ALCOHOL ADDITIVES

A NEW OPPORTUNITY IN TRANSPORTATION FUELS

First Report
Standing Committee
Energy, Mines and Resources

HOUSE OF COMMONS

Issue No. 4

Chairman: Barbara Sparrow

Minutes of Proceedings and Evidence of the Standing Committee on

Energy, Mines and Resources

RESPECTING:

Order of Reference respecting alcohol additives in gasoline

INCLUDING:

The FIRST REPORT to the House

First Session of the Thirty-third Parliament, 1984-85-86

CHAMBRE DES COMMUNES

Fascicule nº 4

Président: Barbara Sparrow

Procès-verbaux et témoignages du Comité permanent de

l'Énergie, des mines et des ressources

CONCERNANT:

Ordre de renvoi relatif aux additifs à base d'alcool incorporés à l'essence

Y COMPRIS:

Le PREMIER RAPPORT à la Chambre

Première session de la trente-troisième législature, 1984-1985-1986

STANDING COMMITTEE ON ENERGY, MINES AND RESOURCES

Chairman: Barbara Sparrow

Vice-Chairman: Aurèle Gervais

COMITÉ PERMANENT DE L'ÉNERGIE, DES MINES ET DES RESSOURCES

Président: Barbara Sparrow

Vice-président: Aurèle Gervais

MEMBERS/MEMBRES

Paul Gagnon
Russell MacLellan
Lawrence I. O'Neil
Bob Porter
Ian Waddell

Paul Gagnon
Russell MacLellan
Lawrence I. O'Neil
Bob Porter
Ian Waddell

(Quorum 4)

Le greffier du Comité

Patricia Russell

Clerk of the Committee

Published under authority of the Speaker of the House of Commons by the Queen's Printer for Canada

Available from the Canadian Government Publishing Centre, Supply and Services Canada, Ottawa, Canada K1A 0S9

Publié en conformité de l'autorité du Président de la Chambre des communes par l'Imprimeur de la Reine pour le Canada

En vente: Centre d'édition du gouvernement du Canada, Approvisionnements et Services Canada, Ottawa, Canada K1A 0S9

ACKNOWLEDGEMENTS

This Committee was reconstituted as the seven-member Standing Committee on Energy, Mines and Resources on March 18, 1986, replacing the previous 15-member Standing Committee on National Resources and Public Works. We are indebted to the former committee members who have helped in preparing this report and are pleased to acknowledge the special contribution of four Parliamentarians: Elliott Hardey, Harry Brightwell, Bill Tupper and Ken James.

In carrying out its mandate to study the feasibility of marketing Canadian gasolines containing alcohols as octane enhancers, the Committee heard testimony from 23 different organizations or individuals (Appendix A) in a series of public meetings held in Ottawa from November 19, 1985 to February 11, 1986. The Committee also received three submissions (Appendix B) and a variety of technical documents made available by interested parties. We extend our thanks to all who contributed to the Committee's study.

The Committee also records its appreciation for the work of its staff: to its advisers, Dean Clay and Lawrence Harris of Dean Clay Associates; to Maija Adamsons and Patricia Russell, Clerks of the Committee; and to the Translation Bureau, Secretary of State, for translating this report.

The Standing Committee on Energy, Mines and Resources has the honour to present its

FIRST REPORT

On Tuesday, October 15, 1985, the Standing Committee on National Resources and Public Works received the following Order of Reference:

That, the Standing Committee on National Resources and Public Works be empowered to study the feasibility of recommending the production and distribution for sale to the motoring public of Canada, gasoline blended with octane enhancers ethanol (3 per cent) and methanol (5 per cent) for the purposes of:

1. removing the additive of lead concentrates and MMT (Methylcyclopentadienyl Manganese Tricarbonyl) from currently-marketed gasolines;

2. creating an expanding market for Canadian-grown corn;

3. utilizing the existing sources and known reserves of natural gas; and

4. reducing the importation of light crude oil products currently used in gasoline production.

On February 14, 1986, it was ordered by the House that all outstanding Orders of Reference before a standing committee prior to February 24, 1986, shall be deemed referred, with the evidence adduced in relation thereto, to the new appropriate corresponding standing committee.

The Committee's report follows.

TABLE OF CONTENTS

PREFACE

The subject of gasoline additives is complex in both its technical and economic aspects. It was not possible to consider the merits of blending methanol and ethanol in gasoline in isolation from other potential blending agents; the Committee therefore examined the broader question of employing a variety of fuel oxygenates (alcohols or ethers) in Canadian gasoline stocks.

The Committee addressed two issues. First, the matter of public policy: is it desirable to add alcohol to gasoline in blends of up to 10%? Second, the practical considerations: is it technically feasible and economically efficient to do so in the Canadian context?

Committee members have presented three recommendations which they believe best address the range of issues and testimony involved.

Pursuant to Standing Order 99(2), the Committee requests a comprehensive response to this report.

RECOMMENDATIONS

(1) **The Committee recommends the use of methanol and ethanol as blending agents in Canadian gasoline.**

(2) **The Committee recommends that the Federal Government more extensively support research, development and demonstration required to introduce alcohol-gasoline blends on a broad basis. This support should include new approaches to fuel alcohol utilization and production—including the derivation of ethanol from sources of starch, sugar and cellulose—which could remove economic or technical constraints to alcohol-gasoline blending.**

(3) **The Committee recommends that the Federal Government, in cooperation with the provincial governments and industry, establish guidelines and standards for alcohol-blended gasoline.**

SUMMARY

The Committee's views on the use of alcohol-gasoline blends can be summarized quite simply. It supports the wider introduction of oxygenated fuels in Canada using methanol and ethanol as blending agents. It recommends federal incentives to promote the research, development and demonstration needed to establish these blends, but not the creation of special subsidies to foster their use. The Committee recommends standards for alcohol-gasoline blending, while advocating the minimum amount of regulation necessary to ensure the safe and satisfactory use of oxygenated fuels in Canada. The industry should determine when such blends are marketable.

In accordance with its mandate, the Committee has considered the use of methanol and ethanol as octane enhancers in Canadian gasoline, together with four other chemicals advocated for use as gasoline additives. These additional blending agents are three "higher" (more complex) alcohols — isopropanol (IPA), isobutanol (IBA) and tertiary butanol (TBA) — and an ether — methyl tertiary butyl ether (MTBE). Because all six additives contain oxygen, they are referred to as *oxygenates*. When added to gasoline, the resulting blend is commonly known as an *oxygenated fuel*.

Methanol, the least expensive oxygenate in this group, cannot alone be blended in gasoline if any water is present in the fuel. Methanol is highly soluble in water and will combine with it to form a separate layer or "phase". To stabilize a methanol-gasoline blend and thus prevent phase separation, another alcohol can be added and is known in this application as a *cosolvent*.

Several reasons suggest that it is in the public interest to encourage the use of methanol and cosolvent ethanol as gasoline additives in Canada.

For many years lead compounds have been added to gasoline to raise its octane rating (to improve the fuel's antiknock characteristics), an important specification in this era of high compression engines. But medical research indicates that lead released into the environment through fuel combustion can create a health hazard, particularly in urban areas. There is evidence that elevated blood lead levels are associated with harmful biochemical and neurophysiological effects, especially in children.

Canada is one of a growing number of countries restricting lead concentrations in gasoline; effective January 1, 1987, the permissible lead level will be lowered to 0.29 grams per litre of gasoline from 0.77 grams per litre. On March 25, 1986, the Federal Government announced its intention of effectively eliminating the use of lead in gasoline by the end of 1992. This follows the trend in the United States where the lead-in-gasoline limit has already been reduced to 0.026 grams per litre. Both methanol and ethanol can serve very well as octane enhancers in replacing lead.

