temperature and an average high temperature of 39°F and 57°F, respectively, are assumed. These temperatures were estimated

---

[35] Memorandum II-A-2 from Jeffrey A. Herzog and Stephen Mayotte to Public Docket No. A-91-02.

from the historical 30-year average low and high temperatures for the months of October through April for the 25 serious and worse ozone nonattainment areas.[36] **(3)**

c. Effects of Stage II Refueling Controls

The assumptions used in establishing the baseline emissions should be representative of the conditions that will be encountered during the time when the reformulated gasoline provisions are in effect. For this reason, baseline emissions are assumed to include the benefits of a Stage II refueling vapor recovery program. By 1995, all serious, severe, and extreme ozone nonattainment areas are required to have implemented Stage II refueling control programs. The efficiency assumed for Stage II controls in determining the emission baseline is 86 percent. EPA's regulatory impact analysis supporting refueling emission regulations estimated the efficiency of Stage II equipment to be 86 percent in areas such as California where the program is very strictly enforced. Because of the severity of ozone pollution in areas that will be covered by the reformulated gasoline program and because strong measures will be required to bring these areas into attainment, it is assumed that Stage II programs in these covered areas will be strictly enforced. For these same reasons EPA is not revising its proposed efficiency assumption for Stage II programs as suggested by some commenters.

3. Emission Effects

a. Definition of VOC

The Act requires reductions in emissions of ozone-forming VOCs. This interpretation is consistent with the focus of Section 211(k) on the areas with the most extreme ozone pollution problem. EPA proposed in the April 16, 1992 SNPRM that methane would be excluded from the definition of VOC on the basis of its low reactivity in keeping with past EPA actions, but included all other VOCs including ethane. EPA further proposed, however, that should the Agency modify the definition of VOC, we might do so for the reformulated gasoline rulemaking as well. As discussed in the February 26, 1993 proposal, EPA has also excluded ethane from the definition of VOC (57 FR 3941). As a result, the performance of fuels meeting the VOC emission requirements under the simple model, as expressed above, are determined on a non-methane, non-ethane basis. This change resulted in slight changes to the simple model equations previously proposed, but the overall results of the simple model are essentially unaffected. The ethane emissions were subtracted from the SNPRM estimates of the VOC emissions. From the Auto\Oil Air Quality

---

[36] Ibid.

Improvement Research Program (AQIRP), ethane emissions were determined to be 3.5 percent of the nonmethane hydrocarbon emissions. Ethane emissions were assumed to be unaffected by fuel changes.

b. VOC Emission Effects

At the time of the proposed rule the impact on VOC and NOx emissions of adding oxygenates to gasoline was calculated using the EPA emission factor database. This database included both normal and high emitting vehicles which are represented in the in-use fleet. The understanding at the time was summarized in an EPA memorandum. **(4)** The oxygenated fuels used in that analysis were lower in aromatics level as is expected with the use of the simple model.

The nonexhaust VOC emission effects were determined using an early version of the MOBILE4.1. The only parameter that had an effect on emissions was assumed to be the Reid Vapor Pressure (RVP). The MOBILE4.1 model was run for several RVP levels and regressed to produced the equation given in the regulations for VOC emissions.

c. Exhaust Benzene Baseline Emissions and Effects

The exhaust benzene emissions can be affected in two ways. Reduction of exhaust VOC emissions through improved combustion or catalyst efficiency should result in reduction of benzene emissions. Also, the benzene fraction of VOC emissions may be reduced either by reduction of fuel benzene or precursors (primarily nonbenzene aromatics) of exhaust benzene. This method is used for the aldehyde emissions as well.

The benzene fraction of exhaust VOC emissions was determined from a correlation developed by Chevron using fuel benzene and aromatics content as parameters. **(5)** The Chevron analysis used a compilation of all of the studies available at the time of the proposal.

Since exhaust VOC emissions are reduced with added oxygenate, benzene emissions are assumed to be reduced proportionally.

Low temperature testing indicated that the benzene and 1,3-butadiene emissions fraction were found to be insensitive to temperature. **(6,7)** Therefore, the winter baseline emissions should be expected to increase as the exhaust VOC emissions increase.

d. Nonexhaust Benzene Emissions

Benzene is the only toxic air pollutant that is emitted in measurable quantities from refueling, evaporative, running loss vapors. Reduction in fuel benzene can be expected to result in proportional reductions in benzene emissions from all of these nonexhaust emissions sources.

The nonexhaust benzene emissions were determined by applying the GM headspace benzene fraction estimate to the mass emissions estimated from the MOBILE model.**(8)** The MOBILE model was used to predict the RVP effect on VOC emissions down to as low as 6.6 psi. Due to differences in the temperature conditions, slight differences in nonexhaust VOC emissions occur between VOC control region 1 and 2. The GM headspace model showed an effect of both RVP and MTBE content on the fraction of VOC emissions that were benzene.

Evaporative benzene emissions include hot soak (evaporative emissions immediately following the shutting off the engine) and diurnal emissions (evaporative emissions from a sitting vehicle as the daily ambient temperature rises). Hot soak emissions occur at higher temperatures than diurnal emissions and the relative volatility of benzene is slightly higher at those temperatures. Running loss emissions occur at roughly the same fuel temperatures as hot-soak emissions and have similar benzene fractions.

Based on the emission factors contained in MOBILE4.1, evaporative and running loss benzene emissions tend to be dominated by emissions from vehicles with inoperative emission control systems (those vehicles likely to "fail" EPA's purge and pressure tests). The benzene fraction of evaporative and running loss emissions from vehicles with properly operating systems (those vehicles likely to "pass" EPA's purge and pressure tests) and from "fail" vehicles, however, are comparable. Hence the benzene weight fraction of evaporative and running loss VOC emissions for a fuel is assumed in the simple model to be described by the relationship originally derived for "fail" vehicles.

One comment suggested that it was not appropriate to use estimates not publicly available, like the GM model for estimating emission impacts. While the GM model itself is not available, the emission estimates from the model are available. Furthermore, the underlying basis of the model has been published by Reddy **(9)**, and a separate program developed by EPA using Reddy's paper as the basis confirmed the estimates from the GM model. Another comment suggested that the headspace model underestimated the benzene emissions with MTBE present. It was explained that the higher average molecular weight of the headspace vapor partially offsets the benzene fraction reduction. If the vapor has a higher molecular weight, it could be concluded that the VOC emissions would be greater. However insufficient data existed to quantify the effect of MTBE on evaporative emissions at constant RVP. EPA believes it is not appropriate to alter the benzene fraction estimate, since there is no quantitative estimate for the mass emission increases claimed by the commenter.

Under winter condition, EPA is assuming that nonexhaust benzene (and all nonexhaust VOC) emissions will be negligible relative to exhaust toxic emissions. A comment suggested that the MOBILE model will predict emissions for wintertime conditions at the higher RVP levels used, and therefore should be included in the toxic model. While the RVP of the fuel is much greater during the winter, the temperatures are much lower. EPA's MOBILE model is based upon data collected above the temperatures experienced in the winter and generally with RVP levels below those of winter fuels. Projecting evaporative emissions in the winter is outside of the capability of the MOBILE model. Biven the lack of adequate data to model nonexhaust VOC and benzene emissions in the winter, EPA is not changing from its proposed baseline and toxics model in this regard.

e. Aldehyde Baseline Emissions and Effects

The baseline emissions for the aldehyde emissions, formaldehyde and acetaldehyde, were determined from the AQIRP results. The baseline emission estimates are slightly different than the SNPRM values to account for the change in the definition of VOC emissions from the SNPRM which excluded ethane. While a comment expressed a concern that AQIRP results should not be used exclusively, only aldehyde emissions effects were determined using the AQIRP data and those exclusively because no other data existed at the time.

The results from AQIRP were used to determine the effects on the formaldehyde and acetaldehyde fraction of exhaust VOC from the addition of oxygenates. Explicit effects were calculated for MTBE, ethanol, and ETBE.

The AQIRP data as released, however, were modified slightly to exclude the acetaldehyde and formaldehyde results for ETBE and ethanol from one of the vehicles (car #5A) due to emission results which were confirmed as being in error. Furthermore, the effect of ETBE on the weight percent of acetaldehyde was based on the test results for ethanol due to the lack of adequate fuel comparability for ETBE-containing fuels. However, for this case, the ethanol results were adjusted based on a comparison of the ETBE and ethanol results on similar fuels for which data was available.

Responding to several comments, the EPA has included aldehyde equations for the use of other oxygenates in the simple model. Methyl tertiary-amyl ether (TAME) and any other methyl ethers are assumed to have equivalent aldehyde emission performance to MTBE. Ethyl tertiary-amyl ether (ETAE) and any other ethyl ethers are assumed to have equivalent aldehyde emission performance to ETBE. Alcohols (with the exception of methanol) are assumed to have equivalent aldehyde emission performance to ethanol. These assumptions were based on the chemical similarity of the oxygenates. Aldehyde equations for mixed oxygenates were also provided.

f. Butadiene Emissions and Effects

At the time of the proposal there was little information on the effect of fuel reformulation on butadiene emissions. A reduction in exhaust VOC emissions was assumed to result in a proportional reduction in butadiene emissions. The baseline emissions were determined from an analysis of the AQIRP.

For wintertime modeling, the baseline emissions were assumed to be the same percentage of the VOC emissions as the summertime emissions. See the benzene discussion above for the rationale.

g. POM Emissions and Effects

There was no data to determine the effect on POM emissions from the use of reformulated gasolines. An assumption was made that the reduction of POM emissions would be the same as the reduction of VOC emissions.

The baseline emissions of POM were determined from work of Schuetzle **(10)**. Table 8 in that paper shows that 18 mg/km of particulate were produced from gasoline vehicles (half of the vehicles were equipped with catalysts, the HC emissions were not reported). Approximately 8.5 mg/km of the particulate was extractable in three separate extracts, (1% ether in hexane (nonpolar fraction), 1/1 ether/hexane (moderately polar), and methanol (polar fraction). Selected standard PAH compounds were recovered at greater than 80%.

The paper indicated the approximate percentage of PAH which is interpreted as synonymous with POM in each fraction for diesel exhaust. The extract from gasoline exhaust was found to be more mutagenic on a gram basis than diesel extract therefore we may be underestimating the POM emissions by applying the same percentage of POM in diesel particulate extract to that for gasoline particulates.

Gas phase POM were assumed zero because the mutagenicity was low. The polar fraction was assumed zero because activity was low and no data was presented. Both of these assumptions lead to a lower estimate of the POM emissions than might have been.

The sum of the nonpolar and moderately polar extract fraction multiplied by the POM fraction in each extract provides an estimate of the fraction of POM in the particulate phase. This estimate multiplied by the amount of particulate extract for gasoline engines provides the 1.4 mg/mi baseline emission estimate of POM.

One comment cited two references which estimated lower POM emissions. Schuermann, et al. (1990) **(11)** reported that 0.2 mg/mi and 0.01 mg/mi of PAH were emitted from cars without and with a catalyst respectively. Only 11 PAH compounds were identified and quantified. Whether these compound were collected from the gas phase or the particulate phase was not discussed in the paper and a more extensive literature review is necessary. The HC emissions were not reported. Westerholm, et al. (1988) **(12)** reported that gas phase PAH emissions from a car without a catalyst were 0.4 mg/mi, and particulate associated PAH was 0.07 mg/mi. The HC emissions were 2.4 g/mi, and the particulate collected was 7.3 mg/mi. The particulate was extracted with dichloromethane (methylene chloride) and no recovery of selected PAH compounds were reported. This raises questions regarding the choice of solvent especially given the low value of recovered PAH from the amount of particulate.

B. Technical Corrections

Several errors were found in the proposed simple model. Baseline values were found to be in error for POM emissions and Region 1 total VOC and toxic emissions. The baseline emissions for the final simple model are given below. Any slight difference between the final baseline levels and those in the proposal are due to the round-off differences when ethane was excluded from the VOC emissions.

Table II-2: Simple Model Baseline Emissions

	Summer		Winter
	Class B	Class C	
Exhaust VOCs (g/mi)	0.444	0.444	0.656
Hot Soak/Diurnal (g/mi)	0.390	0.339	
Running Loss (g/mi)	0.431	0.390	
Refueling (g/mi)	0.040	0.040	
Total VOCs (g/mi)	1.304	1.213	0.656
Exhaust Benzene (mg/mi)	30.1	30.1	40.9
Evaporative Benzene	4.3	3.8	0.0
Running Loss Benzene	4.9	4.5	0.0
Refueling Benzene	0.4	0.4	0.0
1,3-Butadiene	2.5	2.5	3.6
Formaldehyde	5.6	5.6	5.6
Acetaldehyde	4.0	4.0	4.0
POMs	1.4	1.4	1.4
Total TAPs (mg/mi)	53.2	52.1	55.5

C. Caps on Fuel Parameters

The caps on three parameters (sulfur, T90, and olefins) were chosen based on the information at the time indicating that increasing these parameters increased either VOC or NOx emissions. Subsequent comments felt that aromatics and T50 should be capped in addition to the three proposed. Other comments felt that no properties be capped. In addition, some comments felt that the driveability index (a combination of T10, T50, and T90 with the most emphasis on T50 and T90) should be included in the simple model or at least capped.

The basis for the caps was information from the AQIRP technical bulletins **(13, 14)** which showed that T90 had a significant impact on VOC emissions, olefins on NOx emissions, and sulfur on both. Since allowing these parameters to increase over the baseline value was certain to have a detrimental effect emissions, it was necessary to cap them. Since that time additional data and information has been developed for use in the Complex Model. This data confirms that sulfur, T90 (E300) and olefins should be capped either for the purposes of preventing increases in VOC or NOx.

Aromatics and T50 (E200) have also been found to have a significant effect on emissions. As a result, they may also be deserving of caps. However, in the case of aromatics, a separate cap is less important since its level is limited by the toxics requirements in the model. In addition, for both aromatics and T50, applying caps at this point in time would not be appropriate due to the need to provide refiners with adequate leadtime. Similarly, regardless of the relative merits of using the driveability index as a surrogate for or supplement to T10, T50, and T90, it would not be appropriate in the context of leadtime constraints to place a cap on the driveability index of the fuel.

D. Averaging and Trading

Since the air toxics standard is a year-round standard, as long as unequal percent reductions are achieved in the summer and the winter, the overall stringency of the standard is dependent on the relative duration of the two periods. In the proposals, the time period over which refiners could count fuel as being controlled for air toxics relative to the summer baseline was sometimes internally inconsistent, and inconsistent between proposals for various reasons. As a result, EPA received a number of comments on what the appropriate period should be. Based upon the comments, the averaging period for the toxic emissions performance standard will be the same as for the VOC-controlled season. This should avoid confusion and reduce reporting time.

Since the simple model does not include a NOx model, it would not be possible to average NOx emissions as suggested by one commentor.

References

(1) NPRM, 56 FR 31176, July 9, 1991.

(2) SNPRM, 57 FR 13416, April, 16, 1992.

(3) Memorandum II-A-2 from Jeffrey A. Herzog and Stephen Mayotte to Public Docket No. A-91-02.

(4) Lindhjem, C.E., 'Effect of Oxygenates on Emissions', EPA Memorandum to Richard Rykowski, January, 7, 1992.

(5) Chevron Analysis

(6) Stump, F., Tejada, S., Ray W., Dropkin, D., Black, F., Snow, R., Crews, W., Siudak, P., Davis, C.O., and Baker, L., 'The Influence of Ambient Temperature on Tailpipe Emissions from 1984 to 1987 Model Year Light-Duty Gasoline Motor Vehicles-II', Atmospheric Environment, v. 23, 1989, pp. 307-320.

(7) Stump, F., Tejada, S., Ray W., Dropkin, D., Black, F., Snow, R., Crews, W., Siudak, P., Davis, C.O., and Carter, P., 'The Influence of Ambient Temperature on Tailpipe Emissions from 1985 to 1987 Model Year Light-Duty Gasoline Motor Vehicles-II', Atmospheric Environment, v. 24A, 1990, pp. 2105-2112.

(8) Reddy, S.R., Personal Communication to C.E. Lindhjem and P. Bush, April 16, 1991.

(9) Reddy, S.R., 'Evaporative Emissions from Gasolines and Alcohol-Containing Gasolines with Closely Matched Volatilities', SAE-861556.

(10) Schuetzle, D., (1983), 'Sampling of Vehicle Emissions for Chemical Analysis Biological Testing', Environmental Health Perspectives, v. 47, pp 65-80.

(11) Schuermann, D., et al., (1990), SAE-902116.

(12) Westerholm, R.N., et al., (1988), Environmental Science and Technology, 22, pp 925-930.

(13) Auto\Oil Air Quality Improvement Research Program, Technical Bulletin No. 1, 'Initial Mass Exhaust Emissions Results from Reformulated Gasolines', December, 1990.

(14) Auto\Oil Air Quality Improvement Research Program, Technical Bulletin No. 2, 'Effects of Fuel Sulfur Levels on Mass Exhaust Emissions', February, 1991.

III. Complex Model Baselines

Section 211(k) of the Clean Air Act (CAA or the Act) requires that gasoline sold in the worst ozone nonattainment areas of the United States be reformulated to result in reduced emissions of VOC and toxic compounds. The Act also states that the emissions from gasoline in other areas of the United States cannot simultaneously increase above 1990 levels. Refiners must certify their gasolines for sale by showing, through testing and/or the Complex Model, that their fuel meets the requirements of either the reformulated gasoline or anti-dumping programs. In either case, the vehicle emissions must be evaluated relative to the emissions from a specified baseline gasoline (outlined in Section 211(k) of the Act) in a specified baseline vehicle (defined by Section 211(k) as a representative 1990 model year vehicle). Thus the Act implicitly directs EPA to establish and promulgate the baseline emissions against which all emission measurements will be evaluated.

The baselines discussed in this section do not apply to the cost-effectiveness calculations presented in Sections V and VI. Cost-effectiveness is based on in-use emission estimates, and therefore the baseline fuels and baseline emissions cannot be limited to 1990 baseline fuels and 1990 model year vehicles (i.e. the conditions under which the Complex Model was developed). Alternative baselines will be derived and presented in that section.

Baseline emissions are produced from baseline fuels as specified in the Act. Accordingly, this section is composed of two subsections, one for baseline fuels and a second for baseline emissions. This section is directed towards use of the Complex Model. The baselines applied to the Simple Model are covered in more detail in Section II, and baselines applied to the anti-dumping program are discussed in Section VII.

A. Baseline Fuels

The Clean Air Act directs the EPA to use a different baseline fuel during different seasons. The Act provides the EPA with a specific baseline fuel for the high ozone (i.e. summer) season, which EPA has defined as the period from June 1 to September 15. Although the Act refers to this baseline fuel as summer baseline gasoline, its importance in the reformulated gasoline program has resulted in its being commonly referred to as Clean Air Act Baseline Gasoline, or CAAB. The Act does not specify a baseline fuel for the non-high ozone (i.e. winter) season, but instead directs the EPA to establish the parameters of such a baseline fuel itself. Both of these baseline fuels will be discussed below.

1. Summer

Most of the summer baseline fuel parameters are specified explicitly by the Act. The level of oxygen, however, was left to the EPA to determine. As discussed in the July 1991 NPRM [56 FR 31176], the low volume of oxygenated fuels sold in ozone nonattainment areas in 1990 led the Agency to conclude that the oxygen content of the summer baseline fuel should be zero. The final summer baseline fuel specifications are given in Table III-1.

Table III-1: Summer Baseline Fuel

Fuel parameter, units	Value
Oxygen, wt%	0.0
Sulfur, ppm	339
RVP, psi	8.7
T50, °F	218
T90, °F	330
Aromatics, vol%	32.0
Olefins, vol%	9.2
Benzene, vol%	1.53

In addition to the fuel parameters shown Table III-1, the Act also specifies values for a number of other summer baseline fuel parameters that are not included in the Simple or Complex Models:

API gravity	57.4
Octane, R+M/2	87.3
IBP, °F	91
T10, °F	128
End point, °F	415
Saturates, vol%	58.8

The distillation parameters shown in Table III-1 are given in terms of T values, or the temperature at which a given percentage of fuel has evaporated. Distillation characteristics of baseline fuel (or any fuel) can alternatively be described with E values which represent the volume percent of fuel that has evaporated at a given temperature. Since the Complex Model uses E values instead of T values as distillation parameters, the Agency developed a pair of conversion equations. Described in more detail in Section IV.A.2 below, these equations are derived from a simple regression on data from the Complex Model database.

$$E200(\%) = 147.91 - 0.49 \times T50(^{\circ}F)$$
$$E300(\%) = 155.47 - 0.22 \times T90(^{\circ}F)$$

where E200 and E300 are the % evaporated at 200 and 300 °F, respectively, and T50 and T90 are the temperatures at which 50 and

90 percent of the fuel has been evaporated, respectively. Thus the summer baseline fuel distillation parameters used by the Complex Model are:

$$E200(\%) = 147.91 - 0.49 \times 218 = 41\ \%$$
$$E300(\%) = 155.47 - 0.22 \times 330 = 83\ \%$$

2. Winter

The winter baseline fuel was not defined explicitly by the Act. Instead, the Agency was directed to establish specifications for winter baseline fuel. As described in the July 1991 NPRM [56 FR 31176] and revised in the April 1992 SNPRM [57 FR 13416], the Agency based its winter baseline fuel specifications on an analysis of fuel surveys performed by the American Automobile Manufacturers Association and by Southwest Research Institute. The collection of winter season values for each fuel parameter was weighted according to sales data, state fuel consumption data, and population data to obtain the final, nationwide winter baseline fuel. Thus the methodology and results of this analysis remain unchanged from the proposals. The winter baseline fuel specifications are given in Table III-2.

Table III-2: Winter Baseline Fuel

Fuel parameter, units	Value
Oxygen, wt%	0.0
Sulfur, ppm	338
RVP, psi	11.5
T50, °F	200
T90, °F	333
Aromatics, vol%	26.4
Olefins, vol%	11.9
Benzene, vol%	1.64

As for summer baseline gasoline, the distillation parameters shown in Table III-2 are given in terms of T values instead of E values. The conversion equations described above can be used to estimate E values for winter baseline gasoline as well as for summer baseline gasoline:

$$E200(\%) = 147.91 - 0.49 \times 200 = 50\ \%$$
$$E300(\%) = 155.47 - 0.22 \times 333 = 83\ \%$$

3. Response to Comments

A number of commenters took issue with the Agency's decision to define baseline fuel values for E200 and E300 through equations that provide these values from T50 and T90 measurements. These conversion equations were based on single parameter regressions of all the data in the Complex Model database. The commenters suggested that the summer baseline fuel values for E200 and E300 should be based instead on the measured values for these fuel parameters on summer baseline gasoline in the Complex Model database. The average values as provided by the American Petroleum Institute are 41.9% for E200 and 82.1% for E300. The Agency recognizes the merit in this approach. However, the Agency has determined that the use of the conversion equations for the baseline fuel is preferable because this approach is consistent with the use of the same conversion equations for other fuels. "Other fuels" include the winter baseline gasoline (which is not represented in the Complex Model database), fuels that are used in the process of specifying performance standards, and fuels that are candidates for certification with the Complex Model. In addition, while the "summer baseline" gasolines in the Complex Model database were blended so as to match the baseline fuel specifications laid out in the Act, the inevitable variability introduced in the blending and measurement processes (as discussed in Section IV.G) caused the actual composition and properties of "summer baseline" gasolines in the Complex Model database to vary from the Act's specifications.

Commenters also suggested that the conversion equations be based not on all the data in the Complex Model database, but instead on the hydrocarbon-only fuels. The Agency determined that:

1) It was not appropriate to have a different set of conversion equations for hydrocarbon-only fuels and oxygenated fuels; and

2) It was not appropriate to apply conversion equations based on hydrocarbon-only fuels to reformulated gasolines, all of which will be oxygenated.

Thus the Agency has concluded that its conversion equations, based on all the data in the Complex Model database, provide the most reliable means of estimating E200 and E300 values for the hydrocarbon-only baseline gasolines, oxygenated reformulated gasolines, and both oxygenated and hydrocarbon-only conventional gasolines.

The Agency received many comments objecting to the use of a 7.8 psi RVP baseline fuel for summer Class B areas. The Agency agrees with the commenters that the Act makes no provisions for a summer baseline fuel with an RVP of 7.8 psi and that such a fuel is not an appropriate baseline for determining performance standards. Therefore, the Agency has calculated all performance standards relative to CAA baseline fuel with an RVP of 8.7. However, the Agency retains its position that a fuel identical to Clean Air Act baseline gasoline but with an RVP of 7.8 psi provides the most accurate measure of in-use emission reductions in Class B areas. In such areas, EPA's volatility control requirements have capped RVP levels at 7.8 psi. Thus a gasoline with an RVP of 7.8 psi that is otherwise identical to CAA baseline gasoline has been used for the Class B cost-effectiveness calculations presented in Sections V.B and VI.F.

B. Baseline Emissions

While baseline fuels are categorized only by season, baseline emissions are categorized by season, area class, and program phase. They can be subdivided into exhaust and non-exhaust emissions and by pollutant. Thus in the discussions that follow, baseline emission derivations and presentations will be given within the context of these category definitions.

Baseline emissions are based upon a number of derivation approaches and sources. The derivation approaches are specific to the subcategories described above. Of the sources, the MOBILE emissions model is the most important, and therefore will be discussed first in Section B.1. The following two sections outline the scenarios under which the MOBILE model was run. The weighting factors used to calculate toxic emissions will then be discussed and presented in Section B.4. The last two subsections of Section B will present the baseline emissions for summer and winter, respectively.

1. MOBILE Emissions Model

The Agency's MOBILE emission factor model is an integrated set of FORTRAN routines for use in the analysis of the air pollution impact of gasoline and diesel fueled highway mobile sources. MOBILE calculates emissions in terms of grams per mile for both gasoline and diesel-fueled light-duty vehicles (LDVs), light-duty trucks (LDTs), and heavy-duty vehicles (HDVs), and for gasoline-fueled motorcycles. These emissions, or emission factors, can be calculated in any one of five forms: total hydrocarbons (THC), nonmethane hydrocarbons (NMHC), volatile organic compounds (VOC), total organic gases (TOG), or nonmethane organic gases (NMOG). These categories are defined in Table III-3. The effects of various inspection and maintenance programs can also be modeled.

Table III-3: MOBILE Emission Factor Definitions

Emission Factor Option	Compounds included in the emission factor:			
	FID Hydrocarbons	Methane	Ethane	Aldehydes
THC	Yes	Yes	Yes	No
NMHC	Yes	No	Yes	No
VOC	Yes	No	No	Yes
TOG	Yes	Yes	Yes	Yes
NMOG	Yes	No	Yes	Yes

When quantifying emissions from a fleet of vehicles, it is important to realize that emissions will vary over a vehicle's lifetime, generally increasing with age due to factors including normal mechanical aging and possible malmaintenance or tampering. To ensure that the standards set for reformulated gasoline achieve the intended environmental benefits, the Agency assesses emissions on an "in-use" basis, such that emissions from 1990 model year vehicles are the estimated average emissions from those vehicles over their lifetimes.

MOBILE assumes that a 25-model-year "window" of vehicles comprises the in-use fleet in any given calendar year. Any vehicles over 25 years of age are grouped with and modeled as the 25-year-old vehicles. For example, if the calendar year of evaluation were 1990, then MOBILE would assume that the in-use fleet would consist of vehicles ranging in age from one (model year 1990) to 25 (model year 1966 and older).

EPA's MOBILE emissions model is designed to predict motor vehicle emissions on an area-specific basis. In order to use the MOBILE model, it is necessary to specify a temperature range for that area in which motor vehicle emissions are being evaluated. The area distinctions assumed by EPA are roughly consistent with the ASTM area classifications A, B, C, D, and E. For this analysis, a diurnal temperature range of 72 to 92 degrees Fahrenheit was used for Class C areas, and a range of 69 to 94 degrees Fahrenheit was used for Class B areas. These temperatures represent the average minimum and maximum summer temperatures for high ozone days in these areas. For determination of winter baseline emissions in the non-high ozone period, an average low temperature and an average high temperature of 39°F and 57°F, respectively, were assumed for both B and C areas.[37]

---

[37] EPA Memorandum from Jeffrey Herzog and Stephen Mayotte to Public Docket No. A-91-02, "Summer and Winter Temperatures for the Top 25 Serious, Severe, and Extreme Ozone Nonattainment Areas"

MOBILE calculates nonexhaust emissions in three separate categories: running losses, refueling losses, and evaporative losses. Running losses are losses that occur while the vehicle is running, and are brought about by the heating of the fuel tank and fuel lines. Refueling losses occur strictly during refueling of a vehicle, and are due mainly to the displacement of vapors in the fuel tank with fuel. Evaporative losses include both diurnal and hot soak losses. Hot soak losses occur immediately after a vehicle is turned off, and are due to the continued transfer of heat from the engine to the fuel and the concurrent removal of cooling media such as wind and engine coolant. Diurnal losses occur during daily ambient temperature swings.

In the February 1993 NPRM [58 FR 17175], MOBILE5 was used to determine baseline emissions of VOC and NOx for Phase II of the reformulated gasoline program. Since then, MOBILE5a has been released, and it provides slightly different baseline emission estimates than MOBILE5. The changes to the baseline emission estimates are minimal, however, prompting the Agency to replace MOBILE5 with MOBILE5a without opportunity for public comment.

MOBILE5a was initially designed to augment MOBILE4.1 through the addition of post-1990 vehicle based emission controls. Both MOBILE 4.1 and MOBILE5a were intended to predict the same in-use emission for calendar years prior to 1991. However, in the process of adding the post-1990 vehicle controls, EPA also modified its estimates of pre-1991 model year vehicle emissions, causing the two models to produce differing projections for pre-1991 as well as post-1990 calendar year emissions. The most significant changes in MOBILE5a from MOBILE4.1 include:

- The effect of post-1990 vehicle and fuel emission control programs mandated by the Clean Air Act have been added;
- The California low-emitting vehicle program can be modeled;
- A wider range of inspection and maintenance programs can be modeled, most notably programs meeting EPA's definition of "enhanced I/M."
- The basic emission rate equations for 1981 and later light-duty gasoline vehicles have been revised, based on results of the IM240 transient test program at Hammond, IN.
- Speed correction factors for light-duty gasoline vehicles have been revised.

Since the reformulated gasoline program uses 1990 vehicles for its baseline, only those changes that affect 1990 model year vehicles will affect the MOBILE5a output and therefore the Phase II baseline emissions. Thus, only the last two points above contribute to the difference in baseline values between MOBILE4.1 and MOBILE5a. The significance of these changes in the MOBILE model on the derivation of the Complex Model for nonexhaust emissions is demonstrated by the increase in total emissions from MOBILE5a over MOBILE4.1 of 13 percent,[38] when a basic I&M scenario is assumed for MOBILE4.1 and an enhanced I&M scenario is assumed for MOBILE5a.

For the simple model, the Agency derived baseline emissions using a July 11, 1991 version of EPA's MOBILE4.1 emissions model. As described below, EPA also used this version of MOBILE4.1 to generate the baseline emissions for all of Phase I of the reformulated gasoline program (i.e. through 1999). Thereafter, the more recent MOBILE5a model will be used.

2. Inspection and Maintenance Programs

The baseline emissions used in the simple model were determined from MOBILE4.1 under a scenario that included an early definition of enhanced inspection and maintenance (I/M). This early version of enhanced I/M consisted of a short idle test for exhaust emissions and a visual check for tampering or malfunction of the catalyst, the fuel inlet restrictor, and the gas cap. Since publication of the simple model SNPRM, the Agency has promulgated regulations for enhanced I/M programs that diverge in structure and content from the original definition of enhanced I/M. The more recent enhanced I/M program includes a dynamometer-based IM240 exhaust emissions test and fuel tank pressure and canister purge checks for the vehicle's nonexhaust emission control systems. Under the model enhanced I/M scenario, 98 percent of the vehicle population will undergo inspections once a year, and waivers will be granted for 1 percent of the inspected vehicles. The testing procedures for the emission factor evaporative system pressure and purge checks, as well as that for the IM240 transient test, are provided in the final rulemaking on inspection and maintenance program requirements [57 FR 52950]. The enhanced I/M program assumed in the April 1992 SNPRM for the simple model [57 FR 13416] would now be considered more representative of "basic" I/M.

The Clean Air Act requires ozone nonattainment areas to achieve the primary standard (less than 0.121 ppm ozone) within a specified time period depending on the area classification. The Agency's final rule on inspection and maintenance programs directs all states or areas within an ozone transport region that have a 1990 population of 100,000 or more to implement enhanced I/M programs to achieve that standard, regardless of that area's attainment classification. Serious or worse ozone nonattainment areas having a 1980 population of 200,000 or more also are required to implement enhanced I/M programs. Although all of these enhanced

---

[38] Based on total (exhaust + non-exhaust) non-methane, non-ethane VOC emissions for light-duty cars (not including resting losses) in Class C areas using an 8.7 RVP fuel. MOBILE model input files are shown in Appendices III-A and III-B.

I/M programs are required to begin by January 1, 1995, various aspects of the program can be phased in over time. Thus, EPA does not anticipate the full impact of enhanced I/M to be fully effective until January 1, 1999, which is late in Phase I of the reformulated gasoline program. Given that the complex model can be used as early as 1995, the simple model's basic I/M program appears to represent Phase I of the reformulated gasoline program best, while the recently promulgated enhanced I/M is more representative of I/M programs in Phase II.

Under the basic I/M program scenario, MOBILE4.1 predicts that 20 percent of the gasoline-fueled light-duty vehicles on the road would be "failing" vehicles[39] from a nonexhaust emissions standpoint. A nonexhaust failing vehicle is defined as one whose evaporative emission control systems do not work properly, as determined by the pressure and purge checks associated with an enhanced I/M program. This scenario is the one assumed for Phase I. Under the auspices of an enhanced I/M program during Phase II, MOBILE5a predicts that essentially every light-duty vehicle on the road would be designated as "passing" in terms of evaporative emissions because enhanced I/M programs are assumed to have 98 percent compliance and to grant waivers for only 1 percent of failing vehicles.

3. Stage II Refueling Controls

By 1995, all serious and worse ozone nonattainment areas will be required to implement Stage II refueling controls as a means of limiting gasoline refueling emissions. These controls are designed to capture displaced vapors from the vehicle fuel tank and return them to the underground fuel storage tanks at the service station. In the Draft Regulatory Impact Analysis for the simple model, Stage II refueling controls were estimated to decrease uncontrolled refueling emissions by 73 percent. This effectiveness has been carried over to the complex models for both Phases I and II.

On-board refueling controls will begin in 1996. Since the Complex Model is concerned only with 1990-technology vehicles, on-board refueling controls have no bearing on baseline emissions or on emission estimates using the Complex Model.

4. Weighting Factors

The statistical regressions that were used to develop the Complex Model produced separate models (equations) for every vehicle group for each of six exhaust pollutants. This categorization of emission effects was done to most accurately describe the unique combustion chemistry characteristics of

---

[39] Communication with Lois Platte, EPA National Vehicle and Fuel Emissions Laboratory, Sept. 21, 1992

different types of vehicles. However, these separate equations must be weighted according to the in-use contribution of each vehicle type to the total mobile source emissions inventory in order to determine the overall in-use performance of a given fuel. The derivation of these weighting factors will be given in this subsection. The normal emitter in-use contribution of each technology type to the total mobile source VOC emissions inventory is also used in deriving toxic emission baselines, as described in Subsection III.B.5.

EPA subdivided normal emitting vehicles (those that emit less than 0.82 g/mi of VOC) into nine broad vehicle technology types. Each technology group was characterized by a particular combination of emission control technologies. The technologies used to separate normal emitters into technology groups were expected to cause vehicles to respond differently to specific fuel modifications or otherwise influence exhaust emissions. The defining characteristics of each of these nine technology groups is given in Table III-4.

Table III-4: Normal Emitter Technology Groups

Technology group	Fuel system	Catalyst type	Fuel/Air system	EGR?
1	Multi	3-way	CLL/No air	Yes
2	Multi	3-way	CLL/No air	No
3	TBI	3-way	CLL/No air	Yes
4	Multi	3-way + Ox	CLL/Air	Yes
5	Multi	3-way	CLL/Air	Yes
6	TBI	3-way	CLL/Air	Yes
7	TBI	3-way + Ox	CLL/Air	Yes
8	TBI	3-way	CLL/No air	No
9	Carb	3-way + Ox	CLL/Air	Yes

For higher emitting vehicles, EPA has found technology type distinctions to be superfluous for reasons outlined in Section IV.A. Thus all light-duty vehicles fall into one of ten different vehicle groups: either one of the nine normal emitter technology groups, or the higher emitter group. The statistical regressions that derived relationships between fuel parameters and exhaust emissions made distinctions between these ten vehicle categories, and so produced separate models (equations) for each. Since each of these ten equations can give different emission results for identical fuels, their results must be combined in such a way as to reflect the contribution of each vehicle group to the overall in-use emissions of 1990 vehicles.

The contribution of each of the nine technology groups given in Table III-4 to the total mobile-source emissions inventory is determined by two factors: the fraction of the 1990 sales fleet accounted for by each type of vehicle (its sales weighting), and the average emissions for each vehicle type. The sales weightings were derived from reported 1990 light-duty vehicle and truck sales reports submitted by vehicle manufacturers, and are equal to the fraction of 1990 vehicles with the corresponding vehicle technology[40]. Vehicle sales fractions were used to estimate the fraction of total vehicle miles travelled by vehicles of a given technology type. To compute the contribution of each technology group to total emissions, the sales weightings were adjusted to account for differences in the average level of total hydrocarbon and NOx emissions from vehicles in each technology group, as determined through the EPA Emission Factor program[41]. The sales and technology group emissions weightings are given in Table III-5.

Table III-5: Sales Weightings and Emissions by Technology Group

Technology group	Sales weighting	Average g/mi of HC	Average g/mi of NOx
1	0.2631	0.278	0.519
2	0.2871	0.228	0.570
3	0.2181	0.230	0.479
4	0.1143	0.435	0.918
5	0.0431	0.179	0.389
6	0.0053	0.200	0.460
7	0.0525	0.389	0.613
8	0.0	--	--
9	0.0165	0.258	0.712

---

[40] See EPA Memorandum from Joann Jackson-Stephens to Michael Sklar, "Re-analysis of 1990 Sales Fleet (CAFE)," March 1, 1993. Values from this memo were normalized, since 1.41% of the 1990 vehicle sales did not fall into any of the nine technology groups.

[41] See EPA Memorandum from Christian E. Lindhjem to Richard A. Rykowski, "Effect of Oxygenates on Emissions," January 7, 1992.

Note that technology group #8 has a sales weighting of 0.0%, indicating that no vehicles with that particular technology type were sold in 1990 in the U.S. For this reason, technology group #8 will be dropped from subsequent discussions, resulting in a set of eight normal emitter technology groups numbered 1, 2, 3, 4, 5, 6, 7, and 9.

Within the normal emitter class, the relative weighting of the emission results from each technology group is derived from the combination of the sales weightings and the average emissions for that technology group. The relative weighting for each technology group, which applies only to normal emitting vehicles, was derived from the following equation:

$$\text{Technology group weighting} = \frac{\text{Sales weighting * average emissions for the group}}{\Sigma(\text{Sales weighting * technology group emission weighting})}$$

This equation gives the values shown in Table III-6.

Table III-6: Technology Group Weightings for Normal Emitters

Technology group	VOC weighting	NOx weighting
1	0.26896	0.23842
2	0.24071	0.28573
3	0.18446	0.18241
4	0.18284	0.18321
5	0.02837	0.02927
6	0.00390	0.00426
7	0.07510	0.05619
9	0.01565	0.02051
Total	0.99999	1.00000

As stated before, a given vehicle can be categorized as a normal emitter or a higher emitter. Since the weightings shown in Table III-6 apply only to normal emitters, a weighting scheme that applies to all vehicle groups' equations must combine the weightings from Table III-6 with the in-use proportion of emissions attributable to each emitter class. These proportions depend on the inspection and maintenance (I&M) scenario assumed for each Phase of the reformulated gasoline program. The fraction of emissions attributable to normal and higher emitters for both Phases are given in Table III-7.

Table III-7: Emitter Class Weightings By Pollutant and Phase

	Phase I		Phase II	
	VOC	NOx	VOC	NOx
Normal emitters	0.52	0.82	0.444	0.738
Higher emitters	0.48	0.18	0.556	0.262

The final weightings that are applied to the performance estimates for each of the nine separate vehicle group equations for each exhaust pollutant are shown in Table III-8. The normal emitter weightings are calculated from the product of the technology group-specific weightings (Table III-6) and the normal emitter fraction of total emissions (Table III-7). Since the five toxic species of interest are also classified as VOCs, EPA has used the final VOC weightings to weight the individual vehicle group equations for each exhaust toxic pollutant as well.

Table III-8: Vehicle Group Weightings for the Complex Model

Vehicle group	Phase I		Phase II	
	VOC	NOx	VOC	NOx
Normals, technology group #1	0.13986	0.19550	0.11942	0.17595
Normals, technology group #2	0.12517	0.23430	0.10688	0.21087
Normals, technology group #3	0.09592	0.14958	0.08190	0.13462
Normals, technology group #4	0.09508	0.15023	0.08118	0.13521
Normals, technology group #5	0.01475	0.02400	0.01260	0.02160
Normals, technology group #6	0.00203	0.00349	0.00173	0.00314
Normals, technology group #7	0.03905	0.04608	0.03334	0.04147
Normals, technology group #9	0.00814	0.01682	0.00695	0.01514
Higher emitters	0.48000	0.18000	0.55600	0.26200

5. Summer Baseline Emissions

The MOBILE model was used as the basis for estimating fleet-average gram/mile emissions from summer baseline fuel. However, the MOBILE model is equipped only to provide emission estimates for VOC and NOx. Therefore, baseline emissions for toxics were treated separately. Accordingly, the first section below will present the treatment of VOC and NOx baseline emissions, while the following section will present the treatment of baseline emissions for toxics. A table giving the summer baseline emissions for VOC, NOx, and toxics is presented at the end of Section B.5.b.

a. VOC and NOx

To estimate gram/mile emissions of VOC and NOx from summer baseline fuel, only the emissions from 1990 model year vehicles could be considered. To implement this criterion while maintaining a focus on in-use emissions from 1990 vehicles over their lifetime, the MOBILE model was run in the year 2015 with all post-1990 vehicle programs turned off (Tier 1 standards are not included because they do not apply to baseline 1990 vehicles). For the summer season, the daily low and high temperatures modeled were 69 and 94°F, respectively, for Class B areas and 72 and 92°F, respectively, for Class C areas (see Section B.1 above). The conditions under which the baseline emission values were determined for Phases I and II are shown below:

Phase I:
- July 11, 1991 version of MOBILE4.1
- Light-duty vehicles (i.e., passenger cars) only
- Basic I/M program consisting of a 2200 rpm idle test and a gas cap inspection

Phase II:
- MOBILE5a
- Emissions from light-duty vehicles and light-duty trucks were combined by weighting per-mile emissions by the percentage of vehicle miles traveled
- Inspection and maintenance program met EPA's recent guidelines for enhanced I/M, including purge and pressure checks

The Agency designed the Phase I conditions to be identical to the conditions used for the simple model for the reasons outlined in Section 4 of the preamble. The MOBILE model input file for Phase I baseline emission estimates is given in Appendix III-A, while the input file for Phase II baseline emission estimates is given in Appendix III-B.

Although the MOBILE model provides gram/mile estimates of VOC for both exhaust and nonexhaust, the Agency determined baseline emissions slightly differently for these two emission categories.

The reason for this is that the nonexhaust equations in the Complex Model are based on a simple regression using emission estimates from the MOBILE model for various RVPs.[42] The MOBILE model output is given in only two decimal places. Thus when the nonexhaust regression equations are evaluated for an RVP of 8.7 psi (the RVP of summer baseline gasoline), the resulting emission estimate for nonexhaust VOC is slightly larger than the estimate provided directly by the MOBILE model (e.g. 0.492 g/mi vs. 0.483 g/mi for Phase II, Class C). The Agency has determined that the regression equations are more representative of the true relationship between VOC emissions and RVP than the data derived directly from the MOBILE model because of the error introduced in the MOBILE model output through rounding. Therefore, the nonexhaust VOC baseline values were derived from regressions based on the emissions from the MOBILE model instead of from the MOBILE model output directly. The exhaust VOC baseline values, on the other hand, were taken directly from the MOBILE model output since MOBILE provided the only source of baseline exhaust emission estimates.

As discussed in the February 1993 NPRM [58 FR 17175], the definition of ozone-forming VOCs was changed to match EPA guidance that all VOC emission estimates be in terms of nonmethane, nonethane hydrocarbon emissions. The official version of MOBILE4.1 and MOBILE5a both provide VOC estimates in this form directly. However, the July 11, 1991 version of MOBILE4.1 (the MOBILE model used to develop the simple model and the Phase I baseline emissions) gives VOC as nonmethane hydrocarbons only. When using VOC values from the interim version of MOBILE4.1, then, it is necessary to back out the fraction of ethane. Based on an analysis of the Complex Model database, the Agency determined that the average ethane content was approximately 2.95% of exhaust nonmethane hydrocarbon emissions. This value would be expected to change as changes are made to the Complex Model database, but not to such a degree that the Phase I reformulated gasoline program would be affected. Thus the VOC baseline emission values for Phase I were reduced from 0.46 g/mi nonmethane VOC to 0.446 g/mi nonmethane, nonethane VOC by subtracting 2.95% from the nonmethane baseline emission estimate.

The baseline emissions for VOC and NOx as derived from the MOBILE model are summarized in Table III-9.

---

[42] See Section IV.B below for details on the derivation of the nonexhaust model for VOC

Table III-9: Summer Baseline Emissions for VOC and NOx

	Phase I		Phase II	
	Class B	Class C	Class B	Class C
Exhaust VOC, g/mi	0.446	0.446	0.907	0.907
Nonexhaust VOC, g/mi	0.860	0.769	0.559	0.492
NOx, g/mi	0.660	0.660	1.340	1.340

In addition to the fleet-average baseline emissions, emitter class-specific baseline emissions are also needed to calculate the overall emissions performance of reformulated and conventional fuels. To derive emitter class-specific baseline emissions, the fleet and emission inventories must first be apportioned by emitter class. The database on which the MOBILE model is based provided this information. No statistically significant differences in NOx emissions between normal and higher emitters were found. The fleet and emission inventories are shown in Tables 10 and 11 for Phase I and Phase II, respectively.

Table III-10: Phase I Summer Fleet and Emissions Inventory

	Normal Emitters	High Emitters	Overall Fleet
Fraction of in-use fleet	0.82	0.18	1.00
Fraction of VOC inventory	0.52	0.48	1.00
Exhaust VOC emissions, g/mi/car	0.283	1.189	0.446
Fraction of NOx inventory	0.82	0.18	1.00
NOx emissions, g/mi/car	0.66	0.66	0.66

Table III-11: Phase II Summer Fleet and Emissions Inventory

	Normal Emitters	High Emitters	Overall Fleet
Fraction of in-use fleet	0.836	0.164	1.00
Fraction of VOC inventory	0.444	0.556	1.00
Exhaust VOC emissions, g/mi/car	0.482	3.075	0.907
Fraction of NOx inventory	0.82	0.18	1.00
NOx emissions, g/mi/car	1.34	1.34	1.34

VOC baseline emissions for each emitter class were determined by using the following equation, as proposed in the draft Regulatory Impact Analysis:

$$EFI \times ABE = EFF \times EBE$$

where,

ABE = Baseline emissions for the fleet (g/mile)
EBE = Baseline emissions for an individual emitter class (g/mile)
EFF = Emitter class fraction of vehicles in the fleet
EFI = Emitter class fraction of the emissions inventory

ABE, EFF, and EFI are derived from the MOBILE model database, and are given in Tables 10 and 11 above.

b. Toxics

As stated previously, the MOBILE model does not provide emission estimates for toxic compounds. Thus the baseline emissions for toxics must come from another source. In addition, toxic compounds must be treated separately when estimating exhaust and nonexhaust baseline emissions, since exhaust baseline toxic values are derived mainly from the Complex Model database, while nonexhaust baseline toxic values are computed directly from the nonexhaust Complex Model in conjunction with General Motor's vapor model. Baseline emissions of exhaust POM are also treated uniquely due to the lack of POM emissions data. Baseline levels of these three types of summer toxics emissions (exhaust other than POM, nonexhaust, and POM) will be discussed separately in this section.

The Agency has determined that of the five toxic compounds that must be regulated in the reformulated gasoline and anti-dumping programs, benzene is the only one that appears in nonexhaust emissions since it is the only regulated toxic compound naturally occurring in gasoline. As described in Section IV.B, the nonexhaust benzene portion of the Complex Model is derived from the General Motors (GM) vapor equilibrium model. This GM model estimates the fraction of benzene in the vapors above a pool of fuel (conditions simulating a vehicle's fuel tank). The Agency executed a linear regression on the output from the GM model, and combined the resulting regression equations with the nonexhaust VOC equations. Thus the Agency converted benzene fraction estimates into a model that provides benzene emission estimates in grams/mile. For details on the development of the nonexhaust model, see Section IV.B below.

Since the nonexhaust VOC model is based on emission estimates produced from the MOBILE model, the nonexhaust benzene equations in the Complex Model are the most appropriate source for determining baseline emissions of benzene. Deriving the nonexhaust benzene baseline emissions from the Complex Model is also consistent with the method described above for determining baseline emissions for nonexhaust VOC. Thus the summer baseline fuel was simply run through the nonexhaust benzene portion of the Complex Model to determine the baseline emissions of nonexhaust benzene. The results are shown in Table III-12:

Table III-12: Summer Nonexhaust Benzene Baseline Emissions

	Class B	Class C
Phase I	9.659	8.633
Phase II	6.241	5.505

To determine baseline emissions for exhaust toxics, the most complete source of information is the Complex Model database. The Agency therefore performed an analysis of the toxic emissions data in the Complex Model database to determine the average emissions of each toxic pollutant. In this analysis, only the observations used in the development of the Complex Model equations for toxic compounds were considered. Normal emitter averages were estimated separately from higher emitter averages. Also, the normal emitter averages were derived separately for each technology group to mimic the development of the Complex Model for normal emitters. For the same reason, technology group distinctions were <u>not</u> made in the analysis of the higher emitter averages. Average VOC emissions were also calculated for the same observations. The results of this analysis for normal emitters are shown in Tables 13 through 16, while the higher emitter results are shown in Table III-17.

Table III-13: Exhaust Benzene and VOC Emissions for Normal Emitters

TECHNOLOGY TYPE	NUMBER OF OBSERVATIONS	EXHAUST EMISSION VARIABLE	MEAN EMISSIONS (mg/mile)	RATIO*
1	598	BENZENE	9.724	0.0504
		VOC	193.0	
2	431	BENZENE	11.11	0.0484
		VOC	229.7	
3	300	BENZENE	10.73	0.0538
		VOC	199.5	
4	138	BENZENE	8.086	0.0333
		VOC	242.9	
5	22	BENZENE	12.82	0.0398
		VOC	322.4	
6	70	BENZENE	27.58	0.0626
		VOC	440.7	
7	21	BENZENE	9.492	0.0402
		VOC	235.8	
9	8	BENZENE	6.449	0.0574
		VOC	112.3	

*RATIO = MEAN EXHAUST BENZENE EMISSIONS/MEAN EXHAUST VOC EMISSIONS

Table III-14: Exhaust 1,3-Butadiene and VOC Emissions for Normal Emitters

TECHNOLOGY TYPE	NUMBER OF OBSERVATIONS	EXHAUST EMISSION VARIABLE	MEAN EMISSIONS (mg/mile)	RATIO[*]
1	574	1,3-BD	1.225	0.00639
		VOC	191.8	
2	428	1,3-BD	1.599	0.00695
		VOC	230.2	
3	277	1,3-BD	1.056	0.00512
		VOC	206.1	
4	132	1,3-BD	0.868	0.00363
		VOC	239.2	
5	21	1,3-BD	1.951	0.00611
		VOC	319.4	
6	70	1,3-BD	2.154	0.00489
		VOC	440.7	
7	21	1,3-BD	0.791	0.00336
		VOC	235.8	
9	5	1,3-BD	0.824	0.00751
		VOC	109.7	

[*] RATIO = MEAN EXHAUST 1,3-BUTADIENE EMISSIONS/MEAN EXHAUST VOC EMISSIONS

Table III-15: Exhaust Acetaldehyde and VOC Emissions for Normal Emitters

TECHNOLOGY TYPE	NUMBER OF OBSERVATIONS	EXHAUST EMISSION VARIABLE	MEAN EMISSIONS (mg/mile)	RATIO*
1	528	ACET	0.9725	0.00519
		VOC	187.4	
2	427	ACET	1.225	0.00531
		VOC	230.5	
3	276	ACET	1.263	0.00633
		VOC	199.4	
4	134	ACET	1.638	0.00680
		VOC	241.0	
5	21	ACET	1.014	0.00315
		VOC	322.2	
6	66	ACET	2.883	0.00655
		VOC	440.0	
7	21	ACET	1.019	0.00432
		VOC	235.8	
9	8	ACET	0.9363	0.00834
		VOC	112.3	

*RATIO = MEAN EXHAUST ACETALDEHYDE EMISSIONS/MEAN EXHAUST VOC EMISSIONS

Table III-16: Exhaust Formaldehyde and VOC Emissions for Normal Emitters

TECHNOLOGY TYPE	NUMBER OF OBSERVATIONS	EXHAUST EMISSION VARIABLE	MEAN EMISSIONS (mg/mile)	RATIO*
1	529	FORM	2.336	0.0125
		VOC	187.4	
2	425	FORM	2.727	0.0118
		VOC	230.3	
3	277	FORM	3.037	0.0152
		VOC	199.8	
4	135	FORM	5.715	0.0237
		VOC	240.7	
5	21	FORM	2.438	0.00757
		VOC	322.2	
6	70	FORM	6.431	0.0146
		VOC	440.7	
7	21	FORM	2.754	0.0117
		VOC	235.8	
9	8	FORM	3.091	0.0275
		VOC	112.3	

*RATIO = MEAN EXHAUST FORMALDEHYDE EMISSIONS/MEAN EXHAUST VOC EMISSIONS

Table III-17: Average Toxic and VOC Emissions from Higher Emitters

	Number of observations	Average toxic emissions, mg/mi	Average VOC emissions, mg/mi	Ratio[*]
Benzene	269	95.05	2082	0.0457
1,3-Butadiene	270	23.85	2117	0.0113
Acetaldehyde	269	11.45	2117	0.00541
Formaldehyde	269	27.60	2116	0.0130

*RATIO = MEAN EXHAUST TOXIC EMISSIONS/MEAN EXHAUST VOC EMISSIONS

The toxics emission inventory is expected to be roughly proportional to the VOC inventory because toxics are by definition volatile organic compounds (though the effects of fuel modifications on toxics emissions are expected to differ from the effects of the same fuel modifications on exhaust VOC emissions). Therefore, ratios of the average emissions of each toxic pollutant with respect to the average emissions of VOCs for the same observations were also calculated. These ratios were used to compensate for the fact that the observations which contributed to the average values in Tables 13-17 were not based only on summer baseline fuel and were not based on vehicles with representative in-use VOC emission levels. Summer baseline emission values for exhaust toxics were calculated using the following procedure:

1. The normal emitter toxic emission ratios from Tables 13 through 16 were weighted by the normal emitter technology group weighting factors. The normal emitter technology group weighting factors were derived in Subsection III.B.4 above, and are given in Table III-6. They represent the fraction of the mobile source emissions inventory for normal emitters that comes from each technology group.

2. The weighted ratios from step (1) were summed to obtain a single, fleet-average ratio for each toxic emission for normal emitters as shown in Table III-18. This step yields overall toxic-to-VOC ratios for normal emitters that are analogous to the values presented for higher emitters in Table III-17.

Table III-18: Average Toxic and VOC Emissions from Normal Emitters

	Number of observations	Ratio*
Benzene	1588	0.0465
1,3-Butadiene	1528	0.00556
Acetaldehyde	1481	0.00566
Formaldehyde	1486	0.0149

*RATIO = MEAN EXHAUST TOXIC EMISSIONS/MEAN EXHAUST VOC EMISSIONS

3. The ratios in Tables 17 and 18 are based on all the available data in the Complex Model database for which both toxics and NMHC data were available. Since these ratios are not based strictly on summer baseline gasoline, they cannot provide the toxic baseline emissions for summer baseline fuel. To convert the ratios from Tables 17 and 18 into ratios that reflect the effect of summer baseline fuel on toxic emissions when used in representative in-use 1990 vehicles, a correction was made. This correction was carried out in two steps. The first step corrected for the fact that the toxic emission averages are not based on summer baseline gasoline. The second step corrected for the fact that the VOC emission averages are not based on summer baseline gasoline. These two corrections were performed sequentially:

3.1) The average value of each fuel parameter was determined for the same observations that were used to determine the average toxics and VOC values in Table III-17 and 18. This step was performed separately for the normal and higher emitter observations, and for each toxic. Thus there were a total of eight "average" fuel descriptions. Discrepancies between these average fuels and summer baseline fuel caused discrepancies between the ratios in Tables 17 and 18 and the true ratios for summer baseline gasoline. The average fuels for each toxic are given in Tables 19 and 20.

Table III-19: Average Fuels for Normal Emitters

	Benzene	1,3-Butadiene	Acetaldehyde	Formaldehyde
MTBE, wt% oxygen	1.236	1.254	1.311	1.313
ETBE, wt% oxygen	0.021	0.022	0.023	0.021
Ethanol, wt% oxygen	0.198	0.199	0.206	0.209
TAME, wt% oxygen	0.015	0.014	0.013	0.013
Sulfur, ppm	218.6	220.4	218.3	217.9
RVP, psi	8.264	8.268	8.248	8.249
E200, percent evap	47.55	47.49	48.43	48.43
E300, percent evap	84.94	84.90	85.28	85.31
Aromatics, vol%	28.58	28.41	28.15	28.14
Olefins, vol%	7.943	7.969	8.028	8.005
Benzene, vol%	0.953	0.921	0.966	0.964

Table III-20: Average Fuels for Higher Emitters

Fuel parameter	Benzene	1,3-Butadiene	Acetaldehyde	Formaldehyde
MTBE, wt% oxygen	1.457	1.466	1.464	1.457
ETBE, wt% oxygen	0.020	0.020	0.010	0.020
Ethanol, wt% oxygen	0.361	0.346	0.360	0.360
TAME, wt% oxygen	0.009	0.009	0.009	0.009
Sulfur, ppm	255.5	255.7	255.7	254.6
RVP, psi	7.810	7.803	7.810	7.812
E200, percent evap	52.49	52.51	52.55	52.56
E300, percent evap	84.54	84.57	84.60	84.62
Aromatics, vol%	26.03	25.98	25.98	26.01
Olefins, vol%	5.699	5.692	5.683	5.667
Benzene, vol%	0.871	0.867	0.868	0.867

3.2) The Complex Model was used to determine a multiplicative factor to convert emissions of each toxic for the average fuel into emissions of each toxic for summer baseline fuel. This step was accomplished by evaluating the normal emitter toxic equations with the fuels from Table III-19, evaluating the higher emitter toxic equations with the fuels from Table III-20, and evaluating both normal and higher emitter toxic equations with summer baseline fuel. The multiplicative factor can then be written as follows:

$$\text{Toxic correction factor} = \exp(f(b))/\exp(f(a))$$

where f is the normal or higher emitter polynomial equation for the toxic of interest, b is summer baseline gasoline, and a is the average fuel from either Table III-19 or Table III-20. The toxic emission correction factors are given in Table III-21.

Table III-21: Toxic Emission Correction Factors

Toxic pollutant	Normal emitter correction factor	Higher emitter correction factor
Benzene	1.371	1.500
1,3-Butadiene	1.121	1.402
Acetaldehyde	1.011	0.9970
Formaldehyde	0.9373	0.8151

3.3) The ratios from Tables 17 and 18 were multiplied by the appropriate toxic correction factors from Table III-21. This step converted the toxics portion of each ratio to a value representing the toxic emissions from summer baseline gasoline.

3.4) Beginning with the same average fuels, the Complex Model was used to determine a multiplicative factor that will convert VOC emissions for the average fuel to VOC emissions for summer baseline fuel. This step was accomplished by evaluating the normal emitter VOC equation with the fuels from Table III-19, evaluating the higher emitter VOC equation with the fuels from Table III-20, and evaluating both normal and higher emitter VOC equations with summer baseline fuel. The multiplicative factor can then be written as follows:

$$\text{VOC correction factor} = \exp(g(a))/\exp(g(b))$$

where g is the normal emitter polynomial equation for VOC, a is the average fuel from Tables 19 and 20, and b is summer baseline gasoline. Note that the VOC correction factor in this step has the reciprocal form of the factor given in step (3.2) because this step is correcting the denominator of each ratio instead of the numerator. The VOC correction factors are given in Table III-22.

Table III-22: VOC Emission Correction Factors

Toxic pollutant	Normal emitter correction factor	Higher emitter correction factor
Benzene	0.8685	0.9045
1,3-Butadiene	0.8694	0.9039
Acetaldehyde	0.8606	0.9042
Formaldehyde	0.8603	0.9044

3.6) The ratio from step (3.3) was multiplied by the appropriate factors from Table III-22. This step converts the VOC portion of each ratio to a value representing the VOC emissions from summer baseline gasoline. The ratios from Tables 17 and 18 were now fully corrected to represent summer baseline gasoline, and are shown in Table III-23.

Table III-23: Corrected Toxic:VOC Ratios

Toxic pollutant	Normal emitter ratio	Higher emitter ratio
Benzene	0.0554	0.0620
1,3-Butadiene	0.00542	0.0143
Acetaldehyde	0.00492	0.00488
Formaldehyde	0.0120	0.00962

4. Each of the four normal emitter toxic emission ratios from Table III-23 was multiplied by the Phase I VOC baseline for normal emitters, which is 283 mg/mi (Table III-10). For the higher emitter ratios, each value from Table III-23 was multiplied by the Phase I VOC baseline for higher emitters, which is 1189 mg/mi. This step produced the Phase I normal and higher emitter toxics baselines as shown in Table III-24.

Table III-24: Phase I Summer Toxic Baseline Emissions by Emitter Class

Toxic pollutant	Normal emitter baseline, mg/mi	Higher emitter baseline, mg/mi
Benzene	15.66	73.68
1,3-Butadiene	1.533	16.98
Acetaldeyhde	1.391	5.799
Formaldehyde	3.404	11.44

5. The normal and higher emitter toxic baselines were weighted by the fraction of the in-use fleet attributable to each emitter class, and the results were summed to obtain the final Phase I toxic baseline emissions. The fraction of the VOC inventory for Phase I is given in Table III-10. The final Phase I exhaust toxic baseline emissions for summer are shown in Table III-25.

Table III-25: Phase I Summer Toxic Baseline Emissions

Toxic pollutant	Baseline, mg/mi
Benzene	26.10
1,3-Butadiene	4.313
Acetaldeyhde	2.185
Formaldehyde	4.850

6. To obtain Phase II summer baseline emissions for toxics, steps 4 and 5 were repeated using Phase II VOC baselines and fleet fractions (Table III-11). The ratios from Table III-23 were multiplied by 482 and 3075 mg/mi for normal and higher emitters, respectively, and the resulting emitter class-specific baseline emission values were combined via the Phase II in-use fleet fractions of 0.836 and 0.164 for normal and higher emitters, respectively. The final Phase II exhaust toxic baseline emissions for summer are shown in Table III-26.

Table III-26: Phase II Summer Toxic Baseline Emissions

Toxic pollutant	Baseline, mg/mi
Benzene	53.54
1,3-Butadiene	9.382
Acetaldeyhde	4.440
Formaldehyde	9.697

Data on polycyclic organic material (POM) were extremely limited since very few test programs had the capability of measuring POM. The lack of data required EPA to pursue a different approach to establish baseline emissions for POM. An analysis of the limited data available to EPA showed that (1) POM emissions were proportional to exhaust VOC emissions, and (2) the proportionality constant is 0.003355. Thus the POM baseline can be determined from the exhaust VOC baseline for both Phase I and II in the following manner:

Phase I: POM baseline = 0.003355 x exhaust VOC baseline
POM baseline = 0.003355 x 0.446 g/mi x 1000 mg/g
POM baseline = 1.496 mg/mi

Phase II: POM baseline = 0.003355 x exhaust VOC baseline
POM baseline = 0.003355 x 0.907 g/mi x 1000 mg/g
POM baseline = 3.043 mg/mi

The final summer baseline emissions are shown in Table III-27.

Table III-27: Summer Baseline Emissions in mg/mile

	Phase I		Phase II	
	Class B	Class C	Class B	Class C
Exhaust VOC	446.00	446.00	907.00	907.00
Nonexhaust VOC	860.48	769.10	559.31	492.07
NOx	660.00	660.00	1340.00	1340.00
Exhaust benzene	26.10	26.10	53.54	53.54
Nonexhaust benzene	9.66	8.64	6.25	5.51
Acetaldehyde	2.19	2.19	4.44	4.44
Formaldehyde	4.85	4.85	9.70	9.70
1,3-Butadiene	4.31	4.31	9.38	9.38
POM	1.50	1.50	3.04	3.04

6. Winter Baseline Emissions

The calculation of winter baseline emissions was approached in a very different manner than used to estimate summer baseline emissions. EPA chose to use a different approach since insufficient testing has been done under winter conditions to develop a separate Complex Model for the winter season. The Agency determined that the MOBILE emissions model provided the most appropriate sources of information on the fleet-average emissions produced when using winter baseline fuel.

One simplifying factor in the determination of winter baseline emissions is that, as discussed in Section IV.E below, the Agency has determined that emissions of nonexhaust VOC and benzene under winter conditions should be set to zero. Thus baseline nonexhaust emissions under winter conditions do not need to be calculated.

Many aspects of the derivation of winter baseline emissions parallel the derivation of summer baseline emissions. Thus this section will treat VOC and NOx separately from toxics for the reasons discussed in Section B.5 above.

a. VOC and NOx

The MOBILE model was run in a manner identical to that discussed above for the derivation of summer baseline emissions of exhaust VOC and NOx, but with two exceptions. First, minimum and maximum wintertime temperatures of 39 °F and 57 °F were used in place of the summer temperature ranges. Second, the winter baseline fuel was used in place of the summer baseline fuel. The remaining details of running the MOBILE model to determine winter baseline emissions of exhaust VOC and NOx are shown below:

Phase I:
- July 11, 1991 version of MOBILE4.1
- Light-duty vehicles (i.e., passenger cars) only
- Basic I/M program consisting of a 2200 rpm idle test and a gas cap inspection

Phase II:
- MOBILE5a
- Emissions from light-duty vehicles and light-duty trucks were combined by weighting per-mile emissions by the percentage of vehicle miles traveled
- Inspection and maintenance program met EPA's recent guidelines for enhanced I/M, including purge and pressure checks

These conditions are identical to those used to develop the summer baseline emission estimates. Winter VOC baseline emissions for Phase I were corrected to reflect nonmethane, nonethane hydrocarbons in a manner identical to that used to correct summer

VOC baseline emissions. The final winter baseline emissions for exhaust VOC and NOx are shown in Table III-28.

Table III-28: Winter Baseline Emissions for VOC and NOx

	Phase I		Phase II	
	Class B	Class C	Class B	Class C
Exhaust VOC, g/mi	0.660	0.660	1.341	1.341
Nonexhaust VOC, g/mi	0.000	0.000	0.000	0.000
NOx, g/mi	0.750	0.750	1.540	1.540

In addition to the fleet-average baseline emissions, emitter class-specific baseline emissions were calculated using the same method discussed in Section B.5 above for summer baseline emissions. The emitter class fractions of the VOC inventory and in-use fleet are the same in the summer and the winter, so differences between summer and winter emitter class-specific baseline emissions are derived solely from differences in fleet-average baseline emissions. As with the summer baseline emissions, no statistically significant differences in NOx emissions between normal and higher emitters were found. The fleet and emission inventories for winter are shown in Tables 29 and 30 for Phase I and Phase II, respectively.

Table III-29: Phase I Winter Fleet and Emissions Inventory

	Normal Emitters	Higher Emitters	Overall Fleet
Fraction of in-use fleet	0.82	0.18	1.00
Fraction of VOC inventory	0.52	0.48	1.00
Exhaust VOC emissions, g/mi/car	0.419	1.760	0.660
Fraction of NOx inventory	0.82	0.18	1.00
NOx emissions, g/mi/car	0.75	0.75	0.75

Table III-30: Phase II Winter Fleet and Emissions Inventory

	Normal Emitters	Higher Emitters	Overall Fleet
Fraction of in-use fleet	0.836	0.164	1.00
Fraction of VOC inventory	0.444	0.556	1.00
Exhaust VOC emissions, g/mi/car	0.712	4.546	1.341
Fraction of NOx inventory	0.82	0.18	1.00
NOx emissions, g/mi/car	1.54	1.54	1.54

VOC baseline emissions for each emitter class were determined using the same relationship described in Section B.5 above:

$$EFI \times ABE = EFF \times EBE$$

where,

ABE = Baseline emissions for the fleet (g/mile)
EBE = Baseline emissions for an individual emitter class (g/mile)
EFF = Emitter class fraction of vehicles in the fleet
EFI = Emitter class fraction of the emissions inventory

ABE, EFF, and EFI are derived from the MOBILE model database, and are given in Tables 29 and 30 above.

b. Toxics

As stated previously, the Agency has determined that nonexhaust emissions are negligible in the winter. Therefore only exhaust toxic baseline emissions need be determined. Winter emissions of benzene, 1,3-butadiene, acetaldehyde, and formaldehyde are discussed first, followed by a brief discussion of POM. A table giving all the winter baseline emissions is presented at the end of this subsection.

The steps in the derivation of winter baseline emissions for exhaust toxics parallel those presented in Section B.5.b above for summer baseline toxic emissions. Indeed, steps (1) and (2) are identical in both cases. Deviations from the summer baseline emission derivation procedure begin in step 3 and are detailed below:

3. Since the ratios in Tables 17 and 18 represent average fuels in the Complex Model database, they cannot provide the toxic baseline emissions for winter baseline fuel. The conversion of the ratios from Tables 17 and 18

required the same six steps that are described for the summer scenario (i.e. steps 3.1 to 3.6), with the single exception that winter baseline fuel replaced summer baseline fuel in all calculations. The final, corrected ratios representing winter baseline gasoline are given in Table III-31.

Table III-31: Corrected Toxic:VOC Ratios for Winter

Toxic pollutant	Normal emitter ratio	Higher emitter ratio
Benzene	0.0509	0.0635
1,3-Butadiene	0.00601	0.0164
Acetaldehyde	0.00544	0.00538
Formaldehyde	0.0134	0.00983

4. Each of the four normal emitter toxic emission ratios from Table III-31 were multiplied by the Phase I winter VOC baseline for normal emitters, which is 419 mg/mi (Table III-29). For the higher emitter ratios, each value from Table III-31 was multiplied by the Phase I winter VOC baseline for higher emitters, which is 1760 mg/mi. This step produced Phase I normal and higher emitter baselines as shown in Table III-32.

Table III-32: Phase I Winter Toxic Baseline Emissions by Emitter Class

Toxic pollutant	Normal emitter baseline, mg/mi	Higher emitter baseline, mg/mi
Benzene	21.29	111.7
1,3-Butadiene	2.515	28.95
Acetaldeyhde	2.277	9.463
Formaldehyde	5.625	17.31

5. The normal and higher emitter toxic baselines were weighted by the fraction of the in-use fleet attributable to each emitter class, and the results were summed to obtain the final Phase I toxic baseline emissions. The fraction of the VOC inventory for Phase I is given in Table III-29. The final Phase I exhaust toxic baseline emissions for summer are shown in Table III-33.

Table III-33: Phase I Winter Toxic Baseline Emissions

Toxic pollutant	Baseline, mg/mi
Benzene	37.57
1,3-Butadiene	7.273
Acetaldeyhde	3.571
Formaldehyde	7.728

6. To obtain Phase II winter baseline emissions for toxics, steps 4 and 5 were repeated using Phase II VOC baselines and fleet fractions (Table III-30). Thus the ratios from Table III-31 were multiplied by 712 and 4546 mg/mi for normal and higher emitters, respectively, and the resulting emitter class-specific baseline emission values were weighted via the Phase II in-use fleet fractions of 0.836 for normal emitters and 0.164 for higher emitters. The final Phase II exhaust toxic baseline emissions for winter are shown in Table III-34.

Table III-34: Phase II Winter Toxic Baseline Emissions

Toxic pollutant	Baseline, mg/mi
Benzene	77.62
1,3-Butadiene	15.84
Acetaldehyde	7.248
Formaldehyde	15.34

The winter POM baseline can be determined from the exhaust VOC baseline for both Phase I and II with the following equations:

Phase I: POM baseline = 0.003355 x exhaust VOC baseline
POM baseline = 0.003355 x 0.660 g/mi x 1000 mg/g
POM baseline = 2.214 mg/mi

Phase II: POM baseline = 0.003355 x exhaust VOC baseline
POM baseline = 0.003355 x 1.341 g/mi x 1000 mg/g
POM baseline = 4.499 mg/mi

The final winter baseline emissions are shown in Table III-35.

Table III-35: Winter Baseline Emissions in mg/mile

	Phase I	Phase II
Exhaust VOC	660.00	1341.00
Nonexhaust VOC	0.00	0.00
NOx	750.00	1540.00
Exhaust benzene	37.57	77.62
Nonexhaust benzene	0.00	0.00
Acetaldehyde	3.571	7.248
Formaldehyde	7.728	15.34
1,3-Butadiene	7.273	15.84
POM	2.214	4.499

7. Response to Comments

A number of comments have been received concerning the use of the MOBILE model for determining both the baseline emissions for VOC and NOx and the nonexhaust VOC model. Some commenters questioned the appropriateness of using MOBILE4.1 in place of the more recent MOBILE5a. The Agency continues to believe that retention of a MOBILE4.1-derived baseline maintains a consistent baseline and exhaust:nonexhaust ratio throughout Phase I. This consistency also allows refiners the lead time they require in order to comply with baseline changes when they reach Phase II in 2000. These points are discussed in more detail in Section B above and in Section III of the preamble.

Other commenters asserted that the MOBILE models have become an integral part of the RFG rulemaking process, and should therefore be subject to a notice and comment period. The MOBILE models are publicly available, and the EPA has considered comments on their results, as used in this rulemaking, to be valid. However, EPA does not consider the MOBILE models themselves to be subject to notice and comment provisions since they do not, by themselves, constitute a rule. EPA has conducted public workshops on the various iterations of the MOBILE model, including MOBILE5, at which it solicited suggestions and input from the public. The resulting models represent EPA's understanding of the impact of various conditions and policy options on emissions from mobile sources; since the Agency does not have access to a superior source of such information, the Agency has chosen to utilize the MOBILE models to help analyze the impact of its rules on mobile source emissions.

C. Appendices

Appendix III-A:	MOBILE4.1 Input File Used to Develop the Simple Model and the Phase I Complex Model (must be run with interim version of MOBILE4.1)
Appendix III-B:	MOBILE5a Input File Used To Develop the Phase II Complex Model

Appendix III-A: MOBILE4.1 Input File Used to Develop the Simple Model and the Phase I Complex Model (must be run with interim version of MOBILE4.1)

```
1          PROMPT -
MOBILE4.1 v.7/11/91: Simple Model correlations
1          TAMFLG -
1          SPDFLG -
1          VMFLAG -
1          MYMRFG -
1          NEWFLG -
2          IMFLAG - enter I/M program
1          ALHFLG -
2          ATPFLG - enter ATP
2          RLFLAG - Stage II refueling controls
2          LOCFLG - enter LAP record once
1          TEMFLG -
3          OUTFMT - print 112 column descriptive output format
4          PRTFLG - print exhaust HC, CO and NOx results
1          IDLFLG -
3          NMHFLG - print VOC
3          HCFLAG - print HC components
83 20 68 20 00 00 100 1 1 2221 2 11 20 20 20
83 68 20 2221 11 100. 11111212
89 1 086 086
RegNeg           C 71.6 91.6 11.5 08.7 89 1
1 15 19.6 75.0 20.6 27.3 20.6
RegNeg           C 71.6 91.6 11.5 08.5 89 1
1 15 19.6 75.0 20.6 27.3 20.6
RegNeg           C 71.6 91.6 11.5 08.3 89 1
1 15 19.6 75.0 20.6 27.3 20.6
RegNeg           C 71.6 91.6 11.5 08.1 89 1
1 15 19.6 75.0 20.6 27.3 20.6
RegNeg           C 71.6 91.6 11.5 07.9 89 1
1 15 19.6 75.0 20.6 27.3 20.6
RegNeg           C 71.6 91.6 11.5 07.7 89 1
1 15 19.6 75.0 20.6 27.3 20.6
RegNeg           C 71.6 91.6 11.5 07.5 89 1
1 15 19.6 75.0 20.6 27.3 20.6
RegNeg           C 71.6 91.6 11.5 07.2 89 1
1 15 19.6 75.0 20.6 27.3 20.6
RegNeg           C 71.6 91.6 11.5 07.0 89 1
1 15 19.6 75.0 20.6 27.3 20.6
RegNeg           B 69.4 94.0 11.5 08.7 89 1
1 15 19.6 75.0 20.6 27.3 20.6
RegNeg           B 69.4 94.0 11.5 08.5 89 1
1 15 19.6 75.0 20.6 27.3 20.6
RegNeg           B 69.4 94.0 11.5 07.8 89 1
1 15 19.6 75.0 20.6 27.3 20.6
RegNeg           B 69.4 94.0 11.5 07.6 89 1
```

```
1 15 19.6 75.0 20.6 27.3 20.6
RegNeg           B 69.4 94.0 11.5 07.4 89 1
1 15 19.6 75.0 20.6 27.3 20.6
RegNeg           B 69.4 94.0 11.5 07.2 89 1
1 15 19.6 75.0 20.6 27.3 20.6
RegNeg           B 69.4 94.0 11.5 07.0 89 1
1 15 19.6 75.0 20.6 27.3 20.6
RegNeg           B 69.4 94.0 11.5 06.8 89 1
1 15 19.6 75.0 20.6 27.3 20.6
RegNeg           B 69.4 94.0 11.5 06.6 89 1
1 15 19.6 75.0 20.6 27.3 20.6
```

Appendix III-B: MOBILE5a Input File Used To Develop the Phase II Complex Model

```
1          PROMPT -
Phase II Complex model baseline runs for LDGVs & LDGTs
1          TAMFLG -
1          SPDFLG -
1          VMFLAG -
1          MYMRFG -
5          NEWFLG - no CAA mandates are modeled
2          IMFLAG - enter I/M program
1          ALHFLG -
8          ATPFLG - enter ATP; include pressure and purge checks
2          RLFLAG - enter Stage II
1          LOCFLG -
1          TEMFLG -
3          OUTFMT - print 112 column descriptive output format
1          PRTFLG - print exhaust & evap HC only
1          IDLFLG -
3          NMHFLG - print VOC
2          HCFLAG - no HC components
83 20 68 20 03 03 096 1 1 2221 4211 0.80 20.0 2.00 Enhanced IM
83 84 20 2221 11 096. 12211111                     ATP
83 83 20 2221 11 096.                              Pressure test
83 86 20 2221 11 096.                              Purge test
89 1 80. 60.                                       Stage II
1 15 19.6 87.0 20.6 27.3 20.6  1
................ C 71.6 91.6 09.5 08.7 90 1 1 1
1 15 19.6 87.0 20.6 27.3 20.6  1
................ C 71.6 91.6 09.5 08.5 90 1 1 1
1 15 19.6 87.0 20.6 27.3 20.6  1
................ C 71.6 91.6 09.5 08.3 90 1 1 1
1 15 19.6 87.0 20.6 27.3 20.6  1
................ C 71.6 91.6 09.5 08.1 90 1 1 1
1 15 19.6 87.0 20.6 27.3 20.6  1
................ C 71.6 91.6 09.5 07.9 90 1 1 1
1 15 19.6 87.0 20.6 27.3 20.6  1
................ C 71.6 91.6 09.5 07.7 90 1 1 1
1 15 19.6 87.0 20.6 27.3 20.6  1
................ C 71.6 91.6 09.5 07.5 90 1 1 1
1 15 19.6 87.0 20.6 27.3 20.6  1
................ C 71.6 91.6 09.5 07.3 90 1 1 1
1 15 19.6 87.0 20.6 27.3 20.6  1
................ C 71.6 91.6 09.5 07.1 90 1 1 1
1 15 19.6 87.0 20.6 27.3 20.6  1
................ C 71.6 91.6 09.5 06.9 90 1 1 1
1 15 19.6 87.0 20.6 27.3 20.6  1
................ C 71.6 91.6 09.5 06.7 90 1 1 1
1 15 19.6 87.0 20.6 27.3 20.6  1
................ C 71.6 91.6 09.5 06.5 90 1 1 1
1 15 19.6 87.0 20.6 27.3 20.6  1
```

```
................ B 69.4 94.0 09.5 08.7 90 1 1 1
1 15 19.6 87.0 20.6 27.3 20.6  1
................ B 69.4 94.0 09.5 08.5 90 1 1 1
1 15 19.6 87.0 20.6 27.3 20.6  1
................ B 69.4 94.0 09.5 08.3 90 1 1 1
1 15 19.6 87.0 20.6 27.3 20.6  1
................ B 69.4 94.0 09.5 08.1 90 1 1 1
1 15 19.6 87.0 20.6 27.3 20.6  1
................ B 69.4 94.0 09.5 07.9 90 1 1 1
1 15 19.6 87.0 20.6 27.3 20.6  1
................ B 69.4 94.0 09.5 07.7 90 1 1 1
1 15 19.6 87.0 20.6 27.3 20.6  1
................ B 69.4 94.0 09.5 07.5 90 1 1 1
1 15 19.6 87.0 20.6 27.3 20.6  1
................ B 69.4 94.0 09.5 07.3 90 1 1 1
1 15 19.6 87.0 20.6 27.3 20.6  1
................ B 69.4 94.0 09.5 07.1 90 1 1 1
1 15 19.6 87.0 20.6 27.3 20.6  1
................ B 69.4 94.0 09.5 06.9 90 1 1 1
1 15 19.6 87.0 20.6 27.3 20.6  1
................ B 69.4 94.0 09.5 06.7 90 1 1 1
1 15 19.6 87.0 20.6 27.3 20.6  1
................ B 69.4 94.0 09.5 06.5 90 1 1 1
```

IV. Complex Model

The Complex Model is designed to predict emissions as a function of fuel properties. An empirical model is more accurate, faster, cheaper and more practical to use than actual vehicle testing in predicting the emission effects of fuel modifications. Implicit in Section 211(k) the Clean Air Act, and confirmed by actual test data, is the assumption that emissions from vehicles can be linked to the properties of gasolines. The vehicle itself has been found to be the single most significant determinant of the level of emissions from any given vehicle; to identify the effects of fuel property modifications on emissions, EPA found it necessary to separate the emissions effect of each vehicle from fuels' effects. The purpose of the Complex Models developed in the following section is to be able to predict emissions based on fuel properties which are readily measurable and easily controllable.

EPA has developed separate complex models for exhaust and nonexhaust emissions which are based on entirely different data sources. While the exhaust model is based on data from a number of different test programs, the nonexhaust model is based on data generated from EPA's ongoing nonexhaust emissions testing program that has been used to develop EPA's MOBILE emission inventory models. EPA believes this data to be sufficient to model the relationship between fuel properties and nonexhaust VOC emissions since nonexhaust emissions are better understood from a theoretical standpoint and are influenced by fewer fuel properties than are exhaust emissions.

The exhaust Complex Model described in the following sections has undergone some changes since it was proposed in the February 1993 NPRM. These changes have been made in response to the following factors:

- EPA's use of more appropriate data analysis methods
- EPA's improved understanding of the relationship between fuel characteristics and emissions
- Comments received in response to the February NPRM, public workshops, and EPA's docket submission that described a number of alternative exhaust complex models.

The Complex Model described below was developed through an open, iterative process. EPA conducted six separate public workshops to review various iterations of its models and formally submitted five previous versions to the docket. As a result, the Complex Model has been thoroughly peer reviewed, and EPA has considered the suggestions and comments made by various parties seriously in developing the model. While complete consensus between all parties regarding the model and the process used to develop it has not been achieved, the remaining differences are decidedly minor.

A. Exhaust Emissions Model

When EPA began the model building process, several key decisions had to be made regarding the selection of the appropriate dependent and independent variables, the selection of appropriate data, the selection of an appropriate modeling method, and the choice of a simplification methodology. Each of these decisions is reviewed in detail in Sections B.1 through B.5 below.

Fuels can be characterized in terms of a number of different sets of fuel parameters. EPA used the results of individual fuel studies, input from its public workshops, preliminary test results, engineering intuition, available data, and ease of measurement to select the set of fuel parameters used to model exhaust emissions. The Complex Models include the effects of fuel benzene (for benzene emissions only), aromatics, olefins, RVP, E200, E300, sulfur, oxygen content and oxygenate type (for acetaldehyde and formaldehyde emissions only) on emissions. Other parameters were considered by EPA but rejected after considering the comments received at public workshops and the available test data.

In the February 1993 proposal, EPA represented distillation characteristics by parameters measuring the temperature at which specified <u>percentages</u> of the fuel would have evaporated, specifically T50 and T90 (representing the temperatures at which 50% and 90% of the fuel would have evaporated, respectively). At the time of that proposal, EPA indicated that it might replace these temperature-based parameters with parameters measuring the percentage of fuel that had evaporated at a specified <u>temperature</u>, specifically E200 and E300 (representing the percentage of fuel that would evaporate at 200 degrees Fahrenheit and 300 degrees Fahrenheit, respectively). Unlike the temperature parameters, the percent evaporated parameters for a mixture of two fuels can be estimated from a weighted average of the percent evaporated values of its constituent blends, thereby simplifying calculations for refiners and producers of gasoline. EPA has chosen to convert its models to a percent evaporated basis since the NPRM was issued, removing the T50 and T90 terms from its models in the process. The following correlations can be used to convert any temperature basis values to percent evaporated values:

$$E200\ (\%) = 147.91 - (0.49 \times T50(\text{in }^{\circ}F))$$
$$E300\ (\%) = 155.49 - (0.22 \times T90(\text{in }^{\circ}F))$$

These correlations were derived from the Complex Model fuels database. A linear regression model was used to relate all available E200 and E300 values to all corresponding T50 and T90 values in the database. Other non-linear relationships and regressions were investigated, but they gave no more accurate predictions and no greater explanatory power (in terms of the R^2 of the correlations) than the simple linear relationships shown above. Thus, EPA chose to use the linear relationships to convert temperature-based distillation parameters to a percent evaporated basis.

Separate models were developed for exhaust VOC, NOx, and exhaust emissions of the five air toxics specified in Section 211(k), specifically benzene, 1,3-butadiene, formaldehyde, acetaldehyde and polycyclic organic matter. Non-methane hydrocarbon (NMHC) was used as the VOC model's dependent variable for all runs; NMHC was converted to VOC by subtracting out the approximately constant ethane fraction of NMHC (see Sections III and IV.B.2).

1. Data Sources

Since no single study of the effect of fuel modifications on exhaust emissions was designed to look at effects of all fuel parameters independently across their full range, EPA chose to base its exhaust Complex Model on a number of studies. EPA used all data submitted as long as the following conditions were met:

- The data were based on valid tests.
- Data were submitted to EPA in time for development of the exhaust models.
- Data were based on tests of vehicles classified as having "1990 technology" by the vehicles' manufacturer.
- No evidence of inaccuracy, error, or unrepresentativeness existed in the data.

Each of these points are discussed in more detail in Sections A.1.a through A.1.c. Thus, the Complex Models described in this section are based on data generated from a number of different exhaust emission testing studies, rather than relying on the results of a single test program. These models will be used to estimate the exhaust emission performance of reformulated and conventional gasolines based on their fuel properties.

a. Included Studies

The Complex Model database for exhaust emissions includes data from the following studies:

- **EPA's Emission Factors (EF) testing program**, which is designed to examine the effect of oxygenates on emissions. Valid emissions data acquired through approximately August 20, 1992 were used from the EF testing program.

- **The Auto/Oil Test Program**: This program included a number of distinct studies sponsored jointly by companies in the automobile and oil industries. The AMOT study (**Auto/Oil-I**) was parametrically designed to examine the effects of aromatics, olefins, T90 and oxygen (in the form of MTBE) on emissions. All possible combinations of high and low values of each parameter were tested. The Phase I and Phase II sulfur studies (**Auto/Oil-II and VIII**) were designed to determine the effects of different sulfur levels on emissions. The RVP/Oxygenate study (**Auto/Oil-VI**) was designed to isolate the effects of MTBE, ETBE, and ethanol at different RVP levels on emissions. The TAME study (**Auto/Oil-IX**) was designed to investigate the effects on emissions when using TAME as the oxygenate. Matrix A, Matrix A2 and Matrix B heavy hydrocarbon studies which were designed to investigate the effects of E200 and E300 on exhaust emissions.

- The RVP/Oxygenate study sponsored by General Motors, the California Air Resources Board, and the Western States Petroleum Association (**GM/CARB/WSPA**), which examined the effects of RVP, the driveability index (defined as [T10 + (3 x T50) + (1.5 x T90)]), and different oxygenates on emissions.

- The RVP/Oxygenate and Aromatics studies sponsored by the American Petroleum Institute (**API-RVP/OXY and API-Aromatics**). The API aromatics study was designed to analyze the effects of different types of aromatics on emissions; the API-RVP/OXY study was designed to determine the effect of RVP, different oxygenates, and temperature variations on emissions.

- Phase I and Phase II of EPA's reformulated gasoline testing program, performed at Automotive Testing Laboratories (**ATL-I and ATL-II**). ATL-I was designed to examine the effects of sulfur, RVP, oxygen content, and T90 on emissions. ATL-II was designed to study the effects of oxygen content, oxygenate type, T50, T90, distillation end point, olefins and heavy end aromatics on emissions.

- **ARCO's EC-X study**, which was designed to examine the effects of severe, multi-parameter reformulations (involving changes in fuels' oxygen, sulfur, distillation parameter, aromatics, and olefin levels) on emissions.

- Chevron's distillation studies (**Chevron studies A-F**), which examined the effects of T90, T50, T10, driveability index, aromatics, and RVP on emissions.

- **UNOCAL's reformulated gasoline study (#514C)**, which was designed to study the effects of T10, T50, T90, fuel octane, oxygen content, paraffins, olefins, RVP and aromatics on emissions.

Additional information on the scope and intent of these studies can be found in Air Docket A-92-12 [#II-G-1, December 1990; #II-G-2, January 1992; #II-G-3, January 1992; #II-G-4, February 1992; #II-G-5, April 1992; #II-G-6, July 1991; #II-G-7, July 1991; #II-G-8, #II-G-9, February 1992; #II-G-10, February 1991; and #II-G-11, February 1992].

b. Excluded Studies

Not all of the studies received by EPA were used to develop the Complex Model. Studies were excluded from the database if they did not meet the following conditions:

- The study must have based its emissions measurements on appropriate Federal Test Procedure (FTP) driving cycles, vehicle preparation cycles, and measurement procedures. Emission measurements on different driving cycles are not comparable to one another.

- The study must have tested at least one 1990 technology vehicle [see EPA memorandum "1990 Baseline Vehicles," by Korotney and Machiele in Air Docket A-92-12, November 30, 1993], since vehicles that did not have 1990-equivalent technology were excluded from the database. As discussed in the preamble to this rule, Congress specified that the emissions performance of fuels were to be based on their performance in 1990 vehicles. EPA has interpreted this requirement to extend to vehicles from other model years having emission characteristics and emission control technologies that were present in 1990 model year vehicles, since such vehicles should respond similarly to fuel modifications.

- The study results must have been submitted to EPA in time for development of the Complex Model, i.e., by June 1993.

- The study must have included vehicles from more than one manufacturer in order to avoid bias that would not be captured in EPA's technology group distinctions (discussed in Sections IV.A.2.d and III.B.4). For example, each manufacturer employs different catalyst designs and computer controls that are not reflected in EPA's technology group distinctions. A study which included only one manufacturer's vehicles might detect emission effects peculiar to that manufacturer's vehicles.

- The study must have included sufficient quality control measures to separate fuel effects from vehicle effects. Vehicle effects account for as much as 90% of the observed variation in emissions and could, if not properly controlled, overwhelm the effects of fuel modifications.

Studies received by EPA that failed to meet one or more of these criteria included: (1) The NIPER study, which contained no vehicles with 1990-equivalent technology, (2) Toyota's reformulated gasoline study, which included a small number of Toyota vehicles and no vehicles from other manufacturers, and (3) Auto/Oil's high emitter study, which did not maintain adequate quality controls as discussed in Section A.1.c.

c. Excluded Tests

As discussed previously, all data were included in the database unless strong evidence of inaccuracy, gross error, or unrepresentative data existed. EPA recently revised its definition of volatile organic compounds (VOCs) [see 57-FR-3941, February 3, 1992 for details] to exclude methane, ethane and various other substances, since these compounds have reactivities that are considerably less than other hydrocarbon compounds. Since the Clean Air Act requirements for reformulated gasolines call for reductions in "ozone forming volatile organic compounds" (hereafter VOC's), EPA also excluded data in specific tests from the database used to model VOC emissions if such tests did not measure methane as well as total hydrocarbons. EPA has found that the methane fraction of total hydrocarbon emissions tends to be large and displays considerable variation across different fuel reformulations. For tests that measured methane and total hydrocarbons, the methane fraction averaged 14% but ranged from 6% to 22%. EPA has been unable to develop a model that accurately predicts methane emissions or methane fraction of total hydrocarbon emissions. Ethane, by contrast, comprises a relatively small portion of hydrocarbon emissions, averaging 2.95% by mass of nonmethane hydrocarbons. In addition, EPA has found the ethane fraction to be relatively stable (±0.9%) across different fuel reformulations.

Because of this variation in methane fraction, EPA has concluded that a model based on total hydrocarbons cannot be used to estimate VOC (i.e., nonmethane, nonethane hydrocarbons). EPA has concluded, however, that a model based on NMHC can be used to estimate VOC since ethane is a small and relatively constant fraction of NMHC. Some studies measured NMHC emissions directly; other studies measured total hydrocarbon and methane emissions separately, which allows calculation of NMHC via simple subtraction. Approximately 20% of the data available to EPA in studies that met the requirements outlined in Section A.1 above contained neither separate methane and total hydrocarbon measurements nor direct NMHC measurements. These data were excluded from the database used to develop the complex exhaust VOC model.

