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16. Abstract

This annotated bibliography was compiled during the initial phases of the study designed to assess costs associated with fuel conversion projects in selected public transit systems. It is also the prelude to a relatively in-depth analysis of those energy-related projects that specifically address energy conservation and alternative fuel issues as well as technology transfer.

In addition, this phase of the study provides comprehensive information for use by researchers in the field. It is designed to guide scholars whose interest are in applied research, and to aid transportation planners in their research and technology efforts to develop viable alternatives to transportation fuels currently in use.

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Southwest Region University Transportation Center

THE STATE-OF-THE-ART OF ALTERNATIVE FUELS

A Review and Annotated Bibliography of Theoretical, Empirical and Case Studies

by

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PREFACE

This annotated bibliography was compiled during the initial phases of the study designed to assess costs associated with fuel conversion projects in selected public transit systems. It is also the prelude to a relatively in-depth analysis of those energy-related projects that specifically address energy conservation and alternative fuel issues as well as technology transfer.

In addition, this phase of the study provides comprehensive information for use by researchers in the field. It is designed to guide scholars whose interest are in applied research, and to aid transportation planners in their research and technology efforts to develop viable alternatives to transportation fuels currently in use.

The preparation of this volume involved the assistance of numerous persons, including the research staff of the Center for Transportation Training and Research at Texas Southern University and graduate student assistants from the Transportation Studies Department at Texas Southern University. The entire literature search was directed by Mohammed Hamid. He supervised the analysis and data collection process for Phase I of the study. Special recognition must be given to Russell Pentz, Assistant General Manager at the Harris County Metropolitan Transit Authority (METRO) and a special monitor for this project. We also received valuable assistance from Jim Patrick, Director of Systems Assurance and Engineering at METRO during the first phase of the project. Both Pentz and Patrick continue to work with us on other aspects of the study.

The painstaking work of searching for certain reference materials was aided by Shirley Seaborn and Ting Chen, graduate students in Transportation Planning and Management. The library staffs at area colleges and universities,

The Center for Transportation Training and Research Resource Center at Texas Southern University and libraries in Canada and other parts of North America provided valuable assistance by allowing us access to their references and to reproduce restricted materials on alternative fuels.

This phase of the study was supported by a grant from the Office of Energy, State of Texas to the Southwest Region University Transportation Consortium, of which Texas Southern University is a member. The support provided from oil overcharge funds is gratefully acknowledged.

Naomi W. Lede'
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TEXAS SOUTHERN UNIVERSITY
January, 1992

I. USER'S GUIDE

This bibliography provides a description of key studies completed or in progress on alternative fuels, other energy-related studies and technology. It does not attempt to cover all of the existing materials on alternative fuels. It consists of two major sections: **A Selected Review of the Literature** and an **Annotated Bibliography.** The selected review of literature is a brief overview of the important research studies cited in the Annotated Bibliography. It provides a structuring of the materials according to several major classifications: Methanol, Ethanol, Hydrogen, Natural Gas, Propane (LPG), and others. Each of these sections contains selected references on current applied and empirical research pertaining to energy trends and alternative fuels demonstrations and evaluations.

II. A REVIEW OF SELECTED LITERATURE ON ALTERNATIVE FUELS

Studies on issues related to alternative fuels and energy-related efforts in general have yielded an admixture of findings from both public and private sector initiatives. The results from previous studies range from broad applications to the more specialized issue of fuel diversification and utilization for particular transportation modes. For the most part, research and technology efforts have been directed toward assessing the efficacy and associated costs of alternative fuels. A range of estimates on possibilities of substitution for imported oil have been investigated for a variety of alternative fuels such as methanol, ethanol, compressed natural gas, hydrogen, liquefied petroleum gas, and electricity-- to name a few.

This review of selected studies sheds some light on past and present efforts to meet the long-term energy needs of the nation. While the focus is on research and technology in specific cases, the general outlook and forecasts for alternative fuels revealed by the works of previous scholars in the field underpin this study.

The issue of alternative fuels is not new. Interest in petroleum-based fuels, according to Bloch (1984:11), has intensified since the 1970s. There are renewed efforts to explore, develop and test alternative fuels options. The rationale for this sudden upsurge in interest in non-petroleum based fuels can be attributed to the tremendous uncertainty created over oil price supply and demand resulting from the Organization of Petroleum Exporting Countries (OPEC).

Block (1984) summarizes the limited research that has been conducted on alternative fuels for buses, matching results with relevant

objectives. The 69-page report, funded by the U. S. Department of Transportation, examines the issue of alternative fuels for transit buses from the perspective of the 1980s and beyond. It points out that in a time when Federal involvement in alternative fuels developed is of lessened significance and market place actions seem of greater value than government intervention or investment, it is relevant to examine the objectives of diesel fuel alternatives for public transportation vehicle use. The study reveals that there are five fuels that have been identified as possible alternative fuels for bus transit systems: methanol, ethanol, vegetable oils, methane, and hydrogen. All are in production at the present time, with only vegetable oils being produced in significant quantities in the United States from renewable resources. He concentrates his attention on four fuel groups in the study: alcohols; vegetable oils; methane (or natural gas); and hydrogen. An assessment of current developmental status is provided and conclusions regarding future research efforts are presented.

A. General Overview.

The general outlook and forecasts for alternative fuels, as revealed by scholars in the transportation field, suggest and admixture of opinions relative to energy conservation and efficiency. A report from Business Communications, Incorporated (1991:1), for example, says that alternative fuels can replace between 7.3 and 15 percent of imported crude and refined petroleum products needed for transportation by the year 2000. Bloch (1984) provides some insight into alternative fuels as contingency protection in the evaluation he conducted on alternative fuels for transit buses.

Using scenarios and a policy optional approach, Bloch (1984) indicates that the "United States could face minor, moderate or major oil supply disruptions in

coming years. Minor scenarios would mean the loss of less than 7 percent of the free world's oil production. Moderate scenarios involve the loss of over 7 percent but no more than 15 percent of the free world's production (the 1973 Arab Embargo crisis removed around 10 percent of the world's oil)." Major scenarios involve over 15 percent loss in free world production. Scenarios further say that disruptions can last up to a year in length, although given the current oil supply and demand market (which is likely to endure for a few more years at least) shorter disruptions are more likely.

How do alternative fuels fit into this setting of disruption scenarios and policy options? According to Bloch (1984:38), there are no reasonable combinations of scenarios and policy positions under which transit systems would face a cutoff of diesel fuel supplies. At worst, transit systems would face an allocated fuel supply, roughly equivalent to the size of the disruption. Thus alternative fuels would likely serve as blending agents, with diesel fuel still providing the bulk of the need.

"The role of alternative fuels as oil supply disruption contingency fuels includes the following:

- Alternative fuels would never been relied upon to substitute completely for diesel fuel, only to supplement those supplies due either to shortages or high prices.
- Vegetable oils provide the only immediate contingency protection potential but only on a limited spot basis; there are too few supplies to supplement the needs of all transit systems.
- Ethanol would be an adequate contingency fuel in near-term disruption.

- Methanol might be an adequate contingency fuel in a near-term disruption (if oil prices rose but supply was constant) but would definitely provide assistance in the long term.

- Government actions could alter the importance of alternative fuels as contingency measures versus simple allocation of diesel fuel supplies to transit systems.

- Methane and hydrogen should not be considered contingency fuels." (Bloch, 1984)

"Under a business-as-usual scenario, the transportation sector could require as much as 46.2 percent of gasoline consumption to be imported." The Business Communication, Incorporated (BCC) report (1991) noted that the United States could produce at least 1.9 billion gallons ethanol, which would reduce foreign energy dependence by 4.4 percent (Sinor, **Cleans Fuels Report,** 1991:1). The report further asserted that compressed natural gas is a more expensive alternative, but could displace as much as one percent of projected oil imports.

Studies included in this volume also provide insights into other alternative fuels. Liquefied natural gas, like ethanol and methanol, has the potential to reduce the nation's dependence on oil imports. The BCC report forecasts that 94 million gallons of liquefied natural gas (LPG) will be produced for use in motor vehicles, displacing oil imports by 5.576 barrels per day.

B. Emissions From Gasoline and Methanol.

In a volume published in 1990 and edited by Wilfrid L. Kohl, methanol as an alternative fuel is carefully assessed. Part I of the study assesses prospective emissions from methanol versus conventionally fueled vehicles. Philip Lorang (1990) of the Environmental Protection Agency's Office of Mobile Sources explains that the performance standards proposed by the United States government -- an 80 percent reduction of per-vehicle emissions that contribute to

ozone deterioration beginning in the year 2000 -- could probably be achieved by methanol or compressed natural gas vehicles by the year 2000. He also asserts that methanol is the alternative fuel with the best chance of being adopted within the administration's original time frame.