Evidence before the Committee indicates that low-percentage blends of alcohol in gasoline do not create any significant environmental problems. Evaporative emissions may be higher with alcohol-blended gasoline, depending upon the vapour pressure specifications for the resulting fuel, but there are means to reduce such emissions. Exhaust emissions would remain relatively unchanged at the blending concentrations being considered, except for the reduction in lead levels.

Conserving Canada's shrinking reserves of conventional light crude oil provides another rationale for alcohol blending: alcohols can serve as fuel extenders by displacing some of the crude oil required in gasoline production. Methanol is currently manufactured from natural gas, a resource more plentiful in Canada than light crude oil, and could be made from other carbon-rich materials such as coal and wood. Ethanol can be made from ethylene (a chemical produced in petroleum refining), derived from ethane (a constituent of natural gas), or fermented from starch- and sugar-containing feedstocks such as grains and root crops. An experimental process for manufacturing ethanol from cellulosic ("woody" or cellulose-containing) material promises to diversify the potential feedstocks for ethanol production even more.

Alcohol derived from biological materials is promoted by some as a means of substituting a renewable energy resource for petroleum as a vehicle fuel. Care must be taken, however, in examining the energy balance (energy input versus energy output) in producing alcohol because its benefits in this respect may be illusory. For example, ethanol produced at stand-alone plants from crops grown in an energy-intensive agricultural system could consume more energy from nonrenewable sources than would be saved in displacing crude oil in gasoline manufacture and gained in energy credits for the by-products. Coupling an ethanol facility to a methanol plant or to a source of process heat such as a thermal-electric generating station improves the energy balance.

Methanol is in oversupply around the world and selling at depressed prices. Because of limited domestic requirements for this chemical, Canada's three world-scale methanol plants, which represent approximately 10% of global production capacity, must sell 85% of their output in this weak export market. This exposure jeopardizes the Canadian methanol industry. Using methanol as a gasoline blending agent would greatly expand domestic sales and correspondingly reduce the industry's dependence upon a deteriorating international market. It would also enlarge the domestic market for Canadian natural gas producers. The manufacture of methanol currently consumes about 4% of domestic gas output.

Expanded ethanol production using a variety of agricultural materials could also benefit the Canadian agricultural industry, increasing domestic demand as the farm community faces stiff competition selling its produce abroad. Of particular interest, ethanol production provides a market for substandard crops, crop residues and crop surpluses.

The Committee found no serious technical or environmental problems arising from the use of alcohols as blending agents. The fact that various alcohol-gasoline blends are being marketed in a number of countries demonstrates that these fuels can serve satisfactorily in transportation uses. However, the economic feasibility of introducing alcohol-gasoline blends in Canada today is debatable. Although the Committee anticipates that alcohol blends will become economically competitive, the marketplace should decide when that point has been reached. In principle, therefore,

(1) The Committee recommends the use of methanol and ethanol as blending agents in Canadian gasoline.

Another issue to be addressed is whether the cost of the blending agent is more or less than the cost of the materials it displaces in gasoline manufacture. Currently, methanol is the lowest-priced oxygenate, selling for approximately 18 cents per litre. Ethanol costs at least 2.5 times that amount and is not the cheapest cosolvent for the methanol. Consequently a methanol-ethanol blend is not the most cost-efficient alcohol blend for refiners to use today.

Refiners have other options for replacing the octane points to be lost in the coming phase-down of lead in gasoline. For example, the refining process can be modified to yield a larger fraction of higher-octane hydrocarbons. Aromatics and branched-chain hydrocarbons produced by catalytic reforming and isomerization have high octane ratings and can be blended into gasolines in larger quantities. Trade-offs include the capital cost of raising refinery yields of higher-octane hydrocarbons, the additional process energy required in refining, and the diversion of aromatics from petrochemical use to gasoline blending. Another concern is that benzene, one of the aromatic compounds, is a potent carcinogen as well as an octane enhancer.

In the United States, ethanol has become the most popular alcohol for gasoline blending because its use is promoted by a generous system of federal and state subsidies when the ethanol is derived from agricultural materials. This Committee does not want such a system of subsidies introduced in Canada.

Federal funding of research, development and demonstration (R,D&D) into alternative transportation fuels represents a form of support which the Committee does favour. One result of the Government's Economic and Fiscal Statement of November 1984 was the loss of most federal support for R&D into alcohol fuels, especially research into the production of ethanol. The National Conservation and Alternative Energy Initiative of last summer reinstated only a limited part of the lost funding. The Committee has concluded that the best prospect for reducing ethanol prices lies in developing better technologies for ethanol production. Therefore,

(2) The Committee recommends that the Federal Government more extensively support research, development and demonstration required to introduce alcohol-gasoline blends on a broad basis. This support should include new approaches to fuel alcohol utilization and production—including the derivation of ethanol from sources of starch, sugar and cellulose—which could remove economic or technical constraints to alcohol-gasoline blending.

Although the evidence suggests that the price of ethanol will continue to decline, the Committee cannot predict when methanol-ethanol blends will become economically competitive as octane enhancers.

A by-product of ethanol made from grain, "distillers dried grains and solubles" (DDGS), has traditionally been marketed as an animal feed. Recent research suggests the potential for deriving a human food supplement, rich in protein and fibre, from DDGS. A higher-valued by-product would improve the economics of making grain-derived fuel ethanol.

Witnesses stressed that there should be standardization in alcohol-gasoline blending, to ensure uniform fuel quality and to facilitate the exchange and distribution of gasoline stocks. In the United States, instances of illegal overblending by distributors and consequent vehicle damage have raised concern about the addition of methanol to gasoline. There is reluctance on the part of some automobile manufacturers to warrant their vehicles for use with gasoline containing methanol. In Canada, most gasoline is blended at the refinery which allows for controlled addition of methanol to the appropriate base gasoline. Alcohol blending at refineries or bulk terminals should ensure uniform blending according to approved standards.

Restricting blending to the refinery or bulk terminal, however, would prevent independent retailers from fully participating in this new market and limit competition at the retail level. Mohawk Oil has demonstrated over a period of several years that tank blending of alcohol and gasoline can provide an entirely satisfactory fuel. Mohawk first loads a metred quantity of alcohol into its tank trucks and then bottom loads the appropriate amount of gasoline by pumping it up through the alcohol to ensure complete mixing. The Committee has concluded that this is an acceptable means of fuel blending when properly controlled and monitored. The Committee does not approve of blending at the retail station pump. To address these concerns,

(3) The Committee recommends that the Federal Government, in cooperation with the provincial governments and industry, establish guidelines and standards for alcohol-blended gasoline.

Quality standards for retail gasoline are set by the Canadian General Standards Board (CGSB), but these standards are not binding unless incorporated in provincial or territorial legislation. Prince Edward Island, Nova Scotia, Quebec, Ontario and Alberta have embodied CGSB standards in provincial regulations. In Newfoundland, New Brunswick, Manitoba, Saskatchewan, British Columbia, Yukon and Northwest Territories, quality controls are a product of industry self-regulation. New standards for both ordinary gasolines and oxygenated fuels are being considered by the CGSB. The Committee hopes that specifications which result from this review will facilitate, not constrain, alcohol-gasoline blending.