In certain situations, the equivalence ratio (EQR), a calculated quantity which measures the ratio of the actual air:fuel ratio to the ideal air:fuel ratio, has been found to have a very strong influence on emissions [A-92-12 Docket submittals #IV-E-3, December 1992; #II-E-6, December 1992; and EPA memorandum by Rao and Sklar "Analysis of EQR for high emitting vehicles," December 1993]. High variability in EQR is correlated strongly with high variability in measured emissions. High variability in EQR occurs more often in higher emitting vehicles than in normal emitting vehicles (the distinction between normal and higher emitters is discussed in greater detail in Sections IV.A.2.d and III.B.4). EPA's analysis showed that higher emitting vehicles that are not stabilized [A-92-12 Docket submittals #II-B-14, February 1993; and #II-B-12, February 1993] prior to emissions testing exhibit large variations in both EQR and exhaust emission levels. For this reason, data from higher emitting vehicles which were not stabilized prior to being tested were excluded from the database. This led to the exclusion of the entire Auto/Oil high emitter study, as well as all data from higher emitting vehicles tested in the EPA/EF emissions factor testing program.

Finally, all data from tests on Fuel W in EPA's ATL-II program were excluded from the database. Fuel W was created by blending pure chemicals, instead of being composed of typical refinery streams; over one-fourth of the fuel consisted of pure cyclohexane. Since Fuel W's emissions effects differed dramatically from the emissions effects from gasolines with nearly identical sulfur, aromatics, olefin, E200, E300, oxygen, and RVP levels, and since Fuel W's chemical composition differed dramatically from such gasolines, EPA chose to exclude all Fuel W data from the Complex Model database.

d. Excluded Vehicles and 1990 Model Year Technology Vehicles

Section 211(k)(10)(A) of the Clean Air Act requires that the effectiveness of reformulated gasolines be determined in reference to representative model year 1990 vehicles. As discussed in the SNPRM [57 FR 13416 (April 16, 1992)], EPA determined it was reasonable and necessary to look at '1990 technology type' vehicles. This decision was made because: (1) vehicles with similar engine designs, fuel distribution systems, and emission control systems would be expected to respond similarly to fuel changes and (2) much more data is available on emission effects of fuel changes from this expanded set of vehicles than on 1990 model year vehicles alone [see EPA memorandum in docket from Lindhjem to Rykowski, "Effect of Oxygenates on Emissions," December, 1993].

Vehicles included in the studies discussed above were classified as having '1990 technology' if they met both of the following criteria:

(1) The vehicles must be of model year 1986 or later with adaptive learning technology, since over 99% of 1990 vehicles utilized such technology.

(2) The manufacturer of the vehicle must have informed EPA that one or more of its 1990 model year vehicles had engine, fuel distribution, and emission control system designs similar to those on the vehicle in question [see EPA memorandum "1990 Baseline Vehicles," by Korotney, November 30, 1993, in Air Docket A-92-12 for more details].

A list of the included vehicles are given in the vehicles database portion of the Complex Model database, which is reproduced in Appendix IV-F.

2. General Model Specifications

a. Dependent Variables

Based on input from industry, other government agencies and other interested parties, EPA decided to use the natural logarithm (ln) of gross emissions as the dependent variable for all pollutants. Modeling in log space (in which the dependent variable is the natural logarithm of mass emissions per mile) has several distinct advantages [see A-92-12 Docket submittals #II-E-1, August 1992; II-E-2, August 1992; II-E-3, August 1992; II-E-4, August 1992; and II-E-5, June 1992]. First, it increases the explanatory power of the model by increasing the correlation coefficient between emissions and fuel parameters. Second, EPA found that models in log space have more normally distributed residuals (the variation in the dependent variable that cannot be explained by the model) than did models which were not logarithmically transformed. A normal distribution of residuals allows the use of a wide array of powerful statistical tools and standard regression techniques, which enhances the quality and usefulness of the model. Finally, heteroskedasticity (in which the variance of the error differs for different values of the independent variables) is reduced when emissions are transformed using natural logarithms. NMHC and NOx were modeled on a ln(grams/mile) basis while all air toxics were modeled on a ln(milligrams/mile) basis. As discussed in Section A.1, all tests for which methane measurements were not available had to be excluded from the regressions when modeling NMHC emissions. NMHC data were converted to VOC by subtracting the average fraction of ethane.

b. Independent Vehicle Variables

Only vehicles with 1990-equivalent technology were used in developing the regression models for all pollutants. The definition of 1990 technology was specified by the each manufacturer as detailed in Section A.1. Data from any vehicle that did not meet the appropriate 1990 technology definition were excluded from the regressions.

As discussed earlier, the vehicle itself is the dominant influence on emissions from any vehicle-fuel combination. This effect was modeled by including separate independent variables for each vehicle. Dummy variables were used to account for these effects, since they enable the isolation of the vehicles' effects on emissions from fuel effects and are a standard regression technique for handling categorical variables [see Hocking, R.R. (1976), "The Analysis and Selection of Variables in Linear Regression," Biometrics, 32, 1-50.], which take on discrete values. Some vehicles were tested in more than one study. In such cases, separate dummy variables were included for each vehicle in the study in order to minimize "drift" in vehicle emission levels over time and lab-to-lab measurement variation. For each study-vehicle combination, a dummy variable was defined as "1" for observations providing data on the study-vehicle combination and "0" for all other observations. In addition, EPA chose to use a no-intercept model in order to isolate all vehicle effects. EPA found that models with intercepts tended to be biased and did not properly account for vehicle effects. Hence the number of dummy variables in the model for each pollutant equals the number of vehicle-study combinations for which emissions data on that pollutant were available.

c. Independent Fuel Variables

The independent fuel variables were chosen after careful consideration of data availability, expected contribution to emissions based on outside comments and engineering intuition, and preliminary test results. As detailed in Section A.1.a, the independent fuel variables for exhaust VOC, NOx, and 1,3-butadiene emissions included oxygen, sulfur, aromatics, olefins, E200, E300, and RVP. For exhaust benzene emissions, fuel benzene content was added to the list of independent fuel variables. For exhaust formaldehyde and acetaldehyde emissions, the independent fuel variables included aromatics, olefins, E200, E300, sulfur and RVP, as well as separate variables for oxygen content in the form of tertiary amyl methyl ether (TAME), ethanol (ETOH), methyl tertiary butyl ether (MTBE), and ethyl tertiary butyl ether (ETBE).

The fuel components of exhaust emissions were separated into two main categories for the VOC and NOx models. The first category consisted of the effects of individual fuel parameters on emissions. This effect could not always be modeled with a simple linear term relating the fuel parameter to the natural logarithm of mass emissions. In many cases, an additional squared fuel term was required to adequately describe the emissions effect of an individual fuel parameter. The second category of fuel terms consisted of interactive effects between two different fuel parameters. These terms were modeled as a product of the two fuel parameters of interest. Due to the paucity of toxics data, the poorer relative precision of toxics emission measurements when compared to NMHC and NOx measurements, and the limited understanding of fuel effects on toxic emissions, toxics emission models included only linear fuel terms. Initially, EPA chose to pre-exclude all interactive terms from the four toxics models but to allow all squared terms. However, EPA analyses [see EPA memorandum "Alternative Exhaust Benzene Complex Models," from Rao and Sklar to Air Docket A-92-12, December 7, 1993] showed that adding the squared terms to the toxics models did not improve their explanatory power while introducing unexplainable behavior into the models. For these reasons, the toxics models included only linear fuel terms. The specifics of how particular terms were introduced into the model is discussed in Sections A.3 and A.4 below.

The fuel variables were modeled in centered form during the development of the Complex Model (see model development sections below). A centered variable is one in which the variable is expressed as a deviation from some intermediate value in the regression equations rather than being expressed directly. EPA used centered independent fuel variables in developing the Complex Model to minimize collinearity problems. Once the regression were completed, however, EPA chose to simplify the resulting emission models by removing the centering values. This "uncentering" procedure requires algebraic manipulation of the centered regression equations to remove the centering values, yielding equations that contain the uncentered variables. This process is discussed in Section A.8.

d. Emitter Class and Technology Group Distinctions

Emission studies conducted by EPA and others have shown that different vehicles have different emission characteristics. Differences in vehicles' emission control technologies and differences in the state of operation of those technologies account for some of these differences. For these reasons, EPA hypothesized that fuel modifications would have different emission effects on different types of vehicles. To account for these differences, EPA's February 1993 proposal divided vehicles into two "emitter classes" (normal and higher emitters) based on their exhaust emission levels and modeled the response of each emitter class to fuel modifications separately. For the final Complex Model, EPA modeled higher emitters separately and then incorporated the adjustment terms developed from the higher emitter model into an overall in-use model, as discussed in Section A.3 in greater detail [see A-92-12 Docket submittals #IV-B-01, August 1992; IV-B-4, July 1993; IV-E-1, June 1992; and IV-E-6, May 1993 for more details]. These changes were made in response to EPA's evaluation of its proposed model and comments received regarding the regression approach used to develop the NPRM model. EPA continues to believe that the distinction between normal and higher emitters to be both valid and necessary since normal and higher emitters appear to respond differently to many fuel modifications.

In the NPRM, EPA further subdivided vehicles in each emitter class into "technology groups" based on emission control technology with which each vehicle was equipped. Categorization of vehicles into technology groups was used to explicitly account for the effects of differences in emission control technology, which were the basis for the technology group definitions. These control technologies included catalyst type, fuel distribution system, EGR, air injection. The technology group distinctions also implicitly accounted for other vehicle characteristics such as engine design and engine control system, to the extent such characteristics were correlated with specific technology groups.

However, as discussed in the February NPRM, EPA was concerned that technology group distinctions among higher emitters might not be appropriate, since such vehicles' higher exhaust VOC emission levels suggest that their emission control systems do not function properly. In addition, the limited quantity of higher emitter data made it difficult to identify statistically significant differences in emissions response between different technology groups within the higher emitter class of vehicles. The limited higher emitter data caused higher emitter models developed for individual technology groups to have low statistical power and poor fit. Many commenters expressed identical concerns.

Efforts to subdivide higher emitters by characteristics such as exhaust hydrocarbon to NOx ratio, as suggested by several commenters, did not improve the quality of EPA's higher emitter model [see EPA memorandum "Proposed Revisions to Technology Group Definitions for Use in Exhaust Complex Model," from Sklar, Lindhjem and Rao, December 2, 1993]. Thus, EPA's final exhaust models do not divide higher emitters into technology groups. Technology group specific terms were retained when modeling normal emitters, for the reasons discussed in the February 1993 Draft RIA and the April 1992 proposal. However, EPA's final model limits the use of technology group specific effects to represent statistically significant deviations from the average effect across all vehicles, as discussed more fully in the model development section (Section A.4). In response to other comments, EPA attempted to reduce the number of normal emitter technology groups. However EPA was unable to identify an appropriate basis for consolidation and/or combination of the various technology groups [see EPA memorandum "Proposed Revisions to Technology Group Definitions for Use in Exhaust Complex Model," from Sklar, Lindhjem and Rao, December 2, 1993]. EPA considers its retention of emitter class and technology group distinctions to be validated by the presence of emitter class and technology group-specific fuel effects in its final Complex Models presented below.

e. Technology Group and Emitter Class Definitions and Weightings

EPA analyzed emissions data on different technology groups separately since emissions control system designs were expected to respond differently to changes in fuel parameters. These differences have been shown to exist in previous EPA analyses [see EPA memorandum "Effect of Oxygenates on Emissions," from Lindhjem to Rykowski, December, 1993] as well as in the emissions predictions from the February NPRM models. Technology groupings were based on four criteria:

- Fuel delivery system (carburetted, throttle body injection or port fuel injection)
- The presence or absence of exhaust gas recirculation (EGR)
- The presence or absence of air injection
- Catalytic converter type (three-way, three-way plus oxidation catalyst, etc.)

Of the possible combinations based on these four criteria, only the nine most common technology groups were used to develop the model. These nine technology groups encompassed over 99% of 1990 model year sales of cars and light-duty trucks (as discussed in Section E and in the April 1992 SNPRM [92]). Table IV-1 summarizes the definitions of these nine technology groups and the percentage of 1990 vehicle sales accounted for by each group.

Table IV-1
Technology Group Definitions and Sales Weights*

TECHNOLOGY GROUP	FUEL SYSTEM	CATALYST	AIR INJECTION	EGR	PERCENT 1990 SALES
1	Multi (PFI)	3W	No Air	EGR	26.31
2	Multi (PFI)	3W	No Air	No EGR	28.71
3	TBI	3W	No Air	EGR	21.81
4	Multi (PFI)	3W + OX	Air	EGR	11.43
5	Multi (PFI)	3W	Air	EGR	4.31
6	TBI	3W	Air	EGR	0.53
7	TBI	3W + OX	Air	EGR	5.25
8	TBI	3W	No Air	No EGR	0.00**
9	Carb.	3W +OX	Air	EGR	1.65

* Sales weights based on a non-California, 49 state analysis. See EPA memorandum Number IV-B-2 in Docket A-92-12 for more details.

** Projected sales for technology group 8 were non-zero, but actual reported 1990 sales for this technology group were zero.

where

Multi = Multi-Port Fuel Injection
TBI = Throttle Body Injection
Carb. = Carburetted

3W = Three Way Catalyst
3W+OX = Three Way Catalyst plus an Oxidation Catalyst

Air = Supplementary air injection present
No Air = Supplementary air injection not present

EGR = Exhaust gas recirculation used
No EGR = Exhaust gas recirculation not used

EPA has also analyzed the effects of VOC emissions levels on vehicle responses to fuel modifications. Higher vehicle emissions indicate that certain control technologies may not be functioning properly. Such vehicles have been shown in previous

EPA analyses [see EPA memorandum by Lindhjem "Effect of Oxygenates on Emissions," December, 1993] and in the February NPRM models to exhibit different emission responses to changes in fuel properties than normal emitting vehicles equipped with similar emission control technology. Depending upon the failure mode causing a vehicle to be a higher emitter, higher emitters may also exhibit different emission responses to changes in fuel properties than other high emitting vehicles. Because reliable data was not available as to the type of failure mode for vehicles considered to be higher emitters, vehicles were classified as either 'normal' or 'higher' emitters based on their total hydrocarbon emissions on a CAA-type base fuel on a standard FTP test. Vehicles with total hydrocarbon emissions less than twice the applicable standard (0.82 g/mi) were classified as normal emitters. EPA modeled normal and higher emitting vehicles separately to account for differences in the responses of such vehicles to fuel modifications.

As discussed in the February 1993 proposal, the weight assigned to each technology group or emitter class for modeling purposes was set equal to its contribution to in-use emissions. The weighting factor assigned to normal emitters was then broken down further by technology group, again according to their projected contribution to in-use emissions. These estimates are very similar to the numbers shown in the February 1993 proposal, although small changes have been made to account for more complete information about the fraction of 1990 sales accounted for by each technology group. The final in-use eighting factors for the eight normal emitter groups and the one higher emitter group are shown below in Table IV-2. The rationale, derivation and normalization of the weighting factors are discussed in more detail in Section III.B.4.

Table IV-2
Vehicle Group Weightings for the Exhaust Complex Model

Vehicle Group	Phase I		Phase II	
	VOC/Toxics	NOx	VOC/Toxics	NOx
Norm[*]-tg[**] 1	0.13986	0.19550	0.11942	0.17595
Norm-tg 2	0.12517	0.23430	0.10688	0.21087
Norm-tg 3	0.09592	0.14958	0.08190	0.13462
Norm-tg 4	0.09508	0.15023	0.08118	0.13521
Norm-tg 5	0.01475	0.02400	0.01260	0.02160
Norm-tg 6	0.00203	0.00349	0.00173	0.00314
Norm-tg 7	0.03905	0.04608	0.03334	0.04147
Norm-tg 9	0.00814	0.01682	0.00695	0.01514
Higher emitters	0.48000	0.18000	0.55600	0.26200

[*] "Norm" designates normal emitters
[**] "tg" designates technology groups

3. Development Method Overview

The overall process used by EPA to arrive at the final Complex Models for VOC, NOx and air toxics is summarized below. A more detailed discussion of the process can be found in the following sections.

1. A "raw" model was developed which contained all regression terms found to be significant in (1) a forward "stepwise" fit, (2) a re-regression on surviving terms after data outliers and influential points were excluded, (3) a re-regression after deleting terms based on Mallows' C_p criterion to balance overfitting and underfitting, and (4) a final backwards fit to eliminate insignificant terms. Steps 2-4 were not taken during development of the February 1993 NPRM model. These steps are discussed in detail in Section A.4.

2. The raw model was refined by deleting terms whose contribution to the model's explanatory power was small. In general, terms which contributed less than one percent of the model's explanatory power were deleted to produce a refined model which was simpler in form than the raw model without sacrificing its ability to predict the emissions impact of fuel modifications. Note that this step was not

taken during development of the February 1993 NPRM model. These steps are discussed in greater detail in Section A.5.

3. The refined model was simplified. Several commenters expressed concern about the complexity and number of equations in the final Complex Model. To address these concerns, two steps were taken. First, the technology group-specific models for normal emitters were consolidated into a single model for all normal emitters. Second, the fuel variables were uncentered. Both consolidation and uncentering are discussed in Section A.8.

The resulting exhaust emission models contain two equations for each pollutant (one for normal emitters and one for higher emitters). By contrast, the model proposed in February 1993 contained as many as sixteen separate equations for each pollutant. In addition, the final exhaust emission equations have fewer fuel terms than did the February equations. However, EPA does not believe that this less complicated complex model is any less accurate than the complex models presented at public workshops or in the February 1993 proposal. This belief is based on the final models' comparable explanatory power and accuracy in accounting for the emission effects seen in the vehicle testing programs that comprise the Complex Model database, as discussed in Section F.

4. Raw Model Development

As discussed previously, exhaust emissions are affected by both vehicle characteristics and fuel characteristics. This combined effect causes difficulty in trying to isolate the effects of fuel characteristics on emissions. EPA's analysis attempted to separate the vehicle and fuel components of exhaust emissions by using dummy variables to isolate the effect of vehicles on emissions. The vehicle was found to be the single most significant determinant of the level of emissions from a given vehicle on a given fuel, accounting for approximately 90% of the variation in emissions. Fuel properties were found to be a much smaller (5-6%) influence on variation in exhaust emissions. The remaining 4-5% of the variation in emissions remains unexplained.

EPA received a number of comments regarding the models proposed in February 1993. After careful consideration, EPA concluded that the following comments were valid and should be incorporated into its final models:

- Some commenters noted that many emission effects were likely to be consistent across technology groups or emitter classes. They suggested that EPA include such common effects in its models before resorting to technology group-specific or emitter class-specific terms to model vehicles' emissions response to fuel modifications.

- Commenters noted that insufficient data were available to model many potential terms, particularly interactive terms, and that such terms should not be allowed to enter the model.
- Commenters argued that in the case of higher emitters, EPA's models relied on a small fraction of the database to model a large fraction of the in-use emissions. They argued that EPA should have used the more complete data on normal emitters to model higher emittters' response to fuel modifications.

While EPA does not believe that normal emitter data alone should be used to build the higher emitter models, EPA agrees that the normal emitter model, which is based on a more extensive and complete data set than is available for higher emitters, should form the basis of the higher emitter model. EPA used data on higher emitters to develop adjustment terms that reflect the difference between normal and higher emitter responses to fuel modifications.

To incorporate the concerns raised in these comments, EPA has utilized a modified version of the "unified" approach advocated by a number of commenters to develop its final complex models. The techniques used to address these comments are summarized below and are discussed in greater detail in Sections A.4.a and A.4.b:

1. Interactive terms were permitted to enter the model only when sufficient data were available. The February 1993 models included all statistically significant interactive terms, regardless of whether sufficient data were available to estimate such an effect.

2. Models for higher emitters were constructed based solely on data from such vehicles in order to determine which fuel terms had statistically significant effects.

3. The entire database was analyzed using the "unified" approach. The effects of each term on emissions was divided into two parts: an average effect across all vehicles, and a series of adjustment terms for each technology group and for higher emitters. Higher emitter adjustment terms were forced into this model for all terms found to be statistically significant in the higher emitter model, in order to assure that such effects were not obscured by the disproportionately large share of the data on normal emitters.

4. Overly influential data were dropped from the database and the model was re-estimated based on the remaining data (see Section A.4.a for further discussion of influential data).

5. Terms were deleted from the developed model to avoid overfitting and collinearity problems. Mallows' C_p criterion was used to assess the problem of overfitting.

6. The overall fuel terms and the corresponding fuel adjustment terms (for the different technology groups) were computed in the following manner:

    a. An overall effect for the fuel term was estimated using all available data in the database.

    b. The difference between the overall effect and the effect for each vehicle group was identified.

    c. If the difference was significant for one or more vehicle groups, the vehicle group adjustment term with the difference that is the most significant was chosen.

    d. Repeat steps b-c for the remaining vehicle groups until there are no more significant vehicle group adjustment terms.

These approaches were designed to take advantage of the benefits of a regression on the entire database (a "fully unified" approach) without losing sight of the unique behavior of higher emitters. Since higher emitters were severely under-represented in the complex model database compared to their contribution to in-use emissions, EPA believed that a fully unified approach would not have represented higher emitter effects properly. However, the partially unified approach used by EPA allowed the Agency to simplify its emission models without losing explanatory power. By using technology group-specific adjustment terms only if the technology group's response to fuel modifications was sufficiently consistent in nature and different in magnitude from the average normal emitter response, EPA was able to rely on the same set of terms to explain fuel effects across all eight normal emitter technology groups. In the NPRM model, different terms were permitted in each technology group-specific model. As a result, the model for one technology group might include one fuel term instead of another fuel term that might represent the data equally well, while the model for a second technology group might include the second term but not the first. The partially unified approach applied the same term to both groups and only permitted additional terms to enter the model if both the common term and the additional terms were necessary to adequately model the data. A copy of the SAS program used to develop the final complex models for all pollutants can be found in Appendix IV-E.

a. Statistical Development of VOC and NOx Exhaust Models

The final VOC and NOx models are similar to the most accurate of the three sets of models included in EPA's July 14, 1993 docket submittal [A-92-12 Docket submittal #IV-B-4, July 1993], while also including relevant comments regarding specific aspects of the models [see Section B.10]. The following step-by-step procedure was used to develop the "raw" VOC and NOx exhaust emission models.

1. The database was reviewed to ensure that specific studies and observations were excluded according to the criteria outlined in Section A.2. After excluding this data, the database contained 5214 observations for NOx and 4287 observations for VOC (see step 3).

2. Each vehicle in the database was placed into a technology group and an emitter class. Higher emitters were defined as those vehicles which emit greater than 0.82 grams/mile of total hydrocarbons on a base fuel [see A-92-12 Docket submittal IV-B-3, June 1993]. The 0.82 grams/mile represents a cutpoint of twice the VOC emissions standard for cars. The small number of light duty trucks were classified as higher emitters using the same criterion.

3. Total hydrocarbon (THC) emissions were converted to non-methane hydrocarbons (NMHC) by subtracting measured methane emissions from total hydrocarbon emissions. As discussed above, this step can only be performed for those tests in which exhaust methane was measured; other tests were excluded from the database used to model exhaust VOC emissions.

4. Fuel oxygenate levels (in volume percent) were converted to fuel oxygen levels (in weight percent).

5. Mean values for each fuel parameter were calculated across all observations in the database. These values are given below:

    Oxygen: 1.774834 weight percent
    RVP: 8.611478 psi
    E200: 46.72577 percent
    E300: 85.89620 percent
    Sulfur: 204.5779 ppmW
    Olefins: 7.318716 volume percent
    Aromatics: 28.26110 volume percent

    These mean values were used as the centering values for each fuel variable in the regression.

6. Separate dummy variables were included in the regression models for for each vehicle-study occurrence (for the reasons discussed in previous EPA submittals to the docket).

7. A model for higher emitting vehicles was constructed according to the following procedure:

   a. The vehicle-by-study dummy variable terms were included in the model.

   b. The following terms were pre-excluded from the higher emitter VOC and NOx models (details of this step are discussed in step 10 below):

      OXY*E200
      OXY*ARO
      OXY*OLE
      SUL*E200
      ARO*SUL
      SUL*OLE
      SUL*RVP
      E200*E300
      E200*ARO
      E200*OLE
      E200*RVP
      OLE*RVP
      E300*RVP
      ARO*RVP

   c. A stepwise regression on the higher emitter data was performed, with the first step including all linear fuel terms.

   d. In subsequent steps, fuel terms which were statistically significant at the 0.10 level were added to the model. The first step included the vehicle-study dummy variable terms (from step a) and the linear fuel terms. Next, higher order terms (squared and two-parameter interactive terms) were added to the model using a stepwise regression procedure if they were significant at the 0.10 significance level, in keeping with standard EPA practice. The February 1993 proposal used a significance level of 0.15.

   e. Once the stepwise model for higher emitters had been constructed, Mallows' C_p criterion was used to eliminate terms from the model. The C_p criterion was proposed by Mallows [Mallows, C.L. (1973), "Some Comments on Cp," *Technometrics*, 15, 661-675] for selecting a model and is a measure of total squared error. If C_p is plotted against the number of independent parameters (p) in the model, Mallows recommends the model where C_p first approaches p. When such a model is chosen, the parameter estimates are most unbiased and the risk of not including an additional and possibly valid parameter is balanced by the risk of adding an invalid parameter.

   f. A backwards-elimination regression was run to remove linear fuel terms that were no longer significant at the 0.10 level, unless such terms were necessary for hierarchy considerations (as discussed below).

g. A separate higher emitter adjustment term was forced into the "unified" models for VOC and NOx described below for each fuel term remaining in the corresponding higher emitter model resulting from step f. The adjustment terms were the interactions of each significant fuel term with a dummy variable designating the higher emitter vehicle group.

8. A "fully unified" model was constructed as discussed below in steps 9-14.

9. The vehicle-study terms and the overall linear fuel terms were forced into the model. Adjustment terms for higher emitters based on the results of step 7 were also forced into the model.

10. Certain interactive fuel terms were not permitted to enter the model, i.e., they were pre-excluded from the model. Sufficient data did not exist to incorporate all possible fuel terms into the VOC and NOx models. In addition, research into engine-out versus tailpipe emissions indicated that some fuel properties affected catalyst performance alone, while other fuel properties affected combustion efficiency alone. Interactive effects between such properties were considered improbable since different vehicle components are involved. Statistical considerations such as variance inflation also indicated that certain fuel terms should not be permitted to play a role in the models. Variance inflation is an indication of the degree of multicollinearity between two or more fuel parameters. "Large" values (in excess of ten) of variance inflation could lead to serious distortions of regression coefficients. For these reasons, which are discussed in greater detail in EPA's July 14, 1993 docket submittal, the following terms were pre-excluded from the normal emitter NMHC and NOx models:

OLE*SUL
ARO*E200
RVP*E300
OLE*E200
RVP*SUL
ARO*RVP
E200*OXY
E200*RVP
E200*SUL
OLE*RVP
E200*E300

11. The stepwise regression procedure in SAS was used to add terms to the models. Non-linear overall fuel terms (e.g., two-way interactions and squared terms) and normal-emitter adjustment terms specific to individual vehicle groups were added if they were statistically significant at the 0.10 level. The terms described in step 10 were not permitted to enter the model, either as overall terms or adjustment terms.

12. As with the higher emitter model developed in step 7, the model resulting from step 11 was evaluated using Mallows' C_p criterion to balance overfitting and underfitting. This step also helped remove terms with significant variance inflation values, which are indicative of collinearity between terms in the model.

13. Outliers and influential points were removed from the data set and the coefficients for the terms in the model generated in step 12 were re-estimated. Emissions results that are very different from model predictions can have a large impact on the resulting model. These extreme results can be caused by a number of factors that should not be permitted to affect the Complex Models:

    - Errors may have been made in measuring or recording emission or fuel parameter levels

    - Vehicles may have been placed in the wrong technology group or emitter class, or it could have had pre-1990 emission control technology

    - The results may be due to the inherent variability of vehicle emissions.

    Such errors can occur during tests of fuels that are significantly different from other fuels or of vehicle types that are relatively uncommon. In such cases, the erroneous results can distort the regression results significantly since countervailing data from other fuels or vehicles would not be available.

    This problem was addressed by removing such observations from the database and re-estimating the regression equations with the remaining data. Outliers were defined as having an $R_{student}$ value greater than an absolute value of 4 (i.e., they lie more than four standard deviations away from the mean regression result). The probability of a deviation of this size being due solely to the inherent variability of vehicle emissions is less than 0.5 percent. Influential points were defined as having a DFFITS value greater than 1.2. DFFITS provides an estimate of the degree to which the observation, by itself, alters the regression equation. Standard statistical practice is to consider observations with DFFITS values in excess of 1.0 to be overly influential. EPA relaxed this criterion slightly in recognition of the limited data available for many fuel parameter combinations and vehicle types, thereby retaining some observations that arguably could have been excluded. The number of data excluded in this step was small relative to the total number of data available, amounting to approximately 1.6% of the normal emitter VOC data, 1.8% of the higher emitter VOC data, 1.0% of the normal emitter NOx data, and 0.9% of the higher emitter NOx data.

14. To ensure hierarchy (put simply, ensuring hierarchy requires that if an interactive fuel term A*B is in the model, the individual fuel parameters A and B also must be included in the model) while also ensuring that the model was parsimonious in its choice of terms, a series of backwards-elimination runs were conducted to eliminate terms in the model developed in step 13 that were no longer statistically significant at the 0.10 level. Such terms include the linear overall terms and the higher emitter adjustment terms, which were forced into the model initially. In addition, the variance inflation for the remaining terms was examined to assure that the models were free of severe multi-collinearity problems.

    In the first backward elimination run, the nonsignificant nonlinear fuel terms were removed from the model. Mallows' C_p criterion was used to determine the useful terms. In the second backward elimination run, the nonsignificant higher emitter adjustment terms were removed from the model. Again, Mallows' C_p criterion was utilized. In the final backward elimination run, the nonsignificant nonhierarchial linear fuel terms (i.e., those not included in any significant higher-order fuel terms) were removed from the model. Mallows' C_p criterion was utilized to balance overfitting and underfitting.

EPA also reviewed the resulting models for their statistical soundness and overall reasonableness. The SAS code used to arrive at these models can be found in Appendix IV-D-4. The regression coefficients resulting from this methodology are shown in Section A.5 below.

b. Statistical Development of the Toxic Exhaust Models

EPA modeled exhaust toxics emissions in a similar fashion to the method used to develop the VOC and NOx models. All five of the toxic air pollutants that the Clean Air Act specifies for control through reformulated gasoline (benzene, acetaldehyde, formaldehyde, 1,3-butadiene and polycyclic organic matter) are also considered VOCs and are present in exhaust emissions. Benzene is a natural component of gasoline, so exhaust benzene emissions include both unburned benzene and benzene formed in the combustion process through the partial decomposition of more complex aromatic compounds. The four other toxics are not present in gasoline and hence are solely products of combustion.

The work discussed in the SNPRM [92] indicated that exhaust toxics were best characterized in terms of the mass fraction of total VOC emissions. This mass fraction could be multiplied by total VOC emissions to determine mass emissions of toxic compounds. During development of the Complex Model, however, EPA and others found that exhaust toxics models based on milligrams emitted per mile yielded better correlations than models based on the fraction of total VOC emissions. For this reason, EPA chose to construct models to estimate the natural logarithm of toxics emissions (expressed in terms of mg/mile).

Only a few of the studies described in Section A.1 measured exhaust toxic emissions. Hence less data were available for toxics emissions from both normal and higher emitters than were available for VOC or NOx emissions. As a general rule, less data for exhaust toxics than for exhaust VOC or NOx meant that fewer independent fuel variables could be included in the toxics models. For its final toxics models, EPA elected to use only linear fuel terms, eliminating the squared and the two-parameter interactive terms found in the models with more data. EPA concluded that the resulting increase in the accuracy of the linear term coefficient estimates more than offset any reductions in accuracy resulting from exclusion of nonlinear terms. This conclusion is supported by EPA's efforts to develop a number of nonlinear models, all of which had poorer explanatory accuracy than EPA's linear toxics models [see EPA memorandum by Rao and Sklar "Alternative Exhaust Benzene Complex Models," December 2, 1993].

As with the VOC and NOx models, a "partially unified" model was built for each exhaust toxic pollutant. Normal emitter technology group distinctions were retained while all higher emitting vehicles were placed in a single group. The general methodology used to develop the toxic models was essentially the same as that used in developing the VOC and NOx models and is outlined below.

1. Same as step 1 described in Section A.4.a.

2. Same as step 2 described in Section A.4.a.

3. Same as step 4 described in Section A.4.a.

4. The mean fuel parameter values used were identical to those used in step 5 in Section A.4.a for the exhaust 1,3-butadiene toxic model. The exhaust aldehyde models were oxygenate specific and thus the following values were used as the mean values for the different oxygenates (the other fuel parameter centering values are identical to those given in Section A.4.a step 5). The mean value of fuel benzene content is given below for use in the exhaust benzene model:

MTBE:	0.947240 weight percent
ETBE:	0.023203 weight percent

TAME: 0.016443 weight percent
Ethanol: 0.314352 weight percent
Benzene: 1.066682 volume percent

5. Same as step 6 described in Section A.4.a.

6. A higher emitter model was constructed in a manner analogous to that discussed in step 7 of Section A.4. The specific steps followed are outlined below:

    a. Dummy variables for each vehicle-study occurrence were forced into the model.

    b. The following terms were permitted to enter the model via a stepwise regression if they were statistically significant at the 0.10 level (note that in the February 1993 NPRM, terms were included if they were significant at the 0.15 level):

    For BENZENE: Oxygen, Aromatics, Olefins, E200, E300, RVP, Sulfur and Benzene

    For BUTADIENE: Oxygen, Aromatics, Olefins, E200, E300, RVP and Sulfur

    For ACETALDEHYDE: TAME, Ethanol, MTBE, ETBE, Aromatics, Olefins, E200, E300, RVP and Sulfur

    For FORMALDEHYDE: TAME, Ethanol, MTBE, ETBE, Aromatics, Olefins, E200, E300, RVP and Sulfur

    d. Terms were eliminated using Mallows' C_p criterion, thereby balancing overfitting and underfitting risks.

    e. Outliers and influential points, defined using the same criteria described in Section A.4.a, were eliminated and the model was re-estimated.

    f. A backward-elimination regression was used to remove non-significant fuel terms.

    g. For each term identified and retained after step f above, force a separate higher emitter adjustment term into the "partially unified" model described below.

7. "Unified" models for each toxic pollutant were built, as described in steps 9-14. The process was similar to that used to build the VOC and NOx models, as described in Section A.4.a. Outliers and influential points that were

removed in step 7 when building the high-emitter models described in step 7 were re-included in the database. They were removed in step 12 if they were still outliers.

8. The vehicle terms and the higher emitter adjustment terms from step 7 were forced into the models.

9. Models for each toxic pollutant were built stepwise, in a manner similar to the way the VOC and NOx models were built. The following terms were allowed to enter the model as either overall terms or as adjustment terms for normal emitter technology groups via the stepwise process if they were statistically significant at the 0.10 level:

    For BENZENE: Oxygen, Aromatics, Olefins, E200, E300, RVP, Sulfur and Benzene

    For BUTADIENE: Oxygen, Aromatics, Olefins, E200, E300, RVP and Sulfur

    For ACETALDEHYDE: TAME, Ethanol, MTBE, ETBE, Aromatics, Olefins, E200, E300, RVP and Sulfur

    For FORMALDEHYDE: TAME, Ethanol, MTBE, ETBE, Aromatics, Olefins, E200, E300, RVP and Sulfur

10. The C_p criterion was applied to the models resulting from step 9. This step resulted in terms being eliminated from the models when the models' risk of being overfitted exceeded the risk of underfitting that would result from elimination of the term.

11. The model generated in step 10 was used to determine which observations were outliers or influential points, as defined in step 13 in Section A.4.a. These outliers and influential points were removed from the database.

12. A final stepwise backwards-elimination process was pursued to remove fuel terms that were no longer statistically significant at the 0.10 level until all remaining terms are statistically significant. This model was free of variance inflation problems.

13. Same as step 13 described in Section A.4.a.

5. Raw Version of the Exhaust Emissions Complex Model

Following the steps outlined in Section A.4 resulted in the derivation of the raw regression model coefficients shown below:

Raw Regression Coefficients for Exhaust VOC Emissions

Table IV-3

Fuel Term	Centered Raw Model Regression Coefficients for Exhaust VOC								
	TG* 1	TG 2	TG 3	TG 4	TG 5	TG 6	TG 7	TG 9	HIGH**
Oxygen	-.00293	-.00293	-.00293	-.00293	-.00293	-.00293	-.00293	-.00293	-.00293
Sulfur	.000531	.00035	.000531	.000802	.00090	.000187	.000531	.000531	-.000014
RVP	.03274	-.00006	.03274	.03274	.03274	.03274	.03274	.03274	.07378
E200	-.00782	-.00430	-.00430	-.00430	-.00430	-.00430	-.00430	-.00430	-.00430
E300	-.00757	-.00757	-.00757	-.00757	-.00757	-.00757	-.00757	-.00757	.00023
Aro	.00316	.00316	.00316	-.0008	.00316	.00316	.00316	.00316	.00316
Olefins	-.00251	-.00251	-.00251	-.00251	-.00251	-.00251	-.00251	-.00251	-.00251
Aro*E300	-.00029	-.00029	-.00061	-.00029	-.00029	-.00029	-.00029	-.00029	-.00029
E200^2	.000086	.000086	.000086	.000086	.000086	.000086	.000086	.000086	.000086
RVP*Oxy	-.00789	-.00789	-.00789	-.00789	-.00789	-.00789	-.00789	-.00789	-.00789
Sul*E300	.000016	.000016	.000016	.000016	.000016	.000016	.000016	.000016	.000016
Oxy*Sul	0	0	0	-9.3E-5	0	0	0	0	0
Sul^2	0	-1.3E-6	0	0	0	0	0	0	0
Aro^2	0	0	0	-.00031	0	0	0	0	0
E300^2	.000525	.000525	.000525	.000525	.000525	.000525	.000525	.000525	.000525

* "TG" denotes EPA technology groups

** "HIGH" refers to higher emitter model coefficients

Raw Regression Coefficients for Exhaust NOx Emissions

Table IV-4

Fuel Term	Centered Raw Model Regression Coefficients for Exhaust NOx								
	TG 1	TG 2	TG 3	TG 4	TG 5	TG 6	TG 7	TG 9	HIGH
Oxygen	.00309	.00309	-.01890	.00309	.00309	.00309	.00309	.00309	-.00887
Sulfur	.000706	.00046	.00046	-.00007	.00046	-1.5E-5	.00046	.00046	.00027
RVP	.011857	.011857	.011857	.011857	.011857	.011857	.011857	.011857	-.01627
E200	.000915	.000915	.000915	.000915	.000915	.000915	.000915	.000915	.000915
E300	.002465	-.00014	.002465	-.00312	.002465	.002465	.002465	.002465	-.00421
Arom	-.00113	.002143	.002143	.002143	.002143	.002143	.002143	.002143	.002143
Olefins	.00234	.00234	.00234	.00234	.00234	.00234	.00234	.00234	.00234
Sulfur^2	-1.7E-6	-1.0E-6	0	0	0	0	0	0	0
Arom^2	-5.8E-5	-.00021	-5.8E-5	-5.8E-5	-5.8E-5	-5.8E-5	-5.8E-5	-5.8E-5	-5.8E-5
E300^2	0	0	0	0	0	0	0	0	-.00057
Oxy*RVP	0	0	0	0	.024415	0	0	0	0
Oxy*Aro	0	-.00099	0	0	0	0	0	0	0
Oxy*Sul	-9.4E-5	0	0	0	0	0	0	0	0
E300*Ole	.000335	0	0	0	0	0	0	0	0
Oxy^2	0	0	.003359	0	0	0	0	0	0
Olefins^2	.000417	.000417	.000417	.000417	.000417	.000417	.000417	.000417	.000417

Raw Regression Coefficients for Exhaust Benzene Emissions

Table IV-5

Fuel Term	Centered Raw Model Regression Coefficients for Exhaust Benzene								
	TG 1	TG 2	Tg 3	TG 4	TG 5	TG 6	TG 7	TG 9	HIGH
Oxygen	0	0	0	0	0	0	0	0	-.09605
Sulfur	.001054	.000337	.001187	.000337	.000337	.000337	.000337	-.00195	.000337
RVP	0	0	0	0	0	0	0	0	0
E200	-.00948	0	-.00578	0	0	0	0	0	0
E300	0	0	0	0	0	0	0	0	.011251
Arom	.02588	.02588	.02588	.02588	.04859	.02588	.02588	.02588	.01188
Olefins	0	0	0	0	0	0	0	0	0
Benzene	.222318	.222318	.222318	.222318	.222318	.222318	.222318	.222318	.222318

Raw Regression Coefficients for Exhaust 1,3-Butadiene Emissions

Table IV-6

Fuel Term	Centered Raw Model Coefficients for Exhaust 1,3-Butadiene								
	TG 1	TG 2	TG 3	TG 4	TG 5	TG 6	TG 7	TG 9	HIGH
Oxygen	0	0	0	0	0	0	0	0	-.06077
Sulfur	.000506	0	.000544	-.00041	0	0	0	0	0
RVP	0	0	0	0	0	0	0	0	0
E200	-.00731	-.00731	-.00731	-.00731	-.00731	.00579	-.00731	-.00731	-.00731
E300	-.01678	-.01678	-.00625	-.01678	-.01678	-.01678	-.01678	-.01678	-.00806
Arom	-.00401	-.00401	-.00401	-.00401	-.00401	-.00401	-.00401	-.00401	-.00401
Olefins	.028238	.028238	.028238	.028238	.028238	.028238	.028238	.028238	.028238

Raw Regression Coefficients for Exhaust Formaldehyde Emissions

Table IV-7

Fuel Term	Centered Raw Model Coefficients for Exhaust Formaldehyde								
	TG 1	TG 2	TG 3	TG 4	TG 5	TG 6	TG 7	TG 9	HIGH
Sulfur	0	0	0	0	0	0	0	0	0
RVP	0	0	0	0	0	0	0	0	0
E200	0	0	0	0	0	0	0	0	0
E300	-.01023	-.01023	-.01023	-.01023	-.01023	-.01023	-.01023	-.01023	-.01023
Arom	-.00717	-.00717	-.00717	-.00717	-.00717	-.00717	-.00717	-.00717	-.00717
Olefins	0	0	0	0	0	0	0	0	-.03135
MTBE	.046213	.046213	.046213	.046213	.046213	.046213	.046213	.046213	.046213
ETBE	0	0	0	0	0	0	0	0	0
ETOH	0	0	0	0	0	0	0	0	0
TAME	0	0	0	0	0	0	0	0	0

Raw Regression Coefficients for Exhaust Acetaldehyde Emissions

Table IV-8

Fuel Term	Centered Raw Model Coefficients for Exhaust Acetaldehyde								
	TG 1	TG 2	TG 3	TG 4	TG 5	TG 6	TG 7	TG 9	HIGH
Sulfur	.000263	.000263	.000263	.000263	.000263	.000263	.000263	.000263	.000263
RVP	0	0	0	0	0	0	0	0	0
E200	0	0	0	0	0	0	0	0	0
E300	-.01216	-.01216	-.01216	-.01216	-.01216	-.01216	-.01216	-.01216	-.01216
Arom	-.00555	-.00555	-.00555	-.00555	-.00555	-.00555	-.00555	-.00555	-.00555
Olefins	0	0	0	0	0	0	0	0	0
MTBE	-.03646	0	0	0	0	0	0	0	-.05598
ETBE	.316467	.316467	.316467	.316467	.316467	.316467	.316467	.316467	.316467
ETOH	.249326	.249326	.249326	.249326	.249326	.249326	.249326	.249326	.249326
TAME	0	0	0	0	0	0	0	0	0

Exhaust POM (polycyclic organic matter) performance is calculated with the exhaust VOC regression coefficients since POM was assumed to respond to fuel modifications in the same manner as did VOC. EPA made this assumption since POM, while difficult to measure accurately, is itself a VOC. Since data on unique POM responses were not available, EPA considers the VOC model to provide the most reasonable estimate of POM emissions. To calculate mass emissions of POM for a target fuel, the ratio of POM to exhaust VOC emissions for the baseline fuel must be multiplied by the exhaust VOC emissions of the target fuel. The ratio of baseline POM emissions to exhaust VOC emissions is shown in Section III.B.5.

6. Raw Model Refinement

Once the Complex Model regression equations were determined, the Agency took steps to refine the model by eliminating any terms that did not significantly affect its behavior. In this complex model development step, the Agency simplified the model's structure while simultaneously preserving its behavior. EPA chose to refine its model for several reasons. First, EPA recognized that many of the terms in the raw models had relatively little effect on emissions. Second, EPA had received numerous comments asking that the Complex Model be simplified to facilitate its use. The refinement process used by EPA involved two steps:

1) Rank the terms in each pollutant-specific model based on their contribution to the model's explanatory power. This step was accomplished through the random balance approach to model simplification.

2) Execute a least-squares regression on the Complex Model database to develop equations that contain all the original terms except those terms that cumulatively accounted for only a small (generally less than 1%) portion of the model's explanatory power.

This section presents the theory and methodology behind the random balance algorithm, the results of applying the random balance algorithm to the Complex Model, and the least-squares regression approach.

a. The Random Balance Algorithm

Dr. H.T. McAdams of the Advanced Computing Center of Argenta developed a method for simplifying models resulting from statistical regressions. Dr. McAdams based this "random balance algorithm" on the premise that a regression model may include some terms that are statistically significant but contribute very little to the model's explanatory or predictive power. Such terms increase the model's complexity and can be eliminated while retaining the essential behavioral characteristics of the model. This section provides an overview of the random balance algorithm; a detailed description of the random balance algorithm and its use in simplifying the Complex Model can be found in Appendix III-1.

The random balance algorithm, as used to refine the raw Complex Model, can be summarized as follows:

1) Generate 2000 random fuel blends whose fuel parameter values are distributed evenly across the valid range of the raw model. The valid range of the model is discussed in Section D.2.

2) Use the raw Complex Model for exhaust emissions to estimate the gram/mile emissions for each fuel blend. These estimates are fleet-average estimates; they represent the weighted estimates from the eight normal emitter and one higher emitter regression equations using the Phase II weighting factors.

3) Treat the emission estimates from step (2) as a data set, and execute a simple, multi-parameter regression (least squares polynomial fit) on the natural log of emissions. The randomly generated fuels from step (1) operate as independent variables in this step. The resulting single exponential equation has the same behavioral characteristics as the nine-equation raw model.

4) Calculate the contribution to the model's overall sum of squares from individual fuel terms. The sum of squares is a measure of the deviation of individual data points from the

regression curve. The sum of squares provides an indicator of the model's overall explanatory power; the smaller the sum of squares, the greater the model's overall explanatory capability. This step is completed by squaring each of the regression coefficients generated in step (3) and dividing by an appropriate normalizing factor. The approximate orthogonality of the moment matrix resulting from step (2) allows this calculation to be made, as described in more detail in Appendix IV-A.

5) Rank the model terms on the basis of their contribution to the model sum of squares.

The result of this process is a list of all the terms in the exhaust Complex Models, ranked in order of importance. Those terms which are least important contribute the least to the model sum of squares. Decisions can then be made as to which terms can be eliminated from the model without altering its behavior or explanatory power.

b. Ranking of Raw Complex Model Terms

The raw Complex Model contained six exhaust pollutant regression models that were candidates for refinement via with the random balance algorithm. Of these six models, the raw models for benzene, formaldehyde, acetaldehyde, and 1,3-butadiene were strictly linear and contained relatively few fuel terms. The Agency determined that the models for these four pollutants were sufficiently simple to not require refinement. Therefore, only the exhaust VOC and NOx models were refined via the random balance algorithm.

The random balance algorithm yielded a list of terms for the raw exhaust VOC and NOx models ranked in order of decreasing contribution to each model's predictive power. These lists are shown in Tables IV-9 and IV-10. In each table, the first column of values gives the term name, the second column gives the termwise contribution to the model's predictive capability, and the third column gives the cumulative contribution to the model's predictive capability.

Table IV-9
Term Ranking for Raw Exhaust VOC Model

Term name	Term Contribution (percent)	Cumulative Contribution (percent)
RVP	31.56	31.56
E200	27.72	59.28
E300	14.69	73.97
ARO	7.60	81.57
SUL	5.56	87.13
E300*E300	4.96	92.09
OLE	2.66	94.75
E300*ARO	1.98	96.73
E200*E200	1.59	98.32
OXY*RVP	0.87	99.19
SUL*E300	0.65	99.84
OXY	0.08	99.92
ARO*ARO	0.05	99.97
SUL*SUL	0.02	99.99
OXY*SUL	0.01	100.00

Table IV-10
Term Ranking for Raw NOx Model

Term name	Term Contribution (percent)	Cumulative Contribution (percent)
SUL	50.98	50.98
OLE	28.74	79.72
OLE*OLE	8.60	88.32
RVP	3.47	91.79
E200	2.77	94.56
ARO*ARO	1.76	96.32
SUL*SUL	1.69	98.01
E300	0.68	98.69
ARO	0.56	99.25
OXY	0.24	99.49
OXY*ARO	0.16	99.65
OXY*SUL	0.15	99.80
E300*OLE	0.14	99.94
OXY*OXY	0.03	99.97
OXY*RVP	0.02	99.99
E300*E300	0.01	100.00

Tables IV-9 and IV-10 show that some model terms contribute a great deal to the explanatory power of the models, while others contribute very little. These latter terms add complexity to the Complex Model equations without a corresponding gain in explanatory power. The Agency began the refinement process by examining terms which contributed a combined 1 percent or less to the corresponding models' sum of squares. The Agency also sought to retain all linear terms in the refined VOC and NOx models regardless of how much they contributed to the model sum of squares in order to satisfy the provisions agreed to by the Agency in the Agreement in Principle.

Applying the 1 percent cutoff to the VOC model would have eliminated all terms below the OXY*RVP term in Table IV-9. These terms contributed 0.81 percent of the raw model's sum of squares. Hierarchy considerations dictated retention of the linear oxygen term despite its low explanatory contribution. A number of commenters questioned whether the OXY*RVP term should be retained, since fuel oxygen content and RVP were highly correlated in the Complex Model database. In addition, the Agency's modeling efforts indicated that models with the OXY*RVP term exhibited unusual and unexplainable behavior. For these reasons, EPA chose to add the OXY*RVP term to the list of terms to eliminate. Therefore, the following terms were marked for elimination from the raw exhaust VOC model based on the results of the random balance technique: OXY*RVP, SUL*E300, ARO*ARO, SUL*SUL, and OXY*SUL.

Applying the 1 percent cutoff to the NOx model would have eliminated all terms below the E300 term in Table IV-10. These terms contributed 0.75 percent of the raw model's sum of squares. However, hierarchy considerations dictated retention of the first-order aromatics and oxygen terms. Thus the following terms were marked for elimination from the raw NOx model: OXY*ARO, OXY*SUL, E300*OLE, OXY*OXY, OXY*RVP, and E300*E300.

c.   Re-regression of the Raw Complex Model

Once the raw model was developed as described in the Sections A.4 and A.5, it was evaluated using the random balance approach as described in Section A.6 to determine the relative contribution of individual model terms to the predictive power of the raw model. Terms retained after using an approximate cutpoint of 99 percent were then pooled and a regression was run (using SAS) on those terms to determine the coefficients shown in Section A.7 below for each of the exhaust pollutants. Since the toxics models are linear and only very few terms are present in each of the models, the random balance technique was not used to refine the toxics models. Thus, the regression coefficients for the exhaust toxics models are identical to those shown in Section A.5.

7.   Refined VOC and NOx Model Coefficients

Refined Exhaust VOC Model Coefficients

Table IV-11

Fuel Term	Centered Refined Regression Model Coefficients for Exhaust VOC								
	TG 1	TG 2	TG 3	TG 4	TG 5	TG 6	TG 7	TG 9	HIGH
Oxygen	-.00363	-.00363	-.00363	-.00363	-.00363	-.00363	-.00363	-.00363	-.00363
Sulfur	.000515	.000274	.000515	.000836	.000876	.000209	.000515	.000515	-5.4E-5
RVP	.03516	.01038	.03516	.03516	.03516	.03516	.03516	.03516	.04330
E200	-.00683	-.00360	-.00360	-.00360	-.00360	-.00360	-.00360	-.00360	-.00360
E300	-.00824	-.00824	-.00824	-.00824	-.00824	-.00824	-.00824	-.00824	-.00035
Aro	.00355	.00355	.00355	-.00242	.00355	.00355	.00355	.00355	.00355
OLefins	-.00286	-.00286	-.00286	-.00286	-.00286	-.00286	-.00286	-.00286	-.00286
$E200^2$	.000106	.000106	.000106	.000106	.000106	.000106	.000106	.000106	.000106
$E300^2$	.000408	.000408	.000408	.000408	.000408	.000408	.000408	.000408	.000408
Aro*E300	-.00029	-.00029	-.00062	-.00029	-.00029	-.00029	-.00029	-.00029	-.00029

Refined Exhaust NOx Model Coefficients

Table IV-12

Fuel Term	Centered Refined Regression Model Coefficients for Exhaust NOx								
	TG 1	TG 2	TG 3	TG 4	TG 5	TG 6	TG 7	TG 9	HIGH
Oxygen	.004409	.004409	-.00982	.004409	.004409	.004409	.004409	.004409	-.00913
Sulfur	.000747	.000461	.000461	-7.1E-5	.000461	-1.5E-5	.000461	.000461	.000252
RVP	.009077	.009077	.009077	.009077	.009077	.009077	.009077	.009077	-.01397
E200	.000931	.000931	.000931	.000931	.000931	.000931	.000931	.000931	.000931
E300	.002738	-7.7E-5	.002738	-.00302	.002738	.002738	.002738	.002738	-.00401
Aro	-.00139	.002578	.002578	.002578	.002578	.002578	.002578	.002578	.002578
Olefins	.002597	.002597	.002597	.002597	.002597	.002597	.002597	.002597	.002597
Sul^2	-1.6E-6	-1.1E-6	0	0	0	0	0	0	0
Aro^2	-8.0E-5	-.00022	-8.0E-5	-8.0E-5	-8.0E-5	-8.0E-5	-8.0E-5	-8.0E-5	-8.0E-5
Ole^2	.000366	.000366	.000366	.000366	.000366	.000366	.000366	.000366	.000366

8. Simplification of the Refined Complex Model

After the raw exhaust Complex Model was refined (as discussed in Section A.6) to eliminate terms that did not significantly contribute to the model's predictive power, additional steps were taken to simplify its structure. The first step was to reduce the number of vehicle group equations in each pollutant-specific model through an equation consolidation algorithm. The second step was to convert the centered forms of the regression equations to an uncentered form. Both of these simplification steps are described below. EPA's reasons for simplifying the refined Complex Model were similar to its reasons for refining the raw model.

a. Vehicle Group Consolidation

The statistical approach to the development of the exhaust Complex Model resulted in separate equations for each vehicle technology type and emitter class. Since there were eight normal emitter technology type equations and a single higher emitter equation, the raw Complex Model had a total of nine vehicle group equations for each pollutant. The EPA determined that all nine vehicle group equations would not be necessary if the behavior of the model could be duplicated through simpler or fewer equations. Therefore, a vehicle group consolidation algorithm was applied to the refined Complex Model.

The consolidation methodology proposed in the July 15, 1993 submittal to the docket made use of "pseudo-geometric averaging." In this methodology, the weighting factors w_i (described in Section III.B.4) were applied directly to the model term coefficients within the exponentials. Although not strictly mathematically correct, this method allowed the weighted coefficients to be summed across normal emitter vehicle groups, and resulted in a single equation that approximated the original set of eight. Thus the final form of the proposed Complex Model(s) in the July package contained two equations, one representing normal emitters and a second representing higher emitters.

In applying pseudo-geometric averaging to the Complex Model, two factors tended to reduce the accuracy of the consolidated equations:

- Pseudo-geometric averaging resulted in an equation for normal emitters whose emission performance estimates were offset with respect to the refined and raw models' estimates. In other words, the consolidated model had a consistent bias with respect to the refined and raw models.

- The accuracy of pseudo-geometric averaging broke down for large values of the independent variables (fuel parameters).

EPA considered correcting the consistent bias through the application of a fixed correction factor to the consolidated equations. However, EPA found no mechanism to correct the increasing inaccuracy of the consolidated model as the value of the fuel parameters increased. These two sources of inaccuracy implied that pseudo-geometric averaging was not an appropriate consolidation methodology, and EPA chose to discard pseudo-geometric averaging for the final rulemaking in favor of a more accurate and reliable consolidation approach.

EPA followed the same guidelines for these alternative consolidation techniques that it applied to the pseudo-geometric consolidation approach:

1) The unextrapolated forms of the regression equations were used during the consolidation process instead of the extrapolated forms.

2) EPA chose to consolidate the models into two equations, one for normal emitters and a second for higher emitters. Consolidation to a single equation would have required that a separate Complex Model be promulgated for each Phase of the reformulated gasoline program since the vehicle group weighting factors are different in each Phase. In addition, EPA expected any bias or inaccuracy to be more apparent if normal and higher emitters were consolidated into a single equation than if normal emitters alone were consolidated (as had been the case when using the pseudo-geometric consolidation method).

3) The form and emission response characteristics of the consolidated model were to remain similar to the form and behavior of the unconsolidated refined model.

The random balance algorithm, introduced in Section A.6 as a means of refining the raw models, can also be used to develop consolidated regression equations. Consolidation is a by-product of using random balance to rank model terms in order of contribution to the model sum of squares. For the purposes of regression equation consolidation, the random balance algorithm can be summarized by the following three steps:

1) Generate 2000 random fuel blends distributed evenly across the fuels space. The valid range limits discussed in Section D.2 provided the maximum and minimum values for each fuel parameter.

2) For each fuel blend, determine the emissions of VOC, NOx, and toxics in grams/mile for the normal emitter exhaust Complex Model. This step results in fleet average emission estimates for normal emitters that represent the emission-weighted results from the individual regression equations.

3) Treat the emission estimates from step (2) as a data set, and execute a simple, multi-parameter regression (using a least squares polynomial fit) on the natural log of these emission estimates. The fuel parameters for the 2000 fuels from step (1) operate as independent variables in this step.

Thus the random balance algorithm fits a single equation to the results of a set of equations which duplicates their behavior in a simpler form. Details of the random balance algorithm are provided in Appendix IV-A.

The random balance algorithm yields a consolidated equation that will necessarily be biased in its predictions as compared to the unconsolidated model on which it is based. This bias arises because the step (3) regressions are done in natural logarithm space. The least squares fit to the natural logarithm of the emission estimates calculated in step (2) results in normally-distributed emission estimates about the polynomial regression equation. The exponential of the new regression equation is then taken to convert the natural logarithm of emissions back to emissions in grams/mile and place it in the same form as the unconsolidated model. Exponentiation causes the distribution of emission performances calculated in step (2) to become skewed in one direction rather than remaining evenly distributed. As a result, the consolidated model tends to estimate slightly larger emission benefits than the unconsolidated model.

The bias introduced into the consolidated Complex Model through the random balance algorithm is of the same magnitude and direction as the bias introduced by pseudo-geometric averaging. However, EPA has determined that the merits of consolidation outweigh the detriment posed by such bias since it is negligible, as discussed below. In addition, EPA carried out an analysis of the extent of the bias and concluded that no bias correction through fixed correction factors or other means need be implemented. The details of the analysis are given below.

The analysis of the consolidated Complex Model began with the creation of 500 randomly generated fuel blends in an identical manner to step (1) of the consolidation process. Then both the consolidated and unconsolidated models were evaluated for each fuel, and the difference between the two emission performances were recorded. The product of the analysis was a set of performance differences for each pollutant, one for each of the 500 random blends, equal to the performance of the consolidated model for a given pollutant and target fuel minus the performance of the unconsolidated model for the same pollutant and target fuel. If no bias were present, the average performance delta would be zero. Based on the form of the exhaust Complex Model equations, EPA expected the bias to result in negative performance differences. The average performance difference for summer, Class C areas is given in Table IV-13.

Table IV-13
Consolidation Performance Differences

Pollutant	Phase I	Phase II
Exhaust benzene	-0.0762	-0.0651
Non-exhaust benzene	0.0	0.0
1,3-Butadiene	-0.0565	-0.0482
Acetaldehyde	-0.3157	-0.2696
Formaldehyde	0.0001	0.0001
POM	0.0	0.0
Total toxics	**-0.0620**	**-0.0610**
Exhaust VOC	-0.02	-0.02
Non-exhaust VOC	0.0	0.0
Total VOC	**-0.0073**	**-0.0130**
NOx	**0.0043**	**0.0043**

Before drawing conclusions from the values in Table IV-13, a number of comments should be made. First, the models for nonexhaust benzene, nonexhaust VOC, and exhaust POM did not require consolidation, which is why their performance differences were zero. They are included in Table IV-13 because it is the bias for total toxics, total VOC, and NOx which determines the accuracy of the consolidated Complex Model compared to that of the unconsolidated Complex Model. Second, the expected negative value for the performance differences was not exhibited for NOx and formaldehyde. However, the positive performance differences are all very small, and most likely result from two sources:

1) A consolidated equation that represents the behavior of the unconsolidated model very well.

2) Random variation in the calculated emission estimates for the random fuel blends.

The performance differences in Table IV-13 must be examined in terms of their contribution to total toxics, total VOC, and NOx because it is these three quantities that are regulated by the reformulated gasoline program. Thus the average performance differences were weighted according to the gram/mile emission values for Clean Air Act (CAA) baseline fuel to obtain values for total toxics and total VOC. After doing so, EPA has determined that the average performance differences for total toxics, total VOC, and NOx are negligible for the following reasons:

- The measurement uncertainty for the Complex Model fuel parameters create emission estimate uncertainty that is larger than the error introduced by consolidating normal emitter technology groups.

- The error introduced by consolidation for VOC and toxics is small relative to the overall emission reductions required by the program for these pollutants.

- The error introduced by consolidation for NOx is favorable, i.e., on average, the consolidated model slightly overestimates the emissions from a given fuel, though the error for any given fuel may be unfavorable. As a result, fuels that meet the NOx requirements of the program under the consolidated model will, on average, meet the NOx requirements under the unconsolidated model by a slightly larger margin.

For these reasons, EPA decided that the small average performance differences did not require the application of fixed correction factors or other measures in order to assure the integrity of the reformulated gasoline and anti-dumping programs.

b. Uncentering

The statistical approach to the development of the Complex Model included the use of centered independent variables. A centered variable is one in which the variable is represented as a deviation from some fixed value rather than just as its measured value. This fixed value is called the "centering value." Thus the centered form of the aromatics variable could be written as

$$ARO - ARO_c$$

where ARO is the amount of aromatics in a given fuel in units of volume percent, and ARO_c is the centering value of aromatics, also in units of volume percent. Similar centered variables can be constructed for all independent variables in the Complex Model:

$OXY - OXY_c$
$E200 - E200_c$
$BEN - BEN_c$
$ETH - ETH_c$
$SUL - SUL_c$
$E300 - E300_c$
$MTB - MTB_c$
$TAM - TAM_c$
$RVP - RVP_c$
$OLE - OLE_c$
$ETB - ETB_c$

Thus the linear, squared, and interactive terms in the Complex Model take the following forms:

Linear: $c_1 * (RVP - RVP_c)$
Squared: $c_2 * (SUL - SUL_c)^2$
Interactive: $c_3 * (ARO - ARO_c) * (E300 - E300_c)$

where c_1, c_2, and c_3 are coefficients determined through statistical regression techniques. The centering value of each of the 12 independent variables is approximately the mean value of that variable measured across all observations in the Complex Model database. The precise mean value was not used as the centering value for three main reasons:

- The mean values are different for each pollutant, since not all observations measured each pollutant.
- The centering values were calculated before all of the studies included in the Complex Model database were made available to EPA. Once these additional studies were included in the database, the mean values and previously-calculated centering values diverged.
- If the mean values were used as the centering values, then the centering values would have changed as individual observations were excluded based on the outlier and influential point criteria discussed in Section A.4.

The centering values used in EPA's regressions are repeated below:

Table IV-14
Centering Values Used in Exhaust Complex Model

Fuel parameter	Centering value
Oxygen	1.774834
Sulfur	204.5779
RVP	8.611479
E200	46.72577
E300	85.89620
Aromatics	28.26109
Olefins	7.318716
Benzene	1.066683
MTBE	0.947240
ETBE	0.023204
Ethanol	0.314352
TAME	0.016443

Centered independent variables were used in the development of the Complex Model to minimize collinearity problems. Once the regressions were completed, EPA chose to remove the centering values in order to simplify the form of the Complex Model equations. Algebraic manipulations of the regression equations yielded equations that contained only the variables themselves, rather than centered variables. This "uncentering" process resulted in a simplified version of the Complex Model equations.

A hypothetical example can help illustrate the uncentering algorithm. The Complex Model exhaust emission equations take the following form:

$$\text{(A.1)} \qquad Y(t) = [\exp(f(t))/\exp(f(b)) - 1] * 100$$

where "Y(t)" is the percent change in the exhaust emissions of any exhaust pollutant Y, "t" refers to the set of target fuel parameter values, and "b" refers to the set of baseline fuel parameter values. The hypothetical second-order function f can be written in its centered form as

$$\begin{aligned} \text{(A.2)} \qquad f(A,B) = {} & \epsilon_1(A - A_c) + \epsilon_2(B - B_c) + \epsilon_3(A - A_c)^2 + \\ & \epsilon_4(B - B_c)^2 + \epsilon_5(A - A_c)*(B - B_c) \end{aligned}$$

where A and B represent hypothetical fuel parameters (independent variables), and the coefficients ϵ_i are constants that are determined through statistical regressions.

The function f can be expanded to yield

$$\begin{aligned} \text{(A.3)} \qquad f(A,B) = {} & \epsilon_1 A - \epsilon_1 A_c + \epsilon_2 B - \epsilon_2 B_c + \\ & \epsilon_3 A^2 - 2\epsilon_3 AA_c + \epsilon_3 A_c^2 + \epsilon_4 B^2 - 2\epsilon_4 BB_c + \epsilon_4 B_c^2 \\ + & \\ & \epsilon_5 AB - \epsilon_5 AB_c - \epsilon_5 A_c B + \epsilon_5 A_c B_c \end{aligned}$$

Grouping similar terms yields

$$\begin{aligned} \text{(A.4)} \qquad f(A,B) = {} & A * (\epsilon_1 - 2\epsilon_3 A_c - \epsilon_5 B_c) + \\ & B * (\epsilon_2 - 2\epsilon_4 B_c - \epsilon_5 A_c) + \\ & A^2 * (\epsilon_3) + \\ & B^2 * (\epsilon_4) + \\ & AB * (\epsilon_5) + \\ & (-\epsilon_1 A_c - \epsilon_2 B_c + \epsilon_3 A_c^2 + \epsilon_4 B_c^2 + \epsilon_5 A_c B_c) \end{aligned}$$

At this point every variable in Equation (A.4) is expressed in its uncentered form. The coefficients for the second-order terms remain the same while the coefficients for the first-order terms are now functions of the ϵ_i and the centering values. In addition, the function f now contains a constant. Equation (A.4) can be rewritten more succinctly as follows:

$$\text{(A.5)} \qquad f(A,B) = \eta_1 A + \eta_2 B + \eta_3 A^2 + \eta_4 B^2 + \eta_5 AB + \varpi$$

where the η_i and ϖ are defined as follows

$$\begin{aligned} \eta_1 &= \epsilon_1 - 2\epsilon_3 A_c - \epsilon_5 B_c \\ \eta_2 &= \epsilon_2 - 2\epsilon_4 B_c - \epsilon_5 A_c \\ \eta_3 &= \epsilon_3 \\ \eta_4 &= \epsilon_4 \\ \eta_5 &= \epsilon_5 \\ \varpi &= -\epsilon_1 A_c - \epsilon_2 B_c + \epsilon_3 A_c^2 + \epsilon_4 B_c^2 + \epsilon_5 A_c B_c \end{aligned}$$

The η_i and ϖ are constants just as the ϵ_i and centering values are constants. Since the uncentered form of the function f in Equation (A.5) is mathematically identical to the centered form in Equation (A.2), the centered form of the function can be replaced with the uncentered form without altering the model's behavior.

The Complex Model can be simplified still further by deleting constants. Since the exhaust emission performance of a given fuel is calculated using a ratio of two exponentials, constants found in both exponentials will cancel one another when calculating exhaust emission performance. The percent change in the exhaust emissions of a pollutant Y can be calculated from Equation (A.1) as follows (using the hypothetical exhaust emission function f from Equation (A.5) to illustrate the point):

$$\text{(A.1)} \qquad Y(t) = [\exp(f(t))/\exp(f(b)) - 1] * 100$$

Incorporating Equation (A.5) into Equation (A.1) yields

$$\text{(A.6)} \quad Y(t) = \left[\frac{\exp(\eta_1 A_t + \eta_2 B_t + \eta_3 A_t^2 + \eta_4 B_t^2 + \eta_5 A_t B_t + \varpi)}{\exp(\eta_1 A_b + \eta_2 B_b + \eta_3 A_b^2 + \eta_4 B_b^2 + \eta_5 A_b B_b + \varpi)} - 1\right] * 100$$

where A_t indicates the level of fuel parameter A in the target fuel, while A_b indicates the level of fuel parameter A in the baseline fuel. The exponential of a sum of two quantities is defined as the product of the exponentials of each of those two quantities. Thus Equation (A.6) can be written as follows:

$$\text{(A.7)} \quad Y(t) = \left[\frac{\exp(\eta_1 A_t + \eta_2 B_t + \eta_3 A_t^2 + \eta_4 B_t^2 + \eta_5 A_t B_t)\exp(\varpi)}{\exp(\eta_1 A_b + \eta_2 B_b + \eta_3 A_b^2 + \eta_4 B_b^2 + \eta_5 A_b B_b)\exp(\varpi)} - 1\right] * 100$$

The $\exp(\varpi)$ terms cancel one another, and the equation for Y(t) simplifies to

$$\text{(A.8)} \quad Y(t) = \left[\frac{\exp(\eta_1 A_t + \eta_2 B_t + \eta_3 A_t^2 + \eta_4 B_t^2 + \eta_5 A_t B_t)}{\exp(\eta_1 A_b + \eta_2 B_b + \eta_3 A_b^2 + \eta_4 B_b^2 + \eta_5 A_b B_b)} - 1\right] * 100$$

Thus the constant ϖ, which was introduced into the function f through the uncentering algorithm, can be dropped from the function f altogether. The remaining function, devoid of the constant ϖ, then contains only the uncentered variables and their coefficients. Equation (A.8) is mathematically identical to the centered form implied by Equations (A.1) and (A.2), so the centered form of f can be replaced with the uncentered form without altering the model's behavior in any way.

9. Final Complex Models

The simplification methodology described in Section A.8 produces two complex model equations (one for normal emitters and one for higher emitters) for each pollutant. The coefficients shown below represent the final, simplified coefficients for each pollutant. The details of how to compute in-use performances and in-use mass emissions for a target fuel from these coefficients are discussed more fully in Section C.

Final Exhaust VOC Model

Table IV-15

Fuel Term	Final Exhaust VOC Model Coefficients	
	Normal Emitters	Higher Emitters
Oxygen	-0.003641	-0.003626
Sulfur	0.0005219	-0.000054
RVP	0.0289749	0.0432950
E200	-0.014470	-0.013504
E300	-0.068624	-0.062327
Aromatics	0.0323712	0.0282042
Olefins	-0.002858	-0.002858
$E200^2$	0.0001072	0.0001060
$E300^2$	0.0004087	0.0004080
Aromatics*E300	-0.0003481	-0.000287

Final Exhaust NOx Model

Table IV-16

Fuel Term	Final NOx Model Coefficients	
	Normal Emitters	Higher Emitters
Oxygen	0.0018571	-0.00913
Sulfur	0.0006921	0.000252
RVP	0.0090744	-0.01397
E200	0.0009310	0.000931
E300	0.0008460	-0.00401
Aromatics	0.0083632	0.007097
Olefins	-0.002774	-0.00276
$Sulfur^2$	-6.63×10^{-7}	0
$Aromatics^2$	-0.000119	-7.995×10^{-5}
$Olefins^2$	0.0003665	0.0003665

Final Exhaust Benzene Model

Table IV-17

Fuel Term	Final Exhaust Benzene Model Coefficients	
	Normal Emitters	Higher Emitters
Oxygen	0	-0.096047
Sulfur	0.0006197	0.000337
E200	-0.003376	0
E300	0	0.011251
Aromatics	0.026550	0.011882
Benzene	0.222390	0.222318

Final Exhaust 1,3-Butadiene Model

Table IV-18

Fuel Term	Final 1,3-Butadiene Model Coefficients	
	Normal Emitters	Higher Emitters
Oxygen	0	-0.060771
Sulfur	0.0001552	0
E200	-0.007253	-0.007311
E300	-0.014866	-0.008058
Aromatics	-0.004005	-0.004005
Olefins	0.0282350	0.0436960

Final Exhaust Formaldehyde Model

Table IV-19

Fuel Term	Final Formaldeyde Model Coefficients	
	Normal Emitters	Higher Emitters
E300	-0.010226	-0.010226
Aromatics	-0.007166	-0.007166
Olefins	0	-0.031352
MTBE	0.0462131	0.0462131

Final Exhaust Acetaldehyde Model

Table IV-20

Fuel Term	Final Acetaldehyde Model Coefficients	
	Normal Emitters	Higher Emitters
Sulfur	0.0002631	0.0002627
RVP	0.0397860	0
E300	-0.012172	-0.012157
Aromatics	-0.005525	-0.005548
MTBE	-0.009594	-0.055980
ETBE	0.3165800	0.3164665
Ethanol	0.2492500	0.2493259

The final coefficients for exhaust POM are identical to the final coefficients shown for exhaust VOC in Table IV-15.

The aldehyde models are oxygenate specific. In Tables IV-19 and IV-20 the formaldehyde and acetaldehyde models contain MTBE (methyl tertiary butyl ether), ETBE (ethyl tertiary butyl ether), and ethanol terms. These terms represent the amount of oxygen (in terms of weight percent) present in the fuel in the form of the particular oxygenate in question. Data on the effects of MTBE, ETBE, ethanol, and TAME (tertiary amyl methyl ether) on aldehyde emissions were available in the Complex Model database. TAME-specific terms were not found to be statistically significant in the regression equations for either aldehyde and thus do not appear in the final models.

The following procedure should be used to evaluate the emission performance of fuels containing oxygenates other than MTBE, ETBE, ethanol, or TAME. If the oxygenate is any type of methyl ether other than TAME, use the MTBE terms to evaluate its effects on aldehyde emissions. If the oxygenate is any type of ethyl ether, use the ETBE terms to evaluate its effect on aldehyde emissions. This distinction is made because the ethyl/methyl group functionality (in the ether compound) is expected to play the most important role in the combustion chemistry and kinetics which produce the aledhydes. If the oxygenate is an alcohol other than methanol, use the ethanol terms to evaluate its effect on aldehyde emissions. If the oxygenate is neither an ethyl or methyl ether (i.e, if it is any higher order ether), use the ETBE terms to evaluate all toxic performances. This approach was taken since, given the lack of data on the effects of higher order ethers on aldehyde emissions, EPA considers the performance of

ETBE (which is the highest-order and heaviest ether for which aldehyde effects data is available in the database) to be the best available estimate of the aldehyde effects of higher-order and heavier ethers. Fuels containing any other oxygenate (including methanol) in greater than trace amounts cannot be certified using the Complex Model unless the Model is augmented with the results of an appropriately designed and conducted vehicle testing program, as outlined in Section G.

10. Response to Comments

A number of comments have been made on issues related to the development of the Complex Model. These comments are discussed separately below for each subject area.

Although no commenters had objections to vehicle group consolidation, the proposed pseudo-geometric averaging approach to consolidation was considered inappropriate by some. The two main objections to this approach were:

1) It is mathematically incorrect; and
2) It results in a bias in the consolidated model that might have required the use of performance margins to offset this bias.

The Agency showed in the July 15, 1993 docket submission that although pseudo-geometric averaging is not mathematically correct, it does in fact result in a consolidated Complex Model that is sufficiently accurate. Regardless, pseudo-geometric averaging has been replaced by the more reliable and accurate random balance approach to consolidation, eliminating this concern. In addition, EPA's analysis of the final, consolidated Complex Model showed that no margins or offsets need be applied to the regression equations or the performance standards when the random balance approach is used for consolidation. Those parties that commented on the random balance consolidation approach put forth as an alternative consolidation method in the July 15 docket submittal had no objections to its use. Details of the random balance approach and the analysis of any resulting bias are given in Section A.8.

Commenters also expressed concern about the number of equations in the final Complex Model. Several commenters asserted that a single consolidated equation could represent the essential behavior of the Complex Model as well as two or more equations. The Agency chose not to consolidate down to a single equation for the following reasons (see Section A.8 for more details):

- Many potential users of the Complex Model expressed a desire to see separate effects for normal and higher emitting vehicles.

- The Agency recognized that further simplification would yield diminishing returns as the models became simpler. Consolidating into a single equation would require the promulgation of two unique Complex Models, since the vehicle group weighting factors are different for each Phase of the program. Thus the greater simplicity of a single equation would be offset by the need to use separate equations for each Phase.

- The analysis of the consolidated equations showed that no offsets needed to be applied to the model to correct for bias introduced through random balance consolidation to two equations. However, the same would not have been true if the raw model had been consolidated down to a single equation. The differences between normal and higher emitter equations are greater than the differences among normal emitter technology groups, and these greater differences would increase the size of the bias introduced through consolidation. In other words, the bias would be expected to increase and become significant in the context of the reformulated gasoline and anti-dumping programs if the model were consolidated to a single equation for each pollutant.

- Consolidation from two equations to one equation does not significantly increase the simplicity of the Complex Model or decrease the calculation time. A single equation also would not facilitate incorporation of the Complex Model into linear programming models or significantly simplify the derivation and application of extrapolation equations compared to two-equation models.

Some commenters also stressed that "overestimation of emission benefits" was an inappropriate descriptor of the bias introduced through consolidation. These commenters particularly disagreed with the use of this phrase in describing the proposal to implement correction factors or offsets to the consolidated Complex Model. As described above, this phrase is provided as a description of the behavior of the consolidated Complex Model <u>in comparison to the unconsolidated Complex Model only</u>. In other words, consolidation results in Complex Model behavior that is consistently skewed in one direction with respect to the raw vehicle group equations. The Agency did not and does not wish to imply that the consolidated Complex Model provides unwarranted emission benefits when estimating real, in-use emissions. In addition, the proposal to apply margins or offsets to correct for this bias was presented simply as a mathematical correction factor. As stated above, however, the bias is too small to require any such correction factors when using the random balance method to consolidate the normal emitter technology group equations into a single equation.

Another set of comments focused on which of the three EPA options proposed in July [see A-92-12 Docket submittals #IV-B-4, July 1993 and #IV-B-5, July 1993] was most accurate while at the same time fungible and simple to use. Most of the comments focused on the following points:

- Any models that contain extrema points within the allowable range of the model should not be consdiered due to the possible blending problems that they may cause
- Option 2 should be chosen for all pollutants since maxima values in option 1 result in unexplainable behavior
- Option 3 is oversimplifed
- Option 1 has "superior" aromatics and E300 responses and is "most" technically correct and thus should be chosen for all pollutants
- The effect of sulfur on VOC and NOx has been underestimated by all the EPA options
- Olefins should be excluded from the model because reducing olefins increases VOC emissions in all options
- Simplification of emissions equation structure while retaining accuracy is very important

EPA has addressed most of these comments in arriving at the final exhaust models shown in Section A.9. The final model chosen for VOC was the option 1 model with the OXY*RVP term removed, since this term caused the model to behave in ways not supported by the available data and since few well-controlled observations were available to estimate this term. The final model chosen for NOx was the option 1 model. The toxics models are all linear. EPA believes that the ARO*E300 interactive term in the exhaust VOC model is needed to represent the aromatics and E300 effects accurately. The olefins effect in the final VOC model shows emissions to increase as olefins are decreased which is what is expected from data that exist in the Complex Model database. EPA believes the squared terms (Sulfur^2, aromatics^2 and olefins^2) present in the NOx model are necessary to accurately predict fuel effects on emissions. All extrema values (emission maxima or minima) have been handled by appropriate extrapolation procedures (see Section D.3). The predictability analysis in Section F.2 indicates that the final models chosen by EPA for VOC, NOx and toxics accurately predict the exhaust emission effects from fuel modifications. EPA believes that the final models being promulgated are sufficiently simple without sacrificing accuracy.

B. Complex Model for Non-Exhaust Emissions

Vehicle emissions can be separated into two broad categories: exhaust emissions, resulting from combustion of the fuel, and nonexhaust emissions, resulting from fuel evaporation, vapor displacement, and permeation. The Agency has developed nonexhaust models using a different process from that used to develop the exhaust portion of the Complex Model. The nonexhaust model predicts emissions of volatile organic compounds (VOC) and benzene in warmer "Class B" and cooler "Class C" areas; in the regulations, preamble, and other supporting documents for the reformulated gasoline rule, Class B areas are referred to as VOC Control Region 1 and Class C areas are referred to as VOC Control Region 2. The nonexhaust VOC model was derived from EPA's Highway Vehicle Emission Factor MOBILE models, while the nonexhaust benzene model was derived from correlations originally developed from General Motors' thermodynamic vapor equilibrium model. The behavior of the non-exhaust benzene model has been confirmed by EPA through independent emissions testing. The remainder of this section describes the derivation and use of the Complex Model for nonexhaust emissions.

EPA subdivides nonexhaust VOC emissions into evaporative, running loss, and refueling VOC emissions. These emissions are primarily a function of fuel volatility (RVP). Nonexhaust benzene emissions are the only nonexhaust toxic emissions source regulated by the reformulated gasoline program and are primarily a function of RVP, benzene, and MTBE. MTBE is the only oxygenate currently known to inhibit benzene vapor pressure at a given RVP level. The simple model addressed these very same factors, so the Complex Model for nonexhaust emissions follows the same development pattern as that for the simple model: the Complex Model for nonexhaust emissions includes only the effects of fuel benzene, RVP, and MTBE levels on nonexhaust benzene emissions, and RVP on nonexhaust VOC emissions. The July 11, 1991 MOBILE4.1 model with basic I/M and the MOBILE5a model with enhanced I/M were used to estimate nonexhaust VOC emissions for the Phase I and Phase II timeframes, respectively. These two MOBILE models have been described in Section III. The derivation of the Phase I Complex Model for nonexhaust VOC emissions is described in Section B.1 below, while the analogous Complex Model for Phase II nonexhaust VOC emissions is described in Section B.2. The Complex Model for nonexhaust toxics emissions is covered in Section B.3.

1. Phase I Nonexhaust VOC Emissions Model

The Phase I relationship between nonexhaust VOC emissions and RVP was developed by fitting a curve to nonexhaust VOC emission predictions provided by MOBILE4.1. Since the same technique was used to develop the nonexhaust portion of the simple model, the nonexhaust VOC emissions equations in the Phase I Complex Model are exactly the same as the the nonexhaust VOC equations in the simple model.

To assess the relationship between the Reid vapor pressure of a given fuel and the nonexhaust VOC emissions that such a fuel would be expected to produce, MOBILE4.1 was run for the year 2015 with summer temperatures and the basic I&M scenario described previously. Fuel RVP levels ranged from 6.5 to 8.7 psi (the input file is shown in Appendix IV). The year 2015 was chosen as the target year to allow MOBILE4.1 to model a hypothetical in-use fleet composed entirely of vehicles with 1990 technology. Separate results for Class C and Class B areas were produced, since these areas' different average minimum and maximum summer temperatures for high ozone days alter the relationship between RVP and nonexhaust VOC emissions.

Each set of MOBILE4.1 results gave emission factors in terms of total grams of VOCs per mile, categorized by vehicle type (LDV, HDV, etc.) and emission type (refueling losses, evaporative losses, and running losses). Both the simple model and Phase I Complex Model are based on results for light-duty vehicles (i.e., cars). Table IV-21 shows the MOBILE4.1 results that were used to develop the Phase I Complex Model for nonexhaust VOC emissions.

Table IV-21
Nonexhaust Emissions from MOBILE4.1 (July 11, 1991)

Class	RVP	VOC emissions for LDGVs in grams per mile:		
		Refueling Losses	Running Losses	Evaporative Losses
C	8.7	0.04	0.39	0.34
	8.5	0.04	0.36	0.31
	8.3	0.04	0.33	0.29
	8.1	0.04	0.31	0.27
	7.9	0.04	0.28	0.25
	7.7	0.03	0.25	0.23
	7.5	0.03	0.23	0.21
	7.2	0.03	0.20	0.19
	7.0	0.03		0.18
B	8.7	0.04	0.43	0.39
	8.5	0.04	0.40	0.36
	7.8	0.03	0.29	0.27
	7.6	0.03	0.26	0.25
	7.4	0.03	0.23	0.23
	7.2	0.03		0.21
	7.0	0.03		0.20
	6.8	0.03		0.18
	6.6	0.03		0.17

A numeric polynomial regression was carried out for each of the three emission types (running, refueling, and evaporative losses) to produce a relationship giving VOC emissions in grams per mile as a function of the Reid vapor pressure in pounds per square inch. This regression resulted in separate equations for Class B and Class C areas, as shown in Table IV-22.

Table IV-22
Phase I Nonexhaust Emission Regressions as a Function of RVP

Area Class	Vapor source	Curve Fit	R^2
B	Refueling	$0.006668 * RVP - 0.018$	0.685
B	Running	$0.002791 * RVP^2 + 0.1096 * RVP - 0.734$	1.000
B	Evaporative	$0.02293 * RVP^2 - 0.2461 * RVP + 0.7952$	0.999
C	Refueling	$0.006668 * RVP - 0.018$	0.685
C	Running	$0.016255 * RVP^2 - 0.1306 * RVP + 0.2963$	0.998
C	Evaporative	$0.021239 * RVP^2 - 0.2393 * RVP + 0.813$	0.999

Evaporative emissions within the MOBILE emissions model include both hot-soak and diurnal emissions, but they are not given in units of grams per mile. This conversion requires calculation of a hot soak/diurnal ratio from the MOBILE4.1 database. The average weighting over all vehicle ages is 67.9 percent hot soak and 32.1 percent diurnal. Based on these proportions, the evaporative emission equations can be split into separate equations for hot soak and diurnal emissions, as shown in Table IV-23.

Table IV-23
Evaporative Emissions Breakdowns into Hot Soak and Diurnal

Area Class	Vapor source	Curve Fit
B	Hot Soak	$0.01557 * RVP^2 - 0.1671 * RVP + 0.5399$
B	Diurnal	$0.00736 * RVP^2 - 0.0790 * RVP + 0.2553$
C	Hot Soak	$0.014421 * RVP^2 - 0.16248 * RVP + 0.5520$
C	Diurnal	$0.006818 * RVP^2 - 0.07682 * RVP + 0.2610$

2. Phase II Nonexhaust VOC Emissions Model

The Phase II Complex Model takes effect in the year 2000. The equations giving nonexhaust VOC emissions for the Phase II

Complex Model were derived in an analogous manner to that for the Phase I model, with three main differences: MOBILE5a was used instead of the July 11, 1991 version of MOBILE4.1, an enhanced I&M program was assumed instead of a basic I&M program, and emissions from light-duty trucks were considered in addition to emissions from passenger cars. Thus nonexhaust VOC emissions were modeled through curve fits to data produced by the MOBILE5a emissions model (the input file to MOBILE5a is located in Appendix IV). Again, the year 2015 was chosen as the target year to force MOBILE5a to consider only 1990 engine technology and evaporative emission control systems. And as discussed in Section III, an enhanced I&M scenario was assumed to apply to Phase II.

The Phase II Complex Model for nonexhaust emissions was based on the MOBILE5a results for both light-duty cars and trucks because sufficient data on light-duty truck exhaust emission effects of fuel modifications now exist to allow the exhaust emission portion of the Complex Model to cover both vehicle types. When the simple model was developed, very few light-duty trucks had been tested. Emissions from heavy-duty gasoline trucks (HDGTs) have been ignored for two reasons: HDGTs comprise only 3 percent of the vehicle miles travelled by the in-use fleet (as estimated by MOBILE5a), and EPA does not have sufficient data to describe the exhaust emissions performance of HDGTs as a function of fuel parameters. To maintain a consistent basis for both the exhaust and nonexhaust models, EPA chose to exclude heavy-duty gasoline trucks from the baseline emissions inventories and emission models for both exhaust and nonexhaust emissions.

To assess the relationship between the Reid vapor pressure of a given fuel and nonexhaust VOC emissions, MOBILE5a was run for the year 2015 under an enhanced I&M scenario with fuel RVPs ranging from 6.5 to 9.9. Separate results for Class C and Class B areas were produced. Each set of results gave emission factors in terms of total grams of VOCs per mile, categorized by vehicle type (LDV, HDV, etc.) and emission type (refueling, evaporative, and running losses). Table IV-24 shows the MOBILE5a results that were used to develop the Phase II Complex Model for nonexhaust VOC emissions.

Table IV-24
Nonexhaust Emissions from MOBILE5a

Class	RVP	VOC emissions in grams per mile: Refueling Losses		Running Losses		Evaporative Losses	
		LDGV	LDGT	LDGV	LDGT	LDGV	LDGT
C	9.9	0.05	0.07	0.58	0.28	0.23	0.24
	9.7	0.05	0.07	0.51	0.25	0.21	0.22
	9.5	0.05	0.07	0.44	0.23	0.19	0.19
	9.3	0.05	0.07	0.41	0.21	0.18	0.17
	9.1	0.05	0.07	0.39	0.21	0.17	0.15
	8.9	0.05	0.07	0.37	0.20	0.16	0.15
	8.7	0.05	0.06	0.34	0.19	0.14	0.14
	8.5	0.05	0.06	0.32	0.19	0.14	0.13
	8.3	0.05	0.06	0.30	0.18	0.13	0.13
	8.1	0.05	0.06	0.28	0.17	0.12	0.12
	7.9	0.04	0.06	0.26	0.16	0.11	0.11
	7.7	0.04	0.06	0.24	0.16	0.10	0.10
	7.5	0.04	0.06	0.21	0.15	0.09	0.09
	7.3	0.04	0.06	0.19	0.14	0.09	0.09
	7.1	0.04	0.06	0.17	0.13	0.08	0.08
	6.9	0.04	0.05	0.15	0.13	0.08	0.08
	6.7	0.04	0.05	0.14	0.12	0.08	0.08
	6.5	0.04	0.05	0.14	0.12	0.07	0.08
B	9.9	0.05	0.07	0.66	0.29	0.29	0.31
	9.7	0.05	0.07	0.58	0.26	0.26	0.27
	9.5	0.05	0.07	0.49	0.23	0.24	0.24
	9.3	0.05	0.07	0.47	0.23	0.22	0.23
	9.1	0.05	0.07	0.44	0.22	0.20	0.21
	8.9	0.05	0.07	0.42	0.21	0.19	0.19
	8.7	0.05	0.06	0.39	0.21	0.18	0.18
	8.5	0.05	0.06	0.36	0.20	0.16	0.16
	8.3	0.05	0.06	0.34	0.20	0.15	0.15
	8.1	0.05	0.06	0.31	0.19	0.14	0.14
	7.9	0.04	0.06	0.29	0.18	0.13	0.13
	7.7	0.04	0.06	0.26	0.18	0.12	0.12
	7.5	0.04	0.06	0.24	0.17	0.11	0.12
	7.3	0.04	0.06	0.21	0.16	0.10	0.11
	7.1	0.04	0.06	0.18	0.16	0.10	0.10
	6.9	0.04	0.05	0.16	0.15	0.09	0.09
	6.7	0.04	0.05	0.15	0.15	0.08	0.09
	6.5	0.04	0.05	0.15	0.15	0.08	0.08

The default values from MOBILE5a for the percent of vehicle miles traveled (VMT) by each vehicle type was used to produce a weighted average of the results for light-duty cars and trucks. In the MOBILE5a output, these values are listed as 58.2% for light-duty gasoline vehicles (LDGVs) and 29.3% for light-duty gasoline trucks (LDGTs), with the remainder consisting of diesel vehicles, heavy-duty gasoline vehicles, and motorcycles. Normalizing these two values, the relative weighting of VMT becomes 66.5 percent for light-duty gasoline cars and 33.5 percent for light-duty gasoline trucks. These weightings were applied to the values in Table IV-24 above. The resulting values are shown in Table IV-25.

Table IV-25
Nonexhaust Emissions from MOBILE5a

Class	RVP	VOC emissions in grams per mile:		
		Refueling Losses	Running Losses	Evaporative Losses
C	9.9	0.0567	0.4795	0.2333
	9.7	0.0567	0.4229	0.2133
	9.5	0.0567	0.3697	0.1900
	9.3	0.0567	0.3430	0.1767
	9.1	0.0567	0.3297	0.1633
	8.9	0.0567	0.3131	0.1567
	8.7	0.0533	0.2898	0.1400
	8.5	0.0533	0.2765	0.1367
	8.3	0.0533	0.2598	0.1300
	8.1	0.0533	0.2432	0.1200
	7.9	0.0467	0.2265	0.1100
	7.7	0.0467	0.2132	0.1000
	7.5	0.0467	0.1899	0.0900
	7.3	0.0467	0.1733	0.0900
	7.1	0.0467	0.1566	0.0800
	6.9	0.0433	0.1433	0.0800
	6.7	0.0433	0.1333	0.0800
	6.5	0.0433	0.1333	0.0733
B	9.9	0.0567	0.5361	0.2967
	9.7	0.0567	0.4728	0.2633
	9.5	0.0567	0.4029	0.2400
	9.3	0.0567	0.3863	0.2233
	9.1	0.0567	0.3663	0.2033
	8.9	0.0567	0.3497	0.1900
	8.7	0.0533	0.3297	0.1800
	8.5	0.0533	0.3064	0.1600
	8.3	0.0533	0.2931	0.1500
	8.1	0.0533	0.2698	0.1400
	7.9	0.0467	0.2532	0.1300
	7.7	0.0467	0.2332	0.1200
	7.5	0.0467	0.2166	0.1133
	7.3	0.0467	0.1933	0.1033
	7.1	0.0467	0.1733	0.1000
	6.9	0.0433	0.1567	0.0900
	6.7	0.0433	0.1500	0.0833
	6.5	0.0433	0.1500	0.0800

A numeric polynomial regression was carried out for each type of emissions in Table IV-25 to produce a relationship giving VOC emissions in grams per mile as a function of the Reid vapor pressure in pounds per square inch. This resulted in separate equations for Class B and Class C areas, as shown in Table IV-26.