Lorang (1990:21-49) provides an overview of federal proposals and compares them with earlier bills introduced in the House of Representatives and the Senate, respectively. He provides detailed analysis of tailpipe and other types of vehicle emissions (e. g., parking losses, running losses, refueling emissions). He concludes that organized M100 vehicles could achieve an emissions equivalent of 0.19 grams/mile of non-methane hydrocarbons, or a reduction of hydrocarbons equivalent emissions per vehicle of between 67 and 80 percent.

Austin (1990) of Sierra Research, Incorporated argues that the forecasts by the Environmental Protection Agency (EPA) from methanol-fueled vehicles are optimistic and based on relatively low mileage prototypes. He notes that the California Air Resources Board has found evaporative emissions from methanol to be higher than those of gasoline. Jerry Horn of Chevron Research, like Austin, finds some deficiencies in the data cited by Lorang. Horn (1990) points that the EPA presentation compares data on current in-use vehicles with data on M100 prototypes and does not appear to apply the same deterioration factors to M100 vehicles. Horn agrees with the Sierra Research analysis, according to Kohl (1990), that significant further reductions in conventional gasoline vehicle emissions can probably be achieved if regulations such as those enacted in California (requirements for on-board diagnostic systems, more stringent emission standards, and more effective inspection and maintenance) are adopted elsewhere. Horn further questions why the EPA emissions presentation

considered only M100, while M85 is most likely to be introduced first. Of even greater significance, according to Horn (1990) is the fact that automobile companies will not be in a position to manufacture M100 vehicles until further research and development is conducted to overcome cold-start problems and address other concerns such as flame luminosity and fuel tank vapor flammability. He also noted that the M100 technology will have to be improved to reduce formaldehyde and NO_X emissions, especially at higher mileage.

C. Methanol and Urban Ozone.

Part II of the compendium of papers contained in Kohl's **Methanol As An Alternative Fuel Choice: An Assessment** provides valuable information on the impact of gasoline versus methanol emissions on air quality, particularly as related to the causes of urban ozone. The studies utilize air quality models to simulate complex chemical reactions in the atmosphere. For instance, Russell, of Carnegie Mellon University uses an urban airshed model to simulate the likely air quality impacts of methanol fuel for the city of Los Angeles in the year 2010. The assumption is made that about half of the light-duty vehicles were powered by M85 by that time as outlined in the federal proposal. Methanol is assumed to be significantly less reactive than most of the organic compounds in gasoline vehicle exhaust. Peak ozone levels are predicted to decrease up to 9 percent, and exposure to levels of ozone above the federal standard to decrease by about 19 percent. Formaldehyde exposure will not increase significantly.

Russell (1990:77-92) also observes that the effectiveness of methanol as an anti-ozone strategy is very dependent on the ratio of reactive organic gases to nitrogen oxides in the atmosphere. In a similar study by Chang and Rudy (1990) of the Ford Motor Company, a different approach is used. Applying a simple

trajectory model to nine cities in the United States with the highest peak ozone levels, they find that full penetration of optimized M100 vehicles by the year 2015 would reduce peak ozone levels between one and five percent, while the reduction from M85 vehicles is estimated at less than one percent. Again, the authors express concern about formaldehyde levels, especially in commuter tunnels and underground parking garages, while other air toxics are found to decrease with methanol use.

To get a relatively detailed account of the differences in precious studies and approaches and their assumptions, there is need to review a commentary by Jana B. Milford of the University of Connecticut (Kohl, 1990:141-147). The author emphasizes that the ratio of ROG (reactive organic gases) to NO_X is very important. Some areas may reductions in NOx emissions in order to meet the ozone standard, as emphasized in the same reference by Sillman and Samson. The lower reactivity of methanol emissions is also sensitive to other factors, according to Milford, especially the level to which formaldehyde emissions can be controlled.

D. Methanol, Energy Security, and Global Warming.

Several authors have examined the potential impacts of methanol use on energy security in the United States and global warming as well as other related issues. Carmen Difiglio of the U. S. Department of Energy argues that energy security could be enhanced if flexible-fuel methanol powered (presumably M85) vehicles were introduced in sufficient quantities between now and the year 2010 to reduce the nation's gasoline consumption by one-seventh or about one million b/d. This would require two million b/d of methanol, which would probably be imported from a diverse group of countries. Difiglio believes that the world

methanol market is likely to remain more competitive than the oil market. Large capital investments in methanol plants by supplier countries would increase their stakes in uninterrupted revenues and therefore exports.

Kelly (1990) appears to agree with Difiglio generally, but questions some of his economic assumptions. For instance, he asserts that capital costs of methanol plants might be higher than those assumed by Difiglio. He also thinks that it might take longer for a world methanol market to develop. Kelly warns against taking risks to finance and build large methanol plants in countries with large natural gas reserves but which are already short of investment capital.

Deluchi believes that the emissions of greenhouse gases will not be significantly reduced by the use of any fossil fuel feedstocks in the making of transportation fuels. Coal use as a feedstock would be the worst case, says DeLuchi (1990), since it would result in increased CO_2 emissions. The use of natural gas to produce methanol, compressed natural gas (CNG), liquefied natural gas (LNG), or electricity for electric vehicles will at best result in a small reduction of CO_2 equivalent emissions, but under other assumptions it would produce a small increase in greenhouse gases compared to the current gasoline-from-crude oil cycle. DeLuchi concludes that methanol should be no more than a transitional fuel choice on the way to future nonfossil fuel sources (e. g., hydrogen, and electric-powered vehicles).

1. Demonstration Projects. Several demonstrations projects on methanol as an alternative fuel have been documented. The Lubrizol Corporation initiated a program to examine the use of a supplemental fuel additive. Lubrizol's Fuel Products Group and the Detroit Diesel Corporation (DDC) began a joint

development project in August 1989 to assess the use of the fuel additive. The fuel additive is necessary when methanol is used as a fuel. The problem to be addressed by the fuel additive relates to lubricant incompatibility and fuel injector plugging problems, according to the applied researchers. Testing of methanol-fueled, two-stroke cycle diesel engines shows that the a typical environment of methanol fueling aggravates the failure of fuel injectors. Initial analysis of the fuel injectors showed that the sprayed holes were being clogged with deposits. Internal parts of the injectors were also found to be covered with gummy deposits which restricted the movement of the internal parts and the flow of the fuel.

To deal with the issue of clogging and related problems, the Lubrizol Corporation examined the use of a fuel additive designed to provide the following benefits:

- Solubility in neat methanol at all levels
- Corrosion protection
- Lubricity or antiwear features
- Detergency or dispersancy

Through a relatively complex procedures of testing and measuring, Lubrizol developed an additive called Lubrizol 9520A. This product is formulated for use at 0.06 percent by volume in methanol fuel.

The DDC tested the Lubrizol 9520A in a 100-hour engine test. Data from the test indicated no reduction of the flow rate of the injector when the additive was used with various engine lubricants. According to Lubrizol, the additive delivers corrosion protection, lubricity and injector cleanliness.

Further testing was conducted in areas where the highest rate of injector fouling was detected. The results indicated that injector failure was almost eliminated in the field. Also, use of the experimental additive was extended to the DDC's entire fleet of methanol trucks and buses. Following an accumulation of almost 2,000,000 injector miles by these vehicles, there were no failures due to plugging reported. Previous testing had revealed more than 400 such failures due to plugging with an accumulation of 6,000,000 injector miles.

Lubrizol, according to **The Clean Fuels Report**, April, 1990, filed a patent application in December, 1990, and plans to offer Lubrizol 9520A for commercial sale during the second quarter of 1991.

FEV of America has conducted similar work on the development of methanol engines. This company was awarded a contract by the United States Environmental Protection Agency (EPA) to provide design, fabrication, testing and evaluation support on alternative fueled engines, powertrains and fuel systems. The potential projects identified the initial scope of work as: Optimum engine cooling systems, hydraulic launch powertrain system evaluation, engine optimized for low global warming impact, turbo-charged flexible fuel vehicle, M100 use in a two-stroke cycle engine, and specialized fuel injection and ignition system control.

A second EPA-sponsored project was designed to develop and demonstrate a low CO_2 emission vehicle concept using low emission direct injection (DI) M100 methanol engine technology. The findings of these projects are in progress.

The literature indicates that there are methanol plants around the world conducting experimental research on alternative fuels. In India, for example, the Gujarat Narmada Valley Fertilizer Company has started up a new $49 million methanol plant with a production capacity of 100,000 tones per year. The plant uses gas feedstock from Gandhar and Ankeleshwar. The total production capacity of the company is now 120,000 tons per year. It expects to export 50,000 tones of methanol per year.

