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Energy Conservation Benefits Incidental to Microemulsion Fuel Use

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Energy Conservation Benefits Incidental to Microemulsion Fuel Use

A. L. Compere
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Abstract

Microemulsion fuels have small droplets, usually 2 to 100 nanometers diameter, of a non-continuous phase mixed dispersed in base fuel. The dispersed phase consists of a mixture of a surfactant, which can be a fatty acid soap, and water, often with an alcohol added to increase stability. Microemulsions provide a unique opportunity to modify engine performance by changing fuel composition and combustion, including emissions. Although microemulsion fuel physical characteristics are very similar to those of the neat base fuel, they can contain up to 25% biomass-derived materials.

Opportunities for conservation using microemulsion fuels include petroleum sparing, distillate fuel extension during a petroleum supply interruption, and decreased energy cost of emissions control. For example, if microemulsion fuels technology can be develop sufficiently to permit application, it could be used to provide 3 to 8 billion lb of distillate fuel extenders from routinely stored agricultural materials during a petroleum supply interruption. Similar technology has promise for providing diesel fuels which have lowered NO_x and particulate emissions, effectively using a group of biomass materials to extend distillate fuel by direct energy replacement and by decreasing the energy expended in emissions controls. A successful technology might save 0.1 to 0.3 Quads in projected emissions control energy while substituting 0.5 to 0.6 Quads of biomass-derived materials for petroleum at the turn of the century. Recommendations for key research required to determine the most effective uses of this technology are explored in detail.

1. Introduction

Microemulsion fuels have small droplets, usually 2 to 100 nanometers diameter, of a non-continuous phase dispersed in base fuel. The non-continuous phase generally consists of a mixture of a surfactant and water, often with an alcohol added to promote stability. The base fuel can consist of hydrocarbons (diesel fuel, gasoline, or residual fuel oil) or esters (vegetable oil triglycerides or monoesters). The surfactants are generally simple soaps of vegetable or tree oil fatty acids, although the use of long chain alcohols and high-molecular weight surfactants (ethoxylates) has been reported. Microemulsion fuels provide a unique opportunity in fuel flexibility and engine performance: the ability to change fundamental fuel combustion properties combined with the ability to substitute up to 25% alternative materials (byproduct or biomass) for petroleum hydrocarbons.

Microemulsion fuels normally look and perform like a neat petroleum fuel. As with gasohol, the consumer is not expected to find a significant perceptual difference. Based on military fleet tests using standard diesel vehicles, little operational difference is likely to be noticed, and it is likely that the major adjustment required is engine timing. Thus, in a national fuel emergency, it should be possible to extend diesel fuel and heating oil supplies with limited consumer resistance.

To date, the federal record in the area of alternative fuels, most notably ethanol addition to gasoline and substitution of vegetable oils for diesel fuel, has been poor in spite of "massive federal expenditures" (U. S. DOE, 1987). Nonetheless. the U. S. is faced with a need to develop alternative diesel fuels for reasons of national security and fuel flexibility. Based on the gasohol experience, it appears that, to insure use of alternative fuels, these fuels should meet market needs unrelated to conservation. For example, present increases in engine efficiency and in the use of oxygenate fuels are the result of EPA-mandated standards coupled with a consumer demand for improved performance ratings. Similarly, microemulsion fuels which have improved emissions and which provide better performance are likely to find a market if their use can decrease the need for efficiency-robbing diesel engine emissions controls.

This report is an evaluation of the conservation benefits which are incidental to the use of niche-market microemulsions fuels with unique combustion properties. Based on earlier research, it is possible to use microemulsions to modify both NO_x and particulate emissions, currently under consideration by the EPA. Fuel formulations which decrease fire hazard and which increase safety in a number of sensitive applications can also be developed. Point of use agricultural fuels which permit farmers to use coop-produced wet ethanol in agricultural diesel fuels provide direct fuel substitution as well as the ability to get value from spoiled crops. As with oxygenate fuels, the market can provide a considerable impetus to conservation.

2. Market Projections

Across the last 15 years, domestic refiners have seen a tremendous variation — almost a factor of six — in imported crude oil prices. Although the availability of relatively constant supplies of domestic petroleum has provided a calming effect on market fluctuations, large swings in imported oil prices resulting from OPEC market manipulations have caused considerable domestic economic damage. Several domestic conservation programs, including the effort to provide subsidies for the development of fermentation ethanol plants, have focused on the development of methods for augmenting gasoline.