Table IV-26
Nonexhaust Emissions Regressions as a Function of RVP - MOBILE5a

Area Class	Vapor source	Curve Fit	R^2
B	Refueling	$0.004767 * RVP + 0.011859$	0.908
B	Running	$0.017768 * RVP^2 - 0.18746 * RVP + 0.61457$	0.983
B	Evaporative	$0.014039 * RVP^2 - 0.17075 * RVP + 0.60037$	0.996
C	Refueling	$0.004767 * RVP + 0.011859$	0.908
C	Running	$0.016169 * RVP^2 - 0.17206 * RVP + 0.56724$	0.985
C	Evaporative	$0.010853 * RVP^2 - 0.13346 * RVP + 0.48423$	0.993

As stated above, evaporative emissions within the MOBILE emissions model include both hot-soak and diurnal emissions. The ratio of hot soak to diurnal emissions is specific to the area class. For Class B areas, the average weighting of evaporative emissions over all vehicle ages is 47.4 percent hot soak and 52.6 percent diurnal. For Class C areas, the average weighting of evaporative emissions over all vehicle ages is 56.0 percent hot soak and 44.0 percent diurnal. These values differ from the MOBILE4.1 values because of 1) the changes to the diurnal calculations in the MOBILE model that were made when version 5a was being developed, and 2) the change in I/M assumption in Phase II with respect to Phase I. Thus the equations for hot soak and diurnal emissions can be derived from the equations for evaporative losses shown in Table IV-26. The results are shown in Table IV-27.

Table IV-27
Evaporative Emissions Breakdown for MOBILE5a

Area Class	Vapor source	Curve Fit
B	Hot Soak	$0.006654 * RVP^2 - 0.08094 * RVP + 0.28458$
B	Diurnal	$0.007385 * RVP^2 - 0.08981 * RVP + 0.31580$
C	Hot Soak	$0.006078 * RVP^2 - 0.07474 * RVP + 0.27117$
C	Diurnal	$0.004775 * RVP^2 - 0.05872 * RVP + 0.21306$

3. Derivation of Nonexhaust Toxics Equations

The MOBILE model was used to determine the relationship between RVP and nonexhaust VOC emissions because MOBILE is based on the most comprehensive collection of data on this subject. The MOBILE model would therefore be the most natural source of information on the relationship between fuel parameters and nonexhaust emissions of toxic compounds. However, the MOBILE model only provides emission estimates for VOC, NOx, and carbon monoxide. Therefore, it was necessary for the EPA to develop the nonexhaust toxics portion of the Complex Model in a manner different from that used to develop the nonexhaust VOC model.

General Motors (GM) used their proprietary vapor equilibrium model to predict the vapor composition above a pool of fuel (conditions simulating a vehicle's fuel tank). The GM model provided separate estimates for refueling, diurnal, and running losses using a fuel matrix consisting of 12 fuels. These fuels are shown in Table IV-28. Fuels 1, 2, and 3 are the base fuels that were used to produce the subsequent blends.

Table IV-28
GM Tank Vapor Model Fuels

Fuel #	Oxygenate, vol%	Type of blend	RVP
1	none	N/A	7
2	none	N/A	8
3	none	N/A	8.7
4	MTBE, 11%	splash	7.46
5	MTBE, 11%	splash	8.36
6	MTBE, 11%	splash	9.03
7	EtOH, 10%	splash	8.20
8	EtOH, 10%	splash	9.13
9	EtOH, 10%	splash	9.82
10	EtOH, 10%	volatility-matched	7
11	EtOH, 10%	volatility-matched	8
12	EtOH, 10%	volatility-matched	8.7

The fuel benzene content was kept constant at 1 percent by volume in all twelve test gasolines. Different benzene levels were not tested since it is widely accepted that nonexhaust benzene emissions will be proportional to fuel benzene content. Match-blending was carried out by adjusting the concentrations of n-butane and toluene.

EPA believes that fuel tank vapor composition adequately represents the composition of in-use emissions since nonexhaust VOC emissions are dominated by emissions from vehicles which would fail a pressure or purge test. On such "failing" vehicles, the canister has little effect on the composition of emissions, resulting in emissions with compositions essentially identical to their tank composition. Emissions from passing vehicles might have compositions which would differ from the composition of failing vehicle fuel tank vapors. However, nonexhaust emissions from passing vehicles comprise only a small fraction of the total nonexhaust emission inventory. For this reason, EPA believes it appropriate to base its model of the composition of nonexhaust emissions on the composition of nonexhaust emissions from failing vehicles.

The mass percent of benzene in the refueling, diurnal, and running loss vapors as predicted by their tank vapor model was provided directly by General Motors. These values are shown in Table IV-29. The range of temperatures used to obtain these results was 90 °F for refueling emissions, 72-96 °F for diurnal emissions, and 90-115 °F for running loss emissions. Since the same temperature was used for both hot soak and running losses, the results for these two categories of emissions were identical and only the running loss results are shown below.

Table IV-29
GM Tank Vapor Model Results

Fuel #	Mass percent benzene in vapors:		
	Refueling	Diurnal	Running Loss
1	0.828	0.815	0.884
2	0.742	0.731	0.800
3	0.690	0.679	0.748
4	0.722	0.711	0.769
5	0.660	0.650	0.709
6	0.620	0.611	0.670
7	0.720	0.714	0.757
8	0.654	0.648	0.695
9	0.612	0.607	0.656
10	0.829	0.823	0.859
11	0.736	0.730	0.772
12	0.683	0.676	0.721

The values in Table IV-29 indicate that the addition of MTBE to gasoline lowers the mass percent of benzene in the vapor phase, while the addition of ethanol has no effect on the mass percent of benzene as compared to that for the base gasoline alone. To quantify the change in mass percent benzene for MTBE blends, linear curve-fitting was applied to the base fuel and the MTBE blend. Table IV-30 shows the resulting equations giving the mass percent benzene in the nonexhaust vapors for an unoxygenated gasoline (fuels 1, 2, and 3 in Table I-20), and an 11% MTBE blend (fuels 4, 5, and 6 in Table I-20).

Table IV-30
Linear Regressions of GM Model Results

Oxygenate	Vapor source	Equation giving mass percent benzene:	R^2
none	Refueling	1.3972 - 0.081507 * RVP	0.998
none	Diurnal	1.3758 - 0.080274 * RVP	0.999
none	Running loss	1.4448 - 0.080274 * RVP	0.999
MTBE	Refueling	1.2073 - 0.065186 * RVP	0.998
MTBE	Diurnal	1.1868 - 0.063921 * RVP	0.998
MTBE	Running loss	1.2400 - 0.063258 * RVP	0.999

In an effort to simplify the set of equations in Table IV-30, the equations giving the mass percent benzene for MTBE blends were combined with the equations giving the mass percent benzene for unoxygenated gasoline. This was done by assuming that the slope of the equation for a clear gasoline was approximately equal to the slope of the equation for an MTBE blend for a given vapor source. Thus the change in mass percent benzene due to the addition of MTBE to a clear gasoline can be assumed constant over the range of applicable RVPs. The equations from Table IV-30 were evaluated at 8.0 RVP (the approximate center of the range of RVPs for fuels 1-6 in Table IV-28), and the resulting mass percent benzene values for MTBE blends were subtracted from the mass percent benzene values for clear gasoline to obtain a "constant" difference. These results are shown in Table IV-31.

Table IV-31
Differences in Regression Constants Between Blends

Vapor Source	Mass % benzene in vapors for clear gasoline at 8.0 RVP	Mass % benzene in vapors for 11 vol% MTBE blend at 8.0 RVP	Change in mass % benzene with the addition of MTBE to a clear gasoline
Refueling	0.7451	0.686	- 0.0591
Diurnal	0.7335	0.6756	- 0.0579
Running	0.8028	0.7338	- 0.0684
Hot soak	0.8024	0.7340	- 0.0684

An allowance can also be made for fuel MTBE contents of other than 2.0% oxygen by weight (11% MTBE by volume) by multiplying the last column of Table IV-31 by the ratio of MTBE content for the target fuel and a fuel with 11% MTBE. The resulting equations, giving the mass percent of benzene in the nonexhaust emissions for any MTBE-oxygenated or unoxygenated blend, are shown in Table IV-32. Note that in all equations below, "MTBE" is the weight percent of oxygen in the form of MTBE in the fuel ("MTBE" would necessarily be zero for any oxygenate other than MTBE).

Table IV-32
Revised GM Model Regressions

Vapor source	Equation giving mass percent benzene:
Refueling	1.3972 - [0.0591 * MTBE/2.0] - 0.081507 * RVP
Diurnal	1.3758 - [0.0579 * MTBE/2.0] - 0.080274 * RVP
Running loss	1.4448 - [0.0684 * MTBE/2.0] - 0.080274 * RVP
Hot soak	1.4448 - [0.0684 * MTBE/2.0] - 0.080274 * RVP

Two additional steps must be taken to convert the equations in Table IV-32 to equations that provide the nonexhaust emissions of benzene in grams/mile. First, changes in the benzene content of a fuel are expected to result in a proportional change in the benzene fraction of nonexhaust benzene emissions. To account for fuel benzene contents other than the 1 vol% benzene that was used to establish the results in Table IV-29, the equations giving the mass percent benzene (Table IV-32) should be multiplied by the volume percent benzene in the fuel. Second, to obtain benzene emissions in grams/mile for each vapor source, the equations giving the mass percent benzene must be 1) converted to mass fraction benzene by dividing by 100, and 2) multiplied by the total VOC emissions in grams/mile for that vapor source. The final equations are shown in Table IV-33.

Table IV-33
Phase II Complex Model Nonexhaust Benzene Emissions

Vapor source	Equation giving benzene emissions in grams/mile:
Refueling	(BZV%/100) * RFVOC * (1.3972 - [0.0591 * MTBE/2.0] - 0.081507 * RVP)
Diurnal	(BZV%/100) * DVOC * (1.3758 - [0.0579 * MTBE/2.0] - 0.080274 * RVP)
Running loss	(BZV%/100) * RLVOC * (1.4448 - [0.0684 * MTBE/2.0] - 0.080274 * RVP)
Hot soak	(BZV%/100) * HSVOC * (1.4448 - [0.0684 * MTBE/2.0] - 0.080274 * RVP)

BZV% = Volume percent of benzene in the fuel
RFVOC = Total grams per mile of VOC from refueling emissions
DVOC = Total grams per mile of VOC from diurnal emissions
RLVOC = Total grams per mile of VOC from running losses
HSVOC = Total grams per mile of VOC from hot soak emissions

The values for RFVOC, DVOC, RLVOC, and HSVOC for the Phase I and II Complex Models were presented in Sections B.1 and B.2.

4. Validation of Nonexhaust Toxic Emissions Model

Southwest Research Institute was contracted by EPA in July, 1992 to determine how fuel volatility, as measured by the vapor pressure, is affected by the addition of various oxygenates in gasoline blends. As part of this work, SwRI completed a gas chromatograph speciation analysis of a subset of the fuels that were tested and their associated vapors. From this speciation, the mass percent benzene in the vapors and the volume percent benzene in the fuel can be computed and compared to the nonexhaust toxic emissions model described above. Thus, despite the fact that the GM tank vapor model is proprietary, the results of the study carried out by SwRI independently validate and substantiate the nonexhaust benzene correlations described above.

Table IV-34 shows the properties for five fuels whose vapor pressure was measured at both 100 and 130°F. The aromatics content of fuels 3, 4, and 5 was increased through the addition of toluene or 1,3,5-trimethylbenzene as indicated under the aromatics content. Note that the presence of ethanol in fuels 2, 3, and 5 is assumed to have no effect on the mass percent benzene in the vapors (see description of Table IV-29 above).

Table IV-34
SwRI Contract Fuels

Fuel #	Aromatics content	RVP	Oxygenate, vol%	BZV% at 100 Deg F	BZV% at 130 Deg F
1	20%	8.17	none	1.75	1.70
2	20%	9.10	EtOH, 10%	1.74	1.60
3	35% (toluene)	8.01	EtOH, 10%	1.36	1.37
4	35% (trimethylbenzene)	6.93	none	1.40	1.40
5	35% (trimethylbenzene)	8.05	EtOH, 10%	1.36	1.36

Using the volume percent benzene in the fuel and the RVP levels for each of the five fuels shown in Table IV-28, the nonexhaust toxic emissions model described above can be used to predict the mass percent benzene in refueling, diurnal, running loss, and hot soak emissions. These estimates can then be compared to the mass percent benzene measured in the vapors by SwRI. These measured values do not represent specific measurements for either refueling, diurnal, hot soak, or running losses. However, since the difference in emission levels for these four sources results only from the differences in temperatures under which the GM vapor model was run, the values measured by SwRI can be appropriately compared to all four sources. Tables IV-35 and IV-36 show these values for fuel temperatures of 100°F and 130°F, respectively.

Table IV-35
Comparison of Model to Measurements at 100°F

Fuel	Emissions Model benzene mass % prediction:				SwRI measured benzene mass %
	Refueling	Diurnal	Running Loss	Hot Soak	
1	1.28	1.26	1.38	1.38	1.28
2	1.14	1.12	1.24	1.24	1.23
3	1.02	1.00	1.09	1.09	1.00
4	1.17	1.15	1.24	1.24	1.34
5	1.01	0.99	1.08	1.08	1.03

Table IV-36
Comparison of Model to Measurements at 130°F

Fuel	Emissions Model benzene mass % prediction:				SwRI measured benzene mass %
	Refueling	Diurnal	Running Loss	Hot Soak	
1	1.24	1.23	1.34	1.34	1.39
2	1.05	1.04	1.15	1.15	1.11
3	1.02	1.01	1.10	1.10	1.16
4	1.17	1.15	1.25	1.25	1.33
5	1.01	0.99	1.08	1.08	0.92

Overall, the measured values for mass percent benzene given by Southwest Research Institute differ from the values predicted from the toxic emissions model by an average of +2.5 percent and a maximum of 16.7 percent. The average value implies that the nonexhaust model for benzene tends to underestimate the true emissions. However, the repeatability of the RVP measurements in the SwRI study was ±0.16 psi, equivalent to a percent change in benzene emissions of ±3.8 percent (as calculated from the Phase II, Class C nonexhaust equations). Thus the bias implied by the average difference of +2.5 percent appears to be within the measurement accuracy of the study. The data in Tables IV-35 and IV-36 also imply that, for any given fuel, the model predictions for mass percent benzene will differ from measured values by an average of no more than -5.2 percent (95 percent confidence limit). EPA has interpreted these results to suggest that the correlations derived from the GM tank vapor model are sufficiently accurate to form the basis for EPA's model for nonexhaust benzene emissions.

5. Response to Comments

The Agency received a number of comments on the accuracy of the nonexhaust benzene model in light of an analysis of more recent data. This analysis suggested that the fraction of benzene in nonexhaust vapors should be higher than that predicted by the GM model results. Specifically, the analysis of hot soak and diurnal heat build data showed that the weight fraction of benzene in the vapor is a function of the total emissions. At extremely low emission rates the fraction of benzene in the vapor is quite high. As the emission rate increased, however, the benzene weight fraction was found to asymptotically approach a lower limit. The lower limit for hot soak emissions was significantly higher than predicted by the GM model. The lower limit for the diurnal data showed a close correlation to the GM model.

In response to these comments, the Agency has identified two areas in which the requirements of the reformulated gasoline program were compromised in the nonexhaust benzene study offered to it. These two areas are described below:

- The Act requires that the impact of a fuel change on emissions must be restricted to 1990 technology type vehicles for the purposes of the reformulated gasoline and anti-dumping programs. The Agency has determined that carburetted vehicles represent only a small proportion (<2%) of the 1990 fleet. However, a large fraction of the submitted heat build data included carburetted vehicles. Thus the Agency has determined that the conclusions reached as part of the submitted study are not compatible with either the reformulated gasoline or anti-dumping programs.

  The high proportion of carburetted vehicles in the submitted test data is evident from the fact that carburetted vehicles typically have higher hot soak emission rates than fuel-injected vehicles. The primary source of hot soak emissions from carburetted vehicles is the carburetor bowl which is extremely hot and may completely evaporate the fuel. The primary source of hot soak emissions from fuel-injected vehicles is vapors created in the fuel tank at a much lower temperature. Therefore the high emission rate data is probably dominated by carburetted vehicles which may consist of whole fuel vapors. The submitted data and analysis for hot soak emissions support this conclusion since the weight fraction of benzene in the vapor approaches the fuel weight fraction as the emission rate increases.

- The EPA has determined that the low emission rate data for fuel-injected vehicles is not representative of in-use emissions. A large fraction of these emission may be caused by background emissions now characterized as resting loss emissions. Resting losses were not included in the VOC baseline and so should not be included in the toxic baseline. The source of these resting losses has not been determined, but are thought to originate from permeation of fuel lines and tanks. Permeation emissions may be characterized by a high benzene weight fraction.

Based on its review of the submitted data and analyses on the benzene fraction of nonexhaust vapors, the Agency has determined that the General Motors vapor equilibrium model remains the most appropriate and accurate source for developing the nonexhaust benzene portion of the Complex Model.

A number of commenters took issue with the Agency's proposed effect of individual oxygenates on nonexhaust benzene emissions. However, the conclusions reached by the different commenters were contradictory. One commenter pointed to Auto/Oil data which indicated that MTBE increases rather than decreases nonexhaust emissions of benzene. Another commenter supported the suppression of benzene emissions by MTBE, but indicated that recent (unavailable) data supported a similar effect for the oxygenates ETBE and TAME. Given the assailable nature and meager amount of data on the effects of oxygenates on nonexhaust benzene emissions, the Agency has determined that the Simple Model approach to the development of a nonexhaust benzene model is the most appropriate approach for the Complex Model.

C. Determining Emission Performances

1. Definition of Performance

Section 211(k) of the Clean Air Act requires that refiners make gasoline that results in a decrease in emissions of 15 percent (in Phase I of the reformulated gasoline program) over the emissions produced from baseline gasoline. Thus the CAA identifies the measure of "cleanliness" of a given fuel by the percentage difference between its emissions and emissions from the baseline gasoline. For the purposes of this rulemaking, therefore, the performance of a given fuel is defined as the percent change in the vehicle emissions that would occur if baseline gasoline were to be replaced with the given fuel in the fuel tank of a typical 1990 vehicle. The definition of the baseline gasoline depends on the season as described in Section III.A.

The Complex Model is designed to estimate the effects of various fuel parameters on emissions of VOC, NOx, and toxic compounds. If the Complex Model performance of a pollutant is given by Y and the fleet average emissions for that same pollutant in grams per mile terms is given by X, then performance of a target fuel t as compared to a baseline fuel b is calculated from

$$\{[X(t) - X(b)]/X(b)\} * 100 = Y(t) \quad \text{(C.1)}$$

The Complex Model can provide separate emissions performance estimates for three main categories of pollutants: total VOC, NOx, and total toxics. Each category includes emissions from one or more sub-categories. Thus the X term in Equation (C.1) is the sum of the contributions from various sources:

Table IV-37
Contributing Sources to Each Pollutant Category

Pollutant Category	Contributing Sources
VOC	Exhaust VOC Non-exhaust VOC
NOx	Exhaust NOx
Toxics	Exhaust benzene Non-exhaust benzene Exhaust 1,3-butadiene Exhaust acetaldehyde Exhaust formaldehyde Exhaust POM

Note that the non-exhaust portion of the Complex Model contains equations for only benzene and VOC, since other pollutants are found only in exhaust emissions.

2. Exhaust Emissions Calculations

The Complex Model can provide both performance (i.e., percentage change) and mass (i.e., gram per mile) estimates of the emissions from a target fuel as compared to a baseline fuel. The calculations for each pollutant in the exhaust model are performed initially in terms of percentage change from baseline levels, while the non-exhaust model's calculations are performed initially in terms of grams per mile. To obtain total performance estimates as per Equation (C.1), both exhaust and non-exhaust estimates must be expressed in terms of grams per mile. This section focuses exclusively on the derivation of percentage change estimates for exhaust emissions and their conversion to gram per mile estimates. Section C.3. provides details on how this method for determining emissions performance, though different in form from that proposed in the February 1993 NPRM [58 FR 17175], is mathematically identical to the originally proposed method. Note that the derivations shown in this and the following sections are based upon the raw unconsolidated version of the final Complex Model, but the conclusions are equally applicable to the model's consolidated form.

The process used to develop the exhaust emission Complex Model resulted in separate equations for each technology group and emitter class for all six exhaust pollutants. Higher emitting vehicles, however, were not categorized by technology group for the reasons discussed in Section A.2. Hence there are nine distinct equations for each pollutant, one for each of the eight normal emitter technology groups and a ninth for higher emitters. Each of these nine equations relates fuel parameters to emissions and has the following form:

$$\text{(C.2)} \qquad E_i = C_i * \exp(f_i(\text{fuel parameters}))$$

where E is emissions in grams per mile, C is a proportionality constant of unknown magnitude, and the subscript i refers to a specific vehicle group. As described in Section A, the function f_i is a polynomial which can contain linear, squared, and second-order interactive terms.

The value of the proportionality constant C_i is unknown because the statistical development process used to generate the Complex Model did not include the use of intercept terms (see Section IV.A.4 for details). Thus Equation (C.2) can only be used to estimate the relative magnitude of emissions. For example, Equation (C.2) can be evaluated for a specific target fuel and for a baseline fuel, resulting in the following system of equations:

$$\text{(C.3)} \qquad E_i(b) = C_i * \exp(f_i(\text{baseline fuel parameters})) = C_i * \exp(f_i(b))$$

$$\text{(C.4)} \qquad E_i(t) = C_i * \exp(f_i(\text{target fuel parameters})) = C_i * \exp(f_i(t))$$

where b refers to the set of baseline fuel parameter values and t refers to the set of target fuel parameter values. $E(b)_i$ and $E(t)_i$ can be combined to obtain the percentage change in emissions that would occur in a vehicle of vehicle group i if baseline gasoline were replaced with the target gasoline. Mathematically this percentage change is computed as follows:

(C.5) Percentage change in emissions from vehicles of vehicle group i

$$= 100 * [E_i(t) - E_i(b)]/E_i(b)$$

$$= 100 * [C_i\exp(f_i(t)) - C_i\exp(f_i(b))]/[C_i\exp(f_i(b))]$$

$$= [\exp(f_i(t))/\exp(f_i(b)) - 1]*100$$

The final form of Equation (C.5) no longer contains the proportionality constant C_i. As a result, the percentage change in emissions can be calculated directly from Equation (C.5).

To determine the fleet-average percentage change in emissions, the equations for the individual vehicle groups must be combined. Since each vehicle group contributes a different fraction of the total fleet-wide emissions, the individual percentage change estimates for each vehicle group must be weighted to reflect the group's contribution to the overall emissions inventory. The derivation of these weighting factors was discussed in Section III.B.4 above. Thus the total performance estimate for a given pollutant is given by

$$(C.6) \qquad Y = \sum \{w_i * [\exp(f_i(t))/\exp(f_i(b)) - 1] * 100\}$$

where the w_i are the weighting factors given in Table III-8 of Section III.B.4.

Once the target fuel's fleet-average performance estimate has been determined, it must be converted to a gram per mile basis before being combined with the non-exhaust emission estimates. This conversion involves multiplying the fleet-average estimate of the percentage change in emissions by the baseline emission estimates X(b) derived in Section III.B. The conversion has the following form, with X(t) representing the fleet-average emissions from the target fuel in gram per mile terms and Y(t) representing the fleet-average performance of the target fuel in terms of percentage change from baseline:

$$(C.7) \qquad X(t) = X(b) + [X(b) * Y(t)/100]$$

Fleet-average exhaust and non-exhaust emissions, both expressed in gram per mile terms, can be summed for each pollutant. The total percentage change in emissions can then be calculated using Equation (C.1).

The calculations described in this section do not take into account any linear extrapolations. When linear extrapolation is required, the calculation procedures described in this section must be supplemented with other calculations. Both the conditions under which extrapolation is required and the associated calculation procedures are covered in Section IV.D.

3. Comparison of the Current Performance Calculation Method and the Method Proposed in the February 1993 NPRM

The calculation of fleet-average performances for each exhaust pollutant described above circumvents the need for vehicle group-specific gram/mile estimates. This change was made to the proposed method for calculating performances (as laid out in the DRIA for the February 1993 NPRM, 58 FR 17175) to simplify both the calculations themselves and the conceptual approach to the Complex Model. It was also made in response to comments that expressed confusion over the derivation of the proportionality constants (the k_i) used in the February 1993 proposed model. The method described above is, in fact, mathematically equivalent to the originally proposed method, except that the proportionality constants and the calculation of vehicle group-specific gram per mile emission estimates have been eliminated. This section describes the mathematical conversion of the proposed method to the final method described above.

As described previously, the exhaust equations for all pollutants have the form of an exponential of a polynomial function of the eight fuel parameters. Each such equation is unique for every vehicle group and pollutant in the raw (unconsolidated) form of the Complex Model. In the February 1993 Notice of Proposed Rulemaking [58 FR 17175], a procedure for calculating gram/mile values for every vehicle group was outlined. This procedure provided total (fleet average) gram/mile values from the gram/mile values for individual vehicle groups through the following equation:

(C.8) $X = \Sigma\ k_i W_i \exp(f_i)$

X = Fleet average emissions of any pollutant in g/mi
k_i = Adjustment factor for vehicle group i
f_i = Polynomial function for vehicle group i, evaluated with the fuel parameter values for the target fuel
W_i = Weighting factor for vehicle group i (note that these weighting factors are not the same as the weighting factors w_i described in Section III.B.4 but instead are the normalized sales weighting for vehicle group i, unadjusted for differences in baseline emissions across vehicle groups. Thus W_i retains the weighting factor definition given in the February NPRM.)

In Equation (C.8), $k_i W_i \exp(f_i)$ is the gram/mile contribution to the total mobile source inventory from vehicle group i. Equation (C.8) can be written more simply as

(C.9) $X(t) = \Sigma\ X_i(t)$

to show that the total, fleet average gram/mile estimate is made up of the gram/mile estimates from the contributing vehicle groups. Replacing X with X(t) shows that X is a function of the target fuel.

As described in Section C.1 above, the total percent change in the emissions of any exhaust pollutant is given by

(C.1) $\{[X(t) - X(b)]/X(b)\} * 100 = Y(t)$

Substituting Equation (C.9) into Equation (C.1) yields

(C.10) $[(\Sigma\ X_i(t) - \Sigma\ X_i(b))/\Sigma\ X_i(b)] * 100 = Y_i(t)$

where the subscript i denotes individual vehicle groups. This equation can be applied to the raw, refined, or consolidated

Complex Models; using the raw form of the Complex Model, for example, the summations in the above equation can be written as follows:

$$\Sigma X_i(t) = X_i(t) + X_i(t) + \cdots + X_{10}(t)$$

$$\Sigma X_i(b) = X_1(b) + X_2(b) + \cdots + X_{10}(b)$$

where vehicle groups #1 through #9 are the normal emitter technology groups, while vehicle group #10 is the higher emitting vehicles. Equation (C.10) then becomes Equation (C.11):

$$\frac{[(X_1(t) + \cdots + X_{10}(t)) - (X_1(b) + \cdots + X_{10}(b))]*100}{(X_1(b) + \cdots + X_{10}(b))} = Y(t)$$

The terms in the numerator can be grouped according to vehicle group to yield Equation (C.12):

$$\frac{[(X_1(t)_1 - X_1(b)_1) + (X_2(t) - X_2(b)) + \cdot\cdot\ ]*100}{(X_1(b)_1 + \cdots + X_{10}(b))} = Y(t)$$

Equation (C.12) can be separated into ten separate equations, each representing a given vehicle group's contribution to the total percent change in pollutant Y:

(C.13a) $[(X_1(t)-X_1(b))/\Sigma X_i(b)] * 100 =$ Contribution to total percent change in pollutant Y from vehicle group #1

(C.13b) $[(X_2(t)-X_2(b))/\Sigma X_i(b)] * 100 =$ Contribution to total percent change in pollutant Y from vehicle group #2

and so on for (C.13c), (C.13d), etc.

At this point, combining Equations (C.8) and (C.9) gives

(C.14) $X_i(t) = k_i W_i \exp(f_i(t))$

for the target fuel, and

(C.15) $X_i(b) = k_i W_i \exp(f_i(b))$

for the baseline fuel. The adjustment factors k_i are defined as follows:

k_i = $C_i/\exp(f_i(b))$
C_i = Average emissions of pollutant Y from vehicle group i; see EPA memorandum from Christian Lindhjem to Richard A. Rykowski, "Effects of Oxygenates on Emissions," Jan. 7,

1992 and the DRIA for the February 1993 NPRM for further details.

Substituting for k_i in Equations (C.14) and (C.15) results in

$$\text{(C.16)} \quad X_i(t) = k_iW_i\exp(f_i(t))$$

$$= C_iW_i\exp(f_i(t))/\exp(f_i(b))$$

$$\text{(C.17)} \quad X_i(b) = k_iW_i\exp(f_i(b))$$

$$= C_iW_i\exp(f_i(b))/\exp(f_i(b))$$

$$= C_iW_i$$

Equation (C.17) implies that the baseline values $X_i(b)$ are constant. Equation (C.16) implies that the target fuel values are equal to the corresponding baseline values multiplied by the ratio of $\exp(f_i(t))$ to $\exp(f_i(b))$. Using vehicle group #1 as an example, combine Equations (C.13a), (C.16), and (C.17) to obtain

(C.18) Contribution to total percent change in pollutant Y from vehicle group #1

$$= 100*(X_1(t) - X_1(b))/\Sigma\ X_i(b)$$

$$= 100*[C_1W_1\exp(f_1(t))/\exp(f_1(b)) - C_1W_1]/\Sigma\ C_iW_i$$

$$= 100*(C_1W_1)*[\exp(f_1(t))/\exp(f_1(b)) - 1]/\Sigma\ C_iW_i$$

$$= 100*\exp(f_1(t))/\exp(f_1(b)) - 1]*(C_1W_1)/\Sigma\ C_iW_i$$

Equation (C.18) provides vehicle group #1's contribution to the total percent change in pollutant Y. The term $100*[\exp(f_1(t))/\exp(f_1(b))-1]$ provides the percent change in pollutant Y for vehicle group #1, equivalent to Equation (C.5). Thus if the form of Equation (C.18) were duplicated for the remaining vehicle groups and all such equations were summed, the result would be Equation (C.7). Since Equations (C.18) and (C.7) are mathematically equivalent, the method proposed in the February NPRM for calculating performances is mathematically equivalent to the method that has been employed for the final Complex Model.

Since the C_i and W_i are constants, the term C_1W_1 is also a constant, and $(C_1W_1)/\Sigma\ C_iW_i$ is the normalized form of C_1W_1. Thus the final weighting factor w_i for vehicle group #1 (not to be confused with the interim weighting factor W_1) is defined as

$$(C_1W_1)/\Sigma\ C_iW_i = w_1$$

The final weighting factors w_i were derived in Section III.B.4 above.

Although the derivation of the vehicle group-specific percent change equations outlined above uses the raw form of the final Complex Model, the results are applicable to the refined, consolidated, and uncentered forms of the Complex Model as well. As discussed above, the technology group weightings for normal emitters (Table IV-2) were applied to the normal emitter vehicle groups in the random balance approach to vehicle group consolidation. Doing so resulted in a single equation for normal emitters, and the emitter class emission weightings from Table 4 were then applied directly to the two remaining equations for each pollutant. Thus the consolidated and uncentered models contain two vehicle groups for each pollutant instead of the original nine, one for normal emitters and one for higher emitters. The derivations described in this subsection apply regardless of the number of vehicle groups in a given model.

4. Response to Comments

A number of commenters noted the disparity between the quantity of data on higher emitting vehicles in the Complex Model database and the large weighting that higher emitters are given in the Complex Model, particularly for VOC and toxics. Two options were suggested for alternative treatments of higher emitters:

1) Assume that the emissions impact of fuel modifications on higher emitters is generally similar to the emissions impact of fuel modifications on normal emitters. This assumption would imply that the statistical development of the Complex Model should proceed with a "totally unified approach," in which higher emitters would be modeled in the same manner as normal emitter technology groups.

2) Decrease the weighting assigned to higher emitter effects in the final Complex Model.

The Agency's analysis of available data indicated that higher emitters have fundamentally different responses to fuel modifications than do normal emitters. The EPA therefore continued to treat higher emitters as a distinct population of vehicles requiring different analysis techniques than those used to account for normal emitter technology group distinctions. For this reason, EPA decided not to use the totally unified modeling approach.

The Agency acknowledges the disparity between the proportion of higher emitter data and the weighting given the higher emitter equations in the Complex Model. However, the Agency does not believe that the limited available data on higher emitters justifies under-weighting emissions from such vehicles for the following reasons:

- The Agency has no basis for arbitrarily lowering the weighting for higher emitters to a level below the contribution of such vehicles to in-use emissions. Doing so would result in models which are inconsistent with EPA's knowledge of in-use emissions and with EPA's MOBILE models.

- All interested parties were informed of the scarcity of data on higher emitters and the large weight that higher emitters were to receive in the final Complex Model during the early stages of model development, beginning with EPA's first public workshop on the Complex Model held January 21-22, 1992. Despite the Agency's solicitation for additional higher emitter data, the only additional higher emitter data included in the Complex Model database were obtained through EPA-sponsored test programs. The Auto/Oil program did test higher emitters but failed to stabilize their emissions prior to testing. As discussed in Section A.1, EPA considers inclusion of test results from unstable vehicles to be inappropriate.

- The fleet-average ratio of normal emitter emissions to higher emitter emissions is based on an analysis of data used to develop the MOBILE emissions model. Since this data is regarded as the most complete set of available data on the in-use mobile source emissions inventory, EPA considers any other basis for these weightings to be less reliable.

The Agency considers the weighting factors described and derived above to provide the most appropriate allocation of the emissions inventory to each emitter class and technology group.

D. Range and Extrapolation of the Model

Section C presented the procedure for calculating emission performances with the Complex Model equations. The current section describes some of the limitations of those regression equations by addressing two specific issues:

- The fuel parameter ranges within which the Complex Model equations can be applied.

- The methodology for extrapolating the Complex Model equations to cover fuels whose properties are not represented in the Complex Model database.

These limitations on the use of the regression equations arise from the limitations of the Complex Model database. In regions of the fuels space[43] where emissions data is limited or absent, the regression equations may not reliably reflect the response of in-use vehicles to fuel modifications. Limits on fuel parameter ranges and extrapolation techniques are two methods that EPA has chosen to compensate for the limitations of the Complex Model database.

This section is divided into five parts. Section D.1 derives and presents the limits of the data core, which is the subset of the fuels space that contains the bulk of the data in the Complex Model database. The data core delineates the range of fuel parameters within which EPA considers the regression equations to be most trustworthy since sufficient data from the Complex Model database is available. Section D.2 presents EPA's approach to designating the valid range, or the range of fuel parameters within which fuels can be evaluated with the Complex Model. Since the data core is smaller than the valid range, EPA has chosen to employ a type of extrapolation to estimate emission performances between these two ranges. Sections D.3, D.4, and D.5 present the extrapolation methodology in three steps:

1) Section D.3 lays out the Agency's theoretical and mathematical approach to linear extrapolation.

2) Section D.4 identifies the location of inappropriate extrema (minimums and maximums) which can be accommodated in the Complex Model through the application of linear extrapolation.

3) Section D.5 applies the approaches outlined in Sections D.3 and D.4 to the Complex Model regression equations and presents the final extrapolation algorithm and equations.

Both the fuel parameter ranges and extrapolation methodologies are independent of the particular season, program phase, and area class scenarios under which the Complex Model can operate. The specific extrapolation approach to the Complex Model applies to both the reformulated gasoline program and the anti-dumping program, but the limits on the fuel parameter ranges over which the Complex Model is valid differ for the reformulated gasoline and anti-dumping programs.

1. Derivation of Data Core

---

[43] The "fuels space" refers to the multi-dimensional universe in which each axis is represented by a single fuel parameter. A given point in the fuels space specifies a set of fuel properties which represents a single, unique fuel.

As introduced above, the data core is the subset of the multi-dimensional fuels space that contains the bulk of the data in the Complex Model database. It can be pictured as a multi-dimensional box which is defined by upper and lower bounds on each fuel parameter. The data core serves three main purposes:

1) It provides information on the limitations of the Complex Model, which was derived from a database which did not cover all possible fuel formulations.

2) It delineates the range for each fuel parameter within which the regression equations are most reliable.

3) It provides the locations in the multi-dimensional fuels space at which extrapolation should begin.[44]

Specification of the data core is the first step in translating the limitations of the Complex Model database into the limitations of the Complex Model.

For the February 1993 Notice of Proposed Rulemaking [58 FR 17175], the data core was determined from a visual examination of the data in the Complex Model database.[45] This visual examination used frequency distributions of the values of individual fuel parameters. The frequency distributions were simply graphical displays in which the horizontal axis gave the level of a given fuel parameter and the vertical axis gave the fractional frequency of observations of those fuel parameter levels in the Complex Model database. The Agency used the graphical displays to specify the low and high values of each fuel parameter which enclosed the bulk of the data (see the February 1993 Draft Regulatory Impact Analysis for further details).

The Agency has since conducted a more rigorous analysis of the data core based on four main factors:

- Distribution of the data.
- Covariation between fuel parameters.
- Behavior of the Complex Model.

---

[44] Extrapolation generally begins at the limits of the data core. However, extrema also play a role in determining the locations at which extrapolation should begin, as described in more detail in Section D.4.

[45] In the February 1993 NPRM, the data core was referred to as the valid range of the Complex Model, and indeed was coincident with the valid range as defined and specified in Section D.2 below.

- The fuel parameter ranges which encompass various percentages of the data.

The distribution of the data is an extremely important factor because regression equations tend to be most reliable in the regions of the fuels space that contain the most data. Ideally, the data in the database would be evenly distributed (i.e., homogeneous) over a given range for each fuel parameter. To the extent that the database is not homogeneous, the regression equations are that much less reliable.

Homogeneity is particularly important when examining the ends of the data ranges. Since the ends of the data ranges typically have fewer observations than more central portions of the data, the reliability of the regression equations decreases as one approaches those ends. This tendency implies that the limits of the data core should not be coincident with the maximum and minimum values observed in the database since it is near such extreme values where the reliability of the regression equations decreases rapidly.

Covariation between fuel parameters is an issue in determining the limits of the data core because it can obscure holes in the Complex Model database. Some portions of the multi-dimensional fuels space may appear to contain sufficient data when in fact they do not. For example, the bulk of the data for E200 may lie between 35 and 70 percent for a given data set, while most E300 values for the data set range from 70 to 95 percent. However, since fuels with high E200 values typically contain high E300 values and vice-versa, not all combinations of E200 and E300 levels would be well represented in the data set. For example, fuels with high E200 values (e.g., 65 percent) and low E300 values (e.g., 75 percent) would not be well represented in the data set, although the E200 and E300 values individually fall within their respective ranges in the data set. Significant covariation problems can be identified with graphical displays by plotting the levels of one fuel parameter as a function of a second fuel parameter. Covariation can also be identified analytically by determining how well one can predict levels of a fuel paramter if one knows the level of a second fuel parameter. For example, an indication of the degree of covariation between two parameters can be determined by calculating the R-squared value for a regression with one fuel parameter as the dependent variable and a second fuel parameter as the independent fuel variable. High covariation would result in high R-square values.

If a significant correlation exists between two fuel parameters, then the data core limits for one fuel parameter depend on the level of a second fuel parameter. Covariation has the effect of changing the shape of the data core from a multi-dimensional box to some other, more complex shape. EPA's examination of covariation in the Complex Model database revealed substantial covariation between the following fuel parameter pairs:

Benzene and Sulfur
Benzene and Oxygen
Aromatics and E200
E200 and Oxygen
E200 and E300
Aromatics and E300
Olefins and Sulfur
Olefins and Benzene
E300 and Sulfur

However, in no case did the covariation result in the complete absence of emissions data from any portion of the multi-dimensional fuels space. Thus it was not necessary to specify the data core with the upper and lower bounds on each fuel parameter being a function of the values of another fuel parameter. Instead, the upper and lower bounds for each fuel parameter could be determined independently.

The behavior of the Complex Model is also an important factor in determining the extend of the data core. When discussing the model's behavior, the exponential form of the model alters the traditional implications of first- and second-order terms. Since the statistical regressions employed to develop the exhaust emission Complex Model used the natural logarithm of emissions as the dependent variable (see Section A.2), emissions are proportional to the exponential of the resulting polynomials, not to the polynomials themselves. As a result, emissions are not first- or second-order functions of the fuel parameters included in the model in a strict mathematical sense. However, the deviation between the behavior of an exponential of a polynomial and the behavior of the polynomial itself is significant only for large numerical values of the independent variables (the fuel parameters, in the case of the complex model). In the Complex Model, only sulfur measurements ever exhibit such high values, and then only under the anti-dumping program (as discussed in Section D.2). Therefore, the behavior of the polynomial functions which are exponentiated in the Complex Model's exhaust emission equations provides a good approximation to the behavior of the actual exponential equations that comprise the exhaust emission Complex Model. For this reason, the Complex Model exhaust equations themselves will be referred to as being first- or second-order in the discussions that follow based on the form of the exponentiated polynomial with no loss of descriptive accuracy.

With the foregoing discussion in mind, the behavior of the Complex Model can provide additional guidance in defining the limits of the data core. As stated in the introduction to this section, one purpose of the data core is to provide the locations in the multi-dimensional fuels space at which extrapolation should begin, since the regression equations become less reliable than desired outside the data core. Models which exhibit questionable or counter-intuitive behavior are less reliable than models which do not exhibit such behavior. As a result, the range of fuel parameters within which the regression equations are considered reliable should be made more restrictive for those parameters for which the complex model exhibits questionable or counter-intuitive behavior. In other words, the size of the data core should be reduced in such cases so as to restrict poorly-behaved equations to smaller regions of the fuels space than well-behaved equations.

As described in Section D.3, all extrapolations beyond the limits of the data core were linear extrapolations. Since a linear extrapolation of a linear relationship results in the original linear relationship, linear extrapolation of the Complex Model regression equations only alters the second-order relationships included in the Complex Model. Thus the behavior of pollutant models should influence the extent of the data core only for fuel parameters which are present in second-order terms. The data core should be far less influenced by the Complex Model's behavior for fuel parameters present only in linear terms. The second-order terms which are present in the Complex Model are shown in Table IV-38.

Table IV-38
Second-order terms in the Complex Model

Pollutant	Second-order terms in the regression equation
VOC	$E200^2$, $E300^2$, ARO*E300
NOx	OLE^2, SUL^2, ARO^2
Benzene	none
Butadiene	none
Acetaldehyde	none
Formaldehyde	none

As described in Section D.4, second-order terms may create extrema which may not appropriately represent the effects of fuel modifications for all possible fuel parameter values. In some cases the existence and location of extrema are artifacts of the distribution of the data in the Complex Model database. In such cases, limiting the size of the data core helps exclude inappropriate extrema from the model.

Finally, the range which encloses a fixed percentage of the data for each fuel parameter also helps determine the extent of the data core. Not only does such an analysis provide a less qualitative approach to specifying the limits which enclose the bulk of the data, it also provides information on the homogeneity of data at the ends of the data ranges. Table IV-39 shows the results of such an analysis. Table IV-39 includes five range restriction limits. The 98% limits, for example, are determined by allowing 1% of the data to fall below the "low" end of the range and 1% of the data to fall above the "high" end of the range. Similarly, the 95% limits are determined by allowing 2.5% of the data to fall below the low end and 2.5% to fall above the high end. Each limit is pollutant-specific for each parameter since not all pollutants were measured for each fuel-vehicle combination. For example, 96% percent of the acetaldehyde observations were based on fuels with aromatics levels between 11.5 and 45.9 vol%, but 96% of the VOC observations were based on fuels with aromatics levels between 17.9 and 45.9 vol%.

Table IV-39
Limits of the Bulk of the Data

Parameter	Pollutant	98% limits		97% limits		96% limits		95% limits		94% limits	
		Low	High	Low	High	Low	High	Low	High	Low	High
Aromatics	Acetaldehyde	11.3	46.7	11.3	46.6	11.5	45.9	11.5	45.7	11.5	45.7
	Benzene	11.3	46.7	11.3	46.4	11.5	45.9	11.5	45.7	12.7	44.3
	Butadiene	11.3	46.7	11.3	46.6	11.5	45.9	11.5	45.7	11.5	44.3
	Formaldehyde	11.3	46.7	11.3	46.6	11.3	45.9	11.5	45.7	11.5	45.7
	NOx	9.3	47.8	9.8	46.7	11.3	46.7	11.5	46.4	12.7	45.9
	VOC	11.5	47.3	17.9	46.7	17.9	45.9	18.1	45.9	18.1	45.7
Benzene	Acetaldehyde	0.39	2.3	0.39	1.84	0.4	1.8	0.4	1.8	0.4	1.8
	Benzene	0.39	2.3	0.4	1.84	0.4	1.8	0.4	1.8	0.4	1.8
	Butadiene	0.39	1.8	0.4	1.8	0.4	1.8	0.4	1.8	0.4	1.7
	Formaldehyde	0.39	2.3	0.39	1.84	0.4	1.8	0.4	1.8	0.4	1.8
	NOx	0.39	2.4	0.39	2.3	0.39	1.9	0.4	1.84	0.4	1.8
	VOC	0.38	1.8	0.39	1.8	0.39	1.8	0.39	1.7	0.4	1.7
E200	Acetaldehyde	30.96	67.41	31.72	66.87	31.72	66.87	31.88	65.74	34.27	65.37
	Benzene	26.68	67.41	30.96	66.87	30.96	66.87	31.34	65.74	31.72	65.37
	Butadiene	26.68	67.41	30.96	66.87	30.96	66.87	30.96	65.74	31.72	65.37
	Formaldehyde	30.96	67.41	31.72	66.87	31.72	66.87	31.88	65.74	34.27	65.37
	NOx	27.42	67.8	30.02	67.41	30.96	67.41	31.34	66.87	31.72	65.74
	VOC	30.02	67.41	30.96	67.41	31.72	66.87	31.88	66.87	32.65	65.74
E300	Acetaldehyde	71.65	97.28	71.99	97.28	72.02	95.56	72.68	95.31	72.68	95
	Benzene	71.19	97.28	71.65	97.28	71.99	95.56	72.02	95.31	72.68	94.87
	Butadiene	71.19	97.28	71.65	97.28	71.99	95.56	72.02	95.31	72.68	95
	Formaldehyde	71.65	97.28	71.99	97.28	72.02	95.56	72.68	95.31	72.68	95
	NOx	71.65	97.28	71.99	97.28	72.02	95.56	72.02	95.31	72.68	94.87
	VOC	71.65	97.28	71.99	95.56	71.99	95.31	72.02	94.5	72.02	93.87
Olefins	Acetaldehyde	0.6	21.8	1	20.3	1.1	19.3	1.1	18.5	1.1	18.3
	Benzene	1	21.8	1.1	20.3	1.1	19.3	1.1	18.3	1.1	18.3
	Butadiene	0.6	21.8	1	20.3	1.1	19.3	1.1	18.5	1.1	18.3
	Formaldehyde	0.6	21.8	1	20.3	1.1	19.3	1.1	18.5	1.1	18.3
	NOx	0	21.9	0.2	21.8	0.6	20.3	0.9	20.3	1	19.3
	VOC	1	21.8	1	21.8	1.1	20.3	1.1	20.3	1.1	19.3

Oxygen	Acetaldehyde	0	3.81	0	3.81	0	3.48	0	3.42	0	3.42
	Benzene	0	3.81	0	3.81	0	3.42	0	3.42	0	3.37
	Butadiene	0	3.81	0	3.81	0	3.42	0	3.42	0	3.37
	Formaldehyde	0	3.81	0	3.81	0	3.48	0	3.42	0	3.42
	NOx	0	3.42	0	3.37	0	3.37	0	3.37	0	3.34
	VOC	0	3.42	0	3.37	0	3.37	0	3.37	0	3.37
RVP	Acetaldehyde	6.2	9.7	6.2	9.59	6.2	9.55	6.4	9.4	6.4	9.32
	Benzene	6.2	9.59	6.2	9.59	6.2	9.55	6.4	9.32	6.4	9.2
	Butadiene	6.2	9.59	6.2	9.59	6.2	9.55	6.4	9.32	6.4	9.3
	Formaldehyde	6.2	9.7	6.2	9.59	6.2	9.55	6.4	9.4	6.4	9.32
	NOx	6.4	12	6.4	12	6.6	11.5	6.6	10.2	6.86	9.9
	VOC	6.4	12	6.4	12	6.5	11.7	6.6	10.2	6.86	9.9
Sulfur	Acetaldehyde	31	371	31	371	31	371	31	371	31	364
	Benzene	31	371	31	371	31	371	31	371	31	364
	Butadiene	31	371	31	371	31	371	31	371	31	364
	Formaldehyde	31	371	31	371	31	371	31	371	31	364
	NOx	7	466	7	466	10	466	11	452	12	443
	VOC	10	466	12	466	21	466	31	466	31	452

Table IV-39 is particularly useful when evaluating the limits of the data core for fuel parameters which are included in second-order terms as shown in Table IV-38. The second-order effects decrease the reliability of the complex model's emission estimates for fuels with levels of such fuel parameters that are outside the bulk of the data. Thus the distribution of E200 data in Table IV-39 for VOC observations should play a stronger role in setting the limits of the data core than the distribution of E200 data for NOx or benzene, since nonlinear E200 terms are present only in the VOC model. The same considerations apply to the other fuel parameters: the distribution of VOC observations should play a strong role in determining data core limits for E300 and aromatics, while the distribution of NOx data should play a strong role in determining the data core limits for olefins, sulfur, and aromatics.

RVP, oxygen, and fuel benzene content never appear in second-order terms in the exhaust Complex Model. This fact suggests that the effects of these parameters can be extended via the regression curve approach to extrapolation (see Section D.3) with relatively high confidence to parameter levels for which emissions data is scarce or absent. Thus the location of the data core limits for these three parameters has no bearing on their extrapolation. To convert the ranges from Table IV-39 to a more manageable form for these three fuel parameters, the range limits for individual pollutants can be combined into a single set of ranges for all pollutants. The number of observations for each pollutant in the Complex Model database can be used to develop a weighted average across all pollutants for RVP, oxygen, and fuel benzene limits. The weightings are shown in Table IV-40; useable observations are those observations were not deleted as outliers or influential points during the model-building process.

Table IV-40
Number of Useable Observations by Pollutant

Pollutant	Number of observations in the database	Percent of total observations
Acetaldehyde	1785	10.59
Benzene	1872	11.11
1,3-Butadiene	1821	10.80
Formaldehyde	1788	10.61
NOx	5246	31.13
VOC	4342	25.76
Total	16,854	100.00

This analysis allows conversion of the values in Table IV-39 into a form that is more conducive to determining an appropriate data core, as shown in Table IV-41.

Table IV-41
Restricted Limits of the Bulk of the Data

Parameter	Pollutant	98% limits		97% limits		96% limits		95% limits		94% limits	
		Low	High	Low	High	Low	High	Low	High	Low	High
Aromatics	NOx	9.3	47.8	9.8	46.7	11.3	46.7	11.5	46.4	12.7	45.9
	VOC	11.5	47.3	17.9	46.7	17.9	45.9	18.1	45.9	18.1	45.7
Benzene	Overall	0.39	2.15	0.39	1.97	0.39	1.83	0.4	1.79	0.4	1.76
E200	VOC	30.02	67.41	30.96	67.41	31.72	66.87	31.88	66.87	32.65	65.74
E300	VOC	71.65	97.28	71.99	95.56	71.99	95.31	72.02	94.5	72.02	93.87
Olefins	NOx	0	21.9	0.2	21.8	0.6	20.3	0.9	20.3	1	19.3
Oxygen	Overall	0	3.59	0	3.56	0	3.40	0	3.39	0	3.37
RVP	Overall	6.31	10.98	6.31	10.96	6.40	10.71	6.51	9.84	6.66	9.63
Sulfur	NOx	7	466	7	466	10	466	11	452	12	443

Table IV-41 contains both pollutant-specific limits and common limits. The pollutant-specific limits are taken directly out of Table IV-39, and represent the data limits for pollutants whose behavior includes second-order effects. The common limits are determined by weighting all the pollutant-specific data limits according to the values in Table IV-40. The common limits therefore represent the data limits across all pollutants. The final limits of the data core are discussed separately for each parameter.

Aromatics: Since second-order aromatics terms occur in both the NOx and VOC models, EPA chose to be cautious in setting the aromatics limits of the data core. Table IV-39 shows that the VOC limits are always more restrictive than the NOx limits. When moving from the 98% VOC limit to the 97% VOC limit, the low end of the aromatics range jumps from 11.5 to 17.9 vol%, indicating that very few observations are present between those aromatics levels. The low end remains stable at approximately 18 vol% as the data limits become more restrictive. Thus the low end of the data core has been set at 18 vol% aromatics. Between the 96% and 94% limits, the high end remains stable at approximately 46 vol% aromatics. Between the 96% and 97% limits, however, the high end jumps from 45.9 to 46.7 vol%, indicating that the data set begins to become sparse beyond 46 vol%. This conclusion is supported by the 98% high end limit. Thus the high end of the data core has been set at 46 vol%.

Benzene: Since benzene is present in the benzene model only in a linear term, EPA was less cautious in setting benzene limits. The low end appears to be fixed at approximately 0.4 vol% across all examined limits, so EPA set the low end of the data core at 0.4 vol%. Between the 94% and 96% limits, the high end is stable at approximately 1.8 vol%. The high end jumps to 1.97 vol% at the 97% limit and then to 2.15 vol% at the 98% limit, indicating that data become scarce above the 96% limit but are relatively common below it. Therefore the high end of the data core for benzene has been set at 1.8 vol%.

E200: E200 is present in the VOC model in a second-order term, so EPA based its E200 data core limits on a cautious interpretation of the distribution of VOC data. The low end appears to change little between the 95% and 96% VOC limits, indicating that a clump of data exists for E200 values near 31.8 vol%. However, the low end increases to

32.65 vol% at the 94% limit and decreases to 30.96 vol% at the 97% limits; these jumps indicate that data is not homogeneously distributed at the low end of the E200 range. Thus the low end of the data core has been set conservatively at 33 vol%. A similar inhomogeneity exists on the high end: more high end data exists between the 95% and 96% limits than exists between the 94% and 95% limits. Thus the high end of the data core has been set conservatively at 66 vol%.

E300: E300 is present in two separate second-order terms for VOC, so EPA based its E300 data core limits on a cautious interpretation of the distribution of VOC data. The low end is relatively constant at 72 vol%, which indicates that a significant amount of data exists at the extreme low end of the range. Thus the low end of the data core was set at 72 vol%. However, the high-end E300 limits vary significantly across the five data limits examined. EPA therefore set the high end of the data core conservatively at a level of 94 vol%.

Olefins: A second-order olefins term is present in the NOx model, so EPA based its olefins data core limits on a cautious interpretation of the distribution of NOx data. The low end decreases rapidly between the 95% and 98% limits, but is relatively stable between the 94% and 95% limits. Since the low end data begins thinning out dramatically below 0.9 vol%, the low end of the data core was set at 1.0 vol%. On the high end, a data gap exists between the 96% and 97% limits, but significant data appear available between the 95% and 96% limits. Thus the high end was set conservatively at 19 vol%.

Oxygen: The low end of the data distribution is fixed at 0.0 wt% for all five data limits. The high end is constant at approximately 3.4 wt% between the 94% and 96% limits. Above the 96% limit, the high end data becomes thinner. Therefore, the low end of the data core was set at 0.0 wt% and the high end was set at 3.4 vol%.

RVP: RVP is not involved in any second-order terms in the Complex Model, so EPA was less cautious in setting RVP limits for the data core. Although a clump of data exists between the 97% and 98% limits for the low end, the data is much thinner between the 94% and 97% limits. The low end of the data core was therefore set at 7 psi. The high end of the data distribution averages approximately 10 psi across all pollutants and all data limit levels, so the high end of the data core was set at 10 psi.

Sulfur: Sulfur is present in second-order terms in the NOx model, so EPA based the sulfur limits of the data core on the distribution of NOx data. At the low end of the range, the measurement tolerance for sulfur is much larger than the difference between the values for the various range limits. Thus the low end of the data core was set at the average level of 10 ppm sulfur. EPA retained the NPRM high end limit of 450 ppm since there appears to be a significant amount of data near 466 ppm despite the thin amount of data between 443 and 466 ppm. In addition, the NOx model does not exhibit unexpected or inappropriate behavior at sulfur levels of 450 ppm.

Based on the foregoing discussion, the final data range limits enclosing the bulk of the data are summarized in Table IV-42.

Table IV-42
Data Core for the Complex Model

Pollutant	Units	Limits of Data Core	
		Low end	High end
Aromatics	vol%	18	46
Benzene	vol%	0.4	1.8
E200	vol%	33	66
E300	vol%	72	94
Olefins	vol%	1	19
Oxygen	wt%	0.0	3.4
RVP	psi	7	10
Sulfur	ppm	10	450

2. Valid Ranges

The valid range for the Complex Model is here defined as that range of fuel parameters over which the Complex Model (and any applicable extrapolations as described in Section D.5) can be used to evaluate the emission performances of fuels. The Complex Model can be used outside the valid range only if the model is augmented through testing. The valid range is not meant to place absolute fuel parameter restrictions on either the reformulated gasoline (RFG) or anti-dumping programs, but rather on the use of the Complex Model within those programs.

Specification of the valid range is a means of overcoming some of the limitations of the Complex Model database. As described in the previous section, the database from which the Complex Model is derived does not cover all possible fuel blends that might be encountered in the RFG and anti-dumping programs. The limits of the data core (as defined in Section D.1) reflect the limitations of the database and therefore the limitations of the empirically-based Complex Model regression equations. In an effort to mitigate the disparity between the limitations of the database and the needs of the RFG and anti-dumping programs, the Agency has extrapolated the Complex Model regression equations to cover as many fuel blends as possible. Even with extrapolation, however, the Complex Model must be limited to some subset of the fuels space to maintain the accuracy of its emissions performance estimates. These limitations on the valid range of the Complex Model are discussed in this section.

There are a number of factors which must be considered in determining the valid range:

- **The purpose of the valid range**

  Specification of the valid range is intended to make the Complex Model as flexible and useful as possible without sacrificing accuracy and reliability. Insofar as the regression equations and their associated extrapolations are trustworthy, they should be applied to as wide a range of fuel parameters as possible.

- **The needs of the program**

  The intent in developing the Complex Model was and is to provide refiners flexibility in meeting the requirements of the Clean Air Act. Any restrictions in the valid range limit that flexibility.

  The valid range for the Complex Model is specific to the fuels program under which the Complex Model will be used, resulting in two separate valid range sets: one for the RFG program, and a second for the anti-dumping program. There are two reasons for delineating two separate valid range sets:

1) EPA believes it appropriate to permit the Complex Model to evaluate typical 1990 (non-reformulated) gasolines in order to determine compliance with anti-dumping regulations. However, EPA expects reformulated gasolines to fall into more restricted fuel parameter ranges than conventional gasolines. Thus to fulfill the needs of each program, the valid range for the anti-dumping program should be less restrictive than the valid range for the RFG program.

2) The accuracy of the Complex Model is less important for the anti-dumping program than it is for the reformulated gasoline program. EPA believes that greater confidence is needed in estimating emission reductions from the use of reformulated gasolines because of the program's primary mission of achieving emission reductions in the worst ozone non-attainment areas. The anti-dumping program for conventional gasolines only requires that future gasolines produce emissions which are no worse than those of gasolines produced in 1990. Thus the environmental impact of inaccuracies in the model's emission estimates is more severe for the RFG program than for the anti-dumping program.

- **The behavior of the Complex Model**

When the Complex Model predicts emission effects for a given fuel parameter which seem questionable, linearly extrapolating beyond the data core is less reliable, indicating that the valid range for that fuel parameter should approach coincidence with the data core.

Even when the model's predictions seem reasonable, the mathematical form by which the model incorporates emission effects may only be appropriate within the data core. This fact is of greatest concern when examining the location of extrema (maximums and minimums). Extrema produce a "turnover" effect that is an artifact of using second-order polynomials during the regressions, when the underlying phenomenon may obey a decaying exponential function or some other function which does not produce "turnover" effects. Thus the model's emission performance estimates for fuels with parameter levels that are outside the data core and are far from an extrema point may be much higher or lower than the true effect. Depending on the location of extrema, placing the valid range limits too far from the data core could result in emission performance estimates that differ excessively excessively from the true values.

In some circumstances, it may be inappropriate to linearly extrapolate first-order relationships beyond the limits of the data core. A purely linear relationship may overstate or understate the impact of fuel parameter modifications on emissions, particularly for fuel parameter levels which are well beyond the limits of the data core, since the linear relationship is only an approximation of the underlying phenonomenon being modeled. Thus some linear relationships may be most appropriately restricted to the limits of the dat core.

- **The limits of the available data**

  The further one travels from the data core, the less reliable are the emission performance estimates provided by the model, regardless of extrapolation. Thus the size of the data core will affect the size of the valid range.

- **Specific valid range proposals from sources outside EPA**

  In response to the July 15, 1993 package submittal to the docket, a number of commenters provided EPA with specific proposals for the valid range for both the RFG and anti-dumping programs. These valid range proposals provided EPA with a valuable benchmark, and are shown in Tables IV-43 and IV-44. Note that "N/A" indicates that a specific proposal was not made, while "none" indicates that the proposal was for no valid range limit whatsoever.

Table IV-43
Proposals for Reformulated Gasoline Valid Ranges for the Complex Model

Low end of range

	EPA	API	AAMA	Penzoil	ARCO P	Exxon	Mobil
Oxygen	0	0	0	N/A	0	N/A	0
Sulfur	50	0	0	N/A	0	10	10
RVP	6	6	6.7	N/A	N/A	6	6
E200	33	30	40	N/A	30	N/A	33
E300	76	70	80	N/A	70	N/A	76
Aromatics	15	0	15	N/A	0	10	10
Olefins	2	0	0	N/A	0	2	0
Benzene	0.2	0	0	N/A	0	0	0

High end of range

	EPA	API	AAMA	Penzoil	ARCO P	Exxon	Mobil
Oxygen	3.7	3.7	3.7	N/A	3.7	N/A	3.7
Sulfur	500	500	500	N/A	500	600	500
RVP	10	15	10	N/A	N/A	15	15
E200	65	70	65	N/A	70	N/A	72
E300	94	100	95	N/A	100	N/A	94
Aromatics	47	55	40	N/A	55	55	47
Olefins	20	25	20	N/A	25	30	20
Benzene	2	2	1	N/A	2	2	0

Table IV-44
Proposals for Conventional Gasoline Valid Ranges
for the Complex Model

Low end of range

	EPA	API	AAMA	Penzoil	ARCO P	Exxon	Mobil
Oxygen	0	0	0	0	none	none	0
Sulfur	0	0	0	0	none	none	0
RVP	6	6	6.7	6	none	none	6
E200	30	30	35	30	none	none	25
E300	70	70	75	70	none	none	70
Aromatics	10	0	10	10	none	none	10
Olefins	0	0	0	0	none	none	0
Benzene	0	0	0	0	none	none	0

High end of range

	EPA	API	AAMA	Penzoil	ARCO P	Exxon	Mobil
Oxygen	3.7	3.7	3.7	3.7	none	none	3.7
Sulfur	1000	1000	1000	1000	none	none	1000
RVP	10	15	10	12	none	none	15
E200	70	70	70	70	none	none	72
E300	95	100	95	95	none	none	95
Aromatics	50	60	40	55	none	none	50
Olefins	25	30	25	45	none	none	25
Benzene	4.9	4.9	2	5	none	none	4.9

The Agency used all of the above criteria in specifying the valid range for the Complex Model. However, the Agency relied most heavily on the behavior of the Complex Model, the limits of the data core, and the valid range proposals from outside parties, particularly when such proposals were supported by available information. These three factors include elements from all the other criteria, and have the most direct and definable impact on the valid range. The needs of each program are reflected in the valid range proposals in that commenters have a unique perspective on the business ramifications of valid range limitations. The valid range proposals reflect the purpose of specifying the valid range to provide the greatest flexibility to suit private interests. The Agency therefore seriously considered each of the valid range proposals and weighed them against the available data and observed behavior of the model before specifying the final valid range. The final values are shown in Table IV-45.

EPA defined the oxygen limits so as to encompass all oxygenated gasolines which meet EPA's "substantially similar" requirements, including a small blending tolerance. Similarly, the E200, lower E300, and upper aromatics limits were set near to those of the data core while making allowances for these parameters' measurement and blending tolerances. The upper limit for E300 was not constrained since high E300 values appear to result in reduced emissions. However, EPA restricted its linear extrapolation of E300 effects to 95 volume percent; fuels with higher E300 values must be evaluated as if their E300 levels were equal to 95 volume percent. In effect, this approach gives such fuels no additional benefits for E300 increases beyond 95 volume percent since EPA is not confident in its ability to quantify these benefits. Nonetheless, EPA expects such increases to result in lower emissions, so EPA chose not to restrict the upper E300 limit of the model.

Aromatics reductions result in NOx reductions, with the benefits increasing as aromatics levels decrease. As a result, EPA's extrapolation of aromatics' effects likely underestimates the benefits of aromatics reductions below 18 vol%. Since EPA believes its model is unlikely to overestimate the benefits of very low aromatics levels, EPA set a relatively unconstraining lower aromatics limit of 10 volume percent when linearly extrapolating its models. In addition, EPA decided to allow fuels with aromatics levels below 10 volume percent to be certified using the Complex Model, but such fuels' emission performance must be evaluated as if their aromatics levels were at 10 volume percent. This approach provides refiners with greater flexibility without imposing significant risks on the environment. Olefin limits were based on similar reasoning: EPA considers the risk that its model underestimates the NOx increases associated with olefin levels beyond 19 vol% to be minimal.

EPA chose not to extend the upper limit of the valid range for sulfur beyond 500 ppm for the reformulated gasoline program because the NOx model had an emissions maximum at approximately 550 ppm sulfur. This maximum appears to be an artifact of the form of the model (see Section D.4 for further discussion). The available data indicates that as sulfur levels increase, emissions increase but at a decreasing rate. Hence the straight-line extrapolation used by EPA would be expected to deviate significantly from the underlying "true" effect of sulfur as sulfur levels increase to levels substantially above the upper limit of the data core. This deviation is particularly important for the RFG program, which requires fuels to meet absolute emission performance standards. The anti-dumping program, however, requires refiners to meet emission standards relative to their 1990 baseline emissions; as a result, the accuracy of the extrapolation is less critical. EPA has set a less restrictive upper limit to the valid range for anti-dumping since it considers the gain in flexibility to outweigh the possible losses due to less precise extrapolation.

The upper RVP limit was set so as to not exclude any summer gasolines which might be sold in 1995 or later. The lower limit was set so as to encompass the RVP levels that EPA expects to characterize Phase II reformulated gasolines, including the associated measurement tolerance. EPA decided against setting a less restrictive lower limit based on concerns expressed by some commenters that such gasolines might produce driveability problems. Poor driveability tends to result in increased emissions, and EPA has no data which demonstrate emission benefits of lowering RVP levels below 7 psi.

The only pollutant affected by fuel benzene levels is benzene itself. The upper limit for RFG is largely irrelevant, since benzene is limited to a maximum of 1.3 vol% under averaging and 1 vol% under per-gallon compliance. Gasolines containing 5 vol% or more benzene must be labeled as hazardous materials under existing OSHA requirements. EPA believes that this labeling requirement has prevented marketing of such fuels in the past and will continue to do so in the future. For this reason, EPA believes that the 4.9 vol% limit on conventional gasolines encompasses all such fuels that are likely to be produced.

Table IV-45
Final Valid Ranges for the Complex Model

	Reformulated Gasoline		Conventional Gasoline	
	Low end	High end	Low end	High end
Oxygen	0	3.7	0	3.7
Sulfur	0	500	0	1000
RVP	6.4	10	6.4	11
E200	30	70	30	70
E300	70	95	70	100
Aromatics	10	50	0	55
Olefins	0	25	0	30
Benzene	0	2	0	4.9

3. Extrapolation Methodology

The regression equations that comprise the Complex Model are empirical in nature. Thus the strictest possible application of these equations would limit their use to the range of fuel parameters specified by the data core. As discussed in Section D.2, however, the valid range of the Complex Model has been extended beyond these limits. To use of the Complex Model outside the data core, EPA has extrapolated the regression equations in such a manner as to maintain the integrity and accuracy of the relationships between fuel properties and emissions. This section provides the mathematical basis for model extrapolation, while Section D.5 applies this methodology to each of the pollutant models.

The choice of extrapolation methodology applied to a given regression equation depends on one's confidence in the accuracy of the underlying regression equation. The regression techniques considered by EPA include:

- **Regression curve approach**

  This approach uses the regression curve as-is for all areas of the fuels space. It is easy to implement and requires no changes to the derived regression equations. However, it assumes that the regression equation accurately captures the underlying relationship between fuel properties and emissions. It also assumes that trends seen within the data core continue at levels beyond the data core.

- **Flat-line approach**

  This approach uses the regression curve only within the limits of the data. It holds fuel parameters which fall outside the data core at the nearest limit of the data core when evaluating fuel performance by the Complex Model. In graphical form, the slope of the emission performance versus fuel parameter level curve discontinuously becomes zero (i.e., flat) for fuel parameter levels equal to or beyond the nearest limit of the data core.

  This approach is attractive because it is straightforward to implement. It is conservative from a statistical standpoint since it assumes that nothing can be inferred from the regression equations about areas of the fuels space not covered by the data core. However, refiners would be given no incentive at the margin to make high-emitting fuels cleaner if they fall outside the data core. In addition, this approach ignores the results of studies not included in the Complex Model database which indicate that the emission performance versus fuel parameter level curve has a non-zero slope outside the data core.

- **Straight-line approach**

  This approach uses the first derivative of the Complex Model equations to extrapolate those equations. It assumes that the relationship between emissions performance and fuel parameter level at parameter levels beyond the data core can be approximated accurately by the slope of the emissions performance versus fuel parameter curve (in multi-dimensional space) at the limits of the data core.

> This approach preserves the non-zero fuel parameter:emission relationships observed within the data core. It avoids inferring second-order effects for fuels outside the data core. However, this approach can be complex to implement due to the need to take derivatives. In addition, the slope observed at the limits of the data core may differ from the actual slope outside the data core, though this problem is mitigated to some degree since the difference is likely to remain small for fuel parameter values that are relatively close to the limits of the data core.

In addition to the choice of extrapolation approach, the choice of the point from which to start the extrapolation also must be determined before specific extrapolations can be applied to the Complex Model. Ideally, this point would coincide with the limits of the data core. However, the mathematical form of the exhaust complex model is limited to first- and second-order functions of fuel parameters. The actual relationship between fuel properties and emission levels is unlikely to take this form. A full mathematical model of the underlying phenomena or the data included in the Complex Model database may require decaying or growing exponentials, third-order polynomials, square root relationships, or even more complex functions. The Complex Model approximates the actual relationships between fuel properties and emissions using first- and second-order polynomials; such approximations can result in extrema (emission maximums or minimums) which are artifacts of the form of the exhaust Complex Model equations and which do not reflect the underlying data used to develop the model. These inappropriate extrema may occur within or outside of the data core. The extrapolation approaches described above can be used to correct such inappropriate extrema by selecting an appropriate starting point for the extrapolation, such as the extrema point itself. The location of extrema in the Complex Model will be discussed in Section D.4, while the ramifications of those extrema will be addressed in Section D.5.

The regression curve and flat-line approaches to extrapolation are mathematically straightforward to derive and apply. The remainder of this section develops and presents the mathematical basis for the straight-line approach to extrapolation. This approach begins with the performance calculation procedure described in Section C but includes the following additional steps:

1) Determine which fuel parameters for the target fuel fall within the extrapolation range but outside the "allowable range," which is the range within which the unmodified regression equations can be used. The extrapolation range and allowable range for all fuel parameters are specified in Section D.5.

2) Determine the fuel parameter values for an "edge target fuel" in which the fuel parameters that would naturally fall within the extrapolation range are held at the limits of the allowable range. Target fuel parameters that are within the allowable range should remain at their target fuel levels when defining the edge target fuel.

3) Evaluate the performance of the edge target fuel. This step yields a performance estimate at the edge of the allowable range, or an "edge performance" symbolized by Y(et), where "et" refers to "**e**dge **t**arget fuel."

4) Determine the multi-dimensional slope of the emissions versus fuel parameter curve at the point in the multi-dimensional fuels space defined by the edge target fuel's composition. This step is accomplished by calculating the first derivative of the exhaust regression equation(s).

5) Compute the additional performance benefit or detriment due to the fuel parameter(s) that are beyond the allowable range. This step yields an "extrapolation performance factor" symbolized by ΔY which is calculated by multiplying the difference between the target fuel parameter level and the nearest limit of the allowable range by the slope calculated in step (4).

6) Add the edge performance to the extrapolation performance factor to obtain the overall oerformance of the original target fuel.

These six steps can be mathematically summarized as

$$Y(t) = Y(et) + \Delta Y \qquad \text{(D.1)}$$

Determining the fuel parameter values for the edge target fuel and calculating performance estimates for the edge target fuel need no elaboration beyond that given in the steps above. Calculating ΔY, however, is considerably more complex because it requires determining the first derivative of the exhaust model for each pollutant.

As described in Section D.5, the entire non-exhaust model is extrapolated by way of the regression curve approach, i.e., the non-exhaust emissions for any fuel within the valid range can be evaluated directly from the non-exhaust equations. Thus only the exhaust model equations are candidates for straight-line extrapolation. And since the calculations in the exhaust model are first carried out in percentage change terms and must subsequently be converted into gram/mile estimates, it is most appropriate to use the percentage-change performance as the dependent variable in determining the first derivative for the exhaust models. As described in Section C above, the exhaust pollutant performance of a target fuel is calculated from Equation (C.7):

$$\text{(D.2)} \qquad Y(t) = \textstyle\sum_1^i \{w_i * [\exp(f_i(t))/\exp(f_i(b)) - 1] * 100\}$$

where Y is the fleet average percent change in any exhaust pollutant, the w_i are the vehicle group weighting factors, t refers to the target fuel, and b refers to the baseline fuel. This is the equation from which the first derivative, and thus the extrapolation performance factor ΔY, will be derived.

In order to determine the extrapolation performance factor, the first derivative of Equation (C.7) must be determined for the edge target fuel as described in step (4). Since the derivative of a sum is equivalent to the sum of the derivatives, the derivative of each vehicle group term in Equation (D.2) can be evaluated separately. Thus Equation (D.2) is first separated into its vehicle group-specific terms:

$$\text{(D.3)} \qquad Y(et)_i = w_i * [\exp(f_i(et))/\exp(f_i(b)) - 1] * 100$$

Equation (D.3) is shown as being evaluated for the edge target fuel, consistent with step 3) above. The total derivative of Equation (D.3) is derived from the partial derivatives of Equation (D.3) with respect to each of the fuel parameters. Mathematically, this total derivative can be written in its general form as

$$\text{(D.4)} \qquad dY_i = \textstyle\sum_1^j (\partial Y_i/\partial P_j)dP_j$$

where the P_j are the possible fuel parameters in the Complex Model equations for the pollutant of interest. As before, the subscript i refers to the vehicle group, of which there are two in the final Complex Model: one for normal emitting vehicles, and a second for higher emitting vehicles. Note that linear extrapolation of a first-order equation is identical to use of the unmodified original equation and is therefore equivalent to the the regression curve extrapolation approach. Thus the straight line extrapolation approach need not be applied to fuel parameters that are only found in first-order terms.

The total derivative of Equation (D.2) can be written generally as

$$\text{(D.5)} \qquad dY = \textstyle\sum_1^i (w_i * dY_i) = \sum_1^i [w_i * \sum_1^j (\partial Y_i/\partial P_j)dP_j]$$

The general Equation (D.4) can be applied specifically to Equation (D.3) and the results weighted by the w_i weighting factors and then summed to obtain the Complex Model-specific results of Equation (D.5). In other words, the solution to Equation (D.4) is sufficient to solve Equation (D.5).

In order to best illustrate the evaluation of Equation (D.4), a hypothetical second-order function f can be created. Eliminating the vehicle group distinction indicated by the subscript i and instead making the vehicle group distinction implicit, this function can be written as

$$\text{(D.6)} \qquad f(A,B) = \epsilon_1 A + \epsilon_2 B + \epsilon_3 A^2 + \epsilon_4 B^2 + \epsilon_5 AB$$

In the above equation, A and B are hypothetical uncentered fuel parameters, and the coefficients ϵ_i are determined through statistical regressions. Note that all possible combinations of linear, squared, and interactive terms have been included in this hypothetical function. Thus the vehicle group-specific equation giving the performance of a target fuel as a function of the fuel parameters A and B is

$$\text{(D.7)} \quad Y(t) = \left\{ \frac{\exp(\epsilon_1 A_t + \epsilon_2 B_t + \epsilon_3 A_t^2 + \epsilon_4 B_t^2 + \epsilon_5 A_t B_t)}{\exp(\epsilon_1 A_b + \epsilon_2 B_b + \epsilon_3 A_b^2 + \epsilon_4 B_b^2 + \epsilon_5 A_b B_b)} - 1 \right\} * 100$$

where Y(t) is the performance of the target fuel for any pollutant, A_t is the value of fuel parameter A for the target fuel, B_b is the value of fuel parameter B for the baseline fuel, and so on. To determine the total first derivative of Y, partial derivatives of Y with respect to each of the fuel parameters must be derived analytically and summed according to the following equation:

$$\text{(D.8)} \qquad dY = (\partial Y/\partial A)dA + (\partial Y/\partial B)dB$$

dY is called the differential of Y. Since the total derivative will be used to determine the slope of the curve at the edge target fuel, each of the partial derivatives must be evaluated at the edge target fuel:

$$\text{(D.9)} \qquad dY = (\partial Y/\partial A)\big|_{\text{edge}}\, dA + (\partial Y/\partial B)\big|_{\text{edge}}\, dB$$

Since the Complex Model is at most a second-order model (in logarithmic space), the first derivative must be first order. This fact implies that the total differentials for Y, A, and B in Equation (D.9) can be written as finite deviations from the edge target fuel:

$$dY = \Delta Y = Y(t) - Y(et)$$

$dA = \Delta A = A_t - A_{et}$ if $A_t <$ low end of allowable range or
$A_t >$ high end of allowable range

$= 0$ if $A_t \geq$ low end of allowable range and
$A_t \leq$ high end of allowable range

$dB = \Delta B = B_t - B_{et}$ if $B_t <$ low end of allowable range or
$B_t >$ high end of allowable range

$= 0$ if $B_t \geq$ low end of allowable range and
$B_t \leq$ high end of allowable range

The conditional statements associated with each fuel parameter differential quantify the following conditional statement:

> If the value of a fuel parameter for a given target fuel lies within the allowable range, then do not use the first derivative of the model to extrapolate the function Y with respect to that fuel parameter; otherwise, linearly extrapolate from the edge target fuel to the fuel parameter value of the target fuel.

Thus a given fuel parameter differential will be zero if that fuel parameter lies within the allowable range, but will be nonzero if it lies outside the allowable range. Extrapolation occurs only for fuel parameters which lie beyond the allowable range.

The partial derivatives of pollutant Y with respect to each of the two fuel parameters A and B are shown below. Note that f(b) can be considered a constant since the baseline fuel does not change.

$$\partial Y/\partial A = [\exp(f(t))/\exp(f(b))] * 100 * \partial f(t)/\partial A$$

$$= [\exp(f(t))/\exp(f(b))] * 100 * (\epsilon_1 + 2*\epsilon_3 A_t + \epsilon_5 B_t)$$

$$\partial Y/\partial B = [\exp(f(t))/\exp(f(b))] * 100 * \partial f(t)/\partial B$$

$$= [\exp(f(t))/\exp(f(b))] * 100 * (\epsilon_2 + 2*\epsilon_4 B_t + \epsilon_5 A_t)$$

The total derivative for Y can now be assembled for this hypothetical regression equation, and the value of Y for a given target fuel calculated as a function of the fuel parameters A and B. When Equation (D.9) is evaluated with the differentials and partial derivatives shown above, the specific form of Equation (D.1) is produced:

$$\begin{aligned} Y(t) = {} & Y(et) + \\ & [\exp(f(t))/\exp(f(b))]*100*(\epsilon_1+2*\epsilon_3 A_t+\epsilon_5 B_t) * (A_t - A_{et}) + \\ & [\exp(f(t))/\exp(f(b))]*100*(\epsilon_2+2*\epsilon_4 B_t+\epsilon_5 A_t) * (B_t - B_{et}) \end{aligned}$$

(D.10)

And therefore, from Equation (D.1),

$$\begin{aligned}\Delta Y = {} & [\exp(f(t))/\exp(f(b))]*100*(\epsilon_1+2*\epsilon_3A_t+\epsilon_5B_t) * (A_t - A_{et}) + \\ & [\exp(f(t))/\exp(f(b))]*100*(\epsilon_2+2*\epsilon_4B_t+\epsilon_5A_t) * (B_t - B_{et})\end{aligned}$$
(D.11)

Note that the conditional statements described above still apply to the fuel parameter differentials (given as differences) in Equation (D.10).

Equation (D.10) is a vehicle group-specific equation, and therefore represents a solution to Equation (D.1) only for a single vehicle group; Equations (D.10) and (D.11) actually give the solutions for $Y_i(t)$ and ΔY_i, respectively. To obtain the fleet average solution to Equation (D.1), the vehicle group-specific solutions must be weight-averaged with the vehicle group weighting factors w_i according to Equation (D.5). Thus dY_i (or ΔY_i) has been determined only for a single vehicle group in this example, and must be combined with the solutions for dY_i for the other vehicle group in order to determine the overall exhaust emission performance of the target fuel.

4. Extrema

As discussed in the previous section, the second-order polynomial form of the Complex Model can introduce inappropriate extrema into the model. In fact, all second order equations contain extrema points at which the direction of the emission effect changes (from increasing to decreasing or vice-versa). The Agency has considered a number of approaches to mitigate the effects of inappropriate extrema on predicted emissions using the unmodified Complex Model. These approaches and the Agency's concerns with each are reviewed below:

1. The Complex Model could be redeveloped from the original database using growing or decaying exponential functions instead of simple second-order polynomials.

   This approach replaces one assumed functional form for the underlying combustion and catalyst chemistry with a different assumed functional form. Replacing only those second-order relationships which would be better represented with a decaying exponential would require a far deeper understanding of combustion and catalyst chemistry than is currently available. This approach also raises the possibility that other non-polynomial functions should be considered, would compromise the consistency in model form between pollutant-specific models, and could make the use of the random balance method to consolidate the models for normal emitter technology groups impossible.

2. Any second-order terms which result in questionable behavior could be pre-excluded from the Complex Model, which would then be re-estimated.

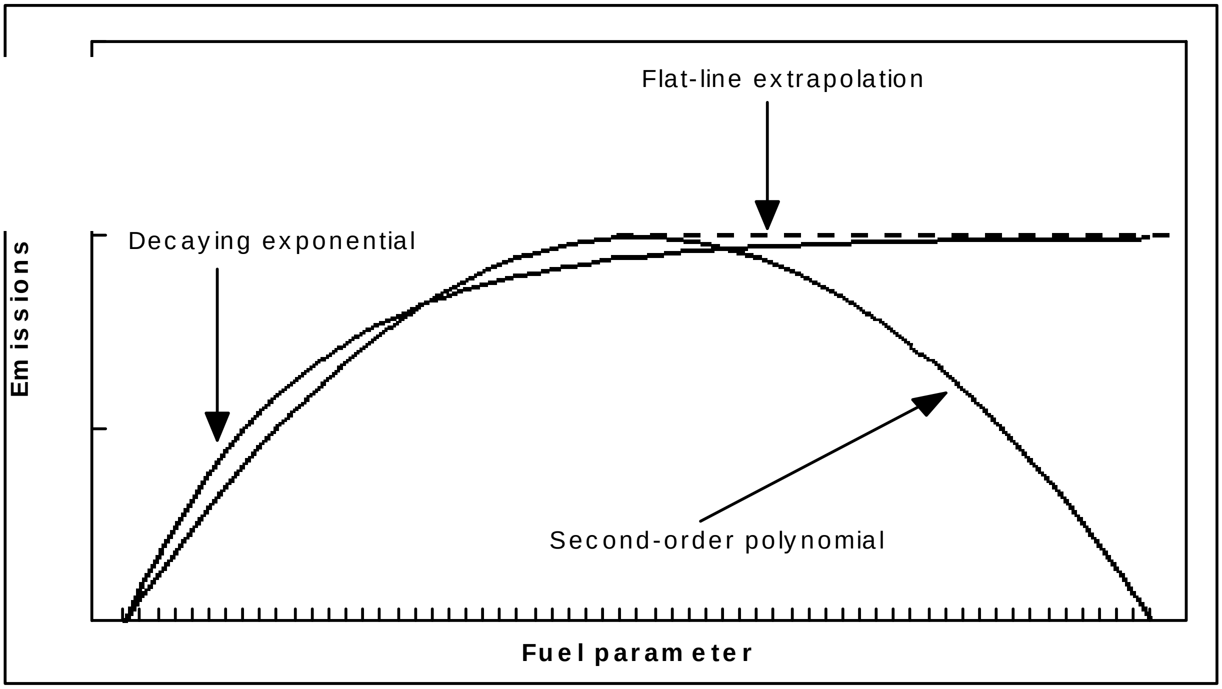
   EPA rejected this approach after careful evaluation, as indicated by the models included in the July 14, 1993 docket submittals. This approach relies on strictly first-order effects, which can result in behaviors that are just as questionable as the second-order effects. Also, linear extrapolation beyond the limits of the data for the affected terms becomes unjustifiable since the model's reliability and accuracy would decrease rapidly as one moved beyond the data core. Further, EPA's efforts to build such models resulted in poorer predictability. Finally, EPA found that because of the covariation between fuel parameters, pre-excluding one second-order term resulted in the introduction of a second-order term for a covarying parameter. For example, when the ARO^2 term was pre-excluded, the resulting model included an $E300^2$ term that was just as troublesome as the original ARO^2 term.

3. One or more interactive terms could be forced into the model in an effort to replace the squared term causing the inappropriate behavior with better-behaved interactive terms.

   This approach assumes that the statistical derivation of the Complex Model has assigned an effect to a squared term which should instead be assigned to an interactive term. All attempts by the Agency to implement this approach resulted in a model which retained the troublesome squared term or which suffered from other behavioral shortcomings.

4. Flat-line extrapolations could be imposed from the extrema points. This approach, which was supported by a number of commenters, is illustrated in Figure IV-1, which also shows a decaying exponential function. Statistical and chemical considerations suggest that some of the second-order terms in the complex model result from phenomena which exhibit such underlying behavior.

Figure IV-1: Mitigating Extrema



> This approach required the fewest assumptions regarding the form of the regression equation, and it resulted in models which behaved in a manner consistent with the available data. In addition, it most closely approximated a decaying exponential effect without compromising the form of the model.

The Agency determined that flat-line extrapolation was the most appropriate method for mitigating questionable effects caused by extrema.

Applying a flat-line extrapolation from an extremum point is equivalent to linearly extrapolating the model from the same point. At the extremum, the slope calculated by the linear extrapolation method is zero (in fact, a zero first derivative is a necessary condition for an extremum) and is thus identical to the slope imposed by a flat-line extrapolation from that point.

The use of flat-line extrapolation implies that the previously stated conditions under which linear extrapolation is to be used must be supplemented. The points at which linear extrapolations are to begin (i.e., the limits of the allowable range) are defined by one of the following two considerations:

1) The limits of the data core.
2) The location of extrema.

The data core is the default criterion since it defines the range of fuel parameters within which the regression equations are most trustworthy. Insofar as the data core does not reach the limits of the valid range, linear extrapolation must be used to extend the regression equations without placing an unwarranted amount of trust in their curvature. If, however, an extremum point is located within the limits of the data core, the model may behave inappropriately. In such cases, the extremum point replaces the nearest data core limit as the limit of the allowable range, and linear extrapolation begins at that point instead of at the end of the data core.

Since the Complex Model regression equations are multivariate, separate extrema can exist for each fuel parameter. Thus the partial derivative of the regression equation with respect to a given fuel parameter must be calculated, set equal to zero, and solved for the fuel parameter of interest to determine the extremum location. When this is done for the Complex Model, the extrema locations shown in Tables IV-46 and IV-47 are identified. Note that "N/A" indicates that either a strictly linear relationship exists between the fuel parameter and pollutant in question, or there is no relationship whatsoever.

Table IV-46
Phase I Extrema Locations for the Complex Model

	VOC	NOx	Toxics*
Oxygen	N/A	N/A	N/A
Sulfur	N/A	554	N/A
RVP	N/A	N/A	N/A
E200	65.8	N/A	N/A
E300	80.3-101.8	N/A	N/A
Aromatics	N/A	36.2	N/A
Olefins	N/A	3.77	N/A
Benzene	N/A	N/A	N/A
MTBE	N/A	N/A	N/A
ETBE	N/A	N/A	N/A
Ethanol	N/A	N/A	N/A
TAME	N/A	N/A	N/A

Table IV-47
Phase II Extrema Locations for the Complex Model

	VOC	NOx	Toxics*
Oxygen	N/A	N/A	N/A
Sulfur	N/A	578	N/A
RVP	N/A	N/A	N/A
E200	65.5	N/A	N/A
E300	79.7-100.9	N/A	N/A
Aromatics	N/A	36.8	N/A
Olefins	N/A	3.77	N/A
Benzene	N/A	N/A	N/A
MTBE	N/A	N/A	N/A
ETBE	N/A	N/A	N/A
Ethanol	N/A	N/A	N/A
TAME	N/A	N/A	N/A

* All four toxics models are linear, and therefore contain no extrema

5. Extrapolation of the Final Complex Model

The linear extrapolation methodology for the Complex Model equations as described above requires the pollutant-specific forms of Equation (D.1) and the specific points at which extrapolation is to begin. Calculation of the first derivative and application of flat-line extrapolation from extrema are required only for the exhaust VOC and exhaust NOx models. The exhaust toxics models are strictly linear, and they and the non-exhaust VOC and benzene models can be extrapolated via the regression curve approach (see Section D.3 for a description of the various extrapolation methodology options). In this section, the definition of the edge target fuel will be reiterated, the points at which extrapolation is to begin (which define the allowable ranges) will be presented, and then the pollutant-specific forms of Equation (D.1) will be derived and presented for both exhaust VOC and NOx.

As described in Section D.3, linear extrapolation beyond the allowable range requires the definition and evaluation of an edge target fuel. It is at the position of the edge target fuel that both the edge target fuel performance and the (multi-dimensional) slope of the curve are calculated. The slope of the curve is used to determine the extrapolation performance factor, and Equation (D.1) is then used to determine the extrapolated performance of the target fuel. The edge target fuel represents the position in the multi-dimensional fuels space that is closest to the position of the target fuel without going outside the limits of the allowable range defined below. Since the allowable range for a given fuel parameter is pollutant-specific, the edge target fuel must also be defined separately for each pollutant. The edge target fuel can therefore be defined as follows:

> All fuel parameters of the edge target fuel are identical to those of the target fuel with the following exception: if a given target fuel parameter is outside of the allowable range, then hold the equivalent edge target fuel parameter to the limit of the allowable range which is closest in value to the target fuel value.

Thus if the target fuel value of aromatics is 52 vol% and the allowable range is defined as 18 to 46 vol%, then the edge target fuel aromatics content should be 46 vol%, since 46 vol% is closer to 52 vol% than is 18 vol%.

The data core and the location of extrema points were specified above to delineate the allowable range, which is the range of fuel parameters within which the Complex Model's exhaust emission equations can be used without modification and outside of which linear extrapolation must be employed. The general guidelines used by EPA to establish the allowable ranges of fuel parameters which are included in second-order (either squared or interactive) terms can be stated as follows:

> If an extremum point for a given fuel parameter is located within the data core limits for that fuel parameter, it indicates inappropriate model behavior. Therefore, linear extrapolation must begin at the extreme point and proceed in the direction deemed most appropriate. If an extreme point is not located within the data core, linear extrapolation must begin at the limits of the data core.

The appropriate direction of the linear extrapolation from an extremum point depends primarily on the following two factors:

1) The position of the extremum point relative to the limits of the data core.

2) The underlying combustion and catalyst chemistry, if known.

2) The emission trends identified in specific studies or in the Complex Model database.

Linear extrapolation of a given fuel parameter from the low end of the data core proceeds downward to lower parameter values, while linear extrapolation from the high end of the data core proceeds upwards to higher parameter values. Any regression equation containing fuel parameters that are strictly linear need not be extrapolated using the straight-line, first derivative technique since such extrapolation is equivalent to using the unmodified equation.[46]

Based on the foregoing discussion, EPA has defined the allowable range for all second-order fuel parameters included in the Complex Model as shown in Table IV-48.

Table IV-48
Allowable Parameter Ranges for Use of the Complex Model Regression Equations

Fuel parameter	Pollutant	Phase I		Phase II	
		Low end	High end	Low end	High end
Sulfur	NOx	10	450	10	450
E200	VOC	33	65.83	33	65.52
E300	VOC	72	vary*	72	vary**
Aromatics	VOC NOx	18 18	46 36.2	18 18	46 36.8
Olefins	NOx	3.77	19	3.77	19

* The high end of the allowable range (in vol%) equals 79.75 + 0.3846*ARO, where ARO is the aromatics content of the target fuel, or 94 vol%, whichever is lower.

** The high end of the allowable range (in vol%) equals 80.32 + 0.3903*ARO, where ARO is the aromatics content of the target fuel, or 94 vol%, whichever is lower.

Only the allowable ranges for those fuel parameters present as second-order terms are shown in Table IV-48; for all other fuel parameters, the Complex Model equations can be used without modification out to the limits of the valid range. Thus the "allowable range" differs from the "valid range" only for those fuel parameters with second-order effects on a given pollutant.

The high and low values in Table IV-48 bracket the range of values for a given fuel parameter within which the exhaust regression equations can be used without modification, and outside of which straight-line linear extrapolation must be employed. The values in Table IV-48 also indicate the points at which the multi-dimensional slope of the emissions versus fuel

---

[46] See discussion in Section D.1 regarding the effect of an exponential function on the behavior of polynomials.

parameter relationship must be evaluated when linear extrapolation is required. For fuel parameters that contain an extremum point somewhere within the data core, the location of that extremum point defined one end of the allowable range. Note that the allowable ranges given in Table IV-48 apply only to the exhaust VOC and NOx portions of the Complex Model; the exhaust toxics models and the nonexhaust VOC and benzene models can be used without modification throughout all areas of the fuels space, based on the regression curve approach to extrapolation described in Section D.3.