TECHNICAL CONSIDERATIONS

A. WHAT ARE THE FUEL OXYGENATES?

When alcohols or ethers, which are oxygen-containing compounds, are added in small percentages to gasoline, the resulting blend is called an oxygenated gasoline. Such gasolines are marketed widely in a number of countries today. Limited use of oxygenated fuels has begun in Canada, in the Western provinces and in the Hamilton, Ontario area.

There are two prime motivations for adding oxygenates to gasoline. First, they boost the octane rating or antiknock charateristics of the fuel, and consequently represent alternatives to lead. The use of lead additives is being restricted in many countries because this metal has been proven to be a health hazard. Lead alters human blood chemistry even at very low concentrations; higher blood lead levels in children correlate with adverse learning and behavioural effects. A relationship has been observed between elevated blood lead levels and high blood pressure in American adult males. The Royal Society of Canada's Commission on Lead in the Environment concluded that such evidence justifies taking precautionary measures to reduce blood lead concentrations in the general population (Royal Society, 1985).

Sales of leaded gasoline constitute a declining share of total gasoline sales but still account for approximately half of the domestic market. The present Canadian standard allows leaded gasoline to contain up to 0.77 grams of lead per litre of gasoline. Actual quantities used average about 0.44 grams per litre over the total supply of leaded fuel and this raises the octane rating by 5 to 10 points, depending upon the base gasoline to which it has been added. On average, lead now contributes about 6 octane points to the leaded half of the gasoline supply in Canada (COFA, personal communication). On January 1, 1987, the Canadian standard for leaded gasoline will be reduced to a maximum quarterly average of 0.29 grams per litre; by December of 1992, the use of lead as a gasoline additive will effectively have been eliminated (Environment Canada, 1986). The industry will have to use other means to maintain octane ratings.

The second reason for adding oxygenates is that they can be utilized to displace part of the crude oil required to manufacture gasoline, substituting other resources such as natural gas and biomass (material of plant or animal origin, apart from the fossil fuels). It is generally accepted that the domestic supply of conventional light crude oil will continue to decline and that it is in the interest of Canada to reduce its dependence on petroleum.

Six oxygenates are considered to be of interest as fuel additives in Canada. Two of these are the simplest alcohols, methanol and ethanol. Three are more complex alcohols: isopropyl alcohol (isopropanol or IPA), isobutyl alcohol (isobutanol or IBA) and tertiary butyl alcohol (tertiary butanol or TBA). The sixth oxygenate is an ether, methyl tertiary butyl ether (MTBE).

Gasolines are highly-tailored, complex hydrocarbon products. Adding oxygenates to gasoline is not a straightforward matter because each of the additives modifies the characteristics of the blended fuel in its own way. There are trade-offs to be considered in both performance and economics.

1. Methanol

Today methanol is made almost exclusively from natural gas. At higher cost, it can be manufactured from other carbon-rich materials such as coal or wood. World methanol manufacturing capacity well exceeds present demand. This oversupply is expected to persist into the 1990s. Three world-scale plants produce methanol in Canada, two in Alberta (Celanese Canada Ltd. at Edmonton and Alberta Gas Chemicals Ltd. in Medicine Hat) and one in British Columbia (Ocelot Industries Ltd. in Kitimat). Their combined capacity is 6300 cubic metres per day (m^3/day) but Canadian demand is only about 800 m^3/day; the remainder is exported, primarily to the United States and Pacific Rim countries. Increasing competition from the Middle East, Eastern Europe and Latin America is reducing Canadian sales outside North America. The overall export picture is uncertain.

The delivered price for methanol in the Ontario market is about 18 cents per litre. Although some observers expect this price to decline further, perhaps to as low as 15 cents per litre by 1990, the industry view is that a constant-dollar price of 18 cents is appropriate to assume for planning purposes (COFA, personal communication).

Gasoline blended with methanol alone is unsatisfactory because the presence of water will cause the methanol and gasoline to separate into distinct layers or phases, methanol having a strong affinity for water. To prevent this separation, the fuel must be kept as dry as possible and other alcohols added to stabilize the blend. When higher alcohols are used to prevent phase separation in methanol-gasoline blends, they are referred to as cosolvents. Ethanol, isopropyl alcohol (IPA), isobutyl alcohol (IBA) and tertiary butyl alcohol (TBA) can all serve as cosolvents. TBA has been most commonly used for this purpose.

It was suggested to the Committee that methanol initially be blended in equal amounts with cosolvent over a period of at least several months, to help purge the gasoline distribution system of water. Thereafter, the concentration of cosolvent could be reduced.

Methanol is utilized as a blending agent today in West Germany (3% methanol with up to 3% TBA as cosolvent), in Austria (3% methanol, 2% TBA as cosolvent and 5% MTBE as an octane enhancer and fuel extender), and in the United States (for example, ARCO's "Oxinol" blend of 4.75% methanol and 4.75% TBA in unleaded gasoline).

Mohawk Oil began marketing a blend of 5% methanol, 3% ethanol and 92% unleaded gasoline in Saskatchewan in 1984, and in Alberta and northern British Columbia in 1985, under the name "EM Gasohol". In the Hamilton region, Alberta Gas Chemicals and Sunoco in 1985 introduced a blend of 4.75% methanol, 4.75% IBA and 90.5% unleaded gasoline under the brand name "V-Plus". Canadian Methanol Canadien has carried out a demonstration marketing of methanol blends at two Domo stations in Winnipeg.

2. Ethanol

Ethanol is perhaps most familiar as beverage alcohol distilled from grains. Ethanol is also made from ethylene, in turn a product of oil refining, or made from ethane which is a constituent of natural gas. Ethanol can be added to gasoline as a cosolvent to methanol or blended with gasoline on its own to produce "gasohol" (a gasoline-alcohol mixture).

Ethanol is being blended in U.S. gasoline at a rate of more than 5000 m^3/day, because of incentives introduced with the National Energy Act of 1978. These incentives apply only to ethanol derived from agricultural feedstocks. Many states have added incentives of their own and gasohol now exceeds 5% of U.S. gasoline sales.

The Brazilian government decided to develop a fuel ethanol industry based on surgarcane, with the target of satisfying 60% of the domestic demand for vehicle fuel with ethanol by 1995. Approximately 15% of Brazilian motor vehicles now operate on neat (essentially pure) ethanol and the remainder use a blend of 22% ethanol in gasoline. This program has been criticized in a recent European study for its alleged negative impact on Brazil's economy, for the environmental problem created with stillage disposal, and for the displacement of food production by fuel alcohol production (CEFIC, 1985).

Canadian ethanol production is limited. Commercial Alcohols Ltd. of Montreal can manufacture about 225 m^3/day from ethylene purchased from Petromont, while Mohawk Oil Ltd. produces about 25 m^3/day from cereals at a distillery in Minnedosa, Manitoba. Mohawk uses this ethanol in a 10% blend with gasoline which it has been marketing since 1981 in southern Manitoba under the name "E10 Gasohol". St. Lawrence Reactors Ltd. of Mississauga is selling a limited quantity of ethanol to Mohawk at a contract price of 44 cents per litre. Industrial grade ethanol reportedly sells today at a price closer to 50 cents per litre. Thus Canada's limited ethanol output is apparently available at a cost of 44 to 50 cents per litre.

Brazil exports substantial quantities of ethanol. Using the laid-down price in the United States as a guide, Brazilian ethanol could be delivered to Sarnia for about 30 to 35 cents (Cdn) per litre, not counting an import duty which raises the cost into the price range of domestic production. Four Canadian companies, including Commercial Alcohols and Mohawk, can benefit from a temporary remission of 7.7 cents per litre in the custom tariff on imported crude ethanol (ethanol containing water and requiring redistillation), but the remission order applies only to ethanol imported for industrial use, not fuel blending. Application has been made for a tariff remission on fuel ethanol imports (Agriculture Canada, personal communication and *Renewable Fuels Report*, 1985).