Ocelot Industries Ltf. of Canada plans to build a C$15 million methyl tertiary butyl ether (MTBE) plant at its petrochemical complex in Mitimat, British Columbia. The plant is a joint effort with Alberta Environfuels, a joint venture of Petro-Canada and Finland's Neste Oy. Alberta Environfuels is building a C$350 million MTBE plant at Edmondton, Alberta which will ship about 12,500 barrels per day of the MTBE to the Kitimat facility.

In the United States Jacobs Engineering Group, Incorporated of Illinois has signed a contract with Marathon Oil Company and started detailed engineering for a petroleum processing facility at its Robinson, Illinois plant. Production from the new facility will include 1,700 barrels of MTBE per day.

In Texas, M. W. Kellog revealed plans to engineer, procure and contract a $200 million grassroots MTBE complex for Mitsui and Company (U. S.A.) at its Deer Park, Texas facility. This complex will produce an estimated 12,500 barrels per strem day of MTBE, virtually all of which will be sold on the Gulf Coast. In Venezuela a new production facility is in operation. The world-scale facility, which cost about $276 million, is a joint venture partnership of Petroguimica de Venezuela and Ecofuel, a subsidiary.

Construction began on a methanol plant in Commerce City, Colorado. The $27 million facility is owned by a partnership consisting of Intermountain Chemical, Inc., a wholly owned subsidiary of Unico, Incorporated acting as the managing general partner. The Methanol produced at the Sand Creek facility will be sold under long-term contracts to Tenneco Methanol Company. This facility is the first of a number of petrochemical manufacturing facilities that Intermountain Chemical plans to develop.

2. Research and Technology. Research on methanol fuels indicates that progress has been made on various aspects of methanol engine technology, ethanol, hydrogen, and natural gas.

A preliminary study sponsored by the United States National Aeronautics and Space Administration (NASA) on the status of hydrogen technology, and performed by the National Hydrogen Association (NHA), shows that hydrogen can be a competitive fuel in today's economy **(The Clean Fuels Report, April, 1991:114).**

E. Gaseous Fuels for Transportation.

A comprehensive discussion on gaseous fuels took place at a conference on "Gaseous Fuels for Transportation" in Vancouver, Canada, August, 1986. The research reflected a wide range of methodological approaches ranging from theoretical models to empirical and case studies to area studies on gaseous fuels and their potential impact. Practical, technical and economic limitations to the utilization of natural gas, liquid petroleum gas and biogas were assessed by Sims (1986:9). Sims' study was real in nature with broad implications for other countries. Recognizing that the agricultural industries of New Zealand and the

United Kingdom are countries heavily dependent on energy inputs -- particularly liquid fuels, Sims attempts to discuss the limitations to the supply and utilization of gaseous fuels by rural sectors. He concludes that the economic viability of an on-farm gas utilization system is very site specific. The gas cost, process cost, excise duty, engine conversion costs all vary within the type of fuel, scale of operation, annual vehicle use, local taxation laws and other influences. The comparable price of conventional fuels, according to Sims (1986:20), must also be include in the calculations. He further notes that when all these factors are taken into consideration it appears that few British and New Zealand farmers could benefit from utilizing gaseous fuels in their agricultural vehicles even where the fuel is produced on site of delivered for other uses.

The study by Sims (1986:21) advances the notion that the economic preference for alternative farm fuels must be for those compatible with existing engines without requiring modifications. This is reinforced by the constraints of the infrastructure which would need to be developed for distribution of a gaseous fuel to the widely dispersed agricultural community.

Gibbons (1986: 23) outlines the supply-demand factors having greatest impact on its production and use in a free-market environment. He concludes that the relative price of propane is a major determinant in the growth or decline of auto-propane demand. This was demonstrated, says Gibbons, in "the free U. S. markets between 1979 and 1981 and in parts of Canada with subsidies during 1981 and 1985. The author also states that North America is close to self sufficiency in propane supply. Marginal supplies are small volumes of seaborne imports which tend to eat the price ceilings. Significant growth in auto propane demand would require additional seaborne imports. Auto propane has to compete on price for a share of the available economic supply, against other end

users, including the petrochemical sector. This will be difficult for auto propane when the economy is growing and petrochemical demand strengthens. Growth in the past has been confined to period of low price, when other end use demand have slackened. In Canada, government assistance programs have been credited with significantly stimulating auto-propane growth, according to Gibbons (1986).

Liquid petroleum gas has been marketed throughout North America, including Australia. Liquid petroleum gas (LPG) was first promoted by the government of Australia as an alternative transport fuel in 1979. This promotion was largely in response to the perception of an oil shortage. Initial government incentives included removal of sales tax on conversion equipment, abolition of the LPG fuel excise, allowable tax depreciation for conversion costs of commercial vehicles, and a public endorsement of LPG by the Prime Minister. These government actions combined with the public perception of an oil shortage resulted, at least initially, in a major increase in the rate of conversion of LPG.

According to the American Gas Association, natural gas vehicles will increase dramatically as a result of clean air legislation. This organization forecasts that by the year 2005 natural gas vehicles could displace as much as 675,000 barrels of oil per day. The American Gas Association's analysis of the effects of the Clean Air Act Amendments of 1990 estimates there will be at least 3.8 million natural gas vehicles on the roads of the United States by 2005, primarily in fleets (**Clean Fuels Report,** April, 1991:115).

Several companies and transit agencies have or will be conducting demonstration projects on gaseous fuels. Washington Gas and Amoco Oil Company are operating a natural gas filing station for fleet vehicles in Washington, D. C. The gas station will provide compressed natural gas for up to

100 participating vehicles. In 1979, Washington Gas began converting its fleet to run on natural gas, and now maintains a natural gas fleet of more than 230 vehicles. All vehicles except one pickup truck have dual fuel capability, allowing them to operate either on compressed natural gas or gasoline.

The Metropolitan Transit Authority of Harris County (METRO) is currently engaged in an alternative fuels initiative to replace diesel fuel with liquefied natural gas (LNG) in its bus engines. After analyzing the technically feasible alternative fuels, Houston METRO officials decided that LNG offers optimal technical and economic advantages over other feasible alternatives. METRO is currently testing prototype mid-size buses on LNG and several 40-foot buses for use in the demonstration project. The agency's long-range plans will involve complying with Texas state law which requires that fleets operate the following percentages of their vehicles on an alternative fuel:

- 30 percent of fleet by September 1994
- 50 percent of fleet by September 1996
- 90 percent of fleet by September 1998.

Three Houston, Texas companies and a Denver, Colorado firm have formed a consortium to lay the foundation for a natural gas vehicle industry. The consortium will conduct research to determine the characteristics of the transportation fuels market and the potential role of natural gas as a motor fuel in the Greater Houston Area (**The Clean Fuels Report**, April, 1991:121). The group is also developing a plan to determine potential operation, marketing and capital requirements for consortium members.

The geographic focus of the research will be seven Texas counties: Brazoria, Chambers, Fort Bend, Harris, Liberty, Montgomery and Walter. The

consortium also anticipates a joint venture that will construct and operate natural gas refueling stations and conversion centers. A similar move has been initiated by Pacific Gas and Electric of San Francisco, California. This company has expanded its network of natural gas service stations. Five new refueling stations have been opened in San Francisco, San Jose, Hayward, San Rafael and Bakersfield.

Finally, a wide range of activities are taking place throughout the United States, North America and other parts of the world. Japan's NKK Corporation has developed a fiber-reinforced plastic (FRP) cylinder for use in natural gas vehicles. The government has granted approval for the cylinder's commercial use under the High Pressure Gas Control Law. The cylinder is 50 percent lighter than cylinders made from steel.

Similar research and demonstration projects are taking place on propane (LPG) as an alternative fuels, ultra-clean coal, reformulated gasoline and electric vehicles. There is need for an in-depth assessment of the state-of-the-art for these alternative fuels. The reader who is interested in outlook and forecasts, company activities, research and technology should consult the latest issue of **THE CLEAN FUELS REPORT, 1992** for a comprehensive coverage of business, government, and technology issues for transportation fuels.

The next sections of this report provide annotated bibliographic data and a comprehensive listing of references.

III. ANNOTATED BIBLIOGRAPHIC DATA

A. General

Bleviss, Debra L. and Peter Walzer. "Energy for Motor Vehicles", **Scientific American,** Sept. 1990, pp. 102-109.

This report describes the world's fleet of cars, trucks and buses. It has a number of 500 million which grows faster than the human population and consumes half of the world's oil. More efficient engines, alternative fuels and new transit systems promise to show the growth in oil consumption and mitigate its environmental consequences.

Douglas, Larry. "The Chemistry and Energetics of Biomass Conversion: An Overview", **Solar Energy Research Institute,** Golden, CO, 1981.

This paper provides an overview of biomass energy systems and a discussion of the research on the chemistry and structures of lignocellulosic biomass, biomass thermal conversion, and biochemical conversion.