The high end of the allowable range for the effect of E300 on VOC is variable due to the ARO*E300 term in the exhaust VOC model. Since the upper and lower limits of the data core for E300 are 72 vol% and 94 vol%, respectively, an extremum point between these values must, by the conditions described above, define one end of the allowable range. EPA derived a relationship defining these extrema by taking the first derivative of the exhaust VOC equations:

(D.12) Phase I E300 extremum =
80.32 vol% + 0.3903 x aromatics vol%

(D.13) Phase II E300 extremum =
79.75 vol% + 0.3846 x aromatics vol%

As per the discussion of extrema in Section D.4, Equations (D.12) and (D.13) indicate that the E300 extremum point can be greater than or less than 94 vol% depending on the target fuel aromatics content. Thus the upper end of the allowable range for the effect of E300 on exhaust VOC is conditional:

> If the E300 extremum as calculated from Equation (D.12) or (D.13) is less than 94 vol%, then the E300 extremum becomes the upper limit of the allowable range for E300. If the E300 extremum is greater than 94 vol%, then the upper end of the allowable range for E300 is 94 vol%.

For exhaust VOC, linear extrapolation must be used if E200, E300, or aromatics are outside of their allowable ranges. To obtain the exhaust VOC-specific form of Equation (D.1), the first partial derivatives of the exhaust VOC equation must be taken with respect to each of these three fuel parameters. Since there are two vehicle group exponential terms for all exhaust regression equations, these partial derivatives must be derived separately for each vehicle group. From Section A.9, the final exhaust VOC regression equation for Phase I is

(D.14) VOC(t) = 100% x 0.52 x [exp(a(t))/exp(a(b)) - 1] +
100% x 0.48 x [exp(b(t))/exp(b(b)) - 1]

where the functions a and b are defined as

$$
\begin{aligned}
a = {} & (-0.003641 \times \text{Oxygen}) + (0.0005219 \times \text{Sulfur}) + \\
& (0.0289749 \times \text{RVP}) + (-0.014470 \times \text{E200}) + \\
& (-0.068624 \times \text{E300}) + (0.0323712 \times \text{Aromatics}) + \\
& (-0.002858 \times \text{Olefins}) + (0.0001072 \times \text{E200}^2) + \\
& (0.0004087 \times \text{E300}^2) + (-0.0003481 \times \text{Aromatics} \times \text{E300})
\end{aligned}
$$

$$
\begin{aligned}
b = {} & (-0.003626 \times \text{Oxygen}) + (-0.000054 \times \text{Sulfur}) + \\
& (0.043295 \times \text{RVP}) + (-0.013504 \times \text{E200}) + \\
& (-0.062327 \times \text{E300}) + (0.0282042 \times \text{Aromatics}) + \\
& (-0.002858 \times \text{Olefins}) + (0.000106 \times \text{E200}^2) + \\
& (0.000408 \times \text{E300}^2) + (-0.000287 \times \text{Aromatics} \times \text{E300})
\end{aligned}
$$

and a(t) refers to the evaluation of function a for the target fuel, b(b) refers to the evaluation of function b for the baseline fuel, and so on. The first partial derivatives with respect to E200, E300, and aromatics can be derived separately for normal emitting vehicles (the first term in Equation (D.14)) and higher emitting vehicles (the second term in Equation (D.14)):

$$
\begin{aligned}
\partial VOC_1/\partial E200 = {} & 100\% \times 0.52 \times [\exp(a(t))/\exp(a(b))] \times \\
& [0.000214416 \times E200 - 0.0144703]
\end{aligned}
$$

$$
\begin{aligned}
\partial VOC_1/\partial E300 = {} & 100\% \times 0.52 \times [\exp(a(t))/\exp(a(b))] \times \\
& [0.000817412 \times E300 - 0.0686242 - 0.00034806 \times \\
& ARO]
\end{aligned}
$$

$$
\begin{aligned}
\partial VOC_1/\partial ARO = {} & 100\% \times 0.52 \times [\exp(a(t))/\exp(a(b))] \times \\
& [-0.0003481 \times E300 + 0.0323712]
\end{aligned}
$$

$$
\begin{aligned}
\partial VOC_2/\partial E200 = {} & 100\% \times 0.48 \times [\exp(b(t))/\exp(b(b))] \times \\
& [0.000212 \times E200 - 0.0135039]
\end{aligned}
$$

$$
\begin{aligned}
\partial VOC_2/\partial E300 = {} & 100\% \times 0.48 \times [\exp(b(t))/\exp(b(b))] \times \\
& [0.000816 \times E300 - 0.0623274 - 0.000287 \times ARO]
\end{aligned}
$$

$$
\begin{aligned}
\partial VOC_2/\partial ARO = {} & 100\% \times 0.48 \times [\exp(b(t))/\exp(b(b))] \times \\
& [-0.000287 \times E300 + 0.0282042]
\end{aligned}
$$

The subscript 1 indicates the normal emitter vehicle group, while the subscript 2 indicates the higher emitter vehicle group. The general extrapolation equation for VOC, per Equation (D.1), is written as follows:

$$
\begin{aligned}
\text{(D.15)} \quad VOC(t) = {} & \\
& 100\% \times 0.52 \times [\exp(a(et))/\exp(a(b)) - 1] + \\
& 100\% \times 0.48 \times [\exp(b(et))/\exp(b(b)) - 1] + \\
& (\partial VOC_1/\partial E200)\big|_{et} \times \Delta E200 + \\
& (\partial VOC_1/\partial E300)\big|_{et} \times \Delta E300 + \\
& (\partial VOC_1/\partial ARO)\big|_{et} \times \Delta ARO +
\end{aligned}
$$

$$
\begin{aligned}
&(\partial VOC_2/\partial E200)|_{et} \times \Delta E200 + \\
&(\partial VOC_2/\partial E300)|_{et} \times \Delta E300 + \\
&(\partial VOC_2/\partial ARO)|_{et} \times \Delta ARO
\end{aligned}
$$

Note that the first two terms are now evaluated for the edge target fuel rather than the target fuel, as are the partial derivatives. The final extrapolation equation for Phase I exhaust VOC is therefore given by Equation (D.16):

<u>Phase I VOC extrapolation equation:</u>

$$
\begin{aligned}
\text{(D.16)}\quad & VOC(t) = \\
& 100\% \times 0.52 \times [\exp(a(et))/\exp(a(b)) - 1] + \\
& 100\% \times 0.48 \times [\exp(b(et))/\exp(b(b)) - 1] + \\
& 100\% \times 0.52 \times [\exp(a(et))/\exp(a(b))] \times \\
& \quad \{\Delta E200 \times [0.000214416 \times E200|_{et} - 0.0144703] + \\
& \quad \Delta E300 \times [0.000817412 \times E300|_{et} - 0.0686242 - \\
& \quad 0.00034806 \times ARO|_{et}] + \\
& \quad \Delta ARO \times [-0.000348061 \times E300|_{et} + 0.0323712]\} + \\
& 100\% \times 0.48 \times [\exp(b(et))/\exp(b(b))] \times \\
& \quad \{\Delta E200 \times [0.000212 \times E200|_{et} - 0.0135039] + \\
& \quad \Delta E300 \times [0.000816 \times E300|_{et} - 0.0623274 - \\
& \quad 0.000287 \times ARO|_{et}] + \\
& \quad \Delta ARO \times [-0.000287 \times E300|_{et} + 0.0282042]\}
\end{aligned}
$$

$$
\begin{aligned}
a = {} & (-0.003641 \times \text{Oxygen}) + (0.0005219 \times \text{Sulfur}) + \\
& (0.0289749 \times \text{RVP}) + (-0.014470 \times \text{E200}) + \\
& (-0.068624 \times \text{E300}) + (0.0323712 \times \text{Aromatics}) + \\
& (-0.002858 \times \text{Olefins}) + (0.0001072 \times \text{E200}^2) + \\
& (0.0004087 \times \text{E300}^2) + (-0.0003481 \times \text{Aromatics} \times \text{E300})
\end{aligned}
$$

$$
\begin{aligned}
b = {} & (-0.003626 \times \text{Oxygen}) + (-0.000054 \times \text{Sulfur}) + \\
& (0.043295 \times \text{RVP}) + (-0.013504 \times \text{E200}) + \\
& (-0.062327 \times \text{E300}) + (0.0282042 \times \text{Aromatics}) + \\
& (-0.002858 \times \text{Olefins}) + (0.000106 \times \text{E200}^2) + \\
& (0.000408 \times \text{E300}^2) + (-0.000287 \times \text{Aromatics} \times \text{E300})
\end{aligned}
$$

The conditions under which the finite differences ΔE200, ΔE300, and ΔARO are nonzero are identical to the conditions under which these fuel parameters require extrapolation. Thus for each of these three fuel parameters which is outside of the allowable range as defined in Table IV-48, the associated finite difference will be equal to the difference between the target fuel value and the nearest limit of the allowable range. However, to simplify the regulations, linear extrapolation from extrema points was replaced with flat-line extrapolations, since for extrema points these two extrapolation methodologies are equivalent. The allowable range conditions can be translated into the following mathematical conditions:

<u>Phase I Conditions for extrapolating exhaust VOC:</u>

If $E200_t < 33$, then $\Delta E200 = E200_t - 33$
Otherwise $\Delta E200 = 0$

If $E300_t < 72$, then $\Delta E300 = E300_t - 72$
If $E300_t > 94$ and $80.32 + 0.39.3 \times ARO_t > 94$, then $\Delta E300 = E300_t - 94$
Otherwise $\Delta E300 = 0$

If $ARO_t < 18$, then $\Delta ARO = ARO_t - 18$
If $ARO_t > 46$, then $\Delta ARO = ARO_t - 46$
Otherwise $\Delta ARO = 0$

These conditions guarantee that the slope of the VOC regression curve at the position of the extrema points will be zero[47] as required by the definition of extrema points.

The Phase II extrapolated performance equation for VOC is identical to equation D.16, except that the vehicle group weighting factors change:

<u>Phase II VOC extrapolation equation:</u>

$$
\begin{aligned}
\text{(D.17)}\quad VOC(t) = {} & \\
& 100\% \times 0.444 \times [\exp(a(et))/0.0620896 - 1] + \\
& 100\% \times 0.556 \times [\exp(b(et))/0.1037675 - 1] + \\
& 100\% \times 0.444 \times [\exp(a(et))/0.0620896] \times \\
& \quad \{[0.000214416 \times E200_{et} - 0.0144703] \times \Delta E200 + \\
& \quad [0.000817412 \times E300_{et} - 0.0686242 - \\
& \quad 0.00034806 \times ARO_{et}] \times \Delta E300 + \Delta ARO \times \\
& \quad [-0.000348061 \times E300_{et} + 0.0323712]\} + \\
& 100\% \times 0.556 \times [\exp(b(et))/0.1037675] \times \\
& \quad \{[0.000212 \times E200_{et} - 0.0135039] \times \Delta E200 + \\
& \quad [0.000816 \times E300_{et} - 0.0623274 - 0.000287 \times \\
& \quad ARO_{et}] \times \Delta E300 + \Delta ARO \times \\
& \quad [-0.000287 \times E300_{et} + 0.0282042]\}
\end{aligned}
$$

$$
\begin{aligned}
a = {} & (-0.003641 \times Oxygen) + (0.0005219 \times Sulfur) + \\
& (0.0289749 \times RVP) + (-0.014470 \times E200) + \\
& (-0.068624 \times E300) + (0.0323712 \times Aromatics) + \\
& (-0.002858 \times Olefins) + (0.0001072 \times E200^2) + \\
& (0.0004087 \times E300^2) + (-0.0003481 \times Aromatics \times E300)
\end{aligned}
$$

---

[47] In fact, the conditions only guarantee that the terms in Equation (D.16) which contain the partial derivatives (which should be zero at extrema points) will be zero. However, mathematically the two approaches are equivalent. The regulations were written with the simplest, most straightforward approach to facilitate implementation of extrapolation.

$$\begin{aligned}
b = {} & (-0.003626 \times \text{Oxygen}) + (-0.000054 \times \text{Sulfur}) + \\
& (0.043295 \times \text{RVP}) + (-0.013504 \times \text{E200}) + \\
& (-0.062327365 \times \text{E300}) + (0.0282042 \times \text{Aromatics}) + \\
& (-0.002858 \times \text{Olefins}) + (0.000106 \times \text{E200}^2) + \\
& (0.000408 \times \text{E300}^2) + (-0.000287 \times \text{Aromatics} \times \text{E300})
\end{aligned}$$

<u>Phase II Conditions for extrapolating exhaust VOC:</u>

If $E200_t < 33$, then $\Delta E200 = E200_t - 33$
Otherwise $\Delta E200 = 0$

If $E300_t < 72$, then $\Delta E300 = E300_t - 72$
If $E300_t > 94$ and $79.75 + 0.3846 \times ARO_t > 94$, then
$\Delta E300 = E300_t - 94$
Otherwise $\Delta E300 = 0$

If $ARO_t < 18$, then $\Delta ARO = ARO_t - 18$
If $ARO_t > 46$, then $\Delta ARO = ARO_t - 46$
Otherwise $\Delta ARO = 0$

The extrapolated performance equations and the associated conditions for NOx are derived in an analogous manner to the equations and conditions for VOC. The results for Phase I and Phase II are shown below:

<u>Phase I NOx extrapolation equation:</u>

$$\begin{aligned}
NOx(t) = {} & 100\% \times 0.82 \times [(\exp(c(et))/1.6437758) - 1] + \\
& 100\% \times 0.18 \times [(\exp(d(et))/0.8353577) - 1] + \\
& 100\% \times 0.82 \times [\exp(c(et))/1.6437758] \times \\
& \{[-0.000001326 \times SUL_{et} + 0.00069205] \times \Delta SUL + \\
& \;[-0.0002381 \times ARO_{et} + 0.0083632] \times \Delta ARO + \\
& \;[0.00073304 \times OLE_{et} - 0.0027735] \times \Delta OLE\} + \\
& 100\% \times 0.18 \times [\exp(d(et))/0.8353577] \times \\
& \{[-0.000159902 \times ARO_{et} + 0.007097005] \times \Delta ARO + \\
& \;[0.000732 \times OLE_{et} - 0.0027603] \times \Delta OLE\}
\end{aligned}$$

$$\begin{aligned}
c = {} & (0.0018571 \times \text{Oxygen}) + (0.0006921 \times \text{Sulfur}) + \\
& (0.0090744 \times \text{RVP}) + (0.0009310 \times \text{E200}) + \\
& (0.000846 \times \text{E300}) + (0.0083632 \times \text{Aromatics}) + \\
& (-0.002774 \times \text{Olefins}) + (-0.000000663 \times \text{Sulfur}^2) + \\
& (-0.000119 \times \text{Aromatics}^2) + (0.0003665 \times \text{Olefins}^2)
\end{aligned}$$

$$\begin{aligned}
d = {} & (-0.00913 \times \text{Oxygen}) + (0.000252 \times \text{Sulfur}) + \\
& (-0.01397 \times \text{RVP}) + (0.000931 \times \text{E200}) + \\
& (-0.00401 \times \text{E300}) + (0.007097 \times \text{Aromatics}) + \\
& (-0.00276 \times \text{Olefins}) + (-0.00007995 \times \text{Aromatics}^2) + \\
& (0.0003665 \times \text{Olefins}^2)
\end{aligned}$$

<u>Phase I Conditions for extrapolating exhaust NOx:</u>

If $SUL_t < 10$, then $\Delta SUL = SUL_t - 10$

If $SUL_t > 450$, then $\Delta SUL = SUL_t - 450$
Otherwise $\Delta SUL = 0$

If $ARO_t < 18$, then $\Delta ARO = ARO_t - 18$
Otherwise $\Delta ARO = 0$

If $OLE_t > 19$, then $\Delta OLE = OLE_t - 19$
Otherwise $\Delta OLE = 0$

<u>Phase II NOx extrapolation equation:</u>

$$\begin{aligned} NOx(t) = {} & 100\% \times 0.738 \times [(\exp(c(et))/1.6437758) - 1] + \\ & 100\% \times 0.262 \times [(\exp(d(et))/0.8353577) - 1] + \\ & 100\% \times 0.738 \times [\exp(c(et))/1.6437758] \times \\ & \{[-0.000001326 \times SUL_{et} + 0.00069205] \times \Delta SUL + \\ & \ [-0.0002381 \times ARO_{et} + 0.0083632] \times \Delta ARO + \\ & \ [0.00073304 \times OLE_{et} - 0.0027735] \times \Delta OLE\} + \\ & 100\% \times 0.262 \times [\exp(d(et))/0.8353577] \times \\ & \{[-0.000159902 \times ARO_{et} + 0.007097005] \times \Delta ARO + \\ & \ [0.000732 \times OLE_{et} - 0.0027603] \times \Delta OLE\} \end{aligned}$$

$$\begin{aligned} c = {} & (0.0018571 \times \text{Oxygen}) + (0.0006921 \times \text{Sulfur}) + \\ & (0.0090744 \times \text{RVP}) + (0.0009310 \times \text{E200}) + \\ & (0.0008460 \times \text{E300}) + (0.0083632 \times \text{Aromatics}) + \\ & (-0.002774 \times \text{Olefins}) + (-0.000000663 \times \text{Sulfur}^2) + \\ & (-0.000119 \times \text{Aromatics}^2) + (0.0003665 \times \text{Olefins}^2) \end{aligned}$$

$$\begin{aligned} d = {} & (-0.00913 \times \text{Oxygen}) + (0.000252 \times \text{Sulfur}) + \\ & (-0.01397 \times \text{RVP}) + (0.000931 \times \text{E200}) + \\ & (-0.00401 \times \text{E300}) + (0.007097 \times \text{Aromatics}) + \\ & (-0.00276 \times \text{Olefins}) + (-0.00007995 \times \text{Aromatics}^2) + \\ & (0.0003665 \times \text{Olefins}^2) \end{aligned}$$

<u>Phase II Conditions for extrapolating exhaust NOx:</u>

If $SUL_t < 10$, then $\Delta SUL = SUL_t - 10$
If $SUL_t > 450$, then $\Delta SUL = SUL_t - 450$
Otherwise $\Delta SUL = 0$

If $ARO_t < 18$, then $\Delta ARO = ARO_t - 18$
Otherwise $\Delta ARO = 0$

If $OLE_t > 19$, then $\Delta OLE = OLE_t - 19$
Otherwise $\Delta OLE = 0$

6. Response to Comments

A number of comments were received concerning the fuel parameter ranges that limit the use of the Complex Model which can be summarized as follows:

- The limits on the use of the Complex Model must allow a refiner as much flexibility as possible.

- The limits on the use of the Complex Model cannot preclude legal 1990 fuels or California Phase II reformulated gasolines.

Some commenters also suggested that all limits on the use of the Complex Model should be removed. As described below, the Agency determined that such limits were both necessary and expedient.

The Agency has recognized the need for flexibility in the reformulated gasoline and anti-dumping programs. This need for flexibility was one of the primary reasons for developing an empirical model that estimates vehicle emissions given the composition of a given fuel. Thus the Simple and Complex models represent a strategy for liberating refiners from the burden of testing every batch of fuel to determine if it complies with the emission performance standards. In this capacity, empirical models offer an increase in flexibility over testing.

However, implicit in the development of an empirical model for vehicle emissions are limits to its applicability. These limitations arise from the limitations of the database used to develop the model. The most important ramification of the limitations of the Complex Model database is that the model cannot be applied reliably to all possible fuel compositions. Since the models are based on test data gathered for a limited range of fuel parameter levels, it would be inappropriate for the Agency to assume that the Complex Model can be applied without restriction to all possible fuels. Further discussion of the limitations of the Complex Model and the criteria used to establish range limits can be found in Section D.

The Agency has made every attempt to set fuel parameter range limits that do not overly restrict the range of gasolines that can be evaluated with the Complex Model. However, the wide variation in the composition of 1990 gasolines makes it impossible to designate range limits that simultaneously cover all possible 1990 gasolines and all possible reformulated gasolines while simultaneously ensuring the reliability of the Complex Model's emission performance predictions. Thus the Agency chose to constrain the range of gasolines covered by the Complex Model in order to ensure the reliability of the model within those limits. As discussed previously, EPA specified less restrictive limits on the use of the model for anti-dumping purposes than for reformulated gasoline purposes. The Agency believes that extension of the valid range of the model beyond these limits would be inappropriate given the limitations of the underlying database. It should be noted that the limits imposed on the range of gasolines which can be evaluated using the Complex Model do not impose limits on the range of gasolines which may be produced and sold under either the reformulated gasoline or anti-dumping programs. The Complex Model may be augmented through vehicle testing. In the case of the anti-dumping program, fuel suppliers could continue to make a fuel identical to their 1990 baseline fuel; alternatively, they could seek approval to produce and sell fuels that are no worse (based on the emission performance trends present in the Complex Model) for each parameter.

Commenters expressed general support for the extrapolation methodology proposed by the Agency. However, the increased complexity in the Complex Model equations introduced through extrapolation led some commenters to suggest that the regression curve approach should be used in all but the most extreme cases (see Section D.3 above for details on the various extrapolation approaches). The Agency has determined that the final extrapolations presented in this section provide the most appropriate approach to contending with the limitations of the Complex Model database for the following reasons:

- Applying linear extrapolation to all second order terms avoids arbitrary determination on the part of the Agency as to which terms exhibit unacceptably "extreme" behavior.
- The limitations of the database, as defined by the data core, are used to determine the points at which extrapolation should begin. Thus the definition of the data core provides an appropriate basis for defining points at which extrapolation should begin.

Some commenters also provided suggestions for the manner in which to extrapolate specific model equations. For the most part, these suggestions applied to the various Complex Model options which were not adopted for the final Complex Model. The Agency has taken the specific extrapolation suggestions that applied to the final Complex Model equations into consideration.

E. Use of the Complex Model Under Non-Summer Conditions

While the VOC performance standard for reformulated gasolines applies only in the summer, the toxics and NOx requirements apply year-round. Similarly, the exhaust toxics and NOx requirements of the anti-dumping program apply year-round. EPA therefore recognizes that the complex model must be extended to cover typical winter fuels in order to estimate the exhaust toxics and NOx emission performance of gasolines during the winter months. Modeling winter emissions performance presents a number of unique difficulties. These difficulties include:

- The data sources described in Section A.1 provide data on emissions performances only under summer conditions.

- The wide range of temperatures encountered during the winter season (September 16th to March 30th) in the various geographical areas (north vs. south) within the United States would make emissions testing and modeling under winter conditions more difficult. The range of temperatures during the summer season tend to be considerably more uniform, particularly within each VOC Control Region.

- The RVP levels of fuels included in the current complex model database range from 7 to 10 psi, while winter fuels tend to have RVP levels in the range of 11 to 13 psi.

For these reasons, the complex model described in Section A cannot be used directly to evaluate fuels with typical winter RVP levels. The method chosen by EPA for extending the complex model for determining performance during wintertime scenarios is described below for both exhaust as well non-exhaust emissions.

1. Non-Summer Exhaust Model

a. Winter Engine Operation

The effect of fuel modifications on exhaust VOC and NOx emissions are thought to be minimally affected by the cooler ambient wintertime temperatures. Auto/Oil data [A-92-12 Docket submittal #II-G-1, December 1990] has shown that most fuel parameters affect emissions in two ways as the fuel is burned in the engine:

- Fuel properties affect the quantity of exhaust emissions generated in the engine itself (i.e., an "engine-out" effect).

- Fuel characteristics affect the efficiency of the catalyst in reducing the level of emissions leaving the vehicle (i.e., a "catalyst" effect).

Most fuel parameters affect both engine-out emissions and catalyst efficiency. Fuel sulfur content is the one fuel parameter which is believed to have only a catalyst effect. It is expected that fuels will encounter almost identical conditions in the combustion chamber (resulting in almost identical engine-out effects) and the catalyst (resulting in almost identical catalyst effects) during most of the driving cycle regardless of the ambient temperature. The only differences between summer and winter engine and catalyst operating conditions are:

- Slightly cooler engine temperatures due to increased heat transfer rates from the engine to the cooler winter air.

- Slightly longer warm-up times for engine and catalyst due to the thermal inertia of the colder engine block, coolant, and catalyst as well as the increased heat transfer rates to the ambient environment during warm-up.

- Slightly longer open-loop engine operation resulting from the longer warm-up time.

- Lower vapor generation rates and reduced canister loading due to lower fuel temperatures and lower ambient air temperatures.

Except for the last point, these differences are not expected to heavily influence the emission effects of most fuel parameters in winter when compared summer conditions. Hence EPA has concluded that most fuel modifications should have similar exhaust emission effects in both summer and winter, despite potentially large differences in ambient temperatures during the two seasons.

This conclusion is supported by data available from the Auto/Oil studies which has shown that the effect of most fuel modifications on exhaust emissions is similar regardless of temperature. Bag1 data taken on the FTP reflects measurements taken during the cold phase of engine start-up while bag3 data reflects measurements taken after the engine heats up to running conditions. Thus, a comparison of the effects of fuel modifications on exhaust emission data from bag1 and bag3 should serve as an indicator of how temperature effects emissions. Data from Auto/Oil [A-92-12 Docket submittal #II-G-1, December 1990] has shown many fuel modifications to result in similar exhaust emission effects in both bag1 and bag3. While the Auto/Oil data confirms EPA's expectation that many fuel modifications would have similar effects under summer and winter conditions, the amount of data provided by the Auto/Oil study is too limited to form the basis of a separate winter model.

EPA does not believe that this conclusion can be applied to RVP, however. As indicated previously, vapor generation rates under summer conditions are substantially higher than under winter conditions for fuels with identical RVP levels. EPA believes that RVP's effects on emissions are due in part to RVP's impact on actual vapor generation in the engine. However, the Agency believes that RVP's primary effect on emissions arise due to the loading and subsequent purging to the engine of the evaporative emissions control canister. Both phenomena are highly temperature-sensitive; fuels with identical RVP levels generate far more vapor and produce far greater canister loading under summer conditions than under winter conditions. Vapor generation and canister loading are a function of a fuel's true vapor pressure, which increases as temperature increases in accordance with basic principles of gas-phase chemistry. Hence EPA is not confident that RVP effects estimated from test data gathered under summer conditions can be used to estimate RVP effects under winter conditions.

b. Winter Baselines and Fuels

The winter baseline emissions of VOC and NOx are derived directly from the appropriate MOBILE models as outlined in Section III.B. Winter baseline toxic emissions are derived from the Complex Model database and the Complex Model itself. All winter baseline emissions are determined using the following fuel parameters, as discussed further in Section III.B:

Table IV-49
Baseline Fuel Parameters Used in Determining Winter Baseline Emissions

Fuel Parameter	Winter Baseline Value
Oxygen (weight percent)	0.00
Sulfur (ppmW)	338.0
RVP (psi)	11.5
E200 (percent)	50.0
E300 (percent)	83.0
Aromatics (volume percent)	26.4
Olefins (volume percent)	11.9
Benzene (volume percent)	1.64

Winter fuel characteristics are comparable to summer fuel characteristics except for Reid Vapor Pressure (RVP). The higher winter RVP levels are needed to maintain similar actual vapor generation rates under winter despite the generally lower fuel temperatures under such conditions (particularly during engine warm-up, when emissions are highest). As discussed previously, the RVP levels of fuels included in the exhaust complex model database ranged from 6.5 to 10 psi, while winter fuels tend to have RVP levels in the 10-14 psi range. RVP's impact on canister loading and purge rates are thought to be the primary causes of its effect on exhaust emissions. Since data on the emission effects of fuels with winter RVP levels under winter conditions are extremely limited, EPA has not been able to model the effects of winter RVP levels on exhaust emissions.

c. EPA Solution

Based on the points discussed in the previous section, EPA proposed in the February 1993 NPRM that for purposes of evaluating exhaust emission effects using the complex model, the RVP of winter fuels be set at the summer statutory baseline RVP value. EPA did not receive comments opposing this approach, which the Agency believes avoids the use of the model to make unfounded predictions. EPA has incorporated this approach in the final reformulated gasoline and anti-dumping requirements, which has the effect of embedding into the Complex Model the assumption that the RVP level of winter gasolines has no effect on NOx or exhaust toxic emissions. Thus, to evaluate wintertime fuels using the complex model, an RVP value equal to that of summer baseline gasoline (8.7 psi) must be used instead of the fuel's actual RVP. This procedure effectively removes the contribution of RVP to winter exhaust emissions. By removing any emissions-related incentives to alter winter RVP levels from 1990 levels, this approach also reduces the likelihood that in-use winter RVP levels, or the associated emissions, will change from their 1990 levels. To the extent that such emissions do not change, the approach outlined above becomes even more appropriate.

2. Non-Summer Non-Exhaust Model

a. NPRM Approach and Comments

In all its prior proposals, the Agency had proposed that winter nonexhaust emissions, including winter nonexhaust benzene emissions, be set equal to zero. EPA received a number of comments requesting that both baseline emissions and the nonexhaust toxics model include winter nonexhaust benzene emissions.

These requests were based on the fact that the year-round benzene limits would result in reduced nonexhaust benzene emissions in the winter months, if such emissions existed. EPA has evaluated this claim, taking into account winter temperature ranges and the effects of different inspections and maintenance programs on such emissions. EPA believes that this claim is valid, since winter non exhaust emissions (including nonexhaust benzene emissions) are unlikely to be zero under all winter temperature ranges.

In the past, the absence of sufficient data on nonexhaust emissions under winter temperature conditions has prevented EPA from developing accurate models of winter nonexhaust emissions. The commenters provided a limited amount of data on winter nonexhaust emissions to support their claim. However, the data submitted was found to contain the following limitations:

- The data submitted in support of this claim were based on measurements of nonexhaust emissions from vehicles with very low nonexhaust emissions that are not representative of actual in-use vehicles.

- The chemical composition of the measured nonexhaust emissions were characteristic of resting losses rather than diurnal, hot soak or running loss emissions. Resting losses are not included in EPA's baseline emission estimates, so the Agency does not consider it fair to include resting losses in its nonexhaust emission models. Speciation of the nonexhaust emissions also revealed the presence of compounds not found in gasoline, suggesting that non-fuel sources of emissions were present.

- No data were submitted on nonexhaust benzene emissions from fail vehicles under winter conditions. Since nonexhaust benzene emissions from such vehicles will comprise a large portion of winter nonexhaust benzene emissions, EPA is concerned that a model based only on pass vehicles would not provide accurate estimates of winter nonexhaust benzene emissions.

b. EPA Decision

For the reasons discussed in the previous section, the data submitted by the commenters on winter nonexhaust emissions cannot be used to evaluate wintertime baseline emissions. Thus, EPA is promulgating models which assume that winter nonexhaust emissions, including winter nonexhaust benzene emissions, be considered zero. However, given the merit of the claims made by the commenters, EPA will consider including a model of winter benzene nonexhaust emissions in the complex model in the future when sufficient reliable data become available.

F. Behavior of Complete Complex Model

1. Fungibility

As the gasoline distribution system currently operates, all gasoline is fungible. Fungibility means that a given batch of gasoline is exchangeable and/or mixable with any other batch of gasoline at any point between the refinery gate and a vehicle's fuel tank[48]. Fungibility simplifies gasoline distribution because it permits gasoline to be stored, transported, and sold without the constraints and costs associated with segregating every batch of gasoline from every other batch. Thus gasoline is always gasoline regardless of whether it derives from a mixture of other gasolines.

Reformulated gasoline (RFG) will be distributed through the same network of pipelines, trucks, and terminals that is currently used for conventional gasoline. However, because RFG is produced to very different specifications than conventional gasoline, the production of RFG potentially will have significant impacts on the fungibility of the gasoline distribution system. These impacts fall into two categories:

1) The difference in production specifications for conventional gasoline and RFG require that all conventional gasoline must be segregated from all RFG at all times.

2) The compliance of a given batch of RFG with the emission standards is determined through the Complex Model which, in general, is not linear. The result of this nonlinearity is that the emissions performance of a mixture of two complying RFGs cannot be easily inferred from the performances of the individual fuels. It may be possible, therefore, that the mixture of two complying RFGs will yield a fuel that is not a complying RFG, according to performance estimates provided by the Complex Model.

The first impact on fungibility, that of segregation of all RFG from all conventional gasoline, cannot be compromised. The compliance of RFG is determined through evaluation of its fuel parameters with the Complex Model. If a batch of RFG were to be mixed with a batch of conventional gasoline, the value of its fuel parameters could change dramatically. The "mixed" RFG would then require re-evaluation with the Complex Model, and would be unlikely to comply with the requirements of the reformulated gasoline program. To assure that conventional and reformulated gasoline is not mixed, conventional gasoline is required to contain a chemical marker. This marker is not permitted to be present in gasoline sold as reformulated gasoline.

The second impact on fungibility requires both elaboration and analysis. The practical and financial requirement that RFG be

---

[48] Some segregation of conventional gasolines already occurs based on fuel RVP, octane rating, and/or oxygenate type and content specifications.

fungible throughout its distribution system requires that RFG batches be allowed to mix with one another in any proportion and at any point between the refinery gate and a vehicle's fuel tank (in practice, the different standards and emission models applicable in VOC Control Regions 1 and 2 require RFG for each region to be segregated). Thus the requirement for a fungible distribution system translates into a requirement that a mixture of two complying RFGs must be a complying RFG. Since RFG compliance is determined through the Complex Model which is not linear, it cannot be assumed that mixtures of complying reformulated gasolines are themselves complying reformulated gasolines. To determine the degree to which certified reformulated gasolines can be mixed and still remain in compliance, an analysis of the behavior of the Complex Model was conducted.

The nonlinearity in the Complex Model is due to the existence of second-order terms and the exponential form of the regression equations. This nonlinearity means that emissions from a mixture of two fuels will differ from the weighted average of the two fuels' individual emissions. However, this mixing may be either beneficial or detrimental to an RFG mixture's compliance status. In other words, the Complex Model may predict any of the following for a mixture of two complying RFGs:

1) The emissions performance of the mixture equals the weighted average of the two original fuels' emissions performances.

2) The emissions performance of the mixture is better than the weighted average of the two original fuels' emissions performances.

3) The emissions performance of the mixture is worse than the weighted average of the two original fuels' emissions performances, but the mixture remains a complying RFG.

4) The emissions performance of the mixture is worse than the weighted average of the two original fuels' emissions performances, and the mixture becomes a non-complying RFG.

Fungibility problems arise only for case (4).

The fungibility analysis involved evaluating the performance of thousands of randomly generated fuels with the Complex Model. Emission estimates for total VOC, NOx, and total toxics were calculated to determine the frequency of occasions in which the mixture of two complying RFGs produced a non-complying RFG. The analysis also provided information on the frequency of occasions in which a mixture of two complying RFGs performed more poorly than could be inferred from the two original fuels, but nevertheless remained a certifiable RFG (case 3). The steps in the analysis can be summarized as follows:

1. Create 24,000 fuels distributed randomly throughout the fuels space defined by the valid range of the extrapolated Complex Model.

2. Retain all "certifiable" and realistic fuels based on VOC performances[49] of -15.0 to -17.0 percent, NOx performances of 0.0 to -2.0 percent, and toxics performances of -15.0 to -30.0 percent. Fuels with emission performance levels beyond these ranges are either not permissible under a per-gallon compliance scenario or are unrealistically low-emitting. Including such fuels makes fungibility problems (in which the mixture does not comply with the per-gallon requirements) even less likely.

3. Generate 50:50 mixtures of pairs of fuels from among those retained from step 2 by averaging the fuel parameter values from the two contributing fuels.

4. Determine the Complex Model performance of the mixtures generated in step 3 for VOC, NOx, and toxics.

5. Calculate the "Fungibility Effect" by subtracting the average performance of the two constituent fuels from the performance of the mixture (the average performance of the two constituent fuels is equivalent to the weighted average of the performances of the two fuels mixed in a 50:50 ratio):

   Fungibility Effect = M - [(0.5 x A) + (0.5 x B)]

   M = Performance of the mixture (% change from baseline)
   A = Performance of the first qualifying RFG (% change from baseline)
   B = Performance of the second qualifying RFG (% change from baseline)

   Fungibility effects were determined separately for each pollutant. Note that negative fungibility effects are beneficial, i.e. negative fungibility effects indicate that emissions from the mixture are lower than would have been expected based on the performance of the two original fuels.

---

[49] Performance is here defined as the percent change in emissions of a target fuel as compared to a baseline fuel

6. Examine the average fungibility effect to determine the impact of fuel mixing on in-use compliance and the potential application of ratchets to the applicable emission standards.

7. Examine fuels for which the fungibility effect was positive (i.e., detrimental) to identify situations that might result in the issuance of a Notice of Violation.

8. Determine cases in which a detrimental fungibility effect caused a mixture of two complying fuels to be non-complying.

The scenario under which the analysis was performed was designed to amplify any fungibility problems that might exist. For this reason, a per-gallon scenario with tight controls on the initial performance estimates was assumed, along with a 50:50 fuel mixing ratio. Averaging scenarios are less binding since NOVs can be issued only for violations of the per-gallon minimum performance requirements, and because the wide range of fuels likely to exist under averaging are unlikely to consist only of fuels with unfavorable fungibility effects. The 50:50 mixing ratio tends to create the largest fungibility effects, since any nonlinear effects are most noticeable at this ratio. Fungibility effects and problems are independent of the program phase, area class, and season assumed for the analysis, since the percentage change estimates for the original fuels and mixtures are largely independent of these conditions. Oxygenate type affects emissions only in the case of the aldehydes and nonexhaust benzene, since such effects are linear, the analysis is independent of oxygenate type. The scenario analyzed below was based on Phase I summer requirements in Class C areas and used MTBE as the oxygenate. The results of the analysis are shown in Figures IV-2 through IV-7, and are summarized in Table IV-50.

Figures IV-2 and IV-3: Results of VOC Fungibility Analysis

Figures IV-4 and IV-5: Results of NOx Fungibility Analysis

Figures IV-6 and IV-7: Results of Toxics Fungibility Analysis

Table IV-50
Summary of Results of Fungibility Analysis

	Total VOC	NOx	Total toxics
Performance of contributing fuels			
Minimum	-16.97	-1.98	-29.99
Maximum	-15.00	0.00	-15.49
Average	-16.01	-0.93	-25.06
Performance of mixtures			
Minimum	-17.77	-3.20	-29.70
Maximum	-15.20	0.43	-20.06
Average	-16.42	-0.99	-25.40
Fungibility effects			
Minimum	- 1.81	-1.68	- 1.19
Maximum	1.01	0.86	0.02
Average	- 0.42	-0.04	- 0.35

A number of conclusions can be drawn from the values in Table IV-50. First, the minimum and maximum performances of the contributing fuels fall within the performance ranges given in step 2, since only complying and realistic fuels were retained from the 24,000 randomly generated fuels. Second, the average performance of the mixtures is better than the average performance of the contibuting fuels for total VOC, NOx, and total toxics, which indicates that, on average, mixing fuels tends to result in beneficial fungibility effects. Other conclusions are discussed separately for VOC, NOx, and toxics:

Total VOC

The average VOC fungibility effect is beneficial, although a small percentage of such effects are detrimental. However, in no case does a fungibility effect result in a mixture of two fuels having emission reductions of less than 15.0%. Thus this analysis shows that although some mixtures of pairs of fuels will have higher emissions than would be implied by the performances of the two constituent fuels, these higher emissions will never result in a mixture of two complying fuels being in non-compliance with the standards for RFG. This conclusion also applies to compliance on average. When complying on average, the performance of individual fuel blends will cover a larger range than when complying on a per-gallon basis. EPA has found that the distribution of VOC fungibility effects becomes more beneficial as the range of performances increases. In addition, EPA found that detrimental fungibility effects are not large enough to result in violations of the per-gallon minimum performance standards under averaging. Finally, the compliance margin imposed under averaging assures that fuels complying on average will result in average VOC performances that exceed the per-gallon standards applicable in each Phase.

NOx

The average NOx fungibility effect is beneficial, although a significant percentage of mixtures resulted in detrimental fungibility effects. EPA found that the vast majority of mixtures with detrimental effects comply with the program's NOx requirements. Of the 124 fuel pairs that survived the screening process of step 2, only two pairs resulted in detrimental fungibility effects that also resulted in NOx noncompliance for the mixture. These two fuel pairs, their mixtures, and the Complex Model performances for each fuel are shown in Table IV-51.

Table IV-51
Fuels Resulting in Non-complying Mixtures

	Fuel #1	Fuel #2	#1 + #2	Fuel #3	Fuel #4	#3 + #4
Oxygen	3.19	2.21	2.70	3.29	2.48	2.88
Sulfur	172	399	285	420	291	356
RVP	8.17	8.04	8.11	8.14	8.08	8.11
E200	38.4	35.2	36.8	45.9	57.0	51.5
E300	91.5	93.4	92.4	90.4	79.3	84.9
Aromatics	44.2	24.5	34.4	22.2	35.6	28.9
Olefins	17.4	9.15	13.3	9.66	7.63	8.65
Benzene	0.371	0.843	0.607	0.968	0.739	0.853
Performance:						
Total VOC	-15.26	-15.49	-15.37	-15.50	-15.07	-16.24
NOx	- 0.22	- 0.99	0.22	- 0.06	- 0.46	0.44
Total Toxics	-27.60	-27.37	-27.79	-29.55	-26.85	-28.38

Such results show that the mixture of two complying RFGs can result in a non-complying gasoline for NOx. However, the following points indicate that such concerns are not warranted:

- The scenario under which the analysis was carried out was designed to amplify fungibility effects and any associated fungibility problems. Under actual in-use conditions, these effects would be substantially smaller or nonexistent since 50:50 ratios of the two fuels are unlikely and since fuels other than the fuels presented above are likely to be mixed. As more fuels are mixed, fungibility effects will tend to reflect the average fungibility effects presented in Figures IV-2 through IV-7.

- None of the four constituent fuels in Table IV-51 are representative of in-use reformulated gasolines:
  - Low sulfur does not typically accompany high olefins, and vice-versa, as in Fuels #1 and #3.
  - Low E200 does not typically accompany high E300 as in Fuels #1, #2, and #3.
  - Ultra-high octane fuels, such as Fuel #1, will most likely not play a significant role in the reformulated gasoline program. In addition, such fuels are unlikely to be mixed with low-octane fuels such as fuel #2 due to the price premium commanded by high-octane fuels and the cost of the additional oxygenate.
- Very few, if any, refiners will produce RFGs whose performances fall as close to the standards as those in Table IV-51 do. To assure compliance with the per-gallon standards given the uncertainties associated with measuring fuel parameter levels, fuel suppliers are likely to maintain compliance margins.
- The oxygenate contents are not at the levels commonly associated with MTBE or ethanol fuels. In fact, fuels #1 and #3 can be produced only with ethanol as the oxygenate.

Thus under in-use conditions, EPA does not anticipate any NOx fungibility problems to arise under per-gallon compliance with the "no NOx increase" provisions of the program. As discussed previously, fungibility effects under averaging are likely to be more beneficial than under per-gallon compliance since the range of performances of fuels produced under averaging will be wider than the range of performances of fuels produced under per-gallon compliance. In addition, EPA found that detrimental fungibility effects are not large enough to result in violations of the per-gallon minimum performance standards under averaging. Finally, the compliance margin imposed under averaging assures that fuels complying on average will result in average NOx performances that exceed the per-gallon standards applicable in each Phase.

Total Toxics

All exhaust toxics, except for POM, have strictly linear relationships with all fuel parameters, and therefore would not be expected to demonstrate either beneficial or detrimental fungibility effects.[50] The non-exhaust benzene models, however, include a negatively squared relationship with RVP, and therefore would be expected to exhibit beneficial fungibility effects at all times. These facts are confirmed in the results for total toxics, as the fungibility effects are almost always beneficial (though POM could contribute a small detrimental fungibility effect). Thus it is apparent that all 50:50 mixtures of complying and realistic fuel pairs also will comply and in fact will almost always have lower emissions of toxics than the weighted average of the contributing fuels' toxics emissions.

2. Predictability and Validation of Exhaust Complex Models

As discussed in the February 1993 NPRM and in previous EPA submittals to the docket, there are two ways by which the accuracy and/or precision of models can be investigated. One way is to inspect the effect of changing one fuel parameter at a time on exhaust emissions and compare the effect to directional effects demonstrated by specific studies in the database. Another way is to compare model predictions on vehicles and fuels from specific test programs to measured emission effects of fuel modifications. Both of these methods will be discussed in this section.

a. Parametric Performance of Complex Models

Table IV-52 summarizes the effects of single parameter fuel modifications on exhaust emissions as predicted by the final (simplified) Phase I Complex Models (see Section A.9) for the 1990 in-use fleet. With the exception of the poorly-understood effects of E200 fuel modifications on exhaust NOx and VOC emissions, the emission effects predicted by the Complex Models for exhaust VOC and NOx are directionally consistent with the effects predicted by the Auto/Oil and ATL studies [See A-92-12 Docket submittals II-G-1 through II-G-5, December 1990; II-B-12, February 1993 and II-B-14, February 1993]. Since emissions data from the Auto/Oil and ATL studies comprise over 50% of the emissions database, the Complex Models appear to demonstrate behavior that is directionally consistent with the data in the Complex Model database. As discussed in Sections III and IV.A, there are far fewer data on

---

[50] Since the exhaust models are in the form of exponentials of polynomials, there is in fact some curvature to "strictly linear" relationships that can contribute to fungibility effects. However, the nature of an exponential function is such that only beneficial effects would be exhibited, and the relatively small order of magnitude of the independent variables (fuel parameters) is such that the exhibited effects would be very small.

toxic emissions than on VOC and NOx emissions. Hence the models' predictions for toxic emissions behavior are expected to be less accurate than the models' predictions of VOC and NOx emission behavior. However, the effects of fuel modifications on exhaust toxic emissions shown in Table IV-52 below are also, for the most part, directionally consistent with the studies that measured and quantified the effects of fuel parameter changes on toxic exhaust emissions [See A-92-12 Docket submittals II-G-1 through II-G-5, December 1990; II-B-12, February 1993 and II-B-14, February 1993].

Table IV-52
Phase I, Summer, In-Use Exhaust Complex Model Predictions
(all numbers are percent change in emissions from CAAB fuel)

Fuel Parameter Changed	VOC & POM	NOx	Benzene	Butadiene	Acet-aldehyde	Form-aldehyde
Oxygen 0->2 wt%	-0.72	-0.02	-8.39	-5.49	-6.07*	+9.68*
Sulfur 339->139 ppm	-4.63	-6.81	-9.19	-1.59	-5.12	---
RVP 8.7->7.7 psi	-3.52	-0.49	---	---	-2.03	---
E200 41->51 %	-4.11	+0.94	-1.73	-7.02	---	---
E300 83->87.3 %	-2.64	-0.01	+2.58	-4.85	-5.10	-4.30
Aromatics 32->27 vol%	-1.94	-0.76	-9.23	+2.02	+2.81	+3.65
Olefins 9.2->4.2 vol%	+1.44	-1.06	---	-16.3	---	+8.15
Benzene 1.53->0.95 vol%	---	---	-12.1	---	---	---

* Calculated assuming oxygen in the form of MTBE

b. Validation of Complex Models

Because of the wide range of fuel parameters tested and the large number of vehicles tested in both the normal and higher emitter categories, EPA's ATL-I and ATL-II programs were chosen for comparison to model predictions of VOC and NOx emissions. Selected fuels with a wide range of different fuel properties, emissions effects, and oxygenate types) from the various Auto/Oil programs were also chosen for comparison to the exhaust Complex Models developed above. The fuels from the different programs and their properties are summarized below in Tables IV-53, IV-54 and IV-55.

Table IV-53
ATL-I Fuels Used for Validation of Complex Model

Fuel	Oxygen (wt %)	Sulfur (ppmw)	RVP (psi)	E200 (%)	E300 (%)	Arom (v %)	Olef (v %)	Benz (v %)
C	2.0 (MTBE)	371	8.3	57.1	85.0	25.4	6.8	1.0
D	2.0 (MTBE)	364	7.6	54.1	83.8	25.8	6.4	1.0
E	2.0 (MTBE)	355	8.5	62.2	92.5	23.6	5.9	0.9
F	2.0 (MTBE)	112	8.3	54.8	83.9	24.2	6.4	0.9
G	2.0 (MTBE)	133	7.7	61.8	92.3	23.8	5.6	1.0
H	3.5 (ETOH)	353	8.0	57.8	84.7	27.3	7.0	1.0

Table IV-54
ATL-II Fuels Used for Validation of Complex Model

Fuel	Oxygen (wt %)	Sulfur (ppmw)	RVP (psi)	E200 (%)	E300 (%)	Arom (v %)	Olef (v %)	Benz (v %)
K	2.0 (MTBE)	311	7.5	48.9	80.0	28.9	7.0	0.8
L	2.0 (MTBE)	307	7.7	52.3	81.8	26.4	7.0	0.8
M	2.0 (MTBE)	345	7.3	42.6	81.7	25.7	7.3	0.9
N	2.0 (MTBE)	337	7.7	52.4	76.2	23.1	7.8	0.6
P	2.0 (MTBE)	288	7.9	53.5	83.7	26.8	9.8	0.8
R	2.0 (MTBE)	320	7.9	53.6	81.1	25.0	7.4	0.6
S	2.0 (MTBE)	327	7.5	52.4	81.6	23.3	1.1	0.5
T	2.0 (MTBE)	59	7.6	52.9	81.4	22.8	1.3	0.5
U	2.0 (MTBE)	66	6.4	52.6	81.3	23.5	1.4	0.5
V	2.0 (MTBE)	31	6.2	50.5	90.8	21.7	2.8	0.8

Table IV-55
Auto/Oil Fuels Used for Validation of Complex Model

Fuel	Oxygen (wt %)	Sulfur (ppmw)	RVP (psi)	E200 (%)	E300 (%)	Arom (v %)	Olef (v %)	Benz (v %)
H (AMOT)	2.7 (MTBE)	313	8.5	65.3	92.0	20.2	20.2	1.52
O (AMOT)	2.7 (MTBE)	288	8.6	47.9	91.9	46.7	19.3	1.38
R3A (HC/A)	2.0 (MTBE)	90	8.48	46.2	87.1	28.2	14.5	0.62
MM (RVP)	2.7 (MTBE)	345	8.0	67.4	91.3	22.2	5.4	1.41
N2 (RVP)	2.7 (MTBE)	313	8.8	65.7	91.3	22.5	4.7	1.31
NN (RVP)	2.7 (ETBE)	313	8.0	50.7	92.6	21.2	3.8	1.50
T (RVP)	3.5 (ETOH)	246	9.3	57.4	93.1	18.1	3.6	1.35

The exhaust emissions data (after converting total hydrocarbons to non-methane hydrocarbons in order to facilitate direct comparisons to percent change predictions from the Complex Models) from these programs were placed in appropriate technology groups and emitter classes and re-weighted according to the revised weighting factors listed in Section III.B.4 for summer Phase II VOC and NOx emissions. Shown in Table IV-56 is a direct comparison of data to predicted exhaust emissions from the final Complex Models for VOC and NOx. The percent change in emissions shown in Table IV-56 for the data as well as predictions by the model (which are in bold type) should be directly comparable since all weightings and classifications used were identical.

Table IV-56
A Comparison of Data to Complex Model Predictions

Study/Fuel	percent change in VOC emissions from base fuel		percent change in NOx emissions from base fuel	
	NORMAL EMITTERS	HIGHER EMITTERS	NORMAL EMITTERS	HIGHER EMITTERS
ATL-I/C	-10.4/**-8.44**	-13.3/**-9.4**	-2.5/**+1.5**	-2.4/**-1.4**
ATL-I/D	-13.4/**-8.77**	-10.8/**-11.3**	-2.9/**+0.35**	+1.5/**-0.4**
ATL-I/E	-14.2/**-11.6**	-7.90/**-8.7**	-3.7/**+1.8**	-9.9/**-5.2**
ATL-I/F	-14.5/**-18.9**	-14.7/**-8.0**	-4.8/**-8.4**	-11.5/**-7.8**
ATL-I/G	-17.8/**-22.8**	-11.4/**-10.5**	-8.5/**-6.8**	-10.2/**-9.3**
ATL-I/H	-9.4/**-10.0**	-20.3/**-10.4**	+5.7/**+1.6**	+3.5/**-2.0**
ATL-II/K	-4.6/**-3.5**	-1.7/**-7.6**	-0.36/**-0.28**	+5.9/**+0.2**
ATL-II/L	-10.2/**-7.3**	-5.3/**-9.4**	-1.3/**-0.19**	+2.6/**-1.2**
ATL-II/M	-5.5/**-2.9**	-3.1/**-8.5**	-4.7/**-0.54**	+6.7/**-0.7**
ATL-II/N	-1.2/**-0.97**	-3.4/**-8.9**	-4.1/**-0.45**	-1.6/**+0.9**
ATL-II/P	-12.2/**-10.3**	-4.3/**-9.8**	-3.9/**+0.72**	+1.1/**-1.6**
ATL-II/R	-10.4/**-6.4**	-2.6/**-9.5**	+1.2/**+0.20**	+0.9/**-1.1**
ATL-II/S	-4.9/**-6.3**	+1.1/**-10.1**	-5.8/**-0.95**	-1.6/**-1.7**
ATL-II/T	-12.4/**-18.1**	-3.1/**-8.7**	-10.6/**-11.7**	-2.8/**-8.3**
ATL-II/U	-12.8/**-20.2**	-4.3/**-13.0**	-11.2/**-12.1**	+5.6/**-6.3**
ATL-II/V	-22.5/**-25.8**	-2.7/**-13.9**	-10.2/**-14.1**	+4.8/**-11.1**
AO/H	-17.8/**-18.4**	---*	+10.6/**+7.8**	---*
AO/O	-15.0/**-15.6**	---	+3.31/**+8.2**	---
AO/R3A	+1.39/**-20.9**	---	+3.89/**-6.3**	---
AO/MM	-10.1/**-14.7**	---	+9.02/**+0.31**	---
AO/NN	-8.10/**-13.9**	---	+13.3/**+0.09**	---
AO/N2	-7.10/**-13.1**	---	+6.39/**-2.3**	---
AO/T	-7.30/**-14.9**	---	+12.0/**-3.6**	---

* Higher emitter were not tested in the Auto/Oil Programs

For the most part, it is evident from Table IV-56 that the discrepancies between actual test results and model predictions are small and would be expected to fall within the 90% confidence interval calculated in the ATL test programs [see A-92-12 Docket submittals #II-B-12, February 1993 and #II-B-14, February 1993]. In some cases, the predictions are poor due to contradicting emissions for similar fuels within the data in the Auto/Oil and ATL studies.

3. Response to Comments

In response to previous EPA submittals to the docket, one commenter expressed the need for the exhaust benzene model to be developed in a different manner. The commenter suggested that the effect of fuel benzene content and fuel aromatics content were overestimated. However, the agency has analyzed many exhaust benzene emission models [see EPA memorandum by Rao and Sklar "Alternative Exhaust Benzene Models," December 2, 1993], including the model suggested by this commenter, and concluded that the exhaust benzene model presented in Section A is the simplest in form and as accurate as any other model for exhaust benzene emissions. EPA, in all of the models that it has developed for predicting exhaust benzene emissions, has found that fuel benzene content and aromatics content have a large effect on benzene emissions, particularly when their effects on emissions from vehicles with emission levels representative of in-use emission levels.

Nearly all commenters expressed the need for a fungible fuel distribution system. The Agency agreed with commenters that fungibility is a critical element of the fuel distribution system. EPA evaluated fungibility throughout the development of the Complex Model. The fungibility analysis methodology described in Section F.1 was originally presented at the June 2, 1993 Complex Model workshop in Romulus, Michigan in response to the need for a fungible model. It has since been affirmed by the participants of that workshop as an appropriate and accurate analysis tool.

In response to the July 15, 1993 docket submission of various Complex Model options, commenters concluded that the Agency was fulfilling its mission to develop a Complex Model that ensured fungibility. The Agency has continued this mission in the development of the final Complex Model, as the results of the fungibility analysis in Section F.1 show. Thus the EPA's analysis shows that, for real in-use fuels, the final Complex Model presents no fungibility concerns.

G. Vehicle Testing

As discussed in Section V of the preamble, the purpose of vehicle testing is to supplement the Complex Model, not to supplant it. Vehicle testing is subject to a number of sources of error and bias. The model is less vulnerable to bias and error since it is based on the results from a number of independent testing programs. Nonetheless, the results of new vehicle testing programs can provide information beyond that available from the test programs represented in the Complex Model database. New vehicle testing programs are particularly valuable when they examine the effects of fuel parameters at previously-untested levels or the effects of fuel parameters that have not yet been tested.

In order to provide useful information beyond that incorporated in the Complex Model, vehicle testing programs need to incorporate a number of measures to assure the relevance of their results. These measures must, at minimum, address the following concerns:

- The emission effects being measured must be the result of the specific fuel modification for which benefits are being claimed.
- The emissions effects being measured, including nonlinear or interactive effects, must be quantifiable across the entire set of vehicles of concern.
- The emission effects must meet the statistical significance and explanatory power criteria used to develop the Complex Model.

To address these concerns, the Agency has promulgated a set of fuel specifications, fuel blending and measurement tolerances, vehicle selection criteria, and data analysis processes to govern vehicle testing programs undertaken to augment the Complex Model. The remainder of this section explains and justifies these requirements. In addition, a summary and analysis of substantive comments received by EPA regarding its prior vehicle testing proposals is presented.

1. Specifications for Fuels Required for Vehicle Testing Programs

a. Orthogonal fuel design

The properties of the fuels tested in a vehicle testing program limit the emission effects that can be determined from the test program's effects. Two fuels with different levels of the fuel property of interest must be tested to determine whether a first-order (i.e., linear) effect of the fuel property on emissions exists and to estimate the size of this effect. Fuels containing three different levels of the fuel property must be tested to determine whether a second-order (i.e., squared) effect exists and to estimate its size. Additional fuels must be tested to determine the presence of interactive effects.

In the ideal case, test fuels would be *orthogonal* to one another. A pair of fuels is said to be orthogonal with respect to a fuel parameter when the two fuels are identical in all respects except for that fuel parameter. As the number of properties being investigated grows, the number of fuels required to construct an orthogonal set of fuels increases exponentially. If two separate levels of each fuel property are to be tested and there are N such properties, then the number of fuels required equals two raised to the Nth power: 2^N. If three separate levels of each fuel property are to be tested in order to determine the existence and size of second-order effects, then the number of fuels required increases to 3^N. In either case, the number of fuels increases rapidly as the number of fuel properties increases. Since the exhaust emission Complex Model incorporates seven fuel properties for VOC, NOx, POM, and butadiene, eight properties for exhaust benzene, and ten properties for acetaldehyde and formaldehyde, an ideal vehicle test program would contain thousands of fuels. Such test programs would be prohibitively costly to conduct.

Three factors reduce the number of fuels required for vehicle testing to more manageable levels, however. First, the number of fuels required for VOC and NOx testing can be reduced if testing is conducted to identify second-order interactive effects only. In other words, by assuming that interactive effects will not take the form ($A^2 \times B$) or ($A \times B \times C$) where A, B, and C are fuel parameters, many fuels need not be tested. This assumption appears reasonable, since the existence of such effects would imply that simultaneous interactions between three separate molecules significantly affect emissions. Such interactions are far less likely to occur than pairwise interactions; in fact, chemical reactions involving three separate molecules typically are modeled as sequential pairwise reactions. By eliminating three-way interactions, a comprehensive test program would require fewer than 50 fuels.

Second, the Complex Model and Complex Model database already include much of the information that a comprehensive program would provide. Hence combining the test program results with the Complex Model and Complex Model database permits the size of the test program to be reduced still further.

Third, the Complex Model does not include all possible effects, despite having analyzed a large body of test data. Since the size of any one test program is likely to produce fewer data than the existing Complex Model database contains, it is unlikely that effects not found when analyzing the Complex Model database would be found in an individual vehicle testing program. As a result, some effects can be eliminated from consideration. In other cases, notably for toxics emissions, measurement uncertainties are sufficiently large to make the identification and accurate estimation of interactive effects difficult. It would be pointless to require testing to identify interactive effects for exhaust toxics since such effects cannot be identified with accuracy from test data.

Given the preceding discussion, EPA has identified fuels that, if tested in a well-designed and well-conducted vehicle testing program, can provide sufficient information to quantify genuine emission effects with sufficient confidence to supplement the Complex Model with the estimated emission effects. Two separate sets of fuels have been identified. The first set of fuels is designed to provide sufficient information to extend the valid range of fuel parameters already included in the Complex Model. In this case, the test program would be designed to quantify the emissions effects of existing Complex Model fuel parameters at levels that have not been adequate tested. The second set of fuels is designed to provide sufficient information to add a new fuel parameter to the Complex Model.

b. Fuels to be tested when extending the range of the Complex Model

As discussed in Section V of the preamble, at least three fuels must be tested when extending the range of the Complex Model. These three "extension fuels" are specified in Tables IV-57 and IV-58. Table IV-57 specifies the level of the parameter being extended; Table IV-58 specifies all other parameters for the three extension fuels.

Table IV-57: Level of Existing Complex Model Parameters Being Extended

Fuel Property Being Extended	Extension Fuel #1	Extension Fuel #2	Extension Fuel #3
Sulfur, ppm	Extension Level	80	450
Benzene, vol%	Extension Level	0.5	1.5
RVP, psi	Extension Level	6.7	8.0
E200, %	Extension Level	38	61
E300, %	Extension Level	78	92
Aromatics, vol%	Extension Level	20	45
Olefins, vol%	Extension Level	3.0	18
Oxygen, wt%	Extension Level	1.7	2.7
Octane, R+M/2	87.5	87.5	87.5

Table IV-58: Levels for Fuel Parameters Other Than Those Being Extended

Fuel Property	Extension Fuel #1	Extension Fuel #2	Extension Fuel #3
Sulfur, ppm	150	150	150
Benzene, vol%	1.0	1.0	1.0
RVP, psi	7.5	7.5	7.5
E200, %	50	50	50
E300, %	85	85	85
Aromatics, vol%	25	25	25
Olefins, vol%	9.0	9.0	9.0
Oxygen, wt%	2.0	2.0	2.0
Octane, R+M/2	87	87	87

These fuels are designed to test the effects of the fuel parameter being extended at three separate levels in order to estimate the linear and squared effects of the parameter in question. Extension Fuel 1 will have levels of the parameter being tested that are equal to the most extreme value for which the augmentation will be valid. Extension Fuels 2 and 3 will have levels of the parameter being tested within the range of the Complex Model, which allows the test program to correlate its results to those for the Complex Model. The properties of these two fuels are near the limits of the valid range of the model for reformulated fuels but are sufficiently far within those limits so as to assure the reliability of the Complex Model correlations (as discussed in Section D, the Complex Model correlations become less reliable for fuels at or near the limits of the valid range of the model).

The three fuels described above do not provide the information needed to evaluate interactive effects. However, EPA does not anticipate that test programs of the size required to augment the model would be sufficient to identify interactive effects that were not included in the Complex Model, which is based on a much larger set of data than would be available from augmentation test programs. Hence EPA does not require testing for interactive effects unless such effects are already incorporated in the Complex Model. For example, the VOC model includes interactive effects for aromatics (with E300) but does not include interactive effects for sulfur. As a result, a test program to extend the range of sulfur levels covered by the model would not be required to test for interactive effects, but a test program to extend the aromatics range would be required to do so.

To evaluate interactive effects, two additional fuels are required. These two fuels must have the following characteristics:

- The parameter being tested must be at the level specified for Extension Fuel 1, i.e., it must be at the most extreme value for which the augmentation will be valid.

- Other parameters which interact with the parameter being tested according to the Complex Model (for any pollutant) must be at two different levels in the two fuels. The first fuel (Extension Fuel #4) must contain these other parameters at the level specified in Table IV-57 for Extension Fuel #2, i.e., at relatively low levels. The second fuel (Extension Fuel #5) must contain these other parameters at the level specified in Table IV-57 for Extension Fuel #3, i.e., at relatively high levels.

- All other parameters must be present at the intermediate levels specified in Table IV-58.

c. Fuels to be tested when adding a new parameter to the Complex Model

More fuels must be tested when adding a new parameter to the Complex Model for several reasons. First, the Complex Model database cannot be used to supplement the results from the vehicle testing program. Second, the Complex Model cannot be used to reduce the testing needed to identify and quantify any interactive effects. In order to quantify linear, squared, and interactive effects for the new parameter, seven fuels must be tested (referred to as "Addition Fuels"). The specifications for these seven fuels are listed in Table IV-59.

Table IV-59: Properties of Fuels To Be Tested When Augmenting The Model With A New Fuel Parameter

Fuel Property	FUELS						
	1	2	3	4	5	6	7
Sulfur, ppm	150	150	150	35	35	500	500
Benzene, vol%	1.0	1.0	1.0	0.5	0.5	1.3	1.3
RVP, psi	7.5	7.5	7.5	6.5	6.5	8.1	8.1
E200, %	50	50	50	62	62	37	37
E300, %	85	85	85	92	92	79	79
Aromatics, vol%	27	27	27	20	20	45	45
Olefins, vol%	9.0	9.0	9.0	2.0	2.0	18	18
Oxygen, wt%	2.1	2.1	2.1	2.7	2.7	1.5	1.5
Octane, (R+M)/2	87	87	87	87	87	87	87
New Parameter*	C	$\frac{C+B}{2}$	B	C	B	C	B

[*] C = Candidate level, B = Baseline level

Addition Fuels 1, 2, and 3 are necessary to determine the linear and squared effects for the parameter being tested. Since emissions performance of reformulated fuels is calculated relative to the emissions performance of Clean Air Act baseline gasoline, Addition Fuel #3 must contain this parameter at a level representative of that found in Clean Air Act baseline gasoline in order to assign proper emissions credit for changes in this fuel parameter. The parameter also must be tested at its "candidate" level, the most extreme level at wich it is to be tested (which can be higher or lower than its level in Clean Air Act baseline fuel), as specified for Addition Fuel #1. The parameter also must be tested at a level midway between these first two levels, as in Addition Fuel #2, in order to estimate the parameter's squared effects on emissions. Squared effects are most easily determined if the parameter levels for the three fuels are evenly spaced. For all three fuels, other fuel parameters must be present at levels which satisfy two requirements:

- They must be at levels typical of reformulated fuels that are likely to be produced during 1995-1999.
- They must be at levels for which the Complex Model correlations are highly reliable, i.e., they must be at levels near the center of their range in the Complex Model database.

Addition Fuels 4 through 7 are necessary to identify and quantify any interactive effects associated with the parameter. Addition Fuels 4 and 5 represent "clean" fuels in that all parameters other than the one being tested are set at levels that generally result in emission reductions from baseline levels. Addition Fuels 6 and 7 represent "dirty" fuels since all parameters other than the one being tested are set at levels that generally result in emission increases from baseline levels. The "clean" and "dirty" levels of these parameters are as widely separated as possible while still remaining within the data core and within the range expected to occur in reformulated gasolines during 1995-1999. Oxygen levels were set so as to be compatible with the use of any oxygenate under the "substantially similar" requirements of existing law. The two "clean" fuels are required to contain levels of the parameter being tested that are equal to those specified for Addition Fuels 1 and 3, respectively; the same is true for the two "dirty" fuels. The wide separation in parameter levels among Addition Fuels 4 through 7 is designed to improve the ability of the analysis method (discussed in Section G.4) to isolate and quantify interactive effects associated with the parameter being tested.

2. Blending and Measurement Tolerances

a. Blending precision

In the course of its own vehicle testing programs, EPA has found that there are limits to the precision to which fuels can be blended, particularly when fuels are blended from representative refinery streams. These limitations appear to be the result of limitations in the design and process control capabilities of modern refineries. EPA's experience, combined with comments received from refiners and fuel blenders, indicates that fuel blenders cannot achieve precisions beyond those specified in Table IV-60. In recognition of these limitations, EPA has required that test fuels blended to the specifications outlined in Section G.1 fall within these tolerances of the specified values.

Table IV-60: Fuel Parameter Blending Tolerances

Fuel parameter	Blending tolerance
Sulfur content	± 25 ppm
Benzene content	± 0.2 vol %
RVP	± 0.2 psi
E200 level	± 2 %
E300 level	± 4 %
Oxygenate content	± 1.0 vol %
Aromatics content	± 2.7 vol %
Olefins content	± 2.5 vol %
Saturates content	± 2.0 vol %
Octane	± 0.5
Detergent Control Additives	± 10% of the level required by EPA's detergents rule
Candidate parameter	To be determined as part of the augmentation process

b. Impact of blending variation

Variation in test fuel properties from those specified in Section G.1 will tend to reduce the statistical power of the test program. Such variations would make estimates of emission effects using simple averages of percent change in emissions per unit change in each fuel parameter impossible. However, the analysis method outlined in Section G.4 can compensate for small deviations from the test fuel specifications by utilizing the existing Complex Model database to help disentangle the effects of fuel modifications from one another.

c. Measurement precision

Any measurement is subject to some degree of uncertainty. This uncertainty can be separated into two types. Uncertainty can result from variations in separate measurements when using the same measurement technique and instruments. Uncertainty can also result from variations in measured values when using different measurement techniques or instruments. The first type of uncertainty can be reduced by taking multiple measurements; as the number of measurements increases, the average measurement becomes an increasingly precise estimate of the "true" value that would be measured if the measurement technique and instruments were applied without error. This type of uncertainty is characterized by its repeatability level, which refers to the probability that two successive measurements of the same sample will fall within a certain range a specified percentage of the time, typically 95 percent. The second type of uncertainty can be reduced by calibrating the measurement technique and instruments being used against a set of known values determined through other, more reliable means. This type of uncertainty often is characterized by its reproducibility level, which refers to the probability that measurements of the same sample at two different facilities will fall within a certain range a specified percentage of the time.

Both sorts of measurement precision can affect the estimates of emission effects from vehicle testing programs. Inaccuracies in estimates of fuel parameter levels or emission levels can cause the analysis method outlined in Section G.4 to provide inaccurate estimates of emission effects. The procedures outlined in the Code of Federal Regulations and §80.56-80.57 of the reformulated gasoline regulations are designed to minimize emission measurement errors, and the procedures outlined in §80.46 are intended to minimize fuel property measurement errors. Nonetheless, some measurement uncertainty is inevitable.

EPA recognizes that for some fuel parameters, the size of the measurement uncertainty can result in substantial uncertainty in emission estimates. Reducing this uncertainty is particularly important in vehicle testing programs since any inaccuracies in fuel parameter measurements can affect the resulting augmentation to the Complex Model. Inaccuracies in the augmentation, in turn, can affect estimates of emission benefits for a large amount of fuel and can influence capital investments by refiners and fuel blenders. As a result, EPA has concluded that the modest costs associated with repeat testing of test fuel properties are more than offset by the gain in modeling accuracy. Hence EPA has required test programs to measure the properties of their test fuels to the accuracy specified in Table IV-61. Test programs must conduct repeat measurements of the fuel properties such that the 95% confidence limits of the measured values for each parameter (based on a standard t-test) about the mean measured values are no larger than the tolerances presented in Table IV-61. Given the repeatability levels for relevant measurement methods, EPA does not expect a large number of repeat measurements to be required. The measurement tolerances, repeatability levels for approved ASTM or EPA measurement methods, and expected number of measurements required for each parameter are presented in Table IV-61 (measurement methods refer to ASTM designations unless specified otherwise). Test programs are responsible for providing documentation regarding the repeatability, reproducibility, and correlation of their measurement techniques as part of their augmentation application.

Table IV-61: Fuel Parameter Measurement Tolerances for Fuel Certification by Vehicle Testing

Parameter	Measurement Tolerance	Method & 95% Repeatability	No. of Repeats
API Gravity, °API	± 0.2	D1288 (± 0.1)	1
Sulfur, ppm	± 10	D2622 (± 10)	1
Benzene, vol%	± 0.02	D3606 (± 0.03)	3
RVP, psi	± 0.05	D5191 (± 0.16)	11
Octane, (R+M)/2	± 0.2	D4814 (± 0.1)	1
E200, vol%	± 2	D86 (± 3)	3
E300, vol%	± 2	D86 (± 1.3)	1
Oxygenate, vol%	± 0.2	GC/OFID	See text
Aromatics, vol%	± 0.5	GC/MS	See text
Olefins, vol%	± 0.3	GC/MS	See text
Saturates, vol%	± 1.0		See text
Candidate parameter	To be determined as part of the augmentation process		

In Table IV-61, no repeatability levels are provided for oxygenate, aromatics, olefins, or saturates. EPA anticipates that oxygenate will be added in measured amounts to a fuel sample of known volume to produce the required test fuels; since the volume of oxygenate to be added can be controlled to extremely high levels of precision and accuracy, EPA does not anticipate that meeting the required tolerances will present petitioners with significant difficulties. The D86 measurement method does not directly yield E200 and E300 values, but it can be modified to do so by setting the sample temperature and measuring the fraction of the sample that is recovered. Alternatively, the D86 method can be used to derive T50 and T90 values, which can then be converted to E200 and E300 values using the correlations presented in Section A. The repeatability levels presented in Table IV-61 are based on this indirect method for determining E200 and E300 values.

The fuel measurement methods promulgated in the reformulated gasoline rule include the use of the GC/OFID measurement method for oxygenates and a gas chromatograph/mass spectrometer measurement method for olefins and aromatics; saturates can be estimated by simple subtraction. These methods have been promulgated since the standard ASTM measurement methods yield unacceptably high repeatability and reproducibility errors. For example, ASTM method D4815 for oxygenates yields 95% repeatability levels of ± 0.83 volume percent for ethanol and ± 1.6 volume percent for MTBE. Such methods would require 18 repeat measurements of ethanol blends on average and 64 repeat measurements of MTBE blends on average. The GC/OFID method has 95% repeatability levels of approximately ± 0.24 volume percent ethanol and ± 0.37 volume percent MTBE. Hence test programs employing the GC/OFID method would need to conduct between two and four repeat measurements for oxygenate concentration. Aromatic and olefin measurements using ASTM method D1319 have 95% repeatability levels of approximately 1.4 volume percent and 1.2 volume percent, respectively, and hence would require 8 and 16 repeat measurements, respectively. EPA believes that the measurement methods promulgated in the final RFG rule for aromatics and olefins are capable of significantlyg better repeatability. Similarly, EPA's in-house experience with the RVP measurement method (D5191) indicates that repeatability levels of 0.05 psi are achievable, which would reduce the number of repeat tests required from eleven to one.

In addition to the requirements outlined in Table IV-61, EPA requires that detergent control additive concentrations be measured to within 2 percent of the level required by relevant EPA regulations. Since detergent control additives are expected to be added to gasolines in small quantities after blending, EPA believes that test programs will be able to control the concentration of such additives to high levels of precision without incurring additional cost.

The required measurement accuracy for test fuel properties is considerably more stringent than the accuracy required for routine testing of reformulated gasoline in the field. EPA believes this greater stringency is warranted. The specifications for test fuels are carefully designed to provide the data needed to evaluate proposed augmentations. Variation in the measured properties of the test fuels would affect the results of an augmentation study. Since these results could influence fuel production decisions for a number of refiners, EPA considers it desirable to eliminate potential sources of error wherever practicable.

The cost of greater fuel property measurement precision is small compared with the total cost of vehicle testing programs. EPA estimates that a typical vehicle test program of the size required to augment the Complex Model could cost on the order of $300,000 to as much as $1 million, depending on the cost of procuring the necessary vehicles; the necessary fuel parameter measurements would cost less than $10,000 (based on typical commercial laboratory fee schedules). Such costs are also small when compared with the potential savings to refiners resulting from augmentations to the model. In addition, EPA expects the accuracy and precision of existing measurement methods to improve, since the reformulated gasoline program introduces strong financial incentives to do so in order to recoup compliance margins and reduce the risk of noncompliance. For these reasons, EPA has decided that the modest costs of greater fuel property measurement accuracy are more than offset by the resulting improvements in the accuracy of augmentations to the model.

However, the Agency does not consider such increased accuracy to be practicable or cost-effective for routine testing of commercial reformulated gasolines. Repeat testing would be required on each batch of gasoline, thereby increasing the cost of reformulated fuels. This cost increase would be particularly onerous for low-volume gasoline marketers, since the increased costs of fuel property testing would be spread across a relatively small volume of fuel. In addition, the uncertainty associated with single measurements of fuel properties will tend to average out across multiple fuel batches produced or sold commercially; such averaging is neither possible nor desirable in a vehicle testing program.

3. Vehicle Fleet Composition

a. Principles of Fleet Balancing

As discussed in Section A, EPA has found that vehicles with different emission characteristics and different emission control technology respond differently to fuel modifications. To capture these effects adequately in a vehicle testing program, the vehicles tested should reflect the emission characteristics and technology distribution of the in-use fleet.

The purpose of the Complex Model is to predict the effect on emissions of fuel modifications. To assure that sufficient information will be available to estimate fuel effects on emissions, EPA has defined two guiding principles for vehicle selection:

1) The proportion of vehicles of each vehicle type included in a test program should reflect the contribution of that vehicle type to in-use emissions.

2) The vehicles included in a test program should include as wide a variety of emission classes and technology groups as possible without violating the first principle.

EPA used these guiding principles to determine the desired composition of vehicle testing fleets.

b. Distribution by Emitter Class

As discussed in Section III.B.4, normal emitters account for 52% of exhaust VOC and exhaust toxics emissions in Phase I and 44.4% of these emissions in Phase II. In keeping with Guiding Principle (1), these proportions suggest that approximately half of the vehicles tested should be normal emitters and half should be higher emitters. By contrast, normal emitters account for 82% of NOx emissions in Phase I and 73.8% of NOx emissions in Phase II, which suggests that 75-80% of all vehicles tested should be normal emitters.

However, the relative scarcity of higher emitter data implies that the effects of fuel modifications on higher emitters is known with less certainty than for normal emitters. To compensate for this greater uncertainty, EPA considered requiring a disproportionate share of the vehicles tested to be higher emitters. At the same time, EPA was reluctant to deviate too far from the emission ratios presented above. Hence the Agency decided to require that half of all vehicles tested be higher emitters. This distribution assures that sufficient data on higher emitters will be available to estimate the effects of fuel modifications with confidence. The Agency considers the increase in the accuracy of emission estimates for higher emitters (for VOC, NOx, and toxics) to more than compensate for the reduction in the accuracy of normal emitter NOx emission estimates that would result from requiring the proportion of normal emitters to match the contribution of normal emitters to NOx emissions. A more thorough discussion of this issue is contained in the April 1992 NPRM.

c. Technology groups

As discussed in Section A.3, EPA has modeled the response of normal emitters by grouping vehicles with different emission control technologies and allowing terms specific to each group to enter the regression equations. This approach was required by the imbalance between the contribution of each technology group to in-use normal emitter emissions and the proportion of test data available for each technology group. If the proportion of test data were to match the proportion of emissions due to each technology group, then the population of test vehicles would reflect the origin of in-use emissions and separate models for individual technology groups would be unnecessary.

EPA has chosen to reduce the burden of vehicle testing by eliminating the need for technology group-specific regression terms. Instead, EPA has chosen to require organizations involved in vehicle testing to recruit a balanced set of normal emitting vehicles according to Principles (1) and (2). As a result, separate models for each technology group need not be constructed when augmenting the model through vehicle testing.

To simplify the process of vehicle specification for the normal emitter test fleet, EPA has developed a schedule to guide vehicle acquisition. The schedule identifies the vehicle characteristics required of the first, second, third, etc. vehicle. An organization conducting vehicle testing is required to include at least ten normal emitting vehicles to assure the statistical validity and reliability of their results; such organizations have the option of testing additional vehicles to increase the statistical power of their test program. Additional vehicles are to be added in the order specified so as to maintain a balanced test fleet. The normal emitting vehicle acquisition schedule is presented below in Table IV-62.

Table IV-62: Normal Emitting Vehicle Acquisition Schedule

Veh. #	Fuel System	Catalyst	Air Injection	EGR	Tech. Group	Manu-facturer
1	Multi	3W	No Air	EGR	1	GM
2	Multi	3W	No Air	NoEGR	2	Ford
3	TBI	3W	No Air	EGR	3	GM
4	Multi	3W+OX	Air	EGR	4	Ford
5	Multi	3W	No Air	EGR	1	Honda
6	Multi	3W	No Air	NoEGR	2	GM
7	TBI	3W	No Air	EGR	3	Chrysler
8	ulti	3W+OX	Air	EGR	4	GM
9	TBI	3W+OX	Air	EGR	7	Chrysler
10	Multi	3W	Air	EGR	5	Toyota
11	Multi	3W	No Air	EGR	1	Ford
12	Multi	3W	No Air	NoEGR	2	Chrysler
13	Carb	3W+OX	Air	EGR	9	Toyota
14	TBI	3W	No Air	EGR	3	Ford
15	Multi	3W+OX	Air	EGR	4	GM
16	Multi	3W	No Air	EGR	1	Toyota
17	Multi	3W	No Air	NoEGR	2	Mazda
18	TBI	3W	No Air	EGR	3	GM
19	Multi	3W+OX	Air	EGR	4	Ford
20	Multi	3W	No Air	EGR	1	Nissan

Legend:

Fuel system:
Multi = Multi-point fuel injection
TBI = Throttle body fuel injection
Carb = Carburetted

Catalyst:
3W = 3-Way catalyst
3W+OX = 3-Way catalyst plus an oxidation catalyst

Air Injection:
Air = Air injection
No Air = No air injection

EGR:
EGR = Exhaust gas recirculation
No EGR = No exhaust gas recirculation

Table IV-63: Technology Group Definitions

Tech Group	Fuel System	Catalyst	Air Injection	EGR
1	Multi	3W	No Air	EGR
2	Multi	3W	No Air	No EGR
3	TBI	3W	No Air	EGR
4	Multi	3W+OX	Air	EGR
5	Multi	3W	Air	EGR
6	TBI	3W	Air	EGR
7	TBI	3W+OX	Air	EGR
8	TBI	3W	No Air	No EGR
9	Carb	3W+Ox	Air	EGR

EPA has not specified a similar schedule for higher emitters since the Agency does not believe technology group distinctions to affect the emissions response of such vehicles to fuel modifications. This issue is discussed more fully in Section A.2.

4. Analysis Process

The analysis process promulgated in the reformulated gasoline rule is designed to extract the maximum amount of information from the limited data available from each vehicle testing program. It incorporates statistical analysis techniques analogous to those used to develop the Complex Model, and it utilizes the existing Complex Model database where possible to supplement the data from individual test programs. The analysis process is designed to achieve the following goals:

- Accurate estimation of the linear and nonlinear emission effects due to the fuel property being tested.
- Accurate estimation of interactive effects between the fuel property being tested and other fuel properties known to affect emissions.
- Isolation of the effects of the fuel property being tested on emissions from normal and higher emitting vehicles.
- Isolation of the effects of the property being tested from the effects of related or correlated fuel properties already included in the model.
- Preservation of already-established Complex Model effects within the data core.

The remainder of this section discusses the rationale for the analysis method and statistical techniques promulgated in the reformulated gasoline rule. It also discusses the basis for the differences in analysis process when testing extension or addition fuels.

a. Analysis method and statistical techniques

The analysis methods to be used to analyze test program data are similar to those used to develop the Complex Model. The basic process involves the following elements; many of these techniques are discussed and justified in greater detail in Section A.

1. Separate analyses are to be conducted for normal and higher emitters, since past experience has shown that emission responses to fuel modifications differ for these two types of vehicles. In addition, petitioners must demonstrate that their higher emitting vehicles were stable over the course of the test program in terms of their emissions on a given fuel. Past EPA testing experience has shown that emissions from higher emitters often demonstrate time trends or variations that are unrelated to and considerably larger than the effects of fuel modifications; control of such variability is necessary if genuine fuel effects are to be identified.

2. All models are to fit polynomials (first-order for toxics, no higher than second-order for VOC and NOx) to the natural logarithm of emissions, as was done for the existing Complex Model. EPA and others have found that transforming emissions using the natural logarithm results in improved model accuracy and more normally distributed residuals.

3. Petitioners must demonstrate that collinearity problems are not exceedingly large. Variance inflation values in excess of 10 will be interpreted to indicate that the models constructed by the petitioner contains severe collinearity problems, in keeping with standard statistical practice.

4. Petitioners must demonstrate that the residuals from their regressions are approximately normally distributed. The statistical analysis process outlined in the regulations requires such a distribution. Models without normally-distributed residuals cannot be generated or evaluated using the more powerful techniques associated with normally-distributed data.

5. Petitioners must demonstrate that their analysis has adequately balanced potential overfitting and

underfitting of the data through the use of Mallows' C_p criterion or other appropriate methods. Underfitted models have too few terms to explain the observed variation in the data; overfitted models have too many terms, some of which are likely to be erroneous.

6. All regressions are to include separate terms for each vehicle-study combination in the form of dummy variables, as was done for the existing Complex Model.

7. To retain consistency with the existing Complex Model, all regressions must retain terms with significance levels of 0.90 or higher.

b. Special Analysis Requirements When Extending Existing Model Parameter Ranges

Test programs designed to extend the valid range of the model for existing Complex Model parameters can utilize the data already available in the Complex Model database. This additional data increases the statistical power of the analysis process and allows the augmentation to be integrated with the existing Complex Model smoothly. The analysis process involves the following unique elements:

1. The test data on all extension fuels tested must be combined with the Complex Model database used to develop the Complex Model being promulgated today. All analyses must be performed on this combined database.

2. The first step in analyzing this combined data set is to fit a standard regression model to the combined database. The model must contain separate terms for each vehicle-study combination. It must also contain all terms present in the existing Complex Model. The coefficients for those terms which do not involve the parameter being extended must be set equal to their values in the existing centered, consolidated Complex Model equations. The coefficients for terms which do involve the parameter being extended (including any linear, squared, and interactive terms) are to be estimated by the regression. This approach assures that the only changes in the existing Complex Model will occur for those terms involving the parameter being extended.

3. In some cases, the existing consolidated Complex Model may not contain a squared term for the parameter being extended. However, the additional data made available through the test program may warrant inclusion of such a term. To allow such terms to be included in the

model, a stepwise regression procedure should be used to determine whether the squared term for the parameter being extended would be statistically significant. The linear term must be retained even if it is no longer significant once the second-order term is added.

4. The fuel terms included in the models described above must be expressed in centered form. The centering value for these terms must be identical to the centering value used to develop the Complex Model being promulgated today. Centering values can be found in Section A.8 and will be made available to petitioners by EPA upon request. These centering values are necessary during development of the augmented model; the same centering values as were used during development of the current Complex Model must be used since the coefficients from that model will be used for a number of terms in the models described previously. Once the augmented model has been developed, it should be uncentered using the process described in Section A.8.

5. The model resulting from the foregoing steps is the augmented model. It can be used for levels of the fuel parameter in question only when it is present in fuels at levels between the extension level and the data core. The performance of such fuels is to be calculated as follows, with all performances being expressed as percentage changes in emissions from baseline levels:

   a. Up to the limits of the data core, the unaugmented Complex Model must be used to determine the percentage change in emissions due to the parameter in question. In other words, the unaugmented model is to be used to estimate the performance of a fuel identical to the target fuel, but with levels of the augmentation parameter set equal to the nearest limit of the data core.

   b. The performance of the fuel described in step (5.a) must be determined using the augmented model.

   c. The performance of the actual target fuel must be determined using the augmented model.

   d. The performance of the actual target fuel, in percentage terms, shall be set equal to the following value:

100 - [(100 + a) * (100 + c)/(100 + b)]

These calculations maintain equivalency with the Complex Model up to level at which the existing Complex Model database becomes so sparse as to make the existing Complex Model equations less reliable. This equivalency is necessary to avoid fungibility problems from being introduced by model augmentations. Without the adjustments described above, a model augmentation might give greater credit for a fuel modification at a given parameter level than the existing Complex Model. As a result, mixing of fuels certified using an unadjusted augmented model and the existing unaugmented model could produce a mixture in which each original constituent met the emission reduction requirements of the program but the mixture itself would not. This situation, and the compliance and certification problems it presents, can be avoided by using the adjustments described above.

c. Special Analysis Requirements When Adding New Model Parameters

Test programs designed to augment the model with a new parameter require a somewhat different analysis process involving the following elements:

1. The first step is to adjust the measured emission levels to account for deviations in fuel characteristics other than the one being tested from those specified. This process involves using the Complex Model to determine the percentage change in emissions between the desired and actual fuels, then adjusting the measured emissions accordingly.

2. The second step is to develop a model based on this adjusted emissions data from addition fuels 1, 2, and 3. This model must include separate dummy variable terms for each vehicle, a linear term for the parameter in question, and a squared term for the parameter in question. If the squared term is not significant, it must be dropped from the model, which must then be re-estimated. If the linear term in the resulting model is not significant, then it must be dropped from the model. In such cases, EPA will not grant the augmentation and the analysis process (and test program) can end. However, the analysis results still must be reported to EPA, since these results may be helpful in revising the Complex Model or evaluating other augmentation petitions.

3. The third step is to build a stepwise regression on a data set which combines the test data from all seven

fuels and the data in the existing Complex Model database. Using this data set, the vehicle terms for the test fleet must be re-estimated. The initial model must include separate terms for each vehicle-study combination; it must also include all terms present in the centered, consolidated Complex Model along with their coefficients, and it must include the linear and squared terms (if statistically significant) and their coefficients as estimated previously based on addition fuels 1, 2, and 3. Interactive terms between the parameter in question and existing Complex Model fuel parameters should be added in a stepwise fashion, subject to the conditions discussed in Section G.4.a. Once the forward-fit model is complete, a backwards elimination process can be used to satisfy Mallows' C_p criterion. However, only the interactive terms added in the stepwise regression process may be deleted in the backwards elimination process. This step assures the equivalency of the augmented and unaugmented Complex Models within the range of the unaugmented model, which is necessary to avoid fungibility problems as discussed in Section G.4.b.

5. The fuel terms included in the models described above must be expressed in centered form. The centering value for these terms must be identical to the centering value used to develop the Complex Model being promulgated today. Centering values can be found in Section A.8 and will be made available to petitioners by EPA upon request. These centering values are necessary during development of the augmented model; the same centering values as were used during development of the current Complex Model must be used since the coefficients from that model will be used for a number of terms in the models described previously. Once the augmented model has been developed, it should be uncentered using the process described in Section A.8.

6. The model resulting from the foregoing steps is the augmented model. It must be used to calculate the performance of all fuels which claim benefits from the parameter in question.

5. Response to Comments

EPA has received a number of comments in response to the April 1992 and February 1993 proposals. The Agency has incorporated such comments into the final regulations governing vehicle testing where such comments were appropriate or adequately supported by data. However, these regulations do not incorporate all the comments received by EPA. What follows is a description of the major comments received by EPA, the Agency's response to these comments, and the Agency's reasons for not incorporating those comments which have not been addressed in the final rule. EPA also received a number of comments which are not relevant to this rulemaking; such comments are not discussed below. Comments have been grouped by topic to simplify matters.

a. Direct Certification

Several commenters requested that vehicle testing be permitted as a direct alternative for fuels certification instead of requiring augmentation of the Complex Model. As discussed in the preamble and in the introduction to this section, however, EPA believes that direct fuel certification through vehicle testing is neither practicable nor desirable. Certification of a specific fuel would not extent to fuels with minor differences in composition or other fuel properties, yet such differences inevitably arise in the course of fuel production. As discussed in Section G.2, fuel producers cannot precisely control the properties of their fuel, which would make production of a specific fuel formulation essentially impossible. Direct fuel certification through testing is also not desirable since, as discussed in the preamble and in Section A, the results of a single test program are less reliable and more vulnerable to accidental or deliberate manipulation than is a model based on the results of multiple test programs.

b. Updates to the Model

EPA originally proposed to update the Complex Model every five years to incorporate the most recently available data on emission effects of fuel reformulations. Several commenters objected to such frequent updates, noting that changes in the model could invalidate investments in refinery technology undertaken to meet standards using the previous version of the model. Commenters called for updates no more often than once every 10-15 years or asked that refiners be able to grandfather fuel certification under an earlier version of the model for ten years. EPA has reconsidered its plans to update the model every five years, in part because it is difficult to predict when sufficient additional data will be available to warrant such an update. Instead, EPA plans to update the model through a formal rulemaking process that will be undertaken when EPA determines that sufficient new information is available to warrant such action. As part of this rulemaking process, EPA will consider the impact of changes in the model on refiners' capital investments.

c. Test Fuels

EPA received numerous comments on its proposed test fuels. Many of the comments received in response to the April 1992 proposal have been incorporated in the final regulations governing vehicle testing. For example, one commenter suggested that the "candidate-baseline" fuel defined in the April 1992 proposal should not specify that the level of the "candidate parameter" be zero, since the parameter may be present at non-zero levels in typical baseline fuels. EPA agrees with this comment and has modified its fuel requirements accordingly. Another commenter objected to the test fuels required to augment the simple model in the April proposal; EPA has since deleted the simple model augmentation option from the rule. A commenter noted that standard deviations cannot be averaged across pollutants, as EPA had proposed in its April 1992 proposal; the final requirements for vehicle testing do not include averaging of standard deviation or variance across pollutants.

One commenter recommended that fuel parameter values for interactive effects testing be no greater than the levels found in industry average gasoline. EPA considers such an approach inappropriate for several reasons. First, industry average gasoline is not representative of expected reformulated fuels in some respects, notably oxygen, RVP, aromatics, and (in Phase II) sulfur levels. Second, interactive effects are more easily and accurately estimated when testing for such effects extends over a wide range of fuel parameters. Third, EPA recognizes that the Complex Model will be used to assure compliance of conventional fuels with the anti-dumping program, and such fuels can have fuel properties that are quite different from those of industry average gasoline. Hence testing only 1990 industry average gasoline for interactive effects would make identification of interactive effects more difficult and would not provide sufficient data to estimate such effects for typical reformulated or conventional gasolines.

A number of comments were received on detergent additive requirements for test fuels. Commenters generally supported requiring such additives in test fuels since they will be required in reformulated gasolines. Some commenters recommended specific additives or specific levels of additives; however, EPA does not consider it appropriate to provide such specificity in this rule. Instead, EPA has required test fuels to meet the detergent additive requirements set forth in EPA's impending detergent additives rule. In a related comment, the Agency was asked to give credit for fuel modifications that result in reduced emissions after extended use. EPA does not believe it appropriate to do so beyond the extent shown in the required vehicle test program. Such benefits are unlikely to be achieved in-use unless two conditions are met: the fuel modifications are used on all gasolines sold by the petitioner indefinitely, and all of the petitioner's consumers exhibit perfect brand loyalty. Absent a showing that such conditions exist and can be assured, EPA does not believe it appropriate to augment the model with emission effects that occur only after extended use. EPA believes that such modifications are more appropriately addressed by other fuels-related programs required by Congress, such as deposit control additives.

Comments were received recommending deletion of the API gravity and end point specifications for test fuels. EPA has deleted these specifications for fuel blending since these characteristics are largely determined by characteristics with specified blending tolerances. EPA has also eliminated the requirement that end point be measured for all test fuels. End point is closely correlated with E300, which is specified; in addition, end point is difficult to measure accurately. However, EPA has chosen to retain the API gravity measurement. This parameter is relatively easy to measure and is specified in the Act for Clean Air Act baseline fuel. The Agency believes that it must be measured to assure comparability with Clean Air Act baseline fuel and is not aware of any measurement difficulties associated with it. Commenters also asked the Agency to establish a minimum octane level instead of a blending tolerance. The Agency has decided to retain its blending tolerance requirement while adding a minimum octane requirement, thereby limiting octane values to the range of 86.5 to 87.5. Such tight control is feasible, as discussed in Section G.2, and EPA believes such control to be necessary to prevent distortion of test results. Octane is known to affect engine performance, per-gallon fuel efficiency, and spontaneous ignition (engine knock), all of which can affect emissions.