American ethanol producers charged Brazil with dumping this commodity into the U.S. market and sought anti-dumping duties on Brazilian fuel ethanol. Although the U.S. International Trade Commission did find that Brazilian ethanol was entering the United

States at lest than fair value, it ruled on March 4, 1986 that these imports had not harmed the domestic ethanol industry and therefore refused to assess anti-dumping duties.

3. Isopropanol (IPA)

Isopropyl alcohol is manufactured from propylene derived either from propane or as a byproduct of oil refining. IPA is presently in oversupply; its price is determined by the chemical market, which accounts for almost all of its use. The present cost of IPA in the depressed Canadian market is about 40 cents per litre.

Shell Chemical in Sarnia runs a 312 m^3/day IPA plant and exports about half of its output. A larger capacity would be required for any major use of isopropyl alcohol as a gasoline blending agent. If all of their production were retained for domestic sale, Commercial Alcohols and Shell Chemical together could produce only enough cosolvent (ethanol plus IPA) to supply about one-tenth of the requirement for a 5% methanol/5% cosolvent blend in Canadian gasolines. Given this low Canadian production capacity, temporary imports of cosolvent would be required if the use of these blending becomes widespread.

4. Isobutanol (IBA)

Isobutyl alcohol or IBA is a byproduct of the manufacture of other chemicals. The chemical market accounts for almost all of its use. BASF Canada Inc. in Montreal manufactured about 100 m^3/day but that capacity has been permanently shut down. The excess supply of IBA has resulted in a selling price of roughly 40 cents per litre.

Large-scale production of IBA is considered unlikely because of a lack of demand for the primary chemical product. Modest quantities would be available to introduce methanol-gasoline blends but not to sustain broad use.

The V-Plus filling stations in Ontario will replace IBA with IPA as the cosolvent for methanol (Alberta Gas Chemicals, personal communication).

5. Tertiary Butyl Alcohol (TBA)

The world's only major manufacturer of tertiary butyl alcohol is ARCO, at one plant on the U.S. Gulf Coast and a second in Western Europe. There is no TBA production in Canada. Tertiary butyl alcohol could be made in Canada from butane, supplies of which are adequate to support any foreseeable use of TBA as a cosolvent. Estimates suggest that TBA could be manufactured in Canada at a cost of approximately 32 cents per litre in Sarnia, and several cents less in Edmonton (Hycarb, 1986). Imported TBA can be landed in Sarnia or Montreal at the present time for about 40 cents per litre.

ARCO blends a gasoline-grade TBA with methanol in the United States to produce an oxygenated gasoline retailed under the name "Oxinol". About one-third of ARCO's American TBA production is required for the Oxinol blend; most of the remaining TBA goes into gasoline alone, as a fuel extender.

TBA has a characteristic which complicates its handling—it freezes at about room temperature and would probably have to be preblended with methanol for fuel use.

6. Methyl Tertiary Butyl Ether (MTBE)

MTBE is manufactured from methanol and isobutylene, and has been used as a gasoline blending component in the United States since 1979. Several oil companies now run MTBE plants in the United States but this is mostly captive capacity (used by the companies for their own gasoline blending) and only limited amounts of MTBE are available for commerce. There is no Canadian MTBE production at present.

The delivered cost of MTBE in Ontario, including Canadian import duty, is about 40 cents per litre. This cost would be substantially lower for a large-scale domestic plant using isobutane and methanol as feedstocks.

An advantage of blending MTBE with gasoline is that the resulting fuel is not susceptible to phase separation in the presence of water. Some refiners therefore maintain that MTBE-gasoline fuels are the technically preferred means of introducing oxygenates into gasolines.

In the United States, current regulations allow up to 11% MTBE to be added to unleaded gasolines. It is the only oxygenate allowed without identification into American fungible product pipelines. (In a fungible product pipeline, all shippers' products are comingled and must meet common specifications.)

7. Observations

No cosolvent for methanol is currently available in Canada in sufficient quantities to allow extensive use in domestic gasoline stocks. Until adequate domestic supplies of cosolvent are established, ethanol could be imported from Brazil and TBA from the United States.

The price spread between ethanol and the other cosolvents is now roughly 10 cents per litre. This is down from a price spead of 15 to 20 cents which prevailed over the last few years. Uncertainty in the short-term price of crude oil complicates this price relationship but the trend has been for ethanol to approach a more competitive position with the other cosolvents. However, the cosolvents now available only as imports (IBA and TBA) could be manufactured within Canada at lower cost from domestic feedstocks, as could MTBE for use as an octane enhancer.

B. GASOLINE BLENDING

All of the oxygenates exhibit different characteristics when blended into gasoline than they do as pure substances. Although a variety of factors must be considered in gasoline blending, two are of particular concern: octane rating and volatility. Other important variables are the water tolerance and oxygen content of the additive.

1. Octane Rating

Octane rating is a measure of the antiknock quality of a gasoline, or its resistance to too rapid combustion in the cylinder of an engine. High compression engines, which have been developed to achieve greater thermal efficiencies and improved performance, require higher octane fuels to prevent spontaneous ignition (detonation) of the fuel-air mixture. Certain substances have the ability to suppress fuel detonation. Among these, tetraethyl lead provides the greatest effect for the least cost, and consequently is the preferred means of boosting fuel octane ratings.

In place of lead, refiners can add small amounts of another metallic octane booster, methylcyclopentadienyl manganese tricarbonyl or MMT. This manganese compound can provide only part of the needed octane, however, because it is substantially less effective than lead. At the concentration allowed in Canadian gasoline (0.018 grams of manganese per litre), MMT adds approximately one octane point and is typically used for "topping up" the octane level of gasoline stocks. Thus other sources of octane are required as well. The refiner can produce higher-octane hydrocarbons by modifying the gasoline refining process and/or can add oxygenates to the base gasoline.

The alcohols and MTBE are good octane enhancers, methanol and ethanol being better at this function than the higher alcohols. Pure methanol has an octane rating ("antiknock index", which is the numerical average of the "research" and "motor" octane numbers) of 120; ethanol has an antiknock index of 118; and MTBE of 109 (Mueller Associates, 1985). A 5% methanol/3% ethanol mix in a regular unleaded gasoline has an antiknock blending value of approximately 112 and would contribute about two units of octane to the resulting gasoline blend. A 10% blend of ethanol in the same gasoline has an antiknock blending value of 118 (Hycarb, 1986).

In general, the alcohol blending value increases as the octane number decreases in the base gasoline, and with decreasing concentrations of aromatic hydrocarbons. This means that alcohol blending values are typically higher for regular gasoline than for premium gasoline.

When Canada effectively eliminates the use of lead in gasolines, the blending value of all of the oxygenates will be significantly increased. Meeting the 1987 standard for leaded gasoline will require refiners to replace approximately two units of lost octane; removing the remaining lead generates the need for another four units. Adding oxygenates to gasoline becomes less expensive than refining progressively larger amounts of high-octane hydrocarbons. Increasing competition between the fuel and petrochemical industries to obtain aromatic compounds will also boost their price.