Ember, Lois R. "Auto, Oil Industries Join Forces to Study Clean Fuels", **Chemical & Engineering News,** Oct. 30, 1989, pp. 17-18.

This article contains enforcement on three of the largest automakers in the United States and 14 of its major refiners who have joined ranks in an expansive study of alternative fuels and alternative fueled-cars and trucks. Cooperative ventures to examine alternative fuels will be needed.

Erickson, Deborah. "Science and Business: Complete Combustion", **Scientific American,** March 3, 1991, pp. 113.

This document provides information on hydrogen which was used as an additive with compressed natural gas that yield the cleanest-burning vehicle fuel alternative to date. The fuel mixture is referred to as "hythane," for hydrogen and methane, the principal component of natural gas.

Falvin, Christopher and Murray Weidenbaum. "Does the United States Really Need a National Energy Policy?" **Editorial Research Reports,** Oct. 12, 1990, pp. 597.

This report argues that the Persian Gulf crisis demonstrates the necessity of a national energy policy for the development of alternative fuel sources. A former chief economic advisor to President Reagan argues that reliance on the marketplace will solve current energy worries.

Flint, Jerry. "Fuel Fantasies", **Forbes,** May 29, 1989, pp. 66-67.

This report shows that Southern California has developed a plan for requiring the use of alternative fuels in buses, trucks and company-owned cars. While engines that run on alternative fuels such as methane may work as well as gas engines, there are major problems.

Goldemberg, Jose. "One Kilowatt Per Capita", **Bulletin of the Atomic Scientists,** Jan. 1990, pp. 13-14.

This article focuses on the urban elites of developing countries who have adopted the energy consumption patterns of industrial economics. These countries are now threatened by their dependency on foreign oil. The need for them to find alternatives sources of energy is discussed.

Hamilton, David P. "Energy R & D Funding Shift Urged", **Science,** Sept. 7, 1990, pp. 1101.

This report recommends more funding be directed toward R&D of alternative fuel sources. During the Reagan Administration, funding for renewable energy source research fell 89 percent.

Horgan, John. "The Finance of Fission", **Scientific America,** June 6, 1989, pp. 82-83.

This article discusses the greenhouse effect and other global problems due to fossil fuel usage. It would seem logical for nuclear power to re-emerge as an alternative fuel, but the high cost has kept investors away from the industry.

Lappe, Frances Morre and Joseph Collins. **Food First: Beyond the Myth of Scarcity,** New York, NY, Ballantine Books, 1979.

The report focuses on a comprehensive and thoroughly referenced account of food production and distribution in the world today. The basic conclusion is that availability of food is more closely related to politics than to lack of arable land or other necessary resources.

Lockeretz, W. et.al. "Maize Yields and Soil Nutrient Levels With and Without Pesticides and Standard Commercial Fertilizers", **Agronomy Journal,** Vol. 72, January-February 1980, pp. 65-72.

This article reports on a study comparing two groups of 26 commercial mixed grain and livestock farms in the western corn belt. One group used conventional fertilizers and pesticides, the other used none. Because of rising costs and uncertain supplies for agricultural chemicals, it is important to establish data on production output that presents alternatives. This study found that the difference was not statistically significant and that conventional yields were higher under favorable growing conditions and lower in unfavorable conditions.

McCorroll, Thomas. "No Fuel Like a New Fuel", **Time,** March 8, 1991, pp. 66.

This magazine article discusses the Persian Gulf War as spurring greater interest in alternative fuels than any time in recent years. General Motors recently announced that it was gearing up to produce the Impact, an electric car, on a major scale.

Miller, William. "A Pollution Solution"? **Industry Week,** September 18, 1989, pp. 89-91.

This article describes the oil industry and auto manufacturer, who question the Clear Air Act proposed by the Bush Administration that would require 30% of all new cars being manufactured to use alternative fuel. Fuels that are mentioned are methanol, ethanol, and natural gas. However, the oil industries as well as the American Petroleum Institute have doubts about this conversion.

Mirga, Tom. "Bus-Conversion Bill Takes Off", **Educational Week,** Vol. 8, April 12, 1989, pp. 10.

This article presents elements of a bill making its way through the Texas legislature. The legistlature would phase out school buses that run on gasoline and replace them with ones powered by cleaner-burning compressed natural gas.

Pleeth, S. J. W. **Alcohol, a Fuel in Internal Combustion Engines,** London, England, Chapman and Hall, 1949.

This book represents the classic text on alcohol fuels. Today, it still contains valuable information on production and use of alcohol fuels.

Ross, Philip E. "Clean-Air Fuels for the 90's", **Popular Science,** Jan. 1990, pp. 47-51.

This article discusses the pros and cons of alternate fuels from an environmental prespective. As urban smog increases, the need for fuels such as natural gas, ethanol, methanol, reformulated gasoline, and even electricity is more important than ever.

Renner, Michael, "Rethinking the Future of Global Transportation", **USA Today,** Sept. 1989, pp. 23-26.

This article discusses the deflation of fossil fuels and increased air pollution in heavily auto-dependent countries which are two alarming effects of mass motorization, that might encourage communities to move from an auto-centered society to an alternative transportation future in which cars, buses, rail systems, bicycles, and walking compliment each other.

Rosen, Jerome. "Running On Methane", **Mechanical Engineering,** May 5, 1990, pp. 66-71.

This report gives pointers about the alternative fuel in vehicles. Up to 700,000 vehicles worldwide are currently powered by natural gas, a safer, cleaner and cheaper alternative to gasoline and diesel fuel.

Rosen, Jerome. "Energy 2000: Denmark's Ambitious Effort", **Mechanical Engineering**, Vol. 113, May 1991, pp. 50-54.

This article describes Denmark's ambitious Energy 2000 plan to drastically reduce the nation's energy consumption and air pollution through the increased use of natural gas and cogeneration technologies and through renewable energy sources.

Seitz, Frederick. "Must We Have Nuclear Power?" **Reader's Digest,** Aug. 1990, pp. 113-118.

This report explains an alternative fuel source that produces no smoke and can create more fuel than it consumes and is cheaper in many regions than coal-fired electricity is nuclear power. Many advantages of using nuclear power to create electricity are discussed.

Underkofler, L.D. and R.J. Hickey, eds. **Industrial Fermentations,** Vol. 1. New York, NY, Chemical Publishing Co., 1954.

This book serves as a basic chemical text on fermentation processes. It includes chapters on fermentation of grain, molasses, sulfite waste liquor, and wood waste, as well as yeast production.

Woodbury, Richard. "How to Break the Middle East Oil Habit", **Time**, October 29, 1990, pp. 30.

This report discusses the ending of the United States dependence on Middle Eastern Oil, bringing the petroleum industry back to the United States, alternative fuels and having no plans to retire.

Woodward, Brain. "Automotive Newsfront", Going for the "Green", **Popular Science**, May 5th, 1991, pp. 33-34.

This article discusses fuels, automobiles, solar energy, vehicles and technology.

Zana, J. Peder. "Pumping Natural Fuels", **Village Voice**, November 14, 1989, pp. 11.

This report discusses a bill that went up before the New York City Council that proposes the city purchase vehicles that run on alternative fuels to reduce air pollution, even though adequate engines that burn the fuels have yet to prove themselves worthy of the task.

B. Natural Gas

Alvin, Caravalo. P. C. "The State-Of-Art of gas Utilization as a Vehicle fuel." **Gaseous Fuels For Transportation,** Vancouver, British Columbia, Canada, Aug. 7-10, 1986, pp. 293-319.

This paper presents the basic characteristics and results of the Brazilian experiments. Research in this field began in 1970's but were theoretical in the nature. Brazil also has a significant experimental fleet which includes many vehicles that have accumulated about 100,000 kilometers.

This research work has improved the technology and the economic viability of gaseous fuels. Because of this research work, programs for using gaseous fuels have been developed for captive fleets, public service companies, alcohol plants and agricultural units.

Bara, M. E. and Brito, A. S. "LNG as a Vehicular Fuel - Brazilian Experience", **Gaseous Fuels For Transportation,** Vancouver, British Columbia, Canada, Aug. 7- 10, 1986, pp. 1159-1170.

This paper discusses the use of liquefied natural gas (LNG) in heavy vehicles and shows the results of field tests of buses running on a dual-fuel diesel cycle (with diesel substitution up to 80%) and an Otto Cycle. Also the economic feasibility of replacement of diesel fuel by LNG will be highlighted. The cryogenic hardware necessary to use LNG as vehicular fuel, which was designed and manufactured by Mangeies/cryometal.

Cavens, P. B. and G. J. Cripps. "Up and Running: Design and Installation of Public Natural Gas Fueling Stations" **Natural Gas for Vehicles Programme,** British Columbia Hydro Burnaby, British Columbia, Canada, pp. 597-616.