Distillate fuel, including kerosene, diesel fuel, and most aviation fuels, is the major fuel for heavy transport and industrial steam and power generation. For this reason, many fuel flexibility and refinery product allocation plans have recommended emergency process changes which produce distillate fuels at the expense of motor gasoline (National Petroleum Council 1980). Development of sources and methods for extending distillate fuel supplies during a crisis could make a substantial contribution to national security during periods of crude oil scarcity and market dislocation.

Microemulsion fuel technology provides a method for augmenting distillate fuel with a varity of biomass materials and industrial byproducts. Although considerable variation in composition is possible, a typical microemulsion fuel might contain 10% partially neutralized vegetable or tree oil fatty acids (surfactant), 5 to 10% alcohol, and 5 to 10% water. The alcohol component, called a coagent, promotes microemulsion stability but is not strictly necessary in order to form a microemulsion. Historically, alcohols ranging between methanol and pentanol have been used as coagents in hydrocarbon continuous microemulsions; however, because of the low flash points inherent in alcohol fuels, byproduct aromatic alcohols with high flash points have been considered.

To evaluate the amount of petroleum sparing possible in a period of crude oil scarcity, the bulk availability of vegetable oils and alcohols relative to distillate fuels will be considered. Energy Information Administration projections provided the information used in fuel production and use estimates shown below, while Department of Agriculture *Outlook* and *Predicast* database (Lockheed-Dialog) were used as sources for information concerning agricultural and industrial chemical byproducts.

Distillate Fuels

As shown in Table 2.1, net petroleum imports sustained a low of around 4.5 million barrels per day for the period between 1982 and 1985. This was due primarily to increased domestic

petroleum production, including the rapidly diminishing Alaskan finds. In 1986, net petroleum imports began to rise. By 1995, Energy Information Administration (EIA) projections place net imported oil at nearly 9 million barrels per day, with a rise to nearly 10 million barrels per day expected by the turn of the century. In constant 1987 dollars, EIA projects a world oil price of $25 to $40 per barrel, or an annual petroleum trade imbalance ranging between $90 and $145 billion by 2000 AD. During a period of supply interruption, it is expected that the price of fuel and its concomitant trade imbalance could double.

Table 2.1. Domestic petroleum balance.

Supply and disposition	Petroleum, 10^6 barrel per day													
	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1995	2000
Consumption	19.5	17.1	16.1	15.3	15.2	15.7	15.7	16.3	16.5	16.7	17.0	17.1	17.7	18.3
Production	10.7	10.8	10.7	10.8	10.8	11.1	11.2	10.9	10.6	10.5	10.3	9.9	8.8	8.4
Net imports	8.8	6.3	5.4	4.5	4.4	4.6	4.5	5.4	5.9	6.2	6.7	7.2	8.9	9.9

Source: Energy Information Administration 1988b.

Table 2.2 shows projected domestic distillate fuels consumption for the period between 1987 and 2000. At present, transportation uses account for roughly half of all distillate fuels consumption. In all projections, EIA has predicted a rise in both the share and the total amount of fuel used for transportation. During this period, it is expected that non-residential uses of distillate fuels will rise slowly, although increased boiler fuel flexibility can cause sudden and marked changes in fuel consumption patterns if a difference in pricing or legal requirements favors either natural gas or fuel oil. The effect of fuel switching was, for example, marked during 1986 when the drop in crude oil prices caused a sudden shift in boiler fuel purchases.

Potential Fuel Extension

The major conservation aspect of microemulsion fuels use is the simple substitution of domestic biomass and byproduct materials for imported petroleum. Microemulsion fuels can incorporate a variety of materials, including vegetable oil free fatty acids, aliphatic alcohols, and aromatic alcohols.

Oils. Table 2.3 shows edible oil production. The U. S. is the world's largest edible oil producer. Soybeans, accounting for over 70% of the world's total production, make up the bulk of domestic edible oil production. The stocks of pressed edible oils, excluding the oil that can be pressed from stored oilseeds, are cyclic, reaching an annual low around October, with a May-July high generally 2 to 3 times higher. Although there is considerable variation in the amount of stored whole oilseeds, the available material will generally represent between one-fourth and one year's production. For example, in an average year, 3 to 8 $\times$ 10^9 lb of soybean oil could be provided from stored soybeans. Due to the seasonal nature of agricultural products, a substantial amount of oil production capacity is available.