One commenter suggested that test fuels be based on typical at-the-pump fuels. However, as discussed in Section G.1, test fuel characteristics must be controlled tightly in order to extract useful information from test program results. At-the-pump fuels do not allow such tight control. In addition, EPA believes that the requirement that test fuels be blended from typical or realistic refinery streams assures that test fuels will have characteristics similar to those of typical commercial gasolines, except for those deliberately altered as part of the test program design.

d. Measurement methods and data requirements

EPA received several comments on its proposed measurement methods and data requirements to support augmentation requests. Commenters suggested that EPA permit the use of equivalent testing methods and notify petitioners of data requirements before testing begins. EPA believes that these comments are adequately addressed by the requirement that petitioners obtain approval for their proposed test program before beginning testing. This requirement provides petitioners with a means of requesting and obtaining approval for the use of equivalent testing methods. It also allows EPA to identify data inadequacies in proposed test programs before testing begins.

Several commenters recommended that EPA base its fuel property measurement methods on standard ASTM methods. EPA has promulgated a set of approved measurement methods which match standard ASTM practices in most cases. However, EPA found it necessary to promulgate alternative methods in some cases in order to assure sufficient accuracy and precision to meet the needs of the program. EPA plans to submit these alternative methods to ASTM for approval. Since such approval can take several years, however, EPA believes it necessary to proceed with the program without ASTM approval for these alternative methods. Interested parties are also permitted to use their own preferred measurement methods if they can demonstrate, to the Agency's satisfaction, that these methods provide comparable accuracy to those promulgated by EPA. In the case of vehicle testing, the Agency recognizes that the required measurement precision may be beyond the capability of a single test using either standard ASTM methods or the methods promulgated by EPA. Such precision and accuracy can be achieved through multiple fuel property measurements or the use of more precise ASTM methods than are standard. As discussed in Section G.2, the modest cost of replicate fuel measurements or more precise measurement methods is more than justified by the gain in modeling accuracy.

Commenters also objected to the requirement that carbon dioxide be measured during vehicle testing. EPA considers this information necessary to assure the quality of the test program. In particular, carbon dioxide data is necessary to evaluate the fuel economy performance of vehicles being tested; unexpectedly low fuel economy provides an indication of vehicle malfunction or improper test procedures.

e. Vehicle Selection

Several commenters suggested that EPA allow test programs to select vehicles at random from the in-use fleet; other commenters recommended basing the distribution of vehicles on 1990 market share alone. However, as discussed in Section G.3, the test fleet composition must reflect the contribution of each type of vehicle to the total emissions inventory. Selecting vehicles at random from the in-use fleet would not achieve such composition except by chance, and selecting vehicles based only on market share would ignore differences in emission levels among vehicles. Further, EPA is concerned that petitioners may restrict their vehicle acquisition efforts to those vehicles expected to respond strongly to the fuel modifications being tested. EPA's test fleet requirements limit petitioners' ability to manipulate the outcome of test programs in this manner. Finally, a test fleet based only on market share or based on random selection from the in-use fleet would be unlikely to result in a sufficient number of higher emitters for two reasons. First, 1990 technology vehicles currently on the road are less likely to be higher emitters than would be the case if the entire fleet consisted of such vehicles, as is necessary to estimate the in-use impact of gasoline formulations on emissions. Second, EPA has found that owners of higher emitting vehicles are less willing to allow their vehicles to be tested than are owners of normal emitters. For these reasons, EPA has decided to retain its test fleet composition requirements instead of permitting random selection of test fleets from the in-use fleet or basing its test fleet requirements only on market share. EPA believes these requirements assure an appropriate mix of technology types, models, emitter classes, and engine displacements.

A number of commenters objected to the test fleet requirements regarding higher emitters proposed in the April 1992 NPRM. EPA believes its current proposal incorporates these comments where valid. As discussed in Section G.3, higher emitters must be tested in order to evaluate the actual in-use emission effects of fuel parameters. Such vehicles account for a large fraction of in-use emissions, and the Complex Model indicates that such vehicles respond differently to fuel modifications than do normal emitters. This conclusion is strengthened by the fact that each interim version of the Complex Model showed higher emitters to respond differently than normal emitters to fuel modifications. In response to comments and its own revised analysis of higher emitters, EPA has eliminated the requirement that higher emitters match the vehicle technology distribution set forth in Table IV-62. As suggested by several commenters, EPA has attempted to classify higher emitters by failure mode in order to assure that the higher emitter test fleet is representative of in-use higher emitters. However, available data is not sufficient to allow such classification and commenters did not submit such data to EPA. EPA asked for and received comment on a proposal to allow intentional disablement of normal emitting vehicles' emission control systems to simulate higher emitters and reduce the cost of procuring a representative test fleet. Most commenters opposed this option, arguing that intentionally disabled vehicles would not be representative of in-use higher emitters. In addition, EPA was unable to determine an appropriate basis for such disablements, asw discussed above. One commenter expressed concern that higher emitters would be much more difficult to locate once enhanced I/M programs are in place. However, EPA's analysis of its I/M Repair Database suggests that approximately one-fourth of the in-use fleet would consist of higher emitters when enhanced I/M is in place. Further, 1990 technology vehicles currently on the road would tend to be higher-mileage, higher-emission vehicles by the time enhanced I/M programs in place, which should make acquisition of higher emitters less burdensome.

Another commenter asked that EPA provide a list of equivalent 1990 vehicles. EPA has not been able to provide a comprehensive list of such vehicles but has included in Appendix IV-F a list of the vehicles in the Complex Model database deemed to have 1990-equivalent technology. Petitioners are encouraged to coordinate their vehicle selection process with EPA and with the vehicle manufacturers to assure that all included vehicles qualify as 1990-equivalent technology vehicles.

f. Analysis method

Commenters expressed concern over a number of requirements in EPA's previous proposals, such as the repeatability requirement and the use of stepwise regression techniques. The final requirements for vehicle testing do not include repeatability requirements except insofar as the vehicle's emission characteristics must be shown to be stable when tested on the same fuel. The need for this requirement is discussed in Section G.4 and Section A. Stepwise regression techniques have been found to be necessary during the development of the Complex Model, as discussed in Section A.4; in fact, one of the commenters who objected to stepwise regression techniques used such techniques in developing their own complex model. No suitable alternative techniques were identified by commenters, and EPA believes the analysis method required for augmentation petitions sufficiently restricts the use of stepwise regression techniques to prevent their mis-application.

Another commenter asked that EPA drop the requirement that emission changes be shown within the first 50 miles of operation upon being acquired for vehicle testing. This requirement has been dropped, in part because the required preconditioning, stabilization, and testing procedures may require greater than 50 miles of vehicle operation.

g. Nonexhaust Testing

EPA's April 1992 and February 1993 proposals allowed augmentation of the nonexhaust model. However, EPA no longer believes that such augmentations should be permitted for reasons discussed in the preamble to this rulemaking. As a result, comments regarding nonexhaust emission testing procedures are no longer relevant.

H. Appendices

Appendix IV-A: The Random Balance Algorithm

Appendix IV-B: Glossary and Nomenclature

Appendix IV-C: MOBILE4.1 Input File Used to Develop the Simple Model and the Phase I Complex Model (must be run with interim version of MOBILE4.1)

Appendix IV-D: MOBILE5a Input File Used To Develop the Phase II Complex Model

Appendix IV-E: SAS code used to develop "raw" exhaust emission models

Appendix IV-F: Included 1990 Technology Vehicles in the Complex Model Database

Appendix IV-A: The Random Balance Algorithm

The random balance algorithm was developed by H. T. McAdams of the Advanced Computing Center of Argenta, Illinois. This appendix is a user's manual developed by Dr. McAdams for the application of this algorithm to the development and simplification of the Complex Model. The mathematical manipulations program that Dr. McAdams uses in all his work is Matlab, such that the algorithm described below is given in the context of Matlab language and instructions.

The random balance algorithm is useful for two purposes:

1)To determine the ranking of terms in the Complex Model in order of their contribution to reduction of the residual sum of squares

2)To consolidate equations for separate tech groups into one or more equations yielding essentially the same outputs as the unconsolidated model

1. RANDOM NUMBER GENERATION

The procedure begins with the generation of a set of N "random blends." In previous applications, N has been taken as 2000. However, other values of N can be used, up to the RAM capacity of the PC being used.

1.1 Linear Terms

The starting point in the random-balance process is generation of a matrix of random numbers. The matrix has N = 2000 rows and as many columns are there are fuel variables (linear terms only) in the model. For VOC, there are seven: oxygen, sulfur, RVP, E200, E3OO, aromatics and olefins.

NOTE: It is important that the random numbers be drawn from a uniform, not a normal, distribution. In the ACCA procedure, the random numbers are uniform on the interval[-0.5, 0.5], but other conventions could be used provided subsequent computations are programmed consistent with the choice of the interval.

Matlab generates random numbers on the interval [0,I] by the simple instruction

```
             x = rand(2000,7)       (1)
```

This produces a 2000 x 7 matrix of numbers randomly distributed between 0 and 1. To transform to the interval [-0.5,0.5], it is necessary only to subtract 0.5 from all values of the matrix. In Matlab, this is done by the simple instruction

```
x = x - 0.5        (2)
```

Or, (1) and (2) can be combined to the single instruction

```
x = rand(2000,7) - 0.5    (3)
```

It is well to check the resulting array for zero mean and unit correlation matrix. Such a check can be done quickly and simply by the instructions

```
meanx = mean(x)       (4)

corrcoefx = corrcoef(x)      (5)
```

Meanx is a row vector for which all elements should be approximately zero. Corrcoefx is a 7 x 7 matrix in which all elements on the main diagonal should be 1, and all off-diagonal elements should be approximately 0. Several types of plots can be easily and quickly made to verify this, notably plot(corrcoefx(:)) or bar(corrcoefx(:)).

1.2 Quadratic and Interaction Terms

The Complex Model potentially contains linear, quadratic and first-order interaction terms. To augment the above random matrix, one needs to annex a set of columns representing squares of the variables (7 columns) and another set of columns representing products of all variables taken two at a time (21 columns).

The square terms can be generated simply by the instruction x.*x. The dot after the first x causes each column to be multiplied by itself row by row, rather than as an inner product.

A simple .m-file to generate all the interactions is intergen.m (see below). It can be easily programmed in another language by simply reproducing the loops shown.

Table IV-A-1

INTERGEN.M

```
function y=intergen(x)
[r,c]=size(x);
for i=1:c,
for j=i+1:c,
q=x(:,i).*x(:,j);
y=[y q];
end
end
```

The linear, square and interaction parts of the moment matrix can be combined simply by writing

```
ucentall = [x x.*x intergen(x)]  (6)
```

The name ucentall is simply a label (anything else would do), but it identifies the result as "all terms of a centered uniform distribution."

As before, one should check the means and correlations and possibly visualize the results as a line or bar plot before proceeding further.

NOTE: Equation (6) will be used in another connection later on.

2. TRANSFORMATION TO REAL FUEL-VARIABLE QUANTITIES

The 2000 x 7 matrix generated above ranges from -0.5 to 0.5. We need to convert these random numbers to corresponding values of the actual parameters. For this purpose, the range [-0.5, 0.5] has to be mapped into the corresponding actual range of the fuel variables.

In previous application of the random-balance methodology, the ranges of the seven variables were as follows:

Table IV-A-2

Fuel variable	Minimum	Maximum
Oxygen	0	3.7
Sulfur	50	350
RVP	7	10
E200	32	64
E300	76	93
Aromatics	20	45
Olefins	2	20

Other values can be used if desired; however, note that it is assumed that all values within the specified range are equally likely.

NOTE: In the EPA July 14, 1993 submission to the docket, the "Limits of Data in the Complex Model Database" are slightly different, but the only notable departure is that the upper limit for sulfur is given as 450 rather than 350.

Changing the range [-0.5, 0.5] to the tabled ranges of the fuel variables is a simple matter of linear transformation:

$$y = x * (Max - Min) + (Max + Min)/2 \quad (7)$$

Thus, for oxygen, the transformation is

$$y = x * (3.7 - 0.0) + (3.7 + 0.0)/2 = 3.7 x + 1.85$$

Similarly, for sulfur, the transformation is

$$y = x * (350 - 50) + (350 + 50)/2 = 300 x + 200$$

and so on.

The Matlab .m-file to perform this transformation is invtran4.m and is listed below.

Table IV-A-3

INVTRAN4.M

```
function y=invtran4(x)
%where x is the 7-column matrix of scaled fuel parameter
% and y is the corresponding matrix of raw fuel-parameter
%values
yl=3.7*x(:,1)+1.85;
%yl is oxygen
y2=300*x(:,2)+200;
%y2 is sulfur
y3=3*x(:,3)+8.5;
%y3 is RVP
y4=32*x(:,4)+48;
%y4 is E200
y5=17*x(:,5)+84.5;
%y5 is E300
y6=25*x(:,6)+32.5;
%y6 is aromatics
y7=18*x(:,7)+11;
%y7 is olefins
y=[yl y2 y3 y4 y5 y6 y7];
%Note: Terms are: oxygen sulfur rvp E200 E300 aromatics
%olefins
%The e200 transformation is based on a range from 32 to 64
%as derived by regressing e200 on t50 and evaluating at 170
%and 235.
%The e300 transformation is based on a range from 76 to 93
%as derived by regressing e300 on t90 and evaluating at 280
%and 360.
```

If ranges are changed, the .m-file would have to be edited to change the affected equations. As an alternative, a general form of the .m-file could be easily written with the ranges specified as a 7 x 2 input matrix. Note, however, the ranges would have to be input each time the transformation were invoked.

2.1 Centered Fuel Variables

The transformation outlined above (invtran4.m) transforms the random numbers in the interval [-0.5, 0.5] into uncentered or raw forms of the fuel variables. Later, the transformed values will be used as inputs to model equations. Generally, the equations in these equations apply to centered variables. That being the case, it is necessary to center the outputs from invtran4.m before using those outputs as inputs to candidate model equations. This, of course, can be easily accomplished simply by subtracting the center value for a given fuel parameter from all 2000 random values in the column representing that variable.

In Matlab, of course, this is a subtraction of a matrix of center values from a matrix of random numbers. The .m-file centerit.m performs this task, and is listed below. The "ones" and "kron" operation simply put the center values into a conformable matrix having the same dimensions as the matrix of random "raw" values of the fuel variables.

Table IV-A-4

CENTERIT.M

```
function y=centerit(x,c)
% where x is a matrix of RAW (UNCENTERED) fuel parameters
% c is a column vector of centering values
% and y is the corresponding matrix of CENTERED fuel
% parameters
[q,junk]=size(x);
wons=ones(q,l);
z=kron(c',wons);
y=x-z;
%This .m-file centers raw variables by subtracting
%centering values.
```

2.2 Uncentered Fuel Variables

There is no reason that the model equations have to be in centered form. If the model coefficients apply to uncentered fuel variables, then the centering transformation (by means of centerit.m) would not be used.

3. COMPUTING EMISSIONS FOR THE RANDOM BLENDS

It is assumed that separate model equations have been developed for each of the tech groups/emission classes. These equations consist of a set of coefficients for 35 algebraic terms consisting of 7 linear terms, 7 quadratic terms and 21 first-order interaction terms. Inasmuch as many of these terms may not even have been included in the model, the excluded terms will have zero coefficients. This fact in no way invalidates what is to follow because the zero coefficients will simply eliminate any contribution from the excluded terms.

It is important to note that the invtran4.m and centerit.m transformations produce only the linear-term values for the random blends. It is necessary, therefore, to generate the quadratic columns of the moment matrix by squaring all entries in the linear-term columns and annexing these 7 columns to the 7 columns representing the linear terms. Likewise, it is necessary to compute all cross-products of the linear columns and to annex these 21 columns to the 14 columns accumulated at this point. Note that this procedure is exactly the same as for the untransformed random numbers in the interval [-0.5, 0.5]. Note, also, that if raw or uncentered variables are used, a similar operation would apply to the raw form of the fuel variables.

What remains is to evaluate each of the group equations for the 2000 random blends by substituting the fuel-parameter values for each blend into the model equation for that group. In Matlab, this is conveniently performed as a matrix multiplication, as shown in the .m-file simple4.m listed below. Note that this routine requires as inputs only the matrix of blends to be evaluated and the matrix of model coefficients. This coefficient matrix consists of 35 rows (one for each term in the equation) and as many columns as there are tech groups and emission classes. The routine has, built-in, the annexation of the required quadratic and interaction terms as well as an exponentiation step required to transform the results from log space to grams/mile space.

Table IV-A-5

SIMPLE4.M

```
function y=simp1e4(x,c)
%where x is a matrix of the blends to be evaluated
%with x in raw, centered or standardized form
%and c is the matrix of the model coefficients
%with c consistent with the form of x
%Note: order of variables must be consistent
%with arrangement of coefficients in c
%For the EPA iteration4 full model, order of terms is:
% oxygen sulfur RVP E200 E300 aromatics olefins
x=(x x.rx intergen(x));
y=x*c;
Y=exp(y);
%Note: This is for models having no intercept given.
```

As employed in the past, the outputs from the above operation were weighted and combined into a single set of 2000 quantities considered as representing the final model output for the unconsolidated model. Revision has to be made, however, to express the model outputs in terms of percent change from a reference or baseline fuel. For this purpose, there should be one more blend in the array input as x. That blend should be the reference or baseline blend to which the outputs of the random blend are to be compared. It should be expressed in centered or uncentered form in agreement with the random blends and should be affixed as the last blend in the list. The simple4.m algorithm will perform all necessary computations for this blend, just as it does for the 2000 or so random blends.

To compute the percent change from baseline, one needs to divide the unscaled grams/mile for every number in a column by the last number in that column. That gives the ratio of the emissions for the target fuel to the emissions for the reference fuel. These numbers then need to be subtracted from 1.0 and multiplied by 100 to yield a percent change from the reference fuel.

The operations described can be executed in Matlab as follows.

First, using the 2001 blends (random 2000 augmented by the reference blend), execute the .m-file below.

Table IV-A-6

CHANGEI.M

```
function y = change(x)
(r,c]=size(x);
q=kron(ones(r,l),x(r,:);
Y=(x./q );
```

This .m-file transforms all computed emissions into corresponding ratios to the emission for the reference blend as evaluated for each vehicle group. For the subsequent computation of term contributions to the sum of squares, it is not appropriate to express the output as percent change. Many of the percent changes will be negative, and if one attempts to fit a regression equation to such data, one will encounter logarithms of negative numbers and the output will be in complex numbers. Rather, one must compute the percent changes from the final reqression equation in the same way that they are computed for the vehicle group equations in the unconsolidated model.

4. COMPUTING TERM CONTRIBUTIONS TO THE MODEL SUM OF SQUARES

Completion of the steps above yields emissions relative to the baseline fuel for the 2000 random blends for each of the technology groups or emission classes. The baseline fuel is also included at this point, but should be deleted from the array for what follows.

We need to fit the 2000 outputs for each of the vehicle groups to a model consisting of the quasi-orthogonal fuel variables, as represented in the matrix ucentall. This matrix consists of 35 columns and 2000 rows, the columns representing the union of the linear, quadratic and interaction terms. For the purpose of examining the relative contributions of terms, we need to square each of the regression coefficients and divide by an appropriate normalizing factor. This normalizing factor is the corresponding diagonal term obtained from the matrix product ucentall*ucentall. Some further computations are required to express the term contributions in percent of cumulative percent, and, of course, some bookkeeping and display niceties have to be performed.

The basic operation is that of multiple regression. Any suitable regression program would suffice, but in the Matlab environment it is convenient to use a .m-file called reggaer.m. (See Appendix IV-A.1)

However, as written, this .m-file would compute the regression coefficients for only one column of input values. Consequently, another .m-file was written to cycle the computation through all columns (i.e., all vehicle groups). At the same time, the program combines the group outputs into a composite output and computes the regression equation for this composite also. This .m-file is called sumvoc.m and is listed below.

Table IV-A-7

SUMVOC.M

```
function [A,C,LIST,SPART]=sumvoc(x,y,wdiag,list,wts)
y=[y y*wts'];
    [qr,qc]=size(y);
        LIST=list;
for i=1:qc,
     [a,c,list,spart]=doitall(x,log(y(:,i)),wdiag,list);
       A=[A;a];
       C=[C c];
       SPART=[SPART spart];
end
```

The routine incorporates another .m-file called doitall.m, which, in turn, incorporates the regression program reggaer.m. The file called doitall.m is listed below.

Table IV-A-8

DOITALL.M

```
function [a,c,list,spart]=doitall(x,y,wdiag,list)
[tpart,apart,f,rr]=reggaer(x,y);
t=tpart(2:36,1);
wdiag=wdiag(2:36,:);
anov=t.*t.*wdiag;
anovper=100*anov/sum(anov);
[h,k]=sort(anovper);
h=h(35:1:1);
k=k(35:-1:1);
cumh=cumsum(h);
a=[sum(anov) apart(2,1) rr];
c=[t anov anovper];
list=list(k,:);
spart=[k h cumsum(h)];
```

First, let us explain the outputs of some of the applicable .m-files.

The .m-file reggaer.m can be thought of as an acronym for:

REGression Good And Easy with R-square

Its outputs are:

t-part	A listing of the regression coefficients, their standard errors and their t-values
a-part	An analysis of variance showing model, residual and total sums of squares, degrees of freedom and mean squares
f	The f-ratio for the model
rr	The r-square for the model

The routine doitall.m augments reggaer.m by incorporating the operation of squaring and normalizing regression coefficients, as required to determine the relative contributions of terms. Note that, for this purpose, it requires as input the diagonal elements of ucentall*ucentall. Also required as input is an alphanumeric listing of the terms. This is the input called list.

The routine called sumvoc.m simply calls doitall.m repeatedly, once for each vehicle group, includinq the composite group. How does the composite get in there? As a result of the first line of code: y = [y y*wts]. This instruction says "Annex to the columns for the vehicle groups one more, which is just the weighted combination of the ones you already have." To execute this instruction, of course, it is necessary to input the weights, as indicated in the .m-file calling sequence.

Note that all that is required is to invoke sumvoc.m. It is not necessary to be concerned with the inner details of what has been discussed above. It is important, however, to have all the inputs:

x	This is a matrix of 2000 rows and 35 columns. The rows are the blends; the columns are the linear, quadratic and interaction terms. For the present application, it is simply the matrix ucentall as developed at the outset of this manual
y	This is the set of emissions or relative emissions for the vehicle groups, as computed by simple4.m or as modified by change.m.
wdiag	This is a column vector consisting of the normalizing factors obtained by multiplying ucentall*ucentall
list	This is a string variable giving a list of the terms represented by the 35 columns of the x-matrix.
wts	This is a row vector of the weighting factors for the vehicle groups.

The program sumvoc.m is, among other things, a summarizing program. Its outputs, as specified in the code, are: A, C, LIST and SPART. These are explained below:

A	Consists of three columns and as many rows as there are vehicle groups. The first column is the sum of the cont n'butions of the term sums of squares for each of groups. The second column is the total sum of squares as computed by the ANOVA part of reggaer.m. The third column is the correlation coefficient for the vehicle group. It will be ideally 1 for all but the last row, which represents the composite model and is an approximation. Usually it will be well above 0.99.
C	This matrix consists of 35 rows and three times as many columns as there are vehicle groups. The first column of each set of three consists of the regression coefficients for the corresponding vehicle group. The second column of each set of three consists of the actual contributions to the sum of squares for the various terms. The third column of each set of three expresses these contributions as percent of the total sum of squares.

LIST	LIST is just that: a listing of the model terms in the order in which they were entered in the model.
SPART	This, like C, is a matrix of 35 rows and three times as many columns as there are vehicle groups. This output summarizes the results of sorting contributions to sums of squares in decreasing magnitude and gives a cumulative view. The first column is simply a listing of the term numbers as ordered according to decreasing contribution to the sum of squares. The second column gives the percent contributions of the ordered terms, and the third column gives the cumulative percent totals.

At this point all the quantities of interest have been computed. However, the display and presentation of results leaves something to be desired. Therefore, a so-called "script" .m-file was written for this purpose; it is called compsum5.m (see Appendix IV-A.2). Note that it requires no inputs; one simply types compsum5 and presses Enter. The output is a formatted display of results in a form which permits easy interpretation.

For compsum5.m to operate, however, the results of the previous computation from sumvoc.m must be available. Also, those outputs must be specifically labeled: a, b, c, d. Therefore, if compsum5.m is going to be used, one must call for sumvoc.m as follows: [a,b,c,d]= sumvoc($,$$,$$$,$$$$,$$$$$), where $, $$, $$$, $$$$, and $$$$$ are the names that have been given to x, y, wdiag, list and wts, respectively. In other words, the input quantities can be given any names appropriate to identify their origin, but the output quantities must be labeled a, b, c and d if compsum5.m is going to be used for display.

5. COMPUTING THE FINAL MODEL EQUATION

After the term contributions have been reviewed and a decision has been made as to what terms are to be retained, the original data are refitted to an equation of the selected form and a set of revised vehicle-group equations are returned.

The steps above are usually repeated, but the main objective is the final, composite equation. However, this equation needs to be put in terms of either centered or uncentered coefficients, not coefficients for the quasi-orthogonal terms used to compute term contributions.

Centered coefficients can be computed simply by fitting the final, composite relative emissions to the desired terms. Any suitable regression program can be used.

Using reggaer.m, one can compute the centered coefficients by the following code:

Table IV-A-9

```
          [tcent,acent,fcent,rcent]=
reggaer([xcent xcent.*xcent intergen(xcent)],
             log(yvoc*wtsvtox'))
```

where yvoc is the final set of computed emissions for the composite, unconsolidated model and wtsvtox is a row matrix of weighting factors for the vehicle groups.

If one desires the uncentered coefficients, simply change the above code to:

Table IV-A-10

```
         [traw,,arawt,fraw,rraw]=
reggaer([xraw xraw.*xraw intergen(xraw)],
            log(yvoc*wtsvtox'))
```

Percent change for a target blend can then be computed by computing the yield for the target and for the baseline blend using the equation:

100*{[(Target yield)/(Baseline yield)] - 1}.

6. SOME CAVEATS

The procedures outlined above are tailored to a data set in which there are seven fuel variables and a total of 35 terms to be considered. If fewer terms are to be included in the model, the extraneous terms can be assigned zero values. However, in the case of toxics, no interaction terms are involved; consequently, it may be cumbersome to carry along extra columns in the matrix. A simpler version of the appropriate .m-files can be used with suitable modification. On the other hand, some of the toxics have more than seven variables (such as separate terms for MTBE, Ethanol, ETBE and TAME). In these cases, it will be necessary to start with a larger matrix of random input values.

It is, of course, possible to put all of the above computations into a very general form which would accomodate all cases, but that has not been done at this point. Such generalization would have both advantages and disadvantages. It would make for a unified approach, but it might necessitate carrying along a large number of irrelevant quantities. Suggestions on this point are solicited.

H. T. McAdams
Advanced Computing Center of Argenta
Argenta, Illinois
8-31-93

Appendix IV-A.1: GENERAL REGRESSION ROUTINE

```
%This .m-file computes the regression equation - i.e., intercept
%and slopes, and computes t for testing the significance of the
%slopes of the regression line against the null hypothesis
%that each slope = 0.
%It also provides an analysis of variance, an f-ratio and r
square.
%The ANOVA gives sum of squares, degrees of freedom
%and mean squares for the mean, regression and residuals.
function [tpart,apart,f,rr]=reggaer(x,y)
     [u,v]=size(x);
     x=[ones(u,1) x];
     tt=x'*x;
     q=inv(tt);
     b=q*x'*y;
%b is the vector of regression coefficients: intercept and slope
      z=y-x*b;
       [h,k]=size(b);
     t1=z'*z;
%tl is the residual sum of squares
     t2=u-h;
%t2 is the residual degrees of freedom
     t3=t1/t2;
%t3 is the residual mean squares
      z=z/(u-h);
%z is the error variance for the regression line
      varb=t3*q;
%varb is the variance of the regression coefficients.
stdb=sqrt(diag(varb));
t=abs(b./stdb);
s1=y'*y;
%sl is the totel sum of squares
[q,r]=size(y);
    s2=q;
%s2 is the total number of degrees of freedom
    s3=s1/s2;
%s3 is the total mean squares
      q1=sum(y)*sum(y)/q;
%ql is the sum of squares for the mean
     q2=r;
%q2 us the degrees of freedom for the mean
     q3=ql/q2;
%q3 is the mean squares for the mean
    w1=b'*x'*y-q1;
%wl is the regression sum of squares
    w2=h-q2;
%w2 is the regression degrees of freedom
    w3=w1/w2;
%w3 is the regression mean squares
      f=w3/t3;
```

```
sumsq=[q1 w1 t1 s1]';
df=[q2 w2 t2 s2]';
meansq=[q3 w3 t3 s3]';
b=b';
stdb=stdb';
t=t';
sumsq=sumsq';
df=df';
meansq=meansq';
tpart=[b' stdb' t'];
apart=[sumsq' df' meansq'];
f=f;
rr=w1/(w1+t1);
```

Appendix IV-A.2: SCRIPT FILE FOR DISPLAYING RANDOM BALANCE OUTPUT

Note: This display is constructed for 10 vehicle groups. As used, the 8th group is a dummy.

COMPSUMS.M

```
sp=        ";
al='The following compares the model sum of squares ';
a2='as computed as a weighted sum of coefficients squared';
a3='(first column) with the model sum of squares';
a4='computed from regular ANOVA (second column)';
aa='Third column is R-square';
disp(al)
disp(a2)
disp(a3)
disp(a4)
disp(aa)
disp(sp)
a(:,1:3)
aS='The following displays, for each of the groups';
a6='the regression coefficients (column 1)';
a7='the termwise contributions to model sum of squares (column
2)';
a8='the percent termwise cont. to model sum of squares (column
3)';
a9='Order of terms is as follows:';
disp(sp)
disp(a5)
disp(a6)
disp(a7)
disp(a8)
disp(a9)
disp(sp)
disp(c)
disp(sp)
gl='Group 1';
disp(gl)
b(:,1:3)

g2='Group 2';
disp(g2)
b(:,4:6)

g3='Group 3';
disp(g3)
b(:,7:9)

g4='Group 4';
```

```
disp(94)
b(:,10:12)

g5='Group 5';
disp(g5)
b(:,13:15)

g6='Group 6';
disp(g6)
b(:,16:18)

g7='Group 7';
disp(g7)
b(:,19:21)

g8='Group 8';
disp(g8)
b(:,22:24)

g9='Group 9';
disp(g9)
b(:,25:27)

g10='Group 10';
disp(g10)
b(:,28:30)

g11='Weighted Composite';
disp(g11)
b(:,31:33)

w3='The following gives, for each group, the term number';
w4='ranked in decreasing order of importance (column 1)';
w5='the percent contribution to model sum of squares (column 2)';
w6='and the cumulative percent contribution to
     model SS (column 3)';
w7='followed by an ordered listing of the term names';
disp(w3)
disp(w4)
disp(w5)
disp(w6)
disp(w7)

disp(sp)
a10=c;
hl='Group 1';
disp(hl)
d(:,1:3)
a10(d(:,1),:)

h2='Group 2';
disp(h2)
```

```
d(:,4:6)
a1O(d(:,4),:)

h3='Group 3';
disp(h3)
d(:,7:9)
a10(d(:,7),:)

h4='Group 4';
disp(h4)
d(:,10:12)
a1O(d(:,10),:)

h5='Group S';
disp(h5)
d(:,13:15)
alO(d(:,13),:)

h6='Group 6';
disp(h6)
d(:,16:18)
alO(d(:,16),:)

h7='Group 7';
disp(h7)
d(:,19:21)
alO(d(:,19),:)

h8='Group 8';
disp(h8)
d(:,22:24)
alO(d(:,22),:)

h9='Group 9';
disp(h9)
d(:,2S:27)
alO(d(:,2S),:)

hlO='Group 10';
disp(hlO)
d(:,28:30)
alO(d(:,28),:)

hll='Weighted Composite';
disp(hll)
d(:,31:33)
alO(d(:,31),:)
```

Appendix IV-B: Glossary and Nomenclature

BZV%	Volume percent of benzene in the fuel
DVOC	Total grams per mile of volatile organic compounds from diurnal emissions
EtOH	Ethanol
GM	General Motors
HDGV	Heavy-duty gasoline vehicle
HDV	Heavy-duty vehicle
HSVOC	Total grams per mile of volatile organic compounds from hot soak emissions
I&M	Inspection and maintenance; also IM, I/M
LDGT	Light-duty gasoline truck
LDGV	Light-duty gasoline vehicle; see LDV
LDT	Light-duty truck
LDV	Light-duty vehicle, equivalent to light-duty car
MTBE	Methyl tertiary-butyl ether
POM	Polycyclic organic matter
RFG	Reformulated gasoline
RFVOC	Total grams per mile of volatile organic compounds from refueling emissions
RLVOC	Total grams per mile of volatile organic compounds from running loss emissions
OXY	Total oxygen content of fuel in terms of weight percent
OLE	Olefins content of fuel in terms of volume percent
SUL	Sulfur content of fuel in terms of parts per million by weight
ARO/AROM	Aromatics content of fuel in terms of volume percent
E200	Percent fuel distilled at 200°F
E300	Percent fuel distilled at 300°F
BEN	Fuel benzene content in terms of volume percent
RVP	Reid vapor pressure in terms of psi
VMT	Vehicle miles travelled
VOC	Volatile organic compounds, measured in grams per mile on a nonmethane, nonethane basis

A,B = Generic fuel parameters

A_t,B_t = Generic fuel parameters for a target fuel

A_b,B_b = Generic fuel parameters for a baseline fuel

A_{et} = Value of generic fuel parameter A at the end of the allowable range

B_{et} = Value of generic fuel parameter B at the end of the allowable range

C_i = Average emissions of any pollutant from vehicle group i

E_i = Unknown gram/mile emissions for vehicle group i, resulting from statistical regressions that disregard intercept terms

$E_i(t)$ = Unknown gram/mile emissions for vehicle group i for a specific target fuel

$E_i(b)$ = Unknown gram/mile emissions for vehicle group i for a specific baseline fuel

f_i = Sum of fuel terms * coefficients for vehicle group i for any fuel

$f_i(t)$ = Sum of fuel terms * coefficients for vehicle group i where the fuel terms represent a specific target fuel

$f_i(b)$ = Sum of fuel terms * coefficients for vehicle group i where the fuel terms represent a specific baseline fuel

$f(t)$ = Second or first order function of fuel parameters for a target fuel

$f(b)$ = Second or first order function of fuel parameters for a baseline fuel

k_i = Proposed adjustment factor for vehicle group i

P_j = Any Complex Model fuel parameter

W_i = Proposed weighting factor for vehicle group i

w_i = Final weighting factor for vehicle group i

X = Fleet average grams/mile of any pollutant for any fuel

$X(t)$ = Fleet average grams/mile of any pollutant for a specific target fuel

$X_i(t)$ = Grams/mile of any pollutant for a specific target fuel for vehicle group i

$X(b)$ = Fleet average grams/mile of any pollutant for a specific baseline fuel

$X_i(b)$ = Grams/mile of any pollutant for a specific baseline fuel for vehicle group i

Y = Fleet average performance of any pollutant for any fuel

$Y(t)$ = Fleet average performance of any pollutant for a specific target fuel

$Y_i(t)$ = Performance of any pollutant for a specific target fuel for vehicle group i

$Y(b)$ = Fleet average performance of any pollutant for a specific baseline fuel

$Y_i(b)$ = Performance of any pollutant for a specific baseline fuel for vehicle group i

Y = Emissions of any exhaust pollutant in percent change from a baseline fuel

$Y(t)$ = Emissions of a generic exhaust pollutant from a target fuel

$Y(b)$ = Emissions of a generic exhaust pollutant from a baseline fuel

ϵ_k = Coefficient determined through statistical regressions

* = Denotes a multiplication symbol. For example, A*B means the quantity A multiplied by the quantity B

Appendix IV-C: MOBILE4.1 Input File Used to Develop the Simple Model and the Phase I Complex Model (must be run with interim version of MOBILE4.1)

```
1          PROMPT -
MOBILE4.1 v.7/11/91: Simple Model correlations
1          TAMFLG -
1          SPDFLG -
1          VMFLAG -
1          MYMRFG -
1          NEWFLG -
2          IMFLAG - enter I/M program
1          ALHFLG -
2          ATPFLG - enter ATP
2          RLFLAG - Stage II refueling controls
2          LOCFLG - enter LAP record once
1          TEMFLG -
3          OUTFMT - print 112 column descriptive output format
4          PRTFLG - print exhaust HC, CO and NOx results
1          IDLFLG -
3          NMHFLG - print VOC
3          HCFLAG - print HC components
83 20 68 20 00 00 100 1 1 2221 2 11 20 20 20
83 68 20 2221 11 100. 11111212
89 1 086 086
RegNeg           C 71.6 91.6 11.5 08.7 89 1
1 15 19.6 75.0 20.6 27.3 20.6
RegNeg           C 71.6 91.6 11.5 08.5 89 1
1 15 19.6 75.0 20.6 27.3 20.6
RegNeg           C 71.6 91.6 11.5 08.3 89 1
1 15 19.6 75.0 20.6 27.3 20.6
RegNeg           C 71.6 91.6 11.5 08.1 89 1
1 15 19.6 75.0 20.6 27.3 20.6
RegNeg           C 71.6 91.6 11.5 07.9 89 1
1 15 19.6 75.0 20.6 27.3 20.6
RegNeg           C 71.6 91.6 11.5 07.7 89 1
1 15 19.6 75.0 20.6 27.3 20.6
RegNeg           C 71.6 91.6 11.5 07.5 89 1
1 15 19.6 75.0 20.6 27.3 20.6
RegNeg           C 71.6 91.6 11.5 07.2 89 1
1 15 19.6 75.0 20.6 27.3 20.6
RegNeg           C 71.6 91.6 11.5 07.0 89 1
1 15 19.6 75.0 20.6 27.3 20.6
RegNeg           B 69.4 94.0 11.5 08.7 89 1
1 15 19.6 75.0 20.6 27.3 20.6
RegNeg           B 69.4 94.0 11.5 08.5 89 1
1 15 19.6 75.0 20.6 27.3 20.6
RegNeg           B 69.4 94.0 11.5 07.8 89 1
1 15 19.6 75.0 20.6 27.3 20.6
RegNeg           B 69.4 94.0 11.5 07.6 89 1
1 15 19.6 75.0 20.6 27.3 20.6
RegNeg           B 69.4 94.0 11.5 07.4 89 1
```

```
1 15 19.6 75.0 20.6 27.3 20.6
RegNeg           B 69.4 94.0 11.5 07.2 89 1
1 15 19.6 75.0 20.6 27.3 20.6
RegNeg           B 69.4 94.0 11.5 07.0 89 1
1 15 19.6 75.0 20.6 27.3 20.6
RegNeg           B 69.4 94.0 11.5 06.8 89 1
1 15 19.6 75.0 20.6 27.3 20.6
RegNeg           B 69.4 94.0 11.5 06.6 89 1
1 15 19.6 75.0 20.6 27.3 20.6
```

Appendix IV-D: MOBILE5a Input File Used To Develop the Phase II Complex Model

```
1          PROMPT -
Phase II Complex Model baseline runs for LDGVs & LDGTs
1          TAMFLG -
1          SPDFLG -
1          VMFLAG -
1          MYMRFG -
5          NEWFLG - no CAA mandates are modeled
2          IMFLAG - enter I&M program
1          ALHFLG -
8          ATPFLG - enter ATP; include pressure and purge checks
2          RLFLAG - enter Stage II
1          LOCFLG -
1          TEMFLG -
3          OUTFMT - print 112 column descriptive output format
1          PRTFLG - print exhaust & evap HC only
1          IDLFLG -
3          NMHFLG - print VOC
2          HCFLAG - no HC components
83 20 68 20 03 03 096 1 1 2221 4211 0.80 20.0 2.00 Enhanced IM
83 84 20 2221 11 096. 12211111                     ATP
83 83 20 2221 11 096.                              Pressure test
83 86 20 2221 11 096.                              Purge test
89 1 80. 60.                                       Stage II
1 15 19.6 87.0 20.6 27.3 20.6  1
................ C 71.6 91.6 09.5 09.9 90 1 1 1
1 15 19.6 87.0 20.6 27.3 20.6  1
................ C 71.6 91.6 09.5 09.7 90 1 1 1
1 15 19.6 87.0 20.6 27.3 20.6  1
................ C 71.6 91.6 09.5 09.5 90 1 1 1
1 15 19.6 87.0 20.6 27.3 20.6  1
................ C 71.6 91.6 09.5 09.3 90 1 1 1
1 15 19.6 87.0 20.6 27.3 20.6  1
................ C 71.6 91.6 09.5 09.1 90 1 1 1
1 15 19.6 87.0 20.6 27.3 20.6  1
................ C 71.6 91.6 09.5 08.9 90 1 1 1
1 15 19.6 87.0 20.6 27.3 20.6  1
................ C 71.6 91.6 09.5 08.7 90 1 1 1
1 15 19.6 87.0 20.6 27.3 20.6  1
................ C 71.6 91.6 09.5 08.5 90 1 1 1
1 15 19.6 87.0 20.6 27.3 20.6  1
................ C 71.6 91.6 09.5 08.3 90 1 1 1
1 15 19.6 87.0 20.6 27.3 20.6  1
................ C 71.6 91.6 09.5 08.1 90 1 1 1
1 15 19.6 87.0 20.6 27.3 20.6  1
................ C 71.6 91.6 09.5 07.9 90 1 1 1
1 15 19.6 87.0 20.6 27.3 20.6  1
................ C 71.6 91.6 09.5 07.7 90 1 1 1
1 15 19.6 87.0 20.6 27.3 20.6  1
................ C 71.6 91.6 09.5 07.5 90 1 1 1
```

```
1 15 19.6 87.0 20.6 27.3 20.6  1
................ C 71.6 91.6 09.5 07.3 90 1 1 1
1 15 19.6 87.0 20.6 27.3 20.6  1
................ C 71.6 91.6 09.5 07.1 90 1 1 1
1 15 19.6 87.0 20.6 27.3 20.6  1
................ C 71.6 91.6 09.5 06.9 90 1 1 1
1 15 19.6 87.0 20.6 27.3 20.6  1
................ C 71.6 91.6 09.5 06.7 90 1 1 1
1 15 19.6 87.0 20.6 27.3 20.6  1
................ C 71.6 91.6 09.5 06.5 90 1 1 1
1 15 19.6 87.0 20.6 27.3 20.6  1
................ B 69.4 94.0 09.5 09.9 90 1 1 1
1 15 19.6 87.0 20.6 27.3 20.6  1
................ B 69.4 94.0 09.5 09.7 90 1 1 1
1 15 19.6 87.0 20.6 27.3 20.6  1
................ B 69.4 94.0 09.5 09.5 90 1 1 1
1 15 19.6 87.0 20.6 27.3 20.6  1
................ B 69.4 94.0 09.5 09.3 90 1 1 1
1 15 19.6 87.0 20.6 27.3 20.6  1
................ B 69.4 94.0 09.5 09.1 90 1 1 1
1 15 19.6 87.0 20.6 27.3 20.6  1
................ B 69.4 94.0 09.5 08.9 90 1 1 1
1 15 19.6 87.0 20.6 27.3 20.6  1
................ B 69.4 94.0 09.5 08.7 90 1 1 1
1 15 19.6 87.0 20.6 27.3 20.6  1
................ B 69.4 94.0 09.5 08.5 90 1 1 1
1 15 19.6 87.0 20.6 27.3 20.6  1
................ B 69.4 94.0 09.5 08.3 90 1 1 1
1 15 19.6 87.0 20.6 27.3 20.6  1
................ B 69.4 94.0 09.5 08.1 90 1 1 1
1 15 19.6 87.0 20.6 27.3 20.6  1
................ B 69.4 94.0 09.5 07.9 90 1 1 1
1 15 19.6 87.0 20.6 27.3 20.6  1
................ B 69.4 94.0 09.5 07.7 90 1 1 1
1 15 19.6 87.0 20.6 27.3 20.6  1
................ B 69.4 94.0 09.5 07.5 90 1 1 1
1 15 19.6 87.0 20.6 27.3 20.6  1
................ B 69.4 94.0 09.5 07.3 90 1 1 1
1 15 19.6 87.0 20.6 27.3 20.6  1
................ B 69.4 94.0 09.5 07.1 90 1 1 1
1 15 19.6 87.0 20.6 27.3 20.6  1
................ B 69.4 94.0 09.5 06.9 90 1 1 1
1 15 19.6 87.0 20.6 27.3 20.6  1
................ B 69.4 94.0 09.5 06.7 90 1 1 1
1 15 19.6 87.0 20.6 27.3 20.6  1
................ B 69.4 94.0 09.5 06.5 90 1 1 1
```

Appendix IV-E: SAS code used to Devlop Raw Exhaust Emission Models

Appendix IV-F: Included 1990 Technology Vehicles in the Complex Model Database

The list below shows the 1990 technology vehicles that are currently in the complex model database used to develop the exhaust models shown in Section A.

V. Environmental and Economic Impact of Phase I Reformulated Gasoline

The Phase I reformulated gasoline standards consist of two fuel specifications (maximum benzene content and minimum oxygen content) and three performance standards applying to VOC, toxics and NOx emissions reductions required of reformulated fuels from 1995-1999. After 1999, the more stringent Phase II emission performance standards, discussed in Section VI, take effect. EPA's April 1992 reformulated gasoline proposal extensively discussed the development of the Phase I simple model standards. Phase I complex model standards and other Phase I issues were discussed in the February 1993 proposal. Comments on and any further developments of the Phase I standards, either under the Simple or Complex Models, were discussed in Sections 2 and 4 above. This section presents both the costs and benefits of the Phase I standards.

A. Introduction

1. Phase I Fuel Control Costs

The cost to produce Phase I RFG was determined for Regions 1, 2 and 3 through the recent refining cost analysis done by Bonner and Moore (B & M).[51] Unlike the Phase II data, individual costs for each parameter change (added oxygenate, reduced benzene and reduced RVP) were not determined in the B & M cost analysis. The cost of the phase I RFG program was calculated in one step for all three parameter changes. Because the RFG specifications differ between summer and winter, the B & M refinery model runs separate summer and winter optimizations off the same base of capital equipment. For accounting purposes, the model allocates all the capital costs only to the winter. This produces appropriate and accurate estimates of annual average costs, but makes it difficult to develop separate winter and summer costs.

---

[51] Bonner and Moore Management Science, "Study of the Effects of Fuel Parameter Changes on the Cost of Producing Reformulated Gasoline," Prepared for EPA under contract through Southwest Research Institute and the National Institute for Petroleum and Energy Research. This data was made available to the public through the following document: "DOE and API Phase II Cost Estimates," EPA Memorandum from Lester Wyborny, FSSB, to the Air Docket, November 4, 1993. The Bonner and Moore work performed for this analysis was based on a revised version of the model used to generate costs for the draft RIA. This new version includes provisions to prevent dumping of fuel components into conventional gasoline.

Therefore, the winter and summer costs are shown averaged together here and represent an annual average per gallon cost.

The costs developed below exclude the cost of oxygenates already required to be used in winter oxyfuel areas. This was done because the winter oxyfuel program began prior to the RFG program and because this oxygenate produces substantial CO emissions reductions which justify the cost of the oxygenate.

The first column in Table V-1 below summarizes the manufacturing costs estimated by the refinery model of producing Phase I RFG. In the adjacent columns of that table, the capital portion of these costs were then adjusted to reflect a 10 percent rate of return on capital from a 15 percent basis. In Table V-2 further below, the costs were further adjusted to account for the change in fuel's heat content; the fuel economy effects were due to the added oxygenates and reduced RVP. The effect of fuel composition on vehicle fuel economy is addressed in the analysis of the Phase II standards in Section VI.

Table V-1: Phase I RFG Costs Based on 10% ROI

Region	Unadjusted Phase I Costs (15% ROI) (¢/gal)	Capital Cost (MM$)	Capital Cost at 10% and 15% ROI (¢/gal)	Adjusted Phase I Costs (10% ROI)(¢/gal)
Region 1	3.34	475	15% 0.93 10% 0.71	3.12
Region 2	1.96	586	15% 1.00 10% 0.75	1.71
Region 3	3.12	1726	15% 1.31 10% 0.99	2.80

Table V-2: Phase I RFG Costs Including Fuel Economy Effects

Region	Adjusted Phase I Refinery Costs (¢/gal)	Fuel Economy Effect (%)	Fuel Economy Effect Cost (¢/gal)	Total Phase I Costs (¢/gal)
Region 1	3.12	1.20	1.02	4.14
Region 2	1.71	1.89	1.61	3.32
Region 3	2.80	1.84	1.56	4.64

Given the mandate for at least 2.0 volume percent oxygen, the cost of producing Phase I RFG is partially determined by the cost of adding oxygenates. The cost of oxygenate addition, however, is largely driven by the purchase cost of the oxygenate, or the raw materials used in producing the oxygenate. When the B & M model was being set up to estimate the RFG program costs, the oxygenate costs were programmed into the model based on the expectations for the future market of oxygenate demand and supply at that time. However, recent indications are that the oxygenate costs may vary significantly from these earlier estimates and that the cost of producing Phase I RFG should reflect these varying oxygenate costs. Furthermore, much of the ethanol that the model estimated would be blended into RFG was done so at an unsubsidized cost (retail cost without the 54 c/gal subsidy). An unsubsidized ethanol cost was used because, at that time, ethanol blends under 10 percent ethanol were not permitted to take advantage of the subsidy. Since then, the subsidy policy has been modified and ethanol blends at less than 9 volume percent are eligible for the excise tax credit. EPA is therefore adjusting these costs to reflect the tax credit available to all ethanol blends.

All of the oxygenate cost projections were made by B & M in a period of strong growth in oxygenate demand and when the possibilities of supply just meeting demand were real. Thus, the B & M projections tend to be quite high in today's terms. For example, B & M projected a merchant MTBE price of $1.05/gal. Despite this being the beginning of the 1993-94 winter oxyfuel season, MTBE has been selling for a few months on the spot market for $0.66-0.75/gal. The summer runup in prices which occurred during 1992 while refiners built up inventories for the winter never materialized in 1993. The same could happen again with the onset of the reformulated gasoline program. Oxygenate prices could be relatively high in late 1994 and early 1995 and then fall back to more reasonable levels. To account for this, a range of MTBE and methanol prices is being used, as shown in the table below. The low end of the ranges reflect today's low energy prices and ample oxygenate supply. The high end of the ranges are those projected by B & M.

For ethanol, B&M projected the historical figure of $1.20/gal, prior to consideration of the tax credit. This price allows ethanol to be competitive as a gasoline extender and doesn't reflect its octane or oxygenate value. During the summer of 1992, ethanol prices reached $1.40/gal and higher. Recently, with wholesale regular gasoline prices in the mid-40's per gallon, ethanol has been selling for $1.00-1.05/gal. To be consistent with the MTBE projections, the range of $1.20-1.60/gal will be used here, or $0.66-1.06/gal after factoring in the $0.54/gal excise tax credit. These are plant gate prices and generally can be used as is throughout the Midwest. However, use in reformulated gasoline, either directly or in producing ETBE, outside the Midwest would involve a significant shipping cost. To account for this, distribution costs for shipping to the Northeast and Gulf coast of 5¢/gal were added onto the price of ethanol, respectively.

Regarding other oxygenates, TAME was not purchased in the refinery modeling, but was produced within the refinery. Thus, the range of methanol prices is adequate to describe its potential cost to refiners. Also, neither ETBE production nor purchase was considered given the technological and economic uncertainties existing at the time of the study. In order to be utilized in significant quantities, ETBE would have to be competitive with MTBE and ethanol, and would thus yield roughly equal or lower costs than those determined below. Table V-3 below summarizes the oxygenate prices used in the model and the oxygenate price range established by EPA.

Table V-3: Oxygenate Costs used in the Phase I Analysis

Oxygenate	Model Costs	Cost Range
Ethanol	$1.20	Before Subsidy $1.20 - $1.60 After Subsidy $0.66 - $1.06
MTBE	$1.05	$0.80 - $1.05
Methanol	$0.57	$0.40 - $0.57

The Phase I costs for Regions 1, 2 and 3 shown in Table V-2 were then adjusted to reflect the range of possible oxygenate costs. The results are summarized in Table V-4. The regional Phase I cost estimates were combined into a U.S. cost by weighting each regional cost by the fraction of RFG produced by that region (see Table VI-# in Section VI).

Table V-4: Final Phase I RFG Costs

Geographic Area	Cost Range (c/gal)
Region 1	2.6 - 4.1
Region 2	2.3 - 6.5
Region 3	3.5 - 4.6
U. S.	3.0 - 4.9 (3.9 average)

Total annual cost to the nation would simply be the cost per gallon from Table V-4 multiplied by the fuel consumption in the reformulated gasoline areas plus any spillover into adjacent areas. The Energy Information Agency projects total national motor gasoline consumption to be 113.9 and 119.8 billion gallons per year in 1995 and 2000, respectively. Interpolating, the estimate for 1998 would be 117.5 billion gallons per year. In the draft RIA for the February NPRM, reformulated gasoline was estimated to represent 32.1 percent of national fuel consumption, including a 10% spillover rate. (Of this total, 13.3% was in Class B areas and 18.8% was in Class C areas.) Combining these figures yields a total annual cost of $1.13-1.85 billion.

2. Emissions Reductions

In-use emission reductions for calendar year 1998 were determined using both MOBILE5.0 and the complex model. Emission reductions were estimated under both basic and enhanced I/M scenarios because both of these I/M programs will be in place in the 1995-1999 period. MOBILE5.0 was used to estimate baseline VOC emissions and the effect of RVP on non-exhaust VOC emissions, as was done in the Draft RIA. The complex model was used to estimate the effect of fuel composition on exhaust VOC emissions. Derivation of the in-use baseline VOC emission projections is described in more detail in Section III.B of the Draft RIA and the baselines themselves are shown in Tables A1-A4 of that section of the DRIA.

Table V-5: 1998 In-Use Baseline VOC Emissions (g/mi)

	Exhaust VOC	Nonexhaust VOC	Total VOC
Basic I/M Program			
Region 1	1.456	0.816	2.272
Region 2	1.449	1.006	2.455
Enhanced I/M Program			
Region 1	0.991	0.570	1.561
Region 2	0.991	0.681	1.672

Assuming fuels meeting the averaging requirements for Phase I RFG under the Simple Model, and the effects of oxygen addition and RVP and benzene reduction on other fuel parameters, as developed in Section VI, the Phase I fuel compositions shown in Table V-6 were developed.

Table V-6: Baseline and Phase I In-Use Fuel Compositions

Fuel Parameter	In-Use Baseline Fuel	Phase I In-Use Fuels	
		Region 1	Region 2
Oxygen	0.0	2.1	2.1
Sulfur	339	309	309
RVP (psi)	7.8/8.7(Region 1/2)	7.1	8.0
E200 (vol%)	41.0	46.7	46.7
E300 (vol%)	83.0	84.9	84.9
Aromatics (vol%)	32.0	25.5	25.5
Olefins (vol%)	9.2	13.1	13.1
Benzene (vol%)	1.53	0.95	0.95

The Phase I complex model was used to evaluate the effect of these fuels on VOC emissions. The resulting percent reductions were then applied to the baseline VOC emissions shown above. The results are shown in Table V-7.

Table V-7: 1998 In-Use Phase I RFG VOC Emissions (g/mi)

	Exhaust VOC	Nonexhaust VOC	Total VOC
Basic I/M Program			
Region 1	1.300	0.617	1.917
Region 2	1.294	0.765	2.059
Enhanced I/M Program			
Region 1	0.886	0.443	1.330
Region 2	0.886	0.535	1.421

The differences in the VOC emissions of Tables V-5 and V-6 represent the benefits of the Phase I RFG program. No substantial NOx emission reduction is expected. To convert the g/mile emission reductions to annual tons, a 1998 national fuel consumption of 113.84 billion gallons was assumed, along with an average gasoline vehicle fuel economy of 20.58, from the MOBILE4.1 fuel consumption model. It was also assumed that RFG would be sold in the 9 mandated areas plus those areas which had opted in by mid-summer 1993. The result is that approximately

18.2 and 12.8 percent of national fuel consumption will be reformulated gasoline in Class C and B areas, respectively.

A significant issue is the calculation of the VOC emission reduction. The VOC controls for reformulated gasoline only apply in the summer, or high ozone season. Most other VOC control programs apply yearround, due to the permanent nature of the controls (e.g., modified painting facilities, motor vehicle control, I/M programs, etc.). The effectiveness of these programs is typically reported on an annual VOC control basis; that is, the emission reductions estimated to occur include VOC emissions reduced in the winter as well as the summer, even though the winter VOC emission reductions have little ozone related value. In order to be comparable with these programs, the benefits of RFG must be put on an annual basis. This means extending the real benefits occurring in the summer to the rest of the year. This is appropriate since the RFG summer VOC emission benefits provide the same in-use ozone reductions as a yearround program which reduces summer emissions to the same degree but also reduces emissions in the winter. To do this, the gram per mile emission reductions were applied to yearround fuel consumption.

Table V-8: VOC Emission Reductions of Phase I RFG
(annualized tons/yr)

	Basic I/M	Enhanced I/M
Class B	118,000	77,000
Class C	187,000	119,000
Total	305,000	196,000

Phase I RFG also reduces cancer incidence due to the reduction in air toxics emissions required. Section VI outlines a methodology for estimating baseline and controlled toxics emissions from MOBILE5 and the complex model. It also outlines a methodology for converting emissions of air toxics into cancer incidence. That methodology was used here. The analysis of the Phase II RFG standards in Section VI also presents a cancer incidence reduction associated with the Phase I standards as a starting point from which to conduct the Phase II analysis.

Only three adjustments of the results of the Phase II analysis need to be made to use the results directly here. The first two refer to baseline emissions. First, the Phase I analysis focuses on the year 1998, while the Phase II analysis focuses on 2003. Second, this Phase I analysis considers the fact that both basic and enhanced I/M programs will exist prior to 2000, while only enhanced I/M is considered thereafter. The result is that the toxics emissions benefits estimated in Section VI, as well as the resulting cancer incidence reduction, need to be increased to reflect the difference between the baseline VOC emissions in Table V-5 above and those estimated in Section VI.

The third difference is that the Phase II analysis assumes that the fuel modifications will only occur in the summer. On the other hand, the Phase I benefits are primarily due to the addition of oxygenate (with its effect on aromatic content) and the reduction of fuel benzene content and will occur yearround. (The toxics benefits of the summer RVP control are very slight and can be ignored in this extrapolation from the Phase II analysis.) Taking all this into account, the Phase I RFG standards will reduce U.S. cancer incidences (assuming one year exposure to both the baseline and controlled levels of emissions) by 24 (assuming basic I/M in place) and 16 (assuming enhanced I/M in place) incidences.

VI. Phase II Reformulated Gasoline Standards and NOx Standards for Reformulated Gasoline

A. Introduction

The development of the VOC and toxics emission reduction standards for Phase II reformulated gasoline (RFG), as well as the NOx emission reduction standards which EPA is also promulgating, is presented here. The statutory requirements, analytical methodologies, and results, as well as public comments received on the proposal and EPA's responses, are discussed below. The Phase II RFG standards and NOx standards can be found at §80.41 and are summarized in section VI of the final rulemaking preamble.

1. Statutory Requirements

Section 211(k) requires that reformulated gasoline achieve the greatest reductions possible in volatile organic compounds (VOCs) and toxics emissions, "taking into consideration the cost of achieving such emission reductions, any nonair-quality and other air-quality related health and environmental impacts and energy requirements. Specifically, section 211(k)(3)(B) of the Act requires that, in the year 2000 and beyond, "aggregate emissions of ozone-forming volatile organic compounds from baseline vehicles[52] when using reformulated gasoline shall be 25 percent below the aggregate emissions of ozone forming volatile organic compounds from such vehicles when using baseline gasoline[53]." Similarly, a 25% reduction in emissions of toxic air pollutants is required. The Act also specifies that the Administrator may adjust the 25 percent reduction level to provide for lesser or greater reductions based on technological feasibility, giving consideration to the cost of achieving such reductions. In no case can the required reduction be less than 20 percent. The Act further provides that emissions of oxides of nitrogen (NOx) cannot increase as a result of the use of reformulated gasoline. These VOC and toxics reductions and NOx limit are known as the Phase II reformulated gasoline standards.

Section 211(c) of the Act allows the Administrator to regulate fuels or fuel additives if "any emission product of such

---

[52] According to section 211(k)(10)(A) of the Act, "baseline vehicle" means representative model year 1990 vehicles.

[53] The formulation for summertime baseline gasoline is defined in section 211(k)(10)(B) of the Act. See further discussion of baseline emissions in section III.

fuel or fuel additives causes, or contributes to, air pollution which may reasonably be anticipated to endanger the public health or welfare." Section 211(c)(2) further provides that EPA cannot control these fuels and fuel additives "except after consideration of all relevant medical and scientific evidence available..., including consideration of other technologically or economically feasible means of achieving emissions standards." In addition, EPA must find that the prohibition "will not cause the use of any other fuel or fuel additive which will produce emissions which will endanger the public health or welfare to the same or greater degree than the use of the [regulated fuel/fuel additive]."

EPA had elected to use this authority to require reformulated fuels to also achieve NOx reductions in order to reduce ozone formation, based on scientific evidence regarding the benefits of NOx control and on the cost-effectiveness of NOx reductions. The determination of the need for and cost-effectiveness of NOx control is evaluated in this study. A discussion of the scientific justification for NOx reductions under the reformulated gasoline program can be found in section B below.

2. Factors to be Considered in Setting the Phase II RFG Standards

An analysis, per the requirements of section 211(k)(1), of the costs, cost-effectiveness, health, environmental and energy impacts of fuel component modifications used to reduce VOC, NOx, and toxics emissions of baseline gasoline is presented below. Because the cost of achieving a Phase II reformulated gasoline standard was specifically mentioned as a consideration in setting the standard, this analysis focuses on the cost-effectiveness of different fuel reformulations which achieve at least the minimum reductions. Since it has been determined that the health and environmental impacts of such fuel reformulations are beneficial and increase as the percentage emission reduction increases, and that the energy impacts are minimal, the Phase II reformulated gasoline performance standards are determined based primarily on cost-effectiveness. A discussion of these impacts is presented in section H below.

EPA received a comment to the proposed standards which stated that EPA must determine whether VOC or toxics are the controlling factor in setting the Phase II RFG standards. As will be shown by the following analysis, EPA has determined that control of toxics below the minimum statutory level (20%) is not cost effective. Hence, the standards will be set based on the cost-effectiveness of VOC and NOx control, not on the basis of toxics control.

B. Scientific Justification for NOx Control

Along with the proposed VOC and toxics standards for Phase II reformulated gasoline, EPA proposed NOx standards, based on the cost-effectiveness and environmental benefits of NOx control. Many comments were received regarding the NOx standards. These comments are summarized below. Several of the comments questioned the scientific evidence for the benefits of controlling NOx to reduce ozone formation. Hence, a discussion of the benefits of NOx reduction in terms of ozone impacts, as well as other environmental and health benefits, is also presented below.

The following discussion summarizes EPA's consideration under §211(c)(2)(A) of the relevant medical and scientific evidence available to the agency, as well as its consideration of other technologically or economically feasible means of achieving NOx reductions through vehicle standards under §202. Furthermore, section H provides a comparison of the cost-effectiveness of other means of NOx control from mobile or stationary sources, and concludes that control of NOx emissions from reformulated gasoline will not pose a greater burden on industry or the public than these alternative technologies. Finally, since the complex model allows consideration of all of the components of gasoline which affect NOx emissions, EPA believes that the NOx standards (determined using the complex model) will not lead to the use of any fuels or fuel additives which will endanger the public health or welfare (through increases in VOC, NOx, or toxics emissions) more than would occur if NOx emissions from reformulated gasoline were not regulated.

EPA has previously established National Ambient Air Quality Standards for ozone, NO_2, and PM-10. In so doing, EPA provided all of the medical and scientific information available to support the fact that regulation of these pollutants is beneficial to public health and welfare. Since NOx emissions contribute significantly to the inventory of ozone and NO_2, and in some cases, PM-10, reductions in NOx emissions will lead to reductions in the inventories of these pollutants.

1. Comments on Proposed Standards

EPA received a variety of comments on the proposed NOx standards. Some commenters claimed that a NOx reduction standard was counter to the regulatory negotiation agreement. The focus of Reg-Neg was on how the provisions of section 211(k) were to be interpreted and implemented; it did not address EPA's authority under section 211(c) to regulate emissions of NOx. The scientific evidence summarized below has convinced EPA of the need to control mobile source emissions of NOx during the summer months in ozone nonattainment areas, and EPA is doing so under the authority granted by section 211(c). EPA has determined that

NOx standards for gasoline sold in ozone nonattainment areas should be coordinated with the Phase II performance standards for VOC and toxics since the environmental benefits of the combined programs generally will be as great as the benefits of the programs implemented separately, while costs will be considerably less. The special distribution and enforcement requirements will already be in place for the Phase II standards and thus neither industry nor government will incur additional costs (beyond manufacturing costs) as a result of implementing an additional NOx standard. Furthermore, EPA has decided to promulgate the NOx standards with the Phase II RFG standards to reduce the burden on the industry of complying with two separate regulations within a short timeframe (which could negatively impact decisions regarding capital investment if they were not well coordinated).

Other comments questioned the ability to control NOx emissions with any parameter other than oxygen. Since EPA requires oxygen in reformulated gasoline (as directed by the Clean Air Act), one comment suggested that the only way to control NOx would be to eliminate the requirement of a minimum oxygen content. The complex model clearly shows that some parameters, most notably sulfur, can have a significant impact on NOx emissions. Furthermore, the model indicates that the addition of oxygen leads to a small (essentially negligible) decrease in NOx emissions. While the impact of various oxygenates on NOx emissions can vary due to other changes in the fuel which accompany oxygen addition, the oxygen alone does not appear to increase NOx in 1990 model year vehicles. In addition, all fuel modifications considered below to reduce NOx emissions were evaluated with fuels already containing 2.1 weight percent oxygen. Hence, it is clear that significant reductions in NOx can be achieved without lessening the oxygen requirement. In any case, section 211(k)(2) allows EPA to waive the oxygen content requirement for reformulated gasoline only if the Administrator determines that compliance with the oxygen content requirement would prevent or interfere with attainment of an applicable NAAQS. EPA therefore could not waive this requirement for the reasons presented by the commenter.

Many comments addressed the cost-effectiveness of NOx control. Some raised questions about the accuracy of the costs used, which impacts the cost-effectiveness determination. The cost-effectiveness analysis presented later in this section uses improved costs and is believed to be representative of the impact of NOx control on the average refinery. Some of the comments supported NOx control on the basis of the cost-effectiveness analysis presented with the proposal, citing the benefits that specific locations would realize by reducing the mobile source contribution to the NOx inventory. As discussed below, although the benefits of NOx reduction vary from city to city, in general most ozone nonattainment areas will benefit from a reduction in NOx in addition to the mandated reductions in VOC emissions.

Some comments questioned the validity of the information which claims ozone benefits from NOx reductions, while others supported the benefits of reducing NOx emissions in ozone nonattainment areas. Most comments centered around the question of how much a given nonattainment area would benefit from NOx reductions in addition to VOC reductions. The following section presents EPA's response to these comments.

2. Benefits of NOx Reductions

EPA proposed NOx standards based on the reduction in ozone formation that is expected to result from a combination of reductions in both VOC and NOx emissions. Gasoline vehicles contributed 20-35% of total urban NOx emissions in 1990, and are expected to continue to represent a large fraction of the NOx inventory in the year 2000.[54] Hence, control of mobile source NOx emissions can be an important step in meeting the air quality requirements of various urban areas.

A recent report by the National Research Council (NRC) concluded that "the optimal set of controls relying on VOCs, NOx, or, most likely, reductions of both, will vary from one place to the next."[55] In response to the NRC report, EPA acknowledged that NOx control in addition to or instead of VOC control is likely to reduce ozone in many areas.[56] Similarly, EPA acknowledges that the magnitude of the ozone benefits for VOC controls is dependent on the particular area.[57]

Many stationary source emission control measures can be applied on a selective basis to individual areas based on their air quality needs. For ozone control strategies based on fuel controls, however, it is extremely difficult if not impossible to

---

[54] Although by the year 2000 a portion of the vehicles will have lower NOx emissions because they will meet the "Tier 1" emission standards, these emissions benefits are expected to be offset by increases in annual vehicle miles travelled.

[55] National Research Council, <u>Rethinking the Ozone Problem in Urban and Regional Air Pollution</u>, National Academy Press, Washington, D.C., 1991.

[56] U.S. EPA, "Summary of Public Comments and EPA Responses on the Draft Report 'The Role of Ozone Precursors in Tropospheric Ozone Formation and Control'," EPA-454/R-93-025, July 1993.

[57] For example, due to the transport of ozone over the region, control strategies that might not benefit one area within the nonattainment region may help an area downwind.

tailor the relative reductions in VOC and NOx emissions to the specific needs of individual areas. The fungible nature of the gasoline distribution system in this country would simply not allow for detailed specific VOC and NOx standards for each and every individual area. Such a requirement would greatly hamper the efficient distribution of the fuel, thereby resulting in extremely large increases in fuel distribution costs, rendering such emission controls through fuel reformulation cost ineffective. The reformulated gasoline standards avoid the vast majority of these concerns by applying one consistent set of fuel standards to a range of areas. By so doing, the program achieves significant ozone reductions on average in a cost effective manner, while at the same time recognizing that the controls would be more effective at reducing ozone in some areas than in others.

With this in mind, EPA proposed in February 1993, that a NOx reduction standard be applied to all RFG areas. While either NOx or VOC reductions by themselves may provide little ozone benefit in a minority of the covered areas, the combination of NOx control with VOC control will ensure that significant ozone reductions are achieved in all of the covered areas. Applying fuel NOx controls nationwide (as is done out of necessity with tighter vehicle emission control standards) would be inappropriate, however, since most of the additional NOx reductions would be achieved in areas for which little or no ozone benefit would result. Therefore, EPA believes it appropriate to apply a NOx reduction standard to the same areas for which the reformulated gasoline standards apply.

The following presents a summary of the scientific evidence which favors NOx reductions for most, if not all, ozone nonattainment areas. The benefits include the primary benefit of reducing ozone precursors as well as secondary benefits which will benefit human health and the environment.

a. Effect of NOx on Ozone

Although both NOx and VOC emissions are regulated for certain types of sources, including motor vehicles, the primary focus of past ozone abatement strategies has been on VOC. This is largely due to the belief that the most cost effective way to reduce ozone formation was to limit the amount of VOC in the ambient air. However, many areas where VOC reduction has been applied as the primary ozone control strategy have not reached attainment. In recent years, improved knowledge of emission sources and atmospheric chemistry has shown that both VOC and NOx emissions can enhance ozone formation. The benefits of either VOC or NOx emission reductions can depend on the ratio of VOC to

NOx in the airshed.[58] This ratio varies spatially and temporally within a given air basin and can differ between severe ozone episodes or more typical ozone exceedances. However, although simple smog chamber experiments typically show that combined VOC and NOx reductions are less effective at controlling ozone than reducing either one alone, the complexity of variations in meteorology, emissions sources, and control feasibility often make combined VOC and NOx control the option of choice in real world situations.[59]

Prior to the development of more sophisticated models, information about the response of ozone levels to VOC and NOx emissions was often based on EKMA modelling. This modelling produces graphical representations (isopleths) of the relationship between VOC and NOx concentrations in the formation of ozone. Regions where ozone formation is either VOC or NOx limited are easily determined from these plots. At low VOC to NOx ratios, less than about 8 on a molar basis, ozone formation is VOC limited, so VOC control is more effective. A low ratio is typical of highly urbanized areas. For VOC to NOx ratios greater than 8, ozone formation is NOx limited, and NOx control is more effective. For instance, the Houston area has been identified by the EKMA analyses as an area in which ozone formation is NOx limited and thus VOC control alone would do little to reduce ozone levels in this area.[60] Many areas downwind of urban centers also have large VOC to NOx ratios and so would be NOx-limited.

Ozone grid-based modelling studies using more sophisticated analytical techniques have shown that NOx control is generally a more effective ozone reduction strategy than VOC control. The recent National Research Council study[61] utilized work in the California South Coast basin[62] to suggest that NOx control is

---

[58] Finlayson-Pitts, B.J. and J.N. Pitts, Jr., "Atmospheric Chemistry of Tropospheric Ozone Formation: Scientific and Regulatory Implications," Air & Waste, Vol.43, August, pp.1091-1100, 1993.

[59] U.S. EPA, EPA-454/R-93-025.

[60] National Research Council, Rethinking the Ozone Problem in Urban and Regional Air Pollution, National Academy Press, Washington, D.C., U.S.A., 1991.

[61] Ibid.

[62] Milford, J.B., Russell, A.G., and McRae, G.J., "A New Approach to Photochemical Pollution Control: Implications of Spatial Patterns in Pollutant Responses to Reductions in

essential to meeting the ambient air quality standards and that even marginal NOx reductions result in improved air quality in most areas. Subsequent studies[63,64,65] have shown that NOx control is an effective ozone reduction strategy for the northeast United States, including the Baltimore, Philadelphia, New York-Connecticut, and Boston-Maine regions. The EPA ROMNET report on ozone modelling for the northeastern states indicated that NOx control reduced ozone for nearly all of the northeastern modelling domain, except New York City and nearby areas. In New York City, ozone levels increased when only NOx emissions were reduced, indicative of VOC-limited ozone formation. When both VOC and NOx emissions were reduced, however, ozone was reduced throughout the modelling domain. Of course, with Phase II reformulated gasoline, NOx emission control will only occur along with significant VOC emission reductions (several times greater than the NOx reductions). Therefore, ozone reductions are expected over the entire region modelled by the EPA study, which includes four of the mandated nine reformulated gasoline regions. These include areas that are VOC-limited as well as NOx-limited for ozone formation as well as most of the opt-in areas. The ROMNET study also suggested that the benefits of NOx controls may extend beyond rural regions since net ozone transport into cities is reduced.

Similar modelling has been performed for the Lake Michigan region (including Chicago, IL; Muskegon, MI; and Milwaukee, WI).[66] The results of this study indicated that NOx control without VOC control could be detrimental for the Lake Michigan

---

Nitrogen
Oxides and Reactive Organic Gas Emissions," Environ. Sci. Technol., v 23, pp. 1290-1301, 1989.

[63] Sillman, S., Samson, P.J., and Masters, J.M., "Ozone Production in Urban Plumes Transported over Water: Photochemical Model and Case Studies in the Northeastern and Midwestern United States," J. Geo. Res., v. 98, n. D7, pp. 12,687-12,699, 1993.

[64] Sillman, S. and Samson, P., "Simulated Ozone over Lake Michigan and the Northeast Corridor: Identifying the Differences between Hydrocarbon-limited and NOx-limited Regions," Presentation at the 86th Annual Meeting and Exhibition, Denver, CO, June 13-18, 1993, 93-WP-68B.05.

[65] U.S. EPA, Regional Ozone Modeling for Northeast Transport (ROMNET), EPA Report 450/4-91-002a, June 1991.

[66] Sillman and Samson, 86th Annual Meeting of Air & Waste Management Association, June 13-18, 1993.

region. As long as VOC reductions are greater than NOx reductions, however, the combination of the two will result in ozone benefits. The sensitivity of the modelling results to the VOC emissions inventory was also tested, and showed that if the VOC emissions inventory was underestimated (as discussed in the next paragraph), NOx emission reductions become universally effective in the Lake Michigan region.

The NRC and EPA[67] have indicated that emissions inventories of VOC and carbon monoxide may have been underestimated in the past. The estimated relative benefits of VOC or NOx control as ozone reduction strategies depends upon the assumption of the emission inventories. As the VOC emission inventory estimate increases, NOx control becomes a more effective strategy for reducing ozone levels. Several changes have led to higher estimates in the VOC emission inventory since the grid models cited in the previous paragraphs were performed. EPA's MOBILE5 emission model estimates significantly higher VOC emissions than the MOBILE4 model which was used in the ozone modelling studies cited above. In addition, indications are that the effectiveness of stationary source controls is not as great as assumed in the ozone modelling studies.[68] This also increases the VOC emissions inventory estimate. Therefore, even though NOx control has been shown to be very effective in reducing ozone, the efficacy of NOx reduction may have been underestimated in past modelling.

Ambient measurements have also indicated that the VOC inventory may be underestimated. Measurements of VOC/NOx ratios have been typically a factor of approximately two higher than predicted from the emission inventories in major cities throughout the U.S.[69,70] The measurement of ambient VOC may be actually too low because measurement methods tend to

---

[67] U.S. EPA, EPA-454/R-93-025, July 1993.

[68] Statement by Bill Oliver, Radian Corp., Presentation at the 1992 Conference on Lake Michigan Ozone and the Clean Air Act, Chicago, IL, September 1992.

[69] Finlayson-Pitts and Pitts, Air & Waste, Vol.43, August, pp.1091-1100, 1993.

[70] Fujita, E.M., Croes, B.E., Bennett, C.L., Lawson, D.R., Lurmann, F.W., and Main, H.H., "Comparison of Emissions Inventory and Ambient Concentration Ratios of CO, NMOG, and NOX in California's South Coast Basin," JAPCA, v 42, pp.264-276, 1992.

underestimate the total.[71] The VOC/NOx ratio of most urban areas was thought to be much lower than ambient measurements would indicate. Several other studies[72,73,74] have concluded through a technique called source/receptor modelling that the VOC emission inventory is underestimated. If the VOC emission inventory is severely underestimated, then regions where NOx control are estimated to increase ozone levels may not exist.

Another concern is that biogenic emissions or their importance may have been underestimated in the past.[75] In the Atlanta area, biogenic emissions of VOC may be high enough that, in the absence of NOx control, even 100% control of anthropogenic VOC would not enable the region to meet the National Ambient Air Quality Standard (NAAQS) ozone standard.[76] In addition, the VOC emissions from biogenic sources tend to be more reactive than those from stationary or mobile sources. Results of EPA's ROMNET study suggest that the impact of biogenics on ozone formation extend beyond the southeastern U.S. to include much of the northeast, as well. To the extent that biogenic VOC emissions compound the air quality problems of a given region, NOx control becomes more effective.

---

[71] Chameides, W.L., Fehsenfeld, M.O., Rodgers, M.O., Cardelino, C., Martinez, J., Parrish, D., Lonneman, W., Lawson, D.R., Rasmussen, Zimmerman, P., Greenberg, J., Middleton, P., and Wang, T., "Ozone Precursor Relationships in the Ambient Atmosphere," J. Geo. Res., v. 97, n. D5, pp. 6037-6055, 1992.

[72] O'Shea, W.J. and Scheff, P.A., "A Chemical Mass Balance for Volatile Organics in Chicago," JAPCA, v. 38, pp. 1020-1026, 1988.

[73] Aronian, P.F., Scheff, P.A., Wadden, R.A., "Wintertime Source-Reconciliation of Ambient Organics," Atmospheric Environmental, v. 23, n. 5, pp. 911-920, 1989.

[74] Harley R.A., Hannigan, M.P., and Cass G.R., "Respeciation of Organic Gas Emissions and the Detection of Excess Unburned Gasoline in the Atmosphere," Environ. Sci. Technol., v. 26, pp. 2395-2408, 1992.

[75] Chameides, W.L., Fehsenfeld, M.O., Rodgers, M.O., Cardelino, C., Martinez, J., Parrish, D., Lonneman, W., Lawson, D.R., Rasmussen, Zimmerman, P., Greenberg, J., Middleton, P., and Wang, T., "Ozone Precursor Relationships in the Ambient Atmosphere," J. Geo. Res., v. 97, n. D5, pp. 6037-6055, 1992.

[76] At this time Atlanta is not participating in the reformulated gasoline program. However, the Atlanta area is a serious ozone nonattainment area.

Areas downwind of urban plumes tend to have high VOC/NOx ratios indicative of NOx-limited ozone formation. This may be due to increases in local biogenic emissions or transformation and subsequent deposition of nitrated compounds created upwind. Reducing the upwind NOx emissions may be the only means for meeting the ozone standard downwind, even if those emission reductions do not improve air quality in the upwind areas. Many nonattainment areas are downwind of other nonattainment areas, particularly in the Northeast corridor and the Lake Michigan region. Hence, NOx emissions can impact more than just emission source areas.

Since reformulated gasoline can assist control of both VOC and NOx emissions from motor vehicles, its use should provide ozone reductions in areas that are either VOC or NOx limited. In the VOC limited areas where NOx emission reductions may cause ozone increases, the magnitude of VOC reductions provided by reformulated gasoline should prevent any ozone increases (as demonstrated by the Lake Michigan and other studies). In the great majority of areas, reformulated gasoline with NOx control will provide reductions in ozone. As such, the RFG program represents an ideal opportunity to reduce ozone in all areas through both VOC and NOx control.

b. Secondary Benefits

The secondary benefits of NOx emission reductions are also important. As discussed below, these include reductions in acid rain, deposition of nitrates in lakes and estuaries, ambient levels of nitrogen dioxide, secondarily formed particulates, and highly toxic nitrated polycyclic organic matter, as well as potential global warming benefits.

NOx emissions from gasoline vehicles are a significant fraction of the overall NOx emission inventory. While the primary cause of acid rain may be sulfur dioxide emissions, the benefit of reducing NOx emissions should not be ignored. NOx emissions can be precursors to acid aerosols in the form of nitrates or by contributing to the formation of sulfates by reaction with sulfur dioxide gas. Hence, any reduction in NOx emissions from gasoline vehicles should help reduce acid rain precursors. (Furthermore, the acid rain benefits of NOx reductions through gasoline reformulation will be enhanced by the fact that the majority of the NOx emission reductions are expected to be achieved through the removal of sulfur from the gasoline.)

Several studies indicate that atmospheric deposition accounts for a significant portion of nitrogen deposited into certain sensitive estuaries (e.g., 25% of the nitrogen in

Chesapeake Bay is due to atmospheric deposition).[77] The atmospheric deposition of nitrates can also contribute to the depletion of oxygen in lakes and estuaries as a result of an increase in the algae and other plant matter growth in these waterways. The benefit of reducing these nitrates through control of gasoline vehicle emissions has not previously been evaluated, but could be significant.

Nitrated particulate matter related to NOx emissions (e.g., ammonium nitrate) has also been shown to be a significant fraction of some area's PM-10 problem.[78] Some particulate nitrates may be toxic, mutagenic, or carcinogenic.[79] These small particles are carried deep into the lung and are known to cause potentially serious respiratory effects. They also contribute to impaired visibility, raising the public's awareness of this air pollution. Any NOx reduction should reduce these particles. Since mobile source NOx emissions are ground-based and distributed over wide areas, reducing these could have more impact on human health than reductions from stationary sources.

EPA has also cited polycyclic organic matter (POM) as an air toxic.[80] The toxicity of these compounds increases greatly when nitrated. A reduction in NOx emissions should reduce the transformation of POM to the more toxic nitrated form.

A change in NOx emissions is also known to affect concentrations of the hydroxyl radical in the troposphere (the lower layer of the atmosphere). The concentration of the hydroxyl radical in turn impacts the concentration of tropospheric ozone, a greenhouse gas. NOx reductions thus could have positive benefits in reducing global warming. However, the impacts of a reduction in U.S. mobile source emissions of NOx on

---

[77] "Progress Report of the Nutrient Reduction Reevaluation," Chesapeake Bay Program, February 1992.

[78] Farber, R.J., Baas, J.R., Pilinis, C., and Countess, R.J., "Modelling the Secondary Component of PM_{10}," PM_{10} Standards and Nontraditional Particulate Source Controls, Chow, J.C. and Ono, D.M. editors, Air and Waste Management Association, Pittsburgh, PA, November, 1992.

[79] California Air Resources Board, "The Effects of Oxides of Nitrogen on California Air Quality," Report No. TSD-85-01, March 1986.

[80] U.S. EPA, Motor Vehicle-Related Air Toxics Study, EPA Report 420-R-93-005, April 1993.

global tropospheric ozone concentrations and the corresponding relationship to global warming are unclear at this time.[81]

In sum, while the benefits of reducing ozone levels as a result of NOx reductions are the primary basis for the controls being promulgated, the other direct and indirect benefits of reducing atmospheric NOx levels also appear to be substantial.

3. Consideration of §202 Motor Vehicle Controls

Before controlling or prohibiting a fuel or fuel additive under §211(c)(1)(A), the Administrator must consider "other technologically or economically feasible means of achieving emission standards under section [202]." This has been interpreted as requiring consideration of regulation through motor vehicle standards under §202 prior to regulation of fuels or fuel additives under §211(c)(1)(A) [**Ethyl Corp. v. Environmental Prot. Agcy.**, 541 F.2d 1, 32 (D.C. Cir. 1976)]. This does not establish a mandatory preference for vehicle controls over fuel controls, but instead calls for the good faith consideration of motor vehicle standards before imposition of fuel controls [541 F.2d at 32 n.66]. This reflects Congress' recognition that fuel controls under §211(c)(1)(A) might logically involve controls on fuel composition itself, while vehicle standards under §202 are generally performance standards, regulating vehicle emissions and not the design or structure of the vehicle. Fuel controls might therefore lead to greater government involvement in the regulation of the manufacturing process than would be expected from vehicle controls [541 F.2d at 11 n.13].

Congress addressed this concern by requiring agency "consideration" of vehicle standards under §202 before imposition of fuel controls under §211(c)(1)(A). It is important to note that the Administrator must in good faith consider such vehicle controls, but retains full discretion in deciding whether to adopt either fuel or vehicle controls, or both [541 F.2d at 32 n.66].

In evaluating motor vehicle controls under §202 in this context, the first major point to consider is that EPA has already imposed more stringent NOx control standards on motor vehicles. The Tier 1 standards for light-duty motor vehicles and trucks require reductions in light-duty motor vehicle NOx emissions starting with model year 1994, with a percentage phase-in of the more stringent Tier 1 standards until they apply to all

---

[81] Hangebrauck, Robert P. and John W. Spence, U.S. EPA, "Ozone and Global Warming," August, 1992.

new model year 1996 and later light-duty vehicles and trucks.[82] In-use compliance with these standards is also phased-in, such that model year 1998 and later new light-duty vehicles must comply with the Tier 1 NOx standard in-use. The same applies for light-duty trucks, with model year 1999 instead of 1998 [56 FR 25787] For heavy-duty vehicles, EPA recently reduced the NOx standard to 4 g/bhp-hr, starting with model year 1998 [58 FR 15781, March 24, 1993]

While these motor vehicle and motor vehicle engine controls are expected to reduce mobile source emissions of NOx, this result is limited by certain basic facts. First, the standards only apply to new motor vehicles and engines. It will therefore take several years after the first model year of the standards before vehicles and engines certified to these standards will make up a significant portion of the motor vehicle fleet.[83] In addition, it is expected that emissions reductions based on the reduction in the NOx standard will be offset to a significant extent by an increase, over time, in total vehicle miles travelled.[84]

In addition to motor vehicle controls under §202, EPA has recently adopted or proposed other controls aimed at in-use NOx emissions from mobile sources. The enhanced inspection and maintenance (I/M) rules call for use of these more stringent I/M procedures starting with 1996 [57 FR 52950, November 5, 1992]. EPA has also proposed standards that would limit NOx emissions from new large horsepower diesel non-road engines, pursuant to §213 of the Act [58 FR 28809, May 17, 1993]. While enhanced I/M programs will directly affect the whole motor vehicle fleet, the non-road engine regulations are similar to the motor vehicle regulations under §202 in that they would apply to new non-road engines only, and therefore involve a certain time before a significant portion of this category of non-road engines is replaced by new engines certified to meet the NOx standards. Finally, the centrally fueled fleets program and the California Pilot program [§§246 and 249] will result in tighter NOx standards for a small segment of the motor vehicle fleet.

---

[82] 56 FR 25724, June 5, 1991. Also, note that the Tier 1 standards apply to light-duty trucks with a loaded vehicle weight rating of 3,750 lbs. or less.

[83] Fleet turnover is included in EPA's MOBILE5a model [58 FR 29409, May 29, 1993]. As of 1990, the median vehicle age was 7 years (i.e., one-half of the vehicles were younger than this and one-half were older).

[84] Ibid.

Additional mobile source controls, whether under §202 or under other authority such as described above, may well be cost effective and reasonable options that EPA might decide to adopt. However, there are certain limitations imposed by Congress on the adoption of more stringent standards. For example, Congress spelled out when and under what conditions EPA may promulgate more stringent NOx standards for light-duty vehicles and trucks. Congress required that EPA conduct a study on whether more stringent standards for light-duty vehicles and trucks should be adopted, and report back to Congress no later than June 1, 1997 [§202(i)(1),(2)]. Based on the study EPA must conduct a rulemaking to determine whether there is a need for such further reductions, whether the technology will be available for such reductions, and whether further reductions in emissions from such vehicles will be cost effective. If these determinations are made in the affirmative, then EPA would proceed to promulgate emissions standards that are more stringent than the Tier 1 standards [§202(i)(3)(C)]. If EPA does promulgate more stringent standards, they may not take effect any earlier than model year 2004, and no later than model year 2006.

It is clear from this that EPA has not, at this time, completed the lengthy process for determining whether or not more stringent standards should be established for light-duty vehicles and trucks under §202(i). Congress established a detailed provision spelling out the procedures to follow and the substantive determinations that must be made before such controls could be adopted. There is no indication, and EPA does not believe, that these mandated procedures and criteria preclude the exercise of discretion under §211(c)(1)(A) prior to completion of the rulemaking under §202(i). Congress required that EPA consider motor vehicle controls, but did not establish a mandatory preference for such controls and did not preclude the adoption of fuel control prior to a decision on Tier 2 motor vehicle standards.

In any case, it is clear that a decision to impose more stringent NOx standards for light-duty vehicles and trucks under §202(i) could not take effect prior to model year 2004. It would then take several years before a significant portion of the in-use fleet would include vehicles or trucks certified to a NOx standard more stringent than the Tier 1 standard. A similar situation would apply to a more stringent NOx standard for heavy-duty engines. The mandatory leadtime and stability provision of §202(a)(3)(C) would preclude imposition of more stringent NOx standards for heavy-duty engines until model year 2001 at the earliest. It would again take several years before a significant portion of the in-use heavy-duty fleet contained engines certified to a more stringent NOx standard. For non-road engines and vehicles, EPA expects to continue to explore NOx controls for this category of mobile sources. But as with motor vehicles, any new or more stringent NOx standards will only apply to new non-road engines, after providing a reasonable period for leadtime. The effect on in-use emissions is delayed based on the time needed before new non-road engines replace earlier models.

Given these circumstances, there are several important reasons why promulgation of a NOx reduction standard for reformulated gasoline is important, whether or not additional vehicle or engine controls are later adopted by the Agency. First, emissions reductions from the NOx performance standard would start as soon as the standard is applicable, with no delay based on fleet turnover time. Significant NOx emission reductions would be achieved right away, in the spring of 2000, while more stringent light-duty or heavy-duty standards would not be expected to significantly affect in-use emissions until much later in that decade. Second, a NOx reduction standard for reformulated gasoline would act to reduce emissions from all mobile sources that use gasoline, whether highway or non-road, while §202 or §213 standards only act to limit emissions from new engines or vehicles in that specific category of mobile sources. Third, this fuel control is specifically aimed at areas of the country that are in nonattainment for ozone, and is limited in time to that part of the year when ozone is of most concern. Vehicle or engine controls, in contrast, apply to all new engines or vehicles, wherever they are used, throughout the year. This fuel control thus allows a more narrow regulatory solution aimed at the specific geographical areas and time periods when control is needed. Fourth, the expected increase in vehicle miles travelled over time leads EPA to believe that this fuel control is needed to continue to achieve the in-use NOx emission reductions necessary for many areas of the country to reach attainment for ozone. Fifth, the NOx controls required in this rule will reduce NOx emissions at a reasonable cost, about $5,000 per ton. This compares favorably with the cost-effectiveness of other mobile and stationary source control strategies, as supported in section H below. Finally, the NOx fuel standard adopted here minimizes any concern there might be that a fuel control would tend to interfere in the production process by directing refiners on how to make their product. The NOx standard is not a fuel recipe, but instead establishes a performance standard, leaving refiners free to produce their gasoline in any way that achieves the desired reductions.

EPA is not at this time determining whether additional vehicle or engine NOx controls should be adopted under §202 or any other provision of the Act. Instead, based on all of the above, EPA believes that a NOx reduction standard for reformulated gasoline under §211(c)(1)(A) is an appropriate exercise of discretion, whether or not the agency imposes additional vehicle or engine NOx controls in the future.

C. Derivation of Fuel Parameter Control Costs

This section describes the methodology used to determine the costs of controlling individual fuel parameters and highlights important factors which influence the estimation of fuel parameter control costs. Also addressed are the fuel economy impacts of different fuel formulations and how they were included in the analysis. A table summarizing the costs derived from this analysis can be found in subsection 5 below.

1. Refinery Modelling and Assumptions

Refinery modelling is the best method currently available for estimating the cost of particular refinery changes, such as those which are required to produce fuel formulations which meet various emission performance standards. Mathematical refinery models are created to estimate the changes in manufacturing costs associated with the control of one or more fuel components. Optimal solutions are found by the model such that all product specifications, for gasoline as well as other refinery products, are met at the lowest cost. The change in manufacturing costs, or the incremental cost of control, is the difference between the cost of producing fuel under a defined base case and the new cost which occurs when a fuel specification is changed.

EPA received many comments on the costs used to develop the cost-effectiveness analysis which supported the proposed Phase II RFG standards. EPA used refinery modeling studies as the basis for the proposed Phase II costs. One comment suggested that the costs used in the analysis did not accurately reflect all of the costs incurred, since they were only based on manufacturing costs. In particular, if the fungibility (the ability of a mixture of two complying fuels to still comply with the standards) of Phase II fuel became an issue, then the costs would be significantly higher than those used here due to the increased complexity of the distribution system. Since EPA has demonstrated (see section III) that fungibility will not be a problem for either Phase I or Phase II reformulated gasoline, such costs do not need to be included in this analysis. An exception to this are fuels containing ethanol, since such fuels must be segregated from non-ethanol containing fuels. However, this segregation has been clearly required throughout all EPA's proposed rules regarding reformulated gasoline. Also, the refinery studies used below either use MTBE-based gasolines not requiring segregation, or use MTBE and ethanol-based fuels with ethanol prices sufficiently high to cover the costs of segregation. Thus, no additional modifications to the analysis are necessary.