This paper examines all aspects of getting the stations "up and running" in a safe and cost effective manner. The paper examines cost effectiveness of alternative station designs, compressor and storage sizing, equipment selection, capital and operating costs and installation and commissioning procedures.

Cumming, R. B. "Canadian Gas Association Natural Gas for Vehicles Business Development Plan." **NGV Development,** Canadian Gas Association, Toronto, Ontario, Canada, pp. 115-130.

This reports discusses the Business Plan Maps as a national strategy for reaching these targets. The Plan gives research and development a high priority to ensure that the NGV product meets the demanding expectations of the general public and that the product range applies to a broad segment of the vehicle population. Marketing strategy is directed toward developing a network of fast-fill public fueling stations.

Delmas, P. "The Supply, Demand and Pricing of Natural Gas for Motor Vehicle Use in Canada." **Gaseous Fuel for Transportation,** Vancouver, British Columbia, Canada, Aug. 7-10, 1986, pp. 71-100.

This paper addresses the potential convertor's concerns about the future availability and pricing of this fuel. To this end reference will be

made to its supply, demand and pricing at present and over the forecast period. The current situation will be described in terms of the logistics of the supply, transportation and distribution systems as well as existing pricing and demand patterns and institutional anomalies. The projections will rely on forecasts done by government agencies such as the National Energy Board (supply and demand) and Energy, Mines and Resources (prices). In order to give adequate context to these projections, references will be made to international supply, demand and prices and the transfer mechanisms by which they are expected to impact on the Canadian market. The anticipated forecast period will be 1986-2005.

Evans, R. L., A. L. Jones, and R. Lorghese. "A Comparison of Natural Gas and Gasoline in a Spark-Ignition Engine." **Department of Mechanical Engineering,** University of British Columbia, Vancouver, British Columbia, Canada, pp. 713-726.

This reports gives the performance of a single-cylinder spark-ignition engine fueled with both natural gas and gasoline. The major differences between the two fuels is the greater spark advance required for natural gas due to its lower burning velocity.

Fratti, Giovanni and Franco Michelini. "Lightweight Composite Steel Cylinders For Natural Gas Vehicles", Faber Industrie Spa, Cividale del Friuli, Italy, pp. 617-644.

This article discusses the CNG conversions of vehicles. It is a constant need in order to support the expansion in this field. The weight of storage cylinders has a wide importance in relationship with vehicles having lightweight bodies.

Foster, J. S. **The Dual-Fuel Transit Bus,** Pro Staff Fuels Ltd. West Vancouver, British Columbia, Canada, pp. 1061.

This paper explains the use of natural gas as a fuel for transit buses which clearly attracts both for economic and environmental reasons.

Gebhardt, P. D. and M. Sulatisky. "Saskatchewan CNG Farm Program" **Saskatchewan Agriculture**, Regina, Saskatchewan, pp. 189-206.

This paper provides and overview of on-farm demonstrations of compressed natural gas use in Saskatchewan. The first part of the paper describes the following: the initial project on the Fahlman farm; the expansion of the CNG demonstrations to five other farms, and the interaction of several provincial government departments, a provincial utility, and the federal government in developing the expanded program. The second part of the paper presents the status of the program and reviews some of the major findings to date, such as the availability of fueling station equipment and the suitability of conversion equipment for both gasoline and diesel engines.

Gram, A. **Demonstration of On-Site Production of Liquid Natural Gas and Conversion of Mining Trucks,** West Vancouver, British Columbia, Canada, pp. 1103-1116.

This report discusses compressed natural gas being a good alternative fuel for vehicles if fuel consumption is low. It further describes the technical details and the economics of the conversion. For large trucks,

liquid natural gas becomes the alternative. A demonstration project in Sparwood, B. C. will show how liquid natural gas can be produced on site and used in large mining trucks.

Jawetz, P. and C. K. Ebinger. "Natural Gas: The Best First Step Away From Oil in Transportation", **The Center for Strategic Studies,** CSIS/Georgetown University, USA, pp. 409-423.

This paper explains the current status of natural gas vehicles, methanol vehicles, ethanol vehicles, and fuels that are blends of petroleum products (gasoline and diesel) with alcohols (ethanol and methanol), as well as the question of the octane gap in the United States gasoline pool. This analysis will be done in the light of strategic as well as economic considerations when analyzing the potential, these fuels have to penetrate the market during the remainder of the century.

Jones, K., R. R. Raine, and S. Zoellner. **"A Study of the Effects of Natural Gas Composition on Engine Performance, Emissions and Efficiency"**, University of Auckland, Auckland, New Zealand, pp. 505-506.

This study describes natural gas and fuels indigenous to New Zealand coming from two different gas fields. The gas composition of the two fields differs significantly. Some of the gas is treated and some is not, leading to a reticulated gas which varies with time and location; in particular, large difference in CO_2 content occur.

Joyce, T. J., Haque Emdadul, Welde, Jouke, Edwards, and Jack, **"Introduction of Compressed Natural Gas as a Vehicle Fuel in Bangladesh"**, Chicago, Illinois, pp. 365-384.

This paper describes the planning and implementation of the project, the problems which were encountered, and the technical and economic benefit which a developing country can realize. The techniques for planning a demonstration and test program which would provide the information needed to formulate a rational CNG conversion program are presented. The selection of fueling station and vehicle conversion equipment, and the installation problems encountered are reviewed. The techniques for vehicle conversion and testing, under local conditions, are described. The existing institutional constraints are identified and possible solutions discussed.

Moran, T. L. and V. B. Fiore. **R&D Opportunities to Enhance The Utilization of Natural Gas as a Vehicle Fuel,** Gas Research Institute, Chicago, Illinois, USA, pp. 281-292.

This report explains that the vehicle conversion costs and performance penalties which result from the conversion of existing vehicles may be reduced or eliminated by the products of research and development. GRI is initiating a research and development programme on compressed natural gas (CNG) applications in 1986, focusing on improvements in the performance and the economics of high-pressure systems in the near term or similar improvements in low-pressure CNG storage and refueling systems in the mid term.

Petsinger, R. E. **Natural Gas Quality in North America,** CNG Services of Pittsburgh, Inc., Oakmont, Pennsylvania, USA, pp. 527-572.

This paper analyzes how natural gas quality varies. It first describes the system which collects and distributes natural gas. It examines the factors which determine the quality of gas supplied to customers. Measures of the gas quality at important points in the system are then analyzed to show the nature and extent of the variations in practice.

Puccetti, F. and Nery, A. E. D. **The Development of the Use of Methane as an Automotive Fuel Principally for City Buses in Brazil, as Conducted by the Private Sector,** Grupo Ultra, Sao Paulo, Brazil, pp. 1139-1158.

This paper describes in detail the design, implementation and results of the first practical experiment conducted by Grupo Ultra in Salvador, Brazil. A comprehensive strategic analysis of the Brazilian environment, focused on demographics/public transportation problems/macro-economic constraints/natural gas reserves - production - consumption, led to the conclusion that natural gas as an automotive fuel is a very good alternative for diesel fuel on public transportation in Brazil. Six buses have been converted to the use of either methane or a mixture of methane and diesel fuel.

Ryder, C. J. "The New Zealand CNG Programme: A Partnership Between the Government and the Private Sector, **Conservation and Alternative Fuels,** Ministry of Energy, Wellington, New Zealand, pp. 335-350.

This paper traces the development of the CNG program with particular emphasis on how the programevolved in response to market and industry needs and expectations. The changing roles and perceptions of the program participants will also be explored.

Seisler, J. "Natural Gas Vehicle Marketing Activities in the United States -1986" **American Gas Association,** Arlington, VA, USA, (undated), pp. 101-114.

This report summarizes activities of the natural gas utility industry and of the manufacturers of NGV equipment and installers.

The number of gas utilities marketing NGVs continue to grow as more companies open semi-public refueling stations, developing NGV rates which provide customer incentives to convert their own utility fleet vehicles. While some utilities are developing marketing strategies and aggressively promoting NGVs, other companies are yet-to-be-convinced of the economic and technical viability of NGVs, particularly in light of the downturn of petroleum prices and the cost of providing compressed natural gas to a relatively small base of NGV customers.

Sharr, C. M. Robert E. Bradbury, and T. Penn Johnson. **Design and Economics of Offshore and land Based Natural Gas-to-Gasoline Systems,** SeaTek International, Inc., Goletka, California, pp. 173-188.

This report presents a barge mounted system: to be grounded for land use and the other for offshore application. Economics are presented based upon estimates of processing system costs and productivity and overall system costs as developed by the authors. The processing system includes proprietary Haldor Topsoe technology for conversion of natural gas to gasoline.

Tissieres, J. N. "Organic Gas for Transportation and Process Fuel in East Africa", **Consult Biomass Conversions,** Lausanne, Switzerland, pp. 351-364.