2. Volatility

Volatility is a measure of how readily a fuel vapourizes at different temperatures. To burn in an internal combustion engine, the fuel must be vapourized; gasoline specifications are intended to ensure vapourization across the range of operating temperatures. The Reid Vapour Pressure, or RVP, is the common specification for fuel volatility and is a measure of fuel evaporation at 100°F (37.8°C).

Vapour pressure of the fuel is important because it affects both the vehicle's driveability and evaporative emissions into the atmosphere. The vapour pressure of an alcohol-gasoline blend is not simply related to alcohol concentration. In fact, fuel vapour pressure increases sharply as the first few per cent of alcohol is added; beyond a 3% alcohol concentration, the blended fuel vapour pressure rises very little. The Reid Vapour Pressure of an ethanol-gasoline blend jumps from 12.5 pounds per square inch absolute (psia) at 0% ethanol to 13.2 psia at 5% ethanol. At concentrations of 10% and 15% ethanol, the Reid Vapour Pressure still measures about 13.2 psia. The boost in vapour pressure is greatest for methanol blending, less pronounced with ethanol, and least with the higher alcohols.

Thus alcohol-gasoline blends evaporate more readily than unblended gasolines, especially if the blending agent is methanol/ethanol. If the vapour pressure specifications of the fuel are required to be the same after blending as before, then the vapour pressure penalty is greatest for methanol at a 3% concentration. Adding more methanol reduces the penalty, the vapour pressure essentially staying constant thereafter. Higher fuel volatility tends to improve vehicle driveability in wintertime, but more readily leads to vapour lock on hot days. As in the case of ordinary gasolines, one would expect seasonal variability to be incorporated into alcohol blends.

Higher evaporative emissions of alcohol-gasoline blends can become an environmental problem, if oxygenated fuels are allowed with higher vapour pressures than ordinary gasoline. If the vapour pressure of the oxygenated fuel is to remain the same as for the unblended fuel, butane can be removed ("backed out") from the base gasoline to offset the rise in volatility caused by adding alcohol. The addition or withdrawal of butane from the gasoline pool is the usual means of adjusting fuel volatility.

The proposed standards for oxygenated gasolines, issued by the Canadian General Standards Board for consideration, would keep volatility and octane specifications the same for oxygenated fuels as for equivalent grades of gasoline. Some argue that this is too restrictive and that alcohol-gasoline blends with higher vapour pressures perform even better under some driving conditions. Others argue that oxygenated fuels are designed to be used interchangeably with regular gasolines and must perform in an automobile engine just as do ordinary gasolines. A fact to keep in mind in this discussion is that adding more aromatic compounds such as benzene to raise the octane rating of gasoline in lieu of lead also increases the vapour pressure of the fuel.

3. Water Tolerance

Alcohols are very soluble in water. If too much water is present in a blended fuel, the alcohol and water will combine in a layer separate from the gasoline. Higher alcohols have greater water tolerance, hence their use as cosolvents for methanol in gasoline. TBA, for example, is a better cosolvent for methanol in this respect than is ethanol—less TBA must be added to methanol to achieve a given resistance to phase separation in the blended fuel. MTBE blends are not prone to phase separation, an important advantage of this oxygenate.

4. Oxygen Content

Automobile engines require oxygen from the atmosphere to burn the fuel. Too much oxygen results in poor combustion. Therefore the amount of oxygenate added to gasoline must be limited. Tests of engines designed to operate on ordinary gasoline indicate that up to 3.7% oxygen by weight can be incorporated in the fuel without adversely affecting combustion. Consequently the proposed CGSB standards for oxygenated fuels set 3.7% as an upper limit for oxygen content. The following list presents the oxygen content of representative alcohol or ether blends in gasoline.

Oxygenate by Volume	*Oxygen by Weight*
10% ethanol	3.72%
5% methanol/3% ethanol	3.80%
4.75% methanol/4.75% IPA	3.89%
4.75% methanol/4.75% TBA	3.64%
7% methanol/3% IPA	4.60%
5% methanol/3% TBA	3.37%
11% MTBE	1.99%

According to these values, not all potential blends, including the blend specified in the Committee's Order of Reference, would conform to the proposed CGSB standard.

5. Heating Values

Alcohols have a lower energy content per litre than does gasoline. Methanol in turn has a lower heating value than ethanol. Therefore, a low-percentage alcohol-gasoline blend may contain 2-3% less energy per unit volume than a comparable unblended gasoline. This effect is partially offset if some butane is left out of the gasoline in introducing the alcohol, since butane also has a relatively low heating value.

There is also evidence to suggest that alcohol blends burn somewhat more efficiently in an internal combustion engine, again offsetting some of the loss in heating value. Actually, the heating values of conventional gasolines probably vary as much between types as do the alcohol-gasoline blends from conventional gasoline. Thus the increase in specific fuel consumption (or decrease in kilometres travelled per litre of fuel consumed) for alcohol-gasoline blends seems unlikely to be large enough to be of concern to the motoring public.

ECONOMIC CONSIDERATIONS

A. THE ECONOMICS OF ETHANOL AS AN OCTANE ENHANCER

The costs and benefits of ethanol as a Canadian-made alternative to lead are difficult to weigh against the economics of other octane enhancers. A number of benefits can be enumerated: increased farm income; more jobs in the production of ethanol; use of renewable resources in production; and acceptable automobile performance without the social costs or risks of lead. At present, however, ethanol is a relatively expensive oxygenate.

The question that must be addressed is what is the most effective and cost-efficient octane enhancer. The technical merits of ethanol have been discussed previously; they have received satisfactory reviews. But the economic situation is less encouraging.

If the ethanol option were to be implemented today, it would require government subsidy. The Committee does not see this as a realistic option. The government's determination to reduce the deficit provides little scope to finance ethanol conversion out of public funds. The market will have to decide when and how ethanol would become a viable alternative to other octane enhancers.

The costs of the ethanol alternative can be divided into two components: conversion costs, which are incurred once; and input costs, the cost of the additive itself.

1. One-Time Conversion Costs

If alcohol-blended gasoline becomes the standard in Canada, all retail service stations will have to be fitted to handle the new blend of gas. The lowest estimate given for this conversion cost was an average of \$400 per station. The highest figure mentioned was \$1000.

As an example, in the province of Quebec there are approximately 4650 service stations. Given the range quoted above, the cost of converting service stations in that province to handle alcohol blends would be between \$1.86 million and \$4.65 million.

In addition to converting retail service stations there would also be a requirement for storage tanks and related connecting pipe at refinery sites. No separate estimate was given for this cost.

The "up front" costs of moving to alcohol blends in gasoline do not appear to be inordinately high. However, the variance in estimates given by witnesses suggests that more detailed evidence should be collected before an assessment is made. The Committee was also advised that refining costs would be affected by the introduction of alcohol blends, and that these costs would vary from refinery to refinery.

2. Ongoing Costs: Alcohol Additives

At time of writing, the least-cost octane enhancers are derived from petroleum. TBA is a good example. Since December 1985, petroleum prices have plummeted. However, the gap between petroleum-derived octane enhancers and ethanol is sufficiently large that petroleum prices could return to their previous highs and ethanol would still be more expensive.

Consideration of ethanol blends therefore requires a marked reduction in the production costs of ethanol.

3. Financing the Ethanol Alternative

The issue of subsidies was thoroughly discussed by the Committee. Start-up incentives for retail outlet conversion were considered as well as temporary assistance to refiners to cover cost differentials due to ethanol purchase and blending.

The range of price increases required to cover blending costs, as quoted by different witnesses, is so wide as to be inconclusive. The Committee was told that gasoline refiners would require additional revenue of from less than one cent per litre to two cents per litre in order to cover the extra costs of the ethanol blend.