The actual amount of edible oil that is available is somewhat larger than is apparent from the production figures. This is because U. S. edible oil producers tend to ship whole, uncrushed oil-

Table 2.2. Projected domestic distillate fuels consumption.

Use	Annual energy consumption, 10^{15} Btu										Annual growth rate
	1987	1988	1989	1990	1991	1992	1993	1994	1995	2000	
Low-Growth											
Residential	1.07	1.13	1.11	1.10	1.08	1.06	1.04	1.01	0.99	0.88	−0.015
Commercial	0.65	0.69	0.70	0.71	0.72	0.73	0.73	0.74	0.74	0.73	0.008
Industrial	1.29	1.29	1.32	1.34	1.36	1.38	1.38	1.40	1.42	1.50	0.011
Transportation	3.43	3.41	3.52	3.62	3.69	3.76	3.84	3.93	4.01	4.25	0.017
Utilities	0.09	0.09	0.04	0.04	0.05	0.07	0.09	0.10	0.09	0.16	0.041
Total	6.53	6.61	6.69	6.81	6.90	7.00	7.08	7.18	7.25	7.52	0.011
Base-Case											
Residential	1.07	1.15	1.12	1.10	1.09	1.07	1.04	1.02	1.00	0.90	−0.013
Commercial	0.65	0.70	0.71	0.72	0.73	0.74	0.75	0.75	0.75	0.77	0.012
Industrial	1.29	1.31	1.33	1.36	1.39	1.42	1.43	1.45	1.47	1.58	0.016
Transportation	3.43	3.42	3.55	3.67	3.77	3.86	3.95	4.04	4.14	4.47	0.021
Utilities	0.09	0.09	0.04	0.04	0.05	0.07	0.10	0.11	0.09	0.17	0.048
Total	6.53	6.67	6.75	6.89	7.03	7.16	7.27	7.37	7.45	7.89	0.014
High-Growth											
Residential	1.07	1.17	1.14	1.12	1.09	1.07	1.05	1.03	1.01	0.91	−0.012
Commercial	0.65	0.71	0.72	0.73	0.74	0.75	0.76	0.76	0.77	0.79	0.015
Industrial	1.29	1.32	1.36	1.40	1.43	1.46	1.47	1.49	1.51	1.64	0.018
Transportation	3.43	3.43	3.58	3.74	3.87	3.97	4.05	4.13	4.24	4.64	0.023
Utilities	0.09	0.09	0.04	0.04	0.05	0.07	0.10	0.11	0.09	0.17	0.049
Total	6.53	6.72	6.84	7.03	7.19	7.32	7.43	7.52	7.62	8.15	0.017

Source: Energy Information Administration, 1987.

Table 2.3. Domestic edible oil production and stocks.

Oil	Oil production, 10^9 lb				Oil stocks, 10^9lb[a]		
	1985	1986	1987	1988[b]	1985	1986	1987
Corn	1.241	1.400	1.445	1.440	0.075	0.120	0.109
Cottonseed	1.070	0.781	1.055		0.107	0.085	0.090
Lard	0.891	0.853	0.900		0.041	0.022	0.029
Peanut	0.258	0.160	0.185		0.018	0.059	0.045
Soybean	11.617	12.783	13.100	12.900	0.632	0.947	1.725
Sunflower	0.585	0.585	0.750		0.066	0.055	0.112
Edible tallow	1.571	1.278	1.250		0.062	0.041	0.035

Source: Schaub, 1988. [a] As of 1 October, usually the minimum for the year. [b] Estimated, based on acreage planted.

seeds, rather than oilseed meals and pressed oil. Although the international market for oilseed meals is good, domestic edible oils require a subsidy of approximately half of their domestic price in order to compete is world markets, and the Department of Agriculture is presently providing a subsidy to foreign purchasers of U. S. edible oils amounting to $130 to $160 per ton under an Export Enhancement Program (Schaub 1988). At their subsidized price, export vegetable oils are roughly comparable to crude petroleum in terms of price per unit volume or unit energy. The subsidy was developed in order to encourage domestic producers to increase their world market share of oilseed meal and pressed oils. For example, the U. S. share of world soybean markets is 72%, while its share of pressed soybean oil and meal markets was 14% in 1986, and 24 to 25% in 1987 (with subsidy). However, these efforts do indicate that there is a very good agricultural base for the production of vegetable oil based fuel extenders. A market of perhaps one-fourth to one Quad, enough to extend all domestic distillate fuels, could be sustained.