This paper surveys the technology of gas production from waste and the biogas potential as transportation and process fuel in the producing regions of Tanzania. The geographical pattern of the distribution and the size of the demand are taken into consideration. Comparison with the alcohol alternative is performed and gross criteria are set up for the characterization of alternative fuels in terms of their application.

Tombi, R. L. **Use of Natural Gas as Fuel in Urban Transportation: A Brazilian Experience,** Gas Department, Cia. Brasileira de Petroleo Ipiranga, Rio de Janeiro, Brazil, pp. 1117-1138.

This document provides a recent discovery of gas which has generated optimistic expectations as to the future role of this fuel in Brazil, mainly in the field of urban mass transportation.

The purpose is to develop CNG technology, and provide a technico-economic evaluation of the following items: performance of Otto Cycle and diesel engines, processes for gas storage and supply, operation and maintenance of supply centers, and costs and fares.

Wyman, R. E. **Natural Gas for Vehicles - Key to Energy Independence,** Canadian Hunter Exploration Ltd., Calgary, Alberta, pp. 385-408.

This report presents the traditional or conventional proven sources of natural gas which are usually the focal point of attention when policies concerning that energy source are made. This can and has lead to serious misunderstandings which in turn lead to bad policies. It is understood that

in most countries and certainly in Canada and the United States, conventional proven reserves of natural gas are only the tip of the iceberg. Beneath that tip are enormous resources of unproven conventional and unconventional sources. Unconventional sources include tight sands, coals, peat, shales, hydropressured and geopressured waters, hydrates and biomass conversion. These resources will provide energy far into the future. The rate at which they will be tapped will be primarily controlled by technology and economics.

C. Liquid Petroleum Gas

Bo, E. "Automotive LPG Market Development In Europe", **Gaseous Fuel For Transportation,** Vancouver, British Columbia, Canada, Aug. 7-10, 1986, pp. 55-70.

This document reports that automotive liquid petroleum gas (LPG) has been sold in Europe for more than 25 years - mainly in Holland and Italy - last year some 1,800,000 tons were sold overall.

The paper will refer to attempts made at coordinating efforts (European automotive LPG specification and Uniform connector) and expectations for the future.

Campbell I. D. and J. B. Gilbert, Road Testing of 400 H. P. **Turbocharged Diesel Engines Converted to Dual-Fuel Operation with Gaseous Fuels,** Gaseous Fuel For Transportation, Vancouver, British Columbia, Canada, Aug. 7-10, 1986, pp. 975-986.

This paper discusses the results of the test in detail. Fuel economy data accumulated over the test period showed essentially no difference between diesel fuel and dual-fuel operations on a total energy basis (1 liter of propane = 0.63 liter of diesel fuel).

Engine durability is reduced when LPG is used but, at about 20% vol LPG substitution, the effect is minimal. For higher levels of LPG substitution, improvements in valve and upper cylinder metallurgy may be necessary, as previously found in other LPG applications.

Eston, De N. E. and R. B. Wachockier. **Duel-Fuel System Methane-Diesel for Urban Buses.** Gaseous fuel For Transportation, Vancouver, British Columbia, Canada, Aug. 7-10, 1986, pp. 1047-1060.

This paper discusses how the conversion kit was developed, the results of dynamometer tests and of two years of operation in a urban fleet bus.

The best solution found was methane, from natural gas, anaerobic bio-digestors or landfills. The gas allows partial substitution (50%) of diesel oil. The engines utilized were the Mercedes-Benz OM-352. A suitable conversion kit to the above conditions was developed.

In the search for an alternative to diesel oil many solutions have been proposed. The ideal solution must: take advantage of diesel engines in operation with minimum modifications and without major alterations to the engine; use a fuel which may be the found and produced all over the country; afford to the vehicle the same or better drivability attainable with diesel fuel; not alter engine maintenance frequency; produce low emissions.

Garcia, P. "One Decade Using Dedicated LPG in a Fleet of Trucks and Light Vehicles", **Gaseous Fuel For Transportation**, Vancouver, British Columbia, Canada, Aug. 7-10, 1986, pp. 1199-1212.

This paper outlines the technical aspects of this conversion program. A technology base was already available overseas concerning the use of LPG in light vehicles. Due to great economic

incentive the extension of the conversion program to include heavy vehicles operating in the fleet was seen as a top priority. The first conversions of large petrol engines powering twelve-ton dump trucks encouraged confidence in the use of the fuel for this application. In 1981 The Council Staff, under contract to the New Zealand Liquid Fuels Trust Board, carried out conversions to dedicated LPG on four heavy truck combinations with gross laden weights in excess of thirty tons.

Gibbons, I. A. **The Supply-Demand for Propane and Automotive Consumption Thereof in the U.S.A. and Canada.** Gaseous Fuel For Transportation, Vancouver, British Columbia, Canada, Aug. 7-10, 1986, pp. 23-34.

This report shows that propane was used as an alternative fuel in North America for over three decades. Growth in its use has tended to come in waves, swelling when LP gas, as it is often called, has been in abundant supply and relatively cheap. Its use has receded in other periods as engines completed their useful lives. However, the volume consumed as engine fuel has remained significant in spite of more wide-spread use of diesel power, growing petrochemical demand or higher prices.

Goetz, W. A. and W. M. Jones. **Spark Ignition Propane Engine for Class 8 Trucks,** Ontario Research Foundation, Mississauga, Ontario, Canada, (undated), pp. 995-1014.

This document describes that fuel consumption data were collected with a diesel and propane engine, on a computer

controlled dynamometer, over a defined duty cycle. The increased volumetric fuel requirement on propane is due to, lower heating value of propane on volume basis and lower thermodynamic efficiency caused by throttling and a reduced compression ratio.

Sharma, J., Sudhakar Das and B. P. Pundir. "LPG as a Supplementary Fuel For Diesel Vehicles", **Engines Laboratory,** Indiana Institute of Petroleum, Dehradun, India, (undated), pp. 959-1014.

This report shows studies were conducted on a heavy duty six cylinder automotive diesel engine with LPG carburetted along with intake air. This approach provides flexibility of operation either in the dual-fuel mode or on diesel operation. Two mechanical designs of an LPG flow regulator were used as components in a retrofit system and are described in the paper. To eliminate roughness of combustion at full load, and quenched combustion at part load, energy substitution by LPG was limited to 40%.

Wallace, J. S., U. Oester, and J. H. Morgan. "Performance and Emissions of a Propane-Fueled Diesel Engine", **Department of Mechanical Engineering,** University of Toronto, Toronto, Ontario, Canada, (undated), pp. 987-994.

This paper reports on an investigation utilizing a continuously operating glow plug for ignition. Experiments have been carried out with a single-cylinder Waukesha CFR cetane rating engine (prechamber diesel) fueled by injected liquid propane.

Fuel injection system modifications necessary for handling propane are described. Performance and emissions data are presented for test carried out with glow plug ignition.

Wauchop, T. S. "Auto Propane: A Program to Create Jobs and Stimulate the Economy", **Inter-City Gas Corporation,** Winnipeg, Manitoba, Canada, (undated), pp. 259.

This paper provides details of the effect of the industry on the balance of trade, reduced energy costs, job creation and improved over-all efficiency within the industry. It also includes projections of auto-propane demand and discusses the effect of auto-propane on the operation of automobiles. A study of the effectiveness of government incentives was presented. In addition, the paper discusses the growth of the propane industry and the improved operation aspects of the industry, as a result of the development of this market.

West, J. P. "A Review of the Marketing of LPG in Australia", **South Australia Institute of Technology,** Adelaide, South Australia, Australia, (undated), pp. 35-54.

This paper reviews the Australian LPG programs and discusses the factors that have impacted on the type and rate of implementation. Of particular importance have been the institutional and marketing considerations. The paper also comments on the future potential for automotive LPG; particularly in the light of recent market research which has identified a

number of key outstanding policy and marketing issues. Related to this are the relative roles of both Government and industry in the implementation process. Mention is also made on broader questions of implementation prerequisites for gaseous fuels; having regard for experiences of both the Australian LPG and New Zealand compressed natural gas programs.

Young, Colin G. "Propane Tank Anti-Boiling Liquid Evaporating Vapor Explosion (BLEVE) Safety System", **Mech Tech Auto**, Mississauga, Ontario, Canada, (undated), pp. 1193-1198.

This report describes a propane tank anti-B.L.E.V.E. (boiling liquid expanding vapor explosion) safety system. The system is designed primarily for rail and road propane tankers and storage tanks, but can also be used on automotive propane tanks. The system is also suitable for use with other fuels, and for low pressure tank, a double-acting twin piston reciprocating pump is used instead of the turbo-charger.

D. Research On Progress

Chambers, Robert and Tom McCaskey. **Liquid Fuels and Chemical Production from Cellulose Biomass: Hemicellulose and Cellulose Hydrolysis Recovery, and Pentose Utilization in a Biomass Processing Complex,** Auburn University, Department of Chemical Engineering, Auburn, AL, (undated).