This spread is not alarming when expressed in cents per litre. Put in aggregate terms, however, the increased cost to the consumer could be anywhere from \$300 million to \$660 million per year, based on the above quotes multiplied by the volume of gasoline purchased nationally in 1984. The Committee cannot recommend government expenditures of this magnitude, due to budget constraints. Any cosolvent must be economically competitive when introduced.

Whether or not subsidies are given, the ultimate burden of this cost will be borne by the public. If a subsidy were paid to the refiners so that gasoline prices remained unchanged, other taxes would have to be raised. If the Federal Government were to lower gasoline taxes so that prices remained the same, again, other taxes would have to be increased to replace the lost revenue.

These options do not directly pass on the added costs to gasoline consumers. Rather, they allow gasoline purchasers a price break at the expense of the wider tax-paying population. Such a change in income distribution obliges those who do not buy gasoline to subsidize those who do.

Another possibility is to require refiners to absorb the increased costs out of profit. Like other fiscal directives, this option would present enforcement difficulties and costs. At present, a strong case cannot be made to put what is equivalent to a surtax on the petroleum companies. This would be inconsistent with current government policy. Also, with petroleum prices declining and industry profits deteriorating, refining is often the least profitable operation in the oil industry.

4. Provincial Incentives

The Manitoba fuel tax on unleaded gasoline is 8 cents per litre, effective April 1, 1985. Gasoline blended with ethanol receives a 2.5 cents-per-litre exemption from the normal gasoline tax. This reduction is made at the pump. The exemption was intended to eliminate the price gap between regular gasolines and the 10% ethanol blend being produced from Manitoba grains by Mohawk.

Unique among Canadian provinces is the Manitoba surcharge of 0.9 cents per litre on leaded gasoline, intended to narrow the price difference between leaded and unleaded gasolines. Taken together, these measures are designed to remove any disincentive for the public to purchase unleaded gasoline in general, and ethanol-blended gasoline in particular.

In Ontario, there is a modest degree of assistance for alcohol blends. The 8.3 cents-per-litre provincial tax levied at the pump is reduced by the proportion of alcohol in the gasoline.

5. Answer Lies in Better Technology

A large drop in the price of ethanol is the only solution to the dilemma. To this end, the Committee supports subsidies for research and development, so that more efficient technologies for ethanol production can be developed. Should such innovation occur, it should be vigorously promoted as a Canadian export in order that the Canadian economy gains maximum benefits from this investment of public money.

One of the uncertainties that must be acknowledged, however, is that corn may not be the preferred feedstock when the research results are known. While "corn technology" may be improved, a comprehensive research program should explore all possibilities, with decisions made on the basis of long-run efficiency and reliability. Ethanol blends should be promoted on their merits of performance and cost; they should not be justified primarily on the basis of the spinoff benefits to corn growers or the agricultural industry as a whole.

Yet there is great potential for the agricultural industry and corn growers especially. With corn prices depressed, farm incomes can only be increased by the marketplace if there is an increase in demand. This new use for corn provides an opportunity for higher sales volumes and higher farm revenues, with the added benefit that even low-grade corn, undesirable for most uses, is satisfactory for the production of ethanol. While such an increase in demand would raise crop sales, it would not be large enough to affect price in most cases, given the large size of the market.

Because corn prices are already at low levels, any reduction in the cost of ethanol production from corn will have to be accomplished in the realm of technological innovation, not input costs.

6. Reliability of Supply

Should corn be the preferred raw material for low-cost ethanol production, there are still reservations on the part of gasoline refiners. Generally their operations are large. If 3% ethanol were to be added to the entire stock of Canadian gasoline, it would require an ethanol supply of about 900 million litres annually, or almost 2.5 million litres per day.

Large gasoline refiners have expressed concern about the reliability of the ethanol supply. Can corn producers and small ethanol plants provide a dependable and adequate stream of production? The answer given by corn growers is "yes". Yet the potential damage to a small agricultural enterprise that cannot meet its ethanol commitments is vastly less than the financial loss and disruption that would befall a large refiner of gasoline, there being only about 30 refineries supplying the entire nation.

Foreign sources of supply present an interim solution to this problem. In fact, ethanol would have to be imported during the initial years of blending until Canadian production became sufficiently large.

However, this emphasizes a further consideration. If ethanol is to provide spinoff benefits to the agricultural industry in Canada, it must not only be cheaper than petroleum-derived substitutes, but also competitive with Brazilian ethanol which is currently available at a price lower than the cost of production in Canada.

7. Effect on Competitive Pricing

Moving to a standard alcohol blend inhibits cross-border gasoline swaps and imports unless Canadian and American standards are the same. This would concern consumers buying from independent dealers who now obtain their gasoline from the cheapest source, whether domestic or imported. If alcohol blending of Canadian gasoline is done at the refinery, retailers would no longer have the option of buying gasoline directly from American refiners. Independent retailers in the Montreal area, for example, would be constrained to buying from domestic refineries in a market with few competing suppliers. An inability to import gasoline would restrict competition at the retail level, keeping prices to the consumer higher than if other sources of supply were available.

8. Existing Subsidy Programs for Ethanol Plants

Although the Committee has refrained from recommending that any new subsidies be established, it would encourage ethanol producers to take advantage of existing financial assistance available through the Department of Regional Industrial Expansion.

The Industrial and Regional Development Program (IRDP) has several categories of projects under which ethanol plants might receive financial assistance. The IRD Program is intended to assist manufacturing and processing operations by paying a percentage of eligible capital costs.

The proportion of costs subsidized by IRDP depends upon the region or "tier" of the country in which the plant is located. As an example, the program would contribute the following percentage of costs to eligible expenditures for establishing a new ethanol production facility using agricultural feedstocks (DRIE, personal communication):

For the "studies component" of costs:	0.0% in Tier 1
(consultants' fees, etc.)	30.0% in Tier 2
	37.5% in Tier 3
	37.5% in Tier 4
For plant establishment:	0.0% in Tier 1
(capital costs)	17.5% in Tier 2
	25.0% in Tier 3
	50.0% in Tier 4

Note that the IRDP is intended to assist start-up or expansion investments. These are one-time payments—not an ongoing subsidy based on volume of output or cost of inputs.

9. Assessing the Costs

The Committee has received a range of conflicting economic estimates. These include projections of the cost of refinery modifications, of refinery utilization rates, of ethanol production itself, and so on. The wide variation calls into question any single study or estimate presented. This would create a major problem were the Committee to attempt to assess the cost of underwriting a portion of an ethanol conversion program, or to identify where in the chain of production and use cost changes would be generated.

Because the Committee has decided that the marketplace should determine when and under what terms ethanol may be introduced into gasoline, the questionable exercise of identifying and tabulating the costs, distortions and secondary economic effects does not become an issue here.

This does not mean that the economic testimony had no value to the Committee. It has been made clear, regardless of the details, that ethanol is not economically viable at present. Yet the technical merits suggest that any impediments to ethanol production and utilization should be removed. If efforts to reduce the cost of producing ethanol by technological innovation are successful, the market may well call for the introduction of this additive. The Committee would greet this development with enthusiasm.

[illegible] ethanol were to be added to the entire stock of Canadian gasoline, it would require an [illegible] over 900 million litres annually.

Rural gasoline retailers have expressed concern about the reliability of the ethanol supply. [illegible] producers and small ethanol plants provide a dependable and adequate supply [illegible]? The answer given by some groups is "yes". Yet the potential damage to a small rural enterprise that cannot meet its commitments [illegible] less than [illegible] and disruption that would befall a large [illegible], there [illegible] supplying the [illegible].

