US Environmental Protection Agency
Air and Radiation
Office of Transportation and Air Quality

MEMORANDUM

Date: March 22, 1996

Subject: A comparison between reformulated gasoline and low RVP gasoline as alternative strategies for meeting NAAQ standards for tropospheric ozone

From: David J. Korotney, Chemical Engineer
Fuels Studies and Standards Group

To: Susan Willis, Manager
Fuels Studies and Standards Group

During both the development and implementation phases of the reformulated gasoline (RFG) program, numerous ozone nonattainment areas have investigated alternative programs which also showed promise for reducing tropospheric ozone levels. One of these alternatives, low RVP gasoline, has been the subject of much debate over the past year. I have gathered some information on the benefits and detriments of these two programs and summarized it in this memorandum to aid in your responses to inquiries on this issue.

Fuel composition and properties

Low RVP gasoline is produced from conventional gasoline by removing the lightest components of the fuel, namely butane. As a result, the volatility decreases. (Volatility measures the tendency of the fuel to evaporate, and is generally measured in terms of the Reid Vapor Pressure [RVP]). Other fuel properties are largely unchanged as compared to conventional gasoline. There is no specification for the RVP level of low RVP gasoline - refiners can produce essentially any fuel and call it "low RVP gasoline." However, it must have a lower RVP than that required under the Phase 2 Low Volatility Regulations. These regulations state that summer RVPs must be less than 9.0 psi in northern (colder) regions and southern (warmer) ozone attainment areas, and 7.8 psi in southern ozone nonattainment areas. Low RVP gasoline typically has RVPs in the range of 6.8 psi to 8.1 psi, with a typical value of 7.0 - 7.2 psi. However, as a very rough rule of thumb, it appears that the RVP for low RVP gasoline will be 0.5 - 1.0 psi lower than what the Phase 2 Low Volatility Rule requires for a given area. One exception to this rule would be several counties in Illinois for which the summer Phase 2 Volatility Standards are 9.0 psi, but low RVP gasoline at 7.2 psi is currently being used.

RFG also has a reduced RVP as compared to conventional gasolines. In fact, it is possible for low RVP gasoline and RFG to have exactly the same RVP. However, in addition to a lower RVP, the benzene content of RFG must be lowered to at least 1.0 vol%, and an oxygenate must be added. Other changes to the fuel will generally also be necessary in order to meet toxics and NOx standards required under the RFG regulations. These changes generally involve lowering the sulfur, olefins, and/or aromatics contents. In Phase II of the RFG program (which begins in the year 2000), RFG is subject to the same oxygen and benzene content standards as for Phase I RFG, but will be more severely reformulated to meet the Phase II emission standards.

Environmental/emissions impacts

The effects that low RVP gasoline and RFG will have on emissions can be categorized by pollutant: NOx, VOC, CO, ozone, and toxics. Of these pollutants, ozone is the most important, since it is primarily in ozone nonattainment areas that the relative benefits and detriments of RFG and low RVP gasoline are being debated. The other pollutants may have direct effects on human health, and so should be included in any comparison between the two fuels programs, but they are generally not the primary reason for considering either program.

Although it is relatively easy to provide qualitative descriptions of the emissions effects of RFG and low RVP gasoline, quantifying those effects is much more difficult; the number of variables and the degree of uncertainty in the measurements necessitates that all calculated values be approached as ballpark figures. In addition, the fact that low RVP gasolines can have essentially any RVP (as long as they meet the Phase 2 Volatility Requirements) makes it quite difficult to make a straightforward comparison between the two fuels. The values that I have included in this memorandum have been assimilated from several sources, including AAMA survey data from 1990 through 1995, Complex Model calculations, an analysis done by Information Resources, Inc., and actual test data. Note that I have not conducted an exhaustive review of all studies and sources of information on the comparative emission effects of low RVP gasoline and RFG. All percent change estimates have been made with respect to a baseline fuel whose properties were given in section 211(k) of the Clean Air Act. This baseline fuel can viewed as an approximation to the national average gasoline.

The primary emission benefits from low RVP gasoline come from reductions in evaporative emissions; exhaust emission reductions are very small or nonexistent. Because NOx is a product of combustion, it will not be found in evaporative emissions. We would expect, then, to see little or no effect of low RVP gasoline on NOx. An evaluation of AAMA fuels survey data, however, indicates that low RVP gasoline may actually increase summer NOx emissions by 1%. RFG, on the other hand, will result in summer NOx emission reductions of approximately 1.5% in Phase I, and 5-7% in Phase II (according to the regulatory requirements under the mandatory Complex Model).