This program focuses on utilization of hemicellulose. The research has been carried out in two major areas: (1) recovery of hemicellulose and cellulose sugars from biomass, and (2) fermentation of hydrolyzates to produce liquid fuel substances. An efficient hemicelluose hydrolysis process using a percolation reactor has been developed.

Clement, L. Davis. **Examination of Cotton-Gin Residue as an Ethanol Feedstock.** Texas Tech University, Department of Chemical Engineering, Lubbock, TX, 1980 - continuing.

This research focuses on (1) developing the most effective fermentation sequence using cellulose feedstocks for bench-scale and pilot plant testing; (2) developing a process for ethanol production using cotton-gin residue as the feedstock; and (3) developing a model environmental impact statement using cotton-gin.

Kendall, Pye E. **Biological Production of Liquid Fuels from Cellulose Biomass,** University of Pennsylvania School of Medicine, Philadelphia, PA, 1976 - continuing.

This project explains the technical and economic problems relating to development of an integrated process for the total conversion of biomass into liquid fuels, chemical feedstocks, and other by products. The major products are two liquid fuels: (1) ethanol for use as a gasoline and (2) a butanol slurry for use as a bunker-C type heating fuel.

Moor, Raymond. **Fuel Alcohol Production by an Operating Farm-Scale Plant: A Cost and Energy Study,** South Dakota State University Department of Microbiology, Brooking, SD, 1977 - continuing.

This project explores the pilot-scale alcohol fuel plant. The primary interests are in fermentation; distillation; and use of the product mash, or stillage. The mash is being used in animal feeding throughs and the alcohol being tested in tractorsfram pickup trucks.

Peck, Harry D. Jr. and Lars Ljungdahl. **The Microbiology and Physiology of Anaerobic Fermatation of Cellulose,** University of Georgia, Department of Biochemistry, Athens, GA, 1979 - continuing.

This research focuses on obtaining the information required to understand, control, and formulate mixtures of anaerobic bacteria capable of degrading cellulose to chemical feedstocks, hydrogen, methane, acetate, and ethanol.

Peterson, Gene. **Bioconversion Program,** California Institute of Technology, Jet Propulsion Laboratory, Pasadena, CA, 1979 - continuing.

This research develops a hybrid microorganism from Zymomonas and Pseudomonas to achieve a one-step process of hydrolysis and fermentation. This would improve the efficiency and reduce the cost of fermentation ethanol production.

Smart, James. "Syngas Catalysis for Alcohol Fuels", **Solar Energy Research Institute**, Golden, CO, September 1981 - continuning.

This research concerns with providing an up-to-date review of the technology, and exploring homogeneous, synthesis gas catalysis. Conventional catalysis is heterogeneous. Recent advances in organometallic chemistry and techniques to couple such catalysts to chemistry and techniques to couple such catalysts. Synthesis gas (CO + H2) is the starting material for production of methanol, mixed low-molecular-weight alcohol, synthetic gasoline, and heavier liquid fuels. Syngas is available from renewable resources by oxygen gasification of wood.

Wan, Edward. **Conversion of Biomass to Methanol,** Science Application, Inc., Mclean, VA, 1978 - continuing.

This study explores the identification and development of alternative systems for producing methanol from biomass resources. A critical systems model is being developed to demonstrate methanol from biomass production systems so that parametric analysis and sensitivity studies can be done.

Wayman, Morris. **Wood as a Source of Ethanol,** University of Toronto, Department of Chemical Engineering, Toronto, M5S 1A4, Ontario. 1975 - continuing.

This process includes: (1) autohydrolysis, (2) lignin extraction, and (3) enzyme-assisted fermentation. A three-step process for preparation of cellulose for alcohol fermentation.

Wise, Donald. **Liquid Fuel Production from Biomass,** Dynatech Co. Cambridge, MA, 1980.

This program develops a basic process for the production of liquid fuel from biomass. It consists of three steps: (1) carboxylic acids are produced from cellulose by nonsterile anaerobic fermentation; (2) acids are separated and concentrated by liquid-liquid extraction, (3) the concentration is converted by electrolytic oxidation to the final alcohol fuel.

Zabriskie, Dane. **Use of Soluble Cellulose Derivatives as an Intermediate in Ethanol Production,** State University of New York at Buffalo, Department of Chemical Engineering, Amherst, NY, 1979.

This research examines the feasibility of improving ethanol fermentation. It utilizes cellulose feedstocks by chemically modifying the cellulose. The approach taken was from a water-soluble cellulose derivative, then homogeneously hydrolyzing this intermediate using cellulose enzymes.

E. Gaseous Fuel

Bergman, H. "Facts Concerning The Utilization of Gaseous Fuels in Heavy-Duty Vehicles", **Gaseous Fuels For Transportation,** Vancouver, British Columbia, Canada. Aug. 7 - 10, 1986.

This report gives the technical and commercial aspects of liquid petroleum gas (LPG) and natural gas of transportation fuels. Benefits and disadvantages of dual-fuel operation. Pure gas engine concepts are discussed, as well as the effect of changing gas compositions on engine performance and engine failure.

Bonnetian, Y. "Gaseous Transportation Fuel: Renault's Opinions and Experience", **Gaseous Fuel For Transportation**, Vancouver, British Columbia, Canada, Aug. 7-10, 1986, pp. 851-866.

This document gives an overview of the different thermal engine gaseous fuels which include: Carbon monoxide (gasogane); Hydrogen; LPG (butane and propane); methane (natural gas, biogas etc).

R. W. Duncan, W. D. Jenkins, and R. F. Webb. "Demonstration of Propane and Natural Gas as Fuels For City Buses", **Gaseous Fuels For Transportation,** Vancouver, British Columbia, Canada, August 7-10,1986, pp. 867-886.

This report discusses a two-year demonstration of propane and compressed natural gas as an alternative to diesel fuel in urban transit bus services. The results of the bus and engine acceptance tests, the operation of the gas and propane-fueled bus fleets in urban and suburban service and experience with the fueling system were presented.

Lowe, W. John. "On The Techno-Economics of CNG Utilization for Vehicle Transport", **Gaseous Fuels For Transportation**, Vancouver, British Columbia, Canada, August 7-10, 1986, pp. 217-258.

This report explains the economics of CNG. It gives the set of assumptions regarding the context in which CNG is used that may affect any set of overall conclusions.

Myers, R. V. "Safety Of Gaseous Fueled Vehicles In Canada." **Gaseous Fuels For Transportation**, Vancouver, British Columbia, Canada, Aug. 7-10, 1986, pp. 1171-1192.

This paper provides a summary of the safety of propane and natural gas fueled vehicles in Canada. Information is provided on vehicle tests conducted for regulatory, development purposes, and tests conducted to determine the compliance of production vehicles with government safety standards. Data is provided on accidents involving the subject type of vehicles and comments are made on the compressed natural gas containers.

Noon, A. "A Bus Operator's Experience in The Conversion of Horizontal Diesel Engines to Operate on both CNG and LPG", **Gaseous Fuel for Transportation**, Aug. 7-10, 1986, pp. 887-902.

This report provides information on the liquid petroleum gas followed by dual-fuel and dedicated compressed natural gas versions of the United States horizontal diesel engines.

Reid, M. H. "Diesel-Natural Gas Engine Option", **Gaseous Fuel for Transportation**, Vancouver, British Columbia, Canada, Aug. 7-10, 1986, pp. 917-936.

This book explains three main conversion options which are dual-fuel and conversion to spark ignition. The system is described and the results of the dynamometer testing were give.

Richards, W. L. "Alternative Gaseous Fuels For Diesel Transport", **Gaseous Fuels For Transportation**, Vancouver, British Columbia, Canada, Aug. 7-10, 1986, pp. 903-916.

This report explains a major study done in New Zealand which has already been completed to establish technical viability. The economics, both from an operators points of view and the national viewpoint, have been considered. It is shown that New Zealand's conversion to natural gas is likely to be economically viable only for the largest trucks.

Ridly, J. D. and R. M. Clements. "A Review of High Energy Ignition Techniques for Alternative Fuels", **Gaseous Fuels For Transportation**, Vancouver, British Columbia, Canada, Aug. 7-10, 1986, pp. 645-654.

This report compares the natural gas (methane) a slow burning fuel, that is difficult to ignite, with gasoline. It is an ideal candidate for investigation with unusual ignition systems designed to enhance the ignition process. The reports will review two such systems: plasma jet ignition and puff jet ignition. Plasma jet devices discharge electrical energy in the order

of a few joules through a specially designed cavity. Puff jet igniters produce a puff of gaseous fuel which is injected directly into the engine cylinder and passes through a conventional low energy spark gap.