Foreign sources of supply present an interim solution to this problem. In fact, ethanol [illegible]

However, this emphasizes a further consideration. If [illegible] is to provide spinoff [illegible] agricultural industry in Canada, [illegible] petroleum- [illegible] but also [illegible] which is currently available [illegible]

Moving to a [illegible] imports [illegible] Canadian [illegible] consumer [illegible] Independent [illegible] in the Maritimes [illegible], for example, would be [illegible]

Although the Committee has refrained from recommending that any new subsidies be established, it would encourage ethanol producers to take advantage of existing financial assistance available through the Department of Regional Industrial Expansion.

The Industrial and Regional Development Program (IRDP) has several categories of [illegible] under which eligible firms might receive financial assistance. The IRD Program is intended to assist manufacturing and processing operations by paying a percentage of eligible capital costs.

ENVIRONMENTAL CONSIDERATIONS

A. METALLIC OCTANE ENHANCERS

Tetraethyl lead has been employed to raise the octane ratings of vehicle fuels for more than 60 years. Methylcyclopentadienyl manganese tricarbonyl or MMT was first tried experimentally as an octane booster in 1957, but is neither as cheap nor as effective as lead. MMT is banned for use in unleaded gasolines in the United States but is allowed in leaded gas. In Canada, MMT can be used in both leaded and unleaded gasolines in amounts up to 0.018 grams of manganese per litre of gasoline. Because lead and manganese are metals, their derivative compounds used in this application are referred to as metallic octane enhancers.

The ubiquitous use of leaded gasolines has distributed this heavy metal throughout the environment, and prompted concern about lead toxicity. The widespread introduction of unleaded gasoline in the Canadian market in 1974 was followed by a sharp decline in automotive lead emissions, from approximately 14,000 tonnes of lead released annually in Canada in 1973 to the 1985 level of about 6000 tonnes (Royal Society, 1985).

Two federal initiatives will further depress lead emissions, beginning in 1987.

1. Regulations of May 16, 1984, under the Clean Air Act, reduce the permissible lead content in leaded gasolines from 0.77 grams per litre to 0.29 grams per litre, effective January 1, 1987.

2. Regulations of August 3, 1985, under the Canadian Motor Vehicle Safety Act, limit the emissions of hydrocarbons, carbon monoxide (CO) and oxides of nitrogen (NO_x) in all new light-duty vehicles (including passenger cars), effective September 1, 1987.

Reducing the permissible lead content of gasoline will cause a sharp drop in lead emissions next year. Limiting emissions of hydrocarbons, CO and NO_x will require catalytic converters on 1988 and subsequent model vehicles, progressively increasing the percentage of motor vehicles requiring unleaded fuel as older models are retired. According to the Royal Society's Commission on Lead in the Environment, these two federal actions are expected to drive national lead emissions down to 700 tonnes per annum (5% of the 1973 peak value) by the turn of the century. The Commission notes, however, that this success is contingent upon vehicle misfueling being effectively controlled.

In its March 1986 announcement of an effective ban on the use of lead in gasoline by December of 1992, Environment Canada projected that automotive lead emissions would be reduced to an annual rate of less than 150 tonnes in 1993 (Environment Canada, 1986). Leaded gasolines would cease to be in the largest man-made source of lead releases to the Canadian environment.

MMT is not seen as a health hazard at the concentration currently allowed in Canadian gasoline, even if used widely as a gasoline additive. Information presented to the Committee indicated that there was no medical evidence of harm at the expected levels of human exposure and consequently no basis for recommending against the use of this metallic octane enhancer.

B. ALCOHOL ADDITIVES

Some concern was expressed that adding alcohols to gasoline might generate higher levels of aldehydes, including formaldehyde, in exhaust emissions. The documentation which the Committee has reviewed indicates that aldehyde levels would increase for the alcohol blends being considered, but that the amounts involved are very small and the catalysts employed for controlling exhaust emissions are quite effective in removing these compounds. The relationship between alcohol concentration and aldehyde emissions appears to be readily predictable.

Adding alcohols to gasoline causes a reduction in exhaust emissions of carbon monoxide, which is a benefit. This may arise from the more efficient fuel combustion brought about by alcohols. Hydrocarbon emissions also appear to be reduced in such blends. The case of nitrogen oxide emissions is unclear; test results range from a small decrease to a small increase. Alcohol additives may depress benzene emissions, benzene being a carcinogen.

It appears that the pollution effect of displacing hydrocarbons with alcohols in low-percentage blends ranges from neutral to modestly beneficial. Considering this and the demonstrable benefits of removing lead from gasoline, the net environmental and health effect of replacing lead with methanol and ethanol as octane boosters is positive. The Commission on Lead in the Environment further concluded that "Alcohol blends present an attractive health and environmental alternative to the increase of aromatic hydrocarbons resulting from severe reforming" (Royal Society, 1986, p. 26).

SELECTED BIBLIOGRAPHY

(1) Beaulieu, Yvan and Terry Goodyear, *Potential for Ethanol Production from Agricultural Feedstocks for Use in Alcohol-Gasoline Blends*, Inputs & Technology Division, Regional Development Branch, Agriculture Canada, Ottawa, December 1985.

(2) Canada, Environment Canada, "Environment Minister to Ban Lead in Gasoline", Release #PR-HQ-086-11, Ottawa, March 25, 1986.

(3) Canada, House of Commons, Special Committee an Alternative Energy and Oil Substitution, *Energy Alternatives*, Supply and Services Canada, Ottawa, May 1981.

(4) Canadian Oxygenated Fuels Association, *Methanol in Transportation Fuel: A Major Opportunity for Natural Gas*, Ottawa, undated.

(5) Canadian Renewable Fuels Association, *Octane Substitution: Lead Removal with a Boost for Canada*, Ottawa, undated.

(6) Conseil Européen des Fédérations de l'Industrie Chimique, *CEFIC Position Paper. Bioethanol: A Viable Use of Renewable Resources?*, Brussels, October 1985.

(7) Coordinating Research Council, Inc., *Performance Evaluation of Alcohol-Gasoline Blends in 1980 Model Automobiles: Phase II, Methanol-Gasoline Blends*, Report No. 536, Atlanta, January 1984.

(8) DeJovine, James M. *et al,* "Gasolines Show Varied Responses to Alcohols", *Oil & Gas Journal*, February 14, 1983, p. 87-94.

(9) Elliott, D. and M. Tsang, *Federal/Provincial Methanol Vehicle Test Program*, prepared for the Road and Motor Vehicle Traffic Safety Directorate, Transport Canada, Ottawa and published by The Transportation Technology and Energy Division, Ontario Ministry of Transportation and Communications, Downsview, March 1983.

(10) Haq, M.A., "Parameters for Phase Separation", *Hydrocarbon Processing*, May 1981, p. 159-162.

(11) Hinkamp, James B., "Study Rates Alcohols as Blending Agents", *Oil & Gas Journal*, September 12, 1983, p. 170ff.

(12) Hycarb Engineering Ltd., *Optimized Linear Program Analysis of the Effect of Oxygenated Fuels on Canadian Oil Refineries*, Preliminary Draft, prepared for Energy, Mines and Resources Canada, Ottawa, January 1986.

(13) Jones, J.M., J.K. Pearson and J.S. McArragher, "The Setting of European Gasoline Volatility Levels to Control Hot-Weather Driveability" in *Alternative Fuels for SI Engines*, International Fuels and Lubricants Meeting and Exposition, Tulsa, October 21-24, 1985, Society of Automotive Engineers, Technical Paper Series #852118, Warrendale, Pennsylvania, 1985.