RFG will reduce total summer VOC emissions slightly more than low RVP gasoline if the volatility (RVP) of the two fuels are equivalent. Any VOC reductions resulting from the use of RFG which are beyond those for low RVP gasoline at the same RVP are primarily due to the effect of the required oxygenate on exhaust VOC emissions. However, in Phase I, low RVP gasoline in colder (northern) regions could have a volatility which is significantly lower than that for RFG in these areas; Phase I Simple Model RFG standards require only 8.0 psi in northern regions, while low RVP gasoline may be produced with an RVP as low as 7.0 psi. In this case, low RVP gasoline could lower summer VOC emissions 10% more than RFG can. This scenario assumes that the low RVP gasoline is being produced at a full 2.0 psi below the Phase 2 Volatility Standards of 9.0 psi in northern areas. In addition, I would not expect to see low RVP gasoline have a lower volatility than RFG in southern regions during Phase I (where RFG will have an RVP of approximately 7.1 psi), or in Phase II for any region of the U.S.

AAMA fuels survey data from both northern and southern regions indicates that RFG may reduce summer VOC emissions nearly 10% more than low RVP gasoline. The survey suggests that the volatility of low RVP gasolines may not be low enough to gain an advantage over RFG in terms of VOC reductions. As I stated above, a straightforward conclusion regarding the relative emission effects of low RVP gasoline and RFG is elusive since the RVP of low RVP gasoline can be set at any level below the Phase 2 Volatility Standards.

Low RVP gasoline will not reduce carbon monoxide (CO) emissions, and in fact may increase them slightly. RFG, on the other hand, will affect CO in a manner similar to oxyfuels, with reductions of at least 10% and possibly as high as 20% year-round. This result is due to the fact that CO emissions are affected primarily by oxygen content, and very little by RVP.

Ozone is created in the atmosphere from complex reactions involving NOx, VOC, and CO (CO has a lower impact on ozone formation than NOx and VOC, and so is often ignored). Ozone has therefore often been termed a "secondary" pollutant, since it is not formed directly by the vehicle. Since RFG is expected to reduce emissions of all three pollutants, while low RVP gasoline will generally only reduce emissions of VOC, RFG will likely have a more significant impact on ozone than will low RVP gasoline on average. In addition, evaporative VOC emissions tend to be less reactive (i.e. produce less ozone) per gram than exhaust VOC emissions. Since low RVP gasoline affects only evaporative VOC emissions, VOC reductions resulting from low RVP gasoline use are less beneficial, in terms of ozone reduction, than equivalent amounts of VOC reductions resulting from RFG use.

Air quality modelling has been insufficient to determine whether VOC control is more important than NOx control or viceversa; the answer appears to depend on the specific area, transport of ozone precursors from one region to an adjacent one, and other modelling assumptions. Insofar as it is unclear whether VOC control is more or less important than NOx control in reducing ozone, it would seem that RFG would generally be preferable over low RVP gasoline. After all, RFG is designed to result in reductions in both VOC and NOx, and by default also results in significant reductions in CO. However, if VOC control is deemed more important than NOx control in a given area, and/or in northern areas in which the use of low RVP gasoline may result in significantly larger VOC reductions than RFG use, low RVP gasoline may be preferable to RFG.

Low RVP gasoline may result in some toxics reductions (on the order of 2% annually) because toxics emissions, particularly evaporative emissions, are sensitive to reductions in RVP. AAMA fuels survey data, however, suggests that low RVP gasoline may actually increase annual toxics emissions by 3%. This counter-intuitive result could be due to the fact that some refiners may choose to replace octane lost through the removal of butanes by increasing the aromatics content. In contrast, annual toxic emission reductions of 20% can be realized with RFG due to changes in fuel properties other than RVP.

Cost and cost-effectiveness

Recent survey data indicates that RFG generally costs 2 - 5›/gal more than conventional gasoline, while low RVP gasoline will cost 1 - 2›/gal more than conventional. These costs are quite similar to the cost estimates calculated as part of the RFG rulemaking (costs for RVP reductions separate from total reformulation costs were included in the Regulatory Impact Analysis). The ranges are due to differences in refinery configurations, availability of high quality crudes, consumer demand, etc. It appears that the oxygenate requirement for RFG drives much of its cost.

RFG will be less cost-effective at reducing VOC emissions than low RVP gasoline if the volatility of the two fuels are equivalent. In other words, the $/ton VOC reduced via RFG can be several times that for low RVP gasoline. Thus low RVP gasoline can be a less expensive strategy for reducing VOCs as compared to RFG. It appears that the primary advantage of low RVP gasoline is its low cost and high cost-effectiveness in reducing VOC emissions. This conclusion, however, must be tempered by the fact that ozone, not VOC, is the primary pollutant at issue when comparing RFG to low RVP gasoline.

As stated in the discussion of the environmental impacts above, ozone is created in the atmosphere from complex reactions involving NOx, VOC, and CO. Since RFG reduces emissions of all three of these pollutants, while low RVP gasoline reduces only VOC, it would appear that RFG will generally be more cost effective at reducing ozone than low RVP gasoline. This conclusion is strongest for those areas where NOx (and possibly

CO) is determined to be a significant contributor to ozone formation. Unfortunately, the determination of the cost-effectiveness of ozone reduction is largely unquantifiable because air quality modelling is open to various interpretations, and often results in different conclusions for different areas.