The energy content of produced oil and retained oil stocks is shown in Table 2.4. Total edible oils, including lard and tallow, were nearly 0.7 Quads in 1987. Although it is expected that 1988 production will be somewhat lowered by poor weather, the trend of rising production is expected to continue across the next few years.

Table 2.4. Energy content of domestic produced edible oil and stocks[a].

	Energy content of produced oil, 10^{15}Btu			Energy content of pressed oil stocks, 10^{15} Btu		
Oil	1985	1986	1987	1985	1986	1987
Corn	0.046470	0.052424	0.054109	0.002808	0.004494	0.004082
Cottonseed	0.040372	0.029467	0.039806	0.004037	0.003207	0.003396
Lard	0.033027	0.031618	0.033360	0.001520	0.000815	0.001075
Peanut	0.009661	0.005991	0.006928	0.000674	0.002209	0.001685
Soybean	0.433909	0.477460	0.489301	0.023606	0.035372	0.064431
Sunflower	0.021906	0.021906	0.028085	0.002471	0.002060	0.004194
Edible tallow	0.059274	0.048219	0.047163	0.002339	0.001547	0.001321
Total	0.644619	0.667085	0.698752	0.037455	0.049704	0.080184

Source: Schaub, 1988. [a] As of 1 October, usually the minimum for the year.

It is important to realize that the energy potential from oilseeds is considerably higher than current production. Oilseeds, as a group, and soybeans, in particular, have undergone a great deal of genetic manipulation to produce desired varietal characteristics. If oils are used in fuels and thereby gain a wider commercial market, it is likely that selective breeding programs can substantially increase oil yields and domestic production in a relatively short period.

Coagents. Domestic production of short to mid-chain length alcohols are shown in Table 2.5. Ethylbenzene production is also shown to provide a measure of the potential production capacities for aromatic alcohols which have been shown to produce microemulsion fuels with high flash points. Although military microemulsion fuels containing amine soaps of unsaturated fatty acids and water have been successfully field tested, present research indicates that the addition of alcohols increases stability.

In order to supplement diesel fuels, growth in alcohols production capacity would be required. However, as can be noted from the reasonably rapid growth of methanol and ethanol produc-

Table 2.5. Coagent production.

Item	Annual coagent production, 10^9 lb				Source
	1985	1986	1987	1988	
Methanol		7.205	7.450	7.800	*Chem. and Engr. News*, 12/14/87, p. 28
Ethanol	5.93	6.58			*Chem. and Engr. News*, 2/17/86, p. 19
			6.27	7.57	*Chem. Marketing Reporter*, 7/6/87, p. 3
2-Propanol			1.36		*Hydrocarbon Processing*, 2/88, p.41
1-Butanol	0.72	0.87			*Chem. and Engr. News*, 6/8/87, p. 30
			0.93		*Hydrocarbon Processing*, 2/88, p.41
Ethanolamine	0.54	0.55			*Chem. and Engr. News*, 6/8/87, p. 30
Ethylbenzene	7.39	8.94			*Chem. and Engr. News*, 6/8/87, p. 30
				9.68	*Hydrocarbon Processing*, 2/88. p. 41

tion, a market demand can cause a substantial amount of growth in production capacity in a short time.

In summary, it is possible to provide a considerable amount of distill ate fuel extension and supplementation using microemulsion fuels. In years where retained agricultural commodities, in particular soybeans, are available, it is likely that fuel supplements could be produced in a short time period and would be of use during a petroleum supply interruption. However, it would be desirable to develop microemulsion fuels as a market for our present excess vegetable oil capacity. This use could replace part of our present export subsidies, while decreasing our need to import petroleum.

3. Conservation Incidental to Emissions Control

From the previous chapter, it appears likely that the materials requir ed to form microemulsion fuels are available in sufficient quantities to provide supplementation for a substantial fraction of the distillate fuels market. However, as has been learned from the difficulties in implementing gasohol use, fuel markets are not necessarily responsive to political demands. In order for a biomass-supplemented fuel to be accepted and used, it needs to provide perceived benefits to the user. These might include lower price per unit energy, improved performance, or decreased emissions.