Another comment suggested that it is inappropriate to use independent refinery models to generate costs for controlling individual parameters, and that aggregate nationwide models should not be used. Rather, costs should be generated from refinery models for regions with high levels of RFG production, such as PADD 1. EPA disagrees. The actual cost of producing reformulated gasoline at various NOx emission performance levels will include the costs for regions having high reformulated gasoline concentrations and those with low concentrations. Both need to be considered if the costs developed here are to be comparable to those of other NOx control programs. The costs imposed on individual regions is important when competitive and regional economic impacts are evaluated. However, national average costs should be used when comparing the cost-effectiveness of the reformulated gasoline program to that of another program.

A third comment suggested that the costs estimated in this analysis should include the costs of complying with the program, not just the manufacturing costs. This is true. However, changing the emission performance standards for Phase II should have little or any effect on the non-manufacturing costs of the program, except for fuel economy effects, which are addressed below. The costs of recordkeeping and other compliance related costs should be the same for Phase II as they were for Phase I and not depend on the level of the Phase II standards. Thus, they do not change in this incremental analysis and need not be included.

Two basic methodologies can be used to estimate the cost of various RFG standards. In one, a version of EPA's complex model for reformulated gasoline is expressed as a series of linear equations and integrated into a refinery model. The refinery model is then used to determine the lowest cost of reducing emissions of the particular pollutants of concern (VOC, NOx and toxics). This method is preferable when the emission effects of fuel changes are known and when sufficient time is available to integrate this emission information with the cost analysis. The weakness of this approach is that the results become suspect whenever the emissions model is changed. Since the refinery model was trading off up to eight fuel parameters at a time based on the coefficients of the emissions model, changes to these coefficients can lead to markedly different results.

The other method more loosely couples the emissions model and the refinery model. The refinery model is used to develop costs for varying individual fuel parameters. The effect of these fuel changes on emissions and their cost are then compared and the most cost-effective fuel modifications identified. The refinery model is then rerun, if necessary, to first modify the most cost-effective fuel parameter, then the second, and so on. This method always results in a less optimum refinery configuration (i.e., higher costs) than the first method, because the refinery model is only evaluating a small number of possible ways to achieve the specified emission reduction. Of course, care must be taken to ensure that emissions of the other pollutants of interest are being maintained or reduced while control of the primary pollutant is being evaluated.

EPA, for its own work (and the work contracted by the Agency), chose to follow the second method for both time and resource related reasons. The complex model was being developed concurrently with the cost analysis. Repeatedly modifying the refinery model to incorporate each new version of the complex model would have been costly and time consuming, and would have delayed the promulgation of the standards. As described below, as fuel modification costs using the first method have become available from other sources (only very recently), the parameter by parameter costs were compared to complex model based costs to ensure basic consistency in the two estimates of how refineries would act to reduce fuel-based emissions.

The majority of the refinery modelling on which EPA estimated its cost estimates was performed by Bonner and Moore (B & M) through an EPA contract with the Southwest Research Institute and a Department of Energy (DOE) contract with the National Institute for Petroleum and Energy Research (NIPER).[85] Bonner and Moore, for EPA, created a specialized version of their refinery model to estimate the cost of the RFG program. In addition to the work done by B & M, EPA staff ran the B & M model to determine costs for two of the parameters, as discussed further below.[86] Other refinery modelling and fuel modification costs used or considered were generated by the Department of

---

[85] Bonner and Moore Management Science, "Study of the Effects of Fuel Parameter Changes on the Cost of Producing Reformulated Gasoline," Prepared for EPA under contract through Southwest Research Institute and the National Institute for Petroleum and Energy Research. This data was made available to the public through the following document: "DOE and API Phase II Cost Estimates," EPA Memorandum from Lester Wyborny, FSSB, to the Air Docket, November 4, 1993. The Bonner and Moore work performed for this analysis was based on a revised version of the model used to generate costs for the draft RIA. This new version includes provisions to prevent dumping of fuel components into conventional gasoline.

[86] Lester Wyborny, U.S. EPA, "Aromatics and E200 Reformulation Costs," Memorandum to the Air Docket, December 10, 1993.

Energy through the Oak Ridge National Laboratory,[87] and for API,[88] WSPA,[89], Auto-Oil[90] and the National Petroleum Council[91] by the Turner, Mason and Company (Turner/Mason). A more complete comparison of EPA's analysis with the other refinery analyses may be found in section G below.

EPA used B & M-estimated Phase II RFG sulfur and olefin costs in the February 26, 1993 proposed rule. That B & M data, like the data used here for the final rule, is most attractive to EPA because unlike other modelling work on the Federal RFG program, it attempts to model the effect of the RFG program on the entire refining industry. However, commenters pointed out that the B & M modelling work for the proposed rule permitted parameter values to increase in conventional gasoline (a violation of the antidumping restrictions), which would lead to low estimated investments and decreased RFG program costs. EPA corrected that situation in the final rule by directing B & M to cap parameter levels in conventional gasoline at 1990 conventional gasoline levels. This approach, while it prevents any shifting of regulated gasoline components to conventional fuel, is overly restrictive in that most refiners will use the complex model to evaluate their conventional gasoline composition after 1994 to compare it to their 1990 gasoline. The complex model would give refiners more flexibility in meeting their antidumping restrictions resulting in some cost savings. Thus, the B & M modelling work for the final rule would tend to be slightly overstated.

2. Factors Influencing Cost

A number of economic reporting factors influence the estimated cost of producing gasoline in addition to the operating

---

[87] Lester Wyborny, U.S. EPA/FSSB, "DOE and API Phase II Cost Estimates," Memorandum to the Air Docket, November 4, 1993.

[88] Ibid.

[89] Turner, Mason & Company, "WSPA Study of the Cost Impacts of Potential CARB Phase 2 Gasoline Regulations," Prepared for the Western States Petroleum Association, November 18, 1993.

[90] Turner, Mason & Co., "Costs of Alternate Gasoline Reformulations, Results of U.S. Refining Study," Prepared for the Economics Committee of the Auto-Oil Air Quality Improvement Research Program, April 1992.

[91] National Petroleum Council, "U.S. Petroleum Refining: Meeting Requirements for Cleaner Fuels and Refineries," August 1993.

costs of a specific refinery. Those factors which impacted EPA's cost analysis are discussed below.

a. Rate of Return on Investment

The internal rate of return is an economic factor used by businesses such as the refining industry in evaluating the economic breakeven point for their investments. Although the refining industry and their consultants often evaluate potential investments at a 15 percent real rate of return, EPA has determined that the historical rate of return for the oil industry is much closer to 10 percent.[92] This appears to reflect the fact that most pre-investment analyses are inherently optimistic and do not quite yield their predicted profits. To reflect both the pre-investment actions of refiners and real results, EPA believes it most appropriate to operate the refinery model with a 15 percent real rate of return hurdle on capital investment to most accurately reflect the tradeoff between operating costs and capital. Once the refinery model has determined an optimum processing approach, capital costs are then reannualized using a 10 percent real rate of return to reflect the actual and historically acceptable performance of capital. This is very similar to the approach taken by the Auto-Oil group in their refinery modeling,[93] where they used a 15 percent real rate of return internal to the refinery model and then present the costs using both 9 and 13 percent real rates of return.

In adjusting annualized capital costs for the parameter changes described below, a 0.171 annual cost recovery factor (i.e., the fraction of total capital investment that must be recovered each year to achieve the specified real rate of return on capital) was used in lieu of the 0.226 cost recovery factor contained in the Bonner and Moore model.[94] In addition, where refinery modeling data were extracted from other studies for direct use or for comparison purposes, the cost recovery factors were adjusted using the same methodology.

b. Cost Amortization

---

[92] U.S. EPA, "Analysis of the Economic and Environmental Effects of Methanol as an Automotive Fuel," Special Report, Office of Mobile Sources, September 1989.

[93] Turner, Mason & Co., April 1992.

[94] U.S. EPA, "Control of Sulfur and Aromatics Contents of On-Highway Diesel Fuel," Draft Regulatory Impact Analysis, July 1989.

Phase II VOC and NOx emission controls are necessary only during the high ozone period. Hence, any capital costs associated with fuel component controls implemented solely to achieve such emissions reductions were amortized only over that period. In the NPRM, EPA used a 4.5 month amortization period. Members of the refining industry and others commented that a 4.5 month period is too short because the high ozone period is 4.5 months long at terminals and refiners will have to begin making RFG in advance to ensure that the fuel distribution system up to and including terminals will have turned over before the starting date. Previous analyses performed in support of EPA's RVP control program showed that fuel had to be produced between 0 and 60 days prior to arrival at a terminal. Thus, EPA has extended the RFG production period to 5.5 months, or 168 days.

The amortization of capital costs estimated by B & M over the high ozone season was accomplished by the following steps. B & M evaluated the cost of reformulating gasoline by running both winter and summer refinery models, which operated off the same set of capital equipment. Thus, the seasonal differences in fuel quality and production volumes were analyzed by the model and any capital equipment built to meet one season's requirements (in this case the summer's) was available during the other season as well. B & M's total annualized capital cost (in $ per year) for each incremental fuel scenario was first multiplied by the ratio of the capital recovery factors described above and then divided by the volume of gasoline production for the ozone period. Incremental annual operating costs (again in $ per year) were taken from both the winter and summer periods and divided by summer RFG production, though practically speaking, those occurring in the winter were quite small and generally negligible. Thus, the operating cost per gallon RFG was essentially that determined in the summer portion of the model.

Since the studies by Turner, Mason, and Co. for the Auto-Oil program and WSPA were completed solely on an annual basis, it was necessary to adjust the costs reported in those studies by amortizing the capital related costs over the high ozone season. This was accomplished by separating the total manufacturing cost into an operating cost and an annualized capital cost, multiplying the capital cost component by the ratio of 12 months to 5.5 months and by the ratio of the capital cost recovery factors described above, and then adding the adjusted capital cost to the operating costs to obtain the adjusted manufacturing cost. This adjustment made their costs consistent with the methodology used for the B & M data.

c. Consideration of Regional Costs

The refinery models used to estimate the costs of reformulating gasoline were designed to model refinery operation changes on a regional basis. Consistent with this approach, EPA directed B & M to divide the nation's refining capacity into three regions: Region 1 corresponds to PADD 1 (Petroleum Administration for Defense District 1), Region 3 to PADD 3, and Region 2, which covers the remainder of the U.S., excluding California.[95] The modelling and the subsequent cost analyses were based on reformulated gasoline production from these three areas.

EPA had B & M evaluate the refining costs for two separate RFG demand scenarios which bracketed the possible opt-in scenarios envisioned for the RFG program. In one, named scenario "A," the covered areas included the mandated nine extreme and severe areas (minus those of California), and those areas which had opted-in to the RFG program as of the summer of 1992. The second, named scenario "B," included the nine mandated areas (minus those in California), all ozone nonattainment areas which have currently opted into the RFG program (prior to Kentucky's recent decision), the Northeast states which are members of the Ozone Transport Commission (OTC), and all other serious and moderate nonattainment areas (California areas excepted). In the case of the OTC states, the attainment areas were included as well as the nonattainment areas. This would mean that all the gasoline sold in the OTC areas would be RFG.

In anticipation of many more nonattainment areas opting-in to the RFG program, scenario "B" was chosen and analyzed for the cost of the RFG program. At the end of the study, however, additional areas and the OTC had still not opted into the RFG program as anticipated by using the "B" scenario. In fact, very few areas have opted into the program since the proposal was made; the nonattainment areas of Kentucky are the only new additions. Analyzing the level of opt-in at this time, only 31 percent of the nation's gasoline (excluding California) would be RFG, which is 22 percent less than that used in the study. If the level of opt-in remains at the current level, it is likely that the costs of the program will have been overstated. However, if many more areas opt-in to the program and the level of RFG approaches that which was modelled, then the costs will more closely represent that of the case modelled.

---

[95] California is imposing its own Phase II reformulated gasoline requirements on gasoline sold in California beginning in 1996. The California Phase II requirements are likely to require more severe reformulation than that of the Federal Phase II reformulated gasoline and to exceed the federal performance standards. Thus, it is likely that the Federal Phase II standards will not affect fuel composition in the State of California.

The amount of RFG required was calculated by applying the fraction of the total state population living in the covered areas to the total state gasoline demand of the year 1990. These fractions were then expressed as a fraction of national gasoline demand and listed in the draft Regulatory Impact Analysis. The calculated nationwide percentage of RFG was next adjusted upward by 10 percent to account for "spillover." Spillover is the amount of RFG which is expected to be sold either outside a covered area, or before or after the required period of the program.

EPA determined this spillover rate based on information available on the oxygenated fuels program, on its own analysis, and on input from B & M. The oxy-fuels program has been estimated to have a 5 percent spillover rate. This program, however, involves minimal reformulation and, in some cases, the fuels can even be blended at the terminals rather than at the refinery. The greater reformulation required to make RFG requires that refiners begin producing it sooner to ensure that RFG formulation will meet the emission reduction standards at the furthest point from the refinery by the program start date each year. However, RFG costs are expected to be greater than those for the oxy-fuel program. Thus, there will be a greater incentive to minimize unnecessary costs, such as spillover. Based on the difference between the two programs, EPA recognized that the spillover rate for the RFG program would be larger than that of the oxygenate program. B & M, based on their expertise in fuel distribution, recommended a 10 percent rate, which seemed reasonable considering the differences between the two programs. Hence, EPA decided to use 10 percent as the spillover rate.

The national RFG production estimate based on the scenario described above, was then subdivided among the three gasoline producing regions, facilitating the modelling on a regional basis. To do this, B & M first placed each RFG area into one of the three regions to determine regional demand for RFG. B & M then used the historical movement of finished gasoline to estimate which regions would supply each region's fuel consumption. Based on this approach, the projected amount of RFG produced by each region is listed in Table VI-1. The last column of Table VI-1 lists the fraction of gasoline produced within that region which is projected to be RFG.

Table VI-1:
Reformulated Gasoline Production Among Various Regions

Bonner & Moore Region (PADDs Included)	Fraction of Total RFG Produced in U.S.	Fraction of Gasoline in Region that is RFG
Region 1 (PADD 1)	0.21	0.96
Region 2 (PADDs 2, 4, and 5; excl. CA)	0.24	0.36
Region 3 (PADD 3)	0.55	0.55

These figures are useful in understanding the cost data in several ways. The regional RFG production fractions listed above were used to weight the costs for each region and develop a national cost estimate. The larger the contribution by any one region to the quantity of RFG produced nationally, the larger the effect of that region's costs on the overall RFG program cost. Hence, the fact that most RFG will be produced in Region 3 is useful in understanding the various trends in costs. Also, the fraction of gasoline produced as RFG in any one region is useful in understanding why costs may be high in one region and low in another. The higher the percent RFG, the higher the relative cost, since more severe reformulation of a refinery's gasoline pool is likely required. Since the assumptions regarding the use of reformulated gasoline by the OTC are significantly higher than what is now expected, the costs estimated for Region 1 are higher than those likely to occur. The Region 1 costs would be considerably lower if a larger non-RFG market had been assumed, since refiners would have had more flexibility in producing their entire product slates.

For similar reasons, marginal costs to produce RFG may be higher for small refiners than those estimated by the regional refinery models, unless a sizeable market exists for conventional fuel. Given the apparent unlikelihood that the Northeast OTC will use Title I of the Clean Air Act to require RFG in attainment areas as well as non-attainment areas, it appears that all regions of the U.S., even Region 1, will have sizeable conventional gasoline demands. This demand will provide a profitable conventional fuel outlet for the fuel from the small, high RFG cost refiners.

In contrast to the Bonner and Moore studies, the above-referenced Turner, Mason, and Co. studies performed for both WSPA and Auto-Oil (and some of the studies performed for API) assumed all the gasoline produced in a specific PADD was reformulated.

Because of the lack of refining flexibility expected from 100% production of RFG, the costs derived from these studies are likely higher than what would be experienced by the average refiner under the expected level of participation in the program. Hence, for the fuel parameter changes for which the Turner/Mason costs had to be used, the overall cost and cost-effectiveness are expected to be overstated and therefore somewhat conservative.

There are a few cases when multi-regional costs were not available for developing national costs. This occurred in two cases when the B & M refinery model data was supplanted by other data determined to be more appropriate. However, to be consistent with the multi-regional approach, it was necessary to develop adjustment factors that would approximate a broader source of costs. These factors would adjust a single regional cost to a (non-California) national cost.

For these cases, the regional to national cost adjustment was made by the same methodology used in the draft RIA. In that case, Turner/Mason, working for Auto-Oil,[96] determined the refining costs to reduce olefins, T-90 and aromatics, and to add oxygen, in each PADD. The cost from each PADD was integrated with the projected production of RFG to develop regional adjustment factors. The following table summarizes the adjustment factors used to adjust costs from certain regions of interest to a non-California national cost, representing the RFG costs in all three regions.

Table VI-2:
Factors for Adjusting Regional Costs to National Costs

Adjustment Made	Adjustment Factor
PADD 5 to National Cost	1.38
PADD 3 to National Cost	1.14
PADD 1 to National Cost	0.89

One comment on the methodology used in the proposal presented results of an informal survey of several members of the refining industry, and used these results to argue that EPA's analysis understated the costs of Phase II RFG. Although the commenter acknowledged that the results were based on only a fraction of the refiners who will be affected by this rulemaking, the commenter summarized the results as follows. First, a number

---

[96] Turner, Mason & Co., April 1992.

of large refineries will not make RFG (i.e., they will only produce conventional gasoline). Second, for the refiners that do make RFG, RFG will constitute a large fraction of the products from that refinery. Finally, costs will likely vary between refiners, and most refiners will be limited by one or two parameters in making RFG. These results led to the conclusion that RFG costs will be higher than those proposed by EPA.

While the commenter's interpretation that the survey results indicates that costs will be higher than those estimated by EPA, the survey can also be interpreted to indicate that costs will be lower than those represented by the oil industry and thus support EPA's approach to estimating costs. First, the fact that not all major refiners plan to produce reform argues for reduced costs, not increased costs. All the refinery models employed to estimate RFG costs model all the refineries in a given region or PADD. These refineries include those whose process configuration is advantageous for producing RFG and those whose processes are not. It is most likely that the refiners who will choose not to make RFG are the ones who cannot do so in a cost-effective manner. If the production costs for such refineries were removed from the calculation of regional costs, the regional costs would be lower than the averages calculated by the existing models.

Second, how the connection between fewer refineries planning to produce RFG and higher RFG fractions for those refiners should affect the use of EPA's RFG cost estimates is not clear. The oil industry's refinery modelling assumed high RFG fractions for all refineries and that is clearly more onerous than the actual situation is likely to be. EPA, through its refinery modelling by Bonner and Moore, assumed more realistic RFG fractions and allowed the refinery model to determine how to produce RFG. One industry comment on EPA's approach has been that it allows the model to build too few, but very large, units to satisfy the RFG demand for an entire region or PADD. This approach is actually confirmed by the oil industry survey. While EPA's approach could potentially underestimate costs by allowing the refinery model too much flexibility in shifting low and high emission components around within this massive regional refinery, EPA finds no evidence that this actually occurred. When the model occasionally produced very low costs for Region 2, which had the lowest RFG fraction, EPA decided not to use these results, but instead based its RFG costs on those estimated by Bonner & Moore for Regions 1 and 3.

Third, the survey indication that most refiners' production of RFG will be limited by one or two fuel parameters is consistent with EPA's modelling approach of focusing on improvements in a single fuel parameter while holding all others constant or allowing them to improve (i.e., lower emissions). While the sophistication of imbedding the complex model into a refinery model is still technically preferred, the survey results indicate that the added sophistication may not significantly affect the results.

3. Fuel Component Control Costs

The costs of modifying the various fuel parameters have been significantly updated relative to those in the draft RIA. In the draft RIA, it was generally necessary to extrapolate costs representing only a single region or PADD to the entire nation. Most often the region for which costs were available (i.e., California) would not even be producing Federal Phase II RFG since the California Phase II RFG standards are more stringent. Although an attempt was made to develop national average costs from that data, such costs are almost inherently less accurate then those developed by actually modelling the refineries of each covered region.

Since the time the draft RIA was developed, a number of studies (performed by both B & M and Turner/Mason) have evaluated RFG costs in more than one region and generally provide much improved estimates of fuel reformulation costs. In addition, EPA funded its own study. The greater access to cost data allows EPA more capabilities in determining and comparing RFG program costs.

The following sections describe the costs estimated for controlling each fuel parameter, including any adjustments made which have not already been described. After all fuel parameter costs have been described and combined with the complex model to estimate the cost-effectiveness of emission control, the results will also be compared to those of refinery studies which imbedded the complex model into the refinery model to generate cost-effectiveness estimates directly. The final costs used in this analysis are summarized in subsection 5 below. The derivation of the final costs are shown in Tables VI-A1, VI-A2, VI-A3 and VI-A4 in the Appendix.

a. RVP Control Costs

The B & M refinery model were used to project the cost of RVP control.[97] The cost of RVP control was modelled from 8.0 psi down to 7.3 psi for the first increment, down to 7.1 psi for the second increment, and down to 6.5 psi for the third increment. Although the ranges over which the parameter values changed for each region did not agree exactly, the costs for the most similar ranges were grouped together. The fuel economy adjusted costs for a RVP reduction from 8.0 to 6.5 psi were about 0.7¢/gal. As shown below in section F, reducing RVP to control VOC emissions

---

[97] Lester Wyborny, U.S. EPA/FSSB, "DOE and API Phase II Cost Estimates," Memorandum to the Air Docket, November 4, 1993.

is very cost effective all the way down to 6.5 RVP. Although a further reduction below 6.5 psi would likely be cost effective, such reductions were not considered because, as discussed in later sections, it is not known whether driveability problems would result at lower RVPs. Also, no exhaust emission data exist below 6.5 RVP, so possible increases in exhaust emissions could not be ruled out.

The low costs for RVP control estimated by the B & M model cost data are corroborated by other studies which also have evaluated the cost of RVP reductions. The NPC study showed that when the fuel economy effect is taken into account, initial RVP reductions down to 7.2 psi were virtually at no cost, while further RVP reductions down to 6.5 psi were made at a 1.2¢/gal cost. Although cost figures were not available from the DOE study, DOE concluded that RVP costs for VOC control were much cheaper and cost-effective relative to other any parameter changes which would also reduce VOC emissions.

b. Sulfur Control Costs

The B & M regional refinery models were also used to estimate the costs of sulfur control. Sulfur control was modelled down to 250 ppm for the first increment, to 160 ppm for the second increment, to 100 ppm for the third increment, and to 50 ppm for the last increment. The sulfur costs for the value of 138 ppm sulfur used in setting the NOx standard was interpolated from the other data using a curve fitting program available in Cricket Graph. As shown in Table VI-A2 located in the appendix, the B & M Region 2 costs are quite low compared to those for Regions 1 and 3. This is likely due to the low fraction of RFG being produced in Region 2, as described above. These very low costs could be realistic, representing the ability of refineries to shift blendstocks between conventional fuel and RFG to reduce sulfur very inexpensively. However, they could also represent an unrealistic flexibility to do this, given that the entire region's refinery capability was combined into a single refinery. Insufficient time prevented further analysis to resolve this issue. In order to avoid the possibility of underestimating the cost of sulfur control, the Region 2 costs were excluded from the analysis and the nationwide cost was generated by weighting the Region 1 and 3 costs using renormalized weightings from Table VI-1 above.

The B & M Region 3 sulfur control costs were compared to Region 3 (PADD 3) cost data generated by Auto-Oil and API, both studies performed by Turner, Mason, and Co. These other studies were adjusted to a 10% rate of return on investment and the capital costs were amortized over the high ozone season to make the studies consistent. As shown in Figure VI-A1 (see the Appendix), the Auto-Oil costs turned out to be very similar to the B & M sulfur costs over the range from 340 ppm down to 100 ppm; about 1.5-1.6¢/gal. The API costs (based on refinery modelling cases VAT and VH), however, are about twice that of the Auto-Oil and B & M costs over a smaller range. The API parameter data for those refinery model runs indicated that there were also some increases in E200 and E300 along with the sulfur reductions.

It is feasible that the refinery model used by API, with the complex model integrated in the model, would have made these changes to realize the necessary reductions in VOC. However, it is doubtful that the model would have actively reduced these parameters considering their higher cost per pollutant reduced as determined in this study. Instead, it is likely that they increased as a result of refinery changes associated with reductions in sulfur or other parameters. If one assumes that E200 and E300 were purposefully reduced by the API version of the model, thereby incurring a reformulation cost, the cost for that refinery model run can be adjusted to account for the full E200 and E300 reduction. The E200 and E300 costs derived in this analysis were used for that purpose. The adjusted API costs are indicated on Figure VI-A1 as a dashed line. Even after this adjustment, the API costs are still substantially higher than that those from B & M and Auto-Oil.

Because of the importance that sulfur reductions play in controlling NOx emissions, EPA held a number of discussions with DOE and API in an attempt to determine the differences between the API costs and those generated by B & M and other studies, like the Auto-Oil study compared here. The discussions centered around several documents which summarized the approaches or critiqued approaches of these models. These documents include a list of the underlying assumptions used in the API refinery modeling runs by Turner/Mason, a critique of the B & M refinery runs by Turner/Mason, and a reply by B & M to the Turner/Mason critique.[98] The numbers used in this final analysis represent EPA's best estimate of the costs of sulfur control, taking all of these other issues into account.

c. Olefins Control Costs

EPA based its cost of olefin reductions on those estimated by Turner/Mason for WSPA[99] instead of those generated by B & M. The B & M estimates were not used because much of the olefin content was used to make oxygenate (in the form of TAME or MTBE) prior to the olefin reduction refinery modelling runs. Since the

---

[98] "Documents Concerning Refinery Modeling for the Reformulated Gasoline Program," EPA Memorandum From Lester Wyborny, RDSD to the Docket, .

[99] Turner, Mason & Company, November 18, 1993.

olefin level was already partially reduced, the cost of reducing olefins in a subsequent step may not reflect the true cost of olefin control at lower oxygen levels. Based on the results of the cost-effectiveness analyses described below, EPA does not expect the overall RFG pool oxygen content to increase much above 2.1 weight percent prior to the reduction of olefins for NOx control, which should reduce the olefin demand from the levels predicted by the refinery modelling.

Turner/Mason estimates of olefin control costs for both WSPA and Auto-Oil were considered for use here. The WSPA estimates were determined to be more desirable for cost-effectiveness purposes because they were expressed as a series of reductions instead of one single large reduction. To compensate for the fact that the WSPA study was based solely on California refineries, the WSPA olefin costs were increased by the 38 percent adjustment factor described above. The WSPA analysis contained cost data for olefin reduction in increments of 11 down to 8 percent, and then down to 5 percent. The cost to decrease olefins from 11 to 8 percent was estimated to cost about 0.4¢/gal, while further reductions to 5 percent were projected to cost 2¢/gal.

d. Oxygen Control Costs

For the February 26, 1993 proposed rule, EPA based its oxygenate costs on the Auto-Oil (A/O) study of the RFG program, which relied upon MTBE as the oxygenate. The purchased price of MTBE was estimated by A/O to be about 60¢/gal. In comments received on the proposed standards, it was suggested that the analysis in the draft RIA underestimated the cost of oxygenate because it used current contract prices for MTBE rather than projections of future prices. As will become evident below, the final rule is based on much higher oxygenate market prices, and even includes a price range of oxygenate costs to account for potential future price fluctuations. Furthermore, the choices of oxygenates was expanded beyond MTBE to include TAME and ethanol.

For the final rule, the per-gallon costs for an oxygen increase from 2.1 percent (the control level under Phase I averaging) to 2.7 percent were initially taken from the B & M refinery model cost data. The model could choose among the production or purchase of TAME and MTBE, or the purchase of ethanol. TAME and MTBE were generally produced at the refinery although MTBE was sometimes purchased from the outside, while the ethanol was always purchased from the outside. Based on this approach and the built-in economic criteria, the model generally preferred ethanol as the most cost effective choice for the addition of oxygen for Phase II RFG.

Table VI-3 below summarizes the oxygenate prices used by the model. To account for the historical fluctuations in oxygenate prices, the cost analysis was expanded to consider a range of oxygenate prices. Table VI-3 also contains the ranges in oxygenate prices which were used in this expanded analysis. The Phase I cost analysis located in section V contains a description of the reasoning behind the values used in the oxygenate price range. In general, the range represents the range in oxygenate prices observed over the last several years.

Table VI-3: Oxygenate Costs

Oxygenate	B & M Model Costs	Cost Range Used by EPA
Ethanol	$1.20	Before Subsidy $1.20 - $1.60 After Subsidy $0.66 - $1.06
MTBE	$1.05	$0.80 - $1.05
Methanol	$0.57	$0.40 - $0.57

The Phase II RFG oxygen addition costs for Regions 1, 2 and 3 determined by the B & M refinery model were then adjusted to reflect this revised range of possible oxygenate prices. In Table VI-4 below, the cost of oxygenate addition determined by the B & M refinery model is listed first followed by the adjusted costs. The regional oxygenate costs were combined into a U.S. cost by weighting each regional cost by the fraction of RFG produced by that region (see Table VI-1). The national average cost was used to determine the cost-effectiveness of adding oxygen to Phase II RFG (above the level of 2.1 wt% oxygen).

Table VI-4: Phase II RFG Oxygen Addition Costs

Geographic Area	Estimated RFG Costs B & M Refinery Model (¢/gal RFG)	RFG Cost Range (¢/gal RFG)
Region 1	1.37	0.62 - 1.23
Region 2	1.12	(0.25) - 0.76
Region 3	1.16	0.32 - 1.00
U. S.	1.20	0.24 - 0.99 (0.61 average)

e. E200 Control Costs

E200 control costs were developed using EPA's in-house version of the B & M model. No other studies evaluated the costs of controlling E200 alone. (E200 was monitored and varied in a number of the refinery studies which imbedded the complex model in a refinery model and which are evaluated in section G below.) While these costs were not reviewed by B & M personnel, in general, the E200 costs seemed reasonable for the changes in gasoline characteristics that occurred. However, because the refinery model was not specifically designed to evaluate all of the E200 control technologies currently available, the costs may be somewhat high. The B & M model estimated the costs of controlling E200 in 3 percent increments.

f. E300 Control Costs

E300 control costs were taken from the Auto-Oil study. Attempts were made to derive the E300 costs in-house using the B & M model. Results of these modelling runs were insufficient, however, because the costs quickly escalated for even small increases in E300. A review of the refinery processes used by the model to increase E300 revealed that the model was not programmed with sufficient analytical tools to make accurate estimates. Thus, the Auto-Oil E300 costs were used instead. Although WSPA costs were also available, those costs were from refinery runs of Padd 5 refiners, which are not even covered by the Federal RFG program. The Auto-Oil costs from Padd 3 are therefore considered more relevant to this study. Furthermore, because both studies were done by Turner/Mason, the costs should have been be derived using nearly identical approaches.

The E300 costs based on Auto-Oil were calculated from T90 control using a formula derived by EPA to convert to E300, the derivation of which is described in section III.[100] The costs were adjusted upward by 14 percent to project PADD 3 costs to nationwide costs. For the E300 study for Auto-Oil, Turner/Mason used increments from 84 to 88% evaporated, 88 to 91% evaporated, and 91 to 96% evaporated. The adjusted cost to increase E300 to 88 percent cost 1.1¢/gal, to increase to 91 percent cost 1.9¢/gal, and to increase to 96 percent cost about 4¢/gal.

g. Aromatics Control Costs

Aromatics control costs were derived from the B & M refinery model by EPA. The aromatics concentration was reduced to 28

---

[100] E300 was calculated from T-90 using the formula: E300 = 155.033 - (T90 x 0.22)

volume percent for the first increment, down to 24 percent for the second increment, and down to 20 percent for the third increment. When the Region 2 costs were compared to Regions 1 and 3, it was decided that their costs should not be not used because of their much lower values. As stated above, because there was insufficient time to verify that the less expensive parameter reductions generated by the Region 2 refinery model for some parameters were made in a realistic fashion, EPA elected to err on the conservative side and drop the costs from the cost analysis. The aromatics costs were therefore based only on Regions 1 and 3.

The B & M aromatics costs were compared to those generated by WSPA and Auto-Oil (which, as PADD 5 models, were adjusted to a nationwide basis by the 1.38 factor developed previously). The WSPA costs were determined to be 2.9 cents per gallon over a 3 percent aromatics change between 25 and 22 percent. The Auto-Oil costs proved to be 12 cents per gallon over an aromatics reduction from 45 vol% to 20 vol%. To provide for a comparison among the data, the Auto-Oil cost was ratioed down to represent a 3 percent aromatics change and the cost was determined to be 1.7 cents per gallon. Both the WSPA and the adjusted Auto-Oil costs are higher than that generated from the B & M models which, for a reduction from 25 to 22 percent, was projected to cost 1.3 cents per gallon. The methodology used by the B & M model is different from that observed in the Auto-Oil study and results in less aromatics reduction upon the addition of oxygen. Considering that aromatics was not a cost-effective means for reducing any of the controlled pollutants even at the lower B & M control cost, and due to time and resource restraints, EPA did not evaluate further the reason for the cost differences among the different models.

The first incremental aromatics reduction from the B & M cost data was not needed in the cost-effectiveness analysis because the aromatics concentration in the Phase I RFG parameter data, which formed a starting point for the Phase II analysis, had already decreased to a level below the lower value of that range. As described more fully below in the parameter interrelationships section, it was necessary to adjust the Phase I parameter values to ensure that the final Phase I RFG parameter values would reflect a sufficient aromatics reduction to meet the toxics requirements.

4. Fuel Economy Effects

Reformulating gasoline to reduce emissions can affect the vehicular fuel economy. In the draft RIA, EPA found that the change in a fuel's heat content is currently the best indicator of the change in fuel economy between fuels of different compositions. In this section, the methodology for estimating the costs attributed to the changes in the heat content of RFG will be described. The changes in fuel economy are associated with specific RFG parameter changes, including increased oxygen content, reduced RVP, reduced aromatics content, and increased E300. As found in the draft RIA, most other fuel components are expected to have relatively minor effects on fuel economy and thus the impacts of these effects were not included in the analysis.

a. Changes in Fuel Economy

In the draft RIA, EPA listed the estimated fuel economy impacts of various fuel parameter changes as determined by Auto-Oil and ATL (under contract with EPA) testing. However, the test data for some of the parameter changes varied significantly in magnitude. This variance is largely attributed to measure uncertainty in both the fuel and emissions, as well as the effect of changes in other fuel parameters that were not controlled by the test programs and variability in vehicle operation between tests. In the draft RIA, EPA found that fuel economy generally changed in proportion to fuel heat content. No comments that were accompanied by any data or engineering analysis not already considered in the draft RIA were received challenging this finding.

In order to estimate the effect of various fuel reformulations on heat content and, therefore, fuel economy, EPA had B & M calculate the heat content of reformulated gasoline as they ran their refinery models for economic purposes. This was done for oxygenate addition and RVP reduction. These calculated effects were used in lieu of the test data, since the test fuels did not necessarily reflect the other changes in gasoline properties likely to accompany either oxygen addition or RVP control. One drawback of B & M calculating the fuel economy effect for RVP is that the evaporative effects were not considered; the RVP adjusted costs for fuel economy effects are expected to be somewhat overstated for this reason. B & M did not evaluate the fuel economy impacts of adjusting E300 or aromatics, and thus the available test data was used. Since the test data also showed a very minor fuel economy impact for olefin reductions, B & M was not asked to evaluate olefins for their fuel economy effect and any effects were considered negligible. Sulfur has not been found to cause a fuel economy impact and also was not studied. The fuel economy impact estimates made from the test data and B & M study are listed below in Table VI-5.

Table VI-5: Fuel Economy Impacts of Fuel Parameter Control

Parameter Studied	Study	Energy Impact per Unit Parameter Change
Oxygen - MTBE	Auto-Oil I	-0.9/wt% increase
	Auto-Oil VI	-0.70/wt% increase
	EPA ATL (Phase I)	-0.5/wt% increase
	Bonner and Moore	-1.05/wt% increase
Oxygen - EtOH	Auto-Oil VI	-0.61/wt% increase
	Bonner and Moore	-0.95/wt% increase
Oxygen - ETBE	Auto-Oil VI	-0.64/wt% increase
RVP	Auto-Oil VI	2.6/psi decrease
	EPA ATL	0.7/psi decrease
	Bonner and Moore	0.3/psi decrease
T90(E300)*	Auto-Oil I	-0.02/deg F increase (-0.0732/%E300 decrease)
	EPA ATL	0.003/deg F increase (0.013/%E300 decrease)
Average: T90/E300		-0.009/deg F increase (-.03/%E300 decrease)
Aromatics	Auto-Oil I	-0.12/vol %

* E300 was calculated from T-90 using the formula: E300 = 155.033 - (T90 x 0.22)

For adding oxygenate, B & M first calculated that conventional gasoline contains about 4.75 million BTU per barrel, and MTBE and ethanol, the oxygenates blended in the largest quantities in their analysis, contain 3.92 and 3.19 million BTU per barrel, respectively. They then calculated the decrease in energy that occurred by supplanting some of the conventional gasoline with oxygenate to yield a fuel containing 2.1 weight percent oxygen (an 11.5 volume percent addition of MTBE or 6.0 volume percent addition of ethanol). The calculation showed that the heating value of the resulting gasoline-MTBE blend would be 2.1 percent less energy dense than conventional gasoline, or that the gasoline/ethanol blend would be 1.9 percent less energy dense than conventional gasoline. As an approximation, EPA assumed that either oxygenate would reduce the energy content of gasoline by about 2 percent.

B & M made a similar calculation for reducing RVP. In their analysis, butane was the only component removed to control RVP; an eight percent decrease in butane content resulted in a 1.2 percent increase in heating value. EPA then calculated that based on an RVP blending value for butane of 60 psi, each two percent reduction in gasoline butane content would result in about one psi change in RVP. The application of these two figures determined that each psi decrease in RVP would result in about a 0.3 percent increase in fuel economy.

b. Fuel Consumption Costs

The percentage changes in fuel economy identified above can be converted to a monetary cost by multiplying them by the retail (less taxes) price of gasoline, here estimated to be 85 cents per gallon. This price is 5 cents per gallon higher than that used in the draft RIA to accommodate the cost of producing Phase I RFG (the high end of the range presented in Section V). This fuel economy cost is then added to the refining cost. The effects of this calculation are demonstrated in the following summary table.

5. Summary of Fuel Parameter Control Costs

The refinery costs determined by the methodologies explained above are listed below in Table VI-6. The costs are expressed in cents per gallon per unit change in the given parameter (i.e., for RVP, the unit quantity is one psi) as indicated by the last column. In all cases, the cost is applicable to the range incremental to the previous range. For example, the cost for sulfur reduction down to 160 ppm covers the cost for reducing sulfur from 250 ppm to 160 ppm, and does not include the cost of reducing sulfur to 250 ppm. To determine the cost for reducing a parameter over part or all of a range, the change in fuel parameter value (final value minus the starting value) would be multiplied by the fuel economy adjusted cost.

The first three columns of the summary table show the cost in each region, as determined by each individual regional refinery model. Where a space for a regional cost is left blank, that cost was either not determined by the B & M refinery model, or the cost was not used for the reasons described above. The regional costs were factored into a national cost using the expected fraction of RFG produced by each region, as described above. The national cost is then adjusted by the fuel economy effect calculated for that parameter, one exists.

Table VI-6: Incremental Costs for Individual Parameter Changes

Fuel Parameter & Control Level	National Average Cost	Fuel Economy Effect (c/gal/x)	Fuel Econ. Adjusted Cost	Units (for columns 2 and 5) (c/gal/x)
RVP to 7.3	0.412	0.220	0.192	x = psi
RVP 7.1 to 7.3	0.416	0.220	0.196	
RVP 7.3 to 6.5	0.427	0.220	0.207	
Sulfur to 250	0.00203	-	0.00203	x = ppm
Sulfur 250 to 160	0.00625	-	0.00625	
Sulfur 160 to 100	0.0125	-	0.0125	
Olefins to 8.0	0.179	-	0.179	x = %
Olefins 8.0 to 5.0	0.922	-	0.922	
Oxygen 2.1 to 2.7	1.14	0.85	1.99	x = %
Aromatics to 28	0.0664	0.085	0.152	x = %
Aromatics 28 to 24	0.305	0.085	0.391	
Aromatics 24 to 20	0.367	0.085	0.452	
E300 (+4) 84 to 88	0.285	0.026	0.311	x = %
E300 (+3) 88 to 91	0.645	0.026	0.671	
E300 (+5) 91 to 96	0.634	0.026	0.660	
E200 (+2,+3) to 58	0.125	-	0.125	x = %
E200 (+3) 58 to 61	0.439	-	0.439	
E200 (+3) 61 to 64	0.989	-	0.989	

D. Derivation of Fuel Parameter Interrelationships

Controlling one parameter of a fuel (a fuel property or component) can affect the levels of other fuel parameters, since the refiner will compensate for the change by adjusting the fuel composition to meet minimum gasoline specifications in the manner which is most cost effective for its refinery. This effect of one fuel parameter on another is hereafter referred to as an interrelationship. To be able to determine the emissions that would result from a change in a single fuel parameter, it is necessary to estimate the final fuel composition based on these interrelationships.

1. Methodology

For the draft RIA, factors representing fuel parameter interrelationships (or fuel component interactions, as they were called in that document) were developed from the available refinery modelling data. In response to this information, EPA received several comments. One stated that the change in fuel properties was underestimated for some parameters and overestimated for others. Specifically, the commmenter claimed that EPA appeared to recognize the dilution effects of adding oxygen, but that it was not clear that this was always included in the analysis. Since specific references to the areas where EPA overlooked the impact of adding oxygen, or other cases where EPA over- or underestimated the impacts of various fuel parameters, it is difficult to respond directly to this comment. As explained below, the analysis of parameter interrelationships has been revised based on new information and is believed to be reasonable. When an interrelationship between two parameters was identified, this was used consistently throughout the analysis.

A second comment raised a concern with the fact that EPA used data from a single PADD when developing these parameter relationships, assuming that the effects seen in this one PADD would be experienced in other PADDs (which is not necessarily the case). The refinery modelling data presented in the draft RIA and used to develop parameter interrelationships was limited in its applicability to the RFG program for several reasons. The data was based largely on a single PADD (usually PADD 5, in some cases PADD 3) model, not on multiple PADD data (which could be averaged to develop a national factor). The refinery costs and operating parameters for one PADD are unlikely to be representative of what a typical refinery elsewhere in the country would experience. Furthermore, refineries in PADD 5, which supply California's fuel, are somewhat different than refineries elsewhere because of the greater percentage of hydrocracker capacity in the PADD, and because of the heavier crude feedstocks used there. California is developing its own RFG program and Federal Phase II RFG will not likely be produced in PADD 5. Hence, for most fuel parameter changes analyzed in this study, parameter interrelationships were developed from new refinery modelling data for multiple regions, generated by the Bonner and Moore (B & M) refinery model; exceptions to this are discussed below.

Data was generated for each of the three regions defined by B & M (discussed in subsection 2.c above). The methodology for determining parameter interrelationships was similar to that used to estimate costs. Each parameter interrelationship was determined for the entire range over which the primary parameter was changed. The interrelationship was expressed as a ratio of the percent change in the secondary (uncontrolled) parameter to the overall change in the primary (controlled) parameter. For example, if reducing the sulfur level from 250 ppm to 160 ppm resulted in a change in olefin content from 5.5 vol% to 5.3 vol%, then it was assumed that for every change of -90 ppm sulfur (within the approximate range of 250 to 160 ppm), the olefins content would change -3.8% [=(5.5-5.3)/5.5 x 100]. The interrelationship factor would thus be 0.042% olefins/ppm sulfur [=-3.8%/-90ppm].

Interrelationship factors were developed for each of the three refining regions. A single interrelationship factor representing the average national impact was then developed by weighting the factor for each region by the fraction of total (national) RFG produced by that region (see Table VI-1 above).

These factors were included in the RFG cost-effectiveness analysis only if it was determined that the factors represented a significant and consistent relationship between the two parameters. These engineering judgements were made on the basis of the magnitude of the factor, the consistency of the trend between the three regions, and the confidence in the refinery modelling outputs (i.e., did the results agree with what would likely happen in a refinery).

The following table presents the results of this analysis of parameter interrelationships. The factors listed in the last column are national parameter interrelationship figures derived from the various refining regions and were used in the RFG cost-effectiveness analysis to represent the interrelationship of various fuel parameter changes. Details of the derivation of these factors are provided below.

Table VI-7: Fuel Parameter Interrelationship Factors

Controlled Parameter	Range of Control	Uncontrolled Parameter	(% Change in Uncontrolled)/ (Real Change in Controlled)
Phase I: Oxygen Benzene RVP	Up to 2.1 wt% Down to 0.95 vol% Down to 8.0 psi	Sulfur	91% of Baseline Value[1/]
		E200	114% of Baseline Value[2/]
		E300	102% of Baseline Value
		Aromatics	80% of Baseline Value
Sulfur	Down to 250 ppm	Olefins	0.033
	250 to 160 ppm		0.011
	160 to 50 ppm		0.046
	Down to 250 ppm	Aromatics	0.008
	250 to 160 ppm		0.013
	160 to 50 ppm		0.042
Olefins	Down to 6.9 vol%	E200	1.791
	6.9 to 5.0 vol%		1.699
RVP	Down to 7.3 psi	E200	4.146
	7.3 to 6.9 psi		2.643
	6.9 to 6.5 psi		5.663
Oxygen	2 to 2.7 vol%	Aromatics	-7.297
	2 to 2.7 vol%	E200	1.064
Aromatics	Down to 28 vol%	E300	-0.583
	28 to 24 vol%		-0.336
	24 to 20 vol%		-0.392
E200	Up to 54 %evap	E300	0.221
	54 to 57 %evap		0.338
	57 to 60 %evap		0.340
E300	Up to 88 %evap	E200	1.282
	88 to 91 %evap		0.600
	91 to 96 %evap		0.707

[1/] The fuel parameter interrelationships of Phase I RFG were combined and represented as a straight percent change from the baseline value (see text).

[2/] For VOC control region 1, the increase in E200 was only 111% from baseline for Phase I RFG, reflecting the fact that more light compounds are removed to reduce the RVP to the lower level of 7.8 psi in this area.

2. Individual Fuel Parameter Interrelationships

a. Phase I RFG Parameters

Although the Phase II RFG analysis is separate from that for Phase I, it is important to understand the parameter interrelationships of the Phase I requirements (2.1 wt% oxygen, 0.95 vol% benzene, and RVP at 8.0 psi) since they determine the starting fuel composition of the Phase II fuel. The standards for Phase II RFG are based on the percent reduction in emissions from the Clean Air Act baseline fuel emissions. However, the cost-effectiveness of Phase II RFG is based solely on the costs incremental to those incurred by refiners in meeting the Phase I standards.

The Bonner and Moore refinery modelling data obtained since the draft RIA included a revised analysis of the production of Phase I RFG. This data was reviewed to determine the Phase I parameter interrelationships.[101] The methodology outlined above for determining the B & M parameter interrelationships for each parameter change could not be followed for the Phase I data because the Phase I refinery model run included changes in all three parameters. To represent the fuel parameter changes resulting from implementation of the Phase I RFG requirements, the overall percent change from baseline for each uncontrolled parameter affected by these changes (aromatics, olefins, sulfur, E200, and E300) was calculated from the B & M data. The results of this calculation are presented in Table VI-8 below.

Table VI-8: Phase I RFG Interrelationships (Bonner & Moore)

Controlled Parameter	Range of Control	Uncontrolled Parameter	% of Original (Baseline) Value
Oxygen Benzene RVP	Up to 2.1 wt% Down to 0.95 vol% Down to 8.0 psi	Sulfur	94
		E200	105
		E300	104
		Aromatics	89

The Phase I parameter interrelationships determined from the B & M data were different than those presented by other studies. Specifically, the addition of oxygen appeared to have little impact on the aromatics content beyond simple dilution, even though other studies, such as that performed by Auto-Oil,

---

[101] Bonner and Moore Management Science, "Study of the Effects of Fuel Parameter Changes on the Cost of Producing Reformulated Gasoline," Prepared for EPA under contract through Southwest Research Institute, (see "DOE and API Phase II Cost Estimates," EPA Memorandum from Lester Wyborny, FSSB, to the Air Docket, November 4, 1993.)

show that aromatics would be reduced beyond the level achieved by dilution since the oxygenates can replace octane usually provided by aromatics. The small change in aromatics by the B & M refinery model is probably caused by the refinery model's large use of olefins to produce oxygenates. Since some of the increase in octane from the addition of oxygenate was offset by the loss in high octane olefins, aromatics could not decrease as much as expected, resulting in higher aromatic values. Because this approach is not expected to be taken by refiners who also must meet the toxics requirement, a more average approach than that by B & M was adopted.

The data presented in the draft RIA, based on Auto-Oil studies, showed a slightly different relationship between the various fuel parameters as a result of the Phase I RFG changes. Although the Auto-Oil data was based on modelling of refineries in a single PADD, most of these relationships were similar to those seen in the new Bonner & Moore data. However, the change in aromatics as a result of the addition of oxygen was more reasonable in the Auto-Oil data. The relationships between parameters calculated from the Auto-Oil data are shown in Table VI-9.

Table VI-9: Phase I RFG Interrelationships (Auto-Oil)

Controlled Parameter	Range of Control	Uncontrolled Parameter	% of Original (Baseline) Value
Oxygen Benzene RVP	Up to 2.1 wt% Down to 0.95 vol% Down to 8.0 psi	Sulfur	86
		E200	120
		E300	104
		Aromatics	71

The parameter interrelationships for the Phase I RFG used as the starting point for the Phase II RFG cost-effectiveness analysis were determined from a combination of Bonner and Moore and Auto-Oil data, since neither study presented the best relationships between parameters for Phase I RFG. For each uncontrolled parameter, the percent change from baseline calculated from these two studies was averaged for each region for which data was available. The national weighted average percent change was then calculated and used in the cost-effectiveness analysis. These combined values are listed in Table VI-7.

b. Impact of Reducing Sulfur Content on Other Fuel Parameters

There are essentially three options available to reduce the sulfur content of gasoline. The majority of sulfur in finished gasoline results from the gasoline components coming from the FCC unit. One option to reduce the sulfur level is to desulfurize the feed to the FCC unit; this would not impact other finished gasoline parameters. The other options are to desulfurize the output of the FCC unit or to use less FCC gasoline in the finished product. These options would result in a reduction in the level of olefins in the final product, since these streams are also high in olefin content. This reduction in olefins decreases the octane of the gasoline, which must be made up by increasing the level of oxygen, aromatics, or alkylates in the finished gasoline.

The refinery modelling data used in this analysis indicated that reducing the sulfur content of reformulated gasoline may have some impact (depending on the refining region and the level of sulfur control) on olefins, aromatics, E200, and/or E300. This data is presented in Table VI-10. In addition, the table shows the percent change in the uncontrolled parameter resulting from each change in sulfur content.

Table VI-10:
Data Used to Develop Sulfur Interrelationship Factors

Controlled Parameter	Region	From	To	Uncontrolled Parameter	From	To	% Change
Sulfur	1	337 ppm	250 ppm	Olefins	6.9 vol%	5.5 vol%	-20.3
		250	160		5.5	5.3	-3.6
		160	50		5.0	4.1	-18.0
	2[1/]	454	250		6.9	6.9	0.0
		250	160		6.9	6.9	0.0
		160	50		5.0	5.0	0.0
	3	441	250		6.9	6.9	0.0
		250	160		6.9	6.9	0.0
		160	50		5.0	5.0	0.0
Sulfur	1	337	250	Aromatics	29.7 vol%	29.7 vol%	0.0
		250	160		29.7	29.0	-2.4
		160	50		27.2	26.3	-3.3
	2[1/]	454	250		31.2	28.3	-9.3
		250	160		29.7	26.3	-11.4
		160	50		26.5	24.4	-7.9
	3	441	250		31.1	30.5	-1.9
		250	160		30.5	30.3	-0.7
		160	50		28.9	27.4	-5.2
Sulfur	1	337	250	E200	51.5 %evap	51.1 %evap	-0.7
		250	160		51.4	50.3	-2.1
		160	50		51.1	52.1	2.0
	2[1/]	454	250		53.7	55.9	4.1
		250	160		53.3	53.0	-0.7
		160	50		52.3	51.8	-1.0
	3	441	250		56.5	57.4	1.6
		250	160		54.5	54.9	0.8
		160	50		53.5	56.8	6.2
Sulfur	1	337	250	E300	85.8 %evap	85.8 %evap	-0.1
		250	160		85.5	85.9	0.5
		160	50		85.9	86.6	0.8
	2[1/]	454	250		85.1	86.8	2.0
		250	160		86.4	87.2	0.9
		160	50		86.5	87.3	1.0
	3	441	250		85.6	86.6	1.1
		250	160		87.7	86.6	-1.3
		160	50		86.7	88.2	1.7

[1/]Data from Region 2 was questionable (as discussed in the text) and was excluded from the analysis.

The data in Table VI-10 shows that only in Region 1 does reducing the sulfur content of the fuel have an impact on olefins; in the other two Regions no impact is indicated. This could be a result of the fact that refiners in Region 1 had little flexibility when reducing sulfur content, since 96% of the gasoline produced in that region was reformulated (under the scenario analyzed here), and thus, refiners were forced to control sulfur in a manner which also affected olefins. For this region, it is likely that the sulfur was removed from the output of the FCC, causing the removal of olefins at the same time. The Region 2 interrelationship numbers may be questionable, because (as discussed previously) the data also indicated that there was less cost than expected associated with controlling sulfur levels in finished RFG. It appears that the B & M model overestimated the existence of hydrotreating capacity in this region, or overoptimized the gasoline production options in this region since less than one-half of the fuel is reformulated. In contrast, although there also appears to be no impact on olefins of reducing sulfur for the Region 3 data, there was a reasonable cost associated with sulfur control in this region. The lack of an interrelationship between sulfur and olefins may be explained by the fact that the Region 3 refineries may elect to desulfurize the feed to the FCC unit without affecting the olefin level.

Other studies, most notably the work performed for Auto-Oil and referenced in the draft RIA, also indicated an interrelationship between sulfur control and olefin content. The magnitude of this interrelationship, as developed in the draft RIA, was somewhat greater than that developed from the B & M data. However, that data was only for one PADD (PADD 3) and therefore is less applicable to the national average than the value developed here. The fact that the A/O study showed a sulfur-olefin interrelationship for PADD 3 refineries while the B & M model did not show an interrelationship in Region 3 demonstrates the variation between the assumptions contained in different models. Either relationship is possible, depending on how the refineries decide to reduce sulfur levels. It would not be appropriate to "mix and match" data from two different models to develop a national average because of such differences. Hence, since the cost data from the B & M model appeared to be reasonable, the results from B & M for Region 3 were used.

A national average factor was derived based on the impacts shown in Regions 1 and 3. Because of the uncertainties in the costs for Region 2, the parameter data were not included when deriving a national average impact of reducing sulfur on olefins. Factors representing the overall impact of reducing the level of sulfur on the olefin content were developed from the data in Table VI-10 for each of the three ranges of sulfur reduction analyzed (down to 250 ppm, 250 ppm to 160 ppm, and 160 ppm to 50 ppm), using the method outlined previously. The factors are listed in Table VI-7.

Table VI-10 also shows that reducing the sulfur content of gasoline typically leads to a reduction in aromatics. This impact is strongest in Region 2; for the reasons outlined above, however, the data regarding the impacts of sulfur control from Region 2 was excluded from the analysis. In Region 1, where olefins are reduced as a result of sulfur removal, one might expect the level of aromatics to increase to provide additional octane; the opposite effect was observed. In Region 3, where sulfur removal does not appear to impact olefins, one may expect there to be no change in aromatics, since the volume of sulfur removed is too small to have much impact on the concentration of aromatics (or any other parameters) remaining. However, the impact indicated by the data is small and is not unreasonable. The data presented in the draft RIA indicated no impact of reducing sulfur content on aromatics. However, since the old data was based only on estimates for PADD 3, and since the change in aromatics resulting from a change in sulfur is seen in both regions in the B & M data, it was determined that this interrelationship should be included in the cost-effectiveness analysis.

The overall impact of reducing the sulfur level on aromatics over each of the three ranges analyzed was estimated by weighting the percent change in aromatics and the real change in sulfur in the manner described in subsection D.1. The results of this calculation are presented in Table VI-7.

The impact on E200 and E300 of a reduction in sulfur, as shown in Table VI-10, tends to be small and is somewhat inconsistent between different regions. Since there is no easily identified change in refinery operations that would likely result in a change in these parameters as a result of a reduction in gasoline sulfur content, it was determined that no interrelationship exists between sulfur and either of these parameters. This is supported by the Auto-Oil RFG study in which reductions in sulfur had no consistent effect on E200 or E300.

c. Impact of Reducing Olefin Content on Other Fuel Parameters

Olefin removal can be achieved through hydrogenation, alkylation or oxygenate production. Hydrogenation will also reduce the level of sulfur, and valuable octane will also be lost due to the reduction in olefins. In the case of alkylation and oxygenate production, the loss of octane-rich olefins would be offset by the addition of oxygenates or alkylates, reducing the need to increase the severity of the reformer to produce more aromatics.

An analysis of the olefin interrelationships determined from the B & M refinery modelling listed in Table VI-11 indicates a definite impact on E200, a minimal impact on sulfur, aromatics, and E300, and no impact on other fuel parameters.

Table VI-11:
Data Used to Develop Olefins Interrelationship Factors

Controlled Parameter	Region	From	To	Uncontrolled Parameter	From	To	% Change
Olefins	1	7.2 vol%	6.9 vol%	Sulfur	334 ppm	337 ppm	+2.0
		5.3	5.0		160	160	0.0
	2	8.9	6.9		454	454	0.0
		6.9	5.0		160	160	0.0
	3	8.9	6.9		441	441	0.0
		6.9	5.0		160	160	0.0
Olefins	1	7.2	6.9	Aromatics	29.7 vol%	29.7 vol%	0.0
		5.3	5.0		28.1	27.2	-3.2
	2	8.9	6.9		29.7	31.2	5.1
		6.9	5.0		25.0	26.5	6.0
	3	8.9	6.9		31.0	31.1	0.3
		6.9	5.0		28.9	28.9	0.0
Olefins	1	7.2	6.9	E200	51.7 %evap	51.5 %evap	-0.4
		5.3	5.0		53.3	52.3	-1.9
	2	8.9	6.9		57.4	53.7	-6.5
		6.9	5.0		53.3	52.3	-1.9
	3	8.9	6.9		57.9	56.5	-2.4
		6.9	5.0		55.3	53.5	-3.2
Olefins	1	7.2	6.9	E300	86.0 %evap	85.8 %evap	-0.2
		5.3	5.0		87.3	86.5	-0.9
	2	8.9	6.9		85.8	85.1	-0.8
		6.9	5.0		87.3	86.5	-0.9
	3	8.9	6.9		85.2	85.6	0.4
		6.9	5.0		86.6	87.3	0.8

The data in Table VI-11 indicates no clear relationship between a reduction in olefins and the sulfur level of the fuel. The only change in sulfur level was shown for Region 1 in reducing olefins down to 6.9%, and in this case sulfur actually increased slightly. Since this is not the expected outcome of reducing olefins, and since the change in sulfur level was very small, a relationship was not defined. The data used in the draft RIA indicated some impact on sulfur due to olefins control, but the data was only for PADD 5 and the magnitude of that impact was difficult to measure. No interrelationship between these parameters was assumed in this cost-effectiveness analysis.

The data in Table VI-11 also indicate that reducing the olefins in the fuel has some impact on the aromatics content, although the impact varies with the region and the level of olefin reduction considered. For example, in Region 1, where there was a decrease in sulfur when olefins were decreased (down to 6.9%), one would deduce that the olefins were removed via hydrogenation and that aromatics content would, if anything, increase to make up for the lost octane. However some isomerization of straight chain hydrocarbon gasoline components to higher octane components that occurred may have eliminated the potential aromatics effect. In Regions 2 and 3, where sulfur was not impacted by the reduction in olefins, one would surmise that the olefins were reduced using alkylation and that perhaps the aromatics content would be reduced, too. But the data shows that the aromatics content of the fuels produced in Regions 2 and 3 actually increase when the olefins content is reduced. Since each PADD was assigned a different methodology for the reduction of olefins, it was not possible to determine an interrelationship between olefins and aromatics for this study. Past studies indicated some change in aromatics as a result of olefins control, but, again, this data was based solely on PADD 5 refinery modelling.

The data in Table VI-11 do show a relationship between olefins and both E200 and E300, although the magnitude of these relationships differs significantly. Since the impact on E300 is small and since the impact varied directionally in different regions, this relationship was determined to be insignificant. However, the relationship between olefins and E200 appeared to be more significant and was consistent across the different regions. In addition, it is reasonable to surmise that E200 would decrease as the C4 and C5 olefins were alkylated to heavier components. Hence, this interrelationship was included in the cost-effectiveness analysis. The factor representing the overall impact of reducing olefins on E200, derived by weighting the results from each of the three regions, is listed in Table VI-7.

d. Impact of Reducing RVP on Other Fuel Parameters

The Reid vapor pressure (RVP) of gasoline is reduced by adjusting the level of butane and other hydrocarbons (primarily pentane) in the fuel. Most reductions in RVP will be achieved by removing butane, however, deep cuts in RVP may require removal of pentanes as well. Both of these hydrocarbons are high in octane and their removal would require that the lost octane be replaced in the finished gasoline. Octane may be added by increasing aromatics or oxygen, or by producing additional alkylates (and using the displaced C4 and C5 hydrocarbons in the process).

As shown in Table VI-12, a reduction in RVP appears to have some impact on aromatics, E200, and E300, but the size of the impact and the agreement between different regions varies. From the standpoint of refinery operations, there is no clear connection between a reduction in RVP and the aromatics content of the finished gasoline. The impact shown here is small, and can be considered insignificant given the small level of RVP reduction considered. Other studies show no impact on aromatics from RVP control. Similarly, the impact on E300 of reducing RVP is small, and the results are inconsistent between the three regions, so no interrelationship was assumed. However, the trend of E200 increasing with a reduction in RVP is sizeable, and can be explained by the fact that removing C4 (and perhaps C5) paraffins would decrease E200. Hence, an interrelationship between RVP reduction and E200 was assumed in the cost-effectiveness analysis.

Table VI-12: Data Used to Develop RVP Interrelationship Factors

Controlled Parameter	Region	From	To	Uncontrolled Parameter	From	To	% Change
RVP	1	7.6 psi	7.3 psi	Aromatics	29.7 vol%	29.8 vol%	0.3
		7.3	6.9		29.8	29.7	-0.3
		6.9	6.5		29.7	29.7	0.0
	2	7.6	7.3		28.4	28.5	0.4
		7.3	6.9		28.5	28.5	0.0
		6.9	6.5		28.5	27.9	-2.1
	3	7.6	7.3		30.5	30.6	0.3
		7.3	6.9		30.6	30.7	0.3
		6.9	6.5		30.7	30.5	-0.8
RVP	1	7.6	7.3	E200	51.1 %evap	50.7 %evap	-0.8
		7.3	6.9		50.7	50.5	-0.3
		6.9	6.5		50.5	49.5	-2.1
	2	7.6	7.3		55.9	55.2	-1.2
		7.3	6.9		55.2	55.0	-0.4
		6.9	6.5		55.0	53.3	-3.1
	3	7.6	7.3		57.4	56.3	-1.9
		7.3	6.9		56.3	55.6	-1.3
		6.9	6.5		55.6	54.5	-2.0
RVP	1	7.6	7.3	E300	85.8 %evap	85.7 %evap	-0.1
		7.3	6.9		85.7	85.6	0.0
		6.9	6.5		85.6	85.5	-0.2
	2	7.6	7.3		86.8	86.7	-0.1
		7.3	6.9		86.7	86.7	0.0
		6.9	6.5		86.7	86.4	-0.3
	3	7.6	7.3		86.6	86.3	-0.3
		7.3	6.9		86.3	86.5	0.3
		6.9	6.5		86.5	87.7	1.4

e. Impact of Increasing Oxygen on Other Fuel Parameters

Adding oxygen to gasoline increases the octane of the fuel; other octane-rich components can then be reduced to produce fuel with the desired level of octane. (Some of this reduction occurs simply via dilution of the other components.) Since many high-octane components of gasoline require severe processing conditions to produce, a reduction in the amount of these compounds required is beneficial to the refinery. It is most likely that the addition of oxygen to the fuel would be offset by reducing the aromatics content through a less severe reforming configuration. It is also possible that other fuel parameters could be affected if the refiner elects to reduce the volume of crude throughput to produce a constant volume of products. This would likely lead to a reduction in sulfur and olefins in the finished gasoline due to changes in the operation of the refinery (primarily the catalytic cracking and reforming operations) in response to the lower volume of crude processed.

The Bonner and Moore refinery modelling data used to estimate the impact of adding oxygen on other fuel parameters is presented in Table VI-13, and indicates that in all three regions both aromatics and E200 are affected by the addition of oxygen. The aromatics content of the fuel is reduced, which is the expected response to the increase in octane provided by the oxygenate. However, this reduction is less than expected and, as stated earlier, is probably caused by the large decrease in olefins observed. The change in fuel composition is expected to result in a minor change in E200, as the data indicates. However, the impact on E300 is small and is inconsistent between regions.

Table VI-13:
Data Used to Develop Oxygen Interrelationship Factors[1]

Controlled Parameter	Region	From	To	Uncontrolled Parameter	From	To	% Change
Oxygen	1	2.0 wt%	2.7 wt%	Aromatics	29.0 vol%	28.1 vol%	3.1
	2	2.0	2.7		26.3	25.0	4.9
	3	2.0	2.7		30.3	28.9	4.6
Oxygen	1	2.0	2.7	E200	50.3 %evap	50.6 %evap	0.5
	2	2.0	2.7		53.0	53.3	0.7
	3	2.0	2.7		54.9	55.3	0.6
Oxygen	1	2.0	2.7	E300	85.9 %evap	85.8 %evap	-0.2
	2	2.0	2.7		87.2	86.5	-0.9
	3	2.0	2.7		86.6	87.3	0.8

[1] Based on data from Bonner & Moore for EPA.

A review of the Auto-Oil data (presented in Table VI-14 below), which was developed by a different model, indicates that an increase in oxygen results in a large decrease in aromatics. This response of the refinery is more expected than the one predicted by the B & M model. However, the Auto-Oil data was developed only for a single PADD, and thus is not directly applicable to a national average estimate.

Since it is reasonable to expect that many refiners will want to have a significant reduction in aromatics upon addition of oxygen, the results from the two data sets were averaged, and the average factors used in this analysis. Since both studies also indicated some interrelationship between oxygen and E200, the average of this impact from the two data sets also was used in the cost-effectiveness analysis presented here. However, although the Auto-Oil data shown in Table VI-14 indicates a relationship between oxygen and E300, such a relationship was not included in this analysis because the Auto-Oil data was only based on PADD 5 and the Bonner and Moore data for the rest of the country did not strongly corroborate such a relationship.

Table VI-14: Auto-Oil Data Used to Develop Oxygen Interrelationship Factors - Based on PADD V Data[/1]

Controlled Parameter	From	To	Uncontrolled Parameter	From	To
Oxygen	0.4 wt%	2.7 wt%	Aromatics	34.4 vol%	23.6 vol%
			E200	43.5 %evap	52.4 %evap
			E300	79.4 %evap	83.1 %evap

[/1] Taken from the scenario xMxx vs. base. The E200 and E300 values have been calculated from the Auto-Oil values for T50 and T90 using the conversion equations developed by EPA (see section III).

f. Impact of Lowering Aromatics on Other Fuel Parameters

Reducing aromatics significantly below the level achieved through addition of oxygenates will require refining changes to make up for the octane loss. The octane could be increased through increased alkylation of C4 and C5 olefins. The reduction in aromatics combined with a conversion of olefins could have an impact on E200 and E300 depending on the changes in distillation resulting from the new composition; these changes would be refinery specific.

The following table presents the data obtained from the B & M refinery modelling to explain the relationship between aromatics and other fuel parameters. Although a change in olefins would be expected, the results from the three regions modelled are very inconsistent, and a trend cannot be determined. The impact of aromatics reduction on E200 similarly is inconsistent and makes it impossible to determine an interrelationship between the parameters based on this data. However, the results for E300, albeit small, are consistent and make sense directionally, as it is reasonable to assume that E300 may increase if the heavier aromatics are removed or reduced. Hence, an interrelationship between aromatics and E300 was included in the cost-effectiveness analysis.

Table VI-15:
Data Used to Develop Aromatics Interrelationship Factors

Controlled Parameter	Region	From	To	Uncontrolled Parameter	From	To	% Change
Aromatics	1	30 vol%	28 vol%	Olefins	5.70 vol%	6.64 vol%	16.5
		28	24		6.64	6.56	-1.2
		24	20		6.56	6.57	0.2
	2	28.3	28		6.9	6.9	0.0
		28	24		6.9	6.9	0.0
		24	20		6.9	6.9	0.0
	3	30	28		6.9	6.9	0.0
		28	24		6.9	6.9	0.0
		24	20		6.9	6.9	0.0
Aromatics	1	30	28	E200	51.3 %evap	53.2 %evap	3.7
		28	24		53.2	55.3	3.9
		24	20		55.3	57.7	4.3
	2	28.3	28		55.8	55.4	-0.7
		28	24		55.4	54.7	-1.3
		24	20		54.7	57.2	4.6
	3	30	28		62.8	58.7	-6.5
		28	24		58.7	59.1	0.7
		24	20		59.1	61.2	3.6
Aromatics	1	30	28	E300	85.9 %evap	86.7 %evap	0.9
		28	24		86.7	88.2	1.7
		24	20		88.2	89.1	1.0
	2	28.3	28		86.8	86.8	0.0
		28	24		86.8	88.3	1.7
		24	20		88.3	89.4	1.2
	3	30	28		86.3	87.6	1.5
		28	24		87.6	88.5	1.0
		24	20		88.5	90.2	1.9

g. Impact of Increasing E200 or E300 on Other Fuel Parameters

Increasing the percent of fuel evaporated at either 200 or 300 degrees Fahrenheit requires a change in the fractionation scheme at the refinery. E300 control will require elimination of many of the heaviest components of gasoline, while E200 control could result in removal or conversion of mid-range components such as olefins. These changes could have an impact on the overall octane value of the fuel, and could thus have implications for other fuel parameters.

The data used to develop the interrelationship between E200 and other fuel parameters is listed in Table VI-16; this data was generated in-house using the B & M refinery model.[102] The results from modelling Region 3 were somewhat questionable since E200 started at a higher level than expected. However, because no other data was available to evaluate E200, the data from all three Regions was used to develop the interrelationships between E200 and other parameters.

---

[102] Lester Wyborny, November 4, 1993.

Table VI-16: Data Used to Develop E200 Interrelationship Factors

Controlled Parameter	Region	From	To	Uncontrolled Parameter	From	To	% Change
E200	1	50 %evap	54 %evap	Olefins	5.14 vol%	5.45 vol%	6.0
		54	57		5.45	5.14	-5.7
		57	60		5.14	7.07	37.5
	2	53	54		6.41	7.23	12.8
		54	57		7.23	8.26	14.2
		57	60		8.26	8.46	2.4
	3	55	58		8.44	8.90	5.5
		58	61		8.90	8.90	0.0
		61	64		8.90	8.90	0.0
E200	1	50	54	Aromatics	29.2 %vol	26.8 %vol	-8.0
		54	57		26.9	23.3	-13.2
		57	60		23.3	21.7	-6.8
	2	53	54		24.9	25.3	1.7
		54	57		25.3	23.6	-6.7
		57	60		23.6	22.2	-6.0
	3	55	58		31.0	33.6	8.1
		58	61		33.6	32.7	-2.7
		61	64		32.7	29.7	-9.2
E200	1	50	54	E300	88.1 %evap	89.1 %evap	1.2
		54	57		89.1	90.1	1.1
		57	60		90.1	91.8	1.8
	2	53	54		89.3	89.4	0.2
		54	57		89.4	90.2	0.8
		57	60		90.2	90.8	0.7
	3	55	58		87.7	88.1	0.5
		58	61		88.1	89.1	1.0
		61	64		89.0	89.8	0.9

The data in Table VI-16 shows some interrelationships between E200 and the parameters aromatics and E300. The data for the relationship between E200 and olefins is inconsistent across the three regions examined, and thus no interrelationship between these parameters was determined. In contrast, the data shows a more significant relationship between E200 and aromatics, although this is a somewhat unexpected reaction of the refineries to increasing E200. Similarly, the data shows a definite and not altogether unexpected relationship between E200 and E300.

The B & M refinery model did not yield satisfactory results for the control of E300. Hence, it was necessary to use the data generated by Turner and Mason for Auto-Oil that was used in the development of parameter relations for the draft RIA. The Turner and Mason data looked at controlling T-90, the temperature at which 90% of the fuel has evaporated. Since the Complex Model now includes E300, the T-90 data was transposed to represent E300 based on the relationship between these two parameters cited previously. This data is presented in Table VI-17. One weakness in this data is that it only represents one region of refineries (PADD 3) rather than modelling several regions covering the entire country. However, it does represent 55 percent of the RFG likely to be produced and provides one measure of how a refinery may react to a need to increase E300.

Table VI-17: Data Used to Develop E300 Interrelationship Factors

Controlled Parameter	Region[1]	From	To	Uncontrolled Parameter	From	To	% Change
E300	PADD 3	84 %evap	88 %evap	Olefins	12.2 %vol	12.6 %vol	3.3
		88	91		12.6	12.4	-1.6
		91	96		12.4	11.5	-7.3
E300	PADD 3	84	88	Aromatics	20 %vol	20 %vol	0.0
		88	91		20	19.5	-2.5
		91	96		19.5	17.3	-11.3
E300	PADD 3	84	88	E200	52.9 %evap	55.6 %evap	5.1
		88	91		55.6	56.7	1.8
		91	96		56.6	58.6	3.5

[1] This data is based on the Turner and Mason work for Auto-Oil. For that study, refineries were modelled in PADD-specific groups. PADD 3 would correspond to the Bonner and Moore Region 3.

The data presented above indicates no clear relationship between E300 and either olefins or aromatics, and a measurable relationship between E300 and E200. The data is questionable for the impact on olefins, because for the first increase in E300 olefins increased, while for the second two increases, olefins decreased. The aromatics data is questionable because in the Turner and Mason work aromatics was limited to a level of 20 vol%, and appears to have reached this ceiling. Hence, the data may not accurately reflect any interactions between E300 and aromatics. The E200 data shows the expected correlation with E300, and therefore this interrelationship was included in the cost-effectiveness analysis.

E. Determination of Emissions Reductions

The cost-effectiveness of a particular fuel component change is determined based on reductions in in-use emissions (i.e., the impact the fuel will have on emissions from vehicles in-use at the time the fuel is sold). In contrast, the actual Phase II reformulated gasoline emission performance standards and NOx standards for RFG are based on the reformulated fuel's effect on 1990 model year vehicle emissions relative to those with Clean Air Act baseline fuel. The following discussion explains how baseline emissions and emission reductions from baseline were determined.

1. Non-Fuel Factors Affecting Baseline Emissions Determination

The determination of both statutory baseline emissions and in-use baseline emissions is affected by many factors, such as specific characteristics of the fleet (age of vehicles, types of vehicles, etc.) or the other regulatory programs in place at the time (e.g., enhanced inspection and maintenance, fuel volatility control). The primary factors affecting the base emissions used in this analysis are briefly discussed below.

a. Enhanced Inspection and Maintenance

Enhanced inspection and maintenance (I/M) programs are expected to be fully implemented and phased in by the year 2000. The program is mandated for all serious and worse ozone nonattainment areas. Under enhanced I/M, emissions are lower relative to a basic I/M program because vehicles are kept in better condition. Vehicles with poorly maintained exhaust and evaporative emission control systems are identified and must be repaired. The impact of enhanced I/M programs on the emission reductions achieved is that the same percentage reduction in emissions applied to a lower baseline emissions value yields lower absolute reductions. Enhanced I/M is assumed in this analysis.

b. MOBILE Model

The MOBILE5a emissions model (with enhanced I/M) is utilized in this analysis to determine the in-use baseline emissions. Different base emissions would result if earlier versions of the MOBILE model were used. Baseline emissions determination is also affected by the average vehicle speed used in the MOBILE model. In this analysis, EPA utilized its standard Federal Test Procedure (FTP) speed of 19.6 miles per hour. EPA is currently investigating other speeds or distributions of speeds to more accurately estimate baseline emissions. Revised speed estimates would likely be higher, decreasing VOC and increasing NOx emissions estimates. However, since the investigation is not yet complete, the FTP value was assumed here.

One comment received on the proposal raised concern with using the MOBILE5 model instead of the MOBILE4.1 model. The exhaust emissions calculated by MOBILE5 are significantly higher than those calculated by MOBILE4.1. The commenter suggested that the cost-effectiveness analysis presented by EPA was optimistic because it was based on a percent reduction in emissions applied to this larger emission inventory, in effect improving the cost-effectiveness of each incremental change in fuel composition because the number of tons over which the costs were spread was large. MOBILE5 (and the subsequent MOBIlE5a model) went through a thorough review process, including a number of public workshops. In particular, EPA believes that the increase in in-use VOC exhaust emissions relative to MOBILE4.1 are real. Non-exhaust VOC emissions did not increase much in MOBILE5 relative to MOBILE4.1, because time and resources did not allow a number of possible modifications in the nonexhaust emission methodology to be implemented. Future modifications to the MOBILE model could produce even higher nonexhaust VOC emissions. In any event, the VOC emissions reductions on which the analysis is based are reasonable. The MOBILE5 model contains the latest information on vehicle emissions and fuel economy. It is the most realistic model available to estimate the fleet emissions in the future that is available.

c. Other Factors Influencing Emissions

Other factors can also influence base emissions and thus the reductions determined from those base emissions. For instance, Stage II evaporative controls (controls at the fuel pump to reduce evaporative emissions when refueling vehicles) are included in the MOBILE5a analysis. Onboard (on the vehicle) refueling emissions controls are not considered, however, since the rules governing them have not been promulgated and such controls were not installed on 1990 model year vehicles. The incremental control of onboard vapor recovery to Stage II is small compared to the total vehicle VOC emissions where both are in place. Given the current court order under which EPA is working (see 58 FR 30731), it is likely that vehicles sold in the year 2000 and/or later will have onboard refueling control systems. For the purposes of this analysis, however, this would not greatly affect the baseline in-use emissions because fewer than 50% of the vehicles would likely have such controls at that time.

2. Baseline Fuel Assumptions

Changes in fuel composition and emissions relative to the Clean Air Act baseline fuel are used to determine the VOC, NOx, and toxics emissions performance standards. The base fuel composition from which the cumulative emissions reductions were estimated (and thus from which the proposed performance standards were determined) was the statutory summertime baseline gasoline presented in section 211(k)(10) of the Act. The baseline emissions are estimated using the Phase II complex model as discussed in section III.

In the draft RIA, northern area (VOC control region 2) emission reductions were determined relative to the statutory baseline.[103] Southern area (VOC control region 1) emission reductions were shown relative to both the statutory baseline and to a baseline with all of the statutory values except for RVP, which was set at 7.8 psi (the 1992 Phase II gasoline volatility requirement for southern ozone nonattainment areas). The proposed standards for southern areas were determined relative to the latter baseline. Several comments were received expressing a concern about setting standards for the two regions relative to different baselines. In this revised analysis, the standards for both VOC control regions are determined relative to the statutory baseline RVP of 8.7 psi.

Based on comments received and on its own analysis, EPA realized that the actual 1990 summertime olefin value was approximately 13 volume percent (vol%) while the value specified in the Act was 9.2 vol%. This difference between the actual 1990 value and the statutory value significantly impacts estimations of emissions, total reductions in emissions, costs, and cost-effectiveness. Additionally, the actual impact on refiners of utilizing an unrepresentative baseline in setting a performance standard could result in anti-competitive impacts. Therefore, in determining cost-effectiveness, EPA used a nationwide summertime baseline olefins value of 13.1 volume percent. This value was determined from the Bonner & Moore modelling work, and includes 1990 olefin levels in California. The value is in agreement with EPA's own estimate based on gasoline surveys in select cities across the country. The baseline emissions when the olefin content is 13.1 volume percent (vol%) and when the olefin content is 9.2 vol% are shown in Table VI-18 below for comparison. Once the percent

---

[103] In the draft RIA, southern areas were called "Class B" and northern areas were called "Class C."

reduction standards are determined based on the cost-effectiveness of the fuel changes relative to the in-use emissions assuming the 13.1 vol% olefin level, refiners must still certify their fuel relative to the statutory baseline fuel containing 9.2 vol% olefins.[104]

Table VI-18:
Phase II RFG Emissions at Different Olefin Levels (mg/mi)[/1]

VOC Control Region	Region 1 (Southern)		Region 2 (Northern)	
Olefin Level	9.2	13.1	9.2	13.1
VOC	1466	1456	1399	1389
NOx	1340	1369	1340	1369
Benzene	52	52	52	52
Acetaldehyde	4	4	4	4
Formaldehyde	8	7	8	7
1,3-Butadiene	7	8	7	8
POM	3	3	3	3

[/1] Determined using Phase II complex model with all other fuel parameters at Clean Air Act summer baseline values.

To determine the cost-effectiveness of Phase II RFG incremental to Phase I, the costs and emissions reductions associated with the Phase I fuel had to be evaluated. Hence, while the Phase II standards are expressed relative to the Clean Air Act baseline, the cost-effectiveness of fuel reformulations in excess of the Phase I requirements were determined relative to a fuel meeting the Phase I definition (2 wt% oxygen, 1 vol% benzene, and 8.0 psi RVP).

Because the Phase II VOC and the NOx emission reduction requirements are only required during the high ozone season, there are no Phase II or NOx control requirements outside of the high ozone season. Phase II toxics control applies year-round. However, toxics control has been shown to be cost-ineffective (see subsection F.3 below as well as the draft RIA), and thus was

---

[104] The Phase I complex model indicates that refiners will be able to meet the Phase I requirements (15% reduction in VOC, no NOx increase) even with an olefins level of 13.1%.

evaluated using the same costs and emissions baselines that were developed for VOC and NOx control. Hence, there is no need for a "wintertime" baseline fuel for Phase II RFG (although the wintertime baseline fuel still applies for the antidumping provisions; see section III).

3. In-Use Basis

The performance standards developed in this document are set as percentage reductions in emissions from the statutory baseline fuel, as described above. However, in-use emissions better estimate the emissions of vehicles that will be on the road during and after the year 2000. Use of the statutory baseline to estimate cost-effectiveness would only represent the emissions reductions that would be achieved from 1990 technology vehicles. Thus it is more appropriate to base the cost-effectiveness, i.e., the cost per actual benefit, on the emissions reduction from the in-use emissions baseline.

Baseline exhaust and nonexhaust emissions of vehicles in-use in the year 2003 (a representative year after 1999) were obtained from MOBILE5a, assuming enhanced inspection and maintenance programs in all severe or worse ozone nonattainment areas. This emissions estimate includes light-duty gasoline vehicles and trucks. To determine the in-use emissions resulting from each fuel parameter change, the in-use baseline emissions were adjusted by the percent change in the Phase II complex model emissions projections calculated from that fuel parameter change.

4. Emission Reductions

Incremental reductions in emissions are determined relative to emissions from a previous fuel formulation, while total reductions are determined relative to the emissions resulting from Phase I RFG and also to the emissions from the statutory baseline fuel. This allows calculation of the cost-effectiveness based on the incremental reduction in in-use emissions. It also permits determination of an emission reduction standard based on the total reduction from the statutory baseline emissions.

To determine each incremental reduction in emissions, the emissions reduction (calculated in grams/mile) must be expressed in terms of the net tons emitted. (The grams/mile numbers can be used directly to calculate reductions in the number of cancer incidences as a result of toxics control, as discussed in section F below). Estimates of the level of fuel consumption and the average fuel economy of the fleet are required to complete this calculation.

Summer fuel consumption estimates in the year 2000 for ozone nonattainment areas in VOC control regions 1 and 2 were estimated based on the 1990 fuel consumption and population data from the

1990 census for the mandated RFG areas, the currently opted-in areas, and for the remainder of the Ozone Transport Region. The *National Petroleum News* (June 1992) showed 1990 fuel consumption to be approximately 115 billion gallons.[105] A DOE fuel consumption projection for the year 2000 is also about 115 billion gallons.[106] Since there was little difference between the actual 1990 and projected 2000 fuel consumptions, EPA used 115 billion gallons per year as its base number. The ratio of the population of an RFG area to its state population was then multiplied by the state summer fuel consumption (from May-September 15--again, estimated from 1990 actual fuel consumption data). Summing these estimates for individual states yielded the total summer fuel consumption for all the RFG areas.

A fleet fuel economy of 20.58 miles per gallon was estimated from the MOBILE4.1 fuel consumption model for the year 2000 and was used in this conversion calculation. This fuel economy includes both light-duty vehicles and light-duty trucks. The MOBILE4.1 model was used because a fuel consumption model based on MOBILE5a has not been developed.

Finally, in order to provide an equitable comparison of the proposed reformulated gasoline VOC and NOx controls with other VOC and NOx control programs, the incremental VOC and NOx emission reductions, in tons, were annualized, i.e., converted from summer tons to annual tons. One commenter recommended that cost-effectiveness be determined on the basis of actual summer tons. While it is true that the RFG program is a summer program, and although ozone formation primarily occurs during summer months, historically EPA has measured the cost-effectiveness of VOC control programs in terms of annual tons reduced. This precedent has been set by stationary source controls, which operate year-round but only achieve ozone benefits in the summer months, as well as mobile source controls, such as the recent gasoline volatility regulations. In annualizing the emission reduction benefits, EPA assumed a summer season of 5.5 months (to account for the lead time needed to produce and deliver RFG). This summer season is longer than the one used in the draft RIA (4.5 months). It was adjusted in response to a comment received which stated that the total time over which refiners must produce reformulated gasoline was understated in the draft RIA (as discussed previously).

A similar analysis methodology was followed for estimating toxics emissions reductions. Baseline values of each toxic were

---

[105] reference (chris b.)?

[106] Energy Information Administration, Annual Energy Outlook: 1993, DOE/EIA-0383(93).

obtained from the Phase II complex model. New emissions were determined from the complex model for each fuel component change. The emission reductions were determined from the sum of the toxics emissions and was determined relative to the previous fuel composition. Thus, tons of toxics reduced are determined from the sum of all of the toxics emissions.

F. Cost-Effectiveness Determination

In this analysis, cost-effectiveness is defined as the cost of an emission control strategy per ton of VOC or NOx emissions reduced or per cancer incidence (CI) avoided (for air toxics). Cost-effectiveness can be used to compare different control strategies or different options within one control strategy (e.g., incremental changes in fuel composition). A low cost per ton reduced (or per cancer incidence averted) is desirable.

In general, for this analysis EPA estimated the incremental emissions reductions associated with a given fuel component change, and determined the incremental cost-effectiveness for that fuel change relative to the previous fuel composition. A copy of the results of this analysis is attached as Tables VI-A5 and VI-A6 in the Appendix. The tables report incremental cost-effectiveness for reductions in VOC, NOx, VOC + NOx (and several related VOC + NOx cost-effectiveness expressions) and toxics for each of the two VOC control regions.

1. Comments on Analysis in Draft Regulatory Impact Analysis

In the draft RIA, EPA presented an analysis of the cost-effectiveness of VOC, NOx, and toxics control based on the refinery costs and emissions reductions estimated in that study. The costs were evaluated in terms of the reductions achieved, and were also expressed on a per-gallon-gasoline-produced basis to more directly reflect the costs to consumers. EPA received comments on many parts of the analysis. One commenter suggested that EPA analyze the cost which would be incurred by each household to bring an area into compliance with the NAAQS, and use this as the basis for the cost-effectiveness analysis. While such an analysis may be interesting from an economic standpoint, it was not required for EPA to perform this type of analysis to determine the cost-effectiveness of the reformulated gasoline program. The methodology used in the draft RIA and here is consistent with the methodology used to analyze and support all other stationary and mobile source emission control programs.

Several commenters presented evaluations of the cost of Phase II RFG over Phase I, based on the proposed standards. These evaluations suggested costs which ranged from 5.5-15¢/gal, depending on the level of VOC control (25-35% reduction). It was estimated by another commenter that the cost for small refiners may be 5¢/gal greater than for large refiners. As will be explained below, EPA has estimated that the cost of VOC control will be significantly less than the range projected by the commenters, depending on the level of control required and the parameters controlled to achieve that standard. However, EPA agrees that some refiners will realize costs higher than the average estimates presented here. A more detailed discussion of the impacts of this rulemaking on small entities is presented in section VIII of this document.

Another comment emphasized the need to use a "valid" complex model when determining the cost-effectiveness for use in setting the Phase II standards. As discussed above, EPA used the final complex model to determine the emissions reductions achievable through incremental changes in fuel parameters. These emissions reductions will be the basis of the cost-effectiveness analysis presented below.

2. Factors Affecting Cost-Effectiveness Determination

a. Phase I Fuel Requirements

In this analysis, the combined effect of the Phase I RFG requirements was evaluated prior to evaluating the effects of additional fuel parameter changes because the costs of these requirements will be incurred by refiners prior to the year 2000. After accounting for the production of Phase I RFG, the most incrementally cost effective fuel changes were made. The analysis proceeded through each potential fuel change until the most costly (highest cost per reduction achieved) parameter change was identified.

b. Complex Model Fuel Parameter Range Limits

The range over which fuel components were allowed to change was governed by the data from which the fuel component control costs were derived, with the additional check that the limits defined by the complex model for each fuel component were not exceeded. If cost data was available for several levels of control of a single fuel component, each level of control was incorporated as a discrete control level, as described previously. The fuel components and the specific levels of control to which each fuel component was held are discussed in section IV.

c. VOC Control Region

Separate cost-effectiveness analyses must be done for each VOC control region because of differences in the nonexhaust emissions experienced in the two regions (resulting primarily from the different average ambient temperatures) which affect the total percent and gram per mile reductions for VOC, NOx, and toxics. Total percent reductions are determined from the CAA statutory summer baseline gasoline composition.

3. Analysis Methodology

For the purpose of this analysis, cost-effectiveness is defined as the ratio of the incremental cost of a control measure to the incremental benefit, e.g., the cost in dollars per ton of VOC or NOx emissions reduced or the number of cancer incidences avoided. The use of cost-effectiveness allows for the relative ranking of various control strategies so that a specified environmental goal can be achieved at minimum cost.

In this analysis, cost-effectiveness was evaluated using incremental fuel parameter controls and costs. In other words, only a single fuel parameter was modified at a time, e.g., RVP was reduced to 7.3 psi from 7.8 psi, or sulfur was reduced from 250 ppm to 160 ppm. The incremental fuel component control cost (in cents per gallon) determined as described in section C above was converted to total incremental cost (in millions of dollars) using the same average fuel consumption data that was used to calculate total emissions. The incremental cost-effectiveness was determined by dividing the total incremental cost by the actual incremental reduction in emissions (in tons or in cancer incidences). Cumulative actual reductions, total cost, and total cost-effectiveness are determined in an analogous manner. Cumulative numbers are identified as "total."

Determining the cost-effectiveness of toxics reduction requires a slightly different approach. Reductions in cancer incidence must be determined separately for each toxic, and then the resulting cancer incidences added together to determine the overall reduction in cancer incidence for each year that the program is in place. Thus, for each toxic air pollutant, emissions reductions (in mg/mile) were converted to cancer incidence per year (CI/yr) using a "unit risk factor" for each toxic and the population of the participating nonattainment area. Each unit risk factor (cancer incidences-per-year per gram-per-mile per person) was assumed to be constant. In the draft RIA, unit risk factors were derived from an EPA paper of 1989. For this analysis, updated unit risk factors were derived from data presented in EPA's recent Air Toxics Study[107]. The factor for converting gram per mile emissions to micrograms per cubic meter used in the Air Toxics Study was adjusted to reflect the carbon monoxide emissions predicted by MOBILE5a instead of using the factor derived from MOBILE4.1 described on page 4-7 of that

---

[107] U.S. EPA, "Motor Vehicle-Related Air Toxics Study," Office of Mobile Sources, Report No. EPA 420-R-93-005, April 1993.

report. The emissions were adjusted from 1988 to the year 2000 with the factor 1.218 to reflect anticipated changes in vehicle miles travelled. The adjustments for ambient conditions and potency of each toxic were used as described in the Air Toxics Study. Table VI-19 presents the unit risk factors derived for this analysis.

Table VI-19: Unit Risk Factors for Air Toxics

Toxic Pollutant	(CI/yr)/(g/mi)/ (person)
Benzene	3.696×10^{-6}
Formaldehyde	4.910×10^{-6}
Acetaldehyde	2.048×10^{-6}
1,3-Butadiene	9.103×10^{-5}
POM	5.344×10^{-5}

The Phase II reformulated gasoline standards can be determined from this cost-effectiveness analysis, by determining the maximum level of control that can be achieved for a reasonable incremental cost-effectiveness. Other factors, such as the economic impact on the industry and the technological feasibility of that level of control, can also be considered when choosing the standard.

EPA received many comments on the methodology used in the draft RIA (which is essentially the same methodology used in this analysis), as well as suggestions for alternative methods of determining cost-effectiveness. One recommended method involved using a refinery model consisting solely of Petroleum Allocation for Defense District (PADD) 1 refineries to develop a relationship between cost and a single pollutant (e.g., VOC), and using this relationship to select an average standard based on a cost-effectiveness limit. According to this commenter, the cost-effectiveness limit should be based on the "knee" in the cost curve (the point at which costs escalate dramatically for an incremental reduction in emissions), i.e., the maximum acceptable cost-effectiveness should be determined individually rather than being based on a preselected value. The standards for other pollutants should then be set based on the fuel composition used to reach the VOC standard.

The methodology used by EPA does not differ significantly from the recommended one. As explained above, the standards were developed using the complex model to determine emissions reductions. Rather than basing the costs on a single region, EPA averaged the costs for several regions, excluding California, based on the relative volumes of RFG produced in each region. In addition to use of the cost-effectiveness limit, EPA also attempted to insure that the standards provided adequate flexibility for individual refiners, prevented typical refiners from incurring unreasonable costs, and did not force the industry to make a fuel with a specified formula.