Toxics reductions through the use of RFG are highly cost-effective, and the $/ton estimate for the reduction of toxics may even be zero in Phase I. When a refiner makes changes to its gasoline in order to meet the VOC and NOx standards for RFG, the toxics standard is virtually always met by default. In other words, no additional reformulation is necessary to meet the toxics standards beyond that required to meet VOC and NOx standards. As far as low RVP gasoline is concerned, determination of the cost-effectiveness of toxics reductions is largely irrelevant since, at best, low RVP gasoline will result in only a small reduction in toxics.

Logistics, policy implications

Regardless of which fuels program is chosen for a given area, an associated system of compliance and enforcement must be established. In the case of RFG which is required in a new area, the enforcement program for that area will be added to the already existing federal enforcement operations, and thus will not burden the state. In contrast, if low RVP gasoline is instead required in a new area, its enforcement program must be created from scratch and run by the state.

There is some concern that the anti-dumping provisions for conventional gasoline under the Simple Model provide enough flexibility to refiners producing low RVP gasoline that decreases in VOC emissions could be accompanied by simultaneous increases in toxics and NOx emissions on the order of 3%. This theoretical occurrence would result from the fact that the anti-dumping program allows 25% increases in sulfur, olefins, and T90 over baseline levels for all conventional gasoline, including low RVP gasoline, until 1998. Any emission increases due to the 25% allowable increases in sulfur, olefins, and T90 cannot be controlled under a low RVP program because low RVP gasoline is by definition a fuel-property based program controlling only RVP. In contrast, RFG is an emissions-based program controlling VOC, NOx, and toxics emissions. As described above, recent AAMA survey data suggests that low RVP gasoline may increase NOx emissions by 1% and toxics emissions by 3% while simultaneously decreasing VOC emissions. Since information on the production source of the low RVP gasoline evaluated in the AAMA survey is lacking, it is impossible to determine if these increases in NOx and toxics are due to the flexibility inherent in the anti-dumping program.

Public perception may play a role in determining which of the two fuels programs should be implemented in a given area. For instance, due to the inclusion of an oxygenate, RFG may result in lower fuel economy (on the order of 2-4%), and may cause accelerated deterioration of some plastic and rubber parts (particularly for ethanol blends). Likewise for low RVP gasoline, cold-start problems tend to increase as the RVP of a fuel decreases. Although these potential consequences of the use of a particular fuels program will invariably go unnoticed by the average consumer, the media have played a significant role in making the public aware of and exaggerating these issues.

Conclusions

The choice between the use of RFG and low RVP gasoline will most likely be decided on the basis of environmental impact and cost. Low RVP gasoline is clearly less expensive in terms of ›/gal, and it is more cost effective in terms of dollars per ton VOC reduced. The choice is complicated, however, by three other issues: 1) the primary pollutant at issue is not VOC, but ozone; 2) toxics and CO also have associated health hazards; and 3) low RVP gasoline can have nearly any RVP level, and thus a wide range of environmental impacts.

The effect that a given fuels program may have on ozone is subject to the accuracy of current air quality modelling. In areas where VOC control is determined to be presently more important than NOx control, either fuel can achieve the necessary results and if no other benefits were desired or necessary, the low RVP fuel would more than likely be the less expensive fuel, depending on the RVP level chosen. However, if NOx control is deemed important, or if the air quality modelling is unavailable or inconclusive, RFG will likely have the greatest effect on ozone.

The health hazards presented by CO and toxics cannot be understated. Since RFG provides CO benefits similar to oxyfuels, areas which are in need of CO emissions reductions (i.e. CO nonattainment areas) or areas which need to maintain CO levels in lieu of an oxyfuels program would benefit from the use of RFG. Conversely, low RVP gasoline may make more sense in areas which have no need to maintain or reduce CO emissions. As far as toxics are concerned, only RFG can provide significant toxics benefits. Areas which are out of attainment for ozone and CO are likely to also have hazardous toxics levels, and so could benefit from the use of RFG.

Areas in which Stage II refueling controls have not been implemented may be good candidates for the use of low RVP gasoline, since both Stage II and low RVP gasoline programs focus on evaporative emissions as a VOC control strategy. However, if a 1 psi waiver has been given to ethanol blends for the area in question, low RVP gasoline may have significantly higher evaporative emissions than RFG (1 psi waivers for the use of ethanol in gasoline are applicable only to conventional gasoline, not RFG). The ethanol industry has carried out analyses which suggests that the ozone reactivity of the incremental emissions resulting from a 1 psi waiver is lower than that from gasoline without ethanol, and thus the increase in evaporative emissions does not result in an increase in ozone formation. EPA has contended that such analyses are faulty, however, and has not to date supported the ethanol industry's conclusions.

Finally, if low RVP gasoline is to provide VOC benefits beyond those obtained from the use of RFG, the RVP of the low RVP gasoline must be at least several tenths of a psi below the Simple Model standards for RFG (7.1 psi in the south and 8.0 psi in the north). Thus the RVP of low RVP gasoline must be lower than about 6.9 psi in the south and 7.8 psi in the north.