Fuel use efficiency and emissions limitation are very closely coupled: *e. g.*, the Environmental Protection Agency, EPA, mandates emissions standards together with fleet fuel use efficiency standards to achieve the goal of air pollution reduction in passenger cars. The use of ethanol as a supplement to gasoline has been driven largely by pollution abatement: the new standards for oxygenate additives to decrease evaporative emissions, combined with the old standards mandating unleaded gasoline for new vehicles and rolling back the lead concentration in unleaded gasoline, have greatly expanded the market for alcohol additives to gasoline. In a similar fashion, it is possible that mandating low-emissions diesel fuel, as well as increasing fuel efficiency standards, will drive the market for biomass supplements to distillate fuels.

Transport

At present, the proposed EPA requirements for decreased diesel NO_x and particulate emissions has created an impasse with the transport industry and with the manufacturers of diesel trucks: meeting emissions standards will unfortunately impose a considerable efficiency penalty on truck owners and operators (Environmental Protection Agency 1988). The standards will start to take effect in 1990, with controls imposed on lighter vehicles first.

As might be expected, manufacturers previously affected by auto emissi ons controls and fleet standards have been investigating mechanical methods for decreasing diesel emissions particulate emissions. Ford Motor Company's emissions research on heavy trucks was outlined by As described by Rao and coworkers (1985). During tests of conventional particulate traps, including ceramic foam, woven wire mesh, and ceramic honeycomb designs, clean trap pressure loss was approximately 12 in. Hg. Pressure drops of 50 in. Hg were typically reached in 75 to 120 miles using traps with a volume approximately equal to that of the engine. Efficiency loss in non-regenerated traps is typically 1% for each in. Hg of exhaust pressure increase.

Ford has been trying to develop a thermally regenerable bypassable trap. This system will last, based on tests, only 30,000 miles, and does require the use of copper, nickel, or cerium octanoate

additives. Ford's lowest reported efficiency losses, typically 2.4 to 3.5%, are more acceptable. Unfortunately, trap systems appear to be comparatively high in NO_x production.

Table 3.1 provides estimates of the effect of best case and expected emissions controls on diesel transport in 1995 and 2000, when such systems are expected to comprise the bulk of domestic fleets. Although there is little difference in effect between EIA low and high growth cases, the substitution of a fuel composition control, such as microemulsion fuels, could conserve around one-third of a Quad relative to the expected case.

Table 3.1. Energy cost of diesel transport emissions controls.

	Low energy cost controls[a]		High energy cost control[b]	
Case	1995, 10^{15} Btu	2000, 10^{15} Btu	1995, 10^{15} Btu	2000, 10^{15}Btu
Low-growth[c]	0.10	0.11	0.30	0.32
Base-case	0.10	0.11	0.31	0.34
High-growth	0.11	0.12	0.32	0.35

[a]Assumes 2.5% energy loss in transportation. [b]Assumes 7.5% energy loss is transportation. [c]Assumes retrofit of older vehicles.

Power Generation, Industrial Combustion, and Acid Rain

Emissions controls by utilities and industry presently concentrate electrostatic precipitation and fuel gas desulfurization of emissions from coal-fired boilers. The cost of these emissions controls are around 10 TWh annually (Samuels 1983). Because the sulfur content of distillate fuels is typically 0.3% or less, flue gas desulfurization is not normally required. However, electrostatic precipitation or other particulate removal processes are presently used where they are cost effective.

In the next decade, this situation is expected to change in response to several factors. Treaty obligations with Canada are requiring the U. S. to sharply curtail its acid emissions. These include SO_x and NO_x from both stationery and mobile sources (Office of Technology Assessment 1984, Committee on Monitoring and Assessment 1986). Exchange of payments between states to cover the damage caused by emissions is also under discussion. Preliminary agreement has been reached between the governors of Ohio and New York, although the legislation is moving slowly through the U. S. Congress. Although the EPA has been acting slowly in promulgating more stringent standards for NO_x emissions, suits by environmental groups, such as the Sierra Club, have caused federal courts to require the agency to move more swiftly (Environmental Protection Agency 1988).