(14) Keller, J.L., G.M. Nakaguchi and J.C. Ware, *Methanol Fuel Modification for Highway Vehicle Use*, Final Report, #HCP/W3683-18, prepared for the Division of Transportation Energy Conservation, Department of Energy, U.S. Government Printing Office, Washington, July 1978.

(15) Mansell, R.L. and B.A. Jordan, "An Economic Evaluation of Methanol Blends in Canadian Markets", *Canadian Public Policy*, vol. XI Supplement, July 1985, p. 455-464.

(16) Marsden, S.S. Jr. "Methanol as a Viable Energy Source in Today's World", *Annual Review of Energy*, vol. 8, 1983, p. 333-354.

(17) Mays, M.A., T.L. Roach and D.A. Drake, *Material Compatibility of Oxygenated Fuels: Fleet Vehicle Fuel System Inspections*, ARCO Petroleum Products Company, Harvey, Illinois, October 1983.

(18) Mueller Associates, Inc., *Gasoline Octane Enhancement: Technology, Economics, and Environmental, Health and Safety Considerations*, prepared for the Office of Environmental Analysis, Assistant Secretary for Environment, Safety, and Health, Department of Energy, U.S. Government Printing Office, Washington, July 1985.

(19) Ontario, Ministry of Energy, *Fuelling Ontario's Future*, Ontario Government Bookstore, Toronto, September 1985.

(20) Ontario, Ministry of Energy, *The Shape of Ontario's Energy Demand*, Ontario Government Bookstore, Toronto, September 1985.

(21) Palmer, F.H. and G.J. Lang, "Fundamental Volatility/Driveability Characteristics of Oxygenated Gasolines at High Underbonnet Temperatures", Fuels and Lubricants Meeting, San Francisco, October 31-November 3, 1983, Society of Automotive Engineers, Technical Paper Series #831705, Warrendale, Pennsylvania, 1983.

(22) Robinson, R.J., *Gasoline Quality Regulations*, Report #TE 85-9, Transportation Energy Division, Energy, Mines and Resources Canada, Ottawa, August 1985.

(23) Royal Society of Canada, *Lead in Gasoline: Alternatives to Lead in Gasoline*, Supplementary Report of The Commission on Lead in the Environment, Ottawa, February 1986.

(24) Royal Society of Canada, *Lead in Gasoline: A Review of the Canadian Policy Issue*, Interim Report of The Commission on Lead in the Environment, Ottawa, September 30, 1985.

(25) Storey, Josh and C.M. Williams, *A Proposal: A Beef-Forage-Grain System for Prairie Agriculture*, Beef Industry Developments, Department of Animal and Poultry Science, University of Saskatchewan, Saskatoon, September 3, 1985.

(26) Taylor, D.J., *Evaluation of Methanol/Isobutanol Gasoline Blend Under Canadian Driving Conditions*, Centre for Alternative Fuels Utilization, Engineering Sciences Division, Ontario Research Foundation, Mississauga, April 12, 1984.

(27) "Two Ontario Waivers Run into Difficulty", *Renewable Fuels Report*, vol. 1, no. 5, March 15, 1985.

(28) Unzelman, George H., "Problems Hinder Full Use of Oxygenates in Fuel", *Oil & Gas Journal*, July 2, 1984, p. 59-65.

APPENDIX A

WITNESSES WHO APPEARED BEFORE THE COMMITTEE

	ISSUE	DATE
Agriculture Canada:	32	November 26, 1985
Jim McKenzie, Director Inputs and Technology Division Regional Development Branch		
Canadian Energy Research Institute:	33	November 28, 1985
Charles Slagorsky Vice-President, Research		
Walter Haëssel Vice-President, Research CERI Energy Research Ltd		
Canadian Oxygenated Fuels Association:	35	December 3, 1985
Jean Bélanger, Administrative Officer		
Ray Colledge, Chairman		
David Walker, Member Executive Committee		
Canadian Renewable Fuels Association:	35	December 3, 1985
Art Meyer, Chairman		
Brian Smith, Secretary		
Terry Daynard, Vice-chairman		
Energy, Mines and Resources Canada:	31 43	November 21, 1985 February 11, 1986
Anthony C. Taylor, Director Transportation Energy Division		
Michel Falardeau, Senior Economist Transportation Energy Division		

Allan J. Dolenko, Chief Bioenergy Section Renewable Energy Division		
Roy Sage Chief, Alternative Fuels Transportation Energy Division		
Environment Canada:	40	December 16, 1985
Vic Shantora Acting Director Industrial Programs Branch		
Glenn Allard Director Program Management Branch		
Vic Buxton Chief Chemicals Control Division		
Hardey, Elliott, M.P.	30	November 19, 1985
Health and Welfare Canada:	43	February 11, 1986
Claire Franklin Chief Environmental and Occupational Toxicology Division Environmental Health Directorate		
Manitoba Department of Energy and Mines:	37	December 9, 1985
William McDonald Executive Director Energy Management Branch		
Mohawk Oil Company Limited:	36	December 5,1985
Art Meyer, Director		
Don O'Connor General Manager Alcohol Fuels Division		
Motor Vehicle Manufacturers' Association:	39	December 12, 1985
James E. Elliot Director of Engineering Chrysler Canada Limited		
Ron M. Bright Director Environmental Control and Vehicle Safety Ford Motor Company of Canada, Limited		

Al Grando, Manager
Alternative Fuels Engineering and
Forward Planning Department
General Motors of Canada Limited

Ontario Corn Producers' Association: 34 December 2, 1985

Terry Daynard, Secretary Manager

Ontario Ministry of Consumer and Commercial Relations: 37 December 9, 1985

Edward Grzesik
Chief Engineer
Fuels Safety Branch

Ontario Ministry of Energy: 37 December 9, 1985

Barry Beale
Policy Advisor, Alternate Fuels

Robert Greven
Manager
Energy Technology Research

Ontario Ministry of Transportation and Communications: 37 December 9, 1985

Toros Topaloglu
Head, Transportation Energy Section

Petro-Canada: 38 December 10, 1985

Robert S. Vincent
Vice-President
Refining and Technology

Peter Hossack
Manager

Technical Services and Product
Application

Petroleum Marketers Association of Canada: 41 January 30, 1986

James R. Conrad
Executive Vice-President

Royal Society of Canada Commission on Lead in the Environment: 42 February 6, 1986

Marcus Hotz
Scientific Officer

St. Lawrence Reactors Limited: 32 November 26, 1985

Brian Smith, Vice-President
Engineering and Business Development

Hank Krech, Executive Vice-President
St. Lawrence Starch Ltd.

Sunoco Group of Suncor Inc.:	38	December 10, 1985
Robin Routley Manager Planning and Business Development		
Techtrol Ltd:	36	December 5, 1985
Pat Foody President Neville Rivington Senior Vice-President and Director Monenco Limited		
Texaco Canada Inc.:	41	January 30, 1986
Doug A. Mitchell Coordinator Government Relations		
Ray A. Shaver Manager Government Relations		
Paul D. McLean Technical Advisor Refining Department		
United Grain Growers Limited:	34	December 2, 1985
Roy Piper, Director		

APPENDIX B

LIST OF ORGANIZATIONS THAT SUBMITTED BRIEFS

Beef Industry Developments, University of Saskatchewan
Imperial Oil Limited
Shell Canada Limited