Ryder, J. C. "The New Zealand CNG Program: A Partnership Between the Government and the Private Sector", **Gaseous Fuels For Transportation**, Aug. 7-10, 1986, pp. 335-350.

This paper traces the development of CNG program with particular emphasis on how the program evolved in response to market and industry needs and expectations. The changing roles and perceptions of the program participants were explored.

F. Ethanol

Distillers Feed Research Council. **Distillers Feeds**, Distillers Feed Research Council, n.d., Cincinnati, OH, (undated).

This pamphlet provides a well-documented and referenced summary of the use of stillage as animal feed.

Distillers Feed Research Council. **Feeds Formulation**, Distillers Feed Research Council, n.d., Cincinnati, OH, (undated).

This pamphlet provides information on distillers dried grains, and condensed distillers solubles in order to produce better formula feeds for animals.

Lipinsky, E. S., et.al. **Sugar Crop as a Source of Fuels,** Vol. I-Agriculture Research, Vol. II-Processing and Conversion Research. Washington, D C, U. S. Department of Energy, 1989, Report No. TID-29400/1 and TID-29400/2.

This report presents the results of a feasibility study on using sugarcane and sweet sorghum as a source of fuels. Field experiments were conducted in Florida, Louisiana, Mississippi, Ohio, and Texas.

Moriarity, Andrew J. "Toxicological Aspects of Alcohol Fuel Utilization", Toronto, Canada, Biomedical Resources International, November, 1977.

This paper presents a full discussion on the toxicology of ethanol and methanol and a comparison with the toxicity of gasoline.

Office of Technology Assessment. **Gasohol - A Technical Memorandum**, Washington, D C, Office of Technology Assessment, U. S. Congress, 1979.

This document discusses ethanol production and gasohol use as well as economics, environmental effects, social impacts, and federal programs and policies.

Paturau, J. M. **By-products of the Cane Sugar Industry,** Amsterdam, The Netherlands, Elsevier Publishing Company, 1969.

This book provides a comprehensive examination of those co-products of ethanol fermentation when molasses is used as the feedstock, as well as, a completed discussion on fermentation ethanol production from sugarcane.

Paul, J. J., ed. **Ethyl Alcohol Production and Use as a Motor Fuel,** Park Ridge, NJ, Noyes Data Corp., 1979.

This book presents information from other sources on economic assessments of ethanol production from biomass, feedstock availability, ethanol production technology, and use of ethanol and ethanol-gasoline blends.

Solar Energy Research Institute. **A Guide to Commercial-Scale Ethanol Production and Financing,** Golden, CO, Solar Energy Research Institute, Report No. SERI/SP-751-877, Springfield, VA, 1980.

This guide is the commercial-scale equivalent of Fuel From Farms. Information for determining feasibility is included.

Solar Energy Research Institute. "Fuel From Farms: A Guide to Small-Scale Ethanol Production", **Solar Energy Research Institute**, Golden, CO,1980, Report No. SERI/SP-4511-519.

This report gives invaluable information on the potential of small-scale, on-farm ethanol production in this guide. Useful decision and planning worksheets and a business-plan case study are included.

G. Methanol

Alison, Jeffrey. "The Methanol Debate Clearing the Air", **Methanol as an Alternative Fuel Choice: An Assessment,** Institutional Energy Program The John Hopkins University, Wasington DC, 1990, pp. 397-409.

This report describes and evaluates the current public debates on methanol. The Environmental Protection Agency (EPA) presented the case for methanol's benefits. Sierra Research presented the case against methanol. EPA believes that methanol, propane, and electricity could meet these emissions standards, and it is possible that reformulated gasoline.

Gibbs, Joseph. "Tomorrow's Engineers Put Methanol to the Test", **Design News**, July 17,1989, pp. 26-27.

This article gives a summary of the Methanol Marathon involving 15 colleges from the Engineering Departments. The department is sponsored by the Society of Automotive Engineers of General Motor and the U. S. Canadian governments. The event sought to simulate innovative designs in methanol-powered case, and show how experimental fuel performs in actual driving conditions.

Hagen, David L. "Methanol as a Fuel: A Review with Bibliography", Warrendale, PA, Society of Automotive Engineers, 1977. Report No. SAE/PT-80/19.

This paper provides historical information on methanol production and use and is an excellent survey of recent studies and research. A comprehensive survey of methanol use is also given.

Kupfer, Andrew. "The Methanol Car In your Future, **Fortune,** September 25, 1989, pp. 71-82.

This article directs its attention towards an auto fuel that reduces emission of pollutions and is supported by the United States government. Methanol is the promising gasoline substitute which numerous attributes such as, more powerful and cleaner, 90% less ozone, less likely to explode in a collision.

Methanol is used and praised by auto makers, professional race drivers and ozone fighters. This article also compares and contrasts methanol with other potential fuel substitutes.

Kneper, MIke. "Fuels in your Future", **Popular Mechanics,** Nov., 1989, pp. 55-57.

This report gives an examination of a possible automotive fuel. In the future, cars may run on electricity, natural gas, hydrogen gas or ethanol to combat air pollution.

Paul, J. K. **Methanol Technology and Application in Motor Fuels,** Park Ridge, NJ, Noyes Development Corp., (undated).

This book explains a variety of sources and covers the production of methanol from coal, solid waste, and natural gas. Reports on the use of straight methanol and methanol-gasoline blends as motor vehicle fuels are discussed. The Mobil process for producing gasoline from methanol is included.

Reed, T. B. "Net Efficiencies of Methanol Production from Gas, Coal Waste or Wood." **Symposium on Net Energetics of Intergrated Synfuel Systems** American Chemical Society, April 1976, Vol. 21, No. 2, Paper No. 16.

This paper discusses and compares the net production energy efficiencies for methanol produced from gas, coal, waste and wood.

H. Butanol

Beesch, Samuel C. "Acetone-Butanol Fermentation of Sugars" **Industrial and Engineering Chemistry**, Vol. 44, No. 7, July 1952.

This article contains information on the microorganisms used for butanol-acetone fermentation and detailed information on the fermentation process.

Prescott, Samuel C. and Cecil G. Dunn. **Industrial Microbiology**, New York, NY, McGraw-Hill Book Company, Inc., 1949.

This study deals with butanol-acetone fermentation and butanol-isopropyl alcohol. Fermentations are included, as well as general discussions on yeasts and saccharification.

Rose, Anthony H. **Industrial Microbiology,** Wasingtion, D C, Butterworth and Co., Ltd., 1961.

This report gives extensive information on industrial microbiology, as well as a chapter on the butanol-aceton fermentation process.

Strobal, M. K. and J. B. Bader. **Economic Evaluation of Neutral-Solvents Fermentation Product Separation,** Oak Ridge, TN, Oak Ridge Station, School of Chemical Engineering Practice, Massachusetts Institute of Technology and Oak Ridge National Laboratory, 1981.

This paper compares the cost of butanol-acetone fermentation using Clostridia as the microorganism with ethanol fermentation. Market costs as well as production costs are included in the calculations.

Underkofler, L. D. and R. J. Hickey, eds. **Industrial Fermentation**, Vol. 1, New York, NY, Chemical Publishing Co., 1954.

This book serves as a basic chemical text on fermentation processes. It contains a chapter on butanol-acetone fermentation.

I. Hydrogen

Dail, Mark A. "Hydrogen Vehicle", **Alternative Transportation Fuels,** May 1979, pp. 85-105.

This report emphasizes the attractiveness of hydrogen as a potential transportation fuel because of its availability and its being a clean source of power. In addition, the actual production and distribution of hydrogen are mentioned. The report goes on discussing the various techniques for storing and refueling stations with hydrogen fuel. While other fuel alternatives do exist, the author recognizes the safety issues and performance of vehicles which use hydrogen fuel. Moreover, the EPA places significant attention on research and testing on emissions, cost, and mileage as it relates to hydrogen fuel and its derivatives.

Hoffman, Peter. "The Forever Fuel: The Story of Hydrogen", Westview Press, Boulder, Colorado, 1981.

This book describes worldwide specific work toward a future hydrogen economy, looking at the auspicious prospects of this potential fuel, its applicability to powering everything from automobiles to airplanes, and the principles and technologies involved in making hydrogen a viable energy alternative.

Mcosh, Dan. "Automotive Newsfront: Sports Car Goes Environmental", **Popular Science**, Dec. 6, 1990, pp. 26-28.

This document explains an alternative to gasoline and liquid hydrogen. Because it has cheap and abundant drawbacks that limited hydrogen-powered vehicles, the Japan effort to overcome the problems were reported.

Siuru, Bill. "R & D In the Fast Lane", **Mechanical Engineering**, Oct. 1989, pp. 62-67.

This report examines the Barrarian Motor Works' (BMW) research into hydrogen and other alternative fuels.

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