As with mobile transportation emissions controls, the increasing stringency of environmental requirements for stationary sources provides an opportunity to mandate fuels which control emissions. Although the opportunity is more difficult to quantify, due to the varied natures of emissions controls imposed by the current airshed requirements and those of the utility and industrial boilers used, a rough estimate of the conservation potential can be made. As Samuels estimated, particulate removal from large combustion operations is on the order of 1% of the total fuel used, or approximately 0.02 Quads. The ability to substitute biomass fuels for petroleum fuels in these cases is around 15% of the fuel burned, or around 0.25 Quads.

4. Conservation Incidental to Specialty Applications

For two somewhat disparate end uses, wet alcohols and reactor backup generator fuels, microemulsion technology permits leveraging of the energy content of the fuel additives. In the case of wet alcohols, the use of a technology in which water is used together with an alcohol and neutralized fatty acid soaps permits elimination of the drying step required for neat alcohol use in gasoline. In the case of reactor diesel backup generators, use of a fuel which could eliminate at least a fraction of the current fires would measurably increase the amount of time that the reactor is producing power. This can substantially decrease the amount of petroleum used to fuel substitute electrical generating capacity. Both uses will be considered in more detail below.

Power Reactor Backup Diesel Generators

The fires in nuclear reactors occur primarily in the control room and in the backup diesel generator areas (Dugan and Lorenz 1983). The diesel generator fires are not usually serious — few exceed a million dollars — but do result in reactor downtime. Microemulsion fuels technology can be used to provide diesel fuels which are fire-safe as measured by conventional pool fire tests. If microemulsion fuels are effective for the prevention of diesel fuel fires associated with reactor operation, net annual savings resulting from increased power generation would be around $25,000,000. In order to supplement the roughly 3 million gallons of fuel consumed by reactor diesel generators, about half a million gallons of biomass-derived fatty acid soaps and byproduct aromatic alcohols would be required. The incremental cost of using a fire-safe microemulsion fuel is expected, based on discussions with petroleum refiners, to be

The major concern in reactor diesel generator technology is reliabilit y. Although the present fuel specifications are limited to ASTM standard diesel fuel specifications, the need to guarantee that the diesel generators provide reliable power backup is paramount: when the generators are inoperative, the reactor goes down. The generators are usually highly reliable large diesels operated at a slow speed, and they are housed in heated enclosures. Fuel is heated and continually circulated to provide instant startup. Cold start and fuel contamination have, to date, proved the most difficult operating problems to overcome, and any fire-safe fuel must meet stringent cold-start requirements.

Although reactor backup diesel generators are the major energy-related use for fire-safe fuels, it is reasonable to expect that a satisfactory fuel will find a number of niche-market applications in fields ranging from weapons production and handling to mining safety.

Wet Alcohols Use in Diesel Fuel

The drying of fermentation produced ethanol is a reasonably energy-intensive process, although considerable progress has been made recently. Drying is critical to the prevention of phase separation when ethanol or methanol is used to extend gasoline. As late as a decade ago, roughly 50% of distillation energy was required for ethanol drying. A number of presently bench research methods seem likely to decrease the drying energy cost to between 10 and 25% of total distillation energy, depending on the exact process arrangements used. Formation of a microemulsion diesel fuel generally requires the presence of an amount of water often comparable to the amount of alcohol, resulting in a savings of the energy that would otherwise be required to dry the ethanol.

The potential of the use wet alcohols in microemulsion fuel is limited by the approximately 4 Quads of distillate fuel consumed in transport. It is unlikely that ethanol or other alcohols could be used to replace more 15% of this, presuming available capacity for alcohols production. Energy savings would depend on technology mix in ethanol plants.

5. Conclusions and Recommendations

Use of microemulsion fuels meets several conservation objectives by permitting substitution of biomass and byproduct materials for petroleum and by sparing the use of additional fuel required to meet 1990's proposed EPA NO_x and particulate emission objectives. It is likely that the agricultural commodities involved could be produced at levels sufficient to supplement domestic transport diesel fuels with reasonably limited market dislocation. This is presently of interest because the export of over 0.3 million tons of pressed oil is being subsidized at a rate of at least

Unfortunately, national needs do not necessarily determine the market for fuels. In the case of gasohol, massive subsidies and a great deal of legislative support did not drive the fuels market. The presently developing and stabilizing market was, however, driven by environmental mandate and by lead replacement for gasoline antiknock. As such, it is an oxygenate fuel market and includes petroleum derived and imported materials as well as fermentation ethanol. Emissions and safety, rather than conservation or imbalance of payments, are likely to determine the initial microemulsion fuel markets. The question is how research and, ultimately, fuel composition, can be planned to increase the conservation inherent in the use of the technology.