4. Results of Cost-Effectiveness Analysis

Tables VI-20 and VI-21 present the results of the cost-effectiveness analysis performed by EPA. The per-gallon costs and (average) cost-effectiveness for VOC and NOx reductions are listed, based on the cost estimates for VOC control region 2 (northern areas). The cost-effectiveness of VOC reductions for VOC control region 1 will be slightly less than those shown in Table VI-20. The incremental cost for each parameter change will be slightly less in region 1 because less RFG will be consumed there, and thus the overall cost will be less. In addition, fewer tons of VOC will reduced in the region due to differences in the emissions predicted by the complex model for the two regions, but the reduced cost overrides the $/ton analysis. In contrast, the cost-effectiveness of VOC control for control region 1 compared to Phase I RFG will be greater than those for control region 2. This is largely due to the fact that the actual emissions reductions achieved in region 1 will be lower than in region 2 since these areas start with a lower RVP fuel (as a result of EPA's fuel RVP regulations). The incremental cost-effectiveness of NOx control is very close between the two regions, largely because the incremental reductions in emissions (mg/mi) estimated by complex model are close. Similarly, the cost-effectiveness for NOx control incremental to Phase-I RFG is quite close between the regions. This is because the baselines are closer than they were for VOC (since RVP has a negligible impact on NOx).

Table VI-20: Fuel Parameter Control Costs and VOC Reductions[1]

Fuel Parameter Control	Incremental Cost (¢/gal)	Cumulative reduction (%)	Incremental Cost-Eff. ($/ton)	Incremental to Phase I ($/ton)
Phase I RVP: 8.0 psi Oxygen: 2.1wt% Benzene: 0.95%				
RVP to 7.1 psi	0.18	22.9	400	400
RVP to 6.7 psi	0.08	25.5	600	400
Sulfur to 250 ppm	0.12	26.1[2]	3,700	600
Sulfur to 160 ppm	0.56	27.1	11,000	1,300
Sulfur to 138 ppm	0.24	27.4	19,000	1,600
Sulfur to 100 ppm	0.52	27.8	24,000	2,300
Olefins to 8.0 vol%	0.78	26.2	(-)	3,700
Aromatics to 20vol%	2.01	27.8	24,000	6,000
Oxygen to 2.7 vol%	0.61	28.2	28,000	6,600
Olefins to 5.0 vol%	2.77	27.4	(-)	11,000
E300 to 88%	0.35	27.4	48,000	11,000
E300 to 91%	2.01	27.5	198,000	14,000
E200 to 44%	0.38	27.7	37,000	14,000
E200 to 47%	1.32	28.4	36,000	15,000
E200 to 50%	2.97	29.0	96,000	18,000

[1] Based on costs and emissions reductions for VOC control region 2 (northern areas). Assumes all costs allocated to VOC control.

[2] RVP control down to 6.5 psi, the limit considered reasonable at this point in time for driveability purposes, would increase this value to 27.2%

Table VI-21: Fuel Parameter Control Costs and NOx Reductions[1]

Fuel Parameter Control	Incremental Cost (¢/gal)	Cumulative Reduction (%)	Incremental Cost-Eff. ($/ton)	Incremental to Phase I ($/ton)
Phase I RVP: 8.0 psi Oxygen: 2.1wt% Benzene: 0.95%				
RVP to 6.7 psi	-	0.4	-	-
Sulfur to 250 ppm	0.12	2.4	1,300	3,200
Sulfur to 160 ppm	0.56	5.8	3,700	3,500
Sulfur to 138 ppm	0.24	6.8	5,200	3,700
Sulfur to 100 ppm	0.52	8.7	6,200	4,200
Olefins to 8.0 vol%	0.78	10.8	8,000	5,000
Aromatics to 20vol%	2.01	11.9	40,000	8,200
Oxygen to 2.7 vol%	0.61	12.5	25,000	8,900
Olefins to 5.0 vol%	2.77	14.1	37,000	12,000
E300 to 88%	0.35	14.1	(-)	13,000
E300 to 91%	2.01	14.2	820,000	16,000
E200 to 44%	0.38	13.9	(-)	17,000
E200 to 47%	1.32	13.7	(-)	19,000
E200 to 50%	2.97	13.5	(-)	24,000

[1] Based on costs and emissions reductions for VOC control region 2 (northern areas). Assumes all costs allocated to NOx control.

As Table VI-20 shows, the largest reduction in VOC emissions can be achieved through reductions in the RVP of the fuel. These reductions can be achieved at a cost-effectiveness well below the $5,000-$10,000/ton levels proposed in the February NPRM. Control of sulfur and other parameters can result in incremental reductions in VOC, but the costs increase dramatically, thereby reducing the cost-effectiveness. Similarly, Table VI-21 shows that the largest reduction in NOx emissions occurs as a result of reducing the level of sulfur in the fuel. Attempts to reduce NOx emissions by controlling other parameters are in most cases cost ineffective and in some cases detrimental.

Overall, controlling RVP to 6.7 psi and sulfur to 250 ppm could yield an overall reduction from baseline VOC emissions of about 26% at an incremental cost-effectiveness of about $3,700 per ton of VOC reduced. However, the total cost-effectiveness of this level of VOC reduction relative to Phase I RFG is only about $600/ton. This latter value is important when comparing the cost-effectiveness of potential VOC standards with alternative methods of VOC control (see section H), since these other programs are usually evaluated based on the cost-effectiveness relative to the baseline rather than the cost-effectiveness of the last increment of control.

Reducing the sulfur level of the fuel further, to 138 ppm, would yield an overall reduction in NOx emissions of 6.8% (plus a total VOC reduction of 27.4%) at an incremental cost-effectiveness of about $5,200 per ton of NOx (assuming that all of the costs are allocated to the NOx control).[108] Again, if one notices the cost-effectiveness incremental to Phase I RFG, this level of NOx control is even more cost-effective at about $3,700/ton. The overall cost-effectiveness of this level of VOC and NOx control relative to Phase I RFG, if each unit of NOx is valued equally to each unit of VOC, is $4,100/combined ton (see Table VI-A6 in the Appendix). If NOx reductions are deemed to be more valuable than reductions in VOC (as some researchers have suggested), the cost-effectiveness of this strategy improves.

NOx reductions exceeding 10% could be achieved with more stringent sulfur control (down to 100 ppm) as well as control of olefins, at incremental cost-effectiveness less than $10,000 per ton of NOx. However, it should be noted that the olefins control is more costly than readily apparent due to an increase in VOC emissions (as predicted by the complex model). Under such a scenario, total VOC reductions would be 27.8%.

Table VI-22 presents the results of EPA's analysis of the cost-effectiveness of toxics reductions. This information is for reductions in total toxics (the five toxics of concern for reformulated gasoline). The cost per cancer incidence is a function of the reduction in each individual toxic, since each toxic has a different risk factor for cancer, as discussed previously. As the table shows, toxics control in Phase II RFG is not cost-effective when expressed either on a $thousand/ton basis or a $million/cancer incidence basis. Toxics control of 25% reduction would cost over $220,000 per ton of overall toxics reduced for the last increment of reduction (from 24.6% to 25.0%), or close to $40 million per cancer incidence avoided. Less than one cancer incidence would be avoided nationwide per year at a toxics reduction of about 25%. The cost-effectiveness

---

[108] If the cost-effectiveness of this level of NOx reduction is credited based on the additional level of VOC control achieved, at a value of $500/ton VOC reduced, the cost-effectiveness of this last increment of NOx reduction is about $5,000/ton NOx.

of toxics control in VOC control region 1 would be even higher (see Table VI-A5 in the Appendix).

Table VI-22: Fuel Parameter Control Costs and Toxics Reductions[/1]

Fuel Parameter Control	Incremental Cost (¢/gal)	Cumulative Reduction (%)	Incremental Cost-Eff. ($M/ton)	Incremental Cost-Eff. ($MM/CI)
Phase I RVP: 8.0 psi Oxygen: 2.1wt% Benzene: 0.95%				
RVP to 7.1 psi	0.18	24.5	100	1,300
RVP to 6.7 psi	0.08	24.6	225	(-)
Sulfur to 250 ppm	0.12	26.1	30	40
Sulfur to 160 ppm	0.56	28.3	90	90
Sulfur to 138 ppm	0.24	29.0	130	200
Sulfur to 100 ppm	0.46	30.0	170	250
Olefins to 8.0 vol%	0.78	30.0	(-)	50
Aromatics to 20vol%	2.01	33.5	200	370
Oxygen to 2.7 vol%	0.61	35.7	95	170
Olefins to 5.0 vol%	2.77	35.9	4,700	300
E300 to 88%	0.35	36.0	1,200	190
E300 to 91%	2.01	36.1	4,800	510
E200 to 44%	0.38	36.5	400	120
E200 to 47%	1.32	36.8	1,400	390
E200 to 50%	2.97	37.1	3,500	860

[/1] Expressed in terms of total toxics reductions. Based on costs and emissions reductions for VOC control region 2 (northern areas). Assumes all costs allocated to toxics control.

Tables VI-A5 and VI-A6 also present information on the reductions in each of the five individual toxics of concern. These tables show that emissions of all toxics except formaldehyde are reduced as a result of the controls listed in Table VI-22. Only the control of E200 and E300 have a positive impact on formaldehyde emissions. RVP control negatively impacts 1,3-butadiene emissions. Olefin control tends to increase emissions of benzene and POM, although this impact varies depending on the levels of the other fuel parameters. The cost-effectiveness of controlling any one of the toxics, if all of the costs were allocated to that control, range from several hundred thousand to several million dollars per ton of pollutant reduced.

G. Comparison with Other RFG Cost-Effectiveness Analyses

Contrary to VOC and toxics cost-effectiveness, which are either very economical or too costly, respectively, NOx cost-effectiveness will figure substantially into the decision-making process for establishing a NOx standard. For this reason, NOx cost-effectiveness values were compared between various refinery models to better understand the cost of reducing NOx. The sulfur reduction cases (sulfur has the largest impact on NOx reductions) from the B & M cost data were compared to the cost data from other models which optimized around NOx reduction (i.e., refinery models into which the complex model was incorporated directly). Even though multiple parameters changed in these other NOx studies, sulfur was still the major factor which the refinery models chose to modify. This observation at least verifies that the models are similar.

An important reason for making the NOx comparison in addition to the sulfur comparisons made above in section C is to allow the comparison with additional studies which could not be used specifically for the sulfur analysis. The cost-effectiveness analysis by DOE,[109] and the Turner/Mason cost-effectiveness analyses for the National Petroleum Council and API could then be compared. Several discussions were held with DOE and with API late in 1993 concerning some of the assumptions made by API in the running of their computer model.[110] These assumptions are important since they determine, to a large degree, the difference in sulfur costs noted above. The DOE staff integrated some of these assumptions into their refinery model. In addition, these later runs allowed the DOE model to incorporate the final version of the complex model (although negligible differences would be expected between the final version and other late versions on which the API model were based). To compare the NPC data, the parameter values for several of the computer runs (case code numbers Q40L and Q6N Base) were entered into the complex model and the resulting NOx changes were noted. The cost-effectiveness calculated from the various refinery models were normalized to the EPA data on the basis of the fuel economy of the vehicle fleet in 2003, the 2003

---

[109] Wyborny, Lester, U.S. EPA, "Documents Concerning Refinery Modeling for the Reformulated Gasoline Program," Memorandum to the Docket.

[110] Ibid.

vehicle fleet NOx emission factors, and the same methodology for calculating cost-effectiveness (annualized tons, 10% rate of return on investment, etc.).

NOx cost-effectiveness was compared separately for PADD 1 and PADD 3 refinery model runs. The plot of PADD 1 cost-effectiveness is shown in Figure VI-A2 located in the appendix. The DOE cost-effectiveness curve is steeper initially than the B & M curve, showing a lower cost-effectiveness value (more cost-effective) at the same percent NOx reduction. The DOE curve changes to a higher cost-effectiveness value after it crosses the B & M line. The DOE data corroborates the B & M data at one point just above the 7 percent NOx reduction line, indicating that greater levels of NOx reduction become less cost effective. The API data parallels the B & M plot but indicates higher cost-effectiveness values (i.e., less cost effective control) at each percent reduction in NOx value.

The plot of cost-effectiveness versus NOx reduction for PADD 3 is shown in Figure VI-A3. This plot shows that the DOE, Auto-Oil and NPC data all corroborate the B & M data by showing similar levels of cost-effectiveness in the range of 6-9% reduction in NOx. In contrast, the API data is significantly higher in cost, as it was for PADD 1.

H. <u>Factors to be Considered in Setting Phase II RFG Standards</u>

Various economic, technological, and environmental factors should be considered in addition to the estimated cost-effectiveness when setting performance standards for Phase II reformulated gasoline. The following sections present EPA's consideration of many of these issues.

1. Comparison to Cost-Effectiveness of Other Control Strategies

The cost-effectiveness of VOC and NOx control under the Phase II reformulated gasoline program is most easily evaluated when compared to other stationary and mobile source VOC and NOx control strategies. Several comments received on the proposed standards recommended that EPA evaluate the cost-effectiveness of the Phase II standards compared to other control measures. One commenter suggested that such a comparison should include the option to adopt programs such as RVP control instead of reformulated gasoline. The draft RIA did contain some comparisons with other mobile and stationary source control programs. That comparison has been expanded here to include a more detailed discussion of the cost-effectiveness of alternative means to control VOC and NOx emissions from stationary and mobile sources.

It is important to note that not all of the other studies compared here used the same methodology used by EPA to determine the cost-effectiveness of Phase II RFG. This analysis is based on the incremental cost-effectiveness of a particular change in fuel composition relative to a previous, less costly change. Most other analyses determine overall cost-effectiveness relative to a baseline value. If multiple options are considered by these studies, the cost-effectiveness of each option is evaluated relative to this baseline rather than relative to the preceding option. Hence, in many cases it is more appropriate to compare the incremental cost-effectiveness of Phase II RFG relative to Phase I RFG with the cost-effectiveness of other studies.

Another factor which will affect the comparison of the cost-effectiveness of Phase II RFG with other control programs is the fact that the Phase II standards are being set now (as agreed in Reg-Neg) even though they will not take effect until the year 2000. The cost-effectiveness of VOC and NOx programs being evaluated seven years from now are expected to be much higher than those estimated here, since many of the less costly controls will already be implemented. Although EPA cannot project what controls may be under consideration by the year 2000, it is reasonable to assume that the Phase II RFG program will be competitive by comparison.

a. Stationary Source Emission Control Cost-Effectiveness

In response to the cost-effectiveness analysis presented in the proposal, one commenter stated that since EPA used average costs which may be low compared to the costs realized in PADD 1 (since PADD 1 will have a high fraction of RFG produced), the cost-effectiveness of Phase II RFG in PADD 1 would greatly exceed the cost-effectiveness of stationary source controls in PADD 1. EPA disagrees, based on the cost-effectiveness estimates presented below. Furthermore, comments received from the state regulators in PADD 1 indicated that the cost-effectiveness of Phase II RFG presented in the draft RIA was competitive with the cost of various control strategies currently in use or planned.

The cost-effectiveness of stationary source VOC emissions was determined from recommended control strategies for severe nonattainment areas.[111] A review of the estimated cost-effectiveness of controlling VOC emissions from stationary sources yielded a wide range of values.[112] Many existing VOC

---

[111] The Clean Air Act section 183(d) Guidance on Cost-Effectiveness; OAQPS, U.S. Environmental Protection Agency; November 1991.

[112] U.S. EPA, "Issues Relating to VOC Regulation Cutpoints, Deficiencies, and Deviations. Clarification to Appendix D of November 24, 1987 FEDERAL REGISTER," Office of Air Quality

control strategies have small costs or even result in savings. However, many other VOC control options have significant costs associated with them. For example, the estimated cost-effectiveness of reducing emissions from automobile and light truck coating operations in assembly plants is $1,000-4,000/ton VOC. Reducing emissions from the production of pneumatic rubber tires is estimated to cost between $150 and $18,800 per ton of VOC reduced. The cost-effectiveness depends on the operation to which control is applied. Control of emissions from floating roof tanks used for storage of petroleum liquids can cost up to $3,700/ton VOC reduced. Reducing emissions from the production of high density polyethylene, polypropylene, and polystyrene resins can cost between $1,000 and $3,000/ton VOC reduced depending on the level of control required at these facilities.

The comparative cost-effectiveness of stationary source NOx emission controls was based on those suggested for utility boilers.[113] In ozone nonattainment areas, standards are being considered that will require controls more stringent than suggested by reasonable achievable control technology (RACT) standards. The RACT standards will likely be met through the use of low NOx burner technology. This technology has a relatively low cost-effectiveness at up to $1,000/ton, but the achievable emissions reduction is limited. In order to meet the ozone air quality standard in many areas, additional control will likely be required particularly by the year 2000. One of the likely strategies utilized will be selective catalytic reduction (SCR) which is estimated to cost $3,000-$10,000/ton NOx.

b. Mobile Source Emission Control Cost-Effectiveness

Although there is some merit to comparison with stationary source control options, it is more appropriate to compare the cost-effectiveness of Phase II RFG with other mobile source control programs. Emissions from mobile sources occur at ground-level and are more widely dispersed than emissions from a large point source. Control of these emissions is therefore more important in trying to reduce the formation of ozone, because mobile source emission control (through fuel or vehicle measures) will help all areas to reduce ozone, while controlling point source emissions will only help a narrow area affected by the emission plume from that source. Hence, estimates of the cost-

---

Planning and Standards, May 25, 1988 (Revised 1/11/90).

[113] "Evaluation and Costing of NOx Controls for Existing Utility Boilers in the NESCAUM Region"; Draft Report prepared by Acurex Corp., prepared for Bill Neuffer, OAQPS, U.S. EPA, October, 1992.

effectiveness of various mobile source control strategies has also been examined.

(1). Mobile Source VOC Control

The cost-effectiveness of several VOC control strategies has been identified for comparison with the Phase II RFG VOC standard. Enhanced inspection and maintenance (I/M) programs will cost between $900-1,700/ton VOC reduced, while basic I/M was estimated to cost $5,400/ton VOC.[114] The Tier 1 standards for light duty vehicles (already implemented for the 1994 model year) were estimated to cost about $6,000/ton VOC. On-board diagnostics are estimated to cost about $2,000 per ton of VOC reduced as a result of this computerized engine monitoring system.

(2). Mobile Source NOx Control

The enhanced I/M program is primarily a VOC and CO control strategy, although NOx reductions are achieved. The cost of NOx emissions reduction is difficult to separate from the costs of VOC and CO emissions reductions. The cost-effectiveness of NOx control through enhanced I/M programs is estimated to be $3,000-6,000/ton[115]. An enhanced I/M program which employs a more stringent NOx cutpoint than typically assumed is estimated to have a cost-effectiveness of $4,000-8,000/ton.

The Tier 1 emissions standards for light duty vehicles will incur an estimated incremental cost of $2,000-6,000/ton NOx if credit is only given for those emission reductions achieved in ozone nonattainment areas during the ozone season (to allow direct comparison with reformulated gasoline). Achieving the Tier 2 mobile source NOx standards (should EPA determine that such standards are necessary to meet air quality requirements) is likely to cost more than $10,000/ton of NOx reduced.

Certain NOx controls for heavy duty vehicles (both highway and nonroad) are likely to be very cost effective in comparison to other programs. Since heavy duty vehicles contribute a large fraction of the NOx inventory, control of emissions from these vehicles has the potential to result in large reductions. EPA is developing and studying such controls. However, heavy duty NOx controls alone are unlikely to achieve the in-use reductions in

---

[114] "Inspection/Maintenance Program Requirements," Final Rule, November 5, 1992, 57 FR 52984.

[115] 40 CFR Part 51 (52950) Inspection/Maintenance Program Requirements; Final Rule; Environmental Protection Agency, November 5, 1992.

NOx necessary to achieve the ozone NAAQS in most areas. All NOx control strategies that are not implemented or are not already under consideration are likely to be very costly; NOx control combined with the reformulated gasoline program is very reasonable by contrast.

2. Cost-Effectiveness Cutoff Limits

In the NPRM, EPA proposed determining the Phase II RFG standards based on a predetermined maximum limit for the cost-effectiveness of that level of control. Two cost-effectiveness limits were presented, $5,000 and $10,000 per ton, and comments were requested regarding the appropriate limit to select. Several comments were received which addressed this subject. One commenter stated that the $5,000/ton VOC limit is appropriate. Another stated that the $5,000-10,000/ton range proposed is the upper end of costs incurred by many areas to achieve VOC control, in effect establishing more costly criteria than required for other programs. The recommendation that EPA choose a low cost-effectiveness target because of weaknesses in the analysis (as presented in the draft RIA) was also received. However, EPA also received the comment that the upper end of the proposed range was reasonable considering the costs currently incurred by many states for existing control programs. (No support was given for this last statement.)

As discussed in the previous section, EPA has examined the cost-effectiveness of a variety of stationary and mobile source VOC and NOx control options. Depending on the type of programs and level of reduction achieved, these programs have a cost-effectiveness ranging from essentially zero (or even a cost savings) to well over $10,000/ton reduced. After considering this information, EPA believes that a cost-effectiveness benchmark of $10,000/ton is too high at this time and that a benchmark around $5,000/ton is more appropriate for the Phase II VOC standard and accompanying NOx standard. However, as explained elsewhere in this document and in the preamble for this rulemaking, other factors were taken into consideration when setting the standards, and hence, the cost-effectiveness limit was not the only deciding factor.

3. Other Economic Considerations

The economic impact on the refining industry of the Phase II reformulated gasoline standards and NOx standards for reformulated gasoline will depend on the severity of the standard. It will also depend on the fuel parameter changes which are necessary to achieve those standards. The costs and cost-effectiveness analyzed here are for the average refinery, and thus, across the industry there will be a variety of costs and economic impacts of this regulation. The cost experienced by the consumer, whether inside or outside of an ozone nonattainment area, will depend not only on manufacturing costs but also on market conditions.

While it is true that the cost-effectiveness for an individual refinery may be different than that used here to set the standards, EPA believes that the standards have been set with enough flexibility to prevent refiners from incurring extreme costs. It is not currently possible to set the standards taking into account the individual cost-effectiveness of each refinery or the emissions reductions achieved in every distinct area using RFG. Such an analysis would require knowledge of the operating costs and configuration of each refinery, as well as the volume of reformulated gasoline produced. However, because EPA considered the ability of refiners to achieve the emissions reductions and thus did not specify a single fuel formulation to meet the Phase II standards, each refiner will be able to choose the refinery configuration that will produce RFG in the most cost-effective manner for that refinery. For example, if the refiner produces a gasoline that is high in olefins, it is likely that he can still meet the NOx standard without incurring costs greater than $10,000/ton NOx (as the costs in Table VI-21 show. Similarly, if a refiner produces a fuel that is high in aromatics, he can meet the VOC standard without incurring significantly higher costs.

4. Energy Factors

Production of Phase II reformulated gasoline subject to performance standards for VOC, NOx, and toxics will require an increase in the amount of energy used at the refinery. An estimate of the energy used depends on many factors, including how the energy balance is evaluated, the type and source of oxygenate, the refinery configuration, and the reformulation approach. Determining an exact energy increase associated with reformulated gasoline production (on the basis of a constant level of gasoline energy produced) is difficult.

Cost-effective control of VOC and NOx will likely be achieved largely through reductions in the sulfur content and Reid vapor pressure (RVP) of the fuel. Removing sulfur from gasoline is an energy intensive process; the amount of energy required varies depending on the sulfur level of the crude used by the refinery. Reducing the RVP of the fuel requires removal of the lighter compounds in the fuel, also an energy consuming process. Overall, it is expected that the energy consumption by refineries in producing Phase II reformulated gasoline will increase slightly over the level of energy used to make Phase I RFG, but the magnitude of this increase is difficult to measure due to the many variables involved.

As discussed in subsection C.4, changes in some parameters impact the energy density of the resulting gasoline (and hence, the fuel economy achieved by the vehicle). Although there may be some increase in energy consumed in the form of gasoline as a result of this (it could take more energy to go one mile), especially as a result of the addition of oxygen, the impact for Phase II fuels is likely to be small. This is because few of the fuel changes which would negatively impact fuel economy, such as increasing the oxygen content to 2.7 wt%, are likely to be cost-effective for refiners to use in meeting the standards.

There may also be energy benefits resulting from reduced consumption of gasoline in areas using reformulated gasoline. Historically, when the retail price of gasoline has risen, consumption has declined. Phase II reformulated gasoline is expected to cost 1.2¢/gallon more than Phase I RFG. It is possible that consumers may reduce gasoline consumption in response to this price increase. As a result, less petroleum will be needed to produce gasoline, potentially leading to a reduction in oil imports. However, the reduction gasoline consumption resulting from the increased price of Phase II RFG is likely to be small compared to the likely impact of Phase I RFG.

5. Environmental and Health Factors

In response to the proposed Phase II RFG standards, EPA received the comment that EPA should detail the value of the health, welfare, and environmental improvements achieved through the standards. Specifically, it was suggested that these benefits be demonstrated in terms of the VOC and NOx reductions achieved. Section F presented EPA's analysis of the cost-effectiveness of various levels of VOC and NOx control, expressed in terms of the cost per ton of pollutant reduced. The following paragraphs discuss the health and welfare benefits of achieving these reductions.

The purpose of the reformulated gasoline program is to reduce ozone formation and cancer incidences due to motor vehicle emissions of VOC and toxics in those areas most in need of such reductions. The most widespread problems among the major air pollutants for which an NAAQS standard has been established is ozone. Ozone is formed through atmospheric reactions of NOx and hydrocarbons in the presence of sunlight. Emissions from both mobile and stationary sources contribute to ozone formation.

Reducing ozone levels (through reductions in emissions of VOC and/or NOx) in highly populated urban areas would help to reduce short-term health effects caused by exposure periods as short as one hour, such as impaired lung function, cough, nausea, chest pain, throat irritation, increased susceptibility to respiratory infection, and increased sensitivity of asthmatics to allergens (e.g., pollen) and other bronchoconstrictors. Exposure to elevated ozone levels can even affect respiratory performance in healthy individuals during exercise outdoors. Long-term health effects of exposure to ozone include accelerated aging of the lungs, reduces elasticity of the lungs, scarring of lung tissue, and permanent reductions in baseline lung function.

Reducing ozone levels in rural areas where fewer people are exposed would enhance agricultural crop yield production, currently estimated to be reduced by as much as 2 to 3 billion dollars per year by existing ozone concentrations.[116] In addition, lower ozone levels would help reduce damage to forest ecosystems which experience lower tree growth rate, foliar damage, and increased susceptibility to stress (e.g., insects, disease, drought) caused by current tropospheric ozone levels. Ozone can also damage watershed areas and marine life.[117] It persists for several days in the lower atmosphere and can travel hundreds of miles.

The environmental benefits to the areas receiving reformulated gasoline are measured in terms of tons of VOC emissions reduced and number of cancer incidences avoided. The benefits of the NOx reduction program similarly are measured in terms of the tons of NOx reduced. In addition to these measurable benefits in terms of ozone precursor reduction and human health, there are many other health and environmental benefits of reducing VOC, NOx, and toxics emissions. Additional information on the benefits of NOx reductions can be found in section B above.

Reductions in mobile source emissions of air toxics (benzene, 1,3-butadiene, formaldehyde, acetaldehyde, and POM) may result in fewer cancer incidences. The number of cancer incidences likely to be reduced as a result of the Phase II standards has been estimated to be quite small, as summarized in subsection F.3.

A number of adverse non-cancer health effects have also been associated with exposure to air toxics, particularly with higher level exposures experienced in particular microenvironments such as parking garages. Benzene is known to cause disorders of the blood. It can also be immunotoxic, and may be a developmental and reproductive toxicant. High level exposure to 1,3-butadiene can cause eye, nose, and throat irritation, while very high exposure can cause effects on the brain leading to respiratory paralysis and even death. Epidemiologic studies of 1,3-butadiene have also indicated a possible association with heart disease,

---

[116] U.S. EPA, "Review of the National Air Quality Standards for Ozone - Assessment of Scientific and Technical Information," OAQPS, EPA-450/2-92-001, June 1989, p.X-25.

[117] Ibid., p.X-26,27.

blood disease, and lung disease at relatively high exposures. Exposure to low airborne concentrations of formaldehyde can lead to irritation of the mucus membranes of the eyes and respiratory tract and potentially to cellular changes in the nasal cavity.[118] A more thorough discussion of the variety of possible non-cancer effects of concern from exposure to air toxics is contained in EPA's Motor Vehicle-Related Air Toxics Study.[119]

In addition to the ozone reductions and decrease in cancer incidences which will be experienced as a result of the reformulated gasoline program, other benefits are likely to occur. For example, the 2.0 volume percent oxygen requirement for RFG will reduce emissions of carbon monoxide (CO) by 10-15 percent, an added benefit to areas which exceed the NAAQS standard for that pollutant. This will occur primarily in Phase I of the RFG program, when the oxygenate mandate takes effect. Additional reductions in CO emissions are likely to occur with Phase II RFG, as well. However, these Phase II benefits cannot currently be quantified as a complex model for CO emissions has not yet been developed.

In areas not receiving reformulated gasoline, no detrimental effects are expected since the gasoline sold in those areas must comply with the anti-dumping provisions. Additionally, it is likely that spillover of reformulated gasoline into these areas will provide even cleaner fuel to those areas.

6. Technological Feasibility

The technological feasibility of producing fuels to meet the Phase II standards was also considered. EPA believes that the refinery modelling results (from which the fuel parameter control costs were estimated) provide adequate support for the feasibility of making the fuel parameter changes used to achieve the standards. The refinery models utilize only well-developed, demonstrated, commercially available technologies, and hence will only produce fuels within the limits of these technologies. Furthermore, one comment received on the proposal supported the technical feasibility of Phase II RFG controls by noting that the California Air Resources Board has set specifications for California Phase II RFG which demonstrate the feasibility of going beyond 25% VOC emissions reductions. Given the incentives

---

[118] Cotruvo, Joseph A. *et al*, "Formaldehyde Risk Assessment Update (1991)," Toxic Air Pollutants from Mobile Sources: Emissions and Health Effects, Proceedings of an International Specialty Conference, Air and Waste Management Association, VIP-23, 1992.

[119] EPA document 420-R-93-005, April 1993.

created by this rulemaking, in all likelihood new technologies will be developed between now and the year 2000 which will reduce the costs for certain types of fuel parameter changes. Thus, EPA believes that the determination of fuel parameter control costs using the results of the existing refinery models is conservative and that the feasibility of producing such emission-reducing fuels is justifiable. This position was supported by many of the comments received.

7. Fuel Safety Factors and Driveability Concerns

Comments concerning the safety of low RVP fuels in vehicle fuel tanks were received which suggested that a minimum RVP level be established and required for RFG. One comment suggested that producers will make RFG with an RVP in the "high 5 psi range" if faced with a standard for an RVP of 6.5 psi. Since no safety studies are available for fuels with such low volatilities, the commenter recommended setting 7.0 psi as the minimum for RFG. Another comment questioned whether the study presented by EPA in the Draft RIA did not adequately address the transitional months (May and September) or the low temperatures and low RVPs that could be experienced in areas on the fringe of nonattainment areas.

In EPA's evaluation of the safety of vehicle fuel tanks with low RVP fuels, a thorough analysis of the safety of low RVP fuel for the summer months (May through September) was performed. This analysis showed that gasoline with an RVP above 5.0 should not yield a combustible mixture in the fuel tank under any likely summertime temperatures. This analysis was based on the 0th and 10th percentile lowest temperatures experienced during these months in the nonattainment areas. The analysis further showed that a fuel tank filled with gasoline at an RVP of 6.0 psi or greater would not contain a flammable mixture. Extending these results to other fuel storage vessels, it is unlikely that gasoline with a minimum RVP of 6.0 psi would lead to flammability problems in pipelines or storage tanks.

Some concerns were raised about driveability problems arising from the use of low RVP fuels. No testing was performed by the Agency or other organizations to evaluate driveability at low ambient summer temperatures. However, EPA expects that driveability of a 6.5 psi fuel in the summer should be similar to current winter fuels, based on the actual vapor pressure of fuels currently in production. EPA discussed this finding with representatives of both the oil and the automotive industries, who did not indicate a concern with fuel RVPs as low as 6.5 psi. However, they did express an uneasiness with lower RVPs. Until such time as data can be gathered to fully evaluate the driveability impacts of low RVP fuels, it is not possible to determine the true driveability impacts of fuels with RVPs lower than 6.5 psi. However, given that most refiners will likely produce gasoline with an RVP around 6.7 psi to meet the Phase II standards, EPA believes it to be appropriate to treat 6.5 psi as a practical lower limit for RVP.

I. Standards

In the draft RIA, EPA presented cost-effectiveness analyses for the use of Phase II reformulated gasoline in each of the two VOC control regions. Based on these analyses, the Agency proposed a range of possible standards for each VOC control region. The standards were proposed as a range instead of a single number because EPA was requesting comment on what level of cost-effectiveness ($5,000 or $10,000/ton) was reasonable to require, and because EPA was considering a variety of minimum levels for the Reid vapor pressure of Phase II RFG. The following sections summarize comments which were received on the proposed standards and present the final standards derived based on the cost-effectiveness analysis presented in this document.

1. Comments on Proposed Standards

Several comments were received on the proposed standards. One comment suggested that since refiners are likely to reduce parameters to levels lower than the mandated limits to ensure compliance with the standards, the cost analysis should be based on a marginal increase in the standard to determine the true cost-effectiveness of the program. Another comment stressed that EPA distinguish carefully between the RFG standards and the characteristics of the gasoline that will be produced to meet the standards within the compliance margins. The concern expressed by both commenters was that EPA would set standards without considering the fact that refiners may be operating near the "knee" of the cost-effectiveness curve (the point beyond which the costs increase dramatically for a relatively small reduction in emissions) at the levels of some parameters required to meet those standards. Because refiners would likely produce fuels with even lower levels of the gasoline parameters to ensure compliance, they may be pushed past the knee in the curve for some of the parameters.

The cost-effectiveness analysis presented here, on which the standards for Phase II RFG will be based, is inherently an average cost analysis, since it is based on regional refinery modelling data. Hence, the standards derived from this analysis will be averaging standards. There is no need for refiners to have a compliance margin in meeting the averaging standard. The difference between the stringency of the averaging standard and the per gallon standard is intended to be roughly equivalent to the compliance margin, as the provisions of section VII of the preamble demonstrate. As determined in Reg-Neg, this difference is 1.5% VOC. As long as the per gallon minimum does not constrain the ability to meet the averaging standard, variations between gallons and measurement error can be accommodated. Refiners will be able to meet the averaging standard exactly, and thus there is no need to artificially adjust the cost-effectiveness analysis to allow for compliance with the averaging standard. Furthermore, since refiners can choose which standard each gallon will meet after it has been produced, any measurement error is in their favor, since they can apply any gallon to the averaging standard. Hence, EPA's standards are actually conservative.

Another recommendation suggested that the incremental cost-effectiveness analysis begin at the statutory minimum (20% reduction in VOC, no net increase in NOx), and that the standards be set at a point on the cost curve to avoid excessive incremental cost-effectiveness. Since the standards are based on an incremental cost-effectiveness analysis the starting point for the analysis is irrelevant. If the standards were set based on the total cost-effectiveness incremental to the Phase I standards, the concern raised by this comment would have been appropriate.

It was also suggested that EPA define the VOC and toxics performance requirements (standards) based on the emissions reductions achieved by a fuel meeting pre-specified design value property limits. The design values suggested by the commenter were based on the parameter values used in the draft RIA to determine the proposed standards. In effect, this would set a fuel specification to ensure that a certain level of VOC control would be achieved, using the complex model to determine that level of control. EPA believes that it is inappropriate to set the standards based on design values. This would severely limit the flexibility of individual refiners in meeting the standards. In effect, this approach would set a fuel specification; the Phase II standards are meant to be a performance standards that can be met with any fuel formulation that is cost-effective to an individual refiner. Furthermore, EPA has revised its cost-effectiveness analysis using the final complex model and updated cost information, so the parameter values used to obtain the proposed standards no longer necessarily are necessary or required to meet the new standards.

Another comment suggested that EPA set the Phase II standards somewhat less stringent than California Phase II reformulated gasoline, and that the federal standards include a cap on olefins, aromatics, and oxygen. EPA has set the standards based on the need for emissions control, the cost-effectiveness of that control, and on the burden to refiners of meeting the requirements. Since the purpose of the complex model is to allow refiners greater flexibility in meeting the performance standards under both Phase I and Phase II, it would be inappropriate to set caps on any fuel parameter for Phase II RFG. The caps on some parameters which EPA has instituted only apply to fuels certified with the simple model. These caps were only intended to provide a safeguard on the emission performance of RFG fuels until such time as those parameters could be modelled.

Two comments concerned the joint requirements of VOC and NOx standards. The first said that the desire to control both VOC and NOx was in conflict because the fuel parameter changes that reduce NOx tend to increase VOC (and vice versa). EPA's revised analysis, using the final version of the complex model, does not support this claim. According to EPA's analysis, it is possible to reduce both VOC and NOx. Reductions in RVP, the main source of VOC control, yields small (minimal) reduction in NOx. Similarly, sulfur reductions to reduce NOx also yield minimal reductions in VOC. The second comment supported the requirement of a NOx standard if it was consistent with the goals of maximizing VOC and toxics reductions. Toxics reductions have already been shown to be cost-ineffective. As the cost-effectiveness analysis in section F demonstrates, NOx control can be achieved with maximum VOC control in a manner which is most cost effective for both pollutants.

2. Final VOC Standards and NOx Standards

Based on the cost-effectiveness analysis and other considerations presented above, EPA is setting VOC reduction standards for Phase II reformulated gasoline and concurrent NOx reduction standards for gasoline sold in areas participating in the RFG program beginning in the year 2000. These standards are shown in Table VI-23 below. The combination of fuel parameters on which the standards are based is just one of many fuel formulations which could be used to achieve the standards. It must be stressed that these standards are performance standards which may be met by the refiner's choice of fuel parameter controls; they are not specifications for fuel composition.

Table VI-23: VOC Standards for Phase II Reformulated Gasoline and NOx Reduction Standards (Percent Reduction in Emissions)

Controlled Emission	VOC Control Region 1	VOC Control Region 2
VOC - per gallon	27.5[1]	25.9
- averaging	29.0	27.4
- minimum	25.0	23.4
NOx - per gallon	5.5	5.5
- averaging	6.8	6.8
- minimum	3.0	3.0

[1] Reductions relative to a base fuel with RVP at 7.8 psi on a per gallon basis would be VOC: 17.2%; NOx: 5.3%

The 5.5% per gallon NOx reduction standard has been determined to be the level of reduction that can be cost effectively achieved. This is based on control of sulfur down to 138 ppm. The VOC standard was determined based on the level of VOC control that can be cost effectively achieved through RVP reduction (i.e., down to 6.7 psi) as well as the VOC reductions achieved by reducing sulfur to meet the NOx standard. If EPA had elected to set only a VOC standard and had pushed RVP down to the practical limit (6.5 psi, as discussed previously), essentially the same level of VOC reduction would have been achieved. However, setting both the VOC and NOx standards based on an RVP of 6.5 psi and sulfur at 138 ppm would severely restrict the flexibility of refiners. Furthermore, such strict standards could pose an undue burden on some refiners with baseline levels of certain parameters (e.g., olefins) above the average. Hence, EPA set the VOC and NOx standards based on the emissions reductions that could be achieved with a fuel containing 138 ppm sulfur and an RVP of 6.7 psi. As this analysis shows, EPA is setting a NOx standard that refiners can meet in a cost effective manner without jeopardizing their ability to meet the VOC standard for Phase II reformulated gasoline. The cost-effectiveness of this level of NOx reduction, if credit is given for the additional VOC reductions achieved at this level of NOx control (on the order of $500/ton VOC reduced), is about $5,000/ton NOx reduced.

As a result of these standards, VOC emissions will be reduced by about 10,000 tons in VOC control region 1 (southern) areas each summer and 32,000 tons in VOC control region 2 (northern) areas. In addition, southern areas will experience a reduction of about 8,600 tons NOx and northern areas will experience a reduction of 13,800 tons NOx. The emissions reductions experienced in southern areas are smaller than experienced in northern areas due to the fact that southern areas are already required to use fuels with lower Reid vapor pressures, and thus the emissions reduction benefits of RFG use in these areas is smaller.

3. Toxics Standard

The statute sets the minimum Phase II standard for toxics reduction at 25%, although EPA has the authority to reduce this down to 20% "based on technological feasibility, considering cost."[120] There was general support in the comments on the NPRM for the fact that the cost-effectiveness of toxics control beyond a 20% reduction is questionable. No substantive comments were received opposing the option of setting the standard at the minimum 20% reduction. The cost-effectiveness analysis presented here indicates that the technology implemented by refiners to comply with the required VOC and NOx reductions will result in a 26% reduction in toxics annually on average. Hence, most refiners will clearly be able to meet a 25% toxics standard. For certain non-average refiners with high baseline levels of various parameters, however, compliance with the VOC and NOx standards may not automatically lead to compliance with a 25% toxics standard. For these refiners, additional reductions in toxics to meet the standard would require expensive controls, putting them at a competitive disadvantage relative to those refiners who comply with the toxics standard "for free" based on their compliance with the VOC and NOx standards.

If marginal reductions in air toxics were cost effective, EPA would be justified in requiring their control. However, this is not the case. The additional toxics control required by the subset of refiners described above results in very high cost per cancer incidence avoided, in excess of $100 million/CI, well beyond the $1-10 million/CI which the Agency believes to be achievable through other programs. In addition, benzene reduction (which, along with aromatics reduction, is one of the two likely means of reducing toxics) would impact only emissions of benzene, not 1,3-butadiene, which has been shown to be of greater cancer-causing risk to the public. (The statutory requirements of section 211(k) requires a focus on reductions in mass emissions of air toxics, not on a reduction in cancer risk, and therefore does not permit EPA to set the standard based on relative cancer risk.) Even though a 25% toxics standard is technologically feasible, the circumstances discussed above raise

---

[120] The toxics standard is a requirement for an average percent reduction over the entire year, not solely in the summer (high ozone) season.

questions about the increased cost to this subset of refiners of implementing additional toxics reduction technology.

Based on these concerns, EPA is setting the per gallon toxics standard at the statutory minimum 20% (and the averaging standard at 21.5%). Despite the fact that the toxics standard is reduced to 20%, EPA nevertheless anticipates that the average in-use toxics performance will still be above 25%, as discussed above. Total toxics emissions will be reduced by about 370 tons in VOC control region 1 annually, and 630 tons in VOC control region 2. Approximately 3-4 cancer incidences will be avoided annually nationwide as a result of this level of toxics reduction.

J. Appendix VI-A: Tables VI-A1 to VI-A6

Table VI-A1 Phase II RFG Refining Costs for Individual Parameter Changes

Parameter and Range of Parameter Change	Region	Cost (¢/gal)	Capital Charge (MM$)	Capital Cost 15% and 10% ROI (¢/gal)	Adjusted Cost @ 10% ROI (¢/gal)	Cost per Unit Parameter Change	Units for Cost	Nation-wide Final Adjusted Cost
RVP: 7.79 to 7.33	1	0.309	79.6	15%: 0.339 10%: 0.257	.226	0.492	c/gal/psi	0.412
7.85 to 7.37	2	0.255	28.4	0.106 0.080	0.229	0.477	c/gal/psi	
7.64 to 7.30	3	0.175	137.6	0.226 0.171	0.120	0.352	c/gal/psi	
RVP: 7.33 to 7.09	1	0.170	57.6	0.245 0.185	0.110	0.461	c/gal/psi	0.416
7.37 to 7.16	2	0.121	10.2	0.038 0.029	0.112	0.533	c/gal/psi	
7.30 to 6.94	3	0.215	225.5	0.371 0.281	0.125	0.347	c/gal/psi	
RVP: 7.09 to 6.5	1	0.568	69.8	0.297 0.224	0.495	0.839	c/gal/psi	0.427
7.16 to 6.5	2	0.482	146.5	0.545 0.412	0.349	0.530	c/gal/psi	
6.94 to 6.5	3	0.219	302.5	0.498 0.377	0.098	0.223	c/gal/psi	
Oxygen: 2.1 to 2.7	1	0.800	(62.6)	(0.267) (0.202)	0.865	1.44	c/gal/%	1.14
2.1 to 2.7	2	0.566	(52.0)	(0.194) (0.147)	0.613	1.02	c/gal/%	
2.1 to 2.7	3	0.521	(322.7)	(0.531) (0.402)	0.650	1.08	c/gal/%	

Table VI-A2 Phase II RFG Refining Costs for Individual Parameter Changes

Parameter and Range of Parameter Change	Region	Cost	Capital Charge (MM$)	Capital Cost 10% and 15% ROI (c/gal)	Adjusted Cost @ 10% ROI (c/gal)	Cost per Unit Parameter Change	Units for Cost	Nation-wide Final Adjusted Cost
Sulfur: 337 to 250	1	0.156	61.7	15%:0.263 10%:0.199	0.0925	0.00106	c/gal/ppm	.00203
453 to 250	2	0.098	75.2	0.280 0.212	0.0298	0.00014	c/gal/ppm	
441 to 250	3	0.514	137.1	0.226 0.171	0.459	0.00240	c/gal/ppm	
Sulfur: 250 to 160	1	0.721	56.1	0.239 0.181	0.662	0.00736	c/gal/ppm	0.00625
250 to 160	2	0.101	11.32	0.0421 0.032	0.091	0.0010	c/gal/ppm	
250 to 160	3	0.756	579.3	0.953	0.524	0.00582	c/gal/ppm	
Sulfur: 160 to 100	1	0.789	(18.0)	(0.077) (0.058)	0.807	0.0135	c/gal/ppm	0.0125
160 to 100	2	-	-	-			c/gal/ppm	
160 to 100	3	0.756	66.0	0.109 0.082	0.730	0.0122	c/gal/ppm	
Sulfur: 100 to 50	1	1.30	91.9	0.392 0.297	1.21	0.0241	c/gal/ppm	0.0149
100 to 50	2	-	-	-	-		c/gal/ppm	
100 to 50	3	0.733	(86.9)	(0.143) (0.108)	0.768	0.0154	c/gal/ppm	

Table VI-A3 Phase II RFG Refining Costs for Individual Parameter Changes

Parameter and Range of Parameter Change	Region	Cost	Capital Charge (MM$)	Capital Cost 15% and 10% ROI (c/gal)	Adjusted Cost @ 10% ROI (c/gal)	Cost per Unit Parameter Change	Units for Cost	Nation-wide Final Adjusted Cost
Aromatics: 29.65 to 28	1	0.313	33.0	0.140 0.106	0.278	0.169	c/gal/%	0.0664
28.34 to 28	2	0.014	18.8	0.070 0.053	(0.003)	(0.009)	c/gal/%	
30.54 to 28	3	0.285	541	0.890 0.673	0.068	0.0269	c/gal/%	
Aromatics: 28 to 24	1	1.011	(275.0)	(1.17) (0.885)	1.297	0.324	c/gal/%	0.305
28 to 24	2	0.237	147.8	0.550 0.416	0.104	0.0259	c/gal/%	
28 to 24	3	1.23	104	0.171 0.129	1.19	0.298	c/gal/%	
Aromatics: 24 to 20	1	1.44	(38.0)	(0.162) (0.123)	1.481	0.370	c/gal/%	0.367
24 to 20	2	0.809	93.5	0.348 0.263	0.724	0.181	c/gal/%	
24 to 20	3	1.43	(83.0)	(0.137) (0.103)	1.46	0.365	c/gal/%	
Olefins: 11 to 8	5	0.3		0.138 0.104	0.390	0.130	c/gal/%	0.179
8 to 5	5	3.0		0.620 0.469	2.00	0.668	c/gal/%	0.922

Table VI-A4 Phase II RFG Refining Costs for Individual Parameter Changes

Parameter and Range of Parameter Change	Region	Cost	Capital Charge (MM$)	Capital Cost 15% and 10% ROI (c/gal)	Adjusted Cost @ 10% ROI (c/gal)	Cost per Unit Parameter Change	Units for Cost	Nation-wide Final Adjusted Cost
E200 +2,+3: 50.37 to 54	1	1.27	(111)	(0.473) (0.358)	1.39	0.384	c/gal/%	0.125
52.97 to 54	2	0.104	0	0	0.105	0.102	c/gal/%	
54.9 to 58	3	0.181	298	0.490 0.371	0.06	0.020	c/gal/%	
E200 +3: 54 to 57	1	2.91	299	1.27 0.961	2.60	0.867	c/gal/%	0.439
54 to 57	2	0.827	414	1.54 1.17	0.452	1.151	c/gal/%	
58 to 61	3	0.955	24	0.039 0.030	0.946	0.315	c/gal/%	
E200 +3: 57 to 60	1	8.56	1037	4.42 3.34	7.49	2.50	c/gal/%	0.989
57 to 60	2	1.22	30	0.112 0.085	1.20	0.400	c/gal/%	
61 to 64	3	1.39	(34)	(0.056) (0.423)	1.40	0.466	c/gal/%	
E300: 84 to 88	3	0.83	410	0.146 0.110	1.00	0.251	c/gal/%	0.285
88 to 91	3	1.32	910	0.325 0.246	1.70	0.568	c/gal/%	0.645
91 to 96	3	1.65	2705	0.965 0.730	2.79	0.558	c/gal/%	0.634

Table VI-A5 Lester's spreadsheet for class B

Table VI-A5, cont'd

Table VI-A5, cont'd

Table VI-A6 Lester's spreadsheet for class C

Table VI-A6, cont'd

Table VI-A6, cont'd

Figure VI-A1

Figure VI-A2

Figure VI-A3

VII. Anti-Dumping Requirements for Conventional Gasoline--RIA

A. Introduction

Section 211(k)(8) of the Act requires that the Administrator promulgate regulations ensuring that the gasoline sold in areas not participating in the reformulated gasoline program not be more polluting than it was in 1990. Such gasoline is known as conventional gasoline. To implement this requirement, EPA is promulgating requirements known as the anti-dumping provisions for conventional gasoline producers and importers. The purpose of the anti-dumping provisions is to ensure that fuel components that cause harmful emissions and that are removed from or limited in reformulated gasoline not be "dumped" into conventional gasoline, and to likewise ensure that environmentally beneficial fuel components not be used to make reformulated gasoline to the detriment of conventional gasoline.

Specifically, the Act requires that average per gallon emissions of specified pollutants from conventional gasoline use must not deteriorate relative to emissions from 1990 gasoline, on a refiner, blender or importer basis. Compliance is measured by comparing emissions of a refiner's[121] post-1994 conventional gasoline against its baseline gasoline. An individual baseline is developed for each refiner based on the quality of its 1990 gasoline, although under certain circumstances the individual baseline is set at the statutory baseline. These requirements apply to all conventional gasoline producers whether or not reformulated gasoline is also produced.

B. Emission Requirements

The Act specifies that EPA regulations ensure that emissions of VOC, CO, NOx and toxics due to conventional gasoline use not increase over 1990 levels, on a refiner basis. Additionally, each of the four pollutants is to be considered separately, except that increases in NOx emissions due to oxygenate use may be offset by equivalent or greater reductions in the other pollutants.

In the July 9, 1991 proposal, EPA discussed how it may be possible to determine, on a seasonal or yearround basis, that emissions of one or more pollutants from conventional gasoline use may or may not increase. Even though emissions reductions

---

[121] For ease in discussion, the term "refiner", as used in this discussion of the anti-dumping program, will hereafter include refiners, blenders and importers. Where appropriate, blenders and importers will be mentioned specifically.

which may be expected to occur on average may not occur for every refiner, blender and importer, any environmental detriment is likely to be minimal. Thus, it is appropriate not to require monitoring of those emissions that are not expected, on average, to increase. Reduced monitoring and compliance requirements will also result in cost savings.

For several reasons, VOC and CO emission increases are not expected in conventional gasoline areas, and thus EPA is not regulating these two pollutants under the anti-dumping provisions. As discussed in the July 9, 1991 proposal, Phase II volatility requirements and spillover of oxygenated and reformulated gasoline are expected to contribute to VOC reductions in conventional gasoline areas. Since outside of the high ozone season there are no VOC controls imposed on reformulated gasoline, there is no need to impose VOC control on conventional gasoline to counteract potential dumping. EPA also does not expect CO emissions to increase, in or out of the high ozone season, primarily due to the oxygenated fuels program.

Toxics and NOx emissions, however, could increase in conventional gasoline areas as a result of reformulated gasoline dumping. The reformulated gasoline benzene cap of 1.0 volume percent, as well as the reduction in aromatics due to the volume and octane contributions of oxygenate, could result in increased toxics emissions in conventional gasoline due to dumping of aromatics and benzene[122]. Because the oxygenate and benzene requirements are yearround, toxics emissions due to conventional gasoline use could also increase yearround. Likewise, the net effect of conventional gasoline fuel component changes (due to the production of reformulated gasoline) could result in increased conventional gasoline NOx emissions. Because of the potential for toxics and NOx emissions to increase, EPA is regulating emissions of these two pollutants under the anti-dumping provisions.

1. Emission Requirements Prior to January 1, 1998

Prior to mandatory use of the complex model on January 1, 1998, the requirements of section 211(k)(8) of the Act will be met by requiring that the annual average exhaust benzene emissions of a refiner's conventional gasoline not exceed its baseline exhaust benzene emissions.

---

[122] It is possible that no dumping of benzene and aromatics would occur. Refiners could choose to modify refinery operations to reduce production of benzene and aromatics rather than divert these two fuel components to conventional gasoline.

The exhaust benzene emissions due to conventional gasoline may be determined using the simple model. Only the effects of fuel benzene and fuel aromatic content on exhaust benzene are included in this model. Monitoring of only the benzene and aromatic content of conventional gasoline is sufficient during this period because, by the simple model, these are the only fuel components which will be removed from reformulated gasoline which affect toxic emissions.

Per the negotiated agreement, anti-dumping compliance using the simple model also requires that the annual average sulfur, olefin and T90 values of a party's conventional gasoline not exceed its baseline values of those parameters by more than 25 percent. These limits will provide additional assurance that conventional gasoline emissions will not rise prior to use of the complex model. EPA does not expect the levels of these parameters in conventional gasoline to naturally increase due to the reformulated gasoline program, since the simple model for reformulated gasoline caps these three fuel parameters at baseline levels and thus does not require their reduction. However, the relaxed caps for conventional gasoline sulfur, olefin and T90 will provide some processing flexibility for refiners while not harming the environment.

The exhaust benzene emissions due to conventional gasoline may also be determined using the complex model. Because all of the parameters affecting exhaust benzene emissions are part of the model (benzene, aromatics, RVP, sulfur, olefins, E300, E200, and oxygen) there is no need for separate "caps" on fuel parameters as associated with the simple model.

While a refiner may choose to use either the simple model or the complex model prior to January 1, 1998, it must use the same model for determining reformulated and conventional gasoline compliance, if both fuels are produced. Commenters suggested that use of the complex model (for reformulated gasoline compliance) by one refinery should not require it at others, nor require it to be used to determine anti-dumping compliance. However, the anti-dumping program is inherently tied to the reformulated gasoline program in that the specific model used to certify reformulated gasoline will affect which fuel components are likely to be dumped. Requiring use of the same model for reformulated gasoline and anti-dumping will ensure that the effect of these components on conventional gasoline emissions will be the same as on reformulated gasoline emissions. Without use of the same model, incentives would exist to shift dirty components to conventional fuel areas using whichever model predicts the lowest emissions increase due to those components. If no reformulated gasoline is produced, the refiner may use either model to comply with the anti-dumping requirements.

A refiner's baseline exhaust benzene emissions are determined by evaluating the refiner's baseline fuel parameter values in the model chosen by the refiner. At the end of a compliance period, the average fuel parameter values of a refiner's conventional gasoline over that period are evaluated in the same model used to determine the refiner's baseline emissions. The resulting emission values are then compared to the baseline emission values to determine if the party is in or out of compliance with the anti-dumping requirements.

2. Emission Requirements Beginning on January 1, 1998

When complex model use becomes mandatory on January 1, 1998, the requirements of section 211(k)(8) of the Act shall be met by requiring that the exhaust toxic emissions and the NOx emissions of a party's conventional gasoline, as determined using the complex model, not exceed that party's baseline exhaust toxic and NOx emissions.

The exhaust toxics emissions requirement under mandatory use of the complex model includes all five pollutants defined in section 211(k)(10)(C) as toxics. These are exhaust benzene, formaldehyde, acetaldehyde, 1,3-butadiene and POM. Benzene emissions occur in both exhaust and nonexhaust emissions, and accordingly, §211(k)(10)(c) does not limit the toxic air pollutant benzene to exhaust benzene. However, as stated, EPA is only promulgating anti-dumping regulations applicable to exhaust benzene. Nonexhaust benzene emissions will be effectively controlled by the summertime volatility controls applicable to conventional gasoline.[123] The sum of the baseline exhaust emissions of each of these toxics is the value that must not be exceeded by the sum of the exhaust emissions of each toxic pollutant due to a refiner's or importer's post-1994 annual average conventional gasoline.

In addition to the exhaust toxics requirement discussed above, conventional gasoline NOx emissions are also controlled when use of the complex model becomes mandatory. However, the Act states that any NOx emissions increase in conventional gasoline due to oxygenate use can be offset by VOC, CO and toxic emission reductions. The VOC and CO emissions reductions which occur with oxygenate use are much greater than any potential NOx

---

[123] No credit can be taken nor penalties received under the anti-dumping program for nonexhaust benzene reductions, or increases. Nonexhaust benzene emissions will decrease, relative to 1990, due to RVP reductions, which are a VOC reduction strategy already considered under the anti-dumping program as the reason for not explicitly controlling VOC emissions.

increase, as discussed in the July 9, 1991 proposal. To allow for the determination of NOx emissions without the effect of oxygenate use, EPA is allowing NOx baseline emissions determination and subsequent compliance to be determined on a nonoxygenate or oxygenate basis, as will be discussed in paragraph C.4.e.

C. Individual Baseline Determination

1. Requirements for Refiners, Blenders and Importers

a. Requirements for Producers of Gasoline and Gasoline Blendstocks

Each U.S. refinery which converts crude oil and its derivatives into gasoline and gasoline blendstocks, and which was in operation for at least 6 months in 1990, must determine an individual baseline using Method 1 and/or Method 2 and/or Method 3-type data (these three data types are discussed in paragraph C.2). Such a refinery is not allowed to have the statutory baseline (further discussed in paragraph C.2.e) as its individual baseline. EPA is requiring at least 6 months of operation in order to ensure that the data is sufficiently representative of the refinery's 1990 gasoline. A refinery in operation for less than 6 months in 1990 gets the anti-dumping statutory baseline as its individual baseline.

The requirement that such a refinery determine an individual baseline rather than use the statutory baseline is to minimize negative competitive and environmental impacts. It is possible that, in 1990, half of the refineries produced gasoline which results in higher emissions than the statutory baseline and half produced gasoline which results in lower emissions. If the statutory baseline were required, those with higher emissions would be penalized because they would have to comply with more stringent requirements relative to complying with their own baseline. Those with lower emissions would be able to produce dirtier gasoline than they did in 1990, and actually could utilize components which were "dumped" (to produce reformulated gasoline). If the statutory baseline was allowed, but not required, again those with lower emissions would benefit, and would be the only ones to use the statutory baseline because they could produce dirtier gasoline. Those with higher baseline emissions would not be penalized, but their post-1994 gasoline would not be able to be any dirtier than their 1990 gasoline. In both cases, the competitive and environmental impacts are adverse. To minimize these results, EPA is requiring that each refiner develop sufficient data, by estimating the quality of their 1990 gasoline based on actual 1990 and post-1990 refinery data, thereby avoiding default to the statutory baseline.

While baseline parameters may be estimated from data on gasoline shipment or production information, baseline volume is that volume of gasoline which actually left the refinery in 1990. While this may be more than was produced in 1990 due to shipments made from inventory, fuel parameters are not likely to differ much from 1990 production. Additionally, the volume of gasoline which was shipped is what actually contributed to emissions. Likewise, gasoline exported in 1990 is not included in the baseline determination since that gasoline did not contribute to motor vehicle emissions in this country. The baseline of an entity which produced only gasoline blendstocks in 1990 (and did not produce gasoline) will be the anti-dumping statutory baseline if in the future such an entity produces gasoline.

b. Requirements for Purchasers of Gasoline and/or Gasoline Blendstocks

Per the April 16, 1992 proposal, EPA is requiring that the individual baseline of a refiner who exclusively purchases blendstocks and/or gasoline and mixes these purchased components to form another gasoline be determined using Method 1-type data. Refiners engaged in this type of refinery operation are commonly called "blenders" or "terminal operators". If a blender does not have data on every batch of 1990 gasoline for each of the required parameters, its baseline will be the anti-dumping statutory baseline.

EPA also proposed this requirement in the July 9, 1991 proposal, at which time it discussed its reasoning behind allowing blenders to only use Method 1-type data. Method 2 or 3-type data, i.e., data based on 1990 or post-1990 blendstocks, would not be appropriate for determining the quality of gasoline produced at a blending facility in 1990, since blendstocks can vary from week to week in both proportion, type and composition. Thus, it is not feasible to determine the quality of a blender's 1990 gasoline by analyzing post-1990 changes in refinery operations. To allow such data would create an incentive for blenders to discover or develop 1990 and post-1990 data on selected blendstocks that would yield relatively high baseline emissions. Confirming the accuracy of this data would be very difficult. Therefore, use of any data other than that on 1990 gasoline composition would not yield a confident estimate of the quality and emissions of the blender's 1990 production.

Some commenters suggested that blenders be allowed the same opportunities as refiners to use 1990 and post-1990 gasoline and blendstock data. Otherwise, they claimed, a blender may have to "reformulate" its conventional gasoline, and would thus be penalized for not measuring a fuel parameter that was not required to be measured in 1990. As stated, EPA does not believe that use of blendstock data or post-1990 gasoline or blendstock data would allow an accurate portrayal of a blender's 1990 production.

One commenter suggested that blenders with insufficient 1990 data, or those not in business in 1990, should have a more stringent baseline than the statutory baseline because they would have an advantage over half of the U.S. refiners (i.e., those cleaner than the statutory baseline). The Act requires EPA to set the statutory baseline as the individual baseline for those with insufficient data from which to develop an individual baseline. The Act does not require any entity to default to a more stringent baseline than either their individual baseline or the statutory baseline, depending on data sufficiency, as determined by EPA. Since there is neither a clear advantage nor disadvantage for use of the statutory baseline by blenders (and no additional supporting data was provided by the commenter to support its claim) it is not appropriate to impose additional requirements or a more stringent baseline on blenders.

EPA is not requiring a blender who blended only gasoline and oxygenates in 1990 and who will continue to only blend gasolines and oxygenates in the future (post-1994) to establish a baseline, although it may. No environmental harm is expected because the gasoline will already have been accounted for in the refiner's baseline and compliance calculations. Additionally, the CO and VOC reductions from oxygenate use should more than offset any NOx increases due to oxygenate.

Finally, because of the blendstock accounting requirements specified in §80.101, refiners as described in this paragraph are required to determine a baseline API gravity (which can be converted to specific gravity), if using Method 1-type data to determine an individual baseline. Because API gravity is routinely determined for gasoline, and thus should exist if other Method 1-type data exists, this requirement, although not proposed, does not impose significant additional burden on such refiners.

c. Requirements for Importers of Gasoline and Gasoline Blendstocks

In the July 9, 1991 proposal, EPA proposed to allow persons importing refinery-finished gasoline to establish a baseline using Method 1, 2 or 3-type data. As proposed, the foreign refineries in which the gasoline was produced would have to establish a baseline in the same way as domestic refineries. EPA also proposed that the importer could only use Method 1-type data if the gasoline was not refinery-finished, i.e., if it was blended outside of a foreign refinery. If lacking sufficient Method 1-type data, the importer would use the statutory baseline as its individual baseline.

In the April 16, 1992 proposal, EPA proposed to allow importers to develop a baseline using only Method 1-type data, or lacking sufficient Method 1-type data, utilize the statutory baseline. EPA also proposed to allow importers which were also foreign refiners, and which imported at least 75 percent of the 1990 gasoline production of its foreign refinery into the U.S. in 1990, to develop a baseline for the refinery in the same way as domestic refiners.

Although this differed from the earlier 1991 proposal, EPA stated that it believed that artificially high baseline emissions could result if importers were generally allowed to use Methods 2 and 3-type data given the inability to track the 1990 gasoline imports of most importers. EPA also stated that to allow importers to develop high baseline emissions without the data required by Method 1 would encourage gaming, e.g., high-emissions producing gasoline could leave the U.S. (from a refiner with a relatively low baseline) and come back in via an importer with a high baseline. This clearly would be dumping, and would be environmentally and competitively detrimental.

EPA also stated that it did not believe that, in general, importers, particularly those who are not refiners, would have adequate 1990 data on their imported gasoline from which to establish an individual baseline. If importers were allowed to establish individual baselines based on 1991/2 data, these baselines could be relatively high since there would be no way to 1) prevent the importer from choosing high emission gasoline to import in 1991/2 simply to get an advantageous baseline, and 2) insure the 1991/2 gasoline was the same as 1990 gasoline imported. Additionally, EPA stated that use of a baseline auditor to verify an importer's baseline would likely be ineffective unless the importer was also a refiner which met the 75 percent criteria.

Most commenters agreed with EPA's proposal. Some felt, however, that the "75 percent" criteria was self-selecting--only those importer/refiners with higher baseline emissions relative to the statutory baseline would choose to develop an individual baseline using Methods 1, 2 and/or 3. Those importer/refiners with relatively low baseline emissions would use the statutory baseline. Use of the statutory baseline could lead to dumping since they would be complying with a baseline which was less stringent than one based on their own 1990 gasoline quality. EPA agrees that "dumping" could occur, but expects it to be minimal since few foreign refineries are likely to meet the "75 percent" criterion. However, requiring those that meet the "75 percent" criterion to develop a baseline using Method 1-, 2- and 3-type data is consistent with the requirements for domestic refiners, which clearly meet the criterion (i.e., in most, if not all cases, more than 75 percent of domestic refineries' 1990 gasoline was utilized in the U.S. in 1990).

One commenter claimed that location, not percent of production imported, dictates enforceability. Enforcement of a non-domestic refinery is governed less by location and more by the willingness of the company and/or country to open its refinery for compliance visitations. Again, not many refineries are expected to meet the 75 percent criteria, and ones that choose to use it to establish a baseline are likely to be receptive to required visitations. Another commenter specifically stated that Canadian refineries should be treated the same as domestic refineries for the purpose of establishing baselines. As stated, EPA believes that it will be relatively easy to accurately determine the quality of the gasoline produced in 1990 for sale in the U.S. at a refinery outside of the U.S. if a significant amount of the production of the refinery came to the U.S. Independent of where the refinery is located, if less than this amount was imported, it will be more difficult to combine information on refinery operations and blendstock and gasoline data (i.e., Methods 2 and 3-type data) and allocate such information so as to establish the quality of the refinery's 1990 gasoline which was sent to the U.S. In any case, 1990 blendstock data or post-1990 blendstock or gasoline data will not provide a reasonable basis for estimating the qualities of gasoline imported into the U.S. in 1990.

Others felt that an importer should be allowed to use all available data to establish a baseline and have its baseline verified by an auditor. However, as stated, EPA believes that significant dumping could occur if all available data is allowed. One commenter suggested that importers with insufficient 1990 data, or those not in business in 1990, should have a more stringent baseline than the statutory baseline because they would have an advantage over half of the U.S. refiners (those cleaner than the statutory baseline). As discussed previously for blenders, however, the Act does not require those with insufficient data to default to a more stringent baseline. Another commenter stated that the statutory baseline composition did not represent the quality of imported gasoline, and suggested that importers should get a statutory baseline that better represented the quality of such gasoline. Again, Congress has already established the statutory baseline that is applicable when an importer has insufficient data on the gasoline it imported into the U.S. in 1990. While EPA has discretion in determining the terms of the wintertime gasoline for purposes of the statutory baseline, EPA is directed to establish the specifications of "1990 industry average gasoline", and not some subset of the industry average.

EPA is retaining the requirements for importers essentially as proposed on April 16, 1992. Thus an importer who imported gasoline into the U.S. in 1990 shall have its individual baseline determined using Method 1-type data. If the importer does not have data for every batch of 1990 gasoline imported, for each of the required fuel parameters, it shall have the anti-dumping statutory baseline as its individual baseline. Additionally, An importer who did not import gasoline (e.g., an importer which imported gasoline blendstocks or which did not import anything) into the U.S. in 1990 but who does so after 1994, shall have the anti-dumping statutory baseline as its individual baseline. Finally, an importer which is also a refiner that imported more than 75 percent of the 1990 gasoline production of a refinery into the U.S. in 1990, must determine a baseline for that refinery in the same manner as domestic refiners, i.e., using Method 1-, 2- and or 3-type data.

2. Types of Data

Compliance under section 211(k)(8) of the Act is measured against the individual baseline of each refiner. As specified in today's rulemaking, the baseline consists of the estimated 1990 emissions and/or appropriate fuel parameters and volumes of each refiner. Additionally, the Act states that if no adequate or reliable data exist regarding the gasoline sold by a refiner in 1990, the refiner must use the statutory baseline gasoline fuel parameters as its baseline fuel parameters.

After consulting with refiners, EPA believes that there likely will be insufficient directly measured 1990 fuel parameter data available, even in the case of some of the largest refiners, from which to determine individual baseline values for each of the required fuel parameters. At the same time, EPA is concerned about the use of the statutory baseline parameters by those without individual baseline data, as discussed earlier in paragraph 1.a. For these reasons, refiners are required to estimate the quality of their 1990 gasoline based on actual 1990 and post-1990 refinery data.

In the proposals, three methods (Methods 1, 2 and 3) were described for refiners to use to determine their baseline parameter values. The methods differed in the type of data used in each. In the proposals, a parameter value was to be determined solely by a single method. For example, if not enough Method 1 data existed to determine a baseline aromatics value, the baseline aromatics value would be determined using Method 2, if enough Method 2 data existed. However, requiring each parameter to be determined only using one method could result in some of the available data not being utilized. In the above example, the Method 1 data that did exist would not be used in the baseline aromatics determination. However, since Method 1-type data is based on 1990 gasoline, it is the best, most accurate data for determining a baseline value, and should be used to the fullest extent possible. Thus in order to improve the use of available data so as to develop an accurate and representative 1990 baseline, EPA is allowing baseline parameter values to be determined using a combination of the methods, or data types, if necessary. The three data types (corresponding to the three proposed methods) are described below.

EPA considers the data required for any of the methods to be adequate and reliable for the purposes of determining baselines, The available data must be used in a hierarchical manner, however, in that available Method 1-type data must be used first, followed by available Method 2-type data, etc. In other words, if insufficient Method 1-type data exists from which to determine a given parameter, Method 2 type data should be used to supplement any available Method 1-type data. If insufficient Method 2-type data exists, Method 3-type data should be used to supplement any available Method 1 or 2-type data. In this way, the best available data is utilized. The data used in each method should support the data and results in the other methods. For instance, the sum of the gasoline blendstock volumes determined or used in Methods 2 and 3 should closely approximate the total gasoline production as determined in Method 1.

a. Method 1

Method 1-type data consists of a refiner's records of 1990 batches, or shipments if not batch-blended, of gasoline. Specifically, the measured fuel parameter value and volume of batches or shipments of gasoline produced or shipped but not exported are included in the baseline determination, as long as no data is double-counted. The distinction between a refinery's 1990 production of gasoline and its 1990 shipments of gasoline was not discussed in the proposals. However, because it is likely that there were differences between 1990 production and 1990 shipments (e.g., due to shipping from inventory) available data on gasoline produced or shipped in 1990 must be used in the baseline determination (although, as stated, double-counting of data must be avoided). The phrase "batches, or shipments if not batch blended" is a slight modification of the proposal language which included only the word "shipments". Commenters stated that many shipments can be made from a single batch, and that sampling the batch and shipments from that batch would result in double-counting the contribution of that batch in the determination of a fuel parameter value. In order to avoid such double-counting, EPA modified the language as shown.

Method 1-type data is the most reliable data available for determining baseline parameter values, as it is actual 1990 gasoline data. However, only those parameters which are subject to pipeline specifications and which are relevant to the reformulated gasoline program, e.g., RVP and distillation properties, are likely to be determinable using Method 1-type data. Even if parameters were subject to pipeline specifications, in some cases the specification was only a threshold value. For instance, one pipeline specification requires gasoline to have no more than 5 volume percent benzene.

Refiners did not likely test for the actual benzene content, other than to determine or estimate that it was less than 5 volume percent. Meeting such a threshold specification would not provide enough data from which to determine a baseline parameter value. Most refiners did not measure the other fuel parameters of interest (to the reformulated gasoline program) which are not pipeline specifications, because there were no such requirements.

Although not specified in the proposals, EPA is requiring that gasoline blendstocks which become gasoline solely upon the addition of a specific type and amount of oxygenate be included in the baseline determination. Additionally, unless evidence is provided which indicates that such blendstocks were blended with less than 10 percent ethanol or nonethanol oxygenates, or were not further modified downstream, the refiner shall assume that said blendstocks were blended with ten (10.0) volume percent ethanol. This requirement provides some assurance that baseline emissions are not artificially low due to selective inclusion or exclusion of such blendstock. Requiring that the blendstock be assumed to have been blended with ethanol (unless otherwise shown) will result in a more stringent baseline than if it were assumed blended with a (lower volume of a) different oxygenate, or even not further modified. Hence, the burden of proof of actual disposition of such product is on the refiner.

Additionally, gasoline entering a refinery by purchase or transfer, including intracompany transfers, and which leaves the refinery unchanged from its arrival state, shall not be included in the receiving refinery's baseline, since it will have already been accounted for in the baseline of the original producer.

b. Method 2

Method 2-type data consists of a refiner's 1990 gasoline blendstock composition data and 1990 production records. Because it consists of 1990 data, Method 2-type data is also expected to be very reliable and useful in accurately estimating 1990 baseline parameter values. Only data on those blendstocks used in the production of gasoline within the refinery are used in the baseline determination. Most of the blendstocks used in a refiner's gasoline are produced in the refinery, however, some are purchased or otherwise transferred from outside of the refinery. All data on any blendstock used in the refinery's gasoline, whether produced inside or purchased outside of the refinery, is to be used in the baseline determination.

The average fuel parameter value of each gasoline blendstock is determined from the measured fuel parameter values and associated volumes of each type of blendstock. The associated volume is the volume of a batch of blendstock, or, for a continuous process, it is the volume proportional to the amount of the blendstock blended into gasoline in that month.

Some commenters suggested that accounting for blendstocks which do not contribute to toxics emissions makes no sense. However, the quality of all blendstocks used in 1990 gasoline contributes to a refiner's baseline toxic emissions determination, and some blendstocks tend to increase toxics while other blendstocks decrease toxics. Another commenter suggested that blendstocks sold for off-site blending be included in the baseline. Such blendstocks are not included in a baseline determination--only those blendstocks which contributed to a refiner's 1990 gasoline production are included. Some commenters suggested that only streams that constituted a minimum fraction of the gasoline, say 2 or 5 percent, be required to be included. However, the quality of even small volume streams could significantly affect baseline parameter and associated emissions, and thus must be included.

c. Method 3

Method 3-type data consists of a refiner's post-1990 blendstock composition data and 1990 production records. As will be discussed, in some cases post-1990 gasoline data may also be used in the determination of baseline fuel parameter values. As for Method 2-type data, when blendstock data is used, only blendstocks used in the production of gasoline within the refinery are evaluated for baseline purposes, whether the blendstocks were produced in the refinery or purchased or transferred from an outside source. The average fuel parameter value of each gasoline blendstock is determined from the measured post-1990 fuel parameter values and associated volumes of that blendstock. The average post-1990 fuel parameter value and the total 1990 volume of each type of blendstock are then used in the estimation of the baseline value of the parameter.

In order to ensure that the fuel parameter values obtained with Method 3-type data adequately represent the 1990 values of those parameters, the refiner must provide a detailed documentation and comparison of its 1990 and post-1990 refinery operations, especially in areas which affect the fuel parameter(s) being determined from Method 3-type data. Circumstances which would cause its post-1990 gasoline to differ from its 1990 gasoline must be accounted for in determining a fuel parameter using Method 3-type data. For instance, if post-1991 data is used, appropriate adjustments must be made for the refinery operational changes that occurred due to the 1992 volatility rules and the oxygenated fuels program, two situations which could cause post-1990 operations to differ from 1990 operations. The refiner must adjust its post-1990 data to account for such situations, perhaps using refinery modeling. In effect, the refiner is "backing out" its 1990 parameter values from its post-1990 data. The required documentation will assist the baseline auditor in its verification and EPA in its review of the refiner's baseline submission.

In the case where a blendstock was used in a refiner's 1990 gasoline but is no longer used, the adjustments made to account for 1990 and post-1990 operational differences will allow determination of that blendstock's composition. In the case where a blendstock was not used in a refiner's 1990 gasoline, but is used now, no data on that blendstock is included in the baseline determination.

EPA received many comments stating that the use of post-1990 gasoline data was more accurate than using post-1990 blendstock data for a Method 3-based determination. In this regard, some commenters suggested letting the baseline auditor verify that differences between 1990 and post-1990 operations were accounted for and that post-1990 gasoline represented 1990 gasoline. In April 1992, EPA proposed that post-1990 gasoline data could be used if each blendstock in post-1990 gasoline was within 10 percent of the volumetric fraction of that blendstock in 1990 gasoline. One commenter said the blendstock fractional requirements were arbitrary, and that there should be no such requirements--the auditor would verify the similarity between 1990 and post-1990 gasoline composition. Another commenter suggested that 10 percent was still too narrow, and that the criterion should be 50 percent, or 10 percent if blendstock fractions were determined relative to the volume of the total blend, not of only the blendstock. Additionally, some commenters cited the lower cost of collecting and analyzing gasoline rather than blendstock data as a reason for allowing post-1990 gasoline data to be used in the baseline determination.

EPA is allowing post-1990 gasoline data to be used to estimate 1990 baseline parameters, subject to certain requirements. In addition to requiring the same detailed documentation of 1990 and post-1990 operations as required when using post-1990 blendstock data, the volumetric fraction of each blendstock in post-1990 gasoline must be within plus or minus ten (10.0) percent of the volumetric fraction of the same blendstock in 1990 gasoline or be within plus or minus two (2.0) percent on an absolute basis relative to the 1990 value.

Under the first criterion, for example, if a refiner's 1990 gasoline contained 30 volume percent reformate, post-1990 gasoline data may be used (provided all other parameter values also conformed to these requirements) as long as it contained 27.0-33.0 volume percent reformate, i.e., +/- 10 percent. Under the second criterion, for example, if a refiner's 1990 gasoline contained 3.0 volume percent dimate, post-1990 gasoline may be used (provided all other parameter values also conformed to these requirements) as long as it contained 1.0-5.0 volume percent dimate, i.e., +/- 2.0 percent on an absolute basis.

These two criteria are expected to cover typical year-to-year blendstock volumetric fraction fluctuations. Larger differences would indicate more significant refinery operational changes. Post-1990 gasoline data for which a single 1990 blendstock does not meet either of the blendstock fraction requirements cannot be used in the baseline determination. However, EPA also received comment that many refiners would not be able to use post-1990 gasoline data, even with the expanded criteria, simply due to butane utilization changes from 1990. Because butane, and thus RVP, were reduced after 1990 due to volatility controls, and because RVP reductions reduce emissions, EPA is exempting butane from the blendstock requirements for using post-1990 gasoline.

If post-1990 gasoline data does not meet the blendstock fraction requirements described above, it will be difficult for a refiner to show similarity or account for differences between 1990 and post-1990 operations without looking into post-1990 operations at the blendstock level, thus making any gasoline data moot. Although the criteria specified for being allowed to use post-1990 gasoline data may disadvantage some refiners which have collected post-1990 gasoline data but not blendstock data (and thus require them to collect additional data after the final rule), EPA has indicated throughout its proposals that Method 3 was primarily based on blendstock data, with gasoline data allowed as the exception.

Finally, as for Method 1-type data (i.e., gasoline data), EPA is requiring that post-1990 gasoline blendstocks which could become gasoline solely upon the addition of a specific type and amount of oxygenate be included in the baseline determination, to provide some assurance that baseline emissions are not artificially low due to selective inclusion or exclusion of such blendstocks.

While the data for Method 1 is obviously more reliable than that required for Method 3, the Agency considers reliance on the data for Method 3 appropriate because it 1) provides a fair approximation of 1990 gasoline, and 2) provides an additional means for determining baseline parameters, thus not requiring the statutory baseline for refiners with insufficient 1990 data for Method 1. As discussed, use of the statutory baseline for refiners should be avoided because of potential and likely negative environmental and competitive effects.

d. E200 and E300

Although not previously included among the fuel parameters for which baseline values are required to be determined, EPA is now requiring that baseline values be determined for the fuel parameters E200 and E300, the percent evaporated at 200°F and 300°F, respectively. Although these two fuel parameters replace T50 and T90, respectively, in the complex model, baseline values of T90 are still required to be determined if producing reformulated gasoline or using the simple model.

EPA expects E200 and E300 values to be determined directly from gasoline or blendstock data, even if distillation information has to be regraphed. If such a determination is not possible, and can be proven, E200 and E300 values may be estimated from otherwise acceptable T50 and T90 data using the following equations:

$$E200 = 147.91 - (0.49 \times T50)$$
$$E300 = 155.47 - (0.22 \times T90)$$

e. Anti-Dumping Statutory Baseline and Emissions

As mentioned earlier, in some cases a blender or importer may not be able, or be allowed, to develop an individual baseline from its own data. In that case, the blender or importer would have the statutory baseline as its individual baseline. Although the compliance period for conventional gasoline is annual (as discussed in the proposals and in §80.101 of this rulemaking), emissions determined using the complex models are determined on a summer and winter basis. Thus, separate anti-dumping summer and winter baseline fuel parameter values are required. For those without unique individual baselines, these values are the statutory summer baseline specified in the Act, and the winter baseline determined by EPA as required by the Act (and as specified in Section II of this document)[124].

Because of the blendstock accounting requirements specified in §80.101, a baseline statutory value API gravity (which can be converted to specific gravity) is also required. As indicated in section 211(k)(10) of the Act, the summer value is 57.4 °API. The corresponding winter value determined by EPA is 60.2 °API.

Because separate summer and winter baseline fuel parameter values are required, the single set of fuel parameters specified in the proposals as the anti-dumping statutory baseline is basically moot with regard to the final rule, except for annual average values of sulfur, olefins and T90. However, for clarification and completeness, it is discussed here. Few substantive comments were received concerning the proposed annual average statutory baseline (which is a weighted average of the summer and winter statutory values), and none led to a change in the proposed fuel parameter values. However, the baseline listed

---

[124] As discussed in Section IV, when the complex model is used to determine emissions, winter RVP is held at 8.7 psi because there are no RVP effects on winter emissions.

in the February 1993 proposal reflected a nonhigh ozone season of September 16-March 31 (and thus a high ozone season of April 1-September 15). The current high ozone season (upstream from retail outlets) is May 1-September 15. The proposed anti-dumping statutory baseline has been modified to reflect the change in fuel parameter values and fuel consumption due to the change in the length of the high ozone season, and is shown below.

Benzene, volume percent	1.60
Aromatics, volume percent	28.6
Olefins, volume percent	10.8
RVP, psi	8.7[125]
T50, degrees F	207
T90, degrees F	332
E200, percent	46.5
E300, percent	82.4
Sulfur, ppm	338
API Gravity	59.1

Finally, the annual average anti-dumping baseline emissions are shown below. These emissions were determined by evaluating the summer and winter statutory baseline fuel parameters in the appropriate summer or winter model or equation, and then determining annual average emissions by weighting the summer and winter emissions by the fuel consumption fractions in the high ozone and nonhigh ozone seasons, 39.6% and 60.4%, respectively. As stated, annual average sulfur, olefins and T90 are shown above.

	Phase I	Phase II
Exhaust Benzene--Simple Model	6.45	------
Exhaust Benzene--Complex Model(mg/mile)	33.03	------
Exhaust Toxics (mg/mile)	50.67	104.5
NOx (mg/mile)	714.4	1461.

3. Data Collection and Testing Requirements

a. Sampling Requirements

---

[125] The RVP that results from combining the CAA statutory baseline RVP of 8.7 psi and the wintertime statutory baseline RVP (determined by EPA) of 11.5 psi is 10.4 psi. However, as discussed above, an RVP of 8.7 is used in the winter complex models. Hence, the annual average RVP shown here is 8.7 psi.

In the April 16, 1992 proposal, EPA briefly discussed sampling requirements for obtaining data from which to determine baselines. In the February 26, 1993 proposal, EPA discussed additional requirements and changes to the requirements previously discussed. The primary reasons for specifying sampling requirements is to ensure that enough gasoline or blendstock samples were taken from which to develop a representative baseline, and to minimize the picking and choosing of data.

In the April 16, 1992 proposal, EPA stated that sufficient sampling must be done, implying that the responsibility for sampling was left to the refiner, but would have to be verified by the auditor, and of course, ultimately accepted by EPA. In the February 26, 1993 proposal, EPA specified specific minimums in order to ensure acquisition of adequate and representative data. Many commenters commented that they had sampled based on the earlier proposal requirements for sufficient sampling, and that EPA's later proposal could void data collected, and the time and money spent. EPA still believes it is the better course to specify minimum sampling requirements, and thus is specifying that for Method 1 and Method 3 gasoline data, at least half of the batches (by number of batches, not volume), or shipments if not batch blended, in a calendar month shall have been tested for a particular parameter. For Method 2 and Method 3 blendstock data, at least weekly sampling of continuous blendstock streams and, if blendstocks are produced on a batch basis, sampling of at least half of the batches of each blendstock produced in a month is required.

However, EPA believes that at least some of the sampling performed in response to the April 1992 proposal may well be adequate. To void such sampling would be an unnecessary waste of resources if in fact it is adequate and representative of the gasoline or blendstock produced or imported over a certain period of time. To avoid this result, EPA will also accept less than the minimum data if the refiner can explain why the data is less than the minimum requirements and why it is sufficient in quantity and quality to use in the baseline determination. Although less than the minimum data required may be used, all available samples must be analyzed and the results used in baseline determination if more than the minimum number of samples are available. In addition, the auditor must verify all of the above information and conclude that the sampling is sufficient in quantity and quality to use in baseline determination.

Since 1990 data is the best data from which to calculate baseline fuel parameter values, it makes sense that data collected closer to 1990 is more easily adjusted to estimate 1990 values than data collected later. Thus to prevent using more data than is necessary in the baseline calculation (because excessive data may skew the results or allow gaming), only data collected through the end of the calendar year in which the minimum data requirements are met are allowed to be used in the calculation of a given baseline parameter. However, data collection may also cease when the minimum requirements are met. In any case, all data collected through the time data ceased to be collected for baseline development purposes must be included in the baseline determination. Picking and choosing of data should thus be minimized even if less than the minimum data is utilized because all data collected must be included in the baseline determination[126].

At least three months of summer and three months of winter data must be available for the determination of a parameter value. Summer months include any month in which any volume of gasoline was produced to meet the federal summer volatility requirements. Winter is any month which could not be considered a summer month. Thus transition months may be used to satisfy the three months of summer data requirement. This requirement will insure that the average parameter values calculated by the above methods will adequately represent a refiner's 1990 gasoline quality and composition, including representative summer and winter data. One commenter suggested that if annual data were available, fuel parameters should be allowed to be calculated on an annual basis instead of requiring separate summer/winter determinations. EPA will accept annual data, however, because annual average baseline emissions are determined on a seasonal basis first, separate summer and winter average baseline fuel parameter values must be determined from the annual data. Some commenters suggested that EPA accept less than three months of summer and winter data if it could be shown that the composition of a blendstock stream did not change seasonally. Although in certain cases this may be true, it is more efficient to require all refiners to meet the minimum requirements than to ascertain whether the quality of a few streams of a few refiners did not change seasonally. In certain instances where a refiner markets its product only in an area or areas which experience no seasonal changes relative to gasoline requirements, e.g., Hawaii, only three months of data are required.

---

[126] Certain data may be excluded from the baseline determination, if it can be shown that the sample was mislabeled or incorrectly analyzed or if the results are significantly different than would be expected based on operating conditions, etc. Such data must be reported, and the auditor must verify the reasoning in support of such an exclusion.

b. Post-Final Rule Data Collection

Many refiners began collecting data to be used in the baseline determination soon after the proposals were published. They were of course taking a risk that significant changes could occur between the proposals and the final rule. Nonetheless, many have estimated their baseline parameter and emissions values, and are working with potential auditors to verify those determinations. However, some refiners began collecting data late, were waiting for the final rule or just recently realized that they need additional data. These refiners are being allowed extra time to complete and submit their baselines, however proof must be given that additional data was needed and indeed was collected after today. The requirement to collect at least three months of data on a refiner's winter gasoline and at least three months of data on a refiner's summer gasoline must still be met.

c. Negligible Parameter Values

In February 1993, EPA proposed that if a refiner can show, and the auditor verify, that a refinery stream contains negligible amounts of one or more of certain fuel properties for which a baseline value must be determined, testing of that stream for the fuel property(ies) is not necessary. The fuel properties discussed were aromatics, benzene, olefins, saturates and sulfur. Saturates are now excluded since a baseline saturates value is not required to be determined. Oxygen was not included in the proposal. It is, however, reasonable to include it because it is a required baseline parameter, and is likely to exist in negligible amounts in many blendstock streams. Although each fuel component uniquely affects emissions, the effect of assuming a zero value, relative to "negligible" threshold values, is not expected to significantly affect emissions.

The proposed minimum values for a fuel component to be negligible in a stream were 1.0 volume percent for benzene, aromatics, olefins and saturates, and 10 ppm for sulfur. The final minimum values are shown below.

Aromatics	1.0 volume percent
Benzene	0.15 volume percent
Olefins	1.0 volume percent
Oxygen	0.2 weight percent
Sulfur	30.0 ppm

Although not explicitly stated in the proposals, this provision applies to blendstock streams on an average basis. Thus fuel parameters deemed negligible for a given blendstock stream are expected, on average, not to exist in the stream at greater than the appropriate minimum. These final values differ from those proposed based on commenter suggestions that more appropriate negligible values should be approximately 10 percent of the expected value of the fuel parameter. EPA agreed with this for all of the parameters except for aromatics, and modified the "negligible" threshold values for these parameters. The "10 percent" level for aromatics would be about 2.8 volume percent. Since some large streams have aromatic contents of approximately this magnitude, it would not be appropriate to credit a large stream with a zero value, even though this would result in a more stringent baseline. Thus the negligible aromatics threshold is unchanged from the proposal.

As stated, a negligible oxygen threshold was not originally proposed, and in fact, there is no statutory baseline oxygen value from which to estimate a 10 percent value. Most non-oxygenate refinery streams contain little or no oxygen. Although accounting for small quantities of oxygen would reduce baseline emissions, resulting in a more stringent baseline, the minor environmental effects of having a slightly less stringent baseline must be balanced against the costs of testing for such small quantities. Thus a de minimis level of 0.2 weight percent was set as the negligible oxygen threshold.

Any properties shown to exist in a refinery stream in negligible amounts shall be assigned a value of 0.0. One commenter suggested accepting benzene, sulfur, olefins and aromatics estimates of zero (for certain identified streams) since any error would result in lower baseline emissions. However, the fuel component values of a given stream do not necessarily uniformly meet the negligible threshold values described above. Hence EPA is requiring each refiner to determine individually for which streams certain fuel components exist, on average, in negligible amounts.

d. Sample Compositing

There have been no major changes in this provision from the proposals. Thus, samples that have been retained but not yet analyzed may be mixed together in volumes proportional to the volume of the batch, or shipment if not batch-blended, from which the sample was taken and the mixture analyzed for the required fuel parameters. Blendstock samples obtained from continuous processes over a calendar month may be mixed together in equal volumes to form one blendstock sample (e.g., all samples of reformate taken in a calendar month may be mixed) and the sample analyzed for the required fuel parameters. Based on comments received, some of the details of the compositing procedure have changed. Specifically, comparison, and adjustment, if necessary, of sample RVP is required, so as to avoid misrepresentation of a sample which may have lost volatile components. Additionally, certain compositing requirements were changed to better reflect refinery conditions.

e. Test Methods

Many commenters were concerned that the test methods they had used to analyze samples would be invalid because they were not the same as the required test methods being promulgated today for reformulated gasoline. EPA had proposed, on April 16, 1992, that sampling and measurement techniques used to determine baseline parameters must yield results which are equivalent to the results obtained per the techniques and methodologies specified for the reformulated gasoline program. However, because of constantly evolving test methods, in addition to the fact that the final regulations concerning reformulated gasoline test methods will only be known today, it would be inappropriate to disallow data not determined using the test methodologies required in the reformulated gasoline program.

Nonetheless, EPA is concerned that the test methods used be adequate. In a modification of the proposal, EPA will accept data determined using methods other than those required under the reformulated gasoline program, upon petition and approval, as long as the methodology or technique was a standard industry-accepted measurement technique at the time the measurement was taken. The baseline auditor will verify that the techniques used to determine the baseline data meet either of the requirements discussed above.

It is possible that the industry-accepted methods in place at the time will yield results which are less accurate than more recent test methods or test methods required beginning in 1995. EPA recognizes this fact, however, it would not be appropriate to waste the resources expended by not accepting data determined under earlier, industry-standard methods. Also, no significant environmental deterioration, if any, is expected by accepting such data because development of new test methods inherently involves consideration of previous test methods, hence any differences should be minimal. No allowances will be made, however, for different analytical methods utilized in the baseline and compliance calculations. It is reasonable not to adjust baseline or compliance values due to different measurement techniques because all refiners should be affected in the same manner if industry standard test methods were used to determine baseline parameter values. However, if data were determined under two test methods, EPA may accept the data determined under the more accurate test method, upon petition and approval.

Although not previously discussed, oxygen content may be estimated using oxygenate purchase, sale and/or blending records or analytically. However, the other fuel parameter values of the oxygenate (e.g., the sulfur content of the oxygenate) must be determined analytically, or be deemed negligible, if allowed. All oxygen associated with allowable gasoline oxygenates shall be included in the baseline oxygen content if oxygen content is determined analytically. Oxygen content shall be assumed to be contributed solely by the oxygenate indicated on the blending records, etc., if oxygen content is determined from such records.

4. Baseline Fuel Parameter Determination

The methodology for calculating baseline fuel parameters, and changes in the methodology from the proposals, is discussed below. The equations and other details can be found at §80.91 in the regulations.

a. Closely Integrated Gasoline Producing Facilities

Many refiners also operate gasoline blending facilities and/or import gasoline and thus would be considered to have multiple modes of operation, i.e., gasoline producing, blending and importing are each considered to be a mode of operation. In the July 9, 1991 proposal, EPA proposed two options for dealing with multiple modes of operation. Under the first option, each mode would have its own baseline (be it a unique baseline or the statutory baseline) and would comply with that baseline. EPA stated that, under this option, post-1994 shifting of gasoline and blendstocks between the modes could occur. Dumping could thus result if each mode were required to comply with a separate baseline. Under the second option, the baselines of each mode would be combined to form a single baseline for compliance purposes. This option could reduce dumping since all of a refiner's gasoline would contribute to its baseline. However it could also provide a refiner significant flexibility and possibly a competitive advantage over those with more limited operations.