Three different areas of microemulsion fuels research appear likely t o provide technologies which meet DOE's current Conservation objectives: fuels incorporating vegetable oil free fatty acids and alcohols as extenders; fuels compositions which minimize NO_x and particulate emissions; and high-flash-point, fire-safe fuels. Different types of research plans are required to answer the questions needed to determine whether and how to best use the technologies.

Biomass fuel extenders. Soybean oil free fatty acids are the most available distillate fuel extender. In the event of a petroleum supply interruption, oil could be pressed from routinely stored soybean stocks and converted to free fatty acids and glycerol. Oil pressing and triglyceride hydrolysis are standard commercial technologies. However, soybean oil is a reasonably variable natural product. The effect of variations in fatty acid composition on the stability and utility of microemulsion fuels is critical to the utility of the technology. The ability to effectively use byproduct streams, such as free fatty acids, currently produced by conventional pressed oil purification process is also key to developing a functional fuel augmentation technology. It is presently possible to obtain byproduct streams containing primarily free soybean oil fatty acids at very low prices. However, these byproduct streams are not well characterized, and the effect of impurities on microemulsion stability, combustion properties, or materials compatibility is poorly understood.

In the event that a petroleum supply interruption does develop and that it is appropriate to extend distillate fuels using microemulsions, a thorough understanding of the phase chemistry

of the systems involved, together with a reasonable ability to predict those fuel compositions which can be made using available materials, including a variety of alcohols, will be key to successful use of the technology. A reasonable understanding of the combustion properties of the fuels will also be required to ensure that they perform adequately without serious equipment damage.

Low emissions fuels. It may be possible to use microemulsion fuels technology, possibly in combination with other emissions modification techniques, to decrease the NO_x and particulate emissions from heavy transport. This could permit meeting EPA heavy transport emissions standards without the loss of energy efficiency imposed by post-combustion emissions controls. However, small combustion bomb tests are required to simply determine whether it will be possible to understand the combustion of microemulsion fuels well enough to specify fuel compositions and appropriate combustion conditions. The type of control possible in combustion bomb experiments is required in order to separate the effect of variation in fuel composition, solution structure, and combustion conditions. Good experimental control is key to success, because the literature provides approximately equal numbers of cases in which emissions were decreased and in which emissions were increased. Fundamental studies suggest that this may be due to changes in the size of microemulsion droplets or to the production of stable hydrate, rather than microemulsion, solutions. However, the engine tests reported did not have a statistical base adequate to permit determination of the cause for emissions variation.

If large-scale use of a microemulsion fuel is likely, the effect of changes in surfactant composition should be explored, since it is likely that mixtures of fatty acids, rather than pure materials, will be used. Our bench tests indicate a difference in solution structure, while ARCO's phase studies indicate a relatively similar performance when pure and mixed fatty acid systems are compared.

Stabilized fire-safe fuels. Although stabilized fire-safe fuels are likely to find only a small, well defined market, calculations indicate that they provide the single largest energy return — in terms of nuclear produced electricity — for the smallest amount of invested energy. Reactor backup diesel generators, for example, are also one of the least technically demanding applications, since these engines are large and run at a low rpm. However, the technical challenge in this area is a need to resolve problems that would limit the cold start capability of backup diesel generators. Potential problems include cold start difficulties *per se*, together with an evaluation of the potential for engine difficulties, such as injector gumming and cylinder wear, which were noted during vegetable oil triglyceride combustion tests. Demisting agent effect on both pool and mist fires should be explored at bench scale and previous results obtained by Southwest Research on pool fires should be confirmed.

Microemulsion fuel technology has the potential, if correctly used, for augmenting distillate fuels with biomass and byproduct materials. Research activities directed toward using this technology to extend fuel during petroleum supply interruptions, to increase the use of biomass materials in fuels, and to control emissions has been outlined. With success, it is likely that microemulsion fuels technology can make a major contribution to U. S. distillate fuels conservation and sufficiency.

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