In the April 16, 1992 proposal, EPA proposed having individual baselines for each mode to minimize anti-competitive effects. Integrated companies which have more than one mode of operation would have more flexibility than smaller refineries if allowed to have a single baseline for their entire operation. Further review of this issue suggested that separate baselines for each mode might instead reduce dumping by not allowing significant quantities of "dirtier" than average gasoline to be produced or imported, a change from the view expressed in the July 9, 1991 proposal. Accounting and compliance determinations would also be less complicated if each mode of operation were subject to its own baseline.

In the February 26, 1993 proposal, EPA requested comment on allowing closely integrated blending operations to be included in the baseline determination of a refinery. For example, a blending facility which receives most of its gasoline and blendstocks from an associated refinery, and very little from outside of the company, would be considered closely integrated. In such a situation, the concern about anticompetitive effects is greatly reduced. EPA also stated that it does not expect "closely integrated" to apply broadly to refiners who happen also to have blending operations. In this proposal, EPA did not propose a similar inclusion of operations for refiners with import operations.

Many commenters supported allowing a single baseline for multiple modes of operation. Some commenters suggested that refiners with import operations also be allowed to develop a single baseline covering their refining and importing operations. One commenter suggested basing individual baselines on whether marketing or producing gasoline occurred at a facility. Requiring 60-75 percent of a blending facility's blendstocks to have come from a single refinery was suggested for defining a closely integrated refinery-terminal relationship. If closely integrated, one commenter suggested that the blending facility baseline be determined using Method 1-type data.

For the reasons described above, EPA is not, in general, allowing a single baseline for multiple modes of operation. However, EPA is allowing refiners with blending facilities which are closely integrated to include a blending facility's production (properties and volumes) in a single baseline. The criteria for being "closely integrated" is that at least 75 percent of the blendstock received at the blending facility in 1990 came from the associated refinery. EPA believes that the "closely integrated" criteria of 75 percent is reasonable because oxygenates and butane, among others, are blended into gasoline after the refinery. Based on the usual amounts (in volume percent) of oxygenates and butanes frequently added outside of the refinery, EPA estimated the "75 percent" criteria. For instance, ethanol blended into gasoline in 1990 was likely blended at the 10 volume percent level. Thus only 90 percent of the gasoline was refinery-produced blendstock (refinery meaning the associated refinery). While EPA could have required 90 percent of a blending facility's blendstock to have come from the associated refinery, in the case of ETBE, up to 17 percent ETBE by volume could be added to gasoline. Thus only 83 percent of the blending facility's gasoline would have been (or will be) refinery-produced blendstock. If butane is added in the winter, even less of the blending facility's gasoline would have been refinery-produced. Using the rule of thumb of 2 volume percent butane per psi increase, approximately 6 volume percent butane would be required to increase the RVP of summer gasoline from 9.0 psi to 12.0 psi, a not uncommon winter fuel RVP. Thus, as little as 77 percent of a blending facility's blendstock could be refinery produced. The 75 percent criterion insures that a significant portion of a blending facility's blendstock comes from the associated refinery, but allows it some leeway in obtaining blendstocks from other sources.

One or more blending facilities may be included in an aggregate baseline (to be discussed in paragraph 5.c) if each blending facility received at least 75 percent of its blendstock from one or more of the refineries in the aggregated baseline with which it is associated. For instance, the 75 percent criteria is satisfied if the terminal received 25 percent of its 1990 blendstock from refinery A and 50 percent from refinery B. Alternatively, it may also have received the entire 75 percent from either refinery A or B, refinery A and B being part of an aggregate baseline. EPA believes it is reasonable to allow this since the blending facility is still dependent on receiving a significant portion of its blendstock from within the company.

Although not previously proposed, some comments were received regarding other types of closely integrated facility relationships. EPA is thus allowing a single individual baseline to be determined for two or more refineries (or sets of gasoline blendstock-producing units) which are geographically near each other but are not within a single refinery gate, and whose 1990 operations were significantly interconnected. The burden is placed on the refiner to show that its two facilities are "significantly interconnected". In this case, the two facilities will have a single set of baseline parameter values and associated emissions.

Some commenters suggested that U.S. refiners with import operations also be allowed to develop a single baseline covering their refining and importing operations. EPA rejected this suggestion because it would be difficult for EPA to track a fuel's production location before the fuel is or was imported, particularly when considering 1990 production. Also, allowing such a situation would amount to trading between foreign and domestic refineries, which was not mandated nor intended by Congress.

b. Seasonal Weighting

In the February 26, 1993 proposal, EPA proposed that a refinery's own production volumes of 1990 summer and winter gasoline (based on whether the fuel RVP met EPA 1990 summertime volatility specifications) be used in the weighting of data on a summer and winter basis. This change from the previous proposal, in which EPA specified a summer/winter split, received a lot of support.

As discussed in paragraph 5.a, the 1990 annual baseline volume is the larger of the gasoline volume produced in or shipped from the refinery in 1990. Thus, a refinery's own baseline volumes of summer and winter gasoline (either on a produced or shipped basis) shall be used for weighting the summer and winter anti-dumping emissions and sulfur, olefins and T90 values. Summer volume consists of the volume of gasoline produced to meet the 1990 Federal volatility requirements. All other gasoline volume, including transition volumes, is considered winter volume (i.e., fuel produced or shipped during transitions from winter to summer is considered winter data because it does meet the summer volatility requirements). Because fuel production can lead fuel consumption by up to 2 months, use of refinery-specific volumes and time periods in the baseline determination will result in more representative baselines.

c. Grade Weighting

To minimize data-skewing due to inconsistent or special sampling situations (for instance, a trial gasoline which was heavily sampled compared to normal sampling), and to thus get a more representative baseline, average fuel parameter values shall be determined first for each grade of gasoline produced, and the resulting values weighted by the fraction of each grade sold in the period over which the value is determined. "Grade" shall mean each traditional grade of gasoline produced in the refinery in 1990, e.g., regular, midgrade, premium, not each different integer octane number as proposed in February 1993. EPA changed this definition based on comments received stating that requiring each octane number was onerous and impractical.

d. Equations

The equations have been modified slightly from the February 1993 proposal to require that specific gravity be included in the determination of baseline sulfur and oxygen contents. Because both of these fuel parameters are determined on a weight basis, and because gasoline and blendstocks vary, sometimes significantly, in weight-to-volume ratio, correct accounting of such terms must include a weight-to-volume conversion.

The equations have also been modified to reflect the separate determination of summer and winter baseline fuel parameter values.

e. Oxygen in the baseline

Congress mandated that reformulated gasoline contain oxygen, but did not mandate a post-1994 conventional gasoline oxygen content.[127] In 1990, some refiners produced or utilized significant amounts of oxygenated gasoline while others used almost no oxygen in their gasoline. The Act requires that, relative to 1990, increases in NOx emissions due to oxygenate use be offset by reductions (on a mass basis) in VOC, CO and toxics emissions.

The issue of how to treat oxygen content in the baseline and for compliance purposes was not addressed in the negotiated agreement nor in the July 9, 1991 proposal. However, the issue was discussed in the April 16, 1992 proposal, and two viable options for dealing with a refiner's baseline oxygen were identified. Under the first option, only a positive difference between the post-1994 annual average oxygen level and the baseline oxygen level would be included in the compliance calculation. If less oxygen were used in post-1994 gasoline than in 1990, the individual baseline value would be used in the compliance calculation, and there would be no penalty for using less oxygen in post-1994 conventional gasoline than in 1990. If more oxygen were used in post-1994 conventional gasoline than in 1990, credit would be given for the effect of the excess oxygen on emissions. The second option excluded oxygen in both the baseline and compliance determinations. Thus there would be no penalty for using less oxygen than in 1990 and no credit for using more oxygen (in conventional gasoline) than in 1990. If no credit is given for oxygen usage above base levels, there may be less processing flexibility relative to conventional gasoline production. In that proposal, EPA noted that Congress purposely did not include oxygen content in the statutory definition of summertime baseline fuel. EPA likewise did not include oxygen content in its determination of the proposed statutory wintertime baseline gasoline.

Several commenters suggested that the baseline be determined on a non-oxygenate basis so as not to penalize those who "reformulated", i.e., produced cleaner gasoline, early. Others supported including only the positive difference between

---

[127] Certain conventional gasoline areas which are CO nonattainment areas are required to contain oxygen during their oxygenated fuel season.

1990 and post-1994 oxygenate use. Others suggested variations--excluding it in the baseline but including it in compliance; excluding it from the baseline and normalizing the values of the other parameters to account for the dilution effect of oxygenate; and including it, as is, in both the baseline and compliance calculations. Relative to other calculations, some commenters suggested that oxygenate volume be excluded from conventional gasoline volumes. Others argued that including oxygenate used in conventional gasoline designated for areas for CO reduction purposes would give credit in one program for another mandated program, and that aromatics markets distortions and increased toxics emissions and dumping could result.

The anti-dumping provisions of §211(k)(8) require a comparison of 1990 and post-1994 emissions, based on 1990 gasoline quality and post-1994 gasoline quality, respectively. The quality of any gasoline includes its oxygen content, thus including oxygen content in the baseline and compliance calculations would be the most appropriate consideration of oxygen content. EPA is therefore requiring baseline parameter values to be determined on an oxygenated basis. However, §211(k)(8)(C) of the Act also requires that increases in NOx emissions, due to conventional gasoline oxygenate use, be offset by reductions in the other three pollutants. As stated earlier, significant VOC and CO reductions will occur even without the reformulated gasoline rulemaking. To ensure that an increase in NOx emissions is not associated with the use of oxygen, EPA is allowing refiners to choose to use either an oxygenated or nonoxygenated baseline when determining NOx emissions. Compliance would be measured on the same basis. Under this provision, a refiner could choose to switch from a nonoxygenated to an oxygenated baseline, beginning with the next averaging period. While EPA is allowing refiners to choose whether to use a nonoxygenated or an oxygenated baseline when determining NOx emissions, the initial decision to use an oxygenated baseline, or the switch from a nonoxygenated to an oxygenated baseline is permanent. EPA is allowing only the onetime change to minimize unnecessary administrative complications due to every refiner potentially changing its baseline NOx value annually. EPA expects a refiner to operate its refinery to its advantage, and thus it is not likely to make such decisions (of whether to use a nonoxygenated or an oxygenated baseline for NOx purposes) lightly. Additionally, Congress intended that the anti-dumping program compare a refiner's 1990 emissions with its post-1994 emissions, based on its fuels' actual average composition, i.e, its actual oxygenated quality, and a change to this baseline for NOx purposes should thus be permanent.

In determining the nonoxygenated parameter values from the oxygenated values, only the physical dilution and distillation effects of the oxygenate shall be considered. For instance, if a refiner's actual (oxygenated) baseline aromatics were 30 volume percent and actual oxygenate use was 5 volume percent, the nonoxygenated baseline aromatics value would be 31.6 volume percent, or 30/(100%-5%). Adjustments to refinery operations that would have been different had oxygenates not been used (i.e., octane) shall not be included because many potential adjustments are possible. In the above example, while it is likely that reformer severity may have been higher had oxygenates not been used (thus resulting in perhaps even a higher aromatics baseline value) such operational effects due to oxygenate use shall not be considered because they cannot be known with certainty.

A few commenters suggested that oxygenate volume be excluded from conventional gasoline baseline volumes. EPA disagrees--Congress specified that certain NOx emissions increases be offset, but did not specify how to deal with baseline volumes, leaving it to EPA's discretion. Additionally, the reason for allowing NOx emissions to be evaluated on a nonoxygenate basis in the first place is so as not to penalize refiners whose emissions increase due to oxygenate use. It is possible that restricting baseline volumes by excluding oxygenate volumes could penalize some refiners. Thus, it would be inappropriate for EPA to restrict the applicability of the individual baseline to the nonoxygenated gasoline volume. The total gasoline volume (including the volume of actual 1990 oxygenate use and the volume of those oxygenates assumed or shown to have been blended as discussed in paragraph 2.a) will thus be used to determine the 1990 baseline volume, as well as for the volumes to determine applicability of the individual baseline.

f. Work-in-Progress

Work-in-progress (WIP) refers to one or more major capital changes or commitment(s) made by a refiner prior to or in 1990, the baseline year for anti-dumping purposes. In those cases, the gasoline produced in 1990 might significantly differ from gasoline produced after the WIP was finished. However, since the anti-dumping baseline is based on 1990 gasoline, a refiner's compliance for post-1994 conventional gasoline would be measured by comparing emissions of conventional gasoline produced after the WIP with the emissions of 1990 gasoline produced prior to the WIP. For some of these refiners, compliance with the anti-dumping requirements (to not exceed 1990 emissions levels) could only be accomplished by not operating, or not fully operating, the new or upgraded unit. The inability to make use of the new or upgraded unit could in turn threaten the financial viability of some companies. EPA is allowing WIP baseline adjustments, under certain circumstances, as discussed below. A WIP adjustment allows a refiner to modify its baseline volumes and fuel parameter values such that they reflect the quality of its gasoline after completion of the WIP. In order to obtain a WIP modification, a refiner must petition EPA and EPA must approve the petition.

(1) Background

In the July 9, 1991 proposal, EPA asked for comments as to whether baseline adjustments should be allowed for major construction, or associated financial commitment, which occurred in 1990 and which would change a refinery's future gasoline quality. At the same time, EPA expressed concern about the legal basis for providing the option of having an "adjusted" baseline when the Act clearly states that a refiner's 1990 baseline is the basis for compliance with the anti-dumping requirements.

WIP was also addressed in the regulatory negotiations, and the negotiated agreement provided general guidelines on which to base the decision for allowing a WIP baseline adjustment. The guidelines were meant to restrict petitions for WIP adjustments to those extreme situations where it would be appropriate to make an adjustment. The guidelines in the agreement were stated as follows:

> "A refiner's baseline will be modified for refinery work-in-progress at year-end 1990 if it can be demonstrated that
>
> 1. such a modification was significant, i.e., if at least a five percent difference between baseline emissions calculated with and without the work-in-progress resulted, and
>
> 2. such work was associated with other regulatory requirements, and
>
> 3. failure to grant credit would result in an extraordinary regulatory burden, i.e., a substantial portion of the refinery's capital would be at risk if the adjustment were not granted, and
>
> 4. such credit would not result in significant environmental harm (e.g., the credit will not cause the refiner to be five percent above the Clean Air Act antidumping baseline, etc.)."

EPA's April 16, 1992 proposal further discussed baseline adjustments for WIP. The guidelines presented in the negotiated agreement were included in this proposal as requirements, all of which had to be met in order to obtain an adjustment. In this proposal, adjustments were proposed to be allowed only for significant differences in exhaust benzene emissions. EPA also stated that authority for a WIP baseline adjustment could be found in Alabama Power Company v. Costle, 636 F.2d 323.357 (D.C. Cir 1979) which explained that agencies possess "equitable discretion...to afford case-by-case treatment--taking into account circumstances peculiar to individual parties in the application of a general rule to particular cases, or even in appropriate cases to grant dispensation from the rule's operation." Thus, in allowing WIP adjustments, EPA would be exercising its "equitable" discretion to afford limited relief to refiners which had work-in-progress and which would be extraordinarily burdened by the anti-dumping requirement that they not exceed their 1990 emissions. EPA proposed that the "substantial" capital-at-risk requirement would be met if the capital involved with the WIP was greater than or equal to 10 percent of the refinery's depreciated plant and equipment value.

In the February 26, 1993 proposal, EPA expanded upon and clarified certain aspects of the WIP criteria. First, EPA proposed that the WIP adjustment also apply to the fuel components which are capped when the simple model is used, and to exhaust toxics and NOx emissions in the years when the complex model is required. The latter emissions requirement is consistent with the negotiated agreement since the first guideline in the agreement states "...at least a five percent difference between baseline emissions...". While allowing a WIP adjustment to apply to the fuel parameters controlled under the simple model (sulfur, olefin and T90) was not specified in the agreement, it is appropriate to allow such adjustments because those fuel parameters are standards with which a refiner must comply. Specifically, EPA proposed that if one or more of the following situations occurred, and all other criteria were also met, a WIP adjustment would be allowed:

1) at least a 25.0 percent difference exists between sulfur, olefin and/or T90 values calculated with and without the WIP adjustment;

2) at least a 5.0 percent difference exists between the refiner's baseline exhaust benzene emissions calculated with and without the WIP adjustment;

3) at least a 5.0 percent difference exists between the refiner's baseline exhaust toxics emissions calculated with and without the WIP adjustment;

4) at least a 5.0 percent difference exists between the refiner's baseline NOx emissions calculated with and without the WIP adjustment.

Also in the February 26, 1993 proposal, EPA proposed and requested comments on allowing either the "10 percent" criteria from the April 16, 1992 proposal or a $10 million minimum cost of the WIP to satisfy the capital-at-risk criteria. Comments were received which stated that the 10 percent requirement could be biased against recently built or recently upgraded refineries because the depreciated value would be higher for these facilities than for older refineries of the same size. The commenter also claimed that newer facilities tend to benefit the environment more than similar, older facilities, and thus could be unfairly penalized, compared to older facilities, by the proposal.

EPA also proposed that WIP include projects actually under construction in 1990 and projects for which contracts were signed in 1990 such that construction would be completed in time to comply with the regulatory requirement motivating the WIP (per the proposed requirement that stated the WIP must be associated with other regulatory requirements).

In the February 26, 1993 proposed regulations, EPA expanded on the last of the criteria outlined in the agreement, that a WIP adjustment not result in significant environmental harm. The agreement suggested that the adjustment not cause the refiner's baseline to be more than five percent above the

"Clean Air Act anti-dumping baseline". In the April 16, 1992[128] proposal regulations, EPA addressed this criteria as follows:

> "...Such a credit would not cause a refiner's baseline exhaust benzene emissions...to exceed the exhaust benzene emissions due to the baseline gasoline...by more than five (5.00) percent.
>
> ...A work-in-progress-adjusted baseline exhaust benzene emission value which is greater than 105 percent of the exhaust benzene emissions due to the a baseline gasoline...shall be allowed if the pre-work-in-progress baseline exhaust benzene emissions value was greater than the work-in-progress-adjusted value."

As stated, EPA's 1993 proposal would expand this criteria by creating parallel requirements to cover the exhaust toxics and NOx emissions and simple model fuel parameters. The language included in the February 26, 1993 also proposed regulations (shown below[129] in paragraph (A)) to cap exhaust emissions and sulfur, olefin and T90 values. Additionally, the language shown in paragraph (A) capped the WIP adjustment of refiners whose unadjusted baseline (parameters or emissions, as applicable) was less than the statutory baseline at 105 percent of the statutory baseline. The language shown in paragraph (B) and (C) allowed refiners whose unadjusted baseline was greater than the statutory baseline to maintain their unadjusted baseline value (and not have to reduce it to 105 percent of the statutory baseline).

> "...(A) Such a credit would not cause a refiner's baseline exhaust benzene emissions, exhaust toxics emissions or NOx emissions,...to exceed the respective emissions due to the baseline gasoline...by more than five (5.00) percent nor allow its sulfur, olefin or T90 values to exceed the corresponding values...by more than five (5.00) percent.

---

[128] From §80.91(c)(4)(iv) of the March 31, 1992 proposed regulations. The April 16, 1992 proposal published in the Federal Register contained only the preamble language, it did not include the associated regulations. However, both the preamble and regulations were completed on March 31, 1992; the April 16, 1992 published preamble differed from the March 31, 1992 preamble only in minor ways to allow it to be printed in the Federal Register. Thus the regulations associated with the April 16, 1992 published proposal are actually dated March 31, 1992.

[129] From §80.91(d)(4)(iv).

> (B) Work-in-progress-adjusted baseline exhaust benzene, exhaust toxics, or NOx emission values,...which are greater than 105 percent of the respective emissions due to the baseline gasoline...shall be allowed if the pre-work-in-progress baseline values were greater than the work-in-progress-adjusted values.
>
> (C) Work-in-progress-adjusted baseline sulfur, olefin or T90 values which are greater than 105 percent of the respective baseline values...shall be allowed if the pre-work-in-progress baseline values were greater than the work-in-progress-adjusted values."

(2) Comments

Most commenters supported allowing WIP adjustments (if all other criteria were met) for significant differences between unadjusted and WIP adjusted values of exhaust toxics emissions, NOx emissions, sulfur, olefin or T90. A few commenters suggested that different complex and simple model emissions requirements have different comparison criteria. Additional comments suggested reducing the threshold values between WIP-unadjusted and adjusted values, i.e., the difference in emission or parameter values which would be the impetus for desiring a WIP-adjustment. Commenters stated that lower differences between these two values (unadjusted and adjusted) were also significant, and the proposed levels were rather high and perhaps impractical. Comments also included the recommendation that if simple model requirements are the impetus for the WIP, that a refiner revert back to an unadjusted baseline when the complex model is used.

Few comments were received regarding the requirement that the WIP be associated with other regulatory requirements. However, additional clarification of the language was requested concerning "..completed in time...to comply...", per the February 26, 1993 definition of WIP as

> "...projects under construction in 1990 and projects which were contracted for and which will be completed in time for the refiner to comply with the regulatory requirement..."[130]

This language was included in the February proposal to ensure that the WIP would be completed in a timely manner, since the WIP was ostensibly being done to comply with a

---

[130] From §80.91(d)(5).

regulatory requirement. Less than timely completion would indicate that the regulatory requirement was not a driving factor in initiating the WIP. Clarification was also requested as to what types of contracts would be considered to have committed the refiner to the WIP. Other suggestions included allowing WIP adjustments for work not necessarily associated with a regulatory requirement, including WIP which would have a beneficial effect on a refinery's overall environmental performance.

Several comments reiterated a concern expressed in the regulatory negotiation discussions, namely, that a WIP adjustment should be an exception, i.e., few refiners should qualify.

As stated above, in the February 26, 1993 proposal, EPA proposed to allow "substantial regulatory burden" to be fulfilled if the WIP value was at least 10 percent of the refinery's depreciated plant and equipment value, or at least $10 million. Some commenters suggested that the WIP requirements be more stringent, ranging from opposition to any modification of capital at risk (presumably from the 10 percent criteria) to increasing the threshold value to $50 million. Other comments suggested reducing the threshold value to $5 million (possibly a more appropriate value for small refiners) or to 5 percent (instead of 10 percent) or eliminating any "dollar" amount because no one should be penalized because its investment fails to meet arbitrary time or cost criteria. Other alternatives suggested include considering 5 percent of the refinery replacement cost or 10 percent of the depreciated book value.

EPA received many comments and suggested language with regard to the simultaneous capping of emissions and parameter values in the February 26, 1993 proposal. Commenters also suggested that the five percent statutory baseline cap was too stringent and that the requirement for showing a difference between unadjusted and unadjusted values was inconsistent with the comparison to the statutory baseline. Other commenters stated that because most new refinery projects are subject to very stringent environmental regulations their overall environmental performance will likely improve.

(3) Final Rule

EPA is requiring that a refiner meet each of three criteria in order to qualify for a WIP baseline adjustment. A fourth criteria is also required to minimize environmental harm due to WIP adjustments.

The first criteria, the showing of significant difference between unadjusted and adjusted values (i.e., calculated with and without the WIP adjustment) has been changed from the February 26, 1993 proposal, considering comments received on this issue. As stated, the February proposal required at least a 25 percent difference in sulfur or olefins or T90 or at least a 5 percent difference in exhaust benzene emissions or exhaust toxics emissions or NOx emissions. Upon further analysis of fuel changes and corresponding emissions, reducing the threshold values seemed reasonable, and neither environmentally nor competitively detrimental. Additionally, reducing the thresholds did not appear to reduce the stringency of the WIP criteria, because the proposed values may have been too stringent, and perhaps unrealistic relative to actual refinery situations. In this final rule, at least the following minimum differences must be shown between WIP unadjusted and adjusted values:

<u>Minimum Differences between Unadjusted and WIP-Adjusted Values</u>

Exhaust benzene emissions (simple model):	2.5%
Exhaust benzene emissions (complex model):	2.5%
Sulfur:	10.0%
Olefins:	10.0%
T90:	10.0%
Exhaust toxic emissions:	2.5%
NOx emissions:	2.5%

Although not previously specified, the differences shown above shall be calculated as follows:

$$\frac{|\text{Unadjusted Value - Adjusted Value}|}{\text{Unadjusted Value}} \times 100 = \underline{\qquad}\%$$

EPA realizes that if many refiners qualified for a WIP adjustment, negative competitive effects could result. Additionally, allowing many adjustments could indicate that EPA has exceeded its equitable authority under <u>Alabama Power</u>, supra (there is, however, no specified limit on the number of refineries which may qualify). EPA has set the above WIP criteria so that adjustments are received only by those exceptionally burdened by the combination of the reformulated gasoline/anti-dumping rules and other legislative or regulatory requirements.

The second criteria requires a showing that the WIP was associated with another regulatory requirement. Obviously, the wording of the agreement, "...associated with other regulatory requirements..." leaves a lot of room for interpretation. EPA is requiring that the WIP be associated with a legislative or regulatory environmental requirement enacted or promulgated prior to January 1, 1991. Such requirements are not limited to gasoline or Federal requirements. For instance, stationary source or other fuel quality regulations are acceptable regulatory requirements. However, the WIP only applies to projects involving gasoline blendstock or distillate-producing units under construction in 1990 or for which contracts were signed prior to or in 1990 such that the refiner was financially committed to permanently changing refinery operations. EPA believes that the contracts should have committed the refiner to purchasing materials and construction of the WIP. As such, a process engineering design contract does not commit the refiner to actually implementing the WIP and would not be considered a WIP contract under this provision.

The third criteria requires a showing that the WIP cost was equal to or greater than 10 percent of the refinery's depreciated book value as of the WIP start-up date or had a cost of at least $10 million. Based on comments, "book" value was substituted for the proposed "plant (including capitalized engineering costs) and equipment" value. Commenters suggested that "book" value was a more universally used and understood term in the refining industry. EPA believes that both the $10 million or 10 percent criteria are fairly stringent requirements, and that more stringent requirements could threaten the viability of some refiners. Less stringent criteria could indicate that the value of the WIP was not actually sufficient to cause hardship should no WIP-adjustment be allowed. Thus, this provision is being promulgated essentially as proposed.

EPA is requiring that determination and verification of the WIP-adjusted baseline fuel parameter values be achieved using data obtained subsequent attainment of reliable operation of the WIP.

Finally, in order to minimize environmental harm due to WIP adjustments, EPA is limiting WIP increases in baseline exhaust benzene, exhaust toxics and NOx emissions and sulfur, olefins and T90 values to the larger of 1) the unadjusted individual baseline value of each emission or fuel parameter or 2) 105 percent of the corresponding anti-dumping statutory baseline value. The "105 percent" values are explicitly stated in §80.91. Note that sulfur, olefins and T90 are only constrained when compliance is determined using the simple model. When compliance is determined using the complex model, the WIP-adjusted values of these three fuel parameters are not subject to the caps. Because a WIP adjustment allows a refinery's entire baseline (fuel parameters, emissions, and volume) to be adjusted, thus affecting all of the emissions and fuel parameters controlled under the anti-dumping requirements, the requirement described above should adequately minimize environmental harm by not allowing extreme changes in emissions or controlled fuel parameters relative to statutory baseline gasoline.

Finally, while it may be true, as commenters suggested, that overall refinery emissions may decrease due to new refinery projects, section 211(k)(8) does not provide EPA authority to consider emissions other than those vehicle emissions specified. Hence, minimization of potential negative environmental effects due to WIP must be relative to the allowed WIP adjustments.

g. Baseline Adjustment for Extraordinary Circumstances

In the February 26, 1993 proposal, EPA asked for comment on whether it should allow baseline adjustments for certain extenuating circumstances. If adjustments were not allowed, ostensibly a refinery's baseline would be unrepresentative of the gasoline it would have produced in 1990 had the circumstance not occurred. EPA requested comment on what criteria would have to be met, or proof given, to demonstrate that 1990 refinery operations were indeed different than if the circumstance had not occurred. EPA also asked for comment as to the degree of financial hardship that might be required to be shown and on additional criteria which might have to be met in order to restrict any such petition to situations falling within the Agency's authority under Alabama Power, as discussed in the April 16, 1992 proposal.

EPA also requested comment as to whether two examples of potential extenuating circumstances should indeed be considered extenuating. The first example was the occurrence of downtime which occurs every 4-5 years and which happened to occur in 1990 (nonannual turnaround). The second example involved disasters which shut down a gasoline blendstock producing unit for 30 days or more. EPA also inquired as to whether requiring 30 days downtime was appropriate.

EPA also requested comment on whether a baseline adjustment should be allowed for the Defense Department's phaseout of JP-4 jet fuel. JP-4 is a naphtha/kerosene blend. Its replacement, JP-8, is a heavier fuel, and is produced from different feedstocks. The most likely alternate use of the JP-4 feedstock is in gasoline. However, that feedstock cannot be used in gasoline without first going through a reformer to increase its octane to suitable gasoline levels. Thus, the average aromatic content of a refiner's gasoline will likely increase relative to its 1990 values if the refiner had produced JP-4. Additionally, total gasoline volume produced will likely also increase relative to 1990, and this increase in gasoline production would be subject to the statutory baseline, instead of the refiner's individual baseline. In certain instances, JP-4 was such a large portion of the refiner's total 1990 production that the refiner may have extreme difficulty in meeting the anti-dumping requirements and could be forced to cease operating.

Many commenters felt that baseline adjustments should be allowed for the above situations as well as for others, including: almost meeting work-in-progress requirements; changes in process units and crude quality; the Persian Gulf War; strikes; neighboring unit owned by another company started up or shutdown subsequent to 1990; loss of a significant market (not limited to JP-4). Others stated that because every site is unique, baseline adjustments should be evaluated on a case-by-case basis. Still others suggested that EPA allow adjustments only for small refiners, or for a certain level of JP-4 production. Regarding the JP-4 situation, commenters felt that relief should be given in the anti-dumping program because of the involvement of two governmental units in creating an apparent conflict for certain refiners.

Several commenters, however, felt that no extenuating circumstance baseline adjustment should be allowed. Among the reasons cited for not allowing adjustments were: competitive inequities; Congressional intent to account for 1990 only; difficulty in defining extenuating circumstances; could be used to void work-in-progress requirements.

The 30 day downtime requirement received some support, and not much in the way of criticism.

After reviewing this issue, EPA has decided to allow baseline parameter and volume adjustments, upon petition and approval, due to the occurrence of unforeseen, unplanned downtime of 30 days or more of one or more gasoline blendstock or distillate producing units due to equipment failure or natural cause beyond the control of the refiner as well as for nonannual turnaround of a gasoline blendstock or distillate producing unit which occurred in 1990 and which resulted in the minimum amount of downtime. Fuel parameter and volume adjustments shall be made by assuming that the downtime did not occur in 1990. Baseline parameter and emissions values calculated with and without the adjustment are to be included in the baseline submission, and any adjustment must be verified by the baseline auditor. EPA believes that it is appropriate to allow adjustments in these cases because the circumstances described above would truly cause a refiner's 1990 baseline to be different than it otherwise would have been.

EPA is also permitting baseline adjustments for certain refiners which produced JP-4 jet fuel in 1990. Specifically, a refiner which owns a single refinery which does not produce reformulated gasoline, and whose ratio of 1990 JP-4 production to 1990 gasoline production equals or exceeds 0.5, may, upon petition and approval, be allowed to adjust its baseline fuel parameter values and volume to reflect its refinery operation had it not produced JP-4 in 1990. EPA believes that it has authority to allow such adjustments due to the discretion afforded EPA by Congress. Specifically, Congress did not prohibit EPA from providing relief in certain instances. Additionally, Alabama Power v. Costle[131] gives EPA "case-by-case discretion" to grant variances or even dispensation from a rule where imposition of the requirement would result in minimal environmental benefit but would extremely burden a regulated party.

As stated, JP-4 baseline adjustments will be allowed only for those refiners which will not produce reformulated gasoline. While the anti-dumping requirements, in general, apply to all conventional gasoline whether or not reformulated gasoline is also produced, in these specific cases no dumping will occur due to reformulated gasoline production. The intent of Congress with regard to the anti-dumping program will be met while not unduly burdening those that meet the specified criteria. Since both the unadjusted and adjusted baselines must be determined, if a refiner granted such an adjustment subsequently produces reformulated gasoline, its conventional gasoline compliance would immediately be subject to its original unadjusted baseline.

JP-4 baseline adjustments are generally limited to single-refinery refiners. These refiners have no way to aggregate baselines[132] so as to reduce the combined burden of JP-4 phaseout

---

[131] Alabama Power Company v. Costle, 636 F.2d 323.357 (D.C. Cir 1979).

[132] As discussed in paragraph 5.c, a refiner with more than one refinery may determine an aggregate baseline, i.e., a conventional gasoline compliance baseline, which consists of the volume-weighted emissions or fuel parameters, as

and the anti-dumping requirements on their operations. As stated, in some cases, if no relief were granted in this area, the viability of a refinery could be at stake.

Finally, JP-4 must have constituted a significant portion of a refiner's 1990 production in order for a significant burden to exist. As such, EPA is requiring that the ratio of the refinery's 1990 JP-4 production to its 1990 gasoline production must equal or exceed 0.5. EPA believes this ratio indicates that a significant amount of the refinery feedstock used for JP-4 production would have to be converted in order to produce gasoline. In its February 1993 proposal, EPA requested comment on what minimum portion of a refinery's 1990 production JP-4 should have constituted for the circumstance to be extenuating. Several different ratio options were suggested by commenters, as follows: JP-4 production to total refinery production, 20%; JP-4 production to gasoline production, 5%; JP-4 production to gasoline production, 75%; and, JP-4 production to gasoline plus JP-4 production, 10%. EPA's 0.5 JP-4 to gasoline ratio is in line with some of the commenters suggestions.

A baseline adjustment may also be obtained for a refiner which has more than one refinery if all of its refineries produced JP-4 in 1990 and meet the threshold criteria and none of its refineries produce reformulated gasoline in a given calendar year. While such a refiner may aggregate its refineries for conventional gasoline compliance purposes, since there will be no dumping (if no reformulated gasoline is produced), EPA believes that minimal environmental harm will result if a baseline adjustment is allowed under these circumstances as well. If one of the refineries produces reformulated gasoline in a given year, the unadjusted baselines of each of the refiner's refineries will be its compliance baseline, or will be part any aggregate baseline in which it is included.

While the adjusted emissions baselines of those approved for JP-4 adjustments are likely to be higher than their actual 1990 baselines (primarily due to increased benzene and aromatics) EPA expects minimal negative environmental affects. Because the number of refineries meeting the criteria is expected to be small and the total production of all such refineries is also small, less gasoline is affected by any baseline adjustments than if the criteria were less stringent. Also, there will be no dumping by these refiners due to reformulated gasoline production. In this situation, EPA believes that any negative environmental effects resulting from

---

applicable, of two or more refineries.

the allowed adjustments are justifiably balanced by the reduced burden on qualifying refiners.

Although EPA is allowing baseline adjustments for the specific circumstances described above, it in no way means this to be a precedent to allow adjustments for actual or so-called extenuating circumstances now or in the future. The language of the Act does not allow EPA to broadly permit baseline adjustments, although under certain, limited circumstances, particularly those which caused a baseline to be different than it otherwise might have been in 1990, EPA is not prohibited from allowing adjustments. In any case, Congress' intended representative baselines be utilized in the anti-dumping program. However, a baseline is neither unrepresentative of 1990, nor incalculable, because of post-1990 changes in crude availability, fuel specifications, fuel markets, etc. Congress certainly knew that these types of changes could affect baseline determinations, yet in creating the anti-dumping requirements it did not require EPA to consider such factors in determining baselines. In fact, no direction was given to account for two mandated fuel changes, Phase II volatility control and lead phaseout. Also, unlike work-in-progress (a specific extenuating circumstance occurring in 1990), provisions for dealing with such situations, while mentioned during the regulatory negotiation discussions, were not part of the negotiated agreement.

It is likely that circumstances for which baseline adjustments are not allowed may cause a refiner's 1990 and other pre-1995 conventional gasoline to be unrepresentative of post-1995 conventional gasoline production and that such circumstances may negatively affect some refiners. However, every refiner will be subject to future changes in markets, fuel quality requirements, etc., all of which will affect the refiner's gasoline quality and ability to comply with its anti-dumping baseline. Thus, except in extreme cases, baseline adjustments due to post-1990 changes which affect refiners would not be practical (due to the myriad circumstances which may exist) nor necessarily fair, and are definitely not supported by the language of the Act nor the intent of Congress. EPA is appropriately not providing for such adjustments.

h. Inability to Meet the Requirements

EPA realizes that every refinery is different with respect to configuration, geography, crude availability, etc. EPA also realizes that many unique situations occurred in 1990 that are probably not covered by the anti-dumping and baseline development provisions being promulgated today. While EPA's goal with regard to baseline development is to develop individual baselines which adequately represent a refiner's or importer's 1990 fuel, it does not want to penalize a refiner's or importer's baseline development for trivial reasons. Thus, if a refiner or importer is unable to comply with one or more of the specified requirements in its baseline development, it may, upon petition and approval, accommodate the lack of compliance in a reasonable, logical, technically sound manner, considering the appropriateness of the alternative. This provision was not included in the proposals, but is included in the final rule because sufficient comment was received indicative of the innumerable details and specific circumstances that exist in the baseline development.

5. Baseline Volume and Emissions Determination

a. Individual Baseline Volumes for Refiners, Blenders and Importers

The individual baseline volume of a refiner which utilizes Methods 1, 2 and or 3-type data to determine its baseline fuel parameters shall be the larger of the total volume of gasoline produced in or shipped from the refinery in 1990, excluding volumes exported. This provision is added because the volumes of 1990 shipments and production could differ, due to shipping from inventory or to not shipping some production at the end of the year. Thus for each refiner, either produced or shipped volumes could be larger. While 1990 gasoline shipments actually contributed to emissions, data is available (by Methods 1, 2 or 3) on 1990 gasoline production. The difference between the shipped and produced gasoline is expected to be negligible with respect to baseline determination. Volumes of oxygenates blended into gasoline at the refinery and oxygenate assumed or shown to have been blended into gasoline downstream of the refinery, shall be included. The baseline volume shall be determined after all adjustments, such as for work-in-progress or extenuating circumstances, have been performed.

For the same reasons discussed above, the individual baseline volume of a blender utilizing only Method 1-type data or having the anti-dumping statutory baseline as its individual baseline shall be also the larger of the volume of 1990 gasoline produced in or shipped from the refinery (blending facility). The individual baseline volume of an importer utilizing only Method 1 or having the anti-dumping statutory baseline as its individual baseline shall be the total volume of gasoline imported into the U.S. in 1990.

b. Baseline Emissions Calculation

Every refiner must develop a set of individual baseline data which include fuel parameter values, volume, emissions and blendstock-to-gasoline ratios. As discussed in Section IV, there are separate complex models from which to determine summer and winter emissions. As such, average baseline fuel parameters must be determined separately for summer and winter. Conventional gasoline baseline emissions (and sulfur, olefins and T90 values) will first be determined separately, on a summer and winter basis, using summer and winter fuel parameter values. As discussed in Section IV, when using the winter complex model, RVP is held at 8.7 psi; thus, the actual average winter RVP (for baseline or compliance purposes) is not a factor in determining winter emissions. The summer and winter emissions (and sulfur, olefins and T90 values) will then be weighted by the respective summer and winter baseline volumes to determine annual average baseline emissions (and sulfur, olefins and T90 values). Compliance is determined in a similar manner.

As also discussed in Section IV, there are two complex models--one for use prior to 2000 and one for use in 2000 and beyond. As such, every refinery will have two sets of baseline total exhaust toxics and NOx emissions--one set applicable prior to 2000, and one in 2000 and beyond. Note that baseline fuel parameter values and baseline volume do not change, only the emissions determined from the baseline fuel parameters. In the case of NOx, it is likely that every refinery will actually have four potential baseline NOx emissions values, depending on whether the nonoxygenated or oxygenated set of baseline fuel parameters is used to evaluate NOx emissions (see discussion in paragraph 4.e).

Regarding baseline emissions, many commenters were concerned about the effect of future revisions to the complex model on 1990 baseline emissions and future compliance, particularly should additional fuel parameters be added to the model. Many thought that the current (final) complex model should be grandfathered for anti-dumping purposes, i.e., that the baseline set per the final rule should always be the basis for anti-dumping compliance, regardless of future complex model revisions. Grandfathering the complex model, as suggested could prevent reformulation of conventional gasoline. Others suggested EPA specify a time frame for establishing baseline values of new parameters added to the model. In the event of revisions to the complex model, EPA will promulgate additional regulations which will consider the impact on conventional gasoline, including consideration of lead time, cost and other factors.

c. Conventional Gasoline Compliance Baselines

The Clean Air Act refers to gasoline sold by a refiner, blender or importer, but does not specify an averaging unit for baseline determination. EPA considered three possible options for baseline determination--refinery basis, refiner basis, or some combination of the two. During the regulatory negotiation, it was agreed that EPA would propose allowing a refiner to elect to establish an individual refinery baseline. In the April 1992 proposal, EPA proposed that a refiner could choose to have an individual baseline for each of its refineries or to have a single refiner baseline (and no individual refinery compliance baselines), but not a combination of the two.

Based on earlier comments, EPA realized that a refiner may desire to have an individual baseline for each of its refineries, if for example, one refinery has low baseline emissions and the other has high baseline emissions, and the low emission refinery will soon be producing primarily reformulated gasoline. If the operations of the high emission refinery do not change, the refiner would be out of compliance with the anti-dumping requirements because the contribution of the low emission refinery fuel in the anti-dumping calculation would be less. Thus, the refiner would be penalized for producing reformulated gasoline while maintaining conventional gasoline operations that are very similar to its 1990 operations. A similar situation could exist for refiners with both California and non-California refineries. If a refiner's California refinery was a low emission refinery which did not produce conventional gasoline in the future (because it was producing California Phase II gasoline[133]), the rest of the refiner's gasoline would be subject to a baseline which included the California refinery's low baseline if all refineries had to be aggregated.

EPA also realized, however, that allowing refiners to simply pick a combination of averaged and individual refinery baselines could give multi-refinery refiners an opportunity to game the system and potentially grant them a significant advantage over single-refinery refiners. Thus in the proposal, EPA stated that a refiner could not have multiple refiner baselines, i.e., either all of its refineries were included in its refiner baseline, or they all had their own baseline.

Most of the comments received on this issue claimed that EPA had not interpreted the Agreement-in-Principle's provision correctly. The agreement, according to the commenters, allowed

---

[133] California Phase II gasoline must be sold yearround in California beginning January 1, 1996.

refiners to decide how to aggregate[134] their refineries' baselines. Some suggested that if aggregations are only allowed as proposed, compliance with the simple model, complex model and/or anti-dumping requirements would be difficult. It was also suggested that refiners should be able to re-aggregate their refineries' baselines annually, or at least once.

A few commenters agreed with EPA's proposal, although some went further and suggested that all refineries should be required to comply with their individual baselines, so as to minimize advantages for multi-refinery companies over single refinery companies. One commenter stated that refinery-specific baselines could actually increase dumping of high emission feedstreams.

Upon further consideration of this issue, EPA is allowing refiners to choose to have one or more individual refinery conventional gasoline compliance baselines and one or more "refiner" baselines (i.e., more than one grouping of two or more refineries to form a compliance baseline). All baseline determination and compliance requirements applicable to refiners also apply to refineries with individual baselines and to aggregate baselines. NOx compliance of all refineries in the aggregate must be on the same basis, oxygenated or nonoxygenated. Moreover, the decision to group or not group refineries is a onetime decision, i.e., refineries cannot be re-aggregated annually. Because of this, and because a refiner's total emissions will be conserved, the possibility of gaming will be reduced. Thus EPA believes that allowing more than one individual or aggregate baseline is equitable as well environmentally sound.

Because baseline aggregation, as well as determination of the 1990 equivalent conventional gasoline volume (per §80.101), depends on a refiner's 1990 baseline volume, refiners which get the statutory baseline as their individual baseline (i.e., were in operation for less than 6 months in 1990) do not have baseline volumes. Hence, the baselines of such refineries cannot be aggregated with other refiners for conventional gasoline compliance purposes.

An individual baseline (including both parameter and emission values) must still be calculated for each refinery. Individual baselines are required for several reasons. First,

---

[134] When two or more refineries are grouped for the purpose of having a single conventional gasoline compliance baseline, the refineries shall be considered "aggregated", and the resulting baseline shall be an "aggregate" baseline.

aggregate baselines are determined by volume-weighting the individual baseline emission values (and sulfur, T90 and olefin values under the simple model) of the included refineries. Second, reformulated gasoline compliance under either the simple model (for sulfur, olefin and T90) or early use of the complex model is on a refinery basis. Finally, individual baselines must be known in the event that ownership of a refinery changes.

As proposed, EPA is also requiring that a refiner establish individual refinery baselines under certain circumstances. Specifically, as discussed in the July 9, 1991 and April 16, 1992 proposals, "localized dumping" could occur in certain geographical areas. If significant increases in toxic emissions are occurring in a conventional gasoline area surrounding a reformulated gasoline opt-in area, and if the area is served by an isolated distribution system, EPA will require refineries in the affected area to have individual baselines for compliance purposes[135]. If the refinery was part of an aggregate baseline, the other refineries constituting the aggregate remain in the aggregate, although the aggregate baseline must be recalculated to reflect the loss of the baseline of the refinery which left the aggregate as required.

Most commenters supported this proposal. One commenter requested that refineries which will produce no reformulated gasoline and which supply an isolated area be exempt from the anti-dumping requirements. The Act requires all domestic refiners, blenders and importers to comply with the anti-dumping requirements, regardless of the location of gasoline production. One commenter requested that this proposal not be limited to a conventional gasoline area surrounding an opt-in area but that it apply to all conventional gasolines areas which may experience localized toxics emissions increases. This suggestion was rejected, in part, because the Act directs EPA to focus on refiners, and not on areas. Additionally, it would be extremely difficult to determine such areas, unless those areas are somewhat isolated. Also, this proposal was discussed at length in the regulatory negotiations, and the associated language was meant to limit its scope. EPA believes this is reasonable as refiners are required to maintain conventional gasoline emissions at their own baseline levels, and because several refiners supply most areas. Except for the isolated areas which are provided for by this provision, few areas are likely to see unidirectional changes in toxics

---

[135] EPA's authority to establish such individual baselines is based on section 211(c) of the Act which allows the Administrator to regulate fuels or fuel additives to protect the public health or welfare.

emissions over an averaging period. This provision attempts to address a narrow problem, and EPA has appropriately limited it to achieve this goal.

d. Baseline Recalculation

Pursuant to this rulemaking, each refinery will have a 1990 individual baseline, whether that baseline is a unique baseline, determined per the regulations, or whether it is the anti-dumping statutory baseline. Its individual baseline is retained forever, whether new units are added to the refinery, or other units are shutdown (the situation of the entire refinery shutting down is discussed below).

In the April 16, 1992 proposal, EPA proposed that baselines would be required to be recalculated under certain circumstances. EPA did not receive significant comment on this issue. The circumstances which would require baselines to be recalculated are discussed below. Only aggregate baselines are required to be recalculated, although a refinery which was part of an aggregate baseline may end up having to comply with its individual baseline under certain circumstances.

If a refinery was in operation for at least six months in 1990 and is later sold, and if the refinery was part of and/or becomes part of an aggregate baseline, any aggregate baseline affected by the sale shall be recalculated to reflect the inclusion or exclusion, as appropriate, of the baseline fuel parameter values, emissions and associated volumes of the refinery being exchanged.

In a change from the proposals, EPA is requiring that if all gasoline producing units in a refinery are shut down for any length of time, and if the refinery is part of an aggregate baseline, the aggregate baseline shall be recalculated due to the shutdown. Excluding the baselines of shutdown refineries is more consistent with the other baseline recalculation situations. However, if a refinery is only partially shutdown, it must still comply with the requirements of the anti-dumping program for any conventional gasoline (and blendstocks, if necessary, per the requirements of §80.102) it produces.

Note that if a shutdown refinery is later sold to another refiner, its old aggregate baseline (if it was one of more than two refineries comprising the aggregate baseline) and its new aggregate baseline, if applicable, would be recalculated. If the shutdown and later sold refinery was one of two refineries comprising an aggregate baseline, the remaining refinery would then have an individual baseline--it could not be re-aggregated, either by combining with another refinery with an individual baseline or by inclusion in another aggregate baseline.

Any baseline changes due to the circumstances described above, or to similar circumstances, must be verified by a certified baseline auditor, and submitted (with appropriate documentation) to EPA within 30 days of the event causing the baseline fuel parameter values to require recalculation.

D. Baseline Auditor

In the regulatory negotiations, although not specified in the negotiated agreement, the concept of having individual baseline determinations verified by an independent source prior to submission to EPA was discussed. The independent source is also known as the baseline auditor[136]. In the July 9, 1991 proposal, EPA briefly discussed its expectations of the auditor, namely that the auditor will verify individual baselines using good engineering judgement. Also briefly discussed were possible auditor certification options. In the April 16, 1992 EPA briefly discussed that it would develop, in consultation with petroleum refining experts, auditor certification criteria as well as technical guidelines for the auditor to follow in its verification. On December 15, 1992, EPA held a workshop to discuss the roles and qualifications of baseline auditors and certain aspects of the baseline approval process. Based on comments received at and following the workshop, as well as comments to previous proposals, in the February 26, 1993 proposal, EPA proposed specific requirements that a potential auditor would have to meet to be able to verify baselines, and also presented its specific expectations of the auditor's verification.

As discussed below, EPA is requiring that the auditor, and any individuals and organizations which participate in substantive aspects of a baseline verification process, meet certain independence and technical criteria, and that the auditor assume responsibility for its verification of an individual baseline. However, ultimate responsibility for the accuracy of its baseline rests with the refiner. Nonetheless, if a refiner uses an auditor which does not meet the specified requirements, its baseline submission will not be accepted until it is verified by an auditor meeting the requirements.

---

[136] EPA recognizes that the term "auditor" usually refers to a person who evaluates financial data. However, in the context of the baseline development discussed in this rulemaking, "auditor" or "baseline auditor" refers to a person or an organization retained to technically evaluate the baseline determination of a refiner for correctness.

Note that those refiners, blenders and importers which can and do utilize the statutory baseline are not required to have a baseline auditor.

1. Auditor Qualifications

a. Personnel

The baseline auditor can be an individual or an organization. However, if it is an organization which is retained for baseline verification, the primary analyst(s) must be identified. The primary analyst is the individual who must sign the statement that is included with the baseline submission indicating that it has reviewed the baseline determination and that the baseline was correctly determined. An auditor may utilize contractors and subcontractors, which may be individuals or organizations. There was a request for EPA to define "auditor", "contractor" and "subcontractor" as well as delineate the qualifications and restrictions associated with each. The auditor is a person or organization retained by a refiner to meet the audit requirements of these regulations. EPA believes the terms "contractor" and "subcontractor" are generally understood, and EPA intends these terms to have these meanings. The primary analyst of the auditor is responsible for the verification, even if parts of the verification were performed by individuals or organizations it, or its organization, hired to perform those parts. EPA is requiring that all individuals or organizations involved in substantive aspects of a baseline verification meet the applicable criteria as specified in §80.92 of the regulations.

EPA is also allowing a baseline auditor to be the same individual or organization which determined a refiner's baseline. Not allowing the dual roles adds considerably to the time required for baseline determination, since the auditor performing the verification (potentially the second outside organization involved in a refiner's baseline determination) must learn about the refinery from ground zero, whereas the person or organization which determined the baseline will have already established a knowledge base. The cost savings could be considerable for smaller refiners who do not have the in-house capability to prepare the baseline. Several commenters who addressed this issue agreed that the auditor should be allowed to also be the baseline preparer, mostly from a cost savings point-of-view. One commenter was concerned that the independence of the review would be lost. While some independence of review may be lost, this concern is minimized by the independence requirements discussed below, and EPA believes that the cost and time savings are relevant considerations.

b. Independence

One of the primary criteria required of the auditor is that it be independent of the organization whose baseline it is verifying. This requirement is intended to mitigate conflicts-of-interest. Any person involved in substantive aspects of a baseline verification, including organizations and individuals associated with the auditor, its contractors and subcontractors, must meet the independence criteria. "Substantive aspects" would include any function that involves analysis, review, calculations, etc. relative to the verification. Thus, for instance, clerical personnel would likely be exempt from these requirements. Also, individuals within the same organization may meet the independence criteria for some refiners but not for others. Independence must only be shown for the refiner on whose baseline verification the person is working. Persons who do not meet the independence criteria may work on developing the baseline, but not on the verification.

The independence requirement is designed to avoid conflict of interest, and thereby minimize the chance that the results of an audit are influenced either intentionally or unintentionally by factors other than the accuracy of the baseline determination, such as a desire to avoid injuring an ongoing financial or other relationship. Another concern in such a situation is that if the auditor also develops the baseline, then as an auditor of themselves they may be influenced to avoid pointing out mistakes made in developing the baseline. EPA believes, however, that this risk is limited in nature, and the benefits in time and cost from allowing the auditor to also develop the baseline outweigh the risks.

Few comments were received relative to the criteria which were proposed in the February 26, 1993 proposal. Thus, EPA is promulgating the following independence requirements. First, no person subject to the independence criteria shall have worked in the past three years as an employee of the refiner or importer whose baseline is being verified. This does not include having been a contractor or subcontractor to the refiner or importer. This is a slight modification of the proposal, where the criterion was five years, and is based on comments received that industry turnover is sufficiently high that three years was also appropriate. EPA agrees that three years is probably sufficient to establish independence.

The second independence requirement requires that personnel subject to the independence criteria be financially independent of the refiner or importer. Thus, no person subject to the independence criteria shall 1) have received more than one quarter of its revenue (a change from income) from the refiner or importer during the previous year (prior to its hire by the refiner or importer) and 2) have a total of more than 10 percent of its net worth (a change from total investment holdings) with the refiner or importer. As indicated, some of these requirements are slight modifications of those proposed, based on comments suggesting more appropriate wording. Income received from the refiner or importer to develop the baseline being audited (verified) is excepted. EPA agreed with the suggestion of one commenter, and is thus including as a requirement, that compensation for baseline auditing services be independent of the outcome of the audit.

c. Technical Ability

Because verification of a refiner's or importer's baseline is likely to be technically challenging, the auditor must be technically able to evaluate a baseline determination. Its technical knowledge must include, but is not limited to, an understanding of: petroleum refining processes; gasoline blending; the effects of process and feedstock changes on the quality of gasoline blendstock streams; associated computational procedures and methods of product analysis. It must have data gathering and analysis skills, and financial knowledge relative to refinery operations and capital equipment.

Few comments were received concerning the proposed specific technical requirements of auditors. In order to increase the likelihood that an auditor will possess the necessary technical knowledge and ability, EPA is requiring that the primary analyst(s) have a minimum amount of refinery-associated experience. Specifically, a primary analyst must have 1) worked at least 5 years in either refinery operations or as a consultant for the refining and gasoline-producing industry, and 2) at least 3 years experience working with refinery computer models, such as those used to evaluate unit operations or for refinery planning and economic analyses, if such models are used in support of the baseline determination and/or verification (the primary analyst must have this experience with the specific model(s) used in the baseline verification). EPA expects the primary analyst to know the relevant details and assumptions of the baseline determination it verified. EPA may allow, upon petition, a primary analyst to have less than the minimum experience if its technical ability can be otherwise satisfactorily demonstrated.

2. Auditor Certification

EPA is requiring that the qualifications of an auditor be shown in a statement which is submitted to EPA. The statement should show how the auditor, its contractors and subcontractors meet the independence and technical criteria. It can also include additional information which may assist EPA in its review of the auditor's qualifications. If the auditor's qualification statement does not adequately address the independence and technical ability criteria, the auditor will not be certified for baseline auditing, and baseline submissions verified by that auditor will not be accepted until such criteria are fully addressed and the auditor is shown to meet all the requirements.

In the February 26, 1993 proposal, EPA proposed that an auditor's qualification statements can be submitted with a refiner's or importer's baseline submission, without the auditor having first been approved by EPA. In this case, the refiner or importer is assuming that the auditor will meet the requirements. However, if the auditor does not meet the criteria, the baseline submission will not be accepted until the baseline has been verified by a qualified auditor. EPA also proposed that qualification statements can also be submitted to EPA prior to a baseline submission by a refiner or importer or at any time by the auditor. If no response was received from EPA within 30 days of application or the date the final rulemaking is published in the Federal Register (whichever is later), the auditor would be deemed EPA-certified.

Most commenters agreed with allowing either refiner, importer, or auditor submission of qualifications, as discussed above. One commenter thought that EPA should notify auditors of approval rather than letting them be certified by default, and that they should be pre-certified. EPA believes however, that refiners could evaluate the requirements described in the February 26, 1993 proposal (which are not much different from those listed in this final rulemaking) and evaluate the credentials of the auditor they want to use to verify their baseline determination. Since its baseline will not be approved unless the auditor meets the qualifications, the refiner or importer is likely to carefully choose its auditor. Thus EPA does not believe that precertification is necessary. In a modification of the proposal, EPA is changing the timing of being certified by default from 30 to 45 days. This allows some additional time for the qualification statement to reach EPA, considering mailing and delivery delays, etc.

As stated, the refiner or importer is responsible for choosing an auditor which meets the requirements. In the February 26, 1993 proposal, EPA had proposed that within thirty (30) days of hiring a baseline auditor, or the date the final rulemaking is published in the Federal Register (whichever is later), each refiner and importer must inform EPA of the name, organization address and telephone number of each auditor hired. However, upon further review, EPA believes that this information only need be provided to EPA once, and that notification in the baseline submission will suffice. The baseline submission must include all auditors hired, whether or not they were retained through completion of the verification or not.

3. Auditor Responsibilities

The auditor is to verify the baseline determination, not necessarily perform a second determination. Based on comments received, it did not appear necessary to require a re-development of the baseline--verification would suffice. During the workshop, EPA had discussed the possibility of requiring auditors to submit a plan of their verification process to EPA prior to beginning the verification. EPA believes that such a requirement would increase the time required to prepare a baseline submission, and impose additional costs, and is unnecessary if the auditor (particularly the primary analyst) is required to meet certain criteria. Since EPA is specifying such criteria, and considering the time and cost aspects, auditors are not required to submit a verification plan.

The auditor's primary responsibility is to insure that all baseline determination and submission requirements are fulfilled. This includes, but is not limited to: insuring that all data is correctly accounted for; that, depending on the circumstance, all the appropriate criteria are met; that calculations are done correctly; that proper adjustments have been made when necessary, such as when using Method 3-type data, or when adjusting for work-in-progress or extenuating circumstances, as allowed.

EPA is also requiring the refiner to include in its baseline submission a statement, prepared and signed by the primary analyst, stating that to the best of its knowledge, it has thoroughly reviewed the sampling methodology and baseline calculations, and that they meet the requirements and intentions of the rulemaking, and that it agrees with the final baseline values (fuel parameters, emissions, volumes, and blendstock-to-gasoline ratios) listed in the baseline submission. As stated, the refiner or importer is ultimately responsible for the adequacy and accuracy of its baseline determination. However, because EPA plans to rely heavily on the auditor's verification, if EPA discovers that an auditor has displayed gross incompetency or intentionally committed a significant error in the verification process, EPA may pursue debarment of the auditor under 18 USC 1001.

In accordance with the refiner being ultimately responsible for the accuracy of their baseline, the refiner will be the first point of contact for questions concerning the baseline determination. In certain situations, a re-verification of all or part of the baseline submission may be required, and the refiner may want to involve the auditor at the start of such discussions.

E. Baseline Submission and Approval

1. Baseline Submission

a. Timing

EPA is requiring refiners and importers to submit two copies of their baseline determination to EPA within 6 months of the date the final rule is published in the Federal Register. Two copies will allow multiple simultaneous review of baseline submissions. The six month timeframe was proposed in the February 26, 1993 proposal and received some support via comments (and minimal negative comments). EPA believes this timeframe is reasonable whether baseline auditors are precertified by EPA or whether the refiner or importer has assumed responsibility for choosing a qualified auditor without pre-certification. It is also reasonable considering the fact that many refiners have already gathered sufficient data, began estimating their baselines, and are working with potential auditors in anticipation of the final requirements. If a refiner must collect data after today, it must submit its baseline to EPA by September 1, 1994. Although this date is very close to the first day of the reformulated gasoline program, refiners will have been able to complete collection of the required minimum data at least 30 days prior to this date (most likely earlier). It will also give EPA time to review and approve the submissions.

EPA will consider petitions for extensions of the deadlines, however, refiners are encouraged to submit baseline submission packages as soon as possible after today.

b. Petitions

In many situations in the baseline determination, a refiner or importer is required to petition EPA in order to be allowed to account for a variance from a requirement. In other situations, the refiner or importer is required to "show" that it meets certain criteria. In either of these situations, approval will be given by the Director of the EPA's Office of Mobile Sources, or designee. As will be discussed below, all petitions must be included in the baseline submission--in fact, in most cases, baseline calculations have to be determined both with and without the requested variance, since the outcome of the request would be unknown. Although not previously proposed, EPA is allowing petitions and "showings" to be submitted prior to the baseline submission deadline although an early decision on the request is not guaranteed. Nonetheless, the baseline submission must be submitted by the applicable deadline, whether or not EPA has decided to approve or disapprove the request.

c. Submission Requirements

Baseline submissions are required from all refiners, including blenders, and importers. Although minimum requirements concerning the information contained in the baseline submissions is specified in §80.93, no set format for the baseline submissions is specified. EPA expects to issue a sample "baseline submission" memorandum soon which refiners and importers may follow in setting up their baseline submissions.

The baseline submission must include a letter signed by the chief executive officer of the company, or designee, which states that the data submitted is the extent of the data available for the determination of all the required baseline fuel parameter values, that sampling methodology and baseline calculations meet the requirements and intentions of the rulemaking, and that the final baseline parameter and emission values listed represent its 1990 gasoline, to the best of its knowledge. If an entity is permitted to utilize the anti-dumping statutory baseline parameters as its individual baseline parameters, and does so, it must also include a letter signed by the chief executive officer of the company, or designee, indicating that insufficient data exists for a baseline determination by the methods allowed for that entity. Where an auditor is required to verify a baseline, the auditor's statement of verification, and the auditor's qualifications if not previously certified by EPA, must be also be included in the submission.

The baseline submission must contain information relevant to the development of the baseline value for each of the following fuel parameters: benzene; aromatics; olefins; sulfur; T50; T90; E200; E300; oxygen, including oxygenate type; and RVP. It must also contain the baseline emissions values and baseline volumes. Additionally, the blendstock-to-gasoline ratio discussed in Section IX of the Preamble and defined in §80.102 must be determined for each calendar year 1990-1993. Although this requirement was not included in the proposals, it makes sense to include it in the baseline submission, and have the auditor verify it as for any other baseline data, because future compliance will be based on this ratio.

Based on comments to its proposals, EPA has determined that a number of its proposed baseline submission requirements, such as parameter measurement dates and extensive crude oil information, were not pertinent to the baseline determination. EPA thus revised its requirements; the minimum information which must be included in the baseline submission is described in §80.93. Certain information on crudes and refinery unit operations is still required because EPA may wish to evaluate baseline submissions using a refinery flow simulation system. EPA may require additional data to aid its review of the baseline submission. A refiner or importer may also include additional information which may be useful to EPA in its evaluation of the baseline submission. In addition to the numerical data requirements, EPA is requiring that a narrative of the development of each baseline parameter value be included in the baseline submission. The narrative should discuss and explain the sampling and calculation methodologies, as well as discuss technical judgement and reasoning. Such a narrative will assist EPA in its review of the baseline submission.

2. Baseline Approval

EPA had proposed that it would publish baseline parameter values, by refinery, for public comment while it reviewed baseline submissions. Based on comments and further review of this issue, EPA believes that no substantive comments could result from publishing such information because of the complexity of the baseline determination. Additionally, EPA realizes that certain aspects of the baseline determination must necessarily remain confidential in order to prevent serious, negative competitive effects.

Several issues were raised in the comments concerning confidential treatment of information submitted by refiners. Issues of confidential treatment for any information submitted is regulated by EPA's Confidential Business Information (CBI) regulations, 40 CFR Part 2 Subpart B. Under the Freedom of Information Act (FOIA), a person has a right to release of documents unless the documents are covered by an exemption such as the CBI exemption. A lot of the information submitted by refiners for baseline approvals might well be CBI, and would be protected under CFR 40 Part 2.

The CBI claim should be made with the baseline submission, or it can be released without further contact with the submitting party (40 CFR 2.203 (a)(c)). In accordance with 40 CFR Part 2, Subpart 2, any person or organization providing information to EPA in connection with the determination of a baseline, including establishing a baseline or investigating baseline determination discrepancies, may assert that some or all of the information submitted, except the baseline emissions or parameter values which are the standard for a refiner, refinery or importer, is entitled to confidential treatment. Such confidential information must be clearly distinguished from other information to the greatest extent possible, and clearly labeled "Confidential Business Information." Information covered by a claim of confidentiality will be released by EPA only to the extent allowed by procedures set forth in 40 CFR Part 2, Subpart B.

Because an entity's baseline will become its standard for compliance with the anti-dumping, and possibly reformulated gasoline, requirements, upon Agency approval of a baseline, the baseline exhaust benzene, exhaust toxics and NOx emissions values and 125 percent of the baseline sulfur, olefins and T90 values will be published in the Federal Register for each applicable gasoline producing or importing facility of a refiner, blender or importer. The standards themselves are not entitled to confidential treatment under 40 CFR 2.301 (e) (special CBI rules applicable to Clean Air Act cases). Since EPA must release them upon request, and because commenters did not provide any clear or compelling reason for not publishing them, and because there are benefits from publishing them (citizen suit enforcement, more information to the general public about EPA's standards, better deterrence to noncompliance), EPA should publish them.

Several commenters suggested publishing a refiner's or importer's anti-dumping index (ADI), a ratio of the individual baseline emissions to the emissions due to the statutory baseline. However, there is little difference between this value and the actual value if the statutory baseline emissions are known. Another suggestion included providing such information only upon request. Again, there is little difference between "on request" and publishing such information at one time. One commenter stated that no where in the statute was publication of baseline data required. As discussed above, no compelling reasons for not publishing a refiner's standards were presented by commenters. Another commenter added EPA could use the "rule of three" which has been used by DOE; in this method, three numbers are averaged and the average reported, however, none of the individual numbers are publicly available. Although in many instances this method may be useful, such as in reporting fuel production by grade, in this case, EPA does not believe its obligation to the public would be fulfilled using the "rule of three" since each refiner has a unique standard with which it must comply, and which will be publicly available.

EPA cannot specify a timeframe for approval of baseline submissions because it cannot regulate itself. EPA realizes, however, the importance of having an approved baseline as far in advance of the first day of the reformulated gasoline program (January 1, 1995) as possible. As such, it will endeavor to review and approve all baselines submitted within the appropriate timeframe in a timely manner. The baseline determination is not a "one-try" effort; EPA will work with the refiner or importer until it is satisfied that the baseline is an accurate reflection of the 1990 gasoline of the refiner or importer.

If a baseline has not been approved by EPA prior to January 1, 1995, then a refiner or importer may still introduce reformulated or conventional gasoline into commerce, with certain limitations. First, the refiner or importer would not be able to use the complex model early, under §80.41, as early use of the complex model requires knowledge of the individual baseline to determine the appropriate performance standard. Once an individual baseline was approved, however, then early use of the complex model would be allowed. Second, both the reformulated gasoline and anti-dumping programs have standards based on the annual averages of either emissions or certain fuel parameters. For example, simple model standards for reformulated gasoline require that the annual average for sulfur, olefins and T90 not exceed the baseline values for these parameters. The anti-dumping standards require that the annual average for these parameters not exceed 125% of the baseline parameter values, and in addition, the average annual emissions for exhaust benzene, exhaust toxics and NOx may not exceed the baseline values for these emissions. A refiner or importer may introduce conventional gasoline into commerce in conventional gasoline areas prior to approval of baseline of the individual baseline, however, the qualities of this gasoline will be used to determine compliance with these various annual averages. Failure to have a baseline approved prior to January 1, 1995 could therefore make it harder to plan for and comply with these annual anti-dumping standards. Finally, failure to have an approved baseline may in certain circumstances make it impossible to certify reformulated gasoline under §80.41. In such a case, the gasoline would be considered conventional gasoline and could not be introduced into commerce in any area covered by the reformulated gasoline program. Refiners and importers are urged to submit accurate, clearly described baseline determinations as soon as possible.

VIII. Compliance with the Regulatory Flexibility Act

The Regulatory Flexibility Act (RFA) of 1980 requires federal agencies to examine the effects of the reformulated gasoline regulation and to identify significant adverse impacts of federal regulations on a substantial number of small entities. Because the RFA does not provide concrete definitions of "small entity," "significant impact," or "substantial number," EPA has established guidelines setting the standards to be used in evaluating impacts on small businesses[137]. For purposes of the reformulated gasoline regulations, a small entity is any business which is independently owned and operated and not dominant in its field as defined by SBA regulations under section 3 of the Small Business Act.

A. Determination and Justification of Small Entity Impacts

The Agency has found that the reformulated gasoline and anti-dumping regulations may possibly have some economic impact on a substantial number of small refiners. However, these regulations may not significantly affect gasoline blenders, terminal operators, service stations and ethanol blenders under the same EPA criteria. Small business entities are not required by the Clean Air Act to manufacture reformulated gasoline. Since most small refiners are located in the mountain states or in California, which has its own (more stringent) reformulated gasoline program, the vast majority of small refiners are unaffected by the federal reformulated gasoline requirements. All businesses (both large and small) maintain the option to produce conventional gasoline to be sold in areas not obligated by the Act to receive reformulated gasoline or those areas which have not chosen to opt into the program.

All refiners will be affected by the anti-dumping requirements, which are less stringent than those for the reformulated gasoline portion of the program. The anti-dumping regulations affecting conventional gasoline are not expected to disproportionately impact small refiners of conventional gasoline.

---

[137] U.S. Environmental Protection Agency, Memorandum to Assistant Administrators, "Compliance with the Regulatory Flexibility Act," EPA Office of Policy, Planning, and Evaluation, 1984. In addition, U.S. Environmental Protection Agency, Memorandum to Assistant Administrators, "Agency's Revised Guidelines for Implementing the Regulatory Flexibility Act," Office of Policy, Planning, and Evaluation, 1992.

In addition, all refiners have the option to use either the simple or complex model during the first years of the reformulated gasoline program. The complex model provides refiners with the ability to adjust the levels of various fuel parameters such as RVP, oxygen, aromatics, olefins, benzene, sulfur, and fuel distillation parameters in meeting the emission performance requirements of reformulated gasoline. As a result, refiners have greater flexibility under the complex model than under the simple model (which focuses primarily on volatility control) in choosing the least-cost method of compliance. Because refineries differ in process unit configuration, raw material requirements, and product mix, the additional flexibility afforded by the complex model should reduce the cost of producing reformulated gasoline. Such a situation is expected to provide a more equitable situation for small refiners, especially those with conversion equipment.

The component of the reformulated gasoline program most likely to unfavorably impact small entities is the fundamental necessity that reformulated gasoline meet more stringent emission standards and thus processing requirements. The Agency is unaware of any alternative options which might relieve the regulatory burden on small entities while simultaneously maintaining the program benefits required by the statute. Exempting small refiners from the reformulated gasoline regulations would result in the failure of meeting CAA performance standards, which is illegal. All reformulated gasoline is required to meet the same performance and compositional standards. Additionally, enforcement of a reformulated gasoline program (with exemptions or less stringent standards), in-use, would be impossible to enforce due to the inherent nature of the fungible gasoline distribution system in existence.

The Agency interpretation of the Regulatory Flexibility Act requires the consideration and promulgation of alternatives or, in lieu of regulatory options, the justification for declining to promulgate alternatives. Nonetheless, any flexibility, in regards to the performance standards, granted to small business entities would unfairly provide a competitive advantage over the business entities not classified as "small". One available option is reducing, but not eliminating, regulatory requirements on small entities. Requirements could be scaled to just offset any competitive disadvantage. However if EPA were to promulgate such guidelines, the small entities that would be eligible to meet these "less stringent" standards 1) would be hindering enforcement, as a result of the fungible gasoline distribution system mentioned above, and 2) would not be meeting statutory provisions, such as the fifteen percent reduction in VOCs and toxics.

It is worthy of note that although EPA has received several comments which claim that the reformulated gasoline regulations will result in closing the small business entities affected by this rule, convincing evidence supporting this claim has not been submitted. Despite the lack of persuasive documentation and the inability to exempt small businesses from the requirements of the reformulated gasoline program, EPA has made accommodations where possible and appropriate. One example of the versatility embedded in the reformulated gasoline regulations, by EPA, is the flexibility available to all refiners, both small and large, to choose to have one or more individual refinery conventional gasoline compliance baselines and one or more "refiner" baselines (i.e. more than one grouping o f two or more refineries to form a compliance baseline). Another example of the flexibility of the regulations is the ability to produce reformulated gasoline on a per gallon or averaging basis. Also, certain refiners who produced JP-4 jet fuel in 1990 may be able to adjust their baselines so as to reduce the compliance burden.

In accordance with Section 604 of the RFA, EPA has prepared the following regulatory flexibility analysis which includes a summary and assessment of the issues raised by public comments on the Initial Regulatory Flexibility Analyses contained in the previous proposals.

B. Summary and Assessment of Issues and Comments

1. Background

As part of the Administrator's effort to ensure that the regulations do not unfavorably affect small business entities, most small business entities which will be affected by this rulemaking were represented in the negotiated rulemaking processes which contributed, in part, to the development of this final rule. The following organizations which represent in whole or in part the interests of affected small businesses were formal participants in the negotiated rulemaking process and signatories to the agreement in principle: National Corn Growers Association, Renewable Fuels Association, Oxygenated-fuels Association, Rocky Mountain Refiners Association, National Council of Farmer Cooperatives, Society of Independent Gasoline Marketers of America, Petroleum Marketers of America Association, Independent Liquid Terminals Association, American Independent Refiners Association, and National Petroleum Refiners Association.

EPA believes that the participation of these parties has helped assure adequate consideration of the special position of smaller entities in the marketplace. During the negotiated rulemaking sessions, the public hearings on the previous proposals, and the public comment period, the small businesses which are potentially affected by the rule made their interests known. A summary of the comments are presented below. Interested readers are referred to both dockets (A-91-02 and A-92-12) of this rulemaking for transcripts of the hearings and copies of all written comments.

2. Oxygenate Treatment

Many of the affected small businesses were concerned about the treatment of oxygenates. Some produce oxygenates and were thus concerned that EPA not favor certain oxygenates in the way that it ensured that there would be no NOx increase. The evidence about the effect of oxygenates on NOx emissions was not complete at the time of the April 1992 supplemental proposal. Some testing had been done which showed that while oxygen in fuel lowers CO and VOC emissions, at some concentrations and in some forms it may raise NOx emissions. When additional data became available, however, there did not appear to be any significant difference between the NOx emission effects of oxygen from different oxygenates. Furthermore, it appeared that reducing the concentration of a number of additional fuel parameters (aromatics, olefins, sulfur, etc.) could reduce NOx emissions. Consequently, under the regulations being promulgated today, all oxygenates are treated equally. Refer to Section II of the preamble for a detailed discussion.

Though all oxygenates are treated equally in the regulations, VOC and toxics emission performance will be different for different oxygenates. Refiners, blenders, and importers must take emission performance into account when reformulating gasoline with various oxygenates. The market for ethanol is still expected to grow as a result of the reformulated gasoline program. Consequently, ethanol market growth will not pose an economic hardship on small or large ethanol producers (refer to Section I of the RIA). It is likely that terminal operators not affiliated with major oil companies would be more likely to do ethanol blending than terminals associated with large refiners. However, EPA has addressed the needs of blenders in its reformulated gasoline enforcement schemes by enabling them to blend oxygenates with reformulated gasoline blendstocks formulated for downstream oxygenate blending. As a result there is no need for blenders to separately certify that they produce reformulated gasoline and/or make baseline comparisons as appropriate. Ethanol blenders will need to change the way they currently do business (unless they choose not to produce reformulated gasoline), but all blenders must do this if reformulated gasoline performance standards are to be met.

3. Definition of Domestic Capacity

Small businesses expressed concerned, through comments, with the definition of domestic capacity to produce reformulated gasoline. Some suggested definitions that would require all constituents of reformulated gasoline to be domestically produced or available at domestic ports. While some of the commenters were concerned with creating a strong domestic market for their oxygenates, many more were concerned that the definition be as broad as possible. If domestic capacity were broadly construed, insufficient supply would not permit EPA to extend the start of the program to opt-in areas. As commenters explained it, an unexpected extension might make a small refiner's investments in improvements less valuable. Small refiners have less of an ability to absorb risk or to obtain financing for investments than do their larger competitors. Thus, small refiners want a broad definition. EPA agrees that it is in the interest of domestic oxygenate producers to have a limited definition in order that demand for their supplies be high. Oxygenate producers, as indeed all gasoline and gasoline component suppliers, will be able to operate most efficiently if uncertainty about opt-ins is minimized.

EPA has not at this time provided a specific definition of domestic capacity. Furthermore, there is no fixed definition of that term in the regulatory negotiation agreement or the Clean Air Act. According to §211(k)(6)(B), EPA must consult with the Secretary of Energy before determining whether an area has insufficient domestic capacity. If the Administrator finds that there is insufficient domestic capacity to produce reformulated gasoline, the start of the program may be delayed in opt-in areas for up to three years. Parties wanting EPA to perform an evaluation of domestic capacity for a specific area should make a formal request to the EPA.

4. Attainment Area Blending of Ethanol

Prior to publication to the 1992 SNPRM, EPA was concerned as to whether there could be an impact on terminal operators and gasoline distributors who currently blend unfinished gasoline components with ethanol for attainment area use. If these blenders were not producing their own ethanol, the Agency surmised that the cost of ethanol to attainment area distributors would rise due to use of ethanol in reformulated gasoline. There will be no associated rise in the price they will receive for their gasoline since they sell into unaffected areas. At the time of the April 1992 supplemental proposal, EPA invited comment as to the extent to which these blenders do not produce ethanol. Since EPA has not received any comments to date on this issue, the reformulated gasoline program was developed and finalized with the assumption that such terminal operators and gasoline blenders were not detrimentally impacted by the regulation.

5. Refiner/Refinery Averaging

Several small business commenters are refiners with only one refinery. These commenters were concerned with the ability of multi-refinery refiners to average their baseline fuels across many refineries for the anti-dumping provisions. They believe that such an averaging provision gives a competitive advantage to large refiners. As discussed in Section __, refiners are allowed to determine the baseline for their refineries on a refinery by refinery basis, a refiner basis, or some other basis. If one refinery's baseline is determined based on its own data, then the calculation of the baseline for the other refineries of that refiner must not include that refinery.

The smaller refiners were also concerned that there be some variance procedure in cases where they serve a future reformulated gasoline area and could not produce reformulated gasoline through no fault of their own. Since these refiners generally have only one refinery and can often supply only one market, they are more likely to be unable to supply reformulated gasoline than a multi-refinery refiner with refineries proximate to the pipeline. Fortunately, the regulations provide a mechanism for sale of conventional gasoline in covered areas under certain very specific conditions. The smaller refiners acknowledged during the regulatory process that strict adherence to these conditions (i.e., no fault, return of economic advantage, continuing efforts, etc.) were necessary to avoid abuse of the provision.

6. Phase II Standards Impact on Small Refiners

Small refiners were worried that compliance with the Phase II reformulated gasoline requirements would be more costly than compliance with the Phase I requirements because of the greater VOC reduction required. Small refineries which choose to produce reformulated gasoline are likely to experience higher costs per quantity of product produced than large refineries. For instance, refining costs in PADD IV, which tends to have much smaller refineries than the other PADDs, are 6-7 cents per gallon higher than for PADD III and V refineries and 3-4 cents higher than for PADD I and II refineries[138]. As stated in the **A/O Economics Bulletin**[139], because of their size, PADD IV refineries get less benefit from economies of scale for capital investments.

---

[138] "Costs of Alternate Gasoline Reformulations, Results of U.S. Refining Study for Economics Committee of the Auto/Oil Air Quality Improvement Research Program," Turner, Mason & Company, April 1992.

[139] "Estimated Costs of Modifying Gasoline Properties, Economics Bulletin No. 2," Auto/Oil Air Quality Improvement Research Program, January 1992.

However, this implies that the small refineries are not technologically limited by the more stringent requirements. Also, there are very few ozone non-attainment areas in PADD IV and none have yet opted into the reformulated gasoline program. Thus, PADD IV refineries are not expected to be impacted by the Phase II standards. In addition, significant relief exists for all refiners, in that the Phase II requirements do not go into effect until the year 2000. Thus, approximately six years of planning and lead time are available for determining the necessary refinery changes.

It is possible that using additional oxygenate in reformulated gasoline may be a cost-effective method of meeting the proposed standards. Some small refiners expressed concern that reformulated gasoline requirements would place them at a disadvantage in producing reformulated gasoline if it limited their ability to use ethanol. However, a Sobotka analysis[140] of this situation concluded that small refineries are not disadvantaged by the federal reformulated gasoline requirements (at current opt-in levels) because they either: (1) do not manufacture gasoline, or (2) do not ship a significant portion of their gasoline output to the affected markets, or (3) could readily serve conventional gasoline markets.

7. Phase II Standards Impacts on Oxygenate Producers

In the 1993 NPRM, EPA was concerned that Phase II Standards would decrease the demand for oxygenates in reformulated gasoline. It is possible that using additional oxygenate in reformulated gasoline may be a cost-effective method of meeting the proposed standards. In that case, oxygenate demand should increase and oxygenate producers should not be adversely affected by the Phase II standards. It is possible that the relative use of various oxygenates could shift from their Phase I usages, because, as stated above, the Phase II proposed standards will be more stringent and will have a slightly different baseline emissions level. However, the use of all oxygenates is still expected to be greater after 2000 than prior to 1995.

8. Regulation Development Representation Deficiency

The Agency also received comments from trade associations, with small entities as members, that were not represented on the regulatory negotiation committee for reformulated gasoline, such as the American Waterways Operators (AWO) and the National Tank

---

[140] "Evaluation of the Use of Ethanol and MTBE in Reformulated Gasoline," Prepared by Sobotka & Co., Inc. for U.S. EPA under Contract No. 68-W9-0077, September 30, 1992.

Truck Carriers (NTTC). As representatives of non-signatory parties to the Agreement-In-Principle, these organizations postulate that EPA did not consider the impact of the proposed regulations on their industries. Although EPA recognizes that NTTC and AWO were not part of the regulatory negotiation, there has been ample opportunity to testify at public hearings and submit comments on the previous proposals to the Agency. In addition, many of their interests were raised through other organizations who require their services. Their issues are similar in some respects to the pipeline and barge industries. Demand for these industries' services may increase, if the need to transport reformulated gasoline to opt-in areas is present. EPA has analyzed comments submitted during the rulemaking process.

EPA also received comments stating that small independent developers and marketers of oxygenated fuels were not represented in the regulation development process, and should have been included. EPA believes that small independent developers and marketers of oxygenated fuels were represented in the regulation development process. Specifically, the American Methanol Institute (AMI), the Renewable Fuels Association (RFA), the National Corn Growers, the National Council of Farmer Cooperatives (NCFC is made up of small blenders, producers and marketers), and the National Petroleum Refinery Association (small refiners make up a portion of NPRA's membership) were all participants in the Reg-Neg process. EPA believes these associations adequately represented small developers and marketers of oxygenated fuels. In addition, the small independent fuel oxygenate developers and marketers who commented did not raise any issues related to the success or failure of their businesses which have not already been addressed.

9. Enforcement Alternatives

NTTC states that the cost of the reformulated gasoline program to the tank truck industry was not considered when the rules were being developed for reformulated gasoline. NTTC further claims that the February 1993 NPRM favors large oil companies private carriers and jobbers at the expense of common carriers. They believe this because the common carriers will not receive any economic benefit from the ultimate sale of the reformulated gasoline product. Private carriers and jobbers would benefit if the product not meeting the reformulated gasoline specifications is sold, whether the uncertified sale was intentional or not. They are particularly concerned that the presumptive liability provisions alone will unduly burden tank truck carriers because they will be forced to pay penalties for reformulated gasoline specification violations over which they have no control. As a result, EPA's final rule makes carriers liable only where the carrier has caused a violation or where a violation is found at the carrier's facility. The scope of the recordkeeping requirements for each type of party (e.g., refiners vis-a-vis retailers of gasoline), and therefore the cost to the party, reflects only that party's opportunity to create or alter the characteristics and quality of reformulated gasoline. Thus, the smaller facilities, such as truck carriers and retailers, have a minimal burden under the regulations whereas refiners and importers have significant requirements.

Some commentors stated that the costs of independent sampling and testing will be disproportionately high for small refiners, because their batch sizes are small in comparison to batch sizes for larger refiners, and because independent labs may not be conveniently located relative to small refineries, requiring long distance sample shipping. It is true that the per-gallon costs of independent sampling and testing will be larger for a refinery producing reformulated gasoline in small batches in comparison to the per-gallon costs for a refiner producing larger batches. Nevertheless, EPA believes this cost difference is insignificant. For a 20,000 barrel batch, a small-sized batch, the per-gallon cost of independent sampling and testing would be $0.0003; for a 50,000 barrel batch, the per-gallon cost would be $0.0001[141]. EPA anticipates that samples collected at refineries located distant from any reliable independent laboratory will be shipped to the laboratory, but does not believe such sample shipping is costly. These conclusions are based on EPA's experience in conducting gasoline quality inspections throughout the country over at least the past dozen years, when its inspectors have shipped several thousand samples per year to EPA's laboratory for analysis.

10. Disproportionate Regulatory Burden

The American Independent Refiners Association (AIRA), a national trade association comprised of small and independent refiners, accounts for twenty to thirty percent of domestic gasoline production. It claims that Congress and several federal agencies, EPA included, have previously recognized the importance of small and independent refiners to a competitive marketplace for petroleum products. AIRA contends that the small, independent sector of the refining industry is particularly vulnerable to the burdens of the previous proposals because they have limited processing flexibility, economies of scale, and limited availability of capitol. As a result, small, independent refiners will experience disproportionate negative disadvantages vis-a-vis major refiners because they have less throughput over which to spread the costs precipitated by the requirements of the proposed rule. In regards to producing reformulated gasoline, if capitol, production, and compliance costs to small refiners are extremely high and burdensome, they need not produce reformulated gasoline.

---

[141] EPA estimates the cost to collect and store a sample will be about $230, and the lab analysis costs will be about $42 (based on an analysis cost of $415 and analysis of 10% of the samples collected at a refinery), for a total of $272.

11. Renewable Oxygenate Provisions

Finally, AIRA criticized EPA's assessment of the Renewable Oxygenate Program (ROP) in regards to small refiners. They perceived that neither of the Initial Regulatory Flexibility Analyses included in the prior proposals nor the 1993 Draft Regulatory Impact Analysis adequately considered small and independent refiners. AIRA specifically commented that the requirements to produce sub-RVP gasoline would disproportionately disadvantage small and independent refiners. EPA is not promulgating the renewable oxygenate provisions published in the February 26, 1993 proposal, and instead is basing the final rule on the provisions as proposed in the April 16, 1992 proposal, as discussed in Section I of this document or Section II of the preamble for reformulated gasoline program.

IX. State Opt-in Provisions

The 1990 Clean Air Act Amendments (the Act) require that by January 1, 1995, Phase I reformulated gasoline be made available in the nine ozone nonattainment areas having a 1980 population in excess of 250,000 and having the highest ozone design values. In the year 2000 Phase II of the reformulated gasoline program begins, requiring even lower emitting gasoline. In an attempt to expand the benefits of the reformulated gasoline program, §211(k)(6) of the Act allows areas, other than those mandated, to choose to participate in the reformulated gasoline program. Areas which so choose are considered to have "opted into" the reformulated gasoline program. Several key issues regarding the opt-in provisions are discussed below.

A. General Provisions

Section 211(k)(6) of the Act specifies that upon application of the Governor of a State, the Administrator shall allow any area in the State classified as a Marginal, Moderate, Serious, or Severe Area for ozone nonattainment to opt into the reformulated gasoline program. The Act also states that opt-in shall become effective on January 1, 1995 or one year after such application is received, whichever is later, and that EPA shall publish each application in the Federal Register upon receipt.

Section 211(k)(6) grants EPA the authority to delay reformulated gasoline in opt-in areas for up to three one-year periods based on insufficient supply. Such a delay could be based on a petition from an outside party, or at EPA's own initiative. At the present time, EPA has yet to receive any such petitions and believes that there will be more than sufficient supply of reformulated gasoline for a January 1, 1995 implementation date, given the current level of opt-in. If a delay is necessary, EPA must delay implementation for areas with a lower ozone classification before issuing any such delay for areas with a higher classification.

B. Phase I Opt-in only

In its February 26, 1993 proposal, EPA requested comments on an option that would permit states to opt into only Phase I of the reformulated gasoline program and maintain the Phase I requirements beyond the year 2000 when Phase II of the reformulated gasoline program begins. EPA received a number of comments and upon review has decided that opting into Phase I of the reformulated gasoline program alone shall not be permitted.

The Act does not compel the EPA to permit Phase I-only opt-in. Section 211(k)(10) defines reformulated gasoline as any gasoline which is certified by the Administrator as complying with subsection 211(k). Per §211(k)(3)(B), the definition of reformulated gasoline is set to change in the year 2000 from its

Phase I definition to the more stringent Phase II requirements. Thus, in the year 2000, Phase I gasoline will no longer be considered reformulated gasoline under §211(k) requirements.

EPA received many arguments for and against allowing Phase I-only opt-ins. Those in favor argued that more areas would likely opt into the program because the Phase I gasoline is better defined, and the economic burden on the consumer would be more predictable and not as onerous as with Phase II. Nonetheless, a number of areas have already opted into the reformulated gasoline program. Supporters also contend that §211(k) of the Act does not preclude Phase I-only opt-in, so it should be allowed. However, as discussed above, the definition of reformulated gasoline in fact changes in the year 2000, thus presenting a regulatory hurdle. Some comments pointed out that under the authority given in §211(c)(4)(C), States could require Phase I gasoline standards separately after the year 2000 as part of a State Implementation Plan (SIP). That section also states that the Administrator may approve such SIP provisions only if EPA determines that such State control or prohibition is necessary to achieve the national primary or secondary ambient air quality standard.

Those opposed to Phase I-only opt-in were primarily concerned with fuel proliferation, or the possibility that both Phase I and Phase II gasoline would be required in the market in 2000. Such a situation presents logistical concerns regarding the manufacture, supply, and distribution of an additional type of gasoline (and potentially additional grades), and enforcement of the entire reformulated gasoline program. EPA believes that the petroleum supply and distribution system will already be strained given the existing reformulated gasoline program. The strain could be exacerbated by allowing Phase I gasoline to endure when Phase II gasoline becomes a requirement for covered areas in the year 2000. The argument was also made that emissions from the increase in tankage and other equipment necessary for handling additional types and/or grades of gasoline would reduce the regulation's environmental benefit, although the extent to which this may occur is unknown.

Given the potential for supply and distribution problems, enforcement problems, and the weak statutory authority in the Act, EPA has decided not to allow Phase I-only opt-ins.

C. Attainment Area Opt-in

A few comments addressed the issue of whether areas in ozone attainment could opt into the reformulated gasoline program. EPA's position is that attainment areas may not opt into the program, with a possible exception given to areas in an ozone transport region.

The opt-in language of §211(k)(6)(A) of the Act clearly limits opt-in to areas in a State classified as Marginal, Moderate, Serious, or Severe for ozone nonattainment. One exception is included in §184(c) of the Act which provides that upon petition of any State within a transport region established for ozone, and based on the recommendation of the area's Interstate Transport Commission, the commission may develop recommendations for additional control measures to be applied within all or a part of such transport region if the commission determines such measures are necessary to bring any area in such region into attainment. This provision gives the commission the opportunity to recommend that an area opt into the reformulated gasoline program, even those areas in the ozone transport region which are already in attainment. Once a commission has made its recommendation, the usual opt-in application procedures and lead times apply.

D. Opt-out

Once an area has opted into the reformulated gasoline program, the issue arises whether it may, at a later date, decide to opt out of the program. This notion was brought up in several comments, even as a possible alternative to the Phase I-only opt-in provision discussed above. While EPA is currently considering opt-out provisions, section 211(k) does not give EPA the authority to develop an opt-out procedure. Thus, EPA is not including any opt-out provisions in this rulemaking, but may pursue separate actions in the future.

E. Opt-In Application

One commenter asked that EPA develop an opt-in application procedure. EPA feels that this procedure is adequately outlined in §211(k)(6)(A) of the Act, which specifies that the Governor of the State must apply to the EPA. EPA has already received a number of applications in the form of a letter simply requesting that an area be opted into the reformulated gasoline program. EPA feels that this process has been an adequate one. Written requests for opt-in may be sent to the Administrator of the Environmental Protection Agency, West Tower Waterside Mall, 401 M Street, S.W., Washington D.C., 20460.

F. Opt-In Lead Time

A few comments requested that extra lead time be given before allowing areas to opt into the reformulated gasoline program. EPA feels that given the existing safeguards in the Act, such a delay is not warranted. §211(k)(6)(B) allows EPA to delay reformulated gasoline in opt-in areas for up to three years based on insufficient supply. This is in addition to the §211(k)(6)(A) provision that reformulated gasoline not be required in opt-in areas until January 1, 1995 or one year after the application is received, whichever is later. A delay could be based on a petition from an outside party, or at EPA's own initiative. At the present time, EPA has yet to receive any such petitions and believes that there will be more than sufficient supply of reformulated gasoline for a January 1, 1995 implementation date, given the current level of opt-in.

G. Define Domestic Capacity

One party's comments contained a request that EPA include specific definitions for domestic capacity. EPA is unable to provide a specific definition of domestic capacity for all areas at this time. According to §211(k)(6)(B), EPA must consult with the Secretary of Energy before determining whether insufficient domestic capacity to produce reformulated gasoline exists. EPA will define domestic capacity as part of any petition to delay opt-in.

H. Opt-in only after Stage II controls and enhanced I/M

One commenter suggested that opt-in should be allowed only after an area has implemented Stage II vapor control and an enhanced inspection and maintenance (enhanced I/M) program. Given the wide variety of air pollution concerns, EPA believes that it is of utmost importance to give States the freedom to implement, through their State Implementation Plans, whatever programs they feel will best allow them to achieve attainment. EPA believes that most opt-in areas will have considered the benefits of Stage II and enhanced I/M, and some will implement these programs, but the decision should rest with the States based on their own needs. EPA is not comfortable in this rulemaking preempting State efforts by requiring that Stage II and enhanced I/M be implemented before allowing opt-in to the reformulated gasoline program, and hence is not promulgating any such